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Ketch Decommissioning

Pipelines and Associated Stabilisation Materials Comparative Assessment

Faroe 02

Faroe Petroleum

Document control

Document history

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Acronyms and abbreviations

Abbreviation	Meaning
BEIS	Department for Business, Energy & Industrial Strategy
CA	Comparative assessment
CAPEX	Capital expenditure
DECC	The Department for Energy and Climate Change
DP	Decommissioning programme
DSV	Diver support vessel
EA	Environmental Appraisal
EC	European Commission
EIA	Environmental impact assessment
FAR	Fatal accident rate
Faroe	Faroe Petroleum (ROGB) Limited
HSE	The Health and Safety Executive
ICES	International Council for the Exploration of the Sea
IMCO	International Marine Contractors Association
IoP	Institute of Physics
KP	Kilometre point
MBES	Multi-beam echo sounder
NFFO	National Federation of Fishermen's Organisation
NUI	Normally unmanned installation
OIW	Oil in water
OGA	The Oil & Gas Authority
OGUK	Oil and Gas UK
OPEX	Operating expenditure
OSPAR	Oslo/Paris convention (for the Protection of the Marine Environment of the North East Atlantic)
PL	Pipeline numbering convention
PLL	Potential loss of life
PLU	Umbilical numbering convention
ppm	Parts per million
ROV	Remotely operated vehicle
SAC	Special area of conservation
SBI	Sub-bottom imager
SCI	Site of community importance
SDS	Subsea Deployment Systems Ltd
SEPA	Scottish Environmental Protection Agency
SNS	Southern North Sea
SSS	Side scan sonar
UK	United Kingdom

1. Introduction

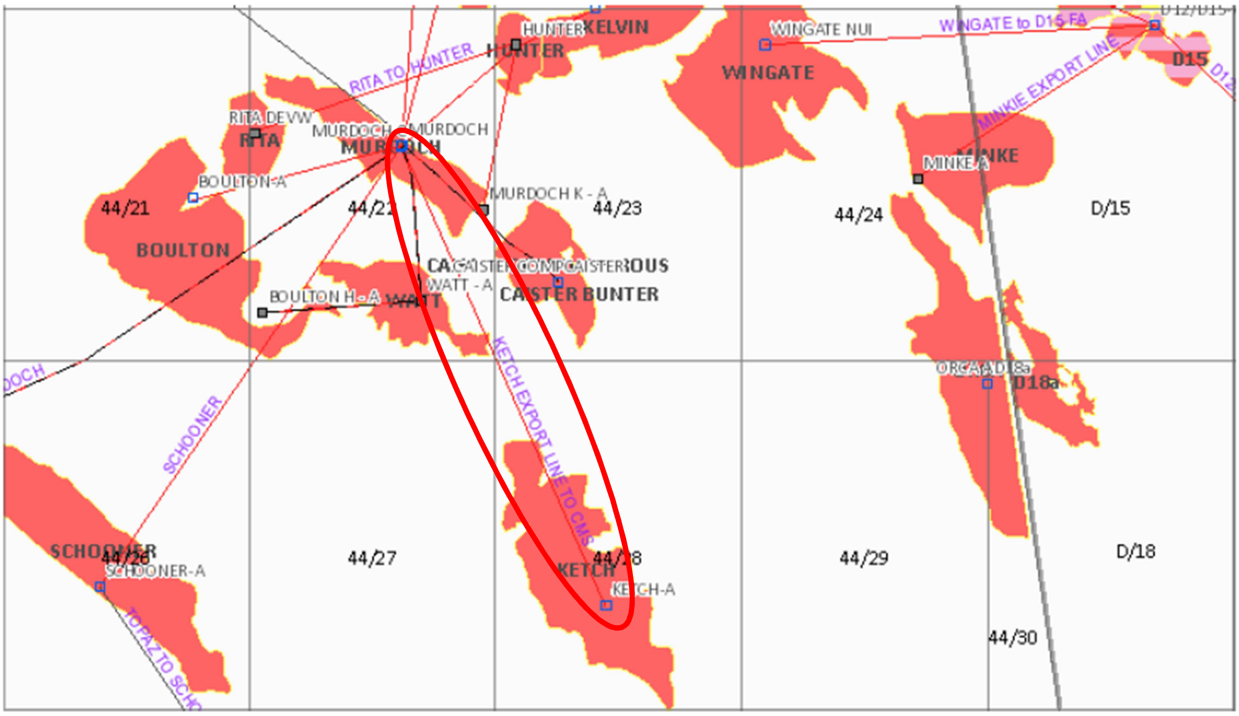
1.1. Background

1.1.1. Decommissioning of Ketch assets

Due to the imminent closure of the Theddlethorpe onshore gas terminal, the Ketch and Schooner gas fields operated by Faroe Petroleum (ROGB) Limited are to cease production and be decommissioned. Faroe has submitted draft decommissioning programmes for the Ketch field assets and a supporting environmental appraisal to BEIS. The Ketch assets are situated in the Silver Pit basin of the Southern North Sea on the UK continental shelf, they consist of:-

- The Ketch platform - A normally unmanned platform (NUI);
- PL1612 – An 18" diameter gas export pipeline from Ketch to the ConocoPhillips operated Murdoch platform and associated pipeline stabilisation features;
- PL1613 – A 3" diameter methanol pipeline from the Murdoch platform to the Ketch platform, piggybacked on the gas export pipeline.

Figure 1: Location of the Ketch pipelines



In accordance with the most recent BEIS Decommissioning Guidance Document [2] Faroe commissioned Jee to perform a comparative assessment study (CA) to objectively and transparently assess a number of different pipeline decommissioning options. Where an Operator identifies a decommissioning option that will see infrastructure remain in the marine environment a comparative assessment of a reasonable number of options must be provided to demonstrate how the preferred decommissioning solution has been identified.

A Comparative assessment is a mandatory requirement for any potential OSPAR derogation candidate or for any decommissioning proposal that will see pipelines left in situ.

This study which incorporates a screening level workshop and detailed level comparative assessment workshop, in accordance with the Oil and Gas UK guidelines [1], comprehensively assesses the various options and identifies the preferred option taking full account of safety, environmental, technical, societal and economic issues:

1.2. Objectives of this study

In accordance with the OGUK and BEIS guidance notes [1] [2], the objective of this study is to perform a detailed comparative assessment (CA) of the available decommissioning options for the pipelines and their associated protective deposits and stabilisation materials (mattresses and grout bags).

1.3. Regulatory guidance

BEIS guidance [2] provides the following clause which outlines the requirement for removal of pipelines:

"10.2. While there are currently no international guidelines on the decommissioning of disused pipelines the UK has adopted the principles and processes associated with OSPAR decision 98/3 in its consideration of pipeline decommissioning. This means that operators must aim to achieve a clear sea bed and robustly assess decommissioning options based on evidence and data."

BEIS guidance also provides the following clause which outlines the requirement for the decommissioning of protective deposits and stabilisation materials:

"11.3. The fundamental principle underpinning a proposal to leave in situ is that evidence must be provided to demonstrate that the deposits would not interfere with other users of the sea, e.g. they would not present a snagging hazard that could interfere with fishing operations."

The default standpoint, as understood from the above excerpt for mattress and pipeline decommissioning, is that the Operator should abide by the clean seabed rule unless a comparative assessment indicates a more appropriate alternative. The CA must consider, amongst other things, safety, efficiency and practicality of the removal operation, the impact on the surrounding environment and the impact on the societies that use that environment.

The BEIS guidance also states that pipelines may be left in-situ (subject to acceptance of a comparative assessment) if they are buried to an appropriate depth such that other users of the sea are not adversely impacted. This is based on the consideration of efficiency of removal and environmental damage likely to be caused in the removal process. This argument has been extrapolated to cover the decommissioning in-situ of pipeline sections exposed on the seabed. These considerations also apply to mattresses and BEIS has indicated [3] that overtrawlability trials should underpin the argument for decommissioning any element in-situ.

2. Executive summary

2.1. Conclusion

The comparative assessment for the Ketch pipelines concluded that the pipelines should be decommissioned in-situ rather than recovered. The pipelines were surface laid and were designed to self-bury, however only short sections of the pipelines have buried or partially buried. The pipelines also have a number of nets attached to them in some of the locations where they are exposed. All the mattresses on the Ketch pipelines will first be removed, the entire length of the Ketch pipelines will then be trenched and buried.

The exception to the above, are the sections of pipelines that form the elevated crossing of the Caister pipeline, adjacent to the Murdoch platform. These sections of pipelines (approximately 60m from the base of the Murdoch Riser) will be fully removed along with the mattresses and grout bags that form the elevated crossing structure. An approximate 10m section of pipeline will also be removed at the Ketch end immediately adjacent to the riser.

2.2. Recommendations

The following recommendations are made as part of this assessment:

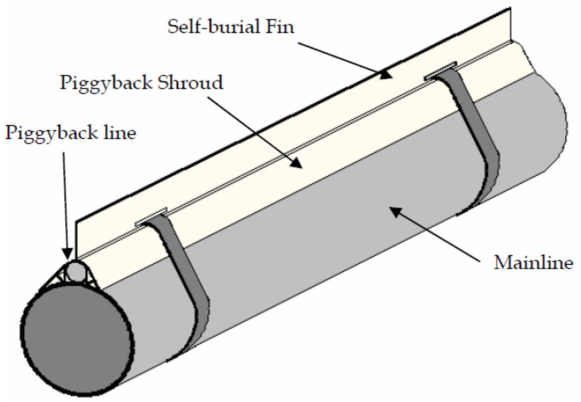
- Best endeavours will be employed to clean the pipelines to 30ppm OIW.
- The pipelines and stabilisation features elevated above the seabed to form the crossing over the Caister pipeline adjacent to the Murdoch platform, (final 60m of pipelines before the Murdoch riser) and the mattresses along the main length of the Ketch pipeline will be removed.
- The pipelines will then be trenched and buried with natural deposits. The activity in the two protected sites will also include mattress removal and burial of pipelines;
- Following completion of the burial of the pipelines, overtrawling trials shall be performed, in consultation with the NFFO, in order to identify any remaining snagging hazards, so appropriate remedial action can be taken. Note that the exception to this are the pipelines within the Dogger Bank SAC and SNS cSAC. These pipelines overtrawlability will be assessed with SSS and MBES to avoid any further physical disturbance in these sensitive marine areas;
- Any remediation required shall be through either localised removal or further burial with natural deposits;
- The timing of decommissioning works shall be scheduled, wherever possible, to minimise impact on marine life through avoidance of periods where species would be particularly susceptible to disruption;
- The region should be monitored following decommissioning at a frequency agreed with BEIS, with further remediation performed as necessary.
- Trenching of the entire length of the remaining pipelines should result in the pipeline ends being sufficiently buried so they do not require biodegradable grout bags to be laid on them to guarantee they remain buried over time. However grout bags have been assumed to be included as a contingency to ensure the ends remain buried.

3. Pipeline details

3.1. General

Ketch field pipelines comprise of a 18-inch Ketch to Murdoch gas export pipeline (designated as PL1612) and a 3-inch Murdoch to Ketch interfield methanol pipeline (designated as PL1613) which is piggybacked to the main gas export line. The pipelines were installed in 1999 and have a design life of 40 years. The pipelines are both 26.7km in length and the pipeline bundle (the export pipeline and the piggybacked line) were laid on the seabed with a spoiler fin to facilitate the self-burial of the pipelines. More data about these pipelines can be found in table 1 and a diagram of the mainline and piggyback line with the spoiler fin can be found in figure 2. The 3-inch piggyback pipeline exports methanol, along with corrosion inhibitor, to Ketch from Murdoch.

Figure 2: 18" Gas Export and 3" MeOH Pipeline Assembly



The Ketch pipelines cross the Caister to Murdoch interfield pipeline close to the base of the Murdoch platform. A short section of the pipeline is raised approximately 2.0m above the seabed and over the Caister pipeline by a pair of ramps formed from mattresses and grout bags.

For external corrosion protection, sacrificial anodes are installed on the pipelines at regular centres to provide protection against external corrosion. Internal corrosion is minimised through the continuous injection of the corrosion inhibitor and methanol into the production header and through monitoring and inspection.

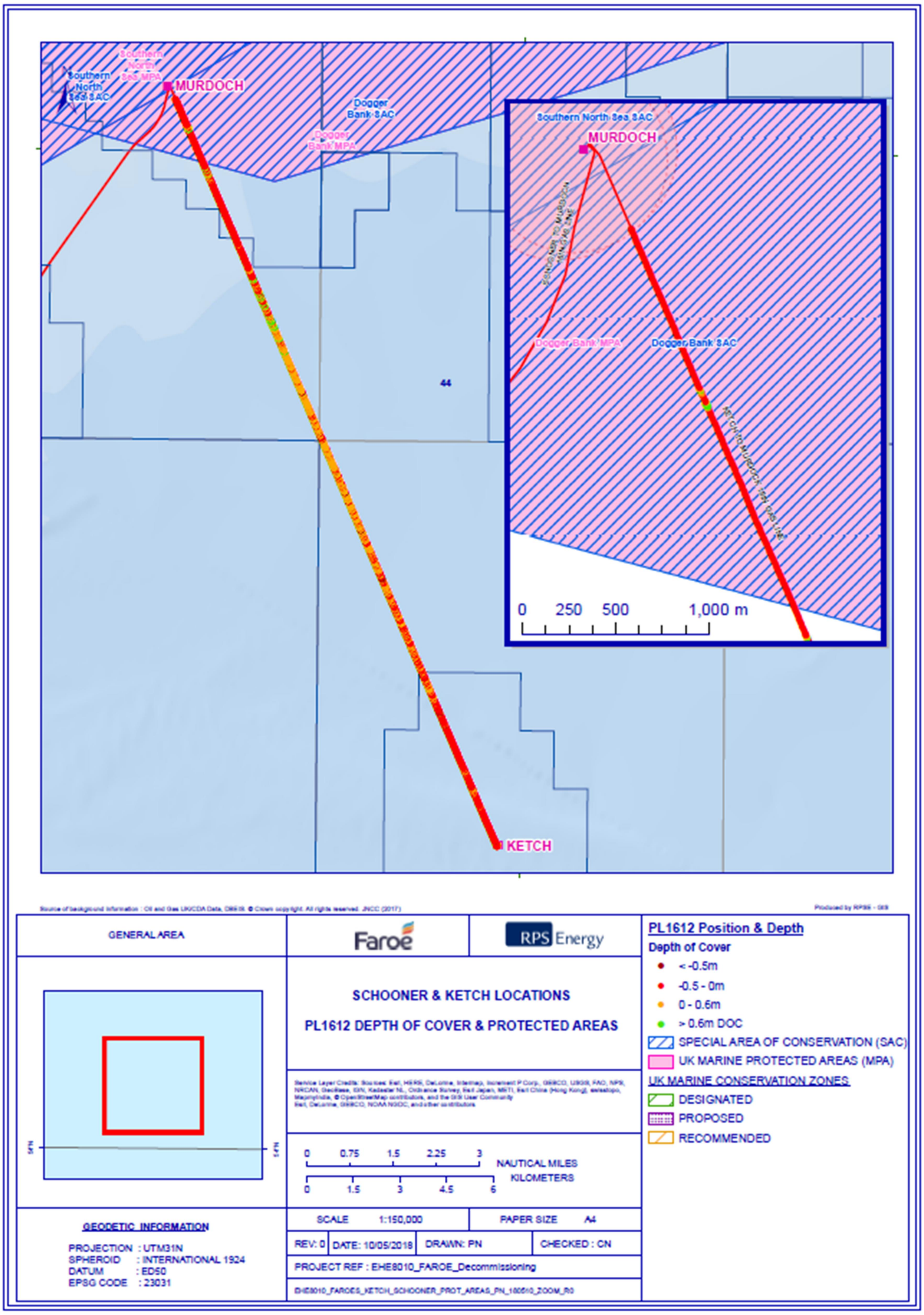
The pipelines have been subject to regular geophysical and subsea visual inspections throughout their lives as part of the integrity inspection program.

The original design of the pipeline assumed that the pipeline would self-bury in the seabed as a result of the self-burial fin. However, in 2010 a Subsea IRM survey revealed that the pipeline is not self-embedding into the seabed as previously predicted and exposes the 3” MeOH/CI piggy-line to the risk of unacceptable damage from fishing interaction [4].

