Corrugated Steel Pipe

Technical Specification Guide

TrueNorth Steel®

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Corrugated Steel Pipe Technical Specification Guide

TrueNorth Steel® manufactures and supplies a wide range of drainage pipe materials to service virtually any application including culverts, stormdrains, irrigation, agricultural drainage, conduits, small bridges and underground stormwater detention systems. We have extensive experience and expertise in assisting engineers, project owners, and contractors with the design and installation of these systems and the selection and specification of the proper materials to meet the project requirements.

We manufacture and supply corrugated steel pipe from 6" diameter through 144" in round and pipe arch shapes using galvanized steel, aluminized steel, and polymer coated galvanized steel. *(192" diameter corrugated steel pipe is available from some locations. Please inquire.)* We also manufacture Spiral Ribbed corrugated steel pipe featuring a Manning's "n" of .012 which is widely utilized for storm drains where a smooth interior pipe is a necessity. Slotted drain for curb drains and sheet flow drainage is available in a wide range of configurations. If it conveys water, TrueNorth Steel has the expertise.

Our manufacturing facilities and stocking locations in Casper, WY; Missoula, MT; Billings, MT; Rapid City, SD; Huron, SD; Fargo, ND; Mandan, ND; and Blaine, MN can manufacture a full range of wyes, tees, elbows, risers, and manholes. Additionally, TrueNorth Steel specializes in prefabricated headwall assemblies for corrugated steel pipe which dramatically speeds up construction, reduces cost and protects culverts from erosion and scour forces.

For those projects requiring larger pipe sizes or specialized shapes such as box culverts, refer to our TruePlate™ Structural Plate guideline.

It is our mission to service our customers in a timely manner with high quality materials from all of our sites. We stock a wide range of sizes, corrugations, coatings and lengths and we pride ourselves in being able to react quickly to emergencies and other unplanned needs. Our own logistics group delivers corrugated steel pipe to your location utilizing our fleet of trucks and trailers.

Our local representatives are very experienced and are available to provide pricing and availability, technical support and field-installation support. We also supply our materials through an extensive network of distributor partners in WI, MN, SD, NE, CO, ND, WY, ID and MT.

This corrugated steel pipe design guide provides extensive information to assist with the design and selection of corrugated steel pipe materials but additional information is available through our website at www.truenorthsteel.com where you can find the contact information for our local representatives.

TrueNorth Steel was established in the upper Midwestern U.S. and Rocky Mountains. Meeting our customer's needs through local manufacturing and support has fueled our growth in the region. When you work with TrueNorth Steel you can be assured that you are supporting your local economy and that you are getting the very best in service, quality and value.

Table of Contents

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TrueNorth Steel® Pipe Material

There are several ASTM specifications (AASHTO equivalents shown in parenthesis) used to identify and specify different CSP materials. Each specification makes provisions for the different corrugations and metal thicknesses (gages) available for CSP. By using height of cover tables the design engineer can relate the pipe size, corrugation, and metal thickness to the varied structural and hydraulic parameters for the application. Each of the pipe specifications also makes use of the following classification system:

- TYPE I — Round Pipe with exterior and interior corrugations
- TYPE IR — Round Pipe with a smooth interior (i.e. Spiral Rib Pipe)
- TYPE II — Type I Pipe reformed into a Pipe-Arch
- TYPE IIR — Type IR Pipe reformed into a Pipe-Arch
- TYPE III — Type I pipe with Class 1 and Class 2 perforations

When the pipe type, size, corrugation and metal thickness is established, the engineer can determine the desired ASTM standard to specify the piping of choice:

Specify ASTM A760 (AASHTO M36} for a galvanized or aluminized coated steel pipe
Specify ASTM A762 (AASHTO M245} for a polymer-coated galvanized steel pipe

Design Specifications

Agency	Reference
AASHTO	Standard Specifications for Highway Bridges—Division I, Section 12 LRFD Bridge Design Specifications – Section 12
ASTM	Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications—ASTM A796
AREMA	Manual for Railway Engineering – Section 4.9

Installation Specifications

Agency	Reference
AASHTO	Standard Specification for Highway Bridges-Division II, Section 26 LRFD Bridge Construction Specifications
ASTM	Standard Practice for Installing Factory Made Corrugated Steel Pipe for Sewers and Other Applications — ASTM A798 Standard Practice for Installing Corrugated Steel Structural Plate Pipe for Sewers and Other Applications — ASTM A807
AREMA	Manual for Railway Engineering – Section 4.12
U.S. Dept. of Agriculture — Natural Resources Conservation Service	Construction Specification Section 51 Paragraph 6 Service
U.S. Dept of Agriculture Forest Service	Specification for Construction of Roads and Bridges, Section 603.04 through 603.08.
Federal Lands Highway	FP92 Section 602.03, 602.05, 602.07, and 602.08

Material Description And Specifications

		Specifications	
Material	**Description**	**AASHTO**	**ASTM**
Zinc Coated Sheets & Coils	Steel base metal* with 2 oz per ft^2 zinc coating	M-218	A929M
Polymer Coated Sheets and Coils	Polymer coatings applied to sheets* and coils*, 0.010 in. both sides	M-246	A742M
Aluminum Coated Coils – Type 2	Steel base metal* coated with 1 oz. per ft^2 of pure aluminum	M-274	A929M
Sewer and Drainage Pipe	Corrugated pipe fabricated from any of the above sheets or coils. Pipe is fabricated by corrugating continuous coils into helical form with lock seam or welded seam, or by rolling annular corrugated mill sheets and riveting or spot welding seams: 1. Galvanized corrugated steel pipe 2. Polymeric pre-coated sewer and drainage pipe 3. Aluminized Type 2 corrugated steel pipe 4. Structural plate pipe	 M-36 M-245 M-274 M-167	 A760M A762M A760M A761M
Cold Applied Bituminous Coatings	Mastic or coal tar base coatings of various viscosities for field or shop coating of corrugated pipe or structural plate.	M-243	A849
Gaskets and Sealants	1. Standard O-ring gaskets 2. Sponge neoprene sleeve gaskets 3. Gasketing strips, butyl or neoprene 4. Mastic sealant		C443 D1056

* yield point – 33 ksi min.; tensile strength – 45 ksi min.; elongation (2 in.) – 20% min.

CSP Structural Design

Standard methods of structural analysis are generally based on research adopted by AASHTO and NCSPA (National Corrugated Steel Pipe Assocation). Standards with slight variations have also been adopted by ASTM. The railway industry, represented by AREMA, maintains distinct material and design standards to ensure railway live loading (E80) and its effects are appropriately managed.

ASTM A796	*Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and other buried applications*
ASTM A998	*Practice for Structural Design of Reinforcements for Fittings in Factory-Made Corrugated Steel Pipe for Sewers and other applications*
AREMA	*Manual for Railway Engineering, Section 4.9, Design Criteria for Corrugated Metal Pipes AASHTO* *LRFD Bridge Design Specifications, Section 3, Loads and Load Factors*
AASHTO	*LRFD Bridge Design Specifications, Section 12, Buried Structures and Tunnel Liners*

CSP Installation

Corrugated steel pipe {CSP) is a flexible pipe material that derives a portion of its structural capacity from the strength and relative stiffness of the backfill envelope. This is the case with all flexible pipes including plastic. The backfill-pipe interaction attained defines the ability of CSP to withstand service loads. National Corrugated Steel Pipe Association, ASTM and AASHTO all provide detailed installation guidance including:

- Installation Specifications
- Backfill envelopes and diagrams
- Backfill material selection
- Backfill placement and compaction

Following these guidelines assures proper levels of backfill - pipe interaction and load carrying capabilities. The following specifications should be used for installation guidance.

ASTM A798	*Practice for Installation Factory- Made Corrugated Steel Pipe for Sewers*
AASHTO	*LRFD Bridge Construction Specifications Section 26, Metal Culverts*
AREMA	*Manual for Railway Engineering, Section 4.12, Assembly and Installation of Pipe Culverts*
NCSPA	*Corrugated Steel Pipe Design Manual*

Pipe Joining Systems

Selection and specification of the appropriate pipe to pipe connection is a critical aspect of culvert and storm sewer design. Specifiers have many options available to address specific applications and in general. The selection criteria are based upon degrees of water tightness or allowable leakage of water into or out of the system, and the resistance of the connection to infiltration of finer particles from the pipe backfill. Most CSP pipe connections function by clamping around the end of each pipe to provide a mechanical connection. CSP pipe connection systems provide excellent resistance to shear and separation across the joint and thus compensate for settlement and shifting of surrounding soils. CSP pipe connections can be supplied in varying widths and with several different types of neoprene gaskets if required.

ASTM A760 Section 9 and AASHTO Sec. 26 Standard Construction Specifications for Highway Bridges provide detailed guidance for specifying CSP connections which are collectively termed "connecting bands". Also, The National Corrugated Steel Pipe Association Corrugated Steel Pipe Design Manual is an excellent resource for information.

Your TrueNorth Steel representative is familiar with all aspects of connecting band evaluation, selection, gaskets, specification, and installation.

Perforated Pipe

ASTM A760, A762 and B745 use a parallel classification system for perforated pipe depending on whether fully or partially (standard) perforated pipe is desired. Key elements in the classification systems are the size, spacing and placement of the perforations. Class 2 perforations provide a minimum open area of 3.3 in^2/ft^2 of pipe surface area.

Specify Class 1 perforations for partially perforated pipe to be used for subsurface drainage. Specify Class 2 perforations for fully perforated pipe to be used for subsurface disposal.

CSP Specification Example

"Pipe shall be a 16 Gage 48-in Diameter Aluminized Type 2-Coated Corrugated Steel Pipe with a 2-⅔"x ½" corrugation in accordance with ASTM A760 for Type I pipe. Pipe joints shall meet the soil tight performance criteria of ASTM A760 and installation shall conform to Section 26 of the AASHTO LRFD Bridge Construction Specifications."

Contact your TrueNorth® Steel representative for specifications or visit *http://www.truenorthsteel.com/culvert-stormwater-support-specifications.php*

Supplemental Manuals

NCSPA Corrugated Steel Pipe Design Manual

NCSPA Service Life Selection Guide (www.ncspa .org)

AREMA Manual for Railway Engineering, Section 4, Culverts

Corrugated Steel Pipe Structural Design

Minimum and Maximum Height of Cover and Resulting Steel Gages

Standard methods of structural analysis are generally based on research adopted by AASHTO and the CORRUGATED STEEL PIPE DESIGN MANUAL. Standards with slight variations have also been adopted by ASTM. The railway industry, represented by AREMA, maintains distinct material and design standards to ensure railway live loading (E80) and its effects are appropriately managed.

ASTM A796 *Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications*

ASTM A998 *Practice for Structural Design of Reinforcements for Fittings in Factory-Made Corrugated Steel Pipe for Sewers and Other Applications*

AREMA *Manual for Railway Engineering, Section 4.9, Design Criteria for Corrugated Metal Pipes AASHTO*

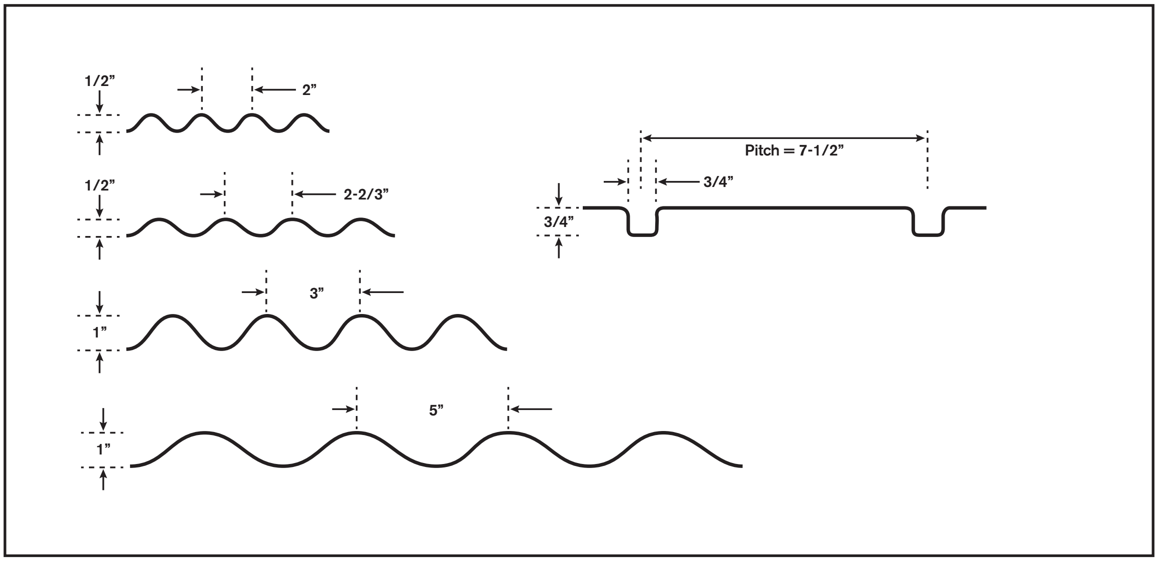
LRFD Bridge Design Specifications, Section 3, Loads and Load Factors

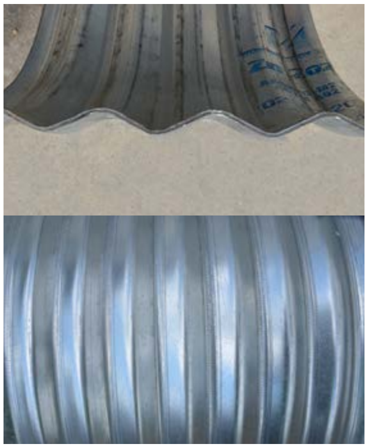
AASHTO *LRFD Bridge Design Specifications, Section 12, Buried Structures and Tunnel Liners*

The American Iron and Steel Institute (AISI) design method described in the National Corrugated Steel Pipe Association's Corrugated Steel Pipe Design Manual may be appropriate for non-highway applications such as mine haul roads, aggregate quarry tunnels, or lower volume roads.

