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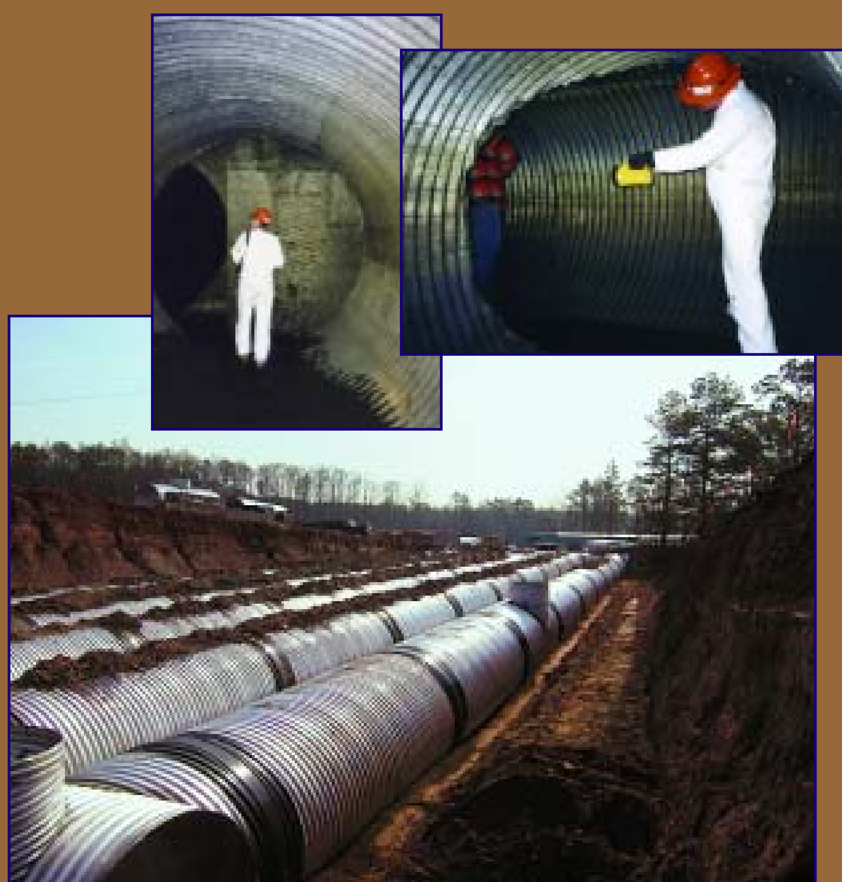
SERVICE LIFE EVALUATION OF CORRUGATED STEEL PIPE

Storm Water Detention Systems in the Metropolitan Washington, DC Area



PREPARED FOR

NATIONAL CORRUGATED STEEL PIPE ASSOCIATION

MARCH 2002

SERVICE LIFE EVALUATION OF CORRUGATED STEEL PIPE

INTRODUCTION

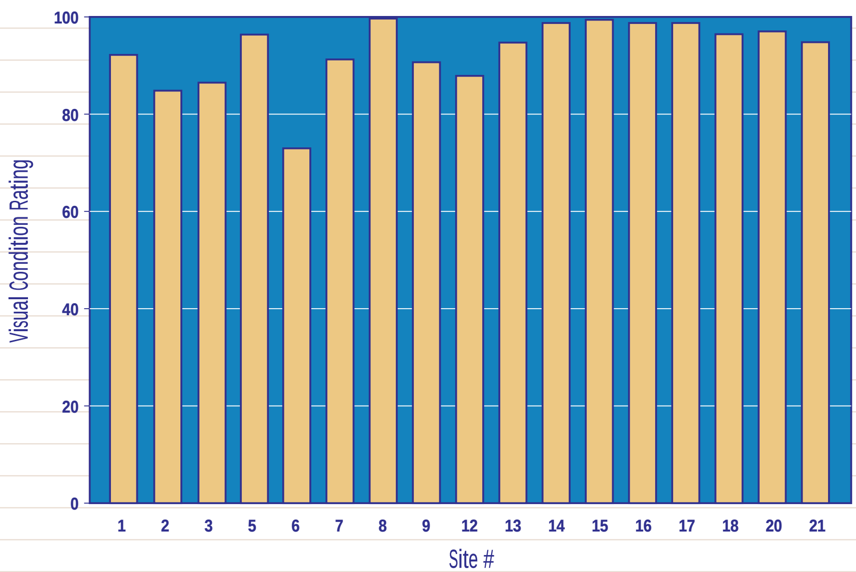
Corrugated steel pipe (CSP) storm water detention systems (plain galvanized, aluminized, or bituminous coated) have been in use in the metropolitan Washington, DC area since the early 1970s. A qualitative condition survey to assess the overall performance of 17 of these systems was conducted by Parsons Brinkerhoff of Baltimore, MD on behalf of the National Corrugated Steel Pipe Association (NCSPA) in early 1998. The overall conclusion of the survey[1] was that the systems were performing extremely well. Figure 1 shows the average condition rating (crown, sides, invert) based on a visual rating scale developed by Corrpro, 1991.[2] Most systems still had the zinc layer intact after about 25 years of service. There were no signs of visible deflection and most joints appeared to be soil tight.

