UKOPA

United Kingdom Onshore Pipeline Operators' Association

Good Practice Guide

Managing Pipelines with Reduced Depth of Cover

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The guidance in this document identifies what is considered by UKOPA to represent current UK pipeline industry good practice within the defined scope of the document. All requirements should be considered guidance and should not be considered obligatory against the judgement of the Pipeline Owner/Operator. Where new and better techniques are developed and proved, they should be adopted without waiting for modifications to the guidance in this document.

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1. INTRODUCTION

The UKOPA Pipeline Product Loss, Incident and Fault Report [1] indicates that third party damage is the most likely cause of pipeline damage and failure. This is supported by European gas pipeline data collected and reported by the European Gas pipeline Incident data Group [2] and by European liquid oil pipeline data collected and reported by CONCAWE [3]. One method in which pipeline operators can protect pipelines from third party damage is to bury them at a sufficient depth so that they are not impacted by normal day to day activities that might occur on the land in which they are buried such as normal cultivation activities related to farming.

Some of the pipelines operated by UKOPA members have now been in the ground for more than 60 years. Inevitably over this period, as a result of natural erosion, farming or construction related activities, the cover over the pipelines at some locations may have been reduced. Additionally some older pipelines pre-date modern pipeline standards and were laid at shallower depths than is now required by more recent pipeline standards.

This document has been developed to provide UKOPA members with practical guidance on the steps that they can take to identify pipelines that have reduced cover and assess the risks associated with reduced cover. The document also discusses potential mitigating measures that can be taken at locations that are deemed to be high risk in order to be able to demonstrate the risks have been made As Low as Reasonably Practicable (ALARP).

2. SCOPE AND APPLICATION

2.1 Scope

The guidance in this document is applicable to all buried pipelines operated by the UKOPA member companies. These pipelines can be categorised as:

- Natural gas transmission and distribution pipelines.
- Petrochemical liquids and gas pipelines.
- Oil and refined liquid pipelines.

For gas pipelines the guidance is generally applicable to pipelines with maximum operating pressures above 7 bar, however the principles of the document can be equally applied to gas pipelines operating at lower pressures.

The management of pipelines located under rivers, streams and ditches, and the consequential impacts of the erosion of the beds of these watercourses, are outside of the scope of this document. The principles in this document can be applied to smaller watercourse crossings, but due to the different risks encountered by pipelines crossing under watercourses, further guidance should be sought to ensure all integrity threats are effectively managed.

Assessment and mitigation of reduced depth of cover of pipelines migrating upwards from their original installation depth due to loss of anti-buoyancy systems or frost heave are outside the scope of this document and further guidance should be sought.

2.2 Application

The guidance in this document is considered by UKOPA to represent current UK pipeline industry good practice within the defined scope of the document. All requirements should be considered to be guidance and should not be considered to be obligatory against the judgement of the Pipeline Owner/Operator. Where new and better techniques are developed and proved, they should be adopted without waiting for modifications to the guidance in this document.

3. CURRENT REQUIREMENTS FOR DEPTH OF COVER

The principal UK legislation in this area is the Pipelines Safety Regulations 1996 (PSR) [4]. Prior to 1996, in addition to the general provisions of the Health and Safety at Work etc. Act (HASWA) 1974 [5], gas pipelines were laid under various Gas Acts [6] [7] whilst other non-gas pipelines were laid under the Pipelines Act 1962 [8]. Whilst PSR include no specific requirements with respect to depth of cover, there are a number of relevant regulations in this area, including Regulation 5 which covers requirements for the design of a pipeline. Regulation 5 states that:

The operator shall ensure that no fluid is conveyed in a pipeline unless it has been so designed that, so far as is reasonably practical, it can withstand.

a) Forces arising from its operation.

b) The fluids that may be conveyed in it; and

c) The external forces and the chemical processes to which it may be subjected.

The key requirement above with regard to depth of cover is (a) forces arising from its operation, i.e. to withstand third party damage the pipelines should be at a sufficient depth that they avoid the majority of activities that might result in third party damage.

The guidance to Regulation 5 also states that:

31 The design and location of the pipeline should take account of the hazard potential of the fluid being conveyed.

32 In general British Standards provide a sound basis for the design of pipelines. Other national standards (e.g. a relevant standard or code of practice of a national standards body or equivalent body or any member state of the European Union) are likely to be acceptable provided the proposed standard, code of practice, technical specification or procedure provides equivalent levels of safety).

