Cadent
Your Gas Network

Appendix 09.32
Pipeline Reduced Depth of Cover
RIIO-2 Spend: XXXX capex

Investment Decision Pack Overview

This Asset Health Engineering Justification Framework outlines the scope, costs and benefits for our proposals. We have prepared an Engineering Justification Paper (EJP) and a Cost-Benefit Analysis (CBA) for these assets.

Overview

We have 4,982 km of high-pressure (HP) pipelines which operate between 7 and 75 Bar, and 2,987 km of intermediate-pressure (IP) pipelines which operate between 2 and 7 bar. Failure of these pipelines can have significant consequences for safety and interruptions to supply. In addition to our general obligation to maintain the safety and reliability of the network, our approach to managing and investing in these assets must allow us to comply with specific obligations under the Pressure Safety Regulations (PSR) and Health and Safety and Work Act 1974. In short, success for these assets is measured by ensuring there are no compliance failures.

Reduced depth of cover (RDoC) on pipelines within arable farmland is one of the highest risks to pipeline integrity through damage from third parties. We have a regulatory mandate to proactively manage these risks through temporary or permanent solutions.

We have a risk-based approach to RDoC interventions. At a programme level, we have considered only one proactive option for high-risk pipes: to continue to manage and intervene on instances of RDoC, continuing our approach adopted in RIIO-1. A ‘repair pipe on failure’ approach has been rejected because it does not allow us to meet our obligations. Low cover in pastureland or farmland or across ditches requires some form of intervention. Where there is a low risk of excavation, our response option often results in additional surveying and/or monitoring or additional marker posts. At a scheme level, a variety of options will be considered including abandonment, land purchase or soil importation.

We have used CBA for illustrative purposes only, to show that even without our regulatory mandate, a proactive approach is optimum.

Our preferred option is therefore to continue to proactively intervene on RDoC risks for RIIO-2. This requires XXXX of expenditure in RIIO-2. The proposed expenditure is based on unit rates achieved in RIIO-1 which were derived from competitively sourced labour and materials. Additionally, we have developed and implemented consistent and standardised designs, where this is practicable, so as to optimise the design development and appraisal process. Consequently, we consider that the proposed expenditure is efficient for the proposed work types and volumes outlined.

	21/22	22/23	23/24	24/25	25/26	Total XXXX
L&BS OPEX Total **XXXX**						
Ops OPEX Total **XXXX**			Redacted due to commercial sensitivity			
Ops CAPEX Total XXXX						
Overall Totex **XXXX**						

Material Changes Since October Submission

No material changes

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2. Introduction

This document provides the investment case methodology for inspection and remedial activities associated with pipelines sections with reduced depth of cover (RDoC) which are consequently more likely to be damaged. RDoC develops because of changes in land profiles over time. Although pipelines would originally have been installed at the correct safe depth, changes in land use and soil erosion have, through time, removed protective layers of soil, meaning that the pipeline is now closer to the surface and more at risk of damage.

The scope covers high-pressure (HP) and intermediate-pressure (IP) pipelines.

The proposed monitoring and interventions support compliance with our obligations under the Pipeline Safety Regulations 1996 (PSR) and specifically Regulation 13 (Maintenance) and to a lesser extent Regulations 15 (Damage to pipeline).

Our approach to considering investment needs during RIIO-2 has been to assess the range and scale of measures that have been or are planned to be taken during RIIO-1 and to forecast likely activity types and their volumes during RIIO-2 based on this experience. The interventions and remedial works are characteristically relatively low volume but potentially high cost, which presents uncertainty when forecasting for individual schemes but at a programme level allows a robust estimate to be developed. We have outlined the assumptions we made in deriving our forecasts and have provided examples to illustrate the scale and cost of some interventions.

There is a wide range of solutions to the risks posed from RDoC; these include:

- Implementing long-term controls such as fencing, signage or slabbing
- Agreeing permanent changes in land use
- Providing physical solutions such as relatively routine ditch crossing protection through to large scale civil engineering and soil importation works to protect multiple pipeline sections
- Diverting pipelines
- Abandoning pipelines

The document cover photograph shows a pipeline ditch crossing in our East of England network after installation of concrete sections which protect the pipeline.

Within this document, we have considered the two different programme options, set out below, and further discussed in Section 7:

Baseline: Reactively repair upon pipe damage or failure

Option 1: Proactively remediate RDoC risk as soon as practicable.
This option is to assess instances of RDoC that have been identified, implement temporary controls and then undertake interventions as soon as practicable to appropriately manage risk (i.e. target a risk outcome broadly in line with normal pipeline operating status).

The primary driver for investment in this area is to ensure the safe and reliable operation of our pipelines in line with safety legislation. However, we have also used CBA to assess the costs and benefits of undertaking proactive remediation of RDoC risks versus allowing our pipelines to be damaged, with the consequences of pipeline failure or leakage. Within our CBA data tables, we have modelled the proactive remediation option (Option 1), including the benefits from avoiding reactive failures, and then added a further CBA case for sensitivity testing (CBA Option 2). This approach is discussed further in Section 7.

3. Equipment Summary

A summary of the HP and IP pipeline lengths (km) by network is shown in the following table. Note that the lengths are taken from the 2018/19 RRP tables.

	HP (km)	IP (km)
East of England	2,498.3	1,906.0
North London	670.1	257.7
North West	930.5	441.6
West Midlands	883.2	381.7
Total	**4,982**	**2,987**

Table 1: HP and IP pipeline length by network

4. Problem Statement

Overview

Pipelines with RDoC are a relatively recent issue for Cadent and other pipeline operators, caused largely by the intensification of farming activities in recent decades and soil erosion by wind and water, which can progressively reduce the cover over the pipeline and so significantly increase the likelihood of damage.

While technology has advanced to enable the mechanical integrity of the pipeline to be monitored and controlled, external interference from third parties represents one of the main threats to the integrity and safety of HP and IP pipelines. This threat, together with the increased risk where pipeline sections have RDoC, is a key reason why Cadent has adopted a proactive approach to the surveying of its pipelines and to the application of temporary controls and permanent interventions where RDoC issues are identified.

When an HP or IP pipeline is constructed, the design codes IGEM/TD/1 (Steel pipelines for high-pressure gas transmission) and IGEM/TD/3 (Steel and PE pipelines for gas distribution) respectively specify a minimum depth of cover. Ensuring that the correct minimum depth of cover is achieved and maintained is a key measure for minimising the risk of damage to the pipeline from third-party activity.

Investment Drivers

Two drivers of investment must be considered: Legislative (Safety) and 'interruptions to supply'. In addition, we recognise the importance of investment plans that provide value for money. We aim to provide the most efficient and cost-effective, long-term solution to minimise customer bills.

Safety (Legislative): We invest in these assets to comply with the Pipeline Safety Regulations (PSR) 1996 (specifically the Regulation 13 requirement to maintain our pipeline assets, to secure their safe operation and to prevent loss of containment). Maintenance is essential to ensure that all pipelines remain in a safe condition and are fit for purpose.

Instruments	Main legislative drivers
Pipeline Safety Regulations (PSR – 1996) (PSR13a – 2003)	As a pipeline operator, we have duties under the Pipeline Safety Regulations (PSR 1996/ PSR13a 2003). • Regulation 8 requires that our pipelines are constructed of a suitable material. • Regulation 9 requires that our pipelines are constructed to be sound and fit for purpose. • Regulation 13 requires networks to ensure that the pipelines they operate are maintained in an efficient state, in efficient working order and in good repair. • These duties are absolute and there is strict liability.

Table 2: RDoC legislative drivers

Interruptions to supply: HP and IP pipelines enable the bulk transportation of gas from our offtakes from the National Transmission System (NTS) to the main centres of population and to large industrial and commercial (I&C) customers in our networks. Consequently, the failure to manage pipeline assets increases the likelihood of interruptions to significant numbers of customers.

