MARATHON BRAE

Brae Area Subsea Assets Decommissioning Comparative Assessment

June 2017 Consultation Draft

Marathon Oil

9000-MIP-99-PM-FD-00003-000, I03

Consultation Draft

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Document Control

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Revision Control

Revision No	Reference	Changes/Comments	Issue Date
0	Draft	Issued for internal comment	October 2015
1	Issued	Incorporating comments	December 2015
2	2nd Issue	Revised to incorporate stakeholder comments	June 2016
3	3rd Issue	Draft consultation issue	June 2017

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Terms and Abbreviations

As low as reasonably practicable (ALARP)	In terms of risk, a risk is as low as reasonably practicable when it has been reduced to the level beyond which the cost of further reduction is grossly disproportionate to any benefit gained.
BEIS	Department for Business Energy and Industrial Strategy
Brae Area	The offshore area encompassing the Brae platforms, and the associated subsea facilities and export pipelines.
CA	Comparative Assessment
Caisson	A tubular structure fitted to the support structure of an offshore installation, containing and providing support for a number of pipes and umbilicals, etc.
Concrete Mattress	A series of concrete blocks linked by a rope matrix that form a flexible structure approximately 5m by 3m that is used for to protect or stabilise subsea facilities.
DECC	Department of Energy and Climate Change (DECC became part of BEIS in July 2016.)
Decommissioning	The process of taking facilities out of use and disposing of them.
EMT	BEIS Environmental Management Team
FishSAFE	A system for disseminating information to fishermen regarding hazards arising from offshore oil and gas facilities. The system allows this information to be overlaid onto electronic charts and plotters [5].
Grout Bag	Stabilisation and protection features consisting of a bag containing cement grout. The bag may be small, sandbag sized, or large mattress sized.
HES&S	Health, Environment, Safety & Security
JNCC	Joint Nature Conservancy Council
LLC	Limited Liability Corporation
Manifold	A subsea system that marshals the production fluids from a number of other subsea facilities.
NFFO	National Federation of Fishermen's Organisations
ODU	BEIS Offshore Decommissioning Unit
Operator	An oil and gas company that operates an offshore facility or field.
OSPAR	Oslo Paris Convention
PIP	Pipe-in-Pipe (type of pipeline configuration)
PMS	Power Management System

Preferred Option	The decommissioning option that offers the best balance when assessed against the comparative assessment criteria.
Riser	The section of a pipeline that runs from the topsides of an offshore platform to the seabed. Normally this is supported by the platform sub-structure.
ROV	Remotely Operated Vehicle
SAC	Special Area of Conservation
Safety Zone	A zone established around an offshore installation that vessels cannot enter without the permission of the offshore installation manager.
Post Decommissioning Safety Zone	A proposed safety zone to be established after decommissioning to reduce the hazard of fishermen snagging nets on platform footings.
SAGE	Scottish Area Gas Evacuation (Pipeline and Terminal)
SCI	Site of Community Importance (European Community)
SEPA	Scottish Environmental Protection Agency
SFF	Scottish Fishermen's Federation
Span	An unsupported length of pipeline that potentially presents a snagging hazard for fishermen's nets, or a hazard to pipeline integrity. Spans occur where the seabed is eroded from beneath the pipeline by tides or other currents. Spans can occur on surface-laid pipelines or, more unusually on buried pipelines.
SSIV	Subsea Isolation Valve. A valve fitted to a subsea pipeline that is designed to close in the event of a leak from the pipeline riser, or connected platform process equipment. This prevents the pipeline contents prolonging, or greatly increasing, the size of any resulting topsides fire or release to the environment.
Subsea Asset	A collective term for items of subsea equipment, including pipelines, wells and wellheads, and manifolds.
TA	Technical Authority
TEE (Pipeline)	A "T" junction in a subsea pipeline.
UK	United Kingdom
UKCS	United Kingdom Continental Shelf.
Umbilical	A collection of hydraulic lines, electrical cables, fibre optics and chemical injection hoses bound together into a single large hose-like structure connecting an offshore platform to a subsea facility, or one subsea facility to another.
Upheaval Buckling	A phenomenon that occurs when a trenched pipeline undergoes thermal expansion and bows upwards.
WYE (Pipeline)	A "Y" junction in a subsea pipeline.

1. Executive Summary

Marathon Oil operates the Brae Area production facilities in the UK sector of the North Sea. The oil and gas fields in the Brae Area are reaching the end of their lives, and Marathon Oil plans to decommission the associated facilities and infrastructure, including the subsea facilities.

Within the UKCS (United Kingdom Continental Shelf), BEIS (Department of Business, Energy and Industrial Strategy, formerly DECC) is the authority governing decommissioning and disposal of offshore installations. The definition of installations includes subsea facilities, such as drilling templates, production manifolds, well heads and protective structures, but not pipelines. The BEIS guidance on pipelines allows the possibility of leaving some subsea pipelines in place, subject to comparative assessment of the impacts of doing so.

Marathon Oil will comply with all statutory and legislative requirements governing the decommissioning of its offshore facilities. Nonetheless, the company wishes to understand the full range of the impacts of decommissioning all of the Brae Area equipment, including pipelines and subsea installations. Therefore, Marathon Oil's comparative assessment includes identifying the preferred decommissioning options for all of the Brae Area subsea facilities. In this context, "preferred" means the option that represents the best balance of safety, environmental and societal impacts.

This document describes the development of the comparative assessment methodology for the Brae Area subsea facilities. This consists of a toolbox, or set of templates, to be applied to the inventory of subsea equipment. To facilitate the overall comparative assessment process, the Brae Area subsea equipment has been grouped into a number of segments. Segments are essentially categories of similar types of equipment. The toolbox contains the preferred decommissioning option for each of these segments. These preferred options are listed in Table 7.1. The application of the Marathon Oil CA methodology described in this document to the facilities in the Brae Area is described in two further detailed reports [13] [14]. The first reports covers Brae Alpha, Brae Bravo, Central Brae, West Brae and Sedgwick facilities, while the second covers East Brae and Braemar. These groupings correspond to those used in the two Brae Area combined decommissioning programmes.

The Marathon Oil subsea facilities comparative assessment tool builds on BEIS guidance [1] in the following areas;

- **Pipeline spans:** The BEIS guidance [1] does not specifically address decommissioning options for pipeline spans. However, the guidance does require that pipeline decommissioning should address any history of spanning. Spans are of particular concern because of the hazard that they represent to fishermen. It is therefore important that measures to address spans provide a permanent solution.

  The preferred options for dealing with spans identified by the comparative assessment are to cut out the span and to rock cover the exposed ends of the pipeline that remains in place, or to infill the void beneath the pipeline, and rock cover the span in place. The objective of both options is to remove any snagging hazard for fishermen. The preferred option in a particular case will be the one that requires the smaller quantity of rock or other materials to make it safe.

- **Trunk Pipeline Gates:** The Brae Area oil and gas export trunk lines will be left in place on the seabed. However, to facilitate trawling using nets that contact the seabed, Marathon Oil proposes to clear "gates" in these pipelines to allow the unimpeded passage of fishing gear. Each gate will be created by removing or burying a length of pipeline. Marathon Oil is consulting stakeholders regarding the preferred size and spacing of these gates.

- **Post Decommissioning Safety Zones:** Following decommissioning, Marathon Oil proposes to establish 'post-decommissioning' safety zones around the Brae Area platform footings (subject to OSPAR 98/3 derogation). The purpose of these safety zones is to assist in preventing fishing vessels inadvertently snagging their nets on the jacket/sub-structure footings [7, 8, & 9]. Marathon Oil proposes to minimise disturbance of the drill cuttings piles, reduce risks to personnel and the use of resources during decommissioning operations by leaving some subsea equipment in place within these zones. Any subsea equipment that is left in place in a post-decommissioning safety zone will be no further from the centre of the remaining sub-structure footings than a defined distance, for example, 250m.
- **Reuse and Recycling of Mattresses Offshore:** Mattresses may be reused[1] to stabilise equipment that is left in place within the proposed post-decommissioning safety zones. There may also be a requirement to re-profile any depression or cavity in the seabed following removal of the subsea equipment. Mattresses may be recycled for this purpose to reduce the overall requirement for imported material. Similarly, mattresses may also be recycled to remediate pipeline spans, reducing the requirement for new fill or cover material.

[1] *The term reuse is defined here to mean using the mattress to perform the same purpose as it is currently, but in a different location offshore. The reuse of a mattress avoids the use of a new mattress. If a mattress is to be recycled, it is to be used in a different role to that currently, for example to reduce the volume of rock cover needed to remediate any depressions left in the seabed following removal of other equipment. In this case the mattress may require remedial rock cover to limit risk to other sea users.*

2. Legislative Requirements

The legislative background to decommissioning subsea facilities in the United Kingdom sector of the North Sea is described in BEIS guidance[1]. This guidance sets out the UK government's policy on decommissioning:

"Government will seek to achieve effective and balanced decommissioning solutions, which are consistent with international obligations and have a proper regard for safety, the environment, other legitimate uses of the sea, economic considerations and social considerations."