Regulation 13, which covers the requirements for pipeline maintenance, states that:

The operator shall ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair.

The guidance to Regulation 13 states that:

59 This regulation deals with the requirement to maintain the pipeline to secure its safety operation and prevent loss of containment. Maintenance is essential to ensure that the pipeline remains in a safe condition and is fit for purpose.

Regulation 16, which covers the requirements for prevention of damage to pipelines, states that:

For the purposes of ensuring that no damage is caused to a pipeline, the operator shall take such steps to inform persons of its existence and whereabouts as are reasonable.

The guidance to Regulation 16 states that:

72 It is important that third parties are made aware of the presence of a pipeline, and that information is available, where appropriate, regarding the location of the pipeline…

Additionally pipelines are captured as pressure systems under the Pressure System Safety Regulations (PSSR) [9].

Regulation 6 of PSSR requires that:

The employer of a person who installs a pressure system at work shall ensure that nothing about the way in which it is installed gives rise to danger or otherwise impairs the operation of any protective device or inspection facility.

In addition to the above Regulations, under the HASWA, duty holders are required to demonstrate that the risks associated with their undertakings have been made ALARP.

The two key standards used by UKOPA members that specify depth of cover requirements are:

1. IGEM/TD/1 for natural gas pipelines [10]

2. PD 8010-1 for non-natural gas pipelines [11]

The current requirements within these standards are:

IGEM/TD/1 Edition 6, Section 7.16 specifies that the depth of cover should be a minimum of 1.1 m in rural and suburban areas (as defined in Section 6.7.1 of the document) and should be 1.2 m below roads (measured from the true clean bottom of the adjacent drainage ditches) and 1.2 m below the bottom of watercourses, canals, and rivers (measured from the lowest anticipated true clean bed level) and 1.4 m below railways.

Recommendations concerning the installation of steel pipelines were first published by the Institution of Gas Engineers in 1965 as Communication 674. Recommendations superseding Communication 674 were published progressively following 1977 as various Editions of IGE/TD/1 culminating in the current Edition (Edition 6) which was published in 2021. Pipelines that were designed and constructed prior to 1965 were laid under various 'Gas Board' standards.

PD 8010-1:2015 requires that the depth of cover should be a minimum of 1.1 m in areas of agricultural or horticultural activity. A minimum of 0.9 m depth of cover is specified in areas of limited or no human activity. A depth of cover of 1.2 m is specified under watercourses, canals, rivers, and roads and in residential, industrial, and commercial areas. Depths of cover between 1.4 and 1.8 m are specified under railways (dependent on the requirements of the appropriate authorities).

The depth of cover requirements for IGEM/TD/1 and PD 8010-1 are summarised in Table 1 below (please refer to the original documents for the relevant definitions of the terms used in this table).

	Historical Requirements (metres)		Current Requirements (metres)	
Location	**Pipelines constructed to earlier editions of IGE/TD/1**	**BS 8010-2:1992**	**IGEM/TD/1 Edition 6**	**PD 8010-1**
Rural and Suburban Areas	0.9 (3 feet) this increased to 1.1 m in Edition 2 (1984)	0.9 for areas of agricultural activity	1.1	1.1 for areas of agricultural or horticultural activity 0.9 for areas of limited or no human activity
Roads	See note 1	1.2	1.2	1.2
Water courses, canals, rivers	See note 1	Agreed in consultation with the water and waterways authorities	1.2	1.2
Railways	See note 1	1.4 for open cut pipelines 1.8 for bored pipelines	1.4	1.4 to 1.8 depending upon requirements of the relevant appropriate authorities

Table 1: Summary of Depth of Cover Requirements in IGEM/TD/1 and PD 8010-1

Note 1: There were no specific cover requirements for road, rail, and watercourse crossings prior to Edition 5 of IGEM/TD/1 other than a requirement in Edition 2 and later editions for greater than 300 mm above the concrete slab that was required when crossing under a ditch.

Some pipeline operators have additional depth of cover requirements above the minimum depths required by the design standards in order to reduce the potential for disruption of farmers' land drainage.

