CHAPTER 8: OPTIONAL PIPE MATERIAL

8. OPTIONAL PIPE MATERIAL 8-1

8.1 Introduction 8-1

8.2 Design Service Life 8-1

8.3 Durability 8-2
8.3.1 Project Corrosion Evaluation 8-2
8.3.2 Project Geotechnical Investigation and Corrosion Tests 8-5
8.3.3 Project Pipe Service Life Estimation 8-7
8.3.4 Special Cases (Jack and Bore Casings, Ductile Iron Pipe, any Ferrous Metals) 8-12

8.4 Pipe Structural Evaluation 8-18

8.5 Documentation 8-28
8.5.1 Project Example Considering all Potential Pipe Applications 8-28
8.5.1.1 Side Drains under Driveways 8-29
8.5.1.2 Cross Drains (including Side Drains under Side Streets) 8-36
8.5.1.3 Storm Drain 8-43
8.5.1.4 Wall Zone Pipe 8-46
8.5.1.5 Gutter Drain 8-47
8.5.1.6 French Drain 8-49

8.6 Specifying Optional Pipe Materials in the Contract Plans 8-50

8. OPTIONAL PIPE MATERIAL

8.1 INTRODUCTION

It is important to consider the array of materials available for culverts. After you complete the initial hydraulic design, evaluate the list of culvert materials shown in Table 6-1 of the *Drainage Manual* to choose among potential options. Chapter 3 of the *Drainage Manual* provides the roughness coefficients needed to evaluate the various materials. The evaluation must consider functionally equivalent performance in durability and structural capacity. For culvert extensions, match the existing culvert material to avoid misleading future maintenance assumptions about the type of buried pipe material. However, if the existing culvert fails a corrosion evaluation when the length of time of service is factored in or if it shows signs of deterioration, the existing culvert should be replaced or rehabilitated (e.g., lined).

8.2 DESIGN SERVICE LIFE

The Design Service Life (DSL) is the minimum number of years that a pipe is required to perform for a particular application in the design of a project. For most applications, a 100-year DSL is required. Specific DSLs for a particular highway type and culvert function are shown in Table 6-1 of the *Drainage Manual*. Refer to the example project in Section 8.5 for further guidance on choosing appropriate DSL.

Although Table 6-1 of the *Drainage Manual* provides comprehensive policy on the selection of Design Service Life, practical considerations sometimes will override the guidance material. For instance, gutter drains are listed as a 25-year DSL application, but if a gutter drain, or any other pipe, is to be located where replacement would require closure or major traffic disruption during the design life of the facility, then a longer DSL is appropriate. Any pipe that is beneath or within the soil zone that provides stability to a structural wall must have a 100-year service life due to the potential for wall damage or failure and because of the difficulty of replacing that pipe in the future.

Changing the diameter may change the Estimated Service Life (ESL) of concrete and metal pipe. This occurs because of the change in wall thickness. As the diameter of concrete and metal pipe increases, so logically does the wall thickness of the pipe. For concrete pipes, the wall thickness increases as a result of the thickness change in the cover over the reinforcing wire, and in metal pipes, the increase is due to the thicker gage metal used for larger-diameter metal pipes.

Refer to Table 6-1 in the *Drainage Manual* for culvert material applications and design service life.

8.3 DURABILITY

The requirements for DSL may vary between projects as well as within a project, depending on the highway functional classification and the application of the culvert.

The projected service life, hereafter referred to as the Estimated Service Life (ESL), of a culvert is the duration of service time after which significant deterioration is predicted to occur. After this point, you would need to consider major rehabilitation, lining, or replacement. For a material to be included in the design of a project, its ESL must meet or exceed the required DSL.

For metal pipe, the time of first perforation (complete penetration) is the service life end point. For concrete culvert, the service life ends when the culvert has experienced a corrosion-related crack in the concrete. The ESL of a specific culvert material is determined from an evaluation of the corrosiveness, based on the environmental conditions of both the soil and water, at the intended culvert site.

For plastic pipe (polyvinyl chloride [PVC], polypropylene [PP], and high density polyethylene [HDPE]), the service life is independent of the environmental conditions. The service life ends when any crack appears in the pipe. Plastic pipes sometimes crack from initial field loadings, but can also crack through a creep/rupture mechanism called slow crack growth. The ESL of plastic pipe is determined by the State Drainage Office rather than by site-specific corrosion analysis.

8.3.1 Project Corrosion Evaluation

There are several types of corrosion that may occur with metal pipes or culverts containing steel reinforcement. Some types of corrosion are more severe, and you need to address them in the design stage of a project. You will need to collect environmental data when designing a culvert system for a specific site. Corrosion rates of culverts containing metal are governed primarily by the four environmental parameters listed and discussed below; these site-specific environmental parameters are used to predict the rate of corrosion and the resultant estimated service life at the site or region of interest:

- pH
- Resistivity
- Chlorides concentration
- Sulfates concentration

pH—The measure of alkalinity or acidity. A neutral soil environment has a pH of 7. When a culvert is placed in an environment in which the pH of the soil is low (≤ 5.0) or high (≥ 9.0), the protective layers of the culvert (concrete, galvanizing, aluminizing, etc.) can weaken, leaving the metal vulnerable to early corrosion. For example, any organic material from decomposing vegetation will lower the pH of the soil.

Instances of high pH values are extremely rare. Observed pH values in virtually all soils and waters in Florida are less than 10. pH values between 5.5 and 8.5 are of no concern. pH values less than 5.5 are common in swampy areas; a pH below 5 is an aggressive environment for reinforced concrete and a pH below 4 is highly aggressive. Generally, a low pH is conducive to steel corrosion. Both a low pH and a high pH (> 8.5), coupled with low resistivity, create a corrosive environment for aluminum.

Resistivity—A measure of the electrical resistance of soils and waters. Resistivity is the inverse of conductivity. Highly conductive media tend to promote corrosion. Corrosion is an electrochemical process. For corrosion to occur, charged ions must migrate through the soil or water from a corroding area (anode) to a non-corroding area (cathode). Soils with relatively high resistivity values (> 3,000 Ohm-cm) impede the migration of these ions, which slows corrosion. Environments with low resistivity values (< 1,000 Ohm-cm) provide an easy path for ions to migrate from anode to cathode, which in turn accelerates corrosion. In general, clayey soils, organic soils, or chloride-bearing soils would tend to generate low resistivity values.

Chloride Concentration—A measure of the number of chloride ions present. Chloride ions react with and break down a protective layer on the surface of metal that otherwise protects against corrosion. When the chloride concentration is high (> 2,000 ppm), the protective layer breaks down quickly, leaving the metal vulnerable to corrosion. In addition, high chloride concentrations result in low resistivity values that allow easy electrical paths for ion migration and accelerated corrosion. Salt water or brackish water will be high in chloride concentrations.

Sulfate Concentration—A measure of the number of sulfate ions present. Sulfate can cause concrete components to deteriorate. If the sulfate concentration is high (> 5,000 ppm), concrete is vulnerable to accelerated deterioration. Sulfate ion concentrations rarely exceed 1,500 ppm in Florida; therefore, the threat sulfate ions pose is not as considerable as that of chloride ions.

Elevated chloride values typically are seen only in or near coastal areas. High sulfates can be seen anywhere but are more prevalent in coastal areas.

There are other factors that may affect service life. These factors are not the primary factors, and as such are not included in the FDOT Culvert Service Life Estimator (CSLE) Program. They are mentioned here to alert you to their potential affects.

Microbially Induced Corrosion—Microbially Induced Corrosion (MIC) is the deterioration of metals resulting from the metabolic activity of microorganisms. MIC primarily affects metal culverts, but also can affect reinforcing steel in concrete culverts. Many types of microorganisms can survive in a wide pH and temperature range. MIC often presents as corroded surfaces covered in slime, black iron sulfide deposits, algal growth, and as a rotten egg odor. The reactions generally are localized and occur at cracks, crevices, and welds. Readily available oxygen and organic carbon can increase the rate of MIC.

Industrial Effluent—Although discharge of industrial effluents to waterways is regulated, these can occur with accidental spills. Mine tailings or minable geologic formations can be a source of acidic runoff. Certain land uses—golf courses, dairy farms, farming operations, coal burning power plants, or cement plants—can all be sources of corrosive media.

Stray Electrical Current—Electric current in proximity to a pipe can induce corrosion. Sources of stray current include electrified rail lines, high-tension electric transmission lines, and cathodically protected gas transmission mains.

Abrasion—Frequent or continuous movement of rapidly flowing, turbulent water containing a bedload of sands, gravel, and debris can erode protective coatings on pipes and also erode the pipe material itself. Bedload is the portion of the total transported sediment that is carried by intermittent contact with the streambed (or culvert invert) by rolling, sliding, and bouncing. AASHTO's *Highway Design Guidelines* (2007) defines bedload by the two- to five-year return frequency. For these storm recurrences, flow velocities greater than 5 fps that carry sand bedload are considered abrasive. Velocities that exceed 15 fps and carry sand, gravel, and rock bedload are considered very abrasive. The CSLE does not include abrasion, so it is not required to be considered. However, if you determine that site and hydraulic conditions are likely to produce abrasive flow conditions, metal pipe suppliers have tables and programs online to estimate loss of wall thickness due to abrasion.

8.3.2 Project Geotechnical Investigation and Corrosion Tests

Because of the varying complexity of projects and soil conditions, it is difficult to establish a rigid format for conducting subsurface investigations. As stated in the Department's *Soils and Foundation Handbook*, "A subsurface investigation should be performed at the site of all new structure and roadway construction, and at widening, extensions, and rehabilitation locations as directed by the District Geotechnical Engineer or project scope." Typically, you would perform environmental corrosion tests, as discussed above, on soil and water at structure locations (e.g., bridge, box culvert, walls), on structural backfill material, and on subsurface materials along drainage alignments. For drainage systems parallel to roadway alignments, perform corrosion tests at maximum intervals of 1,500 feet along the project (see Section 3.2.2.6 of FDOT's *Soils and Foundation Handbook*). To ensure that you collect and analyze sufficient samples, coordinate with the geotechnical engineer on sample locations and depths. In addition to field review of the site and the existing culvert conditions, you can use the NRCS Web Soil Survey to help plan the soils investigation. Soil type parameters—such as pH, steel corrosion potential, and electrical conductivity—may indicate areas where you should obtain site-specific information. Test values are seasonally affected by such factors as rainfall, flooding, drought, and decaying vegetation. Whenever possible, you should perform environmental tests during periods when no unusual weather conditions exist.

Roadway plans include a "Roadway Soils Survey" sheet, as shown in Figure 8.3-1, which identifies a range of values of all tests performed. The complete geotechnical report contains test results for the specific locations sampled, and you can use these data for culvert analysis. Review the data and correlate them to actual field conditions where possible. A prediction of the actual service life of a culvert material at a particular site can be determined by the performance of a similar culvert material in the same or similar environmental condition. If the test data do not correlate with the observed culvert conditions, then request additional testing at the site in question. Ultimately, you should weight conclusive field performance more heavily than predicted service life when field performance and predicted service life disagree.

Analysis of the test data should take into consideration the most corrosive values of the native soils. However, with site-specific project environmental test data available, you won't need to use the most corrosive individual site data for the entire project or extract the most aggressive individual parameter results from the testing data to create a worst-case, project-wide condition. This over-conservatism is unwarranted and unrealistic. Instead, you can review the soil boring strata and apply test data to those locations that are most representative of the soil strata and conditions where the corrosion test data were obtained. There may be particular segments of the project where corrosive conditions exist, and other segments where the corrosion potential is low.

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION
MATERIALS AND RESEARCH

DATE OF SURVEY : 2/15/2007-5/1/2007
SURVEY MADE BY : HARTFORD TESTING COMPANY
SUBMITTED BY : LARRY BALLARD, P.E.

PROJECT NAME: ____________

FINANCIAL PROJECT ID : ____________

DISTRICT : 3
ROAD NO : S.R. 166
COUNTY : JACKSON

CROSS SECTION SOIL SURVEY FOR THE DESIGN OF ROADS

SURVEY BEGINS STA. : 400+00 SURVEY ENDS STA. : 554+00
REFERENCE: BASELINE SURVEY

	ORGANIC CONTENT			SIEVE ANALYSIS RESULTS % PASS						ATTERBERG LIMITS (%)					CORROSION TEST RESULTS				
STRATUM NO.	NO. OF TESTS	% ORGANIC	MOISTURE CONTENT	NO. OF TESTS	10 MESH	40 MESH	60 MESH	100 MESH	200 MESH	NO. OF TESTS	LIQUID LIMIT	PLASTIC INDEX	AASHTO GROUP	DESCRIPTION	NO. OF TESTS	RESISTIVITY ohms-cm	CHLORIDE ppm	SULFATES ppm	pH
1												N.P.		ROCK BASE, ASPHALTIC CONCRETE					
2				4	87-98	77-93	59-82	44-55	3-10			N.P.	A-3	SUBGRADE, GRAY & TAN SAND W/TRACE SILT, LIMEROCK & SHELL					
3	7	3-4	8-20	7	94-100	86-94	65-71	34-45	15-21			N.P.	A-2-4	FILL, DARK BROWN SAND W/SOME SILT & TRACE LIMEROCK	7	34000-43000	40-60	18-72	6.4-8.3
4	3	1-2	15-25	4	84-100	71-93	60-90	53-82	37-45	4	25-38	5-9	A-4	GRAY AND BROWN SILTY SAND W/TRACE CLAY AND LIMESTONE FRAGMENTS	4	23000-26000	60-120	84-96	8.4-8.9
5				3	100	99-100	96-98	75-80	30-34	3	42-44	11-15	A-2-7	TAN AND LIGHT GRAY SILTY SAND W/SOME CLAY AND TRACE SHELL	3	6600-8000	60-120	156-216	7.5-8.2
6	3	18-40	20-60						30-46	3	25-33	10-15	A-8	MUCK, ORGANIC DARK BROWN SILTY SAND W/SOME CLAY					
7				3	100	88-92	73-79	60-69	51-55	3	55-61	38-53	A-7	YELLOW AND GRAY SILTY SAND CLAY					
8	3	16-20	20-58	3	99-100	97-99	88-97	77-80	10-15			N.P.	A-8	MUCK, BROWN SAND W/SOME ORGANIC AND TRACE SHELL	3	20000-35000	120	120	4.6-5.2
9														NATURAL LIMESTONE					

EMBANKMENT AND SUBGRADE MATERIAL

STRATA BOUNDARIES ARE APPROXIMATE MAKE FINAL CHECK AFTER GRADING

▽ - WATER TABLE ENCOUNTERED

GNE - GROUND WATER NOT ENCOUNTERED

The material from Stratum Number 1 is Rock Base under Asphaltic Concrete.

The material from Stratum Number 2 appears satisfactory for use in the embankment when utilized in accordance with Index 505.

The material from Stratum Number 3 appears satisfactory for use in the embankment when utilized in accordance with Index 505. However, this material is likely to retain excess moisture and may be difficult to dry and compact. It should be used in the embankment above the water level existing at the time of construction. This material may not be used in the subgrade portion of the roadbed due to its organic content.

The materials from Stratum Numbers 4 and 5 are plastic materials and shall be removed in accordance with Index 500. They may be placed above the existing water level at the time of construction, to within 4 feet of the proposed base. They should be placed uniformly in the lower portion of the embankment for some distances along the project rather than full depths for short distances.

The material from Stratum Numbers 6 and 8 is ORGANIC/A-8 material and shall be removed in accordance with Index 500, except where noted in the cross sections.

The material from Stratum Number 7 is Highly Plastic material and shall be removed in accordance with Index 500. It may be used within the project limits as indicated in Index 505 only when excavated within the project limits and is not to be used when obtained from outside the project limits.

The material from Stratum Number 9 is the Natural Limestone Formation. Special tools and equipment may be required to excavate and/or dewater this material.

EXHIBIT SS-1
Date: 1/1/08

NOTICE: THE OFFICIAL RECORD OF THIS SHEET IS THE ELECTRONIC FILE SIGNED AND SEALED UNDER RULE 61G15-23.003, F.A.C.

REVISIONS			
DATE	DESCRIPTION	DATE	DESCRIPTION

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

ROAD NO.	COUNTY	FINANCIAL PROJECT ID
166	JACKSON	123456-1-52-01

ROADWAY SOILS SURVEY

SHEET NO.

$USER$ $DATE$ $TIME$ $FILE$

Figure 8.3-1: Example Roadway Soils Survey Sheet

8.3.3 Project Pipe Service Life Estimation

Use the CSLE Program and/or the Tables and Figures in Appendix M to determine types of culvert material that have ESLs that meet or exceed the required DSL. When the DSL, pipe size, pH, resistivity, chlorides, and sulfates are input, the program provides a listing of those materials that meet the DSL. The program also provides a generated report for documentation.

An example of the CSLE input data and printout follows:

DSL: This application is to be a storm drain system that is located on a major urban facility and will function as an urban principle arterial road. The appropriate DSL for this application is 100 years.

