Document 16
Asset Category – Cable Pits
EPN

Asset Stewardship Report 2014

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Document History

Version	Date	Details	Originator	Revision Class	Section Update
1.0	26/02/2014	Initial Draft & content agreed	Henry Lee /Jeremy Wright	N/A	N/A
1.1	06/03/2014	Draft issued for review	Luke Hughes	Major	All sections throughout document
1.2	06/03/2014	Reviewed but costs and vols still need checking	Brian Matthews	Minor	Preface, 1.1, 1.3, 2, 3.2, 4.1, App 8
1.3	06/03/2014	Vols and costs checked & tables updated	Henry Lee	Minor	All sections throughout document
1.4	07/03/2014	Barry Hatton comments included	Brian Matthews	Major	All
2.0	07/03/2014	Final Version	Henry Lee		

Preface

UK Power Networks uses Asset Stewardship Reports ('ASR') to describe the optimum asset management strategy and proposals for different groups of assets. This optimised asset management strategy and plan details the levels of investment required and the targeted interventions and outputs needed. Separate ASRs define the most efficient maintenance and inspection regimes needed and all documents detail the new forms of innovation which are required to maximise value, service and safety for all customers and staff throughout the ED1 regulatory period. Outline proposals for the ED2 period are also included.

Each DNO has a suite of approximately 20 ASR's. Although asset policy and strategy is similar for the same assets in each DNO the detailed plans and investment proposals are different for each DNO. There are also local issues which must be taken into account. Accordingly each DNO has its own complete set of ASR documents.

A complete list of titles of the ASR's, a summary of capex and opex investment is included in '**Document 20: Asset Stewardship Report: Capex/Opex Overview'**. This document also defines how costs and outputs in the various ASR's build up UK Power Networks 'NAMP' (Network Asset Management Plan) and how the NAMP aligns with Ofgem's ED1 RIGs tables and row numbers.

Where 'HI' or asset 'Health Index' information is included please note predicted ED1 profiles are before any benefits from 'Load driven investment.'

This ASR has also been updated to reflect the feedback from Ofgem on our July 2013 ED1 business plan submission. Accordingly to aid the reader three additional appendices have been added. They are;

1. **Appendix 8 - Output NAMP/ED1 Business Plan Data Table reconciliation:** This section explains the 'line of sight' between the UKPN Network Asset Management Plan (NAMP) and the replacement volumes contained in the Ofgem RIGS tables. The NAMP is the UKPN ten year rolling asset management investment plan. It is used as the overarching plan to drive both direct and indirect Capex and Opex interventions volumes and costs. The volume and cost data used in this ASR to explain our investment plan is taken from the UK Power Networks NAMP. Appendix 8 explains how the NAMP outputs are translated into the Ofgem RIGS tables. The translation of costs from the NAMP to the ED1 RIGS tables is more complex and it is not possible to explain this in a simple table. This is because the costs of a project in the 'NAMP' are allocated to a wide variety of tables and rows in the RIGS. For example the costs of a typical switchgear replacement project will be allocated to a range of different Ofgem ED1 RIGs tables and rows such as CV3 (Replacement), CV5 (Refurbishment) CV6 (Civil works) and CV105 (Operational IT Technology and Telecoms). However guidance notes of the destination RIGs tables for NAMP expenditure are included in the table in the Section 1.1 of the Executive Summary of each ASR.

2. **Appendix 9 – Efficiency benchmarking with other DNO's:** This helps to inform readers how UK Power Networks is positioned from a benchmarking position with other DNO's. It aims to show why we believe our investment plans in terms of both volume and money is the right answer when compared to the industry, and why we

believe our asset replacement and refurbishment investment proposals are efficient and effective and in the best interest for our customers.

3. **Appendix 10 – Material changes since the July 2013 ED1 submission:** This section shows the differences between the ASR submitted in July 2013 and the ASR submitted for the re-submission in March 2014. It aims to inform the reader about the changes made to volumes and costs as a result of reviewing the plans submitted in July 2013. Generally the number of changes made is very small, as we believe the original plan submitted in July 2013 meets the requirements of a well justified plan. However there are areas where we have identified further efficiencies and improvements or recent events have driven us to amend our plans to protect customer safety and service.

We have sought to avoid duplication in other ED1 documents, such as 'Scheme Justification Papers', by referring the reader to key issues of asset policy and asset engineering which are included in the appropriate ASR documents.

Contents

1.0 Executive Summary EPN Cable Pits

This document details UK Power Networks (UKPN) non-load related expenditure (NLRE) investment proposals for cable pits in the RIIO-ED1 period.

- There have been 29 disruptive cable pit failures since May 2012 across UK Power Networks (UKPN) network. The incidents have resulted in the serious injury of four members of the public.
- UKPN is investing £11.2M in DPCR5 in the inspection, maintenance, risk mitigation and research of it's 52,801 cable pits.
- UKPN has pioneered research into root cause analysis of cable pit failures partnering with Black and Veatch in the UK and Con Edison in the USA.
- UKPN has developed a comprehensive risk mitigation strategy which has already commenced in DPCR5 and will continue throughout ED1.
- It is proposed to invest £38.5m during the ED1 period for UK Power Networks in total to complete this risk mitigation strategy.
- Cost Benefit analysis shows an overall benefit to society of a ratio of 5:1 in favour of the implementation of the proposed risk mitigation strategy.
- The strategy is based on
    1. A risk based inspection and maintenance regime for all cable pits
    2. Pioneering research into root cause analysis and cost effective mitigation techniques
    3. Implementation of cost effective mitigation to manage cable risk at an acceptable level.

1.1 Scope

It is proposed in the ED1 period a total investment of £2.98m will be made in this asset as detailed below.

INVESTMENT TYPE	ED1 COSTS	NAMP Line	RIGS REFERENCE
Replace Joints (Cable Pit Strategy)	£216k	1.18.09	**Volumes - RIGS Table CV8** Row 18 – Cable Pits **Costs - RIGS Table CV8** Row 18 – Cable Pits
Cable Pit Mitigation	£1,696k	1.47.40	**Volumes - RIGS Table CV8** Row 18 – Cable Pits **Costs - RIGS Table CV8** Row 18 – Cable Pits
Cable Pit Maintain	£680k	2.05.08	**Volumes - RIGS Table CV13** Row 17 – LV Underground Cable Repairs and Maintenance Row 22 – HV Underground Cable Repairs and Maintenance **Costs - RIGS Table CV13** Row 17 – LV Underground Cable Repairs and Maintenance Row 22 – HV Underground Cable Repairs and Maintenance
Cable Pit Inspection	£390k	2.30.15	**Volumes - RIGS Table CV13** Row 16 – LV Underground Cable Inspections Row 21 – HV Underground Cable Inspections **Costs - RIGS Table CV13** Row 16 – LV Underground Cable Inspections Row 21 – HV Underground Cable Inspections

Table 1: Investment areas (Source: 21st February 2014 NAMP Table J)

There are approximately 3,500 cable pits in EPN with the following risk ratings:

- 149 Very High risk pits,
- 228 High risk pits,
- 2,685 Medium risk pits and
- 438 Low risk pits

1.2 Investment Strategy

In May 2012, a disruptive cable pit failure resulted in serious injury to three members of the public and highlighted an urgent need to develop a more robust approach to the management of cable pits. Since then there have been a further 29 disruptive cable pit failures which have resulted in one further injury to the public.

Since 2012, a significant investment has been made by UKPN to understand the root causes of cable pit disruptive failure, identify the highest risk sites and innovate in new technologies to mitigate the risks of further disruptive failures. UK Power Networks has pioneered the strategy, development and investment in risk mitigation of cable pits in the UK.

The investment strategy for ED1 is to significantly reduce the incidence of disruptive failure, ensure the safety of the public and meet our statutory and regulatory obligations.

The investment strategy has been developed using:

- A risk based inspection regime for all cable pits
- Ground breaking research into mitigations to prevent cable pit disruptive failures
- A trial of approximately 5,143 inspections and mitigations to test assumptions on unit costs and mitigation viability
- Expert advice from consultants Black & Veatch who have considerable technical knowledge and expertise in this area

1.3 ED1 Proposals

There were no planned activities in DPCR5 for cable pit inspection and mitigations, and therefore no specific allowance was made for this as part of the DPCR5 settlement. The forecast expenditure in DPCR5 for cable pit inspection, maintenance and mitigation is £0.48m. The cable pit inspection, maintenance and mitigations are continuing through ED1. The yearly DPCR5 investment is £0.24m, which is continuing at an annual investment of £0.37m in ED1.

The inspection programme, which is already underway, will ensure that all pits are inspected and mitigated within eight years. The inspection programme will examine all aspects related to the civil structure, electrical cables and joints and access covers.

A detailed Cost Benefit Analysis (CBA) has been undertaken to determine if there is an economic benefit to the public of the cable pit strategy. The CBA uses Health & Safety Executive (HSE) defined society costs and known cable pit disruptive data to project societal costs over ED1 & ED2 periods. The analysis calculates a cost benefit ratio of 5:1, indicating a comprehensive benefit to society of implementing the strategy (see table 2). For further information refer to Appendix 4.

Cost Benefit Analysis	
Very High	15.8
High	13.6
Medium	3.6
Low	0.0
Overall	5.0

Table 2: Cable Pit CBA

The majority of Very High and High risk cable pits have been inspected and appropriate mitigation and maintenance has been undertaken during DPCR5. The ED1 expenditure will focus on Medium risk cable pits. The cost benefit for this programme of work is 3.6, indicating it also is a comprehensive benefit to society.

Namp Line	Description	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	ED1 Total
1.18.09	Replace Joints (Cable Pit Strategy)	0.035	0.035	0.035	0.035	0.035	0.035	0.001	0.001	0.21
1.47.40	Cable Pit Mitigation	0.28	0.28	0.28	0.28	0.28	0.28	0	0	1.69
2.05.08	Cable Pit Maintain	0.11	0.11	0.11	0.11	0.11	0.11	0.01	0.01	0.68
2.30.15	Cable Pit Inspection	0.058	0.058	0.058	0.058	0.058	0.058	0.019	0.019	0.38

Table 3: EPN Cable Pit expenditure summary for ED1

1.4 Innovation

A series of two trial inspection projects has allowed the development of a comprehensive inspection programme that will capture the key information to enable effective mitigation.
A range of mitigations have been identified utilising industry leading research for possible engineering solutions. The mitigations include infilling of pits, replacement of covers and the provision of fall arrest systems, as well as the development of new policies and procedures.