4. CAUSES OF REDUCED COVER OVER PIPELINES

Reduced cover over pipelines can occur as a result of:

- Natural erosion of the soil, natural shrinkage of soils such as peat containing a high level of organic matter.
- Human activity.
- Being constructed to older pipeline standards with less onerous depth of cover requirements.
- Loss or failure of the anti-buoyancy system. These are installed on pipelines laid in marsh land or peat land bogs at the time of construction to prevent the pipeline floating to the surface. Modern anti-buoyancy systems consist of concrete cladding on the outer coating of the pipeline, however earlier systems may take the form of anchors fitted to saddles around the pipe.

4.1 Natural Erosion

The three main types of natural erosion are:

1. Water erosion.
2. Wind erosion.
3. Gravity.

4.1.1 Water Erosion

4.1.1.1 Rain splash, rill, and gully erosion

The impact of raindrops on the soil surface can break down the soil (soil aggregates) leading to its dispersion. Lighter aggregate materials such as very fine sand, silt, clay and organic matter are more susceptible to rain splash. Although raindrop erosion is more noticeable during heavy rainstorms, the erosion caused by longer lasting less intense rainstorms can also be significant.

Rill erosion occurs when surface water runoff concentrates forming small channels. These are known as gullies when the channels become deeper and wider and interfere with farming machinery operations such as normal tillage of the soil.

The impact of water (and wind) erosion is also exacerbated by changing weather patterns as a result of climate change.

4.1.1.2 River, Stream, and Ditch Erosion

The management of reduced cover as a result of river, stream and ditch erosion is outside of the scope of this document, however the following information is provided in order to assist pipeline operators in identifying where this mechanism may pose a risk to their pipelines.

River, stream, and ditch erosion is often caused by poor construction or poor maintenance of surface drainage systems, uncontrolled livestock access or growing crops too close to stream banks. Rivers and streams also have a natural tendency to meander as a result of erosion of the bank of the river or stream on the outside of a bend and the deposition of silt on the inside of a bend. This can result in rivers or streams bypassing bank reinforcement systems.

The Environment Agency (EA), Natural Resources Wales (NRW) and the Scottish Environmental Protection Agency (SEPA) also now take a less interventionist approach to managing the routes of natural watercourses compared with the approach taken a few decades ago. They are now more likely to let rivers naturally meander rather than instigating physical remedial work when the route of a river changes.

4.1.2 Wind Erosion

The rate and magnitude of soil erosion by wind is affected by a number of factors including:

- Soil particle size - fine soil particles can be suspended in the wind and transported great distances.
- Soil surface roughness - soil surfaces that are not ridged offer little resistance to the wind.
- Excess tillage can also lead to soil surface breakdown and increased wind erosion.

Other factors include lack of natural windbreaks (trees, shrubs etc.) or vegetative cover and low soil moisture levels also increase the amount of wind erosion. In very flat areas of the UK e.g. East Anglia, wind can cause dust storms (known locally within East Anglia as ‘fen blow’). This can occur in the spring during periods of high wind when there is not significant crop growth, and the topsoil is dry.

4.1.3 Gravity

The steeper the slope of a field the greater the amount of soil loss from erosion by water. Soil erosion by water also increases due to the greater accumulation of runoff. Consolidation of small fields into larger fields can result in longer slope lengths with increased erosion potential due to the increased velocity of water. The effect of slopes can also be exacerbated by tillage.

4.2 Natural Shrinkage

Organic soils, such as peat, can naturally decompose due to oxidisation and this can lead to a reduction in its volume. Oxidisation occurs when the organic material comes into contact with the air, this is usually when the water table falls. Cohesive soils such as clay also experience volumetric change when wetted or dried. They will shrink when dry and swell when wet. Clay is particularly prone to ‘shrink-swell’ and is found extensively across England and Wales.

4.3 Human Activity

4.3.1 Farming Activity

Man-made reduction in cover would normally be as a result of farming activities including tillage of the soil or as a result of construction or drainage activities.

In some parts of the UK, man-made reduction in cover is occurring as a result of laser levelling of the land. Laser levelling is a process of smoothing the land surface from its average elevation using laser-equipped drag buckets. This practice uses large horsepower tractors and soil movers that are equipped with global positioning systems (GPS) and/or laser-guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level. The precisely levelled surface facilitates uniform soil moisture distribution resulting in improved crop growth and yield. The timing of the growth can also be controlled using managed drainage controlled by weirs and pumping, these are normally managed by local drainage boards.

