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Evaluation of Classification and Prioritization Criteria Based on the Results of Direct Examinations

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ABSTRACT

The ECDA process requires a continuous effort from the pipeline operator to improve the reliability of classification and prioritization criteria.

Based on the results of the direct examinations, these criteria can be up-graded or down-graded as part of the retrospective evaluation and the number of such re-evaluations can be used as criteria in the long-term assessment of the ECDA effectiveness.

This paper covers criteria evaluation and specific lessons learned by comparing the results of the direct examinations with predictions based on indirect inspections and pre-assessment data collected on more than 30 gas pipelines in Ontario, Canada.

INTRODUCTION

The External Corrosion Direct Assessment (ECDA) as described in NACE Standard RP0502-2002[1] is a continuous improvement process of using existing data and the results of indirect inspection techniques, validated by a series of direct examinations, to identify and address locations where external "corrosion activity has occurred, is occurring, or may occur".

The authors have addressed in previous papers[2,3] various aspects related to indirect inspection techniques and prioritization of multiple indications, as applied by Union Gas Limited (UGL) and Corrosion Service Company Limited (CSCL) to more than 30 gas pipelines in the Province of Ontario.

This paper describes the results of direct examinations on three different pipelines, by comparing the expectations derived from the pre-assessment data to the results of the indirect inspections. The impact of these findings on the classification and prioritization criteria for the specific line is then discussed.

THE CASE OF SHALLOW PITTING IN HIGH RESISTIVITY SOIL

An integrated CIPS/DCVG survey was conducted in 2005 on a 6" dia. pipeline in northern Ontario, protected by a mixed CP system (i.e. 6" lateral pipeline having its own dedicated magnesium anodes bonded into a main line protected by impressed current rectifiers). A moderate DCVG indication (i.e. 47.7%IR) in conjunction with a severe CIPS indication (i.e. -533 mV_{CSE}) was identified at chainage 670.6 m, as shown in Figure 1.

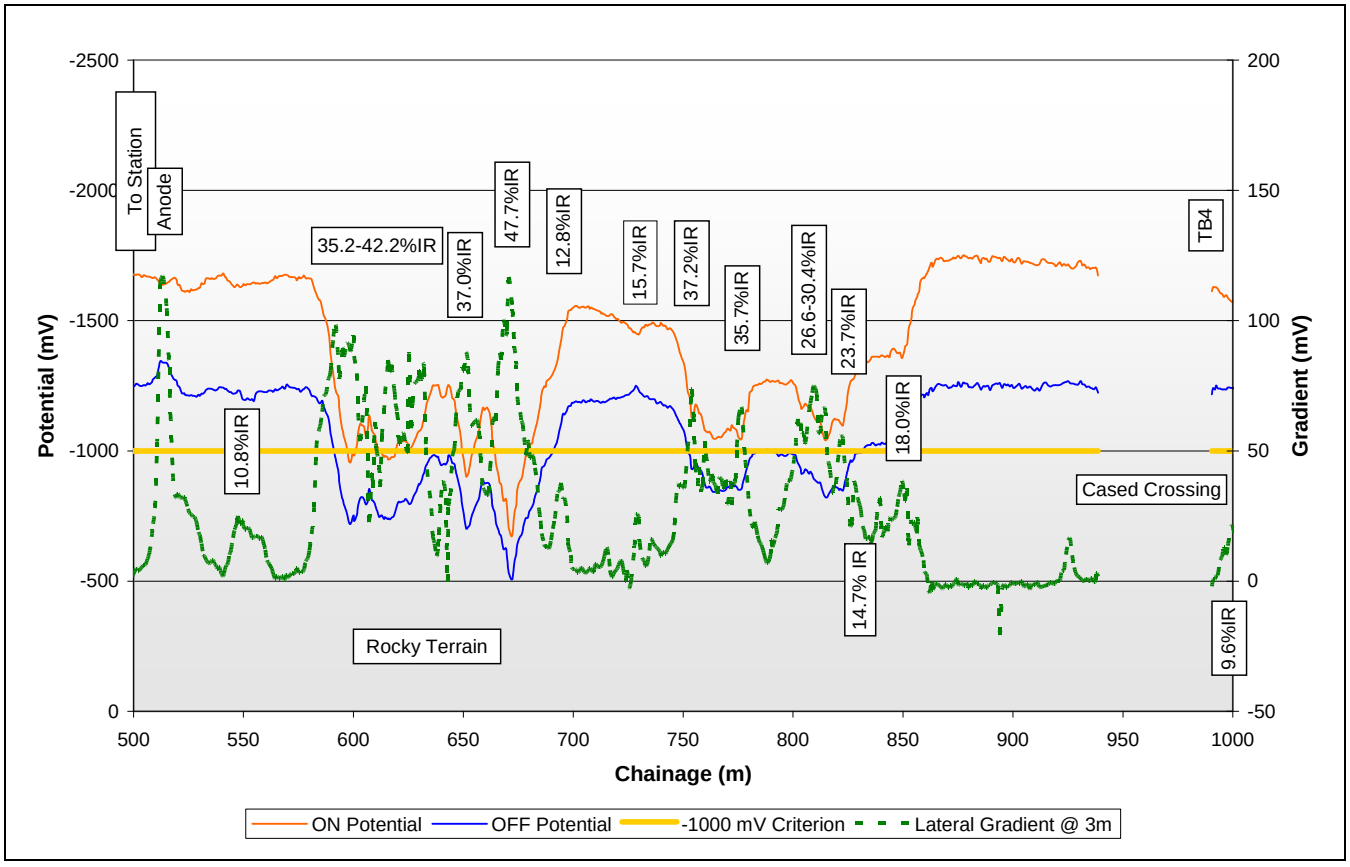

FIGURE 1 • 6" Line. Ch. 500 to 1000m. Integrated CIPS/DCVG Survey

The indication was prioritized as “Scheduled Action Required”, according to the prioritization criteria summarized in Table 1. In this case, the intersecting cell between the 2nd row (DCVG-MD) with the 5th column (CIPS-SV) indicates that a location displaying a moderate DCVG indication in conjunction with a severe CIPS indication is prioritized as scheduled action required (S).

