DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Transportation Laboratory
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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 ± 15°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 determine in Section I:

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

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:

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

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):

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

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

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.

End of Text
(California Test 643 contains 10 pages)

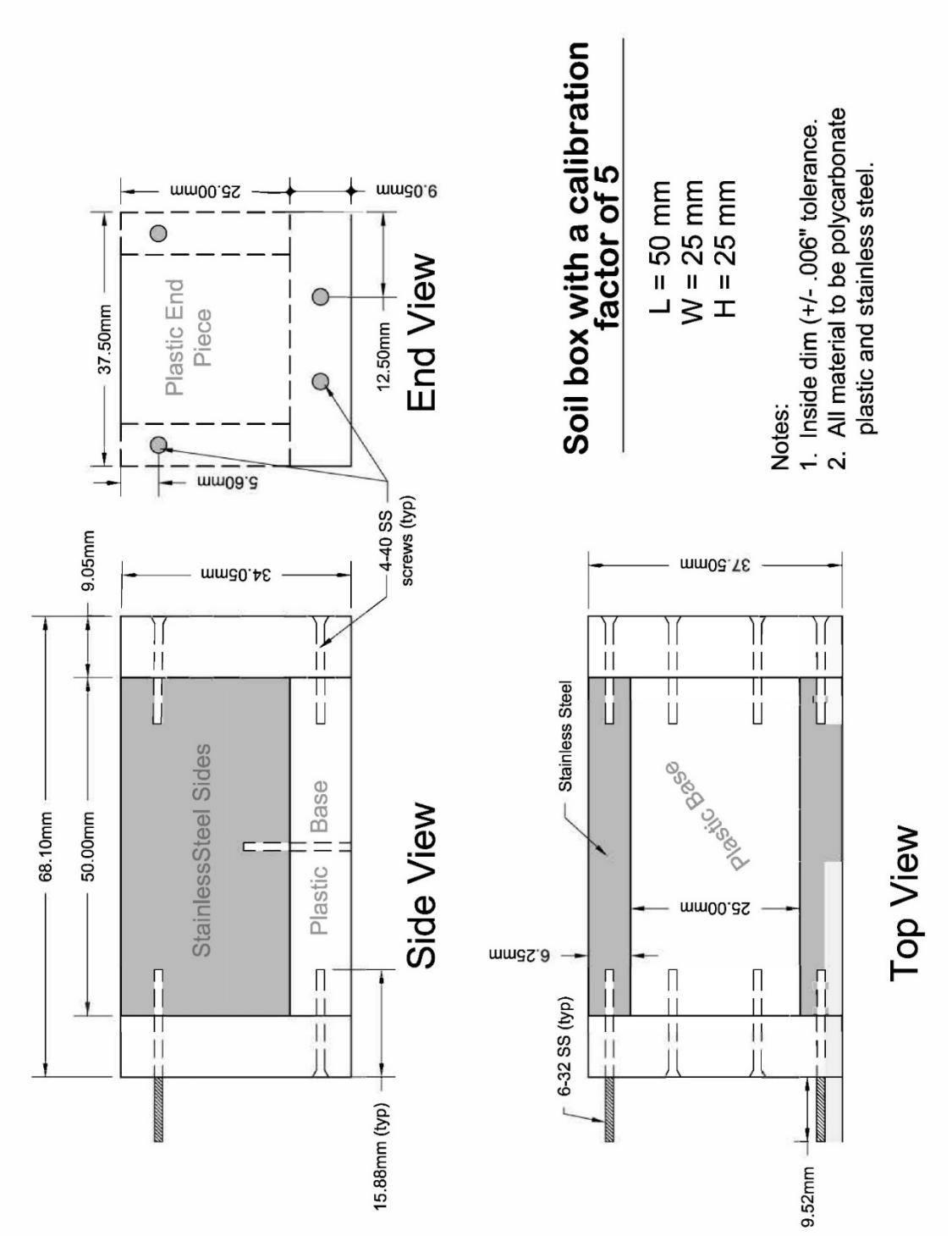


FIGURE 1. Soil Box for Laboratory Minimum Resistivity Determination

DATE REC'D:

CT 643 DATA REPORTING FORM

TL#:

	Total Moisture Content (%) B	Total Water Added (mL) A x B	Soil Sample Resistance R (Ohms)
	11.5		
	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		

Corrosion Test No.	Date Tested:
Project No.	Tested By:
Mass of Soil Sample Tested (A) _______ g	**Sample Temperature (T)** **T** = _______ °C

Minimum Soil Resistivity[1] ρ
(Corrected for temperature and soil box constant)

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

ρ = _______ (Ohm-cm)

Water Resistivity[2]
(Corrected for temperature and soil box constant)

