

NEW MEXICO DEPARTMENT OF TRANSPORTATION

RESEARCH BUREAU

Innovation in Transportation

Comparing Resistivity and Conductivity in Metal Culverts

Final Report

Prepared by:

Agua del Sol Consultants, LLC
PO Box 92797
Albuquerque, NM 87199

Prepared for:

New Mexico Department of Transportation
Research Bureau
2500B Pan American Freeway NE
Albuquerque, NM 87109

In Cooperation with:

The US Department of Transportation
Federal Highway Administration

Report R924020

DECEMBER 4, 2025

DOT FHWA SUMMARY PAGE

1. Report No. R924020	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Comparing Resistivity and Conductivity in Metal Culverts	5. Report Date December 4, 2025		6. Performing Organization Code.
	8. Performing Organization Report No.		
7. Author(s) Jake Collison	10. Work Unit No. (TRAIS)		
9. Performing Organization Name and Address Agua del Sol Consultants, LLC PO Box 92797 Albuquerque NM, 87199	11. Contract or Grant No. CO6444		
	13. Type of Report and Period Covered Final Report 2025		
12. Sponsoring Agency Name and Address Research Bureau New Mexico Department of Transportation 7500B Pan American Freeway NE Albuquerque, NM 87109	14. Sponsoring Agency Code		
	15. Supplementary Notes		
<p>16. Abstract</p> <p>Before installing an underground metal culvert, certain soil characteristics need to be measured to calculate its expected service life. The service life of an underground culvert is a function of the expected amount of corrosion based on the soil, the type of culvert used, and water conditions. The New Mexico Department of Transportation (NMDOT) uses three different soil properties to estimate culvert service life: (1) the soil's electrical conductivity (EC); (2) pH level; and (3) gypsum content. Soil EC measures how easily an electric charge can be passed (conducted) through the soil, with the soil's moisture content having a large effect. Soils with pH lower than 5.5 and greater than 7.3 have been shown to have adverse effects on galvanized coated (zinc coating) steel culverts. Lastly, knowing the amount of gypsum (CaSO₄·2H₂O) in the soil is important because gypsum (specifically, the sulfates within the gypsum, SO₄²⁻) readily corrodes zinc and steel. All three of these soil properties' corrosive potential is further increased with higher moisture content in the soil. With culverts' typical proximity to water, accurate accounting of these soil parameters is crucial in the determination of the type of culvert to be used, based on a minimum of 50 years of service life.</p> <p>This project used in-situ and laboratory measurements of soil conductivity and resistivity to determine the compatibility of the Natural Resource Conservation Service (NRCS) Soils Maps for metal corrosion potential versus the 2018 NMDOT Culvert Resistant Spreadsheet (CRS).</p>			
17. Key Words Metal Culvert, Corrosion, Soil Resistivity, Soil Conductivity		18. Distribution Statement Available from NMDOT Research Bureau	
19. Security Classif. (of this report) None	20. Security Classif. (of this page) None	21. No. of Pages 114	22. Price

Report No. R924020

Comparing Resistivity and Conductivity in Metal Culverts

FINAL REPORT

December 2025

Report Submitted to:

NMDOT Research Bureau
7500B Pan American Freeway NE
Albuquerque, NM 87109
505-412-9553
<mailto:Research.Bureau@dot.nm.gov>
Research Bureau | NMDOT

Prepared by

Jake Collison, PhD

Agua del Sol Consultants, LLC
PO Box 92797
Albuquerque, NM 87199



THIS PAGE INTENTIONALLY LEFT BLANK

PREFACE

The research reported herein examines multiple methods for measuring soil conductivity and resistivity to determine the optimal method(s) for evaluating the service life of galvanized culverts. Additionally, these different measurement methods are compared to each other to provide evidence of the accuracy of the NMDOT's Culvert Resistant Spreadsheet.

NOTICE

The United States government and the State of New Mexico do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report. This information is available in alternative accessible formats. To obtain an alternative format, contact the NMDOT Research Bureau, 7500B Pan American Freeway NE, PO Box 94690, Albuquerque, NM 87199-4690, (505)-841-9145.

DISCLAIMER

This report presents the results of research conducted by the authors and does not necessarily reflect the views of the New Mexico Department of Transportation. This report does not constitute a standard or specification.

ABSTRACT

Before installing an underground metal culvert, certain soil characteristics need to be measured to calculate its expected service life. The service life of an underground culvert is a function of the expected amount of corrosion based on the soil, the type of culvert used, and water conditions. The New Mexico Department of Transportation (NMDOT) uses three different soil properties to estimate culvert service life: (1) the soil's electrical conductivity (EC); (2) pH level; and (3) gypsum content. Soil EC measures how easily an electric charge can be passed (conducted) through the soil, with the soil's moisture content having a large effect. Soils with pH lower than 5.5 and greater than 7.3 have been shown to have adverse effects on galvanized coated (zinc coating) steel culverts. Lastly, knowing the amount of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) in the soil is important because gypsum (specifically, the sulfates within the gypsum, SO_4^{2-}) readily corrodes zinc and steel. All three of these soil properties' corrosive potential is further increased with higher moisture content in the soil. With culverts' typical proximity to water, accurate accounting of these soil parameters is crucial in the determination of the type of culvert to be used, based on a minimum of 50 years of service life.

This project used in-situ and laboratory measurements of soil conductivity and resistivity to determine the compatibility of the Natural Resource Conservation Service (NRCS) Soils Maps for metal corrosion potential versus the 2018 NMDOT Culvert Resistant Spreadsheet (CRS).

ACKNOWLEDGEMENTS

This project was funded by the New Mexico Department of Transportation (NMDOT). The author would like to thank NMDOT Research Bureau for its funding for this project.

The author would specifically like to thank Abigail Moya, Angelo Armijo, David Trujillo, Hao Yin, and Shannon Vigil from NMDOT for help and feedback during the course of this project.

The author would specifically like to thank Kathryn Collison for having to proofread this final report multiple times.

TABLE OF CONTENTS

Preface.....	i
Abstract.....	ii
Acknowledgements.....	iii
Table of Contents.....	iv
List of Figures.....	viii
List of Tables.....	xii
Introduction.....	1
Problem Description and Motivation.....	2
Study Locations.....	2
Literature Review.....	3
Methodologies.....	4
Site Visit.....	4
Soil Testing.....	5
Results from Field Locations.....	5
I-25 MP 77.19.....	5
I-25 MP 107.86.....	6
Culvert Thickness Measurement.....	8
In-situ and Laboratory Soil Measurements.....	8
I-25 MP 113.04.....	9
Culvert Thickness Measurement.....	11
In-situ and Laboratory Soil Measurements.....	11
I-25 NB MP 142.49.....	12
Culvert Thickness Measurement.....	13
In-situ and Laboratory Soil Measurements.....	14
I-25 and Exit 264.....	14
Culvert Thickness Measurement.....	19
In-situ and Laboratory Soil Measurements.....	19
I-25 MP 264.2.....	20
Culvert Thickness Measurement.....	22
In-situ and Laboratory Soil Measurements.....	23
I-25 MP 278.7.....	24

Culvert Thickness Measurement.....	25
In-situ and Laboratory Soil Measurements	26
I-40 MP 121	26
Culvert Thickness Measurement.....	26
In-situ and Laboratory Soil Measurements	30
NM 1 MP 19.24.....	30
Culvert Thickness Measurement.....	31
In-situ and Laboratory Soil Measurements	32
NM 1 MP 20.61 and 20.85	32
NM 1 MP 21.52.....	33
Culvert Thickness Measurement.....	34
In-situ and Laboratory Soil Measurements	35
NM 1 MP 22.01.....	35
Culvert Thickness Measurement.....	36
In-situ and Laboratory Soil Measurements	37
NM 104 MP 42.....	37
NM 104 MP 42.1.....	38
Culvert Thickness Measurement.....	39
In-situ and Laboratory Soil Measurements	40
NM 104 MP 43.....	40
Culvert Thickness Measurement.....	42
In-situ and Laboratory Soil Measurements	43
NM 104 MP 46.9.....	44
Culvert Thickness Measurement.....	45
In-situ and Laboratory Soil Measurements	46
NM 117 MP 55.....	46
Culvert Thickness Measurement.....	49
In-situ and Laboratory Soil Measurements	50
NM 117 MP 55.8.....	51
Culvert Thickness Measurement.....	53
In-situ and Laboratory Soil Measurements	53
NM 117 MP 56.....	54

Culvert Thickness Measurement.....	55
In-situ and Laboratory Soil Measurements	55
NM 117 MP 57.....	56
Culvert Thickness Measurement.....	58
In-situ and Laboratory Soil Measurements	59
NM 128 MP 1.3 and 21.59.....	59
NM 128 MP 21.93.....	60
Culvert Thickness Measurement.....	61
In-situ and Laboratory Soil Measurements	62
NM 181 MP 5.48.....	62
NM 195 MP 1.51.....	63
Culvert Thickness Measurement.....	64
In-situ and Laboratory Soil Measurements	64
NM 290 MP 0.65.....	65
Culvert Thickness Measurement.....	68
In-situ and Laboratory Soil Measurements	69
NM 290 MP 0.91.....	70
Culvert Thickness Measurement.....	72
In-situ and Laboratory Soil Measurements	73
NM 290 MP 1.0.....	73
Culvert Thickness Measurement.....	74
In-situ and Laboratory Soil Measurements	74
US 60 MP 203.41	75
Culvert Thickness Measurement.....	76
In-situ and Laboratory Soil Measurements	76
US 60 MP 204.33.....	77
Culvert Thickness Measurement.....	78
In-situ and Laboratory Soil Measurements	78
Conclusions and Recommendations	79
Soil Resistivity	79
Soil PH	81
References	82

Appendix 1: NRCS Soil Electrical Conductivity	83
Appendix 2: California Test Method 643 (CTM-643)	84
Appendix 3: Resistivity to Conductivity Conversions	93
Appendix 4: Soil Data	94
Appendix 5: Culvert Data	97

LIST OF FIGURES

FIGURE 1: Corrosion rate of metals based on the pH value (2).	1
FIGURE 2: Data collection locations in New Mexico (Google Earth)	3
FIGURE 3: Diagram of Ultrasonic measurement locations	4
FIGURE 4: Culvert on I-25 (NB) MP 77.19.....	6
FIGURE 5: Culvert on I-25 (NB) MP 107.86, outlet side.....	7
FIGURE 6: Inside of the outlet side of the culvert on I-25 (NB) MP 107.86.....	7
FIGURE 7: Outside of the outlet side of the culvert on I-25 (NB) MP 107.86.....	8
FIGURE 8: Diagram of wall thickness measurements taken at I-25 (NB) MP 107.86 culvert.	8
FIGURE 9: Culvert on I-25 MP 113.04, inlet side.	10
FIGURE 10: Inside of the outlet side of the culvert on I-25 MP 113.04.....	10
FIGURE 11: Inside wall of the outlet side of the culvert on I-25 MP 113.04.	11
FIGURE 12: Culvert on I-25 (NB) MP 142.49, outlet side.....	12
FIGURE 13: Culvert on I-25 (NB) MP 142.49, outlet side.....	12
FIGURE 14: Culvert on I-25 (NB) MP 142.49, inside view near outlet side.....	13
FIGURE 15: Culvert on I-25 (NB) MP 142.49.....	13
FIGURE 16: Diagram of wall thickness measurements taken on I-25 (NB) MP 142.49 culvert.	14
FIGURE 17: Location of “Inlet Grate,” tumbleweed-filled “Hole,” and “Outlet” of the 2 separate 24” culverts near NB I-25 and exit 264. The red line is an estimated location of both culverts. .	15
FIGURE 18: Image of “Inlet Grate” between NB I-25 and the offramp for exit 264.	16
FIGURE 19: Image of the tumbleweed-filled “Hole,” outlined in red, and a 5’ 6” long shovel outlined in white from culvert between Exit 264 offramp and I-25.	17
FIGURE 20: Image of 24” (estimated) outlet with a red line highlighting the only metal remaining of culvert between Exit 264 offramp and I-25.....	18
FIGURE 21: Close-up image of the near fully corroded second culvert outlet from culvert between Exit 264 offramp and I-25.	19
FIGURE 22: 72” culvert under I-25 at 264.2, inlet.	21
FIGURE 23: Slight corrosion on the bottom of the culvert underneath the sandy soil present on I- 25 MP 264.2.....	21
FIGURE 24: Outside of the outlet showing extent of corrosion on I-25 MP 264.2 culvert.	22
FIGURE 25: Diagram of inlet wall thickness measurements taken on I-25 MP 264.2.....	23
FIGURE 26: Diagram of outlet wall thickness measurements taken on I-25 MP 264.2.....	23
FIGURE 27: Culvert at I-25 (SB) MP 278.7, inlet side facing North.	25
FIGURE 28: No corrosion was present on the inside of the I-25 (SB) MP 278.7 culvert.....	25
FIGURE 29: Diagram of inlet wall thickness measurements taken on the I-25 (SB) MP 278.7 culvert.....	26
FIGURE 30: 3-36” CMP I-40 MP 121.0, inlet side, westbound I-40 (facing south).	27
FIGURE 31: Diagram of wall thickness measurements taken at I-40 MP 121 A culvert.....	27
FIGURE 32: Diagram of wall thickness measurements taken at I-40 MP 121 B culvert.	28
FIGURE 33: Diagram of wall thickness measurements taken at I-40 MP 121 C culvert.	28
FIGURE 34: Culvert I-40 MP 121 A showing the extent of corrosion roughly 1/3 up the side of the culvert.....	29

FIGURE 35: Culvert I-40 MP B showing the extent of corrosion roughly 1/3 up the side of the culvert.....	29
FIGURE 36: Culvert on NM 1 MP 19.24, inlet side.	30
FIGURE 37: Inside of the inlet side of the culvert on NM 1 MP 19.24.	31
FIGURE 38: Diagram of wall thickness measurements taken at NM 1 MP 19.24 culvert.	31
FIGURE 39: Approximate location of culvert on NM 1 MP 20.61, buried in thick brush.	33
FIGURE 40: Inlet side of culvert on NM 1 MP 20.85.....	33
FIGURE 41: Culvert on NM 1 MP 21.52, inlet side.	34
FIGURE 42: Inside of the inlet side of the culvert on NM 1 MP 21.52.	34
FIGURE 43: Diagram of wall thickness measurements taken at NM 1 MP 21.52 culvert.	35
FIGURE 44: Culvert on NM 1 MP 22.01, inlet side.	36
FIGURE 45: Inside of the inlet side of the culvert on NM 1 MP 22.01.	36
FIGURE 46: Diagram of wall thickness measurements taken at NM 1 MP 22.01 culvert.	37
FIGURE 47: 3-36” culverts on NM 104 MP 42.0, with outer two culverts circled in red for identification and middle culvert completely silted over.	38
FIGURE 48: Culvert on NM 104 MP 42.1, inlet side.	38
FIGURE 49: Culvert on NM 104 MP 42.1 inlet side looking in.	39
FIGURE 50: Diagram of inlet wall thickness measurements taken on NM 140 MP 42.1 culvert.	40
FIGURE 51: Two 60” culverts on NM 104 MP 43, inlet side.	41
FIGURE 52: Western 60” culvert on NM 104 MP 43, inlet side looking in.	41
FIGURE 53: Eastern 60” culvert on NM 104 MP 43, inlet side looking in.	42
FIGURE 54: Western culvert diagram of inlet wall thickness measurements taken from the NM 104 MP 43 culvert.	43
FIGURE 55: Eastern culvert diagram of inlet wall thickness measurements taken from the NM 104 MP 43 culvert.	43
FIGURE 56: Culvert on NM 104 MP 46.9, inlet side.	44
FIGURE 57: Culvert on NM 104 MP 46.9, inlet side looking in.	45
FIGURE 58: Diagram of inlet wall thickness measurements taken from the NM 104 MP 46.9 culvert.....	46
FIGURE 59: Culvert on NM 117 MP 55 inlet before removal of brush.	47
FIGURE 60: Inlet side after removal of brush with collapsed section of the culvert circled in red, NM 117 MP 55 culvert.....	48
FIGURE 61: Close-up of collapsed culvert, roughly 3’ by 2’, NM 117 MP 55 culvert.	49
FIGURE 62: Location of ultrasonic thickness measurement, zero corrosion present, NM 117 MP 55 culvert.....	50
FIGURE 63: Diagram of inlet wall thickness measurements taken on the NM 117 MP 55 culvert.	50
FIGURE 64: Culvert on NM 117 MP 55.8, inlet side.....	51
FIGURE 65: Inside of the inlet side of the culvert on NM 117 MP 55.8, indicating some slight corrosion on the bottom inside of the culvert.	52
FIGURE 66: Outlet of culvert on NM 117 MP 55.8 showing collapsed location.	53

FIGURE 67: Diagram of inlet wall thickness measurements taken on NM 117 MP 55.8 culvert.	53
FIGURE 68: Culvert on NM 117 MP 56, inlet side.....	54
FIGURE 69: Culvert on NM 117 MP 56, close-up of inside on inlet side.	55
FIGURE 70: Diagram of Inlet wall thickness measurements taken on NM 117 MP 56 culvert. .	55
FIGURE 71: Culvert on NM 117 MP 57, inlet side.....	57
FIGURE 72: Culvert on NM 117 MP 57, inlet side, significant corrosion on the upper half of the culvert and minimal to no corrosion on the lower half.	58
FIGURE 73: Diagram of inlet wall thickness measurements taken on NM 117 MP 57 culvert. .	58
FIGURE 74: Very unhappy Western Diamondback Rattlesnake in western culvert at NM 128 MP 21.59.....	59
FIGURE 75: 2-36” culverts on NM 128 MP 21.93, facing south, inlet side (eastern culvert on left and western on right).....	60
FIGURE 76: Eastern 36” culvert on NM 128 MP 21.93 facing south at inlet.	60
FIGURE 77: Western 36” culvert on NM 128 MP 21.93 facing south at inlet.	61
FIGURE 78: Diagram of wall thickness measurements taken at NM 128 MP 21.93 Eastern culvert.....	61
FIGURE 79: Diagram of wall thickness measurements taken at NM 128 MP 21.93 Western culvert.....	62
FIGURE 80: Approximate inlet side of culvert on NM 181 MP 5.48, buried in dirt. Culvert road warning marker circled in red.	63
FIGURE 81: Culvert on NM 195 MP 1.51, inlet side.	63
FIGURE 82: Inside of the inlet side of the culvert on NM 195 MP 1.51.	64
FIGURE 83: Diagram of wall thickness measurements taken at NM 195 MP 1.51 culvert.	64
FIGURE 84: Culvert on NM 290 MP 0.65, inlet side.	65
FIGURE 85: Culvert on NM 290 MP 0.65, inlet side, approximately 10 feet in from the end. Image shows multiple large sections of the culvert’s bottom missing in addition to a large hole halfway up the right side.	66
FIGURE 86: Culvert on NM 290 MP 0.65, inlet side, approximately 10 feet in from end. Image shows a zoomed-in view of the culvert’s bottom where large sections are missing and what appears to be an old, metal bucket stuck in one of the corroded holes.	67
FIGURE 87: Culvert on NM 290 MP 0.65, outlet side, approximately 10 feet in from end. Extreme corrosion with backfill being undermined during last flow event.....	68
FIGURE 88: Diagram of inlet wall thickness measurements taken on NM 290 MP 0.65 culvert.	69
FIGURE 89: Culvert on NM 290 MP 0.65, inlet side. Image of the rocky ground around the inlet of the culvert.	69
FIGURE 90: Inlet of culvert on NM 290 MP 0.91.	70
FIGURE 91: Culvert on NM 290 MP 0.91, inlet side showing corrosion on the inside bottom. .	71
FIGURE 92: Culvert on NM 290 MP 0.91, outlet side with excessive outside corrosion.	72
FIGURE 93: Diagram of inlet wall thickness measurements taken on NM 290 MP 0.91 culvert.	72
FIGURE 94: 24” culvert under NM 290, MP 1.0, inlet side facing south.....	73

FIGURE 95: No corrosion present on the inside of the culvert on NM 290 MP 1.0..... 74

FIGURE 96: Diagram of inlet wall thickness measurements taken on NM 290 MP 1.0 culvert. 74

FIGURE 97: 42” culvert under US 60 MP 203.41, inlet side facing south. 75

FIGURE 98: No corrosion was present on the inside of the culvert on US 60 MP 203.41..... 76

FIGURE 99: Diagram of inlet wall thickness measurements taken on US 60 MP 203.41 culvert.
..... 76

FIGURE 100: 24” culvert under US 60 MP 204.33, outlet side facing north. 77

FIGURE 101: Considerable amount of corrosion on the inside of the culvert on US 60 MP
204.33..... 78

FIGURE 102: Diagram of outlet wall thickness measurements taken on US 60 MP 204.33
culvert..... 78

FIGURE 103: Resistivity at a wet location vs. dry location. 80

LIST OF TABLES

TABLE 1: Soil test results from outlet side of culvert on I-25 MP (NB) 107.86.	9
TABLE 2: Soil test results from inlet side of culvert on I-25 MP 113.04.....	11
TABLE 3: Soil test results from outlet side of culvert on I-25 (NB) MP 142.49.	14
TABLE 4: Soil results from in-situ and laboratory tests from culvert between Exit 264 offramp and I-25.	19
TABLE 5: Soil test results from in-situ and laboratory tests on I-25 MP 264.2 culvert.....	24
TABLE 6: Side-bank soil test results from inlet side on I-25 MP 264.2 culvert.	24
TABLE 7: Soil test results from in-situ and laboratory tests on I-25 (SB) MP 278.7 culvert.	26
TABLE 8: Soil test results from in-situ and laboratory tests for I-40 MP 121 culvert.	30
TABLE 9: Soil test results from inlet side of culvert on NM 1 MP 19.24 culvert.	32
TABLE 10: Soil test results from inlet side of culvert on NM 1 MP 21.52 culvert.	35
TABLE 11: Soil test results from inlet side of culvert on NM 1 MP 22.01 culvert.....	37
TABLE 12: Soil test results from the NM 104 MP 42.1 culvert.	40
TABLE 13: Soil test results from inlet side of the NM 104 MP 43 culvert.....	44
TABLE 14: Soil test results from inlet side on the NM 104 MP 46.9 culvert.	46
TABLE 15: Soil test results from inlet side from the NM 117 MP 55 culvert.	51
TABLE 16: Soil test results from inlet side of NM 117 MP 55.8 culvert.	54
TABLE 17: Soil test results from inlet side of the NM 117 MP 56 culvert.	56
TABLE 18: Soil test results from inlet side of the NM 117 MP 57 culvert.	59
TABLE 19: Soil test results from inlet side of culvert on NM 128 MP 21.93.....	62
TABLE 20: Soil test results from inlet side of culvert on NM 195 MP 1.51.....	65
TABLE 21: Soil test results from laboratory tests on NM 290 MP 0.65 culvert.	70
TABLE 22: Soil test results from in-situ and laboratory tests on NM 290 MP 0.91 culvert.	73
TABLE 23: Soil test results from in-situ and laboratory tests on NM 290 MP 1.0 culvert.	75
TABLE 24: Soil test results from in-situ and laboratory tests on US 60 MP 203.41 culvert.	77
TABLE 25: Soil test results from in-situ and laboratory on US 60 MP 204.33 culvert.	79
TABLE 26: Resistivity at a wet location vs. dry location.....	80

INTRODUCTION

Before installing an underground metal culvert, certain soil characteristics need to be measured to calculate its expected service life. The service life of an underground culvert is a function of the expected amount of corrosion based on the soil properties, the type of culvert used, and water conditions. The New Mexico Department of Transportation (NMDOT) uses three different soil properties to estimate culvert service life: the soil's electrical conductivity (EC); pH level; and gypsum content. Soil EC measures how easily an electric charge can be passed (conducted) through the soil, with the soil's moisture content having a large effect (1). Soils with pH lower than 5.5 and greater than 7.3 (2) have been shown to have adverse effects on galvanized coated (zinc coating) steel culverts, as shown in Figure 1 below. Lastly, knowing the amount of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) in the soil is important because gypsum (specifically, the sulfates within the gypsum, SO_4^{2-}) readily corrodes zinc and steel (2). All three of these soil properties' corrosive potential is further increased with higher moisture content in the soil. With culverts' typical proximity to water, accurate accounting of these soil parameters is crucial in the determination of the type of culvert to be used, based on a minimum of 50 years of service life.