Oil and Gas UK guidance [6] describes legislative requirements pertinent to pipelines as follows:

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

The principal international convention governing decommissioning of offshore installations is the OSPAR Convention. Under this convention, Decision 98/3 bans the disposal of offshore installations at sea. The requirements of the convention are administered by BEIS for the UK Continental Shelf. BEIS has a wide definition of "offshore installation", which includes drilling templates, production manifolds, well heads, protective structures, anchor blocks and anchor points, anchor chains, risers and riser bases. The OSPAR Convention recognises the possibility of decommissioning offshore installations in place under exceptional circumstances. However, any proposal to decommission an installation in place must be supported by a comparative assessment of the decommissioning options, to demonstrate that the proposed solution achieves the optimal balance of safety, environmental, technical, social and economic impacts.

In the UK, there is a requirement for owners of installations and pipelines to draft decommissioning programmes, submit them to BEIS, and obtain approval from the Secretary of State. This requirement is contained in the Petroleum Act 1998, as amended. Decommissioning programmes should include information regarding removal and disposal of equipment and the associated costs. The programmes must be supported by an environmental impact assessment.

The BEIS guidance [1] requires comparative assessment to determine the preferred decommissioning options in certain instances, and for particular types of subsea equipment. In other circumstances, the BEIS guidance stipulates the decommissioning options to be used, without reference to comparative assessment of the available options. Marathon Oil aims to identify the impacts of decommissioning of all of its facilities and has therefore extended its comparative assessment to include all the Brae Area subsea equipment.

3. Comparative Assessment Objectives

Marathon Oil has established a Corporate Responsibility Policy that encompasses 12 principles. The principles of most importance to decommissioning are:

- **Incident Prevention:** To provide a safe and injury-free workplace with the aim of sending all employees and contractors home safely.
- **Environmental Stewardship:** To be committed to environmental protection and to emphasise, to the extent practical, conservation of all resources and the minimisation of wastes, emissions and releases throughout the Company's operations.
- **Communities:** To be a good neighbour.
- **Emergency Preparedness:** To maintain a preparedness and response programme with the goal of protecting employees, contractors and other people, the environment, and corporate resources.
- **Risk Assessment:** To systematically identify potential HES&S risks, assess their relative significance and develop reduction measures to ensure risks are properly addressed.
- **Legislative and Regulatory Compliance:** To comply with all applicable HES&S laws, regulations and other requirements, and to actively participate in the development of responsible laws, regulations and standards regarding HES&S issues.
- **Communication:** To communicate HES&S commitments, responsibilities and performance to the Company's employees, contractors, the public and other key stakeholders.

Marathon Oil's principles are reflected in the overall objectives of the comparative assessment process for decommissioning the Brae Area subsea facilities and in the detailed criteria used in each assessment. The criteria are discussed in Section 6.2.

The overall objectives of the Brae Area subsea facilities decommissioning comparative assessment process are:

- To ensure that any safety risks to other users of the sea during Brae Area subsea facilities decommissioning operations, or as a result of operations, are as low as reasonably practicable.
- To ensure that risks to personnel carrying out the decommissioning work are as low as reasonably practicable.
- To cause minimal practicable disturbance to marine flora and fauna during, or as a result of, decommissioning activities.
- To minimise the use of natural resources and to manage emissions to the environment in a responsible manner.
- To cause minimal practicable disruption to the wider community at sea and on land.

In some instances, these objectives may be incompatible with one another. The comparative assessment process balances the objectives to identify the preferred decommissioning option for each segment. The factors that contribute to achieving each of the objectives are explained in more detail in the following sub-sections. The objectives are also developed further in the criteria used in the comparative assessment. The comparative assessment process considers both the short term and the long term impacts of the various decommissioning options.

3.1 Control of Risks to Other Sea Users

Other users of the sea include the fishing industry, merchant seafarers, naval personnel and leisure users. There is the potential for Brae Area subsea facilities decommissioning operations to affect other sea users.

During decommissioning operations, there is a risk of collision between vessels involved in decommissioning and other vessels. This risk is relevant to all types of vessels that may be in the Brae Area. This risk will be mitigated by management of marine operations in the area and effective watch-keeping on the vessels involved in the decommissioning operations.

Following decommissioning, Marathon Oil proposes to leave the Brae Area platform footings in place. This proposal is dependent on obtaining derogation from OSPAR Decision 98/3. Marathon Oil also proposes to establish 'post-decommissioning' safety zones around the footings. The fundamental purpose of these zones is to mitigate the risk of fishing vessels inadvertently snagging their nets on the jacket/sub-structure footings.

The principal safety hazard within each proposed post-decommissioning safety zone is the derogated jacket footings [7, 8 & 9], and the principal environmental hazard is the disturbance of the drill cuttings [10]. Marathon Oil therefore concluded [12] that some equipment (such as tie-in spools, pipelines and mattresses) would be best left undisturbed on the seabed within the post-decommissioning safety zone.

3.1.1 Equipment In Close Proximity to Sub-Structure Footings

A post-decommissioning safety zone is proposed to mitigate the risk to other sea users from the derogated sub-structure footings [7, 8 & 9].

Given the presence of the post-decommissioning safety zone, Marathon Oil conducted a more detailed risk assessment [12] of the safety impacts associated with removing the seabed surface-laid equipment in close proximity to, and not more than 250m from, the sub-structure footings. This risk assessment compared the risk of removing the equipment against the snagging risk to fishermen as a result of leaving the equipment in place.

The risk assessment concluded that:

- The SSIV structures should be removed, as the risk to fishermen over 500 years from these structures outweighs the risk that will be incurred by decommissioning personnel in removing them.
- The pipelines, flowlines, umbilicals, mattresses and PMS cables on the seabed in close proximity to, and not more than 250m from, the sub-structure footings should remain in place. The risk that decommissioning personnel would incur in removing these facilities is greater than the total risk to fishermen arising from fishing in the area for 500 years.

The assessment and its conclusions excluded environmental, financial and technical issues. Recovering equipment from the seabed around the sub-structure footings will consume resources, generate emissions and disturb the environment.

3.1.2 Equipment Outwith Sub-Structure Footings

Other than equipment around the sub-structure footings detailed in Section 3.1.1, the only other equipment proposed to remain on the seabed in the Brae Area following decommissioning will be:

- Existing rock-covered pipeline at West Brae and Sedgwick.
- The export trunk lines (between trenched 'gates').

The risk to other sea users from this equipment will be mitigated in the following ways:

- The rock-covered lengths of pipeline at West Brae and Sedgwick are overtrawlable, that is they do not present a snagging hazard to fishing gear.
- The export trunk lines are overtrawlable. Marathon Oil also proposes to create gates in the export trunk lines by removing or trenching suitable lengths of pipeline at appropriate intervals. This will facilitate the unimpeded passage of fishing gear.

Marathon Oil will periodically monitor the Brae Area following decommissioning to ensure that equipment left in place on, or under the seabed does not present an unacceptable risk to other sea users. The details of the monitoring schedule will be agreed between Marathon Oil and BEIS.

3.2 Control of Risks to Decommissioning Personnel

The process of decommissioning is potentially hazardous to the personnel who will carry it out. Decommissioning subsea facilities may involve the use of divers, subsea cutting operations, lifting of decommissioned facilities and tools from the seabed to surface vessels, and transporting decommissioned equipment to shore for ultimate disposal. All of these operations involve risks to the personnel carrying them out. Marathon Oil's approach to reducing these risks is to avoid the use of divers and to automate operations as far as practicable. To further control risk to personnel, Marathon Oil will only employ tools and techniques that have been proven in practice. The hazards and risks associated with proven techniques are well understood, which facilitates effective risk management.

3.3 Disturbance of Marine Ecology

Decommissioning of subsea facilities has the potential to disturb the marine ecology. Vessels working in the area may disturb marine mammals through noise, artificial light or their physical presence. Removal of equipment from the seabed may disrupt plant and animal life through direct physical disturbance or by stirring up and displacing sediment. Any new materials that are introduced during decommissioning may also disrupt the environment. The comparative assessment process seeks to balance any impacts on the marine environment with the other objectives.

The comparative assessment process has been developed in parallel to the environmental impact assessment for decommissioning in the Brae Area. Members of Marathon Oil's environmental team have been involved in both processes, and the comparative assessment is informed by the work that has been performed for the environmental impact assessment and vice versa.

3.4 Resources and Emissions

Decommissioning operations will use resources, in the form of fuel for the vessels involved in the operations, fuel for onshore transportation, and energy for reworking equipment for reuse or recycling. The use of fuel will result in atmospheric emissions. If equipment that is brought ashore cannot be reused or recycled, then it may be sent to landfill, which also constitutes consumption of a finite resource. The comparative assessment process seeks to balance the use of resources and production of emissions with the other assessment criteria.

3.5 Impact on the Wider Community

Subsea decommissioning operations impact the wider community in several ways. The presence of vessels at sea or equipment on the seabed during or following decommissioning may disrupt fishing. The work involved in the removal of equipment to shore for reuse, recycling or ultimate disposal will impact onshore communities through noise, transport, odours, etc. Conversely, disposal of decommissioned facilities onshore may generate employment, albeit short term. The comparative assessment process aims to optimise these impacts as far as is practicable, in balance with the other objectives.