TABLE 1 • SUMMARY OF PRIORITIZATION CRITERIA.
TWO INDICATIONS AT THE SAME LOCATION

Coating Holiday (DCVG Indication)		Prioritization															
		Prior History of Corrosion (PHC)				Close Interval Potential Survey (CIPS)				DC Interference (DCI)				AC Induced Corrosion (ACC)			
		SV	MD	MN	Nil	SV	MD	MN	NI	SV	MD	MN	NI	SV	MD	MN	NI
		1	2	3	4	5	6	7	8	9	10	11	12	17	18	19	20
DCVG-SV	1	I	I	S	S	I	S	S	S	I	S	S	S	N/A	N/A	N/A	S
DCVG-MD	2	I	S	M	M	S	S	M	M	I	S	M	M	N/A	N/A	N/A	M
DCVG-MN	3	M	M	M	M	S	M	M	M	I	S	M	M	I	S	M	M
DCVG-BT	4	N	N	N	N	S	M	M	N	I	S	M	N	I	S	M	N
DCVG-NI	5	N	N	N	N	N	N	N	N	I *	N	N	N	I *	N	N	N

***** Consider excavating short sections of line under severe risk of external corrosion, even if DCVG indications were not found.

Legend:

SV = Severe indication
MD = Moderate indication
MN = Minor indication
BT = Below threshold
NI = No indication

I = Immediate action required
S = Scheduled action required
M = Suitable for monitoring
N = No action required
N/A = Not Applicable

The direct examination was performed in August 2006 and revealed a total of seven holidays. For details, see Coating Inspection Map #1 (Figure 2) and Figures 3 and 4 (only holidays #1 and #2 shown).

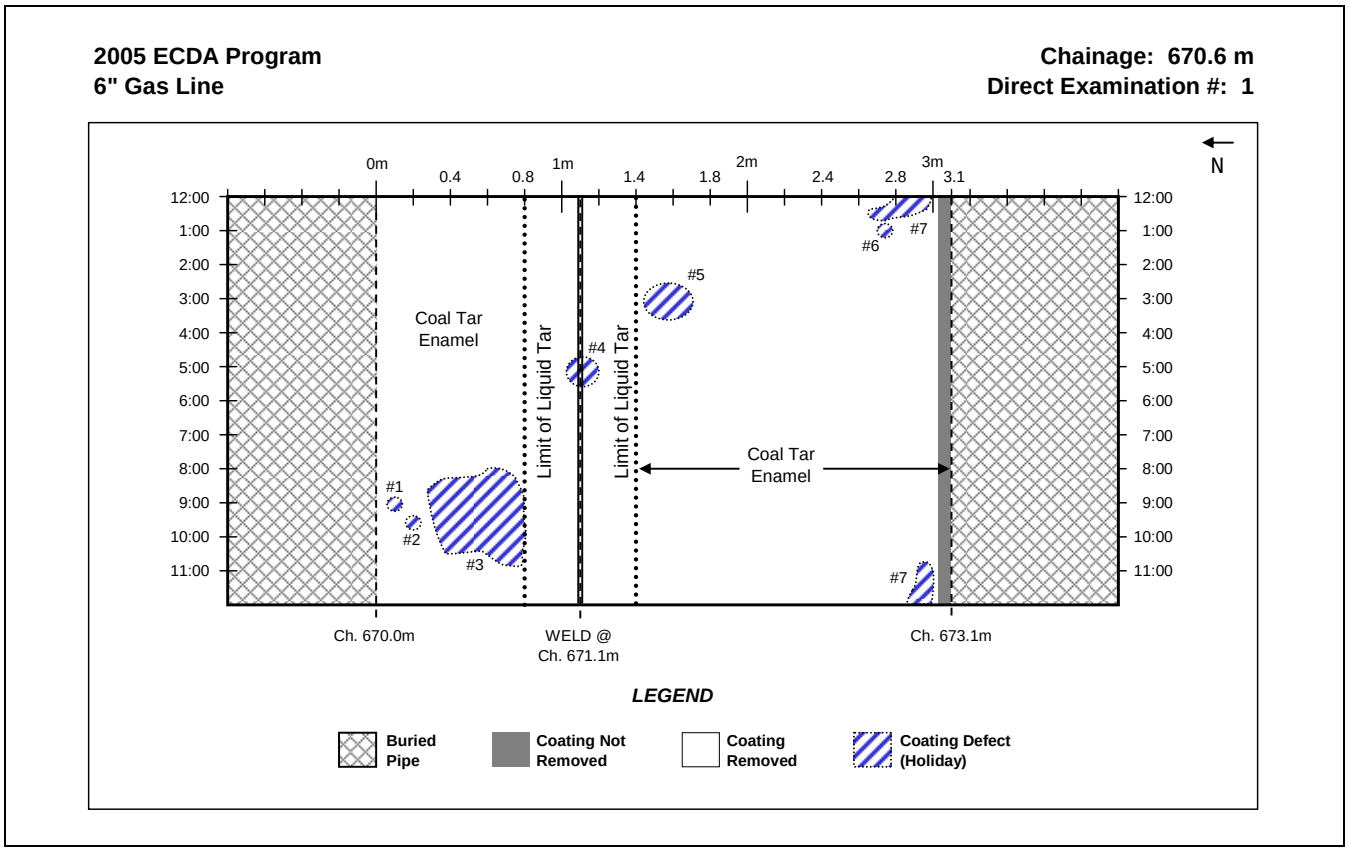

FIGURE 2 • Coating Inspection Map #1

**FIGURE 3 • Site #1. Coating Damage.
4 cm Dia. Holiday #1**

**FIGURE 4 • Site #1. Coating Damage.
3 cm Dia. Holiday #2**

After removing the coating, the pipe displayed surface corrosion, with multiple very shallow pits (i.e. up to 0.015" deep), as shown in Figure 5.