UKPN has a joint agreement with Consolidated Edison to share information, technology and research. This has led to information being made available relating to their research and test data (carried out by Electric Power Research Institute (EPRI)) of a vented, lightweight cover (the Structural Science Composites Ltd (SSC) vented 'S' Panel). UKPN has adopted the SSC 'S' Panel cover as the basis of design of a new cover, the SSC FFP10 cover (Footway Fault Protection).

1.5 Risks and Opportunities

Risk /Opportunity	Description of Risks / Opportunities	Uncertainties
Risk - Low risk pit mitigations	The risk of increased disruptions within low risk cable pits which would require UKPN to subsequently apply the full mitigation hierarchy to low risk pits.	+£5.5m ED1 investment required
Opportunity – Link Boxes	Research into mitigation options and synergies between the cable pit risk hierarchy and mitigation strategy and link boxes, with the potential of applying similar mitigations to link boxes	-

Table 4: Risks and opportunities

2.0 Description of EPN Cable Pits

Cable pits were first introduced in the 1930's to overcome space constraints caused by basements and other underground services and structures.

There was also the anticipation of an increasing electricity demand, where new electricity services would need to be installed and commissioned. Cable pits were categorised into either service (providing supply to domestic or commercial properties), jointing (cable junctions where cable routes needed connecting) or pulling pits (where new cables could be pulled from one pit to another) where a connection or joint may not necessarily have been done.

Cable pits are typically brick structures, of varying size and depth, and may contain a mixture of cables and joints at low voltage and 11kV. Cable pits are not uniform in design and range in size from small pits, which may contain a single cable with a domestic service joint to large pits several metres deep, with a roof structure and more than one access and have multiple cables and joints. Cable pits are accessed from the surface through an access cover; typically concrete infill covers or ductile iron covers of varying shapes and sizes. Table 5 summarises the volume of pits found to date during the trial inspection of 5,143 very high and high risk cable pits in LPN. Some pits have been discovered to be buried and so volume information is not available for these. Figure 1 and Figure 2 show examples of the varying examples of cable pits.

Volume of pit	Dimensions of pit	Number of pits
<1m^3	1m^3 =1m*1m*1m	1013
>1m^3 but <3.375m^3	3.375m^3 =1.5m*1.5m*1.5m	706
>3.375m^3 but <8m^3	8m^3 =2m*2m*2m	515
>8m^3	>2m*2m*2m	327

Table 5: Volume categorisation of cable pits

Figure 1: Example of a small cable (<1m^3) pit with service joint

Figure 2: Example of a large cable pit with a number of cables and joints

3.0 Investment Drivers

3.1 Public Safety

The primary investment driver for cable pits is to minimise risk to members of the public and staff at the lowest possible cost to customers. Additionally, there is an obligation to ensure regulatory compliance with the safety aspects of The Electricity Safety, Quality and Continuity Regulations (ESQCR) 2002.

In EPN high density areas typically comprise of underground cable assets connected to substations. Therefore, safety challenges faced are primarily related to risk management of cables contained in these existing pits.

Public safety risks are potentially increased in EPN where there is a proximity of these assets to densely populated areas. These need to be managed with appropriate levels of inspection and risk management with interventions made to ensure that risks to public safety are minimised, whilst ensuring that the interventions are reasonably practicable and proportionate.

Inspectors are trained to identify and record the condition of both structure and cables/joints as part of the routine inspection that will then be recorded into the Asset Register Ellipse.

Any defects identified through inspection will require resolution in a timescale as defined against the specific defect. Please refer to Section 5 for specific details on different interventions carried by out UKPN to ensure ESQCR compliance.

3.2 Intervention thresholds

As previously mentioned, UKPN has developed a cable pit strategy, detailed in Section 6, which will identify and detail interventions required on cable pits.

As part of the development of the strategy, 5,143 trial inspections are currently being undertaken (due for June 2014 completion), in LPN. Information gathered from these inspections is being analysed to develop the strategy moving forward. This includes collecting condition and defect information, assessing the ESQCR risk rating, as well as identifying any appropriate mitigation that may be required to be undertaken. Although the strategy is initially focussed in LPN where the highest risks have been identified, the strategy will be implemented across all of UKPN’s operational networks.

3.3 Examples of cable pit defects/conditions

The photographs below show examples of poor condition cable pits and associated defects. Figures 3 and 4 show the impact of a disruptive failure of a cable pit. This is described in more detail under section 3.5. Figures 5 and 6 give examples of other typical defects.

Figure 3: Footway disruption following a cable failure

Figure 4: Status of the cable following failure

Figure 5: Poor condition ladder

Figure 6: Poor condition cover

3.4 Incidents and events

AIRLine is the UKPN Accident and Incident Reporting line. Cable pits that are considered as an immediate risk to public safety (either electrically or structurally) must be reported to AIRLine. All staff, contractors and members of the public can report incidents to AIRLine through the customer call centre.

Figure 7 shows an increasing trend of cable pit disruptive failures in London area reported to AIRLine.

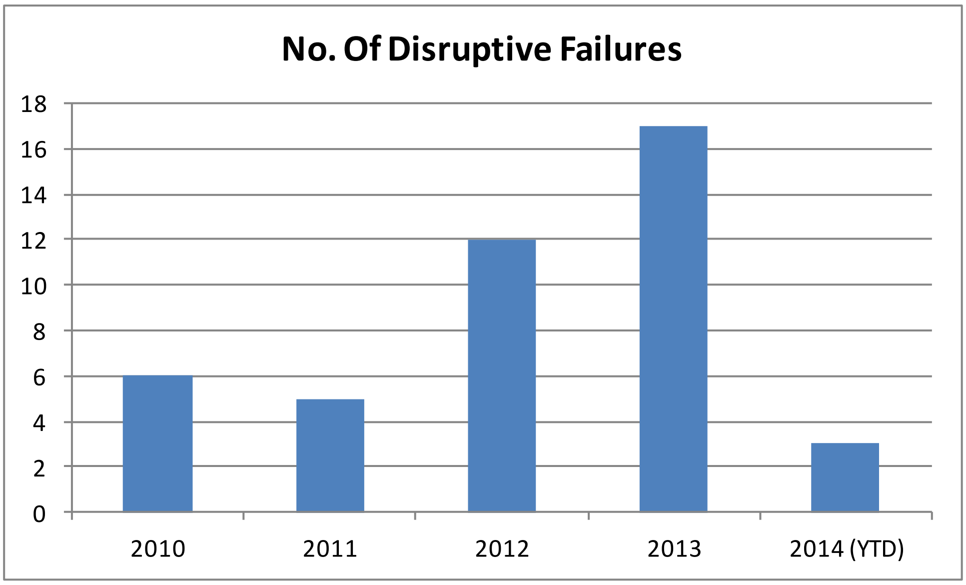

Figure 7: Cable pit disruptive failures

The investigation of a disruptive cable pit failure in May 2012 in LPN identified the root cause for the disruptive failure as leaking gas which had filled the cable pit over a period of time so that the atmosphere was at an explosive level. The recommendations from the investigation included a full review of cable pit strategy as inspection records were not readily available. This initiated the launch of the development of the cable pit strategy project and the capturing of all cable pits and their condition in Ellipse the asset register.

Another disruptive failure of a cable pit in November 2012 in LPN resulted in a member of the public falling into the pit and receiving minor injuries. This required UKPN to address this risk and research various options available to mitigate the risk. The option is to fit a fall arrest grill under the cover where there is a shaft inside the cable pit.

Figure 8 shows the disruptive failure of a cable pit in Pimlico in April 2013. The HSE have continued to actively monitor and support the development of UKPN's cable pit strategy and have regular meetings on progress of inspections and associated mitigation.

Figure 8: Pimlico disruption – April 2013

4.0 Asset Assessment

4.1 Asset Health

The project to capture data from cable pit inspections and the resulting defects commenced in May 2013 and is due for June 2014 completion.

The inspection of 5,143 very high and high risk cable pits is currently being undertaken in LPN to assess and record asset condition and defects. The condition data collected indicates that 72.9% of cable pits have a defect that would require some level of mitigation or remedial works. See Table 6.

An improved inspection and maintenance regime has been developed to minimise risk to members of the public.

Findings from the inspections to date:

- Cable pit condition and size varies significantly
- Of the cable pits inspected, 3,170 have at least one defect and, 583 cable pits have at least two defects.
- 24 cable pits were found with gas present.
- A number of defects, such as poor condition ladders, were rectified at the time of inspection.

Breakdown of Defects	Number of Defects	% of Total Survey
Defect frame & cover	1,485	28.9%
Defect ladder (unsafe)	439	8.5%
Imploded Joint	108	2.1%
Defect buried pit	1,378	26.8%
Defect joint	54	1.1%
Defect label	36	0.7%
Defect structure	932	18.1%
Total Defects	4,432	86.2%
Number of Cable Pits with Defects	3,753	72.9%

Table 6: LPN Trial Inspection – Breakdown of defects

4.2 Asset Criticality

UKPN has developed a comprehensive defect prioritisation model to prioritise the defects identified on the network and ensure they are dealt with the appropriate level of urgency.

Each of the defect categories were reviewed and assigned a risk score based on

- Regulatory Risk
- ESQCR and Safety Risk
- Environmental Risk
- Quality of Supply Risk (QoS)
- Financial Risk

Regulatory, safety and environmental risk are assigned a higher weighting to ensure that they are resolved as a priority.

The priority on a defect is not decided by the inspector but will be applied centrally though the defect prioritisation model thereby ensuring strict control and governance on the process. The model will rely on additional factors such as location risk, equipment risk of the asset (ESQCR, safety, environmental, QoS and financial risk already assigned on the defect category) to arrive at the overall priority. Once the priority is assigned, it will not be subject to change and will have to be resolved as per the agreed resolution time standard.

Based on risk score, each defect category is assigned a priority from P5 to P0 which has a designated resolution time schedule as shown in Table 7.

Defect Criticality	Resolution Time Schedule
P5	< 3 months
P4	12 months
P3	24 months
P2	48 months
P1	During next maintenance
P0	For information only

Table 7: Defect Criticality Definition and Resolution Time Schedule

Breakdown of Defects	Outstanding Defects	Cleared Defects	% Cleared
Defect frame & cover	1424	61	4.1%
Defect ladder (unsafe)	63	376	85.6%
Imploded Joint	41	67	62%
Defect buried pit	1313	65	4.7%
Defect joint	35	19	35.2%
Defect label	0	36	100%
Defect structure	818	114	12.2%
Total Defects	3695	737	16.6%
Number of Cable Pits	3318	685	18.3%

Table 8: LPN Trial Inspection of 5,143 cable pits – Defect clearance (24th February 2014)

4.3 Network Risk

The risk associated with asset failure is a combination of the probability of failure (such as age and duty) and the consequence of failure (such as injury or death). Asset criticality provides a measure of the consequence of failure and is evaluated in terms of the following four primary criticality categories:

- Network Performance (PD monitoring)
- Safety (ESQCR risk level)
- Financial; opex (licence area) and capex (licence area)
- Environmental (site sensitivity).