Livestock movement can cause soil compaction by trampling wet ground leading to loss of soil structure, decrease in soil porosity and less water movement through the soil. Compaction can result in reduced depth of cover and increased water erosion. High activity areas like drinking troughs, feeders, gateways, and sources of water are more likely to be impacted. Larger animals such as cattle are more likely to cause soil compaction that lighter animals like sheep.

Other causes of soil compaction include heavy machinery, notably non-tracked equipment, and surface storage of materials.

Turf harvesting can result in the progressive reduction of depth of cover. Each year topsoil is removed as part of the turf during harvesting. Topsoil would usually be added in preparation for the subsequent years harvest, but the overall depth of cover can reduce over multiple years.

4.3.2 Planned Development

Planned development also impact on soil erosion. Buildings are being located on flood plains and increased areas of land with hard surfaces (e.g. tarmac or concrete) with water subsequently running off into watercourses through man-made channels and drains.

5. MANAGING THE IMPACT OF REDUCED COVER

Managing the impact of buried pipelines with reduced cover requires a three stage approach consisting of:

1. **Identification**: identifying the locations and extent of pipelines with reduced depth of cover.

2. **Risk assessment**: assessing the likelihood and consequences of pipeline damage in order to understand whether mitigating measures are considered to be reasonably practicable.

3. **Response**: managing the risks which may include identifying and implementing remedial measures.

The process should be documented to capture the identified areas, the risk assessment, and any mitigation. These three steps are discussed in the sections below.

5.1 Identification

There are a number of ways in which the locations of sections of buried pipelines with reduced depth of cover can be identified. These include making the best use of existing available information and data, undertaking over-line surveys to determine the depth of cover and/or calculating the depth of cover.

5.1.1 Existing Information and Data

Potential existing sources of data include:

- Depth data taken and recorded during digs to repair inline inspection (ILI) or over-line survey features.
- Locations on the network where pipelines are known to have reduced cover. These could be as a result of known constraints during the construction of the pipeline or known works or farming activity that could have resulted in reduced cover.
- Locations of incidents or near misses that have occurred as a result of reduced cover.
- Construction information which can include strip map data. For older pipelines, the pipeline depth at some locations may be now significantly different from the specified laid depth on the strip maps, however strip maps or other relevant construction data can be used as a starting point when building up a repository or database of known pipeline depth information.
- Known locations of soils with very high organic content, e.g. laid in or near to peat. The British Geological Society is able to supply data that may be able to support identification of these areas.
- Data from historical risks assessments that have been undertaken in the past which may have identified pipeline lengths with reduced cover.

5.1.2 Over-Line Surveys

One way of determining pipeline depth of cover is to make depth measurements as part of an over-line survey. This can either be above specific sections of pipeline that may be known to have potential depth of cover issues, or of the whole of the pipeline network. For pipeline operators that manage very large pipeline networks, it is suggested that this could be done using a risk based approach based on the data sources listed above to target or prioritise any surveys that are being planned.

The over-line survey could be combined with an existing pipeline maintenance or inspection related activity e.g. linewalking or other existing planned over-line survey e.g. Close Interval Potential Survey (CIPS).

Depth measurements should ideally be taken with a suitable pipeline detection device. Care should be taken where multiple pipelines are located in close proximity to ensure the relevant pipeline is surveyed. The pipeline detection device should have an appropriate level of accuracy. If the device has not been recently calibrated, then calibration checks should be undertaken to prove the accuracy of the chosen device prior to the commencement of any survey work.

At the chosen locations, pipeline depth measurements should be taken at sufficiently regular intervals that an accurate picture of pipeline depth can be built up along the length of the pipeline section being surveyed. This could be typically one measurement every 50 m, but it may be appropriate to modify this distance depending on the topography of the land and any known local issues such as a high potential for ground erosion or ground features such as river crossings. Consideration could be given to obtaining depth of cover readings either side of ditch crossings and at aerial marker posts (to demonstrate the marker is over the pipeline). The extent of areas of reduced depth of cover can be identified by taking readings at reduced intervals in both directions along the pipeline until sufficient cover if recorded.