**FIGURE 5 • Site #1. Pipe Exposed.
Close View at Holiday #1**

The corrosion attack was milder than expected at a severe CIPS indication (i.e. -533mV$_{CSE}$ pipe-to-soil OFF potential). The shallowness of the pitting was attributed to the mitigating effect of the very high resistivity soil (i.e. 1,000,000 Ω-cm) on the corrosion rate. The CIPS indication classification criteria used for this line[1] appear therefore to be too conservative in high resistivity aerated areas. Paragraph 6.2.2.3 of NACE RP0169-2002 states that in such soils OFF potentials less negative than -850 mV$_{CSE}$ may be sufficient for protection. The European Standard ISO 15589-1, paragraph 5.3.2.1 recommends a minimum polarized potential of -650 mV$_{CSE}$ for resistivities greater than 1,000 Ω-m (100,000 Ω-cm).

Note that although the identification and prioritization CIPS criteria for this line appear to be too severe, they were not downgraded, since the ECDA process was applied for the first time (NACE Standard RP0502-2002, Paragraph 5.8.4.2). Consideration would be given to using less conservative criteria for future applications under similar conditions.

[1] Pipe-to-soil OFF potentials more electropositive than -799mV$_{CSE}$ were classified as severe indications.

THE CASE OF THE DEPLETED MAGNESIUM ANODE

A moderate DCVG indication (i.e. 36.3%IR in conjunction with a minor CIPS indication (-903 mV_{CSE}) and a moderate DC interference (DCI) indication (i.e. 40 mV positive shift, with a foreign rectifier turned ON) were identified at chainage 306.00 m on an 8" gas pipeline protected by magnesium anodes (see Figure 6).

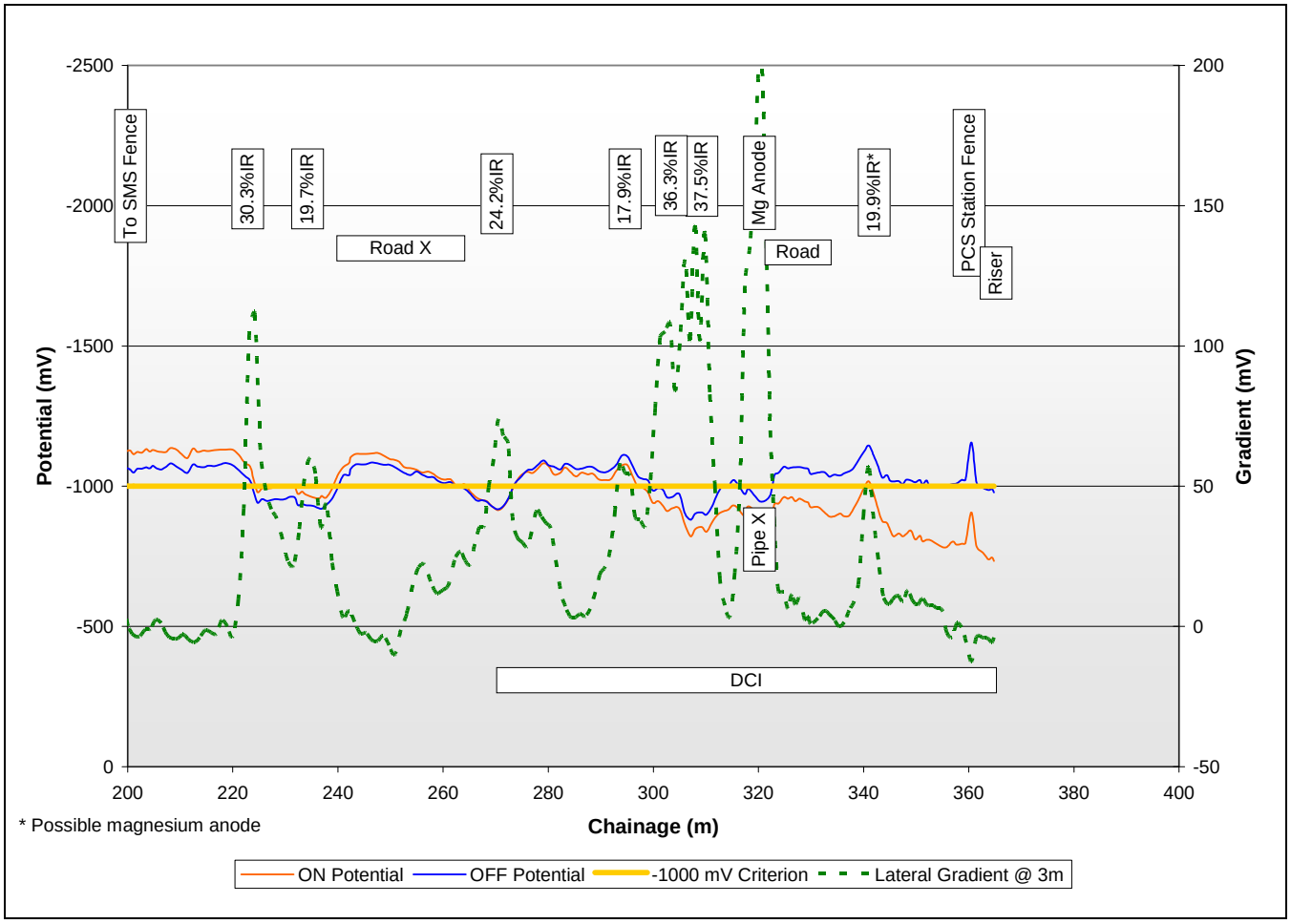

FIGURE 6 • 8" Gas Line. Ch. 200 to 365m. Aligned CIPS/DCVG Data

The indication was prioritized as “Scheduled Action Required”, according to the prioritization criteria summarized in Table 2. In this case, the intersecting cell between the 6th row (DCVG-MD & CIPS-MN) with the 6th column (DCI-MD) indicates that a location displaying a moderate DCVG indication in conjunction with a minor CIPS indication and a moderate DCI indication is prioritized as scheduled action required (S).