The following data were furnished, and a field review gave no indication that these values were suspect:

pH: 7.6

Resistivity: 2,610 ohm-cm

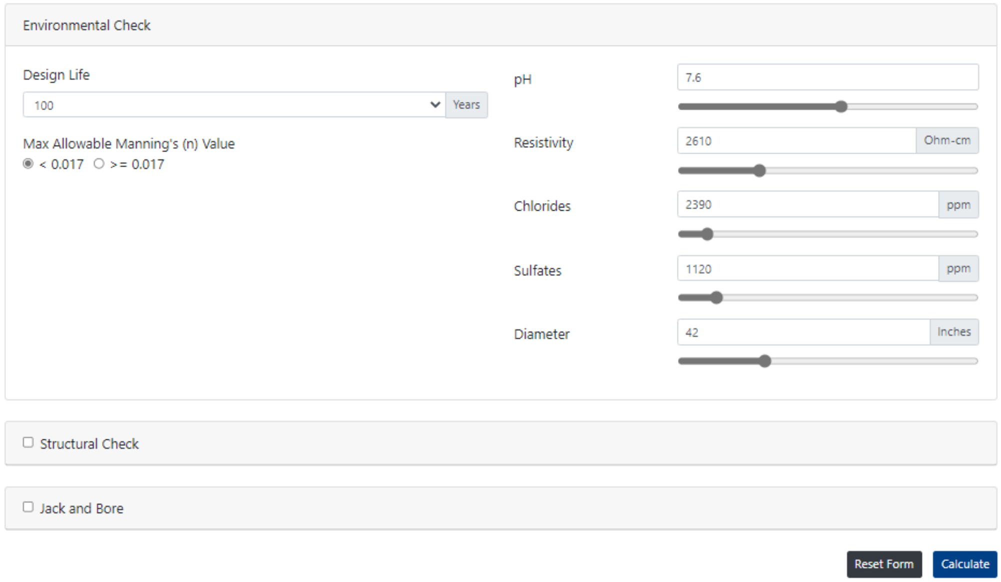
Chlorides: 2,390 ppm

Sulfates: 1,120 ppm

Diameter (Pipe Size): 42 inches; because this is a storm drain system, an n-value of 0.012 was used.

Once the environmental parameters are entered into the CSLE, click on ‘Calculate’ to obtain results from the environmental check. Any time inputs are changed, the Results are cleared and the Calculate button must be clicked on to obtain new results.

Figure 8.3-2 illustrates materials you would use in performing the structural analysis.



Pipe Results

Add Job Information and Generate PDF

	Gage	Type of Culvert	Service Life	Environmental Check	Structural Check
Pass					
	14	(SRAP) Aluminum - Spiral Rib	226	Pass	
		(RCP) Steel-Reinforced Concrete Ellipse	121	Pass	
		(RCP) Steel-Reinforced Concrete Round	121	Pass	
	14	(SRASP) Aluminized Steel - Spiral Rib	108	Pass	
		(HDPE) High Density Polyethylene, CL II	100	Pass	
		(PP) Polypropylene - Class II	100	Pass	
Fail					
		(HDPE) High Density Polyethylene, CL I - Unavailable in this size or not suitable for use		Fail	
		(NRCP) Non-Reinforced Concrete - Unavailable in this size or not suitable for use		Fail	
		(PP) Polypropylene - Class I - Unavailable in this size or not suitable for use		Fail	
		(PVC) Polyvinyl Chloride, ASTM F-949 - Unavailable in this size or not suitable for use		Fail	
		(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use		Fail	
		(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed		Fail	
		(SRSP) Galvanized Steel - Spiral Rib - Unavailable in this size or not suitable for use		Pass	

Figure 8.3-2

Each material has a magnifying glass icon next to it that can be clicked on for additional information. The colored lines indicate warnings: a yellow highlight indicates a warning concerning environmental data; a red highlight indicates a warning based on the structural data [Appendix C of the *Drainage Manual*].

The program allows you to print and save a PDF with the inputs and results by clicking on the 'Add Job Information and Generate PDF' button. This feature allows you to maintain the site data, but vary the corrosion parameters, pipe size, or roughness coefficient then re-analyze and print unique output files. The printouts are intended for use as documentation of the analyses. See Figure 8.3-3.

Florida Department of Transportation

Culvert Service Life Estimator - Version 2.0

(Generated Wednesday, May 18th 2022, 1:29:50 pm)

Job Information			
Project Name:	Optional Materials Example #1	**FM Number:**	N/A
Section Number:	N/A	**Structure Number:**	S-0
County:	Holleywood	**Boring Number/Location:**	B-1/85
Station	00+00	**Designer**	TH

Environmental Data				
Design Life (Years)	100		**pH**	7.6
Max Allowable Manning's n	< 0.017		**Resistivity (Ohms-cm)**	2610
Diameter (Inches)	42		**Chlorides (ppm)**	2390
			Sulphates (ppm)	1120

Gage	Type of Culvert	Service Life	Environmental	Structural
	Passed			
14	**(SRAP) Aluminum - Spiral Rib (1)**	226	Pass	
	(RCP) Steel-Reinforced Concrete Ellipse	121	Pass	
	(RCP) Steel-Reinforced Concrete Round	121	Pass	
14	(SRASP) Aluminized Steel - Spiral Rib	108	Pass	
	(HDPE) High Density Polyethylene, CL II (2)	100	Pass	
	(PP) Polypropylene - Class II	100	Pass	
	Failed			
	(HDPE) High Density Polyethylene, CL I - Unavailable in this size or not suitable for use		Fail	
	(NRCP) Non-Reinforced Concrete - Unavailable in this size or not suitable for use		Fail	
	(PP) Polypropylene - Class I - Unavailable in this size or not suitable for use		Fail	
	(PVC) Polyvinyl Chloride, ASTM F-949 - Unavailable in this size or not suitable for use		Fail	
	(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use		Fail	
	(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed		Fail	
	(SRSP) Galvanized Steel - Spiral Rib - Unavailable in this size or not suitable for use		Pass	

(1) **Special Installation required. Refer to AASHTO Standard Specifications for Highway Bridges or ASTM B788-88 and manufacturer's recommendations.**

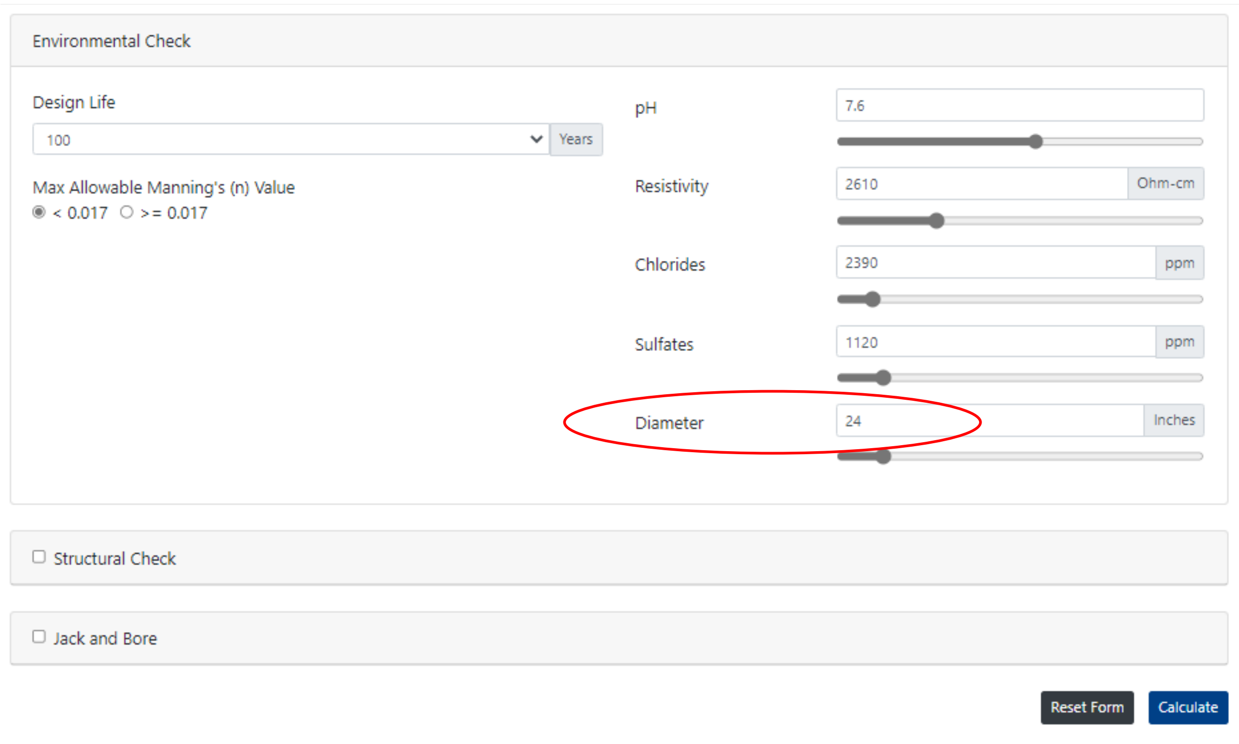
(2) **HDPE not allowed in the Florida Keys for 100 year service life. No restrictions for 50 year service life.**

1

Figure 8.3-3

Give no additional consideration to one material over another having less service life if all meet the minimum required. In looking at the printout, culverts made from steel-reinforced concrete, aluminum, aluminized steel, polypropylene class II, and high density polyethylene class II all meet the 100-year DSL. If the DSL was 50 years, then additional materials may be allowable.

Pipe size affects materials by invoking different gages of metal pipes. Additionally, pipe size affects the life of reinforced concrete pipe because, with larger diameters, the wall thickness increases, as does the cover over the reinforcing steel. See Figure 8.3-4 for allowable materials when the pipe size is reduced to 24 inches, given the same corrosion parameters and DSL as the previous example. Reinforced concrete pipe is no longer allowable, whereas non-reinforced concrete pipe is allowable. The gage of spiral-ribbed aluminized pipe (SRAP) has changed because of the smaller diameter, and PVC is now an allowable option because it is available in the smaller diameter.



Pipe Results

Add Job Information and Generate PDF

	Gage	Type of Culvert	Service Life	Environmental Check	Structural Check
Pass					
		(NRCP) Non-Reinforced Concrete	360	Pass	
	16	(SRAP) Aluminum - Spiral Rib	181	Pass	
	14	(SRASP) Aluminized Steel - Spiral Rib	108	Pass	
		(HDPE) High Density Polyethylene, CL II	100	Pass	
		(PP) Polypropylene - Class II	100	Pass	
		(PVC) Polyvinyl Chloride, ASTM F-949	100	Pass	
Fail					
		(HDPE) High Density Polyethylene, CL I - Unavailable in this size or not suitable for use		Fail	
		(PP) Polypropylene - Class I - Unavailable in this size or not suitable for use		Fail	
		(RCP) Steel-Reinforced Concrete Ellipse - Unavailable in this size or not suitable for use		Fail	
		(RCP) Steel-Reinforced Concrete Round - Unavailable in this size or not suitable for use		Fail	
		(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use		Fail	
		(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed - Unavailable in this size or not suitable for use		Fail	
		(SRSP) Galvanized Steel - Spiral Rib - Unavailable in this size or not suitable for use		Pass	

Figure 8.3-4

8.3.4 Special Cases (Jack and Bore Casings, Ductile Iron Pipe, any Ferrous Metals)

When installing a culvert by jacking and boring instead of open cutting, use the jacked and bored casing as the conveyance pipe except under railroads or in high-pressure designs. Coordinate with the District Rail Administrator and the railroad for design requirements.

You should specify jack-and-bore installation on high AADT roadways, railroads, or in areas where open cut for installation or repair causes significant impacts on users. If the need to install a culvert using jack-and-bore technology was determined after the roadway soils investigation was made, additional soil borings may be necessary. Determine soil conditions along the jack-and-bore alignment so that you can evaluate the feasibility of jack-and-bore installation or of micro-tunneling. You will need corrosion data to estimate service life.

Because jack-and-bore locations typically have a high AADT, this service life estimation example will assume a 100-year DSL. Use the following steps to determine the casing requirements.

1. Run the Culvert Service Life Estimator Program or use the figures or tables in Appendix M with site-specific environmental parameters. If the casing or pipe will be exposed to water (surface or ground) for extended periods of time, compare the environmental parameters of the water with those of the soil. Use the test results that produce the shortest service life for the galvanized steel option. Note that when using the CSLE Program, reduce the DSL as needed for the galvanized steel option (corrugated steel pipe [CSP] or spiral rib steel pipe [SRSP]) to show up as an allowable option. Although the required DSL may be 100 years, you must first obtain the service life for the particular corrosion parameters, or you can use Figure M1 to determine estimated service life.

2. To be conservative, deduct 10 years from the ESL of the galvanized steel option generated by the program (or determined by service life tables/figures).

3. Determine the pitting rate by dividing the wall thickness of the galvanized steel option estimated by the program by the estimated service life determined in Step 2 (ESL – 10 years). From the *Drainage Manual,* Appendix C, identify the wall thickness of the gage pipe called out on the output.

$$\text{Pitting Rate} = \frac{\text{Gage Thickness}}{\text{ESL (years)}} = \frac{0.\text{xxx inches}}{\text{year}}$$

Knowing the pitting rate, you can determine the required wall thickness by multiplying the DSL for the application by the pitting rate.

Required wall thickness = Pitting rate x (DSL)

Using the galvanized steel option shown on Figure 8.3-5:

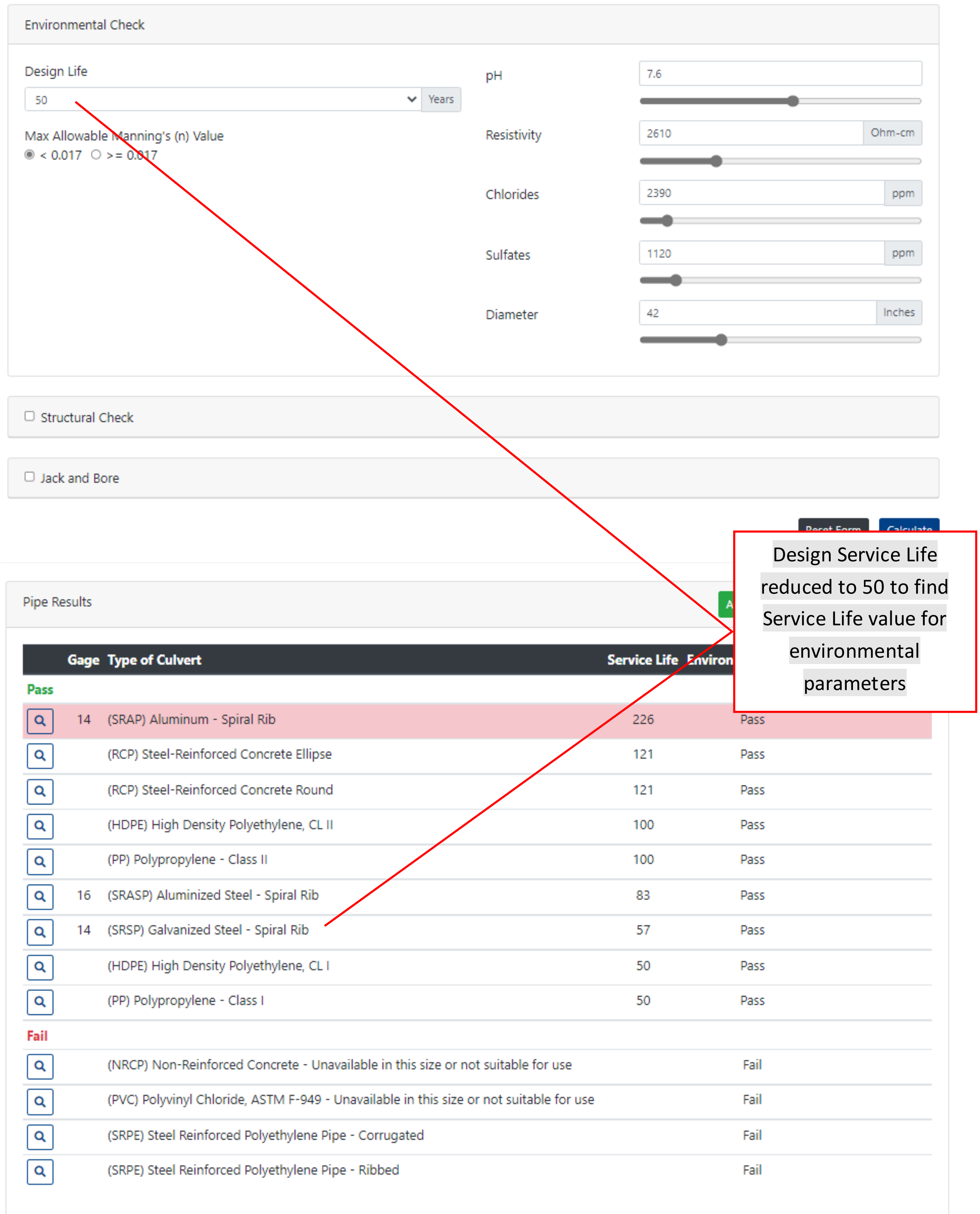

Environmental Check
Design Life
50
Years
Max Allowable Manning's (n) Value
< 0.017
>= 0.017
pH
7.6
Resistivity
2610
Ohm-cm
Chlorides
2390
ppm
Sulfates
1120
ppm
Diameter
42
Inches
Structural Check
Jack and Bore
Design Service Life reduced to 50 to find Service Life value for environmental parameters
Pipe Results
Gage
Type of Culvert
Service Life
Pass
14 (SRAP) Aluminum - Spiral Rib 226 Pass
(RCP) Steel-Reinforced Concrete Ellipse 121 Pass
(RCP) Steel-Reinforced Concrete Round 121 Pass
(HDPE) High Density Polyethylene, CL II 100 Pass
(PP) Polypropylene - Class II 100 Pass
16 (SRASP) Aluminized Steel - Spiral Rib 83 Pass
14 (SRSP) Galvanized Steel - Spiral Rib 57 Pass
(HDPE) High Density Polyethylene, CL I 50 Pass
(PP) Polypropylene - Class I 50 Pass
Fail
(NRCP) Non-Reinforced Concrete - Unavailable in this size or not suitable for use Fail
(PVC) Polyvinyl Chloride, ASTM F-949 - Unavailable in this size or not suitable for use Fail
(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated Fail
(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed Fail

Figure 8.3-5

Estimated service life for galvanized steel culvert = 57 years

Deduct 10 years from this: 57 years – 10 years = 47 years

14 gage = 0.079 inches (thickness of 14 gage galvanized steel culvert per *Drainage Manual*, Appendix C)

Therefore, the pitting rate = 0.079/47 = 0.00168 inches/year

Minimum required wall thickness = 100 years (DSL) x 0.00168 (pitting rate) = 0.1681 inches

Note that the pitting rate determined when other DSLs are input and resultant service lives are obtained will be approximately the same. For example, if a DSL of 25 years is input in the above example, the gage of SRSP allowed is 16 (0.064 inch), with a corresponding service life of 46 years. This results in a pitting rate of 0.00177 inches/year.