Burial processes, in relation to the stabilisation features that are present at the very ends of the pipelines and sit within the scour bowls associated with the platforms, will likely increase after the platforms have been removed, as the scour bowls will naturally infill over time. In addition to this, the pipelines will no longer be held up at their ends, where they are currently connected to the risers, so will have a tendency to sink.

Figure 3 shows the depth of cover to the gas export line PL 1612 and the protected areas that the pipeline passes through. There are very few locations where the depth of cover to the export pipeline is 0.6m or above. 63% of the export pipeline is exposed and nearly all of the piggyback methanol line is exposed.

Figure 3: Ketch Pipelines Depth of Cover and Protected Areas



4. Mattress and grout bag details

4.1. General

Seabed sediments around the Silver Pit field are predominantly dense to very dense sands with a layer of stiff clay below the seabed. Large sand waves and sand banks are found in the area, indicating high seabed currents and mobile sediments.

Review of the latest inspection footage, in conjunction with inspection results from the operating phase indicates that the stabilisation materials present at the Faroe assets consist of segmented concrete mattresses and grout bags. All mattresses observed in the latest video footage were either buried, or partially buried, draped over the pipelines with their edges (and associated lifting loops) buried to varying degrees by the surrounding sediments. This is typical of the region and is a function of the mobile seabed sediments discussed above.

4.2. Stabilisation features

Table 1 below provides details of the mattresses and grout bags that stabilise PL1612 and PL1613. The decommissioning programme [5] references 73 concrete mattresses at several locations along PL1612 and PL1613, Figure 4 over the page shows the pipelines at the Ketch platform.

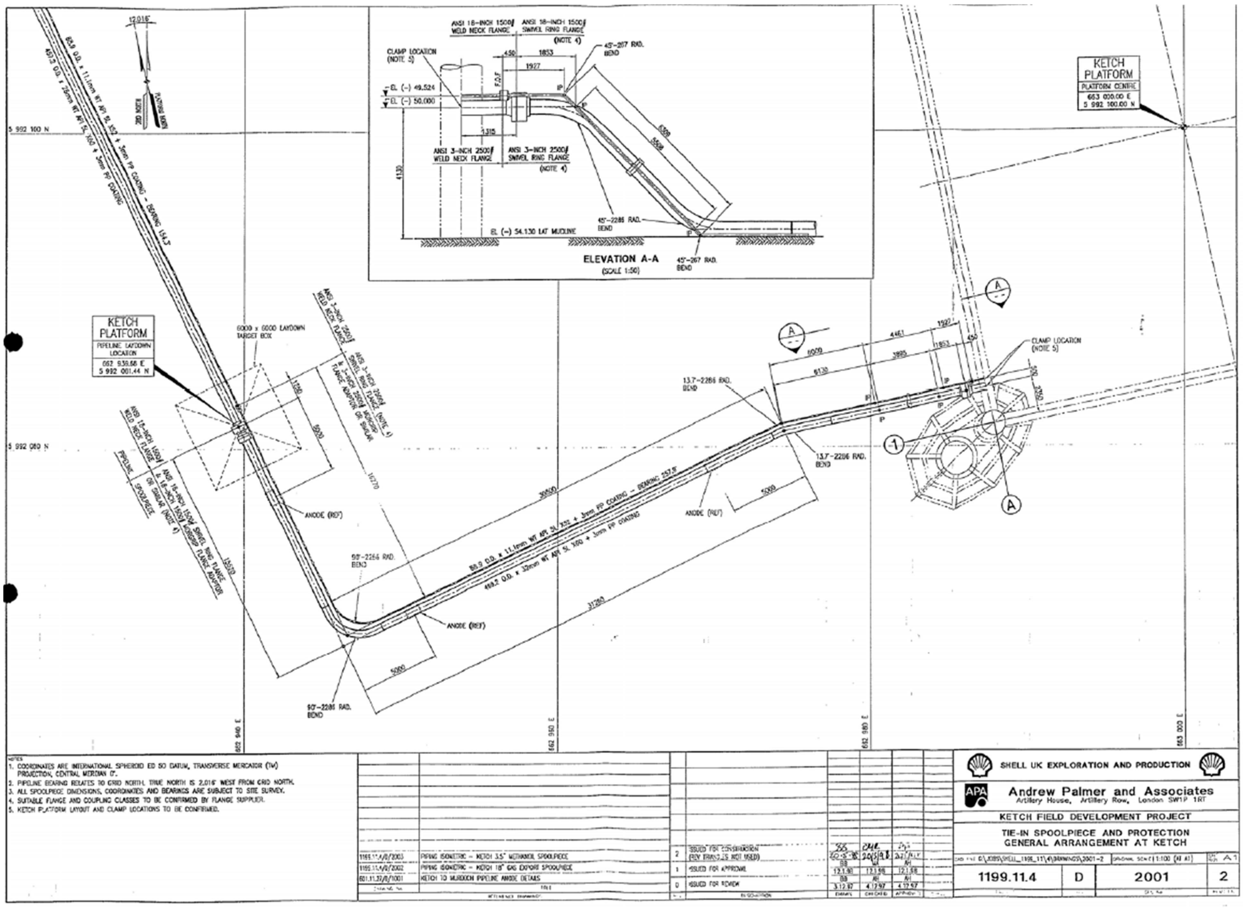
Table 1: Details of Ketch Pipelines'' Stabilisation & Protection Features

Location	KP	Concrete Mattresses / Grout Bags					Reference
		Quantity	Size (m)	Weight mattress (Te)	Total weight	Rope / Bag Type	
Ketch Platform	0.00 – 0.50	0 mattresses 0 grout bags	N/A	N/A	N/A	N/A	1199.11.4-D-2001 Rev 2
Along subsea route	0.50 – 26.147	42 mattresses	6x3x0.3	10	420	Assumed PP	See 140259 Petrofac PL1612/1613 video footage
		10 mattresses	6 x3x0.3	10	100	Assumed PP	UK 15020-SUR-PL-0012 PL1612 Listings, assumed 10 mattresses
Murdoch Platform	0.00 – 0.50	9 mattresses	10x3x0.3	14.76	132.84	18mm PP	1199.11.4-D-30011 Rev 4
		4 mattresses	6x3x0.3	10	40	18mm pp	1199.11.4-D-30011 Rev 4
Caister Ketch pipelines crossing	0.00 – 0.5	8 mattresses	3x2x0.3	2.78	22.24	18 & 22mm PP	1199.11.4-D-30011 Rev 4
		32 grout bags	varies	varies	26	Assumed PP	1199.11.4-D-30011 Rev 4

Location	KP	Concrete Mattresses / Grout Bags					Reference
		Quantity	Size (m)	Weight mattress (Te)	Total weight	Rope / Bag Type	
Total mattresses		73		715.08			
Total grout bags		32			26		

Source: *Ketch mattresses.xlsx. from Faroe ROGB Ketch archive*

Figure 4: Ketch platform pipeline protection drawing



Note that Figure 4; the construction issue tie-in spool piece and protection general arrangement drawing at Ketch, shows no mattresses or grout bags present at this end of the pipeline. Surveys carried out to date have verified that this is the case.

Figure 5: Ketch platform MBES survey

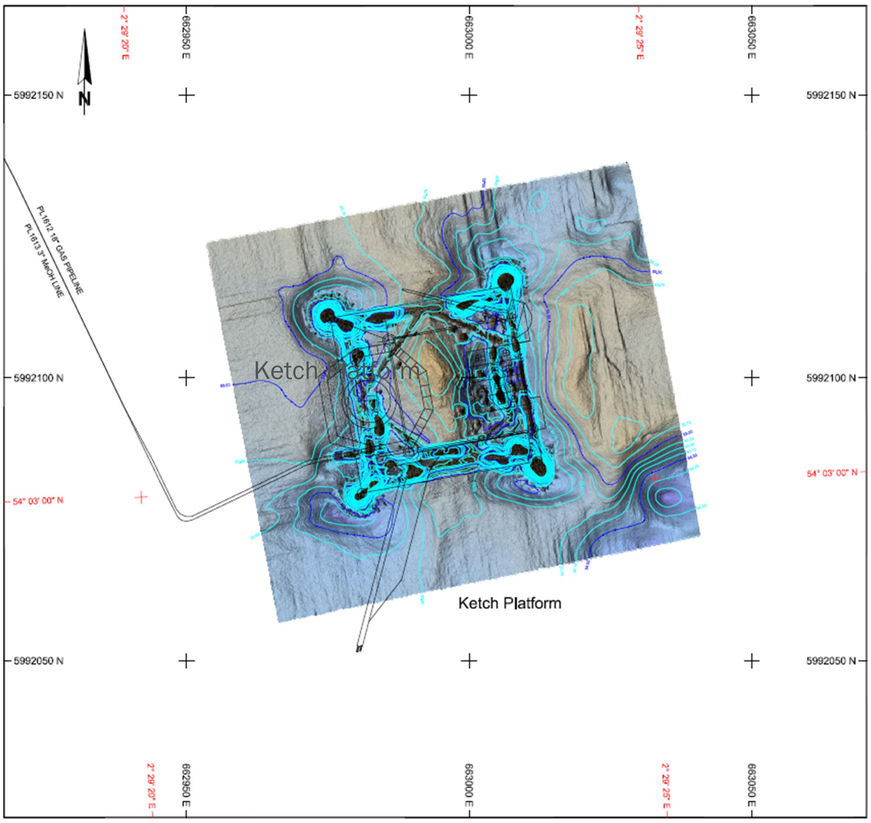
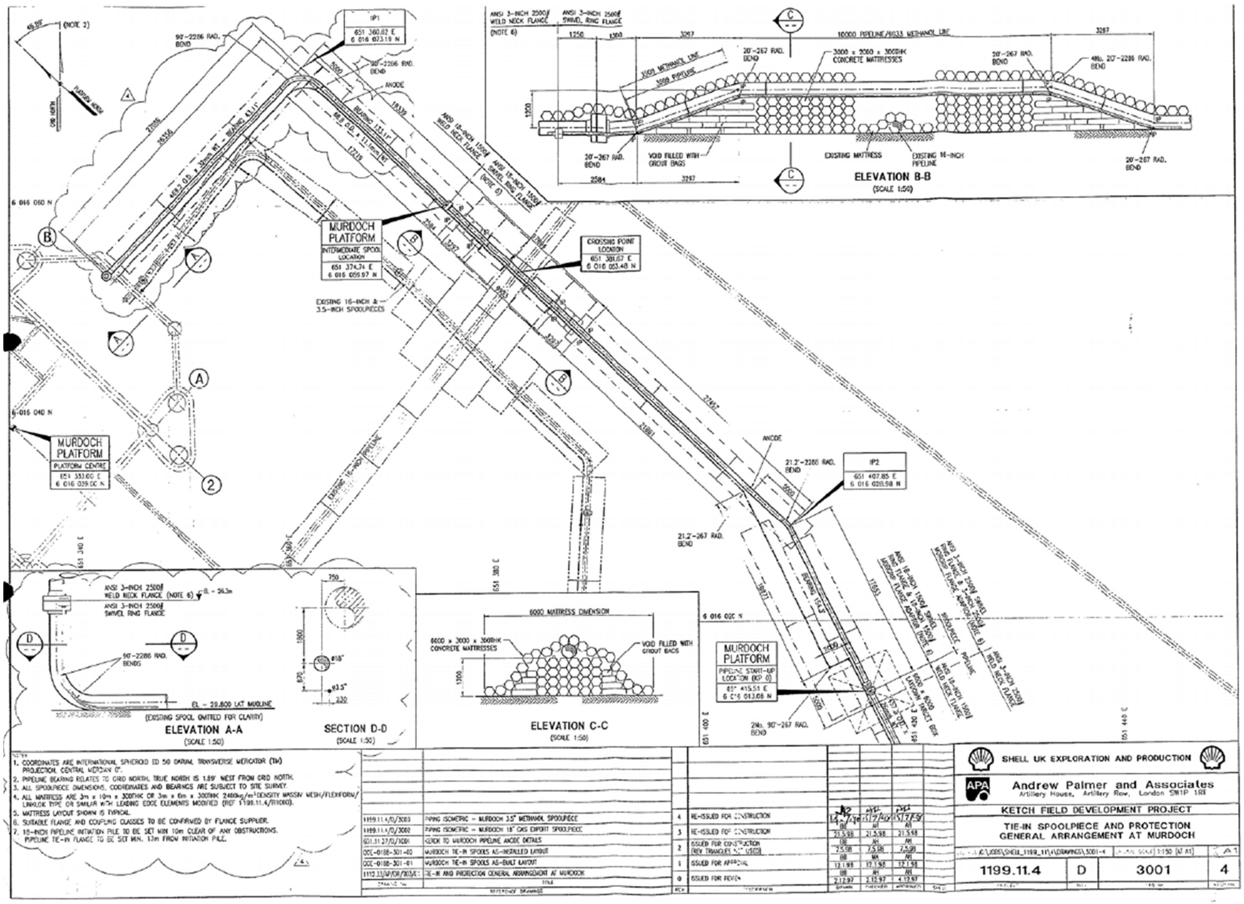


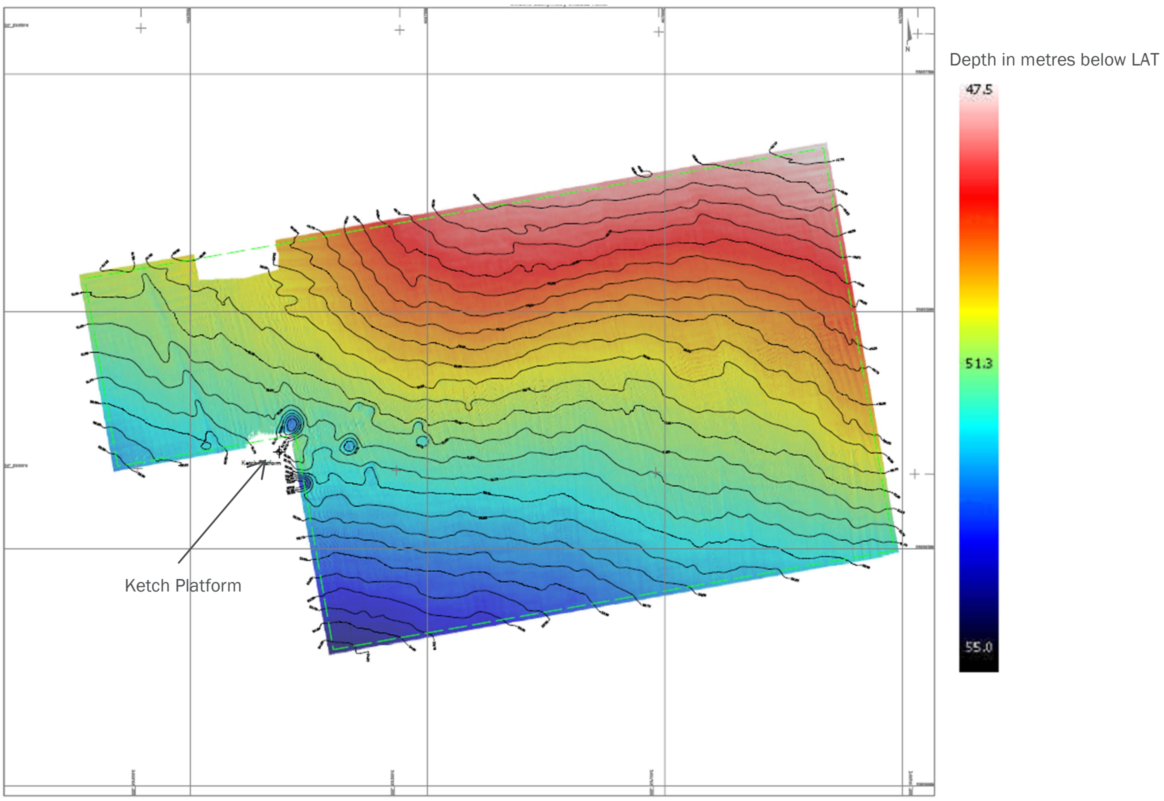
Figure 5 above shows MBES survey plot of the Ketch platform. There are scour depressions at each of the platform legs between 1.6m and 2.6m below average seabed level around the platform. This scour profile is normal for platforms located in this area of the SNS.

