CHAPTER FIVE

DRAINAGE DESIGN

GENERAL DRAINAGE DESIGN INFORMATION 5-1

Refer to the Roadway Standard Drawings for the standard method of pipe installation, guide for shoulder drain installation, sub-drains, endwalls, catch basins, drop inlets, junction boxes, manholes, pipe end sections and other drainage related items.

Plans requiring step by step approval are to be submitted to the Federal Highway Administration (FHWA) for preliminary approval at the time the drainage design is requested. This procedure will allow the FHWA to comment on basic design elements prior to field review.

MASONRY DRAINAGE STRUCTURES 5-2

Optional types of construction are allowed for catch basins, drop inlets, junction boxes, and manholes. Payment will be made under Section 840 of the Standard Specifications for Roads and Structures, dated January 2002. Any questions and information related to the provisions shall be directed to the Contract Officer. Any questions related to the designs shall be directed to the Plan Review Engineer.

Payment for grates, frames, pipe collars, and pipe plugs will also be made in accordance with Section 840 of the Standard Specifications for Roads and Structures.

When it is necessary to replace or convert an existing drainage structure, documentation of the project file is required. Documentation will be the responsibility of the Hydraulic Engineer.

The following chart specifies construction types permitted and an example of computing quantities is also provided.

MASONRY DRAINAGE STRUCTURES (continued) 5-2

TYPE CONSTRUCTION PERMITTED

STRUCTURE	BRICK	CONCRETE	PRECAST	SOLID BLOCK
Brick Catch Basin Std. 840.01	X			X
Conc. Catch Basin Std. 840.02		X	X	
Conc. Open Throat Catch Basin Std. 840.04		X	X	
Brick Open Throat Catch Basin Std. 840.05	X			X
Conc. Bridge Approach Drop Inlet Std. 840.13		X		
Conc. Drop Inlet Std. 840.14		X	X	
Brick Drop Inlet Std. 840.15	X			X
Conc. Grated D.I.,Type "A" Std. 840.17		X	X	
Brick Grated D.I.,Type "A" Std. 840.26	X			X
Conc. Grated D.I.,Type "B" Std. 840.18		X	X	
Brick Grated D.I.,Type "B" Std. 840.27	X			X
Conc. Grated D.I.,Type "D" Std. 840.19		X	X	
Brick Grated D.I.,Type "D" Std. 840.28	X			X
Driveway Drop Inlet Std. 840.30		X		
*Conc. Junction Box Std. 840.31		X	X	
*Brick Junction Box Std. 840.32	X			X
Traffic Bearing Junction Box Std. 840.34	X		X	X
Traffic Bearing Grated Drop Inlet Std. 840.35	X	X	X	X
Traffic Bearing Grated Drop Inlet Std. 840.36		X		
Spring Box Std. 840.41	X	X	X	X
Manhole Std. 840.51, 840.52 or 840.53	X		X	X

* Special design junction boxes or manholes will be required if the depth of fill does not fall within the range specified on the NCDOT Roadway Standard Drawings

MASONRY DRAINAGE STRUCTURES (continued) 5-2

Payment for all of the above structures will be made in accordance with Item 840 - "Masonry Drainage Structures".

* Special Design Junction Boxes or manholes will be required if the depth of fill does not fall within the range specified on the NCDOT Roadway Standard Drawings.

MASONRY DRAINAGE STRUCTURES QUANTITY PER EACH BASIS 5-2A

A drainage structure which incorporates an opening for circular pipe not exceeding 48 inches in diameter will be measured and paid for on a "per each" basis up to a height of 5 feet at the contract price per each for "Masonry Drainage Structures". For an example of figuring quantities for drainage structures, see 5-2C of this Chapter.

MASONRY DRAINAGE STRUCTURES QUANTITY PER LINEAR FOOT BASIS 5-2B

The portion of a drainage structure from 5.1 feet up to and including 10 feet will be figured and paid for at the contract unit price per linear foot for "Masonry Drainage Structures". The portion of the Drainage Structure above 10 feet shall be measured and paid for at 1.3 times the contract unit price per linear foot for masonry drainage structures. The height of the drainage structures will be measured vertically to the nearest tenth of a foot from the top of the bottom slab to the top of the wall.

For an example of calculating quantities for drainage structures, see 5-2C of this Chapter.

FIGURE 1 **5 – 2C**

EXAMPLE FOR COMPUTING QUANTITY OF MASONRY DRAINAGE STRUCTURE

* TOTAL LIN. FT. FOR PAY QUANTITY SHALL BE COL. "A" + (1.3 X COL. B)

	QUANTITIES FOR DRAINAGE STRUCTURES		
		*LIN. FT.	
		A	B
HEIGHT OF STRUCTURES	PER EACH (0' THRU 5.0')	5.1' THRU 10.0'	10.1' AND ABOVE
4.5'	1	–	–
8.0'	1	3	–
15.2'	1	5	5.2
9.0'	1	4	–
18.0'	1	5	8
TOTAL	5	17	13.2
*GRAND TOTAL	5**	35***	

* 17 + (1.3 X 13.2) = 34.2 LIN.FT.
SAY 35 LIN.FT.

PAY ITEMS:
MASONRY DRAINAGE STRUCTURE 5 EACH **
MASONRY DRAINAGE STRUCTURE 35 LIN. FT. ***

MASONRY DRAINAGE STRUCTURES QUANTITY - VOLUME BASIS 5-2D

Any masonry drainage structure which incorporates an opening for circular pipe exceeding 48 inches in diameter, or for pipe arch of any size, will be measured and paid for on a volume basis. The quantity of masonry to be paid for will be the number of cubic yards of cast-in-place concrete, brick, or precast masonry which has been incorporated into the structure. These quantities are provided in the Roadway Standard Drawings.

MINIMUM PIPE CLEARANCE REQUIREMENT FROM INVERT TO SUBGRADE 5-3

	CLEARANCE DISTANCE	
Pipe Size (in.)	R. C. Pipe	C. S. Pipe
RCP	(ft.)	(ft.)
15	2.4	2.3
18	2.7	2.6
24	3.3	3.1
30	3.8	3.6
36	4.3	4.1
42	4.9	4.6
48	5.4	5.1
54	6.0	5.6
60	6.5	6.1
66	7.0	6.6
72	7.6	7.1

NOTE: This is a minimum desirable clearance and can be reduced with Special Structural and/or Installation Provisions.

MAXIMUM ALLOWABLE FILL HEIGHTS
OVER REINFORCED CONCRETE PIPE 5-4

Class III	All sizes 23 feet
Class IV	All sizes 32 feet
Class IV with Method B installation	All sizes 60 feet
Class V with Method B installation	All sizes 90 feet

Use material thickness on all pipe except structural plate pipe. Use gage for structural plate pipe and on all pipe arches. Use Method "B" for R.C. Pipes under fills greater than 32 feet.