In summary, you would need to use a steel casing with a wall thickness of at least 0.17 inches. In the plans, include a note such as: “For corrosion purposes, steel casing must have a minimum wall thickness of 0.17 inches.”

The required wall thickness is for corrosion purposes only. Typically, you will need greater wall thicknesses for the structural loadings associated with the jacking of the steel casing. The CSLE program has a checkbox option for “Jack and Bore”; the window will show the approximate wall thickness of pipe suitable for jack and bore and the associated service life. The Default metal thickness shown is that of a typical steel pipe that you would use for jack and bore. The program uses the thickest galvanized steel pipe gage to determine the pitting rate (even if that particular gage is not available in the given size). That pitting rate is applied to the typical jack and bore pipe wall thickness to estimate service life. If the ESL of the jack-and-bore casing pipe is less than that required, select the “Service Life” option and enter the service life value to calculate metal thickness. The print output from the ‘Generate Jack and Bore PDF’ button contains the pitting rate analysis, pipe size, and the corrosion data.

The minimum thickness that meets service life is that determined by the pitting rate equation. Show the thickness in the construction plans with a note stating it is the minimum thickness to meet service life. The contractor is responsible for determining the wall thickness required for the jack-and-bore pipe to meet Specification 556.

For the example shown in Figure 8.3-6, the minimum metal thickness based on service life is thicker than the typical jack-and-bore pipe because of the aggressive environmental parameters. For this case, an interior carrier pipe should be installed that meets service life and structural requirements.

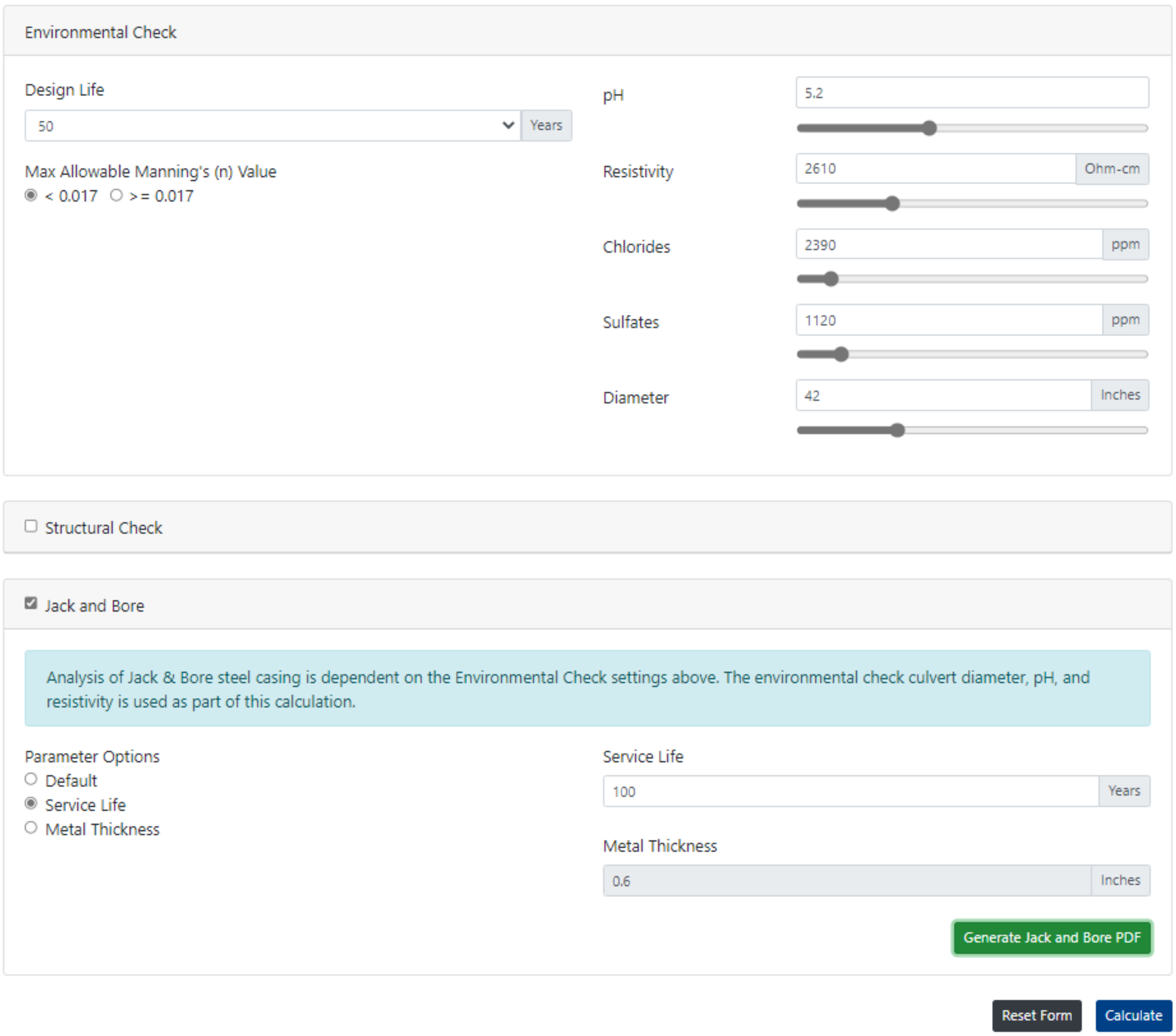


Figure 8.3-6

The printout for this jack-and-bore service life analysis is shown in Figure 8.3-7.

Florida Department of Transportation

Culvert Service Life Estimator - Version 2.0

(Generated Wednesday, October 19th 2022, 10:22:44 am)

Environmental Data				
Design Life (Years)	50		pH	5.2
Max Allowable Manning's n	< 0.017		Resistivity (Ohms-cm)	2610
Diameter (Inches)	42		Chlorides (ppm)	2390
			Sulphates (ppm)	1120

Service Life of Jack and Bore Steel Casing	
1. Data from Service Life Estimator	
Galvanized Steel Service Life (Years)	38
Gage	8
2. Deduct 10 Years From Galvanized Steel Option	
Service Life (Years)	38
Service Life Minus 10 Years	28
3. Pitting Rate Analysis (Inches/Year) = Gage Thickness / Service Life	
Gage Thickness (Inches)	0.168
Service Life (Years)	28
Pitting Rate (Inches/Year)	0.006
4. Determine Casing Pipe Service Life	
Casing Thickness (Inches)	0.5
Pitting Rate (Inches/Year)	0.006002
Steel Casing Service Life (Years)	83.3

Figure 8.3-7

When using the casing alone is not allowed, you should place a note disallowing this practice in the plans to communicate to the Contractor that a VECP (Value Engineering Change Proposal) eliminating the interior pipe will not be approved.

8.4 PIPE STRUCTURAL EVALUATION

After performing the corrosion analysis, the next step in determining the allowable optional material is to determine the acceptability and structural adequacy of these materials. If the pipe is within a walled embankment area—“Wall Zone” as illustrated in the *Drainage Manual*, Appendix D—then the pipe material considered must be within the Wall Zone Pipe column in Table 6-1 of the *Drainage Manual*. All acceptable material types must be evaluated for anticipated loads on the pipe. The *Drainage Manual*, Appendix C, contains cover height tables for the various pipe materials. The information provided in Appendix C was developed based on criteria found in AASHTO *LRFD Bridge Design Specifications*, Section 12.

For each of the acceptable pipe materials based on the corrosion analysis and pipe location within the embankment, verify that the depth of backfill over the pipe is between the minimum and maximum fill heights in the appropriate table in the *Drainage Manual*, Appendix C. If the cover height is outside the limits, the following options are available:

1. Adjust the flow line of the pipe as long as this adjustment does not violate any other design criteria.

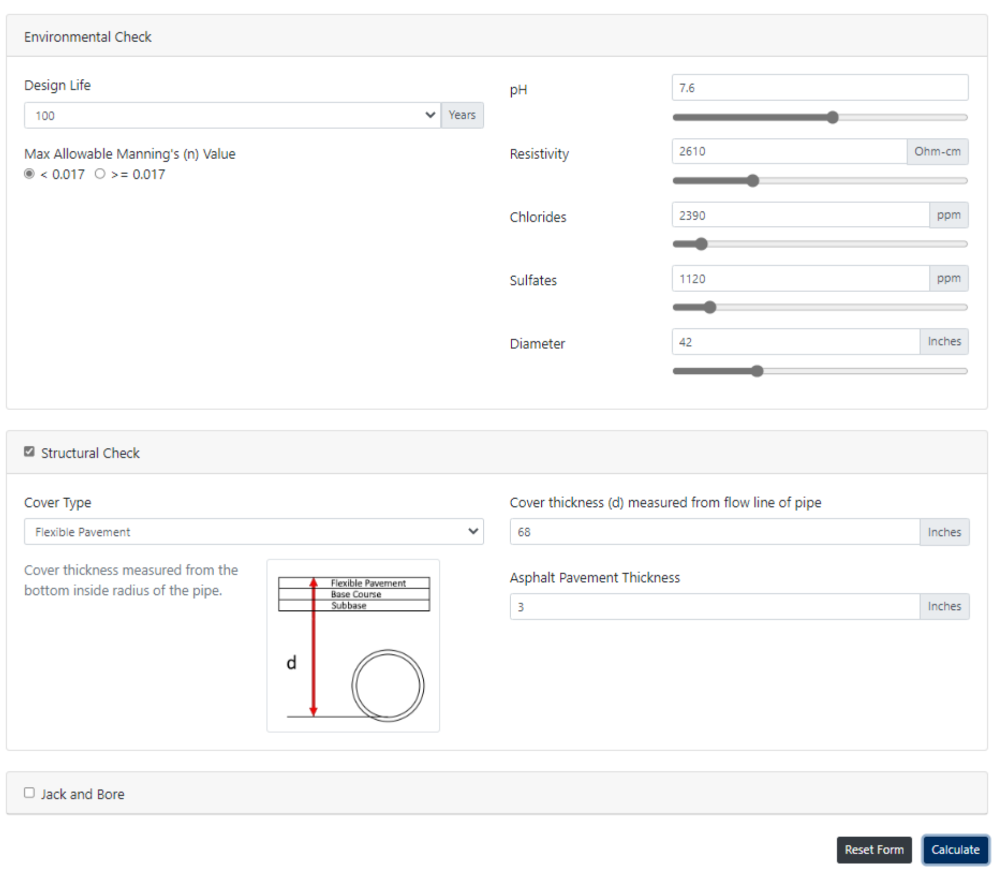
2. Increase the gage of metal pipe or the class of concrete pipe. For metal pipe, verify that the specified gage thickness is available for the corrugation specified.

3. Eliminate the material as an option for the job.

The *FDM* requires that you call out all the acceptable types of pipe materials in the plan. You can establish the required class of concrete, or gage and corrugation for metal pipe, using the CSLE program or the service life tables/figures in Appendix M, and the *Drainage Manual*, Appendix C. The tables in Appendix C have been incorporated into the CSLE; however, you will need to back check the results of the CSLE structural check against the tables in Appendix C for final verification. Generally, it is more efficient to look at the tables when determining the structural suitability than to input discrete height values in the Structural Check option of the CSLE. The tables allow you to readily see the lower and upper limits of allowable cover, whereas the CSLE output provides only a “pass” or “fail” for a particular value.

For example, given the allowable pipe materials shown in Figure 8.3-2, find the pipes that are structurally sufficient for a minimum fill height of 23 inches and maximum fill height of 25 feet.

Using the CSLE program with corrosion data and DSL shown on Figure 8.3-2, click on the box next to "Structural Check." A window drops down for input of pavement type, cover thickness, and pavement thickness. The cover thickness here is input to the flowline of the pipe whereas the cover is shown to the outside crown of the pipe in the Appendix C tables. Pavement thickness is only the thickness of the asphalt or concrete, and does not include the base or subbase. Input a pipe depth of 68 inches (from finished grade to pipe flowline), and 3 inches for the thickness of flexible asphalt pavement and click "Calculate". The CSLE program results in the elimination of HDPE, and PP pipe (Figure 8.4-1). Referring to the *Drainage Manual*, Appendix C, the table for Plastic Pipe, you can see that the minimum cover from top of base course to top of pipe is 24 inches for both HDPE and PP pipe. Based on our inputs to the CSLE program, the cover is [(68-3)-(42)] = 23 inches, not including deduction for pipe wall thickness. The Appendix C table for SRAP shows minimum cover of 21 inches for the 42-inch diameter, 14 gage pipe. Referring to the respective tables for the remaining allowable materials, we find that 12 inches is the minimum cover for both round and elliptical concrete, as well as for the SRSP (SRASP has the same **structural** properties as SRSP).



Pipe Results

Add Job Information and Generate PDF

Gage	Type of Culvert	Service Life	Environmental Check	Structural Check
Pass				
14	(SRAP) Aluminum - Spiral Rib	226	Pass	Pass
	(RCP) Steel-Reinforced Concrete Round, CL I	121	Pass	Pass
14	(SRASP) Aluminized Steel - Spiral Rib	108	Pass	Pass
Fail				
	(HDPE) High Density Polyethylene, CL I - Unavailable in this size or not suitable for use		Fail	Fail
	(HDPE) High Density Polyethylene, CL II		Pass	Fail
	(NRCP) Non-Reinforced Concrete - Unavailable in this size or not suitable for use		Fail	Fail
	(PP) Polypropylene - Class I - Unavailable in this size or not suitable for use		Fail	Fail
	(PP) Polypropylene - Class II		Pass	Fail
	(PVC) Polyvinyl Chloride, ASTM F-949 - Unavailable in this size or not suitable for use		Fail	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use		Fail	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed		Fail	Pass
	(SRSP) Galvanized Steel - Spiral Rib - Unavailable in this size or not suitable for use		Pass	Fail

Figure 8.4-1

Minimum cover and maximum fill heights obtained from the tables in the *Drainage Manual*, Appendix C, are summarized in Table 8.4-1 for the acceptable materials shown in Figure 8.3-2.

Table 8.4-1 Example Project Minimum Cover and Maximum Fill Heights

Allowable material for 42-inch diameter, minimum DSL = 100 years	***Appendix C Allowable minimum cover (in.)***	***Appendix C Allowable maximum fill height (ft.) to finished grade***
14 gage SRAP	21; from top of base	25 ft; special installation
Reinforced Concrete Pipe (RCP); Typical Dry Cast	12; from finished grade	21 ft to 33 ft; CL IV pipe required
RCP; Elliptical Only	12; from finished grade	max 25 ft; CL HE-IV required
14 gage SRASP (use SRSP table)	12; from top of base	54 ft
HDPE CL II	24; from top of base	13 ft
Polypropylene	24; from top of base	15 ft

Preparing a table with the allowable materials and their minimum cover and maximum fill height allows one to quickly ascertain where the materials can be used within the project if locations of the minimum cover and maximum fill are known. Plastic pipe would not be acceptable for installation where the minimum cover is less than 24 inches, and fill heights are greater than 13 feet, but there may be many locations throughout the project where plastic pipe installation would be within the allowable structural limits. That is why it is more efficient to use the tables directly rather than use the CSLE for the structural check.