TABLE 2 • SUMMARY OF PRIORITIZATION CRITERIA.
MULTIPLE INDICATIONS AT THE SAME LOCATION

DC Voltage Gradient Indication	Close Interval Potential Survey Indication		Prioritization											
			Prior History of Corrosion (PHC)				DC Interference (DCI)				AC Induced Corrosion (ACC)			
			SV	MD	MN	Nil	SV	MD	MN	NI	SV	MD	MN	NI
			1	2	3	4	5	6	7	8	9	10	11	12
DCVG-SV	CIPS-SV	1	I	I	I	I	I	I	I	I	N/A	N/A	N/A	I
	CIPS-MD	2	I	I	S	S	I	S	S	S	N/A	N/A	N/A	S
	CIPS-MN	3	I	I	S	S	I	S	S	S	N/A	N/A	N/A	S
DCVG-MD	CIPS-SV	4	I	I	I	S	I	I	I	S	N/A	N/A	N/A	S
	CIPS-MD	5	I	I	S	S	I	S	S	S	N/A	N/A	N/A	S
	CIPS-MN	6	I	S	M	M	I	S	M	M	N/A	N/A	N/A	M
DCVG-MN	CIPS-SV	7	I	I	S	S	I	S	S	S	I	S	S	S
	CIPS-MD	8	I	S	S	S	I	S	M	M	I	S	M	M
	CIPS-MN	9	S	M	M	M	I	S	M	M	I	S	M	M
DCVG-BT	CIPS-SV	10	I	I	S	S	I	S	S	S	I	S	S	S
	CIPS-MD	11	S	S	M	M	I	S	M	M	I	S	M	M
	CIPS-MN	12	M	M	N	N	I	S	M	N	I	S	M	N
DCVG-NI	CIPS-SV	13	I*	N	N	N	I*	N	N	N	I*	N	N	N
	CIPS-MD	14	I*	N	N	N	I*	N	N	N	I*	N	N	N
	CIPS-MN	15	N	N	N	N	I*	N	N	N	I*	N	N	N

***** Consider excavating short sections of line under severe risk of external corrosion, even if DCVG indications were not found.

Legend:

SV = Severe indication
MD = Moderate indication
MN = Minor indication
BT = Below threshold
NI = No indication

I = Immediate action required
S = Scheduled action required
M = Suitable for monitoring
N = No action required
N/A = Not Applicable

The direct examination was performed in July 2006 and revealed three coating holidays and a depleted anode connected to the pipe. For details, see Coating Inspection Map #2 (Figure 7) and Figures 8 and 9 (only holiday #1 and the anode connection are shown).

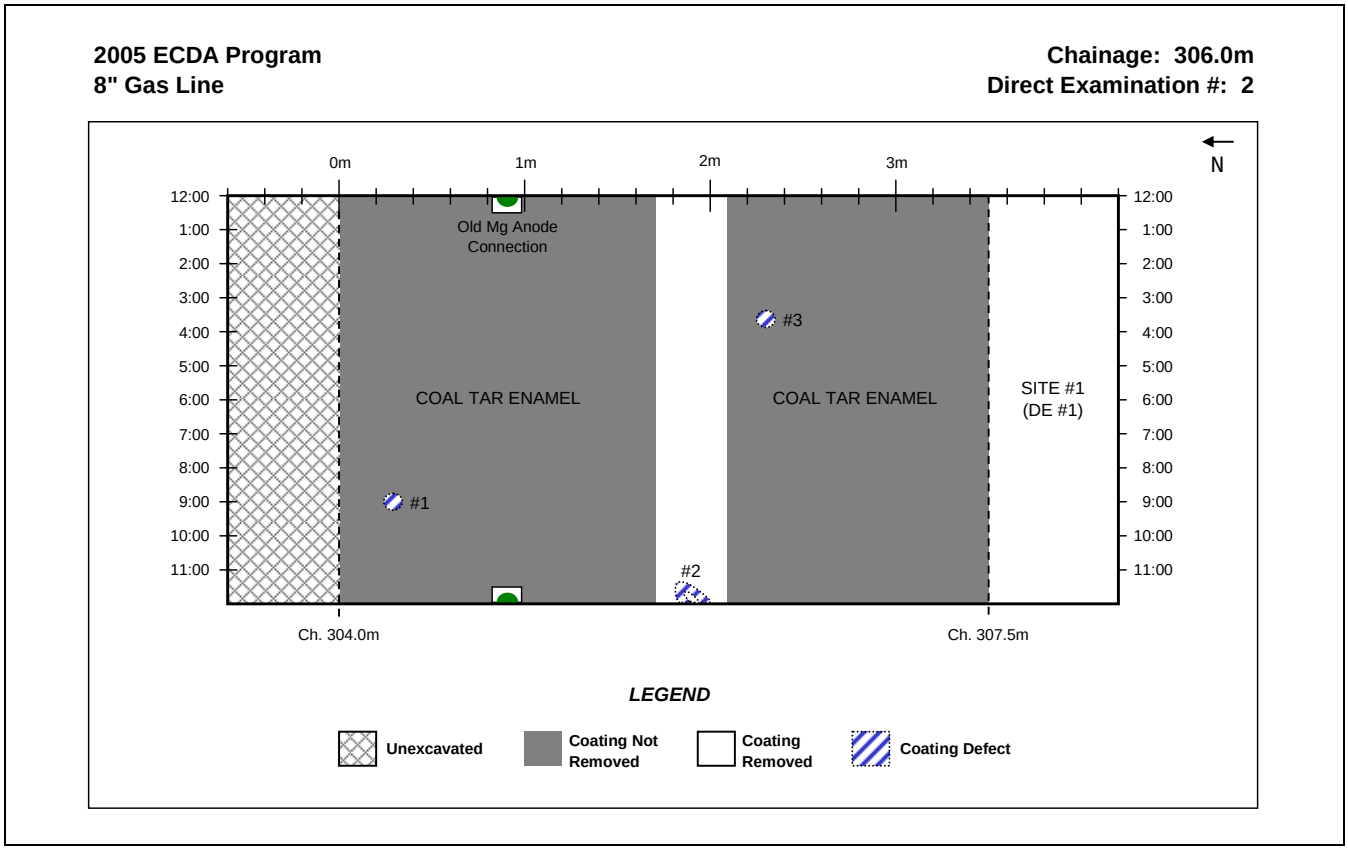

FIGURE 7 • Coating Inspection Map #2

FIGURE 8 • DE #2. Coating Damage. Holiday #1 (Tag #2).