The following tables adhere to AASHTO LRFD Bridge Design Specifications. Note the design assumptions. TrueNorth Steel recommends that each site or application be evaluated by a qualified engineer.

Corrugations





½” x 2-2/3” Corrugation

5” x 1” Corrugation

7-1/2” x ¾” Spiral Rib Corrugation

Conversion Of Nominal Gage To Thickness							
Gage No.	**22**	**20**	**18**	**16**	**14**	**12**	**10**
Uncoated Thickness (in.) Galvanized Thickness* (in.) Galvanized Structural Plate Thickness (in.)	0.0299 0.034	0.0359 0.040	0.0478 0.052	0.0598 0.064	0.0747 0.079	0.1046 0.109 0.111	0.1345 0.138 0.140
Gage No.	**8**	**–**	**–**	**–**	**–**	**–**	**–**
Uncoated Thickness (in.) Galvanized Thickness* (in.) Galvanized Structural Plate Thickness (in.)	0.164 0.168 0.170	– – –	– – –	– – –	– – –	– – –	– – –

Notes: * Also referred to as specified thickness for corrugated steel pipe products.

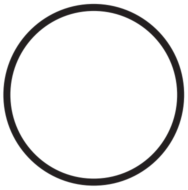
Corrugated Steel Pipe – Galvanized and Aluminized

Approximate Handling Weights by Gage (lbs/ft)

Corrugation	Dia. (in)	18Gage	16Gage	14Gage	12 Gage	10Gage	8Gage
1-1/2″ x 1/4″	6	4	5				
	8	5	6				
	10	7	8				
2-1/2″ x 1/2″	12	8	10	12	16		
	15	10	12	15	20		
	18	12	15	18	24		
	21	14	17	21	29		
	24	15	19	24	33	41	
	27		22	27	37	47	
	30		24	30	41	52	
	36		29	36	49	62	75
	42		34	42	57	72	87
	48		38	48	65	82	100
	54			54	73	92	112
	60				81	103	124
	66				89	113	137
	72					123	149
	78						161
5″ x 1″	48		39	48	65	83	100
	54		44	54	73	93	114
	60		48	59	81	104	126
	66		53	65	89	114	138
3″ x 1″values found by increasing 5″ x 1″ weights by 12%.	72		58	71	97	123	150
	78		62	77	105	134	163
	84		68	83	113	144	175
	90		72	88	121	154	187
	96		77	94	129	165	201
	102		82	100	136	174	212
	108			106	145	186	225
	114			112	153	195	238
	120				161	206	250
	126				172	217	263
	132				180	228	276
	138				187	238	289
	144					248	303
3/4″ x 3/4″ x 7-1/2″	15		13	16			
	18		15	19	26		
	21		18	22	30		
	24		20	25	34		
	27		22	27	38		
	30		25	30	42		
	33		27	33	46		
	36		30	36	50		
	42		34	42	58		
	48		39	48	66	83	
	54		44	54	74	94	
	60		49	60	82	104	
	66			66	90	114	
	72			72	99	124	
	78			78	107	135	
	84				115	145	
	90				123	155	
	96				131	165	
	102				139	176	
	108					186	
	114					196	
	120					206	

Corrugated Steel Pipe Backfill Heights

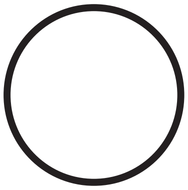
Round Pipe



2-2/3" x 1/2" Corrugations						
Pipe Size (inches)	Minimum cover (inches)	Steel Thickness (gauge)				
		16	14	12	10	8
		Galvanized Thickness (inches)				
		0.064	0.079	0.109	0.138	0.168
		Corrugated Steel Pipe Backfill Heights (feet)				
12	12	219	273	–	–	–
15	12	183	228	255	–	–
18	12	146	182	191	–	–
24	12	109	137	191	–	–
30	12	87	108	153	–	–
36	12	73	91	127	164	–
42	12	62	78	109	141	172
48	12	55	68	96	123	150
54	12	–	61	85	109	134
60	12	–	–	76	98	120
66	12	–	–	–	89	109
72	12	–	–	–	82	100
78	12	–	–	–	–	89
84	12	–	–	–	–	77

The Table is based on the following criteria (ASTM/AASHTO embankment)
1. Pipe Type = Helical or Annular (riveted or spotweld)
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Minimum Fill height taken as Span/8 but not less than 12"
5. Minimum cover for unpaved roadways is from the top of gravel surfacing.
6. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Round Pipe

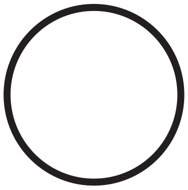


3" x 1" Corrugations						
Pipe Size (inches)	Minimum cover (inches)	Steel Thickness (gauge)				
		16	14	12	10	8
		Galvanized Thickness (inches)				
		0.064	0.079	0.109	0.138	0.168
		Corrugated Steel Pipe Backfill Heights (feet)				
48	12	63	78	110	142	173
54	12	56	70	98	126	154
60	12	50	63	88	113	139
66	12	46	57	80	103	126
72	12	42	52	73	94	116
78	12	39	48	68	87	107
84	12	36	45	63	81	99
90	12	33	42	59	76	92
96	12	–	39	55	71	87
102	18	–	37	52	67	82
108	18	–	–	49	63	77
114	18	–	–	46	60	73
120	18	–	–	44	57	69

The Table is based on the following criteria (ASTM/AASHTO embankment)
1. Pipe Type = Helical or Annular (riveted or spotweld)
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Minimum Fill height taken as Span/8 but not less than 12"
5. Minimum cover for unpaved roadways is from the top of gravel surfacing.
6. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights

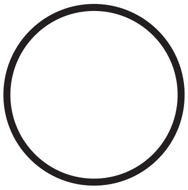
Round Pipe



5" x 1" Corrugations						
Pipe Size (inches)	Minimum cover (inches)	Steel Thickness (gauge)				
		16	14	12	10	8
		Galvanized Thickness (inches)				
		0.064	0.079	0.109	0.138	0.168
		Corrugated Steel Pipe Backfill Heights (feet)				
48	12	56	70	98	126	154
54	12	50	62	87	112	137
60	12	45	56	78	101	123
66	12	41	51	71	92	112
72	12	37	47	65	84	103
78	12	34	43	60	78	95
84	12	32	40	56	72	88
90	12	30	37	52	67	82
96	12	–	35	49	63	77
102	18	–	33	46	59	73
108	18	–	–	44	56	69
114	18	–	–	41	53	65
120	18	–	–	39	50	62

The Table is based on the following criteria (ASTM/AASHTO embankment)
1. Pipe Type = Helical or Annular (riveted or spotweld)
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Minimum Fill height taken as Span/8 but not less than 12"
5. Minimum cover for unpaved roadways is from the top of gravel surfacing.
6. Minimum cover for paved road ways is:
   a) To the top of the base for asphalt surfaces
   b) To the top of the pavement for concrete surfaces

Round Pipe

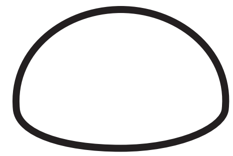


3/4" x 3/4" Rib @ 7-1/2"					
Pipe Size (inches)	Minimum cover (inches)	Steel Thickness (gauge)			
		16	14	12	10
		Galvanized Thickness (inches)			
		0.064	0.079	0.109	0.138
		Corrugated Steel Pipe Backfill Heights (feet)			
15	12	130	182	302	–
18	12	108	151	252	–
24	12	72	100	167	–
30	12	57	80	134	–
36	12	48	67	111	–
42	12	41	57	95	–
48	12	36	50	83	–
54	15	–	45	74	–
60	15	–	40	67	97
66	18	–	–	61	88
72	18	–	–	56	81
78	24	–	–	51	75

The Table is based on the following criteria (ASTM/AASHTO embankment)
1. Pipe Type = Helical or Annular (riveted or spotweld)
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Minimum Fill height taken as Span/8 but not less than 12"
5. Minimum cover for unpaved roadways is from the top of gravel surfacing.
6. Minimum cover for paved roadways is:
   a) To the top of the base for asphalt surfaces
   b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights

Arch Pipe



2-2/3" x 1/2" Corrugations								
Equivalent Pipe Diameter	Span	Rise	Minimum cover (inches)	Steel Thickness (gauge)				
				16	14	12	10	8
				Galvanized Thickness (inches)				
				0.064	0.079	0.109	0.138	0.168
Inches				Corrugated Steel Pipe Backfill Heights (feet)				
15	17	13	18	14	–	–	–	–
18	21	15	18	13	–	–	–	–
21	24	18	18	14	–	–	–	–
24	28	20	18	13	–	–	–	–
30	35	24	18	13	–	–	–	–
36	42	29	18	13	–	–	–	–
42	49	33	18	–	13	–	–	–
48	57	38	18	–	–	13	–	–
54	64	43	18	–	–	13	–	–
60	71	47	18	–	–	–	13	–
66	77	52	18	–	–	–	–	13
72	83	57	18	–	–	–	–	13

The Table is based on the following criteria (ASTM/AASHTO embankment)
1. Pipe Type = Helical or Annular (riveted or spotweld)
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Minimum Fill height taken as Span/8 but not less than 12"
5. Minimum cover for unpaved roadways is from the top of gravel surfacing.
6. Minimum cover for paved roadways is:
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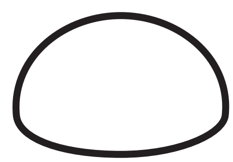
Arch Pipe



3" x 1" Corrugations							
Equivalent Pipe Diameter	Span	Rise	Minimum cover (inches)	Steel Thickness (gauge)			
				14	12	10	8
				Galvanized Thickness (inches)			
				0.079	0.109	0.138	0.168
Inches				Corrugated Steel Pipe Backfill Heights (feet)			
48	53	41	18	21	–	–	–
54	60	46	18	21	–	–	–
60	66	51	18	21	–	–	–
66	73	55	18	21	–	–	–
72	81	59	18	18	–	–	–
78	87	63	18	17	–	–	–
84	95	67	18	17	–	–	–
90	103	71	18	–	17	–	–
96	112	75	18	–	17	–	–
102	117	79	24	–	17	–	–
108	128	83	24	–	–	16	–
114	137	87	24	–	–	16	–
120	142	91	24	–	–	–	16

The Table is based on the following criteria (ASTM/AASHTO embankment)
1. Pipe Type = Helical or Annular (riveted or spotweld)
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Minimum Fill height taken as Span/8 but not less than 12"
5. Minimum cover for unpaved roadways is from the top of gravel surfacing.
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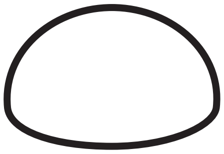
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights

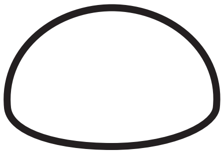
Arch Pipe



5" x 1" Corrugations							
Equivalent Pipe Diameter	Span	Rise	Minimum cover (inches)	Steel Thickness (gauge)			
				14	12	10	8
				Galvanized Thickness (inches)			
				0.079	0.109	0.138	0.168
Inches				Corrugated Steel Pipe Backfill Heights (feet)			
48	53	41	18	–	21	–	–
54	60	46	18	–	21	–	–
60	66	51	18	–	21	–	–
66	73	55	18	–	21	–	–
72	81	59	18	–	18	–	–
78	87	63	18	–	17	–	–
84	95	67	18	–	17	–	–
90	103	71	18	–	17	–	–
96	112	75	18	–	17	–	–
102	117	79	24	–	17	–	–
108	128	83	24	–	–	16	–
114	137	87	24	–	–	16	–
120	142	91	24	–	–	–	16