In order to compare and combine category consequences, each consequence value is equated to a monetary assessment. Once the average consequence of failure for a group has been valued, it is necessary to define the criticality of an individual asset (for each consequence category). The score for each consequence category is then added together and converted to an Ofgem criticality index (C1-4) A detailed methodology for calculating the criticality index can be found in 'Commentary Document 15: Model Overview'.

4.4 Data Validation

A desktop risk assessment has been undertaken to:

- Prioritise the cable pit inspection programme; and
- Determine which of the cable pits pose sufficient risk to require early intervention with identified mitigations based on location and historic records.

The risk assessment was developed to determine as overall risk score for cable pits (ESQCR criticality score) and comprised of the following:

- Identification of the key aspects associated with the risks posed by cable pits;
- Identification of the mitigation actions that may be taken to reduce the risks posed by cable pits;
- Design of a risk assessment methodology that can be applied in a desk-based study and be applied in the field by the inspectors (see Section 4.3);
- Run the desk-based analysis to assess the likely risk posed by individual cable pits and develop the associated ESQCR criticality score; and
- Design the cable pit survey methodology and inspection forms to reflect the risk assessment regime.

The desk top risk assessment has been further developed by Black and Veatch (B&V) (detailed in Section 4.3) using location based risks (consequence) and likelihood risks (equipment), as well as information gained from the on-site inspections, to define the overall risk score for each pit. This is subsequently banded to allow prioritisation of the mitigations and inspections around those pits which could have high impact/likelihood.

4.5 Data Verification

The risk assessment methodology has been aligned to the existing link box risk assessment methodology. It uses inference from known cable pit information and spatial interpolation to model the cable pit risk category, and therefore relies on defined assumptions and parameters. The risk assessment has been calibrated against the twelve events that occurred in 2012 to assess whether these disruptive events could have been identified by the risk assessment and would qualify for mitigations.

The equipment risk (likelihood factors) used within the desk-based approach are as follows:

- The number of joints in the pit (dataset provided by QC Data, who digitised the entire LPN region)

Likelihood Parameter	Rationale	Number of Joints	Equipment Risk
Number of joints within the pit	Failure most often occurs at joints	0 1 2 >=3 (where unknown assume 1 joint)	Low Low Med High

Table 9: Equipment risk ratings for cable pits

The location risk (consequence factors) used within the desk based approach principally relate to:-

- High footfall areas (derived from OS Address Point data analysis), proximity to road junctions (based on OS ITN data), or major transport hubs (based on data from office of Rail Regulation and the Department of Transport)
- Presence within the Enhanced Zone (EZ) where there is dual use of the high and low voltage networks as this may mean more opportunity for cable/joint faults

The following categorisation has been used to determine the location risk, based on categorisation developed for the link box assessment:

Code	Title	Descr	Location Risk
UA	Enhanced Zone	Within the enhanced zone	High
UB	Very High Pedestrian Area	Any medium or low risk area which is subject to consistent high pedestrian traffic or gatherings e.g. - Major rail, tube or bus stations - Close to road junctions	High
UC	Recreational	Within or adjacent areas of people congregation e.g. play areas, sports and activity areas or public attraction	Medium
UD	Transport	Within 10m of public access to rail, underground or DLR station, bus or tram stop or busy car park	Medium
UE	School	Outside a school, in an area where children and parents are likely to gather	Medium
UF	Urban	Footpaths or verges in a residential or built-up areas	Low
UG	Non-Residential	Non-residential footpaths or verges	Low
UH	Secure Site	Within a secure location	Low
UI	Rural	Rural location	Low
UJ	Roads	Surfaced roads	Low
UK	Private	Private land	Low

Table 10: Location risk ratings for cable pits

All available data was used to model this risk assessment. This categorisation can also be applied in the field allowing inspectors to individually calculate each cable pits risk category.

The overall risk score for a cable pit (Table 11) is be determined using a matrix based on combining the Equipment Risk (likelihood) and the Location Risk (consequence).

Development of this risk assessment methodology has included sensitivity testing of the likelihood and consequence scores against the cable pits surveyed during the pilot study. Each cable pit is assigned a risk designation of Very High, High, Medium and Low.

	Location Risk		
Equipment Risk	Low	Medium	High
High	Medium	High	Very High
Medium	Medium	Medium	High
Low	Low	Medium	Medium

Table 11: Overall risk rating for cable pits

From a total number of 3,500 cable pits in the EPN area, the assessment resulted in :

- 149 Very High risk pits,
- 228 High risk pits,
- 2,685 Medium risk pits and
- 438 Low risk pits

4.6 Data Completeness

Analysis of disruptive events involving cable pits during 2012-2014, confirms that the initial information gathering exercise undertaken by QC Data (QCD) and used by B&V to implement a risked based hierarchy using the data is accurate. The number of cable pit failures align in % terms to the risk rating assigned to an individual cable pit by B&V using the available data prepared for the 47,748 cable pits in LPN. Table 12 shows the number of failures in each risk rating.

Risk Rating	Number of failures	Percentage
1	1	3.6%
2	16	57.2%
3	7	25.0%
4	4	14.2%

Table 12: LPN cable pit failures by risk rating

5.0 Intervention Policies

5.1 Interventions: Description of intervention options evaluated

Five categories of interventions have been considered for cable pits:

- Report
- Repair/Maintenance
- Replace
- Mitigate
- Remove

Table 13 gives the individual descriptor for each intervention these are further reviewed in section 6.

Intervention Category	Description
Report	All poor condition assets and defects are reported to UKPN's defect reporting line (AIRLine). This logs the issue and prompts the required intervention.

Repair/Maintenance	Repair minor defects to joints or civil aspects of the pit to ensure the asset poses minimal risk
Replace	Replace major defects, such as frame & covers and severely imploded joints to minimise risk.
Mitigate	Significantly reduce risk posed by: infilling cable pits, installing vented covers or installing fall arrest systems
Remove	Remove cable pit assets where there are major structural defects
Refer to section 6 for further details on intervention and mitigation strategies	

Table 13: Description of each mitigation option available for a cable pit

5.2 Selecting preferred interventions

Each site will be risk assessed and the most cost effective intervention, if required, will be applied. The process used for selecting interventions for cable pits is shown in figure 9.

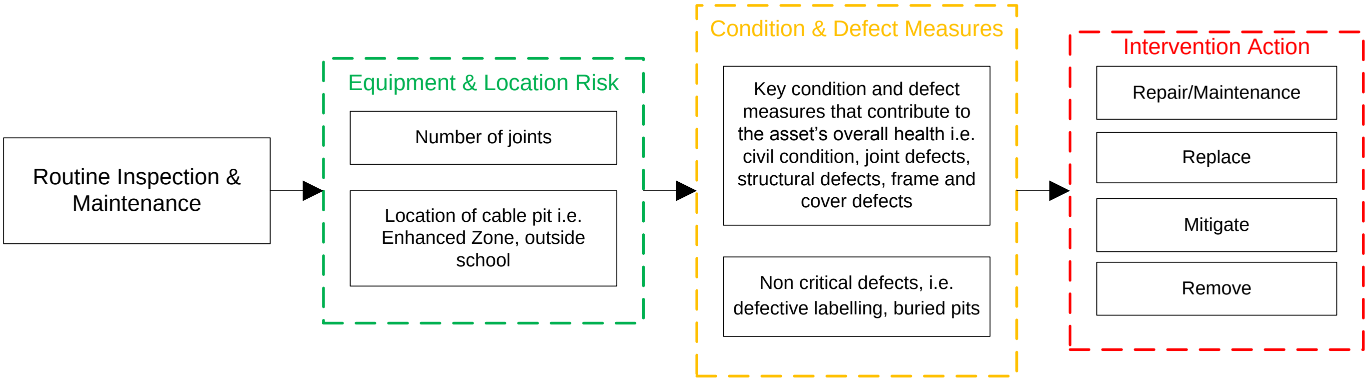

Figure 9: Intervention Decision Flow Chart

6.0 Innovation

Inspection, maintenance and risk management of cable pits is being enhanced as an Industry leading initiative. UKPN is undertaking a complete evidence based evaluation strategy of cable pit risk. An Innovation Funding Incentive project (IFI) has been launched to support the research.

Key aspects of the strategy include:

1. Identification of the key aspects associated with the risks posed by cable pits
2. Identification of the mitigation actions that may be taken to reduce the risks posed by cable pits
3. Design of a risk assessment methodology that can be applied in a desk-based study and be applied in the field by the inspectors
4. Run the desk-based analysis to assess the likely risk posed by individual cable pits and develop the associated Criticality Index
5. Design the cable pit survey methodology and forms to reflect the risk assessment regime

The strategy has been developed and provides recommendations for a future inspection regime. The following supporting documents have been produced during the development of the strategy and can be found in the B&V Cable Pit Strategy:

- Literature review
- Cover mitigations
- Arc suppression blankets
- Risk assessment methodology for cable pits

6.1 Understanding the issues

Research in the area of disruptive failures within cable pits has highlighted a number of findings, including a correlation between disruptive cable pit events and ageing electrical assets. The failures are categorised as either electrical failures, gas present failure or a combination of both. While the failure mechanisms are different, they are thermodynamically similar and therefore the impacts are reasonably similar. However, the presence of gas is known to exacerbate the effects of a disruption up to 20 times that of just an electrical arc failure.

A series of inspections were undertaken to identify the key issues around cable pits. These included issues impacting directly on the capability of the cable pit to withstand/respond to a disruptive event, as well as other structural and health & safety issues. These inspections also helped gain an initial understanding of asset condition and potential maintenance requirements.

These inspections took place in two stages: an initial inspection of 38 pits during November 2012, followed by a further inspection of 373 pits in December 2012. Further inspections took place following disruptive cable pit events to gain better understanding of the failure mechanisms within the cable pits and the impact of the event on the cable pit and surrounding area.

6.2 Defining the strategy

From the literature review and the early inspection work, the following strategy risk hierarchy has been developed and is based on consideration of three key areas, of public safety, equipment faults and risk reduction, and utilises a hierarchy of risk elimination and risk reduction.

It should be noted that:

- Defects will be identified within a systematic inspection regime;
- Eliminating risk is preferable to reducing risk, within a planned programme of mitigation works;
- For smaller pits, which are not likely to require ongoing access, the most practicable way of eliminating the gas explosion potential may be by infilling. This is not appropriate for larger pits due to the size, location and the equipment content;
- It is not considered reasonably practicable to either make every chamber disruption proof or to replace every cover, due to the high costs that would be incurred.