TABLES 5 & 6

5 - 5

CORRUGATED STEEL PIPE – HEIGHT OF FILL LIMITATIONS

2" x" or 2-2/3" x" Corrugations – Riveted, Welded, or Helical Fabrication

Size	Minimum Fill Over Top of pipe	0.064" (16 Ga.)	0.079" (14 Ga.)	0.109" (12 Ga.)		0.138" (10 Ga.)		0.168" (8 Ga.)	
		Cir.	Cir.	Cir.	Elong.	Cir.	Elong.	Cir.	Elong.
		Maximum Fill Above Top of Pipe							
12"	12"	83	90						
15"	12"	67	73	93					
18"	12"	55	67	70					
24"	12"	36	40	47		57			
30"	12"		31	35		40		50	
36"	12"		20	30		35		40	
42"	12"			26	59	29	54	35	58
48"	12"			24	48	25	50	26	52
54"	12"			23	45	24	48	25	50
60"	12"					23	46	23	48
66"	12"	NOTE: WITH METHOD "B" INSTALLATION				20	40	23	46
72"	12"	FILL HEIGHTS MAY BE INCREASED				18	30	22	40
78"	12"	BY 50% OF TABLE VALUES						22	30
84"	12"							22	25

See Roadway Standard Drawings, Std. No. 300.02

5 - 6

CORRUGATED STEEL PIPE ARCHES – HEIGHT OF FILL LIMITATIONS

PIPE ARCH DIMENSION	MINIMUM COVER BELOW SUBGRADE	MINIMUM THICKNESS (t)	MAXIMUM FILL TOP OF PIPE FOR CORNER BEARING PRESSURE IN TONS/SQ. FT.	
Inches	Inches		2 Tons	3 Tons
17 X 13	18"	0.064"	16	23
21 X 15	18"	0.064"	15	22
24 X 18	18"	0.064"	13	19
28 X 20	18"	0.064"	12	18
35 X 24	18"	0.079"	11	17
42 X 29	18"	0.079"	10	15
49 X 33	18"	0.109"	10	14
57 X 38	18"	0.109"	10	14
64 X 43	18"	0.109"	10	14
71 X 47	18"	0.138"	10	15
77 X 52	18"	0.168"	10	15
83 X 57	18"	0.168"	9	14

Heavier gages may be used where required for abrasion, corrosion or other factors, but not for additional fill on arches as corner pressures govern amount of fill.

TABLES 7 & 7A

CORRUGATED ALUMINUM PIPE 5 - 7
3" X 1" CORRUGATION
MAXIMUM HEIGHT OF COVER LIMITS IN FEET

SIZE	AREA	MINIMUM COVER	THICKNESS IN INCHES							
			.075		.105		.135		.164	
			CIR.	EL.	CIR.	EL.	CIR.	EL.	CIR.	EL.
36	7.1	1	24	37	27	51	30	61	34	68
42	9.6	1			23	44	25	51	27	55
48	12.6	1			21	38	22	45	24	48
54	15.9	1			20	34	21	42	22	44
60	19.6	1			19	31	20	40	20	41
66	23.8	1			18	28	19	38	19	39
72	28.3	1			18	25	18	37	19	38
78	33.0	1			18	23	18	31	18	37
84	38.0	1.5			17	19	18	25	18	31
90	44.0	1.5			15		17	20	18	25
96	50.0	1.5			12		16		17	21
102	57.0	2					14		17	
108	64.0	2					11		14	
114	71.0	2							12	
120	78.0	2							10	

SEE ROADWAY STANDARD DRAWINGS, STANDARD NO. 300.02

CORRUGATED STEEL PIPE - HEIGHT OF FILL LIMITATIONS
3" X 1" CORRUGATIONS 5 - 7A
RIVETED, WELDED, OR HELICAL FABRICATION

SIZE	MINIMUM FILL OVER TOP	0.079" (14 GAGE)		0.109" (12 GAGE)		0.138" (10 GAGE)		0.168" (8 GAGE)	
		CIR.	EL.	CIR.	EL.	CIR.	EL.	CIR.	EL.
36	1	47	60	58	88	70	106	82	118
42	1			44	76	51	91	59	101
48	1			36	66	41	80	46	88
54	1			31	59	35	71	38	76
60	1			28	58	31	62	33	66
66	1			26	48	30	58	32	64
72	1			25	44	28	56	30	60
78	1			24	41	26	52	28	56
84	1.5			22	36	24	46	28	56
90	1.5			20	33	22	43	26	53
96	1.5			17	31	20	40	25	49
102	2.0					19	38	23	46
108	2.0					18	35	21	42
114	2.0					16	32	19	38
120	2.0					15	29	18	36

Note: With method "B" installation, fill heights may be increased by 50%.
See Roadway Standard Drawings, Std. No. 300.02

TABLES 8 & 9

5 - 8

CORRUGATED STEEL PIPE ARCHES – HEIGHT OF FILL LIMITATIONS
3" X 1" CORRUGATION
RIVETED, WELDED, OR HELICAL FABRICATION

Equiv. Pipe Dia.	Pipe Arch Dimension	Minimum Cover	Minimum Gage	Maximum Fill Above Top of Pipe for Corner Pressure in Tons/sq. ft.	
	Inches	Inches		2 tons	3 tons
36	40 x 31	12	14(.079)	14	21
42	46 x 36	12	12(.109)	14	21
48	53 x 41	12	12(.109)	14	21
54	60 x 46	12	12(.109)	14	21
60	66 x 51	12	12(.109)	14	21
66	73 x 55	12	12(.109)	19	28
72	81 x 59	12	12(.109)	17	26
78	87 x 63	12	12(.109)	16	24
84	95 x 67	12	12(.109)	15	22
90	103 x 71	18	12(.109)	13	20
96	112 x 75	18	12(.109)	13	18
102	117 x 79	18	10(.138)	12	18
108	128 x 83	24	10(.138)	11	16
114	137 x 87	24	10(.138)	10	15
120	142 x 91	24	10(.138)	10	15

Heavier gages may be used where required for durability or other factors,but not for additional fill,as corner pressures govern amount of fill.

5 - 9

CORRUGATED ALUMINUM PIPE

2" x" or 2-2/3" x" Corrugations – Riveted, Welded, or Helical Fabrication

Size	Minimum Fill Over Top of pipe	0.060" (16 Ga.)		0.079" (14 Ga.)		0.109" (12 Ga.)		0.138" (10 Ga.)		0.168" (8 Ga.)	
		Cir.	Elong.	Cir.	Elong.	Cir.	Elong.	Cir.	Elong.	Cir.	Elong.
Inches		Maximum Fill Above Top of Pipe									
12"	12"	45		45		77					
18"	12"	30		30		43		50		57	
24"	12"			22		30		34		37	
30"	12"			18		25		27		29	
36"	12"					23		24		25	
42"	12"				25	23	42	23	46	23	46
48"	12"					21	29	22	37	22	44
54"	12"						20	21	26	22	31
60"	12"						15	19	19	22	24
66"	12"							14	14	17	17
72"	12"									13	13

With Method "B" installation increase fill heights allowable by 33%

TABLE 10

CORRUGATED ALUMINUM PIPE ARCHES

5 - 10

2" x" or 2-1/2" x" Corrugations – Riveted or Helical Fabrication

PIPE ARCH DIMENSION	CORNER RADIUS	MINIMUM COVER BELOW SUBGRADE	MINIMUM THICKNESS (t)	MAXIMUM FILL TOP OF PIPE FOR CORNER BEARING PRESSURE IN TONS/SQ. FT.	
Inches	Inches	Inches		2 Tons	3 Tons
18 x 11	4-3/4	18"	0.060"	16	23
22 x 13	4-3/4	18"	0.060"	15	22
25 x 16	4-1/2	18"	0.075"	13	19
29 x 18	4-1/2	18"	0.075"	12	18
36 x 22	5	18"	0.075"	11	17
43 x 27	5-1/2	18"	0.105"	10	15
50 x 31	6	18"	0.105"	10	14
58 x 36	7	18"	0.135"	10	14
65 x 40	8	18"	0.135"	10	15
72 x 44	9	18"	0.164"	10	15

Heavier gages may be used where required for abrasion, corrosion or other factors, but not for additional fill on arches as corner pressures govern amount of fill.

