Gaupe
Decommissioning Programme
Comparative Assessment Report

REVISION RECORD

Revision	Description of Revision	Date
R01	First draft, extracted from Armada Hub Decommissioning Project Comparative Assessment Emerging Recommendations Report	24.08.17
A01	Added additional detail on current protection status of pipelines and umbilicals in line with BEIS comments (Section 3.1 and 3.2)	11.10.17
A02	Updated for public consultation, reflecting the change of CoP date	06.03.20

CONTENTS

LIST OF TABLES

LIST OF FIGURES

This page intentionally left blank

1.0 EXECUTIVE SUMMARY

This document sets out the details of the comparative assessment (CA) of feasible decommissioning options carried out for the Gaupe subsea pipelines and umbilicals. It supports the draft Decommissioning Programme for the UK infrastructure associated with the Gaupe subsea tieback [1] to be submitted to the Department of Business, Energy and Industrial Strategy (BEIS) Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) and the statutory and public consultation which accompanies this.

The Gaupe field was discovered in 1984 and started production in 2012. Production from two drill centres on the NCS (Gaupe North and Gaupe South) is routed through separate pipelines to a commingling subsea isolation valve (SSIV) manifold inside the 500m safety zone at Armada, and from there via a flexible production riser to Armada. Two separate umbilicals provide electro-hydraulic control and chemical injection.

Production from Gaupe was temporarily suspended in August 2018. After discussions regarding potential future use were unsuccessful, Cessation of Production (CoP) was declared on 17th December 2019 with notification to the Norwegian Ministry of Petroleum and Exploration (MPE).

The Armada Hub consists of a four-legged, steel-piled jacket and an integrated deck installed in 89m of water in the UK Continental Shelf (UKCS). The Armada Hub is owned and operated by different parties than the Gaupe tieback. The Armada Hub is currently producing with no current plans for Cessation of Production.

This CA covers the Gaupe subsea infrastructure on the UKCS only.

The following emerging recommendations for the subsea infrastructure are based on a comprehensive comparative assessment conducted in accordance with the OPRED Guidance Notes on Decommissioning and the Oil and Gas UK Guidelines on Comparative Assessment.

Recommended Options

1. The trenched and buried pipelines PL2781 and PL2782 will be decommissioned *in situ* with the pipeline ends removed and returned to shore for recycling or disposal;
2. The Gaupe umbilicals (PLU2784 & 2785), trenched and naturally backfilling, will be decommissioned *in situ* with the ends removed and returned to shore for recycling or disposal.

All other infrastructure (outwith the scope of the comparative assessment) will be removed during the decommissioning works:

- All tie-in spools and control jumpers will be removed and recovered to shore;
- All production risers and umbilical risers will be removed and recovered to shore;
- All subsea structures will be removed and recovered to shore;
- It is intended that all mattresses and grout bags will be removed to shore; however, in the event of practical difficulties, OPRED will be consulted.

2.0 INTRODUCTION

2.1 Purpose

This document is intended to provide a record of the comparative assessment carried out for the pipelines and umbilicals associated with the Gaupe Decommissioning Project.

It describes the infrastructure to be decommissioned, the options considered, the comparative assessment (CA) method used and the findings of the comparative assessment.

This Comparative Assessment Report is one of three documents submitted for consultation in support of the Gaupe Decommissioning Project Draft Decommissioning Programme [1] and the Environmental Impact Assessment Report [2]. Upon submission, each of these documents will be available online, on request from Shell and, during the consultation, available for inspection at locations to be advised. Other references cited within each of the documents will also be made available to consultees for inspection by prior arrangement with Shell.

The decommissioning options for the pipelines and umbilicals have been subjected to a process of comparative assessment in order to determine the best method of decommissioning in compliance with the OPRED Guidance Notes [3].

For the purposes of the comparative assessment process, the pipelines and umbilicals were grouped into the following categories to be assessed separately:

- Group A1 - trenched and buried pipelines
- Group A2 - trenched umbilicals with natural backfill

2.2 Regulatory Context

The decommissioning of offshore oil and gas installations and pipelines on the United Kingdom Continental Shelf (UKCS) is controlled through the Petroleum Act 1998, as amended by the Energy Act 2008.

The UK's international obligations on decommissioning are governed principally by the 1992 Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR Convention). Agreement on the regime to be applied to the decommissioning of offshore installations in the Convention area was reached at a meeting of the OSPAR Commission in July 1998 (OSPAR Decision 98/3). The OPRED Guidance Notes [3] align with OSPAR Decision 98/3.

Pipelines do not fall within the remit of OSPAR Decision 98/3 but OPRED requires that operators apply the OSPAR framework when assessing pipeline decommissioning options.

Because of the widely different circumstances of each case, OPRED does not predict with any certainty what decommissioning strategy may be approved in respect of any class of pipeline. Each pipeline must therefore be considered on its merits and in the light of a CA of the feasible options, taking into account the safety, environmental, technical, societal and cost impacts of the options. Cost may only be a determining factor when other criteria emerge as equal.

In accordance with OSPAR Decision 98/3, the Gaupe SSIV manifold will be completely removed and returned to shore for recycling and disposal. This is not subject to derogation

and, as such, the decommissioning methods being considered do not need to be comparatively assessed.

