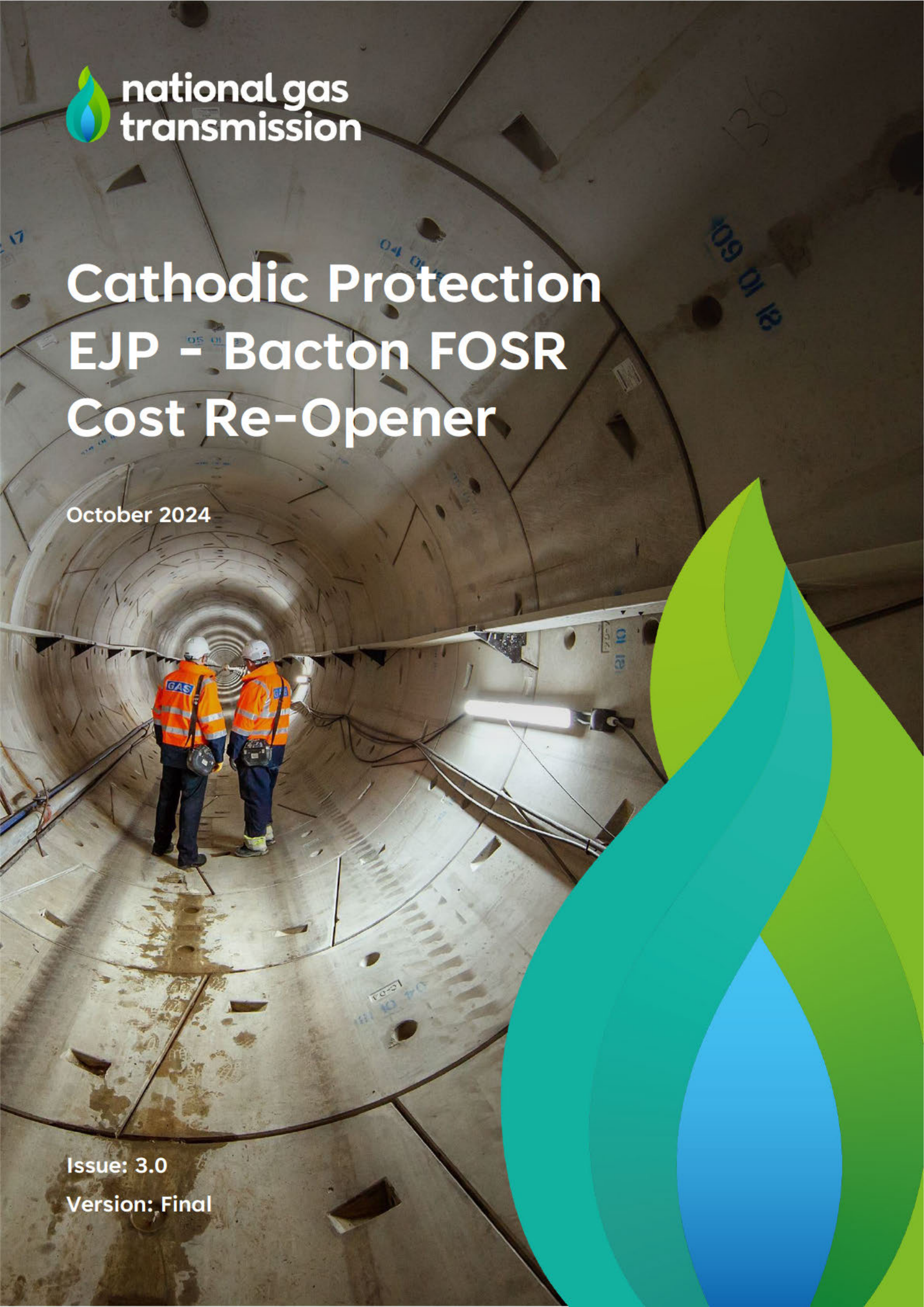

national gas transmission

Cathodic Protection EJP - Bacton FOSR Cost Re-Opener

October 2024

Issue: 3.0

Version: Final

Version control

Version/revision number	Date of issue	Notes
1.0	August 2024	First draft
2.0	October 2024	Internal Review
3.0	October 2024	Final

Contents

1 Executive Summary

1.1.1 National Gas Transmission (NGT) are requesting funding to manage Asset Health and Legislative requirements related to the Cathodic Protection (CP) system at Bacton Terminal. This is aimed at maintaining the ongoing safe, secure and reliable operation of the UK National Transmission System (NTS).

1.1.2 To confirm the current and ongoing performance of the CP system, which is required to protect below ground pipework, a Close Interval Potential Survey (CIPS) survey was undertaken in 2023 (Appendix A) by [redacted] The results of this independent survey confirmed that circa 95% of the CP system falls below the minimum level of protection required. This means that where below ground pipework coating is compromised, corrosion has or will occur. On this basis, and as pipework protection is mandated under Pipeline Safety Regulations (PSR), the independent contractor's recommendation is full system replacement. As such, it is included in the scope of our Asset Health solution.

1.1.3 This EJP proposes asset health interventions which comprises the complete replacement of the CP system, which includes the Distributed Anode System, Reference electrodes, Transformer Rectifiers, Electrical resistance probes and Instrumentation and Control. The proposed interventions will address currently identified asset health issues to support the extension of the terminal's operational life. The RIIO-T2 baseline funding, was used to progress interventions development to conceptual design and commence detailed design.

1.1.4 The consequence of failure has varying impacts on terminal availability and the environment such as gas leaks into the atmosphere, safety events ranging from minor isolations to carryout repairs to complete loss of gas containment. No investment in the CP system will lead to continued and increasing deterioration, limiting effective pipeline protection. This in turn leading to continuous corrosion and ultimately, failure. This will also trigger HSE enforcement action such as an improvement notice as an effective CP system is a mandatory requirement to meet safety regulations. If these assets are not functioning correctly, there is a risk of loss of containment and potential security of supply issues. Ultimately leading to a network unable to meet customer needs.

1.1.5 This Engineering Justification Paper (EJP) emanates from the Bacton Final Option Selection Report (FOSR) submitted to Ofgem in February 2024. The FOSR provided a summary of all the work performed to date to evaluate, cost, analyse and justify the full suite of feasible options available to maintain current levels of network capability and availability for our customers. Intensive work was done with the involvement of specialist contractors and stakeholders to arrive at the optimum approved option (Baseline Asset Health) recommended in the FOSR, a decision that has been accepted by Ofgem.