TABLE 11

STRUCTURAL PLATE STEEL PIPE

6" x 2" Corrugations – Bolted Fabrications Maximum Fill Heights Over Top of Pipe

SIZE	MIN. COVER OVER TOP OF PIPE	0.109" 12 GAGE		0.138" 10 GAGE		0.168" 8 GAGE		0.188" 7 GAGE		0.218" 5 GAGE		0.249" 3 GAGE		0.280" 1 GAGE		0.280" * 1 GAGE 6 Bolts		0.280" * 1 GAGE 8 Bolts	
		CIR.	ELONG	CIR.	ELONG	CIR.	ELONG	CIR.	ELONG	CIR.	ELONG	CIR.	ELONG	CIR.	ELONG	CIR.	ELONG	CIR.	ELONG
60	12"	42	42	61	62	70	81	76	93	86	112	96	132	106	144	184	184	220	220
66	12"	38	38	49	58	60	74	64	85	72	102	80	120	83	130	168	168	198	198
72	12"	35	35	38	51	50	67	53	77	59	93	65	108	71	118	157	157	181	181
78	12"	32	32	36	47	44	62	46	71	51	83	55	100	60	109	143	143	159	159
84	12"	30	30	35	44	39	57	41	66	45	75	49	95	52	102	131	131	145	145
90	12"	28	28	33	40	35	53	37	61	40	72	43	84	45	91	122	122	133	133
96	12"	26	26	31	38	33	50	34	58	36	70	39	78	41	82	115	115	124	124
102	24"			29	36	31	47	32	54	34	65	36	72	38	75	107	107	117	117
108	24"			27	34	29	45	30	51	32	62	34	68	35	70	102	102	112	112
114	24"			26	33	28	42	29	48	31	58	32	63	34	65	96	96	107	107
120	24"			25	31	27	40	28	46	29	56	30	60	33	62	92	92	104	104
126	24"					26	37	26	44	27	52	29	58	30	59	86	86	100	100
132	24"					25	36	25	42	26	50	28	56	29	58	83	83	98	98
138	24"					24	34	25	39	25	48	27	54	28	55	79	79	94	94
144	24"					24	33	25	38	25	46	26	52	27	54	76	76	92	92
156	24"					23	31	23	35	24	43	25	50	26	52	70	70	85	85
168	24"					23	28	23	33	23	40	24	47	25	50	65	65	78	78
180	24"					22	27	22	31	23	37	23	44	24	48	61	61	73	73
192	24"					22	25	22	29	23	35	23	41	23	45	57	57	69	69
204	36"					22	23	22	27	22	33	22	39	23	42	54	54	65	65

* EXCELLENT BACKFILL 95% DENSITY

PIPE CLASSIFICATIONS 5-12

Pipe classifications will be provided by the Hydraulics Unit for cross drains under high type pavement, for special situations, and for storm drains and special drainage systems. (High type pavement is any Portland Cement Concrete Pavement, or any Asphalt Concrete Pavement at least 2″ thick.)

For cross drains under low type pavement, the contractor has the option of using either reinforced concrete pipe culverts or bituminous coated corrugated steel pipe culverts unless otherwise specified by the Hydraulics Unit. Pipe alternates shall be shown on the summary sheets.

For driveway pipe through 24″, the type of pipe will be optional between plain concrete pipe culverts, HDPE smooth lined corrugated plastic pipe and corrugated steel pipe culverts. Pipe shall be shown on the summary sheets. The above procedure will be followed unless otherwise specified by the Hydraulics Unit.

For temporary detours, use plain C.S. Pipe Culverts.

See 5-12, Figure 1 of this Chapter for a detail showing typical pipe installations.

For additional information on drainage quantities sheets, see Part II, 8-2 of this Manual.

MEDIAN DROP INLETS 5-13

Narrow slot grates (Std. No's. 840.24 & 840.29) : use with grated drop inlets on non-controlled access projects and projects with heavy pedestrian traffic.

Wide slot grates (Std. No's. 840.20 & 840.22) : use with grated drop inlets on controlled access projects; however narrow slot grates (Std. No's. 840.24 & 840.29) will be used at locations that pedestrian traffic is anticipated.

Traffic bearing grated drop inlets (Std. No. 840.36) : use within a traveling lane (detour or permanent). Traffic bearing grated drop inlets (Std. No's. 840.35 or 840.36) shall also be used within 4′-0″ of lanes, except when placed in a concrete traffic island.

