Paper No.
C2025-00559

AMPP ANNUAL CONFERENCE + EXPO
APRIL 6-10, 2025 | NASHVILLE, TENNESSEE

Safeguarding Pump Stations: Ensuring Adequate Cathodic Protection with Advanced Monitoring Tools

Zachary Mulder, Steve Wagner, and Jared Fleming
Ottawa County Sanitary Engineering Department
Port Clinton, Ohio 43452
USA

Farzan Zolfaghari, Mehrooz Zamanzadeh, Aaron Ulmer, and Anil Kumar Chikkam
Matergenics Inc
100 Business Center Dr
Pittsburgh, PA, 15205
USA

ABSTRACT

In the water and wastewater industries, corrosion protection typically prioritizes water mains and related components, often overlooking critical infrastructure such as sewage pump stations. However, it is crucial to ensure that the carbon steel walls of pump station dry wells receive adequate cathodic protection (CP) and meet the minimum -850mV CP criterion. Acknowledging this need, the Ottawa County Sanitary Engineering Department proactively implemented impressed current CP systems across its pump stations, aiming for optimal performance and long-term asset protection.

This paper demonstrates how the Ottawa County Sanitary Engineering Department further enhanced infrastructure reliability by conducting a comprehensive evaluation of the installed CP systems, beyond the initial contractor reports. While these reports provide initial verification, they do not ensure ongoing protection once the systems are operational. To bridge this gap, wireless sensors were deployed at the pump stations to continuously monitor real-time structure-to-soil potential data.

These sensors are instrumental in swiftly identifying critical corrosion potentials, allowing for timely corrective actions. Additionally, the sensors' WebView feature facilitates efficient data analysis and visualization, enabling the department to monitor periods of inadequate protection. This strategic, proactive approach ensures the long-term structural integrity of pump stations, safeguarding critical assets and preventing costly failures.

Keywords: Cathodic Protection, Sewage Pump Stations, Corrosion Monitoring, Structure-to-Soil Potential, Impressed Current CP Systems (ICCP), Infrastructure Reliability, Wireless Sensors, Water and Wastewater Industry.

INTRODUCTION

Municipal water and sewer systems rely on buried prefabricated steel pump stations, which are critical components of infrastructure. Corrosion of these buried structures (Figure 1) can have serious financial and operational implications, compromising public safety and resulting in expensive repairs or environmental hazards. Ensuring the long-term integrity of these pump stations is essential, as they often contain pumps, piping, CP test panel, electronic equipment or provide necessary access for future maintenance (Figures 2 – 4).

Figure 1: Photograph showing the exterior of the pump station (i.e., entrance tube) at grade level.

Figure 2: Photograph showing the electronic control systems essential for the automated operation of the pump station, reducing the need for direct human involvement.

Figure 3: Photograph showing pumps and its associated piping in the pump station chamber.

Figure 4: Photograph showing test panel for sacrificial CP system.

To combat corrosion, these stations are typically coated with protective layers on both internal and external surfaces, and manufacturers often incorporate sacrificial magnesium anodes as part of the corrosion management strategy. These anodes are designed to offer CP by delivering a current to the exposed metal areas, especially at points where coatings may have been damaged during installation or fabrication. However, while these systems can initially provide protection, the effectiveness of magnesium anodes is often temporary and varies based on environmental factors.

In many cases, the protective function of sacrificial anodes is limited, and they may fail to offer sufficient defense over time. Soil conditions, moisture, and installation quality all influence the performance of these anodes, leading to inconsistent results. Once the anodes degrade or are consumed, the underlying steel becomes vulnerable to corrosion, posing risks to both the functionality and longevity of the system.

Recognizing the limitations of sacrificial anodes, forward-thinking municipalities, such as Ottawa County, pursue more robust corrosion protection strategies by considering impressed current cathodic protection (ICCP) systems. ICCP systems use an external power source to deliver a continuous protective current, ensuring consistent and effective corrosion prevention, even in harsh environments. When correctly designed and maintained, these systems significantly extend the service life of pump stations, reduce maintenance demands, and help prevent disruptions to critical infrastructure.

