Ensign
Comparative Assessment for Pipelines

SPIRIT ENERGY

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1 EXECUTIVE SUMMARY

A Comparative Assessment of pipeline decommissioning options is a key consideration within Decommissioning Programmes submitted to the Offshore Petroleum Regulator for Environment & Decommissioning (OPRED).

As the principles are the same, this comparative assessment concerns the pipeline decommissioning options, including the offshore and onshore elements. The Decommissioning Programmes [6], are supported by the Comparative Assessment (this document) and Environmental Appraisal [7].

Ensign

The Ensign field lies within the main Southern North Sea (SNS) Gas Province in UK Block 48/14a. The field lies ~109km west of Easington on the coast of Norfolk in water depths of ~25m.

The Ensign gas field was developed using a single installation. The field achieved first production in 2011. The Ensign installation and pipelines are wholly owned by Spirit North Sea Gas Limited. The installation itself is a Not Permanently Attended Installation (NPAI) supported by four-legged conventional piled steel jacket. Until May 2017, gas from Ensign used to be exported to Audrey A using 10" pipeline (**PL2838**) and on to LOGGS using the 20" gas export line PL496. LOGGS used to supply methanol to Audrey A using 3" methanol pipeline PL497 and on to Ensign using 2" pipeline **PL2839**. Both pipelines are ~22.2km long; **PL2839** is piggybacked onto **PL2838**. Decommissioning of PL496 and piggybacked PL497 pipelines are dealt with in the Audrey and Annabel Decommissioning Programmes; these were approved early 2018.

A 10" pipeline (**PL2841**) and umbilical pipeline (**PLU2840**) both ~2.2km long, were also installed for Ensign but never used; these are covered by a Disused Pipeline Notification.

There is a total of ninety-five mattresses that protect the pipelines on approach to the Ensign, Audrey A and the unused Ensign subsea well. A further nine concrete mattresses are buried under deposited rock at two pipeline and cable crossings.

Pipeline decommissioning options

This document summarises a comparative assessment of the preferred options for decommissioning Ensign pipeline numbers **PL2838, PL2839, PLU2840** and **PL2841.**

Two decommissioning options are considered for the pipelines:

- **Complete removal** – This involves the complete removal of a piggybacked pipeline by whatever means would be most practicable and acceptable from a technical perspective;
- **Leave *in situ*** – This involves leaving a pipeline *in situ* with no remedial works but possibly verifying its stability via future surveys.

Since the decommissioning of the pipeline approaches at the Ensign and Audrey A installations and the unused Ensign subsea well would be the same irrespective of which option is pursued, decommissioning of these is not included in the assessment. All options include removal of features such as spool pieces, concrete mattresses and grout bags in accordance with mandatory requirements. Pipelines covered with deposited rock along with any concrete mattresses buried underneath will remain *in situ*.

Comparative assessment

The options were assessed using the OPRED Decommissioning Guidance Notes and Spirit Energy's Comparative Assessment guidelines for the Ensign decommissioning project. During the assessment process, evaluations were made principally on a qualitative basis using Spirit Energy's established corporate risk assessment tables. The following components were assessed from a short-term (project) and longer-term (legacy) perspective:

- Safety;

- Environmental;
- Technical;
- Societal;
- Cost.

Decommissioning assessment

The results of the assessment showed the risks and impacts of all pipeline decommissioning options to be broadly acceptable, although the technical and safety risks associated with complete removal of **PL2838** and **PL2839**, would be 'tolerable' rather than 'broadly acceptable'. This is primarily due to there being limited experience in removing trenched and buried pipelines that are piggybacked [2].

From an environmental perspective, lower risks and impacts would be incurred for the leave *in situ* option than for complete removal.

The societal assessments showed that complete removal would be marginally beneficial because of continuation of employment due to extension of vessel use and onshore waste management activities, although in the short-term, fishing activities might proportionately be disrupted as decommissioning activities increase. Conversely fishing activities could be affected by legacy pipeline surveys and possible remedial work in future, but there is nothing substantial that differentiates the options.

The overall assessment for **PLU2840** and **PL2841** is similar except that in the technical assessment the pipelines are shorter which means that the 'cut and lift' method of removal would be more achievable. This means that the technical element is assessed as 'broadly acceptable and least preferred' rather than 'tolerable' if managed to ALARP. Likewise, the safety element of the onshore work and material handling was assessed as being 'broadly acceptable' and 'least preferred' rather than 'tolerable' if managed to ALARP.

Finally, the leave *in situ* option would cost less to adopt in the short-term than complete removal; for **PL2838** and **PL2839** the difference is significant but less than an order of magnitude less, while for **PLU2840** and **PL2841** the difference in cost is not as significant.

For **PL2838** and **PL2839** the technical and onshore safety aspects of complete removal can be considered significant drivers for leaving the pipelines in place, while such drivers for leaving **PLU2840** and **PL2841** are less prominent. Nevertheless, overall the results of the assessment would suggest that there are no benefits in completely removing the pipelines and so they would be best be left *in situ*.

Summary of decommissioning proposals

The results of the comparative assessment are such that we propose to leave the **PL2838** and **PL2839** *in situ*, along with those concrete mattresses that remain buried under deposited rock.

On the approaches to the offshore installations at each end, the buried pipelines will be cut where they exit the deposited rock and only the exposed sections will be removed. The intention is that all exposed mattresses and grout bags will also be removed.

Decommissioning of the **PL2838** and **PL2839** pipeline components is summarised below.

PL2838, 10” Pipeline (~22.3km long) piggybacked by PL2839 2” Methanol Pipeline (~22.2km long)	Complete Removal	Leave *in situ*
The short-exposed end sections of the 10” pipeline **PL2838** (length ~55m) and piggybacked 2” pipeline **PL2839** (length ~58.5m) lying on the seabed between the Ensign installation risers and deposited rock will be removed.	●	
10” pipeline **PL2838**, piggybacked by 2” pipeline **PL2839** including ends buried under deposited rock at pipeline and cable crossings and on approach to Ensign and Audrey A installations will be left buried *in situ*; total length ~22.1km.		●
The short-exposed end sections of the 10” pipeline **PL2838** (length ~122m) and piggybacked 2” pipeline **PL2839** (length ~101m) lying on the seabed between the deposited rock and the Audrey A installation risers will be removed.	●	

The results of the comparative assessment are such that we propose to leave the **PLU2840** and **PL2841** *in situ*, along with those concrete mattresses that remain buried under deposited rock.

On the approaches to the offshore installations at each end, the buried pipelines will be cut where they exit the deposited rock and only the exposed sections will be removed. The intention is that all exposed mattresses and grout bags will also be removed.

Decommissioning of the **PLU2840** and **PL2841** pipeline components is summarised below

PL2841, 10” Pipeline (~2.2km long) piggybacked by PLU2840 umbilical pipeline (~2.05km long)	Complete Removal	Leave *in situ*
The short-exposed end sections of the 10” pipeline **PL2841** (length ~81.2m) and piggybacked umbilical pipeline **PLU2840** (length ~131m; this dimension excludes length between TUTU and bottom of J-tube, ~50m long) lying on the seabed between the Ensign installation (riser and J-tube respectively) and the deposited rock will be removed.	●	
10” pipeline **PL2841**, piggybacked by umbilical pipeline **PLU2840** including ends buried under deposited rock at Ensign and on approach to the Ensign subsea well will be left buried *in situ*; lengths left *in situ* ~1.9km (**PLU2840**) and ~2km (**PL2841**).		●
The short-exposed end of the umbilical pipeline **PLU2840** (length ~114m) lying on the seabed between the deposited rock and on approach to the Ensign subsea well will be removed. On approach to the Ensign subsea well the 10” pipeline **PL2841** does not extend past the end of the deposited rock.	●	

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TERMS AND ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ALARP	As Low As Reasonably Practicable
Approach	Initial or final stretch of pipeline as it leaves its point of origin or reaches its destination
CO_2	Carbon Dioxide
CSV	Construction Support Vessel
°	Degree
DSV	Dive Support Vessel
EC	European Community
Ensign	Four-leg piled steel jacket that uses the Sea Harvester minimum facilities design. Fixed Not Normally Attended Installation. Gas used to be exported to LOGGS via Audrey 'A', and onto Theddlethorpe
Exposure	A pipeline can be seen on the surface of the seabed but is not free-spanning
FishSAFE	The FishSAFE database contains a host of oil & gas structures, pipelines and potential fishing hazards. This includes information and changes as the data are reported for: pipelines and cables, suspended wellheads, pipeline spans, surface & subsurface structures, safety zones & pipeline gates (www.fishsafe.eu)
Freespan	A section of pipeline where seabed sediments have been eroded or scoured from under a pipeline, resulting in an unsupported – free-spanning - section of pipe
HAZID	Hazard Identification Workshop
HSE	Health, Safety, Environment
ID	Identity (as in tabulated feature)
In or "	Inch (25.4mm)
km, m	Kilometre(s), Metre(s)
KP	Kilometre-Post measured from place of origin
LAT	Lowest Astronomical Tide
LOGGS	Lincolnshire Offshore Gas Gathering System
Megaripple	Megaripples are large sandwaves or ripple-like features having wavelengths greater than 1m or a ripple height greater than 0.1m
£M	£Million
N/A	(Data) Not Available
NORM	Naturally Occurring Radioactive Material
NPAI	Not Permanently Attended Installation
OGUK	Oil & Gas UK
OPRED	Offshore Petroleum Regulator for Environment & Decommissioning
Piggybacked	Connected at intervals to the larger pipeline
Pipeline(s)	Pipeline as defined by OPRED. Includes PL2917 and PL2918
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
Pipespool(s)	Short sections of pipe that are typically flanged and bolted together
Pre-swept	Preparation of seabed to enable consistent burial during installation of pipeline
Qualitative	Result determined using judgement and use of risk and impact matrices
Quantitative	Result determined using numerical data and by calculation

ABBREVIATION	DESCRIPTION
Reel lay	Pipelines are spooled onto a reel mounted on the deck of a pipelay vessel. During installation offshore, the pipelines are spooled off the pipelay vessel in a continuous process
ROV	Remotely Operated Vehicle
S-lay	Pipeline installation method for larger diameter pipelines and piggybacked pipelines. This involves welding the pipeline joints onboard and feeding the pipeline off the end of the lay-vessel onto the seabed
SAC	Special Area of Conservation under the EC habitats Directive
Sandwave	These are a periodic bottom waviness generated by tidal currents in shallow tidal seas. Typical wavelengths range from 100 to 800m and they can be up to between 1 and 5m high.
Spirit Energy	Spirit North Sea Limited, wholly owned subsidiary of Spirit Energy Limited
UK	United Kingdom
UKCS	United Kingdom Continental Shelf

COMPARATIVE ASSESSMENT - ACCEPTABILITY	
	Broadly acceptable, but nothing of note to differentiate the options
Broadly Acceptable / Low[1] & least preferred	Risks broadly acceptable but controls shall be subject to continuous improvement through the implementation of the HSEQ Management System and in light of changes such as technology improvements; performance in other 'broadly acceptable' options is marginally better
Broadly Acceptable / Low[1] & most preferred	As above but performance in other 'broadly acceptable' options is marginally worse
Tolerable / Medium[1]	Risks are tolerable and managed to ALARP. Controls and measures to reduce risks to ALARP require identification, documentation and approval by responsible leader
Intolerable / High[1]	Impacts are intolerable. Controls and measures to reduce impact to ALARP (at least to Medium) and require identification, documentation, implementation and approval

[1] The colour of this highlighted cell is used in the assessment tables

2 INTRODUCTION

2.1 Overview

The Ensign field lies within the main Southern North Sea (SNS) Gas Province in UK Block 48/14a. The field lies ~109km west of Easington on the coast of Norfolk in water depths of ~25m.

The Ensign gas field was developed using a single installation. The field achieved first production in 2011. The Ensign installation and pipelines are wholly owned by Spirit North Sea Gas Limited. The installation itself is a Not Permanently Attended Installation (NPAI) supported by four-legged conventional piled steel jacket. Until May 2017, gas from Ensign used to be exported to Audrey A using 10" pipeline (**PL2838**) and on to LOGGS using the 20" gas export line PL496. LOGGS used to supply methanol to Audrey A using 3" methanol pipeline PL497 and on to Ensign using 2" pipeline **PL2839**. Both pipelines are ~22.2km long; **PL2839** is piggybacked onto **PL2838**. Decommissioning of PL496 and piggybacked PL497 pipelines are dealt with in the Audrey and Annabel Decommissioning Programmes; these were approved early 2018.

A 10" pipeline (**PL2841**) and umbilical pipeline (**PLU2840**) both ~2.2km long, were also installed for Ensign but never used; these are covered by a Disused Pipeline Notification.

Figure 2.1.1 illustrates the field layout and infrastructure.