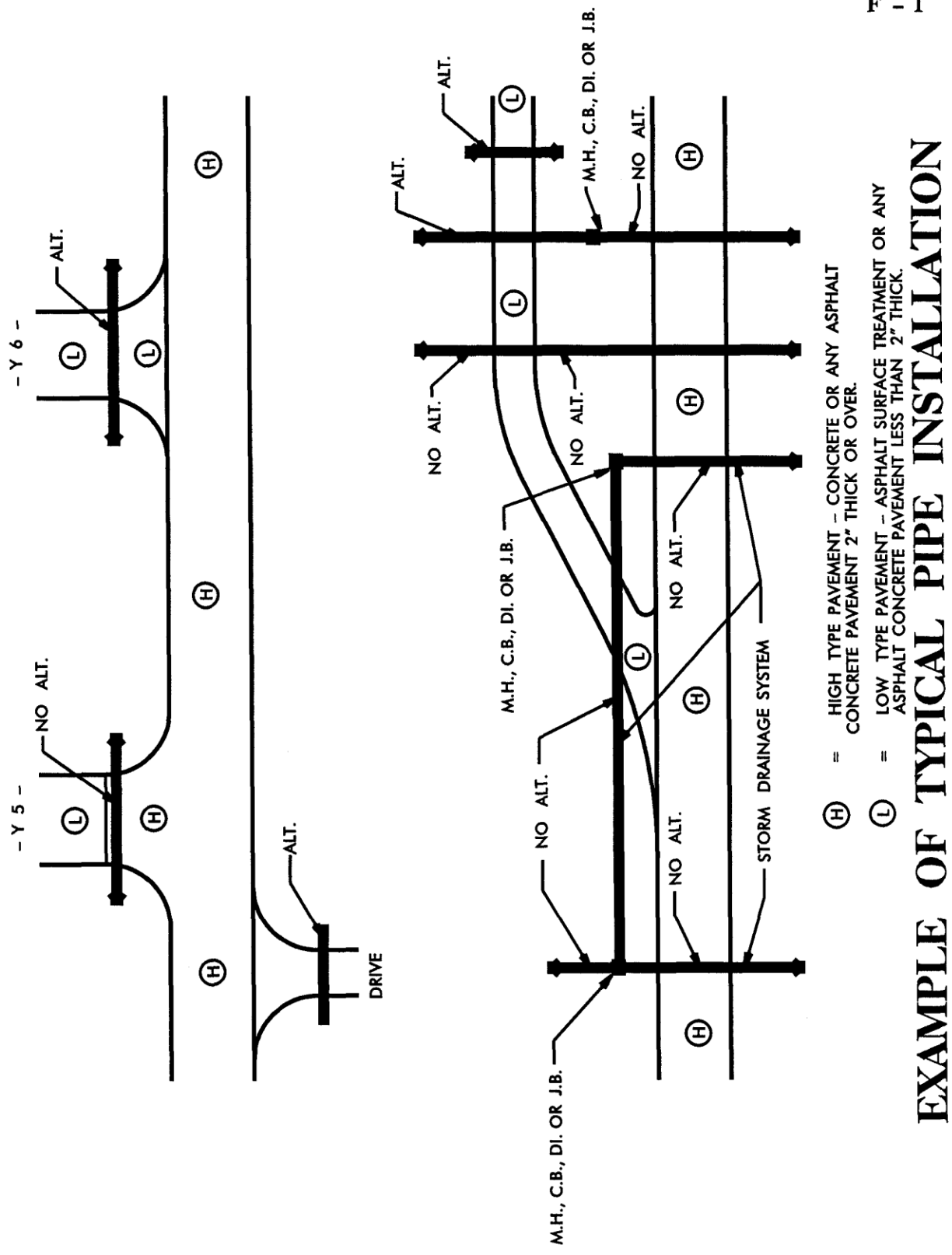
Steel frames and flat steel grates (Std. No. 840.37) : use where it has been determined that traffic bearing grated drop inlets are needed on controlled access projects in locations that pedestrian traffic is not anticipated. The Work Zone Traffic Control Unit or the Hydraulics Unit may specify other locations where these must be used due to special considerations such as in a travel lane.

Traffic bearing grated drop inlet Std. No. 840.36 is used exclusively with steel frame and grates.

STANDARD CATCH BASINS 5-14

Use type "E", "F", or "G" grates on standard catch basins unless specified otherwise by the Hydraulics Unit and discussed on field inspection with Division personnel. See Roadway Standard Drawings, Std. No. 840.03. Catch Basins, Std 840.01 or 840.02, placed in 2'-6" curb and gutter are suitable for use adjacent to travel lanes.

FIGURE 1 **5 - 12**
F - 1



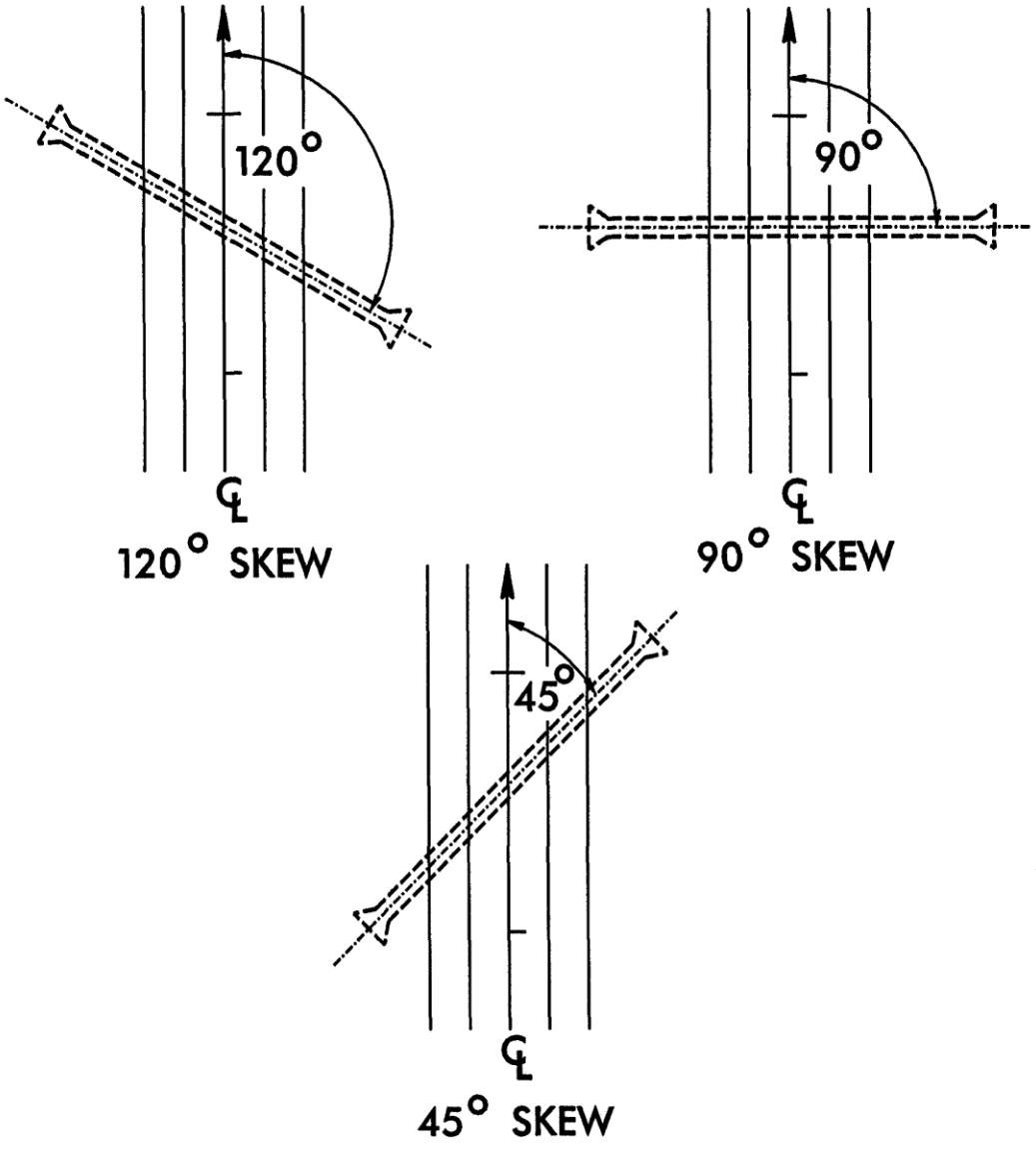
EXAMPLE OF TYPICAL PIPE INSTALLATION

The class of rip rap to be constructed on a project will be specified by the Hydraulics Unit when drainage recommendations are submitted to the Roadway Design Unit. See Part I, 1-5D and 1-5E of this Manual for additional information on rip rap for ditches.