4. Comparative Assessment Scope

The scope of the Brae Area subsea facilities comparative assessment includes: pipelines; umbilicals; power cables; fabricated steel structures; concrete structures; and protection and stabilisation features. The total length of pipelines associated with the Brae Area is in excess of 260 km, the total length of umbilicals is more than 38 km, and the total length of cables is more than 57 km.

Marathon Oil is the duty holder for the majority of the facilities in the Brae Area. There are other operators' subsea facilities in the Brae Area that are connected to Marathon Oil's Brae platforms. These connections include flowlines that export the produced fluids from the third-party facilities to the Brae platforms, and service lines and umbilicals that provide services, and control and communication, from the Brae platforms to the third-party facilities. Decommissioning these facilities is the responsibility of the other operators.

The configuration of the subsea facilities in the Brae Area is shown in Figure 4.1.

4.1 Cleaning

All of the Brae Area subsea facilities will be cleaned to an appropriate standard prior to decommissioning. Cleaning is outside the scope of the comparative assessment as it is not a differentiator between options.

4.2 Pipelines

Pipelines that connect a subsea well to a manifold, or to a platform, are generally classified as flowlines, whereas the term "pipeline" usually refers to larger lines that export produced oil or gas from a platform to a terminal onshore. For the purposes of this comparative assessment, the term "pipeline" is taken to include flowlines.

Pipelines are generally formed from welded lengths of line pipe, with the exception of those parts of the pipelines that connect to the installations at either end of the line. These final sections of pipeline are normally in the form of "tie-in spools", which are connected to the main length of the pipeline by bolted flanges.

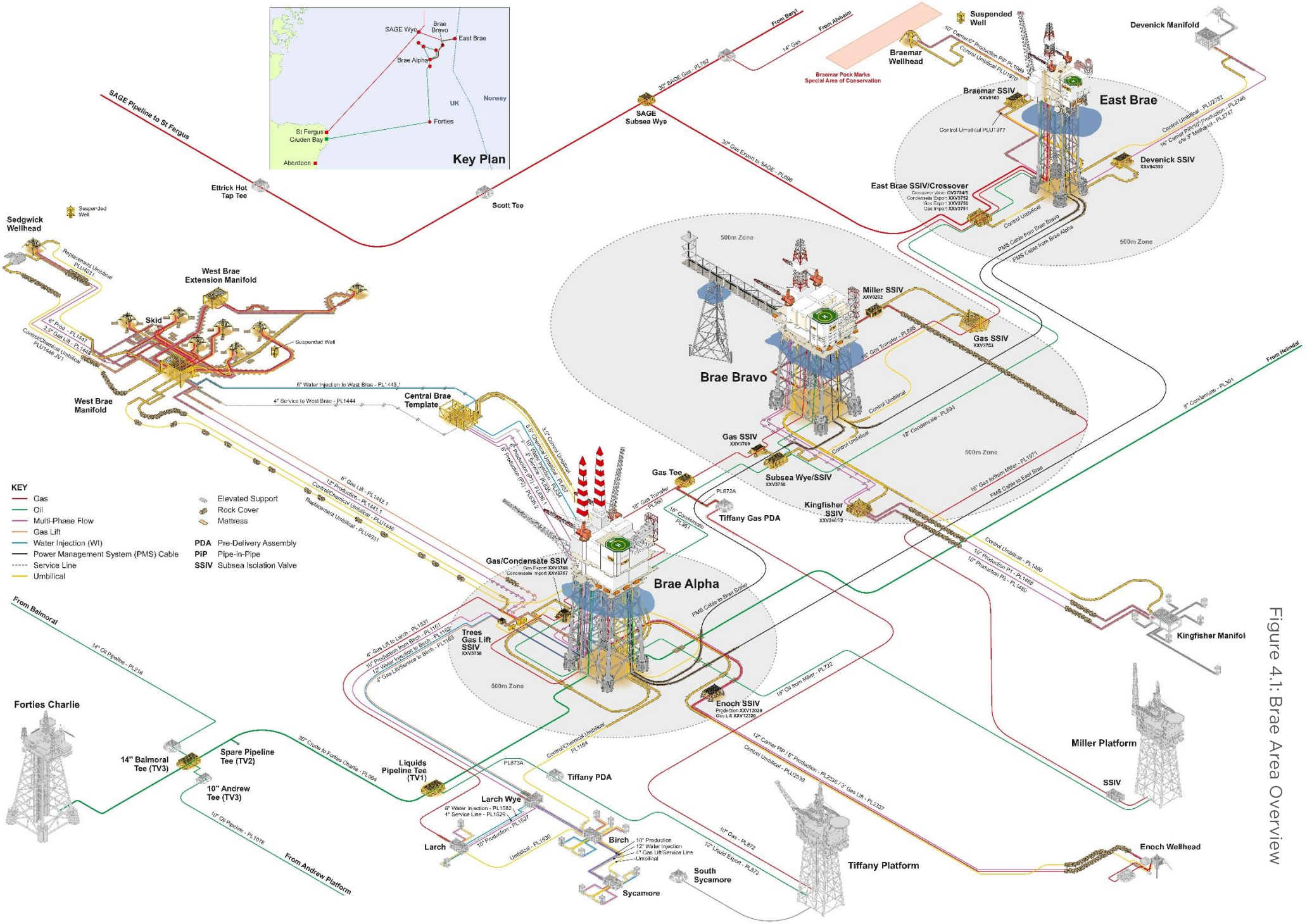


Figure 4.1: Brae Area Overview

4.2.1 Pipeline Removal Techniques

The comparative assessment only considered commercially available pipeline removal techniques that are proven in use. This limits the viable options for the Brae Area to cutting pipelines into manageable lengths of around 10-12m, lifting them onto a vessel, and transferring them to shore. This may be carried out by ROVs or other equipment, or may involve the use of divers.

Marathon Oil discussed reverse installation techniques with potential decommissioning contractors. As a result of these discussions, Marathon Oil believes that reverse installation techniques using S-lay or reel-lay vessels are not viable for rigid pipeline removal. This is due to uncertainties regarding the integrity of pipelines and pipeline coatings. Personnel, vessels and equipment could be at risk if a pipeline snapped or if pipeline concrete coating became detached during reverse installation.

4.3 Umbilicals

4.3.1 Brae Area Umbilicals

Umbilicals connect the subsea facilities in the Brae Area to the Brae platforms. The umbilicals serve either subsea wells or groups of wells, or pipeline SSIVs (Subsea Isolation Valves). The umbilicals transfer control signals, power and chemicals between the platforms and the subsea facilities. The umbilicals are generally surface-laid within the platform safety zones, and trenched for protection between the safety zones and the facilities that they serve.

The Brae Area SSIVs are all located within the safety zones of the Brae Platforms. The zones protect the SSIV control umbilicals from fishing hazards, therefore these umbilicals are surface-laid. Typically, in the areas immediately adjacent to the platforms, the SSIV control umbilicals are stabilised and protected against dropped object hazards by mattresses. Similarly, chemical umbilicals and electro-hydraulic umbilicals that serve the Brae Area subsea production facilities are generally surface-laid with mattress stabilisation and protection in the immediate vicinity of the platforms. Between the immediate vicinity of the platforms and the subsea installations, the umbilicals are laid in the same protective trenches as the pipelines that link these facilities.

4.3.2 Umbilical Removal Techniques

The comparative assessment considered proven umbilical removal techniques. Marathon Oil believes that the only proven viable option is to cut the umbilical into manageable lengths. This may be carried out by ROVs or other equipment, or may involve the use of divers.

Reverse installation techniques using reel-lay vessels may be viable, but are not deemed likely options because of uncertainties regarding the integrity of umbilicals and the consequent risks to vessels, equipment, and personnel. Umbilicals in the Brae Area are trenched or buried over the majority of their length and, by analogy with trenched and buried pipelines, these buried portions are therefore candidates to remain in place [1].

4.4 Power Cables

4.4.1 Power Cables in the Brae Area

Electrical power is generated on the Brae Alpha and Brae Bravo platforms. There is no main power generation on the East Brae platform. The three platforms are connected by a ring main. This forms part of the overall Brae Area Power Management System (PMS) that distributes electrical power between the platforms. The ring main is made up of three subsea power cables: one from Brae Alpha to Brae Bravo, one from Brae Alpha to East Brae and one from Brae Bravo to East Brae.

Over most of their length, the power cables are trenched to a depth of more than 600mm. The portions of the PMS cables immediately adjacent to the Brae platforms are surface-laid, and mattress stabilised and protected.

4.4.2 Power Cable Removal Techniques

The comparative assessment has considered proven power cable removal techniques. The only proven viable option is to cut the cable into manageable lengths of around 10-12m, lift them onto a vessel and transfer them to shore. This may be carried out by ROVs or other equipment, or may involve the use of divers.