The Table is based on the following criteria (ASTM/AASHTO embankment)
1. Pipe Type = Helical or Annular (riveted or spotweld)
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Minimum Fill height taken as Span/8 but not less than 12"
5. Minimum cover for unpaved roadways is from the top of gravel surfacing.
6. Minimum cover for paved roadways is:
   a) To the top of the base for asphalt surfaces
   b) To the top of the pavement for concrete surfaces

Arch Pipe



3/4" x 3/4" Rib @ 7-1/2"							
Equivalent Pipe Diameter	Span	Rise	Minimum cover (inches)	Steel Thickness (gauge)			
				16	14	12	10
				Galvanized Thickness (inches)			
				0.064	0.079	0.109	0.138
Inches				Corrugated Steel Pipe Backfill Heights (feet)			
18	20	16	12	16	–	–	–
21	23	19	12	15	–	–	–
24	27	21	12	14	–	–	–
30	33	26	12	14	–	–	–
36	40	31	12	14	–	–	–
42	46	36	12	14	–	–	–
48	53	41	18	–	14	–	–
54	60	46	18	–	21	–	–
60	66	51	18	–	–	21	–
66	73	55	18	–	–	21	–
72	81	59	20	–	–	–	18
78	87	63	22	–	–	–	17
84	95	67	24	–	–	–	17

The Table is based on the following criteria (ASTM/AASHTO embankment)
1. Pipe Type = Helical or Annular (riveted or spotweld)
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Minimum Fill height taken as Span/8 but not less than 12"
5. Minimum cover for unpaved roadways is from the top of gravel surfacing.
6. Minimum cover for paved roadways is:
   a) To the top of the base for asphalt surfaces
   b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Service Life

Service Life Overview

Corrugated steel pipe (CSP) has been used for more than 100 years in critical storm sewer and culvert applications and was available only as a galvanized coated steel pipe for the first half of this period. With the addition of new material options over the past 50 years, including new high-performance coatings, CSP has increased its value and usefulness in providing extended service life over a broader range of environmental conditions.

Environmental conditions can vary considerably from site to site but there are several variables used to predict service life. The pipe interior (water-side durability) is impacted by effluent abrasion, pH and resistivity, and is typically the controlling factor in service life assignments. The pipe exterior (soil side durability) is affected by soil pH and resistivity, and is generally not the limiting factor in estimating CSP service life due to the lack of moisture and oxygen.

Factors That Influence CSP Service Life

pH ranges between 0 and 14 and is a measurement of acidity (pH < 7.0) or alkalinity (pH > 7.0). The pH value of a substance is a measure of the hydrogen ion concentration in the substance. Most soils fall within a pH range of 6.0 to 8.0, which is considered to be the neutral range and is favorable to the durability of steel pipe. Soils with lower pH values (acidic soils), usually found in areas of high rainfall, tend to be more corrosive and require a thorough evaluation selection of the pipe coating(s).

Resistivity - Corrosion processes related to underground structures involve the flow of current (conductivity) through the ground from one location to another (a corrosion cell). Resistance to current flow through a material is measured as the resistivity of that material. The resistivity value, expressed as ohm-cm, is inversely proportional to the conductivity value. Lower resistivity levels indicate conditions that would accelerate corrosion while higher levels of resistivity indicate conditions that inhibit would not lead to corrosion.

Refer to **Estimated Material Service Life for CSP** on page 17 for recommended environmental ranges for pH and resistivity.

Abrasion is a function of the bed load carried by the effluent and its velocity. Abrasion levels are correlated to the classification system developed by the Federal Highway Administration (FHWA).

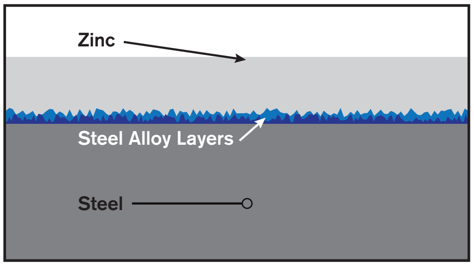
FHWA Abrasion Levels		
Level 1	None	No bed load
Level 2	Low	Minor sand/gravel bed loads (v ≤ 15 ft/sec)
Level 3	Moderate	Sand/gravel bed loads (5 < v ≤15 ft/sec)
Level 4	Severe	Heavy gravel/rock bed loads (v > 15ft/sec)

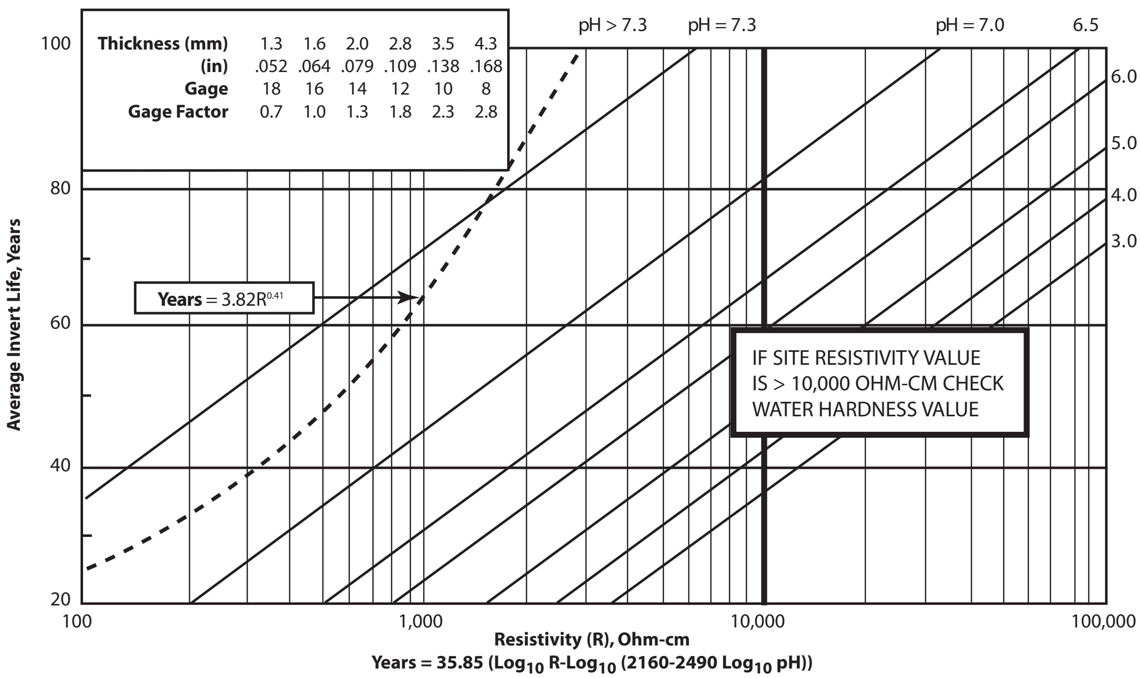
Flow velocities should be based upon a frequent storm event, such as a 2-year storm.
Refer to the Estimated Material Service Life for CSP on page 17 for guidance on recommended pipe materials.

Contact a TrueNorth Steel Representative to assist with service life of CSP.

Galvanized CSP

Galvanized CSP provides a zinc coating weight of two ounces per square foot of surface area. Galvanized CSP has been in use longer than any other material (including RCP) and much has been learned about the service life of this product. A field investigation conducted in the 1960's evaluated the service life of roughly 7,000 culverts in terms of pH and resistivity alone, and was subsequently quantified in the following chart:



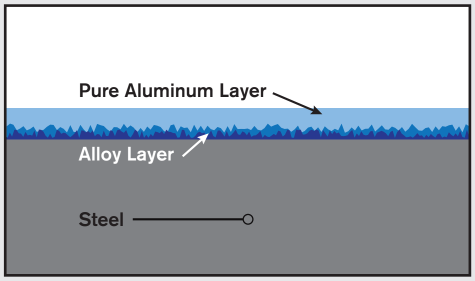


Estimated material service life of galvanized CSP. Use Gage Factor to adjust invert life for pipe gage.

An additional factor that can affect the service life of galvanized coated CSP is the presence of soft water (CaC03 < 50 ppm). Hard water has an excess of this dissolved salt which is deposited on the zinc coating of the pipe in the form of a scale that protects the underlying coating. Had the impact of soft water been recognized at the time of installation the resultant equations would predict longer service life for galvanized CSP installed within the current environmental guidelines. Aluminized Type 2 CSP, nor Polymer Coated CSP, will be adversely affected by the presence of soft water and therefore is the recommended substitute to galvanized CSP in soft water applications.

Aluminized Type 2 (AL T2) CSP

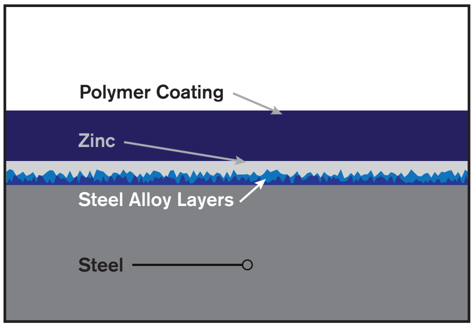
AL T2 is a pure aluminum coating with a weight of one ounce per square foot of surface area (each side). The aluminum coating develops a tenacious, passive aluminum oxide film that withstands a wider range of environmental conditions. The film is stable in neutral and more acidic environments, it does not break down in alkaline



environments until the pH goes below 5.0 or exceeds 9.0, and the film develops regardless of water hardness. AL T2 therefore has distinct advantages over galvanized CSP in the lower pH and soft water environments. Refer to the, **Estimated Material Service Life for CSP.**

Polymer Coated CSP

The Polymer coating is a laminated plastic layer applied to galvanized steel coil. The plastic coating is adhered using a heat-set adhesive and is applied using pressure rollers. The polyolefin laminate has strong adhesion characteristics with the galvanized sheet and is the most durable CSP coating available, outperforming other coatings in both more abrasive and chemically aggressive environments. Installations now dating back more than 40 years show no signs of degradation.



Service Life Assignments – CSP Coatings

There have been significant research undertakings over the past couple of decades to supplement the existing field surveys and related findings. Laboratory testing conducted by the primary coating suppliers along with ongoing field monitoring and other research endeavors combine to provide the following proven service life assignments for the principal CSP coatings:

Estimated Material Service Life for CSP

CSP Material	Estimated Service Life	Site Environmental Conditions	Maximum FHWA Abrasion Level
GALVANIZED CSP	AVERAGE 50 YEARS	$6.0 \leq$ pH ≤ 10.0 $2000 \leq r \leq 10{,}000$ (ohm-cm) Water Hardness (> 50 ppm $CaCo_3$)	LEVEL #2
ALUMINIZED TYPE 2 CSP	MINIMUM 75 YEARS	$5.0 \leq$ pH ≤ 9.0 r > 1500 ohm-cm	LEVEL #2
POLYMER COATED CSP*	MINIMUM 100 YEARS	$5.0 \leq$ pH ≤ 9.0 r > 1500 ohm-cm	LEVEL #3
	MINIMUM 75 YEARS	$4.0 \leq$ pH ≤ 9.0 $r \geq 750$ ohm-cm	
	MINIMUM 50 YEARS	$3.0 \leq$ pH ≤ 12.0 $r \geq 250$ ohm-cm	

NOTE: Refer to the FHWA abrasion levels on page 15 for the definition of FHWA abrasion levels.
* Polymer coating is 0.010 in. on each side.

Excerpted from National Corrugated Steel Pipe Association

Corrugated Steel Pipe Hydraulics

The hydraulics of corrugated steel pipe vary with the type of corrugation. For example, a ½" deep corrugation generally exhibits a lower Manning's "n" roughness coefficient value than a 1" deep corrugation. The Manning's "n" values are also affected by the helix angle of the corrugation. The larger the diameter of the pipe, the higher the roughness coefficient.