The following risk hierarch is being implemented based on HSE methodologies:

1. Eliminate tripping hazards, poor condition covers and unable to lift covers, by replacement with a standard cover. This will also include removing all ladders within pits as all ladders are considered to be unsafe. Implementing a systematic cable pit inspection and cover replacement regime will enable the condition of existing covers to be assessed.

2. Eliminate the disruptive forces caused by an arcing fault and also the potential for gas build up which would exacerbate a disruption, by filling pits with inert material such as sand. This will be applied to pits typically with a volume < $8m^3$. This may include removal of the frame and cover, and subsequent reinstatement if the existing cover is in poor condition. For larger volume pits increasing ventilation will dilute the explosive mix and reduce the likelihood of disruptive failure. The interval between inspections for these pits will also be increased.

3. Eliminate the risk of cover collapse by filling dormant pits with inert material such as sand. This can be applied to pits that do not contain any cables or joints, and may typically be a larger void chamber or in a high footfall area. This may include removal of the frame and cover, and subsequent reinstatement, if the existing cover is in poor condition. The interval between inspections for these dormant pits will also be increased.

4. Reduce the severity of an injury where an arcing fault disruption would result in the cover being ejected and potentially cause a fatality. The mitigation shall ensure that the chamber is able to vent through a vented, hinged or spring-type cover. The cover would open quickly to vent and then close back into its frame, and have an appropriate clear opening. In addition, tethering is also proposed.

5. Reduce the severity of an injury where an arcing fault disruption would result in the cover being ejected with the potential for falling into an open chamber, by providing a fall restraint system. This can be applied to those pits located in a high footfall area, and typically with a high disruption risk. The mitigation is for the pit to be fitted with a fall arrest system such as an open grid floor located just below the cover.

6. Reduce the risk of arcing fault disruption by rectifying joint defects, by implementing a systematic inspection regime. Mitigations will include replacing LV mains joints or LV service joints, or filling modern joints with resin.

7. Reduce the risk of structural failure by implementing a systematic inspection regime to identify and rectify structural defects. Defects may occur within the chamber shaft, walls or roof, and may consist of poor brickwork (cracking, loss of mortar etc.), poor concrete (cracking, spalling etc.), metalwork (corrosion, bending etc.) or other material defects.

The risk hierarchy will not be applied in full to all pits:

- For lower risk pits it is recommended that only the inspections and defect rectification will be applied
- For very high, high and medium risk pits it is recommended that the full risk hierarchy will be applied in priority order

In order to comply with the ESQC Regulations, existing UKPN policy and procedures have been reviewed and any gaps identified. The following procedures have been developed and where necessary revised in order to assist with the implementation of the cable pit strategy.

- Cable Pit Inspectors Guide
- Cable Pit Defect and Condition Handbook
- Removing Cable Pit Covers
- Cable Pit Failure and Incident Reporting
- End-to-End Processes
- Numbering of Cable Pits
- Cable Pit Inspection Form
- Cable Pit Mitigation Form

6.3 Implementing the strategy

The research identified that mitigations are based around one of two priorities: preventive mitigations (where the intention is to prevent the event from occurring) or assumptive mitigations (where the intention is to reduce the negative impacts of a disruption, which has been allowed to occur).

A range of potential mitigations were identified, both preventive and assumptive, based on research into disruptive events currently being considered in the USA. These mitigations were then developed using appropriate engineering solutions and adapted where necessary. A number of mitigations are proposed including deployment of a vented cover, infilling of pits, replacement of defective covers, correction of defects and provision of fall restraint systems as well as the development of new policies and procedures. Further assessment and design is considered necessary due to the limitations associated with the proposed covers and the uncertainty around the forces that occur during a disruptive event.

Figure 10: Example of Sand Infill Mitigations

SSC has developed a composite vented 'S' Panel cover to reduce the severity of an injury associated with a cover being ejected. This cover has been developed with Consolidated Edison (Con Edison) in Manhattan for responding to disruptive pits. UKPN has a joint agreement with Con Edison to share information, technology and research. This has included the research and test data relating to the 'S' Panel, carried out by EPRI.

UKPN has adopted the SSC 'S' Panel cover as the basis of design of a new cover, the SSC (Footway Fault Protection) FFP10 cover. It is a vented composite fibreglass cover which measures 860 x 860mm, and has over 1000 10mm diameter vents over its surface (providing a vent area of ~12%). It has been developed by UKPN in conjunction with SSC, following the principles of the 'S' Panel developed with Con Edison. The 'S' Panel has been tested in arc event simulation tests, based on a chamber exposed to a gas explosion, and supports the use of vents and a locking restraint system to reduce the possibility of ejection of the cover. These covers are locked which will prevent uplift, and will also be tethered in the event of a lock failure. Figures 11 and 12 show examples of where this has been installed.

Figure 11: Example of FFP10 installation – Grosvenor Place

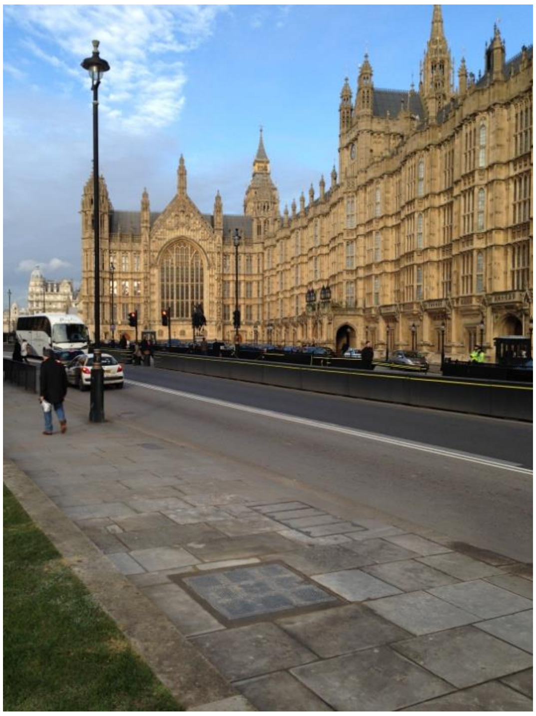

Figure 12: Example of FFP10 installation – Palace of Westminster

6.4 Inspection regime

After the initial inspection it is proposed that the subsequent inspection frequency will be determined from the ESQCR risk rating and any necessary mitigation undertaken. Every cable pit will be inspected once, over a period of 8 years. Once complete, the differing inspection regimes/timescales for each chamber category will then commence. For example, it is proposed that CAT 1 dormant pits will be inspected every 18 years, compared to CAT 2 pits within the enhanced zone which will be inspected every 6 years. The inspection regime currently proposed is as follows:

1. Cable Pits Cat 1 – a dormant pit or one which is used exclusively for telecommunications apparatus [dormant pit will include any pit that has been backfilled]
   - Major inspection every 18 years
   - Maintenance as required

2. Cable Pits Cat 2 – a pit present along HV cable routes and containing HV cables, joints and associated equipment within the primary distribution system or a combination of primary and secondary distribution apparatus
   - Major inspection every 8 years or for those pits within the enhanced zone every 6 years
   - Maintenance as required

3. Cable Pits Cat 3 – any pit that has had an arcing fault reported via AIRline
   - Major inspection every 1 year, for a period of 3 consecutive years without further fault
   - Maintenance as required

4. Cat 4 – any pit with a Very High or High risk rating
   - Major inspection every year
   - Maintenance as required

6.5 Strategy evolution

The cable pit strategy was revised in December 2013, following the ongoing inspection, mitigation and maintenance of the very high and high risk pits (5143) in LPN within the DPCR5 period. It is projected that £5m will be spent during the DPCR5 period inspecting, maintaining and mitigating the very high and high risk pits with LPN. The cost rates have been revised and based on Year 1 mitigation contract rates. The mitigation percentage breakdown has been revised following the substantial completion of Year 1 inspections (~98% complete). As of 21 February 2014, of the 5143 very high and high risk cable pits, 5100 had been visited with 2856 inspections completed. Of the 2244 pits that could not be inspected, 745 were due to not being able to lift the cable pit lids due either to age, traffic conditions or location, 1324 could not be located (confirmed as buried pits), 175 were identified as link boxes. Since August 2013, 1926 mitigations have been completed and 1042 post-inspection joint and structural surveys have been undertaken and are shown in Table 14.

Mitigation Type	No. Installed
Infill (Sand)	1519
Vented Cover (FFP10)	374
Standard Cover (Composite)	23
Fall Arrest System	10
Total	***1926***
Joint Survey	134
Structural Survey	908
Total	***1042***

Table 14: Mitigation Progress (21st February 2014)

A further 4,000 inspections, and associated mitigations, of medium risk pits within LPN are scheduled for 2014 completion. These are located in areas such as Regents Street, Oxford Street and New Bond Street, where there is high public footfall. These further inspections may help understand the characteristics of medium risk pits, will allow for the prioritisation of mitigations (to reduce risk), and may help develop the cable pit strategy.

Following further risk based analysis of cable pits, in particular the risk posed to the public and employees, the revised strategy re-allocates asset replacement (joints) and mitigations funding to CV8 (Safety & Legal). Table 15 outlines the funding allocation for cable pit inspections, mitigations and maintenance.

DNO	Description	Table (Original)	Table (Revised)	DPCR5 Total	ED1 Total	TOTAL
ALL	Replace Joints (Cable Pit Strategy)	CV3	CV8	£843,566	£2,924,064	£3,767,630
ALL	Cable Pit Mitigation	CV6	CV8	£7,207,468	£23,264,617	£30,472,085
ALL	Cable Pit Maintain	CV13	CV13	£2,602,309	£9,428,751	£12,031,060
ALL	Cable Pit Inspection	CV13	CV13	£1,397,478	£5,388,514	£6,785,992
		TOTALS		**£12,050,821**	**£41,005,947**	**£53,056,768**

Table 15: Revised Cable Pit Cost Allocation

Following further analysis of disruptive events in cable pits during 2012-2014, the mitigation strategy for medium risk pits has been revised. Of the 29 cable pit disruptions during the 2012-2014 period, 69% of failures have occurred in medium risk pits as shown in Table 16. On this basis, the full risk hierarchy has been applied to the very high, high and medium risk pits only. The infill strategy has also been altered following on going mitigation works. The ongoing assessment of volumes and construction type of cable pits has enabled UKPN to categorise pits in to four sub-sections, which allow safe infill to take place.