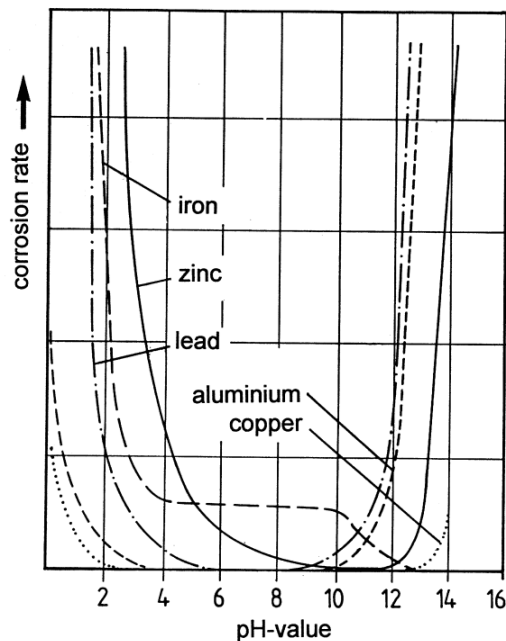


FIGURE 1: Corrosion rate of metals based on the pH value (2).

NMDOT uses the “2018 NMDOT Culvert Resistance Spreadsheet” (CRS) when estimating the service life of culverts. The values of resistivity in the CRS for different types of culverts of varying material (steel, concrete, aluminum, plastic, etc.) and of varying wall thickness with different corrosive inhibitor coatings were collected from manufacturers' specification literature. With all of these manufacturers' values being reported in resistance (ohm-cm), it was assumed by NMDOT that the electrical conductance (milliSiemens per meter, mS/m and millimhos per centimeter, mmhos/cm) values reported by the Natural Resources Conservation Services (NRCS) for soils for New Mexico were directly proportional to each other, based on Ohm's law. Furthermore, the resistivity of the soil is determined in-situ adjacent to the culvert and the values reported by NRCS are from EC tests conducted in a lab from field-collected soil

samples. These two methods, in-situ and laboratory, are significantly different in procedure and produce values of different units, ohm-cm (resistivity) and mS/m (conductivity), respectively. It is assumed that the laboratory test is more accurate than the field tests, which will be evaluated in this project. Providing a better understanding for and evidence that these two methods, although different, produce results that are directly proportional to each other. Providing this information will enhance NMDOT's continued usage of their CRS when calculating service life of culverts.

PROBLEM DESCRIPTION AND MOTIVATION

The major goal of this project is to “determine the compatibility of the Natural Resource Conservation Service (NRCS) Soils Maps for metal corrosion potential versus the 2018 NMDOT Culvert Resistant Spreadsheet (CRS)” from NMDOT Request for Quote for Comparing Resistivity and Conductivity in Metal Culverts (R924020). To accomplish this goal, in-situ soil resistivity measurements adjacent to culverts identified by NMDOT were conducted. Additionally, soil samples were collected at these locations and further analyzed in a laboratory where conductivity (following NRCS Soil Electrical Conductivity test guidelines, Appendix 1) and resistivity (following California Test Method 643 guidelines, CTM-643, Appendix 2) tests were conducted to provide a direct in-situ to laboratory resistivity and conductivity comparison. Validating the assumption that conductance and resistance in soils are reciprocal of each other is another goal of this project. This was assumed to be true when the NRCS Soils Map information was added to the Culvert Resistant Spreadsheet in 2018.

STUDY LOCATIONS

The Drainage Design Bureau (DDB) of NMDOT supplied approximately 34 field locations for study throughout New Mexico, with 24 being accessible for data collection. During this study, eight locations on I-25 were proposed, with two of these locations being inaccessible, so data were collected at the other six locations at Milepost (MP) 107.86, 113.04, 142.49, Exit 264, and 264.2. One location on I-40 was visited at MP 121, which consisted of three separate culverts. Five locations on NM 1 were visited, but two were inaccessible, so data from only three locations were collected. Five locations on NM 117 were proposed, but only four were accessible for data collection as one was buried. Data were collected at one location on 195 at MP 1.51. Three locations were proposed on NM 128, but data were only collected at MP 21.93, due to Western Diamondback Rattlesnake activity at the other two locations. Five locations were proposed on NM 290, with two being inaccessible due to being overgrown, so data were only collected at MP 0.65, 0.91, and 1.0. Five locations were proposed on US 60 as it passes through Mountainair, NM, but only three were accessible for data collection due to standing water. Lastly, one location on NM 181 at MP 5.48 was proposed, but this location was completely buried in sediment and therefore not measured. **FIGURE 2** below shows all the locations in New Mexico where data were collected at.

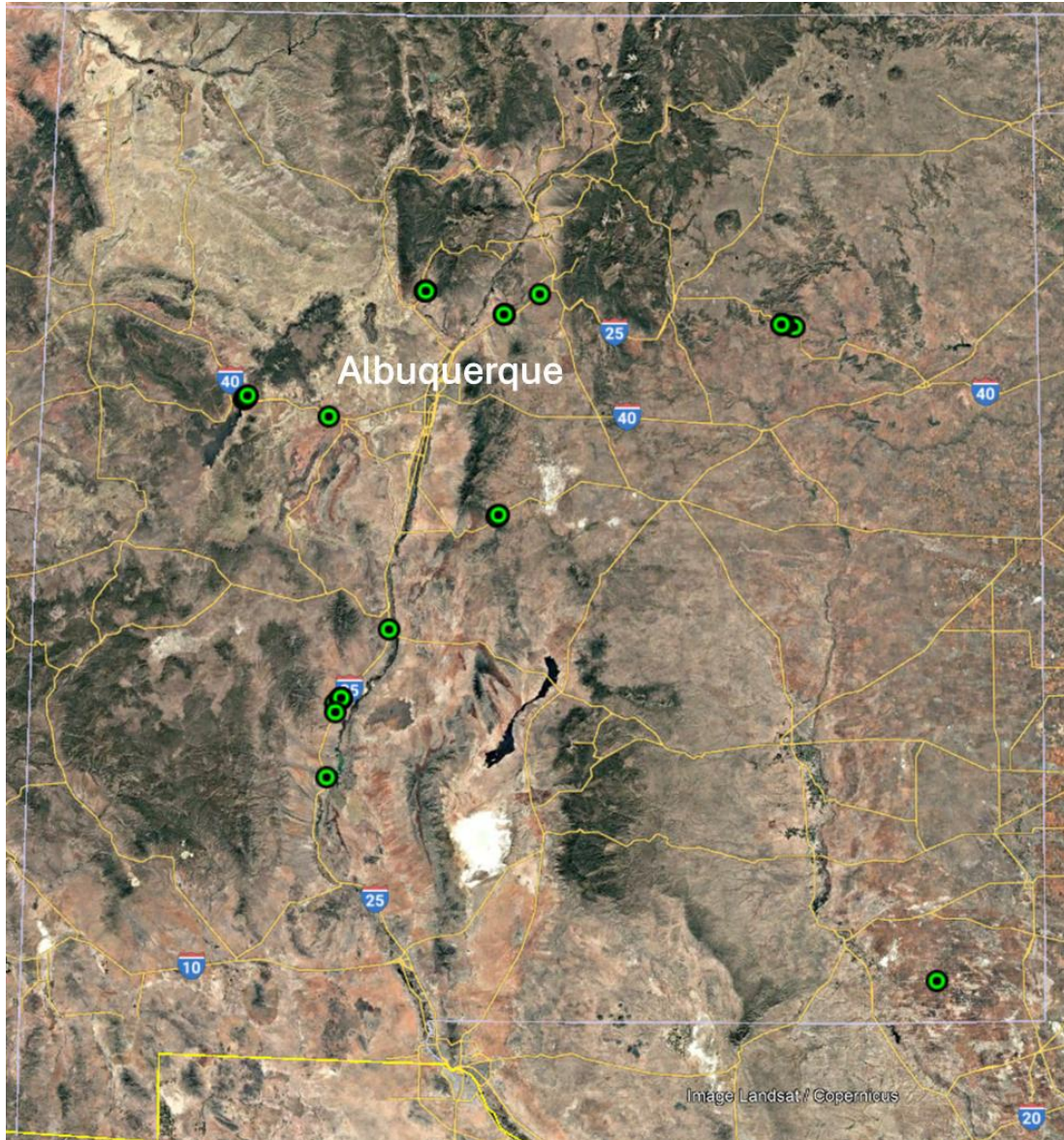


FIGURE 2: Data collection locations in New Mexico (Google Earth)

LITERATURE REVIEW

The most comprehensive and recent literature review about this subject and applicable to this study was by Boyajian and others (3), which was a study funded by CalTrans to improve the existing CalTrans culvert service life equation that was developed in the early 1960s (4). The CalTrans equation is also the base equation in the National Corrugated Steel Pipe Association (NCSPA) service life models (5). This equation only requires pH and resistivity in conjunction with the metal gage. One important aspect that the original CalTrans culvert service life study did not consider was land use surrounding the culvert, which was further compounded by the fact that all the culverts analyzed in that study were in a single district in northwestern California, State Highway District 1. The Boyajian and others (3) study reported that the CalTrans equation overestimated culvert service life (based on a 15% culvert thickness remaining failure rate) in the following land use areas by 24 years in forestland, 15 years in agricultural land, 19

years in rangeland, and 8 years in urban areas. Additionally, the NCSPA design manual mentions that locally based culvert service life studies should be used when available to improve accuracy.

The major takeaway from the Boyajian and others (3) report is the need to take into consideration the surrounding land use when estimating the service life of culverts when using only pH and resistivity in equations. Conducting local studies to determine local culvert service life is further reinforced by the fact the original 1960s culvert service life study conducted by CalTrans (4), which produced the widely used culvert service life equations, mainly consisted of two men stopping at each culvert, “hitting it with a rock hammer,” (1) and determining its service life based on how much the hammer’s spike stuck into the culvert.

METHODOLOGIES

SITE VISIT

Images of the inlet and outlet of each culvert were taken on site arrival. Included in these initial images is a whiteboard that contains the following site-specific information: major road, milepost value, date, longitude, latitude, inlet or outlet, and gage thickness.

After images were taken of the culvert, a Wenner 4-pole ground resistivity test was conducted using an AEMC 6471 Digital Ground Resistance Tester. Ground resistivity tests were conducted near the inlet or outlet of each culvert, contingent on accessibility, at 1m, 2m, and 3m out from the culvert. Proximity to the inlet of the culvert is preferred, as the soil in this location will be most likely to affect the culvert during rain events. Soil samples were collected along every four-pole traverse for later testing in the laboratory, with soils collected from 0-6 inches deep using a soil collection probe. The collected soil samples were stored in airtight containers such that moisture was not lost during transit to the laboratory.

A micrometer was used to measure uncorroded locations on the culvert to help determine the culvert’s gage. Next, an ultrasonic micrometer (Olympus 45MG with 0.001” resolution) was used to measure the thickness of the culverts’ walls at nine locations, with these locations displayed in **FIGURE 3** below.

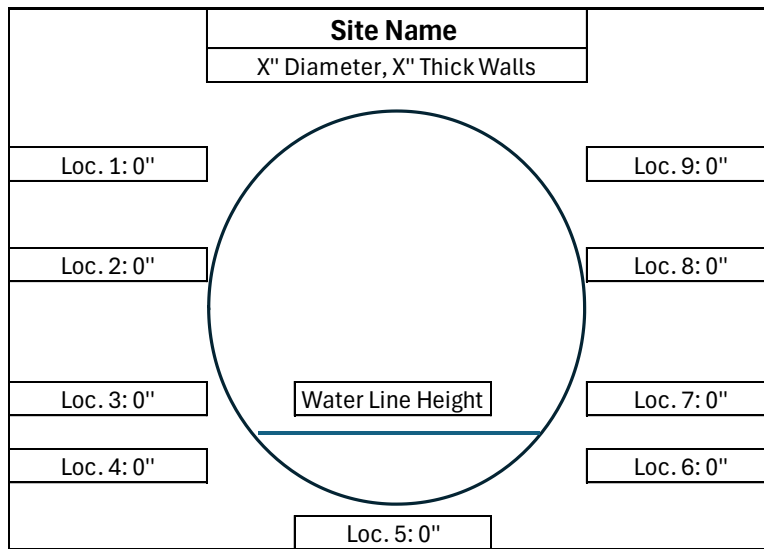


FIGURE 3: Diagram of Ultrasonic measurement locations

Location 5 was always the bottom middle of the culvert, with locations 3/4 and 6/7 on either side of the water/soil line on the bottom of the culvert. Locations 2 and 8 were located at the widest part of the culvert and locations 1 and 9 were located at roughly the 11 and 1 o'clock positions, respectively. The arc length from location 5 to the other locations was recorded.

SOIL TESTING

The soil samples that were collected along each traverse of the four-pole resistivity tests were split into two groups. Group 1 was used in the NRCS soil electrical conductivity (8) test and required no additional preparation. Group 2 was used in the CTM-643 test and was dried in an oven at 115°F for at least 3 hours prior to being used in the test. Group 2 was weighed before and after being dried to determine an in-situ moisture content. For convenience and future reference, the NRCS and CTM-643 tests are included in this document, Appendix 1 and 2, respectively. The NRCS soils conductivity test is the same one used to determine the information found on the NRCS Soils Maps Website, (<https://websoilsurvey.nrcs.usda.gov/app/>), which is used by NMDOT when determining culvert service life. The CTM-643 soils resistivity test is considered the standard soils test for determining culvert service life (3), with the results of the CTM-643 producing the equations used in the NMDOT Culvert Resistance Spreadsheet (4). Additionally, by performing both conductance and resistance tests on the same soil samples, the assumption that conductivity and resistivity are directly proportional to each other can be validated.

For the CTM 643 test, the AEMC 6471 Digital Ground Resistance Tester was used to test for resistivity, and for the NRCS conductivity test and the ASSHTO T 289-91 (9) pH Test, an Apera Instruments A1316 PC60 meter was used.

RESULTS FROM FIELD LOCATIONS

I-25 MP 77.19

This culvert was visited on 11/05/2025, but no data were collected at this location. As seen in **FIGURE 4** below, this culvert has completely failed, creating a roughly 20-25-foot-deep gouge in the interstate's eastern embankment. Using Google Earth images, it appears that this culvert drains the median between north and southbound I-25, but was buried in sediment sometime between Jan 2013 and Nov 2014. No evidence of the median drain was found during the site visit. Additionally, it appears that this culvert failed due to top-down erosion from I-25 runoff coming down the hill to the north, with evidence of erosion in an August 2009 Google Earth image.



FIGURE 4: Culvert on I-25 (NB) MP 77.19.

I-25 MP 107.86

This culvert was visited on 11/05/2025 and is located on northbound (NB) I-25. This culvert had visible corrosion on the bottom inside and slight corrosion on the top outside when in contact with the surrounding soils as seen in **FIGURE 5**, **FIGURE 6**, and **FIGURE 7** below.



FIGURE 5: Culvert on I-25 (NB) MP 107.86, outlet side.



FIGURE 6: Inside of the outlet side of the culvert on I-25 (NB) MP 107.86.



FIGURE 7: Outside of the outlet side of the culvert on I-25 (NB) MP 107.86.

Culvert Thickness Measurement

Using a micrometer on uncorroded locations of the culvert, a thickness of 0.0650”, 0.0658”, and 0.0659” was measured at three different locations, for an average of 0.0656”. The closest gage thickness to this value is 16, with a galvanized thickness of 0.064”. The ultrasonic measurements showed a thickness between 0.047” and 0.070”, with the thinnest measurements taken on the bottom.

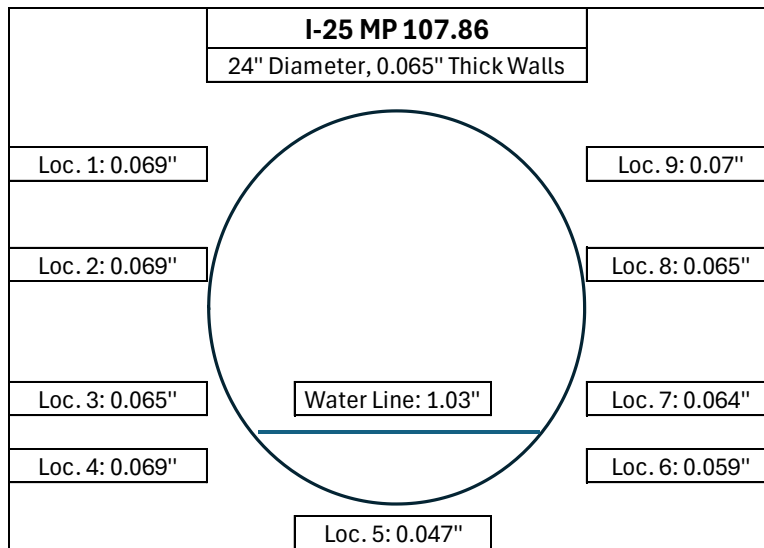


FIGURE 8: Diagram of wall thickness measurements taken at I-25 (NB) MP 107.86 culvert.

In-situ and Laboratory Soil Measurements

In-situ soil resistivity tests were conducted at -1m, -2m, and -3m from the entrance of the culvert, with soil samples being collected at these transects for later analysis in the lab. The outlet of this culvert drained into a concrete-lined area that also contained another culvert that drained the median of I-25. Both culverts combined in this concrete-lined area and were drained by a single, larger culvert. With the outlet of the culvert in question draining into a concrete-lined area, soil samples were collected to the west of

the culvert, between the outlet and inlet, hence the negative values of the three transect locations. Additionally, 1 soil sample was collected 2 meters in front of the inlet. **TABLE 1** below shows the results of field and laboratory soil analysis.

TABLE 1: Soil test results from outlet side of culvert on I-25 MP (NB) 107.86.

I-25 MP 107.86							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
-1m	8052	5096	10900	500	0-2.0	7.4-8.4	7.97
-2m	5013	3562	14000	and up	-	-	7.91
-3m	9158	7480	11800	-	-	-	8.18
2m Inlet	8969	7993	-	-	-	-	7.97

This location had visible corrosion on the outside of the culvert only in locations close to the surrounding soils, as seen in **FIGURE 7** above. Additionally, corrosion was present on the inside bottom of the culvert, as seen in **FIGURE 5** and **FIGURE 6**, above. The slightly greater than 7.3 pH indicated that corrosion on the soil side will govern in this location. With the soil's resistivity being greater than 2000 ohm-cm at this location, the corrosion potential due to the soil's resistance values is negligible, with the corrosion on the inside bottom of the culvert likely a result of runoff from the interstate.

I-25 MP 113.04

This culvert was visited on 11/05/2025. This culvert had visible corrosion on the bottom inside (**FIGURE 10**) and pitting from outside-in corrosion present in multiple locations throughout the culvert, but concentrated near the inlet and outlet areas, as seen in **FIGURE 11** below.



FIGURE 9: Culvert on I-25 MP 113.04, inlet side.

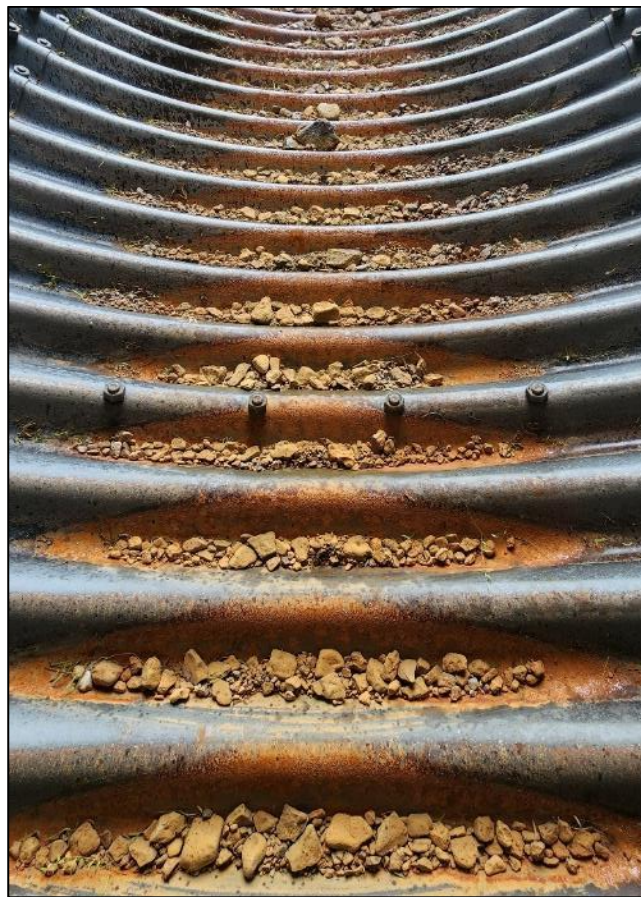


FIGURE 10: Inside of the outlet side of the culvert on I-25 MP 113.04.



FIGURE 11: Inside wall of the outlet side of the culvert on I-25 MP 113.04.

Culvert Thickness Measurement

No micrometer or ultrasonic measurements were taken due to the presence of heavy rainfall that began while on location.

In-situ and Laboratory Soil Measurements

No in-situ soil resistivity tests were conducted at this location due to the presence of large boulders and rocks at the inlet and outlet, as seen in **FIGURE 9** above. Soil samples were collected from the North and South stream banks near the inlet, and from the rocky/sandy soil inside the culvert near the inlet, with the results in **TABLE 2** below.

TABLE 2: Soil test results from inlet side of culvert on I-25 MP 113.04.

I-25 MP 113.04							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
Inside	19380	11236	-	500	0-2	7.9-8.4	8.04
South Bank Inlet	9217	3291	-	and up	-	-	7.99
North Bank Inlet	7994	4197	-	-	-	-	8.02

No visual inspection of the outside of this culvert was available, due to it being encased in concrete, but the presence of corrosion on the outside was seen by the pitting corrosion throughout the culvert caused by outside-in corrosion, concentrated near the inlet and outlet, as seen in **FIGURE 11** above. The slightly greater than 7.3 pH indicated that corrosion on the soil side will govern in this location. With the soil's resistivity being greater than 2000 ohm-cm at this location, the corrosion potential due to the soil's resistance values is negligible.

I-25 NB MP 142.49

This culvert was visited on 11/05/2025. This culvert had significant visible corrosion on the outside, **FIGURE 12** and **FIGURE 13**. There was no corrosion present on the inside portion of the outlet that was not in contact with the soil, **FIGURE 12** and **FIGURE 14**, but further in, there is significant corrosion throughout the inside where the culvert is in contact with the surrounding soils (**FIGURE 15**). The pitting corrosion is clearly seen in **FIGURE 13** and **FIGURE 15** below.



FIGURE 12: Culvert on I-25 (NB) MP 142.49, outlet side.



FIGURE 13: Culvert on I-25 (NB) MP 142.49, outlet side.



FIGURE 14: Culvert on I-25 (NB) MP 142.49, inside view near outlet side.



FIGURE 15: Culvert on I-25 (NB) MP 142.49.

Culvert Thickness Measurement

Using a micrometer on uncorroded locations of the culvert, a thickness of 0.0712", 0.0721", and 0.0710" was measured at three different locations, for an average of 0.0714". The closest gage thickness to this value is 14, with a galvanized thickness of 0.079". The ultrasonic measurements showed a thickness between 0.068" and 0.072", with the thinnest measurements taken on the bottom.

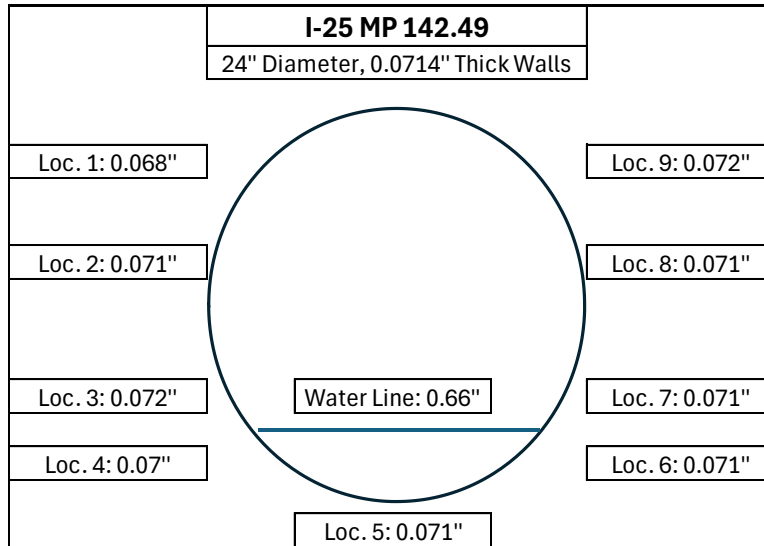


FIGURE 16: Diagram of wall thickness measurements taken on I-25 (NB) MP 142.49 culvert.

