



COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

February 5, 1964

HENRY WARD
COMMISSIONER OF HIGHWAYS

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

MEMORANDUM

D.2.4

TO: W. B. Drake, Asst. State Highway Engineer
Chairman, Kentucky Highway Research Committee

RE: Fourth Annual Performance Survey of Reinforced
Concrete Pipe Culverts; KYHPR-64-22, HPS-HPR-
1(25), Part II.

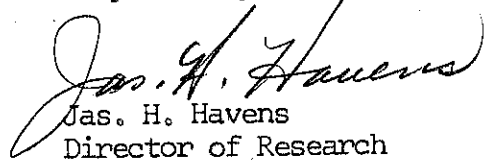
The attached report, entitled: "Fourth Annual Performance Survey of Reinforced Concrete Pipe Culverts," by R. D. Hughes, Research Engineer, is a continuation of a series which was inaugurated in specific response to the BPR's C. M. 22-42, dated November 12, 1959. C. M. 22-42 has reference to C. M. 22-40, dated April 4, 1957. Previous reports submitted in the series are cited in the first section of the current report; reference is also made there to reports of other studies which are related to but are not part of the series. Additional background information will be found in the introductory portion of the report.

Effective July 1, 1963, the project, with which this report is concerned, became identified with the Department's cooperative Planning and Research Program, HPS-HPR-1(25), as authorized by the Bureau of Public Roads PPM 50-1.1, February 5, 1963; and copies of the report are being transmitted to the Bureau in accordance therewith.

February 5, 1964

Although comments and suggestions are invited, no specific response is requested inasmuch as the report is primarily intended to update the performance record of the group of culverts under surveillance.

Respectfully submitted,


Jas. H. Havens
Director of Research
Secretary, Kentucky Highway
Research Committee

JHH:lga

Enc.

cc: Research Committee:

R. O. Beauchamp

R. L. Campbell

T. J. Hopgood

A. O. Neiser

J. C. Moore

D. V. Terrell

File D.1.7

Research Report

FOURTH ANNUAL
PERFORMANCE SURVEY OF REINFORCED
CONCRETE PIPE CULVERTS
KYHPR-64-22; HPS-HPR-1(25)

by

R. D. Hughes
Research Engineer
DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

in cooperation with the
BUREAU OF PUBLIC ROADS
U. S. Department of Commerce

132 Graham Avenue
Lexington, Kentucky

January, 1964

INTRODUCTION

A stylized, rational criterion for the structural design and installation of reinforced concrete pipe culverts was developed by the Bureau of Public Roads in cooperation with Prof. M. G. Spangler of Iowa State College and the American Concrete Pipe Association and was distributed to the various state highway agencies, April 4, 1957, as Circular Memorandum 22-40.* The criterion was intended to bring together and simplify methods for computing the strengths required for various fill heights and conditions of bedding. The several highway agencies were urged to adopt the criterion for use on all Federal-aid projects and accordingly, the Kentucky Department of Highways issued Amendments No. 15 and No. 16 (Feb. 28, 1958) to its 1956 edition of Standard Specifications for Road and Bridge Construction. Standard Drawings No. 11.22 and No. 11.23 were issued along with these amendments. Amendment No. 15 was later superseded by Amendment No. 15a (Dec., 1961). These amendments and standard drawings were faithfully patterned after the criterion outlined by the Bureau of Public Roads but contained some practical modifications which for the most part were incidental to the transformation of the design criterion into specification style. Class B bedding, with its B_1 modification for high fills, was adopted

* Also reported by D. P. Babcock in the Proceedings of the Highway Research Board, Vol. 35, 1956.

as standard. Each is similar to the same respective designation as described in the Bureau's Circular Memorandum 22-40. The strengths needed for the respective conditions and heights of fill were resolved from the criterion and were set forth in "Table for Safe Fill Cover Heights and Classes for Reinforced Concrete Circular Pipe" on the Department's Standard Drawing No. 11.23. Installation procedures were diagramed and outlined on Standard Drawing No. 11.22.

In order to further evaluate the design and installation criterion, the Bureau of Public Roads requested (Ref. C. M. 22-42, dated 11-12-59) that a number of reinforced concrete pipe culverts, designed and installed in accordance with the outlined procedures, be inspected periodically and reported at the close of each calendar year. A group of 113 reinforced concrete pipe culverts was selected early in 1960 for these inspections. The culverts selected are located in Jefferson, Shelby, Franklin, Clark, Montgomery, Scott, Grant and Kenton counties on Interstate Routes I-64 and I-75. Each culvert was inspected during the summers of 1960, 1961, 1962 and 1963. The data reported herein summarize the design and construction factors and the performance for each pipe inspected during these four summers.

Previous reports covering the first-, second-, and third-year performance surveys, respectively are:

1. "Performance Survey of Reinforced Concrete Pipe Culverts," by R. C. Deen and R. D. Hughes, dated March, 1961.
2. "Second Annual Performance Survey of Reinforced Concrete Pipe Culverts," by R. D. Hughes, dated February, 1962.

3. "Third Annual Performance Survey of Reinforced Concrete Pipe Culverts," by R. D. Hughes, dated January, 1963.

The current report, "Fourth Annual...", largely supplants the first and third reports; the second report contained additional discussions and information which might be useful in a subsequent or final report. Other reports related to but not directly a part of this series of performance-survey reports are:

"Performance of a Reinforced Concrete Pipe Culvert, with Standard and B₁ High-Fill Bedding, under Rock Embankment (Scott County, I-75-6(5) 123)," by Ralph R. Taylor; KDH, Aug., 1961.

"Some Effects of Fabrication Practices on the Strength Characteristics of Reinforced Concrete Culvert Pipe," by R. C. Deen and Jas. H. Havens; KDH, Feb., 1963 (To be presented at the 43rd Annual Meeting of the Highway Research Board).

"Camber Design Study, for Concrete Pipe Culverts," by Aubrey D. May; KDH, Feb., 1960 (Note: Manuscript report of same title as above, authored by A. D. May and R. C. Deen, offered to Soil Mechanics and Foundation Division, ASCE, July 1963, for presentation at forthcoming Settlement Conference, June, 1964).

Reference is appropriately made also to the following publication which updates and revises the original, BPR criterion:

Reinforced Concrete Pipe Culverts, Criteria for Structural Design and Installation, U. S. Dept. of Commerce, Bureau of Public Roads; GPO, Aug., 1963.

All prior studies made by the Department in connection with these referenced reports were sustained entirely by State funds. Although most of the field inspections for the year 1963 had been completed prior to July 1, 1963, the project was fully authorized under Part II of HPS-HPR-1(25) July 1, 1963, and henceforth will be subordinately identified as KYHPR-64-22. At least one additional field inspection and annual report is contemplated.

PERFORMANCE SURVEY

The results of the performance surveys are presented diagrammatically in the Appendix. Each installation is diagrammed directly below the tabulation of its respective design and construction data. The inlet of each pipe is on the left of the page, and sections of pipe are numbered from the inlet toward the outlet. All signs of distress observed during the field inspections have been shown by symbols (see legend) on the diagrams. Signs of distress noted during the first inspection are shown in black; signs of distress that developed between the first and second inspections and any changes observed are shown in red; developments or changes in distress between the second and third inspections are shown in green; and signs of distress that developed between the third and fourth inspections or any changes observed are shown in blue. No walk through inspection, as such, was made of the 18-inch and 24-inch diameter pipes. Only visual inspections from the inlets and outlets were made on small diameter installations.

The two culverts on project I-75-6(4) 129 in Scott County had not been installed by the time of the first inspection but were installed prior to the second inspection -- thus, the second, yearly survey represents the first field inspection of those culverts. Fills had not been completed over any of the culverts on project I-75-6(5) 123 in Scott County at the time of the first inspection, nor had pipes been installed at Stations 36+50, S. W. Ramp or 47+40 on U. S. 62. The installation at Station 47+40 on U. S. 62 and all of the remaining fills, except the one at Station 36+50, S. W. Ramp, were completed between the first and second surveys. The

second performance survey represented the first inspection of those culverts. The installation at Station 36+50, S. W. Ramp was complete by the time of the third survey, and that survey represents the first inspection of that installation.

During that time between the first and second surveys, a slide occurred in the fill over the culvert at Station 7+34, F. R. 2 on project I-75-7(11) 151 in Grant County. Several sections of pipe were damaged during the backfilling operation while correcting the slide area. Distresses noted were not of a serious nature, and no corrective measures were required. The culvert at Station 566+65, N. B. L., on the same project, had 33 sections added to the outlet portion during the time between the first and second surveys. Two sections of pipe of the original installation were damaged during placement of the new sections. Damage to those sections was not severe.

Additional sections of pipe were placed at the inlet and outlet of the culvert at Station 428+07 on project I-64-5(5) 93 in Clark County. The sections were placed during the time between the second and third surveys. Twenty sections were placed at the inlet, and 11 sections were placed at the outlet to provide drainage under ramps connecting I-64 and the Mountain Parkway.