2.3 Overview of Field

The Gaupe Field is located in the Norwegian sector of the North Sea and operated by Shell Norge. Production from the Gaupe field started in 2012 and CoP was declared 17th December 2019. The development consists of two production wells, Gaupe North and Gaupe South, located on the Norwegian Continental Shelf (NCS) at a water depth of approximately 85m.

Well stream fluids are routed through separate "pipe-in-pipe" flowlines to a subsea commingling manifold located on the UK Continental Shelf (UKCS) and about 300m from the Armada platform. From there, production fluid is routed to the Armada Hub topsides via a flexible production riser.

Power, chemical injection and hydraulic control of the wells and SSIV is provided from the Armada Hub topsides via an umbilical riser to the SSIV manifold and, from there, separate Electro-Hydraulic Control umbilicals to the two drill centres.

The Armada Hub consists of a four-legged, steel-piled jacket and an integrated deck installed in 89m of water in the UK Continental Shelf (UKCS). The Armada Hub is owned and operated by different parties than the Gaupe tieback. The Armada Hub is currently producing with no current plans for Cessation of Production.

This CA covers the Gaupe subsea infrastructure on the UKCS only.

The location of the Gaupe fields, Armada Hub and hydrocarbon export routes are shown in Figure 1 and the Gaupe Field is shown in Figure 2. A schematic of the Armada Hub including the Gaupe field and nearby tie-backs is shown in Figure 3.

Two 24.6km export pipelines transport gas and condensate to the Central Area Transmission System (CATS) Riser Platform which is bridge-linked to the North Everest Platform.

Lundin are partners for Gaupe which is operated by Shell Norge.