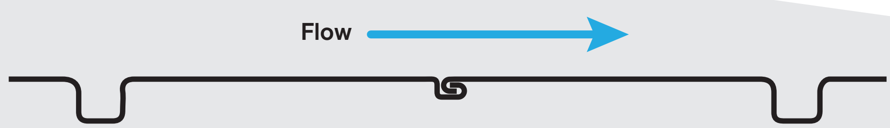
Coefficient of Roughness (Manning's n) for Standard Corrugated Steel Pipe

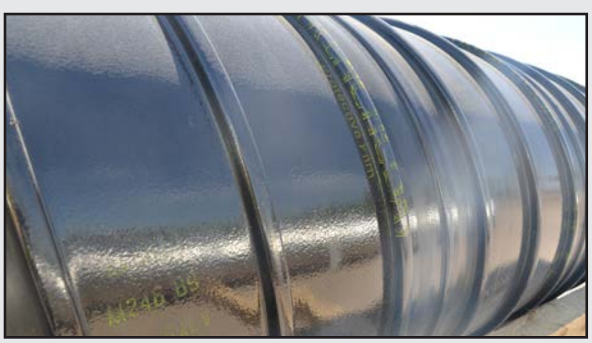
		2-2/3 x 1/2	Helical Corrugation, Pitch x Rise (in.)										
		Annular	1-1/2 x 1/4			2-2/3 x 1/2							
Flowing	Finish	Corrugation	Diameter (in.)										
		All Dia.	8	10	12	15	18	24	30	36	42	48	≥ 54
Full	Unpaved	0.024	0.012	0.014	0.011	0.012	0.013	0.015	0.017	0.018	0.019	0.020	0.021
Full	25% paved	0.021						0.014	0.016	0.017	0.018	0.020	0.019
Part Full	Unpaved	0.027			0.012	0.013	0.015	0.017	0.019	0.020	0.021	0.022	0.023
		All	Pipe Arch Span x Rise (in.)										
		Pipe Arches				17 x 13	21 x 15	28 x 20	35 x 24	42 x 29	49 x 33	57 x 38	≥ 54 x 43
Full	Unpaved	0.026				0.013	0.014	0.016	0.018	0.019	0.020	0.021	0.022
Part Full	Unpaved	0.029				0.018	0.016	0.021	0.023	0.024	0.025	0.025	0.026
		3 x 1	Helical Corrugation, Pitch x Rise (in.)										
		Annular	3 x 1										
		Corrugation	Diameter (in.)										
		All Dia.				36	42	48	54	60	66	72	≥78
Full	Unpaved	0.027				0.022	0.022	0.023	0.023	0.024	0.025	0.026	0.027
Full	25% Paved	0.023				0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023
		5 x 1	Helical Corrugation, Pitch x Rise (in.)										
		Annular	5 x 1										
		Corrugation	Diameter (in.)										
		All Dia.						48	54	60	66	72	≥78
Full	Unpaved	0.025						0.022	0.022	0.023	0.024	0.024	0.025
Full	25% Paved	0.022						0.019	0.019	0.020	0.021	0.021	0.022
			All Diameters										
Smooth Interior Pipe (1)			0.012										

Note (1): Includes fully paved, concrete lined, spiral rib pipe, ribbed pipe with inserts, and double wall pipe.

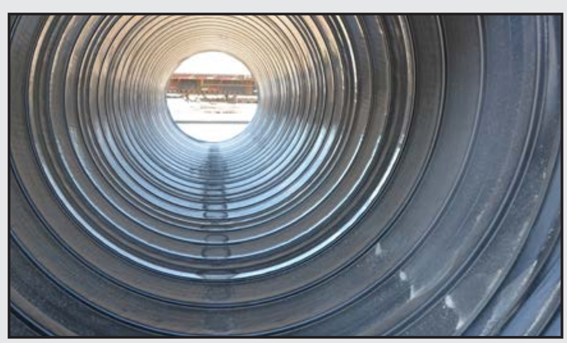
Excerpted from National Corrugated Steel Pipe Association

Traditionally designers have considered corrugated steel pipe to have a higher hydraulic roughness value than smooth interior pipes. Spiral Rib corrugated steel pipe was developed to provide a pipe material with a roughness coefficient of .012 which is equivalent to that of reinforced concrete pipe and smooth interior plastic pipe. The Manning's "n" of .012 was confirmed through full scale testing at Utah State University. Spiral rib corrugated steel pipe can be supplied utilizing Aluminized Steel Type 2 or Trenchcoat polyolefin polymer coating making it the ideal choice for storm drains and for slip lining existing deteriorated pipes.





Exterior of polymer coated spiral rib pipe.



Smooth interior of spiral rib pipe.

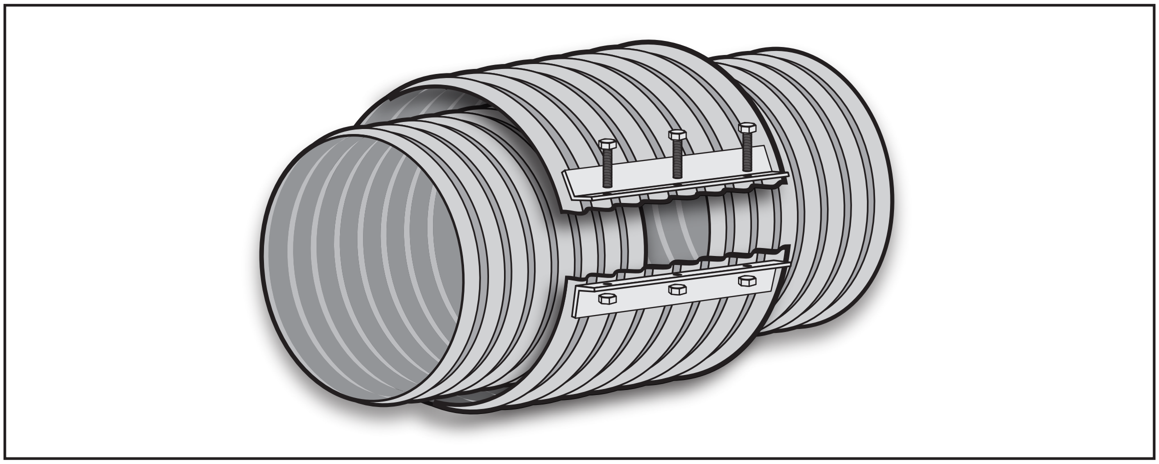
CSP Connection Guide

Corrugated steel pipe connections (connecting bands) are supplied to meet the specific needs of each project. Most culverts and stormdrains require a connection that provides a soil tight mechanical connection that joins the pipe ends. These connections, when properly installed, provide resistance to lateral displacement and in-line (or pull-apart) resistance unlike concrete pipe and plastic pipe connections

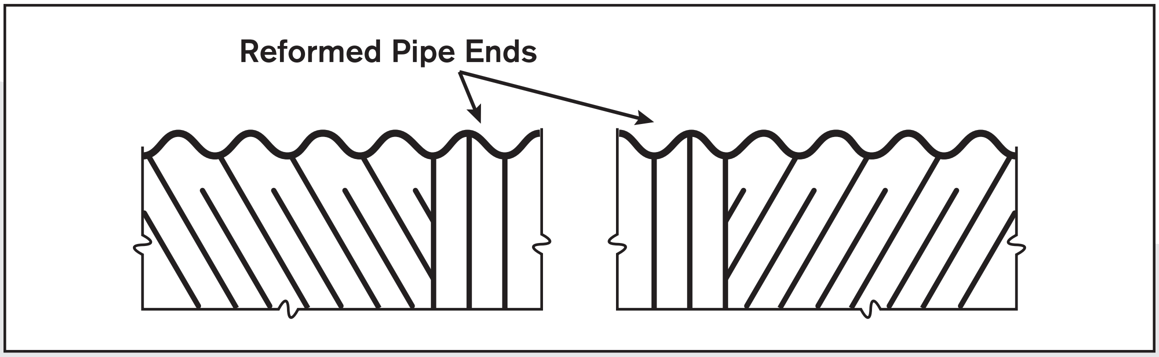
Typical connecting band widths are either 7", 12" or 24" wide and may be supplied with neoprene o-ring or neoprene flat sleeve gaskets. Specialized connections for severe applications include high-strength threaded rods and lugs to provide an extra measure of resistance to displacement.

For complete guidance refer to either section 9 of ASTM A760 or the National Corrugated Steel Pipe Association Corrugated Steel Pipe Design Manual (Refer to page 98). TrueNorth Steel is available to provide support with selecting the appropriate connecting band system to meet your specific needs.

TrueNorth Steel Pipe Joining Systems

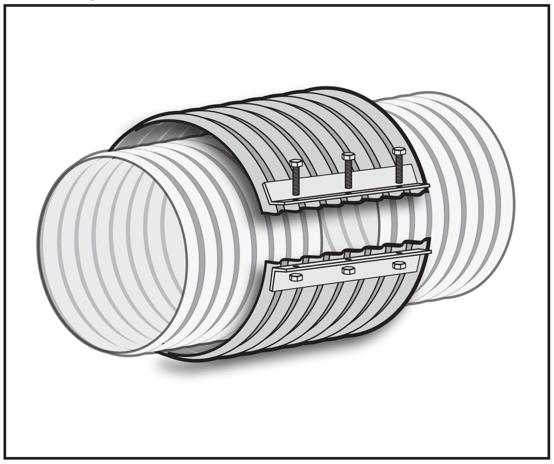


TrueNorth Steel standard pipe joining systems involve wrap-around style metal bands with connecting hardware. Connecting bands are offered in a one-piece or two-piece assembly. Two-piece are more typical with large diameter CSP.



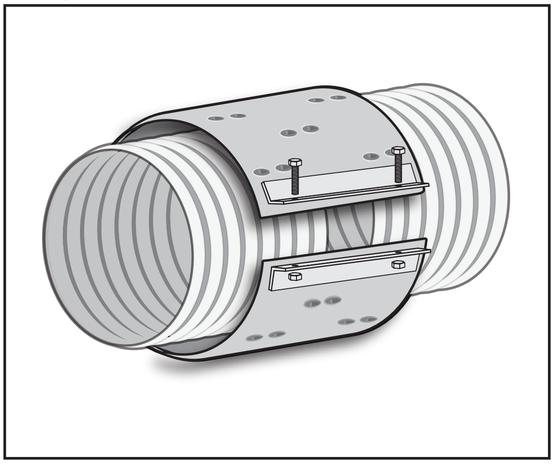
If pipe corrugations are helically formed, the pipe ends are reformed into annular corrugations to engage certain coupling bands. Regardless of the actual pipe corrugation used the annular corrugated ends are reformed with a 2-2/3" x 1/2" corrugation. If requested, pipe may be supplied with un-reformed ends.

Corrugated Bands



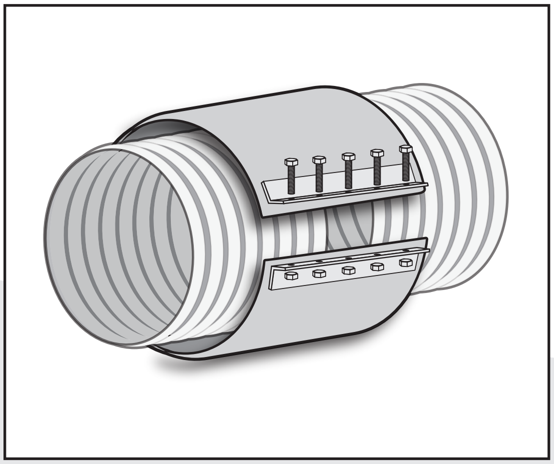
Annular corrugated bands are available in nominal widths of 7”, 12” and 24”.

Dimple Bands



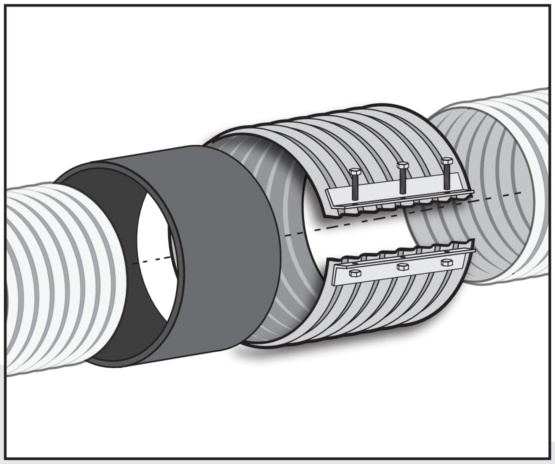
Dimple bands are bands with dimple projections in annular rows. As with flat bands they may be used on pipe with helical ends (i.e., ends that have not been reformed with annular corrugations). Dimple bands are available for 12”-96” CSP. Dimple bands come in widths of 10” or 16”.

Flat Bands



Bands with no corrugations or projections are available in nominal varying widths.