During the first survey, several culverts were found to be in serious distress, and repairs were recommended. The culverts recommended for repair and the repairs made are listed in Table I. The majority of repairs were made between the first and second surveys. Those sections of pipe which were lined with corrugated met-

al pipe and grouted were observed to be in excellent repair when the second, third, and fourth surveys were made. The mortaring and patching (epoxy) of less severe cracks proved to be rather ineffective in that cracks reflected through the patching material. The epoxy used in repair of the cracks was of the type which is adversely affected by moisture.

It is significant to note that the more serious signs of distress developed within the first year after installation. Progressive signs of distress were noted during the second, third and fourth surveys; however, none requiring repair were observed during the last surveys. It appears to be quite evident that signs of major distresses might be expected to appear in a short period of time after installation disregarding unique events such as slides, addition of sections, etc.

Table 1. Repairs made on Pipe Found in Distress During First Inspection

Project No.	County	Station No.	Patching	Corrugated Metal Liners		
				Sec.*	Gauge	Min. Dia.
I-64-3(3)31	Shelby	1255+25		10-13	12	42"
I-64-3(5)45	Franklin	2233+50R	Top & Bottom Sec. 13-32			
I-64-3(7)35	Shelby	1604+04R**	Bottom, Sec. 12-16	11-32	8	48"
		1619+45L		10-41	8	48"
		1633+30L 1635+82L 1637+32L	Lift Holes	13-47	8	42"
I-75-7(5)160	Grant	978+12	Joints, Sec. 67-73 Joints, Sec. 19-21 Joints & lift holes	15-45	10	36"
		1085+44		34-79	8	48"
		1087+50 27+82FR 9a		5-12	8	60"

* Sections numbered from inlet of culvert.

** Repair recommended but not made prior to second inspection.

DISCUSSION

The maximum, safe fill heights for each strength-class of pipe and condition of bedding was determined from the design criterion. Each strength-class of pipe was thereby qualified and authorized for use in situations in which the height of fill did not exceed a specified maximum which was based upon the suggested, minimum, safety factor. In practice, situations arise wherein the fill-height just exceeds the maximum allowable for one strength-class and wherein a higher class pipe provides more strength than is needed. This oftentimes results in greatly increased factors of safety in actual structures and provides further opportunity for evaluating performance from the standpoint of design.

Odd occurrences of shear failures in a long line of pipe might be attributed to local stress concentrations and uneven load-bearing conditions; whereas, a prevalence of shear in a line of pipe having a safety factor which is significantly greater than unity should not be thoughtlessly dismissed. The most perplexing aspect of this evaluation is the fact that the cracking and shear failures observed do not seem to be related to the adjudged, as-built, safety factor. Of course, minor cracking is understandable and perhaps admissible inasmuch as the criterion for design is based wholly upon the ultimate D-load strength rather than the 0.01-in.-crack strength or first-crack strength. On the other hand, even a two-fold safety factor does not seem to preclude shear failures. This suggests the disturbing possibility that such failures may not be related to design; and of course, the possibility that damage could have been caused by heavy earth-moving equipment or by failure to conform with the

LEGEND

Hairline Crack	—	
Crack (.01in. or above)	—	
Shear Failure	—	
Spalling	—	
Broken	—	
Mortar Missing	—	
Steel Exposed	—	
Faulted	—	
Section Settled	—	
Buckling	—	
C. M. Liner	—	
Mortared	—	
Patched	—	
Joint Separated	—	
Hairline Crack Changed To Crack		⊕
Crack Or Cracks To Shear		*****
Mortar Or Patch Out		○
Steel Exposed Through Patch		$\frac{\infty}{P \quad P}$
Hairline Crack Changed To Shear		+++++
Hairline Crack Through Patch		~P~
Crack Through Patch		~~~~~

Black — 1960 Survey

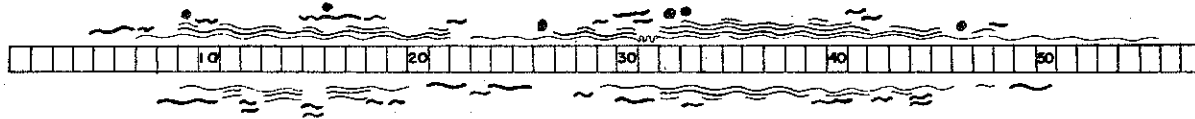
Red — 1961 Survey

Green — 1962 Survey

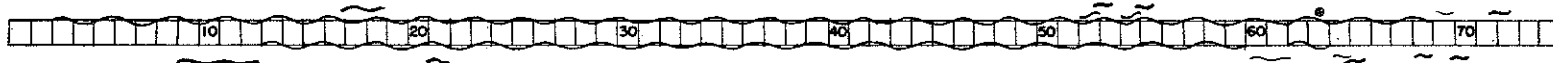
Blue — 1963 Survey

PROJECT NO. I 64-2(5)17 JEFFERSON COUNTY
 WEST OF ENGLISH STATION ROAD TO SHELBY COUNTY LINE

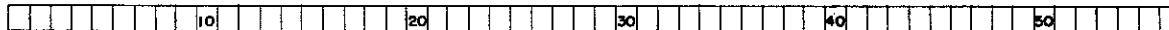
Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
652 + 68	42	228	228	III	B ₁	Positive	3.50	3.50	22.0	25.0	15 R	Soil & Rock	2.47-2.18	North



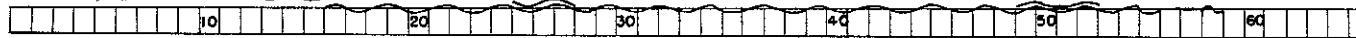
668 + 00	30	296	296	III	Std.	Positive	3.45	3.23	16.0	19.5	45 R	Soil & Rock	1.65-1.36	North
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698 + 00	24	224	224	III	Out to 168'-B ₁ 100' to 224'-Std.	Out. to 52'-Pos. 52' to 140'-Neg. 140' to 224'-Pos.	4.69	4.69	20.0	24.0	0	Soil & Rock	1.32-2.27	North
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744 + 30	30	260	260	III	B ₁	Positive	2.08	2.08	23.5	25.0	30 R	Soil & Rock	2.31-2.18	North
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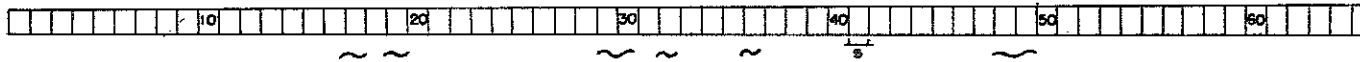


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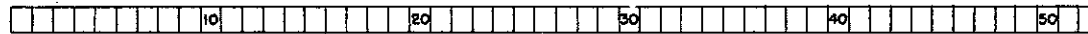
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 WEST OF ENGLISH STATION ROAD TO SHEELEY COUNTY LINE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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776 + 50	30	260	260	III	B ₁	Positive	3.15	3.15	32.0	30.0	15 L	Soil & Rock	1.20-1.81	South
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790 + 35	24	208	208	III	Std.	Positive	3.89	3.89	11.0	15.0	30 L	Soil & Rock	2.41-1.77	North
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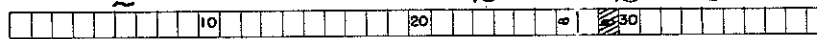


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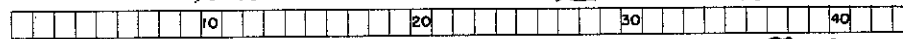
PROJECT NO. I 64-2(3)22 SHELBY COUNTY
 JEFFERSON COUNTY LINE TO JOYCE STATION ROAD

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Glass	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment North (ft.)	Embankment South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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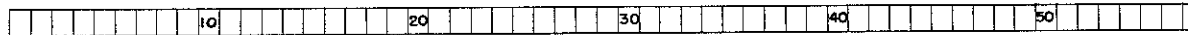
900 + 15	48	156	156	III	Std.	Positive	0.32	0.32	4.5	4.5	0	Soil	5.89	North
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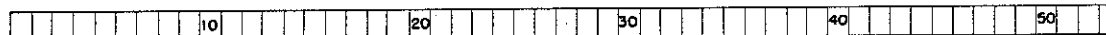
968 + 25	42	172	172	III	Std.	Positive	2.00	2.00	8.0	9.5	0	Rock	3.31-2.79	North
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983 + 90	18	228	228	III	Std.	Positive	1.89	1.89	24	22.5	0	Rock	1.10-1.18	South
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988 + 75	24	212	212	III	Std.	Positive	1.98	1.98	17.0	15.0	0	Rock	1.56-1.77	South
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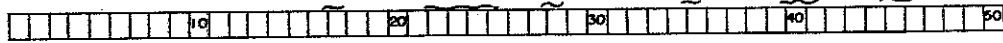


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PROJECT NO. I 64-2(3)22 SHERMAN COUNTY
JEFFERSON COUNTY LINE TO JOYCE STATION ROAD