In May of 2000 the NCSPA retained Corrpro Companies Inc. to perform a more detailed and quantitative evaluation of the corrugated steel pipe storm water detention systems evaluated previously. This work includes determining coating or metal loss and using available methodology to predict service life. This report presents the findings of the study undertaken by Corrpro.

EVALUATION PROCEDURES

Fifteen of the 17 sites were selected for evaluation. Sites 15 and 20 are sand filter systems and were not evaluated because access to the invert would require removal of sand filter media. During the field inspection it was found that one of the systems (Site No. 12) had been removed during redevelopment. In addition, it was not possible to gain access to two of the systems, sites 1 and 18. Thus testing was per-

Figure 1. Average Coating Rating



Rating	Description
100–95	
90	galvanizing intact
80–85	
75	galvanizing partly gone, some rust
60–55	
50	galvanizing gone, significant metal loss
45–40	
35–30	
25	deep pits, heavy metal loss, perforation
20–15	
10–5	
0	major metal loss

[1] "Condition Survey of Corrugated Steel Pipe Detention Systems," NCSPA, Washington, DC, March 1999.

[2] "Condition and Corrosion Survey: Soil Side Durability of CSP," Corrpro Companies, March 1991.

Table 1. Stormwater Detention System Overview

Site No.	Location	Pipe Diameter (inches)	Coating	Corrugation	Pipe Age (years)	Soil Depth to Top of Pipe (feet)	Number of Samples Collected		
							Soil	Water	Coupons
2	Industrial, Montgomery County, MD	48	Galvanized	1x3" Helical	26	2	2	2	3
3	Industrial, Montgomery County, MD	48	Galvanized	1x5" Helical	26	4.25	1	2	2
5	Industrial, Montgomery County, MD	60	Galvanized	1x5" Helical	21	4	2	2	2
6	Commercial, Montgomery County, MD	96	Galvanized	1x5" Helical	21	4	2	2	2
7	Commercial, Montgomery County, MD	96	Galvanized	1x5" Helical	21	2	2	2	2
8	Commercial, Montgomery County, MD	72	Fully Bituminous Coated	1x5" Helical	21	2.5	2	1	2
9	Commercial, Montgomery County, MD	72	Galvanized	1x5" Helical	21	13	1	1	2
13	Commercial, Montgomery County, MD	108	Aluminum Coated Type 2	1x5" Helical	11	6	2	1	2
14	Residential, Fairfax County, VA	67x104	Fully Bituminous Coated	1x5" Helical	6	6	2	2	2
16	Residential, Fairfax City, VA	80	Aluminum Coated Type 2	1x5" Helical	11	11	1	2	2
17	Residential, Fairfax City, VA	65x107	Fully Bituminous Coated	1x5" Helical	6	12	1	2	2
21	Residential, Alexandria, VA	144	Galvanized	1x5" Helical	6	6	1	2	2

formed on 12 sites. Table 1 presents an overview of each site including the numbering, location, land use, system size, age, and sampling performed at each of the sites.

Field Testing Field-testing consisted of performing visual observations, in-situ measurements of soil resistivity, soil pH, and redox potential at each site. Disk coupons (1½ inch in diameter) were obtained from the top and invert at each location for subsequent determination of the remaining zinc layer thickness. A total of 25 coupons were collected. Soil and water samples were also collected from each site for laboratory analysis.

Wherever possible, photographic documentation of the detention systems was made.