CASE STUDY:
UPGRADATION OF THE EXISTING GALVANIC CP SYSTEMS TO ICCP SYSTEMS

Introduction

The six pump stations under consideration feature a combination of steel dry wells and concrete wet wells, all constructed with a similar design. The dry wells, made of steel, are buried at depths ranging from 30 to 35 feet below the surface. Each of these cylindrical well's measure about 10 feet in diameter and extends 9 feet in height at the base. Access to these dry wells is provided through shafts measuring between 36 and 42 inches in diameter. Due to varying ground elevations and dry well depths, the access tubes differ in length, though a typical design assumes them to be around 25 feet long. Most of these stations were installed in 1980, making the infrastructure several decades old and subject to corrosion-related challenges.

A key feature of these sewage lift stations is the absence of electrical isolation between the metallic components. This design choice creates an electrically continuous system, connecting the steel wells with structural elements such as beams, metallic pipes, and the alternating current (AC) grounding systems used during installation. As a result, these lift stations become electrically linked to other buried metallic structures that are also connected to the grounding network.

This extensive electrical continuity leads to a large bare metallic surface area underground, which presents a significant challenge for corrosion control. Sacrificial anodes, typically employed for corrosion protection, lose effectiveness when spread across large interconnected surfaces. These anodes function by gradually corroding in place of the protected metal, but when too much surface area is connected, the anodes deplete quickly. This shortens the lifespan of the anodes and leaves the underlying steel vulnerable to corrosion sooner than expected.

Given the advanced age of the stations, as well as their interconnected electrical nature, relying solely on sacrificial anodes may not provide sufficient long-term protection. To ensure the durability and functionality of these essential pump stations, more robust corrosion management solutions are required. Implementing an ICCP system can be a more effective approach. ICCP systems use a continuous external power source to maintain protection, ensuring the steel remains protected even across extensive connected surfaces.

In conclusion, while these six pump stations have served reliably since their installation, their design—particularly the absence of electrical isolation—poses long-term corrosion risks. Addressing these challenges with advanced corrosion prevention systems, such as ICCP, is essential for preserving the integrity of the infrastructure and maintaining uninterrupted service.

Test Results

Visual Examination

A detailed visual inspection was conducted on the six pump stations under evaluation (Figures 5 - 10). Each station features an external epoxy coating designed to protect the steel structures from corrosion caused by contact with the surrounding soil environment. The interior surfaces of the stations are coated with a polyamide epoxy, which serves as an additional layer of protection against internal corrosion. During the original construction of each lift station, two 17-pound magnesium anodes were installed and directly connected to the exterior shell of the steel dry well to provide cathodic protection.

The interior polyamide epoxy coatings were found to be in good condition, indicating minimal wear and no visible signs of degradation (Figure 11 – 12). Similarly, the external epoxy coatings on the dry wells appeared intact, suggesting that they continue to offer effective protection against corrosion. However, some coating removal was observed at the external surface of the entrance tubes at grade level, likely due to mechanical abrasion or damage during installation. This localized coating loss exposes sections of the steel tubes to environmental elements, increasing the risk of future corrosion. If left unaddressed or if the magnesium anodes become depleted, the CP system may no longer provide adequate defense, further accelerating the potential for corrosion.

Despite this minor coating loss, there was no visible evidence of corrosion on the metallic components within the pump station chamber, including connections and other exposed metal surfaces. This suggests that the anodes and coatings have, so far, provided adequate protection. However, the current state of the coatings, particularly around exposed sections near the entrance tubes, highlights the need for proactive maintenance to prevent potential corrosion in these vulnerable areas.

Figure 5: Photograph showing pump station 2.

Figure 6: Photograph showing pump station 3.

Figure 7: Photograph showing pump station 4.

Figure 8: Photograph showing pump station 5.

Figure 9: Photograph showing pump station 7.

Figure 10: Photograph showing pump station 9.

Figure 11: Photograph showing internal view of the pump station 5.

Figure 12: Photograph showing internal view of the pump station 5.

The visual inspection confirmed that both the internal and external coatings are generally in good condition. However, the exposed sections of the entrance tubes at grade level present a potential risk for future corrosion. To address this proactively, Ottawa County initiated a review of the existing galvanic CP system to ensure it is still providing adequate protection. The County engaged the contractor to conduct condition assessment of the pump stations and CP survey. If the results do not meet the -850mV minimum criterion, [1] plans are in place to upgrade the current galvanic CP system to an ICCP system. This upgrade would offer more consistent, reliable, and long-term corrosion protection, particularly given the advanced age of these pump stations.