Risk Category	No. Of disruptive events	% of Pits	Total No. Of Pits	Disruptive Failures
Very High	5	17%	2296	0.218%
High	4	14%	3499	0.114%
Medium	20	69%	41267	0.048%
Low	0	0%	6739	0.000%
Total	**29**	**100%**	**53801**	**0.054%**

Table 16: Risk categorisation of disruptive pit failures during 2012-2014 (LPN)

Post-inspection surveys have also been added to the mitigation strategy to determine the severity of defects and the levels of remedial work required to ensure risks posed by cable pits are minimised.

Ground Penetrating Radar (GPR) surveys of buried pits have been added to the schedule of works. GPR surveys will determine if cable pits have been infilled and are dormant (requiring no further works) or are still present and require some level of works. UKPN will undertake GPR surveys on a 10% sample of buried pits each year to ensure compliance with the cable pit strategy.

Joint investigations, using innovative partial discharge technology can determine whether defective joints need replacing. A survey of 135 cable pits highlighted that 40% of pits potentially required a joint replacement and three possibly required an urgent joint replacement. Further post removal analysis of the 3 joints indicated that if the joints had not been removed, a disruption could have occurred in the near future.

Structural surveys, undertaken by a civil engineer, indicate the level of work required to rectify structural defects. A survey of 777 cable pits with structural defects has indicated that 65% require remedial works.

6.6 Mitigation innovation

The mitigation proposals for cover replacement assessed two covers as potentially appropriate: the St Gobain Opt-Emax cover (Figure 13) within trafficked areas and the Structural Science Composites (SSC) S Panel (Figure 14):

- The Saint Gobain Opt-Emax cover is a hinged ductile iron cover, which has a range of 'off the shelf' sizes ranging from 600 x 450mm clear opening to 1800 x 750mm clear opening sizes. The hinges are integral to the cover and lock into the frame.

Figure 13: St Gobain Opt-Emax cover

- The SSC 'S Panel' cover is a vented composite fibreglass cover. It measures 605 x 1365 mm and has 750 12mm diameter vents over its surface (providing a vent area of ~10%). It has been developed with Consolidated Edison and is the only product considered that has undertaken load tests on the underside and arc event simulation tests. The testing is based on their use within a chamber exposed to igniting gas and supports the use of vents and a locking restraint system to reduce the possibility of ejection of the cover. UKPN are developing a smaller 'standard size' 800x800 cover that will be fitted to the majority of cable pits where a cover requires changing either due to damage or mitigation.

Figure 14: Structural Science Composites (SSC) 'S' Panel

It should be noted that the St-Gobain covers have not been designed or tested for any specific disruptive forces applied on the underneath of the covers. Further investigative testing and design would be necessary. UKPN therefore favour the SSC 'S Panel' cover and have proposed to adopt this cover as the mitigation recommendation to reduce the severity of an injury associated with a cover being ejected.

UKPN are also researching the use of a fall arrest system (Figure 15) for deep pits to ensure that if the covers are dislodged no person accidently falls in to the pit. The mitigation will consist of an open grid floor just below the cover and applied to pits with ESQCR rating of high or very high, and to those pits with a depth >=3m.

Figure 15: Example of fall arrest installation

Other innovative mitigations such as the use of arc suppression blankets have been considered and rejected on the grounds of effectiveness, practicality and cost.

UKPN are engaged with subject matter experts from the United States to ensure previous lessons learnt on similar cable pit projects overseas are captured to maximise cost efficiency.

7.0 ED1 Expenditure requirements for Cable Pits

7.1 Method: Constructing the Plan

The investment strategy for ED1 has been set to ensure the risk to members of the public and employees is eliminated or reduced. Due to cable pits presenting an unacceptable risk in recent years to members of the public, the cable pit strategy has used:

- proposed inspection regime
- an extrapolation of findings from trial inspections
- risk reduction mitigations applied on the basis of the ESQCR chamber pit risk rating

Table 17 shows the itemised cost estimates associated with the strategy risk hierarchy described earlier. Items 1, 2, 4, 6 and 7 are based on percentages ascertained from the pilot inspections. Items 3 and 5 are based on percentages ascertained from the risk assessment. The inspection (and re-inspection of very high & high risk pits) together with any associated mitigations will be completed during ED1.

Costing						
Risk Hierarchy Item	**Description**	**Unit Price**	**Estimated % of CPs**	**Cable Pit Count**	**Cable Pit Count Total**	**Total Cost**
1. Inspection	All CPs	£75.00	100%		3500	£262,500
1. Ladder removal	Estimated % from survey results, applied to all CPs	£10.00	10%		333	£3,325
1. Joint defect survey	Estimated % from survey results, applied to all CPs	£200.00	5%		158	£31,500
1. Structural defect survey	Estimated % from survey results, applied to all CPs	£180.00	17%		595	£107,100
1. Buried pits	Estimated % from survey results, applied to all CPs	£150.00	26%	3062	80	£11,942
2. Pit infill	Chamber vol <1m^3 - VH/H/M risk pits	£251.00	19%	3062	582	£146,027
2. Pit infill	Chamber vol >1m^3 and <3m^3 - VH/H/M risk pits	£460.00	19%	3062	582	£267,619
2. Pit infill	Chamber vol >3m^3 and <8m^3 - VH/H/M risk pits	£837.00	12%	3062	367	£307,547
2. Pit infill	Chamber vol >8m^3 and <15m^3 - VH/H/M risk pits	£1,381.00	3%	3062	92	£126,859
2. Full pit reinstatement	Cover removal and full reinstatement (<3m^3) - VH/H/M risk pits	£1,145.00	10%	3062	306	£350,599
3. Vented cover - SSC lid	Applied to VH/H/M risk pits - footpath B125 FFP10 cover	£1,446.00	8%	3062	236	£340,929
3. Hinged cover - SSC lid	Applied to VH/H/M risk pits - carriageway D400 hinged cover	£3,174.00	3%	3062	101	£320,720
5. UTL / damaged cover replacement	Applied to VH/H/M/L risk pits - footpath B125 standard cover	£1,277.00	7%		242	£308,396
5. UTL / damaged cover replacement	Applied to VH/H/M/L risk pits - carriageway D400 cover	£3,174.00	2%		60	£188,853
5. Fall restraint	CPs >3m depth, estimated % from survey results - VH/H/M risk pits	£1,381.00	3%	3062	80	£110,367
6. Defect joint	Estimated % from joint defect survey - joint resin fill	£500.00	10%		16	£7,875
6. Defect joint imploded	Estimated % from joint defect survey - replacement joint	£2,500.00	60%		95	£236,250
7. Defect structural	Estimated % from structural survey - remedy minor structural defects	£500.00	32%		190	£95,200
7. Defect structural	Estimated % from structural survey - remedy major structural defects	£3,000.00	9%		54	£160,650
Total Cost	**Based on 3500 cable pits in EPN area**					**£3,384,257**

Costing		
Risk Hierarchy Item	**Description**	**Total Cost**
1.Repeat Inspections	CAT 2.1 - inspections, every 8 Years	£12,534
	CAT 2.2 - inspections, 6 Years in enhanced zone	£24,413
	CAT 3 - inspections, annually for 3 Years	£450
5. UTL / damaged cover replacement	Ongoing - defective cover replacement	£31,571
6. Defect joint imploded	Ongoing - Replace/repair defect joints	£977
7. Defect Structural	Ongoing - Remedy structural defects	£1,023
Total Cost		**£70,968**
	DPCR5 Cost	**£483,465**
	ED1 Cost	**£2,971,760**

Table 17: Itemised Cost Estimates

The total cost of the cable pit strategy is outlined in Table 18 and the programme of inspection, maintenance and mitigation has already commenced. To deliver the complete strategy during ED1 will require the funding outlined in Table 19.

7.2 Additional considerations

If an activity is required in a cable pit as a result of planned work, that would be considered at the time of completion without the need for a revisit. Other considerations may be following the defect identification and inspector intervention.

7.3 Asset volumes & expenditure

The table summarises the ESQCR Safety related expenditure for the ED1 period.

Namp Line	DNO	Description	DPCR5 Total	ED1 Total	TOTAL
1.18.09	EPN	Replace Joints (Cable Pit Strategy)	34,875	210,227	245,102
1.47.40	EPN	Cable Pit Mitigation	283,230	1,699,379	1,982,609
2.05.08	EPN	Cable Pit Maintain	107,586	678,108	785,693
2.30.15	EPN	Cable Pit Inspection	57,775	384,047	441,822
			483,465	**2,971,760**	**3,455,225**

Table 18: EPN Cable Pit Expenditure

As shown in Figures 16 and 17, EPN has increased expenditure during the DPCR5 period to address the challenge posed by disruptive failure of cable pits (Table 5). This expenditure is required to mitigate and minimise any risk to public safety. All cable pits will be inspected over a period of 8 years and these inspections will provide vital information on condition and required mitigations and this in turn will enhance public safety. UKPN is leading the industry with respect to cable pit risk management and has work closely with the Health & Safety Executive (HSE) in developing the strategy to this level of asset management.

The itemised cost estimates provided in Table 18 have been programmed across the ED1 period and beyond. This includes:

- the cost associated with the ongoing inspection regime taking into account the ongoing repetitive inspections and differing time spans between inspections for categories of cable pit
- the ongoing repetitive equipment defect maintenance associated with pit covers, joints and structural condition
- the one off cost associated with risk reduction mitigations

The total expenditure of £2.98m is broken down as follows:

			ED1								
Namp Line	DNO	Description	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	ED1 Total
1.18.09	EPN	Replace Joints (Cable Pit Strategy)	34,875	34,875	34,875	34,875	34,875	34,875	488	488	210,227
1.47.40	EPN	Cable Pit Mitigation	283,230	283,230	283,230	283,230	283,230	283,230	0	0	1,699,379
2.05.08	EPN	Cable Pit Maintain	107,586	107,586	107,586	107,586	107,586	107,586	16,297	16,297	678,108
2.30.15	EPN	Cable Pit Inspection	57,775	57,775	57,775	57,775	57,775	57,775	18,698	18,698	384,047
			483,465	**483,465**	**483,465**	**483,465**	**483,465**	**483,465**	**35,484**	**35,484**	**2,971,760**

Table 19: ED1 Total Cable Pit Expenditure (Per Regulatory Year)