Note that the fill heights shown in the *Drainage Manual*, Appendix C, are calculated using a very conservative approach. In those cases where you encounter very high or very shallow fill heights, you can use methods set forth in AASHTO LRFD *Bridge Design Specifications*, Section 12. Where you must locate pipes within close proximity to walled embankment areas of any type, review the figures in the *Drainage Manual*, Appendix D, to determine what limitations are imposed on pipe location and material. The figures in Appendix D show Wall Zones A, B, and C. Wall Zone criteria allow both longitudinal and transverse Wall Zone Pipe (as listed in the *Drainage Manual*, Table 6-1) in Wall Zone A. You are allowed to use Transverse Wall Zone Pipe conveyances in Wall Zone B, and you may not use pipe conveyances of any type in Wall Zone C. A few of the figures in Appendix D are reproduced here, with examples of where you may place pipes. Wherever possible, it is best to avoid pipe placement in any of the Wall Zones.

Figure 8.4-2 shows a mechanically stabilized earth (MSE) wall at a bridge abutment on shallow foundation and on deep foundation. Wall Zone B extends under the deep foundation whereas Wall Zone C (no pipes) extends under the shallow foundation. The figure shows pipes only within the allowable zones.

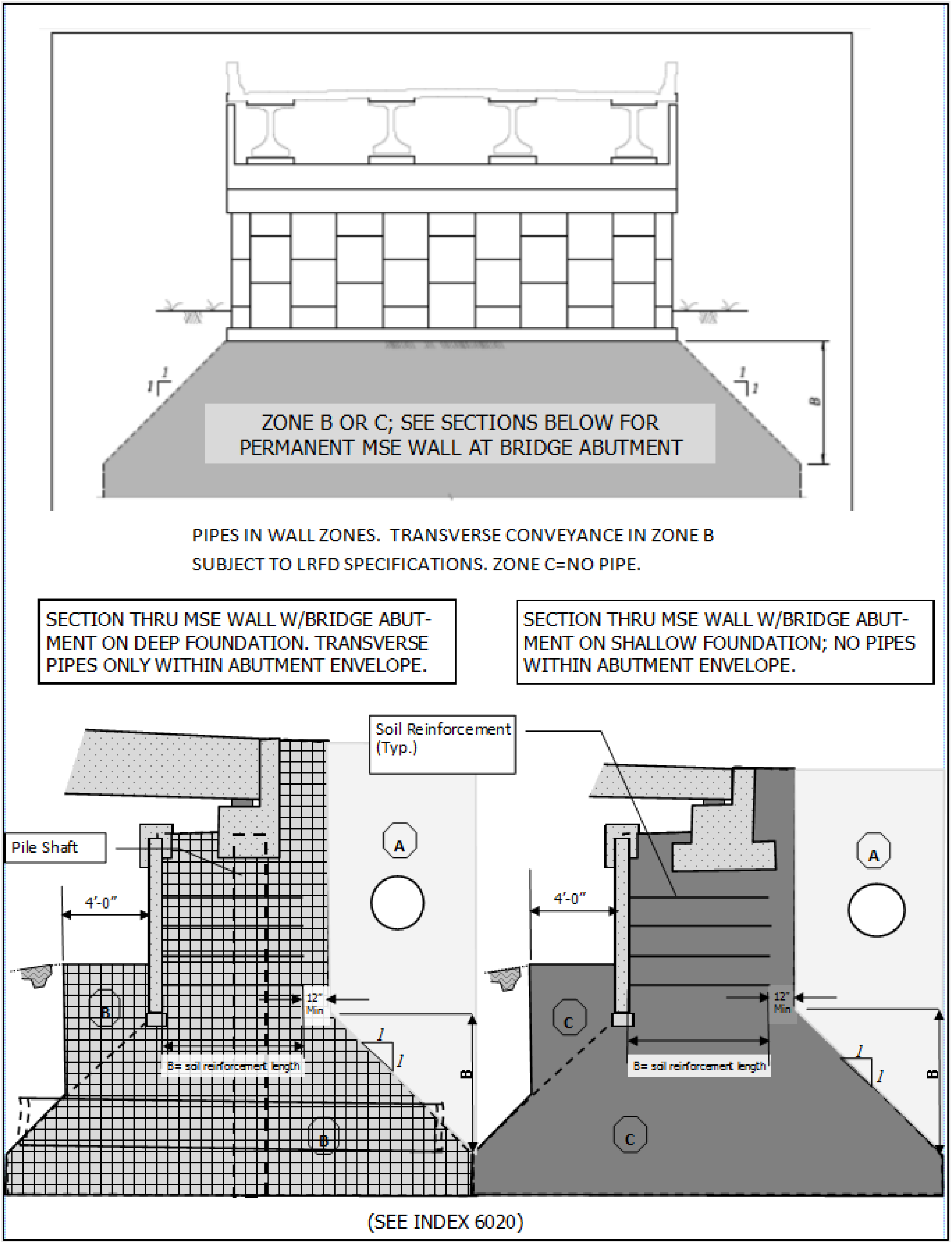

ZONE B OR C; SEE SECTIONS BELOW FOR
PERMANENT MSE WALL AT BRIDGE ABUTMENT
PIPES IN WALL ZONES. TRANSVERSE CONVEYANCE IN ZONE B
SUBJECT TO LRFD SPECIFICATIONS. ZONE C=NO PIPE.
SECTION THRU MSE WALL W/BRIDGE ABUT-
MENT ON DEEP FOUNDATION. TRANSVERSE
PIPES ONLY WITHIN ABUTMENT ENVELOPE.
SECTION THRU MSE WALL W/BRIDGE ABUT-
MENT ON SHALLOW FOUNDATION; NO PIPES
WITHIN ABUTMENT ENVELOPE.
Soil Reinforcement
(Typ.)
Pile Shaft
4'-0"
A
B
C
12" Min
B= soil reinforcement length
(SEE INDEX 6020)

Figure 8.4-2

Another example of pipe within MSE Wall Zone is shown in Figure 8.4-3. Longitudinal conveyances are shown in Wall Zone A. Even though the pipe to the left of the wall is only partially within Wall Zone A, it must meet the Wall Zone pipe requirements. If right of way allows, this pipe should be aligned fully outside of Wall Zone A. The pipe that is within the wall fill embankment can run longitudinally only within the top five feet. Minimize longitudinal runs of pipe in Wall Zone A to the greatest extent practicable. Where inlets are required that would extend into Wall Zone B, the preference would be to outfall transversely to a trunk line located outside of the wall zones. If this is not feasible, then you could use a deeper structure to allow the pipe to outfall transversely through or under the wall; these configurations are not ideal. Any structure or pipe within the reinforcement strap zone must be coordinated with the wall designer.

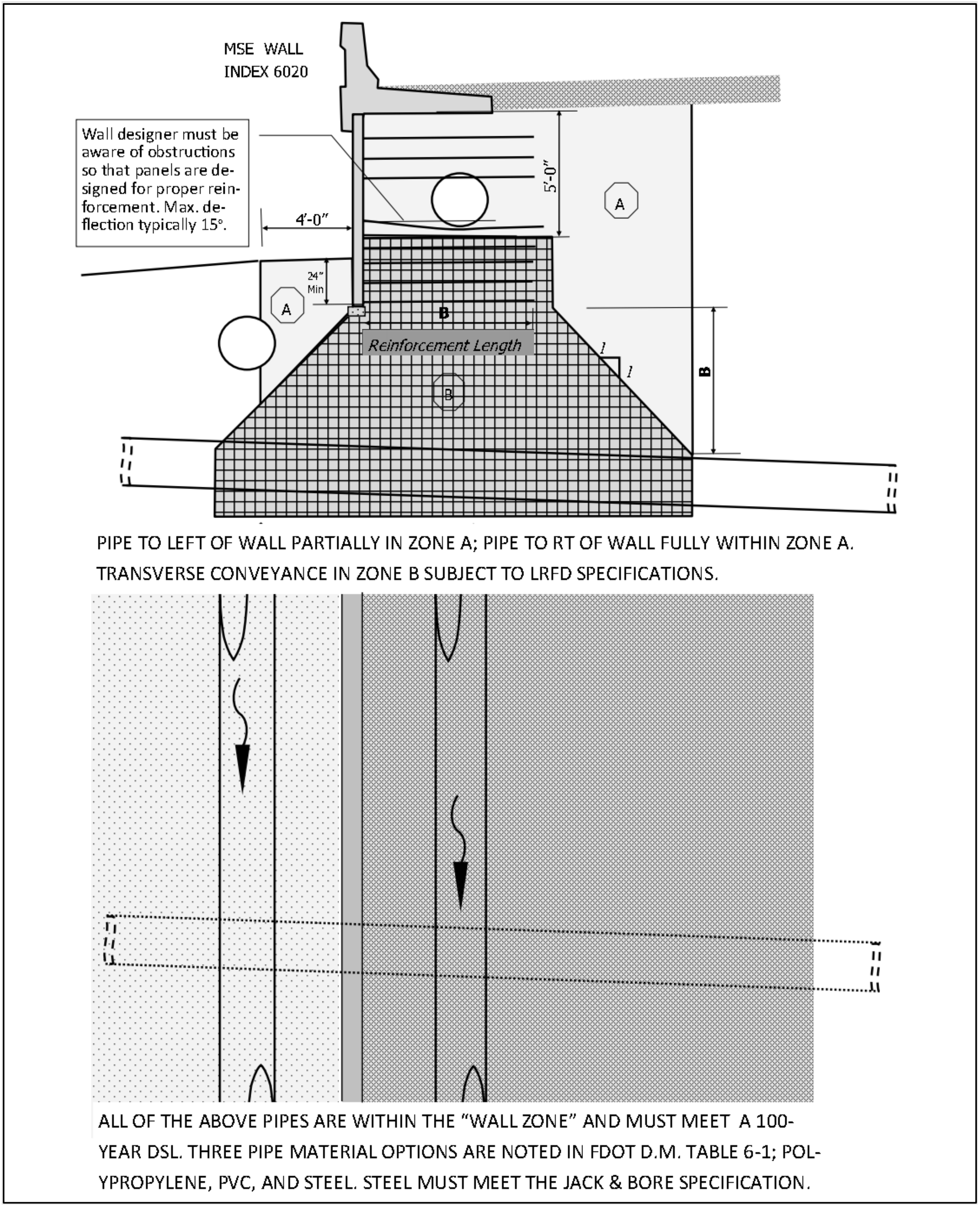

MSE WALL
INDEX 6020
Wall designer must be aware of obstructions so that panels are designed for proper reinforcement. Max. deflection typically 15°.
4'-0"
5'-0"
24" Min
A
A
B
B
B
Reinforcement Length
1
1
PIPE TO LEFT OF WALL PARTIALLY IN ZONE A; PIPE TO RT OF WALL FULLY WITHIN ZONE A.
TRANSVERSE CONVEYANCE IN ZONE B SUBJECT TO LRFD SPECIFICATIONS.
ALL OF THE ABOVE PIPES ARE WITHIN THE "WALL ZONE" AND MUST MEET A 100-YEAR DSL. THREE PIPE MATERIAL OPTIONS ARE NOTED IN FDOT D.M. TABLE 6-1; POLYPROPYLENE, PVC, AND STEEL. STEEL MUST MEET THE JACK & BORE SPECIFICATION.

Figure 8.4-3

Figure 8.4-4 shows a gravity wall and its associated wall zones. Ascertain the wall scheme proposed (there are other schemes) to ensure that any proposed drainage structures meet the wall zone criteria.

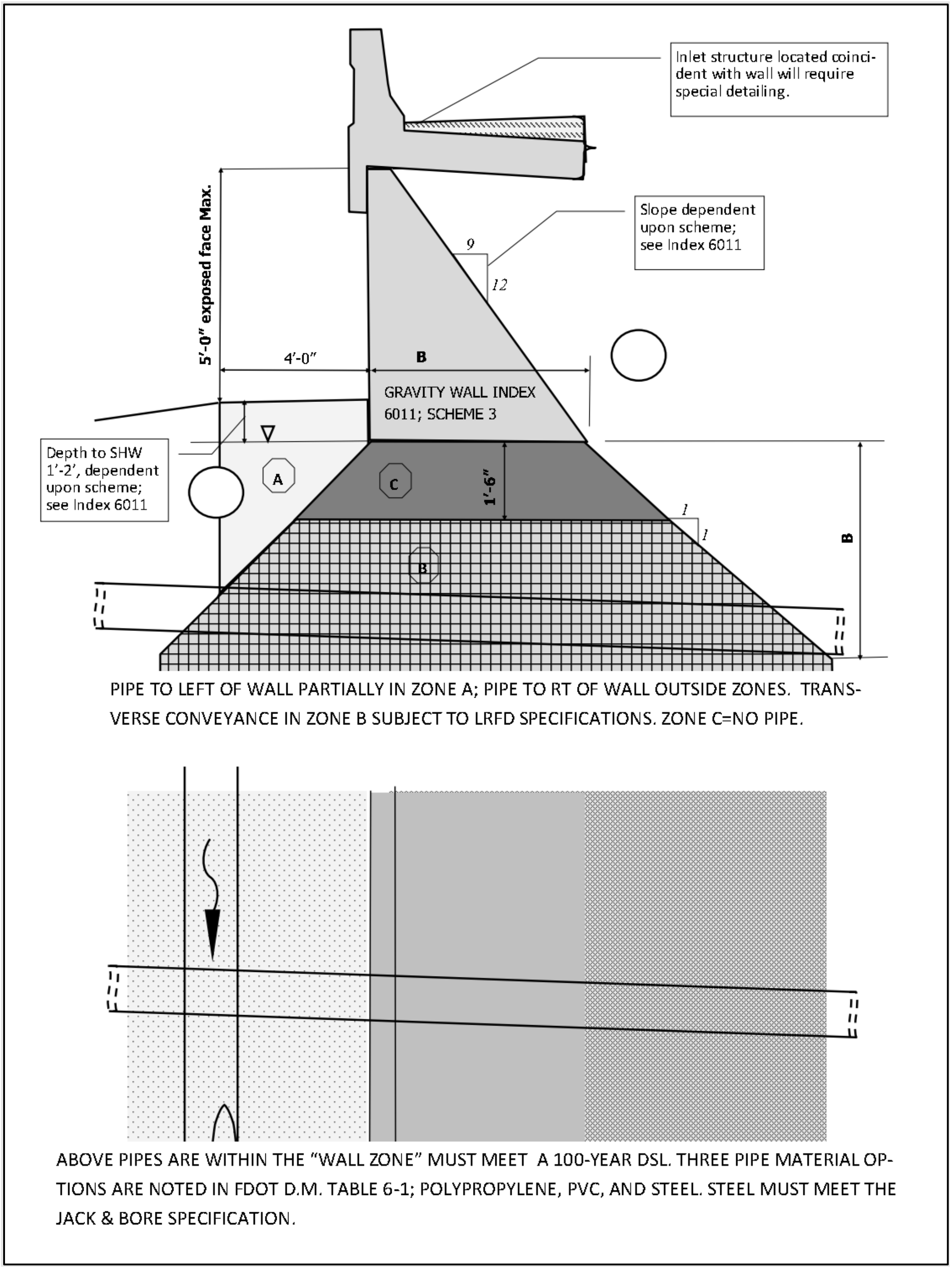


Figure 8.4-4

Figure 8.4-5 shows wall zones associated with a cantilever wall. Note that this configuration, as well as all supporting walls on shallow foundation, has a no-pipe zone, i.e. Wall Zone C, which is directly under the structure and extends out in a trapezoidal shape below the structure. The depth of the trapezoid is dependent upon the particular structure.