Figure 6: Ketch pipelines protection drawing at Murdoch showing Caister pipeline crossing



At the Murdoch platform, mattresses and grout bags were employed to form the Caister pipeline crossing, to elevate the Ketch pipelines above the Caister pipeline. The general arrangement of mattresses and grout bags can be seen in Figure 6. There are no records of the type, number or size of the grout bags. The number, size and weight of the grout bags present in the Caister crossing have been estimated from this drawing.

Figure 7: Geophysical Survey: Swathe Bathymetry - Ketch Platform



4.3. Summary

4.3.1. Mattress configuration and condition

Mattresses that support and cover the Ketch pipelines are designed with polypropylene rope links which are not expected to have deteriorated significantly over field life. The mattress blocks have tapered edges to maximise both stability and overtrawlability. When considering fishing interaction, during the operating lives of these assets, no snagging hazards relating to the stabilisation mattresses, has been identified or consequently remediated.

The recent 2017 surveys have shown that the Ketch mattresses are partially buried to varying degrees. Mattresses are of the segmented type and draped over the pipelines at the Murdoch end and intermittently along the main length, with their edges and associated lifting loops (note that the condition of the mattress lifting loops is not known) buried to varying degrees by the surrounding sediments.

Over time, given the sediment mobility in the area, the level of burial of partially buried mattresses is likely to increase. This will be supported by natural backfilling of the locally scoured sections of seabed once the installation structures (the sources of scour) have been removed.

4.3.2. Grout bags

Grout bags and mattresses have been used as support for pipelines at the Caister pipeline crossover immediately adjacent to the Murdoch platform locations with further mattresses providing protection over.

4.3.3. Seabed

The seabed along the length of the pipeline is characterised by small sand ripples. Figure 7 shows the bathymetry in the Ketch area, there are no large transient features within the seabed and the changes in the level of the seabed are relatively gradual.

4.3.4. Inventory

The following tables give a summary of the pipelines and stabilisation materials associated with Ketch within the scope of this CA.

Table 2: Ketch Stabilisation and Protection Concrete Mattresses

Item	Along the subsea route		Remediation Mattresses (KP 5.7 – KP 12.5)		Murdoch Platform approach		Caister / Ketch pipelines crossings	
	Number	Size/weight (Te)	Number	Size/weight (Te)	Number	Size/weight (Te)	Number	Size/weight (Te)
Concrete mattresses	52	449.3	1 (593m in total length)	853.9	13	246.2	8	34.5
Grout bags (assumed)	-	-	-	-	-	-	32	26

Table 3: Ketch Pipeline (PL1612) Materials

Item	Ketch		Murdoch	
	Length (m)	Size/weight (Te)	Length (m)	Size/weight (Te)
Risers	120	43.3	50	18
Spool Pieces	56.1	19.8	108.6	38.3
Main gas Pipeline	26600	7454.9	-	-

Table 4: Ketch Piggyback Pipeline (PL1613) Materials

Item	Ketch		Murdoch	
	Length (m)	Size/weight (Te)	Length (m)	Size/weight (Te)
Risers	62	1.4	55	1.2
Spool Pieces	45	1	70	1.5
Piggyback Pipeline	26600	587.2	-	-

5. Decommissioning options

The methods available to remove, partially remove, remediate or leave in-situ the pipeline are discussed in the following sections.

5.1. Pipeline Removal

As per the BEIS Guidelines (see Section 1.3) the default preference is to remove pipelines and stabilisation materials from the seabed, unless they and their stabilisation features are buried 0.6m below the seabed.

There are essentially two methods of removing the Ketch pipelines from the seabed which are briefly explained below:-

- Reverse installation technique
- Cut and lift technique

Given that the pipelines are intermittently buried, the use of mass flow excavators will be required to be used for both techniques, to remove seabed materials from the pipelines to gain access to them. This will increase ROV time for the full removal operation, along with environmental disturbance (through the disturbance of the seabed).

5.1.1. Reverse Installation Technique

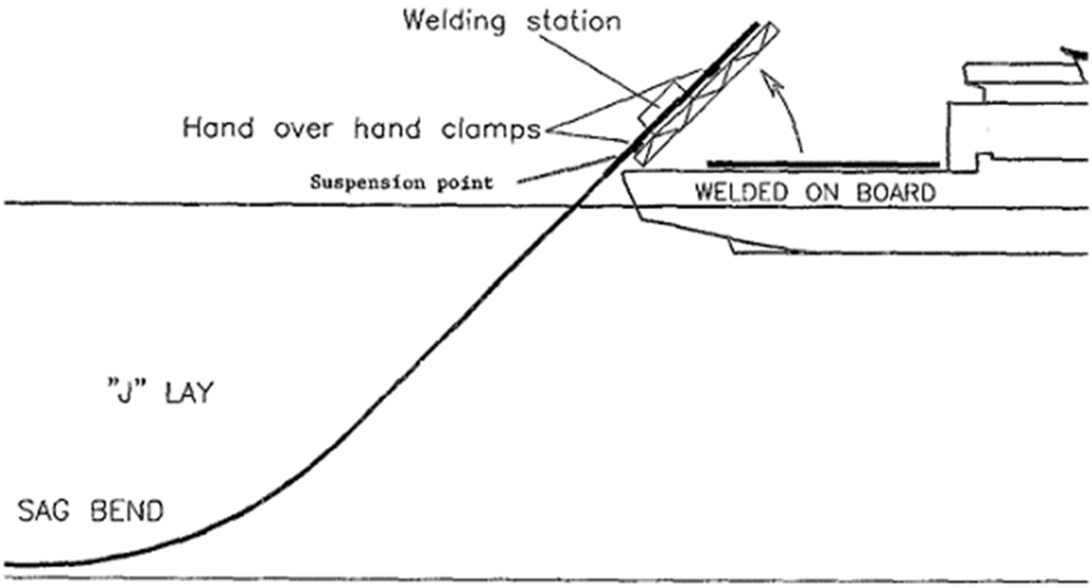
As intimated by the title, the method by which the pipelines were installed is reversed. The pipelines will have been laid using S or J lay methods. The reverse S or J lay method of removing a pipeline requires one end of the pipeline to be lifted through the water column and pulled onto the deck of a pipe laying barge. As the pipeline is pulled onto the barge from the seabed it is progressively cut into sections which can be stored on the barge and / or transferred to another vessel which delivers them to shore for recycling. The S /J refer to the shape the pipeline makes in elevation when it is pulled through the water column from the seabed (see figure 9).

The advantage of this diverless method of removal is that once the buried sections of the pipeline have been uncovered by a mass flow excavator and the pipeline end has been pulled onto the rear of the pipe lay barge, there is relatively little subsea works required. The cutting of the pipeline into more manageable lengths and rigging those sections, so they can be lifted, is all carried out on the deck of the vessel rather than subsea. There are however some significant disadvantages to this method. The pipe lay barge required to undertake the removal operation is large and the process is slow. Relatively high stresses are imposed on the pipeline as it can effectively span a considerable distance through the water column from its touchdown point on the seabed to the rear of the barge. A pipeline that has been on the seabed for 20+ years could have undetected defects or weaknesses that could be exacerbated and result in structural failure, if subjected to the relatively high stresses imposed by the reverse installation removal method. There is therefore a considerable health and safety risk associated with removing the Ketch pipelines in this way.

The Ketch pipelines (export and piggyback methanol pipeline) were laid fixed to one another with the spoiler fin, designed to promote self-burial. This combined configuration and the sheer size of the 18” export pipeline rules out the possibility of the pipeline being reverse reeled and makes reverse installation removal more technically challenging than it would be for a single pipeline.

Fig 7 over the page indicates the J lay method of installing a subsea pipeline. The reversal of this to remove a pipeline would appear similar to this, except the welding station would become a cutting station to chop the pipe into more manageable lengths for transport and disposal.

Figure 8: “J” Lay installation of a subsea pipeline



5.1.2. Cut and lift technique

Over recent years there has been an increase in the number and variety of subsea tools capable of carrying out the cut and lift removal of pipelines. ROVs have been developed that operate suspended from a vessel crane. The crane controls their ascent and descent whilst powerful thrusters on the ROV allow them to hold position or move around laterally. These ROVs can be fitted with a variety of tools that can be used to remove pipelines, such as:-

- Airlifts or mass flow excavators for removing natural deposits
- Hydraulic shears or diamond wire saws for cutting pipes
- Grabs and grapples for lifting short sections of pipe (circa 15 -20m)

The advantages of this form of removal is that it is diverless and fairly simple, it can be undertaken from a much smaller dive support vessel (DSV) or construction support vessel (CSV) compared to the large pipe lay barge required to remove the pipelines by reverse installation. Its disadvantage is that it is a time consuming. The 26.7 km pipelines need to be cut into approximately 1, 335 x 20m sections on the seabed in order to be removed.

A variation to this method is to cut the pipe into longer sections of several hundred metres or kilometres, it can then be lifted by floating it to the surface and towed to shore for disposal.

Figure 9: ROV and various tool attachments that can be utilised to remove pipelines

5.2. Mattress removal methods

Traditionally, mattresses are removed using the lifting loops integrated into their design (which were utilised in the installation process), using a spreader bar arrangement. This can subject mattresses to loads that can cause them to break up, particularly if the mattresses are of steel wire design (Armorflex), are of poor integrity or are damaged. However, the polypropylene rope concrete mattresses, which are present in the Ketch fields, generally maintain their integrity better and are more easily removed using this traditional method.

Previous experience in the North Sea has indicated that if in good condition, exposed and of new construction (circa less than ten years old) mattresses can be removed at a rate of up to one per hour. However, for older mattresses (twenty years old) removal rates can be as low as one every twelve hours [10].

More novel techniques for mattress removal have come onto the market recently and can have significant benefits over traditional techniques in terms of recovery rate. For the purposes of this CA it has been assumed that mattress removal will be carried out by an ROV suspended from a crane fitted with a bespoke mattress removal tool. Figure 8 above shows the successful onshore trial of the Utility ROV mattress recovery tool. The mattresses at Ketch are generally all partially buried to some extent; therefore a mass flow excavator fitted to an ROV would still be required to remove the natural deposits from some of the mattresses prior to their removal.

Figure 10: UTROV Mattress recovery tool

5.3. Removal of grout bags

Grout bag recovery is difficult as these have minimal lifting points attached and as such the factor of safety is far less than that of a standard concrete mattress with sixteen point lift attachments. In previous decommissioning programmes, grout bags (particularly large 1 Te grout bags) have typically been left in situ. “As Built” drawings of the Murdoch pipeline end indicate the presence of several grout bags in the construction of the ramps that form the crossing of the Caister pipeline crossing. For the purposes of this CA, it has been assumed that grout bags will be removed by a grapple fitted to the underside of an ROV suspended from a crane.

5.4. Remediation methods

For the decommissioning option based on the remediation of snagging threats, four main approaches have been considered:

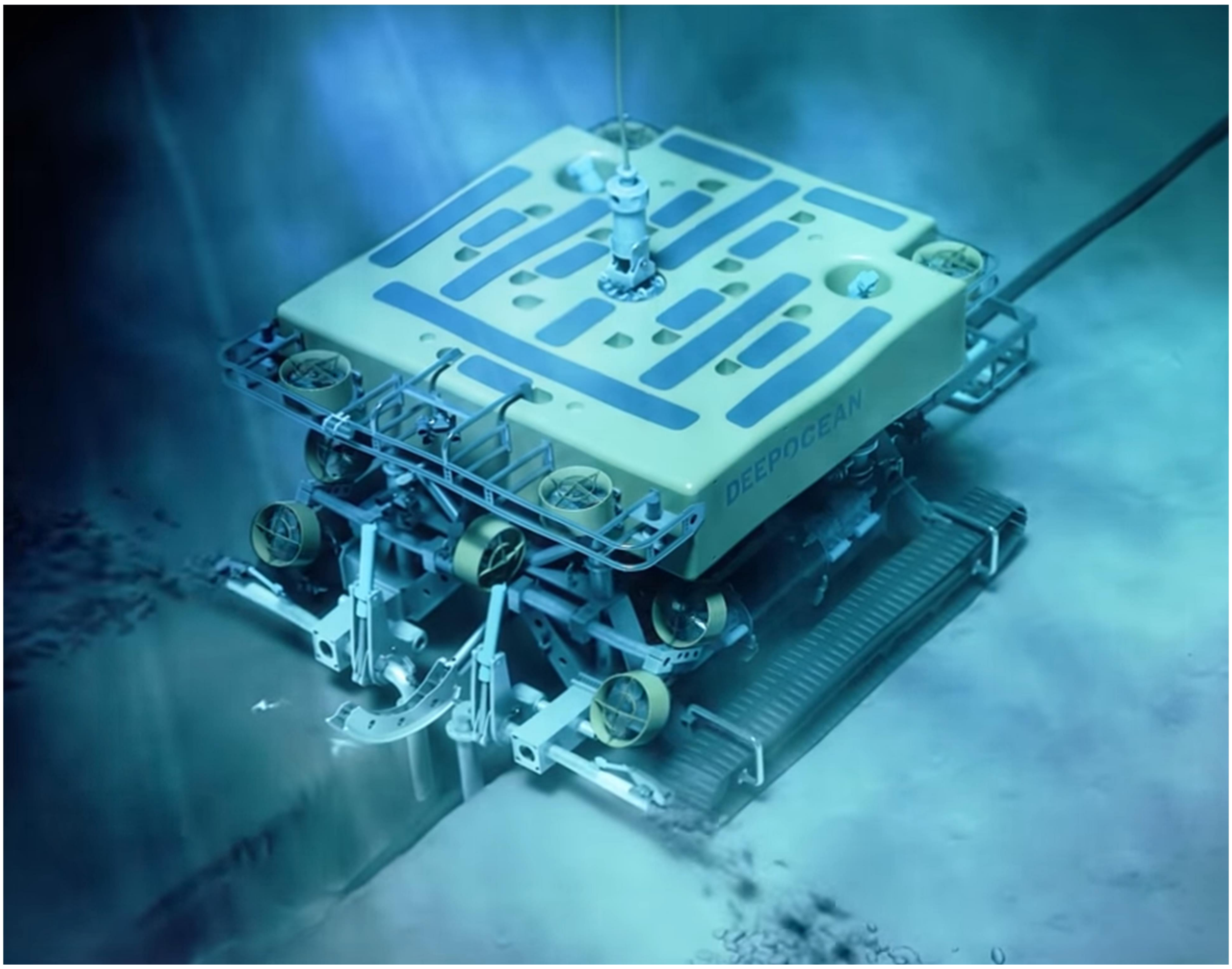
- Bury by trenching and backfilling with natural deposits;
- Bury with rock / gravel;
- Apply existing mattresses to cut ends;
- Apply gravel / grout bags to cut ends.

These techniques are described in more detail in the sub-sections below. It should be noted that there are no umbilicals

5.4.1. Bury by trenching and backfilling

Burying the pipeline sections that have not been sufficiently buried or exposed is feasible and can be performed using methods such as jetting or dredging. Jetting is the process of using high pressure water and air or water eductors to create a trench by fluidising the seabed which is then dispersed in to the water column to be carried away by the current. Dredging is similar to this in that a trench is cut, but mechanically as opposed to using water and air to create the trench. Contractors such as IHC (Hi-Traq), Modus and DeepOcean can provide such vehicles that fluidise the seabed, sinking the pipeline and potentially the stabilisation materials as well, if the seabed soil conditions allow. If the pipelines are buried in this manner it is likely that then ends will be sunk sufficiently that treatment of the cut ends with existing mattresses or grout bags will be unnecessary (However biodegradable grout bags on the pipelines' cut ends have been included as a contingency, to ensure the ends remain buried). During the preparation of the comparative assessment a trenching contractor was consulted to check that burial by trenching was possible given the soil conditions, it was confirmed that the pipelines could be trenched.