To discharge our obligations, we undertake a range of pipeline monitoring activities as part of a pipeline integrity management (PIM) approach. The aim of this approach is to keep the risks associated with operating these assets as low as is reasonably practicable to maintain the safety of the public and our employees.

Our approach to PIM aligns and is consistent with the recognised industry standards IGEM/TD/1 and IGEM/TD/3.

Line walking recommenced in the winter of 2013/14, having ceased as a survey activity in the mid-1990s. During line-walking surveys, in addition to collecting information regarding changes in the environment around the pipeline (e.g. potential building proximity infringements, missing or damaged marker posts), pipeline depth measurements are taken at 50m intervals.

Required outcomes

We have a duty to comply with our PSR obligations. The increase in safety risk arising from 'no investment' where instances of RDoC are identified is unacceptable.

Additionally, customers and stakeholders have consistently told us that deteriorating levels of network safety, reliability and security of supply is not in line with their preferences.

In summary, the required outcomes for this investment are a safe and reliable system. Success is measured by ensuring a safe operation, legal compliance, and avoiding any failure which leads to supply interruptions downstream.

We will consider our investment plans to be acceptable and appropriate if these outcomes are met.

Understanding project success

Success will result in the delivery of a population of pipelines that are effectively maintained, and which present an acceptable level of risk to landowners and their tenants, to our employees and contractors, and to the public.

4.1. Narrative Real-life Example of Problem

The type and scale of intervention or remediation can vary significantly. For the purposes of developing a cost estimate for RIIO-2, we have developed three different types of intervention, based on the most frequent types of work we have delivered during RIIO-1.

We have not assumed that we will have to divert or replace any sections of pipeline that are identified with RDoC.

We have therefore included examples of the three most likely intervention types within this section.

Pipeline ditch crossing remediation

Our annual line-walking surveys during RIIO-1 have identified a number (typically 65 to 80 per year in total) of ditch crossings where the depth of cover over the pipeline has been reduced to an unacceptable extent and intervention is required. This reduction in cover will occur due to either natural erosion over time from flowing water or through routine clearance of the ditch by the landowner.

Each intervention requires liaison and agreement with the landowner and their tenant where appropriate.

Two examples of ditch remediation interventions in our NW network are shown below. In the first example, we have used a flexible, cobbled mat to provide surface protection where a pipe had reduced cover in a small drainage stream. The second example shows the situation before and after remediation where a pipe had become exposed and the remediation required the construction of a culvert to protect the pipe and to provide drainage continuity.

Where the depth of cover has been reduced, the likelihood of damage to the pipeline at this point increases. The consequences of damage to an HP or IP pipeline are significant in that there is an immediate threat to safety should the damage lead to a higher-pressure escape of gas, with the risk of ignition. Additionally, there is a risk to the security of supply to customers supplied by the pipe. Higher-pressure pipelines are the infrastructure that enables the bulk transportation of gas within a network and so, depending on the location and time of year, the supplies to many thousands of customers could be jeopardised.

Figure 1: Ditch remediation using cobbled matting to protect the pipeline

Figure 2: Protection of pipeline via construction of a culvert (before and after intervention)

Pipeline remediation via reinstatement of the required cover

Where a section of pipeline is identified with RDoC then, following the agreement and imposition of temporary controls to protect the pipe, we will carry out an appraisal and risk assessment to help evaluate the options available to manage the risk. Where it is confirmed that some form of intervention is required, we will seek to achieve a mutually acceptable resolution. We will initially consider using negotiated legal agreements (e.g. by restricting activity over the pipeline easement) where the land type and situation allows and the landowner is open to such an approach.

However, it is apparent from our experience in RIIO-1 that many landowners reasonably insist on retaining full access to their land together with an ability to farm it without constraints. In these circumstances, and having exhausted the negotiation of other options, we have considered solutions based on soil importation to reinstate the required depth of cover.

Soil importation works have significant design and environmental permissioning elements. The works may involve the introduction of either base or topsoil, or both depending on the site, and the working strip can typically extend to 25m either side of the pipeline to achieve an acceptable surface profile. The sourcing of soils that are acceptable to both the landowner and the Environmental Agency is required, and stringent permissioning, license and testing requirements apply.

To support our requirement for soil importation to provide long-term asset protection, we undertake annual monitoring for five years to ensure that no significant reduction in pipeline cover is occurring over the short term.

When undertaking soil importation works, we procure the various elements of the work competitively and/or use market-based rates to support negotiation where local soil sources are being considered.

The images below show the scope of a pipeline protection project on the 610mm diameter Papplewick to Basford, Nottingham HP pipeline in our EM network. The pipeline operates at 37 bar and is the main source of supply into the north of Nottingham city. Figure 3 shows the scope of works and Figure 4 shows the works in progress on the same job. There were 21 separate locations of RDoC along approximately 5 km of HP pipeline in this project, and the majority of these were resolved via soil importation. There was also some resolution via agreed change of land use.

The consequences of damage to this pipeline would potentially be severe as the security of supply to tens of thousands of customers would be threatened.

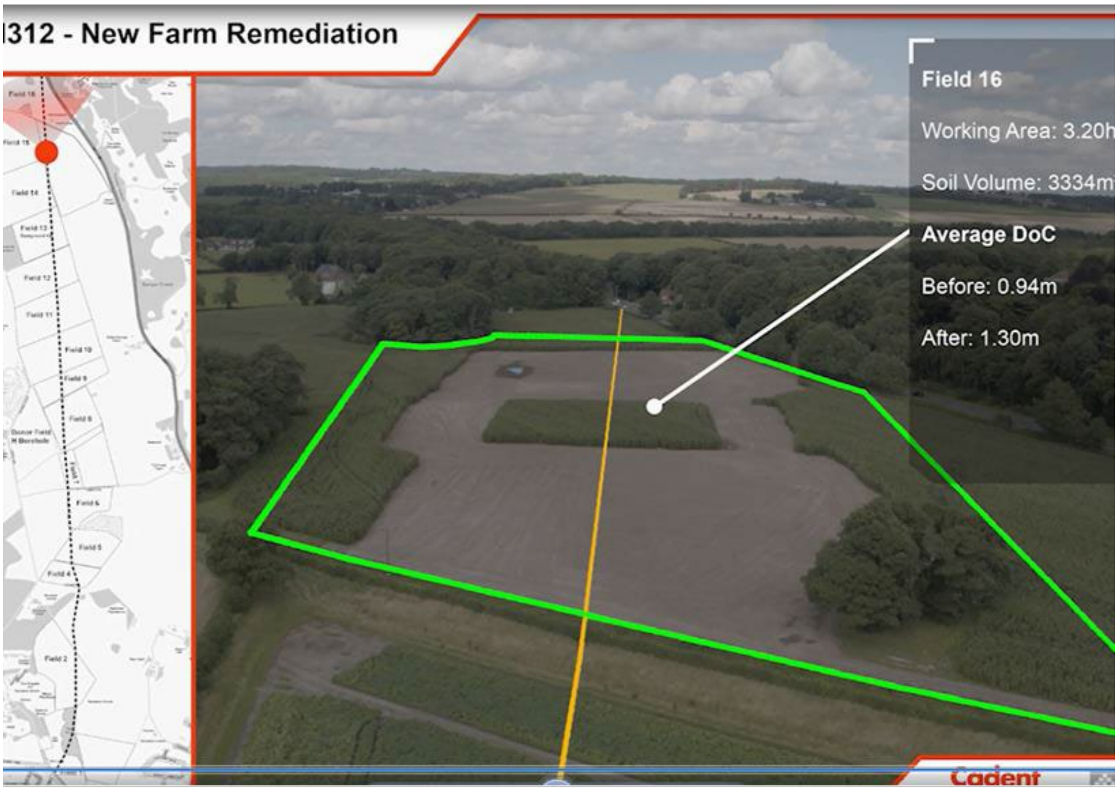

Figure 3: Scope of pipeline protection via soil importation, New Farm, Redhill, EM Network

Figure 4: Pipeline protection via soil importation, New Farm, Redhill, EM Network

Pipeline protection via a negotiated legal agreement

As highlighted above, we will seek to identify options to protect the pipeline sections identified with RDoC. Where action is required, we explore whether options that involve restricting access to, or use of, land over the pipeline can be introduced in agreement with the landowner.

