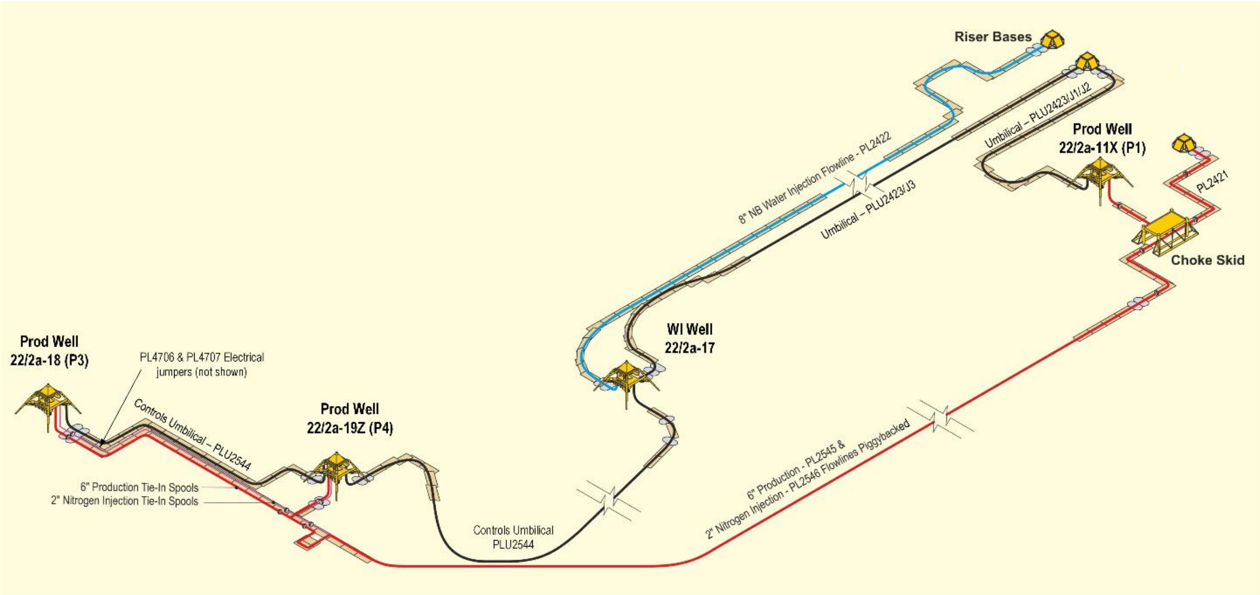
Chestnut Pipeline Decommissioning Comparative Assessment



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Prepared by:	S. Axon	S. Axon	14/10/22
Reviewed by:	J. Mitchell	J. Mitchell	14/10/22
Approved by:	D. Farrell	D. Farrell	14/10/22

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TABLE OF TERMS AND ABBREVIATIONS

Abbreviation	Explanation
~	approximately
3LPP	3-Layer Polypropylene, coating used for carbon steel pipelines and pipework
ALARP	As Low As Reasonably Practicable
approaches	Refer to pipelines as they come nearer to the installations or pipeline structures
Backfill	Reburial of pipeline inside a trench
CA	Comparative Assessment (Report)
Cut and lift	The ‘cut and lift’ method of removing trenched and buried pipelines would involve excavating the pipelines from within the seabed and thereafter cutting the pipeline into recoverable and transportable lengths. The method is usually only viable for short pipelines.
DOC	The blue line on the burial profiles shows the profile of cover. The area between the blue line and maroon line (DOL) shows the depth of sediment above the top of the pipeline. Rock can be used for DOC mitigation to increase DOC to the minimum design requirement
DOL	Pipeline trench profile; depth of lowering to top of pipe
DP	Decommissioning Programme(s)
EA	Environmental Appraisal
e.g.	*exempli gratia*, for example
Exposure	An exposure occurs when the ‘crown’ of a pipeline or umbilical can be seen
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)
FPSO	Floating, Production, Storage and Offloading (Vessel)
Freespan	Refer “span”
Full removal	The full removal options for decommissioning the pipelines would involve using the ‘cut and lift’ method of removal especially for the larger pipeline and the presence of concrete weight coating and piggyback clamps on the platform approaches
GMG	Global Marine Group
HAZID	Hazard Identification
HSEQ	Health, Safety, Environment, Quality
ICES	International Council for the Exploration of the Seas
ID	Identity (as in tabulated feature)
“, in	Inch; 25.4 millimetres
kg	kilogram
km	kilometre
KP	Kilometre Point, usually measured from point of origin, the start of the pipeline at the pipeline flange. A negative KP means that the feature lies between the riser flange and the start of the pipeline
LAT	Lowest Astronomical Tide
Leave *in situ*	Leave *in situ* for pipelines would involve leaving trenched and buried pipelines in situ and risk assessing any exposures and spans
Live weight	The mass or weight of a product (i.e. fish), when removed from the water.
m	metres
MeOH	Methanol
MFE	Mass Flow Excavator provides a method of clearing sediment material from buried objects
MMO	Marine Management Organisation
MPA	Marine Protected Area
n/a	Not Applicable
N,S,E,W	North, South East & West
NFFO	National Federation of Fishermen's Organisations
NIFPO	Northern Ireland Fish Producers Organisation
NSTA	North Sea Transition Authority
NTS	Not to scale (used on illustrations and schematics)
Oceanteam	Oceanteam 2000 Survey Limited
OD	Outside diameter

Abbreviation	Explanation
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
Order of Magnitude	Size difference by factor of 10: one (10^1) means 10-times, two (10^2) means 100-times difference
Partial removal	The partial removal decommissioning option for pipelines would involve excavating trenched and buried pipelines local to the exposed ends of the pipeline and thereafter effecting removal of the section of pipeline using the 'cut and lift' method. Typically, the excavated locations and cut pipeline ends in the seabed may need to be remediated in some way, either by back-filling the excavated material or by depositing rock
Piggybacked	Clamped or connected to another pipeline along part or all of its length
Pipeline	Rigid pipeline, flowline, or umbilical
Pipeline end	Pipeline to pipespool connection; either a flanged or welded joint
Pk	Pockmark (Refer Figure 2.4.1)
PL, PLU	Pipeline (or umbilical) identification numbers
Platform	Installation, typically comprising topsides and jacket
Post-trenching	Post-trenching involves cutting, ploughing, or jetting a trench underneath the pipeline, such that it is lowered into the seabed. Often referred to as re-trenching
PWA	Pipeline Works Authorisation
Qualitative	Result determined using judgement and use of risk and impact matrices
Quantitative	Result determined using numerical data and by calculation
RB	Riser base
Remediation	For the purposes of this document remediation can mean one of, or a combination of the following: post-trenching, removal of exposures and spans, deposition of additional rock
Reportable span	A reportable span is a significant span which meets set criteria (FishSAFE criteria) of height above the seabed and span length (10m long x 0.8m high)
Riser	Pipe that connects the pipeline to the topsides' pipework
Risk	Threat or opportunity; in this report the word "risk" is used to describe a "threat"
ROV	Remotely Operated Vehicle
ROVSV	Remotely Operated Vehicle Support Vessel
SAC	Special Area of Conservation
Scour	Natural degradation of seabed in one area and its aggradation in another caused by local flow of seawater
SDU	Subsea Distribution Unit
SEA	Strategic Environmental Assessment
SENSOL	Spirit Energy North Sea Oil Limited
SFF	Scottish Fishermen's Federation
SPA	Special Protection Area
Span	Sometimes referred to as a 'freespan'. Similar to an exposure except that the whole of the section of pipeline is visible above the seabed rather than just part of it. Once the height and length dimensions meet or exceed certain criteria the span becomes a reportable span
Splash Zone	The splash zone is the section of a jacket that is intermittently in or out of seawater during its service life
Surface installation	Refer "Platform"
SUT	Subsea Umbilical Termination
Te	Tonne(s)
TPF	Tie Piece Flange
Trench	Excavation or depression in the seabed to accommodate pipeline or umbilical
UHB	Upheaval buckling
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
Umbilical	Flexible pipeline manufactured of various materials including steel and plastics typically used to send electrical power, communication signals, chemicals and hydraulic fluid to a manifold or wellhead. An umbilical pipeline will include cables and tubes that are covered with an outer sheath to protect them from damage
UV	Ultraviolet
x	Number of (e.g. 16x = 16 in Number)

Assessment	Description
Broadly Acceptable / Low & least preferred	Risks broadly acceptable but controls shall be subject to continuous improvement through the implementation of the HSEQ Management System and considering changes such as technology improvements; performance in other ‘broadly acceptable’ options marginally better.
Broadly Acceptable / Low & in-between least & most preferred	As above, but performance of this option is marginally better or marginally worse than others.
Broadly Acceptable / Low & most preferred	As above but performance in other ‘broadly acceptable’ options marginally worse.
Tolerable / Medium Non-preferred	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 Not acceptable	Impacts are intolerable. Controls and measures to reduce impact to ALARP (at least to Medium) and require identification, documentation, implementation, and approval.

1. EXECUTIVE SUMMARY

1.1 Overview

The Chestnut oil field is situated in blocks 22/2a of the United Kingdom Continental Shelf and operated by Spirit Energy North Sea Oil Limited. It is located approximately 193km East North-East of Aberdeen, in water depths of ~123m.

The Chestnut field was developed as a single joint development and came onstream in late 2008. It has three production wells 21/2a-11X (P1), 22/2a-19Z (P4), 22/2a-18 (P3) and a water injection well 22/2a-17 that is side-tracked from 22/2a-12. The Chestnut field used to be tied back to the Hummingbird Spirit via three flexible risers PL2422, PLU2423 and PL2421, and these will be removed following departure of the Hummingbird Spirit FPSO from the Chestnut field as described in the Decommissioning Programmes for Phase 1 of the decommissioning works [10].

Production wells P1 and P2 were drilled before the Hummingbird Spirit arrived and production well P3 was drilled in August 2017. All three wells were tied back to the production riser base (RB) via PL2545 (6in, 4.62km long overall). All three production wellheads were provided with chemical and hydraulic fluids via the control RB. Production well P1 was provided with chemical and control fluids using PLU2423/J1 (100mm OD, 85m long), and electrical power using PLU2423/J2 (2x 33mm OD, 82m long). The Water Injection (WI) well was provided with chemical and hydraulic fluids and electrical power using PLU242/J3 (121mm OD, 2.385km long).

From the water injection well, PLU2544 provides chemical and hydraulic fluids and electrical power to production well P4 (formerly P2) (~1km long) onwards to production well P3 (153mm OD, ~100m long). Production well P1 used to provide nitrogen for injection to production well P4 (~1.1km long) and onwards to P3 (~155m long) using PL2546 (2in). PL2545 (6in) is piggybacked by PL2546 (2in).

In 2019 the signal and power cores in PLU2544 were disconnected from the Well P2 Subsea Distribution Unit and at Well P3 and left *in situ* under mattress protection. They were replaced by PL4706 and PL4707 (both ~150m long).

A comparative assessment of the pipelines or umbilicals is a key consideration within the Decommissioning Programmes submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED). The Chestnut wellheads and associated pipeline infrastructure are not situated in an environmentally protected area.

1.2 Pipelines and umbilicals

Decommissioning options and pipeline groups

For the purposes of the assessment the pipelines and umbilicals were split into two groups:

Group 1: Individual pipelines such as PL2422, PLU2423(J3), PLU2544 laid in their own trench;

Group 2: This includes pipelines PL2545 and PL2546 which are piggybacked.

All surface laid pipelines and pipeline ends will be fully recovered.

1.3 Mattresses & grout bags

Since the mattresses and grout bags on the approaches will be removed, these are not included in the comparative assessment. All options include removal of features such as spool pieces, concrete mattresses, and grout bags in accordance with mandatory requirements.

Notwithstanding the above, however, the grout bags and mattresses associated with remedial works carried out in 2010 for PL2422 are subject to a comparative assessment.

1.4 Deposited rock

Deposited rock was used to protect and stabilise sections of PL2545 and PL2546 and to mitigate the effects of upheaval buckling. It is assumed that any deposited rock would be left *in situ*.

1.5 Decommissioning options

1.5.1 Pipelines

As the pipeline burial profiles do not indicate any exposures, two decommissioning options are considered for the pipelines:

- **Complete removal –** This would involve the complete removal of the pipeline(s) by whatever means would be most practicable and acceptable from a technical perspective;
- **Leave *in situ* –** This would involve leaving the pipeline(s) *in situ* with no remedial works, but possibly needing to verify their status via future surveys.

In all instances both options exclude the surface laid pipeline or umbilical ends on the approaches on the basis that these would be completely removed.

1.5.2 PL2422 concrete mattresses and grout bags

For the materials used to remediate a freespan between ~KP0.677 and ~KP0.701 in PL2422 the decommissioning options are described as follows:

- **Complete removal –** this would involve the complete removal of the grout bags and concrete mattresses, removing the short section of PL2422 (~12m long[1]) and replacing the excavated material with deposited rock.
- **Partial removal** – this would involve removal of the overlying concrete mattresses and replacing them with deposited rock.
- **Leave *in situ* –** this would involve leaving the grout bags and overlying mattresses *in situ* with no remedial works.

In all instances legacy surveys will be required.

1.6 Pipeline and umbilical comparative assessment

The comparative assessment was undertaken with a focus on the decommissioning options for the pipelines associated with the Chestnut development. The pipelines were split into pipeline groups 1 & 2 as indicated in Table 4.1.1. All pipelines were assessed for the complete removal and leave *in situ* decommissioning options. The partial removal option was not assessed.

Except for the approaches all the individual and piggybacked pipelines are trenched and buried with historical survey data from 2014 and 2018 indicating that no exposures or spans have occurred. Some remedial work was carried out in 2010 for a 6.45m long freespan in PL2422, the 8in flexible water injection flowline, but the burial status and depth of cover for all pipelines is such that no exposures or spans would be expected to occur in future.

The assessment considered five criteria for both the short-term decommissioning activities and the longer-term for ‘legacy’ related activities. The criteria were: technical feasibility, safety related risks with three sub-criteria, environmental with five sub-criteria, societal effects with three sub-criteria and cost.

Since the decommissioning of the surface laid ends at of the pipelines on the final approaches is the same irrespective of which option is pursued, decommissioning of these is not included in the

[1] The length is stated as 12m long to ensure that the 6.45m freespan is removed along with any associated part of the pipeline that maybe poorly buried. The affected section lies underneath concrete mattresses lying between KP0.677 and KP0.701.

assessment. Therefore, any differences are incremental to the activities associated with surface laid infrastructure.

Once the pipelines had been excavated, reverse reel could be considered technically feasible for the individual flowlines and umbilicals in group 1. The ‘cut and lift’ method would likely be the most viable solution from a technical perspective for the complete removal for the group 2 pipelines. Usually this approach would only be used for relatively short lengths of pipeline. It is perhaps arguable whether these pipelines would be classed as ‘short’ in the context of ‘cut and lift’, but nevertheless, the repeatability of the method renders it technically feasible.

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

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

Differences were found in 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, the assessment concludes that even with the pipelines remaining *in situ* the snagging risk posed to fishermen and other users of the sea would remain low. This is on the basis that the pipelines would remain buried and because currently there is a low incidence of fishing activity in the area.

Finally, there is an order of magnitude in the incremental difference in cost for complete removal of the piggybacked pipelines versus leave *in situ* while the cost for removing the flexible flowlines would be less than an order of magnitude greater than leave *in situ*.

In conclusion, based on the comparative assessment the leave *in situ* option is recommended for decommissioning the pipelines in both groups 1 and 2.

1.7 PL2422 mattresses and grout bags

The comparative assessment was undertaken with a focus on the decommissioning options for the mattresses and grout bags used for remediating a 6.45m long freespan in PL2422 between ~KP0.677 and ~KP0.701.

The comparative assessment considered four criteria for both the short-term decommissioning activities and the longer-term or legacy related activities. The criteria were: technical feasibility, threats to the safety of project personnel or others, such as other users of the sea, environmental impacts and societal effects. Cost was not assessed in detail.

The technology is available to achieve any of the three decommissioning options and there is little risk of outright project failure. For the complete removal option, however, excavation using remote operations combined with relatively rudimentary equipment in the water depths involved (>120m) would be problematic to achieve. Further, although parts of the onshore segregation of materials might be mechanised, experience would suggest that the segregation of grout bag synthetic material from other materials such as grout or sediment will involve manual work. Therefore, from a technical perspective the complete removal option would be achievable but non-preferred. There is little to differentiate the partial removal and leave *in situ* options.

There is nothing significant to differentiate the options for project personnel from a short-term safety perspective. As manual labour will likely be required onshore, the complete removal option would probably be non-preferred. Otherwise, the scope of offshore work is limited and would likely be carried out using remotely operated equipment.

The complete removal option (that is, of the mattresses, grout bags and the associated ~12m length PL2422) would potentially result in additional snagging hazards being left behind – those associated with the short section of pipeline that is removed. Although the cut ends will be buried under rock, the cut ends will nevertheless exist where they didn't before.

The leave *in situ* option would be preferrable from a technical, environmental, short-term safety and cost perspective compared with the complete removal and partial removal options. The complete removal option offers slight benefits from short-term environmental and employment perspectives.

For the complete removal and partial removal options, non-native materials that are already in place would be replaced by rock, a hard substrate that is also non-native material. However, given the small area and volume of material involved there is little to differentiate the options.

Cost has not been examined. However, by inspection for project activities the complete removal option will cost more than either the partial removal or leave *in situ* options, and partial removal will cost more than the leave *in situ* option.

1.8 Summary of decommissioning proposals

1.8.1 Pipelines

The comparative assessment for groups 1 & 2 recommends that the pipelines should be left *in situ* with no remediation. This approach is summarised in Table 1.8.1.

Pipeline ID	Diameter (in, mm)	Comment / Burial status	Length (km)	Complete removal	Leave *in situ*
PL2421(5,6)	6/8in	Pipespools, surface laid	~0.045	X	
PL2422(3)	8in	Flexible flowline, trenched and buried	~2.400		X
PLU2423/J1(2)	100mm	Jumper, surface laid, covered with mattresses	~0.085	X	
PLU2423/J2(3)	2x 33mm	Jumper, surface laid, covered with mattresses	~0.082	X	
PLU2423/J3(4)	121mm	Umbilical, trenched and buried	~2.385		X
PLU2544(2)	153mm	Umbilical, trenched and buried	~0.980		X
PLU2544(4)	153mm	Jumper, surface laid, covered with mattresses	~0.100	X	
PL2545(1)	6in	Pipespools, surface laid	~0.130	X	
PL2545(2)	6in	Pipespools, surface laid	~0.097	X	
PL2545(3)	6in	Pipespools, surface laid	~0.120	X	
PL2545(4)	6in	Piggybacked; trenched and buried, incl. rock	~3.400		X
PL2546(1)	2in	Piggybacked; trenched and buried, incl. rock	~3.400		X
PL2546(2)	2in	Pipespools, surface laid	~0.095	X	
PL2546(3)	2in	Pipespools, surface laid	~0.016	X	
PL4706	28.7mm	Electrical jumper, surface laid	~0.150	X	
PL4707	28.7mm	Electrical jumper, surface laid	~0.150	X	

NOTES:

1. Diameters quoted for pipelines are nominal bore, while diameters quoted for umbilicals are outside diameter;
2. Numbers in brackets refer to pipeline ident no. in PWA Table A.
3. Pipeline spools or jumpers ≤10m long are not listed here on the basis that they would be fully removed.
4. Surface laid pipelines <100m listed in this table have not been subjected to a comparative assessment on the basis that they would be fully removed.
5. Surface laid sections of pipelines and umbilicals on the final approaches would be fully removed to trench depth.

Table 1.8.1: Pipeline decommissioning summary

Following completion of decommissioning activities, a post-decommissioning pipeline survey would be carried out. Following comparison with historical survey data the results would typically be risk assessed with a recommendation for future legacy surveys included in the decommissioning close out report.

1.8.2 PL2422 mattresses and grout bags

The burial status of the concrete mattresses should be confirmed, although the indications are that they will be partly exposed. If they are buried, the recommendation is that they be left *in situ*. If they are found to be partially exposed and are considered to present a snagging hazard, the partial removal option should be implemented. This option involves recovering the overlying concrete mattresses to shore and replacing them with deposited rock, ensuring that the section of PL2422 affected (~12m long underneath the concrete mattresses) will remain buried. Future surveys will be required to confirm burial status.

2. INTRODUCTION

2.1 Overview

The Chestnut oil field is situated in blocks 22/2a of the United Kingdom Continental Shelf and operated by Spirit Energy North Sea Oil Limited. It is located approximately 193km East North-East of Aberdeen, in water depths of ~123m.

The Chestnut field has three production wells 21/2a-11X (P1), 22/2a-19Z (P4), 22/2a-18 (P3) and a water injection well 22/2a-17 that is side-tracked from 22/2a-12. The Chestnut field used to be tied back to the Hummingbird Spirit via three flexible risers PL2422, PLU2423 and PL2421, but these have now been removed.

Production well P1 and P2 (now P4) were drilled before the Hummingbird Spirit arrived and production well P3 was drilled in August 2017. All three wells were tied back to the production riser base via PL2545 (6in, 4.62km long overall). All three production wellheads were provided with chemical and hydraulic fluids via the control riser base. Production well P1 was provided with chemical and control fluids using PLU2423/J1 (100mm OD, 85m long), electrical power using PLU2423/J2 (2x 33mm OD, 82m long). The Water Injection well was provided with chemical and hydraulic fluids and electrical power using PLU2423/J3 (121mm OD, 2.385km long).

From the water injection well, PLU2544 provides chemical and hydraulic fluids and electrical power to production well P4 (formerly P2) (~1km long) onwards to production well P3 (153mm OD, ~100m long). Production well P1 used to provider Nitrogen injection to Production well P4 (~1.1km long) and onwards to P3 (~155m long) using PL2546 (2in). PL2545 (6in) is piggybacked by PL2546 (2in).

In 2019 the signal and power cores in PLU2544 were disconnected from the Well P2 Subsea Distribution Unit and at Well P3 and left in situ under mattress protection. They were replaced by PL4706 and PL4707 (both ~150m long).

The Chestnut pipelines and infrastructure do not encounter any third-party pipeline crossings.

2.2 Chestnut area layout

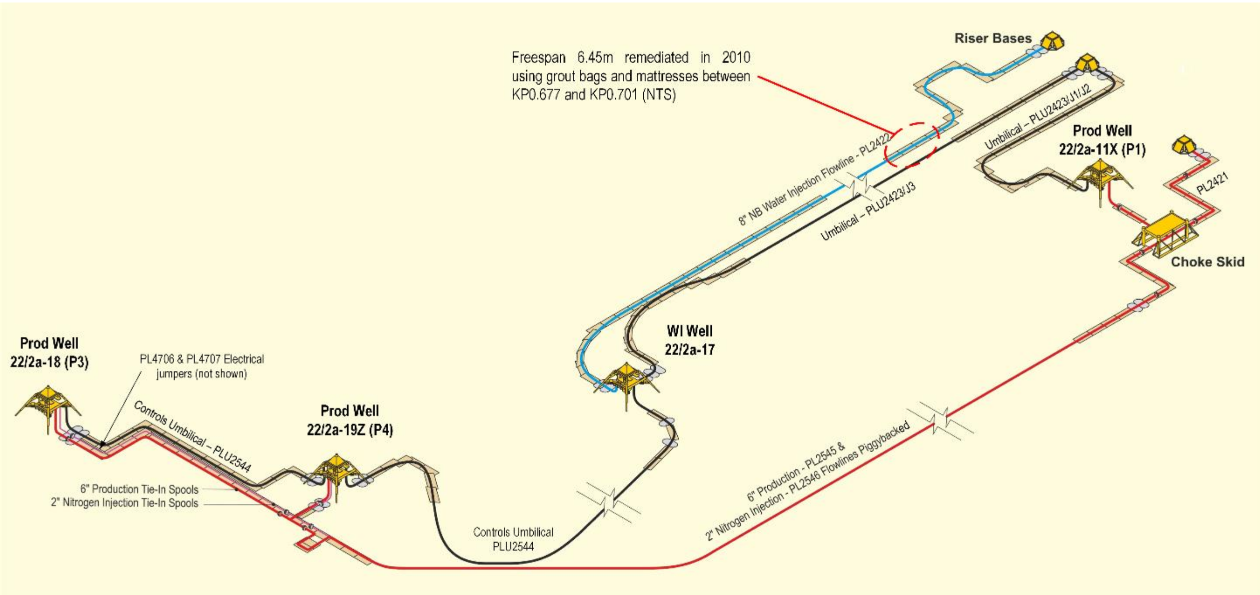


Figure 2.2.1: Chestnut field layout after FPSO sailaway

A summary of the pipelines and umbilicals is presented in Table 2.2.1.