1.1.6 As an Upper Tier, Control of Major Accident and Hazard (COMAH) establishment, NGT has an obligation to effectively manage process safety and demonstrate compliance with COMAH regulations at Bacton. A mandatory safety case must be submitted to the Health and Safety Executive to demonstrate 'all measures necessary' have been taken in the management of the major accident hazard plant and equipment to ensure continued safe operation of the terminal. Conceptual design work and subsequent tenders from Engineering Procurement and Construction contractors have been developed to support the costs for the project provided.

1.1.7 This paper requests direct cost estimate including escalator of [redacted] baseline funding for asset health investment on the Bacton Terminal CP System. Investments have been developed across all asset class themes aligned to the approved Final Option Selection Report (FOSR).

1.1.8 The summary table below sets out key information about the CP Investment project.

Name of Project	CP Assets
Scheme Reference	
Primary Investment Driver	Asset Health
Project Initiation Year	FY2026
Project Close Out Year	FY2029
Direct Cost Estimate (£m, 2018/19)	[redacted]
Direct Cost Estimate with Escalator applied @ (1.23069)	[redacted]
Cost Estimate Accuracy (%)	+15/-10%
Project Spend to date (£)	[redacted] from baseline (Outturn)
Current Project Stage Gate	ND500 (4.3) Develop and Sanction
Outputs included in RIIO-T2	• Completion of the detailed design • Tendering contractor award for build only.
Outputs included in RIIO-GT3	• Delivery, commissioning • Project closure
Outputs included in RIIO-GT4	N/A

Table 1: Summary table for CP Assets

1.1.9 Table 2 below sets out the cost summary for delivering the selected final option for this project.

	RIIO-T2					RIIO-GT3						
£m 18/19	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	Total	Total plus escalator
Direct Costs Phasing (£m)	[redacted]											

Table 2: Bacton Cathodic Protection System Cost Summary

2 Introduction

2.1.1 The Bacton site originally went into service in 1968. The site is now beyond its design life of 40 years. Since then, there have been several significant additions and up-grades to the site including the facilities owned and operated by [redacted] which share the same site as NGT. The Terminal is both a key system entry and exit point on the National Transmission System, which has proved pivotal to securing [redacted]

2.1.2 When first completed, the terminal had a total gas throughput capacity of 112 million cubic metres per day (mcm/d) at standard conditions, further details in Section 7 of the FEED Study report (Appendix B). Bacton Terminal brings in flows from Southern North Sea gas fields, as well as hosting [redacted] This makes it one of the strategic terminals for importing and exporting natural gas.

2.1.3 The terminal has encountered numerous defects on the CP system with some major investments required in the preceding regulatory periods, such as in 2006 when a refurbishment of the system was completed. However, with the forecasted importance and requirement of the site to operate until 2050 as highlighted in the Final Option Selection Report, significant investment needs to be undertaken to ensure optimum safe, availability and reliability of the terminal.

2.1.4 The purpose of the CP system is to protect below ground pipelines and other below ground metal assets from corrosion. It is a secondary backup whenever coatings fail noting that all coating will fail over time, it will also absorb water over time and the required current density will increase resulting in accelerated coating deterioration. The CP system also protects other underground assets connected to the site earth. It is therefore mandatory that the CP system is maintained, functional and effective across the whole site throughout its forecasted life.

2.1.5 Two Close Interval Potential Surveys (CIPS) were completed in 2019 and 2023 to assess the condition of the CP system. These surveys have confirmed the deterioration of the system with the 2023 survey results indicating that the levels of Cathodic Protection were generally below the minimum criteria for this type of system across the entirety of the buried site pipework surveyed as detailed in Section 5 of the Bacton 2023 CIPS Report (Appendix A).

2.1.6 In a significant number of areas, the pipe to soil potentials is unsatisfactory with insufficient current reaching the pipework to achieve effective protection. Furthermore, the pipework were shown to be experiencing a positive shift in potential beyond that of the natural potential of the pipeline, this is consistent with the accelerated corrosion events which were a primary driver for the upgrade work previously undertaken.

2.1.7 Our Bacton Investment Strategy seeks to optimise the management of our assets at Bacton Terminal from RIIO-T2 out to 2050 as detailed in Section 3 of the Bacton Investment Strategy (Appendix G). The condition of the assets and their expected continued deterioration over time presents a gradually increasing risk that needs managing. Several assets are failing which has implications and restrictions on the mode of operation of the terminal, reducing site flexibility. These issues coupled with the consequence of failure has the potential to significantly impact on UK and European Security of Supply.

2.1.8 The terminal has approximately 9000m of underground pipework, which is critical to the operation of the site, hence its integrity should not be allowed to deteriorate. Continued deterioration of the pipework will ultimately result in loss of containment. It is therefore important to undertake all measures necessary to avoid pipework corrosion.

2.1.9 The Bacton site originally went into service in 1968. The site is now beyond its design life of 40 years. Asset health interventions were completed in 2006 to improve its performance and effectiveness. However, further detailed investigations in 2019, 2020 and the 2023 CIPS findings revealed that 95% of the site is not protected as concluded in Section 5 of the 2023 CIPS Report (Appendix A).

2.1.10 In the case of the performance of the 2006 replacement CP system which had a design life of 25 years, it is important to note that substantial changes have occurred on site which could not have in all reasonableness been foreseen as part of the original design, in particular:

- The construction of the [redacted] blast wall has resulted in a cathodically shielded area of the site where the ionic flow to some of our assets has been impaired with the existing system outputs being increased.
- A large section of the below ground pipework has been isolated as a result of the [redacted] decommissioning works, which has resulted in one of the four main Transformer Rectifiers (TRs) providing site wide CP current being isolated, such that it only protects the decommissioned assets. This has impaired the ability to distribute current from the [redacted] side of Bacton site, as this has to be provided from ground beds which are not local to where the current load is. This has also added an additional load on the three (TRs), which have effectively had to work harder to cover the majority of current provided by that fourth TR, which in turn increases anode consumption, whilst not providing efficient current attenuation as the ionic current is being provided from non-localised anode groups.
- Changes to site security arrangements as part of ongoing works to improve our [redacted] has increased the current loading on the earthing system.
- ENI and metering projects such as [redacted] have resulted in additional loading on the CP system, where new assets are equipotential bonded to the commons earthing system. None of these changes were considered in the original design and cumulatively, to a lesser or greater extent, have had an impact on the systems response and life expectancy.

2.1.11 The proposals for the new CP system are specific to meeting the needs of the future operating strategy for the whole Bacton terminal site and will includes allowances for all disciplines and assets e.g., civils, electrical and instrumentation.

3 Equipment Summary

3.1.1 The terminal has approximately 9000m of underground pipework which is protected from external corrosion by pipework coating systems and the CP system which acts as a secondary protection system for the pipework.