Practically, such measures can range from a change use from arable to grazing, through to re-alignment of field boundaries or the erection of fencing to effectively reposition the pipe to the edge of a field or to create a sterilised strip over the pipe.

Another option may be to construct an access road over the pipe to restrict land management activities directly over the pipe. An example of such an approach was the work we undertook in our NW network on the 400mm diameter IP Ormskirk to Southport pipeline. This pipeline provides the main source of supply to the town of Southport (XXXX customers) and so the consequences of damage to the pipeline, outlined above in terms of the threat to both safety and security of supply, would be significant.

The roadway was designed to ensure that the weight of plant on the pipeline was acceptable. Figure 5 below shows the roadway being constructed over the pipeline.

Figure 5: Pipeline protection via roadway construction, Ormskirk to Southport, NW Network

4.2. Spend Boundaries

The assets within the scope of this investment case are the population of HP and IP pipeline sections identified as having RDoC during our annual line-walking surveys.

Our investment proposals for RDoC include the initial assessment of RDoC instances already identified; the agreement and imposition of temporary controls to limit activity over the pipeline while options are developed, negotiated and agreed with landowners; and finally, the undertaking of agreed permanent interventions.

Much of our work to manage RDoC across our pipelines, is delivered through opex spend and is comprised of the following:

- Land and estate fees for landowner negotiations, including compensation costs to landowners
- Installation of matting and/or soil importation and landscaping to reinstate cover (soil importation is the most expensive solution at approximately XXXX per metre)
- Installation of temporary fencing or signage and other temporary protection measures
- Ground and vegetation clearance as part of varying the pipeline easement agreement
- Costs for the Cadent team to manage the RDoC programme of work

Based on our experience during RIIO-1, the capital interventions for RDoC typically relate to ditch remediation.

These RDoC proposals do not include for:

- The annual line-walking surveys which are part of a wider set of pipeline survey and monitoring proposals and covered in our base opex submission.
- Any interventions required that are associated with RDoC situations identified on medium- or low-pressure pipes. Such instances are relatively infrequent given that such pipes are typically installed in the highway or public land and any proposed expenditure will be included in either our opex submission (e.g. for additional marker posts) or in the appropriate distribution capex (e.g. non-rechargeable diversions).

5. Probability of Failure

Probability of pipeline failure

It is rare for a pipeline to fail due to lack of cover. This is mainly because we invest in control measures to identify such situations (i.e. line-walking of HP and IP pipelines) and then minimise the likelihood of damage where an instance of RDoC is identified. These measures may be temporary (e.g. restricting access or certain uses of the land close to the pipe) and/or permanent interventions.

The identification of RDoC as a significant emerging issue for Cadent came about in 2011 and 2012 primarily because of two events. Firstly, approximately 4km of RDoC was identified, following a plant protection request, on the 200mm diameter Roudham Heath to Wissington pipeline in our EA network, which was commissioned in 1970 and operates at 42 bar. While the pipeline had not been damaged, subsequent investigation identified the root cause as a combination of progressive decomposition of the rich peat soil, wind erosion, volume shrinkage and agricultural activity. After evaluation of all available options, the decision was taken to divert the affected section of pipeline in 2013/14.

Secondly, a 300mm diameter steel pipeline at Fillingham in our EM network, operating at 7 bar, was damaged during agricultural activities in September 2012. The pipeline was ruptured and resulted in a high-volume escape which did not ignite. As part of the operational response, a temporary pressure-regulating installation was installed downstream of the damage, and this enabled supplies to be maintained. The incident was investigated by the HSE.

These two instances led initially to progressively wider survey work and then the introduction of line-walking surveys in 2013/14.

Probability of RDoC Incidents

To understand investment needs, we need to understand the probability of RDoC issues emerging.

HP and IP pipelines are subject to line-walking (i.e. an over-land survey) with a frequency of four and ten years respectively. We take depth measurements every 50m along the pipeline. We typically survey approximately 1,250km of HP and 300km of IP pipeline every year.

We have adopted a risk-based approach to the categorisation of pipeline sections identified with reduced depths of cover and these are categorised as either 'red', 'amber' or 'green' in accordance with the table below.

This pipeline integrity risk is not impacted by the supply-demand scenario selected, because the risk is associated with the asset rather than the volume of gas transported.

HP and IP pipelines are subject to line walking (i.e. an over-land survey) with a frequency of four and ten years respectively.

Pipeline Depth (m)	Category
<= 0.6	Red
>0.6 <0.9	Amber
>0.9	Green

Table 3: Pipeline depth risk categorisation from Cadent procedure T/PM/MAINT/14

We have analysed the results of the last six years of data for our EoE network, which shows the following emerging risks:

EM	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Nos. of Line-walking survey depth measurements (HP/IP pipelines)	7,253	8,106	10,341	6,567	7,697	7,244
Red (%)	1.3	1.6	1.2	1.1	2.0	2.4
Amber (%)	7.4	10.2	7.0	4.5	16.4	16.4
Green (%)	91.3	88.2	91.8	94.4	81.6	81.2

Table 4: Categorisation of depth measurements EM network RIIO-1 (HP/IP pipelines)

Red risks in cultivated or pasture land trigger landowner contact to establish appropriate control measures. Red risks associated with ditch crossings also typically trigger a ditch remediation. Some red risks in other areas (e.g. canal towpaths) may result in the pipe remaining in situ with the depth of cover unchanged but with additional control measures such as periodic vantage-point surveys or the installation of additional marker posts if necessary.

The risk-based approach we adopt is detailed in our management procedure MAINT/14.

Based on the above survey results, for the EM network, approximately 100 to 200 depth measurements per annum are identified as a red risk. These will be typically spread across ditch crossings and a small number of larger sites, or many smaller sections of at-risk pipe.

We expect a proportional number of risks emerging in the other three networks. These surveys are showing that there is likely to be an ongoing programme of RDoC management throughout RIIO-2, particularly for the IP pipelines where the first cycle of surveys is still incomplete.

5.1 Probability of Failure Data Assurance

The annual line-walking survey described above provides the depth-of-cover data points (taken approximately every 50m) from which pipeline sections with RDoC are identified.

Indications of RDoC are subject to further investigation and more detailed assessment to confirm the specific lengths and depths of cover profiles of the sections. This enables the identification and evaluation of options and informs discussion, negotiation and agreement with landowners.

The data presented above for our EM network was extracted in October 2019 from the line-walking data portal and consisted of the full data set for line-walking surveys undertaken in 2013/14 to 2018/19 inclusive. The line-walking surveys in 2019/20 have not been completed and so the data presented is partial.

6. Consequence of Failure

The absence of adequate cover is a breach of PSR legislation.

Failure to rectify this issue would result in prosecution and HSE enforcement.

In addition, if pipeline sections with RDoC are not effectively maintained, then there is an elevated risk of the pipeline being damaged, leading either to immediate loss of containment and a higher-pressure gas escape which may ignite or the threat from an escape in the future should pipeline failure occur later.

Such a scenario could put the safety of the public, our employees and contractors, and the security of supply to customers at risk.

We have used the consequences of a pipeline failure as included in our LTS AIM model for this investment case.

Our LTS AIM model includes the following consequences:

- Interruptions to supply (properties impacted)
- Transport disruption
- Property damage
- Fatality or injury
- Emissions (greenhouse gas)

In addition, we have considered the avoided costs from avoiding the need to carry out a reactive repair. From our analysis, we have identified that reactive work typically costs 20% more to deliver than a similar planned job costs.