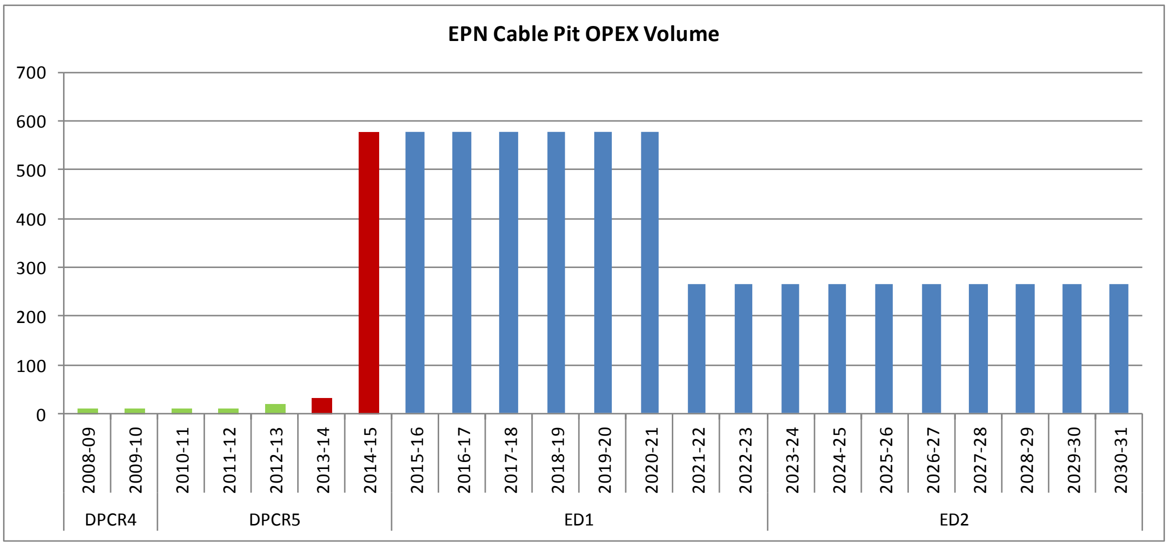

Figure 16 EPN cable pit OPEX volume trend

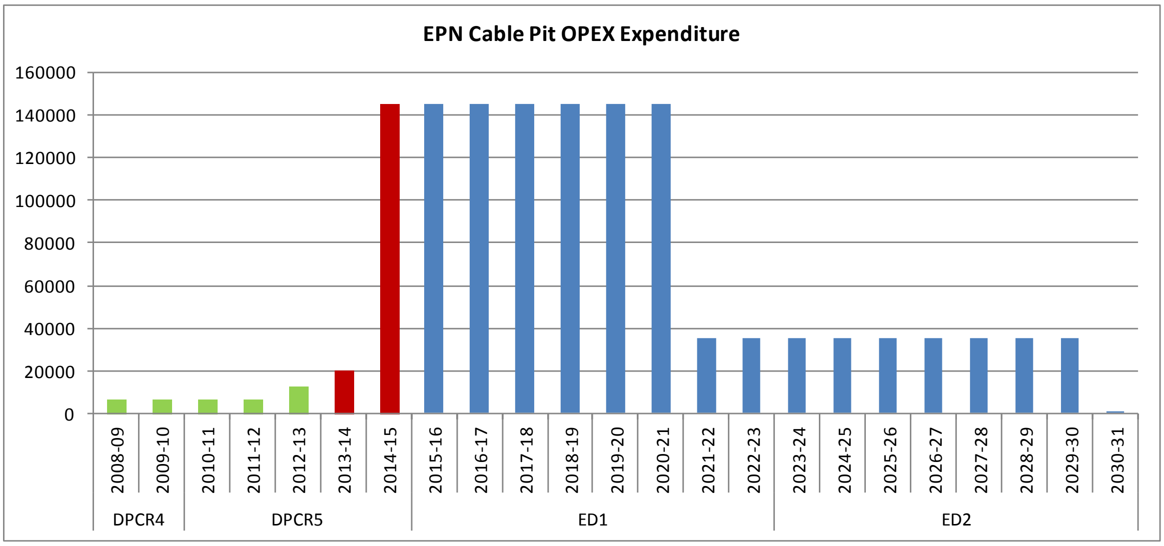

Figure 17: EPN cable pit OPEX expenditure trend

Figure 18 and Figure 19 show the historical and forecast volumes and expenditure on ongoing cable pit inspections, replacement of unable to lift or damaged standard covers, and repair of structural defects. As previously noted, it is proposed to inspect every chamber pit once, over a period of 8 years, but noting all Very High and High risk pits will be inspected in 2014. Once complete, the number of annual re-inspections reduces accordingly, shown in Figure 16. On a similar basis, it is assumed that the rate of cover replacement and structural defect repair will also reduce after the initial 8 year period. All Very High and High risk pits will be inspected annually, however, once the mitigations have been carried out it is suggested that the risk category of each pit will also reduce accordingly.

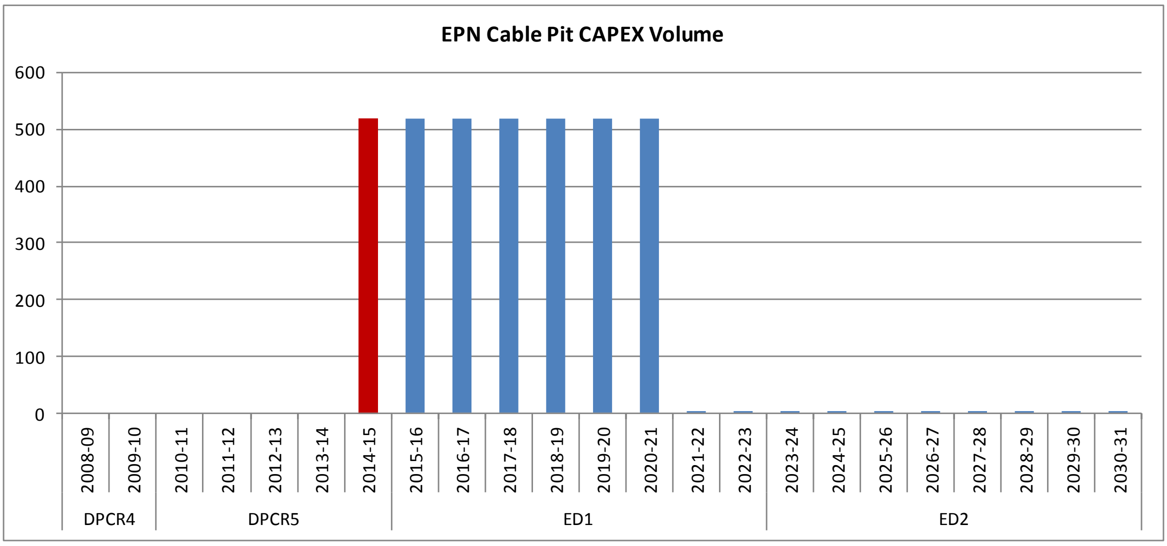

Figure 18: EPN cable pit CAPEX volume trend

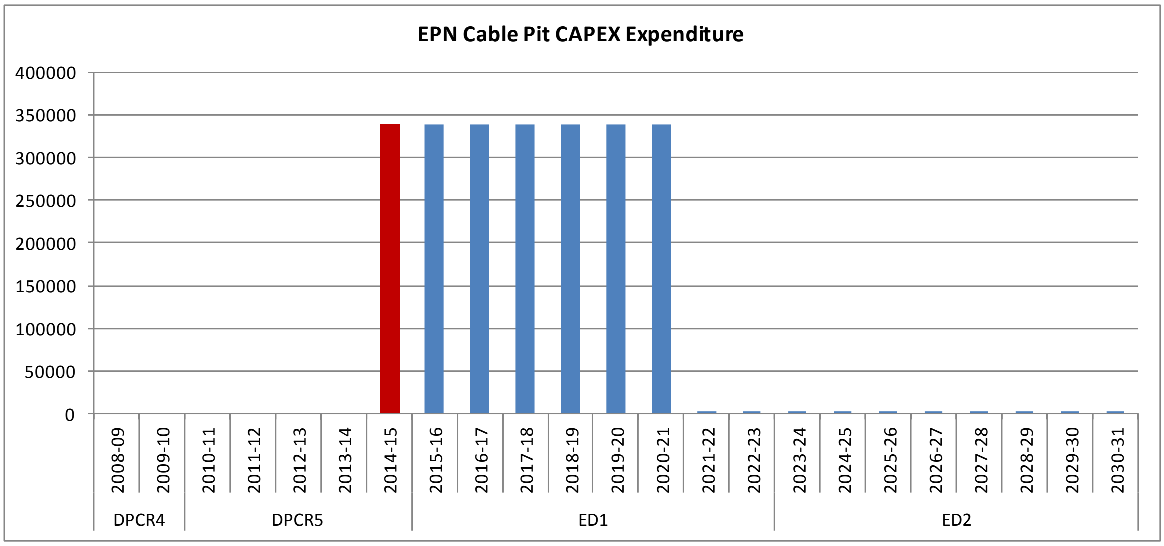

Figure 19: EPN cable pit CAPEX expenditure trend

Figure 18 and Figure 19 show the volumes and expenditure associated with the proposed mitigation measures over an 8 year period. The proposed mitigations measures are: ladder removal, pit infill and reinstatement, dormant (larger) pit infill and reinstatement, provision of vented covers on very high, high and medium risk pits (SSC lid), provision of fall arrest system, and replacement of defective imploded joints. All Very High and High risk cable pits will be mitigated, following completion of the inspectionsin June 2014.

7.4 Commentary

The proposed investment level in ED1 for the inspection programme and mitigation implementation is £2.97m. The majority of Very High and High risk cable pits have been inspected and appropriate mitigation and maintenance has been undertaken during DPCR5. The ED1 expenditure will focus on Medium risk cable pits. The cost benefit for this programme of work is 3.6, indicating it also is a comprehensive benefit to society (further details are included in Appendix 4). .

The level of investment proposed has been determined from the development of a comprehensive inspection regime, risk based mitigation proposals and extrapolation of the increase in incidents that have occurred since 2012.

This investment will significantly reduce the incidence of disruptive failure of cable pits, ensure the safety of the public and meet our statutory and regulatory obligations.

8.0 Deliverability

Progress of the 5,143 (very high and high risk pit) trial inspections, maintenance and mitigation works, during the DPCR5 period, and the subsequent commencement of an additional 4,000 cable pit inspections and associated mitigations, highlight UKPN's commitment to the cable pit strategy and capability to ensure deliverability of the programme.