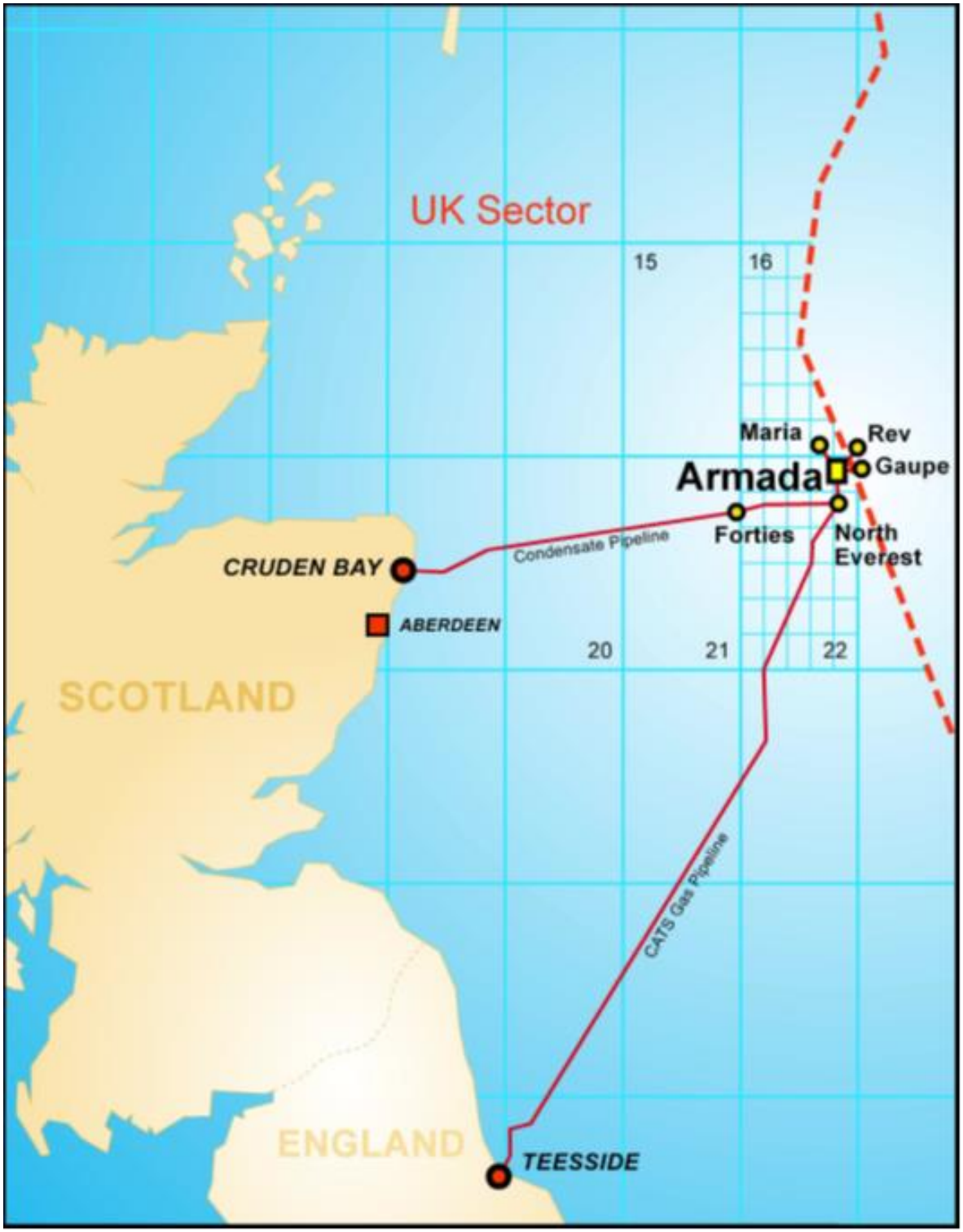


Figure 1 – Location of the Gaupe tieback and Armada Hub

Figure 2 – Location of the Gaupe Field

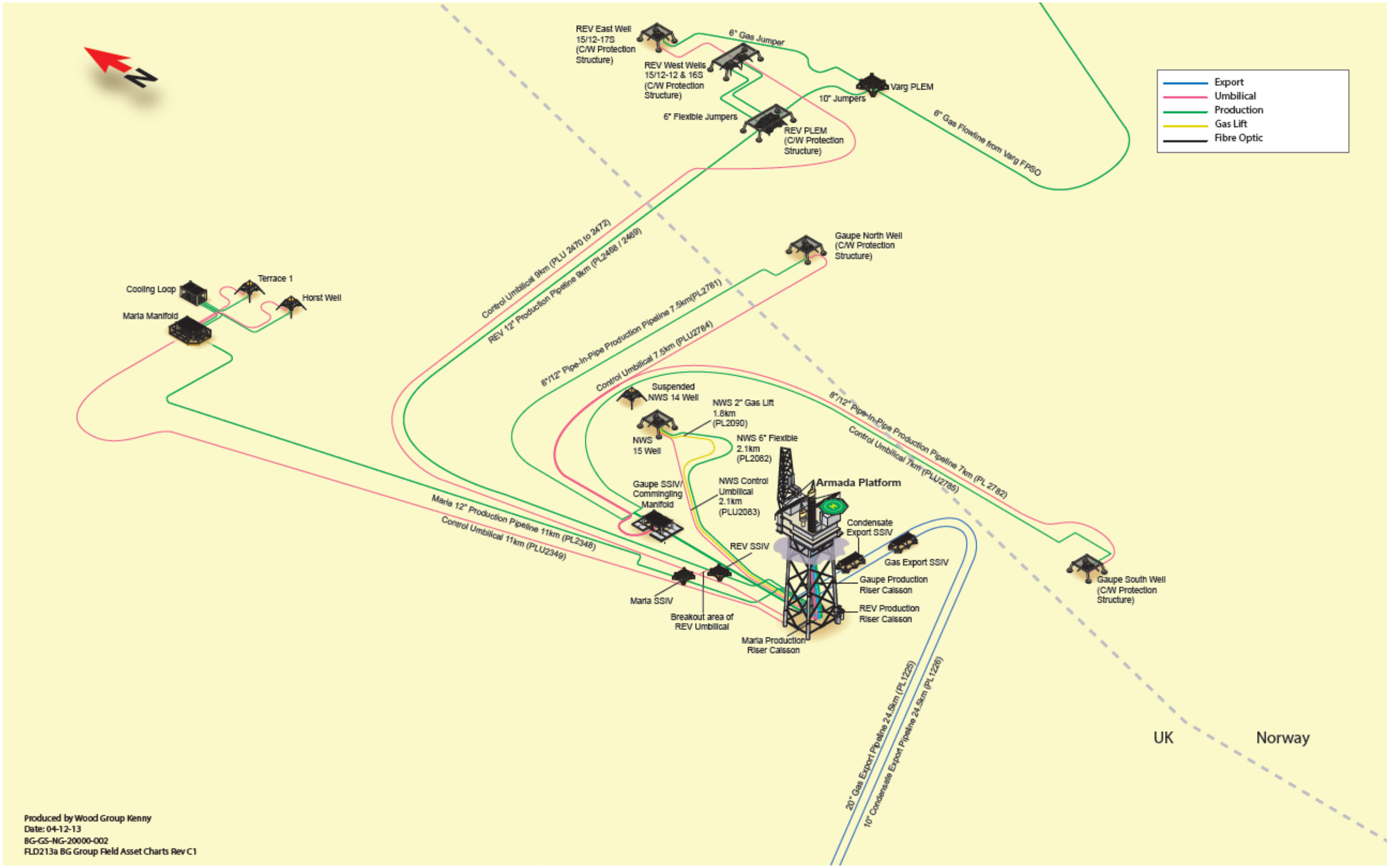


Figure 3 – Layout of the Armada Hub and Third Party Fields

3.0 INFRASTRUCTURE

The following infrastructure, although outwith the scope of the comparative assessment, will be removed during the decommissioning programme, with the sequence and timing of operations subject to confirmation[1]:

- The Gaupe SSIV manifold within the Armada 500m safety zone;
- All tie-in spools and jumpers;
- The flexible production and umbilical risers in J-tubes within the jacket;
- All mattresses and grout bags

3.1 Pipelines

Number	Description	Protection Status
PL2781	8”/12” pipe-in-pipe production pipeline from Gaupe North to Armada (9km) – only the pipeline within the UK Sector (from approximately KP 3.2) is included in this programme	Trenched and buried with mattresses at each end, 9 separate areas of rock-cover totalling 533m to prevent upheaval buckling
PL2782	8”/12” pipe-in-pipe production pipeline from Gaupe South to Armada (7km) – only the pipeline within the UK Sector (from approximately KP 1.9) is included in this programme	Trenched and buried with mattresses at each end, 6 separate areas of rock-cover totalling 260m to prevent upheaval buckling

Table 1 – Pipeline Numbers and Descriptions

Production is routed back to the Armada Hub via the production pipelines noted in Table 1. Production gas is then exported to the CATS Riser platform and from there into the FLAGS export system to St Fergus terminal.

