

AC Corrosion Mitigation

Eastern Gas Pipeline (EGP)

5 March 2026

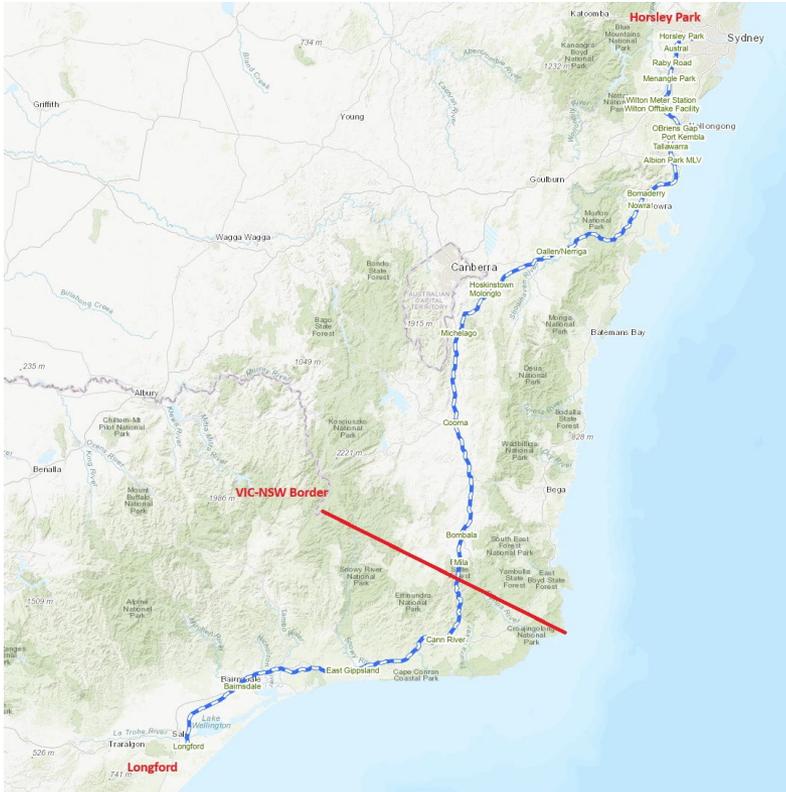
Javad Yousefi - Raj Jeyarajah

Agenda

- Pipeline Background and details including CP and AC history, Javad
- EGP ILI results and findings during verification excavations at KP656, Raj
- AC corrosion criteria and EGP KP656 mitigation project, Javad
- Summary, Raj



Eastern Gas Pipeline



- Commissioned in 2000,
- 798km Gas Pipeline DN450, X70, 14,895 MPag MAOP
- Wall thickness , Standard 9.8 mm, Medium 11.8 mm, Heavy 14.1 mm
- Longford Vic to Horsley Park NSW
- Single layer FBE approx. (500 microns) mainline and HBE (field weld joints)
- Several sections paralleling HV powerlines

Cathodic Protection System

➤ Cathodic Protection System

10 Isolated Pipeline Sections

6 Laterals and Offtakes

21 ICCP and 3 TRAD

467 Test Points

- Up stream & Down stream TR units located at stations are connected to a common anode GBs and produce
- Annual CP surveys has usually indicated compliant CP levels
- All TR units are being monitored via SCADA and have high/low set point