Appendix 1: Age Profiles

Not relevant for cable pit assets: intentionally left blank

Appendix 2: HI and Criticality Profiles

Not relevant for cable pit assets: intentionally left blank

Appendix 3: Fault Data

CABLE PITS DISRUPTIVE FAILURES :							4=VH 1=L
Date	**Year**	**Hub Area**	**AIRline Ref**	**Incident Number**	**Address**	**Description**	**Survey Adjusted Risk**
11/01/2012	2012	LPN	R/12/620	INCD-2244-L	123 Old Brompton Road, London, SW7 3RP	Linkbox at this location has blown its lid off. Was actually a HV joint that faulted in a cable pit. Reported wrongly as a link box.	2
17/04/2012	2012	LPN	R/12/5712	INCD-24874-J	Colonies Public House, Wilfred Street London SW1E 6PR	Cover Of cable pit exploded	4
23/05/2012	2012	LPN	R/12/7726	INCD-28334-J	Junction of Edgware Road and Burwood Place, London W2	Gas Board have identified possible gas leak in the middle of the road a metre away or two from our pit. No sign of any damage to cables in the pit.	2
30/05/2012	2012	LPN	R/12/8479		Uxbridge Rd, junction with Tunis Rd, London, W12	HV fault occurred which caused an explosion in a pit at this location. This prompted the Police to close the road/footpath. The faulty HV cable was isolated and earthed, the pit cover was replaced and the road/footpath was	2
11/06/2012	2012	LPN	R/12/8524		Linkbox 631692. Corner of Cotton Street, Junction of East India Dock Road, London, E14	Open circuit fault between Linkbox 631663 going to Linkbox 631692. Explosion on the corner of Cotton Street where a pit lid flew off and went roughly six to seven feet in the air. There were no injuries and there was a small fire in the pit which was extinguished.	2
17/08/2012	2012	LPN	R/12/13060	INCD-35790-J	46 Francis Street London SW1P 1QN	Cable pit explosion. The problem was discovered to be a faulted service joint. Transco attended to confirm that no gas was found.	2
20/08/2012	2012	LPN	R/12/13207	INCD-35971-J	27 Abingdon Road, London, W8 6AH.	Corner of BT pit has lifted O/S no 27. Suspect joint has blown near here. Check in T/C 11643 to see what fuses have operated. Already raised on faults	2
26/08/2012	2012	LPN	R/12/13592	INCD-2574-L	Regent Street, Junction with Vigo Street, London, W1B	HV fault which resulted in a cable pit explosion. Parked car over pit suffered damage. The council put a steel plate over the hole.	4
	2012	LPN				Bishopsgate. Cable pit explosion.	
05/10/2012	2012	LPN	R/12/15983	INCD-39755-J	W1K 5QS, 44 South Moulton Street, London	London fire service have reported a service pit has exploded at this address. They advise this caused a paving slab to be thrown into the air. Operative advises the supply has been isolated and a faults team is on site carrying out	2
08/10/2012	2012	LPN	R/12/16102	INCD-39977-J	SW11 - O/S Revolution Bar, Jnt Falcon Rd and Lavender Hill, London	Report about an explosion at a Link Box. Engineers are in attendance under INCD-39977-J and advise that it is the Manhole Cover of a Pit which has 3 Passing Mains and 2 HV Cables in it. The operative advises that it looks like a	2
03/11/2012	2012	LPN	R/12/17757	INCD-42445-J	Uxbridge Road / Thistle Road, London W12	Metropolitan Police stating that a man-hole cover has exploded in the footpath. They also state that a member of the public fell in to the hole when the link box exploded.	
18/01/2013	2013	LPN	R/13/993	INCD-48646-J	Grosvenor Gardens, 1 Westminster Bk, T1 LV Links, SW1W	Cable pit blown near to Link Box	
	2013	EPN	R/13/996	INCD-676961-H	8 Wood Lane, Highgate	Cable joint faulted, igniting gas leak, and causing flames from BT pit.	
07/03/2013	2013	LPN	R/13/4235	INCD-51872-J	Rest W1S nr Mulberry Shop, 47-48 New Bond Street, London	Pit explosion. Blew lid off. Pit caught fire.	2
	2013	LPN			O/S Welsh Office, Whitehall, SW1A	Disruptive cable pit	2
	2013	LPN			O/S 111 Jermyn Street, SW1Y 6LS	Disruptive cable pit	3
09/03/2013	2013	LPN	-	INCD-6997-N	Hamilton Terrace	Disruptive cable pit	2
17/06/2013	2013	LPN	R/13/10788	INCD-58366-J	O/S 49-63 Regent Street, W1B 4DY	Disruptive joint in cable pit	3
19/06/2013	2013	LPN	R/12/16102	INCD-3977-J	Lavender Hill	Disruptive joint in Cable Pit	
20/06/2013	2013	LPN	R/12/13060	INCD-35790-J	Frances Street	Service joint failure in cable pit	
27/06/2013	2013	LPN	R/13/6394	INCD-54298-J	Sherwood Street Carnaby Street Panel 38	Disruptive Joint in cable pit	
25/04/2013	2013	LPN	R/13/7177		O/S 74 Pimlico Road London SW1W 8PL	Kevin Vincent (01473 266520) is reporting that there were flames coming out of our Cable Pit in the footpath. UKPN are on site at the moment dealing with the repairs. No reports of injuries. Logged by Chris Chapman	4
08/07/2013	2013	LPN			O/S 128 Grand Drive, SW20 9DZ	Disruptive cable pit	3
02/08/2013	2013	LPN	R/13/14609	INCD-12775-N	o/s Police Station and Liverpool St Station	Cable Pit disrupted.LV main cable had 4mm hole in it and had burnt back a fair way. 2 previous reports of gas in pit	2
02/08/2013	2013	LPN	-	INCD-61332-J	Thayer St Junct of Hind, W1	Jointers found a fault in a six metres deep cable pit. Unable to repair due to gas presence.	4
05/09/2013	2013	LPN	R/13/16666	INCD-63190-J	o/s 19 Ovington Gardens	Disruptive asset in cable pit, roadway cover lifted section 15ft in the air	2
08/09/2013	2013	LPN	R/13/16820	INCD-63342-J	Walm Lane East	Fault on cable between link boxes in a cable pit.	1
16/09/2013	2013	LPN	R/13/17435	INCD-14410-N	o/s 12 Fenchurch Avenue EC3	Disruptive cable pit, LV cable fault, jointer made a cut and two pot end to restore supply.	2
22/10/2013	2013	LPN	R/13/20117	INCD-17112-N	Outside 1 Grosvenor Street, London W1	Disruptive LV UG joint in footway. Someone was caught in the disruption not sure if it was UKPN or Fire Service.	3
15/11/2013	2013	LPN	R/13/21963	INCD-18875-N	Junction of Hanway Street and Hanway Place. W1	Old Pot End joint failure in BT cable pit	4
18/11/2013	2013	LPN	R/13/22140	INCD-18985-N	side of Emmanuel School, Mill Lane. NW6	cable burnt back to main in cable pit cable pit. Cable been burning for some time as jointer unable to separate cores. Also needed to install link box.	2
02/12/2013	2013	LPN	R/13/23100	INCD-66254-J	Breams Building, 22 Chancery lane, London. WC2	three phase service joint disrupted in cable pit. No property damage	2
25/01/2014	2014	LPN	R/14/1755	INCD-69844-J	87 Mount Street, W1	joint failure	3
31/01/2014	2014	LPN	R/14/2437	INCD-22022-N	The Old Star, Broadway	cable failure	3
14/02/2014	2014	LPN		INCD-22645-N	5 Wilton Crescent, SW1	pot end	3

Table 20: Historic Cable Pit Disruptions

Appendix 4: Studies

A detailed cost benefit has been undertaken and this shows there is a positive benefit to completing the cable pit strategy as described in this document.

Cost Benefit Analysis	
Very High	15.8
High	13.6
Medium	3.6
Low	0.0
Overall	5.0

Table 21: Cable Pit CBA

Appendix 5: NLRE Expenditure Plan

EPN EXPENDITURE

				DPCR5		ED1							
Namp Line	**DNO**	**Description**	**UCI**	**2013/2014**	**2014/2015**	**2015/2016**	**2016/2017**	**2017/2018**	**2018/2019**	**2019/2020**	**2020/2021**	**2021/2022**	**2022/2023**
1.18.09	EPN	Replace Joints (Cable Pit Strategy)	£2,214	£0	£34,875	£34,875	£34,875	£34,875	£34,875	£34,875	£34,875	£488	£488
1.47.40	EPN	Cable Pit Mitigation	£817	£0	£283,230	£283,230	£283,230	£283,230	£283,230	£283,230	£283,230	£0	£0
2.05.08	EPN	Cable Pit Maintain	£1,382	£0	£107,586	£107,586	£107,586	£107,586	£107,586	£107,586	£107,586	£16,297	£16,297
2.30.15	EPN	Cable Pit Inspection	£88	£0	£57,775	£57,775	£57,775	£57,775	£57,775	£57,775	£57,775	£18,698	£18,698
Total				**£0**	**£483,465**	**£483,465**	**£483,465**	**£483,465**	**£483,465**	**£483,465**	**£483,465**	**£35,484**	**£35,484**
ED1 Total				**2,971,760**									
ED1 Average				**371,470**									

EPN VOLUMES

				DPCR5		ED1							
Namp Line	**DNO**	**Description**	**UCI**	**2013/2014**	**2014/2015**	**2015/2016**	**2016/2017**	**2017/2018**	**2018/2019**	**2019/2020**	**2020/2021**	**2021/2022**	**2022/2023**
1.18.09	EPN	Replace Joints (Cable Pit Strategy)	£2,214	0	16	16	16	16	16	16	16	1	1
1.47.40	EPN	Cable Pit Mitigation	£817	0	346	346	346	346	346	346	346	0	0
2.05.08	EPN	Cable Pit Maintain	£1,382	0	78	78	78	78	78	78	78	12	12
2.30.15	EPN	Cable Pit Inspection	£88	0	655	655	655	655	655	655	655	249	249
Total				**0**	**1,095**	**1,095**	**1,095**	**1,095**	**1,095**	**1,095**	**1,095**	**262**	**262**
ED1 Total				**7,095**									
ED1 Average				**887**									

Table 22: EPN DPCR5 & ED1 Volumes and Expenditure

Appendix 6: Sensitivity Analysis

Not relevant for cable pit assets: intentionally left blank

Appendix 7: Named Schemes

Not relevant for cable pit assets: intentionally left blank

Appendix 8: Output NAMP/ED1 Business Plan Data Tables reconciliation

			Volumes																	
Namp Line	DNO	Description	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	Total	RIGs Table	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	Total
1.18.09	EPN	Replace Joints (Cable Pit Strategy)	16	16	16	16	16	16	1	1	**97**	CV8	16	16	16	16	16	16	1	1	**97**
1.47.40	EPN	Cable Pit Mitigation	346	346	346	346	346	346	0	0	**2,079**	CV8	346	346	346	346	346	346	0	0	**2,079**
2.05.08	EPN	Cable Pit Maintain	78	78	78	78	78	78	12	12	**491**	CV13	78	78	78	78	78	78	12	12	**491**
2.30.15	EPN	Cable Pit Inspection	655	655	655	655	655	655	249	249	**4,429**	CV13	655	655	655	655	655	655	249	249	**4,429**
	Total		**1,095**	**1,095**	**1,095**	**1,095**	**1,095**	**1,095**	**262**	**262**	**7,095**		**1,095**	**1,095**	**1,095**	**1,095**	**1,095**	**1,095**	**262**	**262**	**7,095**

