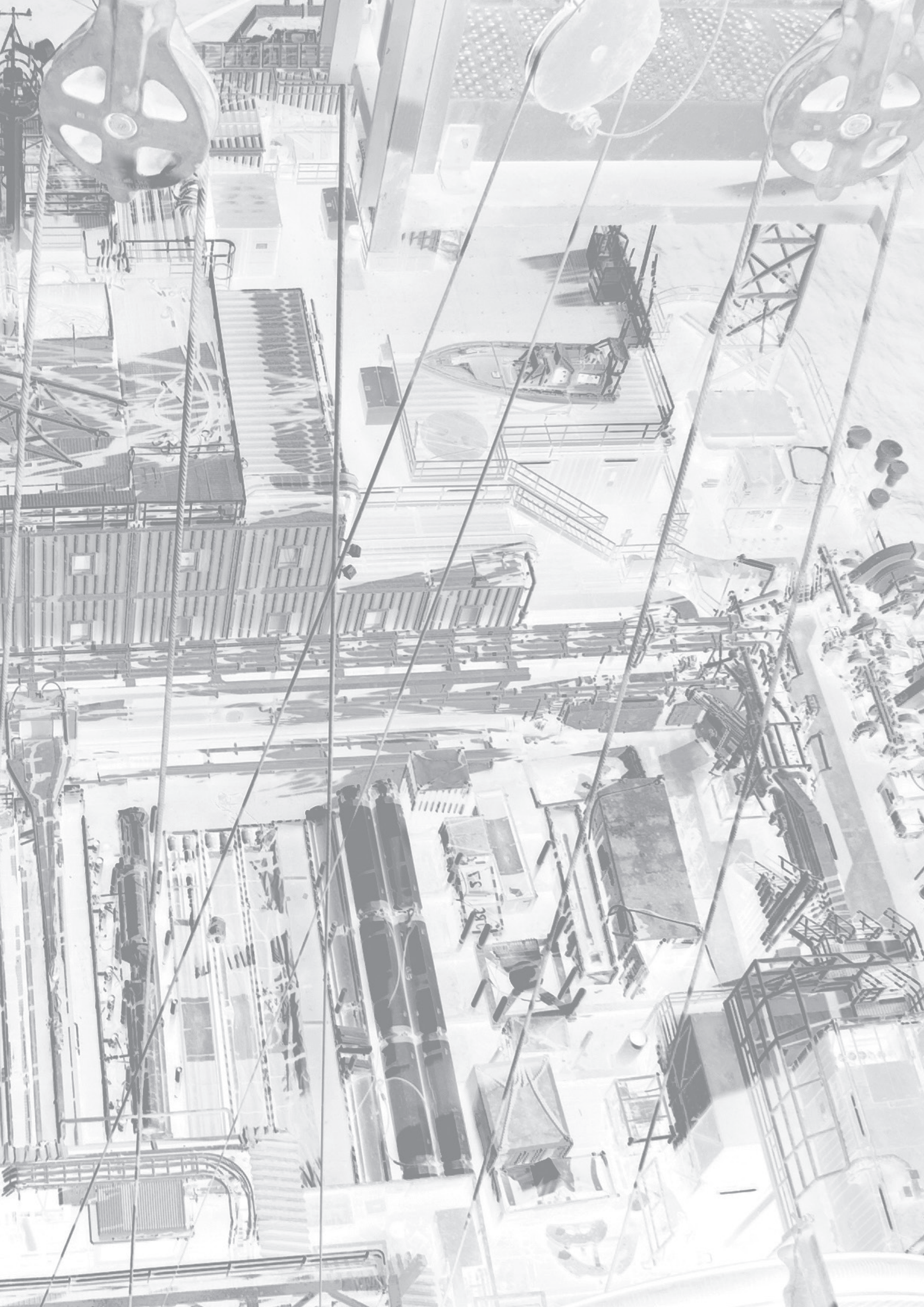
Oil & Gas UK
the voice of the offshore industry

DECOMMISSIONING OF PIPELINES IN THE NORTH SEA REGION 2013



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Abbreviations

CA	Comparative Assessment
EIA	Environmental Impact Assessment
DECC	The Department For Energy And Climate Change, UK Government
HSE	Health And Safety Executive, UK
JNCC	Joint Nature Conservation Committee, UK
MPA	Marine Protected Area
NORM	Naturally Occurring Radioactive Material
PLUTO	Pipelines Under The Ocean
PWA	Pipeline Works Authorisation
UKCS	United Kingdom Continental Shelf

Definitions

Pig	Pipeline maintenance tool used for cleaning or inspecting the inside of a pipeline
Piggy-back	A small diameter pipeline which is physically attached to a larger diameter pipeline using straps to facilitate its installation and/or long term protection
Pipeline span	A section of pipeline where seabed sediments have been eroded or scoured from under a pipeline, resulting in an unsupported section of pipe
S-lay	Pipeline installation method for larger diameter pipelines

1 Foreword

The first major offshore pipeline construction project in the UK was the PipeLines Under the Ocean (PLUTO[1]) project which installed 1,000 miles of pipeline between the south coast of England and France to provide fuel for the invasion of France during World War II [Ref. 1]. In the modern era of oil and gas production, the first pipelines were installed in 1966 to transport gas from BP's West Sole field to a receiving terminal at Easington on the Lincolnshire coast. Since then, in excess of 45,000 kilometres of pipeline, umbilical and cable has been installed across the North Sea region to enable the gathering and delivery of hydrocarbons to receiving facilities and end-users across Europe.

Naturally, in a mature province such as the North Sea, when fields reach the end of their economic life, sections of the transportation infrastructure become redundant and must be decommissioned. The process of decommissioning redundant North Sea assets has been ongoing since the early 1990s with the decommissioning of the Crawford field by BHP. Since then pipeline infrastructure has been decommissioned at a modest rate when systems are deemed to have no future economic life, and no alternative use can be found.

This report aims to provide an overview of the decommissioning performed to date of pipelines and their associated infrastructure. It seeks to cover all areas of the North Sea, including the Irish Sea and West of Shetland, under the jurisdiction of the UK, Norway, Denmark, the Netherlands and Germany, although it is noted that data from some areas is more limited than others.

In the UK and Norway, the decommissioning of oil and gas-related pipelines is considered on a case-by-case basis, using the Comparative Assessment (CA) process to determine the best option for decommissioning. This enables the particular diameter, length and configuration of individual pipelines to be taken into account when considering decommissioning options against the criteria of safety, environmental impact, cost and technical feasibility.

The document draws on research performed by Oil & Gas UK over the period from 2010 to 2013, along with publicly available oil and gas industry data. It provides a picture of the scale of pipeline infrastructure in the North Sea, and the industry's achievements in decommissioning parts of that infrastructure. It also highlights the technical capabilities and limitations that impact the decommissioning options available to owners of pipeline systems.

The report is designed as a reference for industry and others interested in the decommissioning of pipeline infrastructure in the North Sea Region.

[1] 1942 and 1943 saw the development of the first flexible pipeline, the 3 inch 'Hais cable'; and the first rigid reeled pipe, the 3 inch steel 'Hamel pipe' which were installed across the English Channel. These revolutionary pipeline designs provided the allies with the capacity to transport one million gallons of fuel per day to northern France.

2 Key findings

Experience to-date

- Since the West Sole gas export pipeline was installed in 1966, an estimated 2,500 individual pipelines, umbilicals and power cables with a length in excess of 45,000 kilometres have been installed in the North Sea region, including the East Irish Sea and West of Shetland.
- The pipeline inventory is made up of rigid (steel) pipelines and flexible flowlines, and varies in diameter from 2 inches to a maximum of 44 inches. The longest pipeline currently operating in the North Sea region is Franpipe, with a diameter of 42 inches transporting gas 840 kilometres from Draupner E in the Norwegian North Sea, to Dunkirk in France.
- Less than 2 per cent of the North Sea pipeline inventory has been decommissioned so far. Of the pipelines which have been decommissioned, 80 per cent are less than 16 inches in diameter. Half of the larger diameter pipelines (16 inches or greater) decommissioned to date were removed: these were all under 1 kilometre in length and infield pipelines.
- Some pipelines, in particular large diameter trunklines, represent important infrastructure which provides the means of transporting current oil and gas production between facilities and to shore. This infrastructure also provides opportunities for future development of hydrocarbons reserves, or storage of carbon dioxide or gas in the basin. This is a key reason why there is currently only limited experience of decommissioning such pipelines in the North Sea.

Processes:

- Under current regulations across the North Sea, pipeline decommissioning is carried out on a case-by-case basis, with the decommissioning option selected for each pipeline, umbilical and cable confirmed by detailed CA.
- Health and safety is a dominant factor in any CA, with the focus being on minimising risks in the long term to other users of the sea, and in the short term to those carrying out the decommissioning operations.
- An Environmental Impact Assessment (EIA) is prepared to support all pipeline decommissioning plans. Potential environmental impacts are reasonably well understood for the shorter length infield pipelines, and mitigation measures have been established to minimise the effects during and after decommissioning. At present, due to the limited experience of decommissioning larger diameter pipelines in the North Sea, it is difficult to quantify the environmental impact of such decommissioning.
- In the majority of decommissioning cases, it has been demonstrated that the best option is to leave a pipeline in place, either on the seabed, or left buried below the sea floor. This approach is complemented by whatever remedial action is deemed necessary to further reduce any risks to other users of the sea, for example the cutting and removal of exposed pipeline ends.
- A number of tools have been proven in the cutting of steel and flexible pipelines, including those with multiple coatings, concrete, anti-corrosion layers and insulation. Cutting can be time consuming, and can lead to extended risk exposure to divers if multiple cuts are undertaken subsea.
- If removal is identified as the best option, reverse reeling has been used as a means of removing smaller diameter rigid steel and flexible flowlines. On the UK Continental Shelf (UKCS), 45 kilometres of small diameter pipelines are known to have been removed using the this method. Although it has only been used for a small number of pipelines, reel vessels have been adapted in the past to reverse their normal installation mode to remove pipelines.

- There is very limited experience globally of removing pipelines using a reversal of the S-lay installation method. A number of technical challenges exist in the application of this method to large diameter ageing pipelines, and in particular concrete-coated trunklines. These issues relate to the integrity of the concrete weight coating and the steel pipe wall itself after many years of service, both of which would be subject to high forces during recovery.
- The reverse S-lay method of pipeline recovery during a decommissioning programme has never been used in the North Sea and cannot be considered proven, particularly in the application to large diameter concrete coated pipelines.
- Overall, a case–by-case approach is considered appropriate for pipeline decommissioning. As part of the CA process the wide variation in pipeline type, diameter, length, integrity and in-place condition are examined. When safety, environmental and cost considerations are also taken into account, the best decommissioning option for each pipeline can be identified.

Cost and reuse:

- Estimating the costs of decommissioning the total pipeline inventory in the North Sea represents an on-going challenge for the industry. Factors such as limited experience, technical unknowns, integrity uncertainties and the significant variation in pipeline configurations make it very difficult to forecast costs with any real degree of accuracy.
- Reuse opportunities for rigid steel pipelines recovered by the reverse reeling process are limited. Subjecting a pipe to multiple cycles of plastic deformation during both the reeling and reverse reeling processes would likely compromise its integrity.
- Rigid steel pipelines can be recycled along with some of the coatings that may be applied to them. Likewise, flexible pipelines, umbilicals and power cables can be processed to separate their metallic and plastic components and then recycled.
- Potential opportunities may exist for the reuse of flexible pipelines and umbilicals if their post recovery integrity can be confirmed.

3 Introduction

In October 2010, Oil & Gas UK initiated the Decommissioning Baseline Study to compile data, experiences and lessons learned on the decommissioning of North Sea oil and gas infrastructure. A major output from this work was the Oil & Gas UK report 'The Decommissioning of Steel Piled Jackets in the North Sea Region' which was published in October 2012.

In addition to providing this visibility on recent work performed in the decommissioning of steel piled jackets, the Decommissioning Baseline Study also provided significant insight into the decommissioning of oil and gas pipelines.

The networks of pipelines currently installed in the North Sea collectively provide the transportation infrastructure that allows North Sea oil and gas production to be delivered to host platforms or to shore. In many cases, the existence of nearby pipeline infrastructure has led directly to the economic exploitation of marginal fields, which would otherwise be considered uneconomic. Such opportunities remain a key factor in the timing of any pipeline decommissioning.

As fields have reached the end of their economic life, specific parts of the pipeline system naturally become redundant, and with no potential future use, they are available to be decommissioned. Oil and gas pipeline decommissioning has been taking place in the North Sea since the early 1990s, when the Crawford pipelines were decommissioned. Since then, pipeline decommissioning has continued at a modest rate and only when all potential re-use options for the infrastructure, including new field developments, have been carefully considered.

This report has been compiled using the output from the Decommissioning Baseline Study and additional data from the industry to establish a reference on pipeline decommissioning in the North Sea. It provides an overview of the pipeline inventory and the decommissioning performed to date. It also includes a summary of the applicable regulations, health and safety and environmental challenges, and an overview of the technology available, its applications and its limitations.

Unless noted otherwise the general reference to 'pipelines' throughout this document refers to trunklines, rigid flowlines, flexible flowlines, umbilicals and power cables.