Pipeline – Powerline AC Exposure Summary

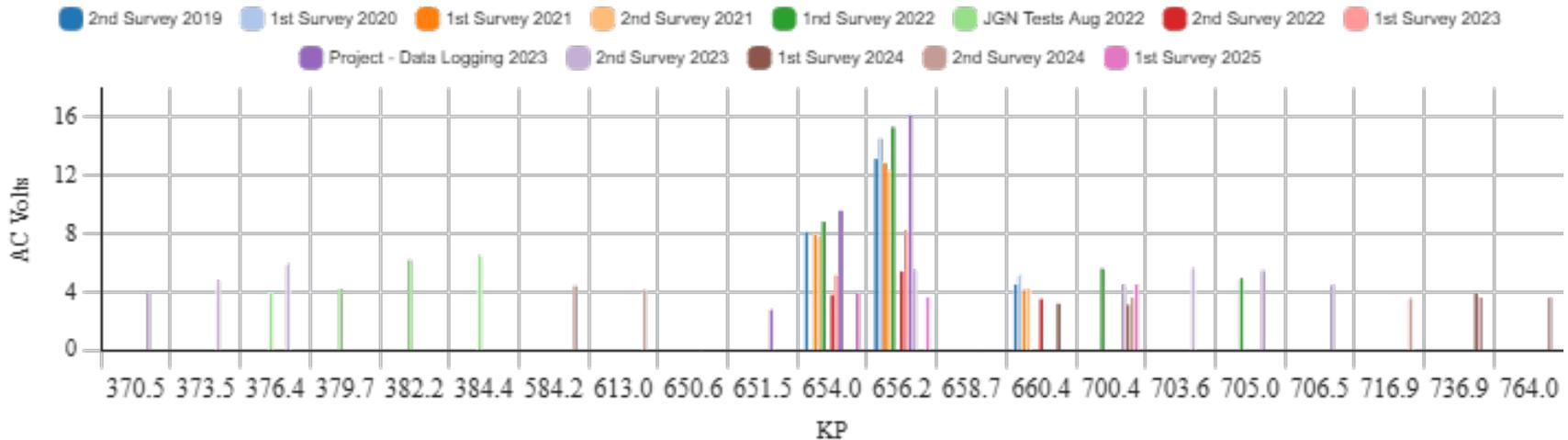


Exposure Range	Distance (Km)	Powerline Voltage
KP 25–48	23 km	66 kV
KP 117–126	9 km	66 & 22 kV
KP 160–221	61 km	66 & 22 kV
KP 315–346	31 km	66 & 22 kV
KP 361–391	30 km	132 & 22 kV
KP 403–475	72 km	132 & 11 kV
KP 564–619	55 km	330 & 22 kV
KP 643–663	20 km	132 kV
KP 673–686	13 km	33 kV
KP 716–777	61 km	330, 132, 66 & 33 kV
Port Kembla Lateral	7 km	132 & 33 kV
Smithfield Lateral	3 km	132 & 33 kV

- Length of parallel with HV: 385 km
- AC mitigation was originally designed for safety (< 15V) only not AC corrosion mitigation

EGP AC Potential - Historical Records > 3.5 V

AC Volts vs KP — All Surveys (2019–2025)



KP 370 - KP 380 (ongoing monitoring)

48 hrs data logging completed (Dec 2025) and soil resistivity completed.

No immediate risk of AC corrosion at this stage (AC current density below 30 A/m²)

KP 650 – KP 660 (immediate action)

Data logging and soil resistivity completed.

Risk of AC corrosion identified at KP 656

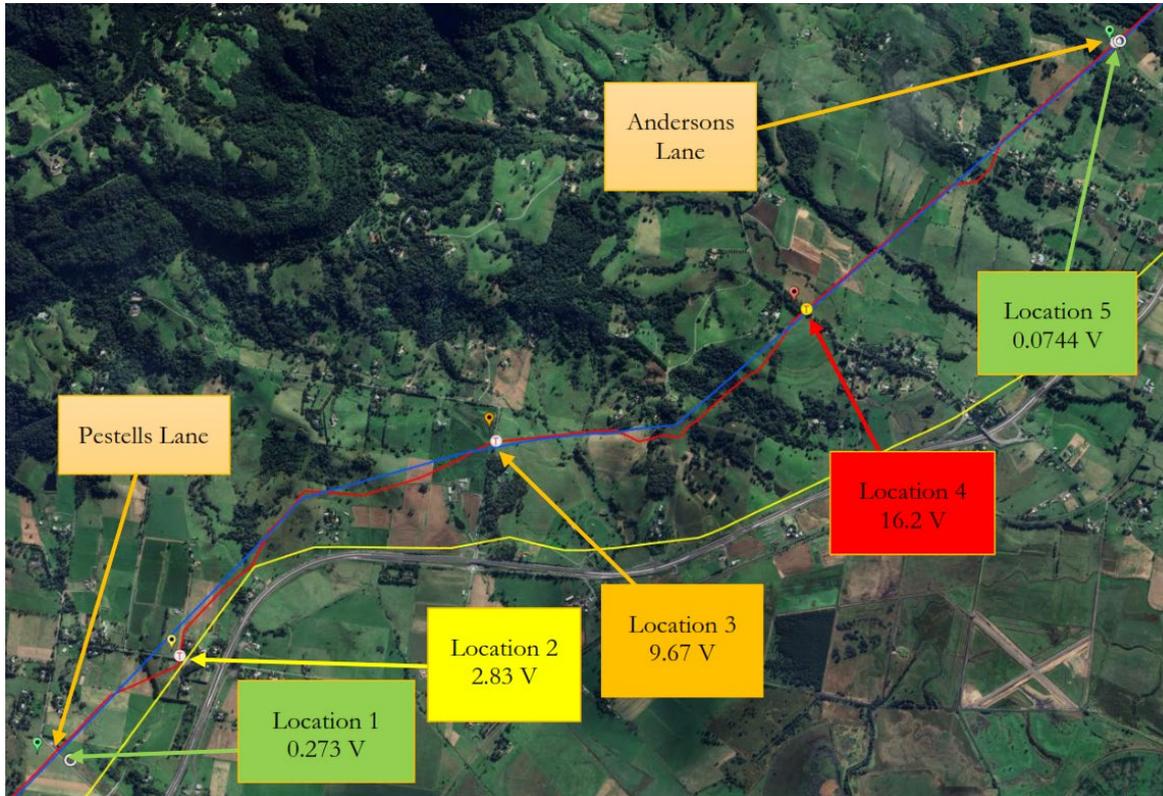
Existing AC mitigation project

KP 700 – KP 716 (further investigation)

48 hrs data logging completed (Dec 2025)

Soil resistivity is scheduled to be completed and AC corrosion risk to be assessed.