3.1.2 The CP system is largely composed of electrical sub assets and associated mechanical, instrumentation and control assets. The scope considers three Switch Mode Power Supplies (SMPS) to provide 3 areas with each sub divided into zones across the terminal with the provisional quantities as follows: [redacted]

[redacted]

Figure 1: Bacton Terminal – CP SMPS Areas (Section 5 Appendix H)

3.1.3 Table 3 below shows the volumes covered in this EJP. The project scope is detailed in section

CP System Reference	Quantity
Vertical Anodes (singles)	133
Horizontal Anode Beds	27
Transformer Rectifiers (TR)	3
Drain points	3
Test Posts (bond)	6
Test Posts (Reference Electrodes)	85-95
Ground beds	160-200
Electrical Resistance probes	2

Table 3: CP Assets Volumes

3.1.4 The proposed asset health interventions, entails the complete replacement of the CP system. This includes the Distributed Anode System, Reference Electrodes, Transformer Rectifiers, Electrical Resistance Probes, and Instrumentation and Control. These interventions will address current asset health issues and support the extension of the terminal's operational life.

Distributed Anodes Principle of Operation

3.1.5 A typical Impressed CP system arrangement which is used to protect approximately 9000m of pipework at Bacton is shown in Figure 2.

3.1.6 The distributed anode system involves multiple anode ground beds strategically located at selected points around the site. Their purpose is to optimise current distribution whilst minimising cathodic interaction with other structures and pipelines to provide a balanced and compliant level of protection to all the buried pipes. This allows individual control over current output of the anodes provided in each zone, ensuring uniform protection against corrosion whilst managing the detrimental effect of over polarisation to the coating system. The anodes are consumed in place of the pipe thus preserving its integrity.

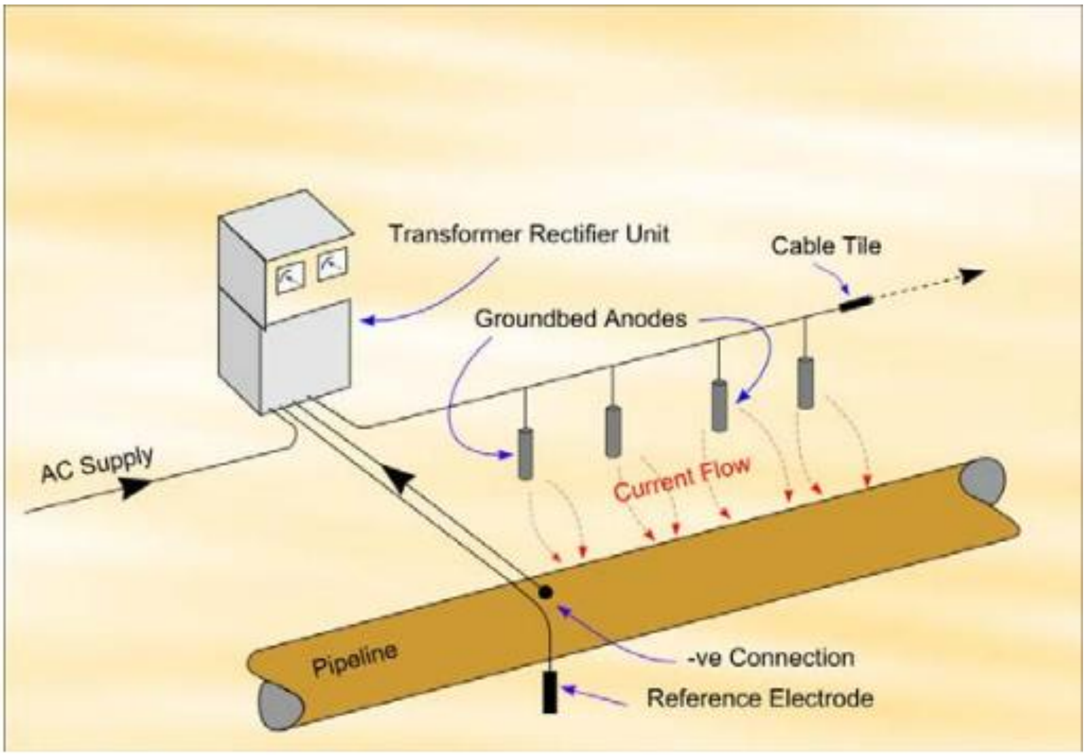

Figure 2: Typical CP system arrangement

Reference electrodes

3.1.7 Reference electrodes are used to measure the structure to electrolyte potential. As the buried pipeline is only half an electrochemical cell, another half electrolyte to metal cell is required to measure the voltage across the cell. Using a reference electrode type suited to the electrolyte is key in maintaining the pipe within the protection criteria. By maintaining the potential of the pipe within criteria set out in normative documents, it can be considered protected from corrosion. Reference electrodes are essential in the assessment of understanding the effectiveness of the CP system.

Transformer Rectifiers

3.1.8 The existing CP system consists of four Transformer Rectifiers (TR's) with each TR located outside within their own kiosk. [redacted] site has its own TR (5th on the diagram below) which is not part of this scope as the interconnector is responsible for maintaining its own CP scheme. Each of the TRs in this scope is connected to a number of ground bed locations.

3.1.9 Transformer Rectifiers convert alternating current into direct current. The current is applied to polarise the structure to a potential sufficient to remain cathodically protected. Figure 3 shows the site location of the existing TRs.

[redacted]

Figure 3: Existing TR Locations

Electrical resistance probes

3.1.10 These are used to monitor the rate of corrosion. The probe simulates a coating defect. By measuring the resistance of the exposed coupon element with reference to the shielded coupon and corrosion rates can be measured by utilising the linear relationship between resistance and metal loss. They are also needed to monitor corrosion rates in areas where there is known interference causing a positive shift in the pipeline potential and accelerated corrosion events.

4 Problem Statement

4.1.1 The performance of the CP system at Bacton has deteriorated to the point where it can no longer provide sufficient current to the majority of the site to be able to maintain effective protection within the upper and lower threshold boundaries as detailed in Section 5 of the 2023 CIPS survey report (Appendix A). This in turn leads to increased corrosion of the buried site pipework. By the nature of its manufacture, steel inevitably has microscopic spots which are electrically more negative or more positive than neighbouring spots. If there is moisture present, a tiny local current will be created between these positive and negative spots. The current and the moisture (in the presence of oxygen) will cause a chemical reaction resulting in corrosion.

4.1.2 The key drivers for this investment are legislation and asset deterioration.

4.1.3 The integrity of the pipework must be maintained to enable continued use and compliance with Pipeline Safety Regulations (PSR).

4.1.4 The CP system ensures pressurised gas containment by avoiding pipework corrosion which introduces weak points. As equipment ages and its condition deteriorates, it is to be expected that additional repair or replacement work may be required.