FIGURE 9 • DE #2. Connection of Depleted Magnesium Anode.

The 36.3% IR is attributed in part to the depleted magnesium anode. Note that the CIPS/DCVG profile displays a drop in the protection level in conjunction with a high voltage gradient (Figure 10), as opposed to an increase in the protection level in conjunction with a high gradient, typical for magnesium anodes.[2]

[2] A typical magnesium anode profile was added for reference.

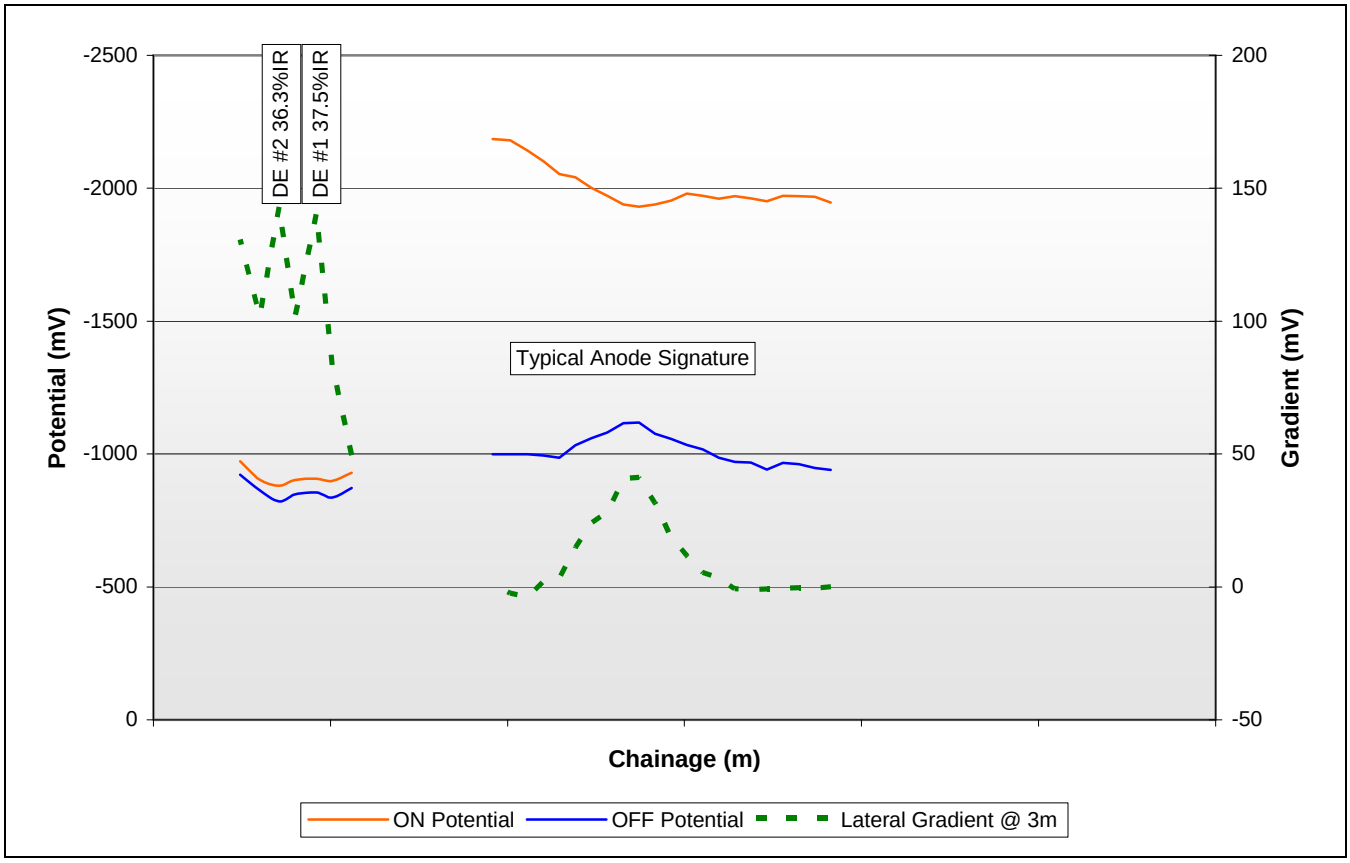

FIGURE 10 • CIPS/DCVG Profile @ Site #2

After removing the coating, the pipe was found in good condition, with only minor staining, as shown in Figure 11.

FIGURE 11 • DE #2 • Pipe Exposed. Close View.

No metal loss was found at this location, indicating that the CIPS identification and classification criteria were too severe for these aerated high resistivity soils.

Furthermore, with no CIPS indications (i.e. when the line is fully protected), all of the DC interference indications would be classified as minor. In hind sight, the prioritization status of this indication could have been downgraded to “Suitable for Monitoring”, matching the results of the direct examination.

It should also be noted that depleted magnesium anodes could display atypical CIPS/DCVG profiles and could subsequently be misidentified as coating holidays, especially in a cluster of DCVG indications.

THE CASE OF THE “SAW TOOTH” GRADIENT

The Close Interval Potential Survey (CIPS) and the DC Voltage Gradient (DCVG) were selected as the main indirect tools for the indirect inspection on a 6" gas pipeline in northern Ontario. The two tools were used independently, since the line was protected by galvanic anodes. During the DCVG survey, the lateral gradient and the pipe-to-soil potential were recorded simultaneously, to allow gradient recording and %IR calculation at every location.

The line displayed a significant number of DCVG indications between chainage 2100 m and chainage 3800 m, which were uniformly distributed along the line, creating an unusual “Saw Tooth” gradient pattern (see Figures 12 and 13).