Figure 11: Deepocean T1000 Jet Trencher ROV



5.4.2. Bury with rock / gravel

Rock / gravel dumping is also a well-established approach to pipeline remediation, often carried out for protection and stabilisation of operational pipelines. Given the nature of the operations, rock dump is likely to be the most disruptive to the surrounding environment through the introduction of alien materials, the disturbance of the seabed during deposition and the potential to introduce localised scouring of the seabed surrounding the berm. The introduction of rock dump can also create snagging hazards for trawlers by the introduction of additional material to the seabed; this can also depend on the sizing of the rocks / gravel being dumped. Rock dumping is usually carried out by rock-dumping vessels which are normally equipped with a dynamic positioning system to allow them to position rocks very accurately. Large cranes or fall pipes are used to dump the rocks from the vessels. Side-discharging by means of crane is usually done in shallow waters, while fall pipes are more commonly used in deep-water rock-dumping operations as seen in Figure 13, below.

Figure 12: Rock burial vessel with a fall crane

5.4.3. Apply existing mattresses to cut ends

The remaining cut ends of the pipelines can create snagging hazards for trawl nets. These cut ends can be remediated by an existing concrete mattress, which can be re-used to cover the cut end to ensure no snagging hazard exists. This can be achieved by the use of the mattress recovery tool in Figure 9, which can reposition mattresses without damaging them, provided they have not deteriorated to a significant extent.

5.4.4. Apply gravel / grout bags to cut ends

In a similar way to applying existing mattresses to cut ends, new or existing gravel, sand, or grout bags can be applied to cut ends to remediate snagging hazards. Grout bags can be placed empty or filled with grout depending on the situation. If empty when placed, they can be injected with grout to be filled to a desirable volume and shape to fit the environment. However, the grout bags themselves are often composed of Polypropylene which, after a period of time, can degrade and break up. In this respect, it would be beneficial to only use new grout bags that are composed of biodegradable materials to avoid adding potentially harmful plastic materials to the seabed.

Figure 13: Grout bag placement on a pipeline

5.5. Selected options for consideration

On the basis of the discussion points above, the following options were considered in this comparative assessment for the decommissioning of the pipelines:

1. Completely remove all pipelines and stabilisation features;
    a. Using a reverse installation technique
    b. Using a cut and lift technique
2. Partially remove pipelines / stabilisation features that present or have the potential to present a snagging hazard;
    a. Using reverse installation technique
    b. Using cut and lift technique
3. Bury exposed pipelines and stabilisation features;
    a. By trenching and backfilling with natural deposits
    b. By rock dumping
4. Leave all pipelines in-situ;
    a. By covering cut ends with gravel / grout bags
    b. By covering cut ends with existing mattresses

6. Environmental and socioeconomic data

An environmental appraisal (EA) has been performed for the Ketch Area. All data and extracts in this section have been taken from this report, unless otherwise specified. For further more detailed information regarding the environment or socioeconomics associated with the decommissioning please refer to the EA.

6.1. Environment

6.1.1. Conservation Interests

The northernmost part of the project area, where the export pipelines join the Murdoch Platform, is within the Dogger Bank SAC and MPA which is located approximately 24.3 kilometres northwest of the Ketch NUI. Most of the decommissioning work will be outside of the Dogger Bank SAC and MPA, but work will encroach into the Dogger Bank SAC and MPA.

The Southern North Sea SAC, located approximately 12 kilometres north of the Ketch NUI, falls out with the project area.

Furthermore, the recommended conservation zone Markham's Triangle is located 24 kilometres southwest of the Ketch NUI and the North Norfolk Sandbanks and Saturn Reef SAC/SCI are located approximately 42 kilometres south-west of the Ketch NUI.

A large number of nationally designated sites are also present along the coastline immediately east of the Ketch field. This coastline includes SSSIs selected for geological interest or presence of special plants, terrestrial invertebrates, breeding seabirds or breeding waterfowl and National Nature Reserves (NNRs) which contain examples of some of the most important ecosystems in Britain, including sand dune, shingle, saltmarsh, mudflat and wet grassland.

6.1.2. Seabed

There are two recommended MCZ areas in the vicinity of the project area; Net Gain 7: Markham's Triangle (approximately 20 kilometres south-east of Block 44/28b) and Net Gain 9: Holderness Offshore (80 kilometres south-west of Block 44/28b). Net Gain 7: Markham's Triangle is an area composed of two broad-scale habitats (moderate energy circalatoral rock and subtidal missed sediment), subtidal sands and gravels and an important habitat are for European eel (*Anguilla Anguilla*). Net Gain 9: Holderness Offshore is an area composed of a broad-scale subtidal sand habitat and areas of subtidal sands and gravels and Ross worm reefs as habitat areas of conservation importance (*Net Gain, 2011*).

6.1.3. Fish

Fish species known to use the project area for spawning and as a nursery are mackerel, plaice, herring, sole, sprat, Nephrops, Whiting, Spurdog, Tope, Cod, Blue Whiting, Ling, european hake, anglerfish and sandeel. In a survey conducted by CEFAS, twenty-six species of Elasmobranch were identified and recorded throughout the North Sea and surrounding waters. Of these, only the spurdog (*Squalus acanthias*), tope shark (*Galeorhinus galeus*), starry smooth hound (*Mustelus asterias*), and starry ray (*Amblyraja radiata*) may be present within the general vicinity of the Schooner and Ketch NUIs (*Ellis et al., 2004*).

6.1.4. Marine Mammals

Cetaceans in the project area are harbour porpoise, Minke Whale and white beaked dolphin. Pinnipeds such as Grey seal (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) are both resident in UK waters and are listed under Annex II of the EU Habitats Directive. Harbour seals are not normally found foraging more than 60 kilometres from shore (*DECC OESEA2, 2011*). Grey seal pupping generally occurs in October, with moulting occurring between February and March (*DECC OESEA2, 2011*). During this period, grey seals will be found either onshore or on foraging trips in the vicinity of their haul-out site. The project area is located 130 kilometres from the coast so it is highly unlikely that these species may be encountered in the vicinity of the decommissioning operations.

6.1.5. Birds

The most common species of seabird found in the area include: Herring gull (*Larus argentatus*), Great black-backed gull (*Larus marinus*), Sabine's gull (*Xema sabini*), Kittiwake (*Rissa tridactyla*), Guillemot (*Uria aalge*), Fulmar (*Fulmarus glacialis*) and Gannet (*Morus bassanus*) (UKDMAP, 1998). Seabird vulnerability to oil pollution ranges from low to very high (JNCC, 1999). High to very high seabird vulnerability in the area generally occurs from July through to May, with low to moderate vulnerability occurring in July (JNCC, 1999).

6.1.6. Onshore Communities

Major communities within this include Hull (a commercial and passenger port, with ro-ro ferry services to Belgium and the Netherlands) and Grimsby (the main port of the Humber, particularly important for commercial fishing landings). Data shows that shipping densities in this area are moderate, with highest activity in the summer months (DECC 2009 and Oil and Gas Authority 2016). Popular seaside resorts along this stretch of the coast include Whitby, Filey and Scarborough which are all popular for their bathing beaches (DECC 2009). The tourism industry is not likely to be impacted by normal offshore oil and gas operations but leisure activities could be threatened in the event of a major accidental spill approaching the coast, however this is unlikely given the coast is approximately 130 kilometres from the project area.

6.1.7. Other Users of the Sea

Oil and gas activity within the project area is moderate compared to other blocks in the SNS.

Blocks 44/26, 44/27 and 44/28 all overlap with a military exercise area (Oil & Gas Authority, 2017). As a result, these blocks are considered to be an area of concern to the Ministry of Defence (Oil & Gas Authority, 2017).

6.1.8. Atmosphere

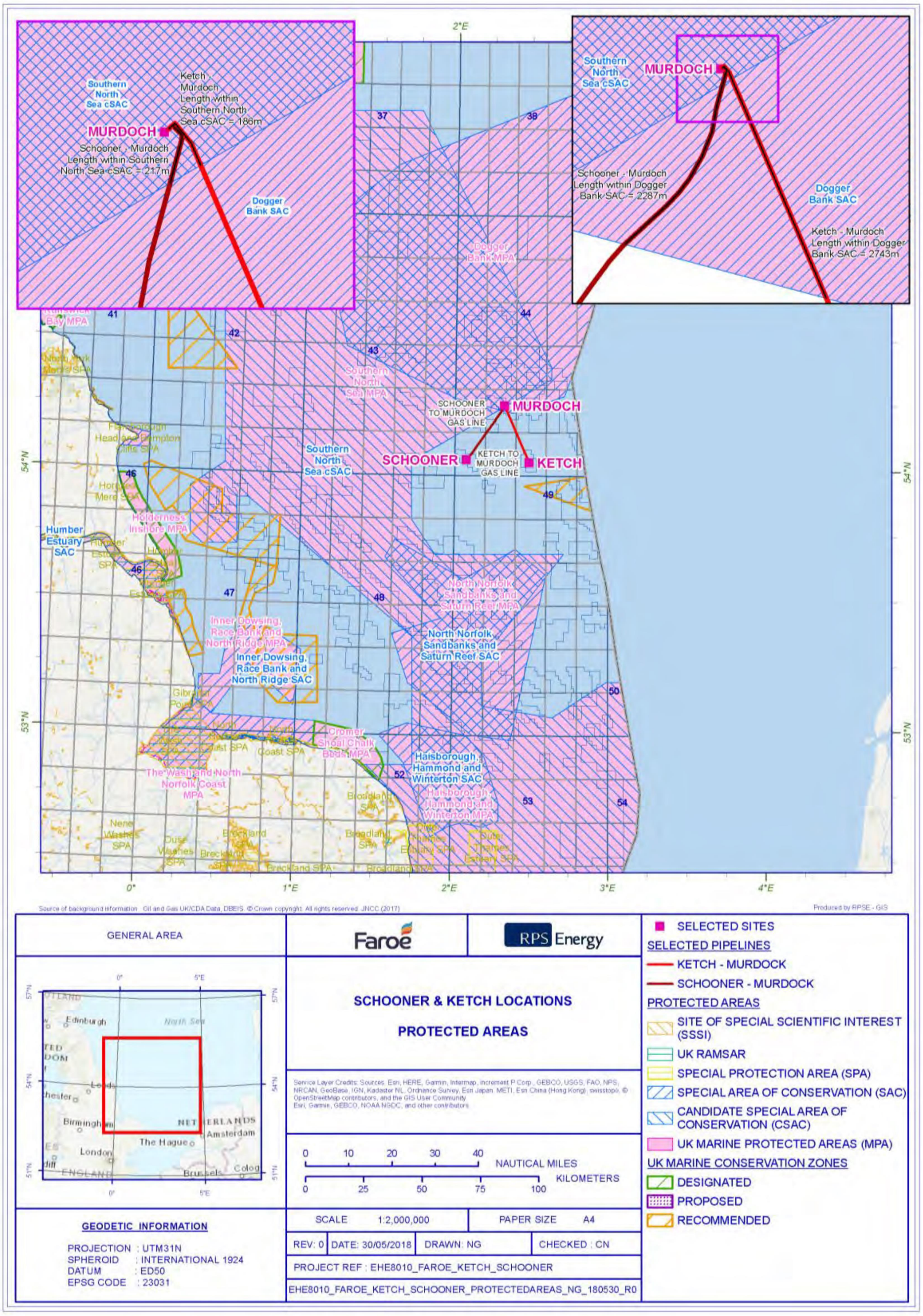
Local atmospheric emissions will be influenced by vessel movements and associated activities during the proposed decommissioning operations. It is expected that these emissions will be localised to the area of interest.

6.1.9. Potential Environmental Impacts and their Management

The Environmental Appraisal provides a review of the key features of the environment in the proposed Ketch Decommissioning Programmes Area in block 44/28b in the Southern North Sea (SNS).

A key consideration when planning and finalising the decommissioning of the Ketch installation and pipelines is a clear understanding of the surrounding environment. In order to understand the potential for the project to interact with the environment, so that appropriate controls can be adopted to mitigate negative impacts, the physical, biological and socio-economic environments have therefore been assessed.

Figure 14: Environmentally Sensitive Areas



Source: RSP Environmental Appraisal – SCKE FPROGB O RA 0001 [11]

6.2. Socioeconomic

6.2.1. Fishing

Commercial fishing activity within the vicinity of the project area is generally low with peak moderate activity in August and September; however, data was undisclosed from December to April (*Scottish Government, 2016*). The project area lies with ICES rectangle 37F2. Landings were predominantly demersal species making up 53.03 per cent of the live weight catches in 2016, followed by shellfish (46.93 per cent) and pelagic making up approximately 0.04 per cent of catches (*Scottish Government, 2016*).

The most common gear types observed in this region were trawls. Data relating to seine nets and gill nets was undisclosed. ICES rectangle 37F2 has a fishing effort of 429.4 effort days per 100 square kilometres per year which is relatively moderate but consistent with fishing efforts for large areas of the Southern North Sea.

6.2.2. Shipping

Shipping in the waters surrounding the Ketch Field is relatively high, due to the presence of a number of international ports within the region. Major ports within this region include Hull (a commercial and passenger port, with ro-ro ferry services to Belgium and the Netherlands) and Grimsby (the main port on the Humber, particularly important for commercial fish landings). Data shows that shipping densities in the project area are moderate, with highest activity in the summer months.

6.2.3. Military

The blocks of Interest do not lie within any military exercise areas.

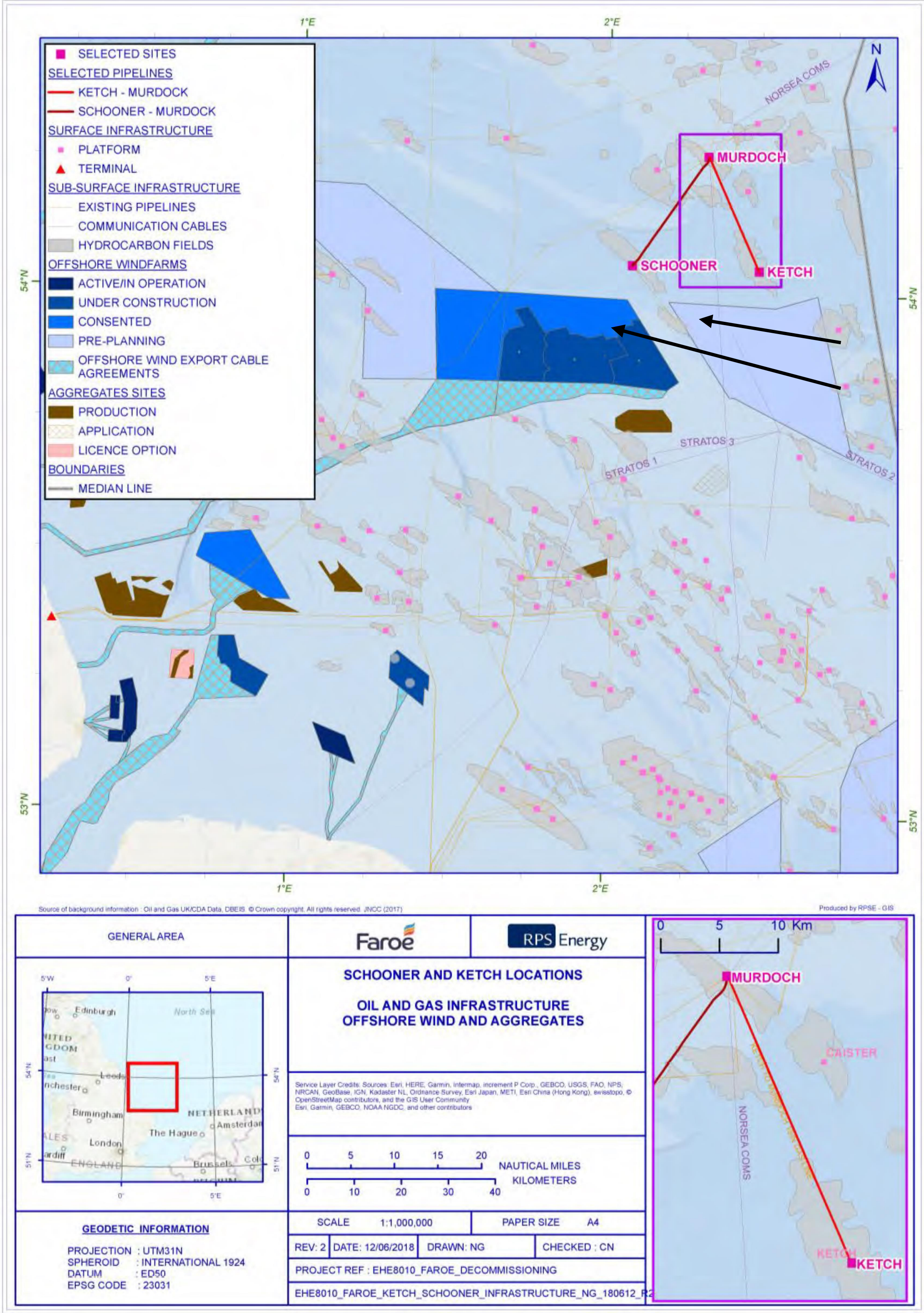
6.2.4. Dredging and dumping activity

There are no offshore licensed dredging areas within the vicinity of the Ketch decommissioning area.