Prior to undertaking the survey, pipeline operators should consider the way in which data is going to be recorded and analysed. For example it may be appropriate to record the measured depth on a handheld personal digital assistant or similar data recording device to facilitate the future storing and analysis of the data. The pipeline operator should also develop a procedure that documents how the collected data will be used to drive the immediate and longer term actions following the survey.

5.1.3 Calculation Approach

Calculating the depth of cover can be performed by combining ground elevation data with Inertial Measurement Unit (IMU) data. This method has the benefit of determining a depth of cover for the entire pipeline route and tests show reasonable accuracy can be achieved.

Ground elevation data over an extensive area, such as a pipeline's footprint, often utilises light detection and ranging (LiDAR) from aircraft. The LiDAR data can be processed to remove natural and built features to produce a bare-earth model.

ILI tools can be fitted with an IMU unit to record the tools movement during an inspection. The IMU data needs be correlated with known refence points along the pipeline route to create an accurate three dimensional centreline model of the pipeline. Known refence points are created by deploying Above Ground Markers (AGMs) prior to an ILI. Each AGM has an accurate ground position and depth of cover measurement documented.

Combining the two georeferenced data sets, the LiDAR and IMU data, allows a depth of cover along the entire pipeline to be calculated. Consideration should be given to the when the data was obtained and its accuracy.

Sonar data combined with IMU data can be analysed to calculate depth of cover at watercourse crossings.

5.2 Risk Assessment

A risk assessment should be undertaken at the locations with identified reduced cover. The risk assessment should take account of:

- The vulnerability of the pipeline to third party damage.
- The susceptibility of the pipeline to third party damage, i.e. likelihood of pipeline failure occurring when it is subjected to third party damage.
- The consequences of pipeline failure.

5.2.1 Pipeline Vulnerability and Susceptibility

The vulnerability will depend on:

- The nature of the land use.
- The depth at which the pipeline is known to be located.

The pipeline's susceptibility to third party damage will depend upon:

- The design of the pipeline i.e. its specified minimum yield strength (SMYS) and wall thickness.
- The existence of any current protective measures that might already be in place (e.g. concrete slabs) at vulnerable locations.

5.2.1.1 Nature of Land Use

Table 2 gives some suggested comparative vulnerability levels based on the nature of the land use above the pipeline. These are only intended as a guide and can be modified to take account of local issues such as amenity use, incident history at any specific location and change in land use.

Nature of Land Use	Potential Risk Level
Farmland with high potential for deep cultivation or ditching activities	High
Road Crossing	High
Roadway	High
Road Verge	High
Construction Site	High
Development Land	High
Residential Property	Medium[note 1]
Farmland – grazing land or land with low potential for deep cultivation or ditching activities	Medium
Amenity Land	Medium[note 2]
Airport	Medium[note 3]
Business Land	Medium
Moorland	Medium
Private Land	Medium
Public right of way, e.g. footpath or bridleway	Medium
Golf Course	Medium
Watercourse	Medium[note 4]
Canal tow path	Low

Nature of Land Use	Potential Risk Level
Woodland	Low

Table 2: Suggested Level of Pipeline Vulnerability Depending on Type of Land Use

Note 1: The risk is dependent on the nature of the property and the likelihood of construction work taking place that could damage the pipeline. If this is a large domestic dwelling with a lot of land around it, consider moving into high risk category.

Note 2: The risk will depend on the nature of the activities being arranged on the amenity land. If this has the potential to cause damage to the pipeline (e.g. being used for touring circuses or fairs), then consider moving into high risk category.

Note 3: Risk will depend on location within the airport perimeter. This is a controlled area so deep construction work without prior notification to the pipeline operator is unlikely, however if the pipeline is close to the end of a runway, consider moving into high risk category as a result of the increased risk of damage from aircraft crashes.

Note 4: If the pipeline is located under a navigable watercourse where it would be vulnerable to damage from large, dropped anchors, then move to high risk category.

5.2.1.2 Pipeline Depth

The UKOPA report produced by GL Noble Denton (now DNV) provides information on how the risk of pipeline third party damage will reduce with increased pipeline depth of cover [12]. The key graph from this report has also been reproduced in IGEM/TD/2 [13] and PD 8010-3 [14].