Wall Thickness and Coating Thickness Measurement

Ultrasonic wall thickness measurements were conducted on the entrance tubes of the pump stations using an ultrasonic wall thickness gauge. Additionally, the coating thickness was assessed with a Positector gauge†. Both measurements were taken at a depth of 1 to 3 feet from the top surface of the entrance tubes to provide consistent data for evaluation. The results, detailed in Table 1, serve as a baseline for future inspections, allowing for comparisons over time to monitor any potential degradation in wall or coating thickness. Figures 13 and 14 provide representative images displaying the coating thickness and wall thickness measurements for Pump Station 5.

These measurements are essential for assessing the structural integrity and protective effectiveness of the pump stations. Monitoring wall thickness helps identify potential metal loss due to corrosion, while tracking coating thickness ensures the protective layer remains intact to prevent exposure to corrosive elements.

Having this baseline data allows for early detection of material deterioration and helps in planning maintenance activities. Significant reductions in wall thickness over time could indicate corrosion issues that require immediate attention, while any thinning of the protective coating may warrant reapplication to prevent metal exposure.

Table 1:
Wall Thickness and Coating Thickness Data

Pump Station	Coating Thickness (mils)					Wall Thickness (inches)				
	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5
2	6.8	19.1	24.7	14.5	12.7	0.306	0.326	0.337	0.347	0.310
3	10.3	15.3	15.8	13.6	14.1	0.302	0.322	0.311	0.313	0.316
4	17.2	15.6	15.2	11.8	12.1	0.312	0.289	0.320	0.318	0.314
5	10.3	12.9	11.5	13.1	17.7	0.314	0.295	0.296	0.322	0.302
7	23	25.8	22.1	20.3	22.6	0.339	0.350	0.317	0.340	0.326
9	5.8	14.9	9.8	5.5	10.3	0.303	0.307	0.290	0.282	0.384

† Trade Name

Figure 13: Photograph showing the coating thickness (in mils) of entrance tube of the pump station 5.

Figure 14: Photograph showing the wall thickness (in inches) of entrance tube of the pump station 5.

<u>Structure-to-Soil Potential Measurements</u>

Structure-to-soil potential measurements for the pump stations equipped with the existing galvanic CP system are summarized in Table 2. The results indicate that none of the evaluated pump stations—specifically stations 2, 3, 4, 5, 7, and 9—met the minimum protection criterion of -850 mV with CP applied. These readings suggest that the magnesium anodes originally installed on the exterior of the dry wells during construction have been depleted over time, reducing the effectiveness of the CP system.

Table 2:
Structure-to-soil potential data of galvanic CP systems

No.	LOCATION/DESCRIPTION	Structure-To-Soil ON Potential (millivolts)					
		PS 2	PS 3	PS 4	PS 5	PS 7	PS 9
1	North Side	-662	-566	-631	-560	-709	-620
2	South Side	-735	-566	-633	-536	-647	-543
3	East Side	-946	-576	-674	-552	-589	-647
4	West Side	-873	-573	-625	-554	-935	-621

Figures 15 and 16 present representative images of the structure-to-soil ON potential measurements for Pump Station 5, illustrating the process used to assess the effectiveness of the existing CP system. These images, along with the data in Table 2, provide a comprehensive view of the current state of the pump stations' corrosion protection systems.

The depletion of the sacrificial magnesium anodes highlights the limitations of the galvanic system, especially given the age of the stations, which were installed in 1980. Without adequate CP, the steel structures become increasingly vulnerable to corrosion, which can compromise their integrity and lead to costly repairs or downtime.

The structure-to-soil potential data, collected and analyzed by the contractor, played a crucial role in guiding Ottawa County's decision-making process. Based on the inadequate readings, the County determined that the existing galvanic CP system was no longer sufficient to provide long-term corrosion protection. As a result, the decision was made to replace the depleted galvanic system with an ICCP system.

Figure 15: Photograph showing the structure-to-soil ON potential of the pump station 5.

Figure 16: Photograph showing the structure-to-soil ON potential of the pump station 5.

Note: Given the absence of a specific NACE (now AMPP) standard for the CP requirements of underground lift stations, Ottawa County referred to NACE SP0285-2011 – "External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection" as a guideline. [1] This standard provided a robust framework for ensuring that the ICCP system would deliver the required protection for the pump stations' carbon steel walls.

<u>CP Design</u>

Almost all six sites have challenges with the drilling due to rocky conditions. Initally, anodes distributed around the pump station was planned, but because of the site conditions, instead of drilling four holes around the pump stations, a single hole with shallow well anode system was planned and the design is shown in Figure 17. Since all six stations feature similar dry well designs, the ICCP systems followed a consistent configuration. Each pump station included four tubular Mixed Metal Oxide (MMO) anodes, arranged vertically within a 10-inch diameter well extending 50 feet deep.