Our AIM model contains the following consequence data (figures pa) for a failure on the LTS network:

Region	Supply interruption: Properties impacted (pa)	Properties damaged (pa)	Value per property	Fatalities (pa)	Minor injuries (pa)	Level of emissions (Kg/m3)
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
All						

Table 5: Consequence of Failure: properties, injury, emissions

Region	National railway (critical)	National Railway (other)	Motorway	A Road	Minor Road
EoE	0.0040	0.0000	0.0004	0.0029	0.0173
Lon	0.0065	0.0000	0.0018	0.0094	0.0184
NW	0.0080	0.0000	0.0033	0.0091	0.0184
WM	0.0058	0.0000	0.0023	0.0055	0.0212
All	0.0054	0.0000	0.0015	0.0055	0.0183

Table 6: Consequence of Failure: Transport Disruption (per annum)

The average social cost of disrupting the transport networks is set out below.

Severity	Value XXXX
Transport disruption: Minor road	Redacted due to commercial sensitivity
Transport disruption: A road (modelled - average A roads)	
Transport disruption: Motorway	
Transport disruption: National rail (critical routes)	
Transport disruption: National rail (other routes)	

Table 7: Social costs from transport disruption

In addition to the risks summarised above, which could directly impact the public and our employees, another consequence of a pipeline failure would be significant unplanned expenditure associated with the initial emergency response and the repair activity. The repair of HP pipelines usually involves flow-stopping and bypass arrangements, significant preparatory civils works, and the establishment of an extensive safe-working zone for a prolonged period, with the associated inconvenience (e.g. to road users and the wider public). This case study is discussed in Appendix 09.09 LTS Pipelines (Piggable / Non-piggable) in Section 4.1.

The cost of an unplanned HP pipeline repair can typically range from XXXX depending on pipe size and location. This illustrative cost range, which is derived from several HP pipeline repairs undertaken for various reasons during RIIO-1, does not take account of the actual or risk-adjusted potential direct costs associated with a wide-scale loss of supply (i.e. network isolation, recommissioning of the network and customers, support to vulnerable customers, compensation payments as appropriate) that could potentially take an extended period of weeks to rectify. These costs could substantially exceed the repair costs. The costs of these lower-probability, more-major costly emergency events have not been included in our CBA.

7. Options considered

We have considered two programme options within the section:

Baseline: carry out no RDoC management activities and reactively intervene after pipeline failure.

Option 1: Proactively manage our RDoC risks. Assess instances of RDoC and then implement temporary controls. Undertake interventions as soon as can be practicably achieved (i.e. target a risk outcome broadly in line with normal pipeline operating status).

We have used CBA for illustrative purposes to demonstrate that, even in the absence of legislation, a proactive approach to managing the risk from RDoC is optimum. We recognize that we have an obligation under PSR to maintain our pipes and allowing them to fail prior to intervention would leave us open to prosecution from the HSE. We have, however, included this CBA for completeness.

The CBA basis of calculation together with the CBA scenarios analysed are explained in Appendix 2.

7.1 : Baseline - Reactively repair upon pipe failure

This option assumes that we do not proactively invest in any of our pipelines with RDoC, carry out no survey depth readings during our line-walking surveys, and merely remediate the pipeline when it fails.

Under this scenario, Cadent would be in breach of its obligations under the PSR, and more generally under the Health and Safety at Work Act (HSWA) 1974, in failing to protect people from the risks associated with these major accident hazard pipelines (as defined by the PSR).

This option is our baseline case. However, this baseline option cannot be forecast in absolute terms due to the high levels of uncertainty. In this scenario, we have set the baseline as zero and, in the options, the ***changes*** in costs are considered. A specific example of this is where we have included the costs of reacting to a failure as avoided costs in each option rather than as absolute levels of anticipated costs in the baseline. This approach has also enabled us to test the sensitivity of the levels of avoided reactive costs more easily.

Our CBA has therefore used a switching analysis to look at what the cost and the impact of failure would need to be for the proactive approach to be more cost-beneficial than a reactive one.

The costs from avoiding such impacts of HP/IP pipeline failure have been added into Option 1 (below) as avoided costs.

7.2 : Programme Option 1 - Proactively remediate RDoC risk as soon as reasonably practicable

This option sustains our current approach to proactively assess and intervene on the higher-risk RDoC situations, using sufficient resources to progress these as soon as is reasonably practicable.

In deriving our RDoC programme of work, through a detailed consideration of the depth of cover and the associated land-use, we have taken a risk-based approach to identifying the RDoC instances that pose a risk of pipeline damage.

This approach is detailed in our management procedure T/PM/MAINT14 and specifically in Sections 4 and 5. The initial risk categorisation is as per Table 2 above. Appendix 2 of T/PM/MAINT/14 then provides a flow chart which enables the appropriate follow-up action to be determined.

When we have categorised the pipeline section in accordance with Table 2 and identified the appropriate follow-up action, we will then consider the options available for each specific scheme.

Evaluating scheme options and negotiating a mutually agreeable solution with the landowner can result in temporary controls remaining in place for an extended period while an agreement is reached. The options available will vary depending on the specific characteristics of each situation. While ditch crossing remediation can generally be progressed readily in agreement with the landowner, for more complex cases we will seek an agreement that minimises the extent of physical works and relies on variations to land use, where practicable. However, many landowners understandably wish to retain unrestricted access to their land, and this drives us towards physical solutions such as re-alignment of field boundaries or access tracks, or soil importation. The order of priority in terms of decreasing preference of solution can be summarised as follows:

Scheme options

- Permanently restricting access via fencing and negotiated easement
- Re-aligning field boundaries or access tracks to position the pipeline outside of the agricultural working area
- Use of protective slabbing over the pipe
- Soil importation to reinstate the required cover
- Purchase of land to enable a change of use
- Diversion of the pipeline to an alternative position

We have applied this approach in developing our capex and opex profiles for RIIO-2.

Our capex and opex profiles have been derived using learning from RIIO-1 on volumes and delivery costs, together with expert judgement on likely emerging work.

- We have a good understanding of the likely numbers and unit costs for ditch remediations based on our RIIO-1 programme.
- Within EoE (East Midlands specifically) we have a known volume of RDoC risks (specific known projects) that will most likely involve some level of soil importation. The risks are known, but the costs of interventions are uncertain until further landowner negotiation is completed; however, we have used unit costs from our RIIO-1 projects to help inform RIIO-2 forecast costs for these schemes.
- We have taken a conservative view of the likely volumes of new RDoC risks that might emerge during RIIO-2, which may also require soil importation, land negotiation and or deed of variation as the final solution across our other networks.

We have calculated our required capex and opex expenditure for RIIO-2 by considering the following work activities. The detailed assumptions to derive these volumes and associated costs are contained in Appendix 1.

Expenditure type	RDoC management activities
Capex	Ditch crossing remediations
Opex	**Soil importation or deed-variation jobs**: An estimate based on known risks and emerging risks, based on likely volumes of soil importation during RIIO-2. **RDoC investigations** (following initial survey) to investigate possible mitigations or solutions. **Vegetation clearance** to support RDoC surveys **Land and Business Support** (Cadent internal team) to: • Arrange land access for ditch crossings • Manage land-related matters to facilitate soil importation or deed of variation • Manage license costs for all temporary RDoC controls.

Table 8: Types of RDoC management activities predicted in RIIO-2

While there are some uncertainties involved in our RIIO-2 forecasts, we can be confident, based on our activities in RIIO-1 and the associated expenditure incurred at a programme level, that there will be a need to undertake significant interventions in each network during RIIO-2.

We have made the following general assumptions in deriving our forecast costs for RIIO-2:

- Opex-based interventions (e.g. soil importation and agreed variations to the deed of easement) would be progressed and implemented as soon as was practicable during RIIO-2.
- In practice, we have assumed that all of the significant extended RDoC instances identified at the end of the RIIO-1 period would be assessed, negotiated and resolved by no later than the end of RIIO-2.