Reverse installation techniques using reel-lay vessels are not considered as proven to be viable. This is because of uncertainties regarding the integrity of power cables and the consequent risks to vessels, equipment, and personnel. The power cables are trenched or buried over the majority of their length and, by analogy with trenched and buried pipelines, these buried segments are therefore candidates to remain in place [1].

4.5 Spans

4.5.1 Spans in the Brae Area

All of the pipelines, umbilicals and PMS cables in the Brae Area have the potential to form spans, i.e., lengths of line that have been undercut and where the line is no longer directly supported on the seabed. It is more likely that rigid pipelines will form spans than umbilicals or cables, which are flexible and tend to conform to the seabed.

Spans fall into three categories:

- **Fishing critical spans.** These pose a hazard to fishermen, as they are large enough to snag fishing nets, and in the extreme can cause the loss of a fishing vessel.
- **Integrity critical spans.** These spans are of a length that can result in pipeline oscillations induced by tides and other currents, leading to fatigue failure of the line. In the event that the pipeline fails, the broken ends may pose a snagging hazard to fishing vessels.
- **Non-critical anomalous spans.** These spans are of insufficient size to be fishing or integrity critical. However, they are recorded as they may subsequently develop into fishing, or integrity, critical spans.

Spans may occur in surface-laid lines, trenched lines or buried lines, although they are more likely to occur in surface-laid lines. Spans form and dissipate as the seabed moves. However, the seabed in the Brae Area is relatively immobile, and spans generally form and dissipate relatively slowly.

4.5.2 Remediation Techniques

Span remediation techniques fall into one of two categories: removal or burial. Removal consists of cutting out the unsupported section of line. This leaves the exposed ends of the line as a potential hazard. It is therefore normal to protect exposed ends with rock cover or mattresses, or to trench the ends in place. Burial consists of covering the entire span, normally with rock cover. Alternatively, the span and the portions of the line adjacent to it could be trenched such that the span is remediated. The volume of rock required to remediate a span could be reduced by using recycled mattresses. If mattresses were used, rock cover would still be required as the top layer of burial material. This would ensure that the remediated span could be overtrawled without the risk of catching all, or part of, a mattress in a fishing net.

The standard approach to dealing with spans on in-service pipelines is to pack out the void underneath the pipeline with grout bags or mattresses, and in some instances to protect the area with rock cover. The decommissioning options available for spans do not differ markedly from the solutions that would be adopted during the service life of the pipeline. In the case of short spans, it may require less material to remediate the entire span in place than to cut the span out and stabilise and cover the two resulting cut ends of the line.

4.6 Fabricated Steel Structures

4.6.1 Fabricated Steel Structures in the Brae Area

The Brae Area subsea facilities include a number of fabricated steel structures. These fall into two groups: structures that are components of subsea installations, and structures that form parts of pipelines. The group of structures that are components of subsea installations includes the Central Brae template structure and West Brae manifold structure. The group of structures that form parts of pipelines include the protection structure on the liquids export pipeline TEEs, and SSIV structures. The subsea structures vary in weight from a few tonnes to several hundred tonnes.

Individual wellhead protection structures are excluded from the comparative assessment scope as these will all be removed to allow plugging and abandonment of the wells.

4.6.2 Fabricated Structure Removal Techniques

When the Brae Area subsea fabricated structures were installed, they were of known weight and proven integrity. At decommissioning, the weight of a structure is likely to be uncertain, as additional components may have been added to the structure, for example piles or grout. The effective weight of the structure may also be increased by suction with the seabed, or marine growth on the structure's members. Similarly, the integrity of a fabricated steel structure that has been submerged in sea water for a number of years may be impaired. As a result, it may not be possible to remove fabricated steel structures by reversing the lifting process used for installation. It may be necessary to cut a structure into sections and to remove it piece small.

Therefore, while it may be possible to remove some structures by lifting them out in one piece, it may be necessary to cut other structures into pieces on the seabed. The pieces would then be lifted out individually, or loaded into baskets or skips for recovery.

4.7 Concrete Components

4.7.1 Subsea Concrete Components in the Brae Area

There are a number of concrete components in the Brae Area. These are generally relatively small and form parts of pipeline crossings and pipeline bridge arrangements at the bases of the Brae platform structures. The concrete items are either supports underneath the pipelines, or protection or ballast structures over the top of the pipelines.

4.7.2 Removal Techniques for Subsea Concrete Components

The weight of concrete components may have actually increased since they were installed due to the build-up of marine growth, or effectively increased because of suction on the seabed.

Concrete components may be removed by lifting them out using the lifting eyes that were used to install them, although the integrity of such lifting points will require verification. If the integrity of the original lifting points cannot be verified, then alternative lifting points will need to be identified. If there are concerns over the integrity of the concrete components, they may be loaded into skips or cargo nets for lifting, either in one piece or broken up into a number of pieces.

4.8 Protection and Stabilisation Features

4.8.1 Types of Protection and Stabilisation Features

In addition to the concrete components, there are numerous other subsea stabilisation and protection features in the Brae Area. These include: mattresses, grout bags and rock cover.

Mattresses typically consist of a matrix of concrete blocks held together with wire or polypropylene rope. Mattresses are flexible and drape over subsea equipment to provide protection from dropped objects, prevent the seabed being scoured away by tides and currents, and stabilise equipment on the seabed. Mattresses are also used in the construction of pipeline crossings. Typical mattresses are around 6m by 3m and weigh 5 to 6 tonnes in air, or 3 to 4 tonnes when immersed in water.

Grout bags are sandbags that are dry filled with cement grout. Typically grout bags are used as supports for pipelines and as scour protection. Different sizes of grout bag are used in the Brae Area varying in weight from a few kilograms to several tonnes.

Rock cover is used to protect subsea equipment from dropped objects and impacts from fishing gear, and to stabilise pipelines on the seabed. Rock cover may also be used to remediate pipeline spans and for scour protection. Rock cover consists of pieces of quarried rock which are typically 25mm to 125mm in size.

4.8.2 Protection and Stabilisation Features Removal Techniques

Concrete mattresses typically consist of a matrix of concrete blocks that are held together by a rope armature. Alternative designs exist for pipeline stability and take the form of multiple 'logs' of concrete held together by rope or wire and placed over or under pipelines to provide support and stabilisation.

Concrete mattresses are normally installed using lifting frames that engage with the loops formed by the rope at the mattresses' edges. These loops may not be suitable for lifting the mattresses out at decommissioning, as they may have degraded over time, and the integrity of the loops cannot be assured. Therefore, mattresses may need to be recovered by loading them into skips or nets on the seabed and then lifting those containers to a vessel on the surface, or by using grabs or grapples to recover the mattresses in pieces directly to a surface vessel. The ropes used in the manufacture of mattresses may be polypropylene or wire. Wire rope has been found to degrade over time to the extent that mattresses of this type may break up on the seabed, making them particularly hazardous and difficult to recover. It is generally accepted that the most hazardous element of mattress recovery is the lifting of the recovered mattress through the splash zone and onto the deck of a vessel.

Grout bags and larger grout mattresses consist of fabric bags that are filled with cementitious grout. They may be particularly difficult to recover as the bag's fabric may have degraded over time. Lifting grout bags directly is unlikely to be practicable and the use of skips, nets, baskets or grabs or grapples to raise grout bags from the seabed may not be possible, as the bags may break up as they are lifted from the seabed to be placed into the skips.

The industry is working to develop automated and efficient means of recovering mattresses and grout bags. Currently the viable means of recovery are generally time consuming and can typically involve the use of divers.

4.9 Third-party Facilities

Marathon Oil will liaise with third-party operators to establish and agree the demarcation of responsibility for decommissioning of the third-party equipment that lies within the Brae platform 500 m safety zones, and the pipelines and umbilicals that connect those structures to the Brae platforms. Marathon Oil will endeavour to collaborate with third-party operators to achieve efficiencies in decommissioning facilities in the same area.

5. Development of Subsea Facilities Decommissioning CA Process

5.1 Background

The facilities in the Brae Area, Figure 4.1, are approaching the end of their productive life. Once production ceases, there will be no further use for the associated facilities in their current locations, and they will be decommissioned over a period that is anticipated to run from around 2016 to 2032.

The overall programme will include decommissioning the subsea facilities. There are a number of options for decommissioning each facility. Marathon Oil's selected decommissioning options must ensure that any safety and environmental risks remaining after decommissioning are acceptable. Equally, the decommissioning operations themselves should not pose an unacceptable risk to the people who carry them out, nor to the environment where decommissioning will take place, or where any waste from the decommissioning operations will be handled or ultimately disposed of. Finally, the cost of decommissioning should not be unreasonably high.

Marathon Oil uses comparative assessment to balance the advantages and disadvantages of the various decommissioning alternatives and arrive at an overall preferred option. In this context, "preferred" means the option that represents the best balance of safety, environmental and societal impacts, taking technical feasibility and cost into account.

Five criteria are used for comparative assessment:

- Health and safety
- Environmental impact
- Technical feasibility
- Socio-economic impact
- Economic feasibility

The Brae Area subsea facilities decommissioning comparative assessment is qualitative and compares the relative scale of impacts of proposed options. The approach adopted is broadly in line with the "Type A" approach described in Oil and Gas UK guidance [4] supplemented by the inclusion of some aspects of the "Type B" approach.