Oil & Gas UK would like to acknowledge the valuable contribution made by the following groups and organisations in the preparation of this document: The Decommissioning Baseline Study JIP Sponsors[2], Premier Oil Plc and Atkins Limited in the preparation of this document. The authors would particularly like to thank the members of Oil and Gas UK's Decommissioning Steering Group Task Group 2 for their significant contribution.

[2] Apache North Sea, BP Exploration Operating Company Limited, CNR International (UK) Limited, ConocoPhillips UK Limited, DONG E&P AS, Fairfield Energy Limited, Marathon Oil Decommissioning Services Limited, Mobil North Sea LLC, Shell UK Limited, Statoil AS, Talisman Energy (UK) Limited, Total E&P UK Limited, Venture North Sea Gas Limited

4 Pipelines in the North Sea

Oil and gas production involves the transportation of many different fluids under different conditions, in varying water depths and oceanographic environments. This has led to a range of type of pipeline being installed across the North Sea. This section provides a description and inventory of the different types of pipeline currently installed and operational in the region.

4.1 Pipeline Types

Figure 1 provides a high level categorisation of the types of pipelines in operation in the North Sea Region.

Figure 1 Pipeline Category Descriptions

Pipeline Description[1]	Typical Dimensions[1]	Applications	Primary Materials of Construction	Additional Coatings
Trunklines	Up to 44 inches diameter, up to 840 kilometres long	Major export infrastructure for oil and gas	Carbon steel	Anti-corrosion[2] coating plus concrete weight coating[3]
Rigid flowlines	Up to 16 inches, diameter, less than 50 kilometres long	Infield flowlines and tie-in spools	Carbon steel or high specification alloy	Polymer anti-corrosion coating
Flexible flowline	Up to 16 inches diameter, up to 10 kilometres long	Infield flowlines and tie-in spools	Carcass of high specification alloys and polymer layers; alloy end-fittings	Polymer external coatings
Umbilical	Between 2 and 8 inches diameter, up to 50 kilometres long	Chemical, hydraulic and communication distribution	Thermoplastic polymer or high alloy steel tubes; wire armoured protection	Polymer external coatings
Power Cables[4]	Between 2 and 4-inches diameter; up to 300km long	Power distribution between and within fields	Copper cores with wire armoured protection	Polymer external coatings

Notes
1. Pipeline descriptions and typical dimensions reflect their use in this document: other sources may differ in the application of this terminology.
2. Anti-corrosion coatings used for these pipelines include: coal-tar enamel, bitumen and fusion bonded epoxy.
3. Concrete weight coatings usually include reinforcing wire or bars.
4. Power distribution cables are often included in an umbilical structure.

4.1.1 Trunklines

Trunklines are major elements of infrastructure transporting large quantities of oil or gas to onshore receiving facilities. Trunklines account for 18 per cent of the total number of pipelines and 63 per cent of the total pipeline length in the North Sea inventory. Typically these pipelines are owned and operated by a single operator, or group of operators, and transport production from a number of fields on behalf of the different field owners. Such pipelines include some of the longest in the North Sea, often having diameters in excess of

30 inches, with the largest being 44 inches in diameter. The longest trunkline currently operating in the North Sea region is Franpipe, (see Section 2).

Large diameter trunklines are installed utilising the ‘S-lay’ pipelay method from a specialist lay-vessel. This involves welding sections of pipe together on the deck of the vessel, then lowering the pipeline to the seabed as a continuous string of pipe, as the vessel moves forward. This process can continue for many kilometres, subject only to the supply of pipe sections and suitable weather conditions.

4.1.2 Rigid flowlines

Flowlines are smaller diameter, shorter pipelines usually associated with a single oil or gas field. So called ‘rigid flowlines’ are manufactured from carbon steel or a high performance steel alloy, with additional coatings providing corrosion protection, and in some cases insulation. These pipelines account for approximately half of the total number of pipelines and 27 per cent of the total length in the North Sea pipeline inventory. Rigid flowlines usually transport oil and gas between subsea infrastructure to a host platform for processing. They can also be used to transport injection water to subsea wells for pressure maintenance purposes. These pipelines are typically less than 16 inches in diameter and are most often installed by the reeling method. This involves fabricating the required length of pipeline onshore before reeling the steel pipe around a large drum on a specialist reel-ship for transportation to the field. The end of the pipeline is anchored in the required location and the pipe unreeled as the vessel moves along the proposed pipeline route. The steel pipe is straightened as it is deployed.

Flowlines may be as short as 10 metres long when installed between a subsea well and manifold (a so called tie-in spool), but in many cases they are a lot longer. For example, Total’s NUGGETS field N4 well is linked to the Alwyn platform via flowlines totalling 67 kilometres in length (Ref 2].

4.1.3 Flexible Flowlines

Flexible flowlines have the same application as rigid flowlines, but are manufactured differently. Instead of having a conventional homogeneous steel wall to contain the fluid, the wall of a flexible flowline is made up of composite layers of steel wire and polymer sheathing, each providing a different function in the structure of the pipe wall. Collectively these layers provide the flexibility in the pipeline.

Unlike a rigid flowline, which is terminated by welding on a standard end flange at an appropriate location, flexible flowlines have specially made ‘end-fittings’ which are connected to each end of the pipeline at manufacture and cannot be easily removed to adjust the length on-site. These types of pipeline are installed using a vessel equipped with a large carousel, often capable of installing a number of similar flowlines in the same campaign.

The preference for using either a rigid or flexible flowline for a given application is driven by many factors including specific design requirements, installation constraints, cost or schedule.

4.1.4 Umbilicals and Power Cables

Umbilicals are commonplace in subsea developments, providing chemical injection, hydraulic and communication support to wells. They are made up of a bundle of 'cores', each of which may be up to one inch in diameter, transporting chemicals or hydraulic fluid. The bundle also often contains fibre-optic or instrumentation cables linking the subsea controls to the host facility. The outer sheath around the bundle of cores is protected by wire armouring, giving the appearance of a single cable with an outside diameter of anything up to 8 inches. Umbilicals are typically installed alongside flowline systems using similar equipment to that used to install flexible pipelines. Like flowlines, umbilicals are routinely trenched below the seabed level.

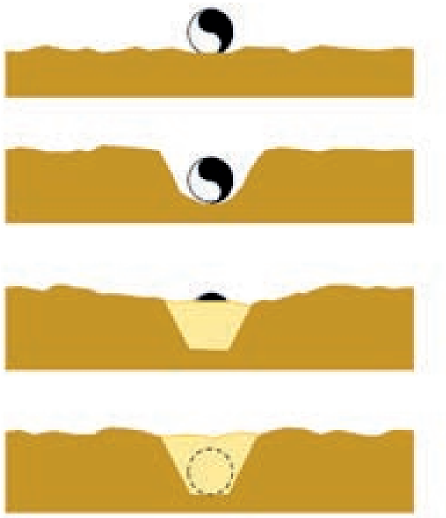
Power cables have a similar structure and installation method to umbilicals except they carry dedicated power to a subsea system or between platform facilities. Often a power cable will be included in an umbilical. When installed separately they are protected in the same way as umbilicals, using an external sheath made up of wire armours and installed in a trench below seabed level.

4.2 Pipeline Configuration

Of particular significance when considering the decommissioning of a pipeline is its on-bottom status, post-installation. The design process for a new pipeline determines whether it is installed resting on the seabed, in an open trench cut in the seabed, or installed in a trench and then buried using seabed soil to a level below the surrounding level of the seabed. Any of these configurations, or variations of them, may be specified at installation. However, changes can occur during the life of the pipeline due to the action of waves and currents on seabed sediments, or from accidental interference by other users of the sea, e.g. fishing gear, anchors, etc.

The various pipeline on-bottom configurations can be generalised into the four categories shown in Figure 2 below.

Figure 2 Pipeline Configuration on the Seabed (Source Atkins)



(A) Fully exposed on unmodified seabed. (Some natural settlement/embedment may have occured.)

(B) Fully or predominantly exposed in trench: crown of pipe below ambient seabed level.

(C) Crown of pipe –max 25% diameter – exposed after natural backfill of trench: top of pipe below ambient seabed level.

(D) Fully buried by either natural or ploughed backfill: top of pipe below ambient seabed level.

The as-designed burial status of a pipeline is driven by a number of factors. There may be a requirement to protect a pipeline from nearby oil and gas operational activities, such as around platforms, or to reduce risks to and from other users of the sea such as fisherman or anchors from moored vessels. In some cases it may be necessary to lower a pipeline into the seabed in areas of high on-bottom currents to ensure its long-term stability. In other cases burial and backfilling of the trench may assist in insulating the pipeline for operational reasons, or by providing resistance to upheaval buckling of the pipe.

After installation of a pipeline, whether it is trenched or not, the seabed around it may move under the action of waves and currents. Over time this may lead to an unburied pipeline being buried (so called self-burial), or a buried pipeline becoming exposed, potentially leading to spanning. (This happens where seabed sediments have been eroded or scoured from under a section of pipeline, which then becomes unsupported.) In cases where a pipeline becomes exposed, the degree of exposure may vary along its length from fully exposed on the seabed (Figure 1, example A), to fully buried in a backfilled trench (Figure 1, example D).

The on-bottom configuration of a pipeline is monitored over its lifetime so that when the decommissioning plan is prepared, its burial history can be used to assist in determining the preferred method of decommissioning.

4.3 Pipeline Inventory and Function

As previously detailed, around 45,000 kilometres of pipelines have been installed in the North Sea Region since 1966. Figure 3 illustrates the aggregated length of pipelines by diameter installed and their range of service.

Figure 3 Pipelines Installed in the North Sea by Diameter and Service (Source Xodus)

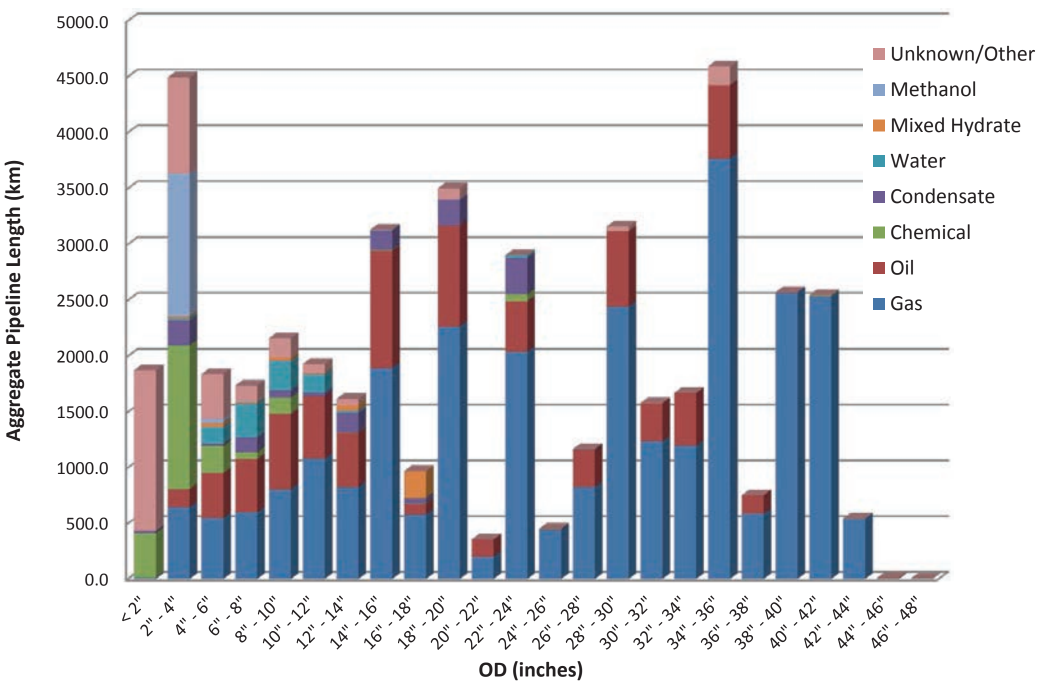


Figure 3 shows that a significant proportion (63 per cent) of the total length of all pipelines installed have a diameter in excess of 16 inches and may be considered as 'trunklines' as defined in Table 1. As would be expected, such pipelines transport mainly oil and gas. It can also be seen that the many kilometres of smaller diameter pipelines carry a much wider range of products from oil and gas to water and chemicals to assist in the production of different hydrocarbon streams.

4.4 Pipeline Ancillary/Associated Equipment

In addition to the pipelines themselves, there are two other groups of associated equipment, which are usually dealt with in the same decommissioning plan as a pipeline. These are concrete mattresses, including grout bags, and pipeline crossings.

4.4.1 Mattresses

Concrete mattresses have been used extensively in the North Sea to provide protection and/or stability to subsea pipelines and umbilicals, including the jumper spools that facilitate the tie-ins to platforms, manifolds and wellheads. They have also been used as an effective intervention device for the rectification of pipeline spans. Flexible mattresses are typically manufactured by joining different shapes of concrete blocks together with polypropylene or Kevlar rope.