Estimating capex to remediate ditch crossings

The assumed number of ditch crossings in each network per year are shown in the table below. This is informed by work volumes carried out in RIIO-1 and the input of operations supervisors who assess and deliver the remedial works. The total across all four networks, implemented in RIIO-1, is 60 to 65 per year. We consider that a flat profile of proposed work volumes is reasonable given that ditch clearing is a routine maintenance activity.

Region	2021/22	2022/23	2023/24	2024/25	2025/26
EoE	27	27	27	27	27
Lon	12	12	12	12	12
NW	10	10	10	10	10
WM	12	12	12	12	12
Total	**61**	**61**	**61**	**61**	**61**

Table 9: Volumes of ditch crossing assumed for RIIO-2

The forecast ditch remediation unit costs in each network for each year of RIIO-2 are shown in the table below. This is based on outturn costs during RIIO-1. We have assumed that we will continue to improve the overall delivery process and degree of standardisation in the solutions we apply.

Ditch Crossing Remediation (XXXX /unit)	
EoE	[redacted]
Lon	
NW	
WM	

Table 10: Ditch remediation costs (XXXX /unit) assumed for RIIO-2[1]

The rationale for the variances are combination of:

- regional variations in labour/contact rates
- varying proportions of pipelines in urban/rural type locations
- WM having a greater proportion of pipelines in canal tow paths

The resulting capex profile for RIIO-2 is set out below in Table 12.

[1] These unit costs have been rebaselined to 18/19 prices and had an average 0.9% efficiency applied to them – to reflect the average efficiency being applied during RIIO-2. Efficiency increases from 0.3% to 1.5% by the end of RIIO-2.

RIIO-2 opex estimate for RDoC

The opex estimate has been derived from estimating:

- Likely volumes of soil importation jobs based on known and emerging risks
- Land and business support (L&BS) costs to manage ditch crossings, manage license costs for temporary controls, and manage soil importation or deed-variation work.
- Other costs to cover investigations, vegetation clearance, and temporary controls

The detailed supporting calculations are set out in Appendix 1.

The following table highlights the known soil importation or deed-of-variation jobs in RIIO-2. Only EoE and NW have known issues at present. We expect there to be several emerging risks that will also require mitigation via soil importation across all four networks. Only the known jobs are summarised below. Calculations estimating emerging risks are included in Appendix 1.

Region	21/22	22/23	23/24	24/25	25/26	Total
EoE	2	1	2	4	3	**12**
NW	1	1	1	0	0	**3**

Table 11: Forecast volumes of known soil-importation projects in RIIO-2

Proposed Capex and Opex Cost profile

Based on the above calculations, and those in Appendix 1, the overall proposed expenditure in XXXX is summarised below. The Land and Business Support (L&BS) costs (typically for the engagement of agents and professional services to support Cadent, and the agents costs for landowners) are shown separately for each network.

Network			21/22	22/23	23/24	24/25	25/26	Total XXXX
EoE	EA	L&BS						
		CAPEX						
		OPEX						
	EM	L&BS						
		CAPEX						
		OPEX						
Lon		L&BS						
		CAPEX						
		OPEX		[redacted]				
NW		L&BS						
		CAPEX						
		OPEX						
WM		L&BS						
		CAPEX						
		OPEX						
L&BS OPEX Total X								
Ops OPEX Total X								
Ops CAPEX Total X								
Overall Totex XX								

Table 12: Option 1 cost profile (X) for RDoC

The supporting assumptions to derive the CBA for this investment case are contained in Appendix 2.

7.3 : Options Technical Summary Table

	Baseline	Option 1
Option title	Reactively repair pipeline following failure	Proactively remediate RDoC risks when they occur
First year of spend	Not applicable	2020/21
Final year of spend	Not applicable	2025/26
Volume of interventions	Not applicable	61 ditches per annum 15 known soil importation or deed-variation projects, + other emerging projects.
Equipment or investment design life	Not applicable	Ditch remediation – 20 years, soil importation variable.
Total installed cost (Total spend request)	Not applicable	Redacted due to commercial sensitivity

Table 13: RDoC Technical Summary Table

7.4 : Options Cost Summary Table

Refer to Table 12: Option 1 cost profile (X) for RDoC, for a cost summary table for Option 1.

8. Business Case Outline and Discussion

We must manage our RDoC risks proactively to ensure we comply with our PSR. We have used CBA for illustrative purposes, which show that, even without this legal mandate, a proactive approach is the optimum approach. The results of our CBA have been included in Appendix 2.

8.1. Key Business Case Drivers Description

Our key business case driver for this investment case is to comply with the Pipeline Safety Regulations to effectively manage pipeline integrity risks through appropriate management of RDoC risks.

The CBA shows that avoiding reactive repairs and avoiding fatalities caused by pipeline failure are the primary drivers.

8.2. Business Case Summary

For this investment case, we have considered a baseline option and an engineering option, which continues the same proactive approach as RIIO-1 and mitigates or remediates known risks within reasonable timescales.

	Baseline	Option 1 (chosen)
Option title	Reactively repair pipeline following failure	Proactively remediate RDoC risks when they occur
First year of spend	Not applicable	2020/21
Final year of spend	Not applicable	2025/26
Volume of interventions	Not applicable	61 ditches per annum 15 known soil importation or deed-variation projects, + other emerging projects.
Equipment or investment design life	Not applicable	Ditch remediation – 20 years, soil importation variable.
Total installed cost (Total spend request)	Not applicable	Redacted due to commercial sensitivity

Table 14: Business Case Summary: RDOC

We have chosen a RIIO-2 programme which continues the same proactive approach as RIIO-1 (Option 1) as the only feasible option which fully complies with our legal obligations under the Pressure Safety regulations and HSWA.

Based on our pipeline depth surveys we are generally finding that about 1% of our HP and IP pipeline asset stock has cover of less than 0.6m. On our 10,467 km of pipeline, this would be equivalent to 105km of pipeline. While only a proportion of this pipeline is located in areas where land use puts the pipe at risk from damage, it is clear that we have a significant volume of pipes at risk from damage due to RDoC.

Our current preferred option is to proactively invest in 370 of our highest-risk RDoC pipelines during RIIO-2. These 370 risks will be mitigated by a blend of interventions which typically include ditch crossings, soil importation or deed-of-variation interventions.

We have used CBA for illustrative purposes only to demonstrate that a proactive approach to managing RDoC is optimum. We recognize that we have an obligation under our Pipeline Safety Regulations to maintain our pipes and allowing them to fail prior to intervention would leave us open to prosecution from the HSE. We have however included this CBA for completeness.

Our CBA switching analysis has looked at how many reactive failures we would need by the end of RIIO-3 for the proactive option to be the most cost-beneficial. The table below summarises this CBA analysis.

	EoE	Lon	NW	WM	Company Level
Breakeven Failures by the end of RIIO-3	14	1	2	1	18

Table 15: Breakeven RIIO-3 Failure levels for the Preferred Option

This **baseline option of reacting upon failure** assumes that we do not invest in maintaining any of these pipelines for RDoC in the remaining years of RIIO-1 and all of RIIO-2 and RIIO-3. The results of the switching analysis tell us that we would only need to suffer from uncontrolled damage (from third-party land-use) on just 5% of these 370 high-risk pipelines within a 12 year period, resulting in a pipeline integrity failure, for the proactive option to be cost-beneficial.

The results above show that EoE has the largest break-even value of 14 failures by the end of RIIO-3. While this might seem high, there are already 12 identified instances of RDoC under close management in RIIO-1 within EOE, within known areas of cultivation or farming. Having no proactive investment over the next 12 years is very likely to lead to each of these resulting in a pipeline integrity failure as well as a further one or two instances occurring where the pipe is accidentally damaged by third-party land-use over the next 12 years.

In the other networks, we would need only one or two pipeline integrity failures over the next 12 years, for a proactive approach to be cost-beneficial. Prior to adopting this proactive RDoC management approach, Cadent suffered two pipeline failures because of third-party damage on pipelines with insufficient cover.