5.2.1.3 Pipeline Design

Pipelines with thicker walls and constructed with high strength steels are more resilient to third party damage. Pipelines with lower design factors will therefore be less susceptible to failure than those with higher design factors. Figures 8 and 9 in IGEM/TD/2 and Figures 8 and 9 in PD 8010-3 show how the risk of pipeline failure as a result of third party damages reduces with reduced design factors and increased wall thickness. Note that experimental work undertaken by Battelle and British Gas has shown that pipelines with design factors less than 0.3 are extremely unlikely to fail as a full bore pipeline rupture. Later work by British Gas also justified that, provided the pipeline wall thickness was greater than 19.1 mm, then ruptures were also very unlikely in pipelines with design factors less than 0.5.

The above attributes (nature of land use, pipeline depth risk factor, pipeline wall thickness and steel grade) can be used to develop an overall risk rating factor for the pipeline. These can be used to determine whether it is necessary to take any of the mitigation measures.

5.2.1.4 Other Factors to Consider When Assessing Vulnerability

In addition to the factors outlined in Sections 5.2.1.1 to 5.2.1.3, the pipeline operator should also consider the rate at which the cover over the pipeline is reducing. For example if the soil is subjected to natural shrinkage as described in section 4.2, it may be possible to estimate the length of time until the cover over the pipeline has reduced by a critical amount. This will define the time frame within which remedial action will need to be taken.

Additional data collected during the regular pipeline surveillance (aerial or vantage point) can give an indicator on the level of activity that has taken place in the vicinity of the pipeline which might result in third party damage.

5.3 Mitigation

There are a number of potential remedial measures that can be implemented at identified high risk locations. Some of these may be location specific and depend upon what is the principal land use above the pipeline and what agreements can be entered into with the landowner. Table 3 lists these mitigation options. It may be appropriate, depending upon the assessed level of risk (see Section 5.2), to implement more than one of these options at a given location.

Measure	Comments
More frequent and/ or improved liaison	Depending on the location this would be with the landowner, tenant, local authority or other appropriate public or private body. They should be made clearly aware of the location of the pipeline and the procedures that they must follow when conducting any work that might have an impact upon the pipeline.
Improved pipeline marking	This would normally involve the installation of marker posts that would clearly identify the location of the pipeline and could highlight the reduced depth of cover.
More frequent monitoring/ surveillance of the pipeline	Depending upon the perceived risk this could either be implemented as a short term measure until one of the other measures listed in this table have been implemented, or it may be viewed as a reasonably practicable long term measure.
Install additional physical protection along the whole pipeline section with reduced cover or just at particularly vulnerable locations (e.g. ditches or the pipeline sections close to roads) if not already protected	The UKOPA Good Practice Guide for impact protection slabs [15] provides guidance and a standard design for a concrete protection slab. The effectiveness of slabbing is increased if brightly coloured marker tape is installed above the concrete slab. If there is insufficient clearance above the pipeline to install concrete or PE slabs, there are PE mesh materials and concrete canvas available which may be suitable. Depending on the situation, if mesh or canvas is to be installed then an appropriate justification should be requested from the supplier with respect to the effectiveness in preventing third party damage, or alternatively suitable testing should be conducted by the pipeline operator.
Agree restrictions on land use with the landowner	This could involve compensation payments to the landowner or tenant. If there is not a physical barrier in place, there is the potential for violations of the agreement without the pipeline operator being aware.
As above but also physically restrict access above the pipeline with fencing	This would probably involve compensation payments to the landowner or tenant. The physical barrier should provide greater confidence that the restrictions on activities above the pipeline will be observed. This may however incur further issues in managing the fenced off land to prevent issues such as pernicious weeds etc. becoming a problem.
Increase cover over the pipeline	This may be a good short term fix but if the causes of the reduced cover have not been addressed there is the potential that over time the cover could again be reduced. Materials that are imported must be compatible with the existing environment to avoid cross contamination.