4.1.5 A critical factor in the corrosion rate of the buried steel pipework and the condition of the coating is the performance of the CP system. The CP system is in place to prevent the corrosion at locations on the pipework where the coating has been compromised. To be effective, the CP system needs to maintain a defined polarised potential at the location which it needs to protect. Most CP systems were designed and installed when the buried structures were new with minimal coating defects. As the coating ages and degrades the current requirement for effective CP protection increases.

4.1.6 The original coating, and most prevalent coating on-site, is coal tar enamel (CTE), dating from 1968. CTE is a thermoplastic material ranging in thickness from 4 to 7mm and includes an inner layer of fibreglass and an outer layer of thermos-glass reinforcement which provides additional mechanical strength. As the site, and therefore the coating ages, we have observed a gradual increase in the cathodic protection current density required to achieve protection. This is characterised by the need to increase TR outputs across the site culminating in them reaching their limit at 100% of output.

4.1.7 Existing cable runs are unlikely to be re-used in a wholesale manner as the anode positioning will change from where the previous runs terminated. Cable jointing should not be undertaken as this introduces additional risks of failure and the risk and complexity of fault finding where there is any concern. It should also be noted that the site has had historical issues with cable damage caused by rodent infestation, and it is not possible to confirm with certainty the condition of all the assets within the cable runs without mass excavation at site. This is not practical, poses risk to operation of the site and adds additional cost to the overall programme of works.

4.1.8 The funding secured through the RIIO-2 Business Plan enabled NGT to carryout requisite investigations to determine condition-based issues to be addressed. A CIPS survey was conducted as part of the works to identify asset health issues and the required resultant interventions as detailed in Section 5 of the 2023 CIPS survey report (Appendix A).

4.1.9 The locations where the primary criteria specified in T/PM/ECP/2 – National Gas Management Procedure for Cathodic Protection of Buried Steel Systems are not achieved is classified as a defect. CIPS defects are categorised into three as shown in Table 4. The table also shows the actual findings in 2023.

Category	Description	Comments	Actual Findings
P1	Both energised "ON" and polarised "OFF" potentials are more positive than the –850mV protection criteria	The pipe to soil potential is unsatisfactory and the locations are not cathodically protected.	110 Category P1 Defects areas were recorded during the survey, totalling 5457m of buried pipework. These potential defects may be vulnerable to external corrosion as the levels of Cathodic Protection at these locations are unsatisfactory. There were 11 locations where the readings suggested that accelerated corrosion was a risk due to the pipeline being positive of the natural potential of steel. Bacton has an established history of these type of accelerated corrosion events.
P2	The polarised "OFF" potential is more positive than –850mV, but the energised "ON" potential is more negative than –850mV. The IR error value is less than 100mV. Potential deviations or fluctuations exist due to external influences which may or may not be identified, e.g., stray currents, AC interactions.	Cathodic Protection levels are unsatisfactory.	67 Category P2 Defects were recorded during the survey, totalling 2562m of buried pipework. These potential defects may be vulnerable to external corrosion as the levels of Cathodic Protection at these locations are unsatisfactory
P3	There is a significant dip in protection although both the "ON" and the "OFF" potentials are more negative than the -850mV protection criteria. The IR error value is between 100mV to 200mV. (Note: Where the IR drop is greater than 200mV there is a high degree of confidence that the survey is not affected by IR issues (no fault))	Cathodic protection levels are satisfactory but further investigation may be required depending on the severity of the defect.	12 Category P3 Defects were recorded during the survey, totalling 140m of buried pipework. This is most likely caused by the poor condition, and low outputs, of the TRUs and ground beds.

Table 4: CIPS defects categories and findings

4.1.10 Results show that the existing CP system is inadequate and in poor condition which is the main cause for the significant number of potential defects recorded during the Bacton 2023 CIPS survey (Appendix A).

4.1.11 The latest report of survey was issued in March 2023 and indicated that most buried piping (8,159 m out of a total of approximately 9,000 m) was not adequately protected by the cathodic protection system. It was evident that the output of the CP system had fallen significantly since the last survey in 2019 and that the performance was consistent with a system coming to the end of its design life. CP system components have a finite operating life and require replacements once confirmed to be defective as detailed in the 2023 CIPS report. Without investment to mitigate the continued deterioration, the ground beds will be fully depleted at which point 100% of the CP system will be ineffective.

Legislation

4.1.12 The following Acts and Regulations are particularly pertinent to the design of a corrosion protection scheme that shall be applied to the buried pipe.

- Pipeline Safety Regulations (PSR) 1996
- Control of Major Accident Hazards (COMAH) 2015
- The Health and Safety at Work Act etc. *(HSWA):1974*
- Gas Act 1986 (amended 1995)

What the investment seeks to achieve

4.1.13 Several short comings of the current system have been identified through surveys and intrusive studies. Therefore, funding and implementing the proposed interventions in this EJP, should produce an efficient CP system which addresses all the identified asset health issues.

4.1.14 The solution should provide long term CP protection of the buried pipework assets at lowest whole life cost. The proposal is to conduct a complete replacement of the Bacton CP system so that it is capable of distributing required current to the main areas of current demand. This will employ localised anode installation as opposed to a flooded distribution system to prevent interaction and interface risks. By being able to operate at lower operational current outputs, it will achieve effective current densities without damaging the coating through over polarisation or causing accelerated corrosion events.

4.1.15 The CP system must be compliant with all legal requirements, safety standards and regulations.

How will we understand if the spend has been successful

4.1.16 To confirm the achievement of the expected quality and operational standards upon completion of the project, the new CP system will be commissioned and should comply to relevant technical specifications, safety standards and legal requirements.

4.1.17 The Cathodic Protection minimum criteria for the protection of iron and steel in typical UK soils should also be achieved as defined within BS EN 12954 – General principles of cathodic protection of buried or immersed onshore metallic structures.

4.1.18 The investment will also be considered successful if the project delivers its scope within its forecasted program, investment funding allocation and re-entry into service.

Narrative Real-Life Example of Problem

4.1.19 To detail the problem at hand and present a real-life example of the current status, a contractor was engaged to carryout Transformer Rectifiers (TR) site surveys during conceptual design studies. Appendix C gives full details of the conceptual design report. It was observed that the entire site was under protected with the TRs turned down. An optimisation survey was conducted to improve the performance of the TRs. The TR outputs recorded during both surveys are stated in the Table 5.