Laboratory Work Samples collected from the field testing were evaluated in the laboratory. *Corrugated steel pipe coupons* were polished metallographically along their thickness to reveal the zinc layer. The zinc layer thickness was measured at ten locations with the help of a low-powered optical microscope and an average thickness was calculated. *Soil samples* were

Table 2. Field Test Data

Site No.	Location	Soil Resistivity*		Potential, mV vs. CSE**			pH	
		Bottom	Top	Bottom	Top	Surface	Bottom	Top
Galvanized Systems								
2	Industrial, Montgomery County, MD	4000	7000	-681	-637	-508	6.85	6.74
3	Industrial, Montgomery County, MD	4000	4000	-562	-620	-549	NM	NM
5	Industrial, Montgomery County, MD	6500	11000	-644	-694	-633	NM	8.14
6	Commercial, Montgomery County, MD	13000	6000	-786	-740	-689	6.85	6.83
7	Commercial, Montgomery County, MD	20000	3300	-741	-546	-722	7.24	7.86
9	Commercial, Montgomery County, MD	50000	NM	-641	-690	-724	NM	7.38
21	Residential, Alexandria, VA	NM	1900	-629	-706	-671	6.27	6.49
Fully Bituminous Coated Systems								
8	Commercial, Montgomery County, MD	20000	2000	-938	-721	-946	NM	NM
14	Residential, Fairfax County, VA	11000	7100	-973	-481	-955	7.14	8.67
17	Residential, Fairfax City, VA	15000	6000	-926	-946	-933	7.16	6.8
Aluminum Coated Type 2 Systems								
13	Commercial, Montgomery County, MD	10000	5500	-664	-672	-425	10.4	10.1
16	Residential, Fairfax City, VA	NM	28000	-617	-665	-613	7.81	8.01

*Soil resistivity determined with a Collins Rod
**CSE = copper sulfate electrode
NM - Not Measured

evaluated to identify the soil type and physical characteristics, determine resistivity, pH, moisture content, chlorides and sulfides. *Water samples* were evaluated to determine pH, resistivity, chlorides, and sulfides.

Utilizing the soil and water analysis data, the predicted service life of the detention system was calculated using a variety of methods:

- Software previously developed by Corrpro Companies[2] for the NCSPA.
- California Method for Estimating Years to Perforation of Steel Culverts
- AISI Method for Service Life Prediction
- The procedures used by Potter in FHWA-FLP-91-006.

FINDINGS

Field Tests Table 2 summarizes the results of the soil resistivity, pH and potential measurements made at each site. Over 80% of the potential readings were found to be in the range of –617 mV to –946 mV with respect to a copper-copper sulfate electrode. Potential readings in this range indicate that the galvanized layer has not corroded away and exposed the bare steel.

ANALYSIS AND DISCUSSION

Table 3 summarizes the laboratory analysis data for the soil samples. These parameters were utilized to calculate the remaining life of the galvanized layer using the software program previously developed by Corrpro for NCSPA[2]. That study of culvert and storm sewer installations concluded indicated that “93.2% of the plain galvanized installations have a soil side service life in excess of 75 years, while 81.5% have a soil side service life in excess of 100 years.”

The software generates service life predictions from a statistical model developed to accurately pre-

Table 3. Laboratory Soil Analysis Data and Soil Side Life Prediction*

Site No.	Sample Location	Soil Type	Sample Color	Moisture (%)	pH	Chloride (ppm)	Sulfide (ppm)	Resistivity (ohm-cm)	16 gage galvanized pipe life (yrs)*	Gage Multiplier	Predicted Pipe Life
Galvanized Systems											
2	Top	sandy clay	gray	23.72	7.4	16	0.3	722	91.5	1.0	91.5
	Invert	loam	gray-brown	27.32	7.7	60	0	1684	70.9	1.0	70.9
3	Top	clay	gray	29.14	7.9	32	0	2538	100.11.0	1.0	100.1
5	Top	silty loam	gray-brown	23.83	7.9	20	0	8696	141.4	1.3	183.8
	Invert	clay	gray-brown	26.51	7.4	27	0	3663	91.7	1.3	119.2
6	Top	silty clay	light red brown	27.52	6.4	37	0	4630	57.4	1.3	74.6
	Invert	silty clay	light red brown	29.18	6.8	28	0.3	5051	67.7	1.3	88.0
7	Top	silty clay loam	light red brown	23.67	6.3	42	0	2941	50.4	1.3	65.5
	Invert	silty clay loam	light red brown	30.21	6.6	9	0	11765	122.9	1.3	159.8
9	Invert	clay	gray-red brown	34.00	7.6	10	0	2899	139.7	2.3	321.3
21	Top	silty clay	light red gray	24.17	6.0	34	0	1992	45.4	1.8	81.7
Fully Bituminous Coated Systems											
8	Top	silty clay loam	yellow gray	25.58	7.7	32	0	2899	94.9	1.3	123.4
	Invert	silty clay loam	yellow gray	27.48	7.6	30	0	3846	96.8	1.3	125.8
14	Side	silty clay loam	light gray brown	23.07	5.7	10	0	7813	79.9	1.8	143.8
	Invert	caliche	light gray brown	32.38	6.6	10	0	10417	115.9	1.8	208.6
17	Invert	silty clay	light red brown	27.95	5.1	12	0	6993	59.3	1.8	106.7
Aluminum Coated Type 2 Systems											
13	Side	silty clay	light red brown	26.73	6.6	30	0	1961	60.6	2.3	139.4
	Invert	silty clay	light red brown	34.33	7.2	18	0	3745	100.1	2.3	230.2
16	Top	silty loam	light gray brown	20.40	4.9	16	0	10417	54.0	1.3	70.2