To ensure efficient conductivity and optimal anode performance, the well must be backfilled with coke breeze, which extends one foot above the uppermost anode. The anodes have to be powered by a air-cooled rectifier unit that accepts 110-volt AC input. Each anode must have its own lead wire, which terminates at the rectifier's positive output terminal through a junction box mounted next to the rectifier. The individual anode leads must connect to a common bus bar via shunts to allow for precise monitoring of the current output from each anode during testing and routine inspections.

The positive output circuit of the rectifier must connect the positive output terminal to the common bus bar, completing the positive circuit. The negative return connection must be mechanically bolted to the entrance tube at or near grade level. From there, the negative lead connects to the rectifier's negative terminal, completing the electrical circuit.

The use of MMO anodes with ICCP technology ensures reliable, long-term corrosion protection by delivering a continuous current, even in demanding environmental conditions. The shunts provide accurate monitoring of each anode's performance, enabling proactive maintenance to extend the service life of the pump stations.

This system design ensures that Ottawa County can protect its infrastructure effectively while facilitating efficient monitoring and maintenance. With the rectifiers and all electrical connections properly managed, the ICCP system must deliver consistent protection and guarantee uninterrupted operation of these critical pump stations.

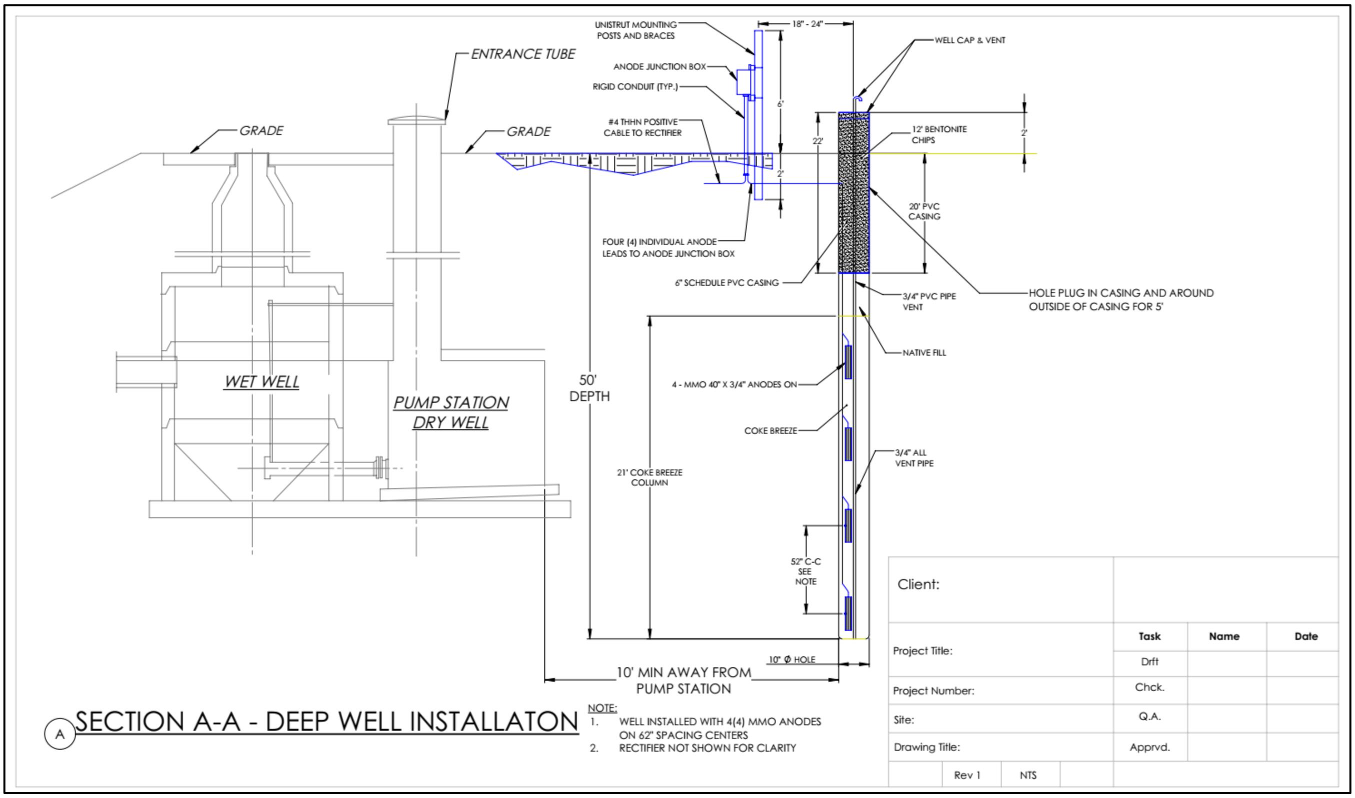

Figure 17: Photograph showing the CP design.