Pipeline ID	From	To	Diameter (in, mm)	Comment / Burial status	Length (km)
PL2421(5)	P1 RB	RB	6/8in	Pipespools, surface laid	~0.045
PL2422(3)	WI RB	WI Well	8in	Flexible flowline, trenched and buried	~2.400
PLU2423/J1(2)	Controls RB	Well P1	100mm	Jumper, surface laid, covered with mattresses	~0.085
PLU2423/J2(3)	Controls RB	Well P1	2x 33mm	Jumper, surface laid, covered with mattresses	0.082
PLU2423/J3(4)	Controls RB	WI Well	121mm	Umbilical, trenched and buried	~2.385
PLU2544(2)	WI Well SUT	Well P2 SDU	153mm	Umbilical, trenched and buried	~~0.980
PL2545(1)	Well P2 SDU	Well P3 TPF	6in	Pipespools, surface laid	~0.130
PL2545(2)	Well P3 TPF	Well P2 TPF	6in	Pipespools, surface laid	~0.097
PL2545(3)	Well P2	Well P2 TPF	6in	Pipespools, surface laid	~0.120
PL2545(4)	Well P2 TPF	Choke manifold	6in	Piggybacked; trenched and buried, incl. rock	~3.400
PL2546(1)	Well P1	Well P2 TPF	2in	Piggybacked; trenched and buried, incl. rock	~3.400
PL2546(2)	Well P2	Well P2 TPF	2in	Pipespools, surface laid	~0.044
PL2546(3)	Well P2 TPF	Well P3 TPF	2in	Pipespools, surface laid	~0.095
PL2546(4)	Well P3 TPF	Well P3	2in	Pipespools, surface laid	~0.016
PL4706	Well P2 SDU	Well P3	28.7mm	Electrical jumper, surface laid	~0.150
PL4707	Well P2 SDU	Well P3	28.7mm	Electrical jumper surface laid	~0.150

NOTE:
1. Diameters quoted for pipelines are nominal bore, while diameters quoted for umbilicals are outside diameter.
2. Numbers in brackets refer to pipeline ident no. in PWA Table A.
3. Jumpers and pipespools 10m or less in length are not listed here.
4. PLU2544 2x Signal & 2x Power Cores (Nos 1,2,3 and 4) disconnected at both SDU and at P3 ends and left in situ under mattress protection.
5. PL4706 replaces the functionality of Cores 1 and 3 in PLU2544 between P2 SDU and Production Well P3.
6. PL4707 replaces the functionality of Cores 2 and 4 in PLU2544 between P2 SDU and Production Well P3.

Table 2.2.1: Pipeline & umbilical summary[2,3]

2.3 Purpose

The purpose of this document is to present a comparative assessment in support of the pipelines in the Chestnut Phase 2 Decommissioning Programmes as per the OPRED guidance notes [9]. The comparative assessment describes the decommissioning options considered for the pipelines. The findings have been determined using a qualitative approach like that adopted for other comparative assessments prepared for several assets being decommissioned in the East Irish Sea and the North Sea UKCS.

2.4 Environmental setting

2.4.1 Overview

The North Sea is a large shallow sea with a surface area of around 750,000km^2. Water depths in the CNS, where Chestnut is located, gradually deepen from south to north from approximately 40m at the Dogger Bank to approximately 123m at the Fladen/Witch Ground [1], [2]. The main topographic features in the CNS are the Dogger Bank, a large sublittoral sandbank located in the southwest corner of the region, marking a division between the southern North Sea and CNS, and the Fladen/Witch Ground, which is a large muddy depression generally considered to define the northern extent of the CNS area [1], [2].

Sand and slightly gravelly sand cover much of the seabed of the CNS region as seen in Figure

[2] Pipeline spools or jumpers ≤10m long are not listed here as they would be fully removed.
[3] Surface laid sections of pipelines and umbilicals on the final approaches would be fully removed to trench depth.

2.4.2 and occurs within a wide range of water depths from the shallow coastal zone to 110m in the north and to below 120m in isolated depths. Sediments may have a significant mud content, particularly in basins and in deeper waters to the north [7]. Coastal areas in the region support a more varied range of intertidal and seabed habitats [3].

The seabed sediments consist of very silty, fine sand down to approximately 0.8m. Underlying the seabed sand veneer, very soft silty clay extends to depths of between 20-30m below seabed throughout the Chestnut area. There is no evidence of significant lateral variations in soil properties within the upper 20m below the seabed, except in the vicinity of pockmarks where fine material has been expunged in the process of escaping gas. Authentic cement sediments associated with the seepage of gas may be present within and around the pockmark features.

On examining the original site survey report from 2006, several small depressions were evident from the Echosounder data [8]. They were limited in size, but a few metres deep in more extreme cases. The size of these depressions was beyond the resolution of the acquisition grid, meaning that there were probably more of them than shown on the bathymetry chart. They were interpreted as pockmarks. Pockmarks are a feature of the Chestnut area (as they have also been found in four subsequent surveys), but Methane-Derived Authigenic Carbonate matter has not been found in the pockmarks examined. The location of the pockmarks in relation to the Chestnut infrastructure is indicated in Figure 2.4.1. The nearest pockmarks (for example Pk10, Pk14 and Pk18) appear to be ~100m from any decommissioning activities and therefore unlikely to be affected.

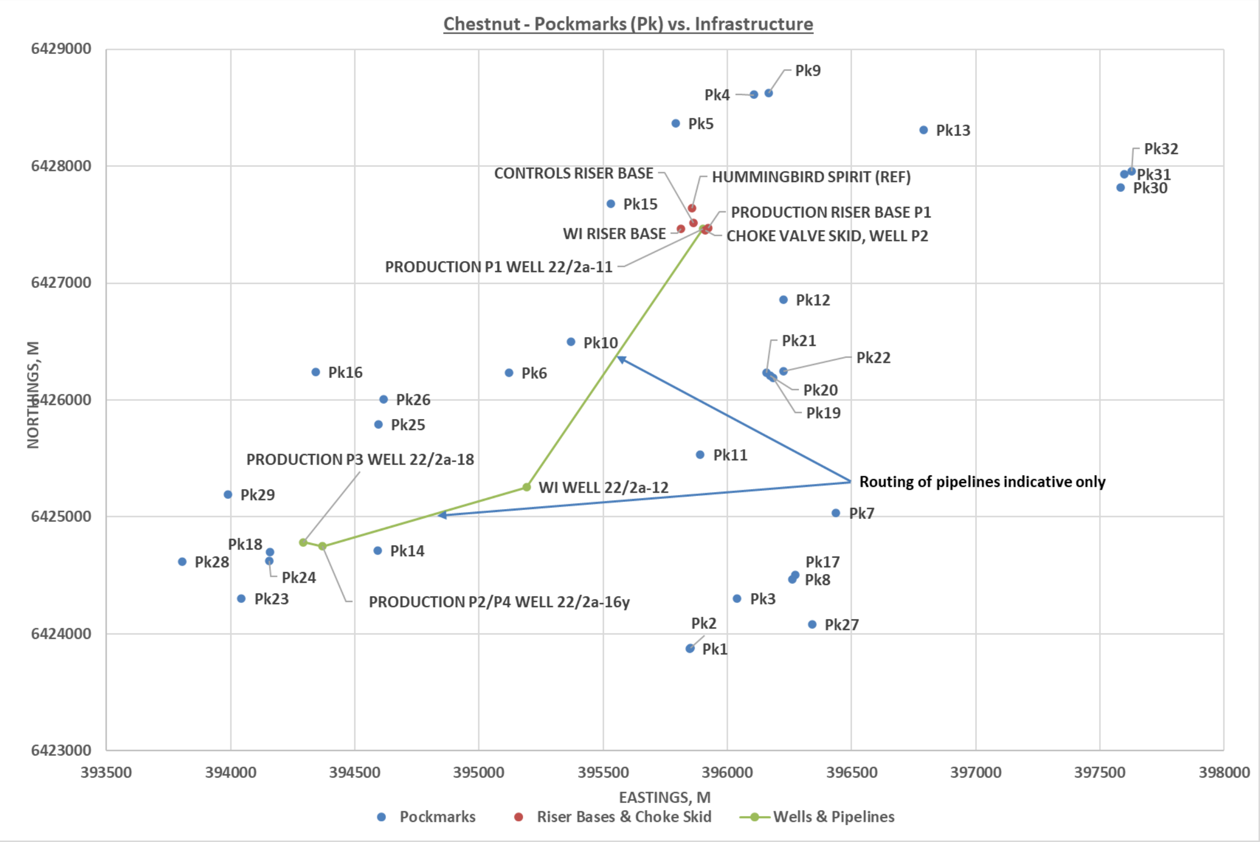


Figure 2.4.1: Pockmarks & Chestnut infrastructure in Block 22/2

The pipelines are located in UKCS block 22/2a in the CNS in a water depth ~123m relative to LAT. The pipelines are not located in a protected area or area of conservation. The nearest MPA is the Norwegian Boundary Sediment Plan ~30km to the north-east, and the nearest SAC is the Scanner Pockmark SAC 45km to the north-west (Figure 2.2.1).

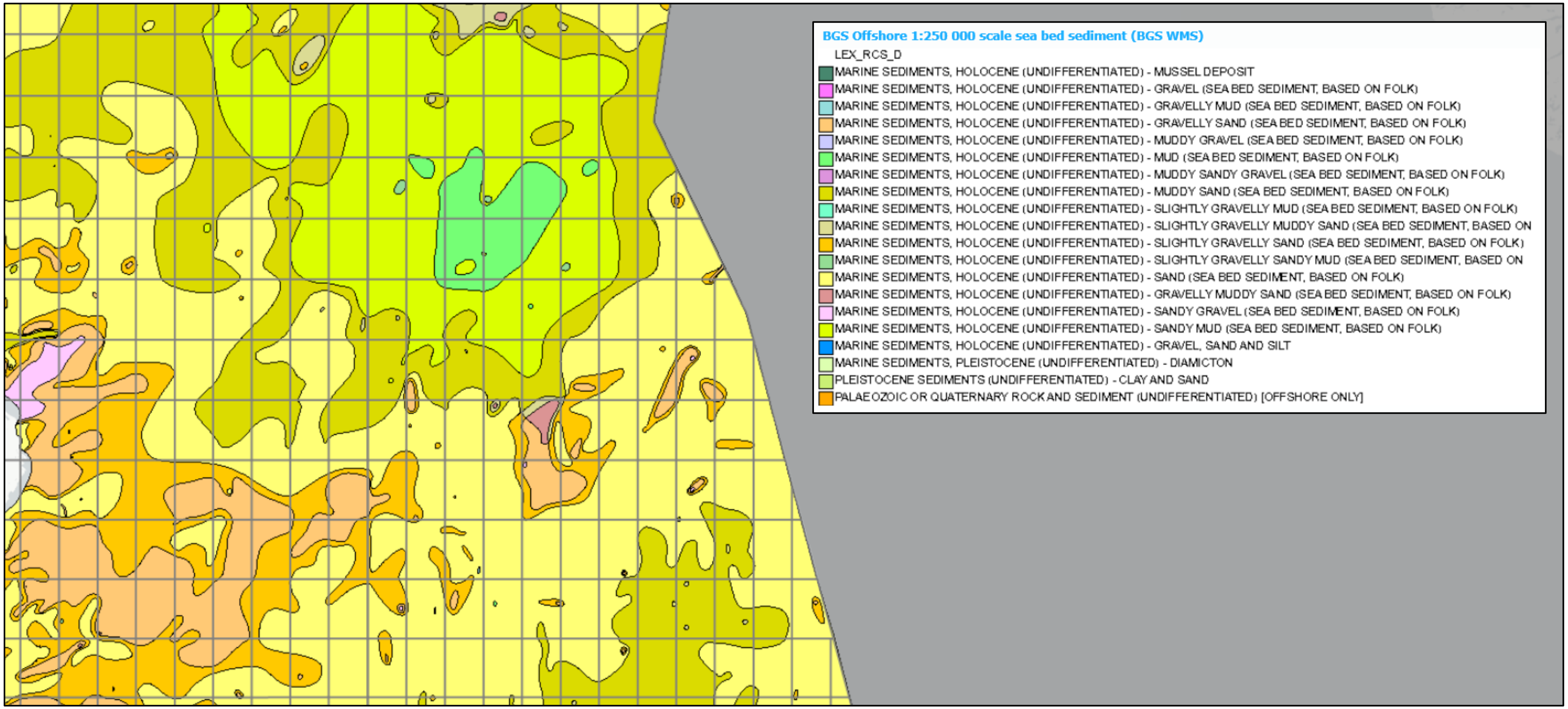
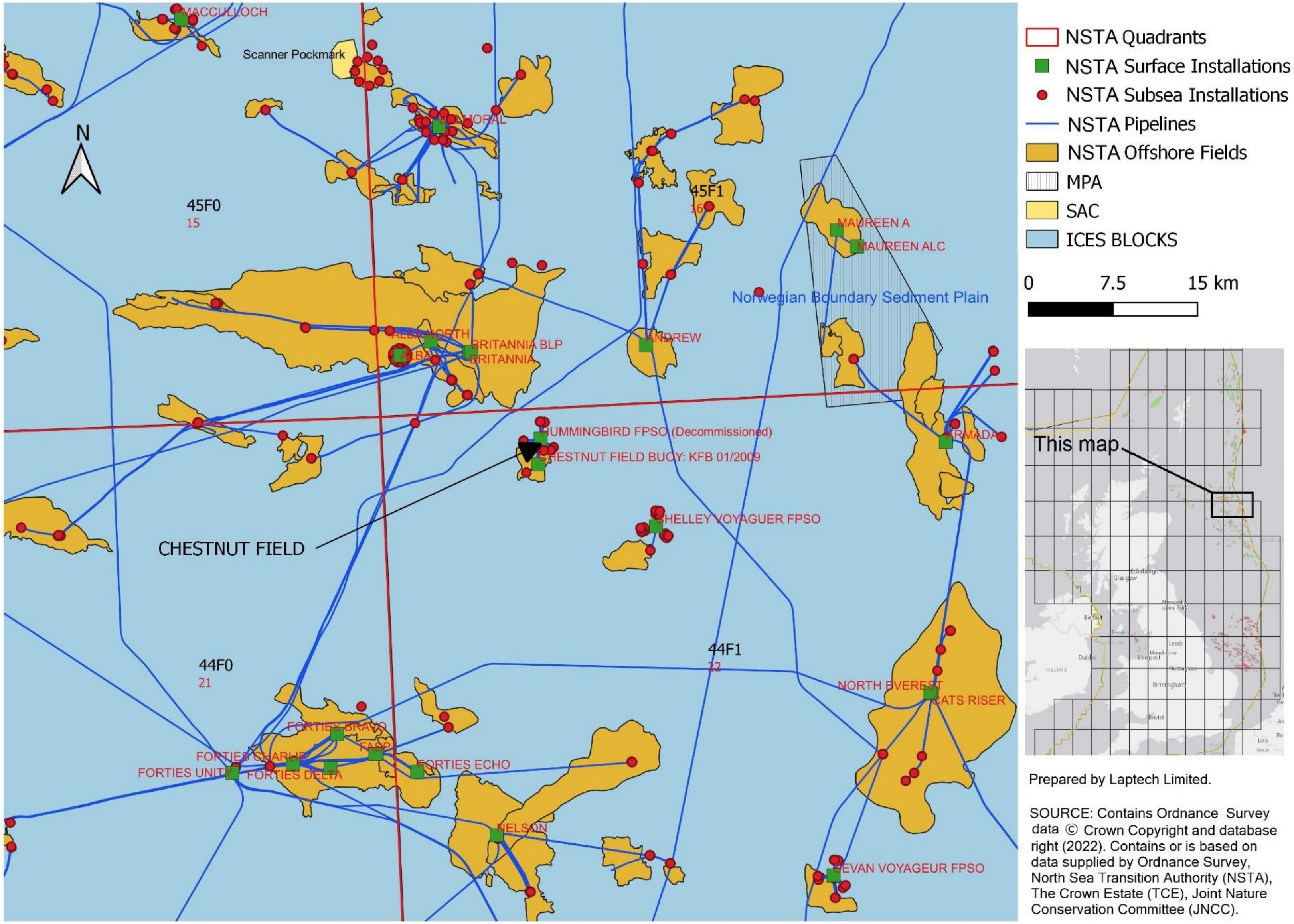


Figure 2.4.2: Sediment Type in Block 22/2



Prepared by Laptech Limited.

SOURCE: Contains Ordnance Survey data © Crown Copyright and database right (2022). Contains or is based on data supplied by Ordnance Survey, North Sea Transition Authority (NSTA), The Crown Estate (TCE), Joint Nature Conservation Committee (JNCC).

Figure 2.4.3: Chestnut field layout

2.4.2 Fishing

As this comparative assessment had been written in advance of the environmental appraisal for decommissioning the Chestnut infrastructure this section provides some background data concerning the fishing effort near the Chestnut area. These data provide context for the safety, environmental and societal aspects of the comparative assessment that are discussed in section 5.4 and section 5.5. Chestnut is in ICES rectangle 44F1 (Figure 2.4.3).

Type of fishing	2015	2016	2017	2018	2019
Demersal, 44F1	671	554	449	370	882
Demersal. UK	169064	180434	182261	176396	164132
44F1 as % of UK Demersal	0.40%	0.31%	0.25%	0.21%	0.54%
Pelagic, 44F1	201	0	0	0	0
Pelagic, UK	389802	369761	394851	385287	310952
44F1 as % of UK Pelagic	0.05%	0.00%	0.00%	0.00%	0.00%
Shellfish	63	0	0	0	0
Shellfish, UK	149832	150440	149598	138305	146802
44F1 as % of UK Shellfish	0.04%	0.00%	0.00%	0.00%	0.00%
Sub-total, 44F1	**934**	**554**	**449**	**370**	**882**
Sub-total, UK	**708699**	**700635**	**726709**	**699988**	**621886**
44F1 as % of UK	**0.13%**	**0.08%**	**0.06%**	**0.05%**	**0.14%**

Table 2.4.1: Live weight (Tonnes) [4]

It can be seen in Table 2.4.1 that there are no records of pelagic or shellfish activity in the area between 2016 and 2019, which might suggest that very little pelagic and shellfish activity[4] has occurred in the Chestnut area in these years. Fishing activity appears limited to demersal related fishing activity. This would concern fishing for species including but not limited to Cod, Haddock, Monk or Angler's fish, Pollack, Whiting, and Ling. The fishing effort in rectangle 44F1 contributes to less than 1% of the UK demersal fishing effort.

2.4.3 Grout bags

The number of grout bags noted in the Decommissioning Programmes [11] has been estimated using engineering judgement based on available data such as as-built drawings and design sketches.

For the purposes of the Comparative Assessment, it is assumed that all grout bags on the approaches will be fully removed.

30x 1Te grout bags were used for remedial works associated with the rectification of a 6.45m long freespan in PL2422 between ~KP0.677 and ~KP0.701 will be subject to a comparative assessment on the basis that if they do not present a snagging hazard, they will be left *in situ*. Refer section 4.2.

2.4.4 Mattresses

There are a total of 173 concrete mattresses used for protection and stabilisation of the transitions and the surface laid Chestnut pipelines and umbilicals. Just one size of concrete mattress has been used: 6m x 3m x 0.15m. A total of 169 concrete mattresses were installed on the pipeline approaches. Four additional concrete mattresses were used for remedial works carried out in 2010 to rectify a 6.45m long freespan in PL2422 between ~KP0.677 and ~KP0.689[5] (Figure 2.4.5).

Figure 2.4.4 gives an indication of what the concrete mattresses might look like. The concrete blocks are mostly held together with 14mm diameter UV stabilised polypropylene rope.

[4] Note that to an extent this may contradict anecdotal information shared by SFF in a meeting 26 May 2021, where it was observed that at one point up to 20 prawn fishing vessels had been seen in the area, although dates were not discussed.

[5] KP references based on 2018 survey data.

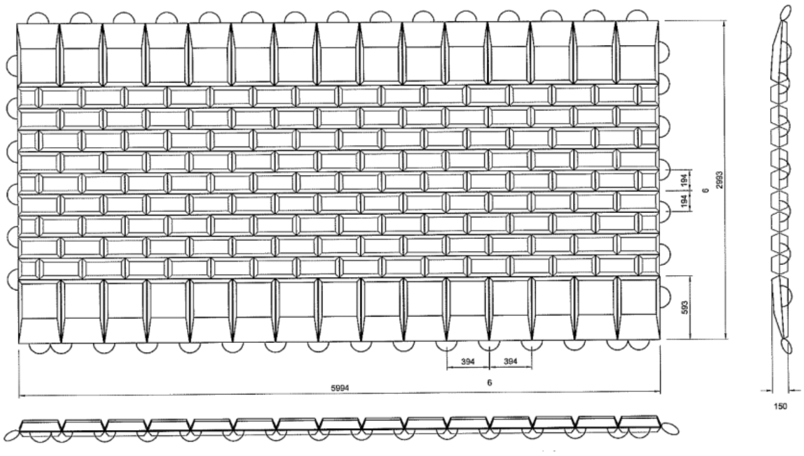


Figure 2.4.4: Typical concrete mattress – 6m x 3m (indicative only)

For the purposes of the Comparative Assessment, it is assumed that all concrete mattresses on the approaches will be fully removed, except for the mattresses used to rectify a span in PL2422. These will be subject to a comparative assessment on the basis that if they do not present a snagging hazard they could be left *in situ*.

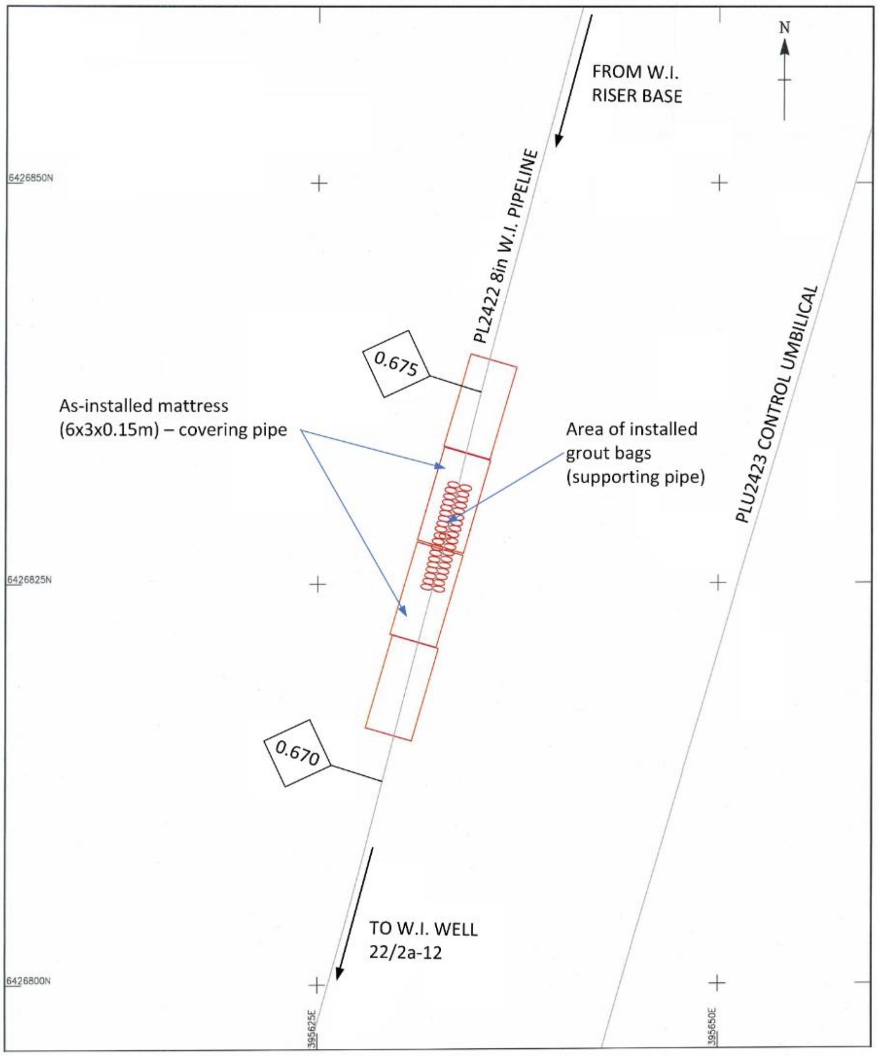


Figure 2.4.5: Span rectification work on PL2422 in 2010

2.4.5 Deposited Rock

Deposited rock was used to protect and stabilise sections of PL2545(4) and to mitigate the effects of upheaval buckling. PL2545(4) is piggybacked by PL2546(1). The total length of rock is ~575m as indicated in Figure 2.4.6, with a total mass (in air) of 4,635Te.