The timescale for planning decommissioning of the Brae Area subsea facilities extends beyond 2020. The comparative assessment process is based on a current understanding of the condition of the Brae Area subsea facilities and feasible decommissioning techniques. This understanding may change in the period to the start of the decommissioning operations. The comparative assessment for the subsea facilities will be reviewed in the period up to the commencement of decommissioning, in light of changes in the understanding of the condition of the facilities, changes in understanding of the environment, or developments in decommissioning techniques.

The Brae Area subsea facilities comparative assessment methodology was developed by Marathon Oil personnel working in conjunction with external consultants [2]. The comparative assessment process for subsea facilities is designed to be transparent and efficient in terms of demands on the time of personnel who prepare, review and use the results. The methodology is designed to clearly show how the team arrived at the preferred decommissioning option. The methodology draws on BEIS guidance notes on

decommissioning [1], Marathon Oil's overall Brae Field Decommissioning Comparative Assessment Process [2] and Oil and Gas UK guidance [4].

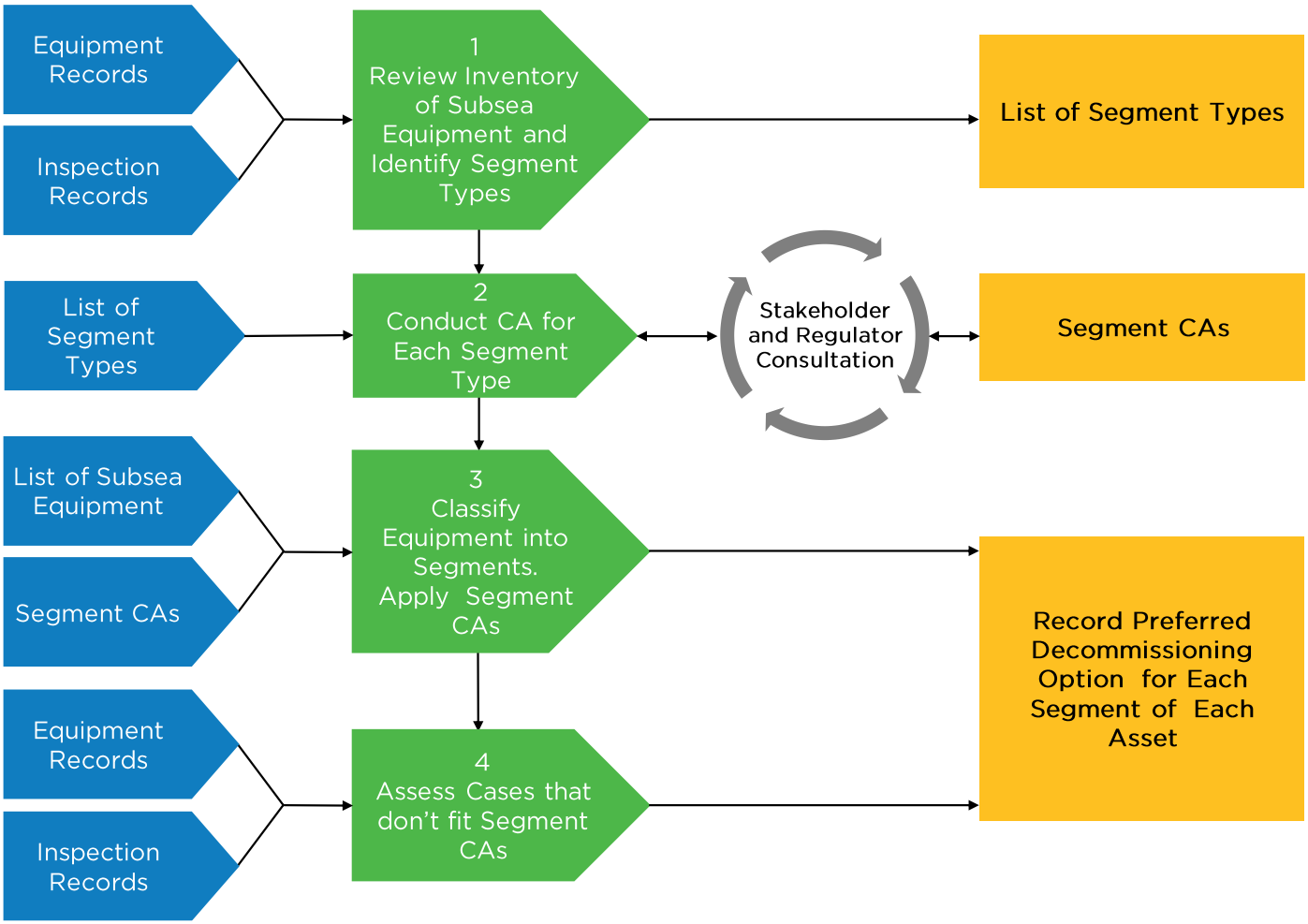
5.2 Process Development

Each subsea facility in the Brae Area can be considered as consisting of a number of different parts or segments. For example, a pipeline from a platform to a subsea well may consist of a portion of pipeline in the platform safety zone that is surface-laid and protected by mattresses or rock cover; an unprotected length of surface-laid pipeline; an SSIV within a protection structure; a portion of pipeline that is trenched and buried; a further surface-laid portion of pipeline; and a termination at a manifold or wellhead structure. The preferred decommissioning options for dealing with the various segments that make up the pipeline may differ. Marathon Oil's comparative assessment process recognises this and essentially consists of dividing the subsea facilities into segment types that can be assessed generically, rather than dealing with each facility in isolation. This approach is designed to promote consistency and maximise the efficiency of the process. The methodology consists of the following steps:

1. Reviewing the inventory of subsea facilities to identify generic "segments" that are logical sections into which the facilities may be classified.
2. Carrying out a comparative assessment for each segment type to determine the preferred decommissioning option for that segment, effectively developing a toolbox of preferred decommissioning options. In some instances, there may not be one preferred option for a particular segment; it may be that there are several options that are equally preferred.
3. Considering each subsea facility in turn by:
    - Breaking it down into its constituent segments.
    - Matching each of those segments with the appropriate segment type and the associated preferred decommissioning option.
    - Reviewing the facility as a whole to identify any opportunities to rationalise options. For example, if the comparative assessment process determines that 90% of a pipeline should be removed to shore and 10% should be buried, consideration will be given to removing 100% of the line.
4. Performing specific comparative assessments for any subsea facilities, or parts of subsea facilities that do not match the generic comparative assessments.
5. Documenting the order of preference of the decommissioning options determined by the comparative assessment process.

The overall comparative assessment process is illustrated in Figure 5.1.

Figure 5.1: Overall Comparative Assessment Process



The development of the subsea decommissioning CA toolbox involved an initial workshop with the stakeholders, and a number of subsequent workshops with Marathon Oil personnel (Section 6.3). At the initial workshop, Marathon Oil presented the proposed methodology to the stakeholders, and sought feedback on the approach and the impacts of the proposed decommissioning options in each stakeholder's particular area of interest. Marathon Oil consulted stakeholders and regulators at meetings outside the workshops to seek further clarification where necessary. During the course of developing the CA methodology, Marathon Oil personnel attended a number of industry conferences, and the information obtained at these conferences also informed the process. Marathon Oil consulted decommissioning contractors to better understand the available decommissioning techniques and their potential impacts. The feedback from stakeholders, regulators and contractors was used to refine and update Marathon Oil's proposed approach.

Marathon Oil conducted a further stakeholder workshop to specifically consider decommissioning options for the Central Brae subsea template. This workshop was particularly useful as it led to Marathon Oil identifying additional decommissioning options for this structure, one of which was subsequently identified as the preferred option.

Ongoing feedback from stakeholders, Subject Matter Experts and the regulators continues to provide support and refinement to the CA process and outcome. This process will continue to ensure that Marathon Oil delivers the most appropriate solution for each item of subsea equipment.

6. Segment Comparative Assessments

6.1 Approach

The Marathon Oil comparative assessment for subsea facilities generally aligns with the Oil and Gas UK guidance "Type A" approach [4]. This is a qualitative approach, in which each option is given a rating of "Most preferred / Lower impact", "Most preferred / Moderate impact", "Least preferred / Higher impact", or "No Significant Impact Across Options". These ratings are colour coded green, amber, red or grey, respectively as shown in Table 6.1.

Table 6.1: O&G UK "Type A" Approach

Performance	Comparative Impact
Most preferred	Lower impact
	Moderate impact
Least preferred	Higher impact
No preference	No significant impact across options

Marathon Oil supplemented the O&G UK "Type A" approach by assigning a score for each option against each criterion in line with the "Type B" approach. In the Marathon Oil methodology, the scores range from '0' for the least acceptable or least preferred option, to '1' for the most acceptable or most preferred option. Marathon Oil uses the scores to provide a higher degree of resolution in the ranking of multiple options against a single criterion than would be achieved by simply assigning the red, amber, green or grey classification from the strict "Type A" approach. Appendix 1 contains the details of the scoring scheme developed by Marathon Oil. The CA process does not use the scores to rank options across multiple criteria, nor aggregate scores to give an overall result as in the O&G UK "Type C" approach.