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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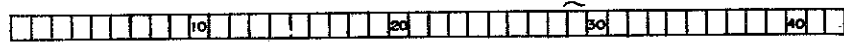
1000 + 50	30	200	200	III	Std.	Out. to 58'-Pos. 58' to 200'-Neg.	1.90	1.90	13.5	12.0	0	Soil	1.96-2.21	South
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1057 + 35	30	212	212	III	Std.	Positive	0.99	0.99	19.0	19.5	15 L	Rock	1.39-1.36	North
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1133 + 10	36	168	168	III	Std.	Positive	1.01	1.01	4.5	6.0	0	Soil	5.89-4.41	North
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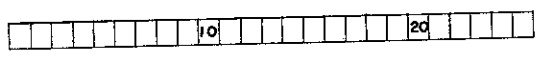
PROJECT NO. I 64-2(3)22 SHELBY COUNTY
JEFFERSON COUNTY LINE TO JOYCE STATION ROAD

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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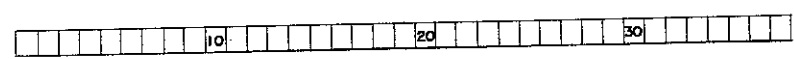
Ramp 1 10 + 70	36	144	144	III	B ₁	Positive	0.90	0.90	29.0		0	Soil & Rock	1.87	North
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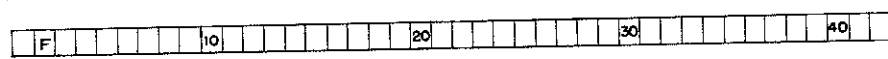
Ramp 5 9 + 50	18	100	100	III	Std.	31'-Pos. 69'-Neg.	2.50	2.50	12.0		0	Soil & Rock	2.21	South
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Veechdale Rd. 70 + 00	18	148	148	III	B ₁	In. to 30'-Neg. 30' to 148'-Pos.	4.39	4.39	28.0		0	Rock	1.94	South
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Veechdale Rd. 74 + 00	24	168	168	III	B ₁	Negative	0.60	0.60	32.5		0	Rock	1.67	South
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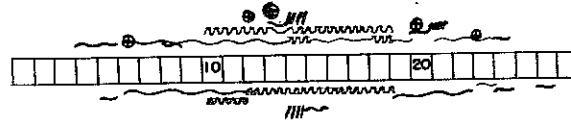


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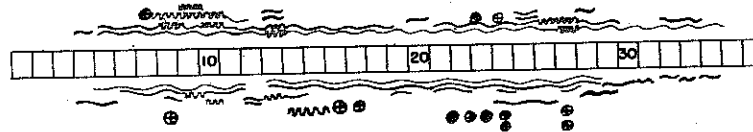
PROJECT NOS. I 64-2(7)29 & I 64-3(3)31 SHELBY COUNTY
 JOYCE STATION ROAD TO KY. 55 (OLD) & KY. 55 (OLD) TO SEVEN MILE PIKE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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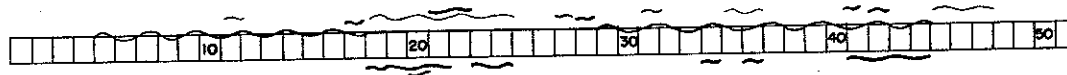
Joyce Station Road 78 + 50	30	108	108	III	B ₁	Positive	1.02	1.02	24		30 L	Soil	2.27	North
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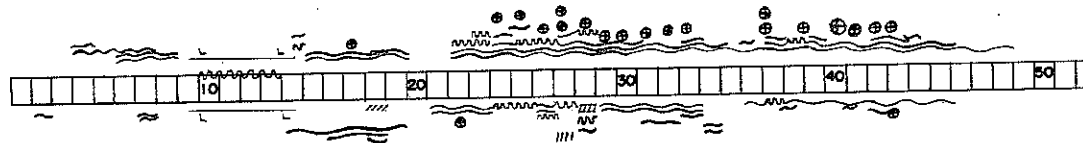
Joyce Station Road 81 + 79	48	144	144	III	B ₁	130' -Pos. 14' - Neg.	2.03	2.03	29.5		17.5 R	Soil	1.84	North
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1168 + 37	42	204	204	III	Std.	Out. to 53' -Neg. 53' to 204' -Pos.	1.10	1.10	13.0		30 R	Soil & Rock	2.04	North
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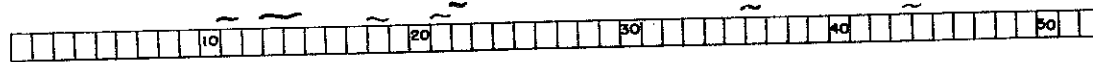
1255 + 25	48	208	208	III	Std.	Positive	2.74	2.74	19	21	0	Rock	1.39-1.26	North
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PROJECT NOS. I 64-2(7)29 & I 64-3(3)31 SHELBY COUNTY
 JOYCE STATION ROAD TO KY. 55 (OLD) & KY. 55 (OLD) TO SEVEN MILE PIKE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
1403 + 10	36	208	208	III	Std.	Positive	2.00	2.00	7.0	6.0	30 L	Rock	3.78-4.41	South

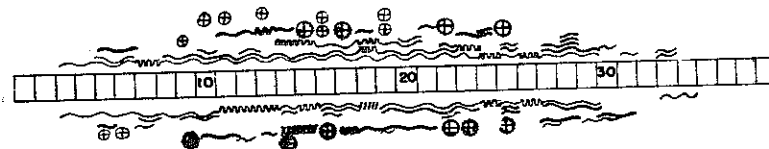


1092

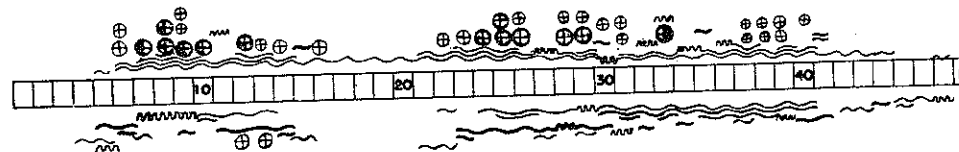
PROJECT NO. I 64-3(7)35 SHELBY COUNTY
SEVEN MILE PIKE TO 5000 ft. EAST OF KY. 714

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment material	Factor of Safety as Constructed	Location of Inlet
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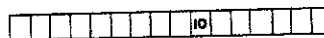
1456 + 90R	42	152	152	III	Std.	Out to 26'-Pos. 26' to 152'-Neg.	6.15	6.32		14.0	45 R	B' Soil & Remin. Soil & Rock	1.89	South
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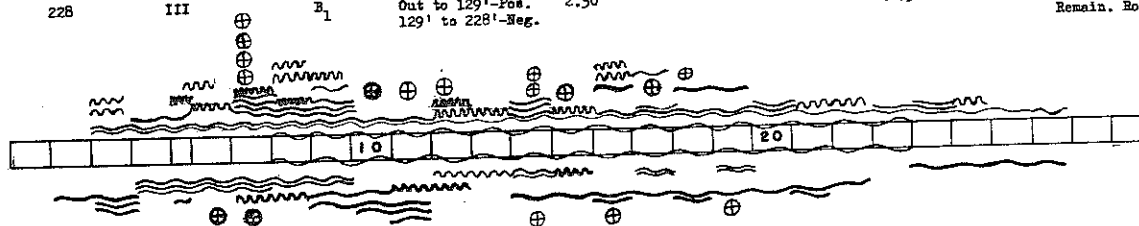
1458 + 35L	42	204	192	III	B ₁	Positive	3.97	3.97	23.5		45 R	Soil & Rock	2.31	South
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1471 + 00R	18	64	64	III	Std.	Negative	0.47	0.47		3.0	30 R	Soil & Rock	8.83	South
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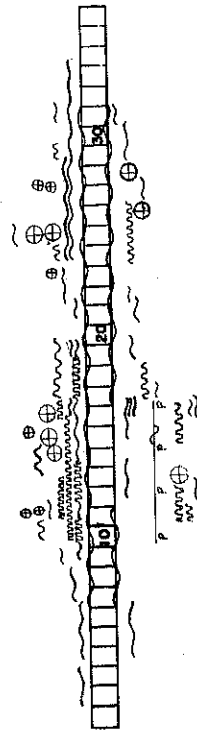
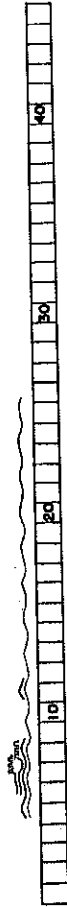


1536 + 51R	72	228	228	III	B ₁	Out to 129'-Pos. 129' to 228'-Neg.	2.50		28.5		45 R	12' Soil & Remain. Rock	1.91	North
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PROJECT NO. I 64-3(7) 35 HENKES COUNTY
 SEVEN MILE PILE TO 5000 FT. EAST OF KY. 714