Therefore, the CBA demonstrates that our proposed proactive programme of work is the optimum approach.

9. Preferred Option Scope and Project Plan

9.1. Preferred option

Option 1 sustains our current approach to proactively assess and intervene on the higher-risk RDoC situations using sufficient resources to progress these as soon as is reasonably practicable, in line with our HSWA and PSR obligations.

As highlighted above, the broad range of factors and environments that need to be assessed where some intervention is required, and the options to be considered, together with the need to achieve agreement with the landowner in each case, mean that there is a higher range of uncertainty in forecasting the proposed workload and expenditure in RIIO-2 at a project level.

However, we can be confident based on our activities in RIIO-1, and the associated expenditure incurred, that at a programme level the identified investment is a continuation of existing requirements. At programme level, our RIIO-1 spend is forecast to be approximately XXXX totex (see Appendix 3), incurred from 2016/17 to 2020/12 in RIIO-1.

9.2. Asset Health Project Spend Profile

The preferred capex and opex spend profile for Option 1 is shown below.

Network			21/22	22/23	23/24	24/25	25/26	Total X
EoE	EA	L&BS						
		CAPEX						
		OPEX						
	EM	L&BS						
		CAPEX						
		OPEX						
Lon		L&BS						
		CAPEX						
		OPEX						
NW		L&BS		Redacted due to commercial sensitivity				
		CAPEX						
		OPEX						
WM		L&BS						
		CAPEX						
		OPEX						
L&BS OPEX Total X								
Ops OPEX Total X								
Ops CAPEX Total X								
Overall Totex X								

Table 16: Option 1 cost profile X for RDoC

For Reduced Depth of Cover our confidence is at Conceptual Design stage, at the programme level, with a range of +/-20%. Costain were commissioned to audit our costing methodologies for several projects. Elements from this project were assessed which confirmed a cost confidence at Conceptual Design stage with a range of +/-20%.

Our RIIO-2 forecasts, as well as adjusting for workload and work mix factors, also include ongoing efficiencies flowing from our transformation activities including from updating and renewing our contracting strategies. Our initiatives are outlined in Appendix 09.20 Resolving our benchmark performance gap. For Capex activities this seeks a 2.9% efficiency improvement by 2025/26 on the end of RIIO-1 cost efficiency level. We have applied an average efficiency to this investment area of 0.90% over 5 years. Commencing at 0.3% in the first year rising to 1.50% in the fifth. All costs in this document are post efficiency.

9.3. Investment Risk Discussion

This programme of work has the following delivery risks:

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.32 - 001	Supply & Demand deliverability risk of Resource availability within the Gas industry	Potential cost increases in labour / commodity markets as demand is greater than supply	Low	Intelligent procurement and market testing. Apprenticeship and Training programmes to fill skills gaps
09.32 - 002	Stretching efficiency targets may not be deliverable (unit costs increase)	Outturn costs are not met increasing overall programme costs.	Low	Established marketplace - ability to manage the known commodity market
09.32 - 003	Unforeseen outages and failures restrict access for planned work	Programme and delivery slippage due to delay of planned outages and or site access	Low	Proactive asset management with ongoing condition surveys and response plans to prevent failures
09.32 - 004	Unseasonal weather in 'shoulder months', Autumn and Spring reduce site access/outage windows	Increased demands affecting access to sites and planned outages delay and cost increases	Low	Controlled forecasting and maintenance of flexibility to react to unforeseen events. Detailed design solutions to minimise outages and reduce exposure.
09.32 - 005	Unexpected / uncommunicated obsolescence during RIIO-2 period of equipment components	Inability to maintain equipment at full capacity with risk of impact upon supply	Low	Maintain a close relationship with equipment supply chain and manage a proactive early warning system where spares / replacements become at risk.

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.32 - 006	Legislative change - There is a risk that legislative change will impact the delivery of our work.	Potential increase in the amount of consultation and information exchange required and require us to align our plans with the safety management processes operated by 3rd Party landowner / asset owners. The potential impact is more engagement and slower delivery	Med	We have established management teams to address these issues. We have also identified UMs for key areas.
09.32 - 007	Refusal to access land and or unacceptable conditions placed by landowners	Working conditions, contractor costs and timescales for delivery	Low	Close working relationships with landowners / agents
09.32 - 008	Undermeasure of topsoil requirements / legislation and supply chain issues	Cost increase and programme delay - difficulty in agreements with landowners / agents	Low	Close working relationships with landowners / agents - early surveys and supply chain understanding

Table 17: Risk Register

10. Regulatory Treatment

This investment will not be processed through the NARMs reporting tool.

Cost variance for low materiality projects such as this will be managed through the Totex Incentive Mechanism (TIM).

This investment is accounted for in the Business Plan Data Table 3.01 LTS, Storage & Entry within the LTS Pipeline Sub Table within the Pipelines (Other Capex) section under the Reduced Depth of Cover line.

It also has elements contained within Table 2.04 Maintenance within the Routine Maintenance Sub Table under the Other Routine Maintenance Section under the LTS Inspection Surveys & Other line and within Non-Routine Maintenance Sub Table under the Other Non-Routine Maintenance section of the table under the Various line.

Appendix 1. Supporting calculations for Option 1

The following section sets out the component parts of the opex estimates for RIIO-2 for RDoC management specifically for Option 1 (preferred option).

The opex estimate has been derived from estimating:

- Likely volumes of soil importation jobs based on known and emerging risks
- Land and Business support costs to manage ditch crossings, manage license costs for temporary controls, and manage soil importation and deed-variation work.
- Other costs to cover investigations, vegetation clearance, and temporary controls.

Estimating soil importation opex costs.

Several sites have been identified where our assessment work to date has indicated that soil importation is required and will be undertaken in RIIO-2. These are in our EoE and NW networks and are listed below. We have also assumed that a number of schemes will be resolved via agreeing a variation to the deed and these are marked '*' in Table A1 below.

However, it should be noted that, while we consider it is reasonable to assume such an outcome in some cases it is not practicable to precisely define those schemes which will be resolved in this way at this time. Many landowners are resistant to such an approach, and agreement can take a number of years to achieve. In our estimating, we have assumed that such outcomes will be achieved at 40% of the rate of soil importation. This assumption may prove to be unrealistic as landowners and agents become increasingly aware, over time, of the approximate cost of alternative options (e.g. soil importation).

	EoE network	NW network
Known work: Sites requiring management using soil importation during RIIO-2	Redacted due to commercial sensitivity	

Table A1: Sites expected to be remediated via soil importation during RIIO-2 (those highlighted '' are assumed remediated via a deed variation)*

In developing our proposed costs, we have drawn on our experience from competitively tendered works in EM which resulted in an overall unit cost for the soil-importation solution of approximately XXXX per metre. We have assumed that we can improve on this by 10% by improved procurement (batching works and developing the market). Consequently, we have assumed a unit cost of XXXX per metre for soil importation and XXXX per metre for deed of variation on average.

While we have identified the above schemes, it should be recognised that, by the nature of this work and the incrementally changing environment around our pipelines, it is likely that line-walking surveys will reveal a wide range of situations that lead to a risk to the integrity of pipelines, and some of these will require mitigating. There is a wide scope of other opex-related solutions that we will implement to mitigate the risk (e.g. moving trees, erecting fences, realigning ditches and hedges).

It is not practicable or realistic to attribute volumes and costs to such activities. Consequently, in addition to the specific sites highlighted above, we have made some broad assumptions in forecasting opex as follows:

EM – all currently known instances of RDoC where remedial action is proposed that are not currently phased for RIIO-1 will be completed in RIIO-2.

EM volumes (km) and costs for soil import and deed variation X	2021/22	2022/23	2023/24	2024/25	2025/26
Soil import volume (km)					
Soil import costX	[redacted]				
Deed variation volume (km)					
Deed variation cost X					
Total Costs (EM)					

Table A2: EM volumes and costs for soil import and deed-variation remediation for RIIO-2

Estimating other opex costs for RDoC management

In addition to the above opex estimates for the EM region (part of the EoE network), we have made several other assumptions to inform the opex estimates for the other networks. As mentioned previously, a wide range of different management activities are needed; these include vegetation clearance for RDoC surveys, investigations, and temporary mitigation or management.