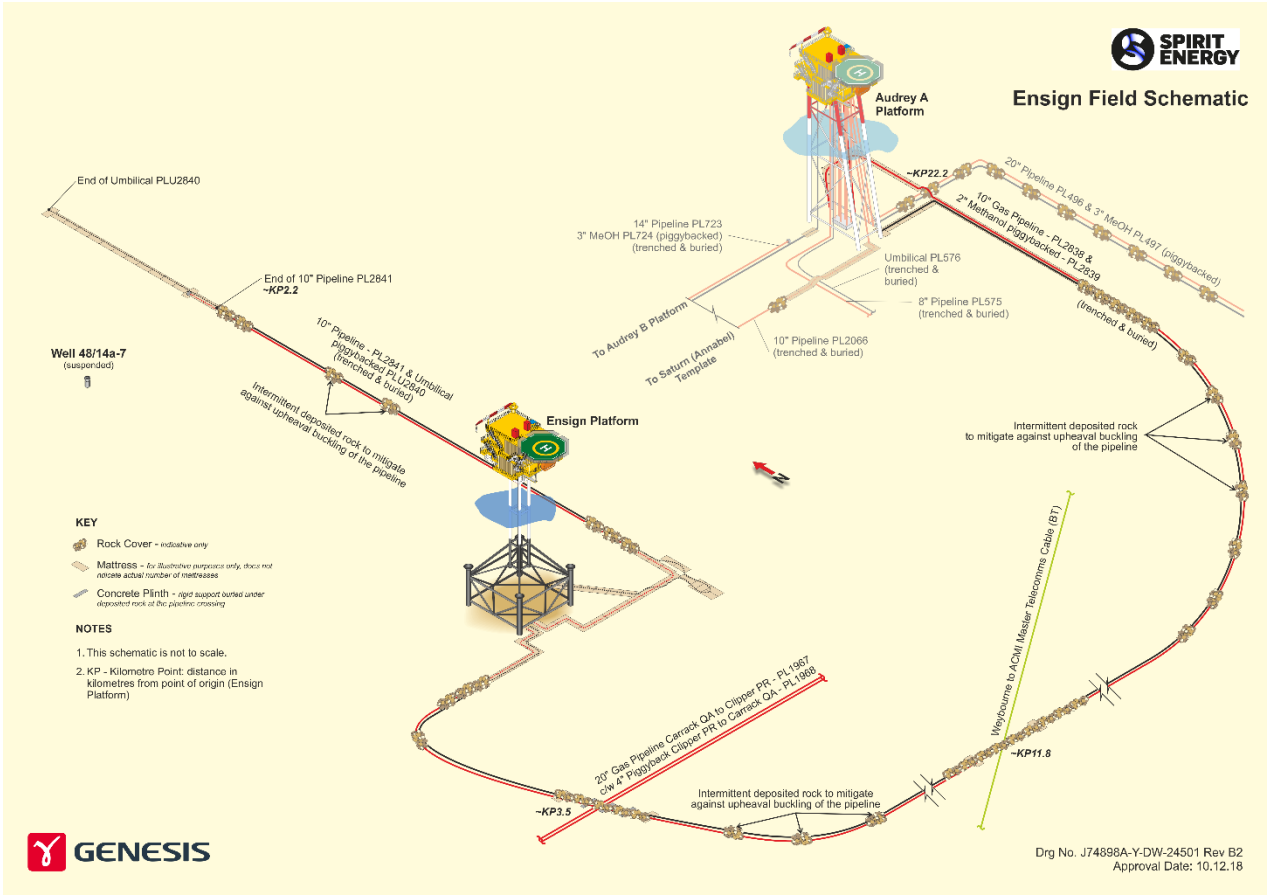

Figure 2.1.1: Ensign Infrastructure Schematic

2.1.1 Infrastructure

PL2838 is the 10" gas pipeline from Ensign installation to Audrey A. The 2" methanol pipeline (**PL2839**) is piggybacked onto the 10" pipeline (**PL2838**) using a series of clamps. The control and chemical injection umbilical pipeline (**PLU2841**) is piggybacked onto the 10" pipeline (**PL2840**).

The infrastructure components of Ensign are:

Pipeline ID	Description, Size & Quantity
PL2838	10” gas pipeline, 22.315km long
PL2839	2” methanol pipeline, piggybacked onto 10” gas pipeline, 22.240km long
PLU2840	Unused control and chemical injection umbilical pipeline (4.8in diameter), 2.190km long
PL2841	Unused 10” gas pipeline, 2.050km long
N/A	For details of the pipelines and stabilisation features please refer Decommissioning Programmes [6]

Table 2.1.1: The Ensign pipeline components

2.2 Purpose

2.2.1 Overview

As the principles are the same, this comparative assessment concerns the options for decommissioning the pipelines. This Comparative Assessment and Environmental Appraisal [7] both support the Decommissioning Programmes [6].

2.3 Environmental Setting

The pipeline area lies in a European Protected Site within the North Norfolk Sandbanks and Saturn Reef SAC and crosses the edge of the Indefatigable Banks and Swarfe Bank and the southern North Sea Harbour Porpoise pSAC. The North Norfolk Sandbanks were formed by tidal processes creating the most extensive example of offshore linear ridge sandbanks in UK waters. The Saturn Reef is a biogenic reef created by Sabellaria spinulosa to the south of the Swarte sandbank [2]. Further details are provided in the environmental appraisal [7].

The North Norfolk Sandbanks are the best example of linear sandbanks in UK waters. The banks are important not only as geological features, but they also support a variety of fish, seabirds and important communities of invertebrates like crabs, starfish and worms.

The area is a feeding ground for thousands of birds who depend on the marine environment for their survival. The seabirds are vulnerable to the effects of hydrocarbon spills all year round, but especially in March, May, July, October and November.

The Ensign field is on the edge of an area protected for harbour porpoise. Two other protected species - common and grey seals can also be found here.

This location is also an important spawning and nursery ground for several different fish species. These include mackerel, herring, plaice, lemon sole, sandeel, sprat, *Nephrops*, whiting and cod. The spawning periods will vary by species throughout the year, but all year round this location is considered sensitive as a nursery for important fish stocks. Fish stocks can be affected by disturbance to the seabed and discharges of chemicals or hydrocarbons.

Harbour porpoise, and white-beaked dolphin have been sighted near the Ensign field.

2.3.1 Seabed

Seabed sediments within the Ensign area comprise silty and gravelly sand. The 10” (**PL2838**) and 2” (**PL2839**) pipelines to Audrey A are completely buried either in natural sediment or deposited rock. The pipelines cross the 20” Carrack QA to Clipper gas pipeline (**PL1967**, piggybacked by the 4” Clipper PR to Carrack QA pipeline (**PL1968**) and the Weybourne to ACMI Master Telecom Cable. The crossing points are covered by deposited rock.

The seabed within the vicinity is generally found to undulate gently, with an average gradient of

<1° and a maximum seabed gradient of 16° associated with megaripples. A minimum water depth of 19.7m LAT was recorded along the **PL2838** and **PL2839** pipeline routes increasing from ~25m LAT at Ensign to a maximum of ~28m LAT near the Carrack pipeline crossing (~KP3.5) before reducing steadily to ~22m LAT at the Weybourne cable crossing (~KP11.8). Thereafter, the seabed comprises seabed ripples increasing in magnitude and average water depth to ~26m LAT at the Audrey A installation.

Water depths along the unused 10" pipeline (**PL2841**) and umbilical (**PLU2841**) increase very gently from ~23m LAT at the end of the deposited rock on approach to the unused well to ~25m LAT at the Ensign installation. The average gradient is less than 1° [1].

The seabed sediments vary considerably along the pipeline route but generally comprised gravelly sands and sandy gravels with localised dense accumulations of gravels, shells, cobbles and boulders observed along the route. The seabed sediments were generally interpreted to comprise sand and gravelly sand around the Ensign installation area and predominantly sand and a gravel along the Ensign ED well to Ensign installation pipeline corridor. Along the Ensign installation to Audrey A (WD) pipeline corridor the seabed sediments were interpreted to comprise predominantly megarippled sand and gravelly sand occasionally present.

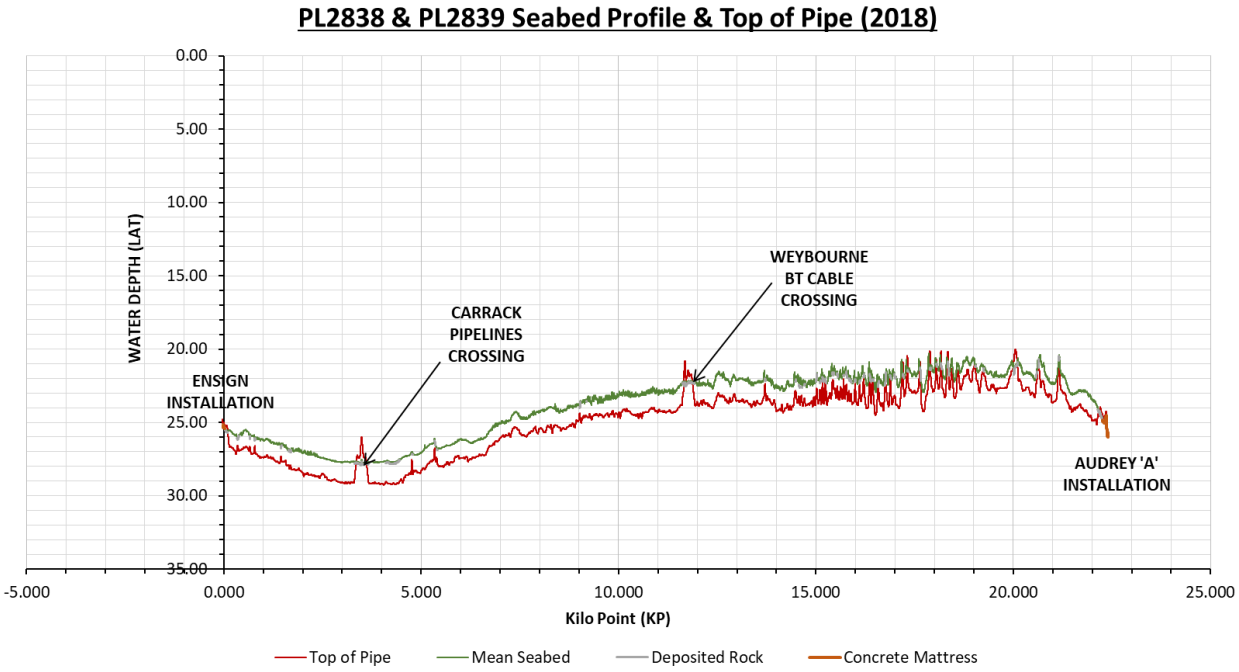

Figure 2.3.1: Seabed Profile for PL2838 & PL2839

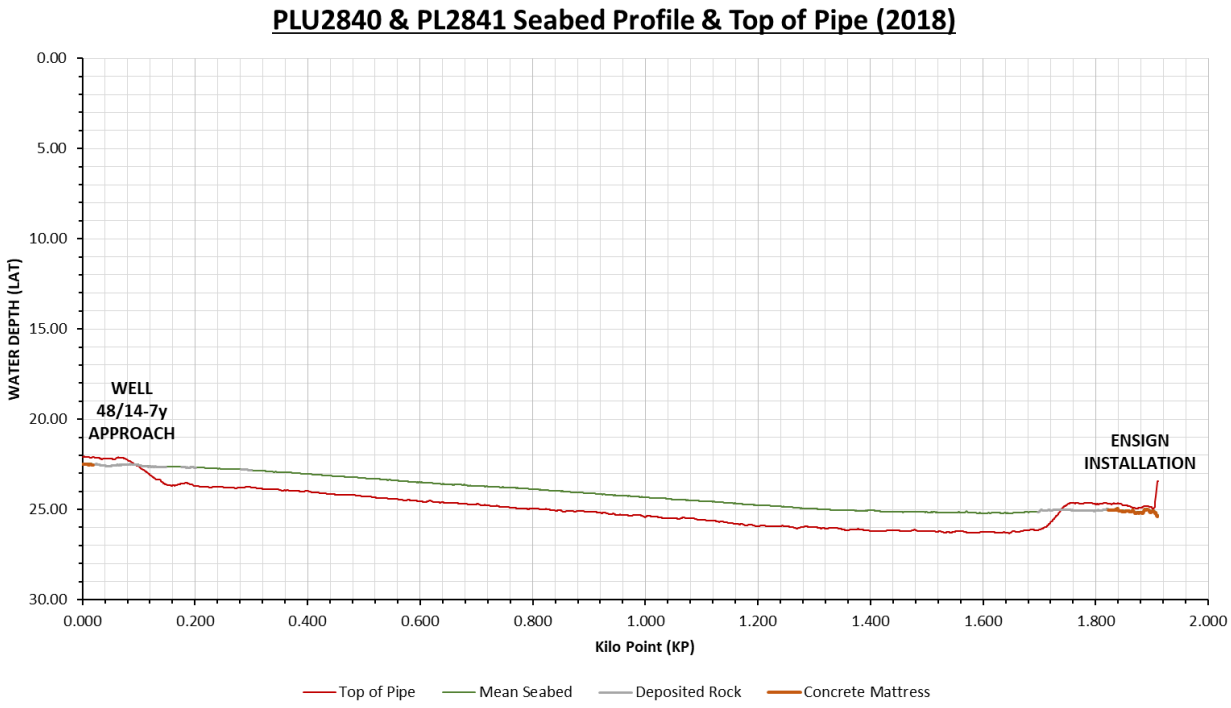

Figure 2.3.2: Seabed Profile for PLU2840 & PL2841

2.3.2 Deposited Rock

Deposited rock is used as a stabilisation and protection feature at various locations along the pipelines, as well as to mitigate upheaval buckling. the locations of which are shown in Figure 2.3.3 and Figure 2.3.4. According to records a total of 21,951Te of rock was used.

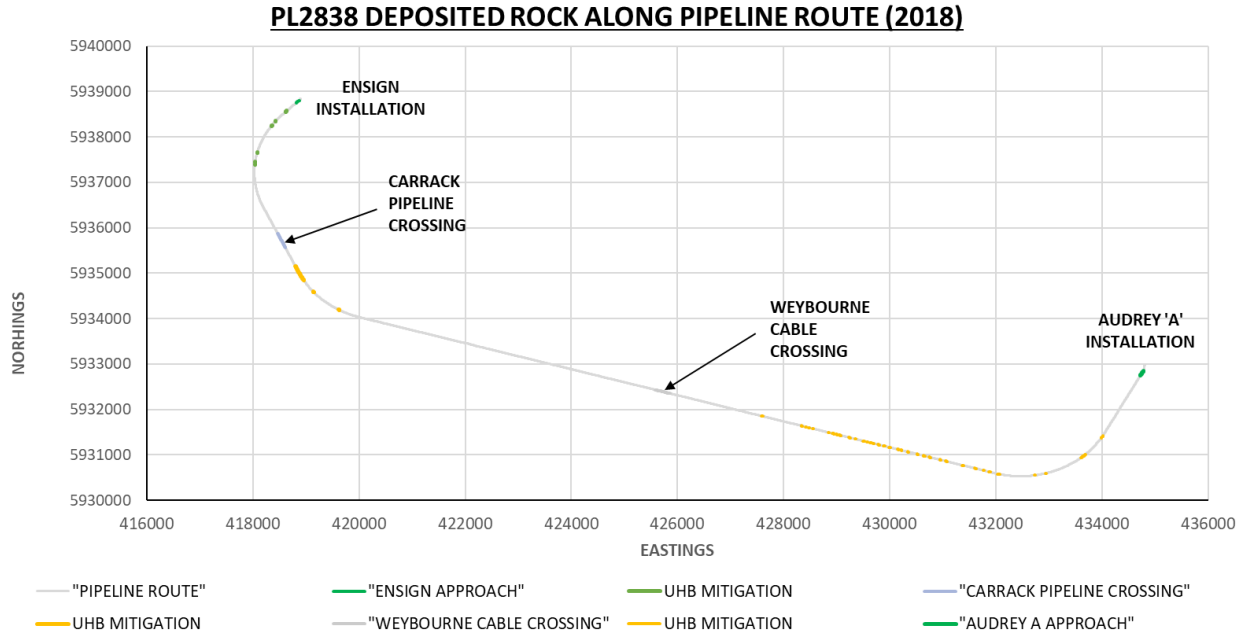

Figure 2.3.3: PL2838 – Locations of deposited rock (2018)