Both Gaupe pipelines were trenched and buried using a towed plough and backfill plough, successfully achieving a typical depth-of-cover of 1.8m along their length. In addition, there are a number of rock covered sections to prevent upheaval buckling. The locations of these rock-covered sections are detailed for each pipeline in Section 6.

As part of decommissioning, all pipelines will be cleaned of hydrocarbons and chemicals to a level of cleanliness demonstrating ALARP.

All tie-in spools, jumpers, mattresses and grout bags will be removed, recovered to the surface and returned to shore for recycling and disposal.

[1] An indicative timetable is shown within the Draft Decommissioning Programme [1]

3.2 Umbilicals

Number	Description	Protection Status
Umbilicals		
PLU2784	Gaupe North Umbilical – only the umbilical in the UK Sector (up to approximately KP 4.3) will be included in this programme	Trenched and natural backfill with mattresses at each end
PLU2785	Gaupe South Umbilical – only the umbilical in the UK Sector (up to approximately KP 5.2) will be included in this programme	Trenched and natural backfill with mattresses at each end

Table 2 – Umbilical Numbers and Descriptions

Umbilicals supply electric-hydraulic control and chemical injection to the SSIV and wells as per Table 2.

The Gaupe umbilicals were installed in pre-cut (ploughed) trenches. The two umbilicals share a common trench from the SSIV. The Gaupe South umbilical continues in this trench while the Gaupe North umbilical has a short surface-laid section before it enters a separate trench to Gaupe North. This surface-laid section of the Gaupe North umbilical was subsequently rock-covered for protection.

The Gaupe umbilicals have a depth-of-lowering of more than 1m. The umbilicals were installed in the open trenches and allowed to backfill naturally. Depth of cover for Gaupe South is typically between 0.3 and 0.5m from KP0 to KP2, and between 0.5m and 1.0m from KP2 to Gaupe South. Depth of cover has increased steadily since installation and is expected to continue to do so.

Where practicable, umbilical cores will be flushed and cleaned during decommissioning activities to achieve cleanliness levels demonstrating ALARP. There are a number of cores with known blockages or leaks which may prevent the contents from being flushed, as discussed in the Environmental Impact Assessment [2].

All umbilical jumpers will be removed, recovered to the surface and returned to shore for recycling and disposal.

3.3 Crossings

There are no crossings associated with the Gaupe production flowlines or umbilicals.

4.0 COMPARATIVE ASSESSMENT METHODOLOGY

The Gaupe Decommissioning comparative assessment has been carried out in compliance with the Comparative Assessment Guideline [4] and the OPRED Guidance Notes [3], with the project specific process outlined in the Armada Hub Decommissioning Project CA Procedure [5]. The Guideline provided the framework for the project's CA process and ensured the steps were fully aligned with the project's internal Value Assurance Framework (VAF) Standard.

The Guideline [4] required that a CA was conducted for each infrastructure group as identified in Section 4.1, following the process outlined in Figure 4.