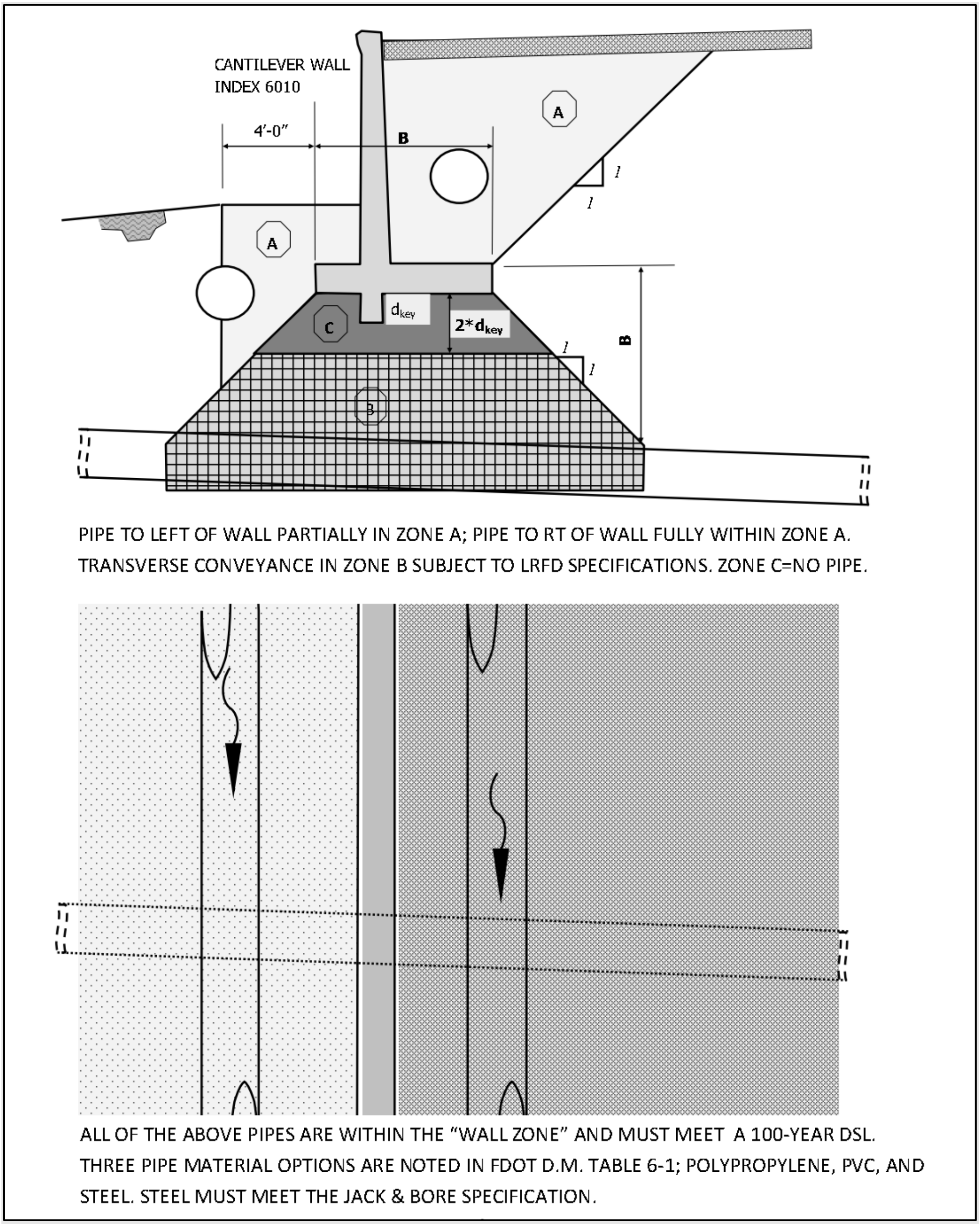


Figure 8.4-5

8.5 DOCUMENTATION

You are required to provide justification if you allow or eliminate a pipe material. You can find documentation requirements in Chapter 6 of the *Drainage Manual*. Requirements include the Design Service Life required for the application, environmental data, and the results of the structural evaluation.

The CSLE program provides an excellent form of corrosion analysis documentation in the printout. The printout documents the site specific environmental parameters, the ESL, and the materials that fail to meet or exceed the DSL. Also, you can add further comments for documentation purposes. An example of additional comments would be: “not allowed per *Drainage Manual*, Appendix C,” “minimum cover not available,” or “maximum cover exceeded.”

8.5.1 Project Example Considering all Potential Pipe Applications

The project consists of widening and resurfacing a state road in northern Leon County, Florida. This particular section of roadway contains both rural and urban sections. The urban section occurs where the roadway approaches and crosses an arterial roadway. The AADT for the roadway within the project limits is 1,500. The roadway project includes widening for bike lanes and turning lanes. You conducted a field review prior to final design; you observed all culverts and side drains for signs of deterioration, siltation, and erosion. All were in reasonably good condition given their current 40-year time of service. The project design includes the following applications:

- Side drain
- Cross drain (replacement and extensions)
- Storm drain
- Wall Zone Pipe
- Gutter drain
- French drain

For this example, each application will be addressed and will include a determination of the design service life, commonly asked questions, and proposed solutions to those questions.

8.5.1.1 Side Drains under Driveways

Due to widening of the roadway, all existing side drains are affected. Referring to Table 6-1, we locate the Side Drain column. From the table, we see that all highway side drains require a 25-year design service life, and that all but three of the listed materials (fiberglass, steel (J&B), and ductile iron) may be applicable.

Check the hydraulics at typical locations to determine if materials with N-values of 0.020 or greater should be included. Generally, if the hydraulic evaluation indicates the structure is outlet controlled, only those materials with N-values equal to 0.012 need be considered. In this case, the roadside ditches have minimal longitudinal slope and hydraulic evaluations of a typical location showed the culvert operated in outlet control, so only materials with N = 0.012 are suitable hydraulically. (See Cross Drains for side drains under side streets.) The design calculations result in pipe sizes that include 18-inch, 24-inch, and 30-inch.

Soil corrosion data obtained at shallow depths along the project were fairly consistent and are shown in Table 8.5-1.

Table 8.5-1. Soil Corrosivity Data for Example

Station	Boring #	pH	Resistivity	Chlorides	Sulfates
527+50	A-1	5.6	32000	20	108
592+00	A-2	6.6	9500	20	118
610+00	A-3	6.8	17000	20	20

You can enter the information for each site into the CSLE program, or you can use the tables or figures in Appendix M to determine suitability for the 25-year DSL. Let's use the figures to more quickly evaluate these three sets of test data. Looking at the tables and figures, we can see that the environmental parameters that affect steel and aluminum are pH and Resistivity. Those that affect reinforced concrete are pH, Chlorides, and Sulfates. This example shows some of the Figures and Tables in Appendix M as Figures 8.5-1 through 8.5-4.

From Figure 8.5-1, we see that—as long as the pH is above 5.5 and the resistivity is above 9,000—the DSL of 25 years is met for 16-gage galvanized steel. For 16-gage aluminized steel, Type II, we see on Figure 8.5-2 that the 25-year service life is met for pH between 4.5 and 9, with resistivity greater than 1,500. Figure 8.5-3 reflects the service life of 16-gage aluminum pipe; we can see that low resistivity values (<5,000) with pH values lower than 6 or higher than 8 adversely affect the service life of aluminum. In our case, the pH values range from 5.5 to 6.8 and the resistivity values are all greater than 9,000; therefore, the required DSL is met.

We will use the table in Figure 8.5-4 to evaluate the suitability of reinforced concrete pipe. The table shows that service life decreases with increasing chloride concentrations and as pH drops below 6. If sulfate concentrations go above 1,500 ppm, the service life should be discounted as noted. Since all chloride values from the samples are 20 ppm or below, there is no adverse effect on reinforced concrete. However, the table values are for 60-inch pipe, which has a thick pipe wall. To estimate service life for 18-inch pipe, the service life of 360 years must be multiplied by 0.36. The minimum service life anticipated for reinforced concrete pipe on this project is, therefore, approximately 130 years.

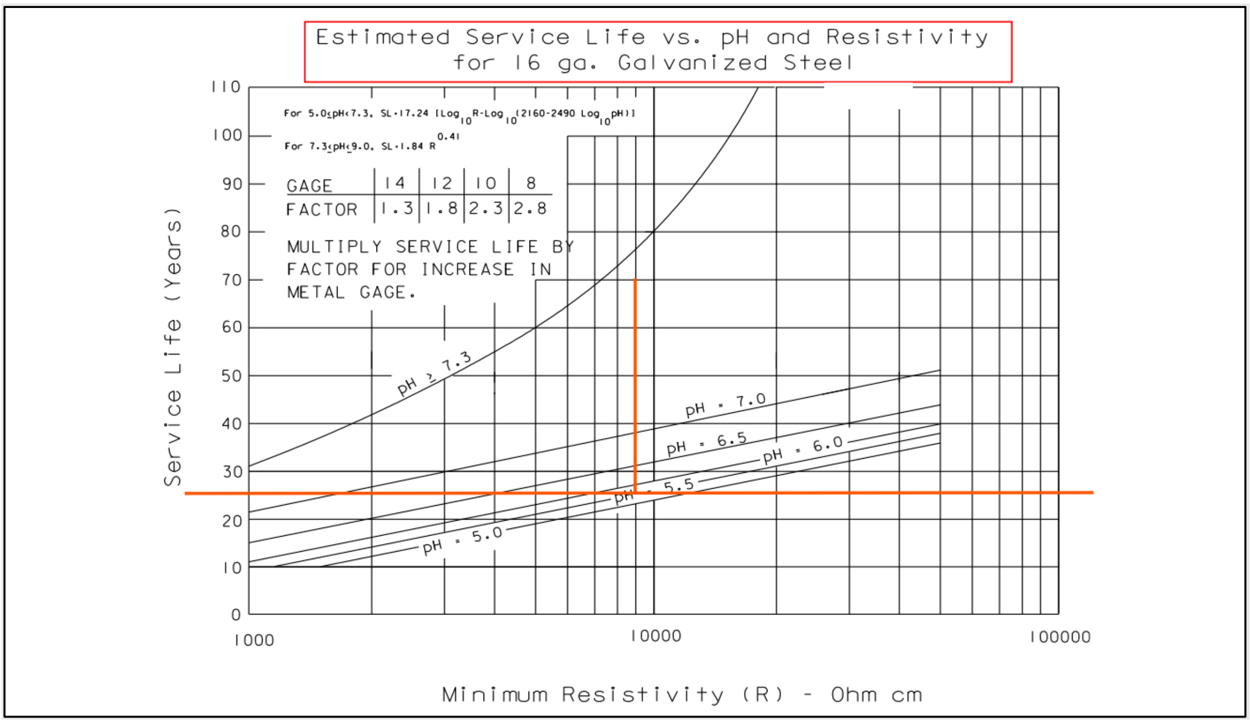


Figure 8.5-1

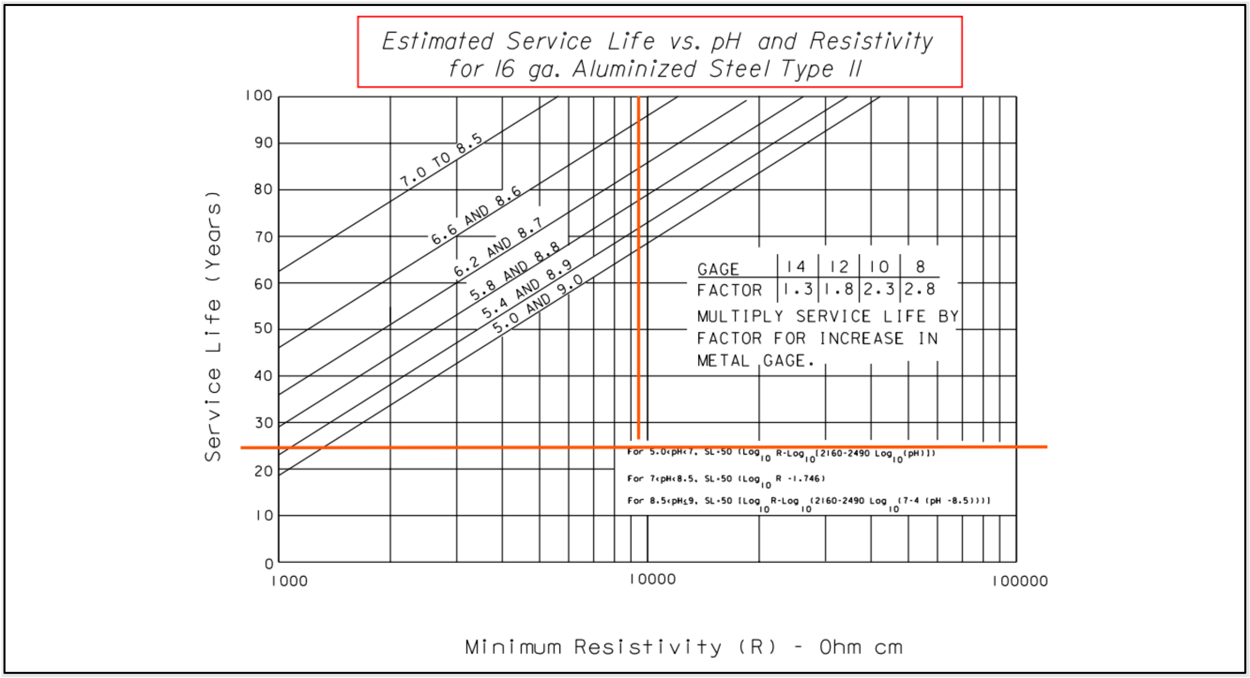


Figure 8.5-2

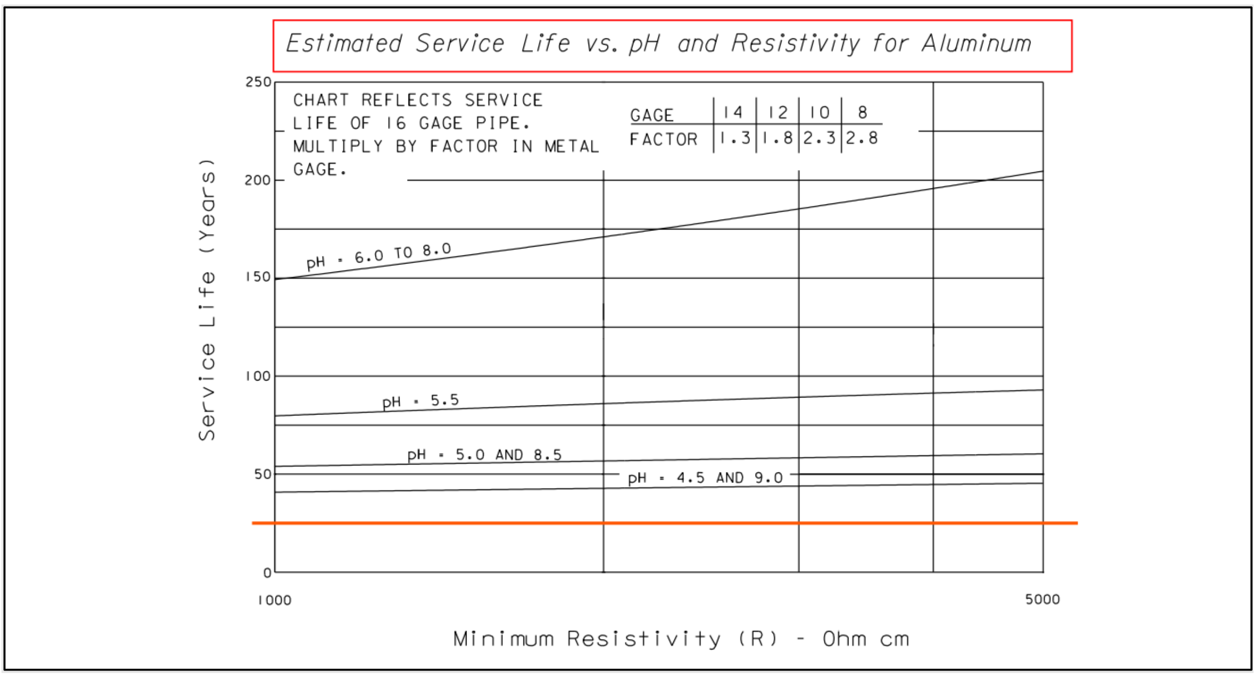


Figure 8.5-3

Estimated Service Life vs. pH and Chlorides for 60" Dia. **REINFORCED CONCRETE** Culverts at 1500 ppm Sulfate Concentration

	Chlorides											
pH	15000	13000	11000	9000	7000	5000	3000	2000	1000	750	500	250
5.0	88	93	99	107	118	135	164	192	250	278	324	360
5.1	89	94	101	109	119	136	165	193	251	279	325	360
5.2	90	95	102	110	121	137	167	194	252	281	327	360
5.3	91	96	102	111	122	138	167	195	253	282	327	360
5.4	92	97	103	111	122	139	168	196	253	282	328	360
5.5	92	97	103	112	123	139	168	196	254	282	328	360
5.6	93	98	104	112	123	140	169	196	254	283	329	360
5.7	93	98	104	112	123	140	169	197	254	283	329	360
5.8	93	98	104	113	124	140	169	197	255	283	329	360
5.9	93	98	105	113	124	140	170	197	255	284	330	360
≥6.0	94	99	105	113	124	141	170	197	255	284	330	360

Conversion Factors for Different Size Culverts

Pipe Dia.	Mult. By	Pipe Dia.	Mult. By
12"	0.36	48"	0.76
18"	0.36	60"	1.00
24"	0.41	72"	1.25
30"	0.48	84"	1.51
36"	0.54	96"	1.77
42"	0.65	108"	2.04

SL Reduction Factors for Sulfates

Sulfate Content	Subtract from SL
1500	0
3200	5
4900	10
6600	15
8300	20
10000	25

Note: Sulfate derating not applicable When Type V cement is used.

$$\text{Service Life (SL)} = 1000(1.107^{C}C^{0.717}D^{1.22}K^{-0.37}W^{-0.631}) - 4.22\times10^{10}(pH^{-14.1}) - 2.94\times10^{-3}(S) + 4.41$$