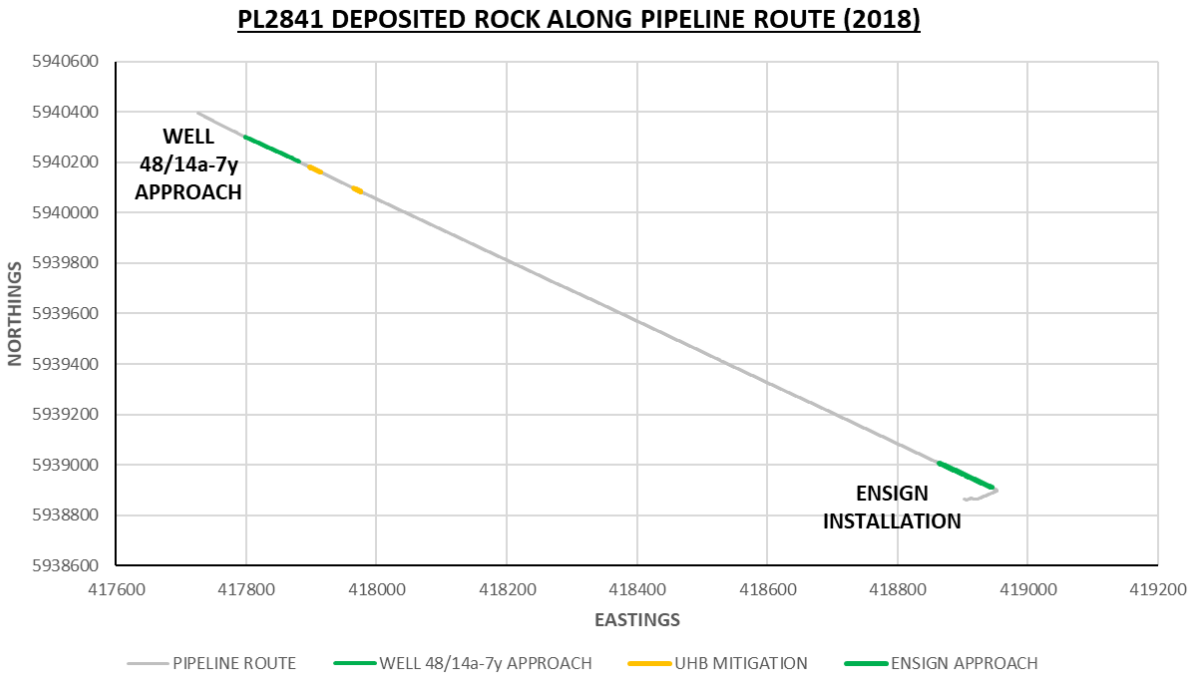

Figure 2.3.4: PL2841 – Locations of deposited rock (2018)

2.3.3 Fate of deposited rock

While it is considered physically possible to remove deposited rock, the decommissioning philosophy in this document is consistent with the Guidance Notes [4], hence all deposited rock will be left *in situ*.

Material left in place will preserve the marine habitat that will have established over the time it has been on the seabed, and in this case its presence will not have a negative impact on the environment or impact on the safety of users of the sea.

Methods that could be used to remove the rock include:

- dredging the rock and disposing of the material at an approved offshore location;
- dredging the rock and transporting the material to shore to be disposed of in an approved manner;
- lifting the rock using a grab, depositing in a hopper barge and transporting it to shore for appropriate disposal.

All the proposed methods would impact on the seabed and associated communities, create sediment plumes, and require additional vessel use with the associated environmental impacts, safety risks, impacts on other users of the sea and additional costs.

2.4 Assumptions, Limitations and Gaps in Knowledge

The most significant assumptions, limitations and knowledge gaps relating to the comparative assessment are listed below. In addition, it should be noted that the presentation of the different categories of risks for comparison has required a degree of engineering judgement.

- A purely qualitative approach has been taken. This has necessarily required a degree of judgement, but since most impacts are related to area impacted, duration of works and vessel time we felt this was appropriate;
- Unless noted otherwise, complete removal of the offshore pipelines would likely be achieved by reverse S-lay or ‘cut and lift’. However, we recognise that there is limited experience of

removing trenched, buried and piggybacked pipelines from the seabed [2], so estimations of the safety risks, technical challenges and cost implications carry some uncertainty;

- The 'complete removal' option assumes that pipelines underneath any pipeline crossing would not be disturbed;
- There are no known exposures on the pipelines outside of the 500m safety zones and Spirit Energy is not aware of any fishing gear snagging reports;
- An environmental survey would be required on completion of decommissioning activities;
- Any offshore pipeline being left *in situ* would be subject to burial surveys;
- Due to the nature of fishing in the area, the seabed sediment type is such that mounds created during any decommissioning operations would not present snagging hazards;
- In the longer-term, deposited rock would not present snagging hazards;
- Demersal fishing is the most prominent type of fishing the area. As well as 'rockhoppers', beam trawling is also used in the area. This type of fishing involves holding the mouth of a fishing net open with a 9-12m long beam[2] that slides over and disturbs the seabed;
- The impact of the procurement of any new materials such as fabricated items or mining of new rock is ignored;
- Impact on commercial activities is inversely proportional to vessel activity;
- Societal benefits and vessel associated environmental impacts and risks are assumed to be proportional to duration of vessel or vehicle use;
- Only a high-level comparison of what differentiates the costs is used.

[2] Typically, this is constructed from a heavy steel tube.

3 THE PIPELINES

3.1 PL2838 10” Pipeline from Ensign to Audrey A

PL2838 is the 10” gas export pipeline approximately 22.3km long overall, and it is piggybacked with **PL2839** (~22.2km long). That is, the 3” methanol pipeline **PL2839** is connected to **PL2838** using clamps. **PL2838** is routed from the Ensign installation to Audrey A (WD) and from there gas used to be comingled with gas from Audrey A (WD) and transported via **PL496** to LOGGS Production Platform. At ~KP3.5 the pipelines cross over the 20” Carrack QA to Clipper PR gas export pipeline and 4” piggybacked Clipper PR to Carrack QA MEG pipeline. At ~KP11.8 the pipelines cross over the Weybourne to ACMI Master cable. When the pipelines were installed the area was pre-swept to the trough of the sandwaves and the depth of pipeline lowering was measuring from the bottom of the trough of the sandwaves. Both pipelines exhibit a good depth of burial and cover along their original trenched and buried lengths.

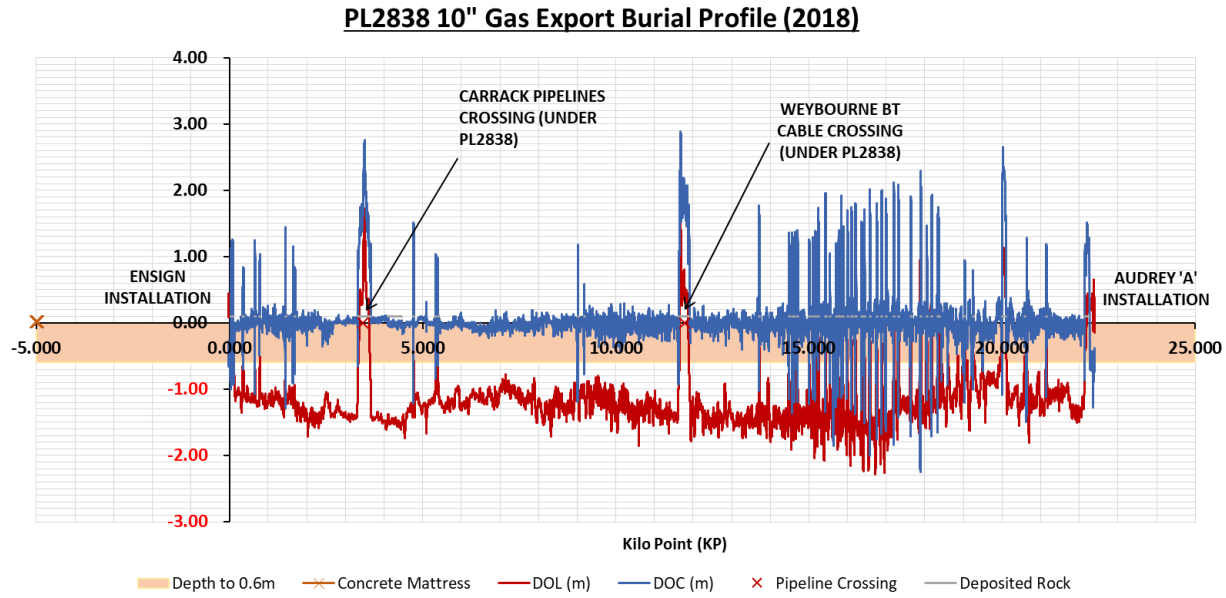

Figure 3.1.1: PL2838 & piggybacked PL2839 burial profile

The OPRED Guidance Notes [4] state that in most cases burial or trenching to a minimum depth of 0.6m above the top of the pipeline is necessary for pipelines decommissioned *in situ*. Notwithstanding where the pipelines lie on the seabed and are protected by concrete mattresses, both pipelines are buried to a depth greater than 0.6m below mean seabed and are stable.

3.2 PL2841 Unused pipeline from Well P1 to Ensign

PL2841 is the 10” gas export pipeline approximately 2.2km long overall, and it is piggybacked by PLU2840, an umbilical pipeline. That is, **PLU2840** is connected to **PL2841** using clamps. **PLU2840** is routed to the end of the concrete mattresses on approach to the suspended subsea well, whereas **PL2840** terminates at the end of the deposited rock. Both pipelines exhibit a good depth of burial and cover along their original trenched and buried lengths.

The OPRED Guidance Notes [4] state that in most cases burial or trenching to a minimum depth of 0.6m above the top of the pipeline is necessary for pipelines decommissioned *in situ*. Notwithstanding where the pipeline and umbilical lie on the seabed and are protected by concrete mattresses, both pipelines are buried to a depth greater than 0.6m below mean seabed and are stable.

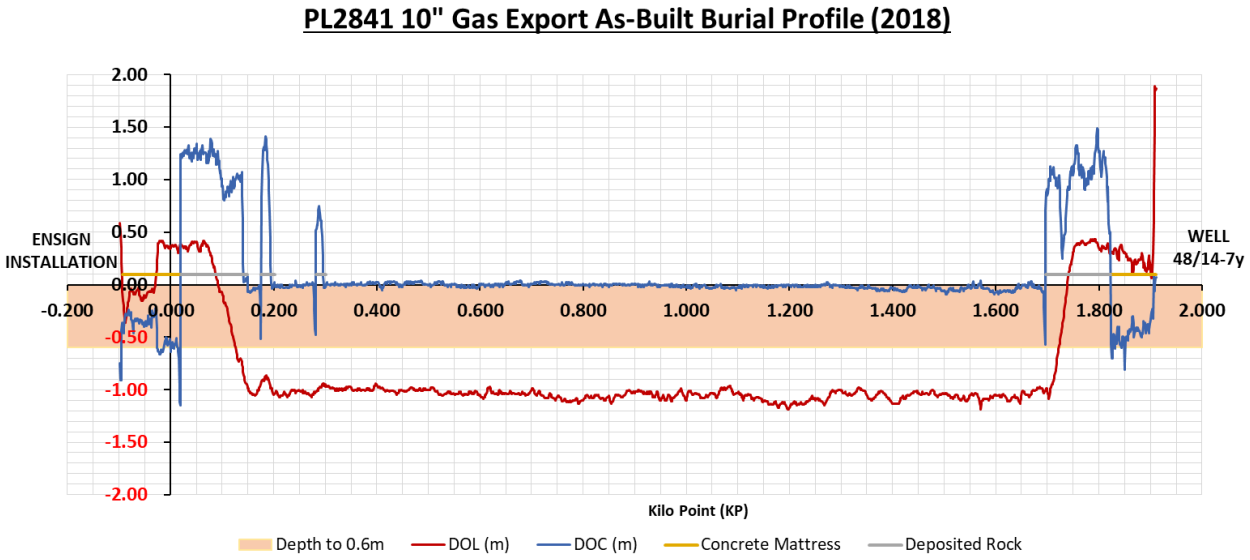

Figure 3.2.1: PL2841 & piggybacked PLU2840 burial profile

Outside of the respective installation 500m safety zones two pipeline crossings have been identified and are shown in Appendix B and listed in Table 3.2.1.

Pipeline or Cable Description	KP	Protection
20" Carrack QA to Clipper PR gas export pipeline (**PL1967**) and 4" piggybacked Clipper PR to Carrack QA MEG pipeline (**PL1968)**	3.5	2x concrete mattresses (6 x 3 x 0.3m) and concrete plinths (2x Type 1 and 2x Type 2) overlain with deposited rock, ~346m long.
Weybourne to ACMI Master cable	11.8	2x concrete mattresses (6 x 3 x 0.3m), 2 x 6 x 3 x 0.15m) overlain with deposited rock, ~289m long.

Table 3.2.1: PL2938 and PL2839 pipeline and cable crossings

3.3 Pipeline crossings

The pipelines considered in this comparative assessment cross over pipelines and cables installed previously as illustrated in Figure 3.3.1. For oil and gas related infrastructure, this can usually be determined by the pipeline number. The higher pipeline number crosses over the top of a pipeline with a lower identification number, so for example, **PL2838** crosses over **PL1967**.

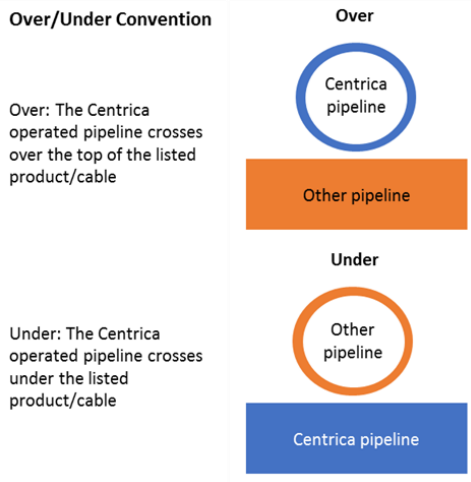

Figure 3.3.1: Over/under convention for pipeline crossings

4 DECOMMISSIONING OPTIONS

4.1 Decommissioning the pipelines

The options detailed in this section are those that have been included in the comparative assessment process. The concrete coated pipeline and methanol line are piggybacked and connected by a series of clamps along their length. Therefore, the options for decommissioning between both are interrelated, so both pipelines are considered as one unit. There would be complications associated with separating the pipelines should they be recovered.

There is an implicit assumption that options for re-use of the pipelines have been exhausted prior to the facilities moving into the decommissioning phase and associated comparative assessment; therefore, this option has been excluded.