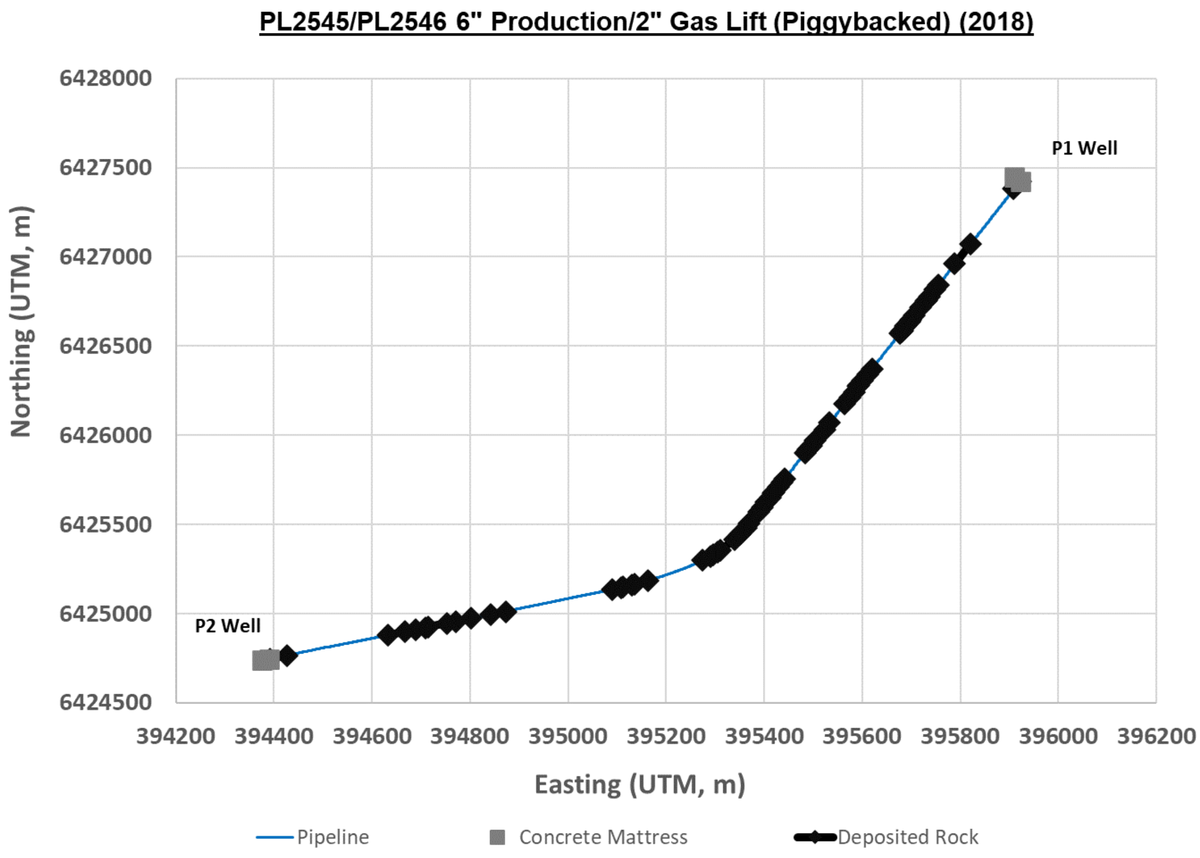


Figure 2.4.6: Deposited rock on PL2545(4) & PL2546(1)

The decommissioning philosophy in this document is consistent with the OPRED guidance notes [8] and the deposited rock has been considered for removal.

It is considered physically possible to remove deposited rock. Methods that could be used to remove the rock include:

- Excavating the rock and disposing of the material at an approved offshore location.
- Excavating the rock and transporting the material to shore and disposed of in an approved manner.
- Lifting the rock using a clamshell grab, depositing it into a hopper barge, and transporting it to shore for reuse or appropriate disposal.

All these proposed methods would impact 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.

Material left *in situ* 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 more negative impact on the environment than was presented when the material was originally installed, nor impact on the safety of other users of the sea.

On the basis of the foregoing, all deposited rock will be left *in situ*.

2.5 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, that includes the following technical assumptions:

- Technically, it is possible that the individual flowlines, umbilicals and pipeline(s), could be removed using reverse reel assuming that their integrity could be assured, and that the overlying seabed sediment could be displaced using a jet trencher or a mass flow excavator before they would be pulled from the trench.
- Technically, removal of piggybacked pipelines could be achieved using the 'cut and lift' method of removal, assuming that the sediment and overlying rock could be excavated or displaced to allow access.
- PL2422 had experienced a freespan 12m long between ~KP0.677 and ~KP0.689. This was rectified in 2010 using 30x1Te grout bags being laid underneath and to the side of the pipeline and 4x concrete mattresses being laid over the top. No exposures or spans have been recorded since, and subject to overtrawl; these will be left *in situ*.
- The impact of the procurement of any new aggregate material is ignored.
- SENSOL is not aware of any fishing gear snagging reports.

The following legacy assumptions have also been made:

- Minimising the number of cut pipeline or umbilical ends would be preferred from a legacy perspective and an environmental perspective.
- An environmental survey would be required on completion of decommissioning activities.
- Any pipeline(s) being left *in situ* and buried would be subject to at least two legacy burial surveys although given the depth of burial it is possible that this requirement could be re-assessed following the post-decommissioning surveys.
- The seabed sediment type is such that any spoil heaps created during any decommissioning operations would not present significant snagging hazards.
- In the long-term, assuming the size and profile or the resulting rock berm is suitable, deposited rock remaining *in situ* would not present snagging hazards.
- The impact of the creation of any new materials such as fabricated items or mining of new rock is ignored.
- The impact on commercial activities would be inversely proportional to vessel activity.
- Societal benefits and vessel associated environmental impacts and risks are assumed to be proportional to vessel duration.
- Only a high-level comparison of what differentiates the costs is used.
- The creation and deposition of additional rock on pipeline or umbilical ends is ignored in the cost assessment.

3. THE PIPELINE(S)

The pipeline(s) are all laid in trenches and the indications are that the trenches were mechanically backfilled. The top of the covering sediment inside the trench is such that it has settled slightly lower than the surrounding seabed sediment. On the final approaches the trenched and buried pipeline(s) are protected and stabilised with concrete mattresses. The surface laid pipespools and umbilical jumpers are all protected and stabilised with concrete mattresses. Grout bags have been used for support and to fill in gaps between the mattresses and quite often grout bags are placed either side of umbilicals that are overlain with concrete mattresses, although following a review of the 'as-built' documentation and deposit consents it is not obvious that this approach has been used for the Chestnut umbilicals.

Deposited rock has only been used to protect and stabilise the piggybacked 6in production PL2545(4) and 2in nitrogen PL2546(1) pipelines, and to mitigate upheaval buckling.

As they would be completely removed, the surface laid pipelines will not be discussed here.

3.1 PL2422(3) 8in flexible flowline between WI RB and WI well, ~2.4km long

PL2422 Ident 3 is an 8in nominal bore flexible flowline that is constructed from composite materials. It is routed between the water injection riser base and the water injection well. The pipe is an unbonded structure consisting of a combination of helically wound steel armour wires and concentric, extruded, or wound polymer layers. The outside and inside diameters are 301mm and 203mm, respectively. It is 2.4km long and it is trenched and buried. As can be seen in Figure 3.1.2 and Figure 3.1.4 the depth of cover is consistent and stable with no exposures or spans arising except on the final approaches where they would be removed anyway as part of the decommissioning activities.

In 2010 a 6.45m long freespan was rectified using 30x 1Te grout bags and 4x concrete mattresses between ~KP0.677 and ~KP0.701. The surveys show that the flowline itself has remained buried.

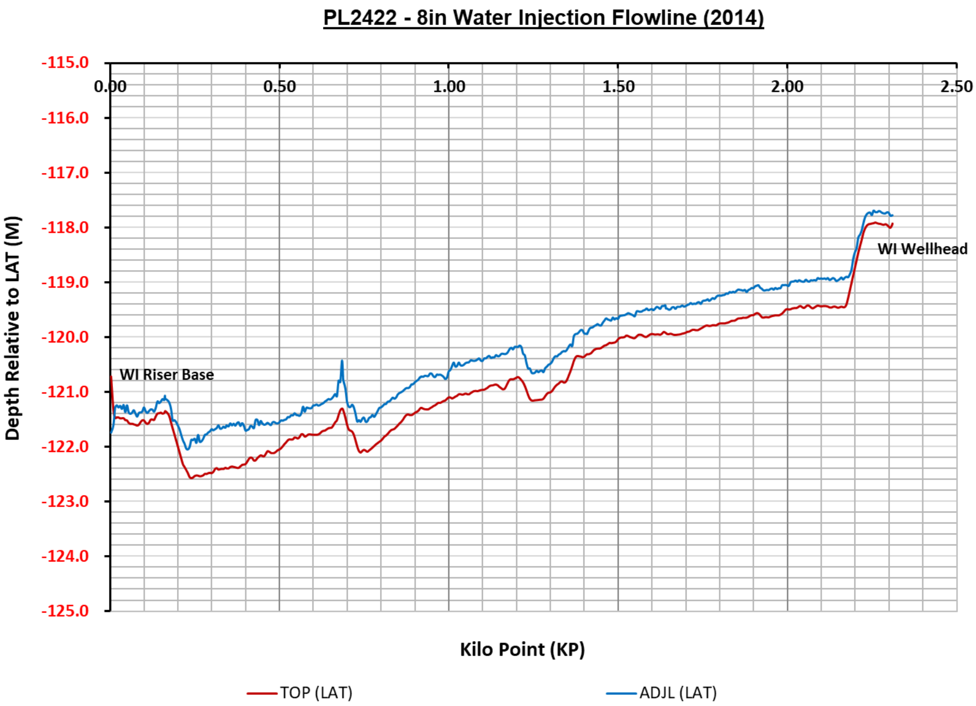


Figure 3.1.1: PL2422 flowline & seabed profile (2014)

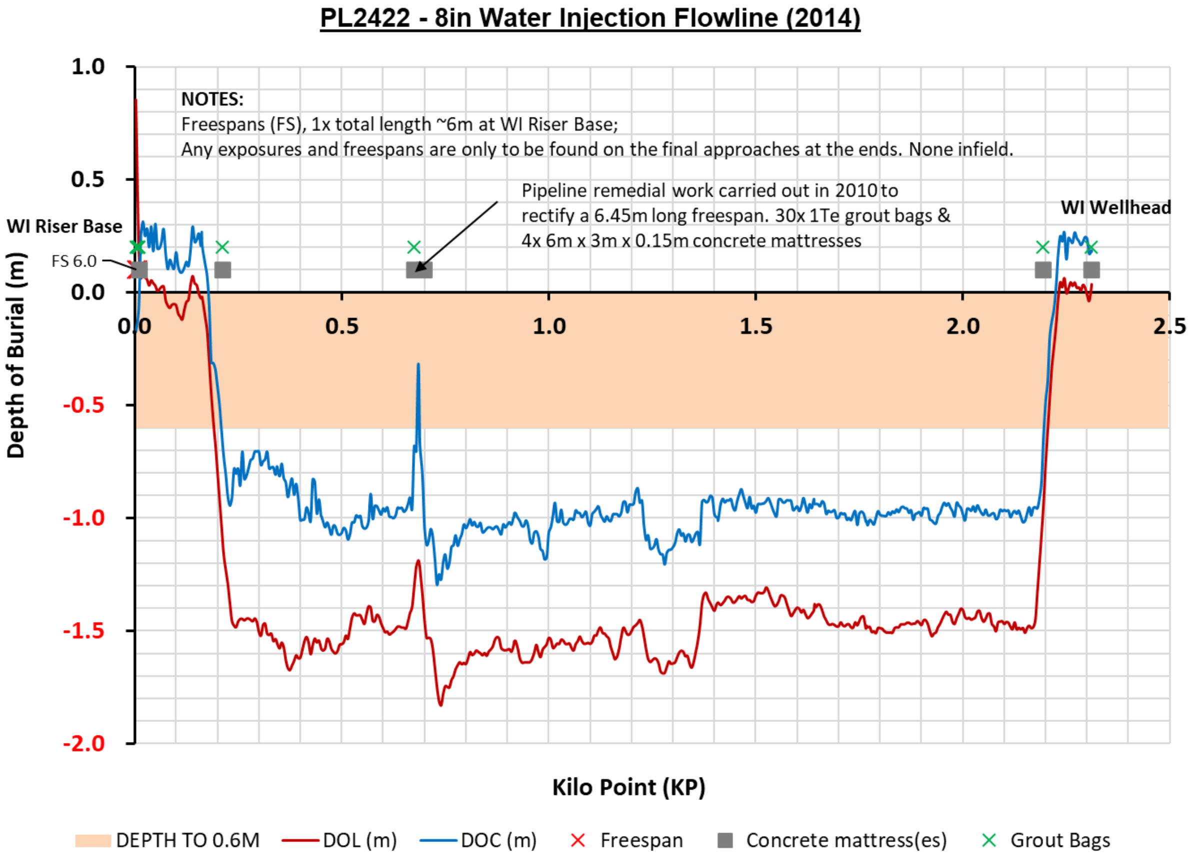


Figure 3.1.2: PL2422 flowline depth of cover profile (2014)

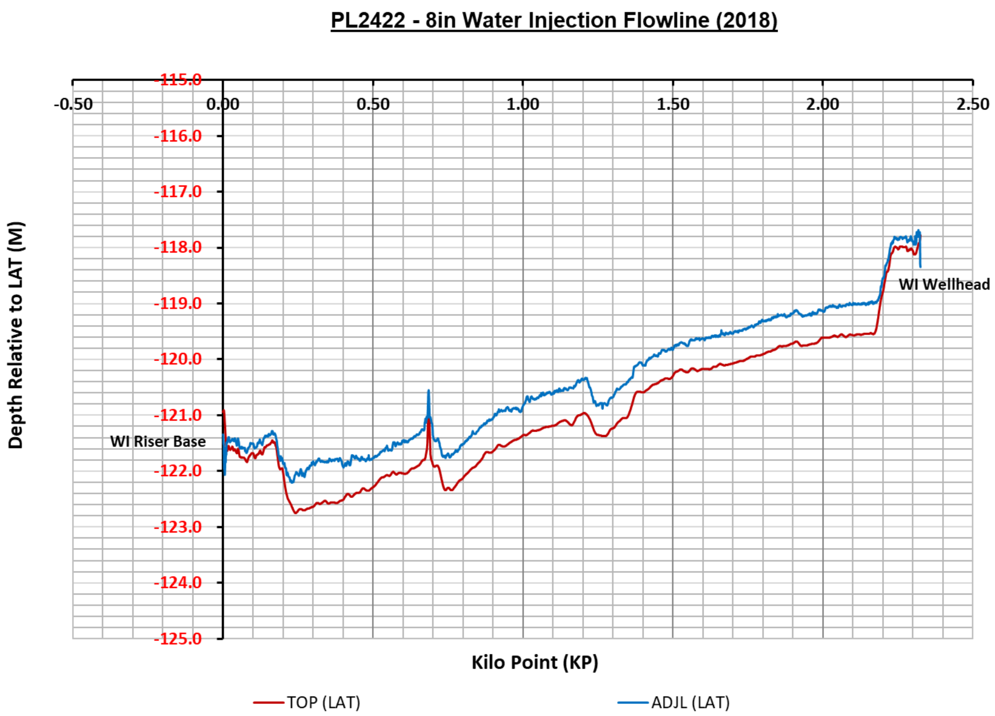


Figure 3.1.3: PL2422 flowline & seabed profile (2018)

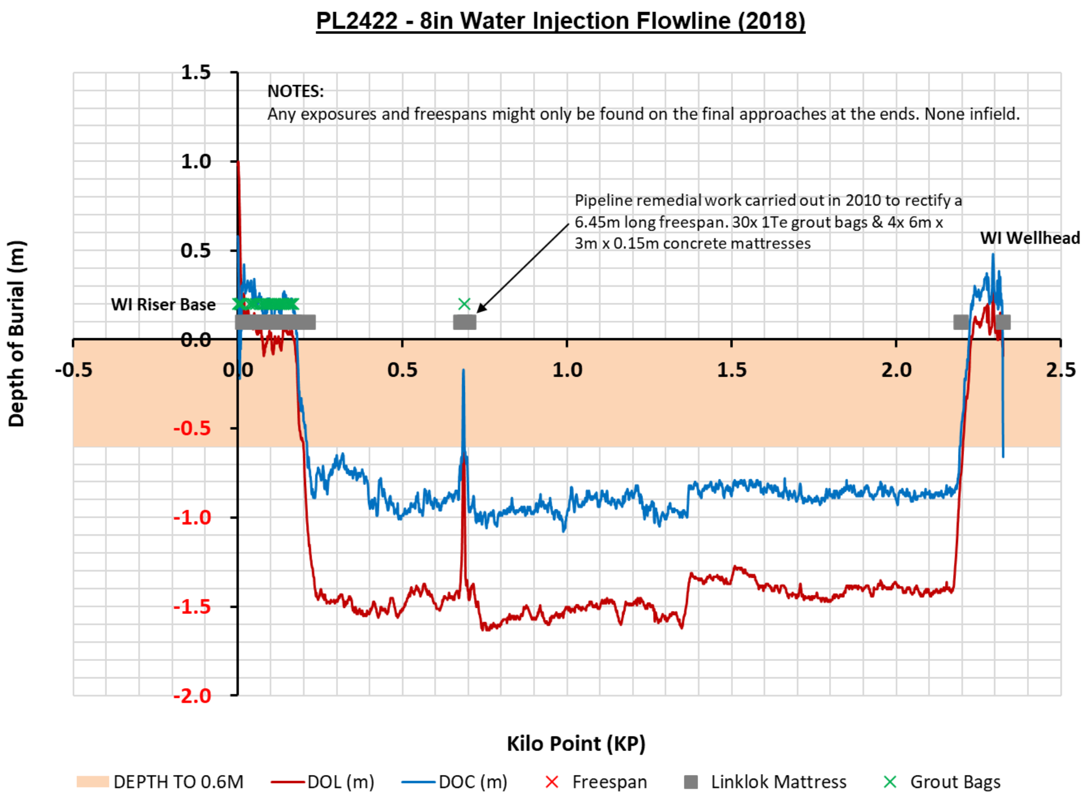


Figure 3.1.4: PL2422 flowline depth of cover profile (2018)

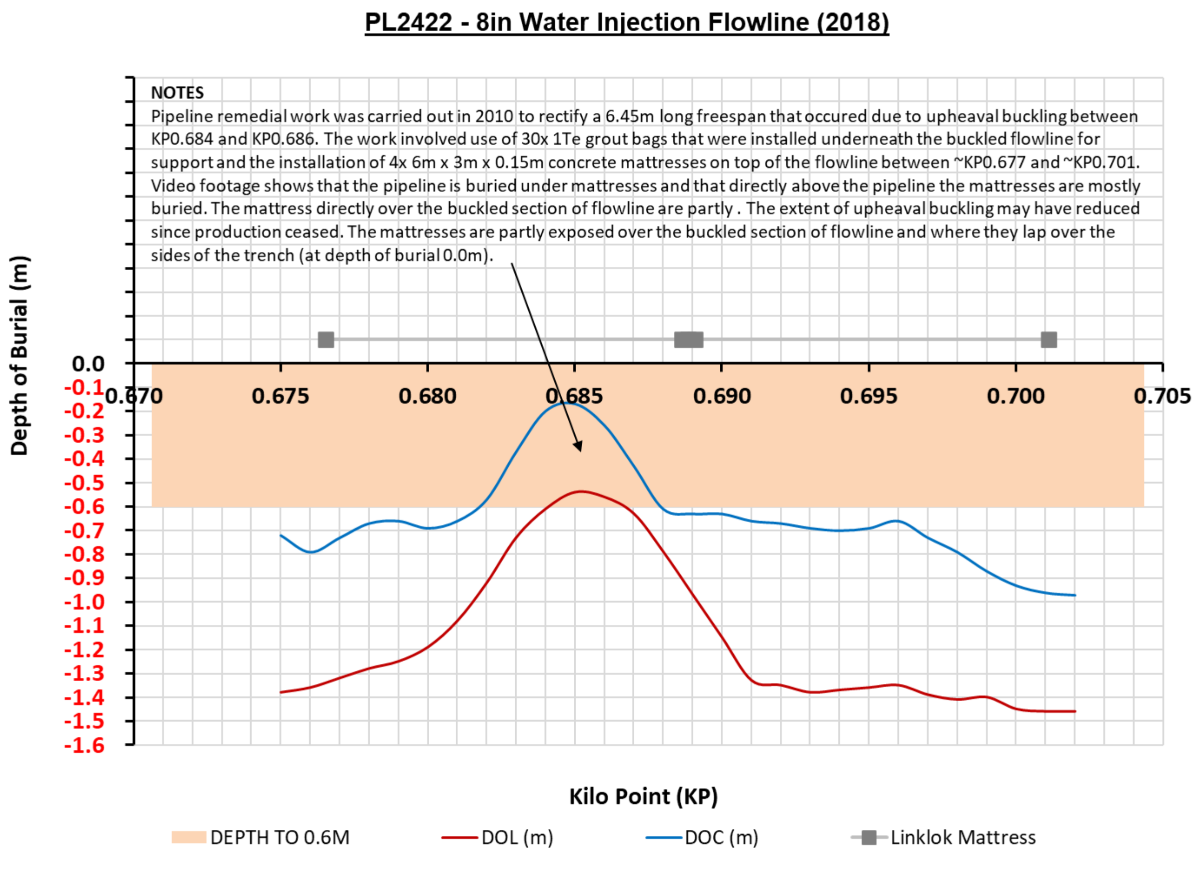


Figure 3.1.5: PL2422 depth of cover between ~KP0.677 and ~KP0.701 (2018)

3.2 PLU2423/J3 121mm umbilical, ~2.385km long

PLU2423/J3 is an umbilical with a 121mm OD. It is constructed from composite materials and routed between the controls' riser base and the water injection well. A cross section is presented in Figure 3.2.1. It is ~2.4km long and it is trenched and buried. As can be seen in Figure 3.2.3 and Figure 3.2.5 the depth of cover is consistent and stable with no exposures or spans arising.