Figure 18: Photograph taken during the drilling process for anodes installation at pump station 5.

Figure 19: Photograph taken during the placement of the anodes and vent pipe in the drilled hole.

CP Installation

The new rectifiers and the junction boxes were installed by Ottawa County at all six pump stations. The modified shallow well anodes system was installed in a 50 feet deep hole, featuring a 20 feet PVC casing at the top, and steel casings where required. Within this setup, MMO anodes were strategically placed at varying depths from the ground level. The anode holes were efficiently backfilled with coke breeze, which is known for its effectiveness in enhancing CP processes. Figures 18 and 19 show representative pictures taken during the drilling and anode installation process.

Figure 20 a): Photograph showing the junction box.

Figure 20 b): Photograph showing the rectifier.

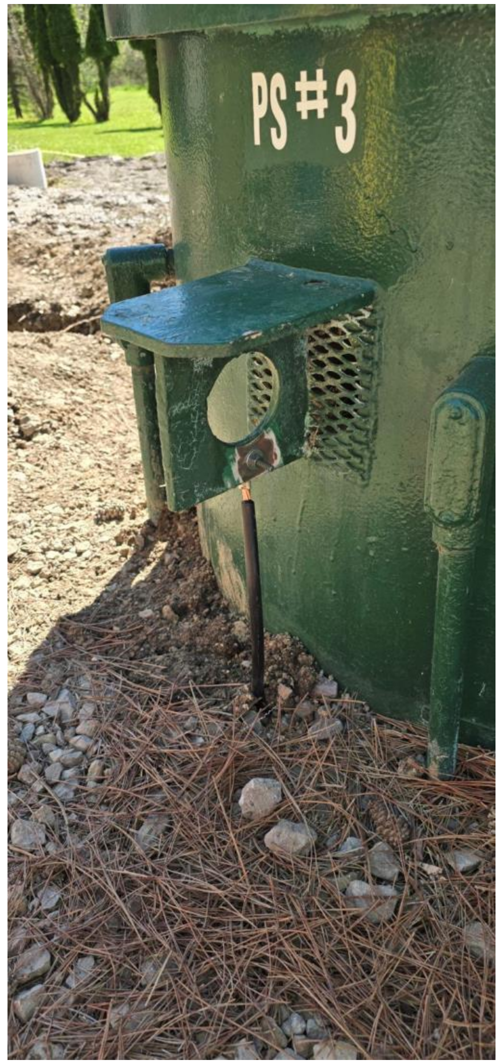

Figure 21: Photograph showing the other end of the header cable connected to the negative terminal of the rectifier is bolted to the structure at pump station 3.

The anode leads were meticulously routed to a junction box (Figure 20 a)). From this central point, a header cable was neatly run to the rectifier (Figure 20 b)), facilitating the effective flow of current throughout the system. One end of the header cable was bolted to the structure (Figure 21) and the other end is run to the negative terminal of the rectifier.

After CP installation, the tap settings in the rectifiers were set to ensure that the structures are receiving adequate CP i.e., more negative than -850 mV in the OFF condition.

Structure-to-Soil Potential Measurements

The structure-to-soil potential measurements were obtained using a portable copper-copper sulfate reference electrode (PRE), placed in contact with the soil or gravel and connected to a digital voltmeter. Specifically, the reference electrode was connected to the negative terminal of the voltmeter, while the structure was connected to the positive terminal.

Initially, ON potentials were recorded. Then, the rectifier was interrupted to obtain the OFF readings. Both the ON and OFF potentials were found to be more negative than -850 mV. Table 3 presents the ON potential data after upgrading to the new ICCP system. The data clearly shows that the ON potentials are more electronegative than -850 mV compared to the previous survey data listed in Table 2. This significant finding indicates that the new ICCP system is highly effective, providing adequate CP to the pump stations. Figures 22 and 23 present representative images of the structure-to-soil ON potential measurements for Pump Station 5, illustrating the process used to assess the effectiveness of the upgraded CP system.