The options considered for decommissioning the pipelines are:

- **Complete removal** – Complete removal of the piggybacked pipelines by reverse S-lay[3], or by 'cut and lift';
- **Leave *in situ*** – Leaving the majority of both the pipelines *in situ* underneath existing burial cover. The end of the offshore section of the pipelines at the Ensign installation will be cut and removed from the point where the pipeline exits the deposited rock.

Since the decommissioning of the pipeline approaches at the Ensign and Audrey A installations and the unused Ensign subsea well would be the same irrespective of which option is pursued, decommissioning of these is not included in the assessment. All options include removal of features such as spool pieces, concrete mattresses and grout bags in accordance with mandatory requirements. Deposited rock that covers the pipelines along with any concrete mattresses buried underneath will remain *in situ*.

For both options the pipeline and cable pipeline crossings and associated mattresses buried under deposited rock will remain *in situ* (Figure A.1.1 and Figure A.2.1). The difficulties associated with recovering **PL2838** and **PL2839** in these areas have not been given undue prominence in the overall assessment.

Further details of the pipeline decommissioning options are shown in Table 4.1.1. Most of the activities detailed in these tables are expected to be undertaken using a suitable vessel such as a pipelay vessel, a Diving Support Vessel or a Construction Support Vessel.

[3] The reverse S-lay technique would involve recovering both pipelines to the vessel before separating the clamps and cutting the pipelines into manageable lengths for transporting onshore. Ideally, this would be a continuous process.

Item	Option 1 Complete Removal	Option 2 Leave *In situ*
The short-exposed end sections of the 10" pipeline **PL2838** (length ~55m) and piggybacked 2" pipeline **PL2839** (length ~58.5m) lying on the seabed between the Ensign installation risers and deposited rock.	Remove. *After recovering the overlying concrete mattresses, recover using 'cut and lift' method, deployed using a CSV or DSV.*	Cut and remove. *Use ROV to cut the pipelines from risers. This may also involve a small amount of local clearance using water jetting.*
10" pipeline **PL2838**, piggybacked by 2" pipeline **PL2839** including ends buried under deposited rock at pipeline and cable crossings and on approach to Ensign and Audrey A installations; total length ~22.1km.	Remove. *Reverse installation of the pipelines most likely using a pipelay vessel for larger deck storage capacity. Uncover the pipeline(s) ahead of removal operations using dredging machine; recover pipelines with a winch through a stinger to the pipelay vessel. Remove piggy back clamps to allow separation of the 2in & 10in pipelines onto laydown area. Cut pipelines into transportable lengths and store on deck. Return pipes to shore for processing.*	Leave *in situ.* No work
The short-exposed end sections of the 10" pipeline **PL2838** (length ~122m) and piggybacked 2" pipeline **PL2839** (length ~103m) lying on the seabed between the deposited rock and the Audrey A installation risers.	Remove. *After recovering the overlying concrete mattresses, recover using 'cut and lift' method, deployed using a CSV or DSV*	Cut and remove. *Use ROV to cut the pipelines from risers. This may also involve a small amount of local clearance using water jetting.*

Table 4.1.1: PL2838 and PL2839 pipeline decommissioning options

Item	Option 1 Complete Removal	Option 2 Leave *In situ*
The short-exposed end sections of the 10" pipeline **PL2841** (length ~131m) and piggybacked 2" pipeline **PLU2840** (length ~81.2m) lying on the seabed between the respective Ensign installation riser and J-tube and deposited rock.	Remove. *Disconnect umbilical from TUTU recover from J-tube and after recovering the overlying concrete mattresses, cut pipe spools and umbilical using 'cut and lift' method, deployed using a CSV or DSV.*	Cut and remove. *After recovering the overlying concrete mattresses use ROV to cut the pipelines from risers. This may also involve a small amount of local clearance using water jetting.*
10" pipeline **PL2841**, piggybacked by umbilical pipeline **PLU2840** including ends buried under deposited rock at Ensign and on approach to the Ensign subsea well; average length ~1.96km.	Remove. *Reverse installation of the pipelines most likely using a pipelay vessel for larger deck storage capacity. Uncover the pipeline(s) ahead of removal operations using dredging machine; recover pipelines with a winch through a stinger to the pipelay vessel. Remove piggy back clamps to allow separation of the 3in & 16in pipelines onto laydown area. Cut pipelines into transportable lengths and store on deck. Return pipes to shore for processing.*	Leave *in situ.* No work
The short-exposed end of the umbilical pipeline **PLU2840** (length ~114m) lying on the seabed between the deposited rock and on approach to the Ensign subsea well. On approach to the Ensign subsea well the 10" pipeline **PL2841** does not extend past the end of the deposited rock.	Remove. *After recovering the overlying concrete mattresses, remove umbilical using 'cut and lift' method, deployed using a CSV or DSV.*	Cut and remove. *After recovering the overlying concrete mattresses, use ROV to cut the pipelines from risers. This may also involve a small amount of local clearance using water jetting.*

Table 4.1.2: **PLU2840** and **PL2841** pipeline decommissioning options

4.2 Decommissioning of the concrete mattresses

The intention would be to remove all the exposed concrete mattresses not buried under deposited rock. The concrete mattresses in this area comprise various masses.

These are made of articulated blocks that are constructed by casting concrete into moulds, with polypropylene rope or nylon rope used to link the blocks together. In the case of Ensign, all mattresses are 6m x 3m, but the nominal mass of the mattresses vary, and are as follows:

- Half-thickness mattress (6m x 3m x 0.15m – 5.3 Tonnes;
- Standard density mattress (6m x 3m x 0.3m) – 8.3 Tonnes;
- Mixed density mattress (6m x 3m x 0.3m) – 8.8 Tonnes; and,
- High density Mattress (6m x 3m x 0.3m) – 10.4 Tonnes;

At the Carrack pipeline crossing there are several concrete plinths installed and covered with rock:

- Concrete plinth type 1 (6m x 2.4m x 1.2m high) – 13.3 Tonnes;
- Concrete plinth type 2 (6m x 2.4m x 1.0m high) – 13.8 Tonnes; and,
- Concrete plinth type 3 (6m x 2.4m x 0.6m high) – 15.3 Tonnes.

For further details please refer Appendix A and Appendix B, and the Decommissioning Programmes.

5 COMPARATIVE ASSESSMENT FOR PIPELINES

5.1 Method

Much of the comparative assessment is qualitative but carried out with enough detail to differentiate the options. However, in some cases, such as cost, it is necessary to examine the differences in more detail and quantitatively to provide clarity. The comparative assessment considers the following generic evaluation criteria and specific sub-criteria in line with OPRED [4] and Spirit Energy's Comparative Assessment Guidance. These elements are considered for short-term work as the assets are decommissioned as well as over the longer-term as 'legacy' risks and impacts.

- Health & Safety:
  - Health & Safety risk to offshore project personnel during offshore execution;
  - Health & Safety risk to mariners;
  - Health & Safety risk to onshore disposal project personnel.
- Environment:
  - Environmental impacts of operations during offshore works;
  - Environmental impacts due to legacy aspects that would be addressed over the longer-term.
- Technical:
  - Risk of major project failure reflecting the complexity of the job;
- Societal:
  - Effect on commercial activities;
  - Employment;
  - Communities or impact on amenities.
- Cost.

Environmental impacts include consideration of such impacts on the atmosphere, protected sites and species, coastal process, seabed the water column and waste in the short-term due to project related activities and over the longer term due to legacy activities offshore.

No scores have been determined but risk matrices have been used to determine if the planned and unplanned impacts would be for example broadly acceptable, possibly acceptable, unlikely to be acceptable or not acceptable. Cells coloured red indicate high risk or high impact and less desirable outcomes. Green coloured cells indicate less risk, less impact and more desirable outcomes. Cells coloured orange sit in-between red and green and may or may not be less, or more, desirable. High costs also attract a 'less desirable outcome' but any differences in cost are compared relative to each other. A relatively high cost therefore would be coloured red whereas a relatively low cost would be coloured green. It should be noted that societal score looked at beneficial as well as detrimental outcomes.

The following paragraphs describe the philosophy and processes followed for the Comparative Assessment using generic, high level evaluation sub-criteria. The results of the assessment are summarised in Sections 6 and 7.

5.1.1 Technical Assessment

The technical assessment is concerned with the risk of major project failure. Technical feasibility confirms whether the method being assessed is physically possible given the technical issues that would be encountered.

The technical evaluation is simply the application of a measure to express the complexity of a job, which can be expected to proceed without major consequence, or failure, if it is adequately planned and executed.

5.1.2 Health & Safety Assessment

Definition: An assessment of the potential health and safety risk to people directly or indirectly involved in the programme of work, or who may be exposed to risk as the work is carried out. Health & safety risk is assessed using three specific sub-criteria.

Sub-criteria:

1. The health and safety risks for project personnel engaged in carrying out decommissioning activities offshore are presented in Table 5.1.1:

Example Description of Hazard	Who or What is at Risk?
Loss of control leading to uncontrolled movement of vessel and pipeline(s), hydrocarbon release, dropped objects	Diving personnel underwater
Limited experience surrounding the process for recovering piggybacked pipelines that are trenched and buried. Pipeline parting or buckling during reverse S-lay operations; fragmenting of the concrete coating during recovery, failure of pipe clamps, uncontrolled movement of pipelines and associated recovery equipment	Vessel-based personnel
Sudden movements during pipeline recovery works leading to dropped objects or swinging loads	Diving personnel, vessel-based personnel, vessel-based assets (e.g. ROVs), subsea infrastructure
Collision between vessels and offshore structures due to mix of shipping lane traffic, product transport vessels, supply and maintenance barges and boats, drifting boats	Offshore personnel and assets
Residual hazardous materials such as methanol, chemicals from umbilical cores, hydrocarbons or NORM from within pipelines released to the local marine environment	Divers and vessel-based personnel

Table 5.1.1: Description of offshore hazards

2. The residual risks to marine users on successful completion of each decommissioning option are presented in Table 5.1.2:

Example Description of Hazard	Who is at risk?
Exposed pipeline sections leading to snagging risk; exposed pipeline floating to surface near shore	Other users of the sea, predominantly fishing vessels

Table 5.1.2: Description of residual hazards to mariners

3. The safety risks for project personnel engaged in carrying out decommissioning activities onshore are presented in Table 5.1.3:

Example Description of Hazard
Residual hazardous materials such as methanol, hydrocarbons or NORM from within pipelines released to the local onshore environment
Onshore cutting – sharp edges and repetitive operations when dismantling pipelines. Fragmenting of the concrete coating
Vehicular collisions when executing the work
Unplanned sudden movements during pipeline dismantling and recovery works leading to dropped objects or swinging loads
Unplanned collapse of cofferdams, or cliff protection

Table 5.1.3: Description of onshore hazards

5.1.2.1 Assessment of sub-criteria:

The difference in potential safety risks between the options is sufficiently large that a HAZID was not deemed to be required at this stage. A Hazard Identification (HAZID) workshop will be carried out when the selected option is developed during detailed design and execution. For the purposes of the comparative assessment we examined the differences and took account of the duration of activities that would be required.

As many of the hazards are common between the complete removal and the partial removal options, only those hazards giving rise to difference between the options were assessed. Examples of this are:

- Where a hazard exists for one option but not the other (e.g. risks relating to pipeline failure during reverse S-lay recovery);
- Where the hazard exists for both options but is different in magnitude (e.g. risks relating to dropped objects if whole pipelines are recovered to shore and then to be cut into transportable pieces).

5.1.3 Environmental Impact Assessment

The comparative assessment uses two sub-criteria for the assessment of environmental impacts. These are described below.

Definition: An assessment of the significance of the risks/impacts to the environmental receptors because of activities or the legacy aspects. Environmental impact is assessed using the following specific sub-criteria.

Sub-criteria:

1. Short-term environmental impacts of operational activities;
    - Emissions to atmosphere;
    - Effect on seabed;
    - Effect on protected areas such as SAC;
    - Effect on water column;
    - Waste.
2. Legacy environmental impacts due to what would be left behind
    - Emissions to atmosphere;
    - Effect on seabed;
    - Disturbance to protected areas;
    - Effect on water column;
    - Waste.

5.1.3.1 Assessment of sub-criteria:

The environmental assessment considers the impacts of the decommissioning options. Environmental impacts include consideration of such impacts on the atmosphere (energy and emissions), beach and seabed (area impacted, and material mobilised into water column), the water column (vessel discharges and effect of material lifted in the water column) and waste (fate and quantity of material) in the short-term due to project related activities and over the longer–term due to legacy activities offshore.

Only the *differentiators* between decommissioning options were included in the overall assessment.

The sub-criteria are qualitative and assessed per the Spirit Energy Environmental Impact Assessment table. Based on experience we can conclude that energy use and the associated emissions to air are unlikely to significantly contribute to greenhouse gas emissions or global warming impacts as by way of example, they are likely to be a very small percentage of the total CO_2 produced from domestic shipping.

An assessment of the environmental impacts of the selected decommissioning option can be found in the Environmental Appraisal [7].

Sub-criteria definitions:

1. Environmental impacts of operations

The severity of environmental risks associated with unplanned events or the impact to the marine and terrestrial environments from planned operational activities.

2. Legacy environmental impacts

The severity of environmental risks associated with unplanned legacy events or the impact to the marine and terrestrial environments from planned legacy activities.

Note that the emissions to air and energy requirements are *representative* - although not quite the same, of the fuel and energy input data used for waste handling activities.

The environmental assessment was developed by identifying the interactions with the environment for the activities required for each of the options. Activities that were not differentiators were screened out. Those remaining activities with associated interactions with the environment were assessed for consequence and duration to ascertain the potential level of significance of the environmental impact. The interactions with the environment were grouped into the four-comparative assessment sub-criteria but the assessment remains qualitative.

5.1.4 Societal Impact Assessment

Definition: An assessment of the significance of the impacts on societal activities, including offshore and onshore activities associated with the complete programme of work for each option and the associated legacy impact. This includes all the “direct” societal effects (e.g. employment on vessels undertaking the work) as well as “indirect” societal effects (e.g. employment associated with services in the locality to onshore work scope, accommodation, etc.).

Sub-criteria:

1. Effects on commercial activities;
2. Employment;
3. Communities and impact on amenities;
4. Infrastructure and Resource Use (onshore execution work only);
5. Traffic (onshore execution work only).

5.1.4.1 Assessment of sub-criteria:

A qualitative assessment has been undertaken to differentiate between options from a societal perspective. This was undertaken through review of relevant data, discussion and textual descriptions.