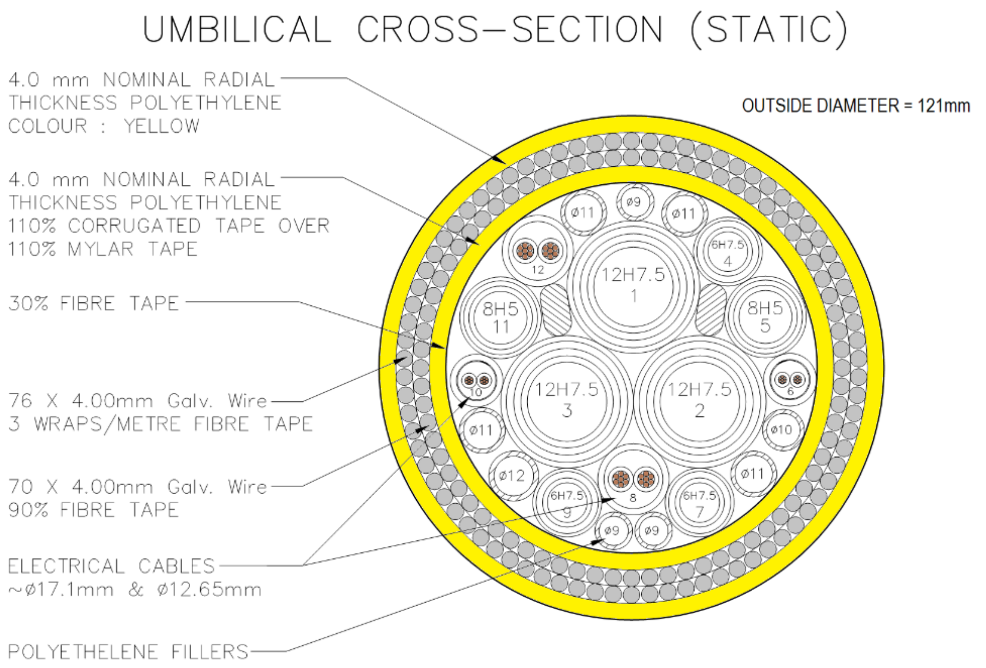


Figure 3.2.1: PLU2423/J3 umbilical cross section, 121mm diameter

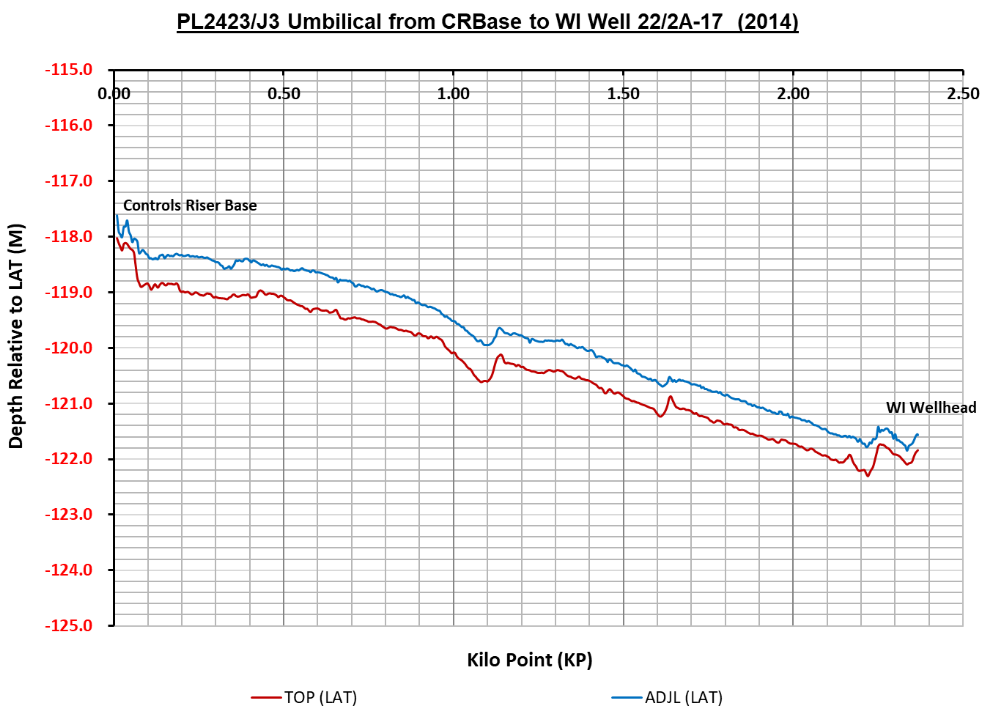


Figure 3.2.2: PL2423(J3) umbilical & seabed profile (2014)

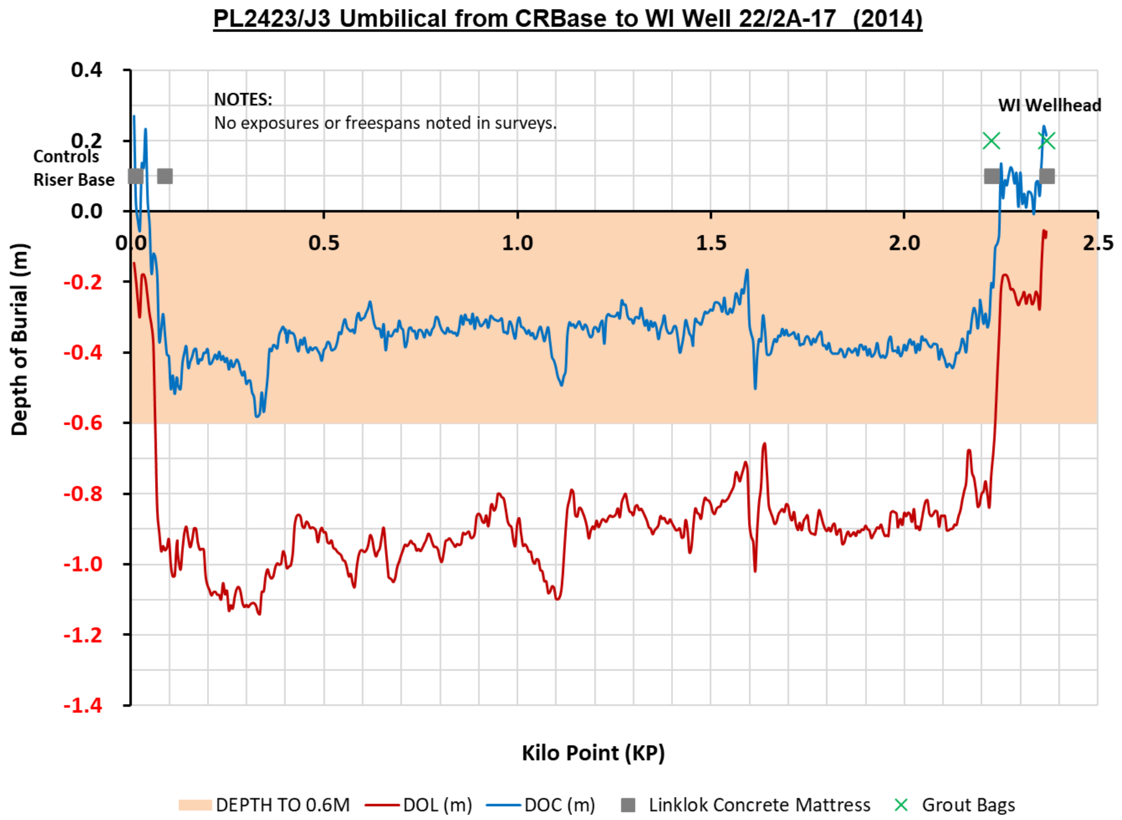


Figure 3.2.3: PL2423(J3) umbilical depth of cover profile (2014)

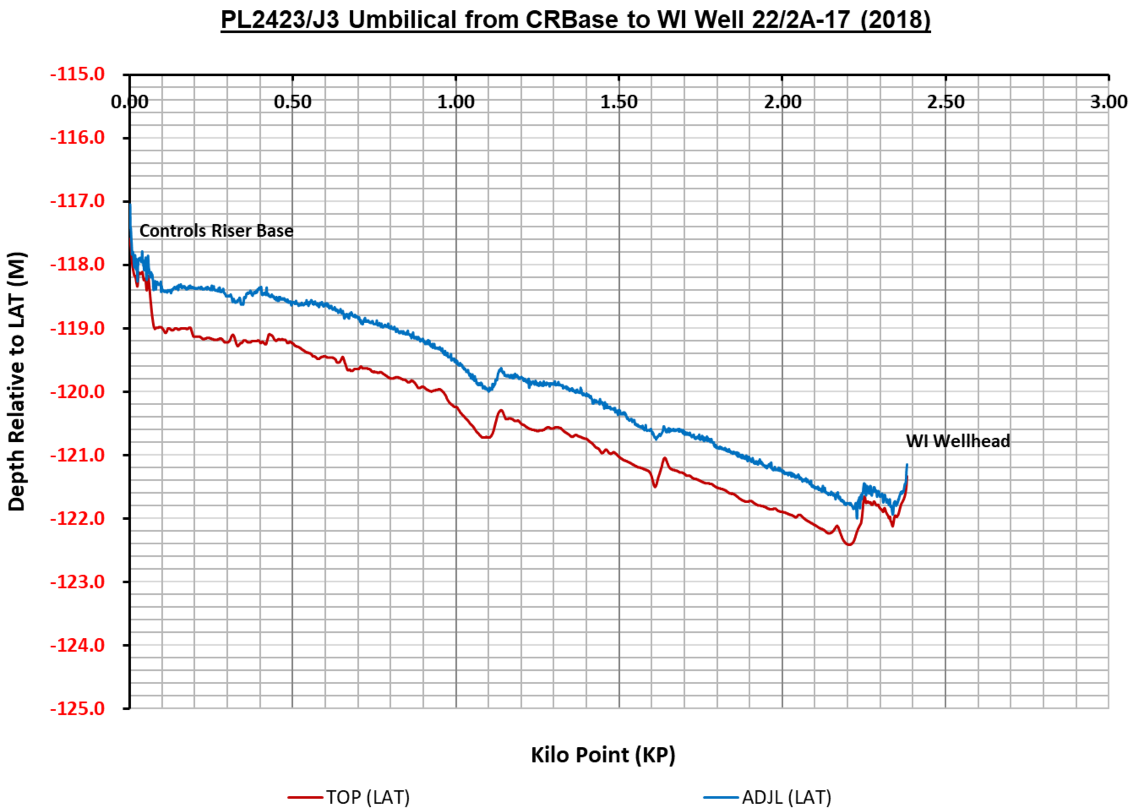


Figure 3.2.4: PL2423(J3) umbilical & seabed profile (2018)

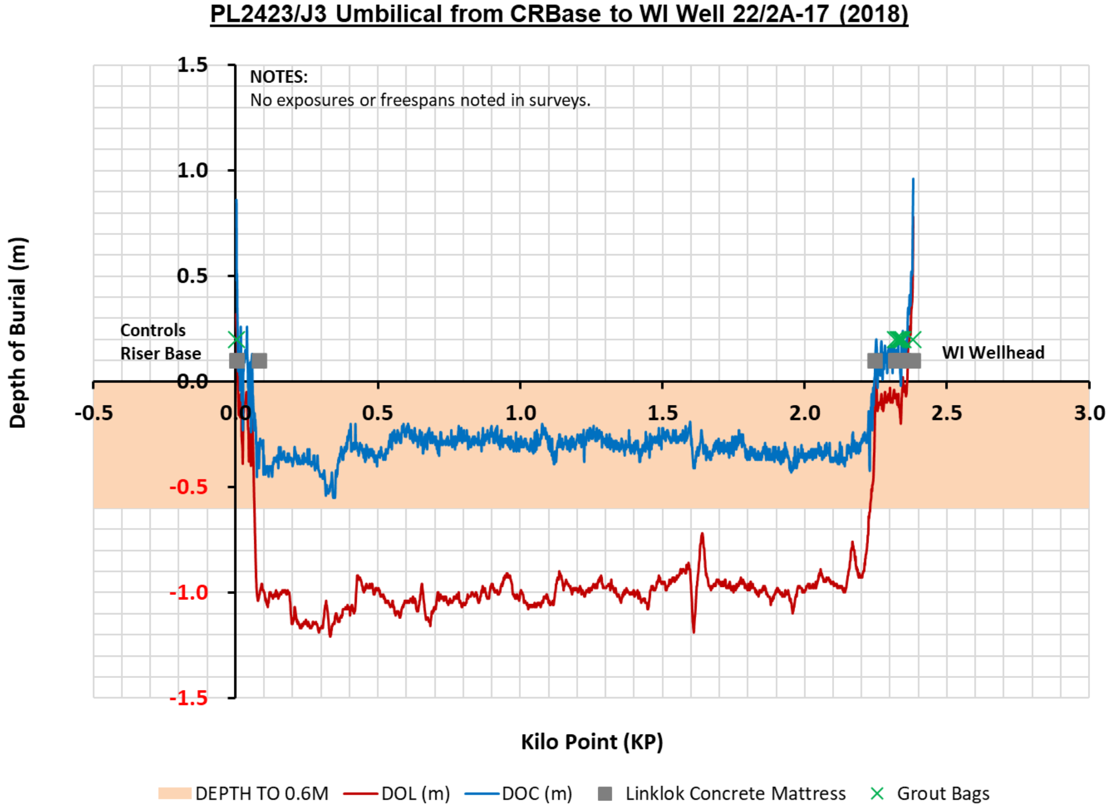


Figure 3.2.5: PL2423(J3) umbilical depth of cover profile (2018)

3.3 PLU2544(2), 153mm umbilical, ~0.980km long

PLU2544 Ident 2 is an umbilical with a 153mm OD. It is constructed from composite materials, and it is routed between the water injection well and the production well P1. A cross section is presented in Figure 3.2.1. It is ~0.98km long and it is trenched and buried. As can be seen in Figure 3.3.3 and Figure 3.3.5 the depth of cover is consistent and stable with no exposures or spans arising.

Note that the burial profile presented in Figure 3.3.2 and Figure 3.3.3 appears to have suffered from a calibration error. Although the profile in the 2014 and 2018 surveys looks the same, in 2014 the umbilical appears to be buried approximately 1m deeper than determined in the 2018 survey. This looks like a calibration error. Although, this discrepancy would not affect the comparative assessment for completeness, future surveys should be checked to confirm that the 2018 profile is likely the correct version.

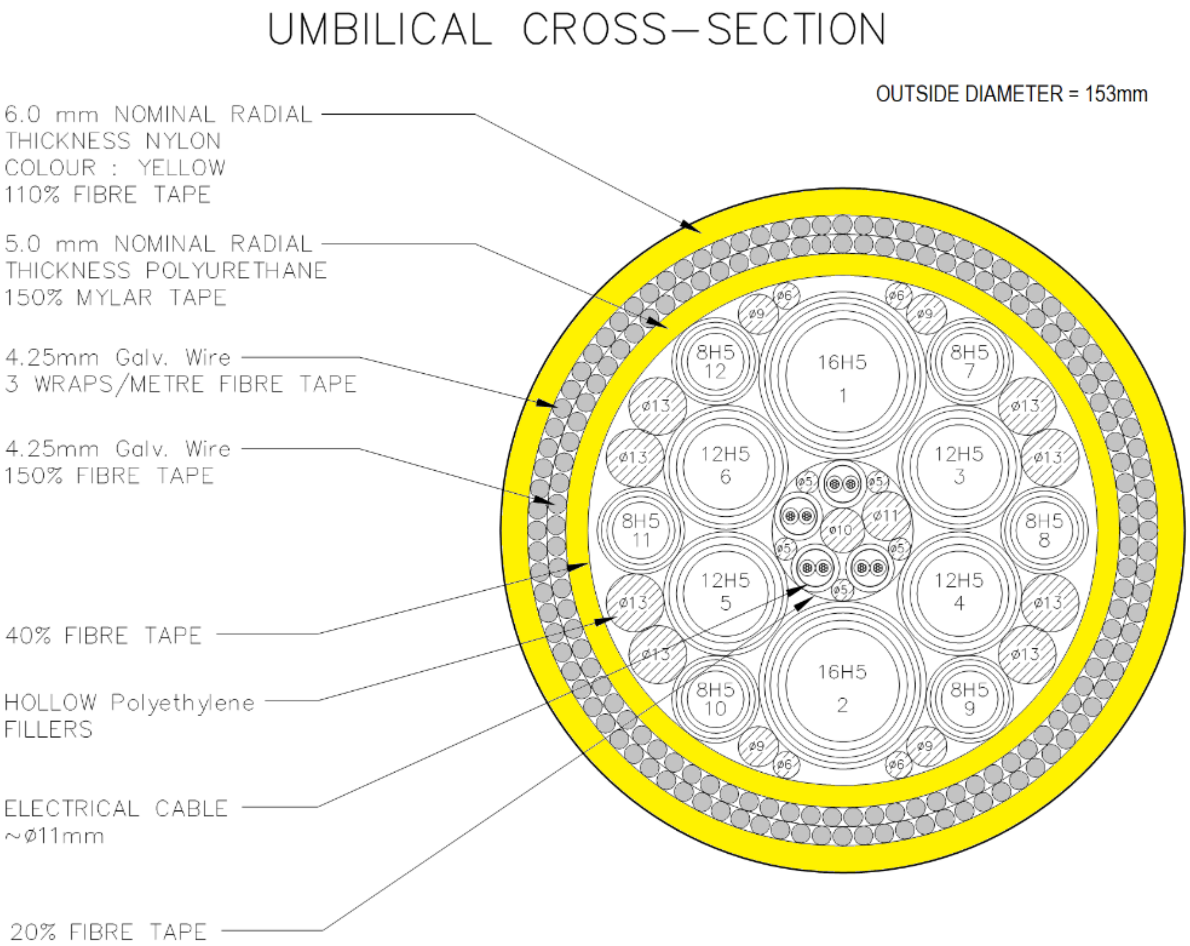


Figure 3.3.1: PLU2544(2) umbilical cross section, 153mm diameter

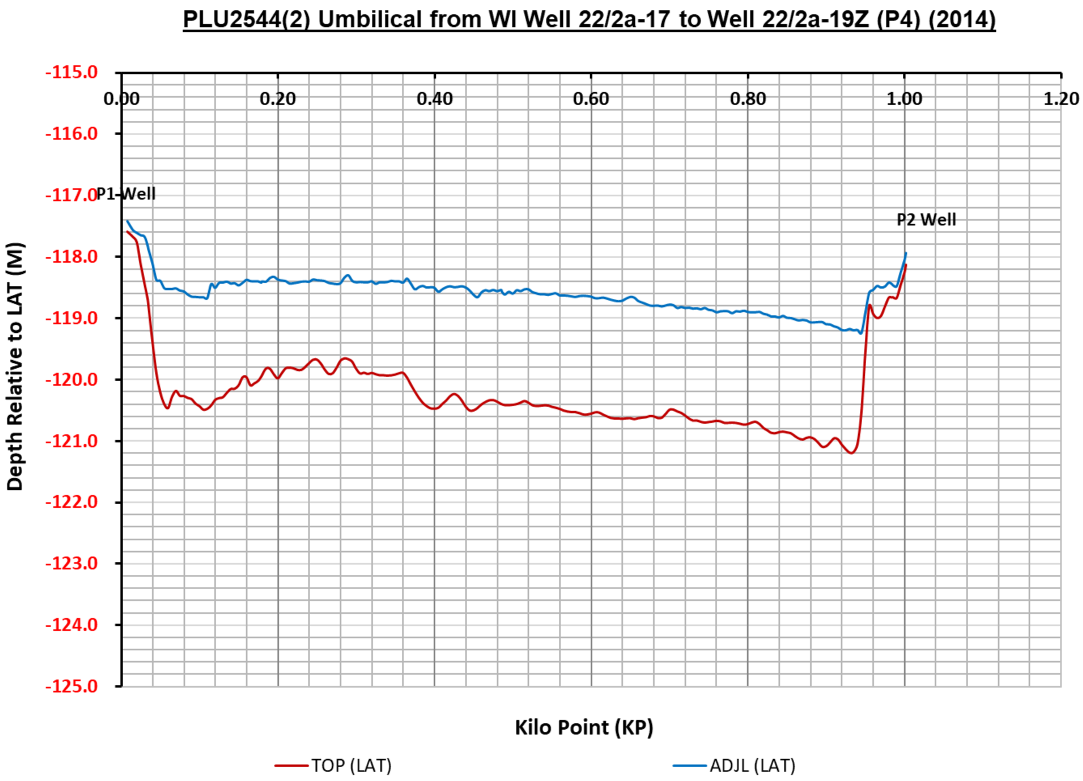


Figure 3.3.2: PL2544(2) umbilical & seabed profile (2014)

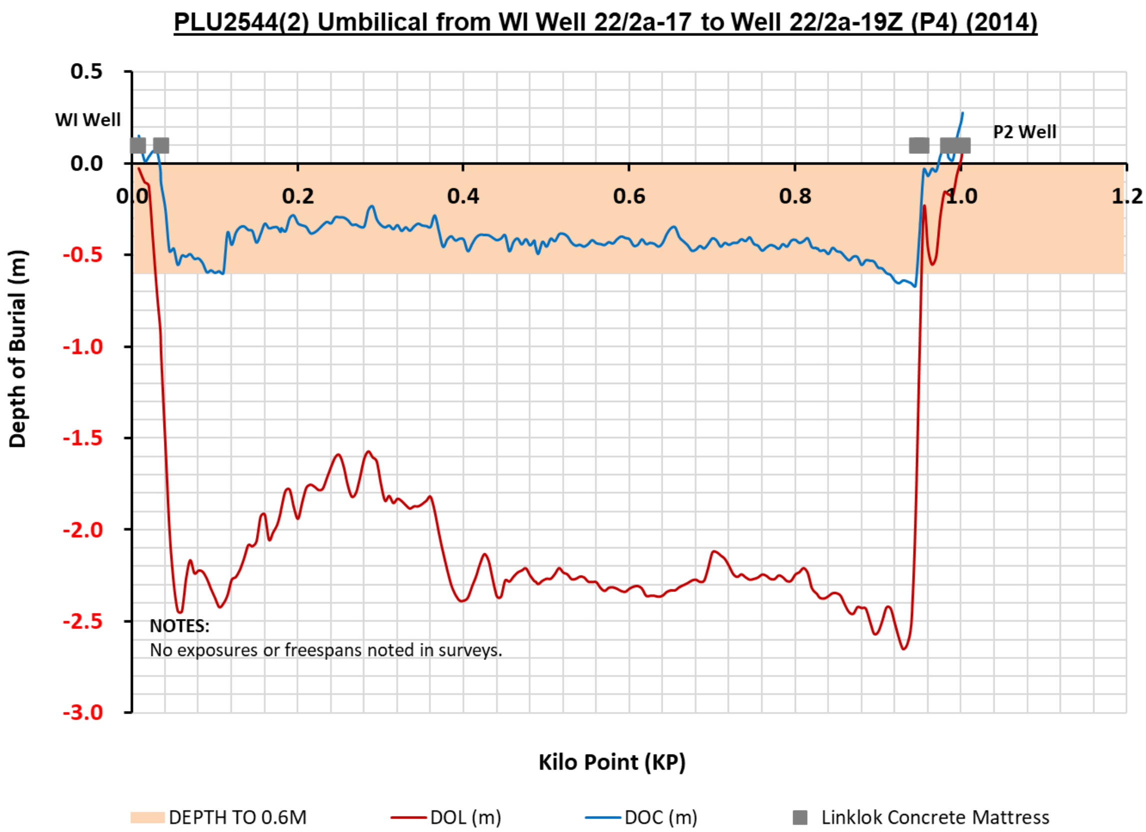


Figure 3.3.3: PL2544(2) umbilical depth of cover profile (2014)

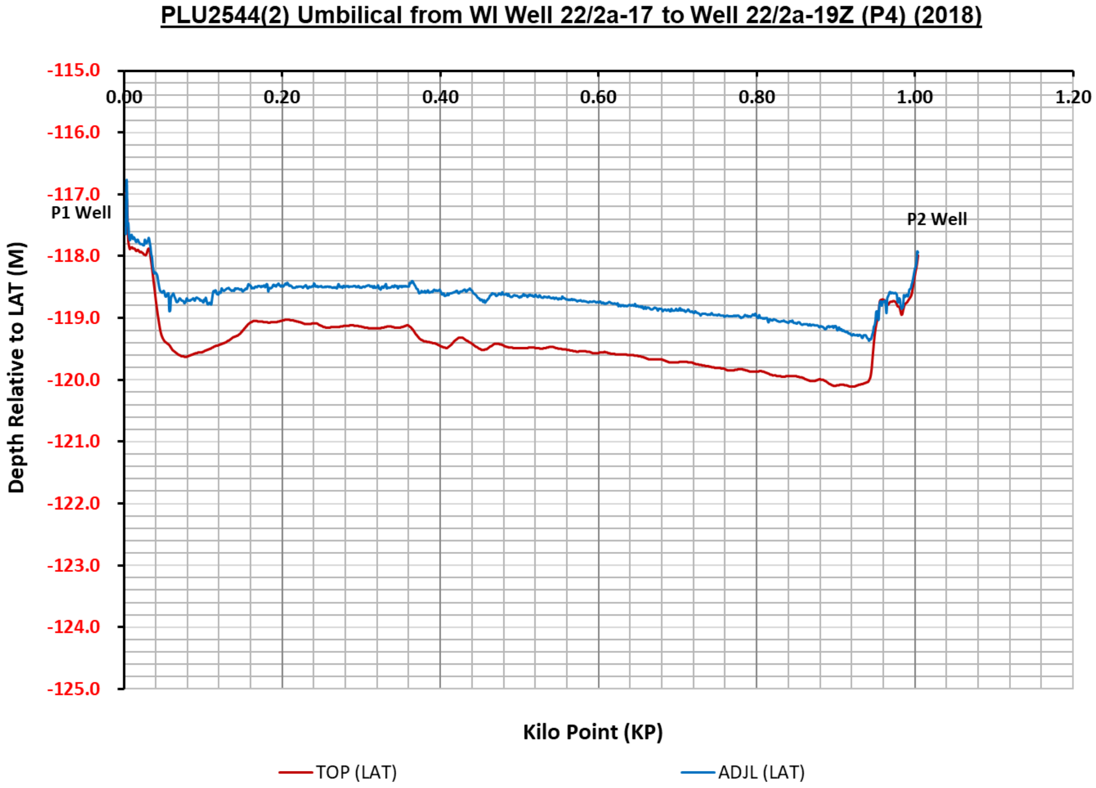


Figure 3.3.4: PL2544(2) umbilical & seabed profile (2018)