*Service life for 16 gage galvanized pipe using software previously developed by Corrpro Companies, Inc for NCSPA dict service life of galvanized CSP for sites where durability is limited by soil side corrosion. The model predicts the condition of the protective galvanized coating over time plus the life of 16 gage black steel. According to the author:

"When the galvanized coating reaches the point that pitting of the steel substrate could begin, the model uses black steel corrosion data from 23,000 black steel underground storage tank sites to analyze overall durability vs. time. The black steel used in the model was 16 gage. Therefore the model does not accommodate added life projections due to the increased thickness of the pipe wall. Use of this data induces significant conservatism also, because, it is based on steel not previously galvanized, and there-

Table 4. Service Life Predictions in Accordance with the California Method and AISI Method

Site No.	Sample Location	pH	Resistivity (ohm-cm)	Gage	California Pred. Life (yrs)	AISI Pred. Life (yrs)	Minimum California	Minimum AISI
Galvanized Systems								
2	Crown Soil	7.4	722	16	28	57		57
	Invert Soil	7.7	1684		40	80	28	
	Water*	5.5	613		5	10		
3	Crown Soil	7.9	2538	16	48	95	31	62
	Water**	7.5	881		31	62		
5	Crown Soil	7.9	8696	14	97	205	34	73
	Invert Soil	7.4	3663		68	144		
	Water	7.4	692		34	73		
6	Crown Soil	6.4	4630	14	33	69	32	67
	Invert Soil	6.8	5051		39	82		
	Water	6.2	5181		32	67		
7	Crown Soil	6.3	2941	14	27	58	27	58
	Invert Soil	6.6	11765		44	93		
	Water	7.3	3165		55	116		
9	Invert Soil	7.6	2899	10	108	231	94	201
	Water	7.9	2066		94	201		
21	Crown Soil	6.0	1992	12	29	61	29	61
	Water	6.2	8333		50	106		
Fully Bituminous Coated Systems								
8	Crown Soil	7.7	2899	14	62	130	62	130
	Invert Soil	7.6	3846		69	147		
	Water	7.6	3135		64	135		
14	Side Soil	5.7	7813	12	44	94	44	94
	Invert Soil	6.6	10417		59	125		
	Water	6.9	4184		54	114		
17	Invert Soil	5.1	6993	12	38	80	38	80
	Water	6.6	12195		61	130		
Aluminum Coated Type 2 Systems								
13	Side Soil	6.6	1961	10	47	100	47	100
	Invert Soil	7.2	3745		84	179		
	Water	7.3	4016		100	214		
16	Crown Soil	4.9	10417	14	30	64	30	64
	Water	6.8	5814		40	85		

Notes: 1. The above resistivity and pH data was obtained from laboratory analysis of field samples.
2. All predictions are for galvanized pipe of the designated gage. No multiplier or "add-on" for additional coating has been used

*This water smelled of antifreeze. It was considered an aberrant condition for service life prediction.