6.2.5. Wind farms

A number of wind farm sites are located near to the project area (see figure 14) The Hornsey 1 wind farm is located approximately 25km from the Ketch platform.

Figure 15: Offshore wind and marine aggregate activity in relation to the Ketch installation and pipelines



Source: RSP Environmental Appraisal – SCKE FPROGB O RA 0001 [11]

6.2.6. Archaeology

There are no charted wrecks in the vicinity of the assets that would be impacted by works associated with the decommissioning of the pipelines.

6.2.7. Tourism and leisure

Leisure based and tourist activities are fairly widespread along the east coast of England. The north Norfolk coast is an important area for water-based activities, particularly dinghy sailing and wind-surfing. Bridlington and Great Yarmouth are both popular embarkation points for sea angling trips. The wildlife in the area is also a significant attraction and during the summer there are regular seal watching trips to Blakeney Point.

The tourism industry is not expected to be impacted significantly by the Ketch Decommissioning Programme operations, however, leisure activities could be threatened in the event of a major accidental spill approaching the coast. This is not applicable to the scope of pipeline decommissioning covered by this CA as the pipelines will have been cleaned and flushed with seawater, prior to any subsea decommissioning work being carried out.

6.3. Summary

6.3.1. Summary of decommissioning impact

The decommissioning scope considered here is limited. Removal and remediation operations will be short term, localised in nature and ultimately will pose little risk to any of the species identified above. However, the timing of decommissioning works should be scheduled, wherever possible, to minimise impact through avoidance of periods where species would be particularly susceptible to disruption. The other factor to be considered is the impact of mass flow excavation on the seabed communities, bottom dwelling species of fish and the commercially important shellfish in the locale.

The area of seabed disturbance at the Murdoch end of the pipeline was assumed to be a corridor width of 10m, allowing sediment to be moved from its current location and deposited either side of the 60m long sections that are being removed. The use of shears is considered to have a negligible impact on the seabed as the tool is rigged from the vessel and sits vertically above the pipeline with minimal contact to seabed. The 10 m corridor area includes disturbed seabed due to recovery of the stacked mattresses that form the Caister crossing.

Table 5: Temporary Seabed Disturbance

Source of Temporary Seabed Disturbance	Assumptions Made	Estimated Area of Direct Impact (km^2)
Cutting and recovery of Ketch pipeline end at Murdoch platform	The area of seabed disturbance was assumed to be a corridor width of 10 m, allowing sediment to be moved from its current location and deposited either side of the 60 m long sections that are being removed. The use of shears is considered to have a negligible impact on the seabed as the tool is rigged from the vessel and sits vertically above the pipeline with minimal contact to seabed. 10 m corridor area includes disturbed	0.0060

Source of Temporary Seabed Disturbance	Assumptions Made	Estimated Area of Direct Impact (km^2)
	seabed due to recovery of 19 mattresses and approximately 32 grout bags.	
Cutting of Ketch pipeline end at Ketch platform	The area of seabed disturbance was assumed to be a corridor width of 10m, allowing sediment to be moved from its current location and deposited either side of the 10m long section that are being removed.	0.0001
Trench and burial of Ketch pipelines to decommission in situ	The area of seabed disturbance was assumed to be a corridor width of 5 m, allowing the sediment to be deposited either side of the pipeline. The full length (26,600 m) of pipeline to be trenched and buried.	0.133
Seabed overtrawl assessment	An assessment corridor of 100m for Ketch pipelines for the entire length of 26,600m	2.660

No impact is anticipated on leisure activities performed in the region, shipping activity in the Ketch area is moderate.

Actual decommissioning activities will only have a short term impact on the local environment. The long term impact of degradation of any items left in-situ on the local marine environment has also been considered as part of the comparative assessment. This includes the deterioration of the polypropylene rope linking the concrete blocks of the stabilisation mattresses. These long term impacts are discussed in detail in Section 9.3 of this report.

7. Workshop terms of reference

7.1. Introduction

These terms of reference were prepared for the Ketch pipelines and stabilisation materials comparative assessment workshops. There were two workshops an initial options screening workshop carried out on 27th February 2018 and a detailed workshop on the 2nd May 2018, which adopted a similar but more detailed format. The purpose of these workshops was to whittle down the options and identify the preferred decommissioning option for the pipelines and their associated stabilisation materials.

7.2. Options

The following options were considered in detail for the decommissioning of the pipelines:

1a) Completely remove the pipelines by reverse installation (S or J lay);

1b) Completely remove the pipelines cut and lift:

2a) Partially remove the pipelines by reverse installation (S or J lay)

2b) Partially remove the pipelines by cut and lift;

3a) Bury by trenching and backfilling with natural deposits;

3b) Bury by rock dump;

4a) Leave in situ – cover cut ends with gravel / grout bags;

4b) Leave in situ – cover cut ends with existing mattresses.

7.3. Comparative assessment methodology

The CA uses the five assessment criteria as described in the guidelines [2] [3]:

- Safety
- Environment
- Technical
- Societal
- Economic

7.3.1. Screening Workshop

The purpose of the initial screening workshop was to reduce the number of options to a shortlist of five or six.

The screening phase workshop reviews and screens out unrealistic options or obvious non-starters, (e.g. due to clearly unacceptable safety risk) from the comparative assessment. This phase documents the reasons for reducing options to a manageable level, which ultimately limits the effort and time expended in reaching a shortlist of decommissioning options. The screening phase results in only technically feasible options and/or methods being carried forward to the next stage.

A simplified, coarse red / amber / green (RAG) scoring system was adopted for the screening workshop, based on qualitative evaluation method A from the OGUK guidelines [1]. Under this evaluation method colour coding represented the relative preference of the options with respect to the criteria. Options were assessed against each sub-criterion in turn. All of the relevant decommissioning options considered were compared, with reference to an individual sub-criterion before moving on to the next sub-criterion. This encouraged and ensured that a common and relevant comparison of each option at sub-criteria level was achieved. Following confirmation of the criteria and sub-criteria to be adopted, a rating template was developed to inform and align the meaning of Red, Amber and Green ratings to the workshop participants.

The screening workshop was attended by an experienced cross disciplinary team that were familiar with the pipelines and / or the methods by which they could be decommissioned…

Table 6 – Simple quantitative RAG scoring adopted for CA Options Screening Workshop

Performance	Comparative impact
Most preferred	(green)
	(amber)
Least preferred	(red)
No preference	(grey)

7.3.2. Detailed CA workshop

The detailed CA workshop evaluates each of the shortlisted pipeline decommissioning options. Evaluation method C from the OGUK guidelines [2] was chosen for the assessment to ensure a clear conclusion is determined. This method uses qualitative and quantitative criteria with relative weighting assigned to the criteria. The criteria, weighting and scoring are described in Section 6.2 and Section 6.3.

The five criteria above are further broken down into sub-criteria, as described below:

1. Safety
    a. Risk to offshore personnel (during decommissioning)

       Quantitatively assesses the safety risk to personnel during offshore operations. FAR data is taken from the SAFETEC JIP [19]. Diver risk has not been taken account of as all the removal and remediation options considered use ROVs and diverless technology in preference to divers.

    b. Risk to other users of the sea (post-decommissioning)

       Quantitatively assesses the safety risk to users of the sea post-decommissioning. The focus of this criteria is the risk to fisherman from overtrawling, leading to a snagging event and loss of life.

    Note: the key differentiators for safety risks are considered to be the risk to offshore personnel during the decommissioning operations (crane operators and vessel personnel) and the residual risk to users of the sea after operations (fisherman due to trawling activity). Therefore, the risk to onshore personnel (transport and waste) and to 3rd parties during the decommissioning was not assessed.

2. Environment (includes Dogger Bank SAC and SNS cSAC)
    a. Energy use

       Estimates the energy used to complete the offshore decommissioning operations, the energy used to recycle materials taken onshore and the energy used to manufacture new materials (to replace those left on the seabed).

    b. Seabed disturbance

       Estimates the impact on the seabed caused by decommissioning

    c. Materials left on seabed

Estimates the percentage of material left on the seabed

d. Impact of macro PP release (from mattress ropes)

   Estimates the effect of macro PP to marine life and the environment when removing or leaving the mattresses in place.

e. Impact of micro-plastic release from PP (from mattress ropes)

   Estimates the effect of micro PP to marine life and the environment when removing or leaving the mattresses in place.

f. Materials discarded to landfill

   Estimates the percentage of material removed that is sent to landfill (otherwise recycled)

Note: At the Murdoch end of the pipelines, the pipelines are within the Dogger Bank SAC and the SNS cSAC. This was taken account of at the initial and follow up detailed workshops. The total area of the pipelines within these habitats is so miniscule in relation to the size of the protected areas that they did not have a huge bearing on the CA outcomes.
Energy usage has been estimated using guidance from IoP (2000) [20].

3. Technical
   a. Technical challenge of stabilisation material removal

      Assesses the technical feasibility of the decommissioning option
   b. Weather sensitivity

      Assesses how sensitive the decommissioning option is to bad weather
   c. Risk of major project failure

      Assesses the risk of major project failure for the decommissioning option
4. Societal
   a. Risk of Fisheries - impact on fish stocks due to introduction of micro-plastics (from mattress pp ropes) to food chain

      Assesses the impact on fisheries due to introducing micro PP to the food chain.
   b. Fisheries - impact of pipelines on fishing activities.

      Assesses the impact of snagging on fisheries.

   Note: the main societal impact from decommissioning pipelines is the risk to fishing. This is scored based on the risk should snagging cause an issue to the industry, reducing the ability to fish in the area. The impact to onshore communities (positive or negative) is not assessed due to the relatively low inventory of materials that would be transported to shore. Hence, it is not a contributing factor. Shipping access is not considered relevant to the scoring as removing or remediating in-situ will not have an appreciable effect on shipping.
5. Economic
   a. Decommissioning cost

      Assesses the cost to perform each decommissioning option
   b. Ongoing liability

      The extent to which the option minimises cost / risk uncertainty.

7.4. Assessment criteria

Table 7: Assessment criteria / sub-criteria

Criteria / sub-criteria	Impact level				
	1 (very low)	2 (low)	3 (medium)	4 (high)	5 (very high)
1. Safety					
1a. Risk to offshore personnel (during decommissioning)	Quantitative scoring				
1b. Risk to other users of the sea (post decommissioning)	Quantitative scoring				
2. Environment					
2a. Energy use	0-10,000GJ	10,001-100,000GJ	100,001-200,000GJ	200,001-400,001GJ	>400,000GJ
2b. Seabed disturbance	None	Localised disturbance (0-100% of equipment footprint)	Localised disturbance (100% of equipment footprint)	Wider area of disturbance (100-200% of equipment footprint)	Wide area of disturbance (>200% of equipment footprint)
2c. Materials left on seabed	0%	0-20%	20-50%	50-80%	>80%
2d. Impact of macro PP release (from mattress ropes)	No macro PP release	Small macro PP release	Moderate macro PP release	High macro PP release	Very high macro PP release
2e. Impact of micro-plastic release from PP (from mattress ropes)	No micro PP release	Small micro PP release	Moderate micro PP release	High micro PP release	Very high micro PP release
2f. Materials discarded to landfill	0%	0-20%	20-50%	50-80%	>80%
3. Technical					

3a. Technical challenge of stabilisation material removal	Regular construction task using generic procedures	Regular construction task using detailed procedures	Non-routine task. High level of historical experience	Non-routine task. Low level of historical experience	Novel technique or equipment. No industry experience
3b. Weather sensitivity	General operations relying only on ability to launch ROV	Standard operations experiencing expected operational downtime for time of year	Requires specific weather window for small number of tasks. Non schedule critical	Requires specific weather window for certain tasks. Schedule can be optimised to accommodate	Requires specific weather window for prolonged period. Operation on critical path
3c. Risk of major project failure	Existing, proven equipment used for specific task for which it was designed for.	Existing, proven equipment used for new application.	Technology research and development required.	Unable to complete operation in scheduled timeframe. Re-work required prior to revisit.	Potential catastrophic failure of major component.
4. Societal					
4a. Fisheries - impact on fish stocks due to introduction of micro-plastics (from mattress pp ropes) to food chain	No release of PP to the food chain	Low release of PP to the food chain	Moderate release of PP to the food chain	High release of PP to the food chain	Very high release of PP to the food chain
4b. Fisheries - impact of pipelines on fishing activities.	Pipelines completely removed, no impact on future commercial fishing activity.	Pipelines partially removed, potential impact on future commercial fishing activity.	Pipelines remain in place and buried, potential for future impact on commercial fishing activity.	Pipelines remain in place. Not marked on charts as a potential hazard.	Pipelines remain in place, not buried, exclusion zone precludes fishing.
5. Economic					
5a. Decommissioning cost	<£1M	£1-5M	£5-10M	£10-15M	>£15M
5b. Ongoing liability	No ongoing liability	Ongoing liability as 0-50% remains.	Ongoing liability as 50-80% remains.	>80% remains	>80% remains with some sections of the pipelines unburied.

7.5. Option scoring and weighting

7.5.1. Score evaluation

The impact level associated with the options for each scoring criteria is used in conjunction with the likelihood criteria presented in Table 8 to determine the ‘risk’ score for that option. The score is defined in Table .

Table 8: Likelihood criteria

Likelihood or level of uncertainty rating		
1	Very low	Very low likelihood, or Very low level of uncertainty (detailed definition and understanding of methodology, hazards and equipment)
2	Low	Low likelihood, or Low level of uncertainty (high level definition and understanding of methodology hazards or equipment)
3	Medium	Moderate likelihood, or Moderate level of uncertainty (general definition and understanding of methodology, hazards or equipment)
4	High	High likelihood, or High level of uncertainty (Basic definition and understanding of methodology, hazards or equipment)
5	Very high	Very high likelihood, or Very high level of uncertainty (limited definition and understanding of methodology, hazards or equipment)

Table 9: Scoring matrix

Likelihood / uncertainty	Impact				
	1 (very low)	2 (low)	3 (medium)	4 (high)	5 (very high)
1 (very low)	1	2	3	4	5
2 (low)	2	4	6	8	10
3 (medium)	3	6	9	12	15
4 (high)	4	8	12	16	20
5 (very high)	5	10	15	20	25

Low risk	Medium risk	High risk

7.5.2. Relative scoring

For each criterion, the risk scores for each option were converted to a relative score. The relative score is based on a scale from 0 to 100; 0 being the most favoured option and 100 being the least favoured option. Values between 0 and 100 were assigned to options that scored in between the worst and best. The scale for this scoring is linear i.e. an option that scored numerically halfway in between the best and worst is given a score of 50.

7.5.3. Swing Weighting

After all options were scored, a swing weighting is assigned to each criterion based on the range between the lowest and highest scoring options. For example, a low weighting was applied if the swing from the top to the bottom of the scale was low and a high weighting if the swing was large. In order to apply the weightings, the swing between options was calculated for each of the assessment criteria.

8. Comparative assessment

8.1. Workshops

There were two comparative assessment workshops held during the preparation and production of the comparative assessment.