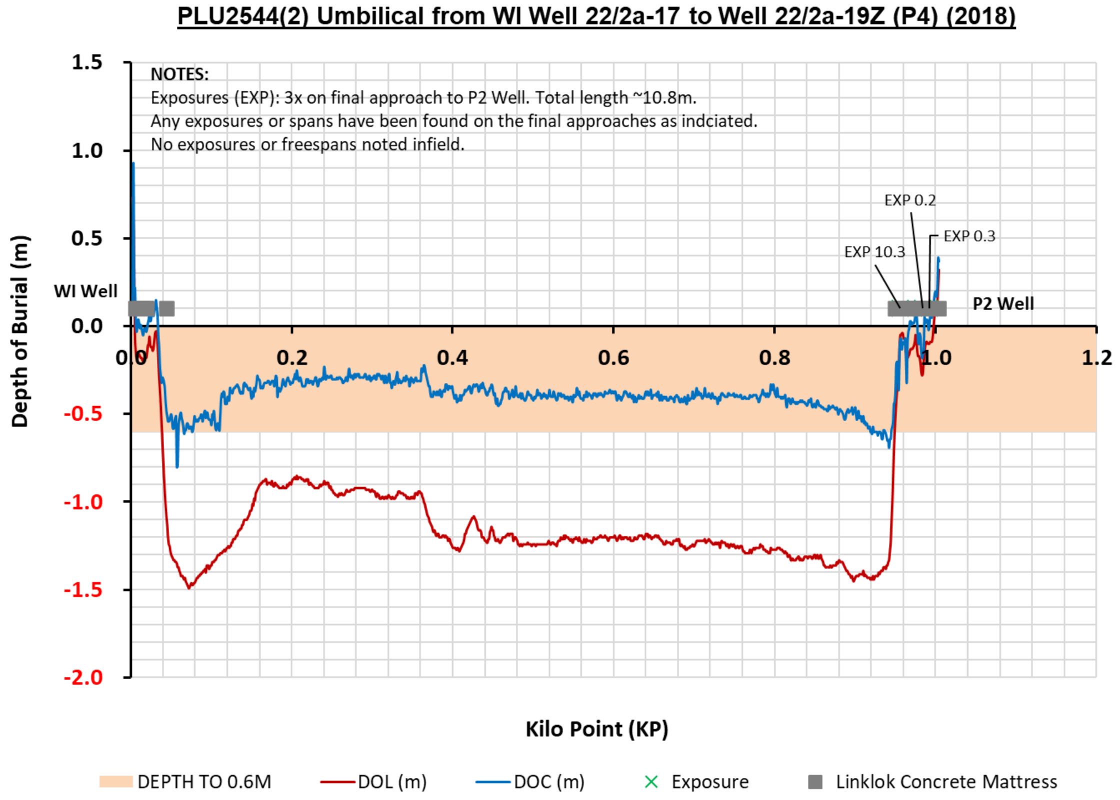


Figure 3.3.5: PL2544(2) umbilical depth of cover profile (2018)

3.4 PL2545(4) with PL2546(1) piggybacked, ~3.4km long

PL2545 Ident 4 is a 6in nominal bore rigid pipeline constructed from carbon steel and it is coated with 3LPP. It is routed between production well P2/P4 to the P2/P4 choke manifold near production well P1. It is piggybacked by PL2546 Ident 1 which is a rigid 2in nitrogen pipeline that is also constructed from carbon steel and coated with 3LPP. The pipelines are both ~3.4km long and trenched and buried. As can be seen in Figure 3.4.2 and Figure 3.4.4 the depth of cover is consistent and stable with no exposures or spans arising.

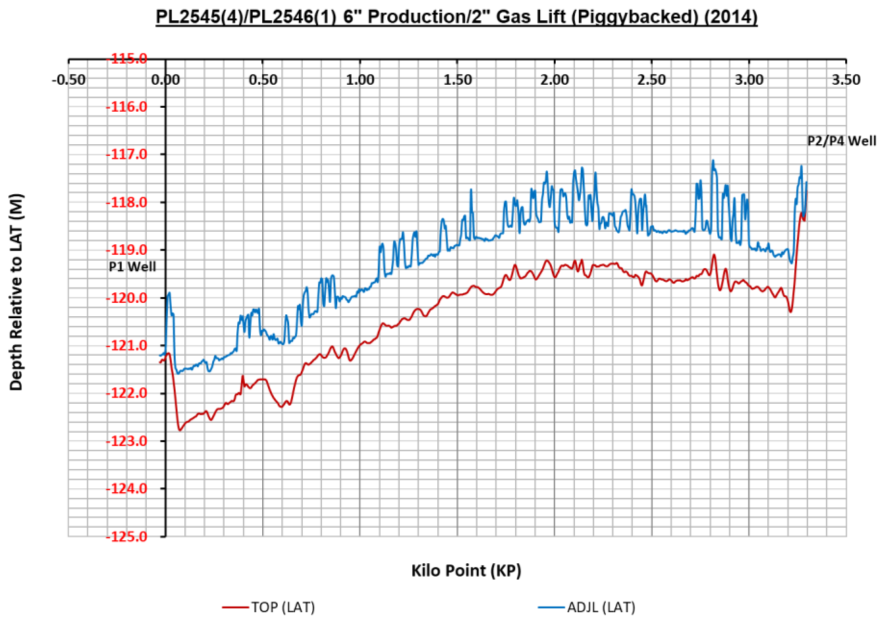


Figure 3.4.1: PL2545(4)/PL2546(1) pipeline & seabed profile (2014)

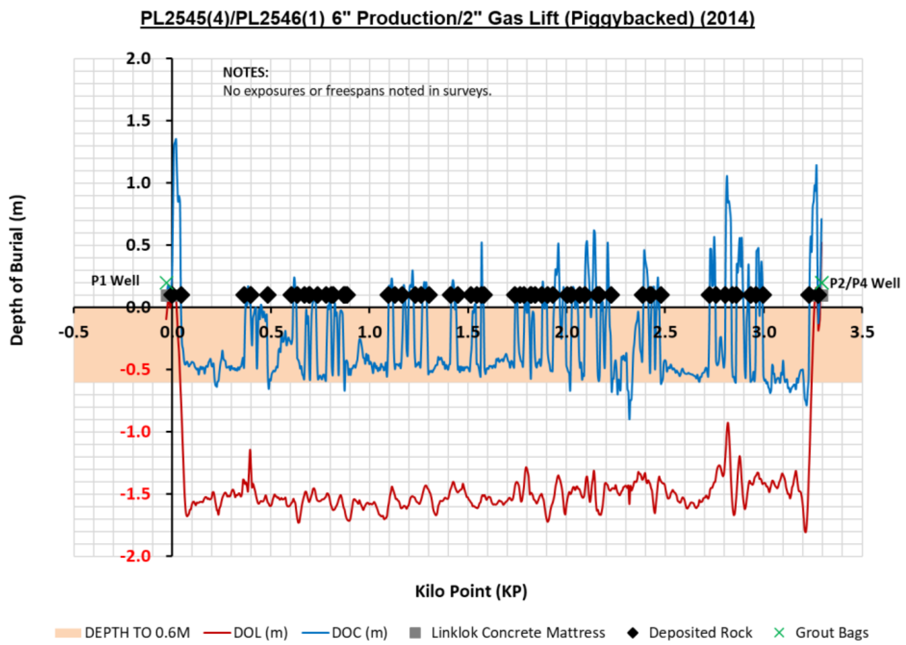


Figure 3.4.2: PL2545(4)/PL2546(1) pipeline depth of cover profile (2014)

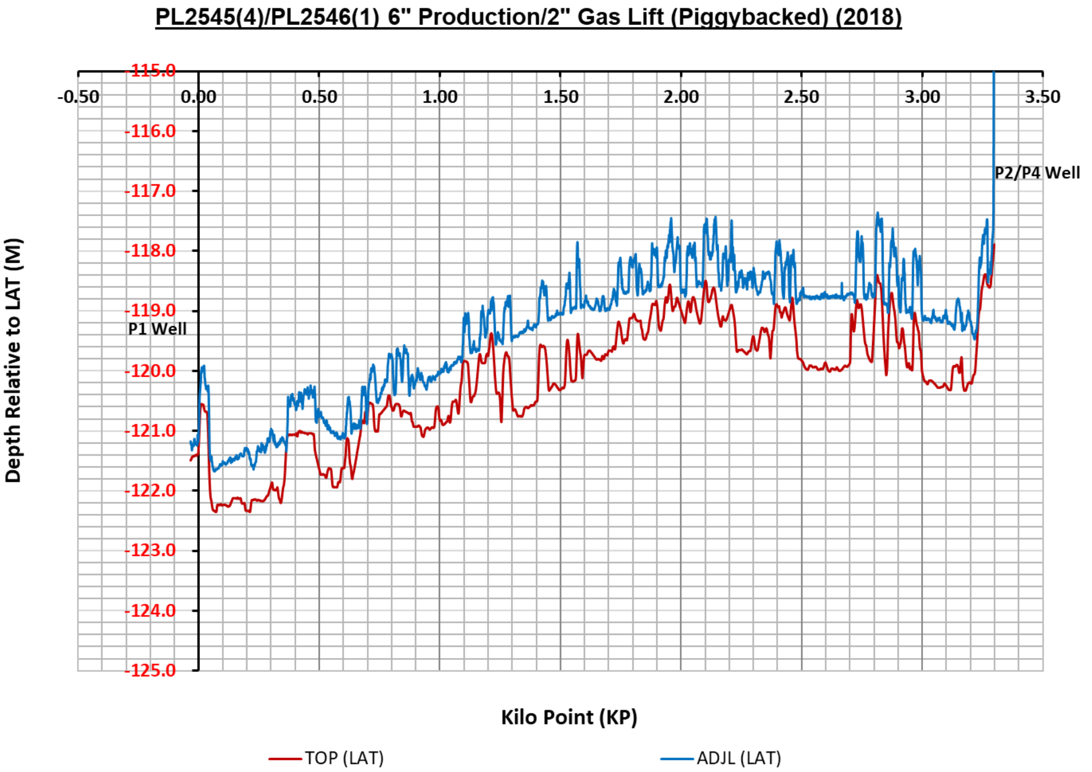


Figure 3.4.3: PL2545(4)/PL2546(1) pipeline & seabed profile (2018)

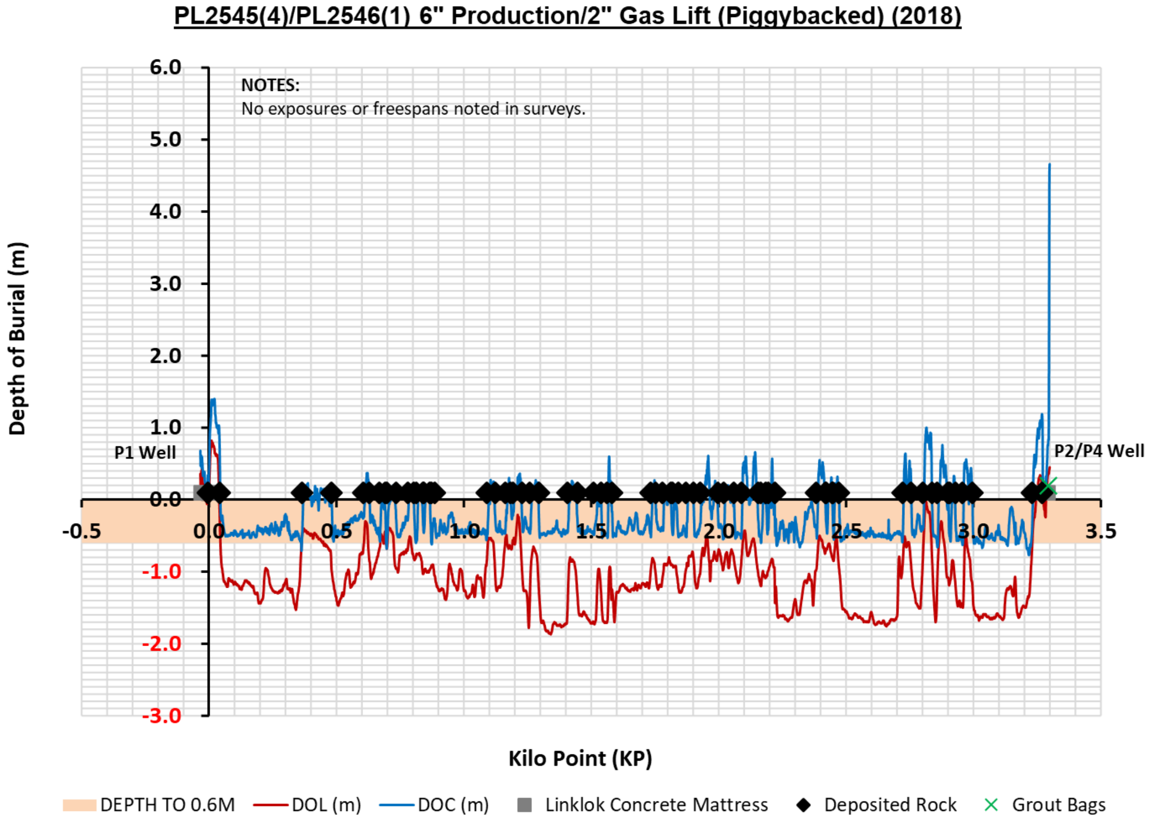


Figure 3.4.4: PL2545(4)/PL2546(1) pipeline depth of cover profile (2018)

3.5 Pipeline exposures and spans

None of the pipelines or umbilicals included in this comparative assessment have been found with exposures or spans infield. Any exposures or spans noted in the burial profiles would be on the final approaches, and these would be destined for full recovery along with the surface laid ends.

In 2010 a 6.45m long x 0.56m high freespan in PL2422 that had occurred because of upheaval bucking was rectified using several 1Te grout bags installed underneath and around the buckled flowline, and with concrete mattresses installed between ~KP0.677 and ~KP0.701 (Figure 3.5.1). No exposures or freespans in the flowline have been observed since. Although the grout bags are buried, the concrete mattresses are partly exposed.

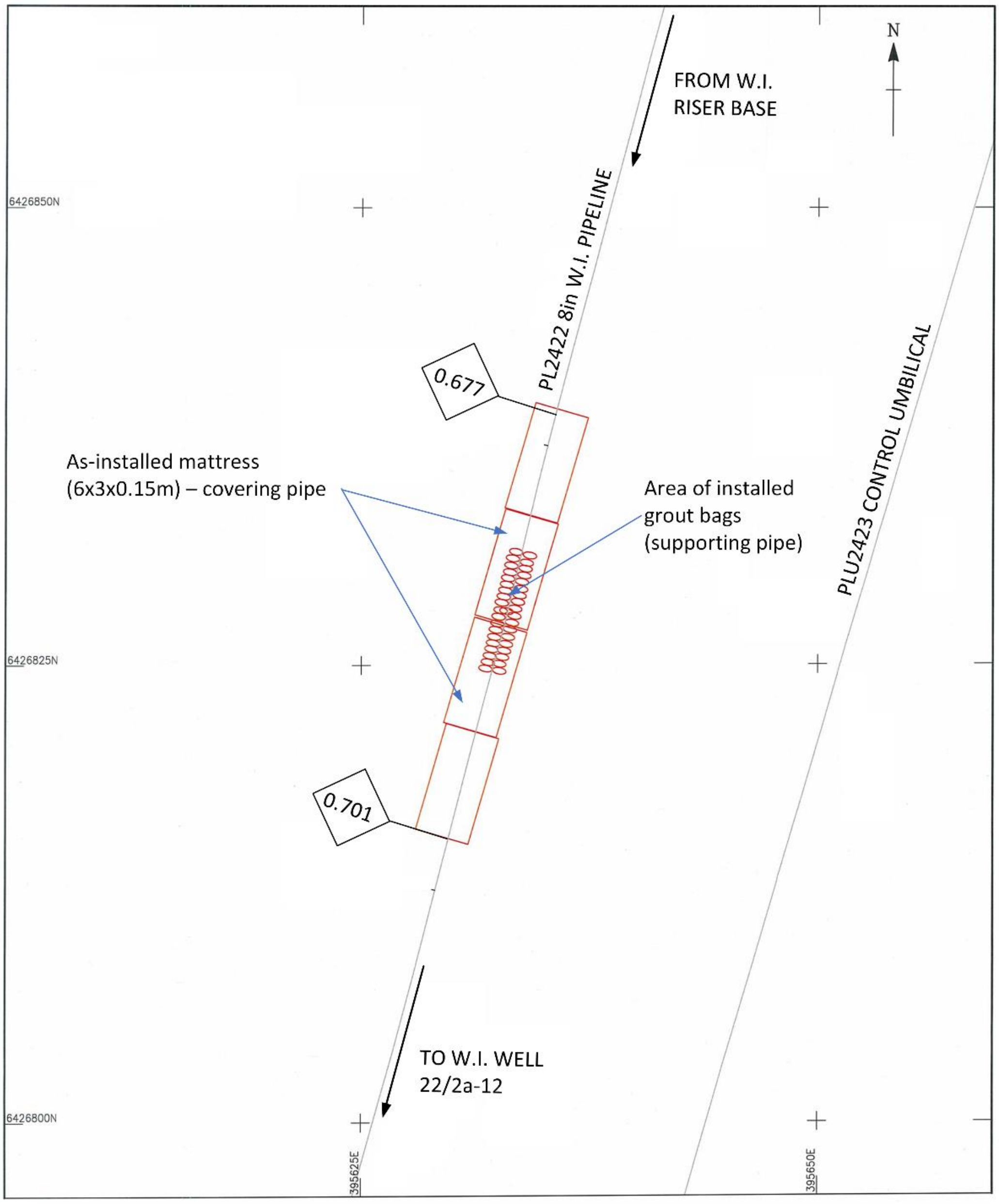


Figure 3.5.1: Freespan rectification work on PL2422 in 2010

3.6 Pipeline crossings

There are no third-party pipeline crossings within the Chestnut pipeline infrastructure.

4. DECOMMISSIONING OPTIONS

4.1 Pipeline decommissioning

There is an implicit assumption that options for re-use of the pipeline(s) have been exhausted before the facilities and infrastructure move into the decommissioning phase and associated comparative assessment. Therefore, the re-use option has been excluded from this assessment. As the pipelines remain buried the two decommissioning options considered are:

- **Complete removal** – this would involve the complete removal of the pipelines by whatever means most practicable and acceptable from a technical perspective.
- **Leave *in situ*** – this would involve leaving the pipeline(s) *in situ* with no remedial works but possibly verifying their status via future surveys.

It is worth noting here that ordinarily a pipeline span such as that in PL2422 at KP0.677 would be considered a candidate for partial removal. However, as subsequent survey data have indicated that the flowline remains buried, it is recommended that the grout bags and concrete mattresses remain *in situ* but be subject to overtrawl[6]. This would be to confirm that no snagging potential would remain following completion of decommissioning activities. As the flowline is not situated in an environmentally sensitive area this should be acceptable. The potential environmental impacts of this approach will be addressed separately in the environmental appraisal prepared in support of the Chestnut Phase 2 Decommissioning Programmes [11].

The pipelines on the approaches will be removed, so these are not included in the comparative assessment. All options include removal of features such as spool pieces, concrete mattresses, and grout bags in accordance with mandatory requirements.

The pipeline(s), groupings and associated decommissioning options are summarised in Table 4.1.1 below.

Pipeline ID	Diameter (in, mm)	Comment / Burial status	Length (km)	Group
PL2422(3)	8in	Flexible flowline, trenched and buried	~2.400	1
PLU2423/J3(4)	121mm	Umbilical, trenched and buried	~2.385	1
PLU2544(2)	153mm	Umbilical, trenched and buried	~~0.980	1
PL2545(4) & PL2546(1)	6in, 2in	Rigid pipelines, piggybacked; trenched and buried, incl. rock	~3.400	2

NOTES
1. Numbers in brackets refer to pipeline ident no. in PWA Table A.
2. All pipelines and umbilicals presented in this table are candidates for either complete removal or leave *in situ*. All other pipelines and umbilicals not listed here will be completely removed.

Table 4.1.1: Pipeline decommissioning options & group summary

[6] The proposal was discussed with SFF in a meeting on 26 May 2021. The remediated section of pipe ~700m south-south-west of Hummingbird Spirit would not have been fished due to its being inside the mooring area. The proposal to carry out overtrawl was discussed to confirm whether the 30x 1Te grout bags and 4x concrete mattresses would pose a snagging hazard should they be left *in situ* following decommissioning. SFF were comfortable with the proposal in principle, but any decision should be supported by visual evidence (e.g. ROV footage). Should any remedial work be required, the preference would be for the 4x mattresses to be removed and replace with deposited rock sufficient to bury the pipeline. A statement to this effect will be included in the DP for Phase 2.

ID	Item Description6	Option 1 Complete removal	Option 2 Leave *in situ*
1	Surface laid sections of the pipelines, associated pipespools and umbilicals down to trench depth, 8in PL2422(3) flexible flowline, 121mm umbilical PLU2423/J3, and 153mm umbilical PLU2544(2).	Completely remove. Uncover any mattresses and underlying pipeline(s) and umbilicals to point of burial in seabed or deposited rock using a jet trencher or mass flow excavator (MFE)[1]. Completely remove mattresses and completely remove short sections of pipelines and umbilicals using reverse reel method.	Remove. As option 1 but using 'cut and lift' method of removal.
2	Trenched and buried section of the pipelines and umbilicals, PL2422(3), PLU2423/J3, and PLU2544(2).	Complete remove PL2422(3), PLU2423/J3 and PLU2544(2) pipeline(s) and umbilicals using reverse reel method[2].	Leave *in situ*.
3	Surface laid sections of the pipelines, associated pipespools and umbilicals from trench depth, PL2422(3), PL2423/J3, PLU2544(2).	Completely remove. Uncover any mattresses and underlying pipeline(s) and umbilicals to point of burial in seabed or deposited rock using a jet trencher or mass flow excavator (MFE)[1]. Completely remove mattresses and completely remove short sections of pipelines and umbilicals using reverse reel method.	Remove. As option 1 but using 'cut and lift' method of removal.

NOTES:

1. Assume any local excavations in the seabed would be mechanically backfilled to reduce snagging hazard; however, this can sometimes be problematic for short lengths, in which case contingency measures may be used. The contingency measures would include the deposition of small quantities of deposited rock at the cut pipeline ends. This environmental impact will be catered for in the Environmental Appraisal. Given that the Chestnut infrastructure is not in an environmentally sensitive area, it is unlikely that there would be an issue with taking this approach.
2. Removal using reverse reel method of removal would only be considered viable if it could be determined that there are no integrity issues with the pipelines. Given the construction of these pipelines and umbilicals, it is unlikely that integrity issues would be a factor.

Table 4.1.2: Options for decommissioning pipelines and umbilicals in group 1

ID	Item Description6	Option 1 Complete removal	Option 2 Leave *in situ*
1	Surface laid sections of the pipelines, associated pipespools to trench depth, 6in pipeline PL2545(4) & piggybacked 2in pipeline PL2546(1).	Completely remove. Uncover any mattresses and underlying pipeline(s) and umbilicals to point of burial in seabed or deposited rock using a jet trencher or mass flow excavator (MFE)[1]. Completely remove mattresses and completely remove short sections of pipelines and umbilicals using 'cut and lift' method.	Remove. As option 1.
2	Trenched and buried section of the pipelines PL2545(4) & piggybacked PL2546(1).	Complete remove PL2545(4) & piggybacked 2in rigid pipeline PL2546(1) using 'cut and lift' method.	Leave *in situ*.
3	Surface laid sections of the pipelines, associated pipespools from trench depth, PL2545(4) & piggybacked PL2546(1).	Completely remove. Uncover any mattresses and underlying pipeline(s) and umbilicals to point of burial in seabed or deposited rock using a jet trencher or mass flow excavator (MFE)[1]. Completely remove mattresses and completely remove short sections of pipelines using 'cut and lift' method.	Remove. As option 1.