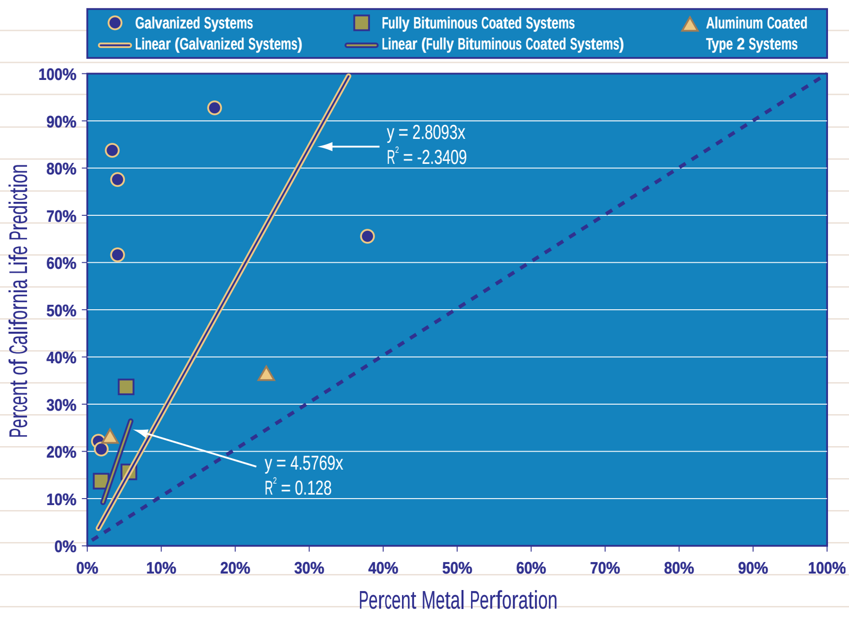
**This "water" was saturated organic matter.

fore, does not recognize the effects of residual galvanizing and the alloy layer formed during the galvanizing in slowing the corrosion process. Additionally, the slowing of the corrosion pitting rate with time for thicker gages cannot be accommodated. However, these shortcomings add conservatism to the service life estimates."

The calculations show the average predicted life of a 16 gage galvanized pipe in these environments is about 86 years. Table 3 also attempts to adjust the service life prediction by using a gage multiplier as recommended by the AISI Method. This shows that the average predicted life of the systems is about 130 years. The minimum predicted service life for any of the systems is 65 years. Taking all of the above factors into consideration, the total service life of the structures would be in excess of 100 years.

Table 4 shows the predicted service life of each detention system using both the California and AISI methods. The California Method was developed by Stratful to predict time to fist perforation, which is not considered the end of service life. The AISI Method (also developed by Stratful) is based on the Caltrans Method but is used to predict average invert service life.[3] For each method, the service life was calculated using each of the environmental samples (soil and water). The minimum of the calculated values for each pipe is then identified in the table. Notice that systems 2, 3, and 7 are very near the end of the California Method predicted service life (first perforation). Yet the systems are all in quite good condition, with most of the galvanized coating still in tact. There would certainly need to be extreme corrosion to occur if they are to have penetrations at the age predicted by the California Method. This suggests that the AISI Method provides a more accurate service life prediction than the California Method for detention systems, however both methods provide very conservative predictions for these environments.

Figure 2. Percent Metal Perforation vs. California Prediction



[3] "Durability of CSP," Richard Stratful, Corrosion Engineering, Inc., 1986.

[4] Durability of Special Coatings for Corrugated Steel Pipe, J.C. Potter, I Lewandowski, and D.W. White, Federal Highway Administration, Report No. FHWA-FLP-91-006, June 1991.

Table 5. Service Life Analysis Using the Technique Developed by Potter

Site No.	Thickness (inches) Original (est)	Min	Percent Perforation	Min. Calif. Pred. Years*	Actual Age Years	Percent of Calif. Pred.
Galvanized Systems						
2	0.058	0.048	17.2%	28	26	92.9%
3	0.058	0.056	3.4%	31	26	83.9%
5	0.072	0.069	4.2%	34	21	61.8%
6	0.071	0.044	38.0%	32	21	65.6%
7	0.071	0.068	4.2%	27	21	77.8%
9	0.128	0.126	1.6%	94	21	22.3%
21	0.099	0.097	2.0%	29	6	20.7%
Fully Bituminous Coated Systems						
8	0.075	0.071	5.3%	62	21	33.9%
14	0.098	0.096	2.0%	44	6	13.6%
17	0.105	0.099	5.7%	38	6	15.8%
Aluminum Coated Type 2 Systems						
13	0.124	0.120	3.2%	47	11	23.4%
16	0.070	0.053	24.3%	30	11	36.7%

*Data from Table 4 of this report

To better understand the relationship between the California Method predictions and existing conditions, Potter correlated percent penetration with percent of California predicted service life expended.[4] While there has been extensive debate over the validity of the technique, it is used as another method to compare service life predictions. Table 5 presents the minimum thickness measured on coupons from each system. That value is compared with the "original" thickness. The original thickness was determined in most cases by measuring overall thickness on the crown of the pipe where the galvanizing was metallographically determined to be in-tact at nominally the original thickness. System 6 was the only system where an original thickness was difficult to determine, but a sufficiently conservative estimate was made based on measurements of the coupons. Figure 2 shows the data plotted in a manner similar to that used by Potter. Best-fit lines were regressed through all of the data for galvanized and asphalt coated pipes. No plot was made for aluminum coated pipes due to a lack of sufficient number of data points.