In-situ and Laboratory Soil Measurements

In-situ soil resistivity tests were conducted at 5m, 7m, and 9m out from the outlet of the culvert, with soil samples being collected at these transects for later analysis in the lab. Additionally, a soil sample was collected near the inlet of this culvert. **TABLE 3** below shows the results of field and laboratory soil analysis.

TABLE 3: Soil test results from outlet side of culvert on I-25 (NB) MP 142.49.

I-25 MP 142.49							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
Inlet	8873	7072	-	500	0-2	7.9-8.4	8.50
5m	3115	2536	22300	and up	-	-	8.09
7m	5800	4177	49700	-	-	-	8.13
9m	2037	1202	46700	-	-	-	7.83

This location had significant corrosion in locations that used to be covered by the surrounding soil and locations in current contact with the surrounding soil. The presence of soils with greater than 7.3 pH indicated that corrosion on the soil side will govern in this location, as seen in **FIGURE 12** and **FIGURE 13** above. With the soil’s resistivity being greater than 2000 ohm-cm at this location and no visible inside-out corrosion on this culvert, the corrosion potential due to the soil’s resistance values is negligible.

I-25 AND EXIT 264

This location consists of two separate culverts (unverified and assumed based on field observations) as displayed in **FIGURE 17**, with the first culvert connecting “Inlet Grate” to “Hole” and the second culvert connecting “Hole” to “Outlet.” The first culvert drains the area between NB I-25 and exit 264’s off ramp with a metal grate at the intake, **FIGURE 18**. The outlet of this first culvert is assumed to be in the

tumbleweed-filled “Hole,” but this was unable to be unverified. The second culvert is assumed to start in the tumbleweed-filled “Hole,” **FIGURE 19**, with the outlet shown in **FIGURE 20**. The inlet of this second culvert was inaccessible due to being buried below 6-10 feet of tumbleweeds, with the bottom of the “Hole” having a few inches of standing water. The outlet of the second culvert was also inaccessible and unsafe for measurement, as it was almost fully corroded away with only small portions of the original metal remaining and was located 4 feet below an actively collapsing trench wall. A close-up image of the outlet culvert’s remaining metal is shown in **FIGURE 21**. Only the area near the “Inlet Grate” was accessible for in-situ tests and soil sample collection, with the data presented in **TABLE 4**.

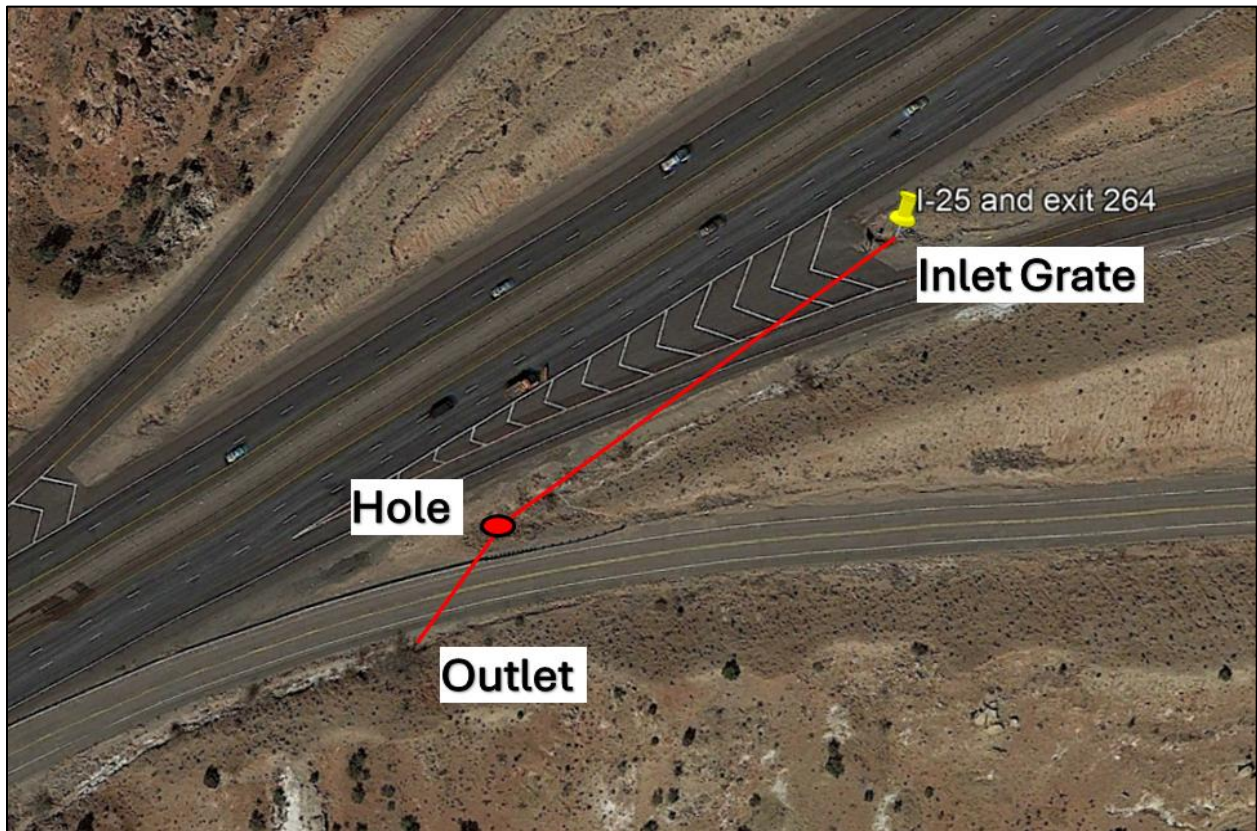


FIGURE 17: Location of “Inlet Grate,” tumbleweed-filled “Hole,” and “Outlet” of the 2 separate 24” culverts near NB I-25 and exit 264. The red line is an estimated location of both culverts.



FIGURE 18: Image of “Inlet Grate” between NB I-25 and the offramp for exit 264.



FIGURE 19: Image of the tumbleweed-filled “Hole,” outlined in red, and a 5’ 6” long shovel outlined in white from culvert between Exit 264 offramp and I-25.



FIGURE 20: Image of 24" (estimated) outlet with a red line highlighting the only metal remaining of culvert between Exit 264 offramp and I-25.



FIGURE 21: Close-up image of the near fully corroded second culvert outlet from culvert between Exit 264 offramp and I-25.

Culvert Thickness Measurement

No culvert thickness measurements were taken, as both inlets were inaccessible (under the grate and buried below 6-10 feet of tumbleweeds) and the outlet was nearly fully corroded with minimal metal remaining and below a 4-foot-tall trench wall that was actively collapsing.

In-situ and Laboratory Soil Measurements

Three in-situ 4-pole resistivity measurements were conducted at the “Inlet Grate” location, 1m, 1.5m, and 2m upslope from the “Inlet Grate.” Soil samples were collected along each 4-pole resistivity measurement transects in addition to a separate road base course sample that was approximately 4” below the local soil. The soil samples collected along each transect only included local soil with no road base course. **TABLE 4** below shows the results of in-situ, laboratory, and NRCS web collected soil data.

TABLE 4: Soil results from in-situ and laboratory tests from culvert between Exit 264 offramp and I-25.

I-25 NB and Exit 264, between I-25 and Off Ramp							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
1m	1377	737	1500	250	0-4	7.9-8.4	8.19
1.5m	670	370	1920	and up	-	-	8.01
2m	1041	501	1830	-	-	-	8.42
Base Course	5112	3024	-	-	-	-	8.36

The higher pH in addition to the lower resistivity values suggest that this location has a very high potential for culvert corrosion, as seen in the nearly fully corroded away culvert in **FIGURE 21** above. This location had similar pH values as the nearby 78" culvert 0.25 miles away, but the soils' resistivity, based on results of CTM-643 tests at both locations, was over 10 times less. This large difference in resistivity could be attributed to this location's higher potential of road salt runoff, located at the downslope of a large hill that frequently requires salting and deicing in the winter months. A future visit to this site is suggested once the tumbleweeds have been removed and following a long, dry period to allow for the soil to dry, permitting access to the second culvert's inlet and outlet.

I-25 MP 264.2

The 78" culvert south of the Cochiti exit that goes under the frontage road east of I-25 and under both lanes of I-25 was visited on 9/25/2024 and then again on 3/25/25. Approximately the first foot of the culvert is 12-gage, 0.1046" thick and the remaining length of the culvert is 16-gage, 0.064" thick. The image below, **FIGURE 22**, is looking into the inlet (west side of I-25). The only location where the outside of the culvert was accessible was at the outlet, which was completely corroded over, but no pitting or holes was observed, **FIGURE 24** below. There was approximately 9 inches of sandy soil on the bottom of the culvert on the inlet side. The culvert had minimal corrosion on the bottom, mostly appearing as scale buildup, **FIGURE 23**.

This large culvert under I-25 and southwest of the Cochiti exit was originally visited on 9/25/2024, where soil samples were only collected from the stream bed near the inlet and did not include side-bank samples. The stream bed consisted of coarse sand with minimal silt and clay particles. Not collecting side-bank soil samples during the initial site visit was an oversight that was corrected on the 3/25/25 site visit. The diameter of the culvert was also measured during this site visit, as there had been some confusion about the actual culvert diameter. The culvert's height and width diameter at the inlet was 80" and 76", respectively, and the culvert's height and width diameter at the outlet was 76" and 80", respectively. An average of the height and width diameter at both locations is 78".



FIGURE 22: 72" culvert under I-25 at 264.2, inlet.



FIGURE 23: Slight corrosion on the bottom of the culvert underneath the sandy soil present on I-25 MP 264.2.

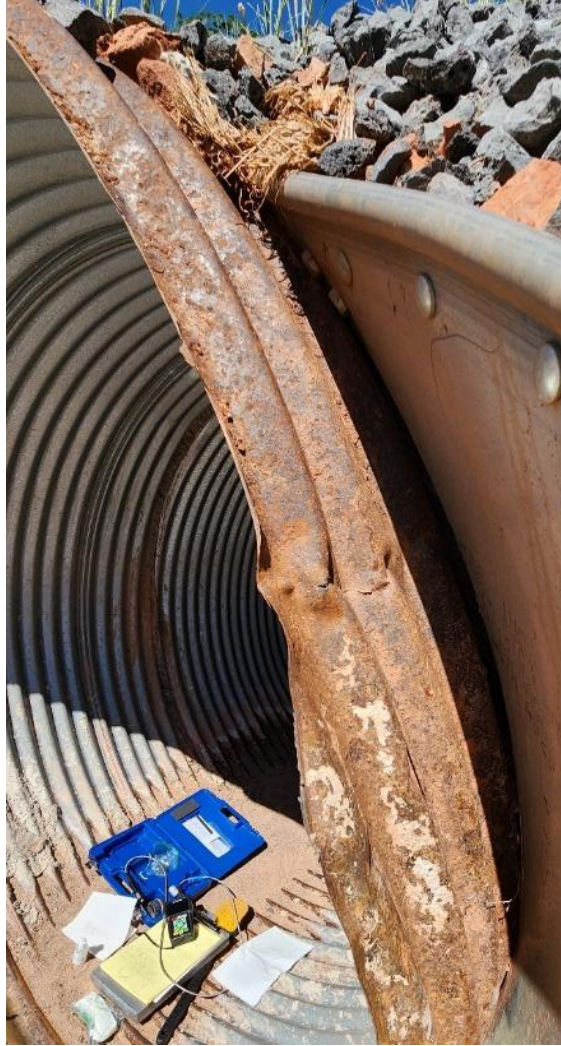


FIGURE 24: Outside of the outlet showing extent of corrosion on I-25 MP 264.2 culvert.

Culvert Thickness Measurement

No exterior culvert was accessible that did not have any corrosion present to take an uncorroded measurement, but based on the ultrasonic measurements taken, it is estimated that the culvert is 16 gage, 0.064" thick. Both the inlet and outlet measurements followed the same pattern: thicker walls above the waterline, thinner walls below the waterline, and thickest measurement on the bottom due to scale buildup as seen in **FIGURE 25** below.

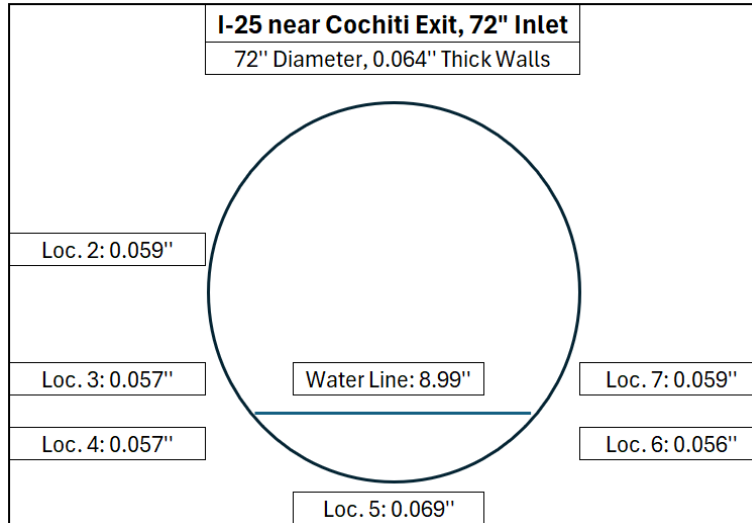


FIGURE 25: Diagram of inlet wall thickness measurements taken on I-25 MP 264.2.

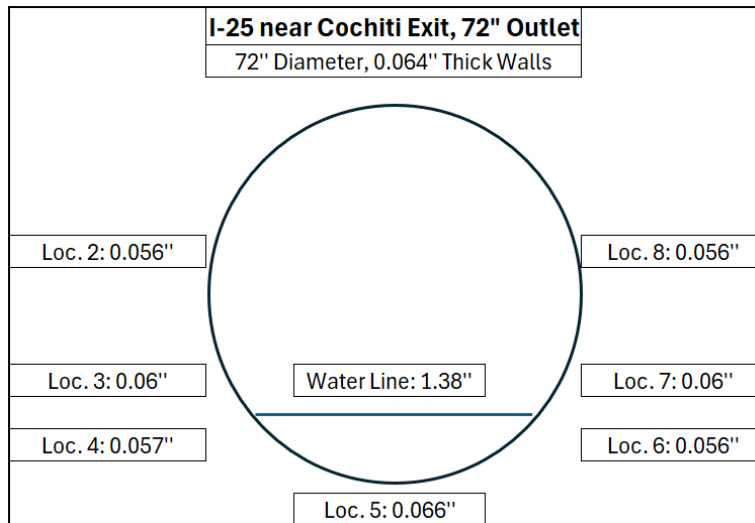


FIGURE 26: Diagram of outlet wall thickness measurements taken on I-25 MP 264.2.

In-situ and Laboratory Soil Measurements

Two in-situ 4-pole resistivity measurements were conducted at this location, 1m and 2m out from the culvert's inlet. Soil samples were collected from within the culvert (0m) and along each 4-pole resistivity measurement transects. **TABLE 5** below shows the results of in-situ, laboratory, and NRCS web-collected soil data. During the second site visit, only soil samples from the side-banks were collected, with the results in **TABLE 6** below. No in-situ resistivity test was conducted.

TABLE 5: Soil test results from in-situ and laboratory tests on I-25 MP 264.2 culvert.

I-25 MP 264.2 on 9/25/24							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	20964	16018	-	500	0-2	7.4-9	8.84
1m	23148	14620	6630	and up	-	-	8.95
2m	19646	15158	7600	-	-	-	8.78

TABLE 6: Side-bank soil test results from inlet side on I-25 MP 264.2 culvert.

I-25 MP 264.2 on 3/25/25							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
1m	10288	7230	-	500	0-2	7.4-9	8.30
2m	9634	4722	-	and up	-	-	8.25
3m	12484	7781	-	-	-	-	8.19

The greater than 7.3 pH values at this location indicate that soil-side corrosion will govern, which matches what was observed in the field. The similar resistivity values (average: 6,577 ohm-cm) between the side-bank soil samples with the CTM-643 test and the in-situ 4-pole resistivity tests (average: 7,115 ohm-cm) conducted on 9/25/24 have a significantly closer agreement than the soil samples collected on 9/25/24 with the CTM-643 test (average 15,265 ohm-cm). This similarity indicated that the soil samples collected on 9/25/24 were insufficient in fully representing the locations' soil characteristics.

I-25 MP 278.7

This 24" culvert under the southbound lane of I-25 is located east of Cerrillos road overpass by 1.2 miles and was visited on 9/25/2024. The image below, **FIGURE 27**, is looking into the inlet (facing north between the south bound and north bound lanes of I-25). There was approximately 2 inches of loamy soil on the bottom of the culvert on the inlet side. The culvert had no corrosion present on the inside, as seen in **FIGURE 28**.



FIGURE 27: Culvert at I-25 (SB) MP 278.7, inlet side facing North.



FIGURE 28: No corrosion was present on the inside of the I-25 (SB) MP 278.7 culvert.

Culvert Thickness Measurement

A value of 0.0581 inches was measured on an uncorroded exposed location with a micrometer, indicating a 16-gage thickness, which has a standard thickness of 0.064 inch when galvanized coated and an uncoated thickness of 0.0598 inches. Based on the ultrasonic thickness measurements taken 1 foot in from the end of the culvert, there appears to be very little corrosion on the outside of the culvert, **FIGURE 29** below.

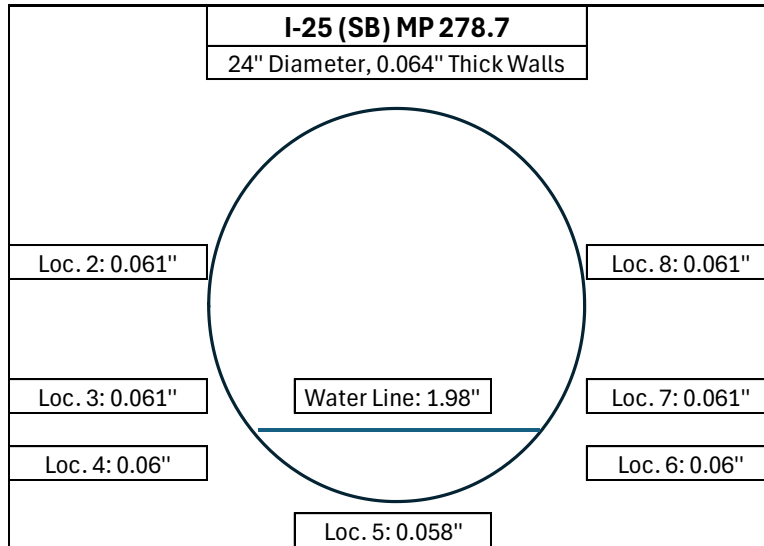


FIGURE 29: Diagram of inlet wall thickness measurements taken on the I-25 (SB) MP 278.7 culvert.

In-situ and Laboratory Soil Measurements

Two in-situ 4-pole resistivity measurements were conducted at this location, 1m and 2m out from the culvert’s inlet. Soil samples were collected from within the culvert (0m) and along each 4-pole resistivity measurement transects. **TABLE 7** below shows the results of in-situ, laboratory, and NRCS web collected soil data.

TABLE 7: Soil test results from in-situ and laboratory tests on I-25 (SB) MP 278.7 culvert.

I-25 (SB) MP 278.7							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	9990	2908	-	500	0-2	6.6-9	8.04
1m	7386	3081	11000	and up	-	-	8.27
2m	7605	3376	8540	-	-	-	8.24

The slightly greater than 7.3 pH values at this location indicated that soil-side corrosion will govern, but no corrosion was visible on the exposed inlet side of the culvert. With the soil’s resistivity being greater than 2000 ohm-cm at this location and no visible corrosion on the inside of the culvert, the corrosion potential due to the soil’s resistance values is negligible.

I-40 MP 121

The three adjacent 36” culverts (**FIGURE 30**) were visited on 9/26/24.

Culvert Thickness Measurement

Prior to any measurements, the ultrasonic thickness gage is calibrated with 0.100- and 0.050-inch-thick steel calibration blocks. The ultrasonic thickness gage was used on multiple locations where there was no corrosion present and a value of 0.059 to 0.061” was measured, which approximately corresponds with

16-gage, 0.0598" uncoated thickness and 0.064" galvanized thickness (National Corrugated Steel Pipe Association, 2017). For purposes of this project, the culvert on the left (east most) will be identified as A, the middle as B, and the right (west most) as C.



FIGURE 30: 3-36" CMP I-40 MP 121.0, inlet side, westbound I-40 (facing south).

The three figures below (**FIGURE 31**, **FIGURE 32**, and **FIGURE 33**) show the wall thickness values for all three culverts for each measurement location. The rib where the wall thickness was measured for each culvert A, B, and C was 5', 3', and 4', respectively, from the end of the culvert with these locations chosen randomly.

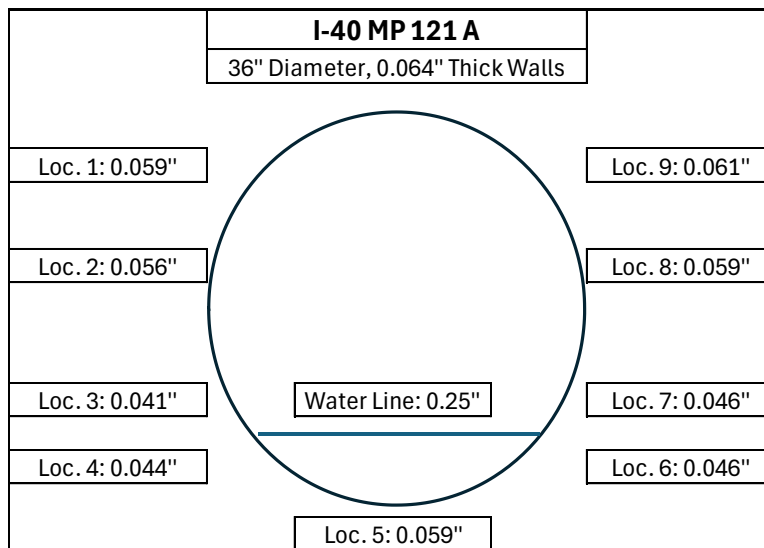


FIGURE 31: Diagram of wall thickness measurements taken at I-40 MP 121 A culvert.

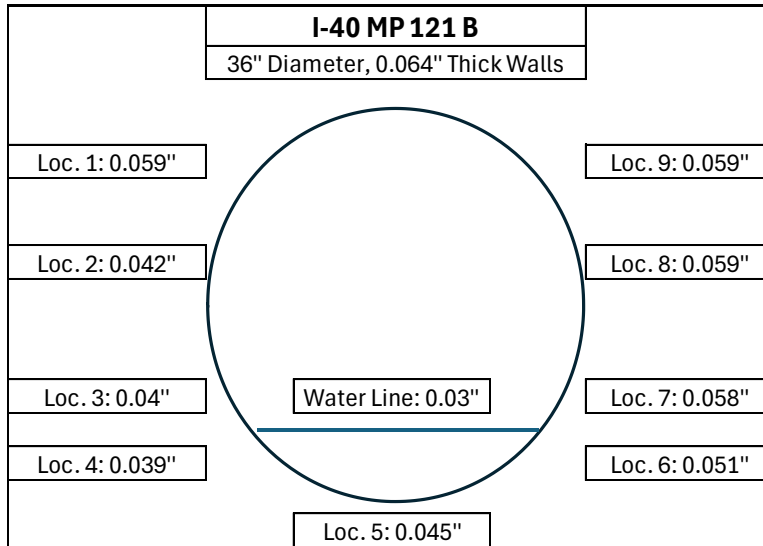


FIGURE 32: Diagram of wall thickness measurements taken at I-40 MP 121 B culvert.