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

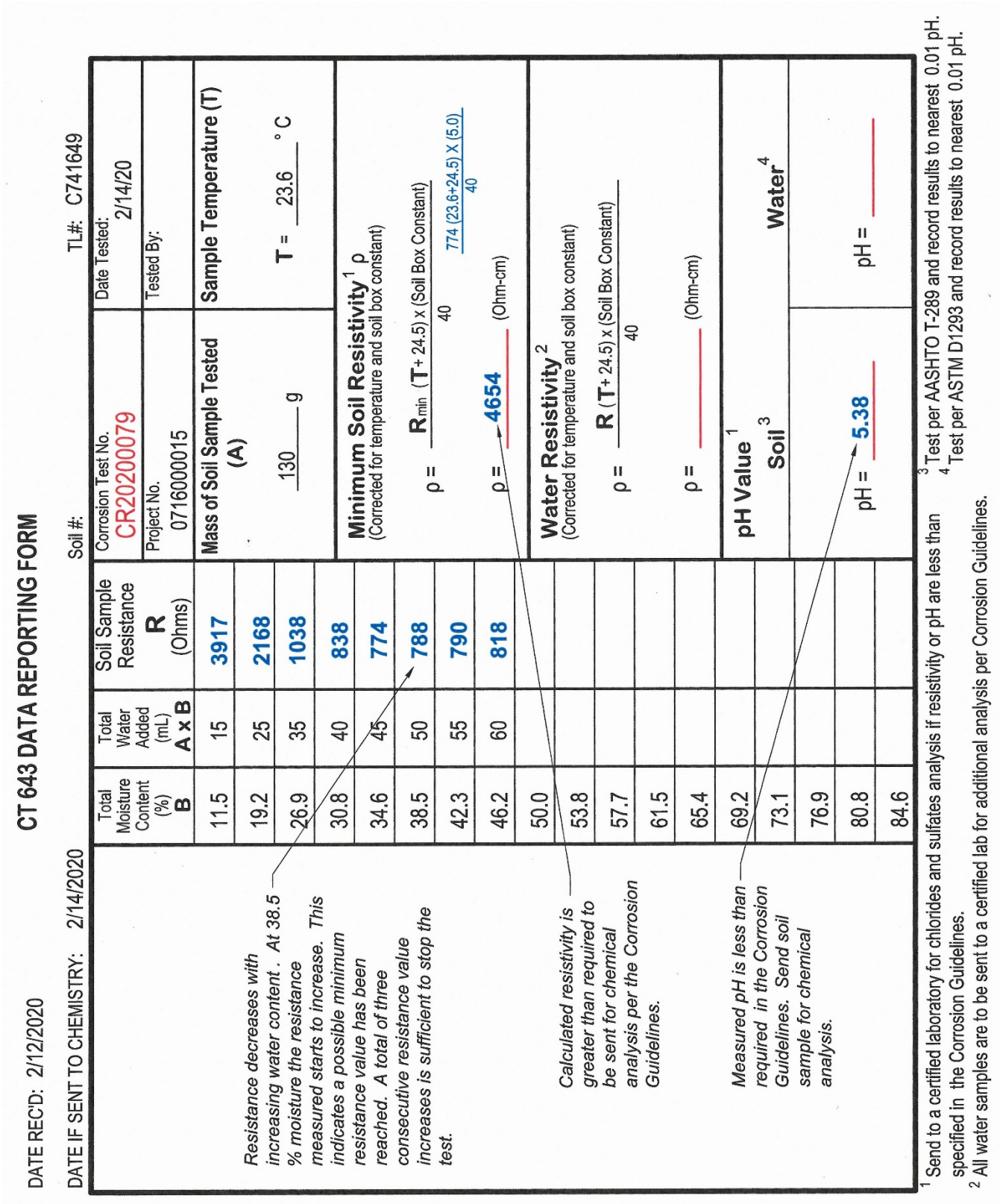
ρ = _______ (Ohm-cm)

pH Value[1]

Soil[3]	**Water**[4]
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



DATE REC'D: 2/12/2020

CT 643 DATA REPORTING FORM

DATE IF SENT TO CHEMISTRY: 2/14/2020

Soil #:

TL#: C741649

Total Moisture Content (%) B	Total Water Added (mL) A x B	Soil Sample Resistance R (Ohms)
11.5	15	3917
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		

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.

Corrosion Test No. CR20200079

Project No. 0716000015

Date Tested: 2/14/20

Tested By:

Mass of Soil Sample Tested (A)

130 g

Sample Temperature (T)

T = 23.6 °C

Minimum Soil Resistivity[1] ρ
(Corrected for temperature and soil box constant)

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

$\rho = \frac{774\ (23.6+24.5) \times (5.0)}{40}$

ρ = 4654 (Ohm-cm)

Water Resistivity[2]
(Corrected for temperature and soil box constant)

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

ρ = _____ (Ohm-cm)

pH Value[1]

Soil[3] pH = 5.38

Water[4] 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 3. CT 643 Data Reporting Form Example