TR Name	Rated Output (V / A)	Output Conceptual Survey (07/02/24)	Output Optimisation Survey (17/04/24)
TR1 – West of site	48V / 10A	2V / 0.5A	40V / 3.1A
TR2 – East of site	48V / 15A	17.5V / 1.8A	41V / 1.2A
TR3 – North of Site	48V / 15A	14V / 1A	45V / 3.25A
TR4 – Centre of site	48V / 15A	20V / 1A	38V / 1.4A

Table 5: Transformer Rectifiers Outputs

4.1.20 The conceptual survey based on the ground beds operating as expected required 2V and 0.5A, but 40V and 3.1A is actually needed to provide the protection at that location. warranting major interventions. Further details of the remediation efforts are shown in Section 5 of the Bacton Terminal CP conceptual design (Appendix C).

4.1.21 Relying on optimising the TRs is not a viable option because the maximum current output from a TR will only be available when the ground bed (GB) to earth resistance allows the TR to deliver its maximum current. Allowing for the back EMF (Electro Motive Force), this will be 3.2 ohms for a 15A TR and 4.8 ohms for a 10A TR.

4.1.22 As the current requirement to achieve protection increases over time, either the voltage needs to be increased or the resistance of the circuit reduced to provide the additional current. As the resistance of the circuit is lowest when the anode material is new, the increase in current can only realistically be achieved by increasing the voltage until it reaches 100% of its output.

4.1.23 The rate of consumption of the anode material is dependent on the amount of ionic current flow that the TR/GB is outputting. As the material is consumed, the resistance of the circuit increases thereby increasing the voltage required to produce the same output; until such time as a combination of the increased resistance and increasing current requirement mean that the TR/GB is no longer able to fulfil its function. Presently it is not possible to deliver the required current because the system of distributed anode ground beds is effectively depleted/consumed.

4.1.24 To better understand the health of an anode, monitoring the TR's change in circuit resistance over time provides a more accurate representation of the systems condition as shown in Figure 4 below.

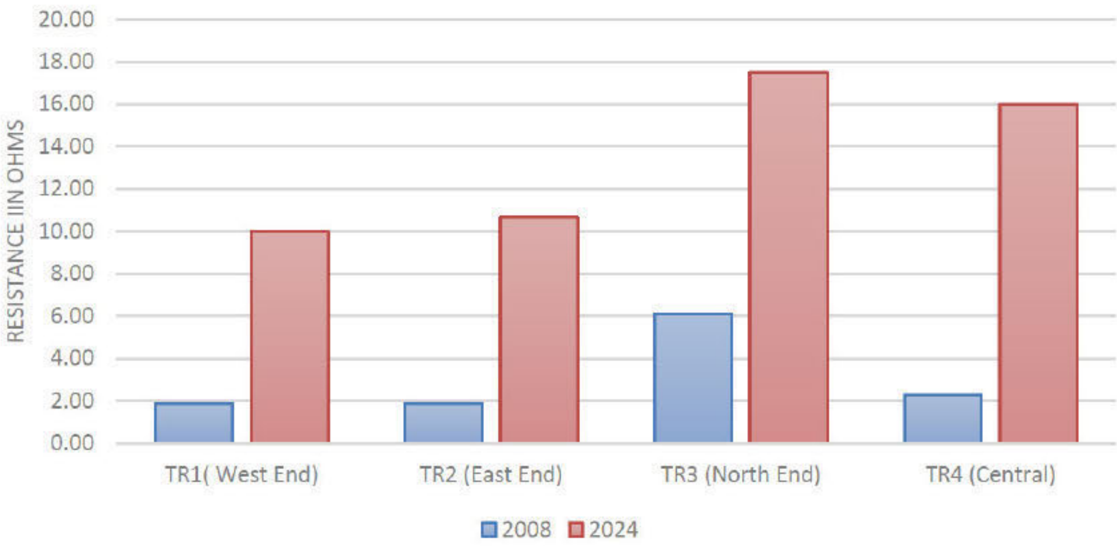

Figure 4: TR Resistance Change 2008 to 2024

4.1.25 Presently the current CP system is at an operational effectiveness of 5% (95% non-compliant) as set out in Section 1.4 of the Bacton Feed Study Report (Appendix B).

Spend Boundaries

4.1.26 The spend of this justification paper covers the replacement of the entire CP system which is composed of the sub-assets listed under the equipment summary section. The entire system of NGT's underground assets and pipework at Bacton terminal will be protected through this scope.

4.1.27 The CP system will cover all the road crossing pipework which falls under the responsibility of NGT. Detailed specific scope boundaries between NGT and [redacted] are detailed in Section 6.10 of the Bacton Terminal CP Conceptual Design Report (Appendix C)

4.1.28 National Gas has five Feeders (No. 02, 03, 04, 05 and 27) leaving the site and all pipelines are isolated from the site via Insulation Joints (IJs). The CP system shall only cover internal pipework up to the respective IJs. IJs are not part of this scope because they have been inspected and found in a good working condition.

[redacted]

Figure 5: Bacton CP System Boundary

5 Probability of Failure

5.1.1 The current CP System is life expired and is 95% non-compliant as concluded in the 2023 CIPS Report (Appendix A).

5.1.2 A CP system and its associated assets do not always immediately fail, instead it will degrade over time as the current demand increases at locations around the site and as the anode material is consumed limiting its ability to provide effective distributed current to a location or buried assets. The impact of poor performance of the system has far reaching effects which results in pipework corrosion.

5.1.3 The rate of corrosion rate for non-protected CP assets is assumed to conservatively be in the order of 0.1mm to 0.2mm a year, meaning that from a new pipe of circa 5mm nominal thickness this would take between 25 and 50 years to corrode through wall while for a 13mm pipe wall thickness this would take between 65 and 130 years. In areas subject to accelerated corrosion mechanisms on a site as in the case within Bacton terminal corrosion rates can easily be 2 to 3 times these assumed rates meaning that without an effective CP system we could see thorough wall failures occurring on the relatively thin wall assets within the next 8 years.

5.1.4 Due to the criticality of the CP system, its current condition has been assessed through detailed system surveys and investigations as articulated under the problem statement section.

5.1.5 As shown in Figure 4, the inspection concluded that the protection has degraded overtime and has now failed. NGT contracted a CP specialist to undertake an optimisation survey to increase the outputs of the TR's. However, this was insufficient to meet the minimum criteria therefore the system must be replaced.

Probability of Failure Data Assurance

5.1.6 The system was holistically investigated with the CIPS report completed in 2019 and subsequently in 2023. In addition, a FEED study and a conceptual design report were completed in 2024 thereby raising the level of data confidence and assurance. Defects were collected for the entire system to inform the investments decision. The findings and interventions were reviewed and verified internally by NGT engineers and technicians to ensure compliance with technical requirements and standards.

6 Consequence of Failure

6.1.1 Without appropriate level of investment, the CP system will not be able to operate as expected and in turn present consequences as detailed in Table 7. It will also fail to conform to the legislative requirements of PSR and safety standards.