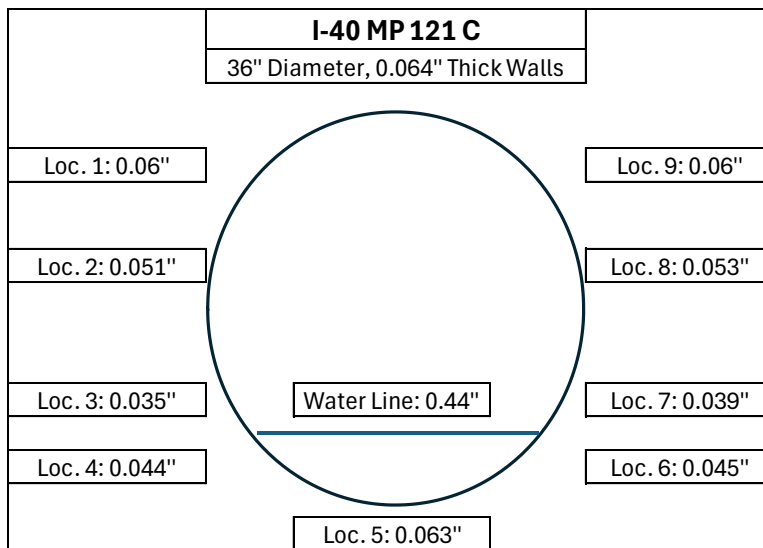


FIGURE 33: Diagram of wall thickness measurements taken at I-40 MP 121 C culvert.

Locations 3 and 4 and locations 6 and 7 showed, on average, the most metal loss due to corrosion, with these regions having the most perforations on all three culverts, as shown in **FIGURE 34** and **FIGURE 35** below for Culverts A and B. In all occurrences of observed corrosion, the corrosion began on the outside of the culvert, with little to no corrosion on the inside of the culvert.



FIGURE 34: Culvert I-40 MP 121 A showing the extent of corrosion roughly 1/3 up the side of the culvert.



FIGURE 35: Culvert I-40 MP B showing the extent of corrosion roughly 1/3 up the side of the culvert.

In-situ and Laboratory Soil Measurements

Two separate in-situ ground resistivity tests were conducted 3 and 6 meters out from the culverts, centered on B (the center culvert) and parallel to the road. The 4 poles were driven 6 inches into the ground and were spaced 2 and 3 meters apart for the 3 - and 6-meter test, respectively. The results of these two tests are shown in **TABLE 8** below.

Soil samples were collected at four different locations at this site, from the bottom of each culvert (labeled 0m), along each of the 4-pole resistivity tests (labeled 3m and 6m), and from behind each culvert through the penetrations (labeled Behind Culvert). Multiple soil tests were conducted on each sample with the results shown below in **TABLE 8**.

TABLE 8: Soil test results from in-situ and laboratory tests for I-40 MP 121 culvert.

I-40 MP 121							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	665	854	-	250-500	2-4	7.4-8.4	7.43
3m	580	834	820	-	-	-	8.06
6m	1019	552	1100	-	-	-	8.06
Behind Culvert	817	459	-	-	-	-	7.65

NM 1 MP 19.24

This culvert was visited on 11/05/2025. This culvert had no visible corrosion on the inside as seen in **FIGURE 36** and **FIGURE 37** below. The culvert’s inlet and outlet were encased in concrete, preventing observation of the outside of the culvert.



FIGURE 36: Culvert on NM 1 MP 19.24, inlet side.



FIGURE 37: Inside of the inlet side of the culvert on NM 1 MP 19.24.

Culvert Thickness Measurement

Micrometer measurements were unable to be collected on this culvert due to it being encased in concrete, but the average thickness of ultrasonic measurements was 0.0803". This average thickness closely matches a 14-gage culvert's thickness of 0.079". The ultrasonic measurements showed a thickness between 0.072" and 0.084", indicating the potential presence of corrosion on the outside of the culvert, with some scaling buildup.

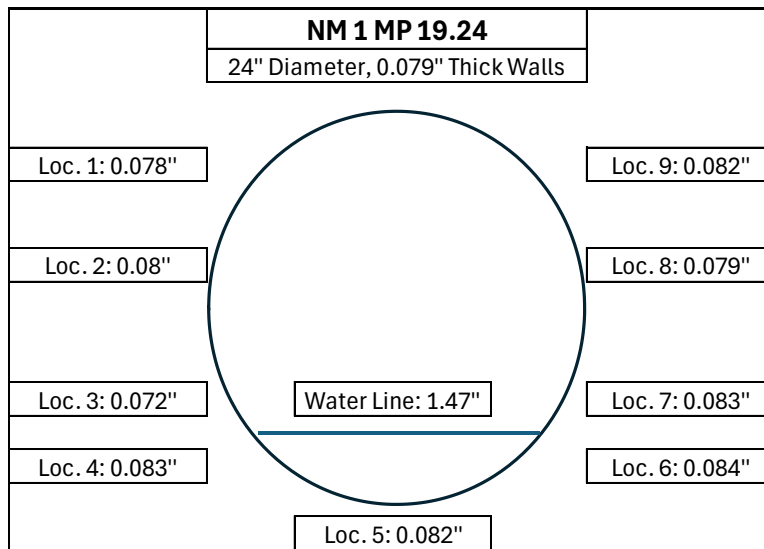


FIGURE 38: Diagram of wall thickness measurements taken at NM 1 MP 19.24 culvert.

In-situ and Laboratory Soil Measurements

In-situ soil resistivity tests were conducted at 1m, 2m, and 3m out from the entrance of the culvert, with soil samples being collected at these transects for later analysis in the lab. **TABLE 9** below shows the results of field and laboratory soil analysis.

TABLE 9: Soil test results from inlet side of culvert on NM 1 MP 19.24 culvert.

NM 1 MP 19.24							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
1m	11641	2816	6680	500	0-2	7.9-8.4	8.27
2m	8929	2610	5420	and up	-	-	8.49
3m	4831	2550	5620	-	-	-	8.26

This location had no visible corrosion on the inside of the culvert and with the culvert fully encased in concrete, the outside of the culvert could not be visually inspected for corrosion. The presence of soils with greater than 7.3 pH indicated that corrosion on the soil side will govern in this location, with the ultrasonic measurements potentially indicating corrosion scale buildup at some locations. If there is corrosion on the outside of the culvert, it is very minor, with no indication of corrosion fully penetrating the metal. With the soil’s resistivity being greater than 2000 ohm-cm at this location and no visible corrosion on the inside of the culvert, the corrosion potential due to the soil’s resistance values is negligible.

NM 1 MP 20.61 AND 20.85

These two culverts were visited on 11/05/2025, but due to thick brush (**FIGURE 39**) blocking access to the culvert at MP 20.61 and rattling from an unseen snake coming from the brush to the left of the inlet (**FIGURE 40**) on the culvert at MP 20.85, both locations were skipped. In lieu of these two culverts, a culvert at MP 19.24 was visited.



FIGURE 39: Approximate location of culvert on NM 1 MP 20.61, buried in thick brush.



FIGURE 40: Inlet side of culvert on NM 1 MP 20.85.

NM 1 MP 21.52

This culvert was visited on 11/05/2025. This culvert had no visible corrosion on the inside as seen in **FIGURE 41** and **FIGURE 42** below. The culvert's inlet and outlet were encased in concrete, preventing observation of the outside of the culvert.



FIGURE 41: Culvert on NM 1 MP 21.52, inlet side.



FIGURE 42: Inside of the inlet side of the culvert on NM 1 MP 21.52.

Culvert Thickness Measurement

Micrometer measurements were unable to be collected on this culvert due to it being encased in concrete, but the average thickness of ultrasonic measurements was 0.087". This average thickness is 0.0078" larger than the closest matching standard culvert thickness of 14-gage with a culvert's thickness of 0.079". The ultrasonic measurements showed a thickness between 0.086" and 0.088", indicating the potential presence of corrosion on the outside of the culvert, with some scaling buildup.

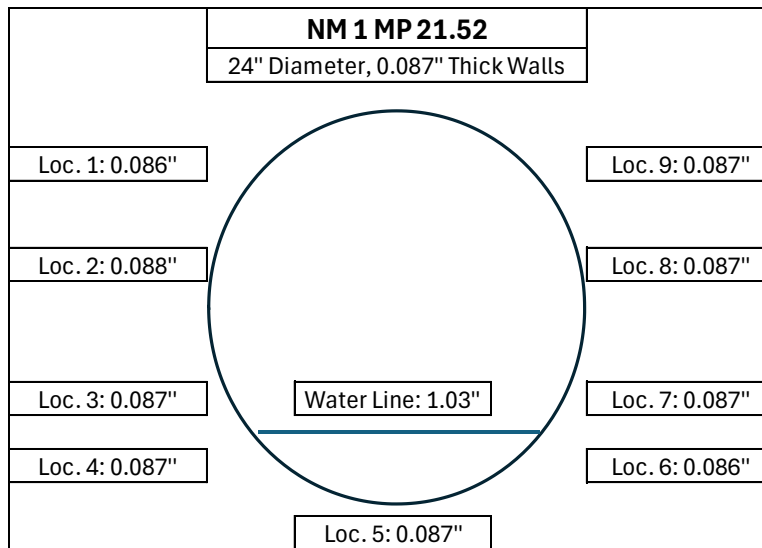


FIGURE 43: Diagram of wall thickness measurements taken at NM 1 MP 21.52 culvert.

In-situ and Laboratory Soil Measurements

In-situ soil resistivity tests were conducted at 1m, 2m, and 3m out from the entrance of the culvert, with soil samples being collected at these transects for later analysis in the lab. **TABLE 10** below shows the results of field and laboratory soil analysis.

TABLE 10: Soil test results from inlet side of culvert on NM 1 MP 21.52 culvert.

NM 1 MP 21.52							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
1m	6693	2208	12000	500	0-2	7.9-8.4	8.06
2m	5479	2677	12400	and up	-	-	8.06
3m	6274	2485	12800	-	-	-	8.01

This location had no visible corrosion on the inside of the culvert and with the culvert fully encased in concrete, the outside of the culvert could not be visually inspected for corrosion. The presence of soils with slightly greater than 7.3 pH indicated that corrosion on the soil side will govern in this location, but ultrasonic thickness measurements were very similar, indicating little to no outside corrosion. With the soil’s resistivity being greater than 2000 ohm-cm at this location and no visible corrosion on the inside of the culvert, the corrosion potential due to the soil’s resistance values is negligible.

NM 1 MP 22.01

This culvert was visited on 11/05/2025. This culvert had no visible corrosion on the inside as seen in **FIGURE 44** and **FIGURE 45** below. The culvert’s inlet and outlet were encased in concrete, preventing observation of the outside of the culvert.



FIGURE 44: Culvert on NM 1 MP 22.01, inlet side.



FIGURE 45: Inside of the inlet side of the culvert on NM 1 MP 22.01.

Culvert Thickness Measurement

Micrometer measurements were unable to be collected on this culvert, due to it being encased in concrete, but the average thickness of ultrasonic measurements was 0.12". This average thickness is 0.009" larger than the closest matching standard culvert thickness of 12-gage with a culvert's thickness of 0.111" for galvanized structural plate. The ultrasonic measurements showed a thickness between 0.119" and 0.12", indicating little to no corrosion on the outside of the culvert.

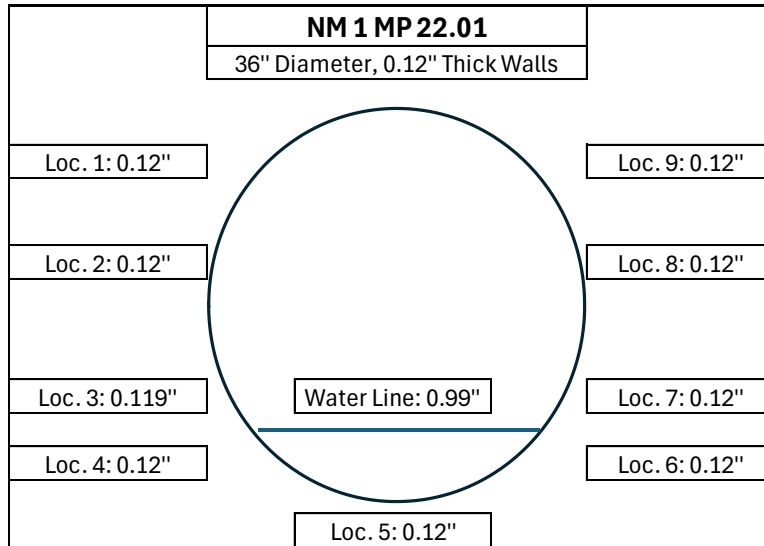


FIGURE 46: Diagram of wall thickness measurements taken at NM 1 MP 22.01 culvert.

In-situ and Laboratory Soil Measurements

In-situ soil resistivity tests were conducted at 1m, 2m, and 3m out from the entrance of the culvert, with soil samples being collected at these transects for later analysis in the lab. **TABLE 11** below shows the results of field and laboratory soil analysis.

TABLE 11: Soil test results from inlet side of culvert on NM 1 MP 22.01 culvert.

NM 1 MP 22.01							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
1m	7369	2783	6190	500	0-2	7.9-8.4	8.20
2m	6969	2236	6170	and up	-	-	8.17
3m	6596	3045	6350	-	-	-	8.19

This location had no visible corrosion on the inside of the culvert and with the culvert fully encased in concrete, the outside of the culvert could not be visually inspected for corrosion. The presence of soils with greater than 7.3 pH indicated that corrosion on the soil side will govern in this location, but ultrasonic thickness measurements were extremely similar, indicating no outside corrosion present. With the soil's resistivity being greater than 2000 ohm-cm at this location and no visible corrosion on the inside of the culvert, the corrosion potential due to the soil's resistance values is negligible.

NM 104 MP 42

Three 36" culverts on NM 104 MP 42.0 were nearly completely silted over (**FIGURE 47** below), with the middle culvert completely silted over.

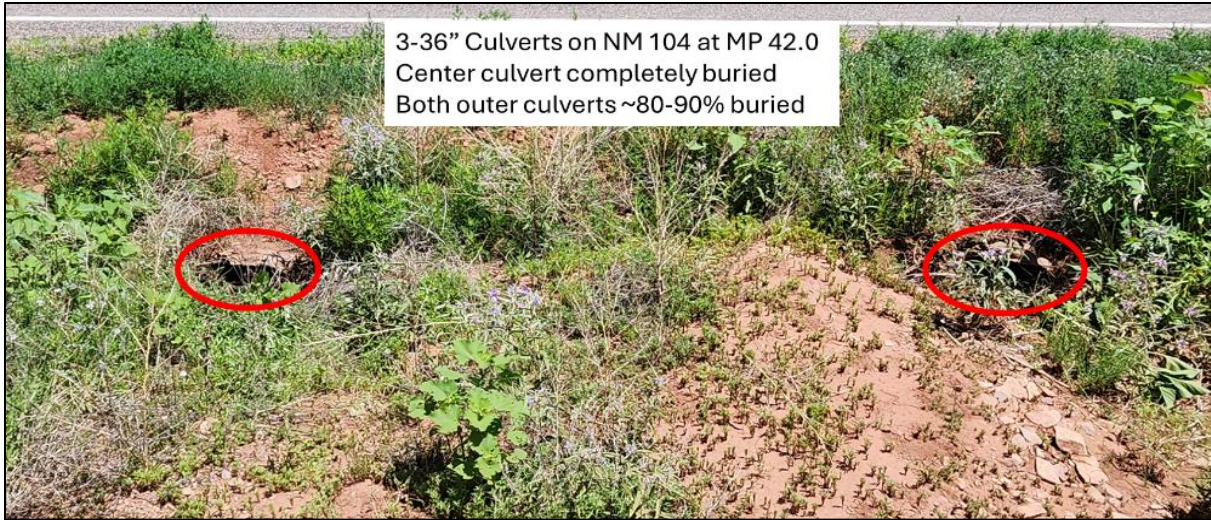


FIGURE 47: 3-36" culverts on NM 104 MP 42.0, with outer two culverts circled in red for identification and middle culvert completely silted over.

NM 104 MP 42.1

This culvert was visited on 6/18/2025. This culvert had little to no corrosion on the inside and outside. The rust coloring on the culvert is due to the red clay soil located in the region and is not rust.



FIGURE 48: Culvert on NM 104 MP 42.1, inlet side.



FIGURE 49: Culvert on NM 104 MP 42.1 inlet side looking in.

Culvert Thickness Measurement

At uncorroded locations three micrometer measurements were taken, 0.0770", 0.0780", and 0.0775", for an average of 0.0775". This thickness corresponds approximately to a 14-gage culvert with a galvanized thickness of 0.079". The ultrasonic measurements showed a thickness between 0.078" and 0.079", indicating no corrosion on the outside of the culvert where it was buried.

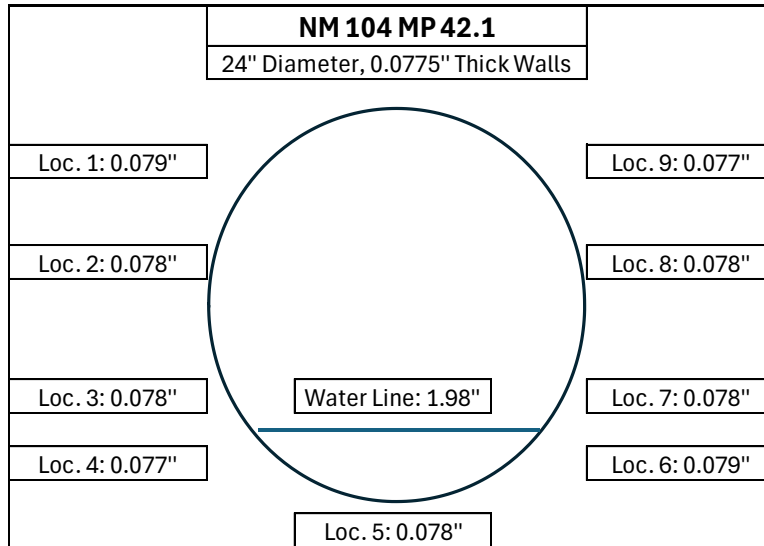


FIGURE 50: Diagram of inlet wall thickness measurements taken on NM 140 MP 42.1 culvert.

In-situ and Laboratory Soil Measurements

Soil samples were collected at 0, 1, 2, and 3m out from the inlet of the culvert.

TABLE 12: Soil test results from the NM 104 MP 42.1 culvert.

NM 104 MP 42.1							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	20877	3184	-	500	0-2	7.4-8.4	7.90
1m	12642	4193	1280	and up	-	-	7.86
2m	17271	4189	1680	-	-	-	7.88
3m	22173	4701	1580	-	-	-	7.95

This location had no visible corrosion on the outside and inside of the culvert, and the ultrasonic thickness measurements indicated no corrosion on the outside of the culvert where it was buried. The presence of soil pH values less than 8 and resistivity values far greater than 2000 ohm-cm contribute to this location having negligible corrosive soils.

NM 104 MP 43

These two culverts were visited on 6/18/2025. There was no corrosion visible on either culvert, with any discoloration of the metal caused by the red clay soil.



FIGURE 51: Two 60” culverts on NM 104 MP 43, inlet side.



FIGURE 52: Western 60” culvert on NM 104 MP 43, inlet side looking in.



FIGURE 53: Eastern 60” culvert on NM 104 MP 43, inlet side looking in.

Culvert Thickness Measurement

Western Culvert: At an uncorroded location, three micrometer measurements were taken, 0.1450”, 0.1440”, and 0.1444”, for an average of 0.1445”. This thickness corresponds approximately to a 10-gage culvert with a galvanized structural plate thickness of 0.140”. The ultrasonic measurements showed a thickness between 0.144” and 0.147”, indicating no corrosion on the outside of the culvert where it was buried.

Eastern Culvert: At an uncorroded location, three micrometer measurements were taken, 0.1450”, 0.1440”, and 0.1448”, for an average of 0.1446”. This thickness corresponds approximately to a 10-gage culvert with a galvanized structural plate thickness of 0.140”. The ultrasonic measurements showed a thickness between 0.140” and 0.146”, indicating very slight corrosion on the outside of the culvert where it was buried.

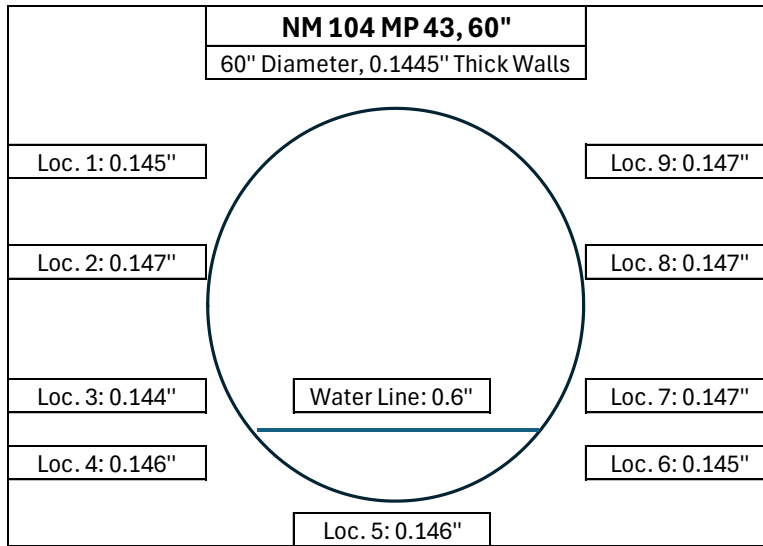


FIGURE 54: Western culvert diagram of inlet wall thickness measurements taken from the NM 104 MP 43 culvert.

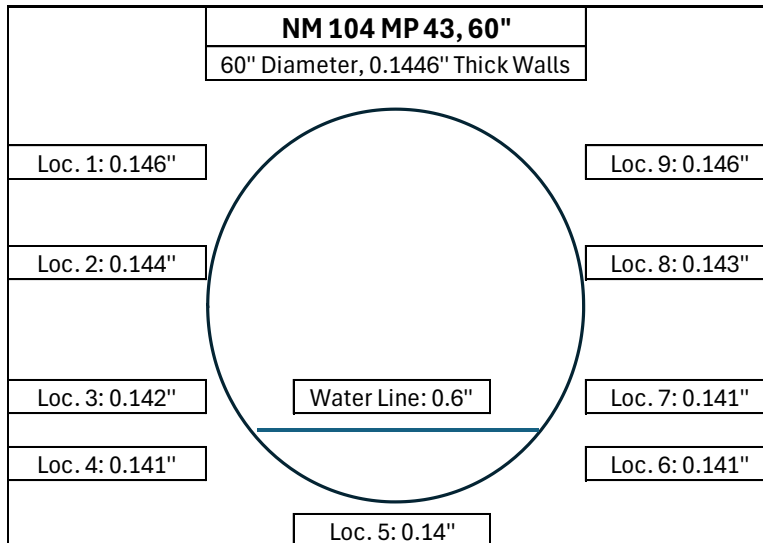


FIGURE 55: Eastern culvert diagram of inlet wall thickness measurements taken from the NM 104 MP 43 culvert.

In-situ and Laboratory Soil Measurements

Soil samples were collected at 0, 3, 4, and 5m out from the inlet of the culvert.

TABLE 13: Soil test results from inlet side of the NM 104 MP 43 culvert.

NM 104 MP 43, 60"							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	19120	2957	-	500	0-2	7.4-8.4	8.06
3m	13774	1945	4300	and up	-	-	7.73
4m	14620	2062	4060	-	-	-	7.67
5m	14472	1926	3610	-	-	-	7.63

This location had no visible corrosion on the outside and inside of the culvert, and the ultrasonic thickness measurements indicated no corrosion on the western culvert and very minimal corrosion on the outside of the eastern culvert where it was buried. The presence of soil pH values only slightly above 7.3 and resistivity values at or greater than 2000 ohm-cm contribute to this location having negligible corrosive soils.

NM 104 MP 46.9

This culvert was visited on 6/18/2025. No corrosion was visible on the outside and inside of this culvert. Any discoloration of the metal is due to the red clay soil in this region.



FIGURE 56: Culvert on NM 104 MP 46.9, inlet side.



FIGURE 57: Culvert on NM 104 MP 46.9, inlet side looking in.

Culvert Thickness Measurement

At the uncorroded location, three micrometer measurements were taken, 0.0768", 0.0780", and 0.0763", for an average of 0.077". This thickness corresponds approximately to a 14-gage culvert with a galvanized thickness of 0.079". The ultrasonic measurements showed a thickness between 0.077" and 0.082", indicating no corrosion on the outside of the culvert where it was buried.