Sleeve Gaskets



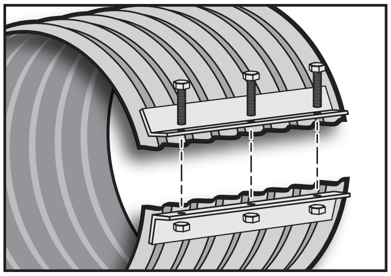
Gaskets are typically made of a 3/8” thick neoprene material to enhance the leak resistance quality of the joint. The sleeve gaskets slide over the pipe ends and underlay the connecting band available in 12” or 24” widths. O-ring gaskets are also available

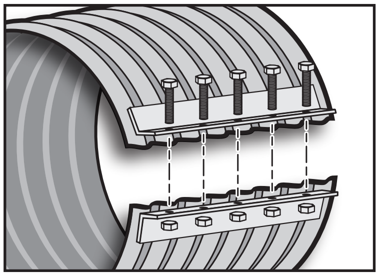
Connecting Band Hardware

Connecting band hardware is available in the different configurations shown below:

Angle Connector

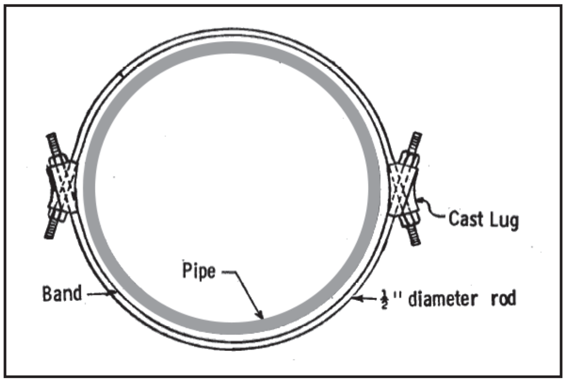
The angle connector assembly uses the three-bolt configuration for 12" wide bands and a five-bolt configuration for 24" wide bands. Bands can be supplied as galvanized, Aluminized Type 2 steel or polymer coated steel to match the associated pipe coating.



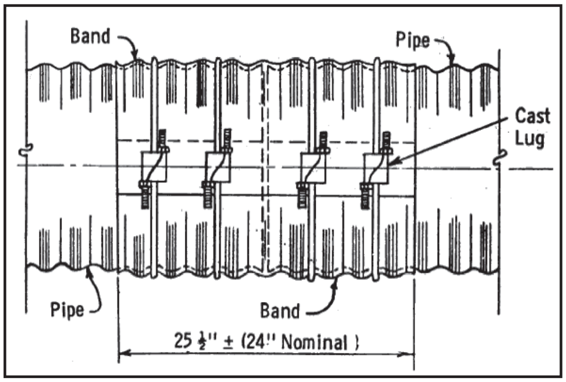


Rod & Lug

This assembly typically consists of dual rod configuration (left) and may be used on corrugated and partially corrugated bands. The multiple rod configuration (right) is used for 24" corrugated bands only.



End View



Side View

Corrugated Steel Pipe Installation Guide

Corrugated steel pipe should be installed in accordance with project specific plans and specifications. In lieu of specific project plans and specifications, CSP should be installed in accordance with ASTM A798 or the National Corrugated Steel Pipe Association Installation Manual that is available on the TrueNorth Steel website.

Corrugated steel pipe interacts with surrounding backfill soils to create a very stable yet flexible "Structure – Soil Interaction System". CSP can carry high live and dead loads but the surrounding soil envelope must be composed of well compacted soil backfill.

A proper installation begins with unloading and handling the CSP. TrueNorth Steel recommends that slings or straps or a properly configured chain or steel cable rigging be utilized to lift the pipe off of the delivery truck. On larger diameter, longer pipe sections, and larger pipe arches, TrueNorth Steel can provide lifting lug attachment points to assist with unloading and placement of the pipe.

Steps for proper installation of CSP

- Creation and stabilization of the trench (in a trench installation) or preparation of the proposed installation site in an embankment situation. See Figures 1 and 2 on page 22.
- Preparation of the foundation and pipe bedding
- Selection of proper backfill material
- Placement and compaction of the soil backfill

Trench Installations

Trench width is a function of pipe diameter or span and providing enough space beside the pipe to place and compact backfill. The trench diagram detail Figure 1 on page 22 provides specific guidance on proper trench dimensions and backfill placement. A trench installation should always be in compliance with all applicable safety regulations.

Embankment Installations

An embankment installation describes the placement of pipe on open ground such as new roadway embankment construction. Embankment installation requires placement of the pipe backfill material (which may be different from the adjacent fill) along with the adjacent fill. The embankment installation diagram detail Figure 2 on page 22 provides specific guidance on the dimensions of the backfill envelope to sides and over the top of the pipe.

Preparation of the Foundation and Bedding

The underlying soils or foundation should have sufficient capacity to support the proposed fill material and should be resistant to settlement. The foundation should also be free from large rocks. Areas of soft material should be removed and replaced with granular fill. More specific guidance is to be found in ASTM A 798 and the National Corrugated Steel Pipe Association Corrugated Steel Pipe Design Manual.

Pipe bedding provides a uniform surface on which to place the pipe and thus should be placed in a manner that provides for the desired final line and grade. The bedding is meant to support the pipe and also provide a "cushion" for the pipe so the top 2" to 6" of the material should be placed un-compacted or lightly compacted. Course sand is an excellent material for pipe bedding. If the underlying foundation soils are finely graded, free from stones and highly plastic clay, organic matter, or other deleterious material then the foundation soils may be sufficient to act as bedding for the pipe.

The bedding may be shaped to match the shape of larger diameter pipes and pipe arches. The shaped bedding aids in the placement of backfill around and under the haunches of the pipe.

Sites that are inundated should be de-watered but if this is not possible it is advised that granular material be dumped in place and graded, as well as possible, to provide a uniform foundation under the pipe and to provide support for the backfill.

Selection of the Backfill Material, Placement, and Compaction

Since CSP depends upon the surrounding backfill for support it is important to select backfill material that is easily compacted, free from organic or frozen material and is non-corrosive. The ideal material is a well-graded gravel or sand material with a limited percentage of fines (clays and silts). Non-plastic silty and clayey material may be used but require additional care during placement and compaction. Plastic clays and silts are not recommended as backfill. Refer to ASTM A 798 section 9 for specific guidance on backfill materials.

Backfill should be placed in controlled lifts of 6" to 8" and should be well compacted (90% of AASHTO T99). While compacting around large diameter CSP care should be taken to monitor the shape of the pipe. Proper placement of backfill under the haunches of pipe arch is important. Improper placement of backfill in this area may result in unacceptable changes in the shape of the pipe. It should be noted that the backfill of any pipe material, including concrete pipe, should be granular in nature and well compacted. Otherwise settlement of overlying pavement is likely to occur. Controlled low strength materials such as grout or cement stabilized sand are obviously excellent backfill material especially under the haunches of the pipe. Care must be taken to avoid floatation of the pipe.

A Guide to Using ASTM Designations for Bedding and Backfill

Soils meeting the requirements of Soil Groups GW, GP, GM, GC, SW and SP as defined in ASTM D2487 are generally acceptable when properly compacted. Soil Groups SM and SC are acceptable but will require closer control to obtain the specified density.

A Guide to Using AASHTO Designations for Bedding and Backfill

Following are recommended backfill materials:

A1	A1-a	Well-graded gravel
	A1-b	Gravelly sand
A2	A2-4	Sand and gravel with low plasticity silt
	A2-5	Sand and gravels with elastic silt
	A2-6	Sands with clay fines
	A2-7	Sands with highly plastic clay fines
A3	Fine sands, such as beach or wind deposited sands	

Examples of Acceptable Bedding and Backfill Gradations for Corrugated Steel Pipe

Material Passing No. 40 Sieve: Max Liquid Limit = 25, Max Plasticity Index = 6

Sample	A	B	C	D	E	F	G	H
Sieve Size	**% Passing**	**% Passing**	**% Passing**	**% Passing**	**% Passing**	**% Passing**	**% Passing**	**% Passing**
2½ inch	-	-	-	-	-	-	-	100
2 inch 100 -	-	-	-	-	-	-		
1½ inch	-	100	100	-	-	-	-	-
1 inch	70 to 100	-	95 to 100	100	-	-	-	70 to 100
¾ inch	50 to 90	80 to 100	-	90 to 100	-	-	100	-
½ inch	-	-	25 to 60 -	-	-	-	-	
¾ inch	-	60 to 90	-	20 to 55	100	100	80 to 100	-
No. 4	0 to 60	30 to 90	0 to 10	0 to 10	90 to 100	95 to 100	60 to 100	25 to 100
No.8	-	-	0 to 5	0 to 5	65 to 100	70 to 100	45 to 95	-
No. 16	-	-	-	-	40 to 85	38 to 80	-	-
No.30	9 to 33	3 to 20	-	-	20 to 60	18 to 60	-	-
No. 40	-	-	-	-	-	-	-	10 to 50
No. 50	-	-	-	-	7to40	5 to 30	7 to 55	-
No. 100	-	-	-	-	0 to20	0 to 10	-	-
No. 200	0 to 20	0 to 20	-	-	0 tolO	0 to 5	0 to 15	5 to 15

A Guide to Using Filter Fabric

The migration of fines from the sides and bottom of the excavation into adjacent pipe embedment voids can result in loss of pipe support. The gradation and relative size of the embedment and adjacent materials must be compatible to minimize this migration. When coarse and open-graded material is placed adjacent to a finer material a filter fabric (or other acceptable means) must be used to prevent particle migration.