NOTES:

1. Assume any local excavations in the seabed would be mechanically backfilled to reduce snagging hazard; however, this can sometimes be problematic for short lengths, in which case contingency measures may be used. The contingency measures would include the deposition of small quantities of deposited rock at the cut pipeline ends. This environmental impact will be catered for in the Environmental Appraisal. Given that the Chestnut infrastructure is not in an environmentally sensitive area, it is unlikely that there would be an issue with taking this approach.
2. Only the 'cut and lift' method of removal is considered viable for these pipelines as they are piggybacked.

Table 4.1.3: Options for decommissioning pipelines in group 2

4.2 PL2422 mattresses and grout bags

The freespan remedial works between ~KP0.677 and ~0.701 involved the deposition of 4x 6m x 3m x 0.3m concrete mattresses overlying 30x 1Te grout bags. The decommissioning options are as follows:

- **Complete removal –** this would involve the complete removal of the grout bags and concrete mattresses, removing the short section of PL2422 (~12m long[7]) and replenishing the excavated material with deposited rock.
- **Partial removal –** this would involve removal of the overlying concrete mattresses and replacing them with deposited rock.
- **Leave *in situ* –** this would involve leaving the grout bags and overlying mattresses *in situ* with no remedial works.

In all instances legacy surveys will be required.

From a survey carried out in 2018 the indications are that the grout bags and flowline (PL2422) are buried, but the overlying concrete mattresses may be partially exposed.

[7] The length is stated as 12m long to ensure that the 6.45m freespan is removed along with any associated part of the pipeline that maybe poorly buried. The affected section lies underneath concrete mattresses lying between KP0.677 and KP0.701.

5. COMPARATIVE ASSESSMENT

5.1 Method

The comparative assessment is largely qualitative, carried out at a level that is sufficient to differentiate between the options. However, in some cases, for example such as cost, it can be necessary to examine the differences in more detail and quantitatively to provide clarity. The comparative assessment considers generic evaluation criteria and specific sub-criteria in line with OPRED guidance notes [9]. These elements are considered for short-term work as the assets are decommissioned as well as over the longer-term as 'legacy' impacts and risks. Please refer Table 5.2.1.

No scores have been determined and no weightings are used. However, 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, high impact, and less desirable outcomes. Green coloured cells indicate less risk, less impact, and preferrable 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 differences are compared relative to each other. A relatively high cost where the cost by difference would be an order of magnitude higher than the lowest cost option therefore would be coloured red, a less than order of magnitude higher cost would be coloured orange and the lowest cost option would be coloured green. The societal assessment examines beneficial as well as detrimental outcomes. Where comparison of options varies by shades of green rather than by red or orange it means there is little to choose between the options.

5.2 Criteria and sub-criteria for pipelines

Criteria	Definition	Sub-criteria (Short-term & Legacy, UNO)	Comments
Technical	A technical evaluation of the complexity of a job that can be expected to proceed without major consequence or failure if it is adequately planned and executed.	Risk of project failure. Technological challenge. Technical challenge.	Assesses the chances of failure, whether equipment is available, maturity of the technology, any integrity concerns, and would contingency planning be needed? The technical challenge considers the viability of a task should the technology be available. The technological challenge concerns the availability of specific technologies to perform a task and the extent of research & development that may be required.
Safety	An assessment of the potential health and safety risk to people directly or indirectly involved in the programme of work offshore and onshore, or who may be exposed to risk as the work is carried out.	Health and safety risks for project personnel carrying out decommissioning activities offshore. Residual risks to marine users on successful completion of decommissioning. Safety risks for project personnel engaged in carrying out decommissioning activities onshore.	Assesses typical offshore and onshore hazards. Offshore hazards include loss of dynamic positioning, sudden movements during recovery of material, dropped objects, collision between vessels. This would relate to the quantity of material being recovered. After decommissioning has been completed typical hazards could relate to exposed mattresses, leading to possibility of snagging of fishing nets. Onshore hazards might include dealing with large quantities of bulk items, onshore cutting, or crushing, sudden movements or dropped objects and these would increase with the quantity of material being handled.
Environmental	An assessment of the significance of the threats or impacts to the environmental receptors because of operational activities or the legacy aspects.	Energy and emissions to atmosphere. Effect on seabed: Seabed disturbance and area affected. Disturbance to protected areas & impact on conservation objectives of the area (e.g., SAC, SPA). Effect on water column: • Liquid discharges to sea. • Liquid discharges to surface water. • Noise. Waste creation and use of resources such as landfill. Recycling and replacement of materials .	None of the flowlines, pipelines and umbilicals are located inside or near an environmentally sensitive area. Although there are pockmarks, none have been found with MDAC and their locations are such that they are unlikely to be affected by these decommissioning activities and so are not considered in this assessment. Otherwise, the comparative assessment considers energy use and emissions, the effect on the seabed, a comparison of the extent of temporary and permanent disturbance, type of material being left *in situ*, compares fate of materials, requirement for materials needing to be manufactured to compensate for materials left *in situ*.

Criteria	Definition	Sub-criteria (Short-term & Legacy, UNO)	Comments
Socio-economic	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.).	Effects on commercial activities e.g., fishing Employment. Communities or impact on amenities.	Decommissioning of infrastructure involves work that is temporary. Assesses impact on commercial activities and job creation.
Cost	Difference in cost.	Difference in cost compared for like-for-like activities. Normalised to demonstrate a sense of scale.	Examines cost by difference for the complete removal and leave *in situ* options. Where applicable the partial removal option is also examined. Common activities such as engineering and management costs, mobilisation and demobilisation of vessels are ignored in the assessment. All other criteria and sub-criteria being equal, cost would be the final differentiator.

Table 5.2.1: Pipeline comparative assessment method – criteria & sub-criteria

5.3 Criteria and sub-criteria for PL2422 mattresses and grout bags

CRITERIA	DEFINITION	SUB-CRITERIA (Short-term & Legacy, UNO)	COMMENTS
Technical	A technical evaluation of the complexity of a job that can be expected to proceed without major consequence or failure if it is adequately planned and executed.	Risk of project failure.	Risk of project failure concerns the possibility of significant unplanned delays not dealt with by contingency planning or having to go back to the drawing board. It assesses the chances of failure, whether equipment is available, maturity of the technology, any integrity concerns, and would contingency planning be needed?
		Technological challenge.	The technological challenge concerns the availability of specific technologies to perform a task and the extent of research & development that may be required.
		Technical challenge.	The technical challenge considers the viability of a task should the technology be available.
Safety	An assessment of the potential health and safety risk to people directly or indirectly involved in the programme of work offshore and onshore, or who may be exposed to risk as the work is carried out.	Health and safety risks for project personnel carrying out decommissioning activities offshore. Residual risks to marine users on successful completion of decommissioning. Safety risks for project personnel engaged in	Assesses typical offshore and onshore hazards. Offshore hazards include loss of dynamic positioning, sudden movements during mattress recovery works, dropped objects, collision between vessels. Typically, these would increase with the quantity of material being recovered. After decommissioning has

CRITERIA	DEFINITION	SUB-CRITERIA (Short-term & Legacy, UNO)	COMMENTS
		carrying out decommissioning activities onshore.	been completed typical hazards could relate to exposed mattresses, leading to possibility of snagging of fishing nets. Onshore hazards might include dealing with large quantities of bulk items, onshore cutting, or crushing, sudden movements or dropped objects and these would increase with the quantity of material being handled.
Environmental	An assessment of the significance of the threat and or impacts to the environmental receptors because of operational activities or the legacy aspects.	Energy and emissions to atmosphere.	The mattresses and pipelines underneath are not located inside an environmentally sensitive area. Assesses the effect on the seabed, the effect on any conservation objectives, extent of temporary and permanent disturbance, impact on biota, type of material being left *in situ*, fate of materials, requirement for materials needing to be manufactured to compensate for materials left *in situ*.
		Effect on seabed: seabed disturbance and area affected.	
		Disturbance to protected areas & impact on conservation objectives of the area (e.g., SAC, SPA, SSSI).	
		Effect on water column: • Liquid discharges to sea. • Liquid discharges to surface water. • Noise.	
		Impact on biota.	
		Waste creation and use of resources such as landfill. Recycling and replacement of materials.	
Socio-economic	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.).	Effects on commercial activities e.g., fishing	Decommissioning of mattresses and grout bags generally involves work that is temporary that will lead to an extension of existing arrangements. Assesses impact on commercial activities and job creation.
		Employment.	
		Communities or impact on amenities.	
Cost	Difference in cost.	Difference in cost compared for like-for-like activities; normalised to demonstrate a sense of scale.	Give the limited scope of work involved, a cost assessment has not been carried out. All other criteria and sub-criteria being equal, cost would be the final differentiator.

Table 5.3.1:Mattress and grout bag comparative assessment method – criteria & sub-criteria

5.4 Comparative Assessment for pipelines in group 1

The ‘complete removal’, and ‘leave *in situ*’ decommissioning options are compared for all the pipelines in group 1. The pipelines considered here are the individual flowlines and umbilicals. All pipelines and umbilicals in this group exhibit excellent cover with no exposures or spans along their routes.

To recap, the pipelines in group 1 are:

- PL2422(3), 8in flexible flowline, ~2.4km long.
- PLU2423(J3), 121mm umbilical, ~2.385m long.
- PLU2554(2), 153mm umbilical, ~3.4km long.

5.4.1 Technical considerations

Both options are technically feasible. There is limited experience in reverse reeling individual trenched and buried pipelines in the UKCS. However, given the type of pipelines being considered here the technical uncertainty was deemed likely to have a slightly adverse effect on technical feasibility.

Technology is currently available to excavate and reverse reel flexible flowlines and umbilicals. This would involve excavation or dispersal of the existing overlying sediment followed by the recovery operations. While the technology is available it could still prove problematic to achieve, but nevertheless feasible.

From a technical perspective the leave *in situ* decommissioning option is also feasible.

5.4.2 Safety considerations

The difference in potential safety risk between the options is sufficiently large that a HAZID would not be considered necessary at this stage. A HAZID would ordinarily be carried out as part of the preparatory activities.

Safety Risk to Offshore Project Personnel

The key differences between the options are as follows:

- Risk to divers – should they be required, and personnel on the vessel from hydrocarbon or hazardous substance releases from recovered pipelines will be greater for complete removal than for leave *in situ* due to the larger volume of material that would be recovered;
- Risk associated with reverse reeling operations, with 8in flexible flowline and the 121mm and 153mm umbilicals needing to be spooled onto a reel on a subsea support vessel attached to the flowlines. The risk to personnel and assets would therefore be greater for complete removal option than for leave *in situ*.
- Increased risk to all activities due to adverse weather is greater for complete removal than for leave *in situ* as the vessels would be in the field for longer.
- Risk associated with legacy survey activities. That is, the risks associated with vessels being used in future are greater for the leave *in situ* option than for complete removal. Typically, in the UK a minimum of three legacy surveys would be required to confirm the condition of subsea pipelines left *in situ*, although such a requirement could be reduced following a risk assessment should they remain well buried and stable.

Given that the activities and techniques are frequently used in the North Sea it is assumed that the risks from all hazards relating to reverse reel methods of removal would be broadly acceptable. It is acknowledged that there is relatively little experience of reverse reeling a trenched and buried pipeline and so this risk could be higher yet tolerable should sufficient mitigation and control measures are adopted. This risk relates only to the complete removal option.

Short-term Safety Risk to Fishermen and Other Marine Users

The risk to mariners in the short-term would be aligned with the duration of activities in the field. While the decommissioning operations are underway vessels would be in the field for longer for the complete removal option than for leave *in situ*. Reverse reel operations would mean that the vessel is attached to a flowline or umbilical and could not move out of the way quickly.

For the leave *in situ* option only the pipeline ends would be dealt with so the duration of activities in the field would be much shorter for this option.

Therefore, while decommissioning activities are occurring, the risk to fishermen and other marine users would be least for the leave *in situ* option.

Residual Safety Risk to Fishermen and Other Marine Users

The type of fishing in the area (ICES rectangle 44F1) is predominantly trawler activity, targeting demersal fish. Therefore, there would be a potential for snagging on equipment left on the seabed, including spoil mounds. In this instance the pipelines could be expected to remain buried because both sets of surveys indicate that there are no exposures or free spans along the flowline or umbilicals.

From this it can be reasoned that decommissioning activities that minimise the disturbance to the seabed, reduce the likelihood of creating snag hazards / spoil mounds and that leave the seabed free of equipment would minimise the impact on local fishing activities. This would be no different to the current situation. Both complete removal and leave *in situ* options would leave the seabed free of equipment. Although the complete removal option has the potential to leave spoil mounds that present snagging hazards, it is possible that with extra effort these could be dispersed, or they would disappear over time.

By completely removing the pipelines the risk of snagging would be removed in perpetuity. Therefore, the complete removal option results in lower residual risks to mariners and other users of the sea.

Theoretically, there would be slightly increased snagging risk associated with the leave *in situ* option even if the infrastructure being left *in situ* does remain buried and stable. However, if required, surveys could be done in future to verify that the risk of snagging would remain low. Should exposures or spans be seen to occur in future, remedial works may be required. In this instance, however, this would seem unlikely.

As discussed in section 4.1, it is worth noting here that ordinarily a pipeline freespan such as that in PL2422 between ~KP0.677 and ~KP0.701 would be considered a candidate for partial removal. However, surveys carried out since the original remedial work was carried out have indicated that the flowline and supporting grout bags remain buried although the concrete mattresses may be exposed and potentially present a snagging hazard but if the edges remain buried the threat to snagging will be relatively benign. The extent to which the mattresses are exposed will need to be confirmed.

Health & Safety Risk to Onshore Project Personnel

The key differences between the options are as follows:

- Risks associated with cutting the flowline or umbilical(s) resulting in injury would be greater for complete removal due to the higher quantity of material returned to shore compared with the leave *in situ* option.
- Risks associated with lifting and handling flowline or umbilical sections would also be greater for complete removal due to larger quantity of material being returned to shore.

Many of the hazards described in the foregoing safety assessment would be common to both decommissioning options. Based on the differences, the leave *in situ* option gives rise to lower risks to onshore personnel for the following three reasons:

- Less onshore work.
- Less material handling.

- Unspooling of flowlines and umbilical(s) would have been done before, but to have to do this at all would increase the risk for onshore personnel compared to the leave *in situ* option.

5.4.3 Environmental considerations

The duration that vessels would be required in the field for the complete removal option would be longer than required for leave *in situ*. This would be reflected in the discharges to sea, noise, energy requirements and emissions to air. Conversely the legacy survey requirements for leave *in situ* would be greater than for complete removal.

The amount of cutting, lifting and disposal requirements are related to the length of pipeline recovered. Therefore, the discharge to sea, discharges to surface water, noise in water from cutting, seabed disturbance from excavation and lifting, and the potential use of landfill space would all be greater for complete removal than for leave *in situ*.

Energy requirements and emissions to air would be such that there would be a difference between options. However, the gap between complete removal and leave *in situ* narrows when indirect energy requirements and emissions required for replacement of unrecovered material are accounted for.

While the complete removal option would result in no materials left in the seabed, the leave *in situ* option would result in materials being left to degrade naturally. For pipelines manufactured mostly from steel this would not be detrimental to the local environment. The deposition of the pipeline coating and steel materials into the marine environment would likely occur very gradually over hundreds of years, and so would be at little detriment to the local marine environment. Flexible flowlines and umbilicals contain a higher content of composite materials and so would take much longer than steel to decompose. The deposition of the composite materials into the marine environment would likely occur very gradually over hundreds of years, and so would be to little detriment to the local marine environment. Any raw material not recovered would need to be replaced by newly manufactured material.

5.4.4 Societal considerations

The main commercial activity in the area would be fishing. The potential effects could be loss of fishing revenue due to exclusion from fishing grounds, disturbance of the seabed 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 number and duration of vessels.

Activities which involve removal or reburial would implicitly disturb the seabed. Therefore, since complete removal would require more activities on the seabed it will have a higher short-term impact on commercial fishing.

Leave *in situ* would leave infrastructure that presents a potential snag hazard. In this situation there would be a greater chance that fishing gear could be lost or damaged, and this would have an impact on commercial fishing. However, the intensity of fishing activity in the area is low, and in this instance the pipelines are buried; and survey data suggests that there have been no reports of spans or snagging. Therefore, it is unlikely that the leave *in situ* removal option will be detrimental to commercial fishing activities.

For both options seabed clearance and risk assessments will be done to verify that residual snag hazards will remain low and would be unlikely to occur.

Therefore, during decommissioning activities the complete removal option could be expected to have a greater impact on fishing activities as it would have the longest duration and cause the greatest disturbance to the seabed. Leave *in situ* would involve leaving the pipelines and flowlines where they are, and although this could result in residual snag hazards in this instance the flowlines and pipelines have exhibited good depth of cover and they remain stable. Surveys may need to be undertaken to confirm that the pipelines remain buried, and while being undertaken fishing activity may be disrupted for a short time, but the impact could be expected to be minimal. Typically at least two legacy surveys sometimes three would be required but the seabed would not be affected.

Employment

The complete removal option would involve more vessel activity with longer durations and more waste management requirements. This option would therefore impact more positively on employment than leave *in situ*. However, the effect on employment would likely result in the continuation of existing jobs, rather than lead to the creation of new employment opportunities. The significance of the positive impact has therefore been assessed as low.

Communities

The port and the disposal site have yet to be established. However, they would be existing sites used for oil and gas activities and they would hold the permits required for managing waste. 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 associated with this project would be an extension of the existing situation. Therefore, the effect on communities is not considered a significant differentiator between options.

5.4.5 Cost considerations

More details of the cost assessment for the pipelines in group 1 are presented in Table E.3.1 and Table E.4.1 in Appendix E. In all instances the complete removal option would cost more than the leave *in situ* option in the short-term but once completed, no more costs would be incurred for future pipeline surveys. Conversely, pipelines that are left *in situ* would likely be subject to future pipeline inspections. Future pipeline surveys can be expected to cost less than the operations associated with complete removal and dealing with the associated waste materials onshore.

For the pipeline(s) in this group and using the assumptions in Appendix E.2, the complete removal option using reverse reel and a subsea support vessel would cost less than an order of magnitude greater than leave *in situ*.

The assessment assumes 1x post decommissioning survey would be required irrespective of the decommissioning options, and 2x legacy surveys would be required for any pipelines being left i*n situ*. reduced from 3x legacy surveys on the basis that the pipelines all exhibit good depth of burial and appear stable.

5.5 Comparative Assessment for pipelines in group 2

The 'complete removal', and 'leave *in situ*' decommissioning options are compared for all the pipelines in group 2. The pipelines in group 2 are piggybacked. The pipelines here are the 6in rigid production pipeline and the 2in nitrogen pipeline. Both pipelines exhibit excellent cover with no exposures or spans along their routes.

To recap, the pipelines in group 2 are PL2545(4) with PL2546(1) piggybacked, ~3.4km long.

5.5.1 Technical considerations

Both decommissioning options are technically feasible. For the group 2 pipelines, technical feasibility and practicality is tempered by the 6in rigid pipelines being piggybacked by the 2in pipeline and this would complicate the recovery process. The pipelines could be recovered in sections using the 'cut and lift' method. This would involve dispersal of the existing sediment and deposited rock followed by 'cut and lift' operations. Although the 'cut and lift' method has been used for relatively short-lengths of pipeline, arguably the length of pipeline(s) probably renders the 'cut and lift' approach impractical.

From a technical perspective the leave *in situ* decommissioning option is also feasible.

5.5.2 Safety considerations

The difference in potential safety risk between the options is sufficiently large that a HAZID would not be considered necessary at this stage. A HAZID would ordinarily be carried out as part of the preparatory activities.

Safety Risk to Offshore Project Personnel

The key differences between the options are as follows.

- Risk to divers – should they be required, and personnel on the vessel from hydrocarbon or hazardous substance releases from recovered pipelines will be greater for complete removal than for leave *in situ* due to the larger volume of material that would be recovered.
- Risk associated with 'cut and lift' operations. Assuming the pipelines could successfully be excavated from a technical perspective the operation should be relatively straightforward. However, to ensure road transportable lengths, the 'cut and lift'; operations would require between ~80 to ~100 sections or pipe to be removed *per km* of pipeline. Arguably, from a safety perspective this would likely be manageable, but the associated risks would increase with the number of operations needing to be performed, and the amount of material transferred and handled on the vessel; No such risks would be incurred for the leave *in situ* decommissioning option.
- Risk associated with reverse reeling operations. In the unlikely event that reverse reeling would be considered a practical alternative, the 6in rigid and 2in piggybacked pipelines would need to be separated as they arrive at the recovery vessel and aim would be for the vessel to remain attached to the pipelines throughout the operation. The risk to personnel and assets would therefore be greater for complete removal option than for leave *in situ*.
- Increased risk to all activities due to adverse weather would be greater for complete removal than for leave *in situ* as the vessels would be in the field for longer.
- Risk associated with legacy survey activities that is, the risks associated with vessels being used are greater for the leave *in situ* option than for complete removal. Typically, in the UK a minimum of three legacy surveys would be required to confirm the condition of subsea pipelines left *in situ*, although such a requirement could be reduced following a risk assessment should they remain well buried and stable.

Given that the activities and techniques are frequently used in the North Sea it is assumed that the risks from all hazards relating to the 'cut and lift' method would be broadly acceptable.

Short-term Safety Risk to Fishermen and Other Marine Users

Please refer the discussion in section 5.4.2 as the considerations are broadly the same.

Residual Safety Risk to Fishermen and Other Marine Users

Please refer the discussion in section 5.4.2 as the considerations are broadly the same.

Health & Safety Risk to Onshore Project Personnel

The key differences between the options are as follows:

- Risks associated with cutting the pipeline(s) resulting in injury would be greater for complete removal due to the higher quantity of material returned to shore compared with the leave *in situ* option.
- Risks associated with lifting and handling pipeline sections are also greater for complete removal due to larger quantity of material being returned to shore.

Many of the hazards described in the foregoing safety assessment are common to both decommissioning options. Based on the differences, the leave *in situ* option gives rise to lower risks to onshore personnel for the following three reasons:

- Less work.
- Less onshore handling.
- Unloading pipespools from a vessel has been done before, but to do this at all for the complete

removal option would increase the risk to onshore personnel as compared to the leave *in situ* option.

5.5.3 Environmental considerations

Please refer the discussion in section 5.4.3 as the considerations are broadly the same.

5.5.4 Societal considerations

Please refer the discussion in section 5.4.4 as the considerations are broadly the same.

5.5.5 Cost considerations

More details of the cost assessment for the pipelines in group 2 are presented in Table E.3.1 and Table E.4.1 in Appendix E. In all instances the complete removal option would cost more than the leave *in situ* option in the short-term but once completed, no more costs would be incurred for future pipeline surveys. Conversely, pipelines that are left *in situ* would likely be subject to future pipeline inspections. Future pipeline surveys can be expected to cost less than the operations associated with complete removal and dealing with the associated waste materials onshore.

For the pipeline(s) in this group using the assumptions in Appendix E.2 the complete removal option using ‘cut and lift’ and a subsea support vessel would cost more than an order of magnitude greater than leave *in situ*.

The assessment assumes 1x post decommissioning survey would be required irrespective of the decommissioning options, and 2x legacy surveys would be required for any pipelines being left i*n situ*. reduced from 3x legacy surveys on the basis that the pipelines all exhibit good depth of burial and appear stable.

5.6 Comparative assessment for PL2422 mattresses and grout bags

5.6.1 Technical considerations

The complete removal of the grout bags, concrete mattresses and the associated part of PL2422 would be technically achievable. Removal of just the concrete mattresses would also be achievable, as would the leave *in situ* option. The deposition of rock to replace any materials removed would also be achievable. Any future survey requirements would also be technically achievable.

As the quantity is relatively small, it is likely that the 1Te grout bags would be recovered using a grab or clamshell dredger mounted on a marine construction vessel. It is unlikely that a dedicated clamshell dredger would be used. A plain suction dredger would also not be used to remove the grout bags, as the process would likely be compromised by the presence of the polypropylene sack material which would clog up the suction pipe. The water depth precludes the use of other types of suction dredgers such as hydraulic cranes, hydraulic dredgers, cutters, bucket wheels, and trailing suction hoppers.

It can be seen the technology is available to achieve any of the decommissioning options and although there is little risk of outright project failure, for the complete removal option excavation using remote operations combined with relatively rudimentary equipment in the water depths involved (>120m) can be problematic to achieve.

The net volume of grout bags that would need to be excavated is estimated to be ~22.5m^3, although it is to be expected that seabed sediment would also be mobilised as part of the recovery operations.