6.1.2 A failure of below ground pipework due to corrosion will result in the release of gas. For underground pipework, this will require full isolation and excavations to access the leaking point. Such a failure is unsafe for site staff and would be notifiable to the Health and Safety Executive under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR). It can also lead to HSE enforcement action. In addition, this could also result in a shutdown of Bacton terminal and Seaward facilities impacting security of supply and export to Europe. Table 6 shows Bacton constraints volumes and fees based on the 2024 Future Energy Scenario.

Table 6: Bacton Terminal Constraints Fees

6.1.3 The ultimate result of a failed CP system is loss of gas containment due to through wall corrosion which has serious safety, availability, environmental and financial consequences. The consequence of failure is further detailed in Table 7 which shows the expected stakeholder impacts because of failures occurring on the CP system.

#	Impact / Consequence			
	Availability	Environment	Financial	Safety
CP System Failure	This is associated with the loss or reduced capacity of Bacton Terminal to receive gas from its suppliers as well as distributing it to its customers. In extreme cases, pipe failures can directly affect gas incomers and outgoing feeders. Failures can also affect the availability of localised parts of the site. In the case of buried pipework, any leak will nearly always result in an isolation being required which can result in flow restrictions impacting security of supply.	Associated with the loss of gas through corroded pipes and venting to manage a pipeline failure. The loss of gas to the atmosphere contributes to greenhouse gasses and global warming. Potential noise excursions result in non-compliance with environmental permits	Mostly associated with the OPEX costs of operating and maintaining the network at the current level of risk post failures. Financial penalties for noncompliance with safety and environmental legislation. Potential financial penalties for being unable to supply gas as and when it is needed and associated	Asphyxiation, fatalities and extensive damage to equipment if pipe ruptures result in a fire outbreak. There is also potential to cause fatal explosions. Exposure of operatives to excessive noise above acceptable levels.

	These situations result in unplanned outages and equipment unavailability resulting in potential customer outages.		entry constraints as shown in Table 6.	

Table 7: Consequences of failure Summary Table

7 Options Considered

7.1.1 In total, four high-level options are considered here for management of the condition issues and associated risks as outlined in previous sections.

- Do Nothing.
- Rehabilitation or partial replacement of the CP system.
- Remedial coating repairs to remove localised current drain defects.
- Replace the CP system.

Do Nothing

7.1.2 No specific intervention to be undertaken save for the typical CP system minimum maintenance legal obligations. Considering the confirmed defects on the system, this option would not meet expectations set out by the HSE.

- This option is not viable due to requirements to operate safe plant in compliance with PSR, COMAH and other safety regulations up to 2050.
- Coating degradation will continue to occur and reach a critical point where no CP System can possibly by designed to protect the site.
- Remediation or failure would result in unplanned outages and shortfall of supply to the network.
- This would leave the buried pipework at risk of failure at unknown rates which may result in a loss of containment event.
- The constraints costs due to major failures affecting the availability of the terminal are detailed in Table 6 above.

Rehabilitation or Partial CP System Replacement

7.1.3 Replace broken TRs and depleted ground beds in addition to reinforcing the existing CP architecture.

- This option would not meet expectations set out by the HSE.
- The original CP System is life expired. This is due to general degradation and breakdown of coating and the nature of being a complex site.
- Partially replacing or upgrading current sources would not be viable as circa 95% of the CP system is not providing minimum levels of required protection. Isolating the areas that are currently still receive the correct protection levels would not be feasible and would not result in the risks being as low as reasonably practicable (ALARP).
- Partial replacement may provide useful CP current to protect some areas but would still leave other areas under protected. Increasing outputs of existing equipment, if operational, to compensate and reach other areas of site would result in over-polarisation locally, which is detrimental to the pipe coating.

- The CP system needs to work as a whole, and the design relies on certain parts of the system working well to prevent other parts to have to work too hard (and the coating blistering becomes an issue).
- The degradation of the ground beds, just through use because they are consumed, results in a large number of changes, effectively equivalent to the replacement of the whole system to be effective.
- In view of the above, for a partial replacement to be effective the costs would be comparable to a full replacement of CP system.
- To complete a limited refurbishment scope of transformer rectifier, test posts and ground beds replacement would incur an indicative base cost of circa [redacted]
- Whilst this option would improve efficiency, it will not rectify all the defects identified and as such is not viable due to requirements to operate safe plant in compliance with PSR, COMAH and other safety regulations.

Remedial coating repairs to remove localised current drain defects

7.1.4 Complete excavation of multiple locations on site. This would be followed by repair or replacement of asset coating to an 'as installed' condition in order to restore the primary protection method.

- This option is not viable due to requirements to operate safe plant in compliance with PSR, COMAH and other safety regulations.
- This option is not economical as it would not address the failing of the secondary system which would therefore need replacing soon in addition to this work in order to sufficiently protect the pipework.
- Where pipeline coating is the primary protection for buried assets, Cathodic Protection systems provide secondary protection to coating holidays. Newly installed pipelines and buried assets are never completely free of coating defects. An effective CP System is always required to maintain the asset.
- Remediating the largest current losses would reduce the current required to protect the site. However, as it is a complex structure, some current will still be needed to allow for current drains such as to earthing systems in addition to that required to protect the asset. This requires a fully operational, fit for purpose CP System, to distribute current to all areas and balanced in areas of current loss.
- Excavations of multiple locations would require significant outages which may not be possible while maintaining gas flow through the site.
- Site pipework has multiple different protective coatings used. Each different application of coating requires a different repair method. In many instances on site, it will be required to fully excavate underneath the pipe in order to conduct the repair. Excavations of this nature carry considerably more risk, time, cost and network restrictions. As such this option has not been costed.

Complete CP System Replacement

7.1.5 This option entails installing a completely new CP system and removing the current one. The existing CP System is end of life and the current configuration is no longer able to provide effective CP current to all buried assets. By fully replacing the CP System it will return the system to A1 condition regenerating the full design life of 40 years.

7.1.6 Techniques to effectively manage and control CP have moved on significantly and one of the biggest benefits of a distributed system with remote monitoring and remote-control capability is the current distribution can be managed more accurately without the trade of a flooded CP current system where over polarisation is the result of try to force current to an area which requires additional current.

7.1.7 Replacement of the CP System to provide protection (without over protecting) to all areas on site reduces digs, coating degradation, risk of failure, further outages and extends the operating life of the site beyond any of the above options. This option is considered most economical for the lifecycle of the asset securing network availability and reducing risk.

Options Selection

7.1.8 The Table 8 below illustrate a process used to select the optimum option for the CP system. All the options considered were compared using a set criterion which is based on variables such as cost and compliance to legislative requirements. The table also summarises the viability of each option and highlights the recommended option.