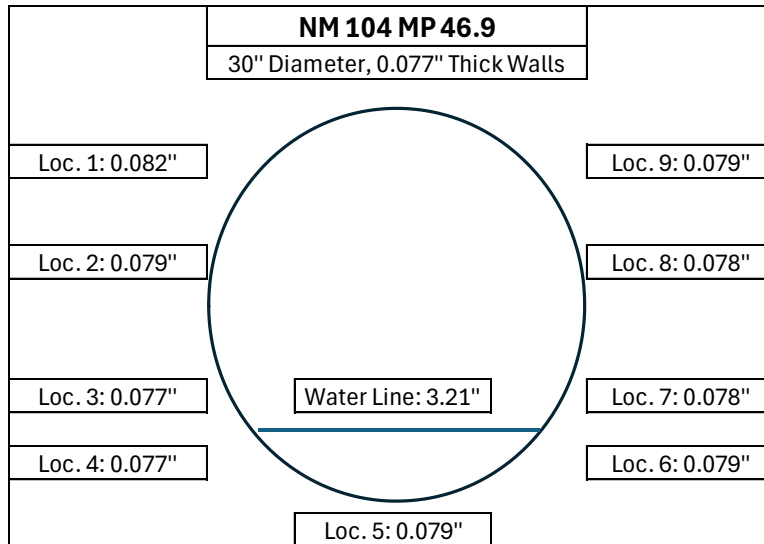


FIGURE 58: Diagram of inlet wall thickness measurements taken from the NM 104 MP 46.9 culvert.

In-situ and Laboratory Soil Measurements

Soil samples were collected at 0, 1, 2, and 3m out from the inlet of the culvert.

TABLE 14: Soil test results from inlet side on the NM 104 MP 46.9 culvert.

NM 104 MP 46.9							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	15649	1976	-	500	0-2	7.4-9.0	7.65
1m	19194	2507	7130	and up	-	-	7.68
2m	15723	2261	9610	-	-	-	7.61
3m	13316	2026	11400	-	-	-	7.50

This location had no visible corrosion on the outside and inside of the culvert, and the ultrasonic thickness measurements indicated no corrosion on the outside of the culvert where it was buried. The presence of soil pH values less than 8 and resistivity values at or greater than 2000 ohm-cm contribute to this location having negligible corrosive soils.

NM 117 MP 55

This culvert was visited on 6/16/2025. The inlet of the culvert was clogged with brush and debris (**FIGURE 59**), which had to be removed to conduct field tests (**FIGURE 60**). There was a section of the culvert that collapsed around 6 feet from the inlet (**FIGURE 61**). This culvert showed zero corrosion on the inside or outside. The inlet side of the culvert has experienced significant damage (**FIGURE 60**), likely due to the removal of sedimentation with heavy equipment.



FIGURE 59: Culvert on NM 117 MP 55 inlet before removal of brush.



FIGURE 60: Inlet side after removal of brush with collapsed section of the culvert circled in red, NM 117 MP 55 culvert.



FIGURE 61: Close-up of collapsed culvert, roughly 3' by 2', NM 117 MP 55 culvert.

Culvert Thickness Measurement

Using a micrometer on uncorroded locations of the culvert, a thickness of 0.073", 0.075", and 0.074" was measured at three different locations, for an average of 0.075". The closest gage thickness to this value is 14, with a galvanized thickness of 0.079". **FIGURE 63** below shows the location where ultrasonic thickness measurements were taken after the removal of around 6" of sand from the bottom of the culvert. As seen below, there are no signs of corrosion on the inside of the culvert. The ultrasonic measurements showed a thickness between 0.065" and 0.071", indicating some slight corrosion on the outside of the culvert where it was buried.



FIGURE 62: Location of ultrasonic thickness measurement, zero corrosion present, NM 117 MP 55 culvert.

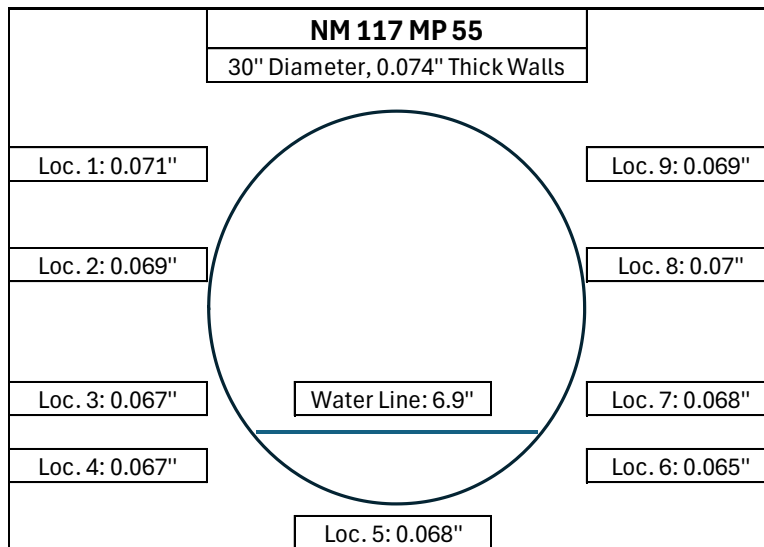


FIGURE 63: Diagram of inlet wall thickness measurements taken on the NM 117 MP 55 culvert.

In-situ and Laboratory Soil Measurements

Soil samples were collected at 0, 1, 2, 4, and 6m out from the inlet of the culvert. The addition of the 6m location was due to a significant amount of sedimentation accumulated near the entrance from runoff events, and a more natural, undisturbed location was included to see if the undisturbed soil varied.

TABLE 15 below shows the results of the field and laboratory soil analysis, with very similar values between the accumulated sedimentation and undisturbed soil.

TABLE 15: Soil test results from inlet side from the NM 117 MP 55 culvert.

NM 117 MP 55							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	11792	6439	-	500	0-2	6.1-8.4	7.70
1m	15649	8010	4780	and up	-	-	7.78
2m	13550	6383	5380	-	-	-	7.75
4m	15649	6685	7310	-	-	-	7.71
6m	15408	5359	7640	-	-	-	7.70

This location had no visible corrosion on the outside and inside of the culvert, and the ultrasonic thickness measurements indicated very minimal corrosion on the outside of the culvert where it was buried. The presence of soil pH values less than 8 and resistivity values far greater than 2000 ohm-cm contribute to this location having negligible corrosive soils.

NM 117 MP 55.8

This culvert was visited on 6/16/2025. The exposed outside of the culvert had little to no corrosion present, as seen in **FIGURE 64** below. **FIGURE 65** below shows some slight corrosion on the inside bottom of the culvert. The outlet of this culvert had a collapsed section, as seen in **FIGURE 66** below.



FIGURE 64: Culvert on NM 117 MP 55.8, inlet side.



FIGURE 65: Inside of the inlet side of the culvert on NM 117 MP 55.8, indicating some slight corrosion on the bottom inside of the culvert.



FIGURE 66: Outlet of culvert on NM 117 MP 55.8 showing collapsed location.

Culvert Thickness Measurement

At uncorroded locations, three micrometer measurements were taken, 0.0669”, 0.0652”, and 0.0658”, for an average of 0.0659”. This thickness corresponds approximately to a 16-gage culvert with a galvanized thickness of 0.064”. The ultrasonic measurements showed a thickness between 0.062” and 0.064”, indicating some slight corrosion on the outside of the culvert where it was buried and the most corrosion on the bottom of the culvert.

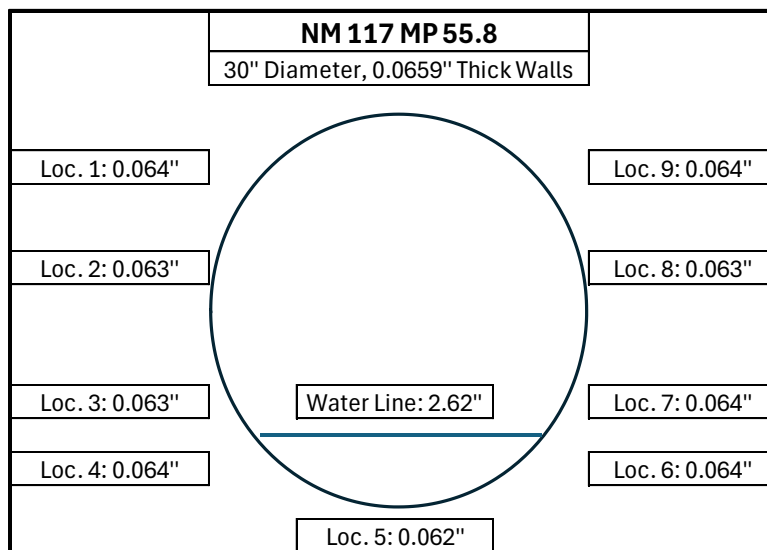


FIGURE 67: Diagram of inlet wall thickness measurements taken on NM 117 MP 55.8 culvert.

In-situ and Laboratory Soil Measurements

Soil samples were collected at 0, 1, 2, and 3m out from the inlet of the culvert.

TABLE 16: Soil test results from inlet side of NM 117 MP 55.8 culvert.

NM 117 MP 55.8							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	6246	3378	-	500	0-2	6.1-8.4	7.86
1m	10235	4864	6240	and up	-	-	7.95
2m	13736	7376	7890	-	-	-	7.98
3m	11947	4829	8290	-	-	-	7.65

This location had no visible corrosion on the outside and very minor corrosion inside the bottom of the culvert, and the ultrasonic thickness measurements indicated very minimal corrosion on the outside of the culvert where it was buried. The presence of soil pH values less than 8 and resistivity values far greater than 2000 ohm-cm contribute to this location having negligible corrosive soils.

NM 117 MP 56

This culvert was visited on 6/16/2025. The exposed outside of the culvert had little to no corrosion present, as seen in **FIGURE 68** below. **FIGURE 69** below shows no corrosion on the inside of the culvert.



FIGURE 68: Culvert on NM 117 MP 56, inlet side.



FIGURE 69: Culvert on NM 117 MP 56, close-up of inside on inlet side.

Culvert Thickness Measurement

At uncorroded locations, three micrometer measurements were taken, 0.0624", 0.0633", and 0.0626", for an average of 0.0628". This thickness corresponds approximately to a 16-gage culvert with a galvanized thickness of 0.064". The ultrasonic measurements showed a thickness between 0.062" and 0.063", indicating some very slight corrosion on the outside of the culvert where it was buried.

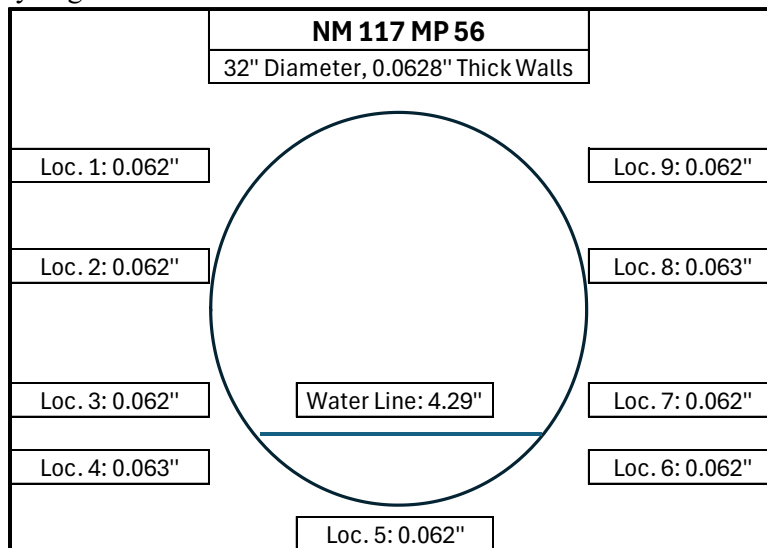


FIGURE 70: Diagram of Inlet wall thickness measurements taken on NM 117 MP 56 culvert.

In-situ and Laboratory Soil Measurements

Soil samples were collected at 0, 1, 2, and 3m out from the inlet of the culvert.

TABLE 17: Soil test results from inlet side of the NM 117 MP 56 culvert.

NM 117 MP 56							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	15198	4021	-	500	0-2	6.1-8.4	7.61
1m	14144	3447	4230	and up	-	-	7.61
2m	17361	2619	7510	-	-	-	7.59
3m	20877	4710	7570	-	-	-	7.65

This location had no visible corrosion on the outside and inside of the culvert, and the ultrasonic thickness measurements indicated very minimal corrosion on the outside of the culvert where it was buried. The presence of soil pH values less than 8 and resistivity values greater than 2000 ohm-cm contributes to this location having negligible corrosive soils.

NM 117 MP 57

This culvert was visited on 6/16/2025. Significant corrosion was visible on the outside of the culvert, as seen in **FIGURE 71** below. Very significant corrosion on the upper half of the inside of the culvert was present, with multiple locations where there were large holes in the culvert where the metal had all but corroded away, as seen in **FIGURE 72** below. Most of the corrosion was located on the upper half of the culvert, with little to no corrosion on the bottom inside.



FIGURE 71: Culvert on NM 117 MP 57, inlet side.



FIGURE 72: Culvert on NM 117 MP 57, inlet side, significant corrosion on the upper half of the culvert and minimal to no corrosion on the lower half.

Culvert Thickness Measurement

At the least corroded location three micrometer measurements were taken, 0.0690”, 0.0660”, and 0.0670”, for an average of 0.0673”. This thickness falls between a 16 (0.064”) and 14 (0.079”) gage. The ultrasonic measurements showed a thickness between 0.050” and 0.069”, indicating some very slight corrosion on the outside of the culvert where it was buried.

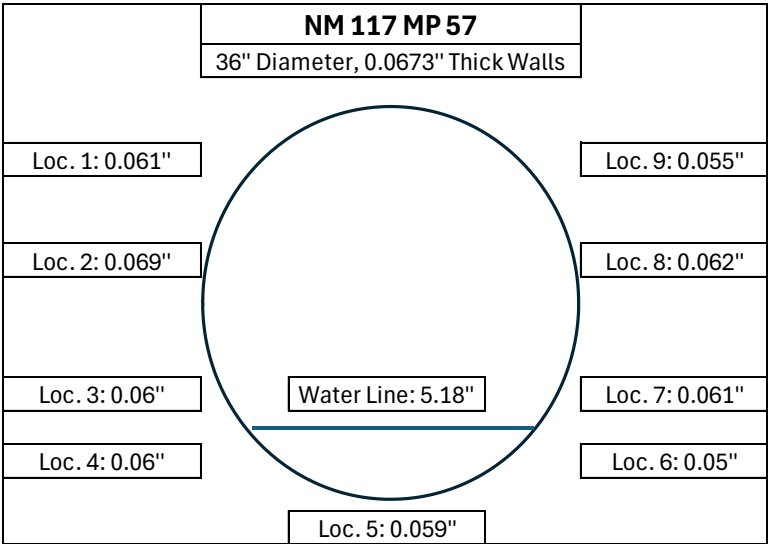


FIGURE 73: Diagram of inlet wall thickness measurements taken on NM 117 MP 57 culvert.

In-situ and Laboratory Soil Measurements

Soil samples were collected at B.C. (Behind Culvert), 3, 4, and 5m out from the inlet of the culvert.

TABLE 18: Soil test results from inlet side of the NM 117 MP 57 culvert.

NM 117 MP 57							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
B.C.	62	132	-	500	0-2	6.6-8.4	8.64
3m	9355	3239	8450	and up	-	-	8.11
4m	8525	2218	25900	-	-	-	7.71
5m	10965	3226	39000	-	-	-	7.72

This location had significant corrosion with up to 3-4” diameter holes in the upper half of the culvert, where all the metal had corroded away. The higher pH values, especially in the samples collected from behind the culvert (B.C.), is the main contributing factor for the corrosion present. The greater than 2000 ohm-cm resistivity values indicate that natural soils are not contributing to the corrosion. The significantly lower resistivity values and higher pH values from the soil sample collected from behind the culvert might be due to deicing/salting of the road in the winter.

NM 128 MP 1.3 AND 21.59

On 11/3/25, the three sites on NM 128 were visited. Of these three sites, data were only collected at NM 128 MP 21.93 because a Western Diamondback Rattlesnake was present (**FIGURE 74**) at NM 128 MP 21.59, and rattling was heard near the entrance of NM 128 MP 1.3.

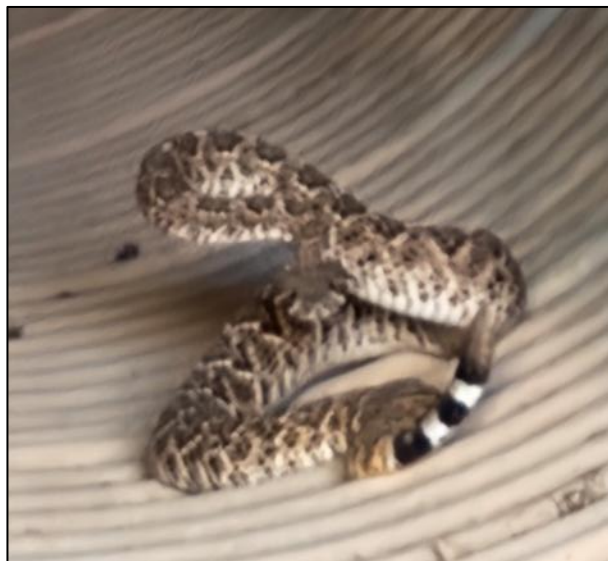


FIGURE 74: Very unhappy Western Diamondback Rattlesnake in western culvert at NM 128 MP 21.59.

NM 128 MP 21.93

This culvert was visited on 11/3/2025. This location had 2-36" culverts that had no corrosion present in either culvert, as seen in **FIGURE 76** and **FIGURE 77** below.

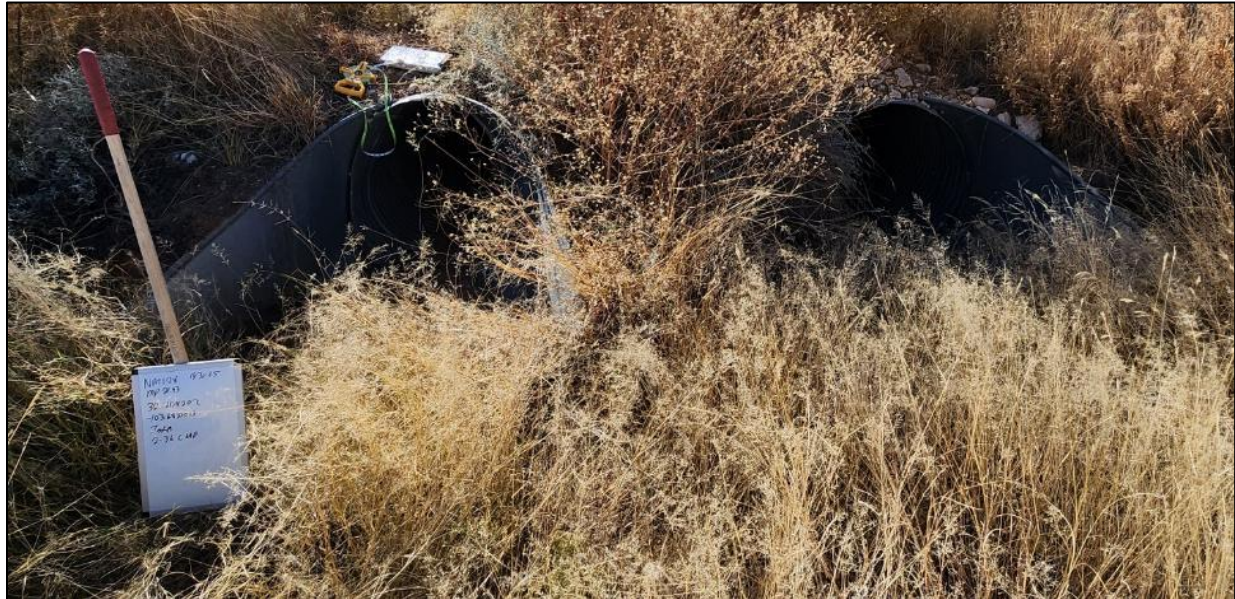


FIGURE 75: 2-36" culverts on NM 128 MP 21.93, facing south, inlet side (eastern culvert on left and western on right)



FIGURE 76: Eastern 36" culvert on NM 128 MP 21.93 facing south at inlet.



FIGURE 77: Western 36" culvert on NM 128 MP 21.93 facing south at inlet.

Culvert Thickness Measurement

Eastern: Using a micrometer on uncorroded locations of the culvert, a thickness of 0.0625", 0.0612", and 0.0619" was measured at three different locations, for an average of 0.062". The closest gage thickness to this value is 16, with a galvanized thickness of 0.064". The ultrasonic measurements were taken 18" from the inlet and showed a thickness between 0.060" and 0.062", indicating no corrosion present on the unseen outside of the culvert.

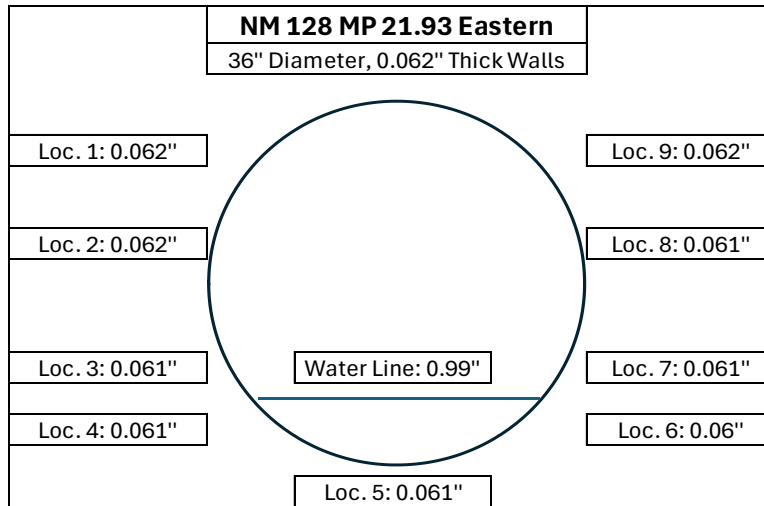


FIGURE 78: Diagram of wall thickness measurements taken at NM 128 MP 21.93 Eastern culvert.

Western: Using a micrometer on uncorroded locations of the culvert, a thickness of 0.0624", 0.0605", and 0.0611" was measured at three different locations, for an average of 0.061". The closest gage thickness to this value is 16, with a galvanized thickness of 0.064". The ultrasonic measurements were taken 18" from the inlet and showed a thickness between 0.059" and 0.063", indicating no corrosion present on the unseen outside of the culvert.

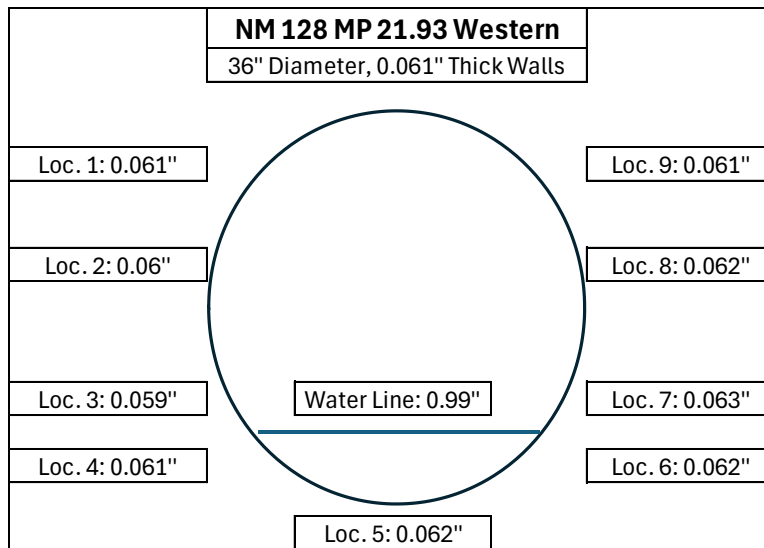


FIGURE 79: Diagram of wall thickness measurements taken at NM 128 MP 21.93 Western culvert.

In-situ and Laboratory Soil Measurements

In-situ soil resistivity tests were conducted at 1m, 2m, and 3m out from the entrance of the culvert, with soil samples being collected at these transects for later analysis in the lab. **TABLE 19** below shows the results of field and laboratory soil analysis.

TABLE 19: Soil test results from inlet side of culvert on NM 128 MP 21.93.

NM 128 MP 21.93							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
1m	9066	10871	29200	500	0-2	6.6-7.8	8.22
2m	10194	9408	29400	and up	-	-	8.15
3m	9149	10495	24000	-	-	-	8.21

This location had no visible corrosion on the outside or inside of the culvert, and the ultrasonic thickness measurements confirm this. The presence of soil pH slightly greater than 7.3 and resistivity values far greater than 2000 ohm-cm contribute to this location having negligible corrosive soils.

NM 181 MP 5.48

This culvert was visited on 11/05/2025, but could not be located. The warning post indicating a culvert as seen in the red-circled area in **FIGURE 80** below indicated the location of a culvert, but it was completely buried on the inlet side, and it also could not be located on the outlet due to very dense brush.