5.1.5 Cost Assessment

Only the incremental costs of the main offshore decommissioning activities are compared, with owners' costs such as engineering, management, insurance, procurement and logistical costs contributing to the difference as a percentage (12.5%) of the offshore work. To simplify the assessment, we have concentrated on the different vessel types that would be required for a specific activity and how long the vessel would be required for. Although different for different activities, common elements such as mobilisation costs and decommissioning of pipeline ends are not included on the assumption that they would be much the same irrespective of which option was being pursued.

For this assessment, complete removal represents the full scope and the leave *in situ* option is compared to this.

We compare the difference in cost for like-for-like activities in the short-term as well as for legacy related activities in the longer-term. From a legacy perspective, all decommissioning options would involve carrying out an environmental survey at the end, so this would not differentiate the costs over the longer-term, but legacy survey costs will be different depending on the option. For example, no legacy surveys would be required for the complete removal option.

This shows the difference in incremental cost as being comparable to the other evaluation criteria (i.e. safety, environmental, technical and societal) and it allows an understanding of the *significance* of the difference.

In the assessment tables that follow we indicate the acceptability or otherwise of the costs. We do, however, recognise that the cost of an option would only be *acceptable* if the other aspects of the comparative assessment show that this would be preferred.

If the incremental difference in cost for one option is assessed to be an order of magnitude greater than the other options being considered it is assessed as being 'Tolerable & non-preferred'.

6 COMPARATIVE ASSESSMENT FOR PL2838 & PL2839

PL2839 the smaller 2" methanol line is connected to **PL2838** the 10" pipeline using a series of clamps. Therefore, we have combined the comparative assessment for both, noting any differences that may arise.

6.1 Technical Assessment

Both decommissioning options – complete removal and leave *in situ*, are technically feasible, although complications would result in the complete removal option being less viable. Complete removal of the pipeline would need to be achieved either by reverse reel, reverse S-lay or by using the 'cut and lift' method of recovery.

All three options were considered for **PL2838/9**, and theoretically, given the right conditions - for example, no integrity issues can be foreseen – all options can be considered technically feasible for both pipelines, although the reverse reel and reverse S-lay methods would need to be preceded by rigorous integrity inspections beforehand.

Either removal method would involve excavating a trench up to 2m deep to recover the pipelines and lifting them up out of the trench. This would need to be achieved either as a continuous process using reverse reel or reverse S-lay or as an incremental process using 'cut and lift', remembering that the 10" pipeline is piggybacked by the 2" pipeline.

The 'cut and lift' method has been used for recovery of short individual pipeline sections already in the southern North Sea, but not for piggybacked pipelines that are trenched and buried. The method would likely be avoided for removing such a long pipeline.

Reverse reel and reverse S-lay would involve separating the pipelines as they arrive on the vessel although it is likely that the piggyback clamps would disintegrate as the pipelines reach the recovery vessel. Using reverse reel, the pipelines would then be spooled back onto separate reels, while the reverse S-lay method would involve cutting them into lengths suitable for transporting onshore, while the 'cut and lift' method would probably involve cutting the pipelines inside the trench before lifting the cut lengths of pipe to a suitable vessel for transporting to shore. Either method would be challenging for single pipe trenched and buried pipelines, but more so for pipelines that are piggybacked. To our knowledge there is little to no experience in removing pipelines that are concrete coated, trenched, buried and piggybacked with another pipeline in the UKCS [2], and as such the technical uncertainty associated with either removal option will likely have an adverse impact on technical efficacy.

The complete removal option is particularly complicated with plenty of technical issues to consider, and the technical uncertainties associated with the pipeline decommissioning options have been assessed using the risk assessment matrix in the comparative assessment guidance, the results of which are presented in Table 6.1.1 below.

Sub-Criterion	Complete removal	Leave *in situ*
Technical feasibility	**Short-term:** Limited experience in the North Sea of reverse reel or reverse S-lay removal of trenched, buried and piggybacked pipelines, and the 'cut and lift' method would likely be avoided for such a long pipeline.	**Short-term:** Stable and buried pipelines have been left *in situ* before and we know this is achievable.
	Legacy: No pipeline surveys would be required in future.	**Legacy:** Pipeline surveys have been undertaken in the past, so this is achievable with no complications.

Table 6.1.1: PL2838/9 Technical Assessment

All things considered, from a purely technical perspective, the 'cut and lift' method would likely be the most viable but only for relatively short-lengths of pipeline.

In practical terms *in situ* decommissioning would be easier to achieve technically. There would be significant technical uncertainties that would need to be overcome for the complete removal option to be considered viable.

6.2 Health & Safety Assessment

Safety Risk to Offshore Project Personnel

The key differences between the options are as follows.

- Risk to personnel on vessel from hydrocarbon or hazardous substance releases from recovered pipelines will be greater for complete removal than for leave *in situ* due to the much larger volume of material that would be recovered;
- Risk of handling large mass of pipeline and associated concrete coating that could fall
- Risk associated with reverse reel, reverse S-lay or 'cut and lift' operations, with the pipelines separated as they arrive at the pipelay vessel, and with the vessel being attached to the pipelines. The risk to personnel and assets is greater for the complete removal option compared to the leave *in situ* option;
- Increased risk to all activities due to adverse weather is greater for complete removal than for leave *in situ* as the time the vessel would be in the field is greater for complete removal than for leave *in situ*;
- Risk associated with legacy survey activities, that is the risks associated with vessels being used, is greater for leave *in situ* than for complete removal. Typically, a minimum of two legacy surveys would be required to confirm the condition of subsea facilities left *in situ*.

The 'cut and lift' method of removal has been used in the North Sea, albeit for relatively short lengths of pipeline. It is presumed that the risks from all hazards are tolerable if managed to ALARP but non-preferred when using reverse reel, reverse S-lay or 'cut and lift' methods of recovery. 'The 'cut and lift' method of removal - although likely viable for short-lengths of pipeline, would not be viable for the complete removal of a trenched and buried pipeline ~22.2km long that is piggybacked by a smaller pipeline. There is little to no experience of reverse S-lay for a concrete coated, trenched, buried and piggybacked pipelines and we believe therefore this risk could be higher but still tolerable if appropriate mitigation and control measures are adopted to manage the work to ALARP. This risk relates only to the complete removal option.

Operational and Legacy Safety Risk to Fishermen and Other Marine Users

There remains the possibility of interaction with other mariners while decommissioning works are being carried out in the field and this potentially would increase with the number of vessels, the location of the work and the frequency of marine traffic. Decommissioning activities involve vessels working in the field, and over the longer term will be related to the duration and number of surveys and any pipeline remedial works that may be required in future. By way of example, for **PL2838/9** the vessel durations associated with the complete removal options will be much longer than for leave *in situ*.

Decommissioning activities that minimise disturbance to the seabed will reduce the likelihood of creating new snag hazards and avoid leaving an open trench. Decommissioning activities that leave the seabed free of equipment will minimise the impact on local fishing activities. Complete removal will leave the seabed free of equipment, while leave *in situ* will present a situation like that currently existing. Although the complete removal option has the potential to leave open trenches that could present snagging hazards, based on the recovery observed since installation, these can be expected to disappear over time.

The risk of snagging fishing gear and the risk of snagging equipment were assessed as broadly acceptable. The key differences between the options are:

- There would be a small risk of snagging static fishing gear on the pipeline in future for leave *in situ* should the burial status change, but this would be eliminated for complete removal;

- For the situation where the pipelines are left *in situ*, legacy surveys will likely be required. Legacy surveys will have risks associated with the use of vessels that are not required for the complete removal option, but their work is routine. Legacy related survey vessels would be in the field for much less time than vessels involved in the complete removal activities; but the difference in risk can be expected to be relatively small.

Health & Safety Risk to Waste Handling Project Personnel

Both pipelines are constructed using materials that would need to be separated and segregated onshore for recycling.

All hazards associated with the handling of the fully recovered pipelines were assessed as 'low and broadly acceptable' but least preferred. The key differences between the two decommissioning options for each are as follows:

- Risks associated with handling the pipelines - resulting in injury, would far greater for complete removal due to the quantity of material returned to shore compared with the leave *in situ* option;
- Exposure to potentially NORM contaminated materials increases with the volume of material recovered;
- Risks associated with dealing with any residues within either pipeline would be greater for complete removal.

The assessment for the piggybacked pipelines is summarised in Table 6.2.1.

Sub-Criterion	Complete Removal	Leave *in situ*
Health & safety risk offshore project personnel	**Short-term:** More offshore work than leave *in situ*. Excavation of the pipeline. No experience in the UKCS of either reverse reel or reverse S-lay of piggybacked, trenched and buried pipelines as a method of removal although there is some experience of using the 'cut and lift' method for short pipelines.	**Short-term:** Only the pipeline ends would be dealt with; Less offshore work than for complete removal. Experience in the UKCS a of removal of pipeline sections. Significantly shorter than for complete removal.
	Legacy: No pipeline surveys or remediation related activities.	**Legacy:** Pipeline surveys will be required, but this activity is considered routine with well managed risks and will be of short duration.
Health & safety risk to mariners	**Short-term:** Duration of vessels in the field is longer than for leave *in situ*. Reverse S-lay means that the vessel is attached to the pipeline and can't move out of the way quickly. The risk to mariners in the short term is aligned with the duration the activities are undertaken in the field.	**Short-term:** Only the pipeline ends would be dealt with; Duration of vessels in the field would be shorter than for complete removal.
	Legacy: No infrastructure left therefore no residual snag hazards. Lower risk as potential snag hazards completely removed. Static fishing gear will not interact with the any temporary trench.	**Legacy:** Post decommissioning surveys and existing data will provide evidence that any pipeline spans or exposures are limited, and therefore the risk to mariners from snagging is low. Degradation of the pipeline if it remains buried, doesn't change the risk. If exposures occur the degradation could change the risk, but only static fishing equipment is used in this area of the southern North Sea.
Safety risk onshore project personnel	**Short-term:** Safety risk is linked to the mass of material returned to shore. Therefore, there would be significantly more onshore cutting, lifting and handling for complete removal than for leave *in situ*.	**Short-term:** No onshore work.
	Legacy. Nothing to differentiate the options.	

Table 6.2.1: PL2838/9 Health & Safety Assessment)

Many of the hazards described above are common to both decommissioning options. Based on

the differences, in the short-term the leave *in situ* option gives rise to lower risks to project personnel for the following three reasons:

- Less offshore work;
- Less handling of materials once onshore;
- Little to no experience in the removal of trenched and buried pipelines that are piggybacked by another pipeline in the UKCS [1], increasing the perceived risk.

By leaving the pipelines *in situ* residual snagging risks will remain, albeit low due to the type of fishing activity in the area. By completely removing the pipelines the risk of snagging by pipeline is removed in perpetuity. Therefore, the complete removal option results in lower residual risks to mariners and other users of the sea. Fundamentally however, we believe that there is little to choose between the options from a safety perspective whether in the short or longer term.

6.3 Environmental impact of operational activities

The duration vessels for complete removal of the piggybacked pipelines would be longer than for the leave *in situ* option. The leave *in situ* option would result in least vessel time working in the field. The impact of this on liquid discharges to sea, noise, emissions to air and energy requirements, water column, seabed, waste, etc. are summarised in Table 6.3.1.

Environmental factors impacted	Complete removal	Leave *in situ*
Atmosphere (energy & emissions)	**Short-term:** Emissions to air is aligned with the duration the activities are undertaken in the field. Duration of vessels in the field is longer than for leave *in situ*. Emissions and use of energy greatest for this option but no offset would be generated because of the energy and emissions needed to create new material to replace any that may be left *in situ*.	**Short-term:** Least amount of energy used, and lowest emissions generated in the short-term, although this is slightly counteracted by the energy and emissions required to create new material.
Seabed disturbance; area affected	**Short-term:** The amount of seabed disturbed is directly related to the length of pipeline being removed and extent of any remedial works. The area affected would be largest for this option.	**Short-term:** The smallest area of seabed would be disturbed with this option.
Disturbance to SAC	**Short-term:** Dredging to access the pipeline to completely recover would open a trench and introduce sediment into the water column and move rock. The area is expected to recover relatively quickly. The rock would remain therefore a change in sediment type. It would be more spread over the seabed. Assuming 5m wide corridor affected the area affected would be 0.11km2, 11ha equivalent to c. 0.003% of the SAC.	**Short-term:** Disturbance to the Special Area of Conservation is related to the area of the seabed effected and the duration of activities being undertaken and the potential for releases and will therefore be least for the leave *in situ*. Limited or no impact on the SAC during execute phase.
Water column disturbance: • liquid discharges or releases to sea • liquid discharges or releases to surface water • noise	**Short-term:** Discharges and releases to the water column are related to the duration of activities being undertaken and will therefore be greatest for the complete removal.	**Short-term:** Discharges and releases would be least for this option, particularly in the short-term.

Environmental factors impacted	Complete removal	Leave *in situ*
Waste creation and use of resources such as landfill. Recycling and replacement of materials	**Short-term:** This option would result in the largest mass of material being returned to shore. No material would be lost as no material would be left *in situ.*	**Short-term:** No material would be returned to shore for recycling and therefore the material would be lost. New manufactured material would be needed to replace the lost material.

Table 6.3.1: PL2838/9 Operational Environmental Impacts

6.4 Environmental impact of legacy activities

On completion of decommissioning activities, a final environmental survey would be carried out, and this would be common for all options and is not a differentiator. For longer-term legacy related activities, a differentiator between options would be the number of pipeline burial surveys that would be required as well as any possible remedial works.

The environmental impact of legacy activities associated with future requirements of ensuring that **PL2838/9** remain buried and stable are assessed in much the same way as operational activities. The impacts of legacy related activities can be expected to be significantly less than those brought about by operational activities during decommissioning work. The results of the assessment are summarised in Table 6.4.1.

Environmental factors impacted	Complete removal	Leave *in situ*
Atmosphere (energy & emissions)	**Legacy:** No pipeline burial surveys required.	**Legacy:** Assume pipeline burial surveys required.
Seabed disturbance; area affected	**Legacy:** No work required in future.	**Legacy:** Pipeline burial surveys do not usually involve disturbance to the seabed, and we assume that no remedial activities would be required otherwise, so no impact.
Disturbance to SAC	**Legacy:** No work would be required in future.	**Legacy:** Assume pipeline burial surveys required.
Water column disturbance: • liquid discharges to sea • liquid discharges to surface water • noise	**Legacy:** No work would be required in future.	**Legacy:** Assume pipeline burial surveys required.
Waste creation and use of resources such as landfill. Recycling and replacement of materials	**Legacy:** We assume that no pipeline remedial activities would be required as the trends to date have indicated that both pipelines would remain stable. Therefore, as part of legacy related activities there is nothing to differentiate the options from a waste perspective.	