FIGURE 1 **5 - 16**
F - 1

PIPE SKEW
SKEW ANGLE DESIGNATIONS

ALL SKEW ANGLE DESIGNATIONS SHALL BE THE ANGLE THAT A PIPE, BRIDGE, CULVERT, OR OTHER STRUCTURE MAKES WITH THE CENTERLINE OF THE ROADWAY AS MEASURED IN A CLOCKWISE DIRECTION FROM THE CENTERLINE. DESIGNATIONS WILL BE FROM 0 - 180 DEGREES.



SKEW ANGLE DESIGNATIONS

DRAINAGE DATA ON PLAN SHEETS 5-17

Pipe symbols, pipe sizes, structure abbreviations and structure numbers shall be shown on plan sheets (See 5-19 of this Chapter for information on structure numbers). Circular symbols shall also be shown on profile to indicate bed elevation at centerline of each cross-drainage pipe.

The minimum size pipe for open ended cross-drainage is 18″. A minimum size pipe of 12″ is required where the inlet is protected with a drainage structure such as a catch basin or drop inlet. The Hydraulics Unit will recommend the use of 12″ pipe at locations where the drainage requirements do not necessitate a 15″ RCP pipe. Smaller drop inlet boxes and catch basins should be utilized with the 12″ pipe.

HYDRAULIC DATA ON PLAN SHEETS 5-18

Hydraulic data related to pipe culverts, will be shown on the Roadway Profile Sheets. This data is required to be shown for all cross-drainage structures at the inlet end. Hydraulic data is not required to be shown for drainage structures that are draining the highway right of way. An example of this is median drainage.

The following hydraulic data will be shown on the profile sheets.

DRAINAGE AREA (ACRES)

Design Frequency	= _____YRS
Design Discharge	= _____CFS.
Design HW Elevation	= _____FT.
100 Year Discharge	= _____CFS.
100 year HW Elevation	= _____FT.
Overtopping Frequency	= _____YRS
Overtopping Discharge	= _____CFS.
Overtopping Elevation	= _____FT.

HYDRAULIC DATA ON PLAN SHEETS (continued) 5-18

Hydraulic data related to box culverts and bridges will be shown on the profile sheet near the proposed structure location. The Hydraulic data to be shown as follows:

Design Discharge = _____CFS.
Design Frequency = _____YRS
Design High Water = _____FT.
100 Year Discharge = _____CFS.
100 Year Frequency = 100 YRS
100 Year High Water = _____FT.

Overtopping Flood Elevation = _____ FT.
Frequency = _____ YRS.
Discharge = _____ CFS.

At bridge sites, the Hydraulics Unit will provide the estimated normal water surface elevation of the stream, river or lake along with the elevation on the date of survey. Any unusual anticipated fluctuations, such as an upstream dam that routinely opens and closes gates, should also be noted. This data will be shown on the profile sheet near the proposed structure location.

Estimated Normal Water
Surface Elevation = _____FT.
Date of Survey = _____
W.S. Elev. at Date of Survey = _____FT.

Hydraulic data to be included in the plans will be included with the drainage recommendations submitted by the Hydraulics Unit. When this information is not submitted, it will be the responsibility of the Roadway Design Project Design Engineer to obtain the information.

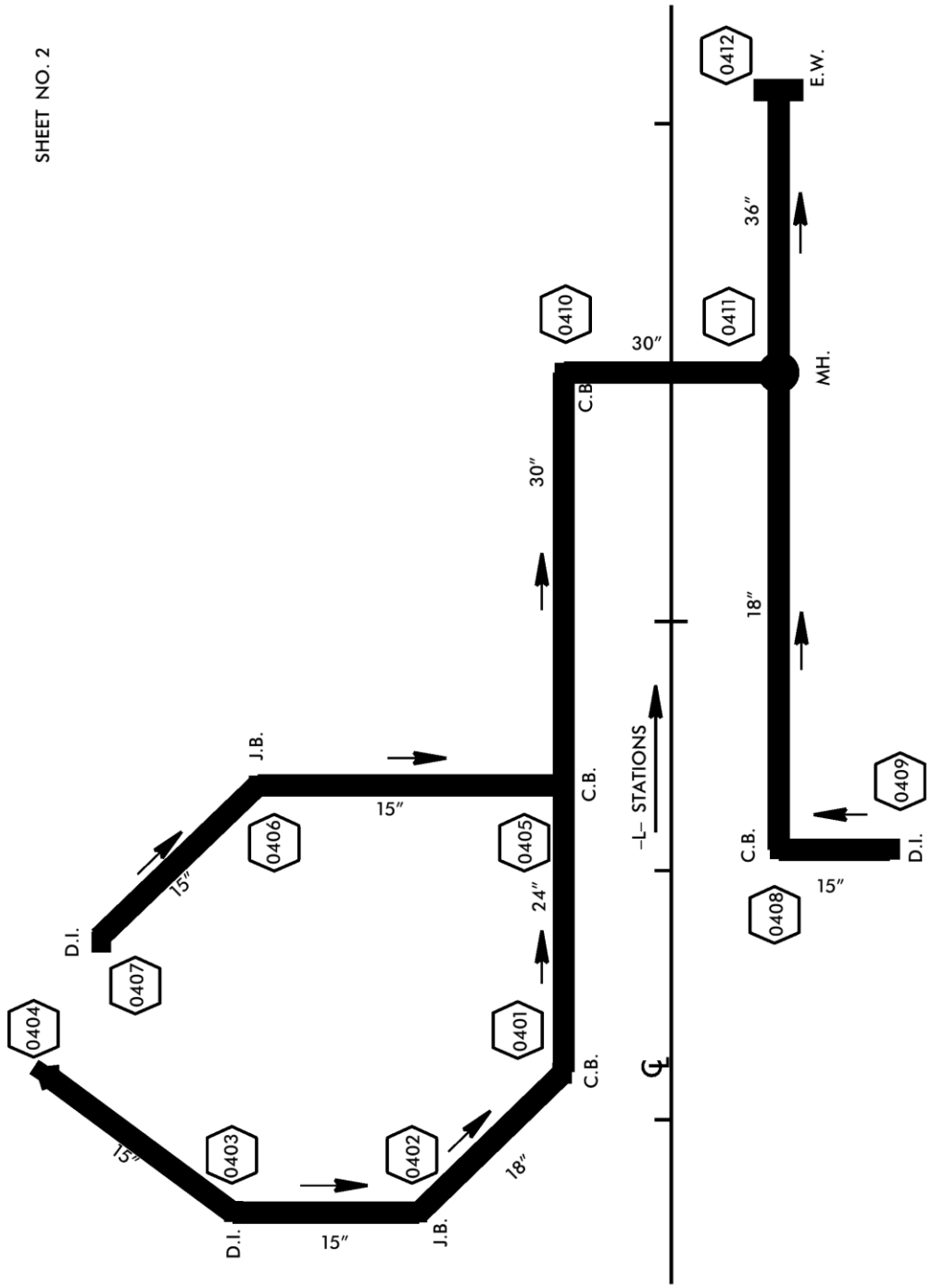
NUMERICAL SYSTEM FOR DRAINAGE LAYOUT 5-19

A numerical system for detailing drainage on plans has been developed to provide plans that are easier to finalize and follow. This system is especially beneficial on large urban projects, curb and gutter projects, and other type projects requiring an extensive system.