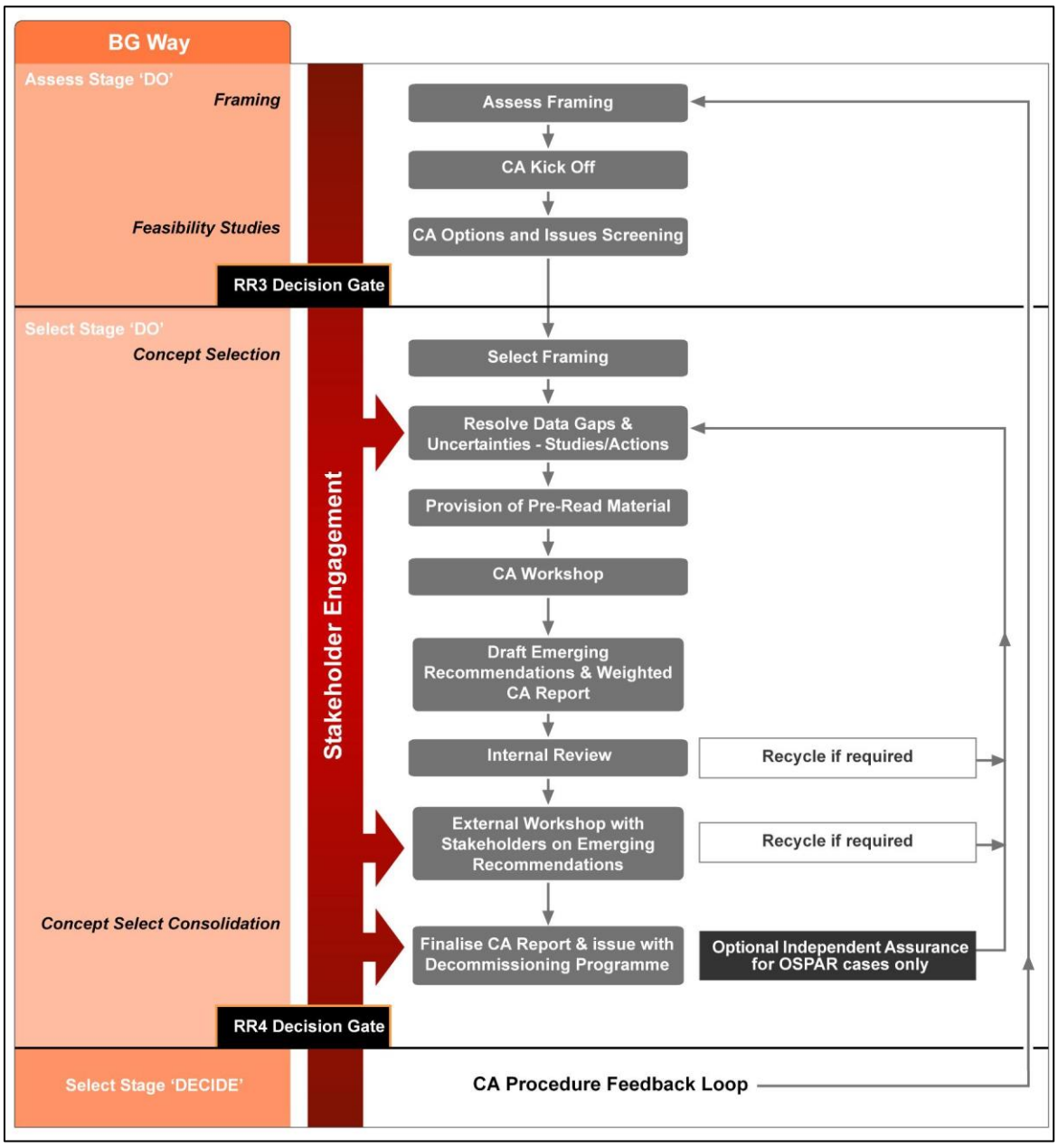


Figure 4 – Gaupe Decommissioning Comparative Assessment Process Flow Chart

Note that the CA was performed utilising BG procedures for Armada Hub Decommissioning as the CA process was initiated before both the Shell-BG integration and subsequent proposed divestment of the Armada Hub to Chrysaor Holdings.

The CA is a process with a series of engagement points (as shown in Figure 4) and opportunities to feedback and refine the CA input data, criteria and methodology in order to ensure that options fully consider all the inputs in a balanced manner.

Shell has engaged stakeholders at every stage of the CA. Stakeholders are defined as "any party who is impacted by, contributes to or who has influence over the project". Engagement with stakeholders maximises the data input to the CA and ensures that options are assessed comprehensively.

The project Comparative Assessment Guideline [4] provides full details of the objective, inputs and outputs from each of the stages identified in Figure 4. The CA process followed on the Gaupe Decommissioning Project is summarised below.

4.1 Identify Scopes

As outlined in Section 2.1, the initial step is to clearly define the scope of the CA. In conformance with the project Guideline [4], the pipelines and umbilicals were grouped into categories sharing similar characteristics which could therefore be assessed together.

The two categories for comparative assessment are shown below.

Type	Type Description	Applicable Armada Items
A1	Trenched and buried pipelines	Gaupe North 8"/12" pipeline (PL2781) Gaupe South 8"/12" pipeline (PL2782)
A2	Trenched and natural backfill	Gaupe North umbilical (PLU2784) Gaupe South umbilical (PLU2785)

Table 3 – CA Groupings to be Assessed

Full details of each grouping can be found in Section 6.

4.2 Identify Options

For details of the decommissioning options considered and the process for identifying feasible options for each scope, see Section 5.

4.3 Data Gathering

Following the initial framing workshop and identification of feasible options, the project undertook a period of data gathering. A series of studies and analyses were completed both internally and by contracted third parties.

The purpose of the data gathering period is to "provide information and specific data to support the assessment of the comparative performance of the options against each other in the evaluation phase" [9].

4.4 Assessment Criteria and Sub-Criteria

To ensure options were assessed consistently and comprehensively the following evaluation criteria and sub-criteria were adopted, in accordance with the OGUK Guidelines [9]:

- Safety
    - Project risk to personnel – offshore
    - Project risk to other users of the sea
    - Project risk to personnel – onshore
    - Potential for a high-consequence event
    - Residual risk to other users of the sea
- Environment
    - Marine impact of operations
    - Energy, emissions, resource consumption
    - Impact of marine end points (legacy impact)
- Technical
    - Risk of major project failure
    - Technology demands / track record
- Societal
    - Commercial impact on fisheries
    - Socio-economic impact on communities and amenities
- Economic
    - Cost
    - Cost risk and uncertainty

The assessment criteria, applicable factors and suggested source data for each sub-criterion are detailed within the project CA Procedure [5]. Most sub-criteria were assessed qualitatively, although there were quantitative inputs to inform these assessments, with two sub-criteria assessed using quantitative data only: energy, emissions, resource consumption; and cost.

4.5 Red / Amber / Green Analysis

Following the data gathering period, a Red / Amber / Green (RAG) analysis of the options was conducted. This coarsely assessed each of the options according to the assessment criteria contained in Appendix 1 of the OGUK Guidelines [9], except where adapted by Table 6 of the CA Procedure [5].