Table 6.4.1: PL2838/9 Legacy Environmental Impacts

6.5 Summary of environmental assessment

The environmental assessment for both pipelines was split into short-term operational impacts and longer-term legacy impacts due to related activities on the seabed.

In the short-term, and from an operational perspective, leave *in situ* would be the favoured option while complete removal would result in no legacy activities being required. All impacts for both options for both pipelines were assessed as broadly acceptable.

In the short-term, the leave *in situ* decommissioning option was considered to cause the least disruption to the seabed and has the least risk of accidental release to sea as the pipelines were being recovered, so would be the most preferred.

In the short-term and due to operational activities, the complete removal option would be least favourable and was assessed as ‘least preferred’. However, the area can be expected to fully

recover within a few years after the initial impact of decommissioning works, and so in the longer-term complete removal was assessed to be the marginally preferred option.

The complete removal option would result in recovery of all the pipeline material for recycling whereas the leave *in situ* option would result in most of the pipeline material being left where it is, and therefore unavailable for recycling. Any raw material not recovered would need to be replaced with newly manufactured material.

6.6 Societal Impact Assessment

The assessment of the other criteria (safety, environment, cost and technical) considers the level of detrimental effect, whereas the assessment of impacts on employment considers the level of benefit, a positive effect. We use vessel durations as an indicator of magnitude of the *continuation* of employment rather than creating new employment. We can discuss short-term effects due to decommissioning operations – 'project' activities - and longer-term impacts due to legacy related activities.

We have also examined potential disruption to commercial activities resulting from the presence of vessels specifically to carry out the decommissioning work. We have taken a somewhat holistic approach.

The societal issues are discussed below and are considered applicable to the piggybacked pipelines together.

Commercial activities

Fishing is the main commercial activity in the area. The potential short-term effects could be loss of fishing revenue due to exclusion from fishing grounds, disturbance of the seabed and associated stocks or loss or damage of fishing equipment.

While the vessels are present in the field and activities are being undertaken, the area will not be accessible for fishing. Therefore, the magnitude of the impact on commercial activities is related to the vessel duration and the time of year. In the short-term, the complete removal activities will incur longer vessel activities. Conversely, the leave *in situ* option would require the least vessel activity.

Activities which involve removal will implicitly disturb the seabed. Therefore, since complete removal will require more activities on the seabed it will have a higher short-term impact on commercial fishing compared to the leave *in situ* option.

Therefore, the complete removal option is expected to have a greater impact on fishing activities as it has the longest offshore duration and the greatest amount of activity disturbing the seabed. The leave *in situ* option would leave most of the infrastructure in the seabed resulting in less work offshore, so there would be less of an impact on local and commercial fishing activities.

While both decommissioning options would require an environmental survey to be completed, only the leave *in situ* options would require pipeline burial surveys. The degree to which these will be required will be governed by the results of each survey, and if it can be demonstrated that each pipeline remains stable and poses no snagging risk such surveys may no longer be required.

While any such surveys are being undertaken, fishing activities may be disrupted for a short-time, but the impact can be expected to be manageable. Typically, one post-decommissioning environmental survey would be required, and for each decommissioning option we have assumed the number of pipeline surveys that would be required so that we can compare the impact of the options. The exact magnitude of the impact will be dependent on the type, frequency and duration of the surveys required.

Disruption to commercial activities would be least when the decommissioning effort in the field is minimised, and this is the case for leave *in situ*, whereas complete removal could potentially result in the most disruption to commercial activities.

Legacy related disruption on commercial activities in the area would be greatest for leave *in situ.*

There would be no legacy activities once decommissioning activities associated with complete removal had been completed because there would be no infrastructure left to inspect. Conversely, the leave *in situ* would require legacy activities to be carried out at least for the foreseeable future.

Employment

The complete removal option has greater vessel duration and waste management requirements and therefore employment opportunities would be greatest for the complete removal option owing to the larger amount of vessel time and onshore dismantling and recycling works. The effect on employment will be the continuation of existing jobs, as opposed to the creation of new opportunities; such opportunities would be least for the leave *in situ* option.

Conversely, legacy related employment opportunities would be least for complete removal and greatest for leave *in situ*. This is because the leave *in situ* options would require legacy activities to be carried out, at least for the immediately foreseeable future.

Therefore, the significance of the positive impact on employment for both options is assessed as low.

Communities

Construction vessels would be in the field for relatively short duration, both within and outside the 500m safety zone. Fishing vessels would be excluded from the area outside the 500m zone, but we believe that when compared to the wider area this would have a relatively small effect but acknowledging that there is a season for high fishing activity. Interaction between the offshore activities and local fishing activities would need to be carefully managed. There is little to differentiate between the options. Shipping will be notified and continue using alternative routing. There could be an effect on other users of the ports and there would be a marginally higher impact for complete removal but overall, we believe that there is little to differentiate the options.

The port and the disposal site for recovered materials have yet to be established. However, they will be existing sites which are used for oil and gas activities and hold the required permits for waste management. The communities around the port and the waste disposal sites are therefore expected to be adapted to the types of activities required and the decommissioning activities will be an extension of the existing situation. Therefore, the effect on communities is not considered a differentiator between options.

The results of the societal assessments for **PL2838/9** are presented in Table 6.6.1. In the short-term, commercial activities would be affected most by the amount of time the vessels were in the field undertaking removal activities. We believe that generally however, there is very little to differentiate the options for each.

Sub-Criterion	Complete removal	Leave *in situ*
Commercial activities	**Short-term:** Impact of decommissioning vessel traffic on local commercial activities such as fishing would be greatest for complete removal.	**Short-term:** Impact of decommissioning vessel traffic on local commercial activities such as fishing would be least for complete removal.
	Legacy: An environmental survey would be required but this is the same for all options. No pipeline surveys would be required.	**Legacy:** Impact of survey vessel traffic on local commercial activities such as fishing would be slightly more with the leave *in situ* option.
Employment	**Short-term:** Decommissioning activities would contribute greatest to continuity of employment for complete removal.	**Short-term:** Decommissioning activities would contribute the least to continuity of employment for leave *in situ.*
	Legacy: Once the pipelines have been completely removed, the opportunity for continuation of employment would be minimal once the environmental survey had been completed.	**Short-term:** Should the pipelines be left *in situ* surveys would need to be carried out. Some jobs would be associated with the manufacture of new material to replace that which is left *in situ*.
	Short-term: Decommissioning activities	**Short-term:** Decommissioning activities

Sub-Criterion	Complete removal	Leave *in situ*
Communities	would contribute greatest to continuity of work in ports and disposal sites for complete removal.	would contribute the least to continuity of work in ports and disposal sites for leave *in situ.*
	Short-term: Once the pipelines have been removed there would be few opportunities for continuity of work in ports and disposal sites.	**Short-term:** Once the pipelines have been left *in situ* there would be few opportunities for continuity of work in ports and disposal sites other than associated with survey related and possible remedial work.

Table 6.6.1: PL2838/9 Societal Assessment

6.7 Cost Assessment

The incremental difference in cost between complete removal and leave *in situ* – including the requirement for legacy surveys - on a like-for-like basis would be least £7.72MM (see Appendix C). If we assume that the 'reverse reel' method would be the cheapest and most viable removal option, the difference in cost would be significant, but less than an order of magnitude higher[4] than for leave *in situ*. For this reason, because of the difference involved the short-term costs for complete removal are classed as "broadly acceptable but low & least preferred". The difference between the two options is summarised in Table 6.7.1.

Sub-Criterion	Complete removal	Leave *in situ*
Cost	**Short-term:** Using the assumption that the pipelines would be removed simultaneously using reverse reel method, the cost of complete removal would be more than the cost of leave *in situ*, but less than an order of magnitude higher.	**Short-term:** The cost of leave *in situ* would be the least expensive of the two options.
	Legacy: Once the pipeline had been completely removed no pipeline burial surveys after decommissioning works had been completed or over the longer-term.	**Legacy:** Future burial surveys will be required. The premise is that if two successive surveys demonstrate that the pipeline remains stable no more surveys would be required.

Table 6.7.1: PL2838 & PL2839 Cost Assessment

6.8 Summary

Once the approaches to the Ensign and Audrey A installations have been decommissioned, leave *in situ* is the recommended decommissioning option for the **PL2838** and piggybacked **PL2839** pipelines.

All things considered, from a purely technical perspective, the 'cut and lift' method would likely be the most viable for complete removal but usually this approach would only be used for relatively short-lengths of pipeline. The reverse reel and reverse S-lay methods of recovery could theoretically be achieved, providing any integrity concerns could be allayed.

In practical terms *in situ* decommissioning would be easier to achieve technically. There would be significant technical uncertainties that would need to be overcome for the complete removal option to be considered viable.

Many of the health and safety hazards described herein are common to both decommissioning options. Based on the differences, in the short-term the leave *in situ* option gives rise to lower risks to project personnel.

By leaving the pipelines *in situ* residual snagging risks will remain, albeit low due to the type of

[4] i.e. larger than 10 times greater.

fishing activity in the area. By completely removing the pipelines the risk of snagging by pipelines is removed in perpetuity. Therefore, the complete removal option results in lower residual risks to mariners and other users of the sea. Fundamentally however, we believe that there is little to choose between the options from a safety perspective whether in the short or longer term.

In the short-term, and from an operational perspective, leave *in situ* would be the favoured option from an environmental perspective, while complete removal would result in no legacy activities being required. All impacts for both options for both pipelines were assessed as broadly acceptable.

The complete removal option would result in recovery of all the pipeline material for recycling whereas the leave *in situ* option would result in most of the pipeline material being left where it is, and therefore unavailable for recycling. Any raw material not recovered would need to be replaced with newly manufactured material.

Disruption to commercial activities would be least when the decommissioning effort in the field is minimised, and this is the case for leave *in situ*, whereas complete removal could potentially result in the most disruption to commercial activities.

Legacy related disruption on commercial activities in the area would be greatest for leave *in situ.* There would be no legacy activities once decommissioning activities associated with complete removal had been completed because there would be no infrastructure left to inspect. Conversely, the leave *in situ* would require legacy activities to be carried out at least for the foreseeable future.

Employment opportunities would be greatest for the complete removal option owing to the larger amount of vessel time and onshore dismantling and recycling works. Such opportunities would be least for the leave *in situ* option.

Conversely, legacy related employment opportunities would be least for complete removal and greatest for leave *in situ*. This is because the leave *in situ* options would require legacy activities to be carried out, at least for the immediately foreseeable future.

The results of the assessments for the pipelines are summarised in Table 6.8.1.

Aspect	Sub-criterion	Short-term or legacy?	Complete removal	Leave *in situ*
Technical	Technical feasibility	Short-term		
		Legacy		
Safety	Safety risk to offshore project personnel	Short-term		
		Legacy		
	Safety risk to mariners	Short-term		
		Legacy		
	Safety risk to onshore project personnel	Short-term		
		Legacy		
Environmental	Atmosphere (energy & emissions)	Short-term		
		Legacy		
	Seabed disturbance area affected	Short-term		
		Legacy		
	Impact on MCZ	Short-term		
		Legacy		
	Water column disturbance	Short-term		
		Legacy		
	Waste creation	Short-term		

Aspect	Sub-criterion	Short-term or legacy?	Complete removal	Leave *in situ*
		Legacy		
Societal	Commercial activities	Short-term		
		Legacy		
	Employment	Short-term		
		Legacy		
	Communities	Short-term		
		Legacy		
Cost (by difference)		Short-term		
		Legacy		

Table 6.8.1: PL2838/9 Summary of Comparative Assessment

7 COMPARATIVE ASSESSMENT FOR PLU2840 & PL2841

PLU2840 the umbilical pipeline is connected to **PL2841** the 10" pipeline using a series of clamps. Therefore, we have combined the comparative assessment for both, noting any differences that may arise.

7.1 Technical Assessment

Both decommissioning options are technically feasible, although complications would result in the complete removal option being less viable. Complete removal of the pipeline would need to be achieved either by reverse S-lay or by using the 'cut and lift' method of recovery.

Two options were considered for **PLU2840** and **PL2841**, and theoretically, given the right conditions - for example, no integrity issues can be foreseen – both options can be considered technically feasible for both pipelines.

Either removal method would involve uncovering the pipelines and lifting them up out of the trench. This would need to be achieved either as a continuous process using reverse S-lay or as an incremental process using 'cut and lift', remembering that the 10" pipeline is piggybacked by the umbilical pipeline. We believe that trying to reverse reel the umbilical while recovering the 10" pipeline would lead to unnecessary technical uncertainties and this technique is not considered further as it would not lead to a material change to the results of the technical assessment.

The 'cut and lift' method has been used for recovery of short individual pipeline sections already in the southern North Sea, but not for piggybacked pipelines that are trenched and buried. The 'cut and lift' method would likely be more palatable and achievable for these pipelines.

Reverse S-lay would involve separating the pipelines as they arrive on the vessel and then cutting them into lengths suitable for transporting onshore, while the 'cut and lift' method would probably involve cutting the pipelines inside the trench before lifting the pipe lengths to a suitable vessel for transporting to shore. Either method would be challenging for single pipe trenched and buried pipelines, but more so for pipelines that are piggybacked. To our knowledge there is little to no experience in removing pipelines that are trenched, buried and piggybacked with another umbilical pipeline in the UKCS [2], and as such the technical uncertainty associated with either removal option will likely have an adverse impact on technical efficacy.

The complete removal option is particularly complicated, with plenty of technical issues to consider, and the technical uncertainties associated with the pipeline decommissioning options have been assessed using the risk assessment matrix in the comparative assessment guidance, the results of which are presented in Table 6.1.1 below.

Sub-Criterion	Complete removal	Leave *in situ*
Technical feasibility	**Short-term:** Limited experience in the North Sea of reverse S-lay removal of concrete coated, trenched & buried piggybacked pipelines, and 'cut and lift' method would likely be avoided for such a long pipeline. The reduced pipeline length suggests that this would be 'broadly acceptable and least preferred' rather than 'tolerable and non-preferred' if managed to ALARP.	**Short-term:** Stable and buried pipelines have been left *in situ* before and we know this is achievable.
	Legacy: No pipeline surveys would be required in future.	**Legacy:** Pipeline surveys have been undertaken in the past, so this is achievable with no complications.

Table 7.1.1: PL2838/9 Technical Assessment

All things considered, from a purely technical perspective, the 'cut and lift' method would likely be the most viable but only for relatively short-lengths of pipeline.

In practical terms *in situ* decommissioning would be easier to achieve technically. There would be significant technical uncertainties that would need to be overcome for the complete removal option to be considered viable.