The numbering system sequence shall be consecutive for the entire project. The numbering shall be in chronological order, beginning at the start of the project and proceeding according to stations. Where drainage structures are opposite each other at the same station, number the structure on the left first. The drainage item numbers shall be shown in the following enclosure to distinguish them from parcel numbers. These structure numbers shall be shown on the Summary of Drainage Quantities sheets with the length of pipe and related items.

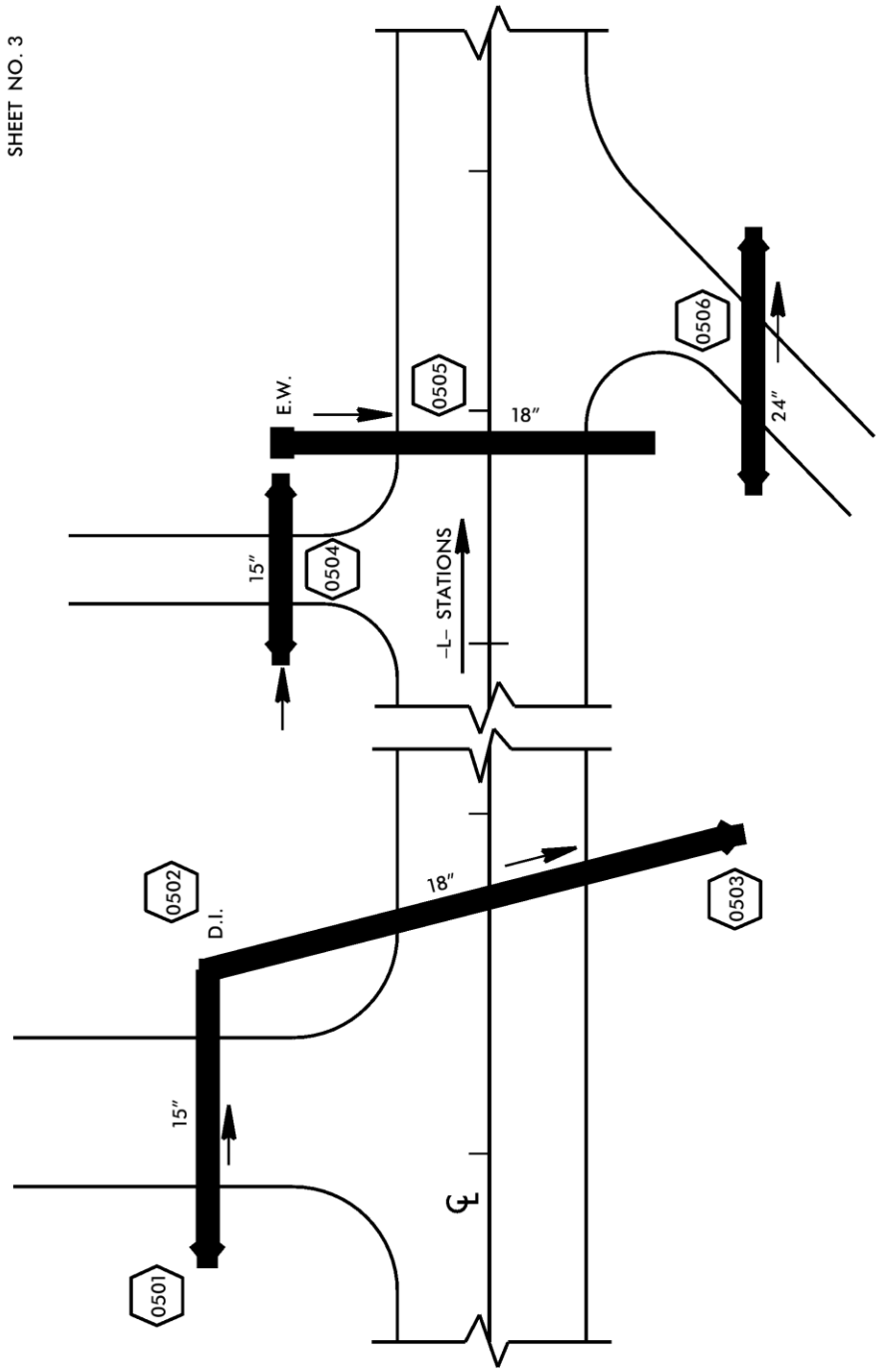
See 5-19 Figures 1 and 2, in this Chapter, for examples of Numerical Drainage layouts.

FIGURE 1 5 – 19
F – 1



NUMERICAL DRAINAGE LAYOUT
FOR COMPLEX DRAINAGE SYSTEM

FIGURE 2 **5 – 19**
F – 2



NUMERICAL DRAINAGE LAYOUT FOR SIMPLE DRAINAGE SYSTEM

PIPE END TREATMENT GUIDELINES 5-20

The following guidelines apply to TIP projects on the primary system. The guidelines do not apply to the secondary road system.

The criteria provided within this section (5-20) is intended as a "Guide" only. Engineering judgment should be used to determine if a different, but more appropriate, treatment is necessary.

The following guidelines for Pipe End Treatment shall be used in conjunction with the guidelines on clear zone distances. (See Part I, 1-4N, of this Manual to determine clear zone distances.)

Recommended Pipe End Treatments are listed below in order of preferential treatment. (Use the first recommendation listed under each heading if practical.)

A. Pipe End Treatment for Cross Pipes On All Roadways
(For further information, See "Roadway Standard Drawings", Std. No's. 310.03 and 310.05)

(1) Pipes Outside Clear Zone
Use endwall on inlet end for 36″or over (unless specified otherwise by Hydraulics Unit).

(2) Pipes Inside Clear Zone
a. Extend all pipe beyond clear zone and use endwall on inlet end for 36″ or over (unless specified otherwise by Hydraulics Unit).
b. Use a Cross Pipe end section (4:1 slope) for 30″ or under. Use guardrail for 36″ or over with endwall on inlet end (unless specified otherwise by Hydraulics Unit). On the outlet end, use a Cross Pipe end section (4:1 slope) with safety bars, or protect with guardrail.

B. Pipe End Treatment For Parallel Pipes
(For further information, See "Roadway Standard Drawings", Std. No's. 310.02 and 310.04)

(1) At Median Crossover Locations
a. Use a grated drop inlet with 10:1 or flatter slopes.
b. At existing locations without sufficient depth for drainage structures, use Parallel Pipe end sections and 6:1 slope.

(2) At Grade Intersections and Driveways

a. * Multilane Highways with Design Speed greater than 50 mph.

1. Place all pipe beyond Clear Zone (see Part I, 5-20, F-2 of this Manual) and use an endwall on inlet end of 36″ or over (unless specified otherwise by Hydraulics Unit).
2. On approach ends, use a grated drop inlet with 6:1 or flatter slopes where practicable and where existing or proposed drainage systems are available.
3. On approach ends, use parallel pipe end section (6:1 slope) for 24″ or under and use guardrail for 30″ or over. Trailing ends require no special treatment other than endwalls on the inlet end for 36″ or over (unless specified otherwise by Hydraulics Unit).

b. * Multilane Highways with Design Speeds ≤ 50 mph and All Two Lane Highways.