Each segment comparative assessment was performed by identifying the feasible decommissioning options for the segment, and considering each option against all of the assessment criteria, taking account of both short term and long term impacts. The Marathon Oil methodology used the experience of the personnel performing the CA, informed by consultation with relevant supply chain companies, specialist consultants, contractors and stakeholders to determine viable decommissioning methodologies for the various options and to understand the impacts that the methodologies have. The overall assessment of the preferred option is made by scoring all the options against each criterion in turn, and then identifying the preferred option by qualitatively considering the options against all of the criteria.

6.2 Comparative Assessment Criteria

Marathon Oil developed comparative assessment criteria [2] from guidance published by BEIS [1], and Oil and Gas UK [4]. The criteria are: Health and Safety; Environmental Impact; Technical Feasibility; Socio-Economic Impact, and; Economic Cost.

Economic Cost is not used as a prime differentiator. It is included for completeness and a measure of proportionality when considering the other four criteria.

An example of a completed assessment record is shown in Table 6.2. In this example, Option 1 scores better than Option 2 for "Risk to Personnel". In terms of the risk to other sea users, Options 1 & 2 score equally. Option 1 scores better than Option 2 for environmental impact. Option 1 scores better than Option 2 against the technical criterion. The 'socio-economic' factors are not strong differentiators as Options 1 and 2 score equally against these sub-criteria. Reviewing all of the criteria together demonstrates that overall Option 1, "Leave in Place as is", is the preferred option in this example.

Where subsea facilities have particular constraints, or do not match one of the generic segments, a specific comparative assessment will be completed by Marathon Oil to determine the preferred decommissioning option in that specific case. For example, the Braemar facilities, which are located adjacent to the Braemar Pockmarks Candidate Special Area of Conservation/Site of Community Importance conservation area, are in this category.

Table 6.2: Example CA Assessment

Top of Pipeline greater than 600mm below Mean Sea Bed level

Criteria	Sub-Criteria	Description	Option 1 Leave in Place as is	Option 2 Remove to Shore	Reasons for Ratings
Safety	Risk to Personnel	Safety risk to project personnel on and offshore during or as a result of the implementation of the Option	0.9-1.0	0.2-0.3	1 – Rated as 0.9-1.0 as general inspection will be required in perpetuity.
					2 – Recovering a pipeline which is in an unknown condition to a surface vessel is inherently hazardous; use of divers likely.
	Risk to Other Users	Safety risk to other users of the sea, such as fishing and other commercial vessels during or as a result of the Option	0.9-1.0	0.9-1.0	1 – Eventually the pipeline will collapse and leave a linear depression in the seabed.
					2 – Removing the pipeline and backfilling the trench may leave a linear depression in the seabed.
Environmental	Energy Consumption/ Emissions	Total energy used and emissions arising from each Option (includes implementation and embodied energy in materials)	0.80	0.40	1 – Taking cognisance of embodied energy and energy usage to monitor pipeline in perpetuity.
					2 – Significant vessel time for disinterring and recovering pipeline, resulting in high to moderate energy usage.
	Impacts of Option	Impacts to the environment during or as a result of the Option	0.9-1.0	0.20	1 – The acceptability rating recognises a small residual risk of contamination following eventual pipeline degradation and collapse. (Any contamination in this scenario is likely to take

Table 6.2: Example CA Assessment

Top of Pipeline greater than 600mm below Mean Sea Bed level

Criteria	Sub-Criteria	Description	Option 1 Leave in Place as is	Option 2 Remove to Shore	Reasons for Ratings
					place over an extended timescale).
					2 – This option extensively disturbs the seabed during uncovering pipe and backfilling trench. The operations generate noise over a long duration. Potential to release contaminates from pipe into water column in a short period of time.
Technical	Technical Feasibility / Challenge	Is the Option technically feasible; to what extent does the Option make use of proven technology; is it likely to fail?	1.00	0.50	1 – Requires no activity.
					2 – Assumes pipeline will be un-trenched and cut into manageable sections and lifted to surface.
Socio-Economic	Commercial Impact on Fisheries	Impacts both during the implementation and as a result of the Option on commercial fisheries	1.00	0.9-1.0	1 – No change from status quo.
					2 – Recognises the potential disturbance to fisheries while the operation is in process.
	Wider Community Impact	Impacts on the health, well-being, standard of living, structure or coherence of communities both during the implementation and as a result of the Option	0.90	0.90	1 – Recognises that there are no opportunities for employment associated with this option, but there is no disturbance to onshore communities.
					2 – Recognises benefits of employment in recovery and recycling, and the potential nuisance to onshore communities from transportation, recycling etc.
Economic	Total Project Cost	Total costs incurred during the implementation and as a result of the Option	0.90	0.10	1 – Recognises the costs associated with monitoring pipelines post-decommissioning.
					2 – Recognises that high costs will be associated with removing pipeline.

6.3 Workshops

Marathon Oil conducted a stakeholder workshop to explain the subsea facilities decommissioning comparative assessment process and to obtain feedback on the proposed process. Individual consultations were also held with stakeholders. These were either consultations with stakeholders who could not attend the workshop, or additional consultations with key stakeholders. The objectives of the workshop and consultations were twofold. Firstly, Marathon Oil wished to present the Subsea Decommissioning Comparative Assessment methodology and to obtain stakeholders' views on the proposed process. Secondly, Marathon Oil wished to understand stakeholders' particular interests regarding the impacts of decommissioning.

The following external bodies were consulted during the development of the process:

- Department for Business, Energy & Industrial Strategy (BEIS), ODU and EMT
- Greenpeace
- Health and Safety Executive
- Joint Nature Conservation Committee
- Marine Scotland
- National Federation of Fishermen's Organisations
- Scottish Environment Protection Agency
- Scottish Fishermen's Federation

The segment comparative assessments were carried out in a number of workshop attended by appropriate Marathon Oil Subject Matter Experts and external consultants. These sessions took place between April and August 2015.

The attendees present at each workshop determined the level of acceptability of each decommissioning option against each of the assessment criteria. Consistency was assured by using the same core team of personnel at each workshop, supplemented by others as required, and by reviewing previous workshops' records.

The levels of acceptability for all of the decommissioning options for a particular segment were recorded in a comparative assessment table using a numerical scale. This scale was used in the workshops to provide greater resolution than a simple light system, and to provide an indication of where a particular decommissioning option lay on the scale of acceptability. The numerical values were not used for comparison between criteria, nor were they summed to give an overall rating for an option. Following the workshops, the record tables were colour-coded to make the results more obvious. The scoring and colour-coding scheme is shown in Appendix 1. The selection of the preferred decommissioning option for a particular segment was made by the team in the workshop, considering the relative acceptability of the decommissioning options against all of the criteria in aggregate. The decommissioning options were ranked in order of preference based on this team assessment.

The preferred decommissioning option for each segment type is tabulated in Table 7.1 in Section 7. The completed comparative assessment records from the workshops are contained presented in a separate report [11]. The record of each segment comparative assessment includes notes of why the acceptability level was chosen for each decommissioning option, and how the overall preferred option was selected. The final decommissioning options recorded in Table 7.1 have been selected on the basis of the workshops and subsequent discussions with BEIS, other stakeholders and appropriate Marathon Oil personnel.

6.4 Subsea Segments

The generic segments for the subsea facilities were determined from the engineering and inspection records for the subsea facilities within the Brae Area. Table 6.3 contains the resulting list of segments.

Table 6.3: Subsea Asset Segments

Segment Type	Notes
Fabricated Steel Structure	Fabricated steel structures are used to provide support to subsea equipment, including valves, manifolds and subsea well templates, and to provide protection from dropped objects and damage from impact by fishing gear. Some structures are classed as installations and others as part of a pipework system depending upon their operational requirements.
Buried/Trenched Pipeline	A trenched pipeline is laid into a trench in the seabed, which may then be backfilled with seabed material or left open. If a trench is left open it may backfill over time due to the action of tides and currents. A trenched pipeline may also be protected by rock cover. The purpose of protection is to prevent fishing gear or dropped objects coming into contact with the pipeline. Trenching may also be used to stop a pipeline from moving laterally on the seabed. In this instance, rock cover or other means are likely to be required to keep the pipeline on the seabed. In the Brae Area, trenched pipelines typically connect subsea wells to platforms or subsea manifolds.
Surface-Laid Pipeline	A surface-laid pipeline is laid onto the seabed; it is not trenched, buried or protected by rock cover or mattresses. The surface-laid pipeline segments in the Brae Area are the large export pipelines, and the pipelines between the platforms. There may be short segments of other pipelines, for example flowlines from wells that are surface-laid inside the platform safety zones.
Fishing-Critical Span	A span is a length of pipeline, umbilical or cable that is not directly in contact with the seabed. Spans can occur if the seabed is scoured away by the action of currents, or if the pipeline, umbilical or power cable buckles because of thermal effects or other causes. A fishing-critical span is a span that is large enough to trap fishing gear. This can be a significant hazard to fishermen.
Integrity Critical Span	An integrity-critical span is a span that does not present a hazard to fishermen, but can cause failure of the pipeline, umbilical or cable. If such a failure occurs, the failed pipeline can present a hazard to fishermen. (Note: a span can be both fishing-critical, and integrity-critical).
Non-Critical Span	A non-critical span is one that is neither fishing-critical, nor integrity-critical. It may develop over time into a critical span.
Buried / Trenched Cable	The Brae platforms are connected by an electrical ring main made up of subsea cables. These cables are trenched and buried to protect them.
Cable on Surface	The Brae Area subsea electrical cables are surface-laid for part of their length within the platform safety zones.