Table 3:
Structure-to-soil potential data of new ICCP systems

No.	LOCATION/DESCRIPTION	Structure-To-Soil ON Potential (millivolts)					
		PS 2	PS 3	PS 4	PS 5	PS 7	PS 9
1	North Side	-1042	-1092	-1559	-1440	-1682	-1284
2	South Side	-1288	-1317	-1518	-1641	-1587	-1213
3	East Side	-1444	-1511	-1590	-1764	-1611	-1229
4	West Side	-1171	-1217	-1704	-1807	-1576	-1222

Figure 22: Photograph showing the structure-to-soil ON potential of the pump station 5.

Figure 23: Photograph showing the structure-to-soil ON potential of the pump station 5.

Structure-to-Soil potential measurements confirm that the newly installed ICCP system is functioning as intended, offering enhanced protection to the carbon steel structures at the pump stations. This ensures that the structures are safeguarded against external corrosion, maintaining their integrity and prolonging their operational life.

Real Time Structure-to-Soil Potentials Monitoring by Sensors

After the installation of the new ICCP system, initial structure-to-soil potential readings may appear satisfactory. However, there is no way to confirm whether the structures are continuously receiving adequate protection until the next survey. To address this limitation, Ottawa County has implemented real-time structure-to-soil potential monitoring using EnviroZense sensors† (Figure 24). These sensors are durable, advanced devices designed to provide real-time data on the structure's protection status.

Figure 24: Photograph showing the real time structure-to-soil potentials monitoring sensor attached to the rectifier.

The sensor continuously monitors the structure-to-soil potentials and sends immediate notifications if the structure is not receiving adequate protection. This system offers Ottawa County a proactive solution for managing corrosion risks. Through the sensor WebView platform, Ottawa County can monitor potential data from each structure in real time. Critical corrosion potentials are highlighted for quick identification, allowing the team to prioritize structures that require immediate attention.

In addition to real-time alerts, the system also graphs data (Figure 25 – 30), providing an easy-to-read analysis of how long each structure has been exposed to corrosive environments. This feature simplifies the tracking of long-term trends and ensures that Ottawa County can take timely actions to preserve the integrity of their infrastructure.

† Trade Name

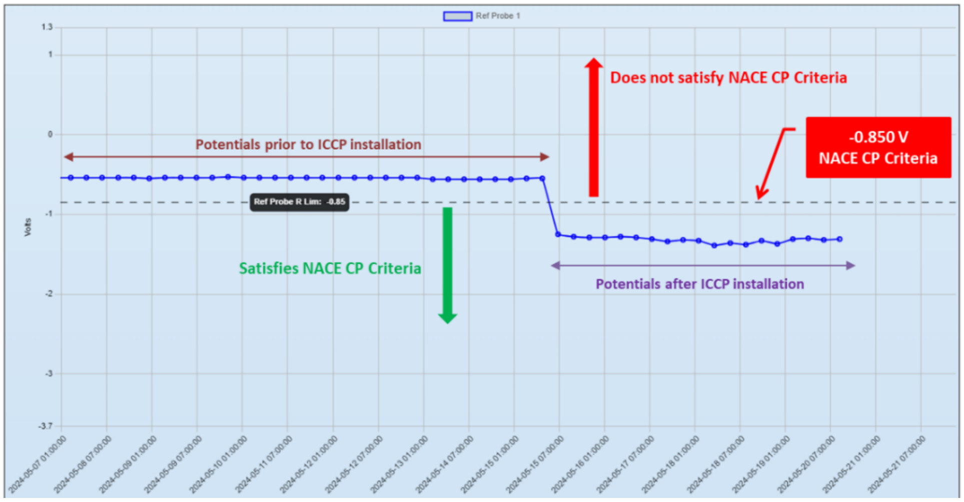

Figure 25: Plot showing the real time structure-to-soil potential data of pump station 2.