No special end treatment is required on two lane highways and multilane highways with design speeds ≤ 50 mph. However, endwall placement is required on inlet end for 36″ or over unless otherwise specified by Hydraulics Unit.

* Note: This treatment for multilane highways applies to new construction and major reconstruction projects. It does not apply to resurfacing, bridge replacement, or spot safety projects. Pipe end treatment on these type of projects (including private installations) will be the same as existing pipes unless accident history warrants special consideration.

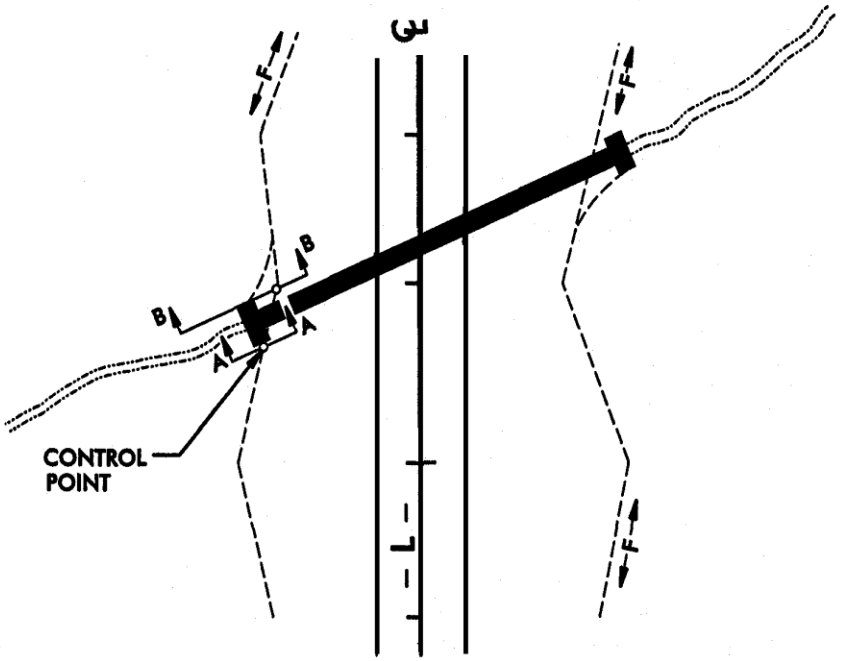
Endwalls shall be constructed perpendicular to the centerline of pipe unless specific site conditions warrant construction of an endwall parallel to the roadway. (See Hydraulics Unit for approval.) It will be necessary to extend the pipe to allow the end of the endwall to tie into the toe of the fill. See Part I, 5-20, F-1 in this Chapter for an example. Any additional backfill material necessary to extend this pipe shall be covered under Section 300 of the Standard Specifications for Roads and Structures. The quantities for the endwalls constructed perpendicular to the centerline of pipe will be based on a 90° skew rather than skew of pipe.

On multiple pipe installations, additional pipe length shall be provided such that a line projected along the face of the endwall is perpendicular to the centerline of pipes.

On minimum type driveways, the total graded width should not be less than 16 feet. Sound engineering judgment should be used in determining the proper driveway width and length of pipe based upon factors such as skew of drive, height of cover, type of drive and unusual traffic patterns.

When sufficient right of way is available, driveway pipe should be located outside the clear roadside recovery area and the roadway ditch should be transitioned accordingly. See Part I, 5-20, F-2 in this Chapter for an example. Providing a clear roadside recovery area is desirable in all locations, but the design will be more compatible on projects with minimum access points. (For example, partial control of access projects or projects on new locations.)

FIGURE 1 **5 - 20**
F - 1



EXAMPLE OF ENDWALL TREATMENT

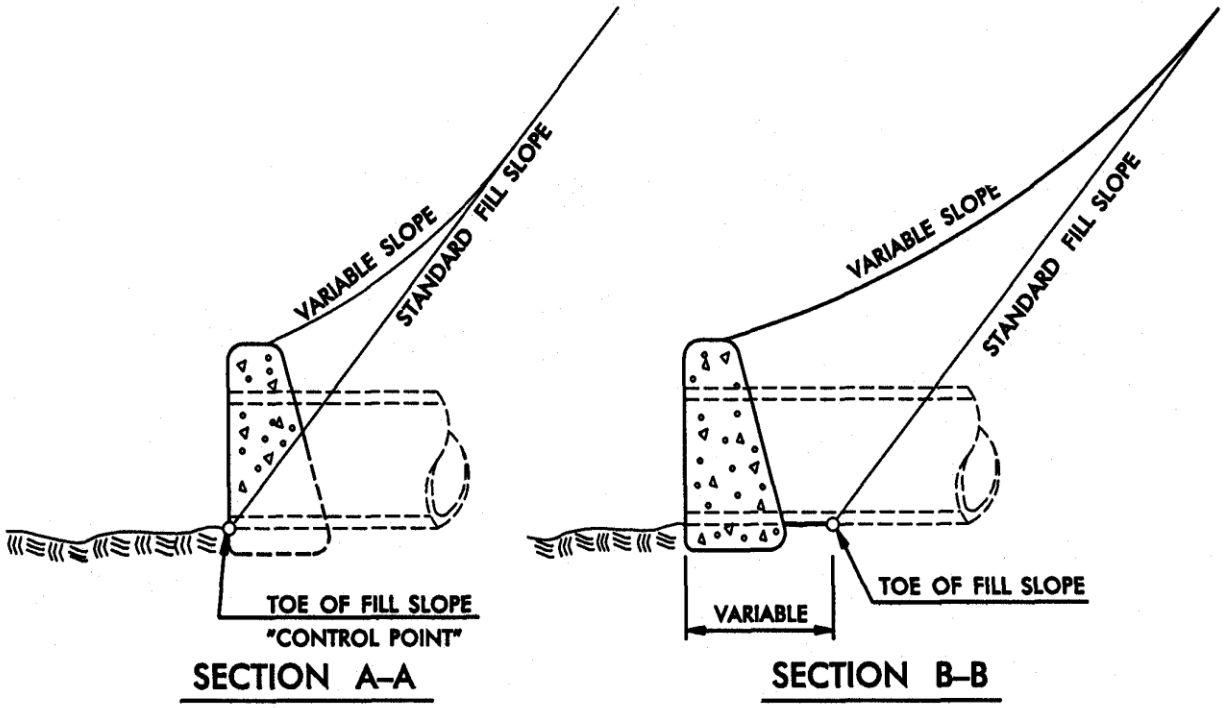
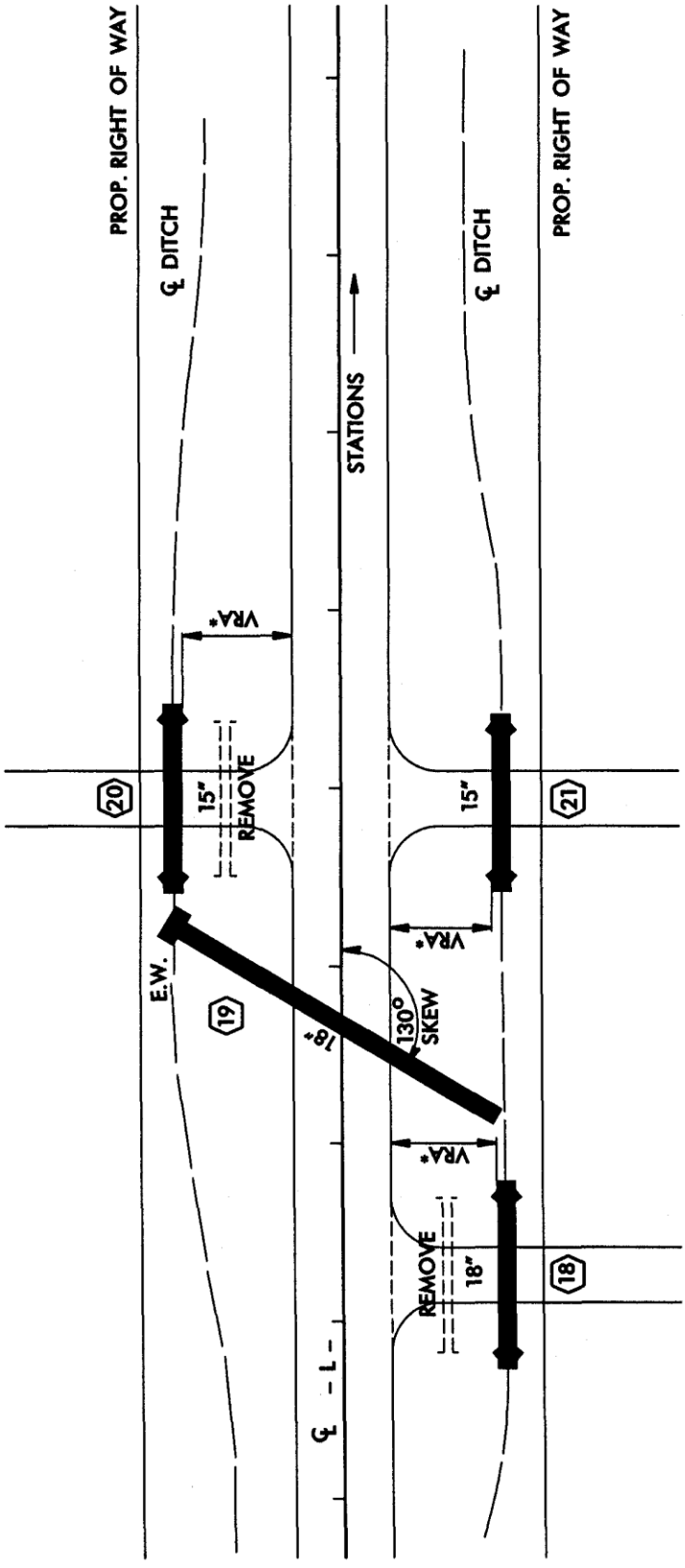