Where: C = Sacks of cement per cubic yard D = Steel depth in concrete K = Environmental chloride concentration in ppm
W = Total percentage of water in the mix S = Environmental sulfate content in ppm

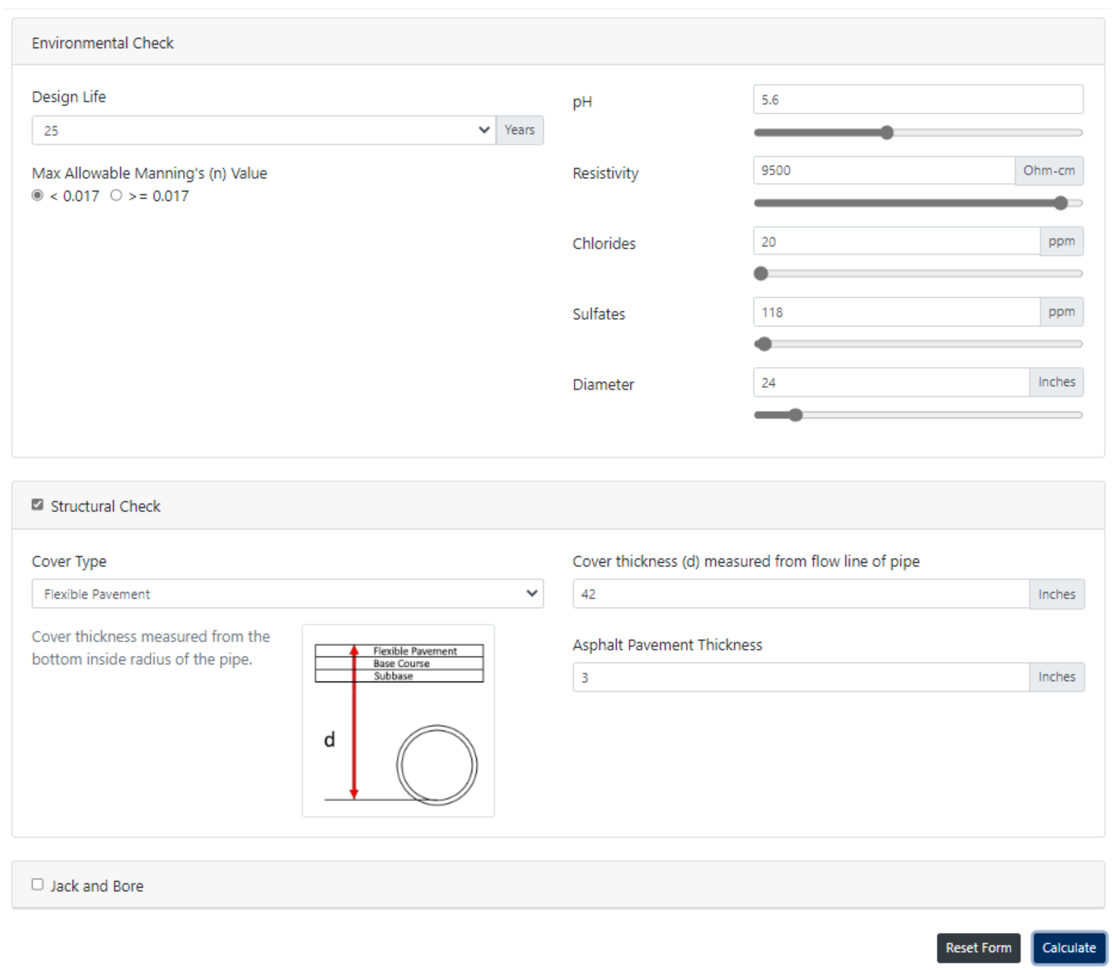
Figure 8.5-4

All roadside ditches are 3.5 feet below the roadway edge of shoulder, and ground at the right-of-way line is at or above the edge of shoulder, so available depth is 3.5 feet. Referring to the cover height tables in the *Drainage Manual*, Appendix C, we see that plastic pipe up to 48 inches in diameter requires 24 inches of cover below the top of base course under flexible pavement. SRAP requires a minimum of 12 inches of cover for pipe diameters up through 24 inches and 15 inches of cover (below the top of base course for flexible pavement) for 30-inch pipe. SRSP requires 12 inches of cover below the top of base course for pipe diameters up through 48 inches. Concrete pipe requires 12 inches of cover from finished grade of flexible pavement.

For 18-inch pipe, 24 inches is available from inside crown of pipe to finished grade, so the plastic pipe minimum cover is not met. Where side drains are 24-inch diameter, there is 18 inches from finished grade to inside crown of pipe and 15 inches from the top of base course. So for 18-inch and 24-inch side drains, you are allowed to use all pipe materials with an N value of ≤ 0.012 except plastic. For 30-inch diameter side drains, there is 12 inches of cover from inside crown of pipe to finished grade; therefore, the SRAP and SRSP pipe cover requirements are not met. Concrete pipe wall is much thicker than other types of pipe materials and must be taken into account. In this case, there will be only 8.5 inches of cover on 30-inch round concrete pipe. The wall thickness for elliptical concrete pipe is slightly greater for a size equivalent to round concrete pipe. A 24-inch by

38-inch elliptical concrete pipe wall is 3.75 inches thick, so there is 14.25 inches of clearance (42 – 27.75). The elliptical concrete pipe is the only pipe that will meet the structural requirement where a 30-inch side drain is needed.

Note that if the structural check is used in the CSLE program, it does not use the 30-inch round equivalent dimension (24-inch by 38-inch) for the elliptical pipe; it uses the 30-inch diameter input and will, therefore, show that all pipes will fail the structural check where there is 42 inches from pipe invert to finished grade under flexible pavement. (See the CSLE output for 24-inch and 30-inch pipe in Figure 8.5-5 and Figure 8.5-6.) So, for pipe arch or elliptical pipe, it is best to use the cover height tables and to calculate the cover available based on pipe dimensions.



Pipe Results

Add Job Information and Generate PDF

	Gage	Type of Culvert	Service Life	Environmental Check	Structural Check
Pass					
		(NRCP) Non-Reinforced Concrete , CL HE I	360	Pass	Pass
		(RCP) Steel-Reinforced Concrete Round, CL I	360	Pass	Pass
	16	(SRAP) Aluminum - Spiral Rib	111	Pass	Pass
	16	(SRASP) Aluminized Steel - Spiral Rib	75	Pass	Pass
	16	(SRSP) Galvanized Steel - Spiral Rib	25	Pass	Pass
Fail					
		(HDPE) High Density Polyethylene, CL I		Pass	Fail
		(HDPE) High Density Polyethylene, CL II		Pass	Fail
		(PP) Polypropylene - Class I		Pass	Fail
		(PP) Polypropylene - Class II		Pass	Fail
		(PVC) Polyvinyl Chloride, ASTM F-949		Pass	Fail
		(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use		Fail	Fail
		(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed - Unavailable in this size or not suitable for use		Fail	Fail

Figure 8.5-5

Environmental Check

Design Life
25 Years

Max Allowable Manning's (n) Value
(•) < 0.017 ( ) >= 0.017

pH: 5.6

Resistivity: 9500 Ohm-cm

Chlorides: 20 ppm

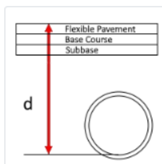
Sulfates: 118 ppm

Diameter: 30 Inches

[x] Structural Check

Cover Type
Flexible Pavement

Cover thickness measured from the bottom inside radius of the pipe.



Cover thickness (d) measured from flow line of pipe
42 Inches

Asphalt Pavement Thickness
3 Inches

[ ] Jack and Bore

Reset Form | Calculate

Pipe Results

Add Job Information and Generate PDF

Gage	Type of Culvert	Service Life	Environmental Check	Structural Check
Pass				
	(RCP) Steel-Reinforced Concrete Ellipse, CL HE I	360	Pass	Pass
Fail				
	(HDPE) High Density Polyethylene, CL I		Pass	Fail
	(HDPE) High Density Polyethylene, CL II		Pass	Fail
	(NRCP) Non-Reinforced Concrete		Pass	Fail
	(PP) Polypropylene - Class I		Pass	Fail
	(PP) Polypropylene - Class II		Pass	Fail
	(PVC) Polyvinyl Chloride, ASTM F-949		Pass	Fail
	(RCP) Steel-Reinforced Concrete Round		Pass	Fail
	(SRAP) Aluminum - Spiral Rib		Pass	Fail
	(SRASP) Aluminized Steel - Spiral Rib		Pass	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated		Pass	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed		Pass	Fail
	(SRSP) Galvanized Steel - Spiral Rib		Pass	Fail

Figure 8.5-6

To present the results in the plans, use notes under the side-drain table stating the allowable materials. In this case, an appropriate note might read:

> *Allowable pipe materials for 18-inch and 24-inch side drains, unless otherwise noted, are: RCP, NRCP, SRSP, SRASP, SRAP and ERCP. Allowable pipe material for 30-inch side drain is ERCP (30-inch-other) only.*

See Section 8.6 for examples of plan quantity presentation.

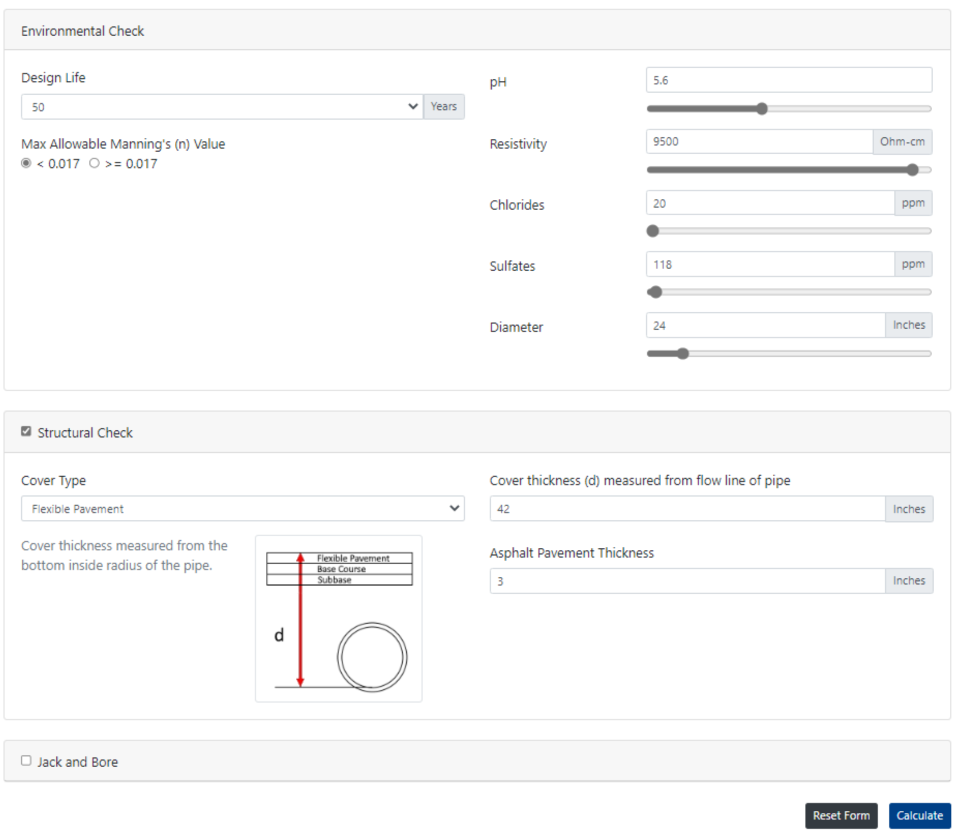
In cases where there is minimal cover and the structural requirements could not be met by using elliptical pipe or pipe arch in lieu of the hydraulically required round pipe, then you will need to analyze alternate pipe configurations. This could include multiple smaller-diameter pipes or, possibly, a larger diameter pipe buried deeper so that the flow area is from normal ditch line to crown. The latter also may require adjustment of the roughness coefficient in the analysis.

For example: if the cover condition at the side drain resulted in less than 12 inches, even with the elliptical concrete pipe, two 24-inch pipes could be used as long as they fit within the ditch. The Mitered End Section (MES) width for a double 24-inch pipe installation is 8.92 feet out to out (Standard Plans, Index 430-022). A 42-inch pipe half buried has the equivalent capacity to a 30-inch (fully open) pipe if the fill has a roughness coefficient only slightly greater than the pipe wall. This installation would be 20 inches narrower than the double 24-inch, with an MES width of 7.25 feet. If you were to use this option, place a note in the plans stating that the pipe size is hydraulically necessary and used to meet cover and dimensional limitations. Additionally, you would need to specify the fill.

8.5.1.2 Cross Drains (including Side Drains under Side Streets)

A cross drain conveys flow under a public roadway. A side street that crosses over a roadside ditch is, therefore, subject to cross drain design criteria, both hydraulic and structural. According to the *Drainage Manual*, Table 6-1, the minimum DSL for a cross drain is 50 years. That minimum applies to minor collectors and local streets, provided culvert cover is less than 10 feet. All other cross drains must have a DSL of at least 100 years. If the cross drain hydraulics show that the structure is outlet controlled, then you may consider only pipe materials with N = 0.012. However, if the cross drain is in inlet control, materials with higher roughness coefficients should be included in the analyses. Where pipe options are limited by minimum cover requirements, consider using multiple smaller-diameter pipes that have sufficient cover as an alternative to a single larger-diameter pipe that requires less cover. However, multiple pipe configurations are more susceptible to debris problems and also may require more extensive endwalls. If you have particular concerns about allowing multiple pipes in lieu of a single pipe cross drain installation, then you should document the rationale for selection of a particular pipe configuration that limits material options.

For the project example, these are local streets with AADT less than 1,000, so the side/cross drains must meet a 50-year DSL. The pipes for the four locations where the side streets cross roadside ditches were hydraulically checked to ensure that the appropriate design frequency flow could be passed without damage to the roadway or offsite properties. The side drains at these locations are 24 inches in diameter. You can classify these "side" drains as cross drains because they are under public roads. Therefore, these structures are not included in the side drain summary table but are instead included with structure numbers in the Summary of Drainage Structures table. The materials for these structures were checked using the CSLE to determine which met the 50-year DSL. See Figure 8.5-7. All materials previously determined are acceptable, but the SRSP has changed from 16-gage to 10-gage so that the service life can be met.



Pipe Results

Add Job Information and Generate PDF

Gage	Type of Culvert	Service Life	Environmental Check	Structural Check
Pass				
	(NRCP) Non-Reinforced Concrete , CL HE I	360	Pass	Pass
	(RCP) Steel-Reinforced Concrete Round, CL I	360	Pass	Pass
16	(SRAP) Aluminum - Spiral Rib	111	Pass	Pass
16	(SRASP) Aluminized Steel - Spiral Rib	75	Pass	Pass
10	(SRSP) Galvanized Steel - Spiral Rib	55	Pass	Pass
Fail				
	(HDPE) High Density Polyethylene, CL I		Pass	Fail
	(HDPE) High Density Polyethylene, CL II		Pass	Fail
	(PP) Polypropylene - Class I		Pass	Fail
	(PP) Polypropylene - Class II		Pass	Fail
	(PVC) Polyvinyl Chloride, ASTM F-949		Pass	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use		Fail	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed - Unavailable in this size or not suitable for use		Fail	Fail

Figure 8.5-7

There are two cross drains that convey offsite runoff under the design roadway. One of the cross drains is located within a sag vertical curve in the rural section of the design roadway; the other is located within the urban section.

The location of the first cross drain has a history of roadway over-topping due to basin diversions and increased runoff from upstream development. It is a 36-inch corrugated galvanized steel culvert with straight endwalls that are located 18 feet from the edge of travel lanes. During the Project Development and Environmental (PD&E) study, it was determined to raise the roadway profile, along with cross drain replacement, to minimize risk to motorists. The location of this cross drain warrants a DSL of 50 years. The new cross drain analysis determined that the cross drain is inlet controlled; therefore, both rough and smooth wall pipe materials were considered. The hydraulic analysis showed that a 54-inch culvert opening is needed to pass the design discharge of 160 cfs.

The location of the second cross drain, a 36-inch RCP, has exhibited no hydraulic insufficiencies. Since it is within an urban section, it should have a DSL of 100 years. The cross drain was analyzed hydraulically and this analysis determined that you could extend the cross drain with no adverse upstream effects.

Specific environmental data were obtained at the site of the two cross drains as follows:

Table 8.5-2: Soil Corrosivity Data Obtained for Two Cross Drains

Station		Boring #	pH	Resistivity	Chlorides	Sulfates
505+00	Rural	A-4	5.2	17,000	51	6
589+00	Urban	A-5	6.9	18,000	42	6

The CSLE program was used to find culvert materials that meet the DSL and structural requirements for the 54-inch culvert. The depth from finished grade to flow line of pipe is 96 inches. The CSLE output file is shown in Figure 8.5-8.