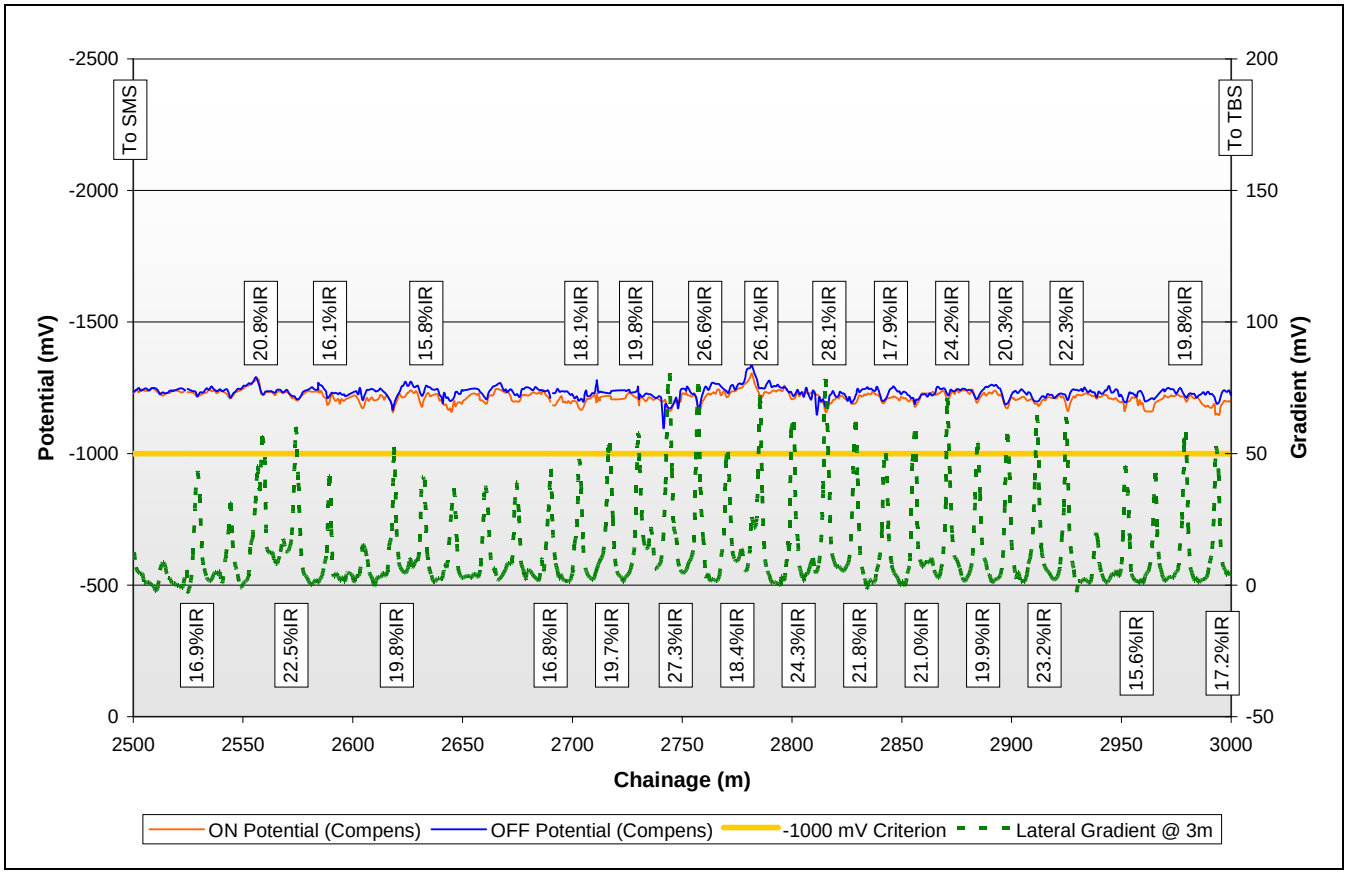

FIGURE 12 • 6" Lateral. Ch. 2500 to 3000m. Aligned CIPS/DCVG Data

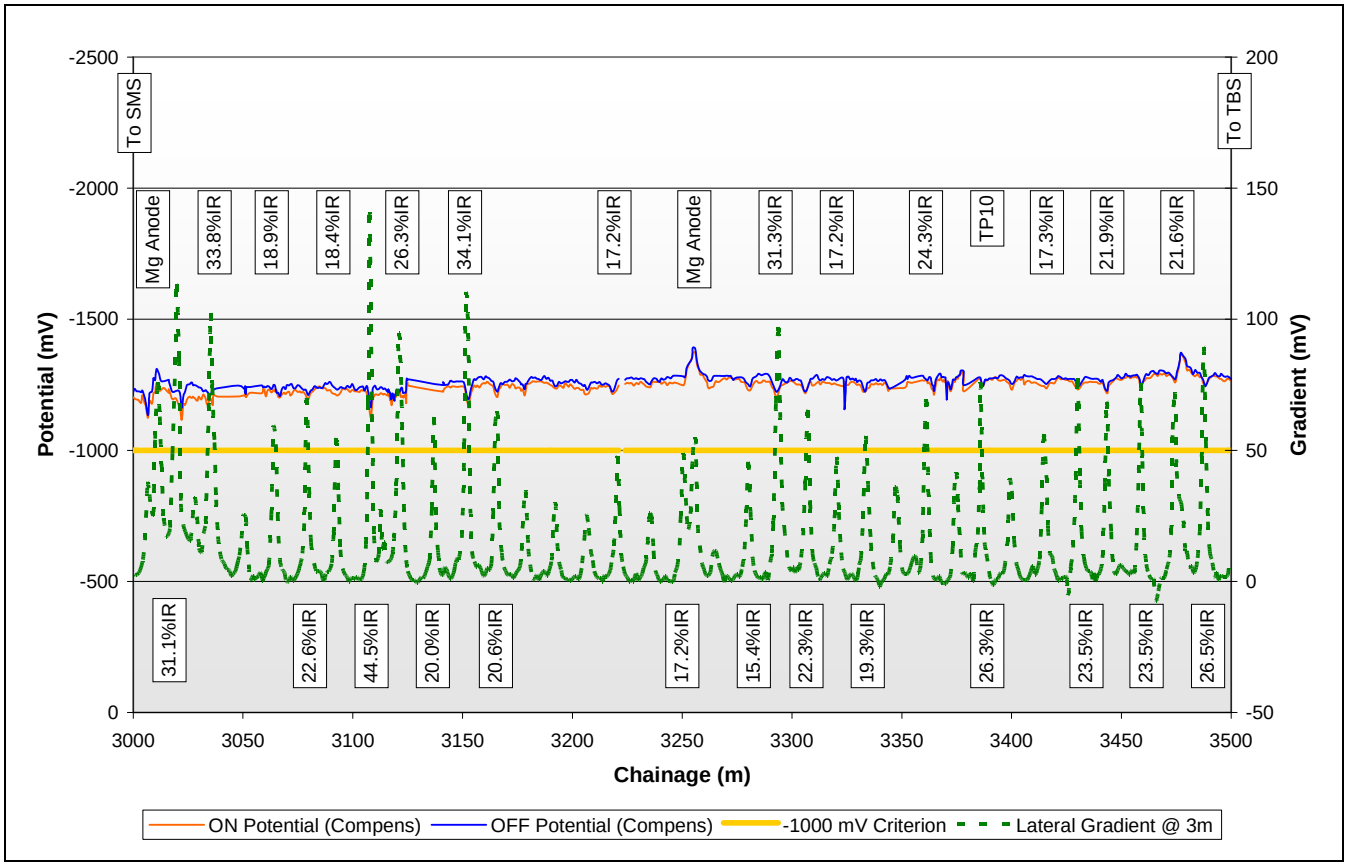

FIGURE 13 • 6" Lateral. Ch. 3000 to 3500m. Aligned CIPS/DCVG Data

The indications were attributed either to depleted distributed anodes or to poor coating at welds. Since the line was fully protected, all the indications were prioritized as “Suitable for Monitoring”.

Two examinations were selected for direct examination in this area:

- Direct Examination #1 (DE#1): Chainage 3107.6 m. ECDA Region #1. Suitable for Monitoring. GPS Coordinates: undisclosed. Estimated Depth: 0.95m. Moderate DCVG indication (i.e. 44.5%IR C-C).