Measure	Comments
Erosion and sediment control	Various erosion and sediment control measures can be employed to prevent or control wind or water erosion of susceptible topsoil. The controls often use a physical barrier to absorb wind or water energy to reduce erosion effects. They can be temporary or permanent depending on design and use and include cellular confinement systems, windbreaks, cover crops, fibre rolls, hay bales and gabions.
Relay the pipeline deeper	Unless the causes of the reduced cover have been addressed there is the potential that over time the cover could again be reduced.
Lift the pipeline and relay at another location	High cost option, there may also be restrictions with respect to alternative pipeline routes.

Table 3: Suggested Mitigation Measures for Reduced Depth of Cover

Under the HASWA and the PSR, pipeline operators are required to demonstrate that the risks have been made ALARP. The measures in Table 3 and associated costs should therefore be considered in context of the risk assessment undertaken in line with Section 5.2. This can either be a pipeline quantitative risk assessment (QRA) at the identified high risk locations, or a more qualitative risk ranking and scoring process may be more appropriate.

Further guidance on undertaking ALARP demonstrations for hazardous pipelines can be found in IGEM/TD/2 and PD 8010-3. The Health and Safety Executive document 'Reducing Risks Protecting People' [16] also provides guidance on the meaning of ALARP and how duty holders can demonstrate that risks have been made ALARP.

Consideration should be given to the whole life cost of the chosen mitigation(s) and the risk reduction benefit compared with the overall risk when conducting the ALARP demonstration. Permanent solution such as concrete slabs may have higher risk reduction benefit, higher initial costs but zero ongoing costs. Short-term solutions such as more frequent landowner liaison or improved marking may not have the risk reduction benefit as a concrete slab but have lower initial costs and ongoing associated costs over the operational life of the pipeline.

It is recommended that a periodic audit to confirm that the standard measures that would be required by IGEM/TD/1 and PD BS 8010 are in place. This would include appropriate liaison with owners/occupiers, tenants, and other relevant authorities. This liaison should ensure that these individuals are aware of the precise location of the pipeline and the process for notifying the pipeline operator should they want to undertake any work that might affect the pipeline.

Depending on the depth of the pipeline it may be appropriate to amend the standard advice regarding the activities the operator needs to be notified about, e.g. any ploughing activities, not just deep ploughing. It should also be ensured that the location of the pipeline is adequately indicated by marker posts at field boundaries, crossing points and if possible, changes in pipeline direction. Consideration should be given to installing additional marker posts. This may depend on which additional measures are also being implemented at the section of pipeline with reduced depth of cover.

5.4 Other Considerations

In addition to the assessment processes detailed above, pipeline operators also need to consider the issues below:

Pipeline operators have a duty under the HASWA to protect the health, safety and welfare of their workforce and the general public. It is therefore recommended that internal pipeline records are updated. It should be ensured that if any work is going to be carried out on, or in the vicinity, of the pipeline, either by third parties or the company's employees, then the relevant individuals are made aware that the pipeline section is less than the standard depth of cover and that this is considered when providing plant protection advice. Working methods, both those of third parties and employees, should take account of these sections of pipeline with reduced depth of cover.

It is also recommended that the landowner and/or tenant is made aware of any sections of pipeline with reduced depth of cover and any restrictions on work/activities in the vicinity of the pipeline. It is considered prudent, from a commercial perspective when discussing any new requirements with the landowner/or tenant, that the pipeline operator reviews the original agreements that were put in place when the pipeline was first installed and any relevant subsequent amendments to these agreements.

6. REFERENCES

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APPENDIX A EXAMPLE PHYSICAL MITIGATION MEASURES

The following are examples of reduced depth of cover mitigation measures currently in use.

Ditch Boards

Figure 1: Left - Plastic ditch board installed over pipeline with reduced depth of cover Right - Depth of cover reinstated, note the marker post at the ditch crossing

Face Plates

Figure 2: Replacement M4/M28 face plates highlighting reduced depth of cover

Aluminium Protection Plates

Figure 3: Aluminium protection plates installed above ground as temporary protection

Fencing

Figure 4: Examples of fencing off affected areas and additional pipeline marking

Erosion Control

**Figure 5: Top – Reduced depth of cover from vehicular movement identified
Middle – Cellular confinement system installed to prevent further erosion
Bottom – Depth of cover reinstated with material appropriate for land use**

Protection Slab

Figure 6: Protection slab and additional markers posts

Concrete Canvas

Figure 7: Ditch remedial using concrete canvas and additional marker posts