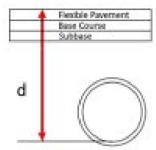
Florida Department of Transportation

Culvert Service Life Estimator - Version 2.0

(Generated Wednesday, May 18th 2022, 1:58:44 pm)

Job Information			
Project Name:	Road Widen	**FM Number:**	00000000
Section Number:	1	**Structure Number:**	CD-1
County:	Holleywood	**Boring Number/Location:**	A-4
Station	505+00	**Designer**	TH

Environmental/Structural Data			
Design Life (Years)	50	**pH**	5.2
Max Allowable Manning's n	>= 0.017	**Resistivity (Ohms-cm)**	17000
Diameter (Inches)	54	**Chlorides (ppm)**	51
Depth to Invert 'd' (Inches)	96	**Sulphates (ppm)**	6
Pavement Thickness (Inches)	3		



Gage	Type of Culvert	Service Life	Environmental	Structural
	Passed			
	(RCP) Steel-Reinforced Concrete Round, CL I	360	Pass	Pass
10	(CAP) Aluminum - 2-2/3x1/2 in. corrugations.	169	Pass	Pass
12	(SRAP) Aluminum - Spiral Rib	132	Pass	Pass
14	(SRASP) Aluminized Steel - Spiral Rib	107	Pass	Pass
16	(CASP) Aluminized Steel - 3x1 in. corrugations.	82	Pass	Pass
16	(CAP) Aluminum - 3x1 in. corrugations	75	Pass	Pass
10	(CSP) Galvanized Steel - 2-2/3x1/2 in. corrugations.	61	Pass	Pass
10	(CSP) Galvanized Steel - 3x1 in. corrugations.	61	Pass	Pass
10	(SRSP) Galvanized Steel - Spiral Rib	61	Pass	Pass
	Failed			
	(CASP) Aluminized Steel - 2-2/3x1/2 in. corrugations.		Pass	Fail
	(HDPE) High Density Polyethylene, CL I - Unavailable in this size or not suitable for use		Fail	Fail
	(HDPE) High Density Polyethylene, CL II - Unavailable in this size or not suitable for use		Fail	Fail
	(NRCP) Non-Reinforced Concrete - Unavailable in this size or not suitable for use		Fail	Fail
	(PP) Polypropylene - Class I - Unavailable in this size or not suitable for use		Fail	Fail
	(PP) Polypropylene - Class II - Unavailable in this size or not suitable for use		Fail	Fail
	(PVC) Polyvinyl Chloride, ASTM F-949 - Unavailable in this size or not suitable for use		Fail	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated		Fail	Pass
	(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed		Fail	Pass

Figure 8.5-8

So, there are 9 options for CD-1 at station 505+00. There are elliptical and metal pipe arch options that you also could include. However, the elliptical or arch options may not be economical to construct. Generally, round pipe is easier to construct, so only the round options need to be shown. If there were utility conflicts, then they could be avoided with a maximum pipe height of 48 inches; then the Steel-Reinforced Concrete Elliptical, 3” x 1” Corrugated Aluminum Pipe Arch, 16 gage pipe; the Corrugated Steel Pipe Arch, 10 gage in both the 2-2/3” x ½” and 3” x 1” corrugations; and the Aluminized Corrugated Steel Pipe Arch, 12 gage, would be acceptable alternates.

You can extend the second cross drain and still meet the hydraulic requirements. Check to verify that this cross drain still will have the required DSL. The corrosion data obtained for this location were input to the CSLE program, along with the depth of cover. The results, shown in Figure 8.5-9, show that the RCP has a service life of 360 years. However, Table M-4 of Appendix M indicates that you should adjust the service life of 360 years by multiplying by 0.54 for 36-inch diameter pipe. This results in 194 years. This pipe has been in service only 40 years, so the DSL of 100 years is met.

When extending cross drains, use the same existing pipe materials. If, upon inspection, the existing pipe shows corrosion or has structural cracking, then you should replace or line the existing pipe. When the extension of an existing pipe results in a minor exceedance of the structural clearance criteria, consider providing additional structural support for the pipe extension rather than replacing the entire cross drain. Encasing the extension in flowable fill typically provides the needed additional support.

Environmental Check

Design Life
100 Years

Max Allowable Manning's (n) Value
◉ < 0.017 ○ >= 0.017

pH 6.9

Resistivity 18000 Ohm-cm

Chlorides 42 ppm

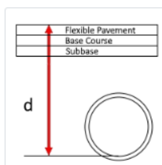
Sulfates 6 ppm

Diameter 36 Inches

☑ Structural Check

Cover Type
Flexible Pavement

Cover thickness measured from the bottom inside radius of the pipe.



Cover thickness (d) measured from flow line of pipe
72 Inches

Asphalt Pavement Thickness
3 Inches

☐ Jack and Bore

Reset Form Calculate

Pipe Results

Add Job Information and Generate PDF

	Gage	Type of Culvert	Service Life	Environmental Check	Structural Check
Pass					
🔍		(NRCP) Non-Reinforced Concrete , CL HE I	360	Pass	Pass
🔍		(RCP) Steel-Reinforced Concrete Round, CL I	360	Pass	Pass
🔍	16	(SRAP) Aluminum - Spiral Rib	255	Pass	Pass
🔍	16	(SRASP) Aluminized Steel - Spiral Rib	120	Pass	Pass
🔍		(HDPE) High Density Polyethylene, CL II	100	Pass	Pass
🔍		(PP) Polypropylene - Class II	100	Pass	Pass
🔍		(PVC) Polyvinyl Chloride, ASTM F-949	100	Pass	Pass
🔍		(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed	100	Pass	Pass
Fail					
🔍		(HDPE) High Density Polyethylene, CL I - Unavailable in this size or not suitable for use		Fail	Fail
🔍		(PP) Polypropylene - Class I - Unavailable in this size or not suitable for use		Fail	Fail
🔍		(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use		Fail	Fail
🔍		(SRSP) Galvanized Steel - Spiral Rib - Unavailable in this size or not suitable for use		Pass	Fail

Figure 8.5-9

8.5.1.3 Storm Drain

Referring to Table 6-1 in the *Drainage Manual*, we find that storm drains require either 50-year or 100-year DSL. A combination of the two DSLs could exist within a project. An example would be where the main storm drain has to be designed to meet the 100-year DSL and you could design the outfall to meet the 50-year DSL.

When choosing the appropriate DSL, use the same steps as those previously stated. Remember, storm drains do not always require the 100-year DSL criteria. Refer to the notes on Table 6-1 for guidance on the selection of DSL.

The 100-year DSL is required for our example project because the storm drain system is located within a curb-and-gutter section (see Note 2, Table 6-1). The corrosion data produced by the geotechnical survey were correlated to the field review observations and these values are not suspect. The corrosion data values are from the most aggressive test site (not the most aggressive parameter value from all test sites) along the applicable subsection of the project.

Table 8.5-3: Soil Corrosivity Data for the Storm Drain Example

Station	To Station	Boring #	pH	Resistivity	Chlorides	Sulfates
550+00	630+00	B-1 thru B-5	5.2	17,000	51	6

Because this is a storm drain system, only the smooth wall pipe options may be considered. The corrosion test data were input to the CSLE program for pipe sizes of 18, 24, 30, and 36 inches. Minimum cover is 25 inches and maximum cover is 11 feet. The CSLE program provided the materials described below for both 18-inch and 24-inch pipe sizes (Figure 8.5-10). For 30-inch and 36-inch, 12-gage SRAP is an additional option. A thicker gage of SRAP is needed because of the low pH and 12 gage is not available in diameters of less than 30 inches. See Figure 8.5-11 for a screen shot of the CSLE program for 36-inch pipe.

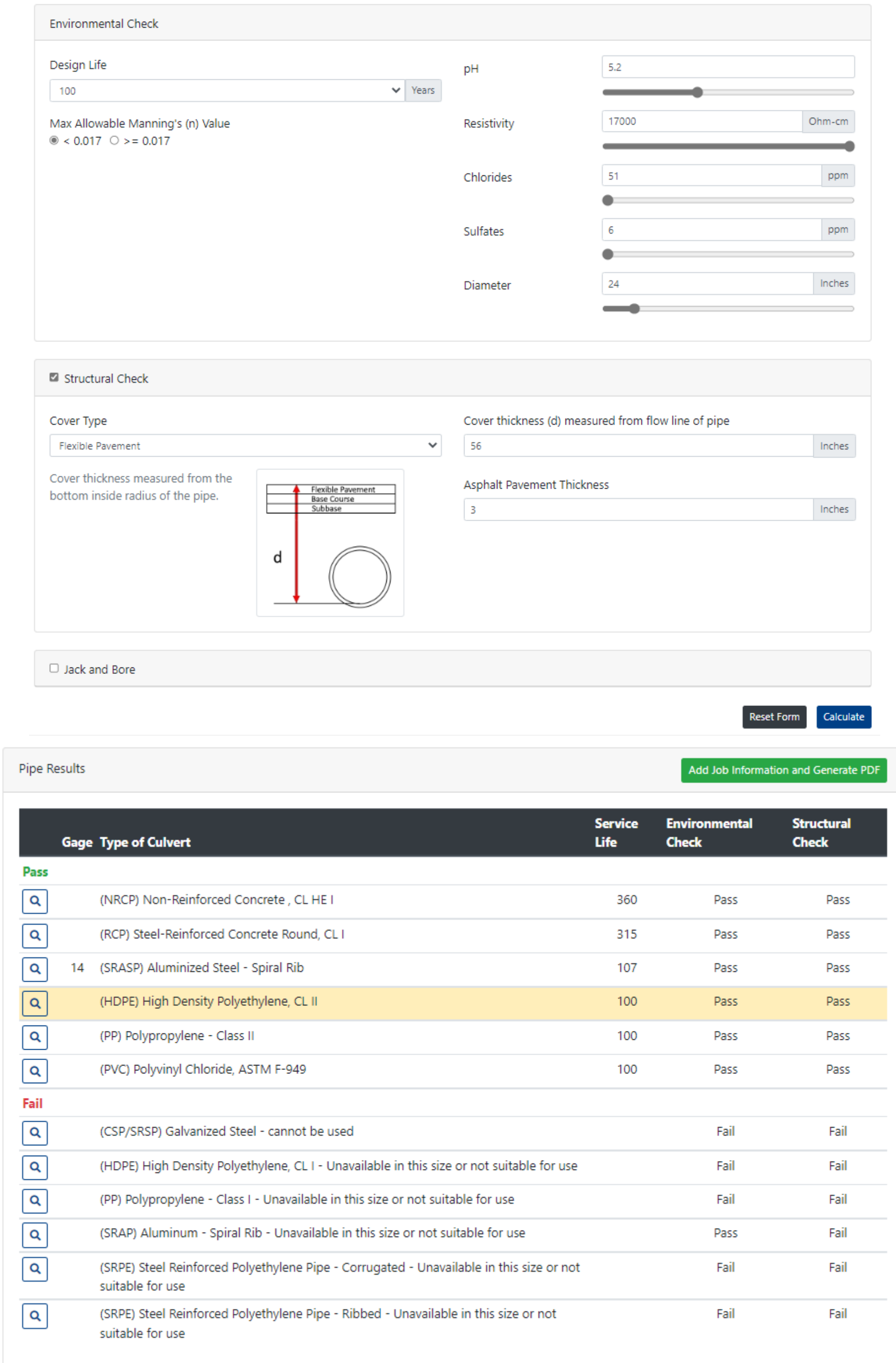

Environmental Check
Design Life
100
Years
Max Allowable Manning's (n) Value
< 0.017 >= 0.017
pH
5.2
Resistivity
17000
Ohm-cm
Chlorides
51
ppm
Sulfates
6
ppm
Diameter
24
Inches
Structural Check
Cover Type
Flexible Pavement
Cover thickness measured from the bottom inside radius of the pipe.
Flexible Pavement
Base Course
Subbase
d
Cover thickness (d) measured from flow line of pipe
56
Inches
Asphalt Pavement Thickness
3
Inches
Jack and Bore
Reset Form
Calculate
Pipe Results
Add Job Information and Generate PDF
Gage Type of Culvert Service Life Environmental Check Structural Check
Pass
(NRCP) Non-Reinforced Concrete , CL HE I 360 Pass Pass
(RCP) Steel-Reinforced Concrete Round, CL I 315 Pass Pass
14 (SRASP) Aluminized Steel - Spiral Rib 107 Pass Pass
(HDPE) High Density Polyethylene, CL II 100 Pass Pass
(PP) Polypropylene - Class II 100 Pass Pass
(PVC) Polyvinyl Chloride, ASTM F-949 100 Pass Pass
Fail
(CSP/SRSP) Galvanized Steel - cannot be used Fail Fail
(HDPE) High Density Polyethylene, CL I - Unavailable in this size or not suitable for use Fail Fail
(PP) Polypropylene - Class I - Unavailable in this size or not suitable for use Fail Fail
(SRAP) Aluminum - Spiral Rib - Unavailable in this size or not suitable for use Pass Fail
(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use Fail Fail
(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed - Unavailable in this size or not suitable for use Fail Fail

Figure 8.5-10

Environmental Check

Design Life: 100 Years

Max Allowable Manning's (n) Value
◉ < 0.017 ○ >= 0.017

pH: 5.2

Resistivity: 17000 Ohm-cm

Chlorides: 51 ppm

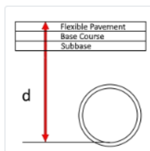
Sulfates: 6 ppm

Diameter: 36 Inches

☑ Structural Check

Cover Type: Flexible Pavement

Cover thickness measured from the bottom inside radius of the pipe.



Cover thickness (d) measured from flow line of pipe: 66 Inches

Asphalt Pavement Thickness: 3 Inches

☐ Jack and Bore

Reset Form | Calculate

Pipe Results

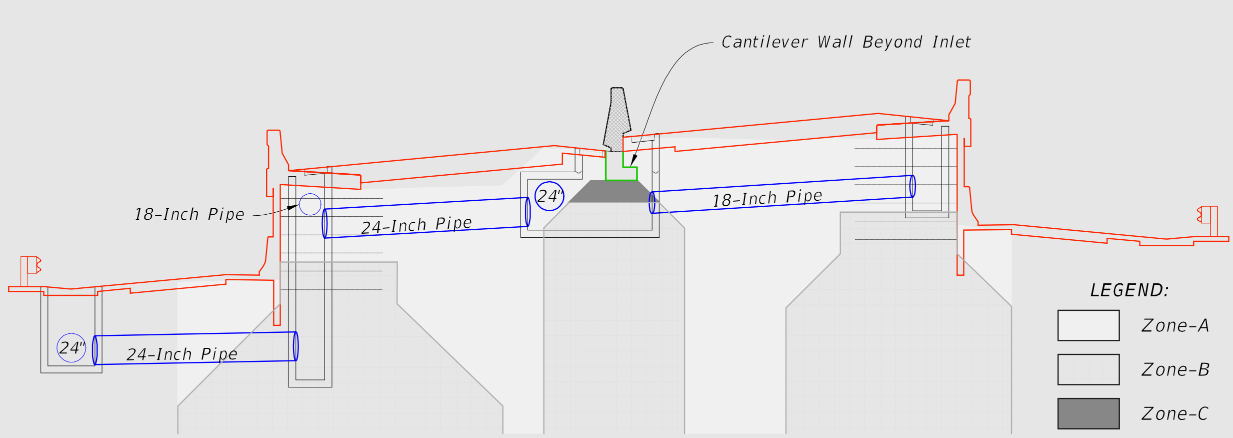
Add Job Information and Generate PDF

Gage	Type of Culvert	Service Life	Environmental Check	Structural Check
Pass				
	(NRCP) Non-Reinforced Concrete , CL HE I	360	Pass	Pass
	(RCP) Steel-Reinforced Concrete Round, CL I	360	Pass	Pass
12	(SRAP) Aluminum - Spiral Rib	132	Pass	Pass
14	(SRASP) Aluminized Steel - Spiral Rib	107	Pass	Pass
	(HDPE) High Density Polyethylene, CL II	100	Pass	Pass
	(PP) Polypropylene - Class II	100	Pass	Pass
	(PVC) Polyvinyl Chloride, ASTM F-949	100	Pass	Pass
Fail				
	(CSP/SRSP) Galvanized Steel - cannot be used		Fail	Fail
	(HDPE) High Density Polyethylene, CL I - Unavailable in this size or not suitable for use		Fail	Fail
	(PP) Polypropylene - Class I - Unavailable in this size or not suitable for use		Fail	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Corrugated - Unavailable in this size or not suitable for use		Fail	Fail
	(SRPE) Steel Reinforced Polyethylene Pipe - Ribbed		Fail	Pass

Figure 8.5-11

8.5.1.4 Wall Zone Pipe

The example project contains an area of elevated, MSE-walled embankment for a divided highway with median barrier wall in super-elevation. The roadway profile is at 0.5 percent and the storm drain piping will follow the slope of the roadway. The roadway storm drain system outfalls under the wall to a shoulder gutter inlet (SGI) within a parallel storm drain system. To ensure that all piping meets the Wall Zone Pipe material restrictions and requirements, sketch the wall zones on the drainage structure sections (see Figure 8.5-12). You can see that the longitudinal pipe coming into the median barrier inlet is within Zone A. The 18-inch lateral pipe from the barrier wall inlet along the MSE wall goes through Zone B transversely and through Zone A.