AC Potentials Data Logging (KP 650 – KP 658)



EGP Pipeline - Red

Twin 132 KV Powerline - Blue

Pipeline (Red) & Twin 132 kV Powerline (Blue)

AC Potential & Soil Resistivity

Location - KP	Top Layer Resistivity (Ωm)	Top Layer Depth (m)	Average AC (V)	AC Current Density (A/m ²) 1 cm ² coating defect	Risk of AC Corrosion
Location 1, KP650.6	9.7	11.5	0.27	6	Low
Location 2, KP651,6	25.4	3.0	2.83	25	Low
Location 3, KP654.0	64.9	2.5	9.67	34	High
Location 4, KP656.2	21.8	0.7	16.19	168	Very High
Location 5, KP658.7	117	0.6	0.07	0.1	None

AC Current Density (A/m²) , $i_{AC} = \frac{8V_{AC}}{\rho\pi d}$

Coating Defect Spread Resistance (Ω) , $R = \frac{\rho}{2d}$

V_{AC} (V) : Average AC Voltage, 24hr

ρ (Ωm) : Soil Resistivity

d (m) : Coating defect diameter

ILI 2012 and 2022

- ILI in 2012 did not identify any corrosion anomalies for EGP, reporting threshold was 10% of WT
- Corrosion rates calculated based on CIGRE TBE 290 and AC voltage datalogging
- Decision made to review 2022 ILI data

Table 10: Extract from CIGRE TB 290 on Testing done for AC Corrosion Rates

Type of corrosion	Distribution range of corrosion rates in test series		
	5 Vac	10 Vac	30 Vac
Average corrosion, $\mu\text{m}/\text{year}$	3 – 26	4 – 27	4 – 66
Localized corrosion, $\mu\text{m}/\text{year}$	11 – 51	12 – 60	33 – 284

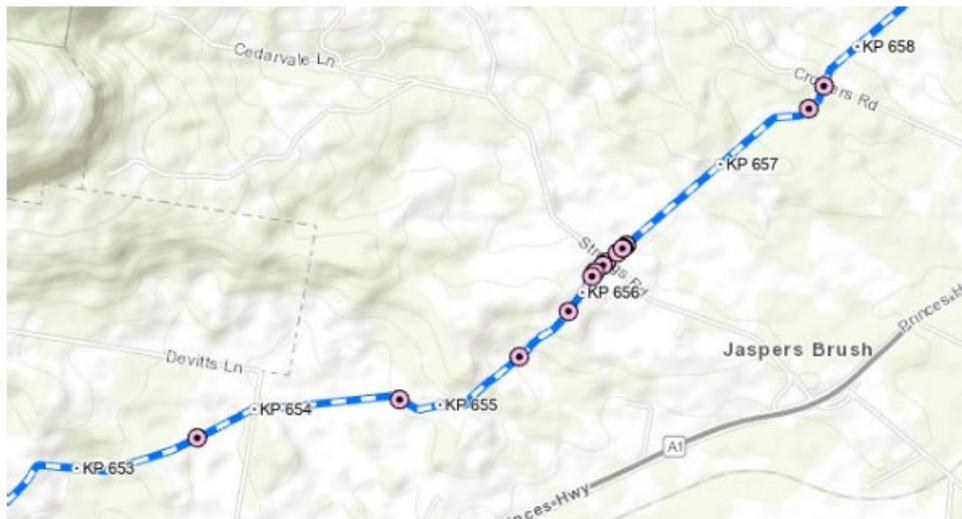
ILI Data 2022

- ILI undertaken using MFL-A tool
- Reported corrosion in area with high induced AC voltage

Log distance (m)	distance to u/s weld (m)	component / anomaly identification	wt nom. (mm)	o'clock position	Length mm	Width mm	max. depth %	surface location
92476.806	-4.605	Corrosion	9.8	4:48	10	15	10	NON-INT
94937.397	-0.239	Corrosion	9.8	9:04	14	16	16	NON-INT
94937.403	-0.245	Corrosion	9.8	7:10	16	18	11	NON-INT
94954.981	-17.823	Corrosion	9.8	12:04	13	19	11	NON-INT
94964.49	-9.23	Corrosion	9.8	5:26	16	25	11	NON-INT
94964.558	-9.298	Corrosion	9.8	4:53	16	17	16	NON-INT
95020.607	-17.278	Corrosion	9.8	3:05	13	17	12	NON-INT
95043.376	-4.491	Corrosion	9.8	4:42	17	18	15	NON-INT
95120.983	-11.916	Corrosion	9.8	6:18	15	20	13	NON-INT
95156.051	-10.358	Corrosion	9.8	4:09	13	18	15	NON-INT
95164.057	-0.083	Corrosion	9.8	5:22	13	19	15	NON-INT
95164.145	-0.171	Corrosion	9.8	4:16	11	15	11	NON-INT
98464.4	-4.931	Corrosion	9.8	5:00	16	23	11	NON-INT