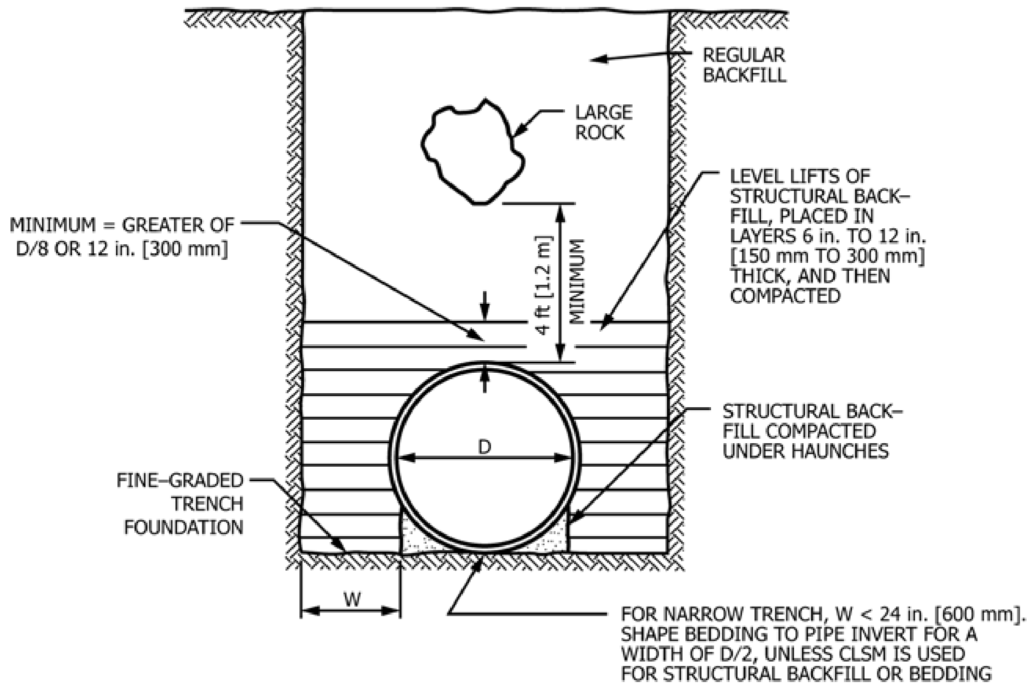


FIG. 1 Typical Trench Installation

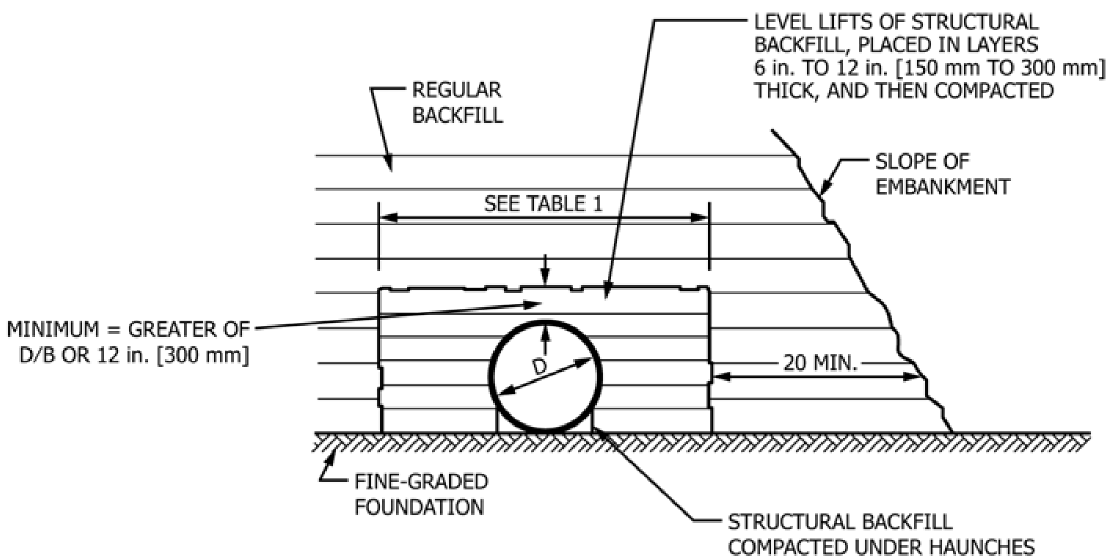
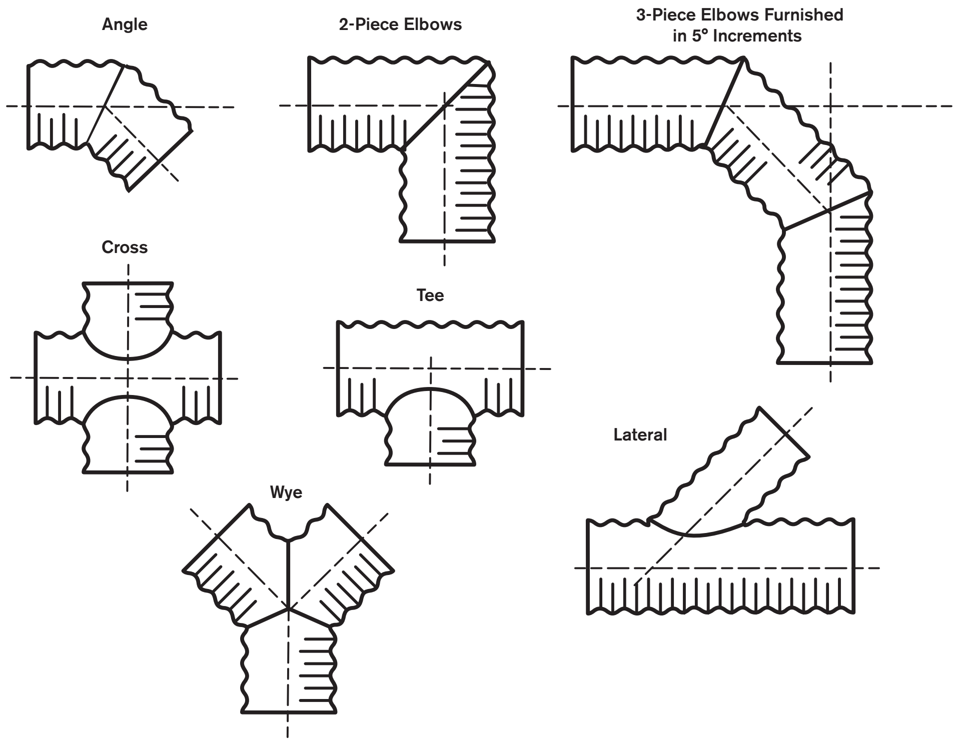


FIG. 2 Typical Embankment (Projection) Installation

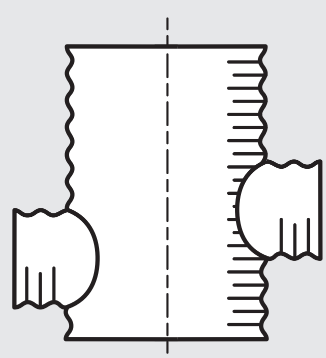
Fittings for CSP

Corrugated metal pipe can be configured to a wide spectrum of fittings including but not limited to those shown below. Bends, tees and wyes can be made to virtually any angle. Corrugated metal pipe pond risers with debris screens are commonly used to preclude dam overtopping. Corrugated metal pipe manhole structures, sumps and junctions are an economical alternative to more costly concrete structures.

Contact your TrueNorth Steel representative for guidance on corrugated steel pipe fittings.



Corrugated Steel Pipe is routinely utilized to construct manholes and pond risers.



End Treatment for Corrugated Steel Pipe

Purposes

The principal purpose of pipe end treatment on corrugated steel pipe culverts is to reduce turbulence and scour at the inlet and outlet, undermining at the outlet, and to increase flow capacity. Other functions may be to retain the fill slope, discourage burrowing rodents, or improve safety. For additional information, see NCSPA Corrugated Steel Pipe Design Manual - chapters 4 and 5, on Hydraulic Design, and Chapters 7 and 8, Structural Design and Special Design.

Types of End Treatment

Types of steel end treatment include: (1) Flared end sections, (2) safety slope flared end sections, (3) pipe cut-end skews and bevels, (4) steel sheeting to serve as a low headwall and cutoff wall, and (5) prefabricated, corrugated steel headwalls, (6) cut back style safety aprons.

End Sections

Steel end sections are fabricated for assembly in the field by attachment to corrugated steel culverts from 6" to 96" diameter or pipe arches from 17" x 13" to 112" x 75". Dimensions and other data are given in the charts on the following pages or Figures 2.29 and 2.30 in the NCSPA Corrugated Steel Pipe Design Manual.

These end sections are listed in standard specifications of state highway departments, county road departments, railroads and other specifying entities. They meet the requirements for efficient and attractive end finish on culverts, conduits, spillways and sewer outfalls.

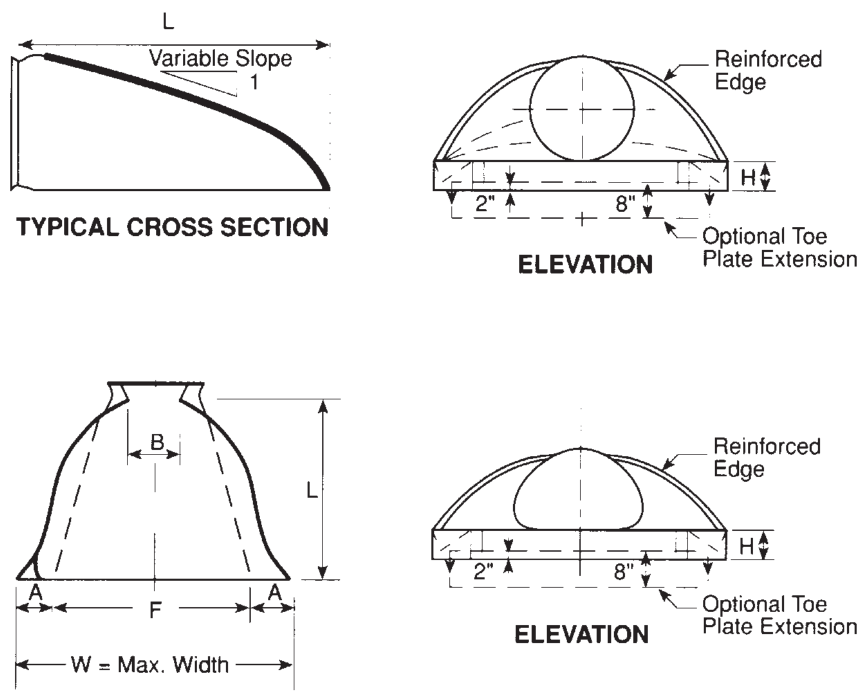
End sections attach to the culvert ends by bolted connections of various designs and can be completely salvaged and reused if lengthening or relocation is necessary.

Flared End Section

Safety Slope Flared End Section

Flared End Sections

Dimensions of steel end sections for round pipe



Pipe Diameter (in.)	Specified Thickness (in.)	A Min. (in.)	B Max. (in.)	H Min. (in.)	F Min. (in.)	L ± 2 (in.)	W Max Width (in.)	Average End Section Slope* (in.)
6	0.052	3	1	3	10	8	24	13/4
8	0.052	5	5	4	14	14	32	23/8
10	0.052	5	6	6	18	14	39	2
12	0.064	5	7	6	22	21	44	21/4
15	0.064	6	8	6	28	26	52	21/4
18	0.064	7	10	6	34	31	58	21/8
21	0.064	8	12	6	40	36	66	21/8
24	0.064	9	1 3	6	46	41	72	21/8
30	0.079	11	16	8	55	51	88	21/8
36	0.079	13	19	9	70	60	105	2
42	0.109	15	25	10	82	69	122	21/8
48	0.109	17	29	12	88	78	131	2
54	0.109	17	33	12	100	84	143	2
60	0.109	17	36	12	112	87	157	17/8
66	0.109	17	39	12	118	87	162	15/8
72	0.109	17	44	12	120	87	169	11/2
78	0.109	17	48	12	130	87	178	13/8
84	0.109	17	52	12	136	87	184	11/3
90	0.109	17	58	12	142	87	188	11/4
96	0.109	17	58	12	144	87	197	11/8

Notes: *Fill slope need not match the end section slope. Fill can be shaped at each site to fit.
1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Some larger sizes may require field assembly.
3. Optional toe plates may be provided to depths specified.

Excerpted from National Corrugated Steel Pipe Association

Dimensions of steel end sections for pipe arch 2-2/3 x 1/2 in. corrugations

Span x Rise (in.)	Equiv/ Round (in.)	Specified Thickness (in.)	A Min. (in.)	B Max. (in.)	H Min. (in.)	F Min. (in.)	L ± 2 (in.)	W Max Width (in.)	Approx. Average End Section Slope* (in.)
17 x 13	15	0.064	5	9	6	28	20	52	21/8
21 x 15	18	0.064	6	11	6	34	24	58	2
24 x 18	21	0.064	7	12	6	40	28	63	21/8
28 x 20	24	0.064	7	16	6	46	32	70	2
35 x 24	30	0.079	9	16	6	58	39	85	17/8
42 x 29	36	0.079	11	18	7	73	46	104	17/8
49 x 33	42	0.109	12	21	9	82	53	117	13/4
57 x 38	48	0.109	16	26	12	88	62	132	17/8
64 x 43	54	0.109	17	30	12	100	69	144	17/8
71 x 47	60	0.109	17	36	12	112	77	156	17/8
77 x 52	66	0.109	17	36	12	124	77	167	15/8
83 x 57	72	0.109	17	44	12	130	77	177	11/2

Notes: *Fill slope need not match the end section slope. Fill can be shaped at each site to fit.

1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Some larger sizes may require field assembly.
3. Optional toe plates may be provided to depths specified.

Excerpted from National Corrugated Steel Pipe Association

Dimensions of steel end sections for pipe arch 3 x 1 in. and 5 x 1 in. corrugations

Span x Rise (in.)	Equiv/ Round (in.)	Specified Thickness (in.)	A Min. (in.)	B Max. (in.)	H Min. (in.)	F Min. (in.)	L ± 2 (in.)	W Max Width (in.)	Approx. Average End Section Slope* (in.)
53 x 41	48	0.109	17	26	12	88	63	130	13/4
60 x 46	54	0.109	17	36	12	100	70	142	17/8
66 x 51	60	0.109	17	36	12	112	77	156	13/4
73 x 55	66	0.109	17	36	12	124	77	168	11/2
81 x 59	72	0.109	17	44	12	136	77	179	15/8
87 x 63	78	0.109	17	44	12	136	77	186	11/2
95 x 67	84	0.109	1 7	44	1 2	1 60	87	210	11/2
103 x 71	90	0.109	17	44	12	172	87	222	11/3
112 x 75	96	0.109	17	44	12	172	87	226	11/4
117 x 79	102	0.109	20	62	12	154	87	234	1 1/2
128 x 83	108	0.109	20	68	12	176	87	256	1 1/2
137 x 87	114	0.109	20	73	12	194	100	274	1 1/2
142 x 91	120	0.109	20	75	12	204	98	284	1 1/2

Notes: *Fill slope need not match the end section slope. Fill can be shaped at each site to fit.

1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Some larger sizes may require field assembly.
3. Optional toe plates may be provided to depths specified.

Excerpted from National Corrugated Steel Pipe Association

2. Safety Slope End Sections

State and federally sponsored research studies show that flatter slopes on roadside embankments greatly minimize the hazard potential to motorists.