8.1.1. Screening workshop

An initial screening workshop was held on the 27th February 2018 that allowed attendees to screen out impractical options at an early stage in the preparation of the CA. This allowed the CA to focus on the realistic decommissioning options to be developed for further comparison and assessment. The methodology of the assessment, the terms of reference and the assessment criteria / sub-criteria were presented, discussed and agreed, prior to commencing the comparative assessment process. The workshop attendees were as follows:

• Paul Barron	Faroe Petroleum	Operations / Decommissioning Manager
• Claire Orr	Faroe Petroleum	HSE Adviser
• Istvan Bartha	Petrofac	Asset Integrity Consultant
• Thomas Gazzard	Petrofac	Offshore Projects and Operations Engineer
• Hugh Miller	Petrofac	Vessel Captain
• Charlotte Nott	RPS Group	Senior Environmental Consultant
• Duncan Murray	Jee Limited	Subsea Engineer
• Mark Lauder	Jee Limited	Head of Structures

8.1.2. Detailed workshop

Following the development of the preferred options a follow up detailed workshop was held on the 2nd of May 2018. Again the methodology of the assessment, the terms of reference and the assessment criteria / sub-criteria were presented, discussed and agreed, prior to commencing the comparative assessment process. The workshop attendees are as listed below:

• Paul Barron	Faroe Petroleum	Operations / Decommissioning Manager
• Claire Orr	Faroe Petroleum	HSE Adviser
• Rick Baker	Faroe Petroleum	Production Superintendent
• Leigh Reeder	Faroe Petroleum	Production Engineer
• Istvan Bartha	Petrofac	Asset Integrity Consultant
• Thomas Gazzard	Petrofac	Offshore Projects and Operations Engineer
• Mike Shearer	Petrofac	Pipeline Technical Authority
• Charlotte Nott	RPS Group	Senior Environmental Adviser
• Duncan Murray	Jee Limited	Subsea Engineer
• Mark Lauder	Jee Limited	Head of Structures
• Charles Keiller	Charles Keiller & Associates	Fisheries Liaison Officer

The results of the assessments performed are discussed in the following sections. Full results have been appended.

8.2. Workshop results

The results of the screening workshop and detailed workshop are given below in the following sections.

8.2.1. Screening workshop results

Figure 15 below shows the results of the screening workshop with the selected options chosen on the basis of the attendees' collected expertise and experience.

Figure 16: Ketch pipelines results of the screening workshop

		Completely remove		Partially remove		Bury		Leave in-situ	
Option	**Description**	Reverse installation	Cut and lift	Reverse reeling	Cut and lift	Trenching and backfilling with natural deposits	Rock dump	Cover cut ends with gravel / grout bags	Cover cut ends with mattresses
Assessment Criteria	**Sub-criteria**								
Safety	Risk to offshore personnel								
	Residual risk to other users								
Environment	Legacy Marine Impact								
	Environmental Impact								
	Energy / Resource Consumption								
Technical	Technical challenge / feasibility								
	Risk of major project failure								
Societal	Fisheries								
	Communities / amenities								
Economic	Decommissioning cost								
	Ongoing liability								
Selected for further study			SELECTED		SELECTED	SELECTED	SELECTED	SELECTED	SELECTED

Key:	Most preferred	
	Least preferred	

The selected decommissioning options to be taken forward for the Ketch pipeline were:

- Option 1b: Completely remove: Cut and lift
- Option 2b: Partially remove: Cut and lift
- Option 3a: Bury: Trenching and backfilling with natural deposits
- Option 3b: Bury: Rock / gravel dump
- Option 4a: Leave in-situ: Cover cut ends with gravel/grout bags
- Option 4b: Leave in-situ: Cover cut ends with existing mattresses

The options that were initially ruled out by the screening assessment were:-

- Option 1a: Complete removal of the pipelines by reverse installation
- Option 1b: Partial removal of the pipelines by reverse installation

The main reasons for rejecting options utilising the reverse installation methodology were concerns regarding safety. The risk to offshore vessel personnel was felt by attendees at the workshop to be considerable as reverse S and J lay places the pipelines under significant amounts of stress. The pipelines have been on the seabed since 1999, any undetected defects or weaknesses could be exacerbated by this form of removal and result in sudden structural failure of the pipelines. Removing the pipelines by reverse S and J lay were also considered to be far and away the most technically challenging decommissioning methods, with the highest risk of project failure. The combined bundle of the export pipeline, piggybacked methanol pipeline and self-burial spoiler fin mean they are more difficult and cumbersome to remove than a single pipeline.

8.2.2. Detailed workshop results

The selected options from the screening workshop were then developed and taken through to the detailed workshop stage where they were compared against the criteria and given a numerical calculated value. These were then totalled and compared to see which option had the lowest overall score – this would be the preferred option.

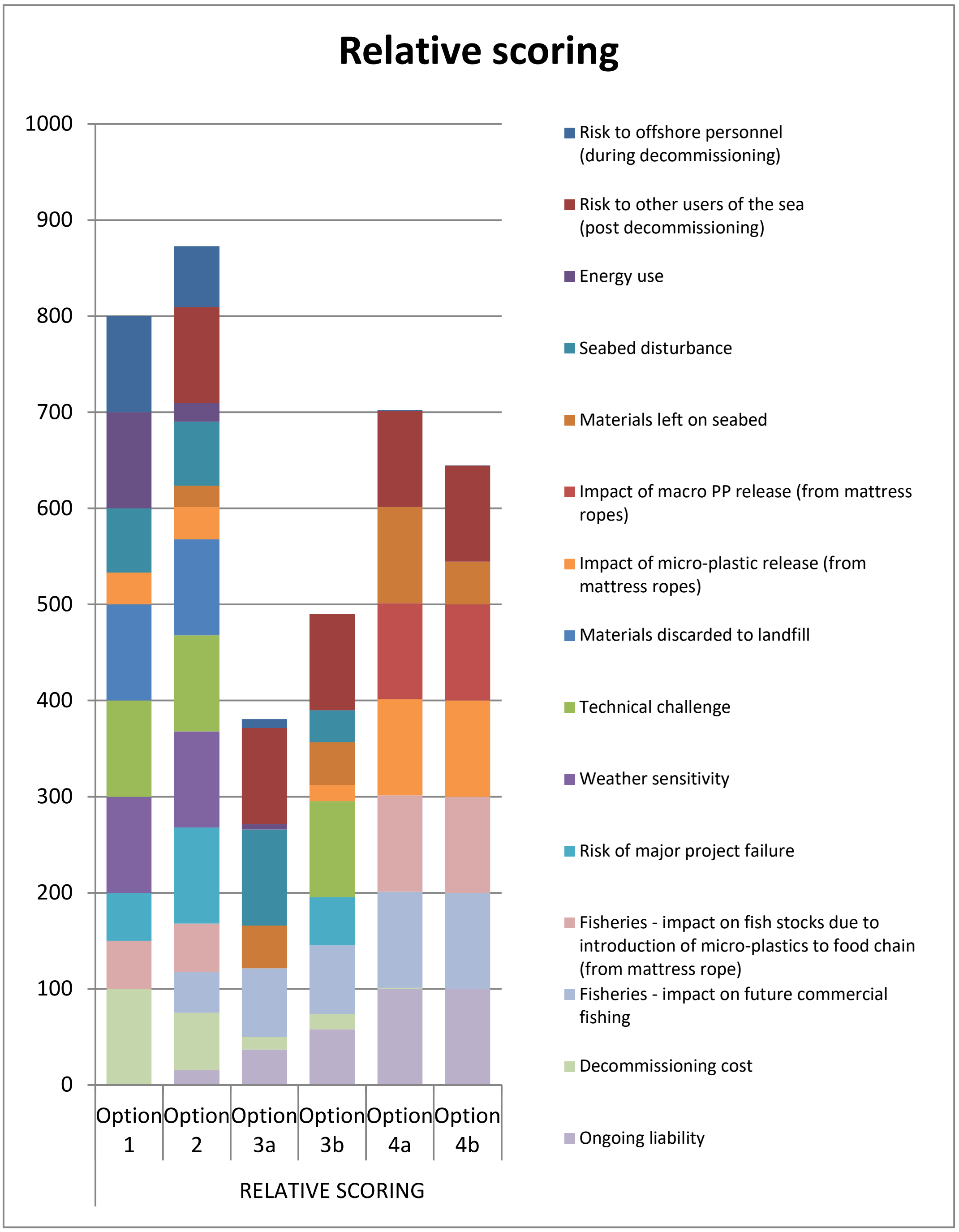
At the start of the detailed workshop it was decided unanimously by the assembled team that the pipelines mattresses and grout bags that comprise the Caister pipeline crossing would be completely removed from the seabed. The pipelines immediately adjacent to the Murdoch platform are raised approximately 2.0m above seabed level over the Caister pipeline. When the Murdoch installation has been removed (The Murdoch installation comprises 3x bridge linked platforms) the installation's 500m safety zone will also cease to exist. The elevated Ketch crossing of the Caister pipeline was therefore considered to be an obvious snagging hazard. Given the Caister crossings size and prominence above the seabed, it was decided that the ketch crossing of the Caister pipeline should be removed in its entirety. The Caister pipeline crossing was therefore removed from the comparative assessment process. The detailed comparative assessment process was applied to the Ketch pipelines from the end of the Caister crossing to the base of the riser on the Ketch platform. It should be noted that the current plan is that ConocoPhillips will remove the Ketch crossing of the Caister pipeline on behalf of Faroe.

Figure 17: Ketch pipeline results from detailed workshop

					RELATIVE SCORING					
Criteria		Sub-criteria		Weight	Option 1	Option 2	Option 3a	Option 3b	Option 4a	Option 4b
1	Safety	a	Risk to offshore personnel (during decommissioning)	1	100	63	9	0	1	0
		b	Risk to other users of the sea (post decommissioning)	1	0	100	100	100	100	100
2	Environment	a	Energy use	1	100	19	6	0	0	0
		b	Seabed disturbance	1	67	67	100	33	0	0
		c	Materials left on seabed	1	0	22	44	44	100	44
		d	Impact of macro PP release (from mattress ropes)	1	0	0	0	0	100	100
		e	Impact of micro-plastic release (from mattress ropes)	1	33	33	0	17	100	100
		f	Materials discarded to landfill	1	100	100	0	0	0	0
3	Technical	a	Technical challenge	1	100	100	0	100	0	0
		b	Weather sensitivity	1	100	100	0	0	0	0
		c	Risk of major project failure	1	50	100	0	50	0	0
4	Societal	a	Fisheries - impact on fish stocks due to introduction of micro-plastics to food chain (from mattress rope)	1	50	50	0	0	100	100
		b	Fisheries - impact on future commercial fishing	1	0	43	71	71	100	100
5	Economic	a	Decommissioning cost	1	100	59	13	16	1	0
		b	Ongoing liability	1	0	16	37	58	100	100
				Totals	800	873	381	490	703	645
				Rank	5	6	1	2	4	3

From the Ketch detailed CA table in Figure 18, the preferred option that is shown with the lowest overall total of 381 is Option 3a which is Bury – Trenching and backfilling with natural deposits.

Figure 18: Ketch Pipeline graphical representation of the relative scoring of each of the sub-criteria assessed



From these results, it can be seen that the option to bury the pipelines by trenching them was deemed the most appropriate for the Ketch pipelines. The top 3 scoring options were:

1. Bury – Trenching – burial with natural deposits;
2. Bury – Rock / gravel dump
3. Leave in-situ – Cover cut ends with mattresses

The second most preferable option for the pipeline is option 3b which is Bury – rock / gravel dump. However, it came to light that rock / gravel dump is a remediation technique that BEIS do not support due to the possibility of the rock / gravel dump providing artificial features that could provide a habitat for invasive species. In addition the NFFO are not in favour of rock dump as rocks can and have snagged trawl nets in the past.

8.2.3. SAFETEC JIP dataset

As decommissioning in the North Sea area is in its infancy, there is little to no data concerning accidents involving offshore workers and divers specifically attributable to the decommissioning process. This was previously confirmed through discussion with the HSE.

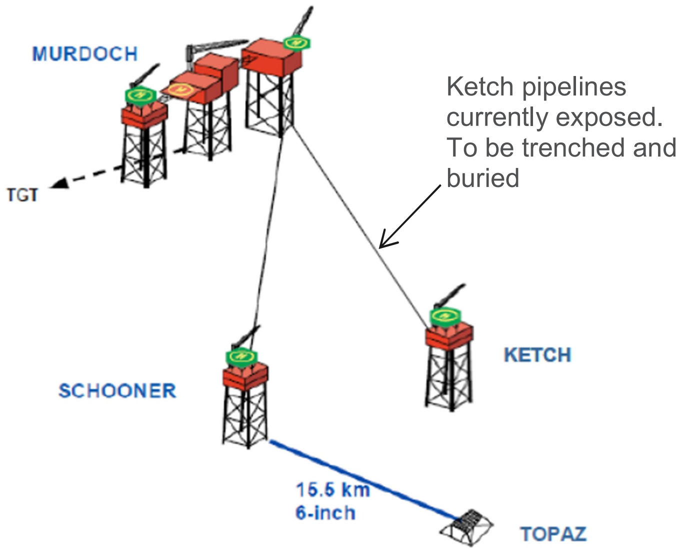
Considering the similarities between the activities performed in construction activities and those performed during decommissioning (such as the lifting operations and associated manual hook-up / disconnection), FAR data for this assessment was obtained from the paper "Risk Analysis of Decommissioning Activities" produced by the SAFETEC JIP. This utilises accident data associated with typical offshore construction activities provided by the HSE and the Norwegian Petroleum Safety Authority from the early 1990s onwards. This is supplemented by data from operators involved in the JIP.

In order to investigate the impact that this data has on the outcome of the assessment (as the data isn't specific to offshore decommissioning but is considered the best fit).

8.3. Assessment conclusions

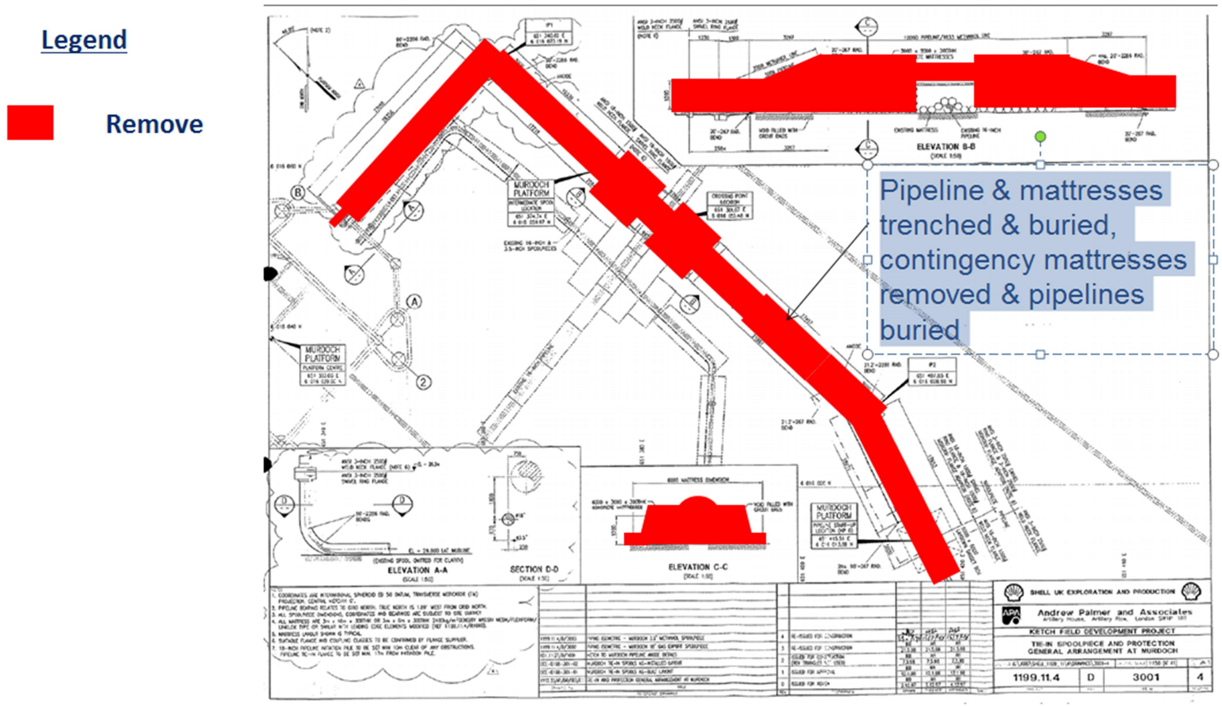
It can be seen from the above that the comparative assessment for the Ketch pipelines and stabilisation materials (mattresses and grout bags) has revealed the most preferable decommissioning option to be to remove the mattresses and trench / bury the pipelines..