Although parts the onshore segregation of materials (e.g. segregation of grout bag material from grout and from sediment) could be mechanised, experience would suggest that most of this work will be manual, and while segregation could be achieved eventually the plastics would need to be cleaned of sediment before they could be sent for incineration for energy recovery.

Figure 5.6.1: Grapple[8], Grab Dredger Vessel[9], Clamshell Bucket[10]

From a technical perspective there is little to differentiate the options although leave *in situ* would be the easiest to achieve.

5.6.2 Safety considerations

The difference in potential safety risk between the options is sufficiently large that at this stage HAZID is not necessary. This would ordinarily be carried out as part of the preparatory activities.

Safety Risk to Offshore Project Personnel

There is nothing significant to differentiate the options for project personnel from a short-term safety perspective. The scope of work is limited, and it would likely be carried out using remotely operated equipment.

The activities and techniques involved in the work are frequently used in the North Sea and manageable. Based on using remote operations, it is assumed that the health and safety risks from all hazards would be broadly acceptable. It is of interest to note that according to UK statistics between 2012 and 2016 the aggregate extraction industry had a worse safety performance than oil and gas[11].

Taking this into account, the short-term health and safety risks to project personnel associated with complete removal can be considered acceptable but non-preferred; it would be better not to carry out the work at all. The partial removal and leave *in situ* options would be preferred.

Health & Safety Risk to Onshore Project Personnel

The key differences between the options are as follows:

- Should deposition of rock be required there would be safety risks associated with the quarrying of rock, its transportation, and transfer to a vessel at quayside, although the risks might be expected to be well managed, so would be low. The quantity of rock required would be relatively small, so there would be little to differentiate the options.
- The risk of personal injury associated with dealing with the recovered mattresses, grout bags and short ~12m length of pipeline, would increase with the quantity of material being returned, and so would be greatest for the complete removal option. The risks associated with the partial removal option would be slightly greater than for the leave *in situ* option.
- Manual labour will likely be required for segregating the grout bag material from the grout and sediment.

Based on the differences, the leave *in situ* option gives rise to lower risks for onshore personnel for the following reasons:

- Less work.
- Less onshore handling and manual labour.
- Unloading mattresses and grout bags from a vessel has been done before, but to do this at all

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[8] Image of "The Claw Grapple" obtained from https://www.integratechnologies.com/the-claw-grapple/
[9] Image obtained from https://www.dredgepoint.org/dredging-database/equipment/kanyu
[10] Image obtained from http://mackmfg.com/
[11] http://www.hse.gov.uk/statistics/tables/index.htm

for either the complete or partial removal options would increase the risk to onshore personnel compared to the leave *in situ* option.

Residual Safety Risk to Fishermen and Other Marine Users

The type of fishing in the area (ICES rectangle 44F1) is predominantly trawler activity, targeting demersal fish. The fishing effort in this area contributes to less than 1% of the UK demersal fishing effort, so the area around Chestnut is not heavily fished.

Nevertheless, there would be a potential for snagging on equipment left on the seabed, including spoil mounds. In this instance the grout bags could be expected to remain buried because both sets of surveys indicate that there are no exposures or free spans along the flowline or umbilicals. The 2018 survey data would suggest that the concrete mattresses are mostly buried inside the tench except for where the flowline had experienced buckling and where they overlap the sides of the trench. Their burial status will need to be confirmed when the decommissioning works are being carried out.

It can be reasoned that decommissioning activities that minimise the disturbance to the seabed, reduce the likelihood of creating snag hazards or spoil mounds and that leave the seabed free of equipment would minimise the impact on local fishing activities.

Both the complete removal and partial removal options would involve the removal of existing material and replacing it with deposited rock. The complete removal option could potentially result in additional snagging hazards being left behind. That is, the cut ends associated with the short section of flowline that is removed. Although these will be buried under rock after the decommissioning activities have been completed, the cut ends will nevertheless exist where they didn't before.

The leave *in situ* option would leave the seabed as it is now. The concrete mattresses may be exposed and potentially present a snagging hazard but if the edges are sufficiently buried the threat of snagging will be relatively benign. The extent to which the snagging hazard would remain can be confirmed by survey.

From a legacy perspective once the decommissioning works involving the deposition of rock for the partial and complete removal options, and post decommissioning surveys had been carried out to confirm, all three decommissioning options would present an acceptable residual safety risk to other marine users.

5.6.3 Environmental considerations

The grout bags are buried, and video footage shows that the concrete mattresses are partly buried, partly exposed. The affected area has been recolonised by local fauna.

Energy use and the associated atmospheric emissions to air can be directly related to duration of activities in the field, and the types and size of vessels involved. In the short-term no vessels would be required for the 'leave *in situ*' option, so the duration of vessels in the field for complete removal and partial removal options would be longer. The least amount of energy and associated emissions is used for the 'leave *in situ*' option.

From a legacy perspective if we assume that no remedial work will be required in future the energy and emissions to air for all three options would be the same.

The impact on the seabed can be directly related to the extent of excavation involved. In the short-term for the complete removal and partial removal options non-native material will be removed from the seabed and replaced, but no remediation activities would be required in future.

The quantity of concrete mattresses to be removed for the complete removal and partial removal options would be the same, whereas no concrete mattresses would be removed for the leave *in situ* option. The volume of grout bags to be recovered for the complete removal option is estimated to be ~16.9m^3. Given the nature of dredging operations, it is difficult to be precise and the removal of grout bags will be accompanied by a quantity of material from the natural seabed. Experience would suggest the overall quantity of material recovered could easily be doubled. The extent of the operation is such that the excavated material would need to be replaced with deposited rock. For complete removal it is estimated that ~215 Te of rock would be required to replace the excavated material (grout bags and concrete mattresses), and for partial removal ~121Te of rock would be required to replace the mattresses.

Fish are driven away by the noise of underwater activities such as excavation and the deposit of material. From an operational perspective the impact on fish and cetaceans can be directly related to vessel durations and type as well as the extent of excavation involved.

The seabed will be impacted both in the short- and long-term for all three decommissioning options and assuming a 5m wide buffer around the four mattresses laid end to end (gross area affected 34m long x 13m wide), the areas affected will be broadly the same (~442m^2). One way or the other, non-native material will remain in the location, but the area affected is relatively small. For the complete removal and partial removal options non-native materials already in place would be replaced by rock, a hard substrate that is also a non-native material. However, given the small area and volume of material involved there is little to differentiate the options.

The nature of the excavation works may be such that it is not possible to verify with certainty that all the grout bags have been recovered. For example, the grout bags could be ripped, and sediment could fall back into the excavation while the work is being carried out. Visibility using an ROV will likely be poor once the sediment has been disturbed. Once the disturbed sediment had settled it would not be possible to confirm the presence or otherwise of any remaining synthetic material. Some may remain after the removal operation.

The polypropylene material used for the 1Te grout bags is a synthetic man-made material. In the short-term during the excavation activity, it is possible that fragments of this synthetic material would be liberated into the water column and float to the surface. Over time these fragments would decompose into microplastics. The fragments and microplastics could become coated with inorganic and organic compounds, and this may cause the floating particles to sink. Either way the resulting fragments and microplastics would pose a danger to a wide variety of biota [4][5].

Should it remain *in situ*, over the longer-term the grout bag material will breakdown and again microplastics will be liberated. However, the material will remain buried, and the quantity of material released in this way would be small. The eventual dispersal of the material into the local environment would occur over a period measured in tens if not hundreds of years.

Based on the foregoing, the complete removal option would be acceptable but least preferred, while the partial removal and 'leave *in situ*' options would be acceptable and preferred.

5.6.4 Societal considerations

Societal considerations assess the effect of the decommissioning options on commercial activities, employment, and communities.

The assessment of the effect on commercial activities is directly related to the quantity and duration of vessel traffic involved in carrying out the operations and the perceived inconveniences while the decommissioning works are being carried out. Apart from transits to and from the work area, the work would be carried outside of the 500m safety zone but in just one specific area.

The assessment of the effect on employment is directly related to the possibilities of extended employment or new employment opportunities and can be related to the quantity and duration of vessel traffic involved in carrying out the work offshore and the extent of onshore work.

The assessment of the effect on communities is directly related to the quantity and duration of vessel traffic and the perceived inconvenience to communities while the vessels are in port being prepared for the work.

At most, any operational work in the field can be expected to take just a few days. There is little to differentiate the decommissioning options from a societal perspective.

5.6.5 Cost considerations

At most, any operational work in the field can be expected to take just a few days and so a cost assessment has not been carried out.

Any costs will correlate with the duration of the operational work and type of vessel. By inspection the complete removal option will be the most expensive option, and the leave in situ option would cost the least. The partial removal option will be less expensive than the complete removal option and more expensive than the leave *in situ* option. The difference in cost is not a significant differentiator between the options.

6. CONCLUSIONS

6.1 Pipelines

The comparative assessment was undertaken with a focus on the decommissioning options for the various pipelines associated with the Chestnut development. The pipelines were split into two groups as indicated in Table 4.1.1. Both pipeline groups 1 & 2 were assessed for the complete removal and leave *in situ* decommissioning options. An assessment of the partial removal option was not considered necessary for any of the pipelines.

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

Since the decommissioning of the surface laid ends at of the pipelines on the final approaches is the same irrespective of the option pursued, decommissioning of these is not included in the assessment. Therefore, any differences are incremental to the activities associated with surface laid infrastructure.

Once the pipelines had been excavated, reverse reel could be considered technically feasible for the individual flowlines and umbilicals in group 1. From a purely technical perspective, the 'cut and lift' method would likely be the most viable for complete removal for the group 2 pipelines but usually this approach would only be used for relatively short lengths of pipeline. It is perhaps arguable whether these pipelines would be classed as 'short' in the context of 'cut and lift', but nevertheless, the repeatability of the method would render it technically feasible.

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

Many of the health and safety hazards described herein would be common to both decommissioning options. Based on the differences, in the short-term the leave *in situ* option would give rise to lower risks for 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 present a potential snag hazard. However, the 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 currently there is a low incidence of fishing activity in the area.

Finally, there is an order of magnitude in the incremental difference in cost for complete removal of the piggybacked pipelines versus leave *in situ*, while the incremental difference in cost for removing the flexible flowlines would be less than an order of magnitude greater than leave *in situ*.

In conclusion, based on the comparative assessment leave *in situ* is the recommended option for decommissioning the pipelines in groups 1 and 2.

6.2 PL2422 mattresses and grout bags

The comparative assessment was undertaken with a focus on the decommissioning options for the mattresses and grout bags used for remediating a 6.45m long freespan between ~KP0.677 and ~KP0.701 in PL2422. The decommissioning options are described as follows:

- **Complete removal –** this would involve the complete removal of the grout bags and concrete mattresses, removing the short section of PL2422 (~12m long) and replacing the excavated material with deposited rock.
- **Partial removal –** this would involve removal of the overlying concrete mattresses and replacing them with deposited rock.

- **Leave *in situ* –** this would involve leaving the grout bags and overlying mattresses *in situ* with no remedial works but possibly verifying their status via future surveys.

The assessment considered four criteria for both the short-term decommissioning activities and the longer-term or legacy related activities. The criteria were: technical feasibility, safety related threats, environmental impacts, and societal effects. Cost was not assessed in detail.

The technology is available to achieve any of the three decommissioning options and there is little risk of outright project failure. However, for the complete removal option excavation using remote operations combined with mechanical equipment in the water depths involved (>120m) would be problematic to achieve. Also, for the complete removal option, although parts of the onshore segregation process might be mechanised, experience would suggest that the segregation of materials such as synthetic materials used for the grout bags from grout or sediment will involve manual work. Therefore, from a technical perspective the complete removal option would be achievable but non-preferred. There is little to differentiate the partial removal and leave *in situ* options.

There is nothing significant to differentiate the options for project personnel from a short-term safety perspective although as onshore manual labour will likely be required, the complete removal option would probably be non-preferred. Otherwise, the scope of offshore work is limited and would likely be carried out using remotely operated equipment.

The complete removal option (that is, of the mattresses, grout bags and the associated ~12m length PL2422) would potentially result in additional snagging hazards being left behind – those associated with the short section of pipeline that is removed. Although the cut ends will be buried under rock after the decommissioning activities have been completed, the cut ends will nevertheless exist where they didn't before.

The leave *in situ* option would be preferrable from a technical, environmental, short-term safety and cost perspective compared with the complete removal and partial removal options. The complete removal option offers slight benefits from a short-term environmental and a short-term employment perspective.

For the complete removal and partial removal options, the non-native materials used for the remedial works would be replaced by rock, a hard substrate that is also a non-native material. However, given the small area and volume of material involved there is little to differentiate the options.

In this instance cost has not been examined. By inspection the complete removal option will cost more than either the partial removal or leave *in situ* options, and partial removal will cost more than the leave *in situ* option. There is little to differentiate the options over the longer-term because legacy surveys will be required whichever option is pursued. Once an option has been implemented, remembering that if the leave *in situ* option proves unsatisfactory the partial removal is the fall-back option it is unlikely that remedial works will be required in future.

The burial status of the concrete mattresses should be confirmed, although the indications are that they will be partly exposed. If they are buried, the recommendation is that they be left *in situ*. If they are found to be partially exposed and are considered to present a snagging hazard, the partial removal option should be implemented. This option involves recovering the concrete mattresses to shore and replacing them with deposited rock. Future surveys will be required in any case to confirm burial status.

7. SUPPORTING DOCUMENTS

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[8] Oceanteam (2006) Chestnut Site Survey, Central North Sea Block 22/02 February 2006, Survey Report No. SSR-0605

[9] OPRED (2018) Offshore Oil and Gas Decommissioning Guidance Notes. Weblink last accessed 15 June 2022: Decom_Guidance_Notes_November_2018.pdf

[10] SENSOL (2021) Combined Decommissioning Programmes for Hummingbird Spirit FPSO Sailaway and Disconnection of Risers, CHESDC-SPT-J-0000-REP-0001

[11] SENSOL (2021) Chestnut Phase 2 Decommissioning Programmes, CHESDC-SPT-Z-0000-PRG-0002

[12] XODUS (2021) Chestnut Phase 2 Decommissioning Environmental Appraisal, CHESDC-SPT-S-0000-REP-0001

APPENDIX A ASSOCIATED INFRASTRUCTURE

Appendix A.1 Production well P1 & riser bases

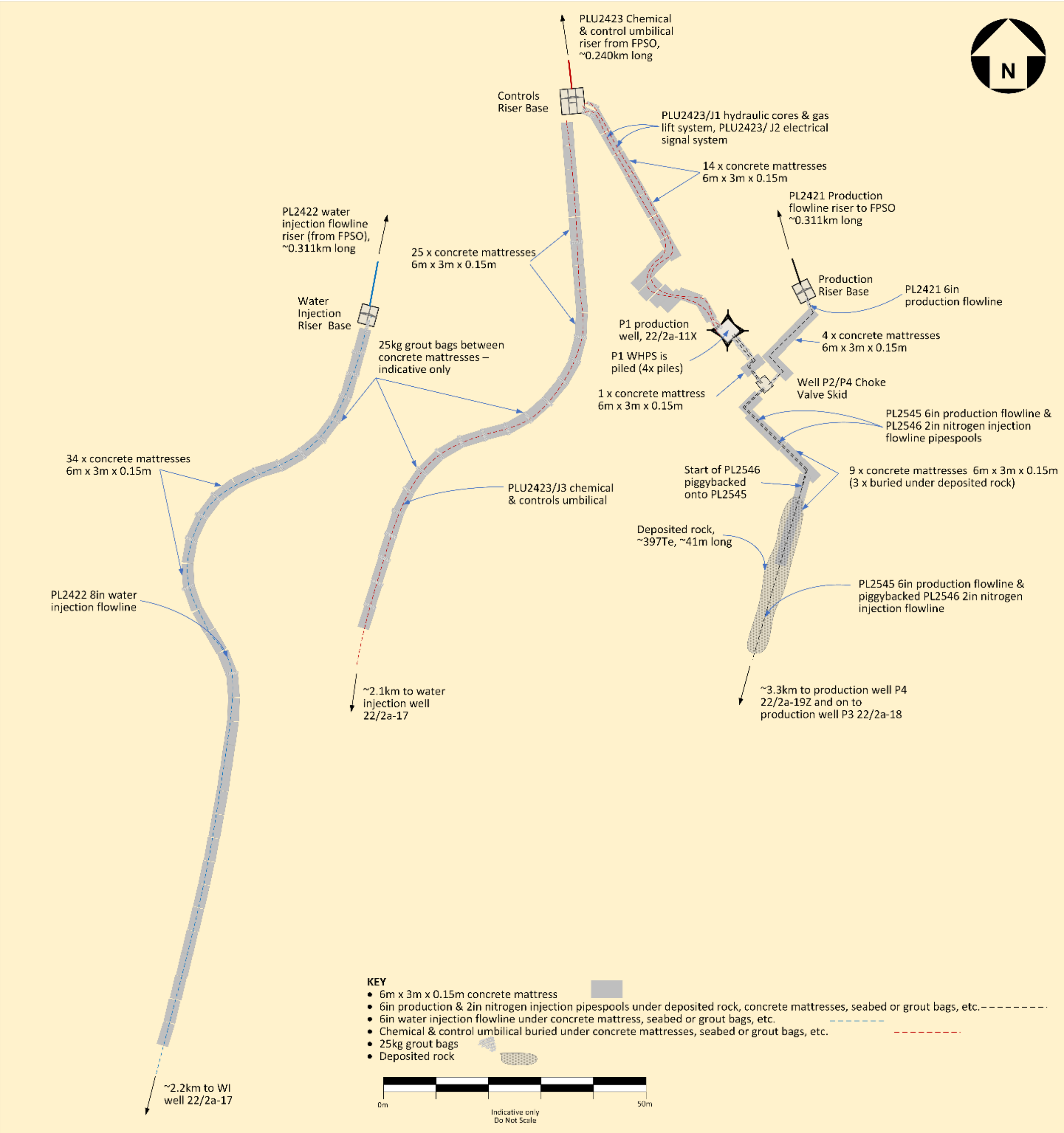

Figure A.1.1: Overview of production well P1, choke valve skid and riser bases

Appendix A.2 Production well P4 & P3 approaches

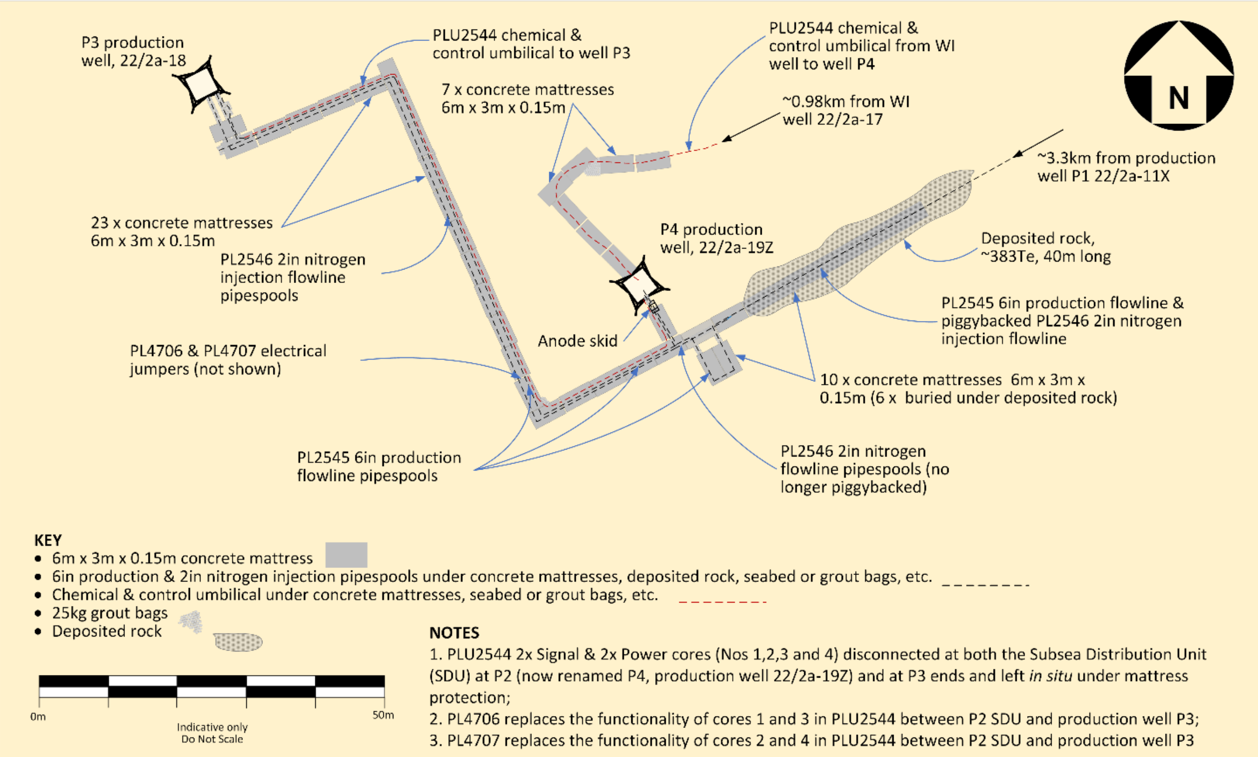

Figure A.2.1: Overview of production well P4[12] & P3 approaches

[12] Production well P2 22/2a-16Y was sidetracked and is now designated P4 22/2a-17.

Appendix A.3 Water injection well approaches

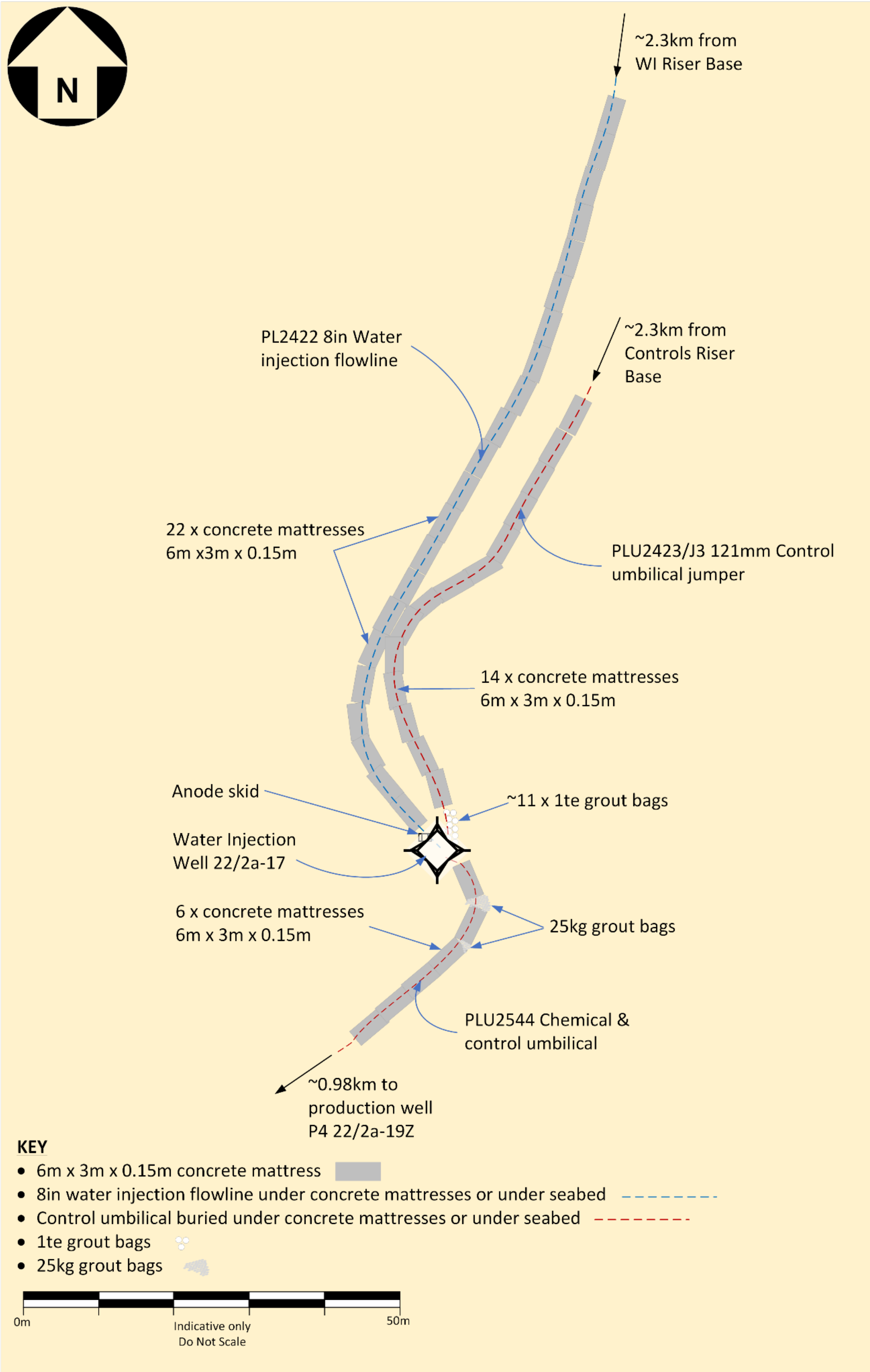

Figure A.3.1: Overview of water injection well approaches

APPENDIX B PIPELINE GROUP 1 – COMPARATIVE ASSESSMENT TABLES

Appendix B.1 Group 1 - Technical Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Leave *in situ*
Technical	**Offshore Execution**	Risk of project failure	Technically, complete removal of the pipeline(s) using the reverse reel method would most likely be achievable. The pipelines are buried sufficient that they would need to be excavated with the excavation probably needing to be backfilled once they had been recovered.	Technically, the pipeline(s) could be left *in situ*.
		Technological challenge	Technology is currently available to excavate and reverse reel PL2422(3), PLU2423(J3) and PLU2544(2).	N/A
		Technical challenge	Excavation of pipeline(s) buried in seabed sediment could prove problematic, but no specific technical issues should arise. The reverse reel method could be used for recovery of individual pipeline(s) whose integrity remains intact. Given their age and that the pipelines in this group are manufactured using composite materials, integrity issues are unlikely to arise. Composite materials are more complicated than steel to separate but it could be done.	Stable and buried pipeline(s) have been left *in situ* before so this approach would be achievable.
Technical	**Legacy**	Risk of project failure	No pipeline surveys would be required in future.	Pipeline surveys have been undertaken in the past, so this is achievable with no complications.
		Technological challenge	No pipeline surveys would be required in future.	The technology is currently available for carrying out pipeline surveys.
		Technical challenge	No pipeline surveys would be required in future.	There would be no technical issues associated with carrying out pipeline surveys in future.