The RAG analysis allowed the project to exclude clearly outlying options and only take forward to scoring those options which could not be clearly differentiated. Results of the RAG Analysis for each scope can be found in Appendices 3 and 4.

4.6 Scoring Workshops

Those options which could not be differentiated by RAG Analysis were carried forward to CA Scoring Workshops involving subject matter experts from the project team and the Scottish Fishermen's Federation (SFF).

The CA Procedure [5] outlined the methodology utilised to score each option, as summarised below.

4.7 Criteria Weighting

The CA Guideline [4] allows projects to decide whether to apply equal weightings to each criterion or derive a custom weighting through a pairwise comparison that is relevant to the particular circumstances of the project.

Weights are introduced to "reflect the fact that the range from 'worst' to 'best' on one criterion might not be equivalent to the range of another criterion… and highlight which criteria are the key drivers / differentiators" [5, §6.6.8.1].

For the Gaupe Decommissioning Project, custom weightings were assessed by pairwise comparison whereby the relative importance of each criterion is assessed against each of the others individually and the scores collated to produce a weighting score for each criterion.

The assessment determined which of the two criteria is most important and by how much, using the following scale:

Letter code	Example	Definition	Numerical score
LetterCode x LetterCode	BC	Criteria are deemed of equal importance	1
LetterCode 1	B1	Moderate importance of the named criteria over the other	2
LetterCode 2	A2	Strong importance of the named criteria over the other	3
Letter Code 3	D3	Very strong importance of the named criteria over the other	4

Table 4 – Pairwise Comparison Scoring Methodology

Each Letter Code denotes the criterion under consideration, e.g. B denotes Environmental, Code D denotes Societal. The numerical code (1 to 3) denotes increasing range of importance.

The codes were converted into the numerical score shown in Table 4 and the inverted score assigned to the opposite comparison, e.g if Option A is assessed to be of strong importance compared to option C, then A > C would be given the score A2, a numerical value of 3; therefore C > A would automatically be given a numerical score of 0.33.

For the Gaupe Decommissioning Project pipelines and umbilicals, the scores were assessed thus:

		A	B	C	D	E		
	Assessment Criteria	Safety Risk	Environment	Technical	Societal	Economic	Geometric Mean	Weighting
A	Safety Risk	1	A2	A2	A2	A2	2.41	41%
B	Environment		1	B2	B1	B1	1.32	23%
C	Technical			1	D1	CE	0.56	10%
D	Societal				1	DE	0.80	14%
E	Economic					1	0.70	12%

Table 5 – Pairwise Comparison Scoring

The scores were then normalised against the sum of the geometric mean values and rounded to the nearest 5% to produce the weighting to be applied to each main criterion.

By this means, the following weights are assigned for this CA:

Criteria	Weighting
Safety	40%
Environmental	20%
Technical	10%
Societal	15%
Economic	15%

Table 6 – Criteria Weighting

Within each main criterion, the sub-criteria were assigned a strict pro rata division of the main criterion weighting. The weightings were assessed and frozen before any option scoring was conducted.

4.8 Sub-criteria Scoring Methodology

A series of workshops were held in which each option was scored for each category according to pre-determined scales for each sub-criterion. The scales are provided in the project CA Procedure [5] and were frozen before any scoring sessions were held.

Each option was given a score between 0.2 (least best) and 1.0 (best) for each sub-criterion according to the scales provided. These scores were agreed by the subject matter experts present at the workshop and informed by the various data sources produced by the project to support the comparative assessment process.

4.9 Collating Overall Scores

The scores for each category and each option are derived by multiplying the sub-criterion score by the pre-determined weighting and summing the results. This is summarised in Figure 5 below: the overall score is produced by multiplying the scores in Box A by the weighting for the corresponding attribute in Box B and then summing the results to produce the score in Box C.

Attribute summary:

	Option 1	Option 2	Option 3	Option 4	Option 5
Overall scoring:	C 0.78	0.69	0.61	0.61	0.50
Overall ranking:	1.0	2.0	3.0	4.0	5.0

		Minimal Removal	Partial Remediation			Total Removal	
Ref.	Attribute	Option 1	Option 2	Option 3	Option 4	Option 5	Attribute weighting
1	Project risk to personnel - Offshore	A 1.0	0.6	0.4	0.2	0.8	B 8%
2	Project risk to other users of the sea	1.0	0.8	0.6	0.8	0.4	8%
3	Project risk to personnel - Onshore	1.0	0.6	0.6	1.0	0.2	8%
4	Potential of a high consequence event	1.0	0.8	0.6	0.8	0.2	8%
5	Residual risk to other users of the sea	0.4	0.8	0.2	0.4	1.0	8%
6	Marine impact of operations on Environment	1.0	0.8	0.8	0.6	0.2	7%
7	Energy, emissions, resource consumption	1.0	0.8	0.8	0.8	0.2	7%
8	Impact on marine end points (legacy impact)	0.2	0.8	0.6	0.4	1.0	7%
9	Risk of major project failure	1.0	0.8	0.6	0.6	0.2	5%
10	Technology demands / track record	1.0	1.0	0.4	0.2	0.2	5%
11	Commercial impact on fisheries	0.2	0.2	1.0	1.0	1.0	8%
12	Socio-economic impact on communities and amenities	0.2	0.2	0.6	0.2	1.0	8%
13	Cost	1.0	0.8	0.8	0.8	0.2	8%
14	Cost risk and uncertainty	1.0	0.8	0.6	0.6	0.2	8%

Figure 5 – Example of Overall Scoring (not actual scoring)

The option with the highest score is considered to be 'the best' option and the lowest score is considered to be the 'least best' option.