Using all data points, the analysis suggests that the galvanized systems are performing 2.8 times as well as the California Method would predict while the fully bituminous coated systems are performing 4.6 times as well as the California Method would predict for galvanized material. It should be noted that this multiplier increases to 7.3 times for galvanized systems if Site #6 is ignored. The inspection of the systems support the conclusion that the galvanized detention systems will last more than twice as long as the California Method might predict.

CONCLUSIONS

1. Corrugated steel pipe storm detention Systems (galvanized, aluminized, or bituminous coated) are performing satisfactorily in service.

2. The service life of detention systems appears to be driven by soil-side corrosion.

3. There is no significant water-side invert deterioration. As a result, it is expected that the service life would be longer for detention systems than for culverts or storm sewers. This may be due in part to an absence of abrasion in the invert of detention systems.

4. The AISI Method appears more realistic in terms of predicting Detention System Service Life than the California Method, though both will provide conservative service life predictions for most environments.

5. Visual observations and measurements of remaining galvanized layer thickness on coupons are in concurrence with theoretical calculations using previously developed software for remaining life prediction.

6. Physical inspection of these systems along with the analytical approach presented herein support the prediction of a functional service life for these galvanized detention systems in excess of 100 years.

7. Corrugated steel pipe manufacturers provide a range of coatings and material thicknesses that make it possible to design a detentions system in practically any environment that will last in excess of 100 years where corrosion is the life limiting factor.

SITE 2: 48" Detention System, Montgomery County

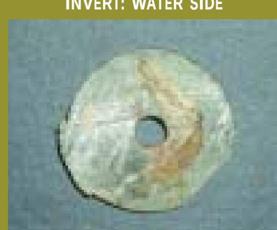
CROWN: SOIL SIDE

INVERT: SOIL SIDE

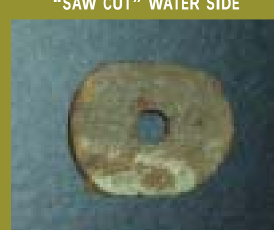
INVERT: "SAW CUT" SOIL SIDE

CROWN: WATER SIDE

INVERT: WATER SIDE



INVERT: "SAW CUT" WATER SIDE



Water Data

pH	5.5
Chloride, ppm	139
Sulfide, ppm	0
Resistivity, ohm-cm	613

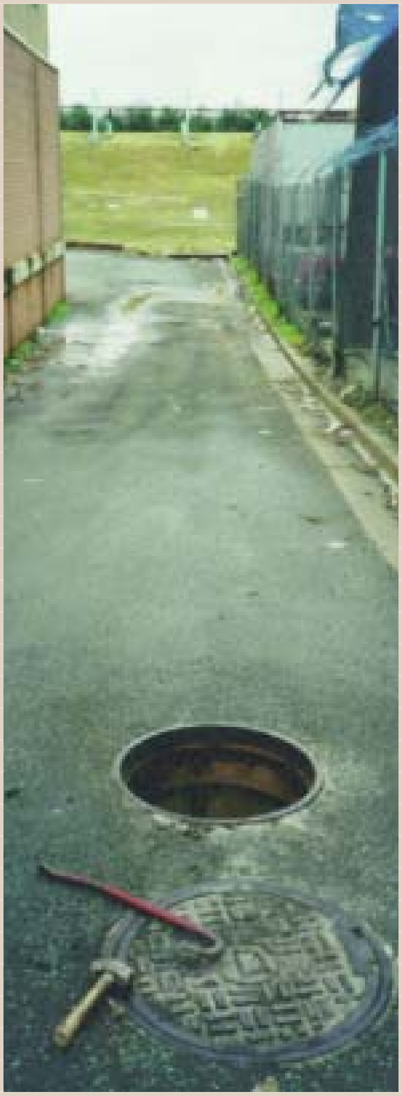
Soil Data

Moisture %	23.72	27.32%
pH	7.4	7.7
Chloride, ppm	16	60
Sulfide, ppm	0.3	0
Resistivity, ohm-cm	722	1,684

General Information

Age of Inspection:	26 years
Coating Type:	galvanized
Diameter:	48"
Corrugation:	1x5" helical
Land Use:	industrial
Location:	Montgomery County, Md.