Table 23: NAMP to ED1 Business Plan Data Reconciliation

Appendix 9: Efficiency benchmarking with other DNO's

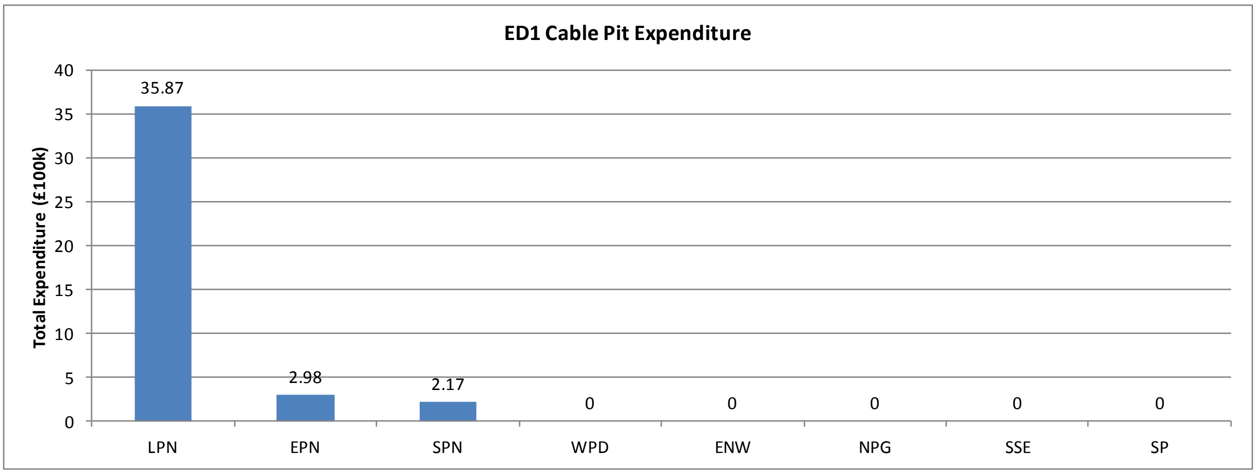

Figure 20: Cable Pit Expenditure/DNO

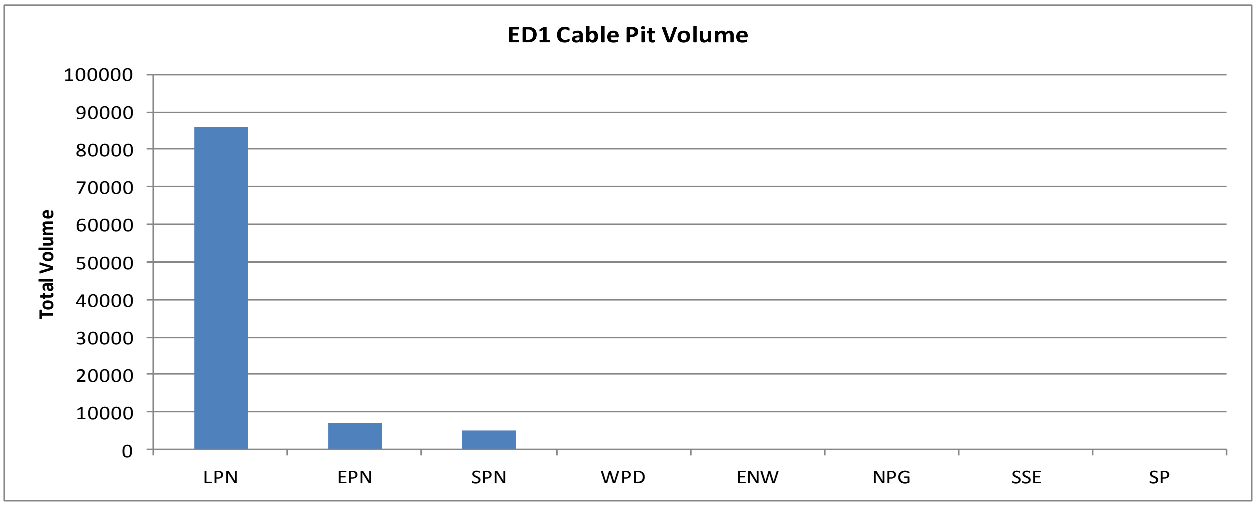

Figure 21: Cable Pit Volumes/DNO

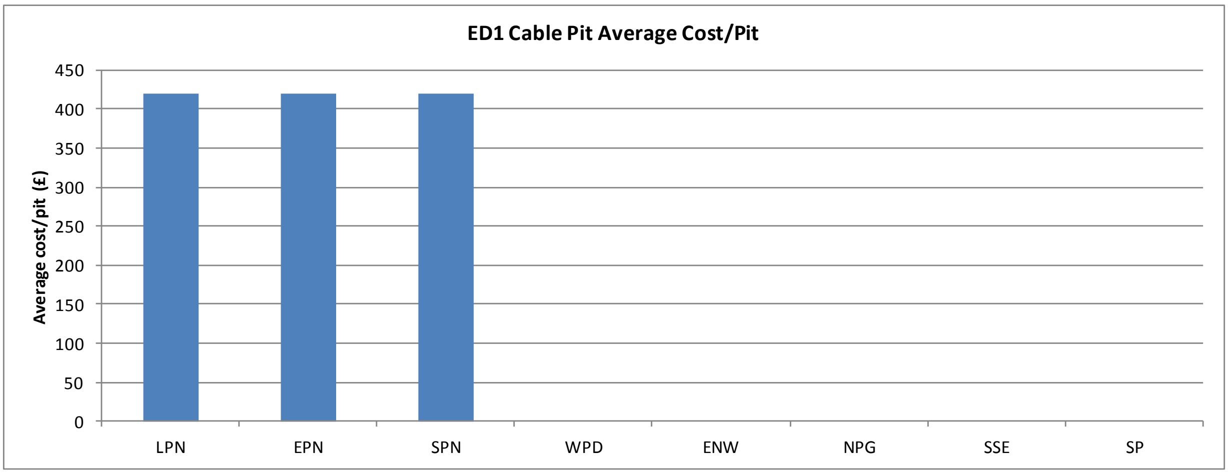

Figure 22: Cable Pit Average Cost/Pit

Appendix 10: Material changes since June 2013 Submission

Changes between the July 2013 submission and the March 2014 re-submission are summarised and discussed below.

Asset type	Action	Change type	2013	2014	Difference	Comment
Cable Pit	Joint Replacement	Volume	94	97	+3	As below
		Investment (£m)	0.24	0.21	-0.03	
		UCI (£k)	2.5	2.21	-0.29	
Cable Pit	Mitigation	Volume	1940	2079	+139	As below
		Investment (£m)	0.48	1.7	+1.22	
		UCI (£k)	0.25	0.82	+0.57	
Cable Pit	Maintenance	Volume	689	491	-198	As below
		Investment (£m)	0.41	0.68	+0.27	
		UCI (£k)	0.59	1.38	+0.79	
Cable Pit	Inspection	Volume	4815	4429	-386	As below
		Investment (£m)	0.08	0.38	+0.3	
		UCI (£k)	0.019	0.088	+0.069	

Table 24: ED1 Material Changes (Source: 21st February 2014 ED1 Business Plan Tables)

Joint Replacement

Further analysis of degraded and failed joints has revealed internal degradation of the joints in certain conditions occurs faster than previously thought. For this reason within the ED1 period more joints will require replacement than had previously been included.

The additional analysis has also allowed us to secure firm unit costs, developing an efficiency saving of £290 (~12%) on every joint replacement carried out.

Mitigation

Since July 2013, the mitigation trial programme has successfully mitigated approximately 500 cable pits ranging in size from 1 to 8m^3 . This programme of works now means UKPN Networks has a clear understanding of the costs involved. This has led to the following submission revision changes:

- The overall increase in unit volumes is due to:
    - The requirement to apply the full risk mitigation hierarchy to all Very High, High and Medium risk pits. Initial analysis had indicated that only a proportion

of Medium risk pits would require the application of the full risk mitigation hierarchy. However a significant number of disruptive failures have now occurred in Medium risk pits making the application of the hierarchy necessary across all Medium risk pits.

 - There was also some reduction in volumes based on the number of pits found to be buried but for the reasons stated above the overall change is a small increase.

- An increase in unit cost for cable pit mitigations is due to:
  - The increase in the number of cable pits where a vented/hinged/tethered lockable cover will be required. This is due to findings in the trial where it was found many cable pits do not have the required uniformed shape that allows sand infill and would not sufficiently fill the voids within the cable pit to prevent build-up of gas.
  - The increased unit cost for vented/hinged/tethered lockable covers which are now based on actual costs incurred to date rather than estimates.
  - Actual inspection demonstrating that a large number of cable pits are larger than originally estimated resulting in increased cost of mitigation. Table 25 shows this movement in more detail.

Mitigation CAT	2013		2014		Volume Difference
	Volume	Risk CAT	Volume	Risk CAT	
Buried	0	-	875	VH/H/M/L	+875
$<1m^3$	1,811	VH/H/M	582	VH/H/M	-1,299
$>1m^3$ & $<3m^3$	57	VH/H	582	VH/H/M	+525
$>3m^3$ & $<8m^3$	48	VH/H	367	VH/H/M	+319
$>8m^3$ & $<15m^3$	24	VH/H	92	VH/H/M	+68

Table 25: Size recategorisation of cable pits for infill mitigation (2013 vs 2014) – UCI increase justification

  - An additional secondary mitigation of a fall restraint system where cable pits are found more than 3m in depth and cannot be infilled. Revised estimates show these will be required on 3% of cable pits and were not originally included within the strategy.

Maintenance

There is an increase in investment required because:

- There is an increase in carriageway cover replacements required, and following innovative development of the cover, the average cost of the maintenance programme has significantly increased.
- Following the inspections it has been found that significantly more structural works are required, this is due to the poor condition of many cable pits found.
- Following further development and obtaining firm prices for cover replacements the unit cost of the cover and installation has increased.
- Overall volumes have decreased following revised analysis but for the reasons stated above there is still an overall increase.

Inspection

The inspection investment has increased due to an error in the submitted volumes and costs in the July 2013 submission. This has resulted in a higher but realistic UCI and a reduction in the required number of inspections required.