EXAMPLE OF MULTI-LEVEL ROADWAY PIPING SCHEME WITH MSE WALL AND CANTILEVER RETAINING WALL; WALL ZONES SHOWN.

- CONCRETE BARRIER WALL INLET INDEX 425-032 SUPER-IMPOSED ON MEDIAN BARRIER CANTILEVER WALL (RETAINING) INDEX 521-001. 'J' BOTTOM USED TO AVOID LONGITUDINAL PIPE (24-Inch) WITHIN WALL ZONE B.
- LATERAL PIPE (18-Inch FROM BARRIER WALL INLET INDEX 425-031 ADJACENT TO MSE WALL) DOES NOT VIOLATE WALL ZONE C NO PIPE RESTRICTION BECAUSE THE ZONE IS WITH THE WALL AHEAD AND BACK OF THE INLET.
- 18 Inch ENTERING LEFT BARRIER WALL INLET IS WITHIN ZONE A.

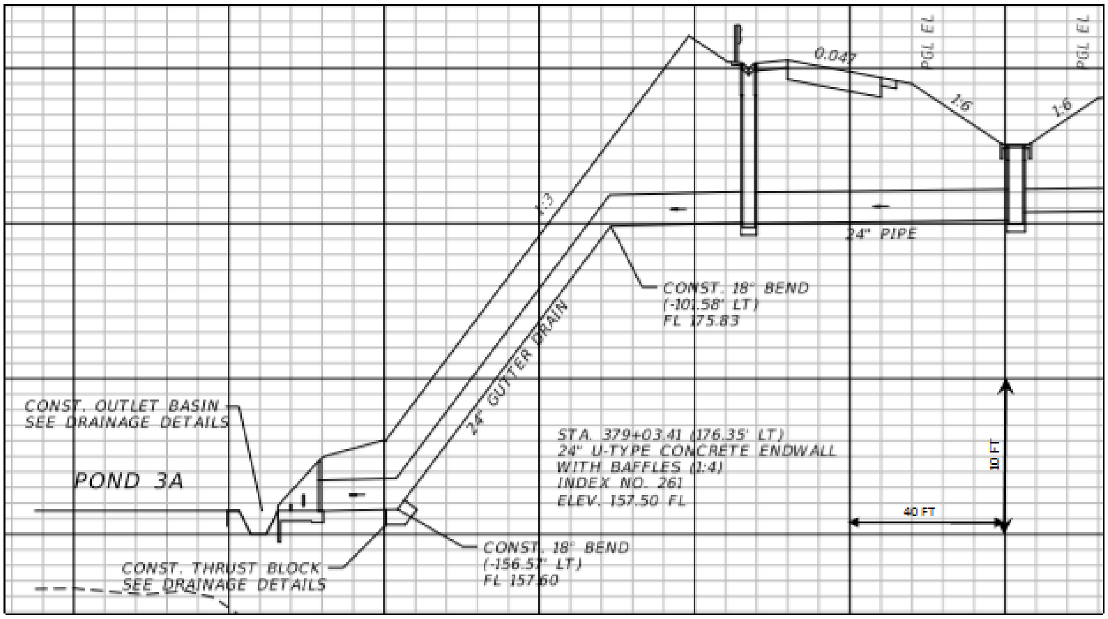
Figure 8.5-12

Zone C is below the median barrier cantilever wall, which is back and ahead of the median barrier inlet. The pipe options, as shown in the *Drainage Manual*, Table 6-1, are: polypropylene, PVC, and J&B Steel. The steel pipe will cost substantially more than the PVC or polypropylene, so it would be included as an option only if structurally necessary. In this case, the 24-inch pipe from the barrier wall inlet to the SGI has 13.5 feet of cover, so polypropylene may be acceptable. However, because this pipe is under the wall with roadway on both sides of the wall, you are encouraged to use the methodology in the AASHTO LRFD (Load Reduction Factor Design) *Bridge Design Specifications*, Chapter

12, to ensure that the pipe installation will withstand the load conditions. Consider the need for resilient connections at structures, particularly where there may be some differential settlement.

8.5.1.5 Gutter Drain

From Table 6-1 in the *Drainage Manual*, you identify a required DSL of 25 years for the gutter drain. The process is the same as for performing the analysis for the side drain application discussed previously. However, when sizing gutter drain and choosing materials, only use materials having an N-value of > 0.020. A gutter drain is defined as a pipe used along steep slopes to convey stormwater from shoulder gutter inlets on elevated roadways to drainage conveyance systems at a much lower elevation. These pipes should be configured so that they can be replaced without disturbing the roadway and so that they are not placed too deep within the embankment to prohibit future excavation. Minimize joints where possible. See Figure 8.5-13 for an illustration of gutter drains.



ABOVE, THE GUTTER DRAIN WAS PLACED AT SHALLOW DEPTH TO ALLOW REPLACEMENT. PIPE TO THE RIGHT OF THE GUTTER DRAIN IS STORM DRAIN (100-YEAR DSL).

THE EXAMPLE BELOW HAS A DEEP INLET (>16 FT) AND THE PIPE WOULD BE DIFFICULT TO REPLACE; THIS WOULD MORE APPROPRIATELY BE CLASSIFIED AS STORM DRAIN.

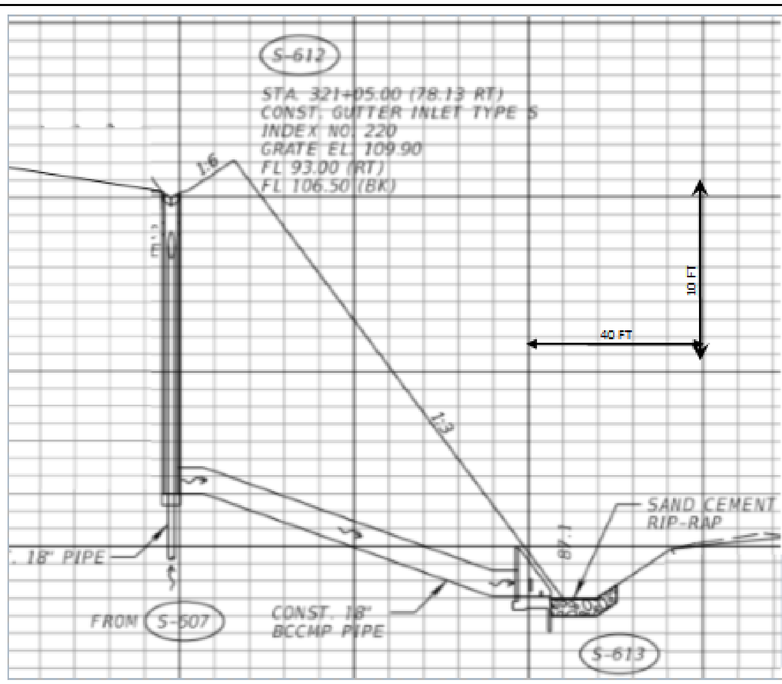


Figure 8.5-13

8.5.1.6 French Drain

A French drain is used for stormwater treatment and/or attenuation. The *Drainage Manual*, Table 6-1, shows that either a 50-year or a 100-year DSL is used for French drains. The location of the French drain system determines which DSL to use. See Figure 8.5-14. Consider a case where you place a French drain in an urban location along the trunk line located under the sidewalk, parallel and adjacent to the roadway. The French drain is not under the roadway, but replacement of the French drain would require reconstruction of the outside lane due to the depth of cut and angle of repose of the soil. Even though the French drain reconstruction might be performed using sheeting to avoid impacting the roadway, the cost of the sheeting makes this installation expensive enough to elevate the service life to 100 years. A similar situation occurs when a pipe installation is adjacent to buildings. In these cases, sheeting required during replacement is costly; thus, the pipe should have a longer, 100-year DSL. Conversely, if the French drain is located in a swale along a rural roadway, the lower DSL may be appropriate.

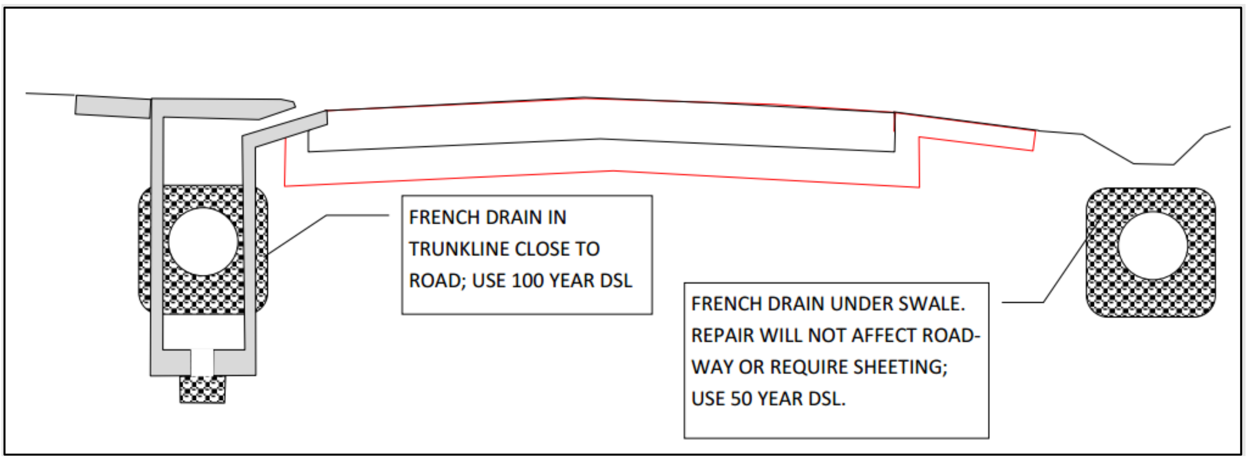


Figure 8.5-14

For these applications, consider whether a roughness coefficient ≥ 0.020 will result in a hydraulically acceptable design. Where the French drain also is the primary storm conveyance system, only materials with N-value = 0.012 need to be considered. Where the French drain is “offline” or is a secondary conveyance, analyses should consider N value ≥ 0.020. After ascertaining the hydraulic needs, use the CSLE program or the figures and tables in Appendix M to select materials that meet the required DSL based upon the corrosion data and pipe size. Then determine minimum and maximum cover and use the CSLE program or Appendix C of the *Drainage Manual* to select pipe materials that meet the structural requirements.

8.6 SPECIFYING OPTIONAL PIPE MATERIALS IN THE CONTRACT PLANS

Show the optional pipe materials for cross drains, storm drains, French drains, and gutter drains in the project plans, as illustrated in the *FDM.* The Optional Pipe Tabulation Sheet includes: the size; class of concrete; gage, corrugation, and type of metal; and type of plastic pipe that may be applicable to particular pipes within the project.

Side drains are listed in a Summary of Side Drains table. The two formats within *Basis of Estimates*, Chapter 8, have columns for five round and five "other" pipe sizes with corresponding MES widths; one has additional columns for offset and flowline. You shouldn't modify the tables except to "hide" columns not used or to change pipe sizes as needed. As noted in the side drain example in Section 8.5, you should place notes stating allowable side drain options below the table. Include any particular exceptions in the Design Notes column. Do not use the Construction Remarks column since that is reserved for the construction phase of the project. The two Summary of Side Drain tables are shown in Figure 8.6-1. See the current version of *Basis of Estimates* for the most current form of these tables.

SUMMARY OF SIDE DRAIN & MITERED END SECTIONS																							
LOCATION	SIDE	PIPE LENGTH - LF										MES - EA										DESIGN NOTES	CONSTRUCTION REMARKS
		ROUND					OTHER					ROUND					OTHER						
STA. TO STA.		15"	18"	24"	30"	36"	15"	18"	24"	30"	36"	15"	18"	24"	30"	36"	15"	18"	24"	30"	36"		
SUB-TOTAL:																							
TOTAL:																							

SUMMARY OF SIDE DRAIN & MITERED END SECTIONS																											
LOCATION						PIPE LENGTH - LF										MES - EA										DESIGN NOTES	CONSTRUCTION REMARKS
STA. TO STA.	SIDE	BACK		AHEAD		ROUND					OTHER					ROUND					OTHER						
		OFFSET	℄	OFFSET	℄	15"	18"	24"	30"	36"	15"	18"	24"	30"	36"	15"	18"	24"	30"	36"	15"	18"	24"	30"	36"		
SUB-TOTAL:																											
TOTAL:																											

Figure 8.6-1

French drains also may be listed in a Summary Table; however, that table form has only the actual limits of pipe/French drain and does not have a column for the structures or the non-perforated pipe without the gravel envelope that extends a minimum of four feet on each side of the drainage structure. If you decide to use this Summary Table, then the Summary of Drainage Structures (SDS) tabulation should include the drainage structure and non-perforated pipe and a separate column for the French drain segment. You can note the pipe options allowable for French drains below the French Drain Summary Table or within the Design Notes Column. You cannot use dissimilar types of pipe within a continuous run of pipe, and the non-perforated pipe should be of the same material as the perforated pipe.

All other pipes that are listed in the SDS tabulation should have options listed in the Optional Materials table. When elliptical pipe or arch pipe are the only allowed options, these are listed in the Summary of Drainage Structures under the column heading “Other” with the round equivalent size. The Optional Materials tabulation for these pipes should include elliptical or arch pipe configurations that meet the DSL and structural requirements. There are two Optional Materials tabulation formats; one includes flowlines and one does not. Generally, flowlines for all options will be the same. However, in some cases, minimum cover will control storm drain flowlines and it will be necessary to list the required alternate flow lines. If round pipes meet the required clearances, there is no need to even list elliptical and arch pipes as options since they usually are more expensive than their round equivalents. For instance, where a round concrete pipe and arch metal pipe meet all requirements, it is not necessary to list elliptical concrete as an option.

You can group pipe options by size and, if necessary, by location (station to station) or by structure numbers. The structure numbers are listed as “Exceptions” in the “STR No.” column next to the corresponding pipe size column. If the exceptions all have the same limited options, the options can be listed with that group; otherwise, show the exceptions individually with allowable material. Ideally, you can group the options by pipe size and you can use the suitable materials for a spectrum of sizes. The intent of allowing options is for the contractor to choose acceptable materials from a fair, competitive pipe supply market, not to have numerous materials installed within a particular storm drain system. In general, if you group material options by pipe size, one Optional Pipe Tabulation Sheet is sufficient to describe allowable options for most projects.

Figure 8.6-2 is a spreadsheet format of the Optional Pipe Tabulation sheet containing the optional materials determined for the examples in Section 8.5.

STRUCTURE	SIZE (Inches)	MATERIAL	PLOTTED	AS BUILT	REMARKS
STORM DRAIN	18,24	NRCP, CL I	X		
		RCP, CL I			
EXCEPT S-100		SRASP (14 ga.)			
THROUGH S-105		HDPE, CL II			
		POLYPROPYLENE			
		PVC ASTM F-949			
S-100 THRU S-104	18,24	POLYPROPYLENE			
WALL ZONE PIPE		PVC ASTM F-99	X		
S-105 WALL ZONE PIPE	24	PVC ASTM F-949	X		
CROSS DRAINS	24	RCP, CL I	X		
CD-1, CD-2, CD-3, CD-4		NRCP, CL I			
		SRAP (16 ga.)			
		SRASP (16 ga.)			
		SRSP (10 ga.)			
STORM DRAINS	30, 36	NRCP, CL I	X		
		RCP, CL I			
		SRASP (14 ga.)			
		SRAP (12 ga.)			
		HDPE, CL II			
		POLYPROPYLENE			
		PVC ASTM F-949			
CD-5	36	RCP	X		
CD-6	54	RCP CL I, SRAP (12 ga.)	X		
		SRSP (10 ga.), SRASP(14 ga.)			
		2-2/3 x 1/2 corr-CAP, CSP, both 10 ga.			
		3 x 1 corr-CAP, CASP, both 16 ga.			
		3 x 1 corr-CSP, 10 ga.			
GUTTER DRAIN	18,24	2-2/3 x 1/2 corr-CAP, 14 ga.	X		
		2-2/3 x 1/2 corr-CASP, 14 ga.			
		2-2/3 x 1/2 corr-CSP, 14 ga.			FULLY BITUMINOUS COATED

Figure 8.6-2

Note that both of the Optional Materials Tabulation forms have a “PLOTTED” column. It is important to check the material used for determining clearances at drainage structures. If spiral rib pipe was assumed/used to determine clearances at structures and concrete is listed as a pipe option, then the thicker wall of concrete pipe may not fit into the structure. Structure fit may be another rationale for choice of pipe material. For example, pipes with thinner walls would allow for smaller precast openings, which in turn allows for smaller angle between pipes entering a round structure.

For design/build projects, you still need to create materials analyses to demonstrate suitability of the pipe to be installed, and then you can include the analyses in project documentation. You can include either an optional materials tabulation sheet in the construction plans or make sure that the pipe material to be installed is noted somewhere in the plans, such as on the plan sheets or on the Summary of Drainage Structures.