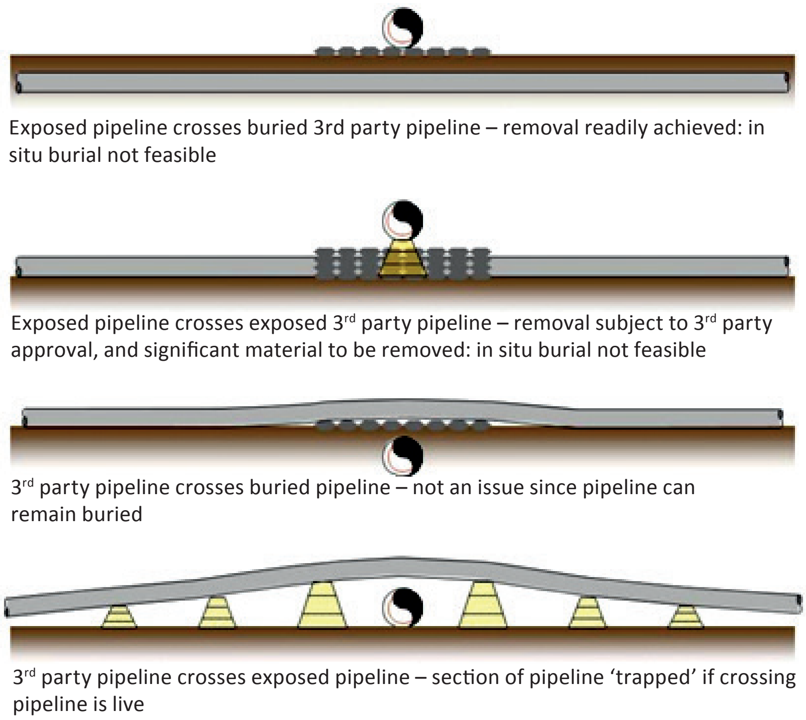
Older mattresses installed in the 1970s were made from bitumen or aggregate poured into mattress bags. The use of bitumen mattresses stopped in the early 1980s.

The exact number of concrete mattresses in the North Sea is not readily available. Oil & Gas UK estimates suggest that between 35,000 and 40,000 mattresses have been deployed on and around oil and gas subsea infrastructure since operations began in the North Sea.

4.4.2 Crossings

The need to cross other pipelines along a designated pipeline route is inevitable in a well developed basin such as the North Sea. Many crossings have been constructed over the productive life of the basin with increasing numbers being required as the region matures. Pipeline crossings are significant in terms of decommissioning because of the direct impact they can have on decommissioning operations and the option selected. If a pipeline which is being decommissioned crosses or is crossed by another operating pipeline, the section of the pipeline at the crossing will be left in situ until such time as the operating pipeline is also decommissioned. This means that a decommissioned pipeline is cut some distance away from any crossings along its length, typically no closer than 50 metres from the operating pipeline. In each case the responsibility for the decommissioning of the sections left in place needs to be established between the parties. Unless otherwise agreed, the financial responsibility will remain with the owner of the respective pipelines. There are many ways that a pipeline crossing may be constructed. The examples shown in Figure 4 illustrate how a configuration changes depending on burial status and what typical pipeline configurations must be constructed.

Figure 4 Examples of Pipeline Crossing Configurations (Source Atkins)



Crossings are usually constructed using concrete mattresses, grout-filled bags or bespoke cast concrete structures. There must be a minimum clearance between two pipelines at a crossing of 300 millimetres, and a concrete mattress usually provides this clearance and protection between the two pipes. The other materials used to construct the crossing depend on the required height of the crossing pipeline. Smaller crossings can be built from a small number of mattresses and/or grout filled bags. Larger crossings are required for larger diameter pipelines and are often made using purpose-built cast concrete sections.

This shortens installation times when compared to the placement of large numbers of mattresses or grout bags. In many cases crossings are buried in rock dump to provide protection to the crossing, and to reduce any potential snagging hazards.

5 Decommissioning Regulations for Pipelines

5.1 Overview

Although a number of international treaties govern the disposal of waste at sea, including the management of decommissioned offshore structures, there are no international regulations or guidelines, relating specifically to the decommissioning of pipelines. At present, pipeline decommissioning is covered within national legislation.

In the UK, the Petroleum Act 1998 [Ref 3] outlines the requirements for owners of installations and pipelines to obtain approval for their decommissioning programme from the Secretary of State. The decommissioning programme should contain details of cost and proposals for removal and disposal. It must be supported by an EIA and is submitted to the Department for Energy and Climate Change (DECC).

Pipelines should be the subject of a separate decommissioning programme unless they are located within the same field as other equipment or installations to be decommissioned at the same time.

In addition to the approval of the decommissioning programme for a pipeline, the following may also be required:

- Confirmation that the requirements of the Coast Protection Act 1949 Section 34 Part II have been satisfied
- Fulfilment of notification requirements for the Health and Safety Executive (HSE) under regulation 22 of the Pipeline Safety Regulations 1996 [Ref 7]
- Any environmental consents or permits required during decommissioning activity
- Disposal of materials on shore must comply with relevant health and safety, pollution prevention and waste requirements/permits

If part or the entire pipeline is to be removed or the decommissioning programme would result in a change to any part of the Table A information in the original Pipeline Works Authorisation (PWA) then a PWA Variation would also be required.

If the approved decommissioning programme for a pipeline contains proposals for the placement of associated materials on the seabed such as rock dump, then a licence must be obtained under the Marine and Coastal Access Act 2009 [Ref 4] in England and Wales or the Marine (Scotland) Act 2010 [Ref 5].

In Norway, pipelines and cables are not specifically referred to in Chapter 5 Decommissioning, of the Petroleum Act 1996. They are, however, covered by a separate White Paper 47 (1999–2000), 'Disposal of Pipelines and Cables on the Norwegian Continental Shelf'.

5.2 Notification of Disused Pipelines

In the UK, the owner of a pipeline must notify the DECC when a pipeline reaches the end of its operational life. Under certain circumstances, this may be before other facilities in the same field. In such cases the DECC may consider the deferral of decommissioning for the pipeline until the end of the whole field life.

Some pipelines may represent important UKCS infrastructure and provide the means for future development of hydrocarbons reserves, or storage of carbon dioxide or gas in the basin. To allow for the future reuse, the decommissioning of such pipelines may also be deferred.

The deferral of pipeline decommissioning to the end of field life or for possible reuse is carried out under the 'Interim Pipeline Regime' (IPR). The DECC will send the pipeline owner a Disused Pipeline Notification form requesting details on the status of the pipeline. The DECC will consult with other government departments and then issue a letter outlining the conditions under which it is prepared to defer decommissioning to a specified date. If reuse of the pipeline is considered viable, then suitable and sufficient maintenance of the pipeline is required of the owner.

6 Decommissioning Options

6.1 Selection of Decommissioning Options

As noted previously, pipeline decommissioning in the UK is regulated by the DECC and guidance is provided in the DECC Guidance Notes [Ref 6]. In addition, the Pipeline Safety Regulations 1996 [Ref 7] provide requirements for the safe decommissioning of pipelines. There are a number of options for the decommissioning of offshore pipelines, and these are evaluated by comparative assessment in accordance with the DECC Guidance.

Options for the decommissioning of pipelines, mattresses and pipeline crossings are described below. These descriptions present the technical options for decommissioning: the CA process would also take account of safety, environmental and societal impact and cost in order to determine the optimum decommissioning option for a specific pipeline and associated infrastructure.

6.2 Pipelines

When developing the options for decommissioning a pipeline, the primary options can be grouped into sub-options of either leave in situ or removal. Typically they are summarised as:

- Leave in situ – minimal intervention
- Leave in situ – minor intervention
- Leave in situ – major intervention
- Removal by reverse reeling
- Removal by reverse S-lay
- Removal by cut and lift

6.2.1 Leave In Situ

In the UK, the DECC provides guidance on pipelines, including any piggy-back pipeline or umbilical which cannot easily be separated, which may be candidates for in situ decommissioning. The cases highlighted by the DECC are:

- Those which are adequately buried or trenched and which are not subject to development of spans and are expected to remain so
- Those which were not buried or trenched at installation but which are expected to self-bury over a sufficient length within a reasonable time and remain so buried
- Those where burial or trenching of the exposed sections is undertaken to a sufficient depth and is expected to be permanent
- Those which are not trenched or buried, but which nevertheless are candidates for leaving in place if the CA shows that to be the preferred option (e.g. trunklines)
- Those where exceptional and unforeseen circumstances due to structural damage or deterioration, or other cause, means they cannot be recovered safely and efficiently

The various sub-options of intervention prior to in situ decommissioning of pipelines are described below. In all cases, pipelines are cleaned to an appropriate level as part of the decommissioning operations.

6.2.1.1 Minimal Intervention

For a pipeline that was trenched and buried at installation and can be shown to have remained buried along its length over its lifetime, the option to decommission the pipeline in situ may require minimal intervention. After cleaning, a pipeline is usually left filled with seawater with the ends left open to the sea. Potential snagging hazards at the pipeline ends would be removed to complete the decommissioning plan. This would represent a 'minimal intervention' decommissioning option and may include cases where a pipeline is expected to self-bury over time.

6.2.1.2 Minor Intervention

In addition to the tasks described above for a stable buried pipeline, there may be a need for selected removal or remedial burial of short sections of pipeline along its length, which could present a potential hazard to other users of the sea. This could include sections of pipelines which lie on the seabed between the trench and the former location of a subsea structure. Likewise, sections of pipeline that have become scoured and formed spans may also be removed as part of a decommissioning plan.

Under these circumstances, sections would typically be removed by subsea cutting and lifted to the surface by a suitably equipped support vessel. Other options available are remedial trenching of exposed sections, or using rock-dump to remove the snagging hazard.

For a trunkline which is installed on the seabed and where CA has shown that in situ decommissioning is the best option, similar minor intervention may be required. This could involve rectification works on sections prone to scour and the development of spans, and management of the pipeline ends.

6.2.1.3 Major Intervention

A pipeline initially installed on the seabed, or which was originally trenched may have significant sections that have required intervention over its lifetime. In these circumstances, the preferred option may be to decommission the pipeline in situ and carry out major intervention works, rather than complete removal. After cleaning and removal of the tie-ins at each end, the pipeline, or significant sections of it, may be trenched below the surrounding seabed level. Alternatively, significant sections may be removed by utilising the cut and lift or reverse installation methods.

Where a pipeline is trenched, the depth of trenching is determined by the need to remove any hazards to other users of the sea, taking account seabed and soil conditions and other determining factors. A typical target depth suggested by the DECC [Ref 6] is 0.6 metres to the top of the pipe.

6.2.2 Removal

For small diameter pipelines, flexible flowlines and umbilicals which are installed on the seabed and not trenched, the DECC guidance [Ref 6] is that these shall normally be removed. For more significant removals the following section describes the options.

6.2.2.1 Reverse Reeling

For pipelines with a diameter of 16 inches or less, which are not concrete coated, a possible method of removal is by a reversal of the reeling installation process. Reeling is the installation method described in Section 4.1.2 and has been used extensively across the North Sea for both rigid and flexible flowlines.

The installation of rigid pipelines by the reeling method relies on the plastic deformation of the pipe wall during installation to ensure the reeled pipeline will subsequently lie straight on the seabed. When the process is reversed for the removal of a pipeline, the pipe is reeled onto the specialist reel vessel and is once again plastically deformed so that it sits on the recovery reel. The length of pipeline that can be recovered is limited by the size and capacity of the reel. Once the pipeline is on the reel it is taken to a shore-based facility and removed by reversing the process once again.

Due to the nature of the reeling and unreeling process, it is unlikely that a rigid pipeline recovered using this method could be reused. The multiple cycles of plastic deformation of the pipeline wall could potentially compromise its long term integrity. The steel from recovered rigid pipelines is recycled.

This method is also used in the recovery of flexible flowlines. The structure of the wall of a flexible flowline means it doesn't experience the same deformation cycles as the rigid pipeline during the reeling and unreeling process. Multiple reeling and unreeling cycles should not, therefore, compromise the longterm integrity of a flexible flowline. In theory, such pipelines have the potential for reuse if a suitable application is found. It is, however, the responsibility of the end-user to demonstrate the integrity of a recovered flowline (see Section 13.2).

6.2.2.2 Reverse S-lay

Larger diameter and concrete coated trunklines are typically installed using the S-lay method as described in Section 4.1.1. Although it has never been used before in the North Sea, a potential removal method is the reversal of the S-lay installation process. This method is often considered in the CA for decommissioning pipelines in excess of 16 inches diameter and/or concrete coated.

This method would involve recovering a pipeline end to the deck of a specialist S-lay vessel. The vessel would then move along the route of the pipeline, stopping at suitable points where a cut would be made to remove a section of pipe from the recovered pipeline string on the deck of the vessel. These sections would then be transferred to a suitable transportation barge for onshore recycling.

Although there have been some examples of the application of this method in the shallow water (less than 24 metres water depth) of the Gulf of Mexico, a number of significant technical limitations currently exist which preclude its large scale application, i.e.:

- High tension forces would need to be applied to the pipeline during recovery from the vessel tensioner system to the outer surface of the concrete weight coat to bring the pipe onto the deck and hold it in place for cutting. The integrity of aged concrete weight coating cannot be assured and would need to be carefully assessed to confirm that the necessary tension could be generated, without the concrete coating disintegrating and the control of the pipeline being compromised.
- This tension would also be applied into the steel wall of the pipeline and after many years of operation, the integrity of the pipe wall along its length under the high recovery loads would need to be confirmed.
- There is the potential for very large quantities of materials to be recovered during the decommissioning of a large diameter trunkline. There is no established supply chain/disposal route for the quantities of concrete, steel and anti-corrosion coatings which would be taken onshore during a major pipeline removal campaign.