SITE 3: 48" Detention/Infiltration System, Montgomery County



Water Data

pH	7.5
Chloride, ppm	66
Sulfide, ppm	0.3
Resistivity, ohm-cm	881

Soil Data

Moisture %	29.14%
pH	7.9
Chloride, ppm	32
Sulfide, ppm	0
Resistivity, ohm-cm	2,538

General Information

Age of Inspection:	26 years
Coating Type:	galvanized
Diameter:	48"
Corrugation:	1x5" helical
Land Use:	industrial
Location:	Montgomery County, Md.

CROWN: SOIL SIDE

INVERT: "SAW CUT" SOIL SIDE

CROWN: WATER SIDE

INVERT: "SAW CUT" WATER SIDE

SITE 5: 60" Detention System, Montgomery County

CROWN: SOIL SIDE

INVERT: SOIL SIDE

CROWN: WATER SIDE

INVERT: WATER SIDE

Water Data

pH	7.4
Chloride, ppm	193
Sulfide, ppm	0
Resistivity, ohm-cm	692

Soil Data

Moisture %	23.83	26.51%
pH	7.4	7.4
Chloride, ppm	20	27
Sulfide, ppm	0	0
Resistivity, ohm-cm	8,696	3,663

General Information

Age of Inspection:	21 years
Coating Type:	galvanized
Diameter:	60"
Corrugation:	1x5" helical
Land Use:	industrial
Location:	Montgomery County, Md.

SITE 6: 96" Detention System, Montgomery County

Water Data

pH	6.2
Chloride, ppm	16
Sulfide, ppm	0
Resistivity, ohm-cm	5,181

Soil Data

Moisture %	27.52%	29.18%
pH	6.4	6.8
Chloride, ppm	37	28
Sulfide, ppm	0	0.3
Resistivity, ohm-cm	4,630	5,051

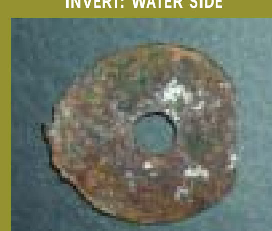
General Information

Age of Inspection:	21 years
Coating Type:	galvanized
Diameter:	96"
Corrugation:	1x5" helical
Land Use:	commercial
Location:	Montgomery County, Md.

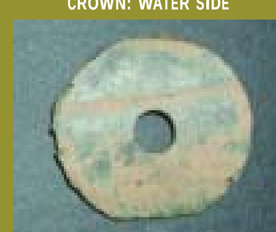
INVERT: SOIL SIDE

CROWN: SOIL SIDE

INVERT: WATER SIDE



CROWN: WATER SIDE



SITE 7: 96" Detention System, Montgomery County

CROWN: SOIL SIDE

INVERT: SOIL SIDE

CROWN: WATER SIDE

INVERT: WATER SIDE

Water Data

pH	7.3
Chloride, ppm	14
Sulfide, ppm	0
Resistivity, ohm-cm	3,165

Soil Data

Moisture %	23.67	30.21%
pH	6.3	6.6
Chloride, ppm	42	9
Sulfide, ppm	0	0
Resistivity, ohm-cm	2,941	11,765

General Information

Age of Inspection:	21 years
Coating Type:	galvanized
Diameter:	96"
Corrugation:	1x5" helical
Land Use:	commercial
Location:	Montgomery County, Md.

SITE 8: 72" Detention System, Montgomery County

Water Data

pH	7.6
Chloride, ppm	40
Sulfide, ppm	0
Resistivity, ohm-cm	3,135

Soil Data

Moisture %	25.58	27.48%
pH	7.7	7.6
Chloride, ppm	32	30
Sulfide, ppm	0	0
Resistivity, ohm-cm	2,899	3,846

General Information

Age of Inspection:	21 years
Coating Type:	fully bituminous coated
Diameter:	72"
Corrugation:	1x5" helical
Land Use:	industrial
Location:	Montgomery County, Md.

CROWN: SOIL SIDE

INVERT: SOIL SIDE

CROWN: WATER SIDE

INVERT: WATER SIDE

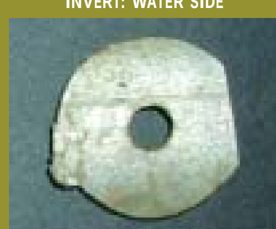
SITE 9: 108" Detention System, Montgomery County

SIDE: SOIL SIDE

INVERT: SOIL SIDE

SIDE: WATER SIDE

INVERT: WATER SIDE



Water Data

pH	7.9
Chloride, ppm	34
Sulfide, ppm	0
Resistivity, ohm-cm	2,066

Soil Data

Moisture %	34.00%
pH	7.6
Chloride, ppm	10
Sulfide, ppm	0
Resistivity, ohm-cm	2,899

General Information

Age of Inspection:	21 years
Coating Type:	galvanized
Diameter:	108"
Corrugation:	1x5" helical
Land Use:	commercial
Location:	Montgomery County, Md.