  Depleted anode core or poorly coated weld with no metal loss due to external corrosion was expected at this location.

- Direct Examination #2 (DE#2): Chainage 3121.0 m. ECDA Region #1. Suitable for Monitoring. GPS Coordinates: undisclosed. Estimated Depth: 0.41m. Minor DCVG indication (i.e. 26.3%IR C-C) in a cluster of DCVG indications.

  Depleted anode core or poorly coated weld with no metal loss due to external corrosion was expected at this location.

The direct examinations were conducted in September 2007. At DE#1, a 20cm x 5cm holiday was found at the weld, as shown in Coating Inspection Map #3 (Figure 14) and in Figure 15.

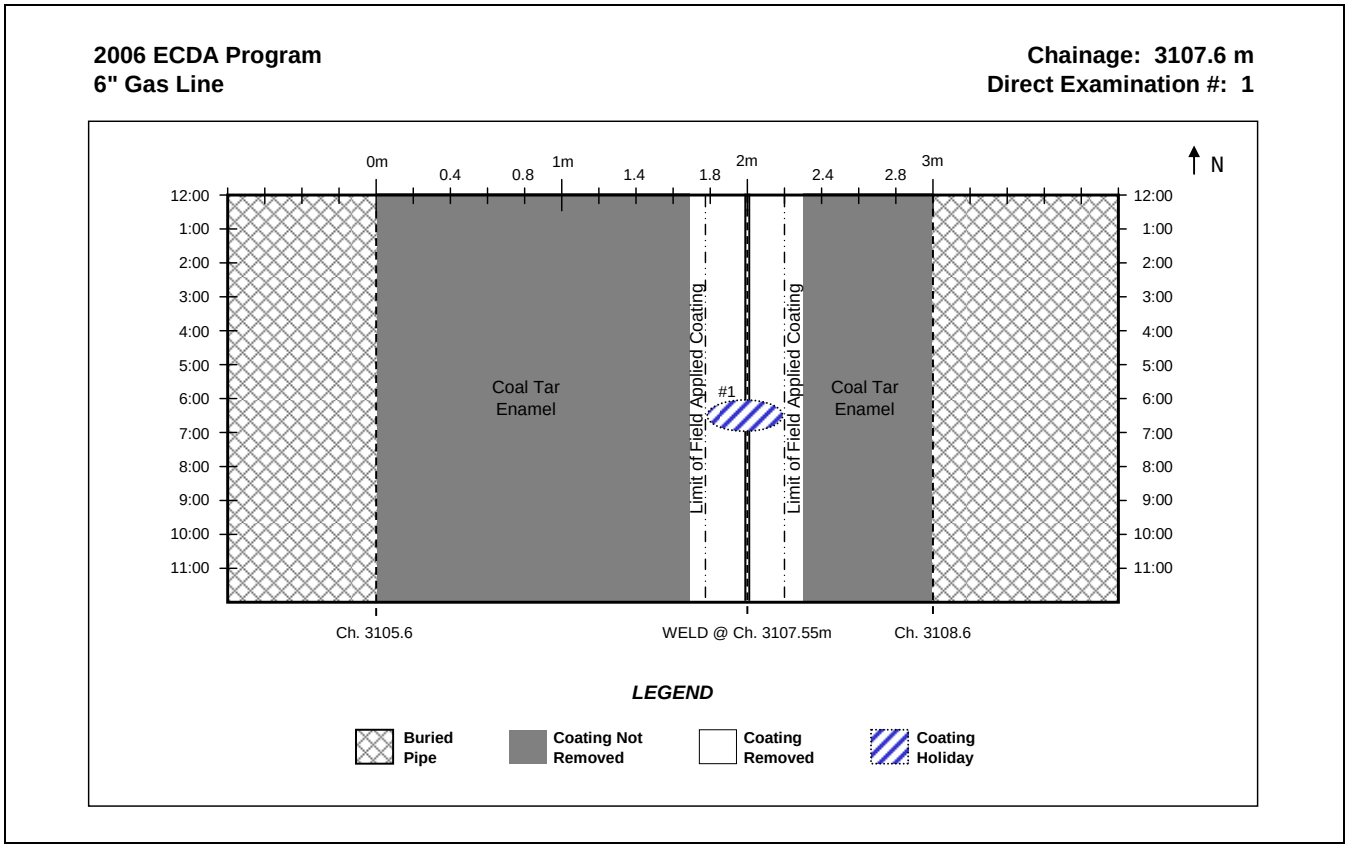

FIGURE 14 • Coating Inspection Map #3

FIGURE 15 • DE #1. Coating Damage.
20 cm x 5 cm Holiday #1.