6.2.2.3 Cut and Lift

Another possible method used for the removal of pipeline sections is the so-called 'cut and lift' method. This can be used for any diameter or length of pipeline. This is the process whereby a pipeline is cut into sections subsea by diver-operated cutting tools or using remotely operated cutting equipment, and the sections are then recovered to a surface vessel using an on-board crane.

This option has been widely used for removing shorter sections of pipe, either for the removal of a short pipeline in its entirety, or when discrete sections are being removed under a decommissioning plan. It is usually the preferred removal option for short sections of pipe, when it is impractical or prohibitively expensive to mobilise major removal equipment.

Most significantly, the cut and lift method does create greater risks to the personnel carrying out the offshore operations, especially divers. It has therefore been preferable to limit that risk exposure by avoiding extensive offshore cut and lift programmes.

6.3 Ancillary Equipment

6.3.1 Mattresses

The DECC guidance on mattresses and grout bags is that they should be removed from the seabed at decommissioning. The guidance does, however, recognise that in some circumstances it might be better for badly degraded mattresses to be decommissioned in situ. In such circumstances, a CA is required to demonstrate that the best decommissioning option has been chosen. It is common practice to remove mattresses and grout bags during the decommissioning of a pipeline and associated tie-ins, without a separate CA being performed.

The feasibility of removal depends mainly on the age of the mattress, and its burial status. Bitumen mattresses can be difficult to recover as they can break up when lifted. Similarly, older block-type mattresses can disintegrate during recovery due to the degradation of the polypropylene rope holding the blocks together. In such circumstances, the risk to personnel performing the decommissioning increases and the operator may request permission to decommission such mattresses in situ.

Some mattresses are fitted with fronds to promote sediment deposition after deployment. These, and other mattresses, can become buried over time, and under such circumstances the operator could request that they are decommissioned in situ.

Technology options for the removal of mattresses are described in Section 12.8.

6.3.2 Crossings, Grout Bags and Concrete Formwork

If a pipeline being decommissioned crosses other operational pipelines, it is usual practice to leave the constructed crossing in place until all pipelines are decommissioned. This avoids unnecessary risks to the 'live' infrastructure. This represents a deferral of the decommissioning works.

As for all pipeline infrastructure, operators are required to consider all options for decommissioning a crossing. Any proposal to leave all or part of a crossing in situ must be supported with evidence demonstrating the reasons why this is preferred. Such reasons may include sufficient burial, impracticalities or safety concerns with removal, or any other exceptional circumstance. Many crossings are rock dumped for protection, which may be a valid reason why the crossing should be left in situ.

Formwork used to construct larger crossings is installed using dedicated lifting pad-eyes or slings, built into the concrete structure. The feasibility of removing such items by reversing this process requires confirmation of the integrity of the lift points. Under such circumstances it may be demonstrated that decommissioning in situ is preferred.

7 Safety

7.1 Overview

In the UK under the Safety Case Regulations [Ref. 8] and prior to any decommissioning work beginning, the Safety Case for an installation must be updated and submitted to the HSE. The Safety Case for an installation will include those elements of a pipeline that are safety critical and in close proximity to an installation, for example isolation valves. The Safety Case must demonstrate that the proposed decommissioning arrangements reduce the risk to people to the lowest level that is reasonably practicable.

The notification requirements under the Pipeline Safety Regulations 1996 [Ref 7] must also be fulfilled. These regulations ensure that a pipeline is designed, constructed and operated safely, and provide a means of ensuring pipeline integrity, thereby reducing risks to personnel and the environment . Under the regulations, pipelines should be decommissioned in such a manner that they do not become a danger to people. Offshore, the extent of the obligation to remove a pipeline will depend on the diameter of the pipeline, its location on the seabed, its stability and the local subsea conditions [Ref 7].

Safety is paramount and integral to all phases of decommissioning projects, and so forms a key part of the CA of the pipeline decommissioning options. In the CA, safety is typically considered on two different timescales:

- The health and safety challenges that may pose a risk to personnel during decommissioning operations in the short term
- The health and safety challenges that may pose a risk to other users of the sea in the long term

7.2 Short Term Operational Health and Safety Challenges

The main health and safety challenges that may pose a risk to personnel during decommissioning operations, are common to all pipeline decommissioning options. However, those options which require the least intervention, and therefore the use of fewer vessels and offshore workers, may represent a lower risk to personnel.

The main health and safety challenges are as follows:

- Lifting – the potential for large numbers of vessel-based lifts and the uncertainties surrounding structural integrity of an aged pipe section, concrete mattresses, or the lift points of concrete formwork
- Diving – significant diver intervention may be required to support extensive subsea cutting and lifting operations
- Hazardous substances – residual materials within pipelines such as methanol, chemicals from umbilical cores, wax deposits, hydrocarbons or Naturally Occurring Radioactive Material (NORM) scaling
- Integrity – hidden flaws and structural degradation in the steel pipe wall or concrete coatings of aged pipelines, or auxiliary equipment such as grout bags or mattresses which were not designed for removal after many years in service
- High levels of activity – there are many workers at all stages of a decommissioning project, onshore and offshore, potentially working in a dynamic, constantly changing environment
- Poor weather – this extends the duration of offshore tasks by prohibiting work, and increases the number of man-hours required offshore
- Marine growth – management of waste and odour

A number of techniques are employed to reduce and/or mitigate the risks to personnel. Those methods which have proven successful include regular updating of work plans and emergency procedures throughout the project; permit-to-work systems; safety initiatives such as good quality ‘toolbox talks’, sharing of experience and lessons learned; and technology improvements and training.

7.3 Long Term Health and Safety Challenges

The in situ decommissioning options for pipelines potentially pose a long term health and safety challenge in the form of snagging risks to other users of the sea. At particular risk are fishermen who use demersal bottom trawling gear offshore, or fixed gear fisheries near shore. A snagging risk on a decommissioned pipeline may be caused by:

- Pipeline spans due to seabed scour under a pipeline
- Exposed pipeline ends
- Long term ridges in the seabed from trenching operations
- Exposed pipeline crowns due to deburial of pipelines
- Uneven degradation of exposed pipelines over time
- Anchor scars or mounds
- Steep sided rock dump profiles

A number of initiatives are employed to reduce the potential snagging risk to fishermen. Immediately after decommissioning operations are complete, debris on the seabed is removed, and typically, trawl sweeps by fishing vessels with chain trawls are carried out along the decommissioned pipeline corridor. This helps to identify any potential snagging hazards, which can then be managed.

The ends of decommissioned pipelines, or cut sections of pipelines, pose a potential risk to fishermen. This can be reduced with remedial measures such as the placement of rock dump or grout bags at the ends to round them off, and create an over-trawlable profile. Early consultation with the fishing industry assists in establishing the most appropriate remedial measures to reduce or remove the hazard.

Owners of pipelines decommissioned in situ will carry out regular surveys to monitor and inspect the condition of the pipeline. The details of disused pipelines are reported to the Hydrographic Office and recorded in the FishSAFE database [Ref 9]. This database contains information on all oil and gas infrastructure on the UKCS. It is provided to fishermen twice a year as an overlay to their on-board navigational plotters. The provision of data through the FishSAFE project is funded by the oil and gas industry. Further details on interaction with the fishing industry during operations and decommissioning can be found in the Oil & Gas UK Fisheries Liaison Officer Guidelines [Ref 10].

8 Environmental Impact

8.1 Overview

In the UK, the decommissioning programme for a pipeline must be supported by a CA of the options and an EIA.

The CA helps select the best decommissioning option by comparing each on basis of complexity, safety, economics and impact to the environment.

The EIA identifies the likely environmental and societal impacts of decommissioning activities, and proposes mitigation measures to avoid, or reduce to acceptable levels, any significant effects. The EIA also assesses cumulative impacts as well as those that have the potential to affect Marine Protected Areas (MPAs).

The regulations of the Norwegian Petroleum Act of 1996 also require that an EIA is carried out as part of the preparation for decommissioning infrastructure assets including pipelines.

The potential environmental impacts and areas for mitigation that are considered as part of the EIA are highlighted below. The potential significance of the environmental impact is related to the length of pipeline to be decommissioned.

8.2 Environmental Impacts

8.2.1 Gaseous Emissions/Energy Usage

Gaseous emissions may cause a local reduction in air quality and contribute to wider climate change processes. Emissions of primarily CO_2, but also smaller quantities of CO, NOx, SOx and VOC, are generated during the combustion of fuel by vessels used for cutting, lifting and transportation of recovered pipelines. Emissions would also be generated through the production of new raw materials such as steel, to replace an equal quantity of material in pipelines which are decommissioned in situ.

Emissions can be calculated from industry standard data, and project-specific estimates of likely fuel consumption by vessels and the replacement of lost material will be included in the EIA.

8.2.2 Discharges to Sea

Discharge of sewage and food waste, ballast water and treated bilge water may occur during vessel operations. These would cause localised and transient deterioration in water quality, but pose no real long-term hazards to birds, fish, benthos or plankton.

Any chemicals that are used to clean and flush pipework during decommissioning are strictly controlled through the Offshore Chemical Regulations 2002 [Ref 11]. Pipework is flushed through the existing processing route to the onshore terminal or transported by shuttle tanker ashore.

All pipelines are cleaned before decommissioning, however, there is a possibility that a small amount of residual deposits will remain on the inside of the pipe. As a pipeline which has been decommissioned in situ degrades, there is a possibility that such deposits on the inside of the pipeline will break down and be released into the water column. Any such release would be very gradual and any impact would be highly localised.

All discharges to sea during decommissioning operations are permitted activities that are regulated by DECC.

8.2.3 Underwater Noise

Underwater noise is generated from vessel operations, particularly from the use of dynamic positioning systems, as well as from cutting and seabed excavation works. This has the potential to cause disturbance to any marine mammals in close proximity to the decommissioning operations.

The potential disturbance to marine mammals will be assessed in the EIA process. Decommissioning operations follow the Joint Nature Conservation Council (JNCC) guidance on mitigating the impact of any noise. Marine Mammal Observers are used on board vessels and mitigation measures may include not commencing operations until the area is shown to be clear of mammals, and perhaps a soft-start to noisy operations.

8.2.4 Physical Disturbance to the Seabed

Decommissioning operations may result in limited disturbance to the seabed around pipelines. For example, sediment could be disturbed to enable access for cutting and lifting, for pipeline burial through jetting, or through the placement of remedial materials such as rock dump. Each of these operations would result in various degrees of physical disruption to the seabed, localised sediment re-suspension and potential smothering of benthic animals.

The extent of physical disturbance is likely to be similar or less than that caused during installation, and would occur in narrow corridors along the route of the pipeline. The potential impact would be assessed through the EIA process. Recovery rates for benthic communities are likely to be very rapid.

Any additional materials placed, such as rock dump, will have a very small footprint on the seabed and may provide additional hard substratum which can be colonised by mobile and encrusting organism communities. The long term effect of the introduction of small areas of substratum into parts of the North Sea with naturally sandy or muddy sea beds is not fully understood at present, and is carefully considered in the EIA and by the regulators.

8.2.5 Waste and NORM

In some cases the selected decommissioning option for a pipeline is to bring the pipeline onshore for disposal. It is likely that the majority of a pipeline would be recycled. There may be some materials that would be consigned for disposal (such as some plastic hoses). This may include the residual contents of pipelines which may have built up during their operational life; for example, waxy deposits, oily sludges or NORM scale. All residual contents would be recovered and deposed of in accordance with current permit requirements at licensed sites.

Disposal of materials to landfill will reduce the future capacity for such disposal, which may result in a landfill resource issue in future as more infrastructure is decommissioned.

The transportation to an onshore facility and subsequent disposal of pipelines may cause disturbance to local communities through noise, odour from marine growth, dust and increased traffic. The potential impact depends on the location of the site and volumes to be processed and will all be assessed within the EIA.

8.2.6 Metals

Sacrificial anodes are used as protection structures on pipelines to reduce corrosion and maintain integrity during its operational life. These anodes are made from zinc or aluminium-zinc-indium and may contain trace amounts of mercury, copper, cadmium or lead.

As the anodes deplete over many years, there is a possibility that trace amounts of metals could migrate through the sediment and in some circumstances could be accumulated by some marine species. The impact of such metals depends on the rates at which they dissolve, migrate through the sediment, and dissolve in the water column, and the degree to which they are bioavailable. It also depends on physical factors such as water depth, temperature, oxygen levels and flow over the surface of the pipeline. This is, however, likely to be an impact of low significance.

The levels of lead, cadmium and mercury found in sediment in the North Sea has been falling since 1990, and inputs from pipeline anodes are considered to be insignificant in comparison with other sources such as riverine and coastal industries [Ref 12].

9 Monitoring and Liability

Residual liability for decommissioned offshore infrastructure is determined in the UK by the Petroleum Act 1998 [Ref 3], whereby the liability for any structures left in situ rests with the facility owner in perpetuity. Norwegian legislation is less definitive and future liability is agreed between the facility owner and the State, and may be assumed by the State based on an agreed financial compensation.