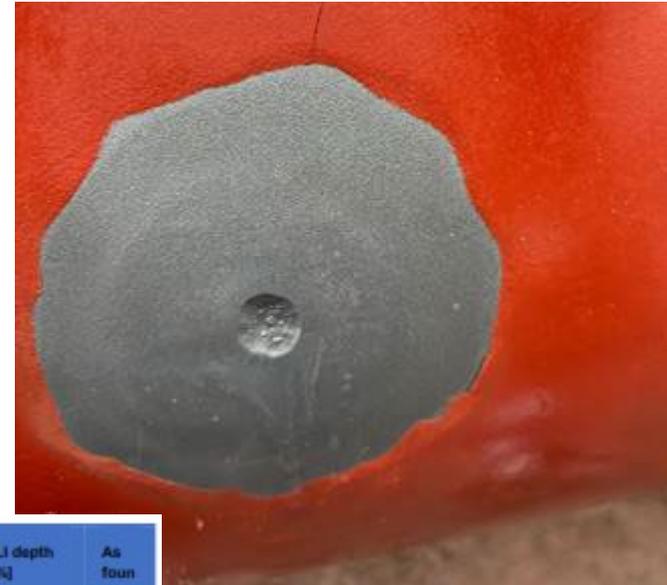
Comparison to 2012 ILI

- ILI vendor confirmed all reported corrosion features visible in signal and under reporting threshold
- Linear corrosion rate calculated using tool tolerance and conservatively assuming features were 1% in previous ILI, corrosion rate is $\sim 0.25\text{mm/year}$ or 2.5% of WT



First Round of Dig ups

- To validate if features are due to AC corrosion as some corrosion features reported were mill anomalies two features were subject to dig up
- Controls were put in place for dig ups in high AC area – including installing PCR at nearest TPs and checking AC voltages prior to works
- Dig up confirmed AC corrosion
- Characteristic – small coating defect, small circular dimples in the pit



log dist. [m]	to uls w. [m]	wt nom. [mm]	o'clock	anomaly identification	ILI length [mm]	As found length mm	ILI width [mm]	As found width mm	ILI depth [%]	As found depth %
94937.397	-0.239	9.8	9:04	Corrosion	14	20	16	20	16	17
94937.403	-0.245	9.8	7:10	Corrosion	16	20	18	20	11	19
94964.49	-9.23 (2.54m to downstream weld)	9.8	5:26	Corrosion	16	18	25	19	11	20
94964.558	-9.298	9.8	4:53	Corrosion	16	20	17	23	16	21

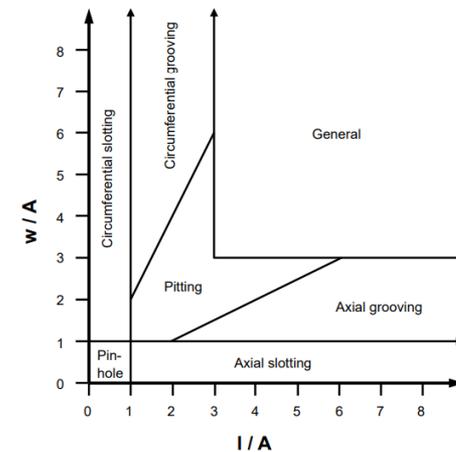
2025/6 Further digs and ILI validation

- Further validation digs undertaken (7 sites), including features that were below reporting threshold of 10%. This was achieved by getting ILI vendor to check signal data
- Overall ILI data was within specification for sizing
- All reported corrosion identified as AC Corrosion
- Some unreported pitting, due to being below tool detection capability

Section / KP approx.	O'clock	As found O'clock	ILI Length [mm]	As found length (mm)	ILI width [mm]	As found width (mm)	ILI depth [%]	As found depth %
KP653.663	4:48	4:57	10	8	15	10	10	18
KP656.115	12:04	12:09	13	12	19	13	11	18
	12:00	11:50		6		5	<10%	10
KP656.181	3:05	3:23	13	12	17	16	12	12
	4:42	4:52	17	20	18	17	15	21
KP656.282	6:18	6:50	15	16	20	16	13	21
	4:40	5:11		10		10	<10%	14
KP656.315	4:00	4:00					<10%	9
	4:09	4:00	13	13	18	23	15	16
KP656.325	5:22	5:17	13	16	19	18	15	20
	4:16	4:11	11	9	15	10	11	21
KP659.596	8:20	8:20		5		5		16
	5:00	5:11	16	17	23	13	11	20
	6:30	7:54		4.86		5.9	<10%	14