7.1.9 Option 4 is selected as the most optimum which meets all operational and safety requirements.

	Options Considered			
Solution considerations	Option 1	Option 2	Option 3	Option 4
	Do Nothing	Rehabilitation or Partial Replacement of CP System	Remedial Coating Repairs	Replace CP System
Meeting HSE Requirements	Fail - risk prohibition notice Could result in the through wall corrosion and failure of below ground pipework that results in a release of gas notifiable to the HSE under RIDDOR.	Fail - risk prohibition notice Could result in the through wall corrosion and failure of below ground pipework that results in a release of gas notifiable to the HSE under RIDDOR.	Fail – repairing coating defects with the CP system ineffective neglects the required redundancy.	Delivers in line with HSE expectations
Cost	Lowest Cost	Medium	Highest Cost	Medium Cost
Deliverability	No work required	Would not resolve the protection levels on site leaving pipework at risk. It would also add to coating degradation.	Would cause major site disruption which would impact upon delivery of other planned investments across the site.	NGT program confirmed deliverability
Compliance	Fails on a compliance basis/prudent operator and would not comply with our COMAH Safety Case, which requires us to maintain effective Cathodic Protection	Fails on a compliance basis/prudent operator and would not comply with our COMAH Safety Case, which requires us to maintain effective Cathodic Protection	Fails on a compliance basis/prudent operator and would not comply with our MAPD Safety Case, which requires us to maintain effective Cathodic Protection	Compliant

Solution considerations		Option 1	Option 2	Option 3	Option 4
		Options Considered			
		Do Nothing	**Rehabilitation or Partial Replacement of CP System**	**Remedial Coating Repairs**	**Replace CP System**
Environmental Impact		High potential for unplanned gas release due to degradation of protection	High potential for unplanned gas release due to degradation of protection	Requires lots of outages which require venting.	Low carbon footprint
Maintenance	**Ongoing OPEX**	High Opex cost associated with loss of containment events	CAPEX cost required with ongoing high OPEX cost.	CAPEX cost required with ongoing high OPEX cost.	CAPEX investment with lowest OPEX cost
	Risk	High risk - unsafe for personnel to work in vicinity of unmitigated defects	High risk - unsafe for personnel to work in vicinity of unmitigated defects	High risk - unsafe for personnel to work in vicinity of unmitigated defects which would continue to form in coming years	Sufficient protection in place to reduce formation of defects and adequately manage the risk
Security of Supply		Failure of station pipework could affect the terminals flow capability leading to a UK wide supply deficit	Failure of station pipework could affect the terminals flow capability leading to a UK wide supply deficit	Failure of station pipework could affect the terminals flow capability leading to a UK wide supply deficit	Ensures adequately protected pipework to minimise impact to security of supply
Overall viability		Not viable	Not viable	Not viable	Viable

Table 8: CP System Options Assessment

8 Preferred Option Scope and Project Plan

8.1.1 The assessments outlined in this paper and the associated discounting and costing of options demonstrates that the most viable, cost effective and logical options to take forward in this reopener is the complete replacement of the CP system.

8.1.2 This is in line with the Ofgem decision in accordance with Special Condition 3.10.7, to approve the option identified by National Gas Transmission as the Final Preferred Option which is Option 1 Base Case Asset Health. See Section 5 of the Bacton Terminal site development consultation (Appendix D).

8.1.3 The focus is therefore on ensuring this is delivered at the lowest Whole Life Cost to consumers. It has been identified that the criteria for replacing the CP system lie mainly on 95% of the pipework being under protected.

Project scope

8.1.4 A new replacement CP system is required to address the foregoing issues. This design intends to control the CP current from each group of ground beds via a dedicated power supply to each group controlled from a kiosk and/or via a remote-control interface. The new system will be assessed to confirmed it is working within its prescribed limits.

8.1.5 The new CP system will address the effects of both CP shielding and interference by increasing localised current distribution to allow effective protection to be achieved at a lower cathodic output thereby reducing the risk of ionic current finding preferential paths to earth in the same way as this was resolved by the last CP replacement. The new design will also address CP shielding by using improved current control and instrumentation technology capable of monitoring and optimising CP current attenuation.

8.1.6 The subsequent design is required to provide a CP system with a minimum of 25 years design life, in line with the life extension of Bacton terminal to 2050. The scope items below are as detailed in Section 1.2 of the Bacton Terminal CP Conceptual Design Study (Appendix C).

8.1.7 The existing Transformer Rectifier (TR) kiosks are to be removed, and new modular CP power sources are to be installed within external CP kiosks.

8.1.8 Existing ground beds to be disconnected and abandoned, with new distributed ground beds arrangement to be designed and installed.

8.1.9 The existing drain points (DP) are to be abandoned with new drain points installed in accordance with T/SP/ECP/7.

8.1.10 Full site test post coverage is required, with existing test posts being upgraded where suitable and new test posts being installed at key locations across the site including pit wall transitions and where it is considered that significant measurement errors exist when making surface measurements. All test posts shall be located outside of hazardous areas and have permanent monitoring equipment installed.

8.1.11 Electric Resistance (ER) probes installed at locations where historically it has been difficult to achieve effective CP. They are also needed to monitor corrosion rates in areas where there is known interference causing a positive shift in the pipeline potential and accelerated corrosion events

8.1.12 Existing bonds are to be removed, and new bonds installed with associated test facilities included, where required.

8.1.13 Table 9 below, gives the indicative milestones for delivering the project across RIIO-T2 and RIIO-GT3. To note, materials and equipment for the CP system replacement are not considered long lead items. Their expected delivery times range between 8 and 10 weeks for most items which in some cases can be 'off the shelf' components.

	Activity Name	Indicative Completion Dates
001	Anticipated Contract Award	August 25
002	Detailed Design Complete	Competed
003	Anticipated Construction Start date	September 25
004	Completion of Works including demobilisation	September 27
005	Completion Handover Documents	November 27
006	Project Closure	March 28

Table 9: Outline Project Milestones

Final costs

8.1.14 To ensure robustness of the FOSR costs, NGT employed the use of a Designer / Main Works Contractor (MWC) to validate scope, understand some of the engineering challenges associated and to help refine details as well as building up an externally priced estimate showing how the market would cost works of this nature. NGT Utilised [redacted] to undertake this work as they were already in contract with NGT for the first stage of work undertaken to supplement the FOSR submission in February 2024. Further details are highlighted in Section 4 of the Overarching document.