7.2 Health & Safety Assessment

Please refer section 6.2 as we believe that the various environmental impacts for **PLU2840** piggybacked onto **PL2841** are broadly similar to those assessed for **PL2838** and **PL2839** but on a much smaller scale and with much less to differentiate the options. Therefore, for brevity, we propose not to repeat the discussion here. The reduced pipeline length suggests that this would be 'broadly acceptable and least preferred' for **PL2838** and **PL2839** rather than 'tolerable and non-preferred' if managed to ALARP. Otherwise there is no material change to the results of the assessment.

The assessment for the piggybacked pipelines is summarised in Table 6.2.1.

Sub-Criterion	Complete Removal	Leave *in situ*
Safety risk onshore project personnel	**Short-term:** Safety risk is linked to the mass of material returned to shore. Therefore, there would be significantly more onshore cutting, lifting and handling for complete removal than for leave *in situ*. The reduced pipeline length and smaller amount of material to be handled might suggest that this aspect would be 'broadly acceptable' rather than 'tolerable'.	**Short-term:** No onshore work.
	Legacy. Nothing to differentiate the options.	

Table 7.2.1: PL2838/9 Health & Safety Assessment)

7.3 Environmental impact of operational activities

Please refer section 6.3 as we believe that the various environmental impacts for **PLU2840** piggybacked onto **PL2841** are broadly similar to those assessed for **PL2838** and **PL2839** but on a much smaller scale and with much less to differentiate the options. Therefore, for brevity, we propose not to repeat the discussion here as there no material change to the results of the assessment.

7.4 Environmental impact of legacy activities

Please refer section 6.4 as we believe that the various environmental impacts for **PLU2840** piggybacked onto **PL2841** are broadly similar but on a much smaller scale and with much less to differentiate the options. Therefore, for brevity, we propose not to repeat the discussion here as there no material change to the results of the assessment.

7.5 Summary of environmental assessment

Please refer section 6.5 as we believe that the various environmental impacts for **PLU2840** piggybacked onto **PL2841** are broadly similar but on a much smaller scale and with much less to differentiate the options. Therefore, for brevity, we propose not to repeat the discussion here as there no material change to the results of the assessment.

7.6 Societal Impact Assessment

Please refer section 6.5 as we believe that the various societal impacts for **PLU2840** piggybacked onto **PL2841** are broadly similar but on a much smaller scale and with much less to differentiate the options. Therefore, for brevity, we propose not to repeat the discussion here as there no material change to the results of the assessment.

7.7 Cost Assessment

The incremental difference in cost between complete removal and leave *in situ* – including the requirement for legacy surveys - on a like-for-like basis would be least £0.56MM (see Appendix C). If we assume that the 'cut and lift' method would be the most viable removal option, the difference in cost would be significant, but less than an order of magnitude higher[5] than for leave *in situ*. For this reason, because of the difference involved the short-term costs for complete removal are classed as "broadly acceptable but low & least preferred". The difference between the two options is summarised in Table 7.7.1.

Sub-Criterion	Complete removal	Leave *in situ*
Cost	**Short-term:** The cost of complete removal would be higher than for the leave *in situ* option but less than an order of magnitude higher.	**Short-term:** The cost of leave *in situ* would be the least expensive of the two options.
	Legacy: Once the pipeline had been completely removed no pipeline burial surveys after decommissioning works had been completed or over the longer-term.	**Legacy:** Future burial surveys will be required. The premise is that if two successive surveys demonstrate that the pipeline remains stable no more surveys would be required.

Table 7.7.1: PLU2840 & PL2841 Cost Assessment

7.8 Summary

Once the approaches to the Ensign installation and subsea well have been decommissioned, leave *in situ* is the recommended decommissioning option for **PLU2840** and piggybacked **PL2841**.

All things considered, from a purely technical perspective, the 'cut and lift' method would likely be the most viable for complete removal but usually this approach would only be used for relatively short-lengths of pipeline. The reverse reel and reverse S-lay methods of recovery could theoretically be achieved, providing any integrity concerns could be allayed.

In practical terms *in situ* decommissioning would be easier to achieve technically. There would be

[5] i.e. larger than 10 times greater.

significant technical uncertainties that would need to be overcome for the complete removal option to be considered viable.

Many of the health and safety hazards described herein are common to both decommissioning options. Based on the differences, in the short-term the leave *in situ* option gives rise to lower risks to project personnel.

By leaving the pipelines *in situ* residual snagging risks will remain, albeit low due to the type of fishing activity in the area. By completely removing the pipelines the risk of snagging by pipelines is removed in perpetuity. Therefore, the complete removal option results in lower residual risks to mariners and other users of the sea. Fundamentally however, we believe that there is little to choose between the options from a safety perspective whether in the short or longer term.

In the short-term, and from an operational perspective, leave *in situ* would be the favoured option from an environmental perspective, while complete removal would result in no legacy activities being required. All impacts for both options for both pipelines were assessed as broadly acceptable.

The complete removal option would result in recovery of all the pipeline material for recycling whereas the leave *in situ* option would result in most of the pipeline material being left where it is, and therefore unavailable for recycling. Any raw material not recovered would need to be replaced with newly manufactured material.

Disruption to commercial activities would be least when the decommissioning effort in the field is minimised, and this is the case for leave *in situ*, whereas complete removal could potentially result in the most disruption to commercial activities.

Legacy related disruption on commercial activities in the area would be greatest for leave *in situ.* There would be no legacy activities once decommissioning activities associated with complete removal had been completed because there would be no infrastructure left to inspect. Conversely, the leave *in situ* would require legacy activities to be carried out at least for the foreseeable future.

Employment opportunities would be greatest for the complete removal option owing to the larger amount of vessel time and onshore dismantling and recycling works. Such opportunities would be least for the leave *in situ* option.

Conversely, legacy related employment opportunities would be least for complete removal and greatest for leave *in situ*. This is because the leave *in situ* options would require legacy activities to be carried out, at least for the immediately foreseeable future.

The results of the assessments for the pipelines are summarised in Table 6.8.1.

Aspect	Sub-criterion	Short-term or legacy?	Complete removal	Leave *in situ*
Technical	Technical feasibility	Short-term		
		Legacy		
Safety	Safety risk to offshore project personnel	Short-term		
		Legacy		
	Safety risk to mariners	Short-term		
		Legacy		
	Safety risk to onshore project personnel	Short-term		
		Legacy		
Environmental	Atmosphere (energy & emissions)	Short-term		
		Legacy		
	Seabed disturbance area affected	Short-term		
		Legacy		

Aspect	Sub-criterion	Short-term or legacy?	Complete removal	Leave *in situ*
	Impact on MCZ	Short-term		
		Legacy		
	Water column disturbance	Short-term		
		Legacy		
	Waste creation	Short-term		
		Legacy		
Societal	Commercial activities	Short-term		
		Legacy		
	Employment	Short-term		
		Legacy		
	Communities	Short-term		
		Legacy		
Cost (by difference)		Short-term		
		Legacy		

Table 7.8.1: PL2838/9 Summary of Comparative Assessment

8 CONCLUSIONS

8.1 Overview

The comparative assessment was undertaken with a focus on the decommissioning options for 10" pipeline **PL2838** piggybacked by 2" pipeline **PL2839**, and 10" pipeline **PL2841** piggybacked by umbilical **PLU2840.**

The assessments considered five criteria in both the short-term for decommissioning activities and the longer-term for 'legacy' related activities. The criteria were: safety related risks with three sub-criteria, environment with five sub-criteria, technical feasibility, societal effects with three sub-criteria and cost.

Since the decommissioning of the pipeline approaches to the installation and subsea well is the same irrespective of which option is pursued, decommissioning of these is not included in the assessment. Therefore, any differences are incremental to the activities associated with dealing with the pipeline approaches.

8.2 Conclusion for PL2838 and PL2839

Both pipelines are trenched and buried with no exposures evident from when they were first installed or from more recent survey data. The assessment found that for the complete removal option the technical feasibility, short-term safety risk to project personnel both offshore and onshore would be 'tolerable' rather than broadly acceptable or preferred. Otherwise, except for cost we believe that there was little to differentiate the options.

From a purely technical perspective, the 'cut and lift' method would likely be the most viable for complete removal but usually this approach would only be used for relatively short-lengths of pipeline.

In practical terms *in situ* decommissioning would be easier to achieve technically. There would be significant technical uncertainties that would need to be overcome for the complete removal option to be considered viable.

Many of the health and safety hazards described herein are common to both decommissioning options. Based on the differences, in the short-term the leave *in situ* option gives rise to lower risks to project personnel.

Differences are found between the safety assessment with more work required offshore and onshore for complete removal than leave *in situ* and consequently higher safety risk. Conversely there would be lower safety risks to mariners arising from complete removal than for leave *in situ* because the pipelines would no longer be present as a potential snag hazard. However, our assessment concluded that even with the pipelines remaining in situ the snagging risk posed to fishermen and other users of the sea would remain low on the basis that the pipelines would remain buried and because of the predominant type of fishing in the area.

Finally, there is an order of magnitude in the incremental difference in cost for complete removal versus leave *in situ*.

In conclusion, based on the comparative assessment leave *in situ* is the recommended option for decommissioning the offshore and nearshore sections of the pipelines.

8.3 Conclusion for PLU2840 and PL2841

Please refer section 6.4 as we believe that the various environmental impacts for **PLU2840** piggybacked onto **PL2841** are broadly similar but on a much smaller scale and with much less to differentiate the options. Therefore, for brevity, we propose not to repeat the discussion here but focus instead on two elements – technical assessment and onshore project personnel safety, where we think these is a small material change to the results of the assessment.

In the technical assessment the pipelines are shorter which means that the ‘cut and lift’ method of removal would be more achievable. This means that the technical element is assessed as ‘broadly acceptable and least preferred’ rather than ‘tolerable’ if managed to ALARP. Likewise, the safety element of the onshore work and material handling was assessed as being ‘broadly acceptable’ and ‘least preferred’ rather than ‘tolerable’ if managed to ALARP.

Finally, there is less than an order of magnitude in the incremental difference in cost for complete removal versus leave *in situ*.

In conclusion, based on the comparative assessment leave *in situ* is the recommended option for decommissioning pipelines **PLU2840** and **PL2841**.

9 REFERENCES

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[7] Spirit Energy (2018) Environmental Appraisal, CEU-DCM-SNS0104-REP-0002.