We have used our learning from RIIO-1 and expert judgement to derive our RIIO-2 opex estimates for these activities. These are set out below.

Network	Assumptions for RDoC opex costs for RIIO-2
EA (part of EoE)	
Lon	
NW	Redacted due to commercial sensitivity
WM	
All networks: RDoC Investigations	

Table A3: Assumptions on other opex costs for RDoC management

Estimating Land and Business Support

The Land and Business Support (L&BS) team within Cadent provides support to contact landowners, arrange access, gain temporary access, pay land compensation costs and manage pipeline easements, among other roles.

Many of the RDoC activities have an associated opex cost which covers for labour hours from this team.

For each ditch crossing, the L&BS team need to spend time to arrange access and contact landowners. For each ditch crossing, the team estimate that there is a labour cost (opex) of XXXX per ditch.

The following table shows the resulting L&BS opex profile to support each ditch-crossing remediation.

L&BS Costs to support ditch crossings (X)	2021/22	2022/23	2023/24	2024/25	2025/26
EoE					
Lon					
NW			Redacted due to commercial sensitivity		
WM					

Table A4: L&BS costs to support ditch crossing remediation for RIIO-2

The L&BS team also assist with land matters for all soil importation and deed-of-variation jobs.

The following assumptions have been made in deriving the L&BS support for soil importation.

Region	Assumptions for L&BS support for soil importation/deed of variation
EoE	
Lon	
NW	Redacted due to commercial sensitivity
WM	

Table A5: Assumptions to derive L&BS support for soil importation and deed variations

The resulting cost profile is shown below for L&BS support (soil importation and deed of variation)

L&BS Costs to support ditch crossings X		2021/22	2022/23	2023/24	2024/25	2025/26
EoE	EM	Redacted due to commercial sensitivity				
	EA					
Lon						
NW						
WM						

Table A6: L&BS costs to support soil importation and deed-of-variation remediation for RIIO-2

Estimating the License costs for temporary RDoC controls

License costs for temporary controls continue to be paid until a permanent solution is implemented. An estimate has been made of the 'spill over' of such costs from controls initiated in RIIO-1 and forecast to continue into RIIO-2 due to negotiations not concluding (provided by Senior Land Officer, 13 March 2019), and these are summarised below. The EoE network forecast is based on the significant number of such licenses and our experience of the length of time it can take to achieve a resolution.

L&BS License costs spill over into RIIO-2 X	2021/22	2022/23	2023/24	2024/25	2025/26
EoE	Redacted due to commercial sensitivity				
Lon					
NW					
WM					

Table A7: L&BS License costs initiated in RIIO-1 and spilling over into RIIO-2

Appendix 2. Basis of calculation for CBA

The following section sets out our approach to CBA, the assumptions made in deriving the benefits for each technical option, and the results of the CBA shown in the data tables.

Approach to CBA

We have used 'switching analysis' to assess the optimum option for this investment area, because of the uncertainty we have around the probability of a pipeline failure, as a result of pipelines with RDoC (and therefore damage from third-party land use). As stated in Section 6, we have used the consequence of failure from our LTS AIMS model to inform this manual CBA calculation.

We have used the switching analysis to help us identify the probability of failure that would make the programme breakeven – the switching point. We have then used expert judgement to assess whether this switching point is a reasonable minimum probability of failure. Taking an extreme case as an example, a break-even probability or failure rate for the identified stretch of pipe of 1 in 2 years would not be reasonable whereas 1 in 500 years clearly would.

Switching analysis, as set out the in HM Treasury Green Book, is a form of sensitivity analysis that identifies the input values required to change the cost-benefit analysis results.

> *'A switching value refers to the value a key input variable would need to take for a proposed intervention to switch from a recommended option to another option or for a proposal to not receive funding.* *(HM Treasury Green Book, p33)*

As set out in the Green Book, the switching analysis approach is particularly useful where there are significant future uncertainties, making specification of accurate risk scenarios problematic. It is the most appropriate approach to CBA in this area as we are able to model the consequences of a pipeline failure using our AIM models. However, the probability of the failure is very uncertain.

We have modelled the following CBA scenarios within the CBA data tables; the results of this analysis are discussed in Section 8.

CBA Option	Modelled Costs	Modelled Benefits
Baseline: Reactively replace pipe failures	N/A Costs of reacting to failure are included as benefits (i.e. costs avoided) in relevant Options below	N/A No activity is being undertaken
Chosen Option: **Proactively remediate RDoC risk as soon as practicable**	RIIO-2 costs as submitted for engineering Option 1.	Societal costs that are avoided by the option: • Reactive Costs • Interruptions to supply • Transport disruption • Property Damage • Emissions • Health & Safety We have assessed the break-even failure rate level.
CBA Option 2: **Scenario to sensitivity Test of Option 1 without WTP** **(included as Option 2 in the CBA template).**	RIIO-2 costs as submitted.	As in chosen option - without Interruptions to Supply included in the analysis

Table B1: CBA options analysed within CBA data tables

As noted in the above table, we have taken an alternative approach to modelling the CBA for our baseline case. This baseline option cannot be forecast in absolute terms due to the high levels of uncertainty. In this scenario, we have set the baseline as zero and, in the options, the *changes* in costs are considered. A specific example of this is where we have included the costs of reacting to a failure as avoided costs in each option rather than as absolute levels of anticipated costs in the baseline. This approach has also enabled us to test the sensitivity of the levels of avoided reactive costs more easily.

For this scenario, we have used a switching analysis to look at what the cost and the impact of failure would need to be to result in the proactive approach being more cost-beneficial than a reactive one.

The costs from avoiding such impacts of HP/IP pipeline failure have been added into Option 1 (below) as avoided costs.

Below we summarise how the avoided societal costs associated with the investment are computed.

Calculating the Benefits for Option 1

Annual avoided Reactive Costs

(Annual rate of reactive repair) x (Cost of reactive repair)

The cost of reactive repair is assumed conservatively to be 1.2 times that of proactive repair. This is because evidence shows that emergency reactive costs are substantially more than planned proactive costs (in the region of 40% to 60% higher). Furthermore, our experience of reactive pipeline repair that may occur as a result of pipeline failure is that it costs in the region of XXXX, which is substantially above the cost of proactive repair.

The annual rate of reactive repair is the failure rate, the break-even value of which is assessed via switching analysis.

These avoided reactive costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.

The calculation at the company level is:

Failure rate x 1.2 x XXXX

Annual value of interruptions to supply

(Annual rate of interruption to supply) x (Number of properties affected) x (WTP to avoid interruption) x (Volume of interventions)

The annual rate of interruption to supply is the failure rate, the breakeven value of which is assessed via Switching analysis.

The number of properties affected is forecast via the AIM model and the WTP to avoid an interruption of the likely length of 24 hours to 1 week is XXXX. As the AIM model is for LTS and the sleeves relate to a wider range of pipelines, the failure of which may affect a lower number of properties than the LTS pipelines, we have taken only 10% of the properties affected in the AIM model as a conservative estimate of properties affected.

Region	Number of Properties affected by any failure in LTS AIM model
EoE	732
Lon	1,198
NW	918
WM	772
All	**838**

Table B2: Number of properties affected

The calculation at the company level is:

Failure rate x 0.1 x 838 x XXXX x 370

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years, in line with average asset lives across the business.

Annual value for transport disruption

Our pipelines run under or adjacent to roads and can therefore disrupt transport in the case of failure.

(Annual rate of disruptions to transport network) x (Number of days affected) x (Social cost of transport disruption) x (Volume of interventions).

The annual rate of interruption is the failure rate, the break-even value of which is assessed via switching analysis.