Table 6.3: Subsea Asset Segments	
Buried/Trenched Umbilical	Typically, umbilicals are trenched and buried between the Brae platform safety zones and the subsea facilities that they serve. The exceptions to this are the umbilicals to the SSIVs as these lie entirely within the safety zones.
Umbilical on Surface	Umbilicals are on the surface within the Brae platform safety zones and for the last few metres to the subsea facilities that they serve.
Live Crossing	A live crossing occurs where a Marathon Oil pipeline, umbilical or cable crosses, or is crossed by, a third-party pipeline or cable that is still in use.
Dead Crossing	A dead crossing occurs where a Marathon Oil pipeline, umbilical or cable crosses, or is crossed by, another Marathon Oil facility or a third-party pipeline or cable that is no longer in use.
Concrete Mattress	Concrete mattresses are used to stabilise and protect subsea pipelines cables and umbilicals. Various mattress types are installed in the Brae Area.
Grout Bag	Grout bags are effectively sand bags that are dry-filled with cement grout.
Concrete Block/Cover/Tunnel (Hazardous to Fishermen)	Various concrete structures are in use in the Brae Area to support and protect other subsea facilities. Very large concrete items are a snagging hazard for fishermen; smaller concrete items can be a hazard to fishermen if they are lifted in fishing nets.

The number of subsea segments was rationalised during the course of the comparative assessment workshops. For instance, initially pipeline spans, umbilical spans, and cable spans were considered separately. However, it was subsequently determined that there are no significant differences between spans in these different types of subsea facilities. Similarly, “overtrawlable” and “non overtrawlable” fabricated structures were initially assessed as different segments. However, over the course of time overtrawlable structures may deteriorate and become non-overtrawlable. Therefore, Marathon Oil considered fabricated structures as one segment for comparative assessment purposes.

6.5 Decommissioning Options

The workshops identified decommissioning options for the subsea facility segments. The decommissioning and disposal options for all of the segments can be characterised into the following main categories:

- Remove to shore
- Reuse or recycle offshore
- Trench in place
- Rock cover in place
- Leave in place as is

Not all of these options are necessarily relevant to all segments. The specific decommissioning options selected for each segment comparative assessment were recorded on the individual comparative assessment record sheets [11]. The comparative assessment only considered viable decommissioning options; that is, methodologies and technologies that have been proven in offshore decommissioning projects. Marathon Oil will keep developing methodologies and technologies under review and will revisit the comparative assessments if further options are demonstrated to be viable.

7. Comparative Assessment Conclusions

Table 7.1 presents the conclusions from the comparative assessment. This defines the options for the equipment segments that make up the Brae Area subsea inventory, and the preferred decommissioning methods as identified by the comparative assessment.

These conclusions have been formulated following the initial stakeholder workshop, which identified the key issues associated with the decommissioning options for the various subsea equipment segments, and allowed stakeholders to communicate their views.

These topics were carried forward into subsequent workshops with Marathon Oil's SMEs and specialist consultants to identify decommissioning options for subsea equipment segments. The conclusions reached in the workshops regarding the preferred options were subsequently refined and developed following further consultations with stakeholders, particularly the fishing industry, BEIS as the responsible regulator and industry bodies. Marathon Oil also consulted decommissioning contractors, and used information from industry conferences and publications in formulating the final preferred decommissioning options. The refinements from this ongoing review and challenge are associated with:

- Mattresses and grout bags reuse, recycle and disposal options.
- Treatment of large, piled subsea structures.
- Management of equipment within the proposed post-decommissioning safety zones.
- Utilisation of gates on long surface-laid trunk lines to facilitate un-impeded transit of demersal fishing gear.

7.1 Brae Area Subsea Assets CA Toolkit

The data in Table 7.1 is the culmination of the comparative assessment and subsequent risk assessment process that is described within this document. This table provides the decision support for the decommissioning scope for each of the segments within the Brae Area. For each segment type, the 1st preference is the default option. If, based on the criteria detailed in columns A and B this preference is not appropriate, applicable or achievable, then the 2nd preference listed in column C is selected. If the second preference is not appropriate, applicable or achievable when assessed against the details in columns C and D, then the 3rd preference in column E is selected, etc. Note: Not all segments of the same type will have the same preferred option as there may be unique or specific factors that influence the preference.

Table 7.1: CA Conclusions

	Column A	Column B	Column C	Column D	Column E	Column F	Column G
Segment	1st Preference (Most Preferred)		2nd Preference		3rd Preference		4th Preference (Least Preferred)
A.1: Fabricated Steel Structures (forming part of pipelines)	If a structure is in a post-decommissioning safety zone, in close proximity to sub-structure footings, and risk assessment shows risks of leaving in place are ALARP, leave in place	If structure is not candidate to remain in place then…	Remove to shore	If structure cannot be removed to shore then…	Profile with rock cover in place or bury	-	-
A.2: Fabricated Steel Structures (forming, or part of installations)	Remove. If it is technically challenging, or poses significant safety risk to remove a structure, complete an asset specific comparative assessment and risk assessment to determine most appropriate, balanced decommissioning option.						

Table 7.1: CA Conclusions

	Column A	Column B	Column C	Column D	Column E	Column F	Column G
Segment	1st Preference (Most Preferred)		2nd Preference		3rd Preference		4th Preference (Least Preferred)
B.1.1: Buried/Trenched Pipeline (Top of pipe more than 600mm below seabed)	Leave in place (make safe any exposed ends)	If the pipeline is deemed to pose an intolerable risk to other sea users, then…	Retrench in place	If the risk to other sea users cannot be addressed by trenching, then…	Rock cover in place	If the risk to other sea users cannot be addressed by rock cover, then…	Remove to shore
B.1.2: Buried/Trenched Pipeline (Top of pipe less than 600mm below seabed)							
B.2.1.1: Surface-Laid Pipeline (Mattress/grout bag stabilisation)	If a pipeline is in a post-decommissioning safety zone, in close proximity to sub-structure footings, and risk assessment shows risks of leaving in place are ALARP, leave in place	If pipeline is not candidate to remain in place then…	Remove mattresses/grout bags (See G.1 & G.2 for treatment of mattresses and grout bags). Remove pipeline to shore.	If it is not practicable to move or remove mattresses/grout bags and remove pipeline to shore, then…	Rock cover or trench pipeline in place	-	-
B.2.1.2: Surface-Laid Pipeline (Rock cover stabilisation/protection)	Leave in place (make safe any exposed ends)	If rock covered pipeline presents an intolerable risk to other sea users, then…	Move or remove rock cover and trench pipeline in place	If it is not possible to trench pipeline in place, then…	Move or remove rock cover and remove pipeline to shore	-	-

Table 7.1: CA Conclusions

	Column A	Column B	Column C	Column D	Column E	Column F	Column G
Segment	1st Preference (Most Preferred)		2nd Preference		3rd Preference		4th Preference (Least Preferred)
	BEIS guidance recognises rock covered pipelines as candidates for leaving in place.						
B.2.2: Surface-Laid Pipeline (No rock cover stabilisation/protection)	Trench in place	If trench in place is not feasible, reasonably practicable or possible, then…	Leave pipeline in place	If leaving pipeline in place presents an intolerable risk to fishermen, then…	Rock cover in place	If line length is short, for example a tie in spool, then…	Recover to shore
	BEIS guidance recognises "Trunk" lines as candidates for decommissioning in place on the seabed. The definition of a trunk line is taken to be that given by Oil and Gas UK [6]. Depending on the length of a surface-laid pipeline it may be possible to clear "gates" through the pipeline for fishing access by either trenching or rock covering short lengths of the pipeline.						
C.1: Fishing-Critical Span (Pipeline, cable or umbilical)	Cut out span and remove to shore (make safe any exposed ends)	If the span is short and less material is required to cover the entire span than to cover the exposed cut ends, then…	Rock cover full span in place	-	-	-	-