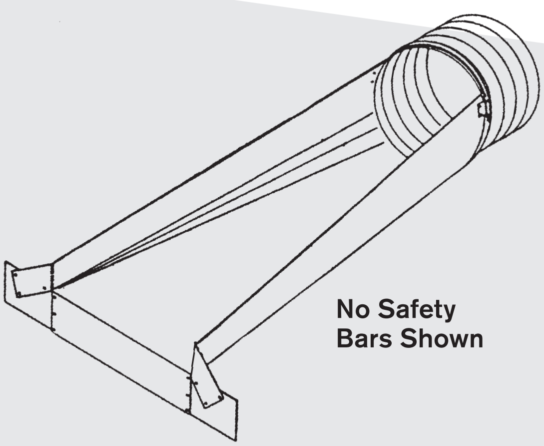
Application of this concept, with the design of 4:1, 6:1, and 10:1 roadside slope, has contributed significantly to improving the safety of our highways. The use of safety slope end sections on highway culverts maintains the safe design of the flattened roadway embankments.

Pre-fabricated safety slope end sections are available with 4 :1, 6 :1, and 10:1 slopes and are designed to fit around pipe diameters from 12" through 60" and pipe arch sizes from 17" x 13" through 83" x 57". While safety is the primary reason for using safety slope end sections, the tapered flare improves the hydraulic efficiency of the culvert at both the inlet and outlet ends. A deep toe plate anchors the end section while preventing scour and undercutting. The flat apron or bottom panels eliminate twisting or misalignment of the end treatment.

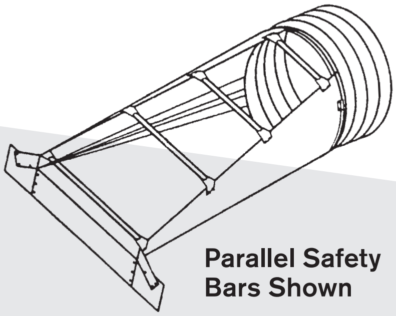
Cross-drainage structures are those oriented under the main flow of traffic. On Cross-drainage structures, a small culvert is defined as a pipe with a 36" span or less or multiple pipes with a 30" span or less. Safety bars are not required on 30" spans or less when used in a cross-drain application. Single structures with end sloped sections having spans greater than 36" can be made traversable for passenger size vehicles by using 3" diameter safety bars to reduce the clear opening spans. The use of safety bars to make safety slope end sections traversable should not decrease the hydraulic capacity of the culvert.

Parallel drainage structures are those that run parallel to the main flow of traffic. They typically are used under driveways, field entrances, access ramps, intersecting side roads and median crossovers. These culverts present a significant safety hazard because they can be struck head-on by impacting vehicles. As with cross drains, the end treatments on parallel drains should match the traversable slope. Research shows that for parallel drainage structures, 3" diameter safety bars set on 24" centers will significantly reduce wheel snagging.

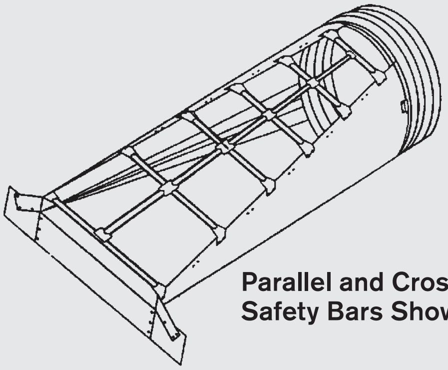
Safety slope end sections are efficient and provide an attractive end finish on cross and parallel drainage structures. They attach to the culvert end by bolted connections and can be salvaged if lengthening of the structure or relocation is required. Dimensions and other data are given in the tables on the following page.



No Safety Bars Shown



Parallel Safety Bars Shown



Parallel and Cross Safety Bars Shown

Dimensions of safety slope end sections for pipe arch. 2-2/3 x 1/2 in., 3 x 1 in. and 5 x 1 in. corrugations

Pipe Dia. (in.)	Specified Thickness (in.)	Dimensions (in.)				L Dimensions					
		A	H	W	Overall Width	Slope	Length (in.)	Slope	Length (in.)	Slope	Length (in.)
12	.064	8	6	18	34	4:1	N/A	6:1	29		
15	.064	8	6	21	37	4:1	20	6:1	30	10:1	70
18	.064	8	6	24	40	4:1	32	6:1	48	10:1	100
21	.064	8	6	27	43	4:1	44	6:1	66	10:1	130
24	.064	8	6	30	46	4:1	56	6:1	84	10:1	160
30	.109	12	9	36	60	4:1	80	6:1	120	10:1	220
36	.109	12	9	42	66	4:1	104	6:1	156	10:1	280
42	.109	16	12	48	80	4:1	128	6:1	192		
48	.109	16	12	54	86	4:1	152	6:1	228		
54	.109	16	12	60	92	4:1	176	6:1	264		
60	.109	16	12	66	98	4:1	200	6:1	300		
66	0.109	16	12	72	104	4:1	224				
72	0.109	16	12	78	110	4:1	248				

Excerpted from National Corrugated Steel Pipe Association

Dimensions of safety slope end sections for pipe arch. 2-2/3 x 1/2 in. corrugations

Pipe Dia. (in.)	Span x Rise (in.)	Specified Thickness (in.)	Dimensions (in.)				L Dimensions					
			A	H	W	Overall Width	Slope	Length (in.)	Slope	Length (in.)	Slope	Length (in.)
15	17 x 13	.064	8	6	23	39	4:1	20	6:1	30	10:1	70
18	21 x 15	.064	8	6	27	43	4:1	20	6:1	30	10:1	70
21	24 x 18	.064	8	6	30	46	4:1	32	6:1	48	10:1	100
24	28 x 20	.064	8	6	34	50	4:1	40	6:1	60	10:1	120
30	35 x 24	.079	12	9	41	65	4:1	56	6:1	84	10:1	160
36	42 x 29	.109	12	9	48	72	4:1	76	6:1	114	10:1	210
42	49 x 33	.109	16	12	55	87	4:1	92	6:1	138		
48	57 x 38	.109	16	12	63	95	4:1	112	6:1	168		
54	64 x 43	.109	16	12	70	102	4:1	132	6:1	198		
60	71 x 47	.109	16	12	77	109	4:1	148	6:1	222		
72	83 x 57	.109	16	12	89	121	4:1	188	6:1	282		

Notes:
1. End sections available in galvanized steel or aluminized steel, Type 2.
2. Cross bars and parallel bars are 3 in. Schedule 40 galvanized pipe with flattened ends bent to match end section contour.
3. Edge of side wall to be rolled edges reinforced with a 7/16 in. diameter or #4 galvanized steel rod.
4. For attachment to structure use Type 1 for circular pipe through 24 in. diameter, use Type 2 for 30 in. and larger circular pipes and all arch pipes (see Figure 2.29).

Excerpted from National Corrugated Steel Pipe Association

CSP Beveled and Skewed End Treatment

TrueNorth Steel beveled end sections are a practical and visually attractive way to complete an installation that incorporates a slope at either end of a culvert. Beveled ends at the pipe inlet limit scour and beveled ends also limit undermining at the outlet end. When the ends of corrugated pipe are beveled or skewed to match the embankment slope they will deliver improved hydraulic characteristics. Additional benefits of beveled and skewed ends include retaining the fill slope, discouraging burrowing rodents and improving roadside safety.

Typical bevel angles are 3:1 and 4:1 but other angles are available as are skew cut ends to match culverts skewed to the roadway centerline. A combination of bevel and skew is also available.

Beveled ends can be a full bevel cut but TrueNorth Steel recommends the use of "step beveled" ends which incorporate a vertical cut at the at the top of the bevel and a similar vertical cut at the tip of the beveled end section. The vertical "step" cuts at the top of the bevel increase the stiffness of the bevel and the vertical "step" at the bottom of the bevel eliminates the possibility of the bottom being damaged by hydraulic uplift forces.

Your TrueNorth Steel representative is available to advise you on skew and bevel cut ends on CSP.

1½:1 Bevel Top and Bottom Step

3:1 Bevel Top and Bottom Step

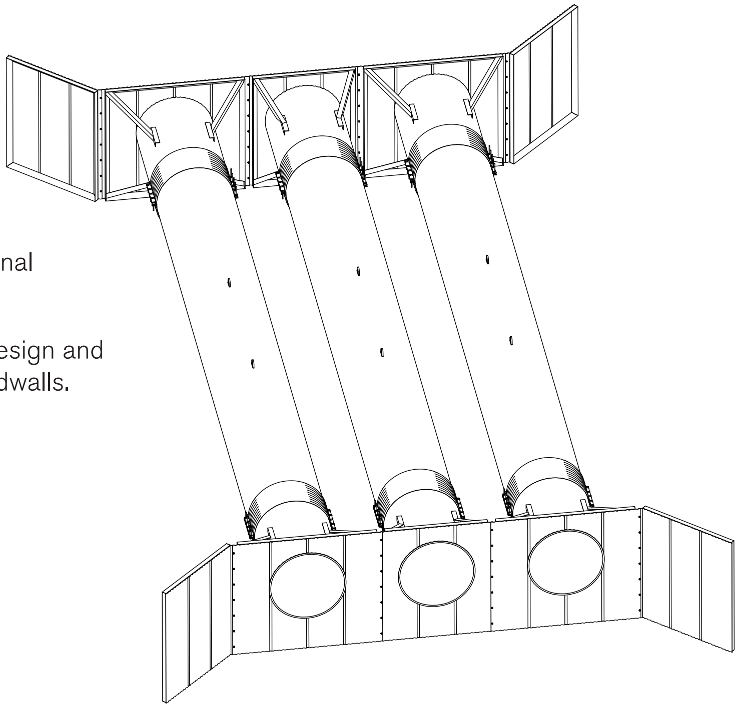
Corrugated Steel Headwalls, Wingwalls and Cutoff Walls

Corrugated steel pipe is widely utilized for drainage culvert applications and many of these applications require a headwall to protect the surrounding soil and streambed from scour and erosion. Concrete headwalls can be expensive and very difficult to construct especially in more remote locations. A more economical option and one that can be constructed at virtually any location is a prefabricated steel headwall.

Prefabricated steel headwalls are designed to accommodate pipe diameters from 12" to 144", skewed end pipes and pipe arches. Wingwalls, if required, can be designed and provided as well.

Headwalls are pre-attached to the end of the pipe and pre-assembled at the factory to assure proper fit and finish. Assembly and construction is simple and quick and does not require prior experience but TrueNorth Steel will be on the jobsite to assist if required. Designs sealed by a Professional Engineer can be provided.

Let TrueNorth Steel assist you with the design and construction of your drainage culvert headwalls.



Perforated CSP

Perforations are supplied per AASHTO M-36 and ASTM A760

CSP can be perforated to provide drainage through the bottom portion of the pipe. Holes will be spaced down the length of the pipe at the prescribed spacing and the holes range in diameter from 3/8" to 2". Slots may also be provided. Common applications for this perforation configuration include infiltration and ventilation of potato and sugar beet storage piles.

CSP can also be fully perforated around the entire circumference of the pipe. The most common hole diameters are 3/8" and 5/16". The most common application for fully perforated CSP is underground stormwater retention systems (which provide for infiltration into the underlying soil) or filtration systems.

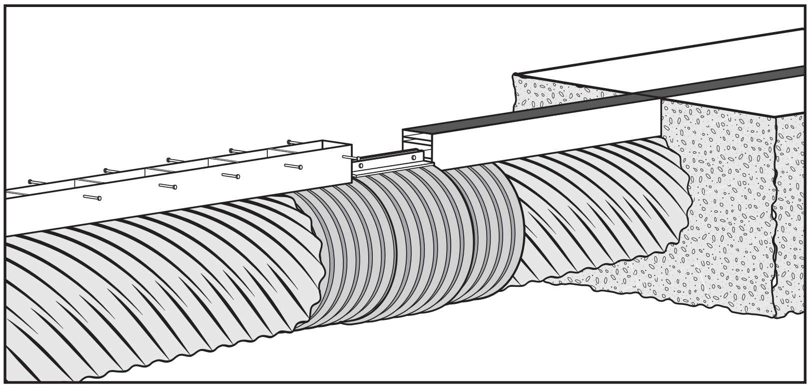
The table below provides the open area of the perforations by pipe diameter and pipe corrugation type for 3/8" diameter holes. 5/16" holes provide approximately 30% less open area.