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment North (ft.)	Embankment South (ft.)	Slew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
1592 + 10R	60	136	136	III	Std.	Positive	0.96	0.96	12.5	12.5	45 L	4.5' Soil & Remain. Rock	2.12	South
1595 + 91E	36	220	220	IV	B ₁	Positive	3.24	3.18	42.5	42.5	15 R	Soil & Rock	1.92	North
1596 + 71L	36	184	180	III	B ₁	Positive	3.24	3.34	34.0	34.0	15 R	12' Soil & Remain. Rock	1.60	North
1604 + 04R	48	144	144	III	B ₁	Positive	0.90	1.17	24.5	24.5	0	8' Soil & Remain. Rock	2.22	North



PROJECT NO. I 64-3(7)35 SHELBY COUNTY
 SEVEN MILE PIKE TO 5000 ft. EAST OF KY. 714

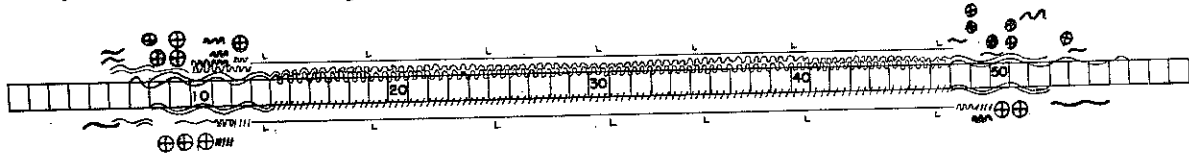
Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet	
1619 + 44 R	60	168	168	III		Positive	2.80	2.18		24.0	30 L	10' Soil & Remain. Rock	2.27	North	
1619 + 45 L	60	160	160	III	B ₁	Positive	2.56	1.44	27.5		15 L	Rock	1.98	North	
1633 + 30 L	54	200	200	III	B ₁	Positive	2.75	3.16	32.0		30 L	Soil & Rock	1.70	North	
1635 + 82 R	72	208	208	IV	B ₁	Positive	2.64	2.60	40.5	0		14' Soil & Remain. Rock	2.01	North	

195

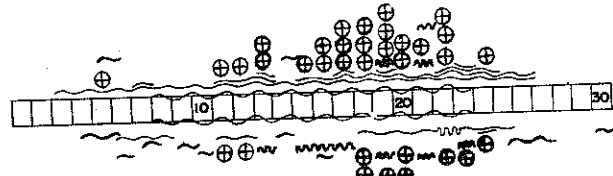
PROJECT NO. 1 64-3(7)35 SHELBY COUNTY
 SEVEN MILE PIKE TO 5000 ft. EAST OF KY. 714

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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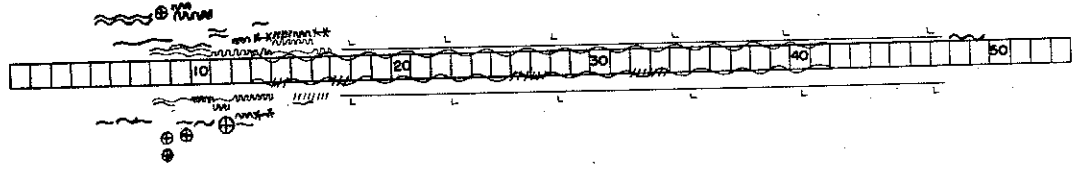
1637 + 32 L	48	236	236	III	B ₁	Positive	4.11	4.38	39.0		30 R	Soil	1.39	North
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1653 + 30 L	54	120	120	III	Std.	Positive	2.56	2.58	18.0		15 L	Soil	1.47	North
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1635 + 69 L	36	212	212	III	B ₁	Inlet to 56'-Pos. 56' to 186'- Neg. 186' to 212'-Pos.	4.25	5.37	39.0		15 L	8' Soil & Remain. Rock	1.39	North
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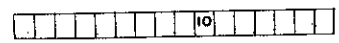


196

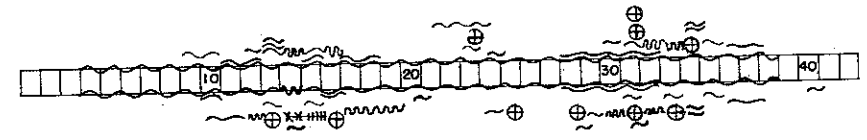
PROJECT NO. I 64-3(5)45 FRANKLIN COUNTY
 SHELBY COUNTY LINE TO .3 MILES EAST OF NEW KY. 35

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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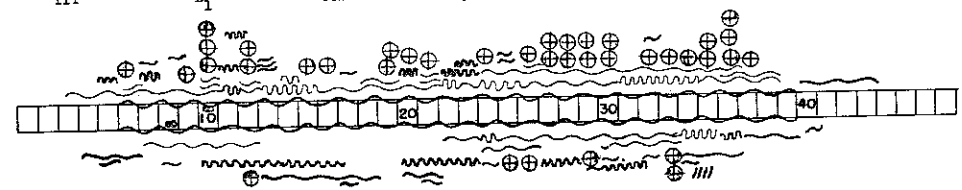
2043 + 50 R	18	64	64	III	Std.	In. to 19'-Neg. 19' to 64'-Pos.	0.78	0.78		3.0	0		8.83	North
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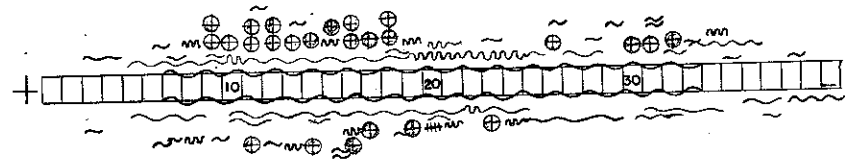
2054 + 75 R	30	168	168	III	Std.	Positive	3.79	3.39		19.5	45 L	Soil & Rock	1.76	North
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2059 + 00 R	36	188	188	III	B ₁	Positive	3.09	3.09		23.0	45 R	Rock	2.37	South
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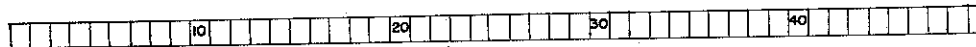
2060 + 85 L	42	160	160	III	Std.	Positive	1.69	1.50		18.0	45 R	Soil & Rock	1.47	South
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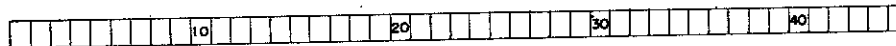
197

PROJECT NO. I 64-3(5)45 FRANKLIN COUNTY
 SHELBY COUNTY LINE TO .3 MILES EAST OF NEW KY. 35

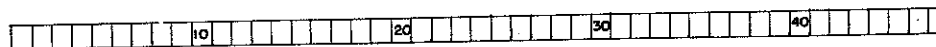
Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
2064 + 92 R	24	196	196	III	Std.	Positive	8.67	8.67		22.5	45 L	Soil & Rock	1.18	South



2129 + 50 R	18	176	176	III	Std.	Positive	5.40	4.66		20.0	45 L	Soil & Rock	1.32	North
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2152 + 50 R	18	152	148	III	Std.	In. to 13'-Neg. 13' to 148'-Pos.	1.64	1.35		27.0	0	Soil & Rock	0.98	South
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2154 + 50 L	48	132	132	III	Std.	Positive	0.53	0.53	14.5		45 R	Soil & Rock	1.83	South
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108

PROJECT NO. I 64-3(5)45 FRANKLIN COUNTY
 SHELBY COUNTY LINE TO .3 MILES EAST OF NEW KY. 35

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet	
2233 + 50 R	36	144	144	III	B ₁	Positive	2.57	2.57	25.0	0	0	Soil & Rock	2.18	North	
2246 + 00 L	18	132	132	III	B ₁	Positive	0.76	0.76	22.0	0	0	Soil & Rock	2.47	North	
2343 + 00	18	200	176	III	Std.	Positive	1.30	0.74	10	0	0	Soil & Rock	2.65	North	
9 + 50 Ramp "J"	30	232	220	III	B ₁	In. to 69'-Pos. 69' to 220'-Neg.	9.22	9.73	28.5	38.5	0	Soil & Rock	1.91-1.41	South	

199

PROJECT NO. I 64-3(5)45 FRANKLIN COUNTY
 SHELBY COUNTY LINE TO .3 MILES EAST OF NEW KY. 35

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
38 + 00 Ky. 35	30	148	148	III	Std.	Negative	0.68	0.66	24.0	0	0	Soil & Rock	1.10	North