SITE 13: 108" Detention System, Montgomery County

Water Data

pH	7.3
Chloride, ppm	7
Sulfide, ppm	0
Resistivity, ohm-cm	4,016

Soil Data

Moisture %	26.73	34.33%
pH	6.6	7.2
Chloride, ppm	30	18
Sulfide, ppm	0	0
Resistivity, ohm-cm	1,961	3,745

General Information

Age of Inspection:	11 years
Coating Type:	aluminum coated type 2
Diameter:	108"
Corrugation:	1x5" helical
Land Use:	commercial
Location:	Montgomery County, Md.

SIDE: SOIL SIDE

INVERT: SOIL SIDE

SIDE: WATER SIDE

INVERT: WATER SIDE

SITE 14: 67"x104" Detention System, Fairfax City

SIDE: SOIL SIDE

INVERT: SOIL SIDE

SIDE: WATER SIDE

INVERT: WATER SIDE

Water Data

pH	6.9
Chloride, ppm	32
Sulfide, ppm	0
Resistivity, ohm-cm	4,184

Soil Data

Moisture %	23.07	32.38%
pH	5.7	6.6
Chloride, ppm	10	10
Sulfide, ppm	0	0
Resistivity, ohm-cm	7,813	10,417

General Information

Age of Inspection:	6 years
Coating Type:	fully bituminous coated
Diameter:	67"x104"
Corrugation:	1x5" helical
Land Use:	residential
Location:	Fairfax City, Va.

SITE 16: 80" Detention System, Fairfax City

Water Data

pH	6.8
Chloride, ppm	133
Sulfide, ppm	0
Resistivity, ohm-cm	5,814

Soil Data

Moisture %	20.40%
pH	4.9
Chloride, ppm	16
Sulfide, ppm	0
Resistivity, ohm-cm	10,417

General Information

Age of Inspection:	11 years
Coating Type:	aluminum coated type 2
Diameter:	80"
Corrugation:	1x5" helical
Land Use:	residential (SFH)
Location:	Fairfax City, Va.

CROWN: SOIL SIDE

INVERT: SOIL SIDE

CROWN: WATER SIDE

INVERT: WATER SIDE

SITE 17: 65"x107" Detention System, Fairfax City

SIDE: SOIL SIDE

INVERT: SOIL SIDE

SIDE: WATER SIDE

INVERT: WATER SIDE

Water Data

pH	6.6
Chloride, ppm	121
Sulfide, ppm	0
Resistivity, ohm-cm	12,195

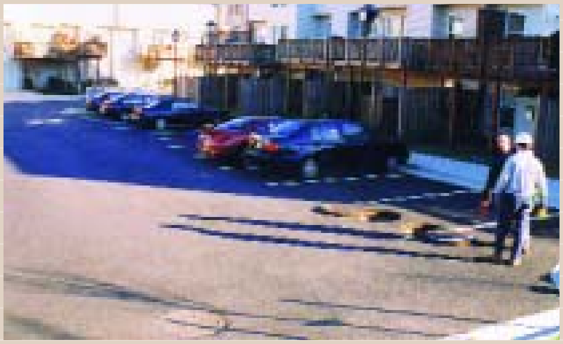
Soil Data

Moisture %	27.32%
pH	5.1
Chloride, ppm	12
Sulfide, ppm	0
Resistivity, ohm-cm	6,993

General Information

Age of Inspection:	6 years
Coating Type:	fully bituminous coated
Diameter:	65"x107"
Corrugation:	1x5" helical
Land Use:	residential
Location:	Fairfax City, Va.

SITE 21: 72" Detention System, Alexandria



Water Data	
pH	6.2
Chloride, ppm	120
Sulfide, ppm	0
Resistivity, ohm-cm	8,333
Soil Data	
Moisture %	24.17%
pH	6.0
Chloride, ppm	34
Sulfide, ppm	0
Resistivity, ohm-cm	1,992
General Information	
Age of Inspection:	6 years
Coating Type:	galvanized
Diameter:	72"
Corrugation:	1x5" helical
Land Use:	residential
Location:	Alexandria, Va.

CROWN: SOIL SIDE

INVERT: SOIL SIDE

CROWN: WATER SIDE

INVERT: WATER SIDE

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