The results of the scoring workshops are presented in Section 6 of this document.

4.10 Sensitivity Analysis

Two pre-determined sensitivity analyses were applied to the weighted outcome of the CA scoring. The purpose of each sensitivity analysis is to determine if the order of preference changes when alternative weightings are applied.

The two sensitivity checks applied are as shown in Tables 7 and 8 below.

Criteria	Weighting
Safety	20%
Environmental	20%
Technical	20%
Societal	20%
Economic	20%

Table 7 – Sensitivity Check A – Equal Criteria Weighting

Criteria	Weighting
Safety	47%
Environmental	23%
Technical	12%
Societal	18%
Economic	0%

Table 8 – Sensitivity Check B – Economic Removed as a Criterion

For each category, the results of each sensitivity analysis are presented in the conclusion.

An additional sensitivity check was conducted to gauge what impact the use of divers would have on the order of preference. In line with the project's HSSE and Asset Integrity Management Strategy [7], "diving activities [are] to be minimised wherever possible" and the CA was conducted with this assumption. However, during later project phases, it may become apparent that the use of divers achieves a risk level which is ALARP, i.e. as low as reasonably practicable.

If, following an ALARP demonstration during the Define Phase, a higher proportion of diving activities are used for the decommissioning options this may impact on the CA scores for various sub-criteria, namely *Project Risk to Personnel – Offshore*; *Project Risk to Other Users of the Sea*; *Energy, Emissions, Resource Consumption*; and *Cost*.

This sensitivity check was performed for each scope and each option for which there are subsea intervention activities that can be conducted by Remote Operated Vehicle (ROV) or divers.

5.0 DECOMMISSIONING OPTIONS

For both scopes listed in Section 2.1, the following options were initially considered. Full details of what each option entails can be found in the Decommissioning Technology Report [6].

5.1 Options considered

The following methods of decommissioning were identified.

5.1.1 Total removal by reverse reeling

Where the pipeline or umbilical is trenched or buried, it would first require to be untrenched or exposed, typically utilising the excavation methods discussed in the Technology Report [6]: mass flow excavator, subsea dredge or mechanical excavator.

The pipeline or umbilical would then be re-reeled to a fully specified reel-lay vessel, recovered to a transport reel or carousel on the back deck of the vessel and returned to shore for disposal.

5.1.2 Total removal by cut-and-lift

Where the pipeline or umbilical is trenched or buried, it would first require to be untrenched or exposed, typically utilising the excavation methods discussed in the Technology Report [6]: mass flow excavator, subsea dredge or mechanical excavator.

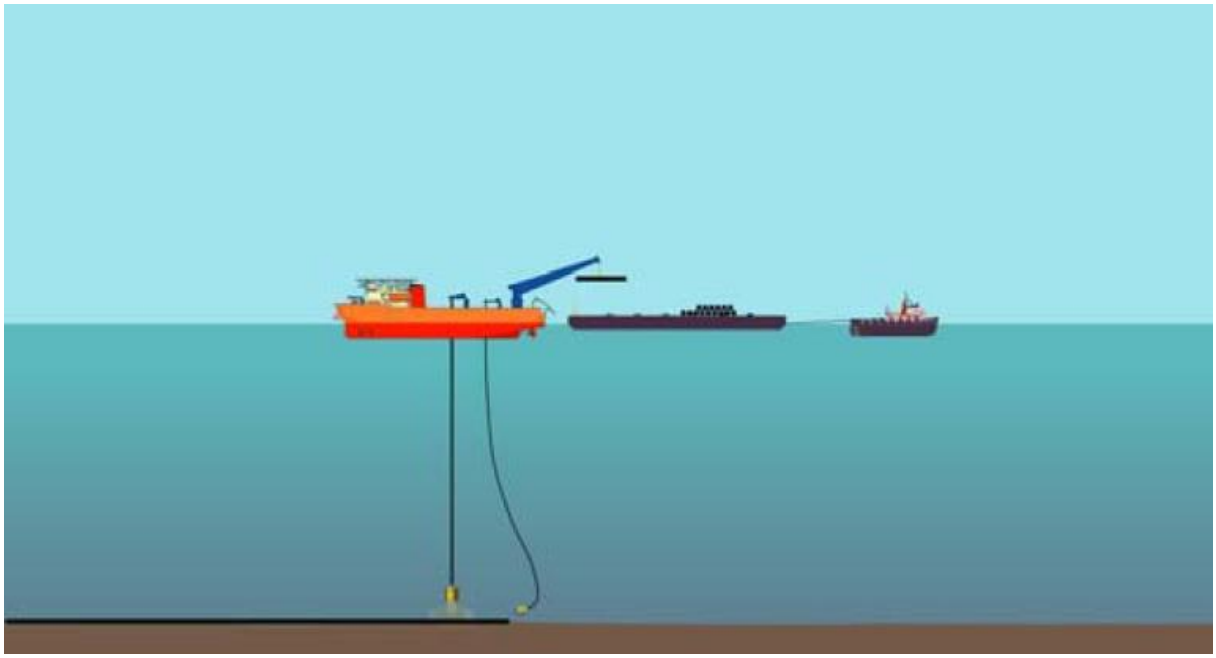


Figure 6 – Cut-and-Lift Illustration

The pipeline or umbilical would then be cut into (typically) 24m sections on the seabed using one of the cutting methods discussed in the Technology Report [6] before being recovered, either individually, in bundles or lifting frames, to the back deck of a Construction Support Vessel (CSV) or support vessel.