Exfiltration Area Standard Perforation Patterns
AASHTO M-36 Class2

Approx. Area per Lineal Foot of Pipe		
Pipe Dia. (inches)	Corrugation Pattern	
	Column #1 2-2/3" x 1/2" and 3"x1" Steel Pipe Sq. Inches	Column #2 5"x1" Steel Pipe Sq. Inches
12	12.2	–
15	15.3	–
18	18.3	–
24	24.4	–
30	30.5	–
36	36.6	–
42	42.7	–
48	48.9	–
54	55.0	56.5
60	61.1	62.8
66	67.2	69.0
72	73.3	75.3
78	79.4	81.6
84	85.5	87.9
90	91.6	94.2
96	97.7	100.4
102	–	106.7
108	–	113.0
114	–	119.3
120	–	125.5
Hole Dia.	3/8"	3/8"

CSP Slotted Drain Guide

CSP Slotted Drain Offerings



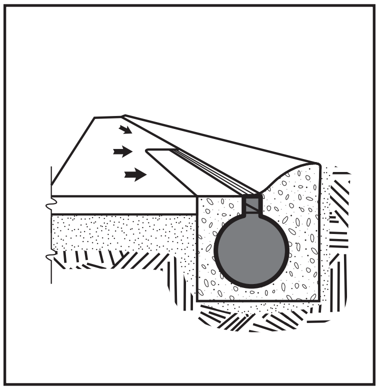
Features

- **Pipe Diameters: 12” - 36”**
- **Pipe material: 16 & 14 gage**
- **Standard grate heights: 2-1/2” & 6”**
- **Variable slotted drain heights available**
- **Slot Width: 1-3/4”**
- **Corrugated Band Connectors**
- **Heel Guard Mesh***

* when specified

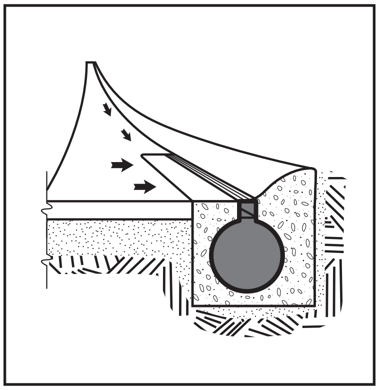
Slotted drain pipe is used for typical curb-and-gutter applications such as an on-grade opening, at the bottom of a slope as a sag inlet, or as a sheet flow intercept for wide, flat areas. Graphs on pages 36-37 are used to determine the lengths of slotted drain pipe needed for a particular application and a design flow rate.

On-Grade Opening



For a given cross-slope (Sx) and longitudinal gutter-slope (S) the required slotted drain pipe length can be determined for a given flow rate. A cost effective practice is to carry up to 35% of the total flow to the next inlet. The Slotted Drain Carryover Efficiency figure on page 37 shows a carryover efficiency curve to utilize this practice.

Sag Inlet

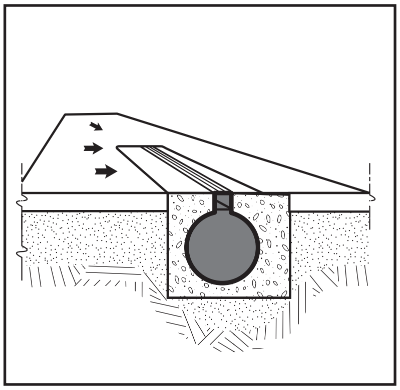


Where slotted drain pipe is installed at a low point or sag in the grade, the slotted length is calculated from the equation $L_R = \frac{1.401\ Q_d}{\sqrt{d}}$

where:

- L_r = **Slot length required for no carryover, ft**
- Q_d = **Total design flow, $ft^3/_s$**
- d = **Maximum allowable depth of water in the gutter, ft**

Sheet Flow Intercept



An effective use of slotted drain pipe is to intercept sheet flow from wide, flat areas (e.g. parking lots, airport terminals, highway medians, loading docks). The slotted drain pipe is placed transversely to the grade to intercept flow uniformly along its length.

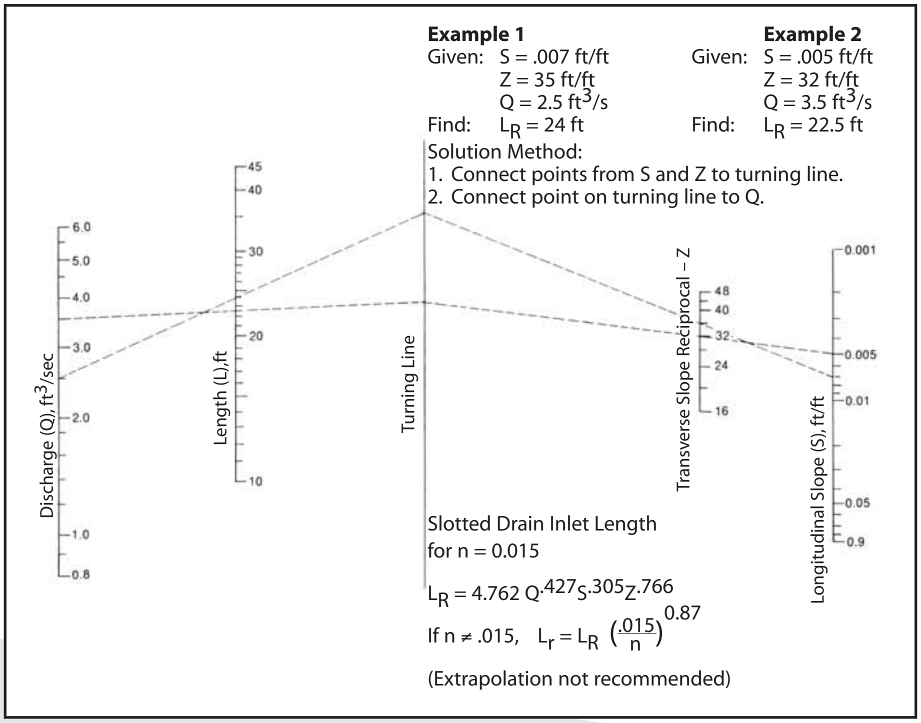
Installation

Lengths of slotted drain pipe are placed, aligned and banded together in a prepared trench. Care is taken to make sure the slot matches pavement finished grade throughout the alignment. The pipe is then encased in concrete or lean concrete grout up to the top of the pipe. The finish course of pavement is then installed up to the top of the slot.

Slotted Drain Design

Slotted drain inlets are typically located as spaced curb inlets on a grade (sloping road- way) to collect downhill flow, or located in a sag (low point). The inlet capacity of a slotted drain may be determined from the graph below, where:

S = Longitudinal gutter or channel slope, ft/ft
S_X = Transverse slope, ft/ft
Z = Transverse slope reciprocal = $1 / S_X$, ft/ft
Q= Discharge, ft^3/s
L = Length of Slot, ft



Slotted drain design nomograph

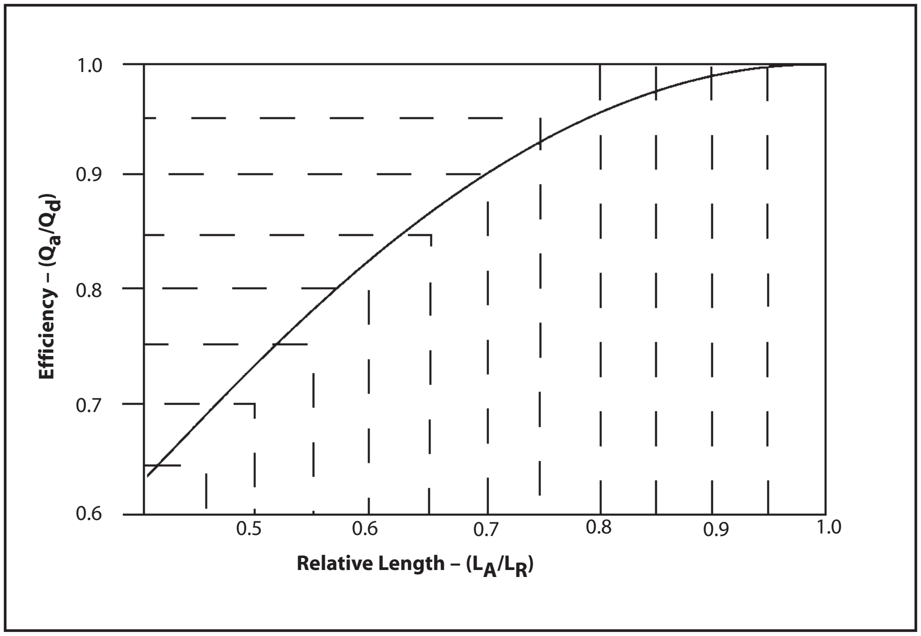
It is suggested that the length of a slotted drain be in increments of 5 or 10 feet to facilitate fabrication, construction, and inspection. Pipe diameter is usually not a factor but it is recommended that it be at least 18 inches

For a series of slotted drain curb inlets on a grade, each inlet will collect all or a major portion of the flow to it.

Once the initial upstream inlet flow is established, the nomograph above is used to determine the required length of slot to accommodate the total flow at the inlet.

The length of slot actually used may be less than required by this table. Carryover is that portion of the flow that does not form part of the flow captured by the slotted drain. While some of the flow enters the drain, some flows past the drain to the next inlet. The efficiency of a slotted drain, required in order to consider carryover, is shown in on the next page, where:

where: Q_d = Total discharge at an inlet, $ft^3/_s$
Q_a = An assumed discharge, $ft^3/_s$



Slotted drain carryover efficiency

If carryover is permitted, the designer must assume a length of slot such that the ratio of the assumed length of slot to the length of slot required for total interception and no carryover (L_A /L_R) is greater than 0.4 but less than 1.0. In other words, the designer must decide on a length of slot that will provide an acceptable carryover efficiency. Where carryover is not permitted, L_A must be at least the length L_R.

Economics usually favor slotted drain pipe inlets designed with carryover rather than for total flow interception. There must be a feasible location to which the carryover may be directed.

For additional information on calculating slotted drain length to account for carryover, refer to the National Corrugated Steel Pipe Association Corrugated Steel Pipe Design Manual.

Geogrids

Tensar

Cellular Confinement – Petroleum

GEOSYSTEMS

Stormwater Pollutant Treatment

AquaShield WATER TREATMENT SOLUTIONS

Gabions

MACCAFERRI

Geotextiles - Woven and Non-Woven

Erosion Control – Permanent and Temporary

Well Pits (Cellar Rings)

Pipe Rehabilitation and Slip Lining

Water Control Gates and Valves

Waterman FRESNO Valves & Castings, Inc.

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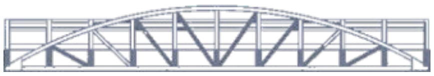
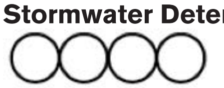


ECO Arch™ – Fish Passage Crossings

Structural Plate Pipe – TruePlate™

Stormwater Detention and Retention



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North Dakota - Fargo	1522 40th Street North	Fargo, ND 58102	(701) 282-0910
North Dakota - Mandan	2522 Memorial Highway	Mandan, ND 58554	(701) 663-0321
South Dakota - Huron	220 4th Street NW	Huron, SD 57350	(605) 352-8643
South Dakota - Rapid City	3272 Lien Street	Rapid City, SD 57702	(605) 394-7200
Minnesota - Blaine	3575 85th Avenue NE	Shoreview, MN 55126	(763) 780-1760
Montana - Billings	1501 South 30th Street W	Billings, MT 59102	(406) 656-2253
Montana - Missoula	5405 Momont Road	Missoula, MT 59808	(406) 542-0345
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TrueNorth Steel®

Corrugated Steel Pipe

Technical Specification Guide

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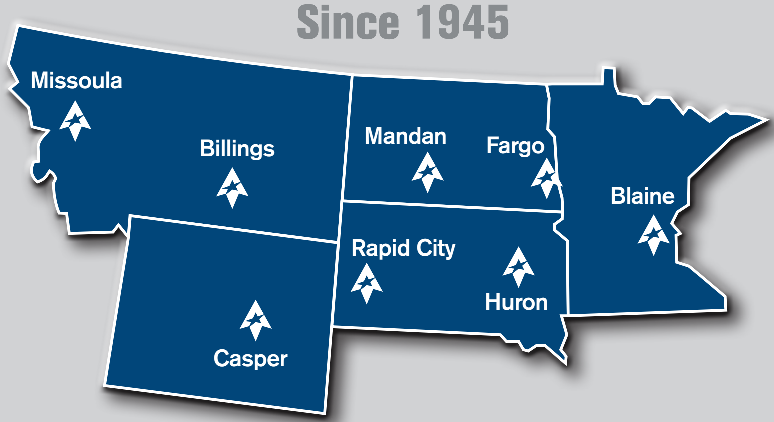

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STRUCTURAL

TANKS

CORRUGATED PIPE

BRIDGES

LOGISTICS