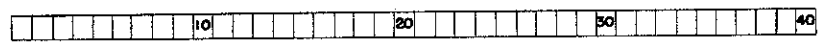


300

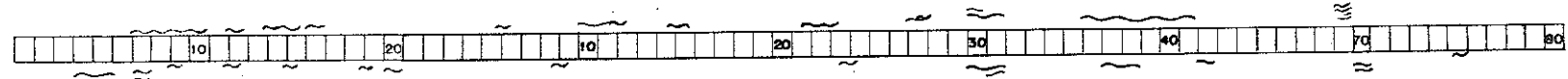
PROJECT NO. I 64-5(5)93 CLARK COUNTY
WINCHESTER TO MONTGOMERY COUNTY LINE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	*Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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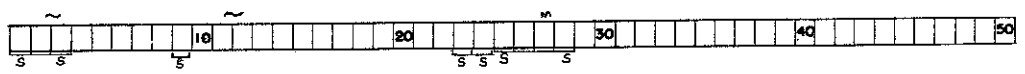
419 + 50	18	160	160	III	Std.	Positive	0.94	0.81	5.0	5.0	0	Soil	5.3	North
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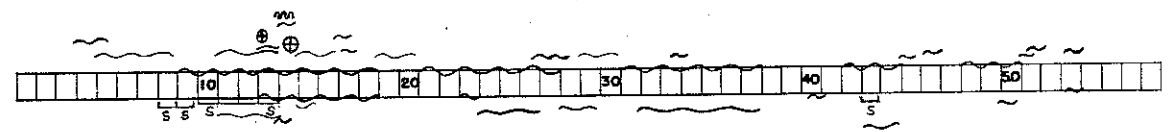
428 + 07	36	204	396	III	Std.	Positive	1.76	1.72	15.0	17.0	0	Soil & Rock	1.77-1.56	North
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438 + 90	42	200	200	III	Std.	Positive	0.70	1.08	9.0	10.0	15 R	Soil & Rock	2.94-2.65	North
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450 + 40	48	244	228	III	Std.	Positive	1.19	0.88	17.0	17.0	30 R	4' Soil & Remain. Rock	1.56	North
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100

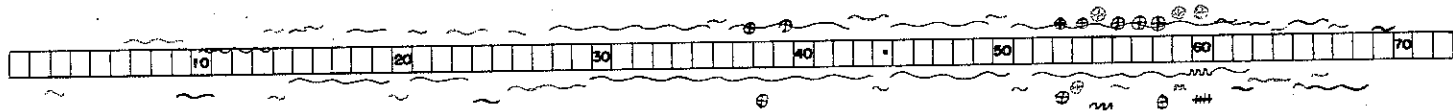
PROJECT NO. I 64-5(5)93 CLARK COUNTY
 WINCHESTER TO MONTGOMERY COUNTY LINE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	*Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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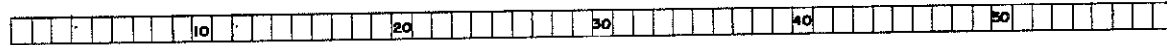
487 + 00	18	240	240	III	B ₁	In. to 127'-Neg. 127' to 240'-Pos.	3.33	3.33	30.0	27.0	0	Soil & Rock	1.81-2.01	South
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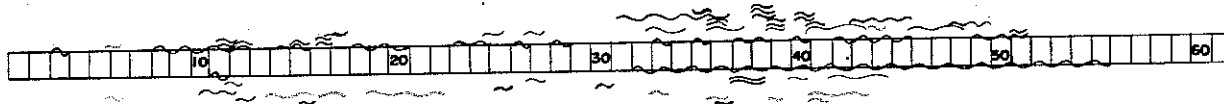
557 + 00	30	300	288	III	Std.	Positive	2.23	1.56	17.0	19.5	45 L	Soil & Rock	1.56-1.36	North
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573 + 50	24	232	232	III	Std.	Positive	1.74	1.34	18.5	19.5	30 L	Rock	1.43-1.36	North
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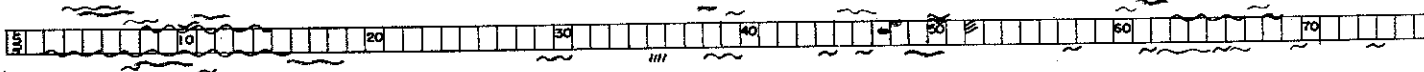
602 + 82	42	244	244	III	Std.	Positive	2.05	1.73	16.0	15.0	0	Rock	1.66-1.77	South
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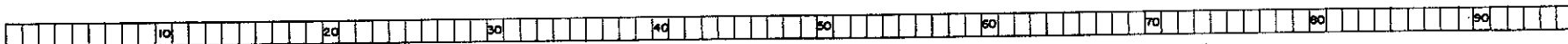
202

PROJECT NO. I 64-5(5)93 CLARK COUNTY
WINCHESTER TO MONTGOMERY COUNTY LINE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	*Projection	Design Grade (%)	Actual Grade (%)	Embankment North (ft.)	Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
609 + 50	42	308	304	III	B ₁	Positive	1.88	0.97	23.0	21.0	45 L	Rock	2.36-2.59	South



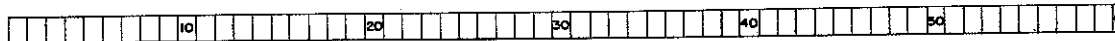
656 + 50	18	372	380	III	B ₁	Positive	4.89	5.05	34.0 Ramp #0°-41.5	39.0	20 L	Soil & Rock	1.60-1.39	North
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725 + 50	30	268	264	III	B ₁	In. to 209'-Pos. 209' to 264'-Neg.	3.17	3.30	31.0	34.0	15 L	Rock	1.73-1.60	North
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749 + 65	24	236	240	III	Std.	Positive	5.17	5.21	16.0	20.0	15 L	Rock	1.06-1.32	North
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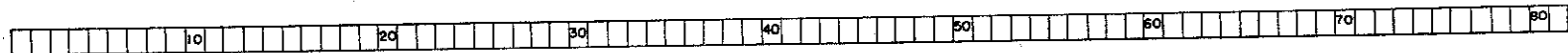
*All pipes laid with negative projection regardless of design projection values shown in tables.

PROJECT NO. I 64-5(6)100 CLARK-MONTGOMERY COUNTY

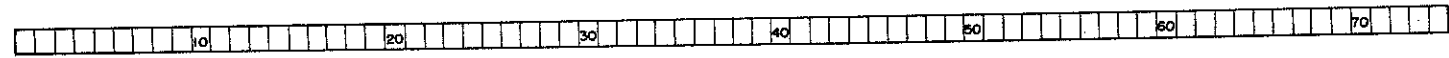
WEST CLARK COUNTY LINE TO U. S. 60

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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788 + 00	24	328	324	IV	B ₁	Positive	2.35	4.02	47.0	45.5	15 R	10' Soil & Remain. Rock	1.73-1.79	South
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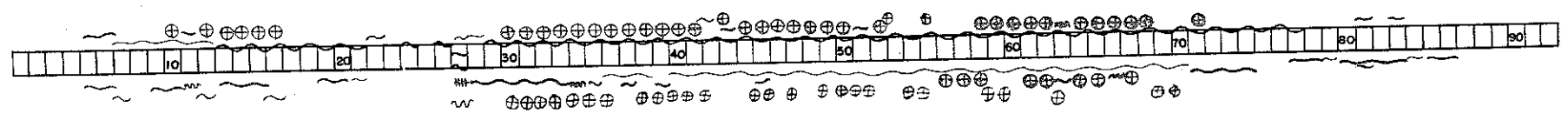
804 + 80	24	308	296	IV	B ₁	Positive	4.87	4.40	43.5	39.0	15 L	7' Soil & Remain. Rock	1.87-2.09	South
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824 + 31	18	188	180	III	Std.	Positive	7.39	9.45	16.0	10.0	0	Soil	1.66-2.65	South
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866 + 50	30	352	368	III	B ₁	108'-Pos. 260'-Neg.	1.27	2.17	28.5	31.5	45 R	Soil	1.91-1.73	North
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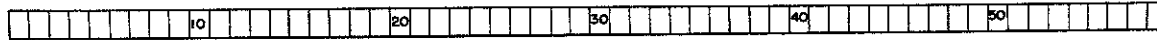
700

PROJECT NO. I 64-5(6)100 CLARK-MONTGOMERY COUNTY

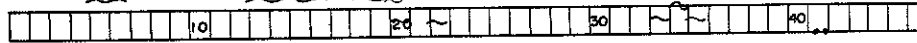
WEST CLARK COUNTY LINE TO U. S. 60

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment North (ft.)	Embankment South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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901 + 50	18	232	232	III	B ₁	Positive	4.35	4.83	28.0	24.5	0	14' Soil & Remain. Rock	1.94-2.22	South
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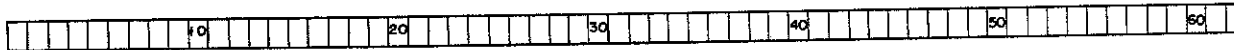
931 + 00	30	180	184	III	Std.	Positive	0.56	0.89	4.5	4.0	30 L	Soil	5.89-6.62	North
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938 + 28	48	272	280	III	Std.	Positive	1.62	1.25	9.0	8.5	45 R	4' Soil & Remain. Rock	2.94-3.12	South
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967 + 65	18	240	252	III	B ₁	Positive	3.28	4.13	25.0	28.0	15 L	9' Soil & Remain. Rock	2.18-1.94	North
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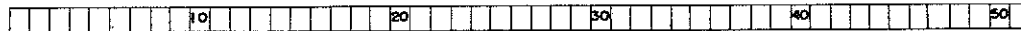
205