POF 100

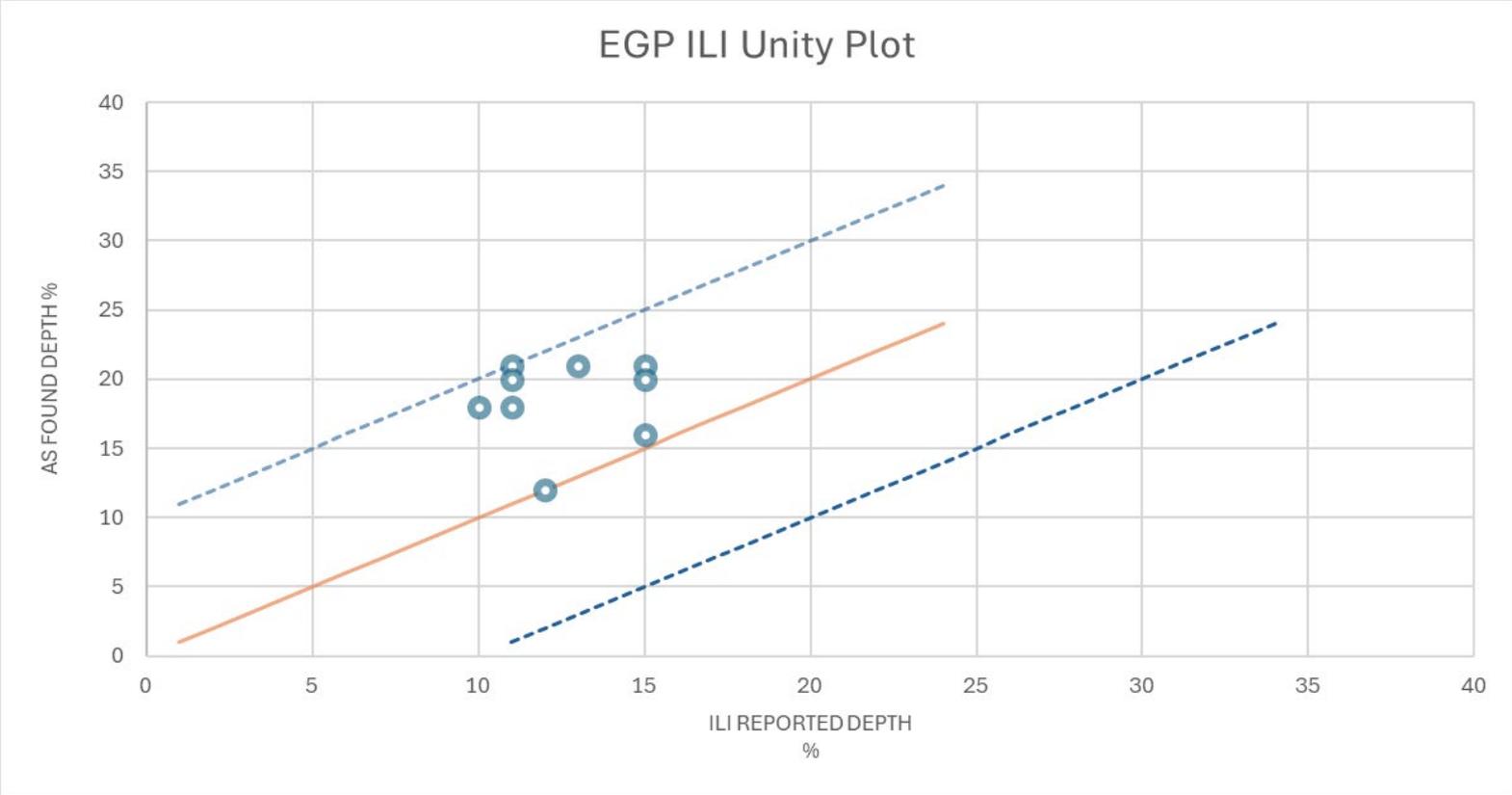
Specifications and requirements for in-line inspection of pipelines



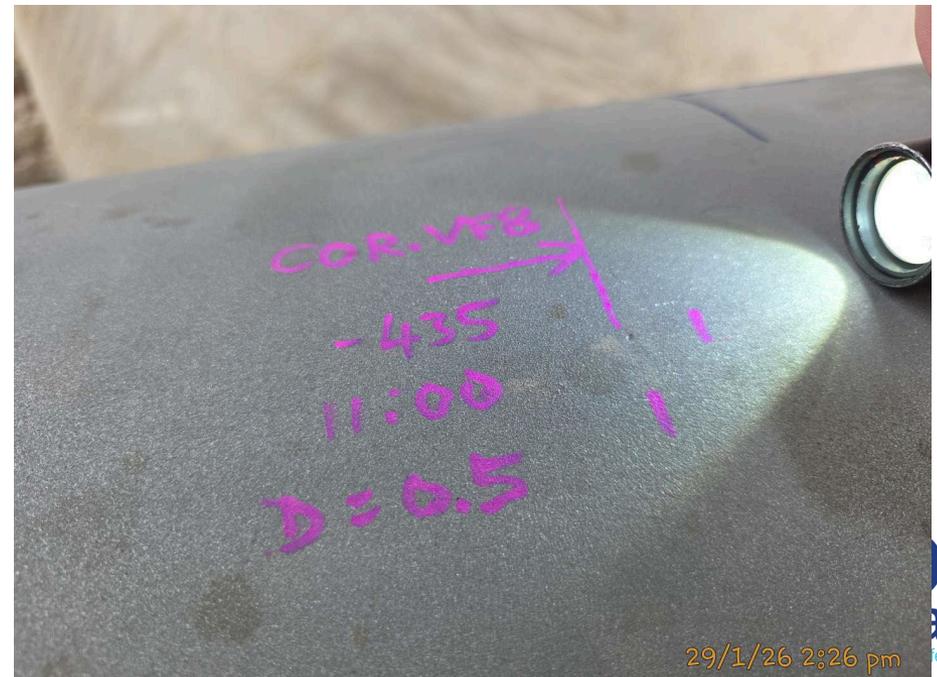
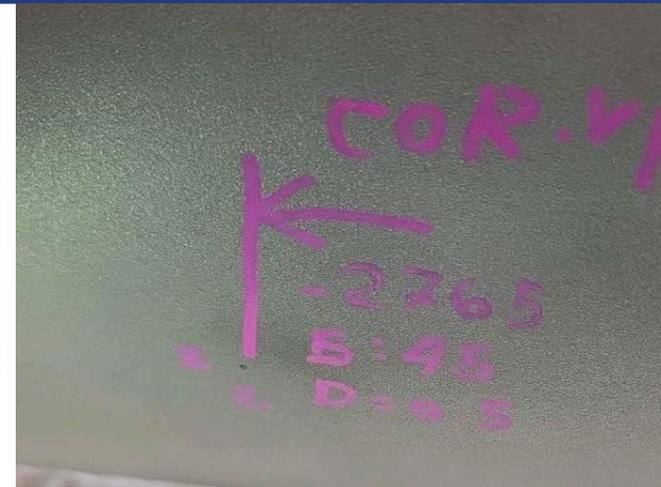
The geometrical parameter A is linked to the NDE methods in the following manner:

- If $t < 10$ mm then $A = 10$ mm
- If $t \geq 10$ mm then $A = t$

ILI vs Dig Up Unity Plot



Dig up photos



AC Corrosion Criteria Review - Australia

AS 2832.1-2015 (CP for Pipelines)

AS 4853-2012 (Electrical Hazards on metallic Pipelines)

- AC Voltage & Soil Resistivity (easier to measure/implement)
 - 4 V a.c. for soil resistivity $\leq 25 \Omega.m$
 - 10 V a.c. for soils whose resistivity is $> 25 \Omega.m$
 - AC Current Density (requires coupons/probes and/or calculations)
 - Corrosion is Likely , AC CD $> 10 A/m^2$ & $>$ DC current density
 - Corrosion is highly Likely , AC CD is larger than $100A/m^2$
- ❖ Above criteria are adopted from EN15280 (superseded by ISO 18086) and CIGRE TB 290

AC Corrosion Criteria Review – European & American

- **ISO 18086-2019**

AC CD $< 30 \text{ A/m}^2$ on a 1 cm^2 coupon (24 hr average)

AC CD $> 30 \text{ A/m}^2$ & DC $< 1 \text{ A/m}^2$ on a 1 cm^2 coupon (24 hr average)

- **NACE SP21424-2018**

AC CD $< 30 \text{ A/m}^2$ if DC current density $> 1 \text{ A/m}^2$

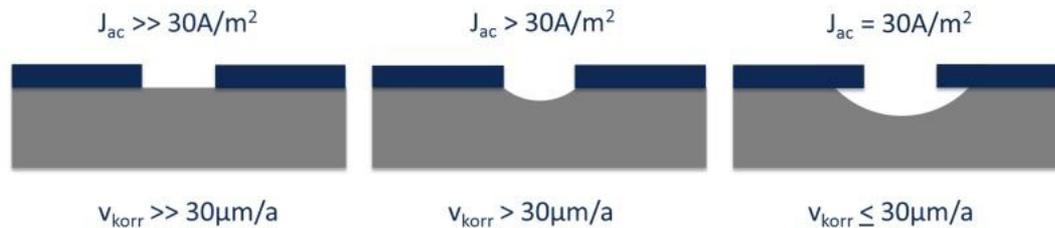
AC CD $< 100 \text{ A/m}^2$ if DC current density $< 1 \text{ A/m}^2$

Corrosion rate $< 0.025 \text{ mm/y}$ (1mpy) measured with weight loss coupon

AC Corrosion Criteria – Further Information

Application of a new criteria from German Standard GW 28 – 2018

- No severe AC corrosion leading to leakage was observed with wall thickness $> 5\text{mm}$
- Rate of AC corrosion over time will decrease till it reaches negligible levels. This is because of steel surface increase (below schematic)