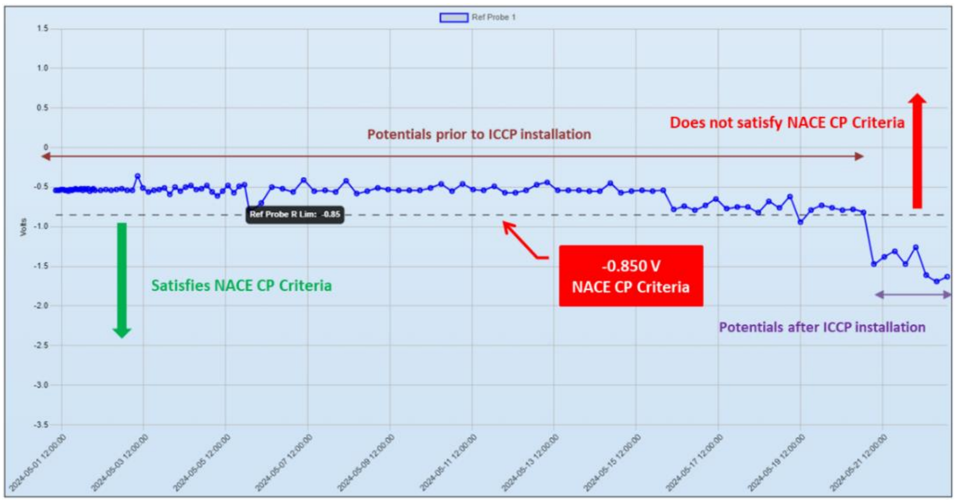

Figure 26: Plot showing the real time structure-to-soil potential data of pump station 3.

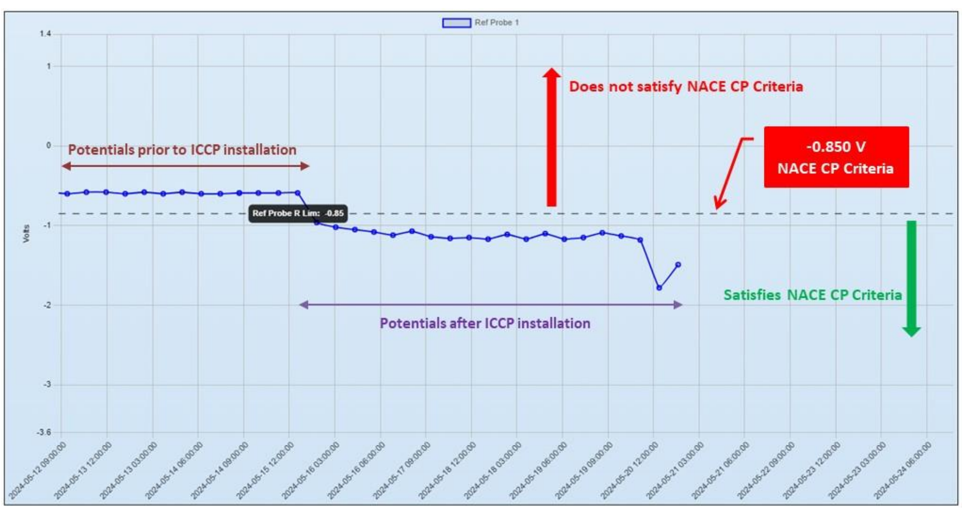

Figure 27: Plot showing the real time structure-to-soil potential data of pump station 4.

Figure 28: Plot showing the real time structure-to-soil potential data of pump station 5.

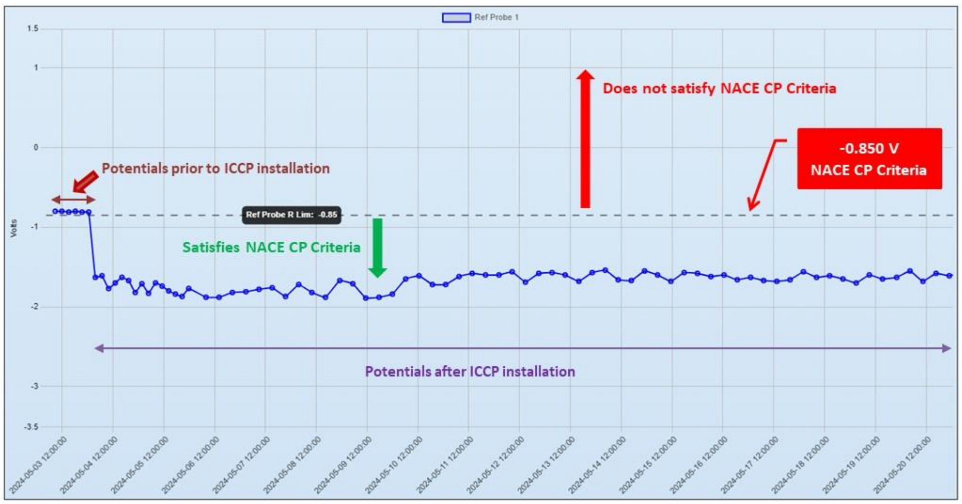

Figure 29: Plot showing the real time structure-to-soil potential data of pump station 7.