FIGURE 80: Approximate inlet side of culvert on NM 181 MP 5.48, buried in dirt. Culvert road warning marker circled in red.

NM 195 MP 1.51

This culvert was visited on 11/05/2025. The exposed outside of the culvert had a significant amount of corrosion present, as seen in **FIGURE 81** below. **FIGURE 82** below shows the presence of corrosion only on the upper inside portion of the culvert.



FIGURE 81: Culvert on NM 195 MP 1.51, inlet side.



FIGURE 82: Inside of the inlet side of the culvert on NM 195 MP 1.51.

Culvert Thickness Measurement

At uncorroded locations, three micrometer measurements were taken, 0.0778”, 0.0759”, and 0.0771”, for an average of 0.0769”. This thickness corresponds approximately to a 14-gage culvert with a galvanized thickness of 0.079”. The ultrasonic measurements showed a thickness between 0.077” and 0.085”, indicating the presence of corrosion on the outside of the culvert, with some scaling buildup.

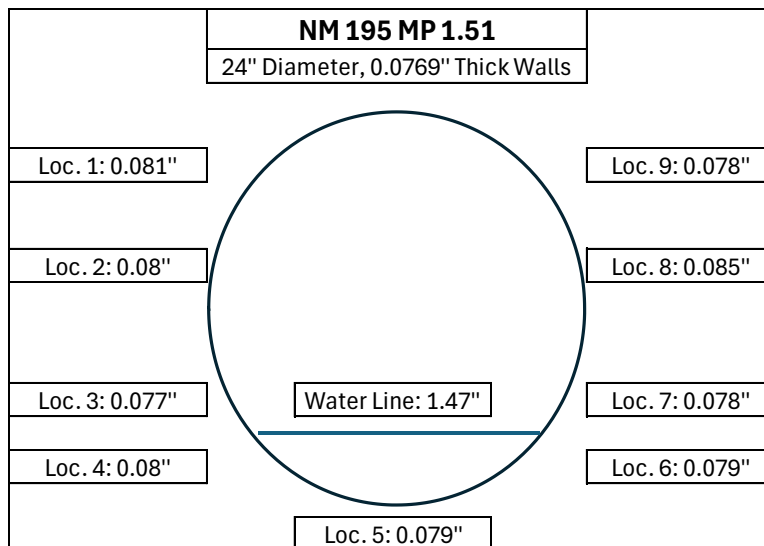


FIGURE 83: Diagram of wall thickness measurements taken at NM 195 MP 1.51 culvert.

In-situ and Laboratory Soil Measurements

In-situ soil resistivity tests were conducted at 1m, 2m, and 3m out from the entrance of the culvert, with soil samples being collected at these transects for later analysis in the lab. **TABLE 20** below shows the results of field and laboratory soil analysis.

TABLE 20: Soil test results from inlet side of culvert on NM 195 MP 1.51.

NM 195 MP 1.51							
Soil Sample Location	NRCS Test Method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
1m	11641	1645	3090	500	0-2	7.9-8.4	8.27
2m	8929	1800	2550	and up	-	-	8.49
3m	4831	1844	2080	-	-	-	8.26

This location had considerable corrosion on the outside, specifically in locations in contact with surrounding soils and on the upper inside portions of the culvert. Due to the small size of the culvert, ultrasonic measurement samples were unable to be collected on the inside of the culvert where it was buried and were instead collected 8 inches from the culvert’s opening. The presence of soils with greater than 7.3 pH indicated that corrosion on the soil side will govern in this location. This corrosion is easily seen in **FIGURE 81** and **FIGURE 82** above. The soil’s resistivity being below 2000 ohm-cm indicated that some of the corrosion was also caused by this lower resistivity value.

NM 290 MP 0.65

The third culvert investigated on NM 290 was located at MP 0.65. This culvert is a 48” culvert made from galvanized structural plate. This culvert had extreme corrosion, with multiple areas where the undermining of the culvert’s backfill occurred during the last time water flowed through it. The following images show the extreme amount of the corrosion present on this culvert, with multiple large holes present near the inlet and outlet. There are potentially additional large holes in the culvert’s walls in the middle section, but it was not deemed safe to venture further in to investigate.



FIGURE 84: Culvert on NM 290 MP 0.65, inlet side.



FIGURE 85: Culvert on NM 290 MP0.65, inlet side, approximately 10 feet in from the end. Image shows multiple large sections of the culvert's bottom missing in addition to a large hole halfway up the right side.



FIGURE 86: Culvert on NM 290 MP 0.65, inlet side, approximately 10 feet in from end. Image shows a zoomed-in view of the culvert's bottom where large sections are missing and what appears to be an old, metal bucket stuck in one of the corroded holes.



FIGURE 87: Culvert on NM 290 MP0.65, outlet side, approximately 10 feet in from end. Extreme corrosion with backfill being undermined during last flow event.

Culvert Thickness Measurement

A value of 0.1147" was measured on an uncorroded exposed location with a micrometer; the closest gage thickness is 12 for galvanized structural plate. Based on the ultrasonic thickness measurements taken 6 feet in from the end of the culvert, on the inlet side, there is a considerable amount of surface corrosion and scaling on the inside and outside of the culvert, especially above and below the corroded waterline.

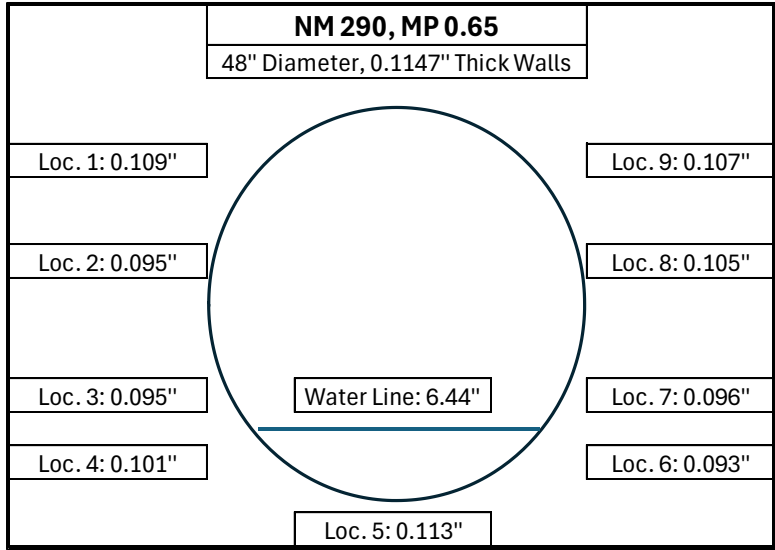


FIGURE 88: Diagram of inlet wall thickness measurements taken on NM 290 MP 0.65 culvert.

In-situ and Laboratory Soil Measurements

No in-situ 4-pole resistivity tests were conducted at this location due to a rocky terrain preventing the resistivity test probes from being driven into the ground, as seen in **FIGURE 89** below. Soil samples were collected at 0m, 1m, 2m, 3m, and from behind the culvert in the large hole midway up, shown in **FIGURE 87**. The results of the laboratory tests are in **TABLE 21** below.



FIGURE 89: Culvert on NM 290 MP 0.65, inlet side. Image of the rocky ground around the inlet of the culvert.

TABLE 21: Soil test results from laboratory tests on NM 290 MP 0.65 culvert.

NM 290, MP 0.65							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	9434	8717	-	500	0-2	7.4-8.4	9.06
1m	11111	6786	-	and up	-	-	8.26
2m	9911	5282	-	-	-	-	7.96
3m	4975	3768	-	-	-	-	8.93
Behind Culvert	80	112	-	-	-	-	8.14

The higher pH values at this location indicate that soil-side corrosion will govern, which is verified by the thickness measurements being less than the original thickness, especially above and below the waterline. The soil conductivity of the sample from behind the culvert shows a significant difference than the others collected at this site and from nearby sites. This extremely small resistivity value is potentially explained by deicing sprays and salt used in this mountainous location, greatly increasing the conductivity of the soil and therefore substantially decreasing the soil's resistance.

NM 290 MP 0.91

This is the second culvert investigated along NM 290, within 0.5 miles of the culvert that was visited on 12/4/24 at MP 1.0. The culvert at MP 1.0 was recently replaced, as the existing culvert was completely corroded out. Investigating additional culverts in the vicinity of the one at MP 1.0 was requested by NMDOT. A suitable culvert to investigate (accessible at inlet and outlet) was located at MP 0.91.



FIGURE 90: Inlet of culvert on NM 290 MP 0.91.



FIGURE 91: Culvert on NM 290 MP 0.91, inlet side showing corrosion on the inside bottom.



FIGURE 92: Culvert on NM 290 MP 0.91, outlet side with excessive outside corrosion.

Culvert Thickness Measurement

A thickness of 0.086 inches was measured on an uncorroded exposed location with a micrometer, with the closest gage thickness being 14-gage that has a standard galvanized thickness of 0.079". Ultrasonic thickness measurements were taken 1 foot in for the end of the culvert on the inlet side, with the results displayed in **FIGURE 93** below.

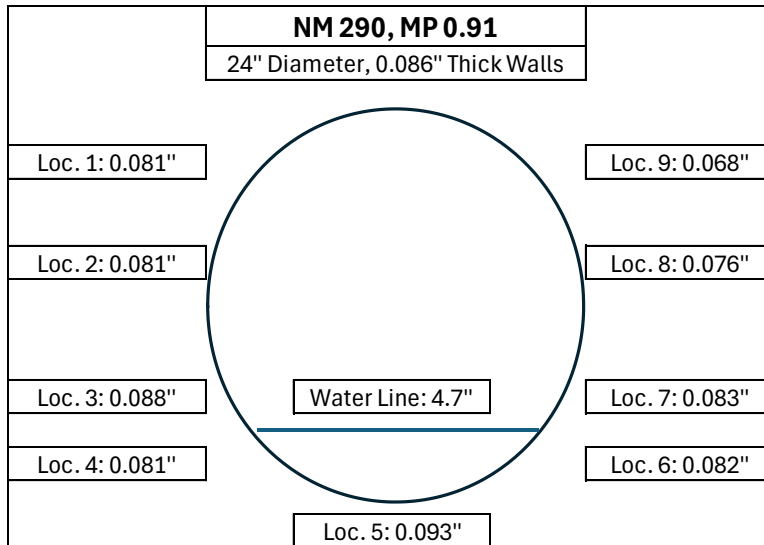


FIGURE 93: Diagram of inlet wall thickness measurements taken on NM 290 MP 0.91 culvert.

The majority of the measurements were less than the uncorroded thickness of 0.086", indicating outside corrosion, as there was minimal corrosion on the inside above the waterline level.

In-situ and Laboratory Soil Measurements

Three in-situ 4-pole soil resistivity tests were conducted at 2m, 3m, and 4m out from the inlet, and soil samples were collected along each of these transects in addition to soil at 0m, directly in front of the culvert’s inlet. The results of these tests are in **TABLE 22** below.

TABLE 22: Soil test results from in-situ and laboratory tests on NM 290 MP 0.91 culvert.

NM 290, MP 0.91							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	9452	3656	-	500	0-2	7.4-8.4	7.83
2m	10593	4340	9290	and up	-	-	8.19
3m	9524	4371	11800	-	-	-	8.22
4m	10695	4749	9860	-	-	-	8.28

The greater than 7.3 pH found in the soil at this location indicated that soil-side corrosion will govern. Evidence of this is seen clearly on the outside of this culvert’s outlet and to a lesser extent on the inlet side.

NM 290 MP 1.0

This 24” culvert is located northeast Jemez Pueblo on NM 290 and was visited on 12/4/24. This culvert was recently replaced due to the prior culvert being completely corroded out. The image below, **FIGURE 94**, is looking into the inlet (facing south). As this culvert was recently replaced, there was zero corrosion present on the inside or outside, as seen in **FIGURE 94 and FIGURE 95** below. There was approximately 4 inches of sandy soil on the inside of the culvert.



FIGURE 94: 24” culvert under NM 290, MP 1.0, inlet side facing south.



FIGURE 95: No corrosion present on the inside of the culvert on NM 290 MP 1.0.

Culvert Thickness Measurement

A value of 0.0615 – 0.0618 inches was measured on an uncorroded exposed location with a micrometer; the closest gage thickness is 16 with a standard galvanized thickness of 0.064 inch. Based on the ultrasonic thickness measurements taken 1' 7" in from the end of the culvert, there was no corrosion on the inside and outside of the culvert, see **FIGURE 96** below.

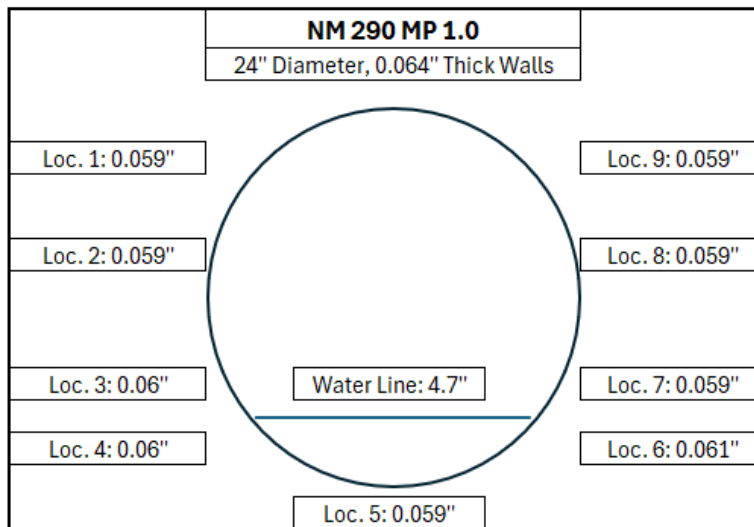


FIGURE 96: Diagram of inlet wall thickness measurements taken on NM 290 MP 1.0 culvert.

In-situ and Laboratory Soil Measurements

Three in-situ 4-pole resistivity measurements were conducted at this location, 2m, 3m, and 4m out from the culvert’s inlet. Soil samples were collected from within the culvert (0m) and along each 4-pole resistivity measurement transects. **TABLE 23** below shows the results of in-situ, laboratory, and NRCS web-collected soil data.

TABLE 23: Soil test results from in-situ and laboratory tests on NM 290 MP 1.0 culvert.

NM 290 MP 1.0							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	10406	10250	-	500	0-2	7.4-8.4	8.61
2m	3759	2260	258	and up	-	-	8.65
3m	3704	2500	1490	-	-	-	8.40
4m	2155	1420	1560	-	-	-	8.40

The higher pH values coupled with the lower resistivity values indicate a high potential for corrosion at this location from the soil side and from the inside. The 2m in-situ resistivity test may have been too close to the culvert’s flared wingwalls, causing a highly conductive path, resulting in a lower resistivity measurement.

US 60 MP 203.41

This 42” culvert under US 60 is located southwest of Mountainair and was visited on 12/3/24. This culvert was identified as DS-01 in the Preliminary Drainage Report, US 60 Roadway Improvements, CN 5101350. The image below, **FIGURE 97**, is looking into the inlet (facing south). There was no soil on the bottom inside of the culvert, but there was evidence of a waterline approximately 8 inches up from the bottom. The culvert had no corrosion present on the inside or outside, as seen in **FIGURE 98**.



FIGURE 97: 42” culvert under US 60 MP 203.41, inlet side facing south.



FIGURE 98: No corrosion was present on the inside of the culvert on US 60 MP 203.41.

Culvert Thickness Measurement

A value of 0.117 inches was measured on an uncorroded exposed location with a micrometer; the closest gage thickness is 12 with a standard galvanized thickness of 0.111 inch when in galvanized structural plate form. Based on the ultrasonic thickness measurements taken 1 foot in from the end of the culvert, there appears to be very little corrosion on the outside of the culvert, **FIGURE 99** below.

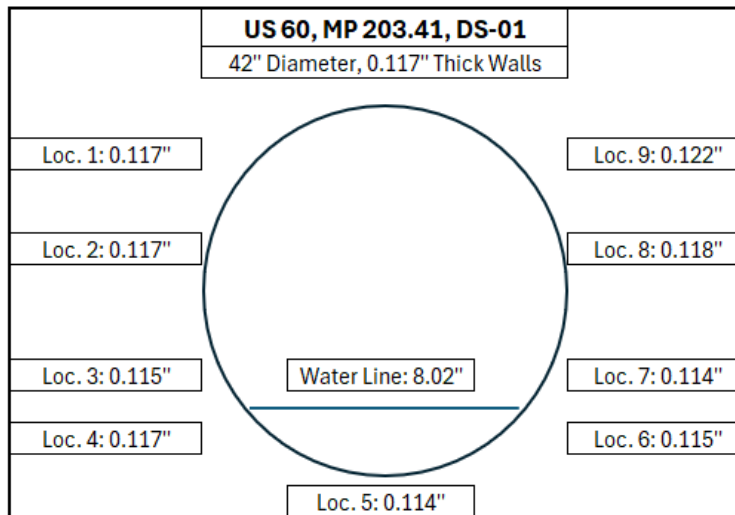


FIGURE 99: Diagram of inlet wall thickness measurements taken on US 60 MP 203.41 culvert.

In-situ and Laboratory Soil Measurements

Three in-situ 4-pole resistivity measurements were conducted at this location, 1m, 2m, and 3m out from the culvert's inlet. Soil samples were collected from within the culvert (0m) and along each 4-pole resistivity measurement transects. **TABLE 24** below shows the results of in-situ, laboratory, and NRCS web collected soil data.

TABLE 24: Soil test results from in-situ and laboratory tests on US 60 MP 203.41 culvert.

US 60, MP 203.41, DS-01							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	4587	2905	-	500	0-2	6.6-8.4	8.03
1m	3731	3090	5260	and up	-	-	8.00
2m	3497	3190	6450	-	-	-	8.07
3m	4405	3575	7900	-	-	-	8.12

The slightly higher pH values at this location suggest that soil-side corrosion will govern, which is indicated by 4 of 5 ultrasonics measurements at and below the waterline being less than the original thickness.

US 60 MP 204.33

This 24” culvert is located west of the intersection of US 60 and Sunset Ave in Mountainair and was visited on 12/3/24. This culvert was identified as DS-06 in the Preliminary Drainage Report, US 60 Roadway Improvements, CN 5101350. The image below, **FIGURE 100**, is looking into the outlet (facing north). The inlet of this culvert was adjacent to a parking lot, making in-situ resistivity test at that location impossible, so the tests were conducted near the outlet instead. A considerable amount of corrosion was present on the outside, **FIGURE 100**, and on the inside, **FIGURE 101**, of this culvert. There was approximately 10 inches of soil on the inside of the culvert.



FIGURE 100: 24” culvert under US 60 MP 204.33, outlet side facing north.



FIGURE 101: Considerable amount of corrosion on the inside of the culvert on US 60 MP 204.33.

Culvert Thickness Measurement

A value of 0.078 – 0.080 inches was measured on the least corroded exposed location with a micrometer; the closest gage thickness is 14 with a standard galvanized thickness of 0.079 inch. Based on the ultrasonic thickness measurements taken 1 foot in from the end of the culvert, there was a considerable amount of surface corrosion and scaling on the inside and outside of the culvert, **FIGURE 102** below. There was some pitting, but no holes observed in the culvert.

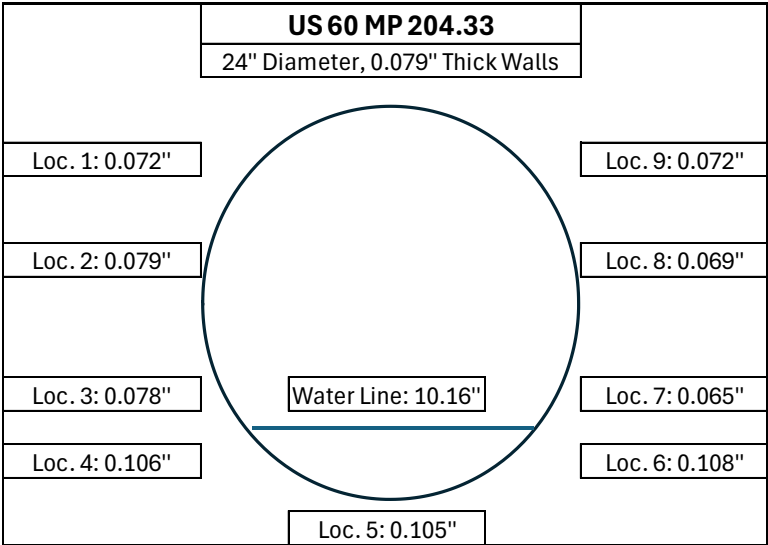


FIGURE 102: Diagram of outlet wall thickness measurements taken on US 60 MP 204.33 culvert.

In-situ and Laboratory Soil Measurements

Three in-situ 4-pole resistivity measurements were conducted at this location, 0.5m, 1m, and 2m out from the culvert’s outlet. Soil samples were collected from within the culvert (0m) and along each 4-pole

resistivity measurement transects. **TABLE 25** below shows the results of in-situ, laboratory, and NRCS web collected soil data.

TABLE 25: Soil test results from in-situ and laboratory on US 60 MP 204.33 culvert.

US 60 MP 204.33							
Soil sample location	NRCS Test method (ohm-cm)	CTM-643 (ohm-cm)	In-situ 4-pole res. Test (ohm-cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/cm)	NRCS Web Data (pH)	AASHTO T 289-91 (pH)
0m	5206	4615	-	500	0-2	7.9-8.4	7.91
0.5m	4444	3801	2070	and up	-	-	8.16
1m	4329	4169	3280	-	-	-	8.53
2m	3584	4310	3800	-	-	-	8.24

The slightly higher pH values at this location suggest that soil-side corrosion will govern, which is indicated by 4 of 6 ultrasonics measurements above the waterline being less than the original thickness. The measurements below the waterline all had significant scale buildups.

CONCLUSIONS AND RECOMMENDATIONS

SOIL RESISTIVITY

In this study, the resistivity of soils was determined using three different methods: in-situ with a 4-pole ground resistivity test, the NRCS soils electrical conductivity testing method, and the CTM-643 for laboratory resistivity testing method. Additionally, soil resistivity was collected from the NRCS Web Soil Survey website for each study location. The resistivity of soil is highly dependent on the moisture content of the soil, where very dry soils typically have higher resistivity due to the lack of dissolved salts needed to create a conductive path; conversely, very wet soils also have increased resistivity because the water dilutes the salinity of the soil, which also reduces conductive paths.

The in-situ 4-pole resistivity testing method provides only one resistivity data point that is highly dependent on the soil’s moisture content, which in New Mexico is more than likely on the drier side. The average moisture content for all 93 soil samples processed in this study was 7.77%, with a minimum of 1.3% and a maximum of 20.0% (Appendix 4). The NRCS soils electrical conductivity testing method also only provides one resistivity data point (after converting conductivity to resistivity, Appendix 3), which requires 10 ml of a moist soil sample (not dried first) that is added to 50 ml of distilled water, producing a slurry of roughly 250% moisture content.

The laboratory-based CTM-643 soils resistivity testing method produces 5-10 resistivity values at different soil moisture contents, where the lowest resistivity value is selected as the value to represent the soil sample. **FIGURE 103** below shows two full sets of CTM-643 resistivity results, one from a study location that had 6.4% in-situ moisture content and one from a study location that had 19.8% in-situ moisture content. Additionally, **FIGURE 103** also shows the resistivity from both of these two study locations from the in-situ 4-pole resistivity method as a single data point each. For the location with drier soils, the in-situ method produced a resistivity value of 11,000 ohm-cm at 6.4% (over 3.5 times greater than the minimum resistivity value from the CTM-643 testing method of 3,081 ohm-cm at 25% moisture content) whereas the wetter soils location had an in-situ soil resistivity value of 1,560 ohm-cm at 19.8% moisture content. The laboratory-based CTM-643 testing method resistivity value closely matched the in-

situ resistivity with 1,420 ohm-cm at 20% moisture content (**TABLE 26**). Conversely, the NRCS laboratory method tested soils at roughly 250% moisture content, resulting in a diluted-salts soil slurry with 7,386 and 2,155 ohm-cm for the dry and wet locations, respectively. Lastly, the NRCS Web Data has a range of 0-2 mmho/cm for both of these locations, or, in resistivity units, 1,000 ohm-cm (assuming an average value of 1 mmho/cm and converting it to ohm-cm, Appendix 3).