PROJECT NO. I 64-5(6)100 CLARK-MONTGOMERY COUNTY

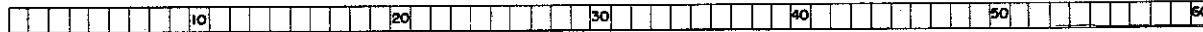
WEST CLARK COUNTY LINE TO U. S. 60

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment North (ft.)	Embankment Height South (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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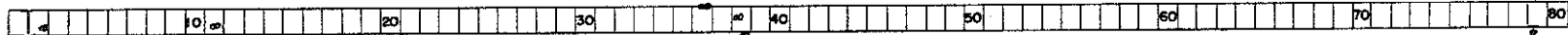
1043 + 90	24	228	204	III	Std.	Positive	3.29	4.61	15.0	11.5	15 R	10' Soil & Remain. Rock	1.77-2.30	South
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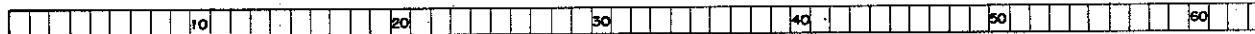
1081 + 10	18	244	240	III	Std.	Positive	3.28	3.54	16.5	19.5	0	10' Soil & Remain. Rock	1.61-1.36	North
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1107 + 50	60	320	320	III	B ₁	Positive	1.09	7.82	24.0	25.5	45 R	5' Soil & Remain. Rock	2.27-2.13	North
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1229 + 73	18	252	252	III	Std.	Positive	3.61	3.57	12.5	16.0	0	6' Soil & Remain. Rock	2.12-1.66	North
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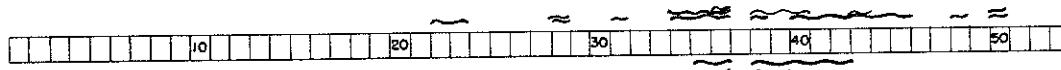


200

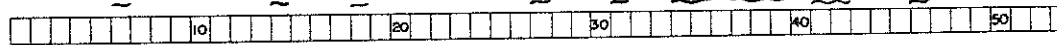
PROJECT NO. I 75-6(5)123 SCOTT COUNTY

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height West (ft.)	Embankment Height East (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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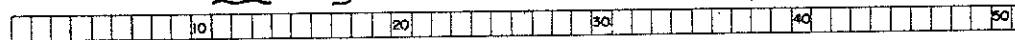
65 + 30	48	208	212	III	B	Positive	0.77	0.63	12.0		30 R	Soil & Rock	2.28	East
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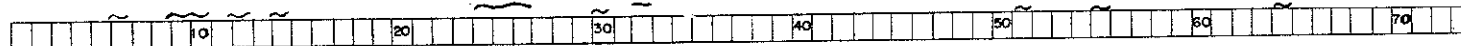
110 + 50	36	212	212	III	B	Positive	1.98	4.08	20.0	15.0	15 L	Soil & Rock	1.37 - 1.83	East
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153 + 25	42	204	204	III	B	Positive	1.86	1.70	8.0	12.5	15 L	Soil & Rock	3.43 - 2.19	East
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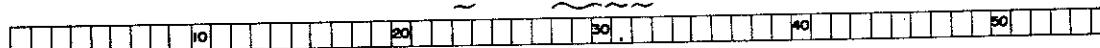
166 + 25	36	296	294	III	B	Positive	2.03	1.93	19.0	14.5	30 L	Soil & Rock	1.44 - 1.83	East
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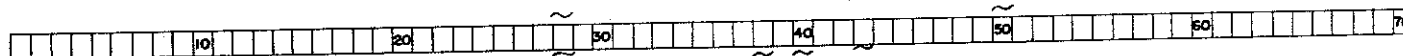
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PROJECT NO. I 75-6(5)123 SCOTT COUNTY

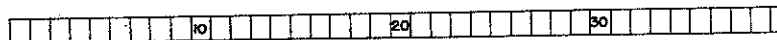
Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment West (ft.)	Embankment Height East (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
212 + 30	30	220	220	III	B ₁	Positive	1.86	2.35	22.0	27.0	0	Soil & Rock	2.55 - 2.08	East



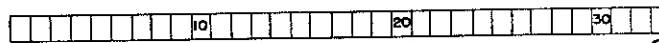
322 + 00	54	284	283	III	B ₁	Out to 176'- Pos. 176' to Inlet-Neg.	1.13	-1.23	21.0	22.5	30 R	Soil & Rock	2.67 - 2.49	West
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36 + 50 SW Ramp	30	152	156	III	B ₁	Out to 56'-Pos. 56' to Inlet-Neg.	2.43				30 R			East
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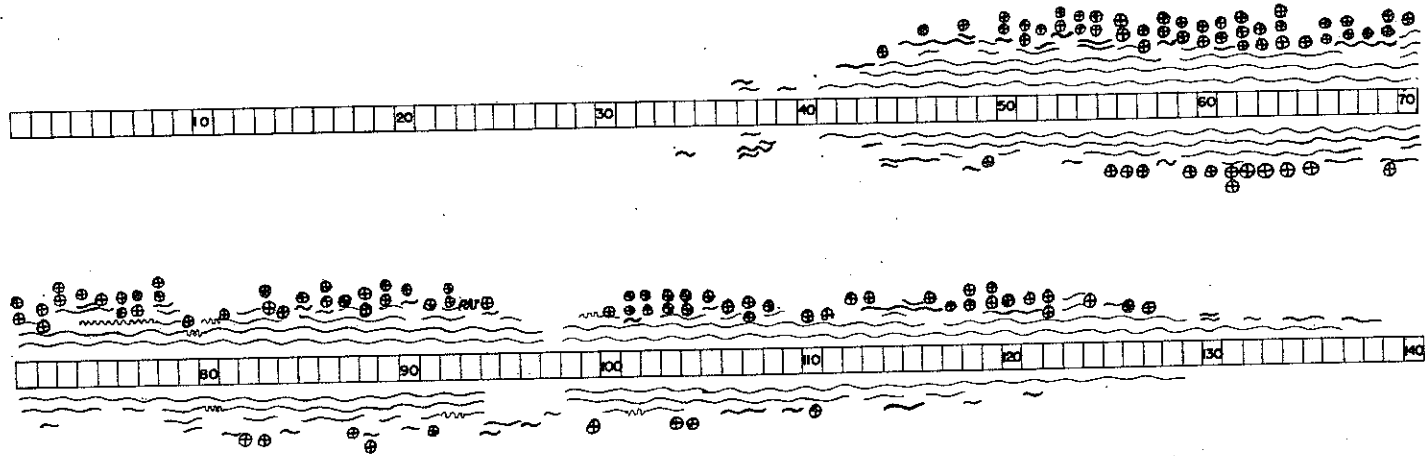
47 + 40 U. S. 62	30	132		III	B ₁	Positive	5.15	5.02	24.5	18.0	0	Soil & Rock	2.29 - 3.12	East
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BOB

PROJECT NO. I 75-6(5)123 SCOTT COUNTY

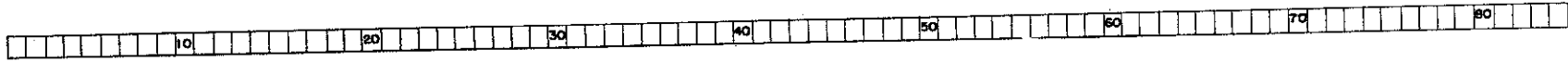
Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height West (ft.)	Embankment Height East (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
37 + 50 US 460 SW Ramp	48	560	560	III	B & E ₁	Positive	1.23	1.22	36.0	34.0	51 R	Soil & Rock	0.78 for B 1.60 for E ₁	East



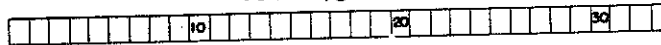
609

PROJECT NO. I 75-6(4)129 SCOTT COUNTY

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height West (ft.)	Embankment Height East (ft.)	Skew (°)	Embankment Material	Factor of Safety As Constructed	Location of Inlet
71 + 00	24	336	336	IV	B ₁	Positive	3.57	0.19	35.5	34.0	25 R	Soil & Rock	2.37 - 2.47	East