Figure 19: Remediation of Ketch pipelines



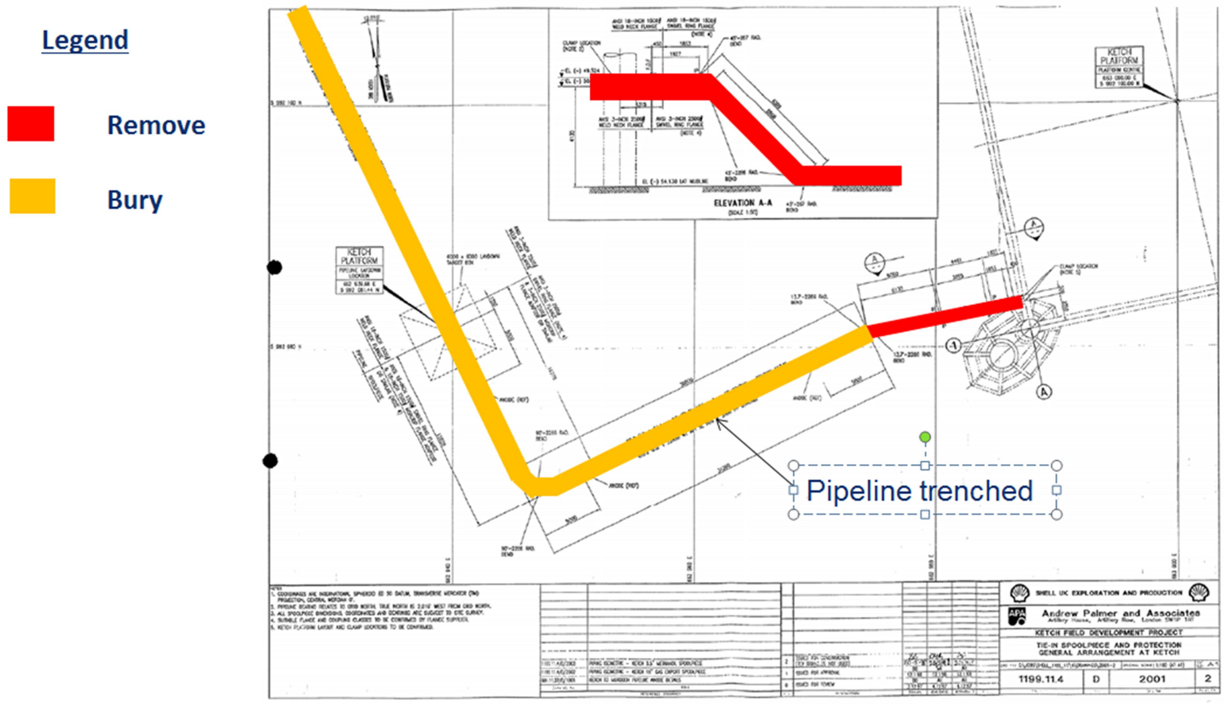
The exception to the above, are the sections of pipelines that form the elevated crossing of the Caister pipeline, adjacent to the Murdoch platform. These sections of pipelines (approximately 60m from the base of the Murdoch Riser) will be fully removed along with the mattresses and grout bags that form the elevated crossing structure. The pipelines and mattresses, beyond the removed Caister crossing that have been installed intermittently along the pipeline will also be removed. If problem are encountered removing any of the mattresses, i.e. mattresses breaking up when they are lifted, BEIS will be consulted.

Figure 20: Treatment of pipelines and stabilisation features at Murdoch platform end



Only the short lengths of the pipelines immediately adjacent to the Ketch riser will be removed at the Ketch platform end. The remainder of the pipelines will be trenched and buried. The entire pipeline which is due for burial has sections in the cSAC and SAC. Ketch pipelines at the Murdoch end have 186m in the cSAC and 2.743km in the Dogger Bank SAC.

Figure 21: Treatment of pipelines and stabilisation features at Ketch platform end



8.4. Safety and societal factors

One of the principal issues considered in the decommissioning process is that of personnel safety. When the level of burial of a large portion of the Ketch pipelines is also considered, requiring excavation of the pipelines prior to commencement of lifting operations, the efficiency of the recovery operations will be significantly reduced even with the use of a mass flow excavator.

Neglecting the integrity of the mattresses, which isn't expected to be significantly compromised, the increased duration of the recovery operation alone will inherently increase the likelihood of fatal accidents. As such, the decommissioning of the pipelines in-situ will minimise the amount of offshore work and therefore the likelihood of incident, which is beneficial.

However, the other primary safety consideration when considering decommissioning of items in-situ is that of the other users of the sea. As stated by BEIS [3]:

"The fundamental principle underpinning a proposal to leave [stabilisation materials] in situ is that evidence must be provided to demonstrate that the deposits would not interfere with other uses of the sea, e.g. they would not present a snagging hazard that could interfere with fishing operations."

The overall risk to fishermen is dependent on the following factors:

- The presence of snagging hazards;
- The fishing activity in the area, which is deemed to be moderate (refer to section regarding fishing activity in section 3.4.1 of the Schooner and Ketch EA);;
- Type of fishing vessels / fishing gear used in the area.

From a potential snagging perspective, it has been indicated that the NFFO consider that pipelines could be left in-situ subject to the completion of an overtrawl survey. This survey would identify any snagging hazards present, allowing remediation in line with the preferred decommissioning option defined by the comparative assessment. However, ongoing monitoring will be required to ensure that snagging hazards do not develop over time. This is not considered likely as:

- The pipelines and their stabilisation features will be trenched and buried. The nearby Schooner pipelines are a similar size to the Ketch pipelines. They were trenched when they were installed in 1997, as opposed to the Ketch pipelines which were laid on the seabed and expected to self-bury. The Schooner pipelines are therefore a good analogue for how the Ketch pipelines are likely to behave if they are trenched. To date the Schooner pipelines have remained >99% buried. No snagging hazards associated with the Schooner pipelines have developed or been remediated during the asset operational phase. So it is unlikely that snagging hazards will develop on the Ketch pipelines if they are trenched and buried.
- Mattresses are commonly installed to protect pipelines from dropped objects and from fishing interaction (outside of exclusion zones). Therefore, they are designed to be overtrawlable and the chamfered leading edges of the mattresses present at Ketch support this.

Finally, the probability of a fatal snagging incident on the stabilisation materials present at the Ketch asset per year, assuming random trawling, is low at 7.535×10^{-7}. Furthermore, this calculation is conservative with Seine gear incorporated (that wouldn't be likely to be in contact with the seabed to snag). It also neglects safety equipment such as audible and visual warnings on the vessel when snagging hazards are approached (FISHSAFE) and load limiting devices in vessel warps that would help to prevent a snag leading to a vessel capsize as attempts are made to recover the gear.

8.5. Environmental factors

At the Murdoch end of the pipelines the final 2.743Km of both pipelines are located in the Dogger Bank SAC and 186m are located in the SNS cSAC. From an environmental perspective the de-burial and removal of buried pipelines and stabilisation features, regardless of depth, disrupts the seabed and any bottom dwelling species present and introduces sediment into the water column, causing the migration of organisms that would otherwise remain undisturbed.

Conversely, whilst leaving pipelines and stabilisation features in-situ alleviates the above effects, it introduces a potential long term environmental concern as materials such as the polypropylene rope in the mattresses that cover the pipeline degrading and this must be assessed prior to considering this option. The addition of alien materials to the seabed to mitigate snagging hazards and mattress degradation also impacts the local environment, smothering the existing benthic flora and fauna and resulting in local habitat change. However, these impacts are localised and, with only non-unique species present, not considered significant overall.

Mattress re-use offshore could be considered as an environmentally beneficial compromise between the two extremes above. This however is more complex that it appears at first glance. Reuse of mattresses offshore relies on the integrity of the mattress for two operations and two transitions through the splash zone, making it a high risk operation if there are any doubts about the mattress integrity.

The alternative is to re-use mattresses onshore, which has been successfully completed on other projects. However this again is not without its complications. Mattresses are considered a controlled waste and, as such, re-use requires authorisation under the Waste Management Licensing regulations via a WML exemption, or where the mattress is crushed and reused as aggregate, use must meet WRAP protocol. The Scottish Environmental Protection Agency (SEPA) require that any reuse of mattresses not manufactured in accordance with BS EN197-1:2011 (British Standard Institute, 2011) is supported by a demonstration that the materials are suitable for the proposed reuse and that reuse presents no significant environmental risk. The sampling regime must be agreed with SEPA prior to exemption application.

From this, it can be seen that the reuse of mattresses, either onshore or offshore, has risks associated with it. Furthermore, the extent of the permitting process alone highlights the threat posed to the onshore environment from the re-use of concrete mattresses installed subsea many years ago (under significantly different regulatory regimes in many cases).

Pipeline recycling, however is widespread and commonplace in decommissioning subsea pipes, so this is not a significant concern, with recycling facilities available onshore.

9. Assessment of long term degradation of materials

9.1. Impact of long term degradation on the marine environment

9.1.1. Carbon steel

Once the CP system is depleted, corrosion at areas of bare metal will eventually break down the carbon steel pipe into its naturally occurring elements. The basic cause of metal corrosion is the instability of steel in its refined form: metals tend to revert to their natural states through the process of corrosion. The main product from steel corrosion is rust, and this rust – or iron oxide – is the original state of iron found in naturally occurring iron ore, which is not considered hazardous to the environment.

The formation of a snagging hazard, through pipeline corrosion, is also considered very unlikely. This would require material loss through corrosion over the pipe circumference, which would compromise the structural strength of the remaining pipe steel to such a level that it would be insufficient to hold a snagging load. Furthermore, as the pipelines will be left buried, any potential snagging hazards would not be exposed to fishermen. This results in a very low snagging risk due to pipeline deterioration post decommissioning.

In regards to the pipelines, failure rates are very difficult to predict because of the variety of materials they are composed of and natural variations in the environment that they exist in. Degradation of the pipelines is expected to occur between 70 and 250 years. Export and methanol pipelines are coated with polypropylene. It is not just the degradation of the polypropylene coating to be considered as the pipelines also degrade from the inside, where there is no coating. If the pipeline were to degrade to such an extent that holes have started to appear the corrosion will be global, so shards around the area where the hole has appeared will not have sufficient strength to hold a snagging load.

9.1.2. Concrete

The long term degradation of the concrete mattress segments is not considered to have significant impact on the environment or local fisheries. Concrete is considered environmentally friendly by IMCA and any mould releasing agents would have dissipated over the operating life. Any spalling would lead to the formation of small chunks with size similar to that of gravel dump, which is not considered a threat to fishermen.

According to a paper by Bryant Mather of the U.S. Army corps of engineers [6], concrete continuously immersed in seawater, even if the water contains dissolved salts, may be regarded as being in protected exposure. This tends to minimise the potential for chemical reaction by removing changes in the degree of saturation as a means for flow into and out of the concrete of solutions containing ions capable of chemical attack. These would typically be sulphate, chloride, carbonate, bicarbonate and magnesium ions. Furthermore, in cooler waters (such as at ambient seabed temperatures in the North Sea), chemical action is less severe and deterioration will be dominated by abrasion or impact damage and any acids deposited by lithofagous organisms. This is expected to be a slow process, as illustrated by the current condition of the mattresses and the ongoing use of structural concrete in UK waters. Note: the gas pipelines are not concrete coated.

9.1.3. Polypropylene

Typically, the properties of polypropylene (used as rope to link the concrete mattress segments together and as an exterior coating to both the pipelines)) make it resistant to acids, alkalis and organic solvents. This also results in excellent microbial resistance (minimising the rate of biodegradation). Breakdown in the marine environment, at water depths eliminating the presence of significant quantities UV radiation, (the Ketch mattresses are located at depths where UV radiation is mostly filtered out by the sheer depth of the water column and the turbidity of the water) is typically through fragmentation from abrasion or agitation.

Rates of degradation of polypropylene rope are some of the lowest of all synthetic rope types in use in the marine environment, with experimental work performed at the university of Glasgow [7] suggesting weight reduction of the order of 0.39% per annum. Whilst degradation is slow (a fact supported by the remaining strength of polypropylene rope in mattresses allowing removal some 15 years or more after installation in some cases), the long term impact of the degradation of the polypropylene rope is through release to the environment in both macro and micro form.

As polypropylene is less dense than seawater, larger (macro) sections of polypropylene rope released from a degrading mattress would tend to float, adding to the floating plastic debris already present in our coastal waters. This poses a significant entanglement threat to seabirds and marine mammals present in the region (noted in section 6.1), with the possibility of smaller sections being ingested, forming intestinal blockages and ultimately leading to starvation.

The other consideration relating to the deterioration of the polypropylene rope is the potential for release of secondary micro-plastics into the environment. Secondary micro-plastics are produced by fragmentation of the primary polymer and are defined as particles with size less than 5 mm. The potential risks associated with micro-plastics are numerous and include the following:

- Ingestion by plankton and lower level organisms, resulting in the introduction of plastic to the food chain. A recent study discussed in the UNEP frontiers 2016 report revealed plastic debris to be present in the guts of a quarter of fish sampled from markets in Indonesia and California. This could increase direct exposure of plastic-associated chemicals to higher marine mammals and humans.
- Ingestion by fish, resulting in diminished reproductive ability or death and thereby limiting stocks.
- Transport of persistent organic pollutants (POPs), many of which are hydrophobic, through absorption into the plastic surface. Plastic resin pellets collected from oceans and beaches at various locations have been found to contain POPs at orders of magnitude higher concentrations than the water.
- Increase of persistent organic pollutants (POPs) in the food chain.
- Modifications to the local ecosystem due to the accumulation of the plastic particles, such as reduced thermal conductivity and increased drainage of sediments, resulting in loss of the local flora and fauna.

It can be seen that, whilst research into the effect of micro-plastics on the environment is in its early stages, their impact could be significant.

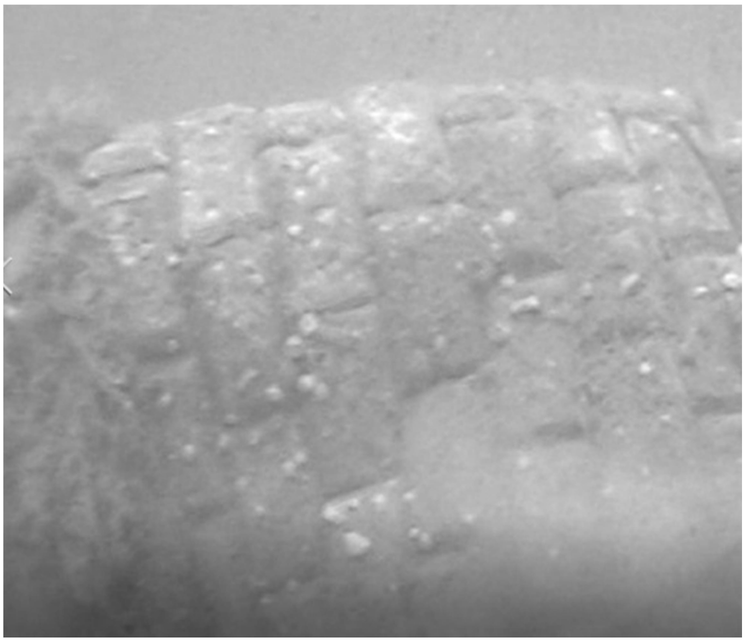
Finally, it should be remembered that although the global impact of polypropylene on the environment could be significant, we are dealing with small quantities here. Whilst this does not detract from the importance of mitigating the impact of the polypropylene rope on the environment (as can be seen in the assessment below), the mass of this rope in the exposed and partially exposed mattresses was estimated to be 1.3 tonnes. This is only a fraction of the estimated 8 million tonnes of plastic waste thought to be escaping to the oceans each year.

9.1.4. Mitigation

The long term degradation of any buried mattresses left in-situ as part of the decommissioning process is unlikely to have a detrimental effect on the environment, fisheries and ultimately the food chain. Seabed sediments will contain debris such as spalled concrete, greatly limit the abrasion and agitation leading to fragmentation of the polypropylene and prevent the release of any polypropylene at both the macro and micro scale. This will therefore eliminate the associated risks to marine life and those financially dependent upon it.