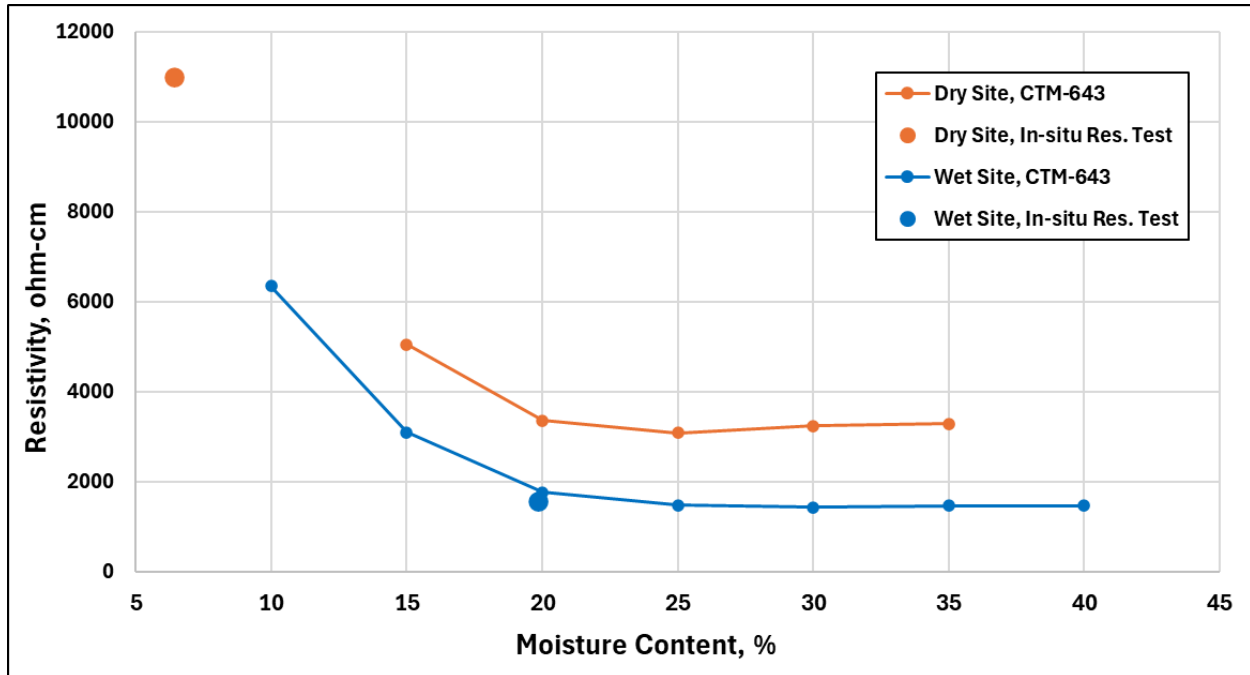


FIGURE 103: Resistivity at a wet location vs. dry location.

TABLE 26: Resistivity at a wet location vs. dry location.

In-situ Moisture Content (%)	In-situ 4-pole res. Test (ohm-cm)	CTM-643 Moisture Content at Min. Ohms (%)	CTM-643 (ohm-cm)	NRCS Test method (ohm-cm)	NRCS Web Data (ohm-cm)
6.4	11000	25	3081	7386	~1000
19.8	1560	20	1420	2155	~1000

If the in-situ soil’s moisture content happens to be close to the minimum resistivity value when an in-situ 4-pole resistivity method is conducted, then the resistivity value measured will more closely match the actual minimum soil resistivity value, but one does not know ideal moisture content before conducting this test. As seen in this study, when using the in-situ 4-pole resistivity method in dry climates, the resistivity values tend to be far greater than the actual value produced by the CTM-643 method (Appendix 4). The average resistivity from all soil samples in this study from the in-situ 4-pole method was 9,502 ohm-cm whereas the average from the CTM-643 method was 4,282 ohm-cm, over twice as much. The NRCS conductivity testing method, with its far wetter soil conditions, produced a study-wide average resistivity of 9,463 ohm-cm, also over twice as much as the CTM-643 average value.

Based on the results from this study, the CTM-643 soil resistivity testing method is considerably more accurate and precise than the other methods tested, but this method takes a considerable amount of time to perform, with four separate soil samples from one location taking 5-7 hours to complete after the soil is dried. The in-situ 4-pole method takes only 20-30 minutes to complete four transects, and the NRCS soil conductivity test only takes a few minutes to process four samples. Least accurate of all is the NRCS Web Soil Survey, which only took a minute to get a broad range of soil resistivity per study location. Out of 24 study locations for this project, 22 had the same 0-2 mmho/cm value of salinity. Of these 22 locations, some had no visible corrosion while others had extreme corrosion where little of the culvert remained.

SOIL PH

The other soil parameter tested in this study was pH. Two sources of pH were used: one was from testing soils samples using the American Association of State Highway and Transportation Officials' (AASHTO) T 289-91 (2013) method, and the other was from the NRCS Web Soil Survey website. The AASHTO pH test required 30g of dried soil that had 30g of distilled water added to it, which was then measured by a calibrated pH meter. The NRCS Web Soil Survey website produced a range of soil pHs, with 17 out of 24 study locations having a range of 7.4-8.4 pH. Culverts in this study within this 7.4-8.4 pH range had either no visible corrosion or had extreme corrosion with large holes throughout the culvert, suggesting that this range in pH values is not a good indication on the corrosive potential of the soils where culverts are installed.

Outside-in corrosion of culverts is expected when the pH is greater than 7.3, as was seen in this study, where the average measured pH was 8.08, minimum value was 7.43, and maximum value was 9.06 (Appendix 4). Locations in this study that had the highest pH also had the most corrosion and deterioration of the culverts, specifically the culverts on NM 290. The pH test is helpful for identifying outside-in corrosion, but with all locations in the study having a pH greater than 7.3, outside-in corrosion should be expected at most locations within New Mexico due to our desert soil conditions that tend to be more alkaline (greater than 7.0 pH).

REFERENCES

- (1) Galtung-Døsvig, T. Durability of buried galvanized steel structures in British Columbia (T). 1995. Retrieved from <https://open.library.ubc.ca/collections/ubctheses/831/items/1.0050395>
- (2) Korrosion und Korrosionsschutz im Bauwesen, 1996, Teil I und II, von Ulf Nürnberger. 1346 Seiten mit rd. 720 Abbildungen – davon 120 Seiten Farbabbildungen, gebunden, Bauverlag, Wiesbaden und Berlin 1995, DM 348,00, ISBN 3-7626-3199-4, Materials and Corrosion 47(10):579-580.
- (3) Boyajian, David, Maalouf, Sarni, Zirkian, Tadeh, 2019, California Corrugated Steel Pipe (CSP) Culvert Service Life, State of California Department of Transportation, Sacramento, CA.
- (4) Beaton, J.L. and Stratfull, R.F., 1962, Field test for Estimating the Service Life of Corrugated Metal Pipe Culverts, Report 62-06.
- (5) National Corrugated Steel Pipe Association, 2018, Corrugated Steel Pipe Design Manual, Second Edition, Dallas, Texas.
- (6) California Department of Transportation, Division of Construction (Caltrans). (1978). Method for Estimating the Service Life of Steel Culverts: California Test 643. Sacramento, CA.
- (7) California Test 643, Method of test for laboratory resistivity and pH for soil and water, 2020, California Department of Transportation, Division of Engineering Services, Sacramento, CA.
- (8) USDA Soil Survey Field and Laboratory Methods Manual, Soil Survey Investigations Report No. 51, Version 2, 2014, Page 293. <https://www.nrcs.usda.gov/sites/default/files/2023-01/SSIR51.pdf>
- (9) The AASHTO 289-91 test followed procedures set forth in AASHTO Designation: T 289-91 (2013), Standard Method of Test for Determining pH of Soil for use in Corrosion Testing.

APPENDIX 1: NRCS SOIL ELECTRICAL CONDUCTIVITY

Equipment

1. Beakers, polypropylene, 100-ml
2. Stirring stick
3. Cylinder, polypropylene, 25-mL
4. EC meter, pocket-type or hand-held

Reagents

1. Distilled water
2. Potassium chloride (KCl), 0.010 N. Dry KCl overnight in oven (110 °C). Dissolve 0.7456 g of KCl in distilled water and bring to 1-L volume. Conductivity at 25 °C is 1.4 dS m⁻¹. Alternatively, KCl calibration solutions, commercially-prepared (e.g., 20-ml calibration solution packets).
3. Material Safety Data Sheets (MSDS)

Procedure

1. Calibrate EC meter using calibration solution.
2. Measure 10 mL of moist sample into a 100-mL beaker. (Samples should have been refrigerated if they were collected 1 or 2 days prior to the testing. They should have been frozen if they were stored longer.)
3. Measure 50 mL distilled water (5 times the volume of soil) into a second 100-ml beaker.
4. Pour the 50 mL distilled water into the beaker containing 10 mL of soil and briefly stir for 10s.
5. Allow mixture to settle. Coarse textured samples will settle in as little as 15 min. Fine-textured samples and those that have a high content of organic matter may require overnight settling (and should be refrigerated).
6. Immerse tip of calibrated hand-held EC meter into mixture, being careful not to stick the electrode into the soil phase of the mixture.
7. Allow readings to stabilize. Read and record EC1:5vol of the unfiltered supernatant.

Source: USDA Soil Survey Field and Laboratory Methods Manual, Soil Survey Investigations Report No. 51, Version 2, 2014, Page 293. <https://www.nrcs.usda.gov/sites/default/files/2023-01/SSIR51.pdf>

APPENDIX 2: CALIFORNIA TEST METHOD 643 (CTM-643)

This page intentionally left blank

California Test 643

STATE OF CALIFORNIA—CALIFORNIA STATE TRANSPORTATION AGENCY

April 10, 2020



DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Transportation Laboratory 5900 Folsom Blvd.
Sacramento, California 95819-4612

METHOD OF TEST FOR LABORATORY RESISTIVITY AND PH FOR SOIL AND WATER

A. SCOPE

This method describes the procedures for determining the minimum resistivity of soil or water samples and the pH of soil or water samples. Samples shall not be tested at temperatures below 0°C or above 25°C.

B. REFERENCES

- AASHTO T 289-91 (2018) Standard Method of Test for Determining pH of Soil for Use in Corrosion Testing
- ASTM D1293-18 Standard Test Methods for pH of Water
- ASTM E11-17 Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves
- California Test 201 Method of Test for Soil and Aggregate Sample Preparation
- California Test 417 Method of Testing Soils, Concrete Patching Materials and Waters for Sulfate Content
- California Test 422 Method of Testing Soils, Concrete Patching Materials and Waters for Chloride Content

California Department of Transportation Corrosion Guidelines

C. APPARATUS AND MATERIALS

1. Resistance Meter: The resistance meter shall be an alternating current (AC) system or a 12-V direct current (DC) system with a Wien Bridge (AC bridge), a phase sensitive detector and a square wave inverter to produce a nominal alternating signal at 97 Hz.
2. Soil Box: The soil box shall be calibrated for use with the resistivity meter. See Figure 1 for details of the soil box. See Section I for the method for calculating the soil box constant.
3. Resistors: Various resistors are required. They include: 100, 200, 300, 500, 700, 900, 2K, 3K, 5K, 10K, and 20K (nominal ohm values, 1 % precision).
4. Sieve: A U.S. Standard No. 8 sieve with square openings conforming to ASTM E11.

5. Sample Mixing Container: They shall be non-corroding, such as plastic or stainless steel.
6. Spatula: A spatula is required for mixing materials.
7. Oven: The temperature of the oven may not exceed 60°C at any time during sample drying. As a practical operating range, the oven should be maintained at $45 \pm 15^\circ\text{C}$.
8. Scale: A scale or balance shall have a capacity of 5 kg with an accuracy of ± 0.1 g.
9. Water: All water used shall be distilled or deionized water with a resistance of 100,000 ohm or greater.
10. Graduated Cylinder: A graduated cylinder with a capacity of 100 mL or larger.
11. Splitter and Pans: A sample splitter is required with splitting pans. Refer to California Test 201.
12. Thermometer: A thermometer with an accuracy of 0.5°C .
13. Protective gloves. Nitrile or latex type glove that prevents skin from coming in contact with soil.

D. VERIFICATION OF THE RESISTANCE METER and pH METER

1. Verify the resistance meter according to the manufacturer's instructions and these procedures.
2. Connect each pair of test leads of the resistance meter to the lowest value resistor and read the meter. Repeat this process with the other resistors.
3. If the meter readings are within 10 % of all the resistor values, the meter is functioning satisfactorily. Meters should be verified at least once every six months and a record of verification dates maintained for each meter.
4. Verify the standardization of the pH meter once a month per the manufacturer's instructions or per the procedure in AASHTO T 289-91. Record the dates and any problems.

E. PREPARATION OF SOIL SAMPLES

1. Field sample shall be dried in the oven (not to exceed 60°C). Do not crush rocks.
2. After drying, sieve the sample over the No. 8 sieve and use passing material for the test.
3. Split out enough material passing No. 8 sieve to obtain a sample size such that after adding water and compacting, the soil box will be slightly overfilled with some material remaining in the container. This may entail using a trial and error process based on the size of the soil box. Soil boxes come in different sizes depending how they are constructed. The soil box in Figure 1 is an example of a smaller configuration.

F. DETERMINING THE MINIMUM RESISTIVITY OF A SOIL SAMPLE

1. Clean all equipment (mixing container, soil box, etc.) with water and thoroughly dry prior to testing each new sample.
2. The quantity of water (in mL) to begin mixing with can be calculated by multiplying the weight of the sample by 11.5 percent. Figure 2 Column B shows the cumulative moisture content for each step of the test. Record the volume of water added (rounded to the nearest whole mL).
3. Add the calculated water quantity to the soil sample in the mix container and thoroughly mix with the spatula. Coat the soil grains with moisture until there are no visible dry grains of soil.
4. After mixing the soil in the container begin placement of the soil material into the soil box in layers and compact each layer by hand (generally 3 to 4 layers are needed to accomplish this task). Compact the material as densely as possible into the soil box applying moderate effort using your fingers. For dry soils, a tamping device is acceptable during the initial compaction. For sticky, clay type soils, the use of a spatula is permitted for initial compaction. Continue this procedure for succeeding layers to maintain a uniform density with minimal voids. Stop when the compacted sample is higher than the edges of the soil box. Any soil not used retain in the container for additional testing as stated in Step 7.
5. Trim the excess material flush with the top surface of the soil box using a straight edge. The top surfaces of the soil box should be clean and dry prior to measuring and recording the resistance for water added. The excess material should be returned to the container for use in Step 7.
6. Measure the resistance of the soil with the resistance meter in accordance with the instructions furnished by the manufacturer. Record the test value in the Data Reporting Form (Figure 2). Remove all soil material from the soil box to the mixing container using the spatula to be recombined with any material remaining in the mixing container.
7. Repeat Steps 4-6 increasing the moisture as shown in Figure 2 and recording the volume of water used (in mL) to develop a curve with the lowest value being the minimum resistance. When the recorded values cease to decrease and begin to increase, the minimum resistance may have been reached. For confirmation, continue repeating steps 4-6 for at least 3 measurements past the lowest value to ensure that there is no false bump. A false bump occurs when the resistance values begin increasing then start to decrease. Should this happen, continue testing until the resistance values flatten out or continue to increase for three measurements. If the lowest value is the starting value after four readings, then use the start value as the minimum resistance. See Figure 3 an example of results. Measure and record the temperature of the soil after recording the final soil resistance reading. In some soils, the minimum soil resistance occurs when the specimen sample is in a slurry condition.

When this occurs, it is necessary to thoroughly mix the soil slurry and then pour the soil slurry into the soil box until it is full and level with the top of the soil box. Then measure the resistance.

8. Use the following formula to normalize the minimum resistance measurement for the sample to the standard ground temperature of 15.5°C and for the soil box constant as determined in Section I:

$$\rho = \frac{R_{min}(T + 24.5) \times (\text{Soil Box Constant})}{40}$$

Where:

ρ = minimum resistivity of the soil sample corrected to the standard ground temperature of 15.5°C, ohm-cm

R_{min} = minimum resistance of the soil sample at the sample temperature, T

T = sample temperature, °C

This formula is valid for sample temperatures between 0°C and 25°C. Round calculated resistivity to the nearest whole number.

H. DETERMINING THE MINIMUM RESISTIVITY OF A WATER SAMPLE

1. Thoroughly clean the soil box of all soil particles and rinse it a minimum of three times with water. Alternately, a separate box used only for water samples can be used with a simple rinse before each use.
2. Fill the soil box with water and measure its resistance. Empty the soil box and remove any remaining water with a paper towel.
3. Fill the soil box with the test water and measure its resistance. Measure water temperature in °C. Record the resistance value and the water temperature in the Data Reporting Form (Figure 2).
4. Calculate the Resistivity of the water sample using the following formula:

$$\rho = \frac{R(T + 24.5) \times (\text{Soil Box Constant})}{40}$$

Where:

ρ = resistivity of the water sample corrected to the standard ground temperature of 15.5°C, ohm-cm

R = resistance of the water sample at sample temperature, T

T = sample temperature, °C

This formula is valid for sample temperatures between 0°C and 25°C. Round calculated resistivity to the nearest whole number.

I. DERIVATION OF SOIL BOX CONSTANT

If the soil box constant is not known, it can be derived from the following equation (see Figure 1):

$$\frac{\text{Surface Area of One Electrode (cm}^2\text{)}}{\text{Measured Average Distance Between Electrodes (cm)}} = \text{cm}$$

$$\frac{(25.0 \text{ mm} \times 0.1 \text{ cm/mm}) (50.0 \text{ mm} \times 0.1 \text{ cm/mm})}{(25.0 \text{ mm} \times 0.1 \text{ cm/mm})} = 5.00 \text{ cm}$$

Where:

electrodes = number metal surfaces inside the box. In Figure 1, two of the inside walls of the box are stainless steel for two electrodes.

J. pH OF SOIL AND WATER

1. Determine pH of soil per AASHTO T 289-91 with replacement of Section 6.2 with the passing fraction separated over the No. 8 sieve. Report results to nearest 0.01 pH unit.
2. Determine pH of water per ASTM D1293-18 "Method B". Under Section 22 (Procedure, Batch Samples) use 30-40 mL of sample water taking a single pH reading. Report results to nearest 0.01 pH unit.

K. REPORTING OF RESULTS

1. Record the results in the Data Reporting Form.
2. Soil and water that have a minimum resistivity and or pH equal to or less than stated in the most current Corrosion Guidelines are required to be tested by a certified lab for sulfates and chlorides per California Test 417 and California Test 422.

L. HEALTH AND SAFETY

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Refer to the Safety Manual for your Laboratory.

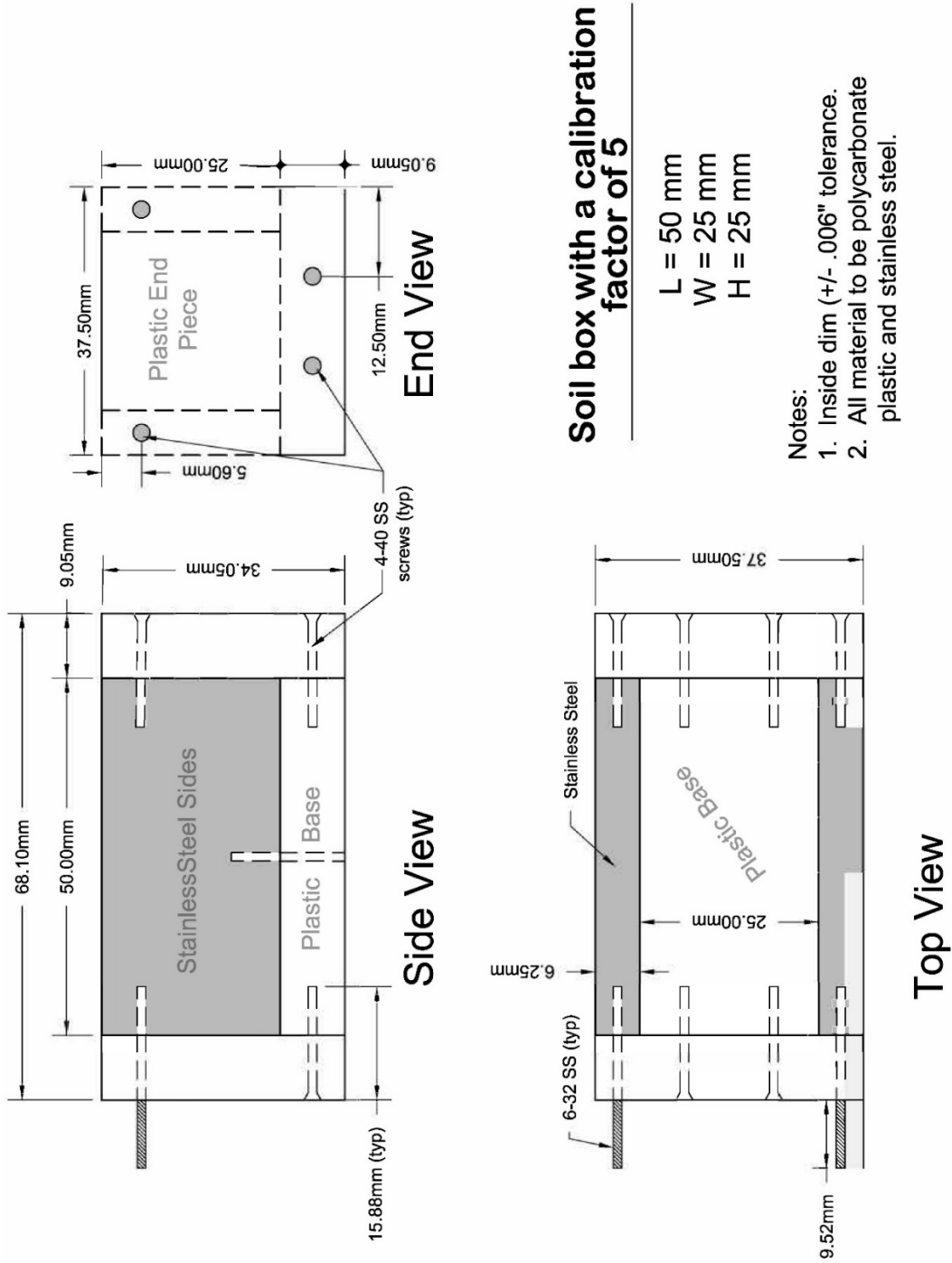


FIGURE 1. Soil Box for Laboratory Minimum Resistivity Determination

CT 643 DATA REPORTING FORM

DATE RECD: _____

TL#:

	Corrosion Test No.	Date Tested:	
	Project No.	Tested By:	
Total Moisture Content (%) B	Soil Sample Resistance R (Ohms)	Mass of Soil Sample Tested (A)	Sample Temperature (T)
11.5		_____ g	T = _____ °C
19.2			
26.9			
30.8			
34.6			
38.5			
42.3			
46.2			
50.0			
53.8			
57.7			
61.5			
65.4			
69.2			
73.1			
76.9			
80.8			
84.6			
		Minimum Soil Resistivity¹ ρ (Corrected for temperature and soil box constant) $\rho = \frac{R_{min} (T + 24.5) \times (\text{Soil Box Constant})}{40}$ $\rho = \text{_____ (Ohm-cm)}$	
		Water Resistivity² (Corrected for temperature and soil box constant) $\rho = \frac{R (T + 24.5) \times (\text{Soil Box Constant})}{40}$ $\rho = \text{_____ (Ohm-cm)}$	
pH Value¹		Water⁴	
Soil³		pH = _____	
		pH = _____	

¹ Send to a certified laboratory for chlorides and sulfates analysis if resistivity or pH are less than specified in the Corrosion Guidelines.
² All water samples are to be sent to a certified lab for additional analysis per Corrosion Guidelines.
³ Test per AASHTO T-289 and record results to nearest 0.01 pH.
⁴ Test per ASTM D1293 and record results to nearest 0.01 pH.