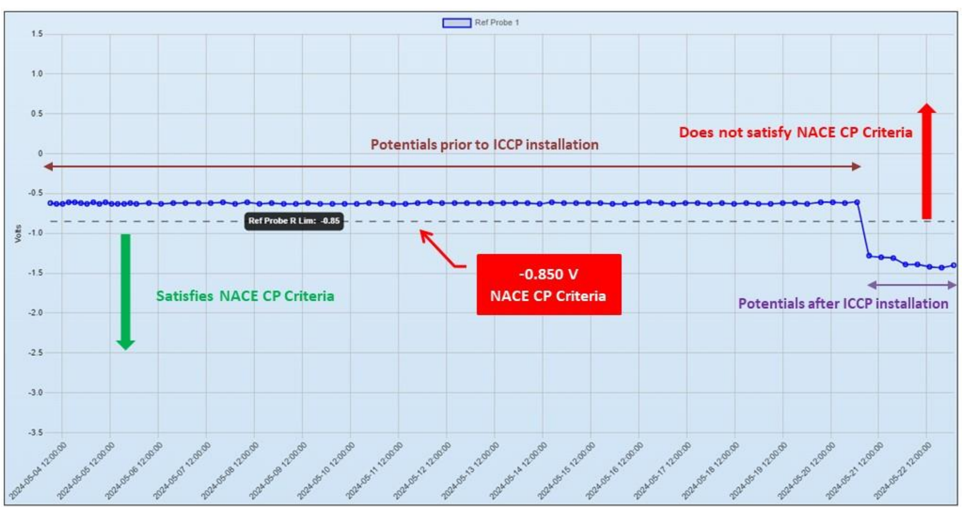

Figure 30: Plot showing the real time structure-to-soil potential data of pump station 9.

Conclusions for Case Study

The evaluation and upgrading of the CP systems at Ottawa County's pump stations demonstrate the importance of proactive corrosion management. The initial reliance on sacrificial anode systems proved insufficient for long-term protection, especially given the advanced age of the infrastructure and the interconnected nature of the metallic components. The use of galvanic CP systems failed to meet the necessary -850 mV protection criterion, leaving the steel structures vulnerable to corrosion and potential failure.

The transition to ICCP system has proven to be a highly effective solution, delivering consistent protection by maintaining continuous current to the steel structures. The post-installation structure-to-soil potential measurements show significant improvement, with all stations exceeding the -850 mV threshold, indicating that the new ICCP system is successfully providing the necessary corrosion protection.

Additionally, the incorporation of real-time monitoring sensors further enhances the effectiveness of the CP system by allowing for continuous surveillance of structure-to-soil potentials. This real-time monitoring enables Ottawa County to detect and address any instances of inadequate protection immediately, thus preventing potential damage and ensuring the long-term integrity of the pump stations.

CONCLUSIONS

Ottawa County Sanitary Engineering Department has demonstrated a proactive and effective approach to managing corrosion protection for its critical infrastructure, particularly sewage pump stations. While the water and wastewater industries often focus on water mains and similar components, Ottawa County recognized the importance of protecting the carbon steel walls of pump station dry wells, ensuring they meet the necessary -850 mV minimum CP criterion.

By implementing ICCP systems across its pump stations, the County has shown foresight in optimizing long-term asset protection. This initiative reflects Ottawa County's commitment to safeguarding its infrastructure from corrosion-related damage, while also enhancing operational reliability.

Moreover, Ottawa County's comprehensive evaluation of the installed CP systems goes beyond initial contractor reports, showing their dedication to ensuring sustained protection. The deployment of wireless sensors to monitor real-time structure-to-soil potential data exemplifies their strategic approach to corrosion management. These sensors enable quick identification of critical corrosion potentials, allowing for timely interventions that protect the infrastructure.

The County's use of advanced monitoring tools, such as the WebView feature, further enhances their ability to track and analyze corrosion risks, preventing failures before they escalate. Ottawa County's proactive measures not only ensure the long-term integrity of pump stations but also set a strong example for how infrastructure management should be conducted in the water and wastewater industries.

REFERENCES

1. NACE SP0285-2021, "External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection" (Houston, TX: NACE).