FIGURE 2 **5 – 20**
F – 2



CLEAR ROADSIDE RECOVERY AREA FOR ACCESS ROADS

*VRA = VEHICLE RECOVERY AREA

NOTE: SEE 1-4M PART I OF THIS MANUAL, FIGURES A, B, C & D FOR VEHICLE RECOVERY AREA.

SHOULDER DRAIN 5-21

Shoulder drains shall be installed in accordance with the guidelines noted on Std. No's. 816.01, 816.02 and 816.03 of the Roadway Standard Drawings.

Shoulder drain location and shoulder drain detail sheets will be determined by the Pavement Management Unit. This information will be sent to the Resident Engineer for use in field installation of shoulder drains.

When specific shoulder drainage plans are not provided, the following criteria are to be used as guides for the location, quantity and installation of shoulder drains:

(1) Sag Vertical Curves -- Install continuous drains for the full length of sag vertical curves.

(2) Low Side of Superelevated Curves -- Install continuous drains throughout the length of the curve.

(3) At other locations – As directed by the Resident Engineer.

(4) Pipe outlet shall be connected into drainage structures wherever possible. If not connected to drainage structure, end of pipe shall be protected by concrete pad for outlet end of shoulder drain.

NOTE: The Geotechnical Unit lists underdrain locations but Does Not list any shoulder drain locations.

UNDERDRAIN 5-22

Underdrains and Blind Drains shall be installed in accordance with the guidelines noted on Std. No. 815.03 of the Roadway Standard Drawings. The Geotechnical Unit will list underdrain locations in their recommendations. The need for additional underdrains shall be discussed at Field Inspection.

Following are guidelines for the use of shoulder berms, gutters and curbing on the outside edge of fill shoulders. Their purpose is to minimize the shoulder and slope erosion resulting from sheet flow off the pavement.

Existing Facilities

When erosion at the curb on existing installations causes undermining of the curb and erosion of fill slopes, the following guidelines should remedy the problem.

On existing facilities with 2′ or 4′ paved shoulders, removal of the curb and stabilizing the shoulder and slope is generally the most cost-effective solution.

On 10′ paved shoulder facilities, extending the paved shoulder to abut the curb is the preferred treatment. In all cases, the Hydraulics Unit and the Geotechnical Engineering Unit should assist in defining the proper solution based on individual site conditions.

Proposed Construction

Shoulder Berm

In general, it is better to allow surface water to flow across the fill shoulders and down the slope. Certain conditions will sometimes make it necessary to use positive control of sheet flow. These conditions include, but are not limited to:

(1) Easily erodible soils or soils not conducive to vegetative growth along shoulder and embankment.

(2) Extreme values of runoff flow and velocity due to/or in combination with:

- Width of Pavement
- High superelevation rates
- Steep roadway grade

(3) Roadside development which might require stricter control of runoff.

The decision for or against intercepting sheet flow at the shoulder edge should be made only after consideration of input from the Hydraulics Unit, the Geotechnical Engineering Unit, and the Division Engineer. The determination should be made on a project-by project basis. Shoulder treatment should be fully addressed during the preliminary field inspection. The most current listing of Field Inspection questions can be found on our computer website:

https://connect.ncdot.gov/projects/Roadway/Pages/Roadway-Design-Manual.aspx

When a need is determined, an earth shoulder berm should be used, (See Roadway Standard Drawings, Std. No. 846.03). Portions of the flow line at the outlet points will require shoulder berm gutter Std. No. (846.01). The flow line between outlets will require stabilization with Matting for erosion control or concrete depending upon soil characteristics. Coordination should be made with the Hydraulics Unit to determine the type of drainage pick-up structures and outlet spacing. Input from the Geotechnical Engineer Unit and Division Engineer should be obtained regarding the method of stabilizing between outlets.

A shoulder berm can only be used where guardrail is otherwise required with the face of the rail directly above the flow line. This may sometimes require a further addition to the overall shoulder width in order to maintain a minimum usable shoulder (See Part I, 1-4B of this Manual for shoulder criteria).

Expressway Gutter

When positive control of sheet flow is needed and guardrail is not warranted, an expressway gutter shape is required , (See Roadway Standard Drawings, Std. No. 846.01). The specific method of stabilizing the flow line should be determined as noted for shoulder berms. Expressway gutter used in combination with guardrail must be recommended by the Hydraulics Unit.