Table 7.1: CA Conclusions

	Column A	Column B	Column C	Column D	Column E	Column F	Column G
Segment	1st Preference (Most Preferred)		2nd Preference		3rd Preference		4th Preference (Least Preferred)
C.2: Integrity-Critical Span (Pipeline, cable or umbilical)	Cut out span and remove to shore (make safe any exposed ends)	If the span is short and less rock is required to cover the entire span than to cover the exposed cut ends, then…	Rock cover full span in place	-	-	-	-
C.3: Non-Critical Span (Pipeline, cable or umbilical)	Leave in place and monitor	If monitoring demonstrates the span is growing to the point where it will become fishing or integrity-critical, then…	Cut out span and remove to shore (make safe any exposed ends)	If the span is short and less rock is required to cover the entire span than to cover the exposed cut ends, then……	Rock cover full span in place	-	-
D.1: Buried/Trenched Cable (Top of cable below seabed level)	Leave in place (make safe any exposed ends)	If the cable is deemed to pose an intolerable risk to other sea users, then…	Remove to shore	-	-	-	-

Table 7.1: CA Conclusions

	Column A	Column B	Column C	Column D	Column E	Column F	Column G
Segment	1st Preference (Most Preferred)		2nd Preference		3rd Preference		4th Preference (Least Preferred)
D.2: Surface-Laid Cable (Mattress/grout bag stabilisation)	If a cable is in a post-decommissioning safety zone, in close proximity to sub-structure footings, and risk assessment shows risks of leaving in place are ALARP, leave in place	If cable is not candidate to remain in place then…	Remove mattresses/grout bags (See G.1 & G.2 for treatment of mattresses and grout bags). Remove cable to shore	If it is not practicable to move or remove mattresses/grout bags and remove cable to shore, then…	Rock cover or trench cable in place	-	-
E.1: Buried/Trenched Umbilical (Top of umbilical below seabed level)	Leave in place (make safe any exposed ends)	If the umbilical is deemed to pose an intolerable risk to other sea users, then…	Remove to shore	-	-	-	-

Table 7.1: CA Conclusions

	Column A	Column B	Column C	Column D	Column E	Column F	Column G
Segment	1st Preference (Most Preferred)		2nd Preference		3rd Preference		4th Preference (Least Preferred)
E.2.1: Surface-Laid Umbilical (Mattress/grout bag stabilisation)	If a umbilical is in a post-decommissioning safety zone, in close proximity to sub-structure footings, and risk assessment shows risks of leaving in place are ALARP, leave in place	If umbilical is not candidate to remain in place then…	Remove mattresses/grout bags (See G.1 & G.2 for treatment of mattresses and grout bags). Remove umbilical to shore	If it is not practical to remove mattresses/grout bags and remove umbilical to shore, then…	Rock cover or trench umbilical in place	-	-
E.2.2: Surface-Laid Umbilical (Rock cover stabilisation)	Leave in place (make safe any exposed ends)	If rock covered umbilical presents an intolerable risk to other sea users, then…	Remove rock cover and trench umbilical in place	If it is not feasible or reasonable to trench umbilical in place, then…	Remove rock cover and remove umbilical to shore	-	-
F.1: Live Crossing (Marathon asset crossing a live third-party asset)	Leave until the third-party facility is decommissioned and then decommission as a dead crossing.						
F.2: Dead Crossing (All lines in crossing are dead)	Treat crossing components as per the preferred options for the individual components of the crossing						

Table 7.1: CA Conclusions

	Column A	Column B	Column C	Column D	Column E	Column F	Column G
Segment	1st Preference (Most Preferred)		2nd Preference		3rd Preference		4th Preference (Least Preferred)
G.1: Unburied Concrete Mattress	Reuse mattress to stabilise equipment in post-decommissioning safety zone	If the mattress cannot be reused in a post-decommissioning safety zone, then…	Recycle mattress to remediate seabed depressions following removal of structures or remediate pipeline spans	If mattress cannot be reused or recycled offshore, then…	Remove to shore for recycling or disposal	If mattresses cannot be removed then…	Bury in place
G.2: Unburied Grout Bag	Reuse grout bag to stabilise equipment in post-decommissioning safety zone	If the grout bag cannot be reused in a post-decommissioning safety zone, then…	Recycle grout bag to remediate seabed depressions following removal of structures or remediate pipeline spans	If the grout cannot be reused or recycled offshore, then…	Remove to shore for recycling or disposal	If grout bags cannot be removed then…	Bury in place

Table 7.1: CA Conclusions

	Column A	Column B	Column C	Column D	Column E	Column F	Column G
Segment	1st Preference (Most Preferred)		2nd Preference		3rd Preference		4th Preference (Least Preferred)
G.3/G.4: Concrete Block/Cover/Tunnel/support	If a concrete component is in a post-decommissioning safety zone, in close proximity to sub-structure footings, and risk assessment shows risks of leaving in place are ALARP, leave in place	If concrete component is not candidate to remain in place then…	Remove component to shore for recycling or disposal	If the component cannot be moved, then…	Bury or rock cover in place		

8. References

[1] Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998, Version 6, DECC, March 2011.

[2] Brae Field Decommissioning Comparative Assessment Process, 9000-MIP-99-PM-RT-00003-000, Marathon Oil Decommissioning Services LLC, November 2014.

[3] Guidelines on Stakeholder Engagement during Decommissioning Activities, EN025, O&G UK, 2013.

[4] Guidelines for Comparative Assessment in Decommissioning Programmes, Oil and Gas UK, October 2015.

[5] http://fishsafe.eu/en/home.aspx

[6] Decommissioning of Pipelines in the North Sea Region 2013, Oil and Gas UK.

[7] Brae Alpha Sub-Structure Comparative Assessment, 9020-MIP-PM-TT-00001-000, Marathon Oil Decommissioning Services LLC.

[8] Brae Bravo Sub-Structure Comparative Assessment, 9010-MIP-PM-TT-00004-000, Marathon Oil Decommissioning Services LLC.

[9] East Brae Sub-Structure Comparative Assessment, 9030-MIP-PM-TT-00001-000, Marathon Oil Decommissioning Services LLC.

[10] Brae Area Drill Cuttings Piles: Evaluation and Management Including Comparative Assessment Using Net Environmental Benefit Analysis, 9000-RMB-99-EV-RT-00001-000, Marathon Oil Decommissioning Services LLC.

[11] Brae Area Subsea Facilities Decommissioning Option Comparative Assessment Workshop Record 0000-MIP-99-PM-RT-00008-000, Marathon Oil Decommissioning Services LLC.

[12] Risk Assessment of Leaving Decommissioned Equipment in Place Adjacent to Sub-Structure Footings, 9000-MIP-99-PM-RA-00002-000, MMI Engineering Limited.

[13] East Brae Subsea Facilities Decommissioning Comparative Assessment 9030-MIP-99-PM-FD-00001-000, Marathon Oil Decommissioning Services LLC.

[14] Brae Alpha And Brae Bravo Subsea Facilities Decommissioning Comparative Assessment, 9000-MIP-99-PM-FD-00004-000, Marathon Oil Decommissioning Services LLC.

Appendix 1 – Scoring Scheme

Table A1.1: CA Scoring Scheme												
Risk Factor Criteria	Nature of Assessment	Sub Criteria	Description	Level of Acceptability										
				Low				Moderate						High
				0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Safety	Mainly Quantitative	Risks to personnel	Safety risk to project personnel on and offshore during or as a result of the implementation of the Option	A region of high risk – considered unacceptable whatever the level of benefit associated with the activity. Risk is deemed intolerable.				A region of intermediate risk – tolerable region where people are prepared to tolerate the risk to secure the benefits.				A region of low risk – broadly acceptable region risks in this area are generally regarded as insignificant and adequately controlled.		
		Risks to other users	Safety risk to other users of the sea such as fishing and other commercial vessels during or as a result of the Option											
Environ-mental	Quantitative / Qualitative	Energy Consumption / Emissions	Total energy used and emissions arising from each Option (includes implementation and embodied energy in materials)	High energy consumption / emissions				Moderate energy consumption / emissions				Low energy consumption / emissions		
		Impacts of Options	Impacts to the environment during or as a result of the Option	The proposed operations cause significant environmental disturbance that is widespread and / or long-lasting.				The proposed operations cause some, possibly significant, environmental disturbance that is localised and of short duration.				The proposed operations may provide a benefit, no change or at worst negligible environmental impacts.		

Table A1.1: CA Scoring Scheme						
Technical	Mainly Qualitative	Technical Feasibility/ Challenge	Is the Option technically feasible and to what extent does the Option make use of proven technology	Equipment and techniques have no track record, or global shortage of resources, or high probability of failure.	Equipment and techniques have a limited track record or require development, or resources not available locally, or possibility of failure.	Equipment and techniques are known and have a track record of success, and resources plentiful, and failure extremely unlikely.
Socio-Economic	Mainly Qualitative	Commercial Impact on Fisheries	Impacts both during the implementation and as a result of the Option on commercial fisheries	There is a significant disamenity.	The proposed operations may result in small impacts.	There are tangible positive benefits or possibly no discernible negative impacts.
		Wider Community Impact	Impacts on the health, well-being, standard of living, structure or coherence of communities both during the implementation and as a result of the Option			
Economic	Quantitative	Total Project Cost	Total costs incurred during the implementation and as a result of the Option	Cost is an important metric, but it is not used as a prime differentiator. It is included for completeness and a measure of proportionality when considering the other four criteria.		

9000-MIP-99-PM-FD-00003-000, I03

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