8.1.15 Table 10 provides a breakdown of the final costs for the project split by several categories.

[redacted]

[redacted]

Table 10: Preferred Option Final Costs

Asset Health spend Profile

8.1.16 Table 11 shows the spend profile for our preferred options in 2018/19 pricing.

	RIIO-T2					RIIO-GT3						
£m 18/19	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	Total	Total plus escalator
Direct Costs Phasing (£m)	[redacted]											

Table 11: CP System Spend profile of preferred option

8.1.17 The cost accuracy at this stage of the project is estimated at +15/-10% in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance.

8.1.18 This report has explained the safety and operational risk concerns NGT has regarding the failed CP system and the implications of these on terminal operations. The interventions are necessary to ensure the safety of site personnel and ongoing 24/7/365 operation of the terminal facility.

8.1.19 Removal and the subsequent replacement of Cathodic Protection assets at Bacton Terminal totals [redacted] (2018/19 Prices).

Deliverability Challenges

8.1.20 Due to the complexity of the site, there are significant challenges in delivering this work, a few of which are highlighted below. This is all captured in the estimated cost.

- All excavations require additional planning, temporary works, and a more complex dig strategy as Bacton is a COMAH site.
- All excavations will be completed in accordance with relevant safety regulations and standards.
- The dense population of buried services, plant and equipment leads to above ground complications with heavy machinery.
- Co-ordination with other projects on site to allow continued operation of a live strategically important site.
- Evolving scope leading to additional works required.

8.1.21 Despite the challenges detailed above, NGT has completed a series of deliverability assessments to confirm the scope is deliverable within the planned program. Table 11 above, gives the outline milestones for delivering the project across RIIO-T2 and RIIO-GT3.

8.1.22 Deliverability has also been aligned to the existing RIIO-T2 works and RIIO-GT3 planned work, and other adjacent work aligned to customer outages e.g., IUK shutdown.

9 Conclusions

9.1.1 This report has explained the approach that NGT has taken to manage the Bacton terminal CP system and the implications of not continuing to invest in the CP systems. As detailed in this paper, it is of paramount importance to secure the necessary investment to maintain compliance with legislation.

9.1.2 The need to preserve the performance of CP systems to protect pipeline systems is well understood within the industry and the option presented in this paper meet with current industry guidance and international standards.

9.1.3 Failure to obtain funding will put our pipeline assets at unreasonable risk, leaving Bacton terminal vulnerable to integrity incidents caused by corrosion and would ultimately result in an abdication of NGTs statutory duties.

10 Appendices

10.1 Appendix A- Bacton 2023 CIPS Report

File: [redacted]

10.2 Appendix B – FEED Study Report

File: [redacted]

10.3 Appendix C– Bacton CP Conceptual Design Report

File: [redacted]

10.4 Appendix D – Bacton Terminal Site Development Consultation

File: [redacted]

[redacted]

10.6 Appendix F – [redacted]

File: [redacted]

10.7 Appendix G – Bacton Investment Strategy Summary

File: [redacted]

10.8 Appendix H – Bacton Investment Strategy Summary

File: [redacted]

11 Glossary

Glossary	
CBA	**Cost Benefit Analysis:** A mathematical decision support tool to quantify the relative benefits of each site option.
CDS	Conceptual Design Study
COMAH	Control of Major Accident Hazards (COMAH) Regulations 2015. Bacton Terminal is one of two designated NGT COMAH establishments. The other being St Fergus Terminal
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations 2002
ECI	Early Contractor Involvement
EJP	Engineering Justification Paper
Entry Capacity	Holdings give NTS users the right to bring gas onto the NTS on any day of the gas year. Capacity rights can be procured in the long term or through shorter term processes, up to the gas day itself. Each NTS Entry point has an allocated Baseline which represents a level of Capacity that NGT is obligated to make available for delivery against on every day of the year
EPC	Engineering Procurement and Construction
Exit Capacity	Holdings give NTS users the right to take gas off the NTS on any day of the gas year. Capacity rights can be procured in the long term or through shorter term processes, up to the gas day itself. Each NTS Exit point has an allocated Baseline which represents a level of Capacity that NGT is obligated to make available for offtake on every day of the year.
FEED	**Front End Engineering Design:** The FEED is basic engineering which comes before the detailed design stage. The FEED design process focusses on the technical requirements as well as an approximate budget investment cost for the project.
FES	**Future Energy Scenarios:** An annual industry-wide consultation process encompassing questionnaires, workshops, meetings and seminars to seek feedback on latest scenarios and shape future scenario work. The Future Energy Scenarios document is produced annually by National Grid ESO and contains their latest scenarios.
FOS	Future Operating Strategy
FOSR	Final Option Selection Report
GS(M)R	**Gas Safety (Management) Regulations:** The Gas Safety (Management) Regulations 1996 (GS(M)R) apply to the conveyance of natural gas (methane) through pipes to domestic and other consumers
HSE	**Health and Safety Executive**

Glossary	
IPA	**Infrastructure and Projects Authority**
LNG	Liquified Natural Gas, Natural gas that has been cooled to a liquid state (around -162°C) and either stored and/or transported in this liquid form.
MWC	Main Works Contractor
(G)NDP	**Network Development Process:** The process by which NGT identifies and implements physical investment on the NTS.
NEA	Network Entry Agreement
NEC	New Engineering Contract
NGT	National Gas Transmission
NTS	**National Transmission System:** The high-pressure system consisting of Terminals, compressor stations, pipeline systems and offtakes. Designed to operate at pressures up to 94 barg. NTS pipelines transport gas from Terminals to NTS offtakes.
OEM	**Original Equipment Manufacturer**
Ofgem	**Office of Gas and Electricity Markets:** The regulatory agency responsible for regulating Great Britain's gas and electricity markets.
PFD	**Process Flow Diagram**
PSSR	Pressure Systems Safety Regulations 2000
RAM	**Reliability Availability Maintainability**
Re-opener	Re-openers are a type of RIIO uncertainty mechanism. Depending on their design, they allow Ofgem to adjust a licensee's allowances (in some cases up and in some cases down), outputs and delivery dates in response to changing circumstances during the price control period.
RIIO	**Revenue = Incentives + Innovation + Outputs**: RIIO-T2 is the second transmission price control review to reflect the framework; it sets out what the transmission network companies are expected to deliver and details of the regulatory framework that supports both effective and efficient delivery for energy consumers.
SOL	**Safe Operating Limit**
Uncertainty Mechanism	Uncertainty mechanisms exist to allow price control arrangements to respond to change. They protect both end consumers and licensees from unforecastable risk or changes in circumstances.

Glossary	
UKCS	**United Kingdom Continental Shelf:** The UK Continental Shelf (UKCS) is the region of waters surrounding the United Kingdom, in which the country has mineral rights. The UK continental shelf includes parts of the North Sea, the North Atlantic, the Irish Sea and the English Channel; the area includes large resources of oil and gas.
UID	Unique Identifier

[redacted]

national gas transmission