Thus, if a pipeline is decommissioned in situ in the UK, there remains a liability on its owner to monitor its condition and to ensure it remains safe for other users of the sea. Guidance from the DECC [Ref 6] provides for a post-decommissioning survey along the pipeline corridor, typically extending to 100 metres either side of the pipeline alignment.

A second survey is typically performed a year later from which the stability of the remnant infrastructure is confirmed. An environmental survey is also performed post-decommissioning during which samples are collected for analysis. The future monitoring plan for the site is agreed with the regulator through a risk-based approach. In Norway, pipelines that are laid on the seabed are surveyed after decommissioning usually with an ROV. Environmental surveys (chemical, physical and biota) are carried out at the site twice after operation of the pipelines has ceased.

10 Cost of Pipeline Decommissioning

As noted, the methods used for decommissioning pipelines across the North Sea are based on a case-by-case evaluation of options using the CA approach. With a total inventory in excess of 2,500 individual pipelines and a total length of 45,000 kilometres, determining an overall cost of decommissioning this inventory with even a modest degree of accuracy represents a significant challenge. A number of other factors emphasise the complexity of the task:

- With limited actual pipeline decommissioning experience, there is minimal cost data available for benchmarking
- Some of the principle methods being considered for decommissioning large diameter pipelines are unproven and hence the actual cost of applying these methods is yet to be determined (i.e. reverse S-lay)
- An execution model, which seeks to realise economies of scale by combining decommissioning campaigns across groups of fields and operators, has yet to be determined

Oil & Gas UK seeks to provide indicative costs based on operator provided data in its annual Decommissioning Insight Survey [Ref 13], and this work is continuing. Further collaborative effort is underway to develop a credible and detailed cost model for the total cost of pipeline decommissioning.

11 Pipeline Decommissioning to Date

The pipelines decommissioned in the North Sea to date and described as such in publically available sources are presented in Appendix A and summarised in Figure 5.

Figure 5 Pipelines and Umbilicals Decommissioned in the North Sea To Date (2013)

Pipeline Description	Diameter Range	Number of Pipelines	Total Length (km) Estimated[1]
Trunklines	16 to 32 inches	17	62
Flowlines (Rigid and Flexible)	up to 14 inches	123	692
Umbilicals and Power Cables	up to 8 inches	20	79
Totals	-	**160[1]**	**833**

Note 1: This data is from publically available resources, and diameter and length data is not available for all pipelines/umbilicals decommissioned so far.

Case studies for the Shelley, North West Hutton and Tristan NW pipeline decommissioning projects are included in Appendix B. These projects illustrate the range of projects performed to date in the North Sea Region.

Figure 5 shows that pipeline decommissioning in the North Sea Region is still at a very early stage. Less than 2 per cent of the total length of the existing North Sea pipeline inventory has so far been decommissioned.

Of the total number of pipelines which have been decommissioned 80 per cent are less than 16 inches in diameter. Half of the larger diameter pipelines already decommissioned were removed. These were all under one kilometre in length and infield pipelines. The remaining pipelines have been left in situ. The longest large diameter trunkline to be decommissioned so far is the 35 kilometre Piper A to Claymore 30 inche export line, which was decommissioned in situ.

12 Technology

12.1 Overview

When evaluating a preferred option for decommissioning a pipeline and its associated equipment, the availability and track record of technology provides the context for the other key CA criteria of safety, environmental impact and cost. Key technology areas in pipeline decommissioning are:

- Pipeline cleaning
- Trenching, burial and de-burial
- Subsea cutting
- Lifting
- Reverse installation methods
- Mattress removal

The current status of technology in these areas is noted in the following sections. Examples of the pipeline decommissioning projects completed to date are provided in Appendix B.

12.2 Pipeline Cleaning

Prior to decommissioning, a pipeline will be depressurized and any hydrocarbons removed. It is then purged of its contents and cleaned in accordance with the Pipelines Safety Regulations [Ref 7]. This may involve the use of pigs, which are pipeline maintenance tools used for cleaning or inspecting the inside of a pipeline.

Whether a pipeline is removed or decommissioned in-situ, it is thoroughly cleaned to ensure that pollutants are not released to the environment in unacceptable quantities. For a pipeline decommissioned in-situ, the pipeline is cleaned to minimise potential contamination of the marine environment by discharge of any residual hydrocarbons from the pipeline as it degrades over time.

Cleaning and purging is carried out following cessation of production, pipeline system depressurisation and removal of bulk hydrocarbons. The cleaning programme is developed based on the specific needs of each system, but a typical programme may include:

- Chemical cleaning to detach hydrocarbon residue from the pipe wall (using bulk surfactants or gel pigs)
- Bi-directional magnetic cleaning to remove ferrous debris
- Bi-directional brush cleaning to remove other loose debris
- Bi-directional disc cleaning pig to scrape the remaining softer material from the pipe wall

Bi-directional magnetic cleaning and brush cleaning may require multiple passes until the line is at the required cleanliness i.e. the water quality emerging with the pigs is within allowable contaminant levels. Depending on the condition of the pipeline, and the cleaning schedule adopted during operation, the cleaning programme at decommissioning may include foam pigs or specialist mechanical cleaning pigs.

12.3 Trenching and Burial

The technology for trenching and burial of pipelines is well established. A number of contractors offer a range of trenching tools capable of trenching and burying pipelines of various diameters in all soil types.

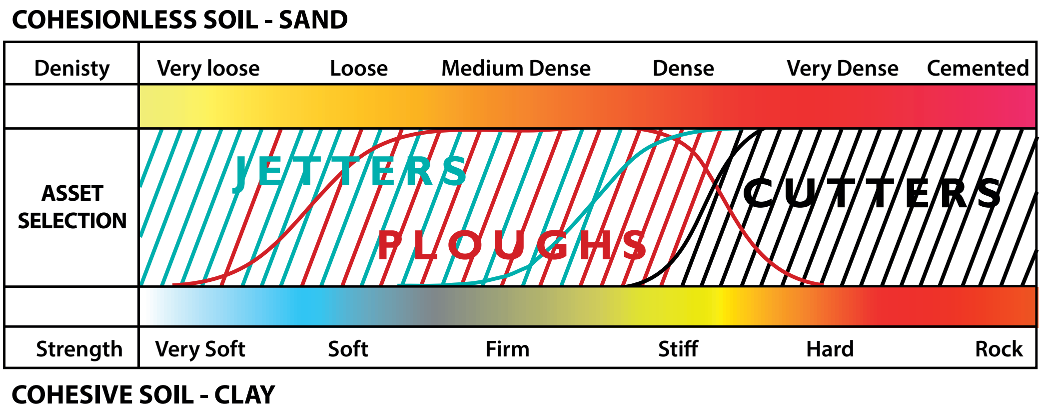
Technology exists for post-lay trenching and burial of pipelines, and for remedial burial, this technology is readily applicable to decommissioning. There is limited experience of pipelines being buried specifically for decommissioning in situ. It was, however, the preferred option for decommissioning the 20 inch oil export pipeline in BP’s North West Hutton decommissioning programme. Similarly the Frigg - Oseberg ‘Frostpipe’ oil pipeline was approved for selective burial of exposed sections along its route.

There are three main types of tool in common use on subsea pipelines:

- Jetting machine
- Cutting machine
- Plough

The applicability of each trenching method to a burial operation will depend on a number of factors, most generally the size of the pipeline and the type and strength of soil. Figure 6 gives a general view of the applicability of the types of tools available. There are also hybrid tools available that combine jetting and trenching functions to cover a wider range of soil conditions.

Figure 6 Trenching Method Suitability (Source Atkins)



Jetting systems vary from complex excavators to simple trenching sleds. Jetting tools can work in sand, silt and medium clay. Jetting excavators can also be used in deburial operations to remove non-cohesive materials, including rock dump.

Jetting produces wide shallow trenches in loose sand, and therefore may not provide sufficient burial for decommissioning. In denser sands and weaker cohesive soils the trench shape is well defined.

Cutting trenchers are essentially the same as jet trenching vehicles but use mechanical means of creating an open trench such as chain cutters, wheels, disks, etc. The soil is cut under the pipe and the material is entrained using a dredge pump system and ejected to the side of the trench.

A trenching plough operates by being positioned astride the pipeline with the cutting share open. The pipeline is picked up by fore and aft grabs creating a span in the pipeline. Rollers are closed around the pipe to support the load during burial process and the share is closed beneath the pipe. The rigid pipeline is lowered into a ‘V’ cut trench, formed by mechanical deformation of the seabed by the pipeline plough as the plough is pulled forward.

The excavated trench material is deposited in berms on both sides of the formed trench and can be removed on completion of the trenching pass by a backfilling process. Some trenching ploughs exist that can be used to backfill trenches on a second pass. Otherwise, a separate backfill plough will be used in combination with the trenching plough.

Figure 7 Pipeline Trenching Plough

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12.4 Deburial and Dredging

There are a number of contractors offering Mass Flow Excavators (MFEs) capable of dredging and deburial operations during pipeline decommissioning, as well as local pipeline burial. MFEs can be employed in most soil conditions, and are capable of excavating rock dump.

MFEs work using rotating propellers to create a high speed, low pressure aerated column of water to fluidise the seabed material for either burial or deburial operations. A MFE during deployment is shown in Figure 8.

Figure 8 Mass Flow Excavator

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12.5 Subsea Cutting

There are several different methods and types of equipment for cutting pipelines subsea as part of the decommissioning programme. The main types of cutting equipment fall into the following categories:

- Abrasive Water Jet
- Diamond Wire Cutting
- Reciprocating Cutting
- Hydraulic Shears

These are all termed 'cold cutting tools' and can be operated by divers, mounted to an ROV, or operated directly from onboard a vessel. So called 'hot' cutting tools also exist, but these have limited application during decommissioning and are not discussed further here.

In all pipeline-cutting applications, the cutting device must gain access around all or part of the pipeline circumference, and this may require dredging underneath the pipeline to position the tool. In addition to potential access constraints, the selection of the appropriate tool for cutting pipeline sections will depend on the size of the pipeline and the coatings applied to it. In all cases, tool selection will be based on finding the safest approach, which minimizes the risks posed to personnel by the operation.

Abrasive water jet is a commonly used subsea cutting method and consists of a high-pressure jet of water and sand/grit mix, which is directed onto the item to be cut. Typically, the abrasive water jet will operate at 10,000-15,000 psi. This method is very versatile, and due to the relatively small cutting head the process can be used where access is restricted. In some tools, the water jet is capable of cutting through both sides of the pipe simultaneously, and hence need only rotate half way around the pipe to complete a cut. Others require access around the complete circumference.

Diamond wire cutting tools are commonly used on pipeline decommissioning and intervention projects around the world. A diamond wire cutting machine consists of a continuous loop of diamond-encrusted wire mounted on a pulley system which is driven either hydraulically by a hydraulic power unit on board the deployment vessel, or subsea by a workclass ROV. They can also be driven electrically when working at greater water depths. As with abrasive water jetting, dredging of pipelines on the seabed may be required to position the tool at the location to be cut.

Depending on the number and type of cuts being made, a diamond wire may require regular replacement. This is an expensive and time-consuming operation, which is performed on the deck of the support vessel. For larger diameter, concrete coated pipelines, the diamond wire may need replacing after every cut, which would limit its applicability in a major cut and lift operation on a long distance trunkline.

There are two main types of reciprocating tool: the band saw and the guillotine. Both tools use a serrated steel blade: the guillotine cutter uses a reciprocating mechanism to ‘slice’ down into the pipe with a back-and-forth motion, while the band saw has a continuous flexible blade driven round a number of pulleys. Both tools are clamped to the pipe in order to perform the cut.

The guillotine cutter can cut a maximum diameter of 32 inches and can be fully ROV controlled. Likewise, the band saw is either diver or ROV controlled, but tooling up to 48 inches cut diameter is available. For both tools, the speed of cutting and the life span of the blades are dependent on the materials being cut. Large diameter concrete coated pipe will be particularly slow to cut and will lead to the highest blade consumption. This makes these cutters a less attractive option for long-distance trunklines.

Hydraulic shears are traditionally used onshore or on the deck of an offshore platform. These are mounted on the boom of an excavator and dismantle facilities using the ‘piece-small’ method. Recently however, they have been used for subsea application, and also in major projects such as the decommissioning of the North West Hutton platform.

For subsea application the shear is suspended from the vessel crane and placed in position for each cut. Although the tool has had limited use subsea, its simple operation could make it suitable for making multiple cuts along long pipelines without recovery to the deck for replacement of consumables, etc. At present the tool is only deployable with diver assistance, but it is understood that an ROV operable device is under development.

One disadvantage of the hydraulic shear is that it does not produce a 'clean' cut, which may represent a hazard to personnel during handling and may make the handling of cut pipe sections themselves difficult. It is noted that there is no published evidence of shears being used for pipeline decommissioning to date.

12.6 Lifting

There is a need during the 'cut and lift' process of decommissioning to lift the cut pipeline sections from the seabed to a transportation vessel. This is performed using routine lifting techniques, but will usually require diver support. As noted above, some cutting techniques produce a coarse cut, which can influence how the lifting equipment is attached to the pipe section. This can slow down the lifting operations and may have a significant impact on the duration of lifting operations for long lengths of pipeline.