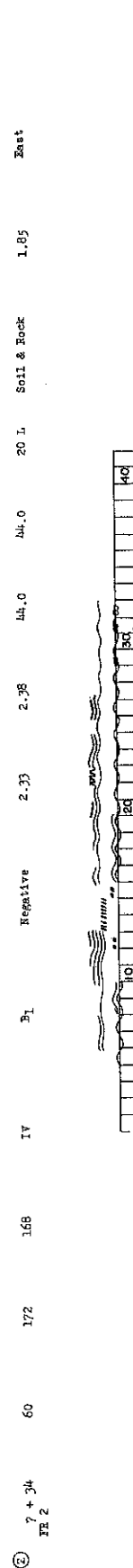
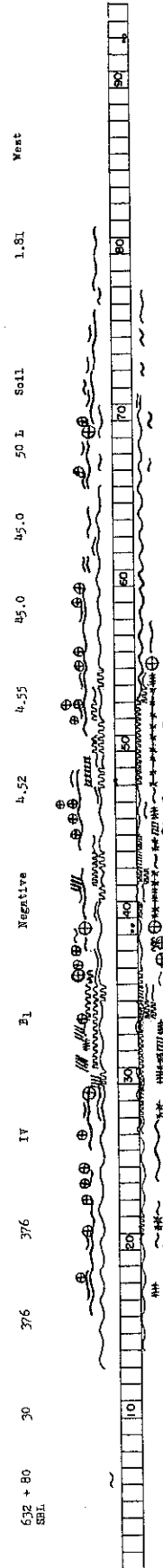
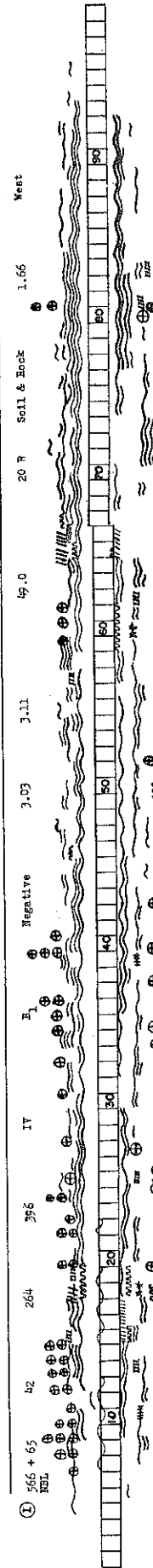


97 + 50	30	132	132	III	B ₁	Positive	0.97	1.17	18.0	16.5	30 R	Soil & Rock	3.12 - 3.40	East
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PROJECT NO. I 75-7(11)151 GRANT COUNTY

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (\$)	Actual Grade (\$)	Embankment Height West (ft.)	Embankment Height East (ft.)	Spew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
① 565 + 65 REL	42	264	256	IV	E ₁	Negative	3.05	3.11	49.0	49.0	20 R	Soil & Rock	1.66	West
562 + 80 SBL	30	376	376	IV	E ₁	Negative	4.52	4.55	45.0	45.0	50 L	Soil	1.81	West
② 7 + 34 FR 2	60	172	168	IV	E ₁	Negative	2.33	2.38	44.0	44.0	20 L	Soil & Rock	1.85	East



- ① 90° Bend Sections 66-67, Sections 67-99 added after 1960 survey
- ② Slide occurred summer 1961, pipe damaged during replacement of embankment.

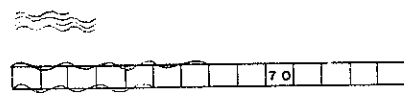
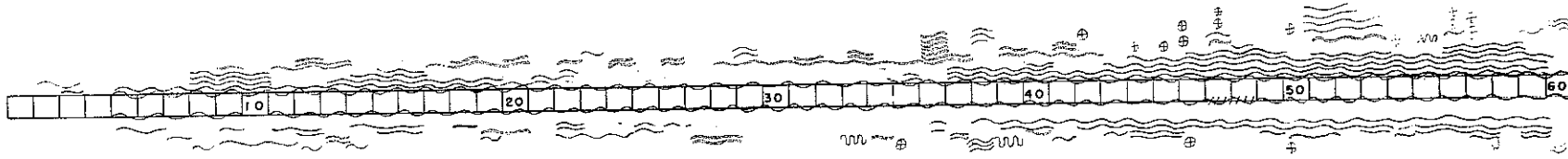
PROJECT NO. I 75-7(3)155 GRANT COUNTY
 SOUTH OF CLAY LICK CREEK TO NORTH OF CASSON ROAD

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height West (ft.)	Embankment Height East (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
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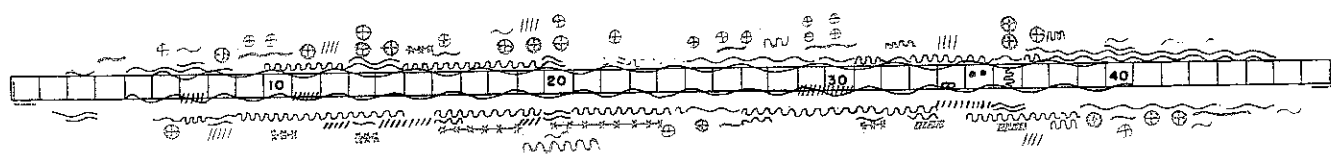
782 + 00	42	300	300	IV	B ₁	Out. to 58'-Neg. 58' to 300'-Pos.	2.17	2.18	41.0	44.0	5 L	15' Soil & Remain. Rock	1.99-1.85	West
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794 + 60	72	372	444	III	B ₁	Positive	1.91	1.91	35.0	32.5	45 R	Soil & Rock	1.55-1.67	East
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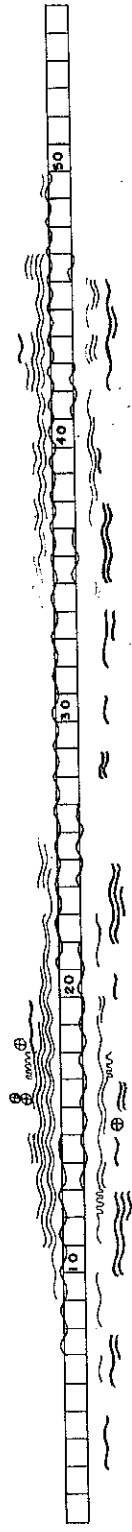
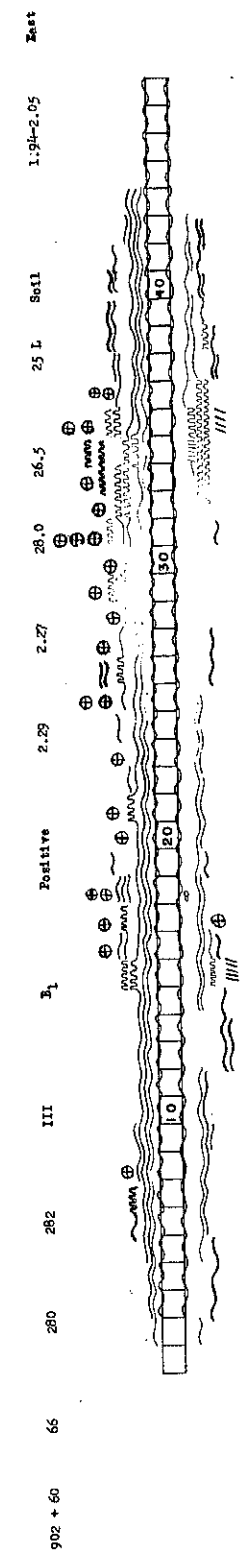
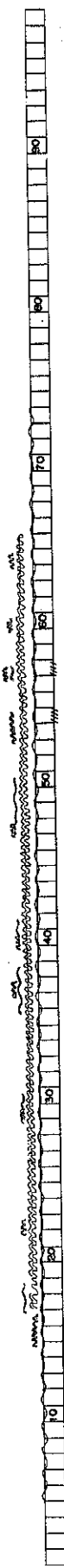


807 + 16	36	292	282	III	B ₁	Negative	6.10	6.36	39.0	33.0	20 L	Soil & Rock	1.39-1.65	East
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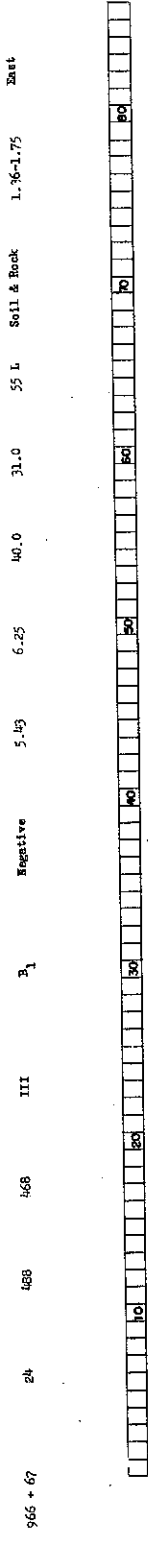
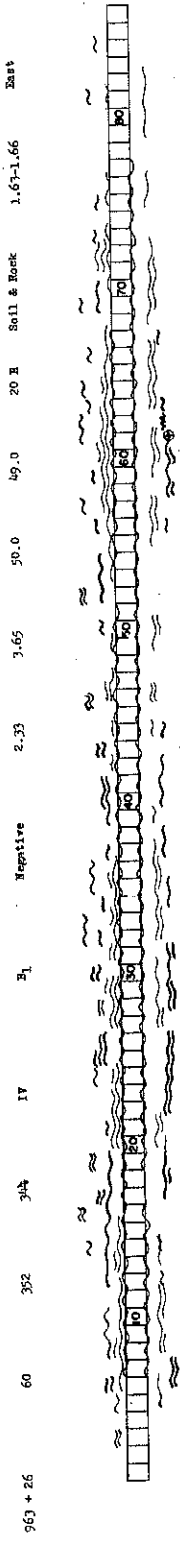
PROJECT NO. I 75-7(3)155 GRAFF COUNTY
 SOUTH OF CLAY LICK CREEK TO NORTH OF CASSON ROAD