AC System Modelling Vs. Data Loggers

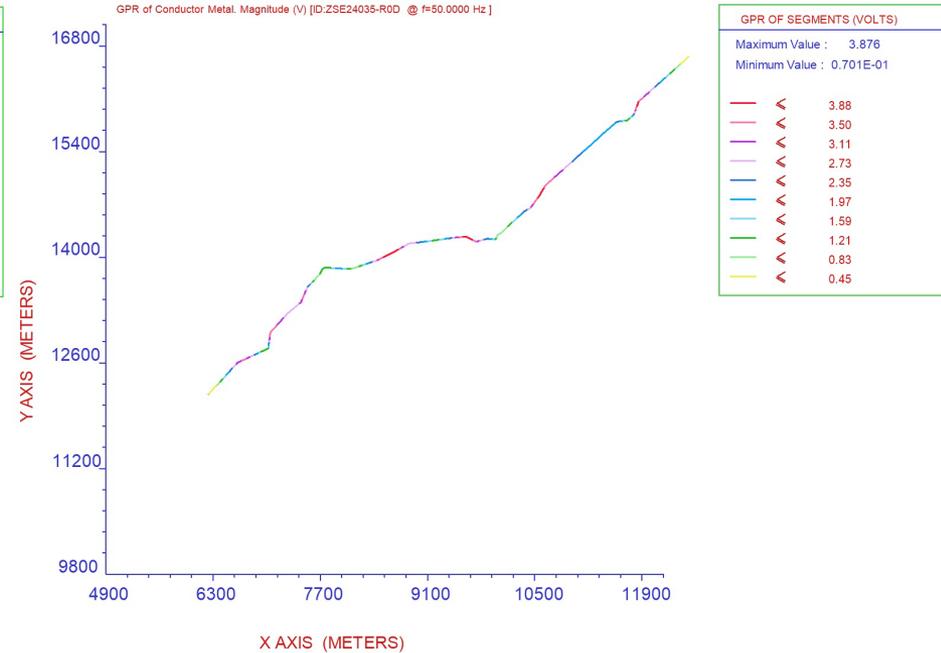
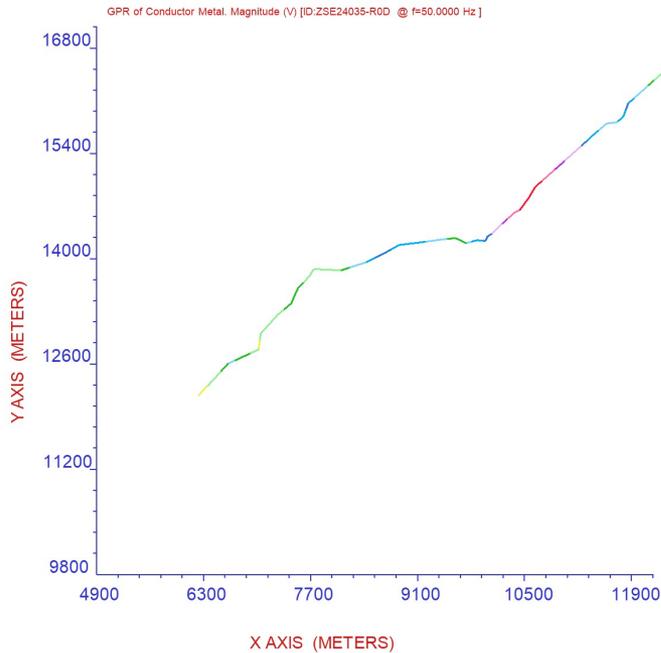


Location	Logged average AC (V)	Modelled AC (V)
1 – KP 650.6	0.273	0.670
2 – KP 651.6	2.83	1.40
3 – KP 654.0	9.67	8.70
4 – KP 656.2	16.2	16.2
5 – KP 658.7	0.0744	0.0940

- Above : AC Voltage Measurements VS Modelled Voltages (Existing System)
- Left : CDEGS Model of the Pipeline and 132 kV Circuits

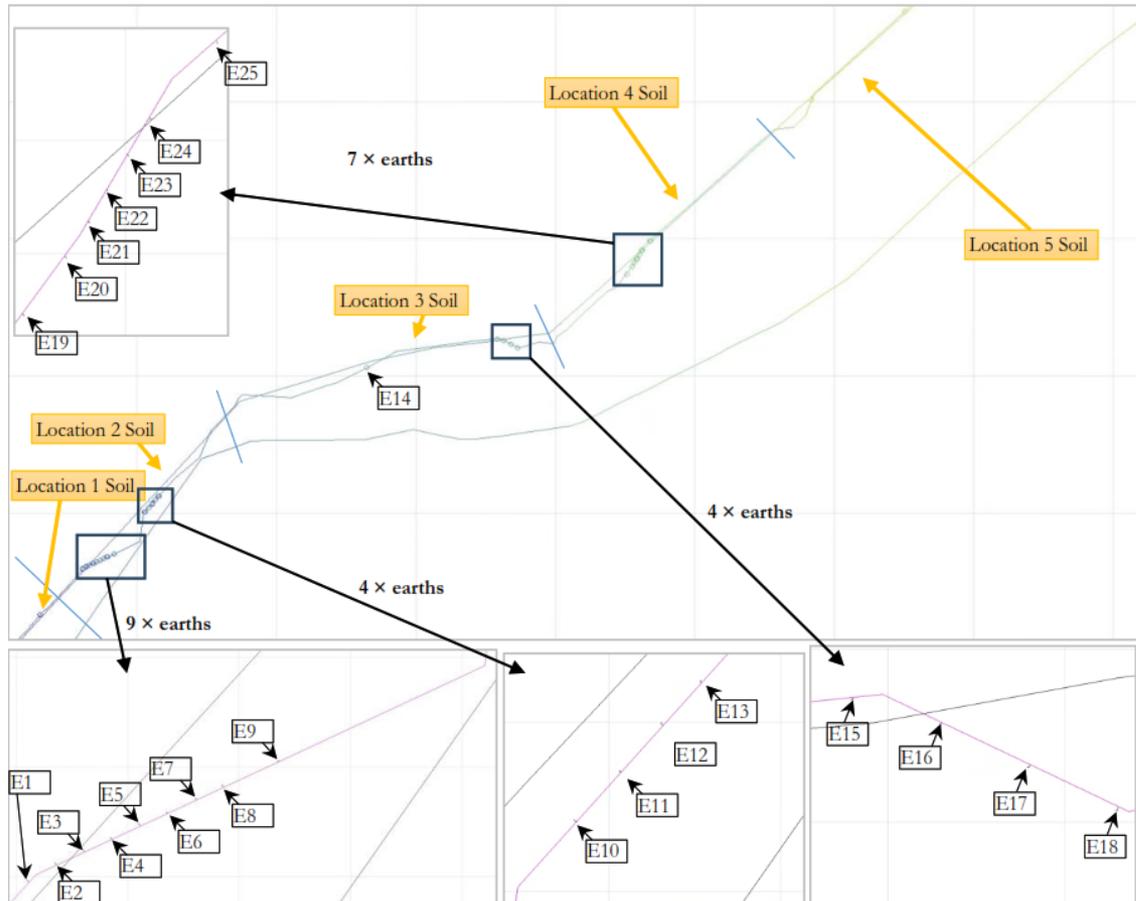
Twin-circuit 132 kV powerline is simplified as a single conductor, representative of the total imbalance of the superimposed magnetic fields of each conductor in both circuits. An overall current magnitude of 230.6 A in this single-conductor system, representative of the same cyclical nature of the logged voltages, is found to be the best match in this model