12.7 Reverse Installation Methods

12.7.1 Reverse Reeling

Reverse reeling is the process by which rigid or flexible pipelines can be recovered from the seabed by reeling them from the seabed using a specialist reel vessel. The process is described in Section 6.2.2.1.

For rigid pipe, there are a limited number of specialist reel vessels available from the leading installation contractors. These vessels are usually engaged in installation activities, but can be and have been adapted to recover pipelines as part of a decommissioning project. Vessels such as Technip's Apache II (Figure 9) and Subsea 7's Seven Navica (Figure 10) are capable of performing this work.

Figure 9 Apache II Reeling Vessel

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Figure 10 Seven Navica Reeling Vessel

Flexible flowlines and umbilicals also require specialist equipment to carry out the recovery operation but more vessels are available to perform this work.

Although the use of these vessels for both rigid and flexible pipeline recovery has not been common, both methods have been used in decommissioning projects and can be considered proven.

12.7.2 Reverse S-lay

The process by which pipelines could be removed at decommissioning by the reverse S-lay process is described in Section 6.2.2.2. As noted, this is not an operation that has been carried out in the North Sea, although it is understood that there is some experience of removing short lengths of small diameter pipelines using this method in shallow water in the Gulf of Mexico.

Examples of pipelay vessels utilising the S-lay method for installation of pipelines are Saipem's Castoro Sei and Allseas' Audacia (Figure 11).

Figure 11 Dynamically Positioned Pipelay Vessel Audacia

This image is reproduced with kind permission from Allseas.

These vessels are examples of high specification installation vessels that have operated regularly in the North Sea installing large diameter pipelines. Neither has been used to remove long lengths of pipeline as part of a decommissioning project.

In general, reverse S-lay has not been used for the decommissioning of large diameter pipelines, however a number of issues have been identified regarding the feasibility of the process. These are noted in Section 6.2.2.2.

Further study is necessary before the reverse S-lay process can be considered feasible for decommissioning long distance large diameter pipelines.

12.8 Mattress Recovery

The recovery of mattresses is a diver and vessel-intensive operation, with the time taken to perform the work very much dependent on the age and condition of the mattresses being recovered.

As yet, no established technique or technology has been universally adopted for mattress recovery. It is likely that the majority of newer mattresses (ie those installed within the last 10 years) will have blocks linked with polypropylene or Kevlar ropes. The lifting loops could be expected to be in good condition, although this would have to be confirmed, and these mattresses could be recovered to surface using handling frames and/or speedloaders. Speedloaders are a lifting arrangement deployed on the seabed onto which a number of mattresses can be lifted using lifting frames before the speedloader is recovered to the surface.

For older mattresses, or for mattresses that have broken up, a conventional grab tool can be deployed to recover the mattress pieces directly to the service vessel, or to a basket subsea and then recovered.

A review of mattress recovery projects to-date shows that it is possible in some cases for newer mattresses to be recovered in less than an hour. For older mattresses, which may have been subsea for 20+ years, the recovery time can be upwards of 12 hours per mattress.

For specific decommissioning programmes, sample mattresses can be recovered during the pre-commissioning surveys to review their condition and to confirm the required recovery method, or the feasibility of reusing the mattresses within the field.

13 Recycling and Reuse

13.1 Recycling

When lengths or sections of steel rigid pipelines are recovered as part of a decommissioning programme, the steel itself is recycled using a proven supply chain. All steel pipelines have an anti-corrosion coating and often have insulation coatings applied. Where possible these coatings are removed and recycled, otherwise they are sent to landfill.

For recovered flexible flowlines, umbilicals and power cables, the metallic end fittings can be removed and recycled, or in some instances reused. This is described in the Shelley Close Out Report [Ref. 14]. The metallic elements of the carcass of flexible flowlines, and the wires used in armouring layers in umbilicals and power cables, can also be recovered using specialist equipment and then recycled. Such processes separate out the plastic materials from the different layers, which can then be recycled if possible.

A decommissioning project typically achieves recycling or reuse rates in excess of 95 per cent of the recovered materials, and in some cases up to 98 per cent. Similar rates can be achieved for pipeline decommissioning projects, depending on the volume and type of non-recyclable coatings recovered with the pipelines.

13.2 Reuse

Integrity is a key issue when considering the reuse of pipelines or pipeline materials. For rigid steel pipelines, recovered in a single length by the reverse reeling process, the pipe wall will have been subject to significant reverse cycle plastic deformation during its original deployment and then recovery process. This can significantly affect the long term integrity of the pipe structure and would rule it out for reuse. Hence, no steel pipeline recovered in this way has been reused.

It would be possible to demonstrate that a decommissioned pipeline left in situ could be reused for alternative service and operating conditions and this is regularly considered.

Flexible flowlines, umbilicals and power cables are readily recovered by reverse reeling as part of a decommissioning programme. Such materials can theoretically be reused, but proving that the integrity of the complex multi-layered structure of such components has not been compromised during the handling and operational process is difficult, and often recycling is the only realistic option.

14 Public Consultation

14.1 Requirements for Consultation

In the UK there is a statutory requirement for operators to consult with stakeholders who may be affected by decommissioning proposals under section 29(3) of the Petroleum Act 1998 [Ref 3]. This includes the decommissioning of oil and gas pipelines.

In Norway the cessation of production plan requires a separate impact assessment programme to be prepared. This ensures the public are properly informed and provides various stakeholders with the opportunity to express opinions and inputs into the scope and execution of the project.

14.2 Statutory Consultees (UKCS)

Annex H of the DECC Guidance Notes [Ref 6] specifies those organisations that should be contacted as part of statutory stakeholder consultation. These are Global Marine Systems, Northern Ireland Fishermen's Federation, Scottish Fishermen's Federation and The National Federation of Fishermen's Organisations UK. Annex E and Section 6.14 of the Guidance Notes also identify Government departments with a relevant role and to whom copies of a draft decommissioning programme must be sent.

14.3 Consultation Process

On the UKCS statutory consultation starts at the point at which a draft decommissioning programme is submitted to the DECC. A period of 30 days for the consultation is stated in the DECC guidelines.

Decommissioning proposals are announced by placing a public notice in appropriate national and local newspapers and journals, and by placing details on the Internet. This notice indicates where copies of the draft decommissioning programme can be viewed and to whom representations should be submitted.

Typically the programme is available to download from the Internet with hard copies available for inspection at the operator's offices. The results of consultations are reported in the decommissioning programme when it is submitted for final approval.

Further guidance can be found in the Guidelines on Stakeholder Engagement for Decommissioning Activities on the Oil and Gas UK website at: http://www.oilandgasuk.co.uk/knowledgecentre/decom_guidelines.cfm
In Norway the plan for cessation of production must be presented by the operator two to five years ahead of the cessation of production. The plan for cessation is subject to public hearing.

15 References

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3 UK Petroleum Act 1998
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4 Marine and Coastal Access Act 2009
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5 Marine (Scotland) Act 2010
http://www.scotland.gov.uk/Topics/marine/seamanagement/marineact

6 DECC Guidance Notes Decommissioning Programmes
https://www.og.decc.gov.uk/regulation/guidance/decomm_guide_v6.pdf

7 Pipeline Safety Regulations 1996
http://www.hseni.gov.uk/l82_a_guide_to_the_pipelines_safety_regulations_1996.pdf

8 Offshore Safety Case
http://www.hse.gov.uk/offshore/safetycases.htm

9 FishSAFE project
http://www.fishsafe.eu/en/home.aspx

10 Fisheries Liaison Officer Guidelines
http://www.oilandgasuk.co.uk/knowledgecentre/Fisheries.cfm

11 Offshore Chemical Regulations 2002
http://www.legislation.gov.uk/uksi/2002/1355/contents/made

12 OSPAR CEMP Assessment Report 2011
http://www.ospar.org/documents/dbase/publications/p00563_cemp_2011_assessment_report.pdf

13 Oil & Gas UK Decommissioning Insight Report
http://www.oilandgasuk.co.uk/knowledgecentre/market_information.cfm

14 Shelley Close out Report
https://www.gov.uk/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines

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Appendix A: Table of Decommissioned Pipelines in the North Sea Region

Country	Operator	Pipeline Type	Location		Length	Diameter	Fluid type	Installation Date	Decommissioning Option
			From	To	km	inches			
NL	GDF Suez		L10-K	L10-B/L10-A (s)	5.8	11		1984	
NL	GDF Suez		K12-A/L10-A	K12-E	3.9	2		1986	
NL	GDF Suez		K12-E	K12-C	6.3	11		1986	
NL	GDF Suez		L10-S1	L10-AP	11.5	7		1988	
NL	GDF Suez		K12-E	L10-S1	4.6	4		1988	
NL	GDF Suez		L14-S1	L11a-A	6.0	7		1990	
NL	GDF Suez		K12-S1	K12-BP	4.9	7		1991	
NL	GDF Suez		K11-B	K12-C	16.1	14		1995	
NL	NAM		K11-FA-1	K8-FA-1	6.0	7		1978	
NL	NGT		L11-A	NGT-pipe	11.8	11		1990	
NL	Taqa		P15-B	P15-C	3.4	10		1985	
NL	Taqa		P15-B	P15-C	3.4	6		1985	
NL	Taqa		P15-C	P15-B	3.4	6		1985	
NL	Taqa		P15-B	P15-C	3.4	4		1985	
NL	Total		K5-EN/C	K5-D	2.7	12		1997	
NL	Total		L4-PN	L4-A	11.4	10		1999	
NL	Total		K4-BE	K4-A	8.0	10		2000	
NL	Unocal		Q!-Helder-B	Q1-Helder-AW	1.8	9		1986	
NL	Unocal		Q!-Helder-B	Q1-Helder-AW	1.8	9		1987	
NL	Unocal		Q1-Haven-A	Q1-Heder-AW	5.8	9		1989	
NL	Wintershall		K13-B	K13-AP	9.2	10		1977	
NL	Wintershall		K13-D	K13-C	3.5	10		1978	
NL	Wintershall		P12-C	P12-SW	6.9	8		1990	
NL	Wintershall		P14-A	P15-D	12.6	10		1993	
NL	Wintershall		P2-NE	P6-A	38.2	10		1996	
NO	ExxonMobil		Odin	Frigg TCP2	26.0	20	Gas		
NO	Gassco AS		Frigg TCP2	Vesterled T	_	32	Gas		
NO	Total		Frigg TCP2	Oseberg A	82.0	16	Oil		
NO	Total	Trunkline	DP2	TCP2	0.7	26	Gas		Removal
NO	Total	Trunkline	DP2	TCP2	0.7	26	Gas		Removal
NO	Total	Flowlines	DP2	TCP2	0.7	4	Condensate		Removal
NO	Total	Flowlines	DP2	TCP2	0.7	8	Chemical		Removal
NO	Total	Power	DP2	TCP2	0.7	3	Power		Removal
UK	_		Ardmore	to Sal 2	1.4	_			
UK	_		Ardmore	to Sal 2	1.4	_			
UK	Apache		Forties E	Forties A	4.0	6	Oil	1986	
UK	Apache		Forties D	Forties C	3.6	20	Oil	1975	
UK	BHP	Flowlines	Douglas	Lennox		12	Gas		Leave in situ - minor intervention
UK	BHP	Flowlines	Esmond	Forbes		10	Gas		Leave in situ - minor intervention
UK	BHP	Flowlines	Esmond	Gordon		12	Gas		Leave in situ - minor intervention

Country	Operator	Pipeline Type	Location		Length	Diameter	Fluid type	Installation Date	Decommissioning Option
			From	To	km	inches			
UK	BHP	Flowlines	Esmond	Forbes		2	Gas		Leave in situ - minor intervention
UK	BHP	Flowlines	Esmond	Gordon		12	Gas		Leave in situ - minor intervention
UK	BP	Flexible Flowlines	Don	Don		4	Oil		Removal
UK	BP	Flexible Flowlines	Don	Don		4	Water		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.8	10	Oil		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.8	8	Oil		Removal
UK	BP	Umbilical	Schiehallon & Loyal	Schiehallon & Loyal	0.7	8			Removal
UK	BP	Umbilical	Schiehallon & Loyal	Schiehallon & Loyal	0.7	8			Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.7	10	Oil		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.7	10	Oil		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.7	10	Oil		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.7	8	Oil		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	1.4	8	Gas		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	2.9	12	Water		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.7	8	Oil		Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.8	10	Oil		Removal
UK	BP	Flowlines	Ninan Tee	North West Hutton		10	Gas		Leave in situ - minimal intervention
UK	BP	Trunkline	North West Hutton	Cormorant A		20	Oil		Leave in situ - major intervention
UK	BP	Trunkline	Hutton (TLP)	North West Hutton	<0.5	12	Oil		Leave in situ - minimal intervention
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.7	10			Removal
UK	BP	Risers	Schiehallon & Loyal	Schiehallon & Loyal	0.7	10	Oil		Removal
UK	BP	Rigid Flowlines	Don	Thistle	17.3	8	Production		Leave in situ - minimal intervention
UK	BP	Rigid Flowlines	Don	Thistle	13.1	8	Water		Leave in situ - minimal intervention
UK	BP	Umbilical	Don	Thistle	17.7	3	Chemical		Leave in situ - minimal intervention
UK	BP	Flexible Flowlines	Don	Don		4	Water		Removal
UK	BP	Flexible Flowlines	Don	Don		4	Oil		Removal
UK	BP	Flexible Flowlines	Don	Don		4	Oil		Removal
UK	BP	Flexible Flowlines	Schiehallon & Loyal	Schiehallon & Loyal	1.9	12			Removal