For exposed or partially exposed mattresses, the concrete segments themselves (along with any seabed sediments present in buried sections) initially prevent the release of polypropylene at both the macro and micro scale by eliminating almost all of the exposure of the polypropylene rope to the seawater, as shown in the figure below.

Figure 22: Partially exposed mattress, illustrating minimal PP exposure at block transitions



As the concrete deteriorates and spalls, the exposure of polypropylene rope within will increase. This will increase the dispersion of micro plastics as the polypropylene rope degrades in the local abrasive conditions (albeit in small quantities and at a low rate). The ultimate release of longer sections of rope will add to the floating plastic debris already present in our coastal waters (again, only in very small quantities), acting as a continuing source of secondary micro-plastics. However, as discussed above, the rate of deterioration of concrete is likely to be slow, (1000s of years) as it will be dominated by abrasion and any acids deposited by lithofagous organisms rather than chemical attack.

9.2. Conclusions - degradation of materials

From this assessment, it can be concluded that the long term degradation of any buried mattresses left in-situ as part of the decommissioning process is unlikely to have a detrimental effect on the environment, fisheries and ultimately the food chain. Seabed sediments will contain debris such as spalled concrete and prevent the release of polypropylene at both the macro and micro scale, eliminating the associated risks to marine life and those financially dependent upon it. This assumes that these materials remain buried.

Comparative assessment was utilised to determine the most appropriate means of mitigating the impacts of long term degradation of buried and partially exposed mattresses, considering risks due to:

- Concrete degradation and associated release of polypropylene (particularly at the potentially most damaging micro scale) during mass flow excavation and removal operations;
- Long term degradation if left in-situ in the buried or partially exposed state;
- Potential remediation to prevent concrete degradation leading to the release of polypropylene to the environment.

This assessment revealed the most appropriate approach to mitigate the impact of long term degradation, taking into account the commercial and technical sensitivities assessed, would be to remove the mattresses and bury the pipeline by trenching, which would bury the mattresses with natural deposits. If mattresses prove difficult to remove, i.e. ropes breaking during removal BEIS will be consulted. The contingency option in this event will be to bury the mattresses with the pipelines. Concrete is considered environmentally friendly by the IMCA (any mould releasing agents would have dispersed over operating life) and any spalling would lead to the formation of small chunks with size similar to that of gravel dump (which is not considered a threat to fishermen).

References

[1] Guidelines for Comparative Assessment in Decommissioning Programmes, Issue 1, OGUK, October 2015

[2] Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines, BEIS, December 2017

[3] Reality, preparation and action in a low oil price environment, DECC

[4] KA-TN-U-0001, Ketch Pipeline Technical Note, Petrofac, Rev 06

[5] Ketch Decommissioning Programmes, Jee, Rev 3

[6] Effects of sea water on concrete, B Mather, US Army Corps of Engineers, 1964

[7] Microplastic Pollution in the Clyde Sea Area, N Cooper Weldon, 2014

[10] Mattress Solutions Report Prepared by Jee Ltd on behalf of Zero Waste Scotland and Decom North Sea, 2015

[11] Faroe Schooner & Ketch Decommissioning EA Rev 01C. SCKE FPROGB O RA 0001, 2018.

Appendices

A. PLL of trawling in the Ketch area

B. Detailed CA sheets

C. Comparative assessment assumptions

A. PLL of trawling in the Ketch area

Figure 23: Otter gear data

Otter gear									Area covered by trawl	Number trawls
	2009	2010	2011	2012	2013	2014	2015	Average	(km2)	(/yr)
Swept area (km2/yr)	237953	228064	190365	216440	218150	207588	218575	**216734**	6.048	35836
Fishing days (days/yr)	168598	163742	202436	188350	203500	208373	192994	**189713**		
Intensity multiplier in Ketch area (based on 2015 data)	9									
Trawl velocity (m/s)	2.1									
Trawl duration (hrs)	4									
Number of trawls per day	2									
Gear width (m)	100									
Number of rigs	1									

Figure 24: Beam gear data

Beam gear									Area covered by trawl	Number trawls
	2009	2010	2011	2012	2013	2014	2015	Average	(km2)	(/yr)
Swept area (km2/yr)	96812	100868	94169	96118	94677	88705	90611	**94566**	1.07136	88267
Fishing days (days/yr)	85161	100460	81633	94252	91232	90017	88257	**90145**		
Intensity multiplier in Ketch area (based on 2015 data)	2									
Trawl velocity (m/s)	3.1									
Trawl duration (hrs)	2									
Number of trawls per day	2									
Gear width (m)	12									
Number of rigs	2									

Figure 25: Dredge gear data

Dredge gear									Area covered by trawl	Number trawls
	2009	2010	2011	2012	2013	2014	2015	Average	(km2)	(/yr)
Swept area (km2/yr)	9672	10009	8684	12513	12123	14025	12633	**11380**	0.6048	18816
Fishing days (days/yr)	52435	52866	57485	53284	50135	49970	48473	**52093**		
Intensity multiplier in Ketch area (based on 2015 data)	0									
Trawl velocity (m/s)	2.1									
Trawl duration (hrs)	2									
Number of trawls per day	2									
Gear width (m)	10									
Number of rigs	2									

Figure 26: Seine gear data

Seine gear									Area covered by trawl	Number trawls
	2009	2010	2011	2012	2013	2014	2015	Average	(km2)	(/yr)
Swept area (km2/yr)	76694	71348	64303	66956	68130	66629	69243	**69043**	15.12	4566
Fishing days (days/yr)	9551	9685	9391	10661	11741	11063	10023	**10302**		
Intensity multiplier in Ketch area (based on 2015 data)	4									
Trawl velocity (m/s)	2.1									
Trawl duration (hrs)	4									
Number of trawls per day	2									
Gear width (m)	250									
Number of rigs	1									

Figure 27: PLL calculations for Ketch Area

Area of North Sea (km2)	Total trawls	Gear snags resulting in fatalities [3]	Probability of fatal snag across North Sea	Area of ICES blocks surrounding Ketch	Ratio of area to overall trawled	Fishing intensity multiplier for Ketch area [3]	Probability of fatal snag in Ketch area
750,000	(/yr)	(/yr)		(km2)			
	147485	0.4	2.71214E-06	7256	0.018523293	15	7.53567E-07

PLL calculations give a value of 7.5356 x 10^{-7}, which is the probability of a fatal snag in the Ketch area per year.

B. Detailed CA sheets

Criteria		Sub-criteria		Swing	Weighting	Option 1 - Completely Remove - Cut and Lift: Impact	Likelihood	Risk matrix scoring	Score justification	Relative risk scoring	Weighted risk scoring	Option 2 - Partially Remove - Cut and Lift: Impact	Likelihood	Risk matrix scoring	Score justification	Relative risk scoring	Weighted risk scoring
1	Safety	a	Risk to offshore personnel (during decommissioning)	1.18E+02	1	N/A	N/A	3.99E-02	Calculated risk (PLL)	100	100	N/A	N/A	2.53E-02	Calculated risk (PLL)	63	63
		b	Risk to other users of the sea (post decommissioning)	7.54E+13	1	N/A	N/A	0	No materials left in-situ therefore no risk to other sea users	0	0	N/A	N/A	7.536E-07	Some materials left in situ, risk matrix reflects this probability of a fatality due to overtrawling a point in the area surrounding the Schooner assets.	100	100
2	Environment	a	Energy use	6.47E+01	1	N/A	N/A	280,292	Calculated energy usage 280,292 GJ	100	100	N/A	N/A	57,448	Calculated energy usage 57,448 GJ	19	19
		b	Seabed disturbance	1.50E+00	1	4	2	8	I: Wider area of disturbance (100-200%) (5) - removing partially buried pipelines using mass flow excavator. Also disperses sediment in to water column with impact with local flora and fauna. L: High level definition (2) - could cause more damage to seabed than accounted for.	67	67	4	2	8	I: Wider area of disturbance (100-200%) (4) - removing partially buried pipelines using mass flow excavator. Also disperses sediment in to water column with impact with local flora and fauna. L: High level definition (2) - could cause more damage to seabed than accounted for.	67	67
		c	Materials left on seabed	9.00E+00	1	1	1	1	I: None (1) - all materials removed L: Detailed definition and understanding (1)	0	0	3	1	3	I: >80% of materials being left (4) L: Detailed definition and understanding (1)	22	22
		d	Impact of macro PP release (from mattress ropes)	3.00E+00	1	2	2	4	I: PP debris may be released during recovery process in small quantities. No long term on-site release as bulk PP from exposed (or partially exposed) mattresses will have been removed (2) L: Moderate level of uncertainty regarding the size of PP debris that would be released into the environment during the recovery and the impact on marine life and birds as a result. Quantities will be small. (2)	0	0	2	2	4	I: PP debris may be released during recovery process in small quantities. No long term on-site release as bulk PP from exposed (or partially exposed) mattresses will have been removed (2) L: Moderate level of uncertainty regarding the size of PP debris that would be released into the environment during the recovery and the impact on marine life and birds as a result. Quantities will be small. (2)	0	0
		e	Impact of micro-plastic release from PP (from mattresses ropes)	3.00E+00	1	2	4	8	I: High initial release during removal process due to agitation from mass flow excavator and fraying of PP ropes during recovery process. No long term on-site release as bulk PP from exposed (or partially exposed) mattresses will have been removed (3) L: High level of uncertainty regarding the quantity of PP that would be released into the environment during the recovery and the overall impact of PP micro-plastic release on the surrounding area (especially given the small quantities here). Plankton has been found with micro-plastics present in their systems and studies have been performed that suggest affected organisms develop gut and gill blockages, lethargy and ultimately die (4). Impact on the food chain is yet to be determined.	33	33	2	4	8	I: High initial release during removal process due to agitation from mass flow excavator and fraying of PP ropes during recovery process. No long term on-site release as bulk PP from exposed (or partially exposed) mattresses will have been removed (3) L: High level of uncertainty regarding the quantity of PP that would be released into the environment during the recovery and the overall impact of PP micro-plastic release on the surrounding area (especially given the small quantities here). Plankton has been found with micro-plastics present in their systems and studies have been performed that suggest affected organisms develop gut and gill blockages, lethargy and ultimately die (4). Impact on the food chain is yet to be determined.	33	33
		f	Materials discarded to landfill	3.00E+00	1	2	2	4	I: 100% (3) - of the materials removed, most will be able to be recycled. L: Detailed definition and understanding (2) - currently there is pipeline recycling onshore.	100	100	2	2	4	I: 80% (3) - of the materials removed, most will be able to be recycled. L: Detailed definition and understanding (2) - currently there is pipeline recycling onshore.	100	100
3	Technical	a	Technical challenge	1.00E+00	1	2	2	4	I: Routine task. High level of historical experience (2) L: High level definition and understanding (2) - need for controlled seabed removal around pipelines to expose lifting points and free sediment to reduce lifting loads.	100	100	2	2	4	I: Routine task. High level of historical experience (2) L: High level definition and understanding (2) - need for controlled seabed removal around pipelines to expose lifting points and free sediment to reduce lifting loads.	100	100
		b	Weather sensitivity	5.00E-01	1	3	1	3	I: Requires specific weather window for prolonged period. Operation and critical path (5) - lifting of materials through the splashzone is dependent on seastate and associated vessel characteristics. L: Detailed definition and understanding (1) - lifting tasks and weather criticality are well understood in the offshore industry.	100	100	3	1	3	I: Requires specific weather window for prolonged period. Operation and critical path (5) - lifting of materials through the splashzone is dependent on seastate and associated vessel characteristics. L: Detailed definition and understanding (1) - lifting tasks and weather criticality are well understood in the offshore industry.	100	100
		c	Risk of major project failure	2.00E+00	1	2	2	4	I: Existing, proven equipment used for specific tasks for which it was designed for but still moderately high risk of failure. (3) L: High level definition and understanding (2).	50	50	3	2	6	I: Existing, proven equipment used for specific tasks for which it was designed for but still moderately high risk of failure. (3) L: High level definition and understanding (2)	100	100
4	Societal	a	Fisheries - impact on fish stocks due to introduction of micro-plastics to food chain (from mattress ropes)	2.00E+00	1	2	4	8	I: High initial release during removal process due to agitation from mass flow excavator. No long term on-site release as bulk PP from exposed (or partially exposed) mattresses will have been removed (3) L: High level of uncertainty regarding the quantity of PP that would be released into the environment during the recovery and the impact of PP micro-plastic on the fisheries (especially given the small quantities here) (4)	50	50	2	4	8	I: High initial release during removal process due to agitation from mass flow excavator and fraying of PP ropes during recovery process. PP debris may also be released to break down over time. No long term on-site release as bulk PP from exposed (or partially exposed) mattresses will have been removed (3) L: High level of uncertainty regarding the quantity of PP that would be released into the environment during the recovery and the impact of PP micro-plastic on the fisheries (especially given the small quantities here) (4)	50	50
		b	Fisheries - impact of pipelines on commercial fising activities.	7.00E+00	1	1	1	1	I: Pipelines completely removed, no impact on future commercial fishing activity (1) L: Very low likelihood (1) .	0	0	2	2	4	I: Pipelines partially removed, potential impact on future commercial fishing activity if remaining parts of pipelines bcome unburied n the future(2) L: Low Likelihood (2)	43	43
5	Economic	a	Decommissioning cost	1.48E+01	1	N/A	N/A	21,014,603	Calculated cost £21,014,603	100	100	N/A	N/A	13,009,266	Calculated cost £13,009,266	59	59
		b	Ongoing liability - The extent to which the option minimises cost / risk uncertainty	1.90E+01	1	1	1	1	I: No ongoing responsibility as all materials removed. (1) L: Very low likelihood (1)	0	0	2	2	4	I: Some ongoing liability as 1% to 50% of pipeline material is left in-situ (2) L: Low likelihood - some level of uncertainty here as ongoing liability is a vague term; who does the responsibility lie with when companies fold, what level of monitoring is needed etc. (2)	16	16
			Totals							800	800					873	873
			Rank							5	5					6	6

	Option 3a - Bury - Trenching and Backfilling with Natural Deposits: Relative risk scoring	Weighted risk scoring	Option 3b - Bury - Rock Dump: Relative risk scoring	Weighted risk scoring	Option 4a - Leave In Situ - Cover Cut Ends with Gravel / Grout Bags: Relative risk scoring	Weighted risk scoring	Option 4b - Leave In Situ - Cover Cut Ends with Mattresses: Relative risk scoring	Weighted risk scoring
Totals	381	381	490	490	703	703	645	645
Rank	1	1	2	2	4	4	3	3

C. Comparative assessment assumptions

- Vessel rates have been assumed as per C.

Table C: Vessel and operational rates

Vessel type	Cost (£/day)
DSV	150,000
Cut and lift pipelines	120,000
Removal of materials	10,000
Rock dump vessel	75,000
Trenching vessel	150,000
Ongoing monitoring	25,000
Barge	15,000
Mob / demob	25,000
Survey vessel	50,000
Tug	10,000
Hydrodigger (mass flow excavator)	10,000

- Wait on weather assumed to be 10%
- Engineering studies are assumed to be £25,000 per asset and £150,000 in project management costs for the full removal option. This is pro-rated as follows:
  - Full removal using traditional techniques: 100%
  - Removal using novel techniques: 150%
  - Partial removal using traditional techniques: 75%
  - Partial removal using novel techniques: 125%
  - Decommission in-situ with remediation: 75%
  - Decommission in-situ: 50%
- Cost of trawler for trials is negligible
- Cost contingency of 10%
- Ongoing liability costs not quantified (this is a separate economic sub-criteria to cost)
- Personnel requirements have been assumed as per Table 2.

Table 2: Personnel requirements

Activity	Personnel
DSV crew	25
Rockdump crew	15
Tug crew	10
Crane ops	3

- 24hr working day
- Logistics for changing personnel not included
- Transitions between work locations not included
- Safety risk contribution from onshore transport, overtrawling trials and survey vessel are considered negligible
- FAR for rockdumping is equivalent to that of a barge (rockdumping vessel not included in SAFETEC JIP Fishing vessel energy consumption is negligible (from overtrawling trials)
- Onshore transport lorry fuel consumption 8mpg
- Lorry capacity 20 tonnes
- Round trip from port to place of recycling/disposal is 100 km.

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