Initial AC Mitigation System Modelling



- Modelled Steady State Pipeline AC Voltage (Existing) , top left
- Modelled Steady State Pipeline AC Voltage (Mitigated System) , top right,
Mitigated model is based on installation of 25 off 1Ω earth points to reduce the entire 8 km section consistently below 4V AC

Initial AC Mitigation System Modelling - Continue



- Groups of earth points distributed at 4 locations
- Two earth point configurations were proposed and evaluated by Jemena; Earth electrodes and Zinc Ribbons
- Earth electrodes were chosen by Jemena due to significant cost difference (on-third and analysis for the following were selected by Jemena
- Jemena has decided to explore additional scenarios. These scenarios were selected to compare the optimum option against the original conservative 25 earth electrodes :
 - For the entire 8km section, re-model for 7 & 10 volts AC
 - For only the inner 2km section, re-model for 4, 7 & 10 volts AC

Selected AC Mitigation System

Earthed Point	Mitigation Focus KP650 to KP658			Mitigation Focus KP654 to KP656.2			Required Earthing for 1 Ω (Refer Table 3-3)
	4 V	7 V	10 V	4 V	7 V	10 V	
E1	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E2	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E3	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E4	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E5	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E6	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E7	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E8	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E9	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E10	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E11	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E12	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E13	⬇	⊗	⊗	⊗	⊗	⊗	Location 2 Soil
E14	⬇	⊗	⊗	⊗	⊗	⊗	Location 3 Soil
E15	⬇	⬇	⊗	⬇	⊗	⊗	Location 3 Soil
E16	⬇	⊗	⊗	⬇	⊗	⊗	Location 3 Soil
E17	⬇	⊗	⊗	⬇	⊗	⊗	Location 3 Soil
E18	⬇	⬇	⊗	⬇	⬇	⊗	Location 3 Soil
E19	⬇	⬇	⬇	⬇	⊗	⬇	Location 4 Soil
E20	⬇	⊗	⊗	⬇	⊗	⊗	Location 4 Soil
E21	⬇	⊗	⊗	⬇	⊗	⊗	Location 4 Soil
E22	⬇	⊗	⊗	⬇	⊗	⊗	Location 4 Soil
E23	⬇	⊗	⊗	⬇	⊗	⊗	Location 4 Soil
E24	⬇	⬇	⬇	⬇	⬇	⬇	Location 4 Soil
E25	⬇	⬇	⊗	⬇	⬇	⊗	Location 4 Soil
TOTAL	25	5	2	11	3	2	-
Resultant KP650 to KP658 Max. Voltage	3.86 V	6.97 V	7.36 V	6.71 V	7.22 V	7.26 V	Selected AC Mitigation System
Resultant KP654 to KP656.2 Max. Voltage	-	-	-	3.87 V	5.89 V	7.36 V	

- 11 Earth electrode system were selected to be installed between locations 3 & 4
- Each of 11 earth electrodes (E14 to E25) consists of a semi-deep earth well (10m and 15m depth)
- Each earth electrode will be connected to EGP via an SSD decoupler
- Residual AC voltages expected to be less than 6.71 V in the inner 2km and less than 3.87 V outside

Summary

- AC corrosion is a credible threat that needs to be considered in-line with Standard requirements, further guidelines are provided in international standards
- Undertake soil resistivity and AC datalogging to understand risk level.
- ILI is effective in identifying AC corrosion – consider pinhole specification
- AC mitigation works planned for completion in 2026 for EGP