APPENDIX A INSTALLATION & WELL APPROACHES

Appendix A.1 Ensign NPAI Approaches

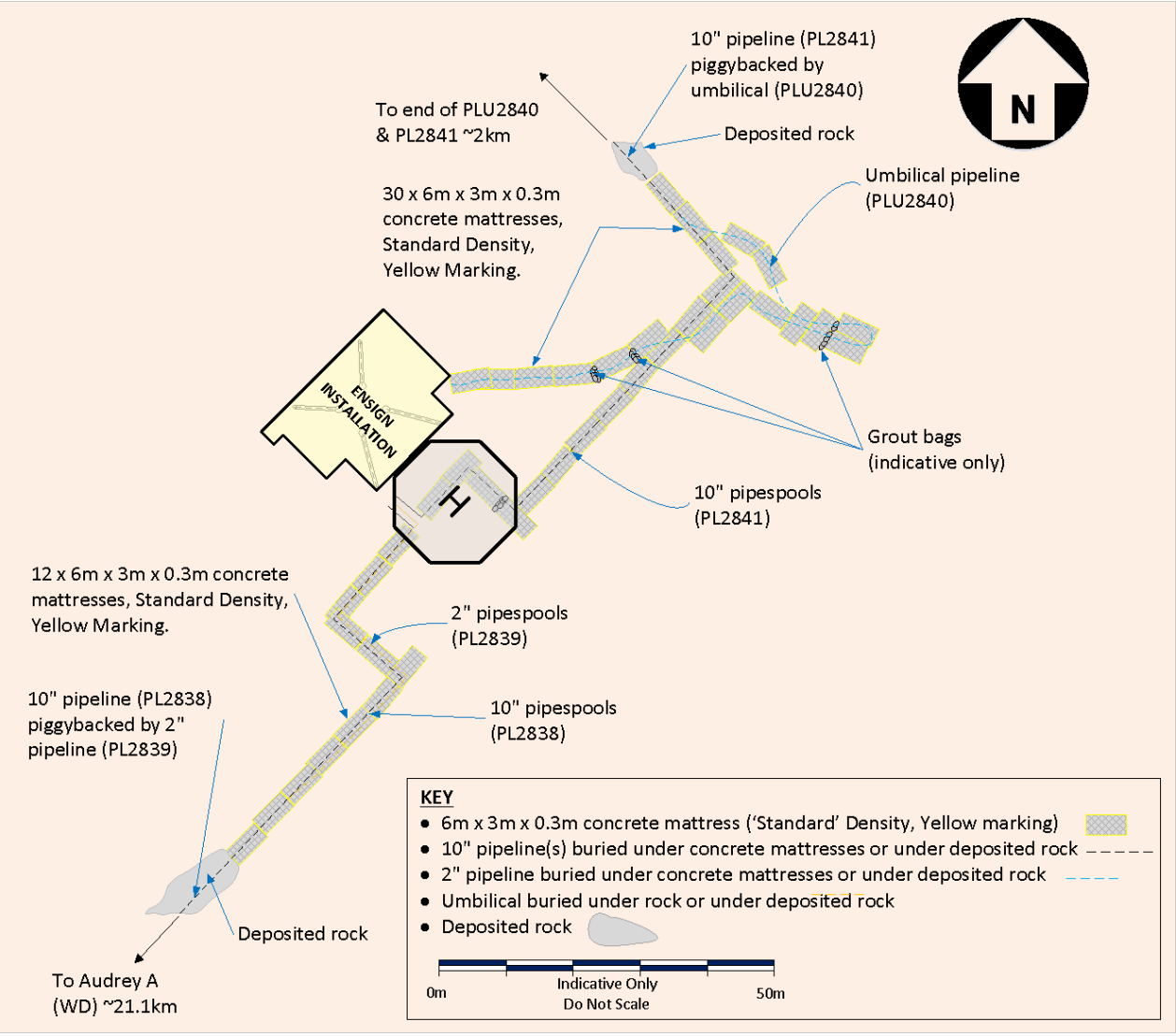

Figure A.1.1: Ensign NPAI Approaches

Appendix A.2 Ensign Unused Subsea Well Approaches

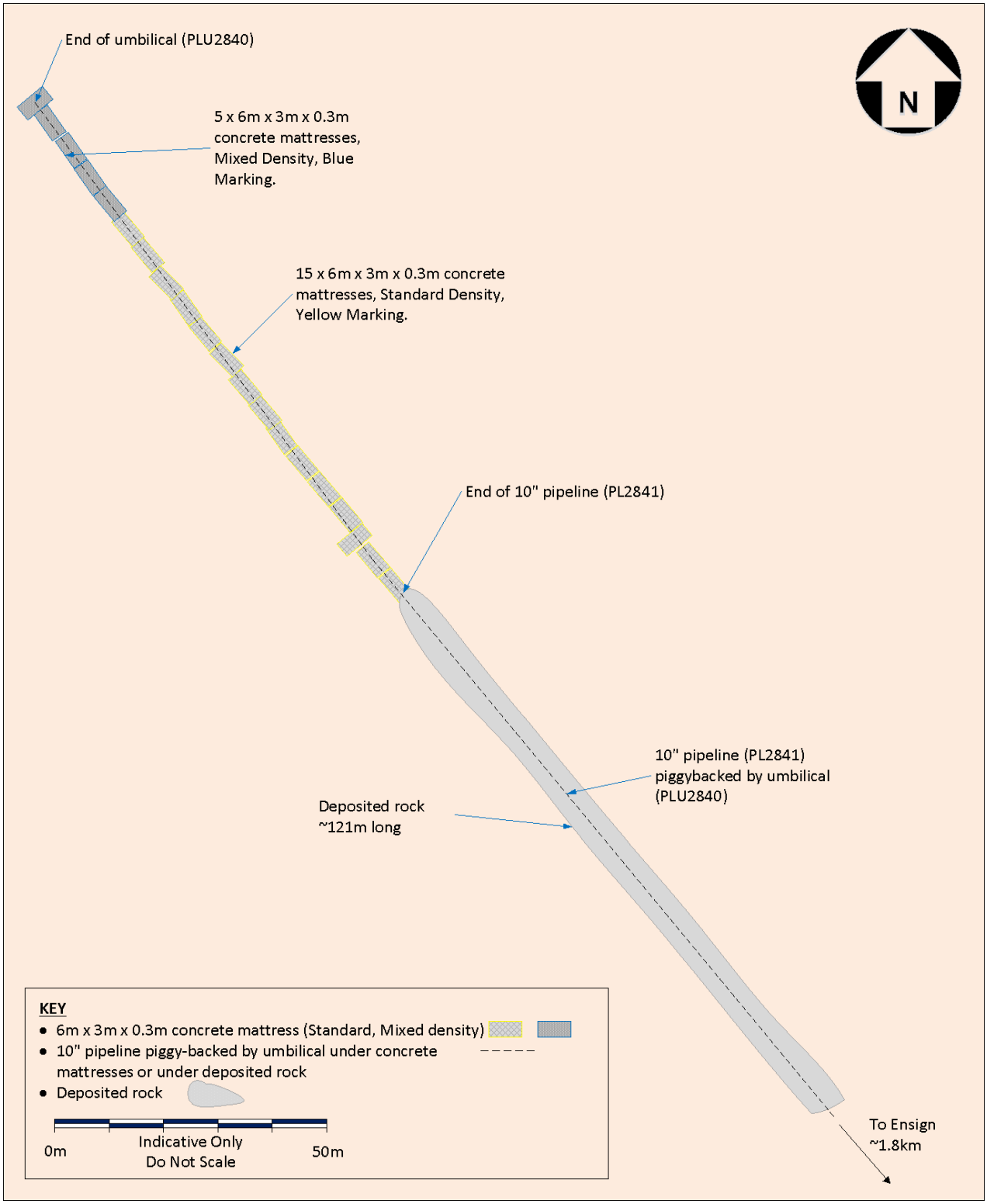

Figure A.2.1: Ensign Subsea Well 48/14a-7y Approach

Appendix A.3 Audrey A Approaches

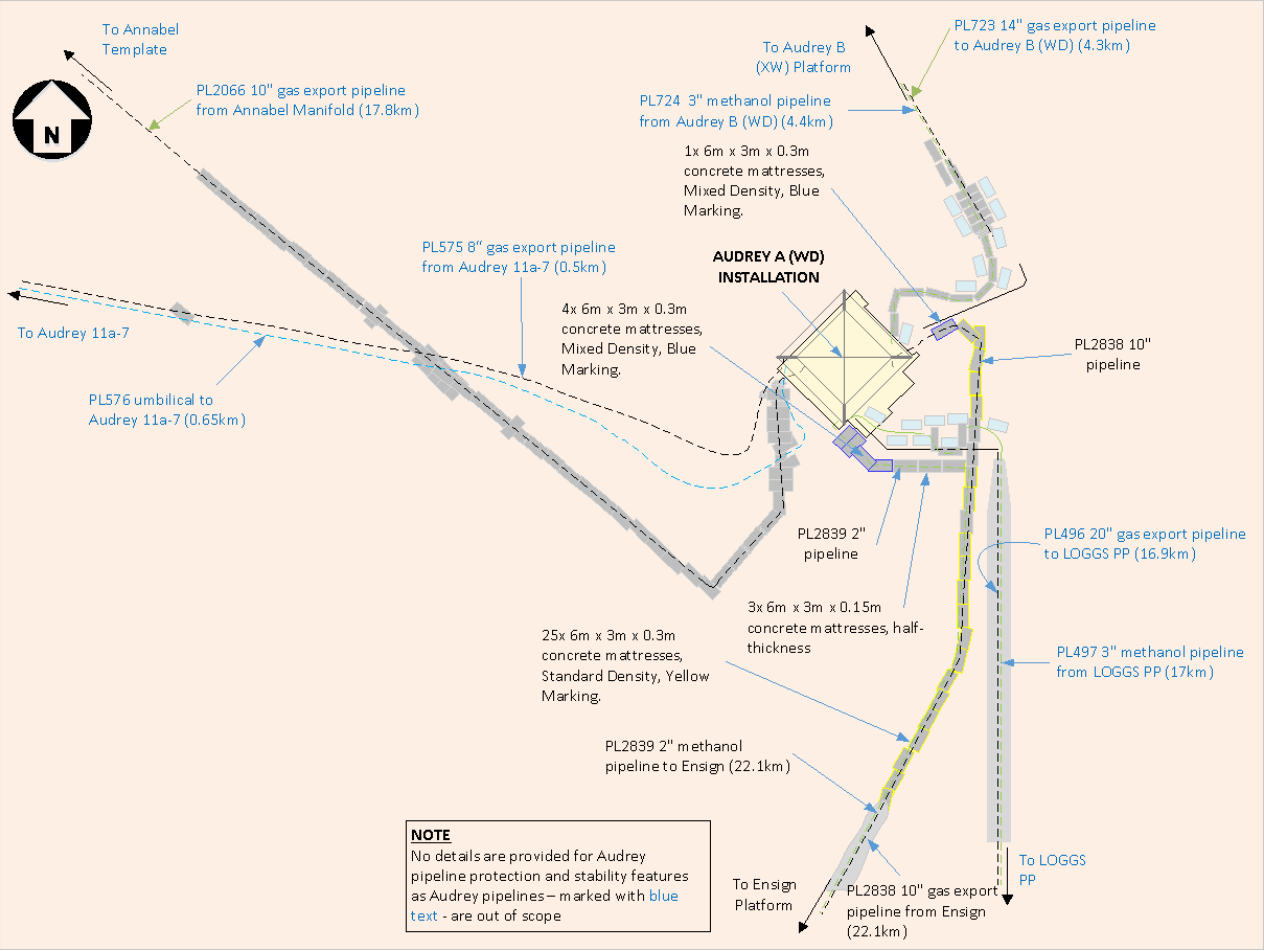

Figure A.3.1: Audrey A Installation Approaches

APPENDIX B PIPELINE AND CABLE CROSSINGS

Appendix B.1 Carrack Pipeline Crossing

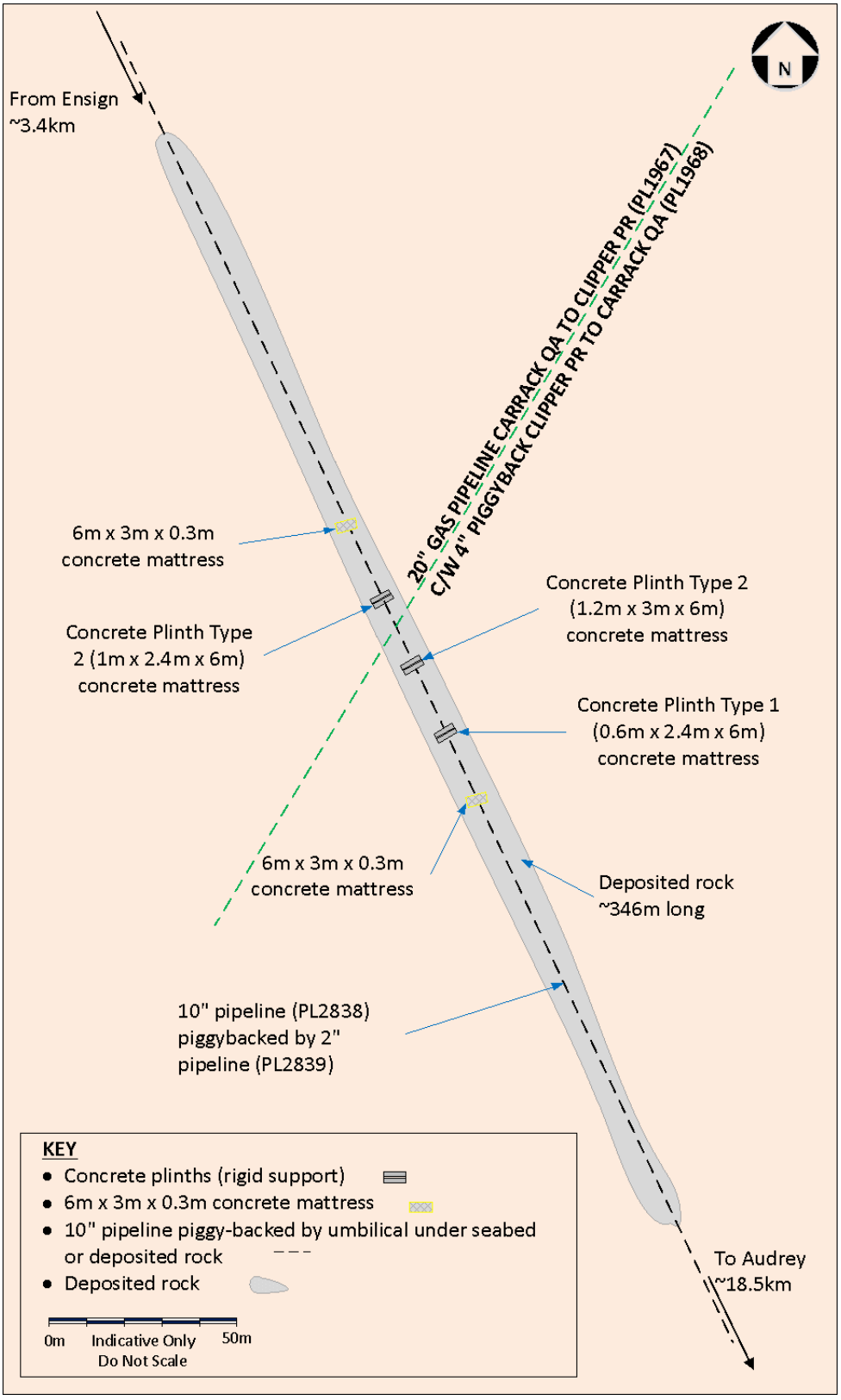

Figure B.1.1: Carrack Pipeline Crossing

Appendix B.2 Weybourne to ACMI Cable Crossing

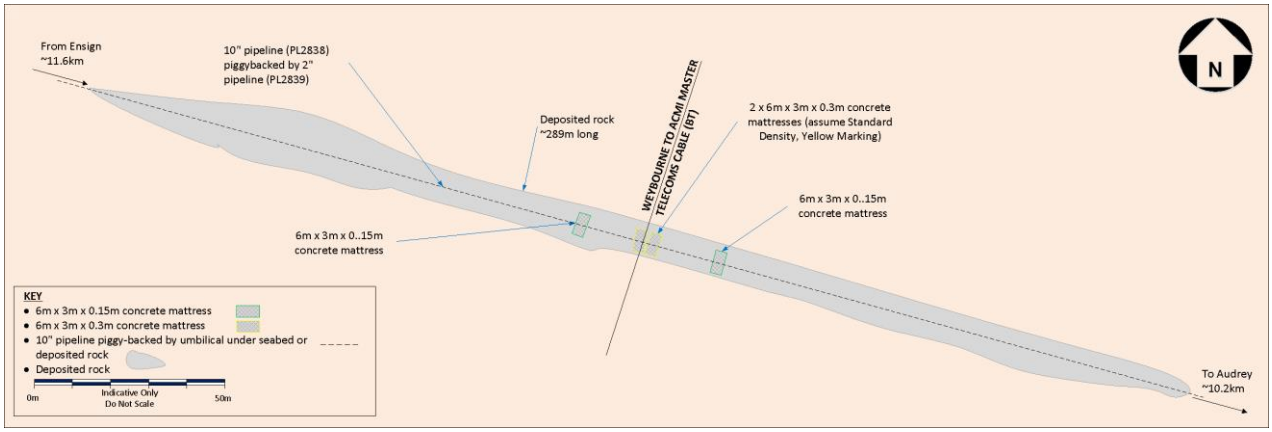

Figure B.2.1: Pipeline Approaches to Ensign Installation

APPENDIX C COST AS A DIFFERENTIATOR

The following section details the qualitative comparative assessment made to distinguish the decommissioning options. Not that any figures quoted do not account for the overall costs of decommissioning the pipelines – they only account for the difference in cost once activities common to both options have been discounted.

The assessment was carried out in accordance with the Spirit Energy Comparative Assessment Guidance. Health and safety criteria were assessed with the HSE Risk Matrix, environmental and societal criteria were assessed with the Environmental Impact table and the technical criteria were assessed with the Project Risk Assessment Matrix. The colour coding is as follows:

High / Intolerable & not acceptable	Medium / Tolerable non-preferred	Low / Broadly Acceptable & most preferred	Broadly Acceptable / Low & least preferred

Appendix C.1 Pipeline Decommissioning Cost by difference

PL2838 & PL2839	Complete Removal (£M)	Leave *in situ* (£M)
Cost	£9.42	£1.69
Sub-total Normalised	**5**	**0.9**

Table C.1.1: PL2838 & PL2839 Option costs by difference

PLU2840 & PL2841	Complete Removal (£M)	Leave *in situ* (£M)
Cost	£1.76	£1.26
Sub-total Normalised	**5**	**3.5**

Table C.1.2: PLU2840 & PL2841 Option costs by difference