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Reinforcement Weight (ft.)	Reinforcement Height (ft.)	Slope (%)	Reinforcement Material	Factor of Safety as Constructed	Location of Inlet
835 + 90	36	388	394	IV	B ₁	Positive	0.13	0.13	48.0	47.0	40 R	10' Soil & Remain. Rock	1.70-1.73	West
902 + 60	66	280	282	III	B ₁	Positive	2.29	2.27	28.0	26.5	25 L	Soil	1.94-2.05	East
928 + 95	48	324	330	IV	B ₁	Positive	2.16	2.58	50.0	47.5	5 R	20' Soil & Remain. Rock	1.65-1.72	East



PROJECT NO. I 75-7(5) 160 GENT COUNTY
 SOUTH OF SHERMAN-RT. 2108 ROAD TO KENTON COUNTY LINE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment Height West (ft.)	Embankment Height East (ft.)	Skew (°)	Subsidence Material	Factor of Safety as Constructed	Location of Inlet
935 + 70	54	420	420	IV	B ₁	Positive	1.05	1.05	44.0	45.0	45 L	20' Soil & Remain. Bank	1.85-1.90	East
963 + 26	60	382	344	IV	B ₁	Negative	2.33	3.65	50.0	49.0	20 H	Soil & Rock	1.67-1.66	East
965 + 67	24	488	468	III	B ₁	Negative	5.45	6.25	40.0	31.0	55 L	Soil & Rock	1.76-1.75	East



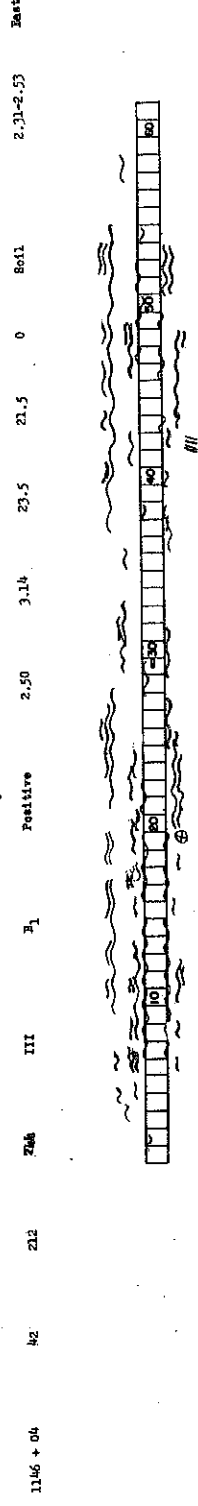
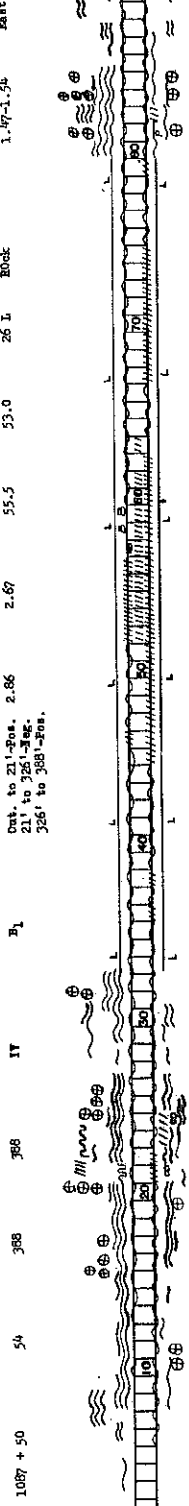
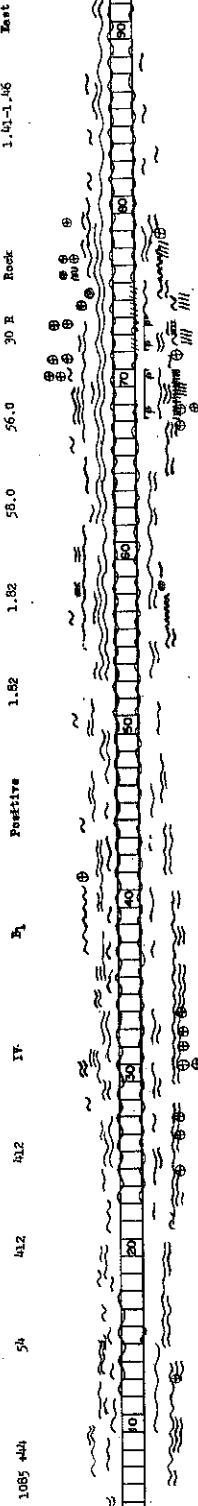
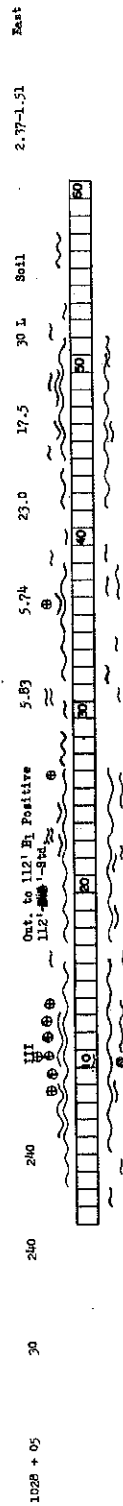
PROJECT NO. I 75-7(5) 160 GRANT COUNTY
 SOUTH OF SHERMAN-MT. ZION ROAD TO KENTON COUNTY LINE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment West (ft.)	Height East (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet	
978 + 12	42	280	272	III	E ₁	Positive	2.36	2.30	40.0	38.0	0	Rock	1.76-1.83	East	
988 + 18	36	296	300	IV	E ₁	Positive	2.03	2.00	42.0	43.0	15 L	Rock	1.94-1.90	East	
1001 + 22	30	276	284	III	E ₁	Positive	3.99	3.88	28.0	25.0	30 R	Soil & Rock	1.94-2.18	East	
1004 + 33	36	292	292	III	E ₁	Positive	3.42	3.42	29.0	26.0	35 L.	Soil & Rock	1.87-2.09	East	

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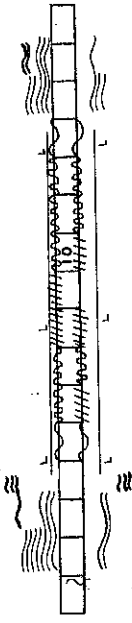
PROJECT NO. I 75-7(5) 160 GRANT COUNTY
 SOUTH OF SHERMAN-WT. HIGH ROAD TO LENOX COUNTY LINE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Abutment West (ft.)	Abutment East (ft.)	Sew (ft.)	Embankment Material	Water of Safety or Constructed	Location of Inlet
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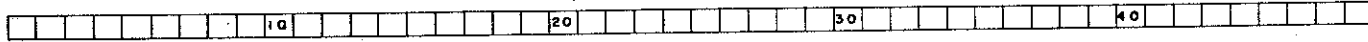
PROJECT NO. 175-7(5) 160 GRADE COUNTY
 SOUTH OF SHEWAN-WT. ZION ROAD TO KENTON COUNTY LINE

Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment West (ft.)	Embankment East (ft.)	Skew (°)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
27 + 82 FR 9A	72	112	126	III	E ₁	Negative	0.54	1.96	25.0	25.0	35 E	10' Soil & Remain. Rock	2.18	East

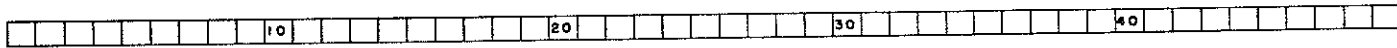


PROJECT NO. I 75-8(12) 161 KENTON COUNTY
 BOONE COUNTY LINE TO SOUTH OF U.S. 25 INTERSECTION

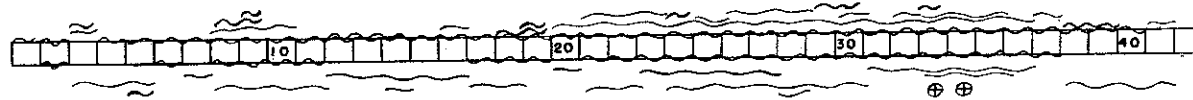
Station Number	Diameter (in.)	Design Length (ft.)	Actual Length (ft.)	Class	Bedding	Projection	Design Grade (%)	Actual Grade (%)	Embankment West (ft.)	Height East (ft.)	Skew (o)	Embankment Material	Factor of Safety as Constructed	Location of Inlet
194 + 21	18	296	288	III	Std.	I to 128-Neg. 128 to 288-Pos.	I to 96+16.3 96' to Out-2.9	14.1 3.2	24.0	17.0	30 L	Soil	1.10-1.56	East



275 + 50	24	344	294	III	Std.	Positive	3.49	1.36	15	15	45 R	Soil	1.76	East
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342 + 60	48	264	252	III	Std.	Inlet & Outlet-Pos. 50' in mid.-Neg.	1.44	4.84	26.0	24.0	21 L	10' Soil & Remain. Rock	1.02-1.10	East
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213