The number of days affected is forecast by the AIM model and set out in the table below.

Region	National railway (critical)	National Railway (other)	Motorway	A Road	Minor Road
EoE	0.0040	0.0000	0.0004	0.0029	0.0173
Lon	0.0065	0.0000	0.0018	0.0094	0.0184
NW	0.0080	0.0000	0.0033	0.0091	0.0184
WM	0.0058	0.0000	0.0023	0.0055	0.0212
All	**0.0054**	**0.0000**	**0.0015**	**0.0055**	**0.0183**

Table B3: Number of transport days disrupted

The average social cost of disrupting transport networks is set out below.

Severity	Value X
Transport disruption: Minor road	
Transport disruption: A road (modelled - average A roads)	
Transport disruption: Motorway	Redacted due to commercial sensitivity
Transport disruption: National rail (critical routes)	
Transport disruption: National rail (other routes)	

Table B4: Societal valuations for transport disruption

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years, in line with average asset lives across the business

The social cost of rail disruption is based on a conservative analysis of Department of Transport data and a conservative assumption for a single day of disruption.

Annual value for property damage

Some of our pipelines run close to properties and as such can create damage in case of failure. Given the nature of these pipelines, however, the number of properties in close proximity is low.

(Annual rate of property damage) x (number of properties affected) x (Social cost of property damage) x (Volume of interventions)

The annual rate of property damage is the failure rate, the breakeven value of which is assessed via switching analysis.

The number of properties affected is forecast by the AIM model and set out in the table below.

Region	Number of Properties Damaged per failure	Value per property
EoE	0.03	
Lon	0.26	[redacted]
NW	0.13	Redacted due to commercial sensitivity
WM	0.08	[redacted]
All	**0.09**	

Table B5: Properties impacted X

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years, in line with average asset lives across the business.

Annual Probability of Fatality/Injury

(Annual rate of injury) x (Number of injuries) x (Volume of interventions)

The input to the template in this area is the annual probability, and the annual value is calculated within the template.

The annual rate of injury is the failure rate, the break-even value of which is assessed via switching analysis.

The number of injuries is forecast via the AIM model as shown in the table below.

Region	Number of Fatalities	Number of Minor Injuries
EoE	0.005	0.005
Lon	0.024	0.024
NW	0.013	0.013
WM	0.012	0.012
All	**0.010**	**0.010**

Table B6: Impacts on safety

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.

(Annual rate of emissions) x (Amount of emissions per failure) x (Volume of interventions)

The input to the template in this area is the annual expected amount of emissions, and the annual value is calculated within the template.

The annual rate of emissions is the failure rate, the break-even value of which is assessed via switching analysis.

The level of emissions is forecast via the AIM model as shown in the table below.

Region	Level of emissions (kg/m3)
EoE	821.36
Lon	1177.26
NW	762.69
WM	1539.58
All	**986.61**

Table B7: Impact on emissions

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years, in line with average asset lives across the business.

CBA results

The results of the CBA at the company level are shown in the table below. As we have used switching analysis the NPV is set at 0.00 to understand the level of failures that would result in a zero NPV.

Option Name	PV Expenditure & Costs	PV Environment	PV Safety	PV Other	Total PV	NPV (relative to baseline)
Baseline	Redacted due to commercial sensitivity					
Preferred Option						
Preferred Option without WTP						

Table B8: Results of Switching Analysis

The annual benefits associated with the break-even failure rate are set out in the table.

Benefit	Breakeven Level
Avoided Cost	Redacted due to commercial sensitivity
Interruptions to Supply	
Transport Disruption	
Property Damage	
Probability of a fatality/minor injury	
Probability of minor injury	
Emissions	

Table B9: Breakeven Level of Annual Benefits (with WTP)

Our CBA switching analysis has looked at how many reactive pipeline failures we would need by the end of RIIO-3 for the proactive option to be the most cost-beneficial. The table below summarises this CBA analysis.

	EoE	Lon	NW	WM	Company Level
Breakeven Failures by the end of RIIO-3	14	1	2	1	18

Table B10: Breakeven RIIO-3 Failure levels for the Preferred Option

This **baseline option of reacting upon failure** assumes that we do not invest in maintaining any of these pipelines for RDoC in the remaining years of RIIO-1 and all of RIIO-2 and RIIO-3. The results of this switching analysis tell us that we would only need to suffer from uncontrolled damage (from third-party land-use) on just 5% of these 370 high-risk pipelines within a 12 year period, resulting in a pipeline integrity failure, for the proactive option to be cost-beneficial.

The results above, show that EoE has the largest break-even value (14 failures) by the end of RIIO-3. While this might seem high, there are already 12 known instances of RDoC under close management in RIIO-1 within EOE, within known areas of cultivation or farming. Having no proactive investment over the next 12 years is very likely to lead each instance to result in a pipeline integrity failure, with a further one or two instances occurring where the pipe is accidentally damaged by third-party land-use over the next 12 years.

In the other networks, we would need only one or two pipeline integrity failures over the next 12 years for a proactive approach to be cost-beneficial. Prior to adopting this proactive RDoC management approach, Cadent suffered two pipeline failures because of third-party damage from pipelines with insufficient cover.

We have undertaken a sensitivity test on the conservative avoided reactive costs used in this analysis, to test the implications on the results of using the high value of XXXX pipeline repair cost as experienced at King's Lynn. This reduces the breakeven failure rate by 75%, meaning that if the reactive costs of fixing a pipeline failure were all as large as in the King's Lynn case then it would only require 4.5 failures over RIIO-3 rather than the 18 set out in Table B10 above. We already have 12 under close management.

Therefore, the cost-benefit analysis demonstrates that our proposed proactive programme of work is the optimum approach.

Appendix 3: RIIO-1 Spend

Any RDoC risks are often time-consuming to investigate, negotiate and then permanently resolve. There is often a considerable lag between the time the risk if first identified and when the problem is permanently resolved. In the interim period, temporary mitigation, landowner negotiations and ongoing investigations may be required over many years.

During RIIO-1, we delivered a wide range of RDoC management activities comprised of the following:

- Land and estate fees for landowner negotiations, including compensation costs to landowners
- Installation of matting and/or soil importation and landscaping to reinstate cover (soil importation is the most expensive solution at approximately XXXX per metre).
- Installation of temporary fencing or signage and other temporary protection measures
- Ground and vegetation clearance as part of varying the pipeline easement agreement.
- Costs for the Cadent team to manage the RDoC programme of work, including extensive landowner negotiation costs, fees and licence costs

The resulting spend profile is shown below:

Pipeline RDoC HN37 Opex (xxx)									
Network	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	Total
EoE									
Lon									
NW					Redacted due to commercial sensitivity				
WM									
Total									

Table C1: RDoC opex expenditure in RIIO-1[2]

The increase in spend in 2019 to 2021 is due to the planned delivery of the permanent solutions for a large number of more-complex jobs during these years (soil importation).
This opex spend profile is shown graphically below.

Redacted due to commercial sensitivity

Figure C1: Spend profile (opex) for managing RDoC

Our capex expenditure is generally associated with the protection of ditch crossings and typically involves building new culverts or other pipe-protection solutions across ditch inverts.

In general, our ditch remediation workload during RIIO-1 has involved between 10 and 40 ditches each year in each network at a typical unit cost of XXXX.

[2] The figures quoted above are in nominal prices.

We have developed a standardised approach to the design and construction of ditch remediations during RIIO-1 to minimise costs. However, the range of solutions required remains broad and can include the construction of culverts and the installation of flumes.

Pipeline RDoC Capex()									
Network	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	Total
EoE									
Lon									
NW				Redacted due to commercial sensitivity					
WM									
Total									

Table C2: RDoC capex expenditure in RIIO-1 [3]

[3] The figures quoted are in nominal prices.

This capex spend profile has been shown graphically below.

Redacted due to commercial sensitivity

Figure C2: Spend profile (capex) for managing RDoC