FIGURE 2. CT 643 Data Reporting Form 91

CT 643 DATA REPORTING FORM

DATE REC'D: 2/12/2020

DATE IF SENT TO CHEMISTRY: 2/14/2020

TL#: C741649

Soil #:

Total Moisture Content (%) B	Total Water Added (mL) A x B	Soil Sample Resistance R (Ohms)	Corrosion Test No. CR20200079	Date Tested: 2/14/20
			Project No. 0716000015	Tested By:
			Mass of Soil Sample Tested (A)	Sample Temperature (T)
11.5	15	3917	130 g	T = 23.6 °C
19.2	25	2168		
26.9	35	1038		
30.8	40	838		
34.6	45	774		
38.5	50	788		
42.3	55	790		
46.2	60	818		
50.0				
53.8				
57.7				
61.5				
65.4				
69.2				
73.1				
76.9				
80.8				
84.6				

<p>Minimum Soil Resistivity¹ ρ (Corrected for temperature and soil box constant)</p> $\rho = \frac{R_{min} (T + 24.5) \times (\text{Soil Box Constant})}{40}$ $\rho = \frac{774 (23.6 + 24.5) \times (5.0)}{40}$	<p>Water Resistivity² (Corrected for temperature and soil box constant)</p> $\rho = \frac{R (T + 24.5) \times (\text{Soil Box Constant})}{40}$ $\rho = \frac{\quad \times \quad}{40} \quad (\text{Ohm-cm})$
<p>pH Value¹ Soil³</p> <p>pH = <u>5.38</u></p>	<p>pH Value⁴ Water</p> <p>pH = _____</p>

Resistance decreases with increasing water content. At 38.5 % moisture the resistance measured starts to increase. This indicates a possible minimum resistance value has been reached. A total of three consecutive resistance value increases is sufficient to stop the test.

Calculated resistivity is greater than required to be sent for chemical analysis per the Corrosion Guidelines.

Measured pH is less than required in the Corrosion Guidelines. Send soil sample for chemical analysis.

¹ Send to a certified laboratory for chlorides and sulfates analysis if resistivity or pH are less than specified in the Corrosion Guidelines.
² All water samples are to be sent to a certified lab for additional analysis per Corrosion Guidelines.
³ Test per AASHTO T-289 and record results to nearest 0.01 pH.
⁴ Test per ASTM D1293 and record results to nearest 0.01 pH.

FIGURE 3. CT 643 Data Reporting Form Example

APPENDIX 3: RESISTIVITY TO CONDUCTIVITY CONVERSIONS

The NRCS Web Soil Survey, <https://websoilsurvey.nrcs.usda.gov/app/>, provides electrical conductivity (EC) in two different locations. After you have selected an Area of Interest (AOI), click on the Soil Data Explorer tab. This will open a new set of tabs, and under the Soil Properties and Qualities tab, there is a list of Properties and Quantities on the left side of the screen. If you expand the Soil Chemical Properties (double arrows icon on the right side), Electrical Conductivity becomes visible. When you expand the Electrical Conductivity area, you will be given a few drop-down boxes and an area to enter Top Depth and Bottom Depth. For this study, the Aggregation Method drop down box was set to Weighted Average, the Top Depth was set to 0 inches, and the Bottom Depth was set to 6 inches. After these inputs are entered, click View Rating. Under the main map on the right, there will be a data list; find the Map Unit Symbol associated with your study location, and you will find the Rating (decisiemens per meter) for that area below the map.

The other location where you can find EC information is on the Soil Reports tab. After your AOI is selected, click on the Soil Data Explorer main tab to open a new set of tabs. Click on the far-right tab called Soil Reports. On the left side of the screen, there will be a list of soil reports; find Soil Chemical Properties and expand it by clicking the double arrows icon on the right side. This will reveal Chemical Soil Properties; click the double arrow icon and then View Soil Report. Below the map on the right, a new data list will open. Find the Map Symbol associated with your study location, and the value under the heading Salinity (mmhos/cm) will be an EC range for your location.

Both of these EC values have different units, one in dS/m (decisiemens per meter) and the other in mmhos/cm (millimhos per centimeter). An easy way to convert both of these EC values to a resistivity value that is useful in the CRS spreadsheet is:

$$1 \text{ dS/m} = 1 \text{ mmhos/cm} = 1000 \text{ ohm-cm}$$

Or, put it into an equation form, where X is either the dS/m or mmhos/cm value, to get an ohm-cm value:

$$\frac{1,000}{X}$$

During lab soil testing, if your sensor gives you an EC value of $\mu\text{S/cm}$, use the following to get ohm-cm value, where X is the EC value:

$$\frac{1,000,000}{X}$$

APPENDIX 4: SOIL DATA

Site Name	Location	AASHTO T 289-91 (pH)	NRCS Web Data (pH)	Soil Moisture Content (%)	In-situ 4- pole res. Test (ohm- cm)	CTM-643 Moisture Content at Min. Ohms (%)	CTM-643 (ohm- cm)	NRCS Test method (ohm- cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/c m)	Corrosion Amounts (Degree, description, location, path)
I-25 MP 107.86	-1m	7.97	7.4-8.4	5.75	10900	25	5096	8052	500 +	0-2	Moderate, scaling/pitting, inside-bottom and outside, outside-in
I-25 MP 107.86	-2m	7.91	7.4-8.4	6.16	14000	20	3562	5013	500 +	0-2	Moderate, scaling/pitting, inside-bottom and outside, outside-in
I-25 MP 107.86	-3m	8.18	7.4-8.4	5.37	11800	30	7480	9158	500 +	0-2	Moderate, scaling/pitting, inside-bottom and outside, outside-in
I-25 MP 107.86	2m Inlet	7.97	7.4-8.4	4.56	-	25	7993	8969	500 +	0-2	Moderate, scaling/pitting, inside-bottom and outside, outside-in
I-25 MP 113.04	Inside	8.04	7.9-8.4	2.20	-	40	11236	19380	500 +	0-2	Minor, small holes/pitting, inside bottom and upper half, outside-in
I-25 MP 113.04	South Bank	7.99	7.9-8.4	4.60	-	25	3291	9217	500 +	0-2	Minor, small holes/pitting, inside bottom and upper half, outside-in
I-25 MP 113.04	North Bank	8.02	7.9-8.4	8.84	-	25	4197	7994	500 +	0-2	Minor, small holes/pitting, inside bottom and upper half, outside-in
I-25 MP 142.49	Inlet	8.50	7.4-8.4	2.14	-	20	7072	8873	500 +	0-2	Considerable, large holes, everywhere, outside-in
I-25 MP 142.49	5m	8.09	7.9-8.4	3.64	22300	30	2536	3115	500 +	0-2	Considerable, large holes, everywhere, outside-in
I-25 MP 142.49	7m	8.13	7.9-8.4	2.46	49700	40	4177	5800	500 +	0-2	Considerable, large holes, everywhere, outside-in
I-25 MP 142.49	9m	7.83	7.9-8.4	3.42	46700	40	1202	2037	500 +	0-2	Considerable, large holes, everywhere, outside-in
I-25 (NB) Exit 264	1m	8.19	7.9-8.4	9.79	1500	25	737	1377	250 +	0-4	Extreme, little metal remains, everywhere, both
I-25 (NB) Exit 264	1.5m	8.01	7.9-8.4	4.10	1920	40	370	670	250 +	0-4	Extreme, little metal remains, everywhere, both
I-25 (NB) Exit 264	2m	8.42	7.9-8.4	6.10	1830	30	501	1041	250 +	0-4	Extreme, little metal remains, everywhere, both
I-25 (NB) Exit 264	Road Base	8.36	7.9-8.4	5.79	-	25	3024	5112	250 +	0-4	Extreme, little metal remains, everywhere, both
I-25 MP 264.2	0m	8.84	7.4-9	4.68	-	55	16018	20964	500 +	0-2	Moderate, scaling, inside-bottom and outside, outside-in
I-25 MP 264.2	1m	8.95	7.4-9	2.97	6630	40	14620	23148	500 +	0-2	Moderate, scaling, inside-bottom and outside, outside-in
I-25 MP 264.2	2m	8.78	7.4-9	2.82	7600	35	15158	19646	500 +	0-2	Moderate, scaling, inside-bottom and outside, outside-in
I-25 MP 264.2 (side bank)	1m	8.30	7.4-9	5.34	-	30	7230	10288	500 +	0-2	Moderate, scaling, inside-bottom and outside, outside-in
I-25 MP 264.2 (side bank)	2m	8.25	7.4-9	7.20	-	35	4722	9634	500 +	0-2	Moderate, scaling, inside-bottom and outside, outside-in
I-25 MP 264.2 (side bank)	3m	8.19	7.4-9	6.08	-	25	7781	12484	500 +	0-2	Moderate, scaling, inside-bottom and outside, outside-in
I-25 (SB) MP 278.7	0m	8.04	6.6-9	11.59	-	30	2908	9990	500 +	0-2	None visible
I-25 (SB) MP 278.7	1m	8.27	6.6-9	6.39	11000	25	3081	7386	500 +	0-2	None visible
I-25 (SB) MP 278.7	2m	8.24	6.6-9	6.24	8540	25	3376	7605	500 +	0-2	None visible
I-40 MP 121	0m	7.43	7.4-8.4	4.27	-	41	854	1504	250-500	2-4	Significant, large holes, upper 2/3's, outside-in
I-40 MP 121	3m	8.06	7.4-8.4	6.93	820	26	834	1724	250-500	2-4	Significant, large holes, upper 2/3's, outside-in
I-40 MP 121	6m	8.06	7.4-8.4	9.14	1100	26	552	981	250-500	2-4	Significant, large holes, upper 2/3's, outside-in
I-40 MP 121	Behind Cul.	7.65	7.4-8.4	9.76	-	21	459	1224	250-500	2-4	Significant, large holes, upper 2/3's, outside-in

Site Name	Location	AASHTO T 289-91 (pH)	NRCS Web Data (pH)	Soil Moisture Content (%)	In-situ 4- pole res. Test (ohm- cm)	CTM-643 Moisture Content at Min. Ohms (%)	CTM-643 (ohm- cm)	NRCS Test method (ohm- cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/c m)	Corrosion Amounts (Degree, description, location, path)
NM 1 MP 19.24	1m	8.27	7.9-8.4	7.51	6680	30	2816	11641	500 +	0-2	None visible
NM 1 MP 19.24	2m	8.49	7.9-8.4	7.53	5420	25	2610	8929	500 +	0-2	None visible
NM 1 MP 19.24	3m	8.26	7.9-8.4	6.24	5620	30	2550	4831	500 +	0-2	None visible
NM 1 MP 21.52	1m	8.06	7.9-8.4	8.78	12000	25	2208	6693	500 +	0-2	None visible
NM 1 MP 21.52	2m	8.06	7.9-8.4	7.01	12400	30	2677	5479	500 +	0-2	None visible
NM 1 MP 21.52	3m	8.01	7.9-8.4	8.41	12800	25	2485	6274	500 +	0-2	None visible
NM 1 MP 22.01	1m	8.20	7.9-8.4	10.42	6190	25	2783	7369	500 +	0-2	None visible
NM 1 MP 22.01	2m	8.17	7.9-8.4	13.32	6170	30	2236	6969	500 +	0-2	None visible
NM 1 MP 22.01	3m	8.19	7.9-8.4	8.66	6350	30	3045	6596	500 +	0-2	None visible
NM 104 MP 42.1	0m	7.90	7.4-8.4	15.76	-	20	3184	20877	500 +	0-2	None visible
NM 104 MP 42.1	1m	7.86	7.4-8.4	12.32	1280	20	4193	12642	500 +	0-2	None visible
NM 104 MP 42.1	2m	7.88	7.4-8.4	11.98	1680	20	4189	17271	500 +	0-2	None visible
NM 104 MP 42.1	3m	7.95	7.4-8.4	9.98	1580	20	4701	22173	500 +	0-2	None visible
NM 104 MP 43	0m	8.06	7.4-8.4	10.88	-	20	2957	19120	500 +	0-2	None visible
NM 104 MP 43	3m	7.73	7.4-8.4	16.12	4300	25	1945	13774	500 +	0-2	None visible
NM 104 MP 43	4m	7.67	7.4-8.4	14.96	4060	30	2062	14620	500 +	0-2	None visible
NM 104 MP 43	5m	7.63	7.4-8.4	16.38	3610	35	1926	14472	500 +	0-2	None visible
NM 104 MP 46.9	0m	7.65	7.4-9	15.80	-	30	1976	15649	500 +	0-2	None visible
NM 104 MP 46.9	1m	7.68	7.4-9	9.92	7130	30	2507	19194	500 +	0-2	None visible
NM 104 MP 46.9	2m	7.61	7.4-9	10.21	9610	30	2261	15723	500 +	0-2	None visible
NM 104 MP 46.9	3m	7.50	7.4-9	10.66	11400	30	2026	13316	500 +	0-2	None visible
NM 117 MP 55	0m	7.70	6.1-8.4	7.30	-	25	6439	11792	500 +	0-2	None visible
NM 117 MP 55	1m	7.78	6.1-8.4	3.78	4780	25	8010	15649	500 +	0-2	None visible
NM 117 MP 55	2m	7.75	6.1-8.4	4.95	5380	25	6383	13550	500 +	0-2	None visible
NM 117 MP 55	4m	7.71	6.1-8.4	6.57	7310	25	6685	15649	500 +	0-2	None visible
NM 117 MP 55	6m	7.70	6.1-8.4	3.99	7640	25	5359	15408	500 +	0-2	None visible
NM 117 MP 55.8	0m	7.86	6.1-8.4	2.81	-	30	3378	6246	500 +	0-2	Minor, scaling, inside bottom, inside-out
NM 117 MP 55.8	1m	7.95	6.1-8.4	3.66	6240	25	4864	10235	500 +	0-2	Minor, scaling, inside bottom, inside-out
NM 117 MP 55.8	2m	7.98	6.1-8.4	2.57	7890	25	7376	13736	500 +	0-2	Minor, scaling, inside bottom, inside-out
NM 117 MP 55.8	3m	7.65	6.1-8.4	3.14	8290	20	4829	11947	500 +	0-2	Minor, scaling, inside bottom, inside-out
NM 117 MP 56	0m	7.61	6.1-8.4	5.11	-	15	4021	15198	500 +	0-2	None visible
NM 117 MP 56	1m	7.61	6.1-8.4	7.59	4230	20	3447	14144	500 +	0-2	None visible
NM 117 MP 56	2m	7.59	6.1-8.4	10.51	7510	20	2619	17361	500 +	0-2	None visible
NM 117 MP 56	3m	7.65	6.1-8.4	7.50	7570	20	4710	20877	500 +	0-2	None visible
NM 117 MP 57	Behind Cul.	8.64	6.6-8.4	3.94	-	40	132	62	500 +	0-2	Considerable, pitting/small holes, top and sides, outside-in
NM 117 MP 57	3m	8.11	6.6-8.4	3.36	8450	30	3239	9355	500 +	0-2	Considerable, pitting/small holes, top and sides, outside-in
NM 117 MP 57	4m	7.71	6.6-8.4	6.52	25900	30	2218	8525	500 +	0-2	Considerable, pitting/small holes, top and sides, outside-in
NM 117 MP 57	5m	7.72	6.6-8.4	6.30	39000	25	3226	10965	500 +	0-2	Considerable, pitting/small holes, top and sides, outside-in

Site Name	Location	AASHTO T 289-91 (pH)	NRCS Web Data (pH)	Soil Moisture Content (%)	In-situ 4- pole res. Test (ohm- cm)	CTM-643 Moisture Content at Min. Ohms (%)	CTM-643 (ohm- cm)	NRCS Test method (ohm- cm)	NRCS Web Data (ohm-cm)	NRCS Web Data (mmho/c m)	Corrosion Amounts (Degree, description, location, path)
NM 128 MP 21.93	1m	8.22	6.6-7.8	1.52	29200	25	10871	9066	500 +	0-2	None visible
NM 128 MP 21.93	2m	8.15	6.6-7.8	1.87	29400	25	9408	10194	500 +	0-2	None visible
NM 128 MP 21.93	3m	8.21	6.6-7.8	1.66	24000	25	10495	9149	500 +	0-2	None visible
NM 195 MP 1.51	1m	8.27	7.9-8.4	5.54	3090	25	1645	11641	500 +	0-2	Moderate, scaling, inside-top and outside, outside-in
NM 195 MP 1.51	2m	8.49	7.9-8.4	5.66	2550	25	1800	8929	500 +	0-2	Moderate, scaling, inside-top and outside, outside-in
NM 195 MP 1.51	3m	8.26	7.9-8.4	3.99	2080	30	1844	4831	500 +	0-2	Moderate, scaling, inside-top and outside, outside-in
NM 290 MP 0.65	0m	9.06	7.4-8.4	1.31	-	35	8717	9434	500 +	0-2	Extreme, massive holes, everywhere, both
NM 290 MP 0.65	1m	8.26	7.4-8.4	6.69	-	25	6786	11111	500 +	0-2	Extreme, massive holes, everywhere, both
NM 290 MP 0.65	2m	7.96	7.4-8.4	4.49	-	20	5282	9911	500 +	0-2	Extreme, massive holes, everywhere, both
NM 290 MP 0.65	3m	8.93	7.4-8.4	2.23	-	20	3768	4975	500 +	0-2	Extreme, massive holes, everywhere, both
NM 290 MP 0.65	Behind Cul.	8.14	7.4-8.4	2.56	-	50	112	80	500 +	0-2	Extreme, massive holes, everywhere, both
NM 290 MP 0.91	0m	7.83	7.4-8.4	7.95	-	25	3656	9452	500 +	0-2	Abundant, scaling, everywhere, both
NM 290 MP 0.91	2m	8.19	7.4-8.4	7.67	9290	15	4340	10593	500 +	0-2	Abundant, scaling, everywhere, both
NM 290 MP 0.91	3m	8.22	7.4-8.4	6.24	11800	15	4371	9524	500 +	0-2	Abundant, scaling, everywhere, both
NM 290 MP 0.91	4m	8.28	7.4-8.4	6.07	9860	20	4749	10695	500 +	0-2	Abundant, scaling, everywhere, both
NM 290 MP 1.0	0m	8.61	7.4-8.4	3.15	-	40	10250	10406	500 +	0-2	None visible
NM 290 MP 1.0	2m	8.65	7.4-8.4	20.00	258	20	2260	3759	500 +	0-2	None visible
NM 290 MP 1.0	3m	8.40	7.4-8.4	16.45	1490	20	2500	3704	500 +	0-2	None visible
NM 290 MP 1.0	4m	8.40	7.4-8.4	19.83	1560	30	1420	2155	500 +	0-2	None visible
US 60 MP 203.41	0m	8.03	6.6-8.4	14.50	-	25	2905	4587	500 +	0-2	None visible
US 60 MP 203.41	1m	8.00	6.6-8.4	16.74	5260	25	3090	3731	500 +	0-2	None visible
US 60 MP 203.41	2m	8.07	6.6-8.4	16.09	6450	25	3190	3497	500 +	0-2	None visible
US 60 MP 203.41	3m	8.12	6.6-8.4	14.11	7900	25	3575	4405	500 +	0-2	None visible
US 60 MP 204.33	0m	7.91	7.9-8.4	15.93	-	30	4615	5206	500 +	0-2	Abundant, scaling, everywhere, both
US 60 MP 204.33	0.5m	8.16	7.9-8.4	17.99	2070	25	3801	4444	500 +	0-2	Abundant, scaling, everywhere, both
US 60 MP 204.33	1m	8.53	7.9-8.4	11.34	3280	20	4169	4329	500 +	0-2	Abundant, scaling, everywhere, both
US 60 MP 204.33	2m	8.24	7.9-8.4	10.55	3800	20	4310	3584	500 +	0-2	Abundant, scaling, everywhere, both

APPENDIX 5: CULVERT DATA

Site Name	Lat.	Long.	Inlet or Outlet	Diameter (in)	Uncorroded Thickness	Approx. Gage	Distance from end	Ultrasonic Measurement Locations and Metal Thickness (in)								
								1	2	3	4	5	6	7	8	9
I-25 MP 107.86	33.530472	-107.192628	Outlet	24	0.0656	16	8	0.069	0.069	0.065	0.069	0.047	0.070	0.065	0.064	0.059
I-25 MP 113.04	33.599222	-107.156995	Inlet	160												
I-25 MP 142.49	33.945823	-106.883664	Outlet	24	0.0714	14	9	0.068	0.071	0.072	0.070	0.071	0.071	0.071	0.071	0.072
I-25 (NB) Exit 264	35.514679	-106.227972	Both	24?												
I-25 MP 264.2	35.513147	-106.232569	Inlet	78		16	24		0.059	0.057	0.057	0.069	0.056	0.059		
I-25 MP 264.2	35.513147	-106.232569	Inlet	78		16	24		0.056	0.060	0.057	0.066	0.056	0.060	0.056	
I-25 (SB) MP 278.7	35.614467	-106.018556	Inlet	24	0.0581	16	12	0.000	0.061	0.061	0.060	0.058	0.060	0.061	0.061	0.000
I-40 MP 121 (East)	34.993738	-107.273514	Inlet	36	0.0723	14	60	0.059	0.056	0.041	0.044	0.059	0.046	0.046	0.059	0.061
I-40 MP 121 (Middle)	34.993738	-107.273514	Inlet	36	0.0723	14	36	0.059	0.042	0.040	0.039	0.045	0.051	0.058	0.059	0.059
I-40 MP 121 (West)	34.993738	-107.273514	Inlet	36	0.0723	14	48	0.060	0.051	0.035	0.044	0.063	0.045	0.039	0.053	0.060
NM 1 MP 19.24	33.573967	-107.192686	Inlet	24	0.0803	14	8	0.078	0.080	0.072	0.083	0.082	0.084	0.083	0.079	0.082
NM 1 MP 21.52	33.597393	-107.165701	Inlet	24	0.0868	14	13	0.086	0.088	0.087	0.087	0.087	0.086	0.087	0.087	0.087
NM 1 MP 22.01	33.602571	-107.159770	Inlet	36	0.1200	12	13	0.120	0.120	0.119	0.120	0.120	0.120	0.120	0.120	0.120
NM 104 MP 42.1	35.466789	-104.569126	Inlet	24	0.0775	14	7	0.079	0.078	0.078	0.077	0.078	0.079	0.078	0.078	0.077
NM 104 MP 43 (East)	35.465403	-104.553997	Inlet	60	0.1446	10	42	0.146	0.144	0.142	0.141	0.140	0.141	0.141	0.143	0.146
NM 104 MP 43 (West)	35.465403	-104.553997	Inlet	60	0.1445	10	35	0.145	0.147	0.144	0.146	0.146	0.145	0.147	0.147	0.147
NM 104 MP 46.9	35.454144	-104.491351	Inlet	30	0.0770	14	12	0.082	0.079	0.077	0.077	0.079	0.079	0.078	0.078	0.079
NM 117 MP 55	35.070587	-107.792440	Inlet	30	0.0740	14	12	0.071	0.069	0.067	0.067	0.068	0.065	0.068	0.070	0.069
NM 117 MP 55.8	35.078318	-107.780060	Inlet	30	0.0659	16	19	0.064	0.063	0.063	0.064	0.062	0.064	0.064	0.063	0.064
NM 117 MP 56	35.079379	-107.778111	Inlet	32	0.0628	16	10	0.062	0.062	0.062	0.063	0.062	0.062	0.062	0.063	0.062
NM 117 MP 57	35.090045	-107.770201	Inlet	36	0.0673	14	20	0.061	0.069	0.060	0.060	0.059	0.050	0.061	0.062	0.055
NM 128 MP 21.93 (East)	32.217420	-103.683702	Inlet	36	0.0618	16	18	0.062	0.062	0.061	0.061	0.061	0.060	0.061	0.061	0.062
NM 128 MP 21.93 (West)	32.217420	-103.683702	Inlet	36	0.0613	16	18	0.061	0.060	0.059	0.061	0.062	0.062	0.063	0.062	0.061
NM 195 MP 1.51	33.206586	-107.237155	Inlet	24	0.0769	14	8	0.081	0.080	0.077	0.080	0.079	0.079	0.078	0.085	0.078
NM 290 MP 0.65	35.625324	-106.712603	Inlet	48	0.1147	12	72	0.109	0.095	0.095	0.101	0.113	0.093	0.096	0.105	0.107
NM 290 MP 0.91	35.624701	-106.708299	Inlet	24	0.0860	14	12	0.081	0.081	0.088	0.081	0.093	0.082	0.083	0.076	0.068
NM 290 MP 1.0	35.624923	-106.707299	Inlet	24	0.0617	16	19	0.059	0.059	0.060	0.060	0.059	0.061	0.059	0.059	0.059
US 60 MP 203.41	34.512503	-106.256594	Inlet	42	0.1170	12	12	0.117	0.117	0.115	0.117	0.114	0.115	0.114	0.118	0.122
US 60 MP 204.33	35.520333	-106.244496	Outlet	24	0.0790	14	12	0.072	0.079	0.078	0.106	0.105	0.108	0.065	0.069	0.072