Country	Operator	Pipeline Type	Location		Length	Diameter	Fluid type	Installation Date	Decommissioning Option
			From	To	km	inches			
UK	BP	Flexible Flowlines	Schiehallon & Loyal	Schiehallon & Loyal	4.5	_			Removal
UK	BP	Flexible Flowlines	Schiehallon & Loyal	Schiehallon & Loyal	2.0	10	Oil		Removal
UK	BP	Flexible Flowlines	Schiehallon & Loyal	Schiehallon & Loyal	0.1	10	Oil		Removal
UK	Bridge Energy	Flowlines	Tristian NW	Tristian NW	15.5	6	Production		Leave in situ - minor intervention
UK	Bridge Energy	Umbilical	Tristian NW	Tristian NW	15.3	4			Leave in situ - minor intervention
UK	CNRI	Flowlines	Staffa	Ninan	9.6	9	Oil		Removed
UK	ConocoPhillips		Hutton (TLP)	N W Hutton	8.0	12	Oil		Leave in situ
UK	ConocoPhillips		Maureen platform	ALC		24	Oil		Leave in situ
UK	ConocoPhillips		Maureen platform	Moira	10.0	6	Oil		Removal - reverse reel
UK	ConocoPhillips		Maureen platform	Moira	10.0	2	Gas		Removal - reverse reel
UK	ConocoPhillips		Maureen platform	Moira	10.0	4			Removal - reverse reel
UK	Hamilton		Moira	Maureen*	10.1	7	Oil		
UK	Hess	Flexible Flowline	Fife	Fife	2.0	6	Production		Leave in situ - minimal intervention
UK	Hess	Flexible Flowline	Fife	Fife	1.7	7	Water		
UK	Hess	Flexible Flowline	Fife	Fife	<0.1	4	Water		Removal -reverse reel
UK	Hess	Flowlines	Fife	Fife		_	Gas		Removal -reverse reel
UK	Hess	Flowlines	Fife	Fife		_	Chemical		Removal -reverse reel
UK	Hess	Flexible Flowline	Fergus	Fergus	7.4	7			Leave in situ - major intervention
UK	Hess	Flowlines	Fergus	FPSO	5.6	7	Oil		Leave in situ
UK	Hess	Flowlines	Fergus	Fergus		_	Chemical		
UK	Hess	Rigid Flowline	Flora	Flora	8.0	8	Production		Leave in situ - minimal intervention
UK	Hess	Rigid Flowline	Flora	Flora	7.0	3	Gas		Leave in situ - minimal intervention
UK	Hess	Rigid Flowline	Flora	Flora	8.4	8	Water		Leave in situ - minimal intervention
UK	Hess	Flowlines	Flora	Flora	9.5	6	Chemical		
UK	Hess	Flexible Flowline	Fife	Fife	2.0	6	Production		Removal - reverse reel
UK	Hess	Rigid Flowline	Flora	Angus	18.8	8	Oil	2002	Leave in situ
UK	Hess	Rigid Flowline	Angus	Flora	10.4	3	Gas	2002	Leave in situ
UK	Hess	Flowlines	Ivanhoe/ Rob Roy	Claymore	40.0	14	Oil	1990	Leave in situ - minor intervention
UK	Hess	Flowlines	Ivanhoe/ Rob Roy	Tartan	23.0	8	Gas	1990	Leave in situ - minor intervention
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	8	Production		
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	8	Oil	2000	Removal
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	5		2000	Removal

Country	Operator	Pipeline Type	Location		Length	Diameter	Fluid type	Installation Date	Decommissioning Option
			From	To	km	inches			
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	4	Gas	2000	Removal
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	8	Water	2000	Removal
UK	Hess	Flowlines	Rob Roy	Ivanhoe/ Rob Roy	1.6	4	Chemical	2000	Removal
UK	Hess	Flowlines	Rob Roy	Rob Roy	<0.1	4	Power		Removal -reverse reel
UK	Hess	Flowlines	Rob Roy	Rob Roy	<0.1	2	Gas		Removal -reverse reel
UK	Hess	Flowlines	Rob Roy	Rob Roy	<0.1	4	Water		Removal -reverse reel
UK	Hess	Flowlines	Rob Roy	Rob Roy	<0.1	_	Chemical		Removal -reverse reel
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	8	Oil	2000	
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	5		2000	
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	4	Gas	2000	
UK	Hess	Flowlines	Ivanhoe	Rob Roy	1.6	8	Water	2000	
UK	Hess	Flowlines	Rob Roy	Ivanhoe	1.5	_	Chemical	2000	Removal of dynamic sections
UK	Hess	Flowlines	Ivanhoe	Ivanhoe	<0.1	4	Power		Removal -reverse reel
UK	Hess	Flowlines	Ivanhoe	Ivanhoe	<0.1	2	Gas		Removal -reverse reel
UK	Hess	Flowlines	Ivanhoe	Ivanhoe	<0.1	4	Water		Removal -reverse reel
UK	Hess	Flowlines	Ivanhoe	Ivanhoe	<0.1	_	Chemical		Removal -reverse reel
UK	Hess	Umbilical	Flora	Angus	10.5	1	Chemical		Leave in situ - minimal intervention
UK	Maersk				_	9	Oil		
UK	Maersk				_	2	Fibre		
UK	Nexen		SCOTT	SCOTT	1.7	_			
UK	Oryx	Flowlines	Ninian	Hutton TLP	8.6	8	Gas	2000	
UK	Perenco	Flowlines	Welland	Thames	17.5	16	Production		Leave in situ - minimal intervention
UK	Perenco	Flowlines	Thames	Welland	17.2	3	Chemical		Leave in situ - minimal intervention
UK	Perenco	Flowlines	Welland	Welland	8.0	8	Gas		Leave in situ - minimal intervention
UK	Perenco	Flowlines	Welland	Welland	5.8	8	Gas		Leave in situ - minimal intervention
UK	Perenco	Flowlines	Welland	Welland	3.9	8	Gas		Leave in situ - minimal intervention
UK	Perenco	Umbilical	Welland	Welland	8.0	4			Leave in situ - minimal intervention
UK	Perenco	Umbilical	Welland	Welland	5.8	4	Chemical		Leave in situ - minimal intervention
UK	Perenco	Umbilical	Welland	Welland	4.2	4	Chemical		Leave in situ - minimal intervention
UK	Premier	Umbilical	Shelley	FPSO	2.4	3	Power		Removal - reverse reel
UK	Premier	Flowlines	Shelley	FPSO	2.0	8	Production		Leave in situ - minimal intervention
UK	Shell		Brent South UTA	TO BS-2	_	_	Condensate		
UK	Shell		Brent South UTA	TO BS-1	_	_	Condensate		
UK	Shell		Brent South WI2	TO OP4	_	_	Water		
UK	Shell	Flowlines	Leman AP	Leman CD		8	Chemical		

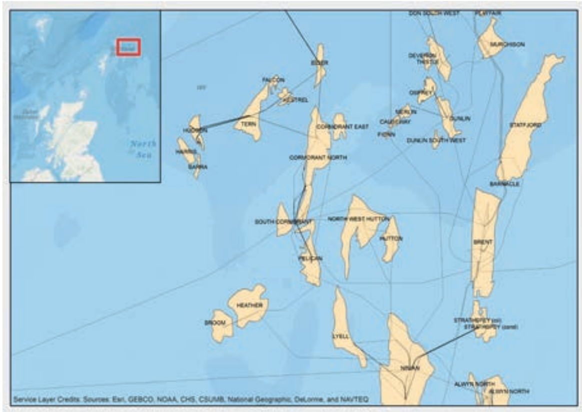
Country	Operator	Pipeline Type	Location		Length	Diameter	Fluid type	Installation Date	Decommissioning Option
			From	To	km	inches			
UK	Shell		Leman BT	Leman BP		4			
UK	Shell	Flowlines	Inde M	Inde J	3.4	12	Gas	1985	Leave in situ - minor intervention
UK	Shell	Flowlines	Inde JD	Inde M	3.7	3	Condensate	1985	Leave in situ - minor intervention
UK	Shell	Flowlines	Inde K	Inde N	2.4	10	Gas	1987	Leave in situ - minor intervention
UK	Shell	Flowlines	Inde K	Inde N	2.4	3	Condensate	1987	Leave in situ - minor intervention
UK	Shell	Trunkline	Inde J	Inde AT	3.9	20	Production	1971	Leave in situ - minor intervention
UK	Shell	Trunkline	Inde K	Inde AT	9.1	24	Production	1972	Leave in situ - minor intervention
UK	Shell	Flowlines	Inde L	Inde J	3.2	16	Gas	1977	Leave in situ - minor intervention
UK	Shell	Flowlines	Statfjord	Brent South		10	Oil		Not in use
UK	Silverstone	Flowlines	Tristian NW	Davy NUI	15.5	6	Gas		Leave in-situ - minimal intervention
UK	Talisman	Trunkline	Piper A	Piper/Claymore	35.2	30	Oil		
UK	Talisman	Trunkline	Tartan	MCP01		18	Gas		
UK	Talisman		Claymore		2.0	14		1999	
UK	Talisman		Claymore Spur		7.3	30		2000	Leave in-situ - minimal intervention
UK	Total	Power	TP1	FP	0.5	3	Power		Removal
UK	Total	Power	TP1	FP	0.5	4	Power		Removal
UK	Total	Power	CDP1	TP1/QP	0.5	3	Power		Removal
UK	Total		TP1	FP	0.5	3			Removal
UK	Total		TP1	FP	0.5	4			Removal
UK	Total	Risers	MCP01 Talisman Pipeline		0.5	18			Removal
UK	Total	Trunkline	MCP01 Frigg Pipeline		0.5	32			
UK	Total	Trunkline	MCP01 Vesterled Pipeline		0.5	32			
UK	Total		Alwyn North		4.7	6	Water	2000	
UK	Total	Umbilical	CDP1	TP1/QP	0.5	8	Chemical		Removal
UK	Total	Trunkline	CDP1	TP1/QP	0.5	26	Gas		Removal
UK	Total	Trunkline	CDP1	TP1/QP	0.5	26	Gas		Removal
UK	Total	Flowlines	CDP2	TP1/QP	0.5	4	Condensate		Removal
UK	Total	Trunkline	TP1	FP	0.5	24	Gas		Removal
UK	Total		TP1	FP	0.5	2			Removal
UK	Total		TP1	FP	0.5	2			Removal
UK	Venture	Umbilical	Kittiwake	Kittiwake	_	3	Chemical		Removal - Cut and lift
UK	Venture	Flexible Flowlines	Kittiwake	Kittiwake	_	8	Production		Removal - Cut and lift
UK	Venture	Flowlines	Kittiwake	Kittiwake Sal	3.0	8	Oil	2005	Removal -reverse reel

Data in this table was obtained from publicly available sources via DECC and DEAL. In some instance the full data-set required for individual pipelines was not available.

Appendix B: Case Studies of Pipeline Decommissioning Projects

North West Hutton

Operator	BP
Water depth	143 metres
Pipelines	10 inch 12.6 km Oil Import 20 inch, 12.8 km Oil Export



Field Description

The North West Hutton field is located in Block 211/27a of the UKCS. The facilities at North West Hutton comprised a steel platform, wells and pipelines that were installed to produce hydrocarbons and associated products from the North West Hutton reservoir, discovered in 1975.

The North West Hutton facilities were installed and commissioned between 1981 and 1983. The platform is operated by Amoco (UK) Exploration Company, on behalf of Amoco UK Petroleum Limited, a subsidiary of BP plc. BP own 25.8 per cent of the field, and the other owners are CIECO Exploration and Production (UK) Limited with 25.8 per cent, Enterprise Oil U.K. Limited with 28.4% and Esso Exploration and Production UK Limited with 20 per cent.

The North West Hutton field began production in 1983, and by the time of cessation of production in January 2003 the field had produced some 126 million barrels of oil.

Pipeline Decommissioning Execution

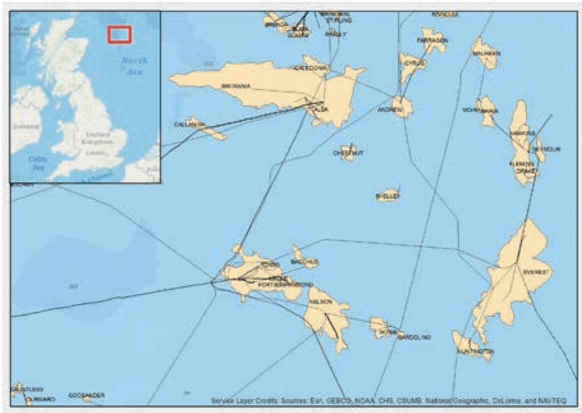
Decommissioning of the North West Hutton pipelines took place in 2011 and 2012.