At DE#2, four holidays were found, with holiday #4 and additional small holidays located in the weld area, as shown in Coating Inspection Map #4 (Figure 16) and Figure 17.

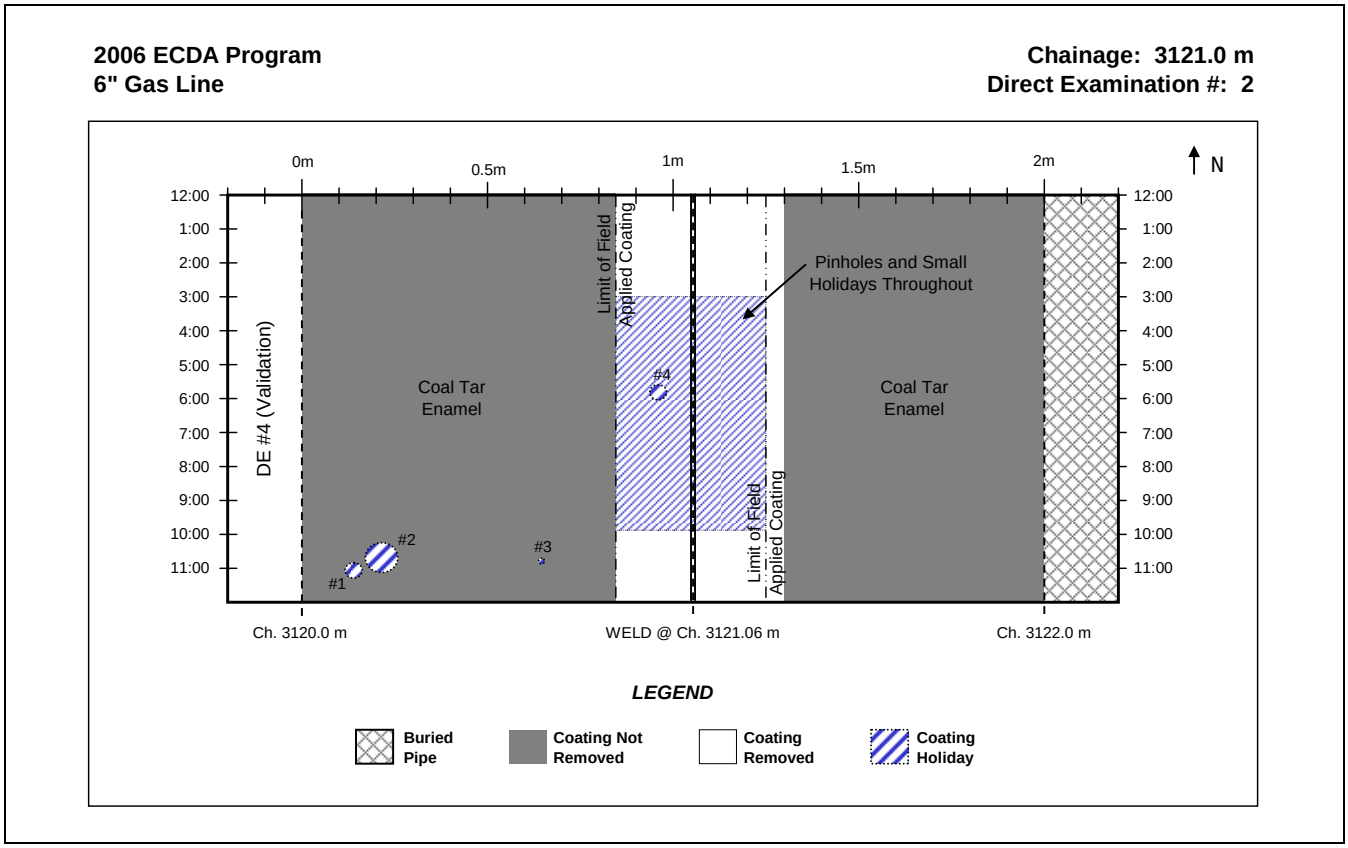

FIGURE 16 • Coating Inspection Map #4

**FIGURE 17 • DE #2. Coating Damage.
5 cm Dia. Holiday #4.**

After removing the coating, the pipe was found in good condition, with no metal loss, as shown in Figures 18 and 19.

FIGURE 18 • DE #1. Pipe Exposed at 20 cm x 5 cm Holiday #1.

FIGURE 19 • DE #2 Pipe Exposed at Holiday #4. Close View.

The direct examinations confirmed the conclusions of the first two ECDA steps and as such, the classification and prioritization criteria defined for this line were considered adequate.

CONCLUSIONS

The results of the ECDA direct examinations performed on more than 30 gas pipelines in Ontario indicated that the classification and prioritization criteria were adequate, except for high resistivity, aerated soils, where the CIPS criteria appeared to be too severe. Consideration should be given to using less conservative criteria for future applications. (i.e. compatible with the -650 mV_{CSE} protection criterion recommended in European Standard ISO 15589-1 in soils with resistivities higher than 100,000 Ω-cm).

The indirect inspection tools used in these projects (i.e. CIPS and DCVG) proved extremely reliable under the most demanding conditions, however depleted magnesium anodes displaying atypical pipe-to-soil potential/gradient profiles could not be accurately differentiated from coating holidays in high resistivity soils.

REFERENCES

1. NACE Standard Recommended Practice RP0502-2002, “Pipeline External Corrosion Direct Assessment Methodology”, Houston, 2002.

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3. R. G. Reid, S. M. Segall, R. A. Gummow, “New Concepts in the Prioritization of Multiple ECDA Indications”, Corrosion 2007, Paper No. 07161, Nashville, Tennessee