Table B.1.1: Pipeline group 1 - Technical Assessment

Appendix B.2 Group 1 – Safety Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Leave *in situ*
Safety	**Offshore Execution**	Health & safety risk offshore project personnel	More offshore work than leave *in situ*. Excavation of the pipeline. There is experience of recovering individual pipelines by reverse reel.	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 less work and therefore a shorter duration of activities than for complete removal.
		Health & safety risk to mariners	Duration of vessels in the field would be longer than for leave *in situ*. Reverse reel would mean that the vessel is attached to a pipeline and could not move out of the way quickly. The risk to mariners in the short-term is aligned with the duration the activities would be undertaken in the field.	Only the pipeline ends would be dealt with; duration of vessels in the field would be shorter than for complete removal.
		Safety risk onshore project personnel	Safety risk is linked to the quantity and type of material returned to shore. Therefore, there would be significantly more onshore cutting, lifting, and handling for complete removal than for leave *in situ*. Composite materials are more complicated than steel to separate but it can be done.	No onshore work except for that associated with the pipelines ends, which would be common for both options.
Safety	**Legacy**	Health & safety risk offshore project personnel	No pipeline surveys or remediation related activities.	Pipeline surveys would be required, but this activity is considered routine with well managed risks and would be of short duration.
		Health & safety risk to mariners	No infrastructure left therefore no residual snag hazards. Lower risk as potential snag hazards completely removed. Although bottom dredging, demersal fishing nets should not adversely interact with the temporary excavations.	Post decommissioning surveys and existing data provide evidence that any pipeline spans or exposures are limited, and therefore the risk to mariners from snagging would be low. Degradation of the pipeline if it remains buried, would not change the risk. If exposures occur the degradation could change the risk, but the risks of snagging individual exposures would remain low.
		Safety risk onshore project personnel	Nothing to differentiate the options.	

Table B.2.1: Pipeline group 1 - Safety Assessment

Appendix B.3 Group 1 – Environmental Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Leave *in situ*
Environmental	**Offshore Execution**	Energy & emissions	Use of energy and 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*.	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	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 the complete removal option.	The smallest area of seabed would be disturbed in the short-term with the leave *in situ* option.
		Disturbance to Protected Area	The Chestnut pipelines do not currently reside within a Special Conservation Area or a Marine Protected Area, so there is nothing to differentiate the options.	
		Effect on Water Column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	Discharges and releases to the water column are related to the duration of activities being undertaken and would therefore be greatest for the complete removal option.	Discharges and releases would be least for the leave *in situ* option, particularly in the short-term.
		Waste creation and use of resources such as landfill. Recycling and replacement of materials	This option would result in the largest quantity of material being returned to shore. No material would be lost as no material would be left *in situ*.	No material would be returned to shore for recycling and therefore the material would be lost. Newly manufactured material would be needed to replace the material not recovered to shore.
Environmental	**Legacy**	Energy & emissions	No pipeline burial surveys or remedial would be required as the pipelines would have been completed removed.	Assume pipeline burial surveys would be required.
		Seabed disturbance, area affected	No pipeline burial surveys or remedial work would be required as the pipelines would have been completed removed.	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 Protected Area	The Chestnut pipelines do not currently reside within Special Conservation Area or a Marine Protected Area, so there is nothing to differentiate the options.	
		Effect on Water Column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	No pipeline burial surveys or remedial would be required as the pipelines would have been completed removed.	Assume pipeline burial surveys would be required.
		Waste creation and use of resources such as landfill. Recycling and replacement of materials	As the pipeline(s) would have been removed, no further waste would be created.	It is assumed that no pipeline related remedial activities would be required, as the surveys to date have indicated that the pipelines would remain stable. Therefore, as part of legacy related activities there is nothing to differentiate the options from a waste perspective.

Table B.3.1: Pipeline group 1 – Environmental Assessment

Appendix B.4 Groups 1 – Societal Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Leave *in situ*
Societal	**Offshore Execution**	Effect on commercial activities	The impact of decommissioning vessel traffic on local commercial activities such as fishing would be greatest for complete removal.	The impact of decommissioning vessel traffic on local commercial activities such as fishing would be least for leave *in situ*.
		Employment	Decommissioning activities associated with the complete removal of pipelines would contribute greatest to the continuity of employment.	Should the pipeline(s) 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*.
		Communities or impact on amenities	Once the pipelines have been removed there would be few opportunities for continuity of work in ports and disposal sites.	Should the pipeline(s) be 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.
Societal	**Legacy**	Effect on commercial activities	Environmental and pipeline route surveys might be required following completion of decommissioning works, but this is the same for all options. No pipeline surveys would be required in future.	Impact of survey vessel traffic on local commercial activities such as fishing would be slightly more with the leave *in situ* option
		Employment	Should the pipeline(s) have been completely removed, the opportunity for continuation of employment would be minimal once the post decommissioning surveys had been completed.	Should the pipeline(s) be left *in situ* surveys would need to be carried out.
		Communities or impact on amenities	Should the pipeline(s) have been removed there would be few opportunities for continuity of work in ports and disposal sites	Should the pipeline(s) 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 B.4.1: Pipeline group 1 – Societal Assessment

Appendix B.5 Group 1 – Cost Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Leave *in situ*
Cost	**Offshore Execution**	Group 1 – Individual pipeline(s)	Using the assumption that individual pipelines could be removed using the reverse reel method, the costs would be greater than for leave *in situ*, but less than an order of magnitude greater when accounting for the need for post-decommissioning surveys and removal of the pipeline ends, which would be the same for both options.	The cost of leave *in situ* would be the least expensive of the options.
Cost	**Legacy**	Individual pipeline	Should the pipeline(s) have been completely removed no pipeline burial surveys would be required in future.	Future burial surveys would be required. Given the pipelines have exhibited a good depth of burial the premise is that if two - rather than three, successive surveys demonstrate that the pipeline remains stable no more surveys would be required.

NOTES:

1. For assumptions refer Appendix E.2;
2. The assessment assumes 1x post decommissioning survey would be required irrespective of the decommissioning options, and 2x legacy surveys would be required for any pipelines or umbilicals being left *in situ.*

Table B.5.1: Pipeline group 1 – Cost Assessment

APPENDIX C PIPELINE GROUP 2 – COMPARATIVE ASSESSMENT TABLES

Appendix C.1 Group 2 - Technical Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Leave *in situ*
Technical	**Offshore Execution**	Risk of project failure	Technically, complete removal of the pipeline(s) using the 'cut and lift' method would most likely be achievable. The pipelines are buried sufficient that they would need to be excavated with the excavation probably needing to be backfilled once they had been recovered.	Technically, the pipeline(s) could be left *in situ.*
		Technological challenge	Technology is currently available to excavate and 'cut and lift' PL2545(4) and PL2546(1).	N/A
		Technical challenge	Excavation of pipeline(s) buried under deposited rock could prove problematic. 'Cut and lift' method would likely be the preferred method for removing the piggybacked pipelines.	Stable and buried pipeline(s) have been left *in situ* before so this approach would be achievable.
Technical	**Legacy**	Risk of project failure	No pipeline surveys would be required in future.	Pipeline surveys have been undertaken in the past, so this is achievable with no complications.
		Technological challenge	No pipeline surveys would be required in future.	The technology is currently available for carrying out pipeline surveys.
		Technical challenge	No pipeline surveys would be required in future.	There would be no technical issues associated with carrying out pipeline surveys in future.

Table C.1.1: Pipeline group 2 - Technical Assessment

Appendix C.2 Group 2 – Safety Assessment

Criteria	Aspect	Sub-criteria	Option 1 Complete removal	Option 2 Leave *in situ*
Safety	**Offshore Execution**	Health & safety risk offshore project personnel	More offshore work than leave *in situ*. Excavation of the pipeline. There is experience of recovering short lengths of piggybacked pipelines by 'cut and lift'.	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 less work and therefore a shorter duration of activities than for complete removal.
		Health & safety risk to mariners	Duration of vessels in the field would be longer than for leave *in situ*. To an extent 'cut and lift' would mean that the vessel is attached to a pipeline and could not move out of the way quickly. The risk to mariners in the short-term is aligned with the duration the activities would be undertaken in the field.	Only the pipeline ends would be dealt with; duration of vessels in the field would be shorter than for complete removal.
		Safety risk onshore project personnel	Safety risk is linked to the quantity and type of material returned to shore. Therefore, there would be significantly more onshore cutting, lifting, and handling for complete removal than for leave *in situ*.	No onshore work except for that associated with the pipelines ends, which would be common for both options.
Safety	**Legacy**	Health & safety risk offshore project personnel	No pipeline surveys or remediation related activities.	Pipeline surveys would be required, but this activity is considered routine with well managed risks and would be of short duration.
		Health & safety risk to mariners	No infrastructure left therefore no residual snag hazards. Lower risk as potential snag hazards completely removed. Although bottom dredging, demersal fishing nets should not adversely interact with the temporary excavations.	Post decommissioning surveys and existing data provide evidence that any pipeline spans or exposures are limited, and therefore the risk to mariners from snagging would be low. Degradation of the pipeline if it remains buried, would not change the risk. If exposures occur the degradation could change the risk, but the risks of snagging individual exposures would remain low.
		Safety risk onshore project personnel	Nothing to differentiate the options.	

Table C.2.1: Pipeline group 2 - Safety Assessment

Appendix C.3 Group 2 – Environmental Assessment

Please refer Table B.3.1 as the societal assessment would broadly be the same.

Appendix C.4 Group 2 – Societal Assessment

Please refer Table B.4.1, as the societal assessment would broadly be the same.

Appendix C.5 Group 2 – Cost Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Leave *in situ*
Cost	**Offshore Execution**	Piggybacked pipelines	Using the assumption that the piggybacked pipelines could be removed using the 'cut and lift', the costs would be more than an order of magnitude greater than for leave *in situ*.	The cost of leave *in situ* would be the least expensive of the options.
Cost	**Legacy**	Piggybacked pipelines	Should the pipeline(s) have been completely removed no pipeline burial surveys would be required in future.	Future burial surveys would be required. Given the pipelines have exhibited a good depth of burial the premise is that if two - rather than three, successive surveys demonstrate that the pipeline remains stable no more surveys would be required.

NOTES:

1. For assumptions refer Appendix E.2;
2. The assessment assumes 1x post decommissioning survey would be required irrespective of the decommissioning options, and 2x legacy surveys would be required for any pipelines or umbilicals being left *in situ.*

Table C.5.1: Pipeline group 2 – Cost Assessment

APPENDIX D PL2422 MATTRESSES AND GROUT BAGS – COMPARATIVE ASSESSMENT TABLES

Appendix D.1 PL2422 mattresses & grout bags - Technical Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Partial removal	Leave *in situ*
Technical	**Offshore Execution**	Risk of project failure	While there is little risk of outright project failure dredging using mechanical equipment in the water depths required could prove problematic.	There is little risk of outright project failure for the partial removal option, and the removal of the concrete mattresses (4x).	No mattress removal or dredgiong activities would be required. There is no risk of project failure for the leave *in situ* option.
		Technological challenge	The technology exists to remove the (4x) concrete mattresses, short section of PL2422 (~12m) and (30x) 1Te grout bags.	The technology exists to remove the (4x) concrete mattresses.	The technology exists to leave the concrete mattresses, grout bags and buried flowline *in situ*.
		Technical challenge	Using mechanical dredging equipment in the water depths involved will be imprecise and could prove problematic.	The should be no issues with removing the concrete mattresses. Proprietary equipment is available, and mechanical equipment could be used as contingency.	There are no particular issues with leave *in situ* from a technical perspective.
Technical	**Legacy**	Risk of project failure Technological challenge Technical challenge	Future surveys will be required for all decommissioning options. There is nothing to differentiate the options.		

Table D.1.1: PL2422 mattresses & grout bags - Technical Assessment

Appendix D.2 PL2422 mattresses & grout bags – Safety Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Partial removal	Leave *in situ*
Safety	**Offshore Execution**	Health & safety risk offshore project personnel	It is assumed that the work would be carried out using remotely operated equipment such as mattress handling equipment, grab or clamshell dredger, hydraulic shears, pipe handling clamps, ROV. Procedures and processes will be standard operating practices for this type of equipment. Therefore, there is little to differentiate complete removal from partial removal from a project safety perspective.	It is assumed that the work would be carried out using remotely operated equipment such as mattress handling equipment, grab or clamshell dredger, ROV. Procedures and processes will be standard operating practices for this type of equipment. Therefore, there is little to differentiate complete removal from partial removal from a project safety perspective.	There are no issues with leave *in situ* from a project safety perspective.
		Health & safety risk to mariners	Existing material will be replaced with rock. Although two cut pipe ends will remain they will be buried under rock. Slightly higher risk of snagging but not really a differentiator compared to the other options.	Existing concrete mattresses will be replaced with rock, and the flowline will remain buried.	A survey will determine whether the existing materials will pose a snagging hazard, and if they do the partial removal option would be implemented. Therefore, the leave *in situ* option would not present a snagging hazard to fishermen.
		Safety risk onshore project personnel	The onshore segregation of materials will mostly be mechanised, but the segregation of the synthetic grout bag materials from aggregatre material will likely be carried out using manual labour.	The onshore segregation of materials will likely be fully mechanised, using mechanical equipment.	No onshore resources would be required.
Safety	**Legacy**	Health & safety risk offshore project personnel Health & safety risk to mariners Safety risk onshore project personnel	Future surveys will be required for all decommissioning options. There is nothing to differentiate the options.		

Table D.2.1: PL2422 mattresses & grout bags - Safety Assessment

Appendix D.3 PL2422 mattresses & grout bags – Environmental Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Partial removal	Leave *in situ*
Environmental	**Offshore Execution**	Energy & emissions	Emissions to air are aligned with the duration the activities are undertaken in the field and size of vessels. Duration of vessels in the field is longer for this option so use of energy and the associated emissions to air will be greatest for this option.	Emissions to air are aligned with the duration the activities are undertaken in the field and size of vessels. Duration of vessels in the field is less for this option than for complete removal and so will use of energy and the associated emissions to air.	Emissions to air are aligned with the duration the activities are undertaken in the field. No field work is required for this option.
		Seabed disturbance, area affected	Area of seabed impacted for complete removal is largely the same as that affected by partial removal ($442m^2$). There is nothing to differentiate the complete removal and partial removal options.	Area of seabed impacted for complete removal is largely the same as that affected by partial removal ($442m^2$). There is nothing to differentiate the complete removal and partial removal options.	Area of the seabed impacted and material mobilised into the water column is aligned with the quantity of material removed. Area impacted is less than for complete or partial removal options.
		Effect on Water Column: • Liquid discharges to sea; • Liquid discharges to surface water; • Noise.	Discharges and releases to the water column and noise are aligned with the duration of activities undertaken in the field and type of operation. Duration of vessels in the field is longer than for partial removal or leave *in situ*.	Discharges and releases to the water column and noise are aligned with the duration of activities undertaken in the field and type of operation. Duration of vessels in the field is shorter than for complete removal but longer than for leave *in situ*.	Discharges and releases to the water column and noise are aligned with the duration of activities undertaken in the field and the type of operation. No field work is required for this option.
		Impact on biota	The area around Chestnut is not heavily fished and fish and cetaceans will be driven away by the noise of dredgers. During recovery some	The area around Chestnut is not heavily fished and fish and cetaceans will be driven away by the noise of dredgers. During recovery some	No field work is required for this option.

			fragments of synthetic material (e.g. grout bags, polypropylene rope) would be liberated into the water column, potentially posing a danger to fish and cetaceans in the area.	fragments of synthetic material (e.g. polypropylene rope) would be liberated into the water column, potentially posing a danger to fish and cetaceans in the area	
		Waste creation and use of resources such as landfill. Recycling and replacement of materials	Steel, and depending on salt content the recovered grout and concrete mattresses will likely be recycled as raw materials. Synthetic materials such as polypropylene will likely be incinerated as recovered energy.	Depending on salt content the recovered grout and concrete mattresses will likely be recycled as raw materials. Synthetic materials such as polypropylene will likely be incinerated as recovered energy.	No materials would be recovered to shore for this option.
Environmental	**Legacy**	Energy & emissions	Future surveys will be required for all decommissioning options. There is nothing to differentiate the options.		
		Seabed disturbance, area affected			
		Effect on Water Column: • Liquid discharges to sea. • Liquid discharges to surface water. • Noise.			
		Waste creation and use of resources such as landfill. Recycling and replacement of materials			

Table D.3.1: PL2422 mattresses & grout bags – Environmental Assessment

Appendix D.4 PL2422 mattresses & grout bags – Societal Assessment

Criteria	Aspect	Sub-criteria	Complete removal	Partial removal	Leave *in situ*
Societal	**Offshore Execution**	Effect on commercial activities	The impact of decommissioning vessel traffic on local commercial activities such as ports, fishing, wind farm activities and ferries would be greatest for complete removal.	The impact of decommissioning vessel traffic on local commercial activities such as ports, fishing, wind farm activities and ferries for partial removal would be less than for complete removal.	No field work is required for this option.
		Employment	Decommissioning activities associated with complete removal would contribute greatest to continuity of employment, but the duration of the work would be small.	Decommissioning activities associated with partial removal would contribute less to continuity of employment than complete removal, and the duration of the work would be small.	No field work is required for this option.
		Communities or impact on amenities	Decommissioning activities would affect local marine activities greatest for complete removal but the duration of activities would be small. Apart from transits to and from the work area, all the work would be carried out at just one location and the duration of work will be very small. There is little to differentiate the complete removal and partial removal options.	Decommissioning activities would affect local marine activities greatest for complete removal, but the duration of activities would be small. Apart from transits to and from the work area, all the work would be carried out at just one location and the duration of work will be very small. There is little to differentiate the complete removal and partial removal options.	No field work is required for this option.
Societal	**Legacy**	Effect on commercial activities	Future surveys will be required for all decommissioning options. There is nothing to differentiate the options.		
		Employment			
		Communities or impact on amenities			

Table D.4.1: PL2422 mattresses & grout bags – Societal Assessment

APPENDIX E COST AS A DIFFERENTIATOR

Appendix E.1 Overview

The following section details the qualitative comparative assessment made to distinguish the decommissioning options. Note that the 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 costs have been normalised and categorised as indicated in Table E.1.1.

High / Intolerable & not acceptable	Medium / Tolerable non-preferred	Low/Broadly acceptable & most preferred	Low/Broadly acceptable but least preferred
More than 10x least cost	More than 2x least cost	Cheapest cost	Less than 2x cheapest cost

Table E.1.1: Categories of Impact – Cost Assessment

Appendix E.2 Assumptions

The following key assumptions have been used in the cost by difference assessment:

- Operator and contractor management and engineering costs are excluded on the basis that this cost would be incurred whichever decommissioning option would be pursued.
- Any pipelines being removed would need to be excavated.
- Mobilisation and demobilisation cost of vessels are *excluded* for two reasons: The first is because mobilisation and demobilisation costs would be incurred for the overall decommissioning activity, not just for one pipeline, and the other is that for the purposes of this assessment it has been assumed that the same type of vessel – a subsea support vessel, furnished with reels, ROV equipment, excavation equipment and hydraulic cutting spread.
- For surveys it has been assumed that one post decommissioning pipeline survey would be required for each pipeline, and because the pipeline(s) all exhibit a good depth of cover (at least) two legacy pipeline surveys for those instances where a pipeline or part thereof would be left *in situ* following completion of decommissioning activities.
- The costs associated with mobilisation and demobilisation of survey vessels is excluded since it is not a differentiator, and because mobilisation and demobilisation costs would be incurred for the overall survey activity, not just for one pipeline.
- It is assumed that the 'cut and lift' method would be used to remove pipeline ends and to fully remove piggybacked pipelines otherwise the full length of individual pipeline(s) would be reeled onto a drum on the back of the subsea support vessel.
- It is assumed that individual flowlines and umbilicals would be reverse reeled onto a subsea support vessel.
- Trench backfill costs are not accounted for.
- The costs associated with piggybacked pipelines have been combined on the basis that the piggybacked pipelines would be dealt with at the same time.

A point to note is that although 'cut and lift' is used for the cost assessment for piggybacked pipelines should attempts be made to use a pipelay vessel there would be a cost over and above a standard mobilisation or demobilisation of a pipelay vessel as an auxiliary reel, deflector and ancillaries would be required.

Appendix E.3 Pipeline decommissioning cost by difference (excl. legacy surveys)

PIPELINE ID	PIGGYBACKED	GROUP ID	END REMOVAL LENGTH	COMPLETE REMOVAL LENGTH	LEAVE *IN SITU* (£M)	COMPLETE REMOVAL (£M)	PIPELINE END REMOVAL NORMALISED	COMPLETE REMOVAL NORMALISED
PL2422(3)	N	1	336m	2,400m	£0.18	£0.93	0.97	5.0
PLU2423(J3)	N	1	294m	2,385m	£0.11	£0.45	1.25	5.0
PLU2544(2)	N	1	72m	980m	£0.09	£0.18	2.5	5.0
PL2545(4) & PL2546(1)	Y	2	57m	3,400m (each)	£0.19	£3.79	0.2	5.0

NOTES:

1. Includes 1x post-decommissioning survey but no legacy surveys;
2. Cost by difference also accounts for removal of mattresses along with pipeline ends;
3. Flowline and umbilical ends removed using reverse reel onto a subsea support vessel, rigid piggybacked pipelines, or parts thereof, removed using ‘cut and lift’.

Table E.3.1: Pipeline cost assessment (excl. legacy surveys)

Appendix E.4 Pipeline decommissioning cost by difference (incl. legacy surveys)

PIPELINE ID	PIGGYBACKED	GROUP ID	END REMOVAL LENGTH	COMPLETE REMOVAL LENGTH	LEAVE *IN SITU* (£M)	COMPLETE REMOVAL (£M)	PIPELINE END REMOVAL NORMALISED	COMPLETE REMOVAL NORMALISED
PL2422(3)	N	1	336m	2,400m	£0.20	£0.93	1.1	5.0
PLU2423(J3)	N	1	294m	2,385m	£0.15	£0.45	1.7	5.0
PLU2544(2)	N	1	72m	980m	£0.10	£0.18	2.9	5.0
PL2545(4) & PL2546(1)	Y	2	57m	3,400m (each)	£0.23	£3.79	0.3	5.0

NOTES:
1. Please refer notes for Table E.3.1;
2. Includes 1x post-decommissioning survey and 2x legacy surveys rather than 3x because all pipelines exhibit good depth of burial.

Table E.4.1: Pipeline cost assessment (incl. legacy surveys)