The 10 inch, concrete coated, gas import pipeline carried gas from the Ninian Tee to the North West Hutton platform. The pipeline was trenched at installation and remained buried at the time of decommissioning, and the CA of options concluded that the pipeline should be decommissioned in situ. The pipeline ends and ancillary equipment, such as mattresses, were removed and recovered to shore for recycling or disposal.

At installation, the 20 inch, concrete coated oil export pipeline was laid on the seabed between the North West Hutton and Cormorant Alpha platforms. To remove any potential long-term risks to other users of the sea, the decommissioning option selected using CA was to trench and bury the pipeline below the seabed. At three crossings along the length of the pipeline, sections of the pipeline were removed and recovered to shore, with the pipeline ends remaining in the trench. All mattresses used to protect the pipeline were recovered to shore for recycling or disposal.

Shelley

Operator	Premier Oil
Water depth	92-96 metres
Pipelines	8 inch 2.0km, Production 3.5 inch, 2.4km, Control Umbilical



Field Description

The Shelley field is located in Block 22/02b and 22/03a of the UKCS, approximately 192 kilometres from the north east coast of Scotland and 32 kilometres from the UK/Norway median line.

The Shelley facilities consisted of two production wells with Xmas trees and fishing-friendly protective structures, and a subsea production manifold inside a protection structure. These were tied back to the Sevan Voyageur FPSO by a 2.02 kilometre long trenched and rock dumped rigid 8 inch production pipeline and a 2.42 kilometre trenched electro/hydraulic control umbilical. Both of these were located in a 10 metre wide corridor between the production manifold and the FPSO.

The field began producing in August 2009, but reservoir performance did not meet expectations so cessation of production occurred in July 2010. The Shelley facilities were decommissioned during 2010 and 2011, and details can be found in the publicly available decommissioning close-out report.

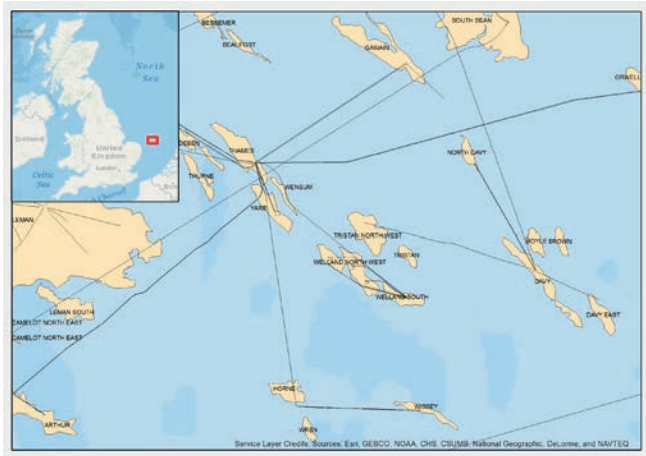
Pipeline Decommissioning Execution

From a comparative assessment of decommissioning options, exposed sections of the trenched and rock dumped 8 inch production pipeline were removed, with the pipeline cut as close to the rock dump berm as possible. The remaining trenched and rock dumped sections were decommissioned in situ. Prior to removal operations, the production pipeline was flushed, achieving oil in water concentration of less than 30 parts per million.

The exposed sections of the rigid production pipeline were cut using a hydraulically powered subsea saw, with the resulting short sections protruding from the rock dump protected from snagging using grout bags. The cut sections of pipe were returned to shore for recycling. The 2.42 kilometre long electro-hydraulic umbilical was removed in sections and returned to shore for disposal. The umbilical was cut using a hydraulic guillotine cutter on the deck of the recovery vessel. The short tie-in sections of flexible pipe at each end of the pipeline were recovered to shore for refurbishment and potential reuse. All mattresses were recovered to shore and reused as foundation materials by a local farmer.

Tristan NW

Operator	Bridge Energy (Formerly Silverstone Energy Limited)
Water depth	25-35 metres
Pipelines	6 inch 15.5km, Production 4 inch, 15.3km, Control Umbilical



Field Description

The North West Hutton field is located in Block 211/27a of the UKCS. The facilities at North West Hutton comprised a steel platform, wells and pipelines that were installed to produce hydrocarbons and associated products from the North West Hutton reservoir, discovered in 1975.

The North West Hutton facilities were installed and commissioned between 1981 and 1983. The platform is operated by Amoco (UK) Exploration Company, on behalf of Amoco UK Petroleum Limited, a subsidiary of BP plc. BP own 25.8 per cent of the field, and the other owners are CIECO Exploration and Production (UK) Limited with 25.8 per cent, Enterprise Oil U.K. Limited with 28.4% and Esso Exploration and Production UK Limited with 20 per cent.

The North West Hutton field began production in 1983, and by the timeof cessation of production in January 2003 the field had produced some 126 million barrels of oil.

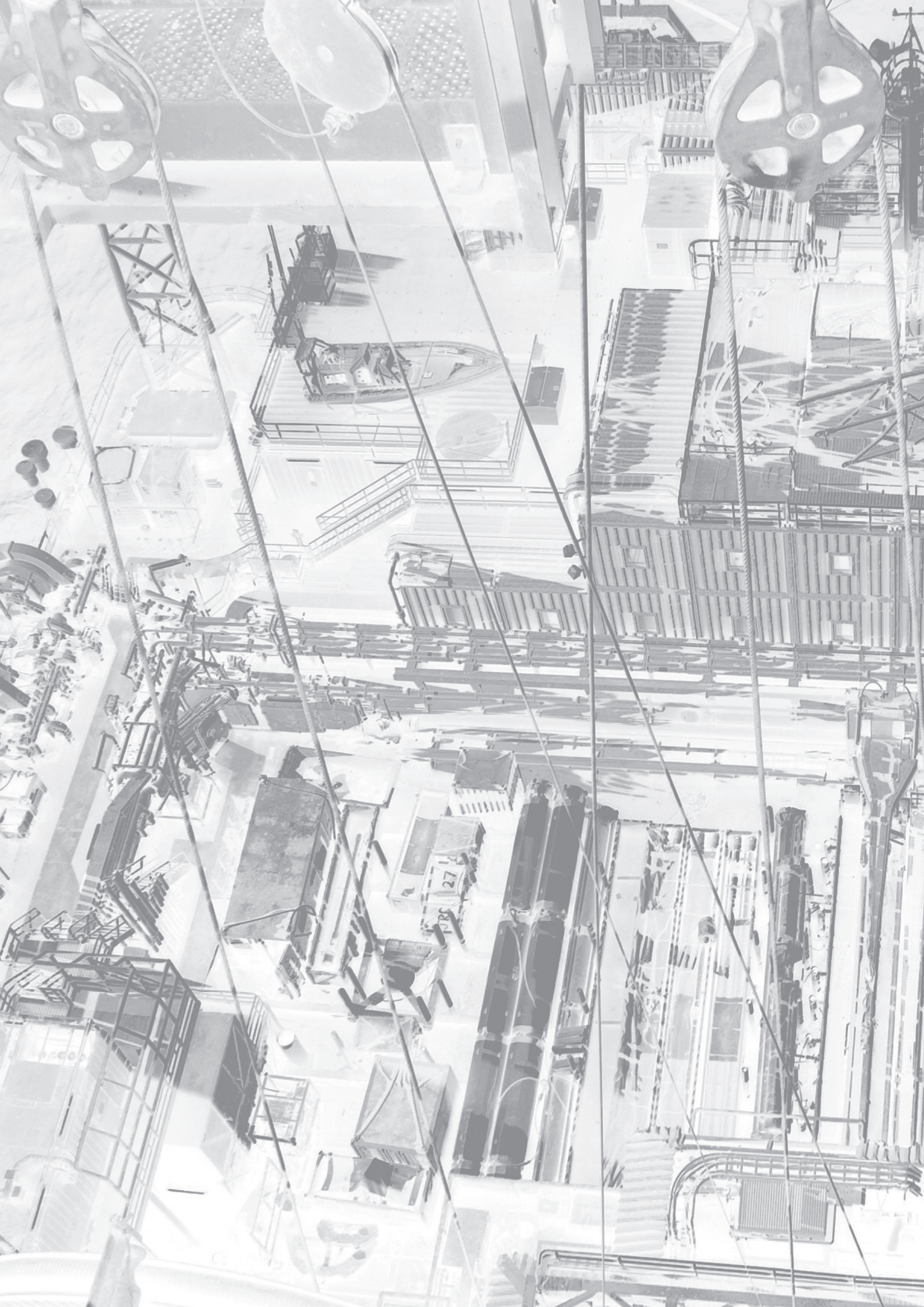
Pipeline Decommissioning Execution

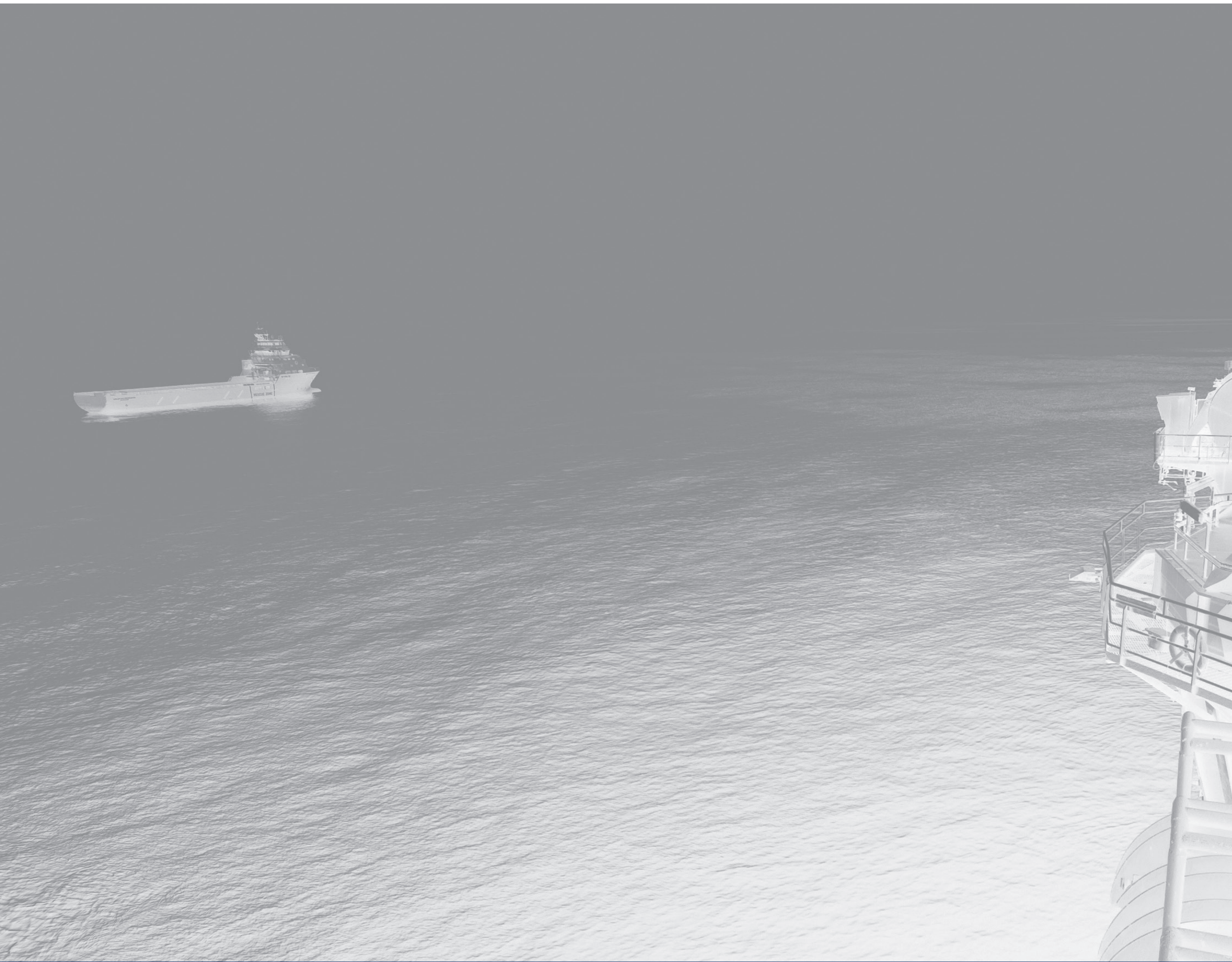
A detailed CA was performed to identify the best option for decommissioning the 14.8 kilometre length of trenched and buried production pipeline with piggy-backed umbilical. Options were comprehensively assessed and compared on the basis of their safety risk, environmental impacts, CO2 emissions, technical feasibility and cost. This assessment indicated that the best option would be to remove the sections of pipeline and umbilical lying on the seabed at either end of the line, and leave the combined pipeline and umbilical in its present trench, buried by natural sediment and areas of spot rock dump.

The production well, umbilical and production pipeline were flushed and cleaned, with all production fluids disposed of via the Davy Normally Unmanned Installation (NUI), or, for the umbilical, to sea.

The infrastructure at the Tristan NW Field was then completely removed to shore, with the exception of the 14.8 kilometre trenched section of the pipeline and piggy-backed umbilical, its existing cover of spot rock dump, and the rock dump previously protecting the 250 metre coil of umbilical at the Tristan NW wellhead.

This equipment was decommissioned in situ in accordance with the approved decommissioning plan.
All materials recovered to shore were recycled, and nothing was sent to landfill.





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