5.1.3 Backfill existing trench to increase burial depth

The Gaupe umbilicals were laid into pre-cut trenches to backfill naturally. Where there is sufficient spoil in the berm adjacent to the trench, there may be an option to mechanically backfill the existing trench without the need to cut a new one.

5.1.4 Leave *in situ*

No decommissioning activities are undertaken and the pipeline or umbilical is left in its current state with future monitoring surveys conducted to ensure it remains safe.

5.1.5 Leave *in situ* with exposed ends rock-covered

The main length of pipeline or umbilical is left in its current state but the ends at the Armada Complex are rock-covered to a target depth in accordance with BEIS guidelines.

“The ends” are defined as the transition section where the pipeline or umbilical leaves its trench or existing rock-cover and any surface laid areas on approach to the platform, manifold or wellhead.

All mattresses and grout bags would be removed from the ends prior to rock-cover being applied.

5.1.6 Leave *in situ* with exposed ends buried

The main length of pipeline or umbilical is left in its current state but the ends at the Armada Complex are buried to a target depth in accordance with BEIS guidelines using either a jetting spread or mechanical plough.

“The ends” are defined as the transition section where the pipeline or umbilical leaves its trench or existing rock-cover and any surface laid areas on approach to the platform, manifold or wellhead.

All mattresses and grout bags would be removed from the ends prior to burial activities.

5.1.7 Leave *in situ* with exposed ends cut and removed

The main length of pipeline or umbilical is left in its current state but the ends at the Armada Complex are cut into manageable sections (~24m) and recovered to the backdeck of a CSV for recovery to shore.

“The ends” are defined as the transition section where the pipeline or umbilical leaves its trench or existing rock-cover and any surface laid areas on approach to the platform, manifold or wellhead.

The pipeline / umbilical will be cut within the trench at a point where the pipeline / umbilical is buried to a target depth in line with BEIS requirements. The cut section would be recovered to the back deck of a CSV and returned to shore for recycling and disposal. To ensure the cut end remains buried and does not present a future snagging risk 5 – 10 tonnes of rock, as required, would be placed over the cut end and profiled flush with the surrounding seabed. An illustration of the cut location and rock placement is shown in Figure 7 below.

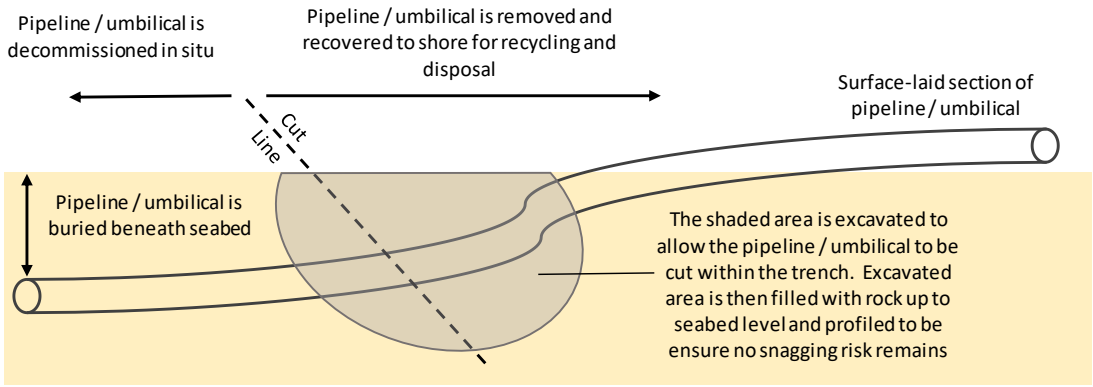


Figure 7 – Ends Cut-and-Removed Illustration

All mattresses and grout bags would be removed from the ends prior to the cut-and-lift activities.

5.2 Initial Framing and Options to be Assessed

In accordance with the process identified in Section 4, each option was coarsely assessed for each scope at the Initial Framing Workshop held on 25th August 2016. This workshop identified the feasible options for each scope and the data inputs required to adequately assess them for CA. Details of the workshop can be found in the Armada Hub Decommissioning Project CA Framing Workshop Report [8].

Following a period of data gathering, a Red / Amber / Green (RAG) analysis was conducted for each scope. This assessed each option using the assessment criteria provided in Appendix A of the OGUK Guidelines [9], adapted for two sub-criteria as shown in Appendix 2 of this document.

The RAG analysis provided a coarse screening of the decommissioning options and enabled the project to exclude any options which the colour coding revealed to be significantly worse than the other options considered.

Following this analysis, the options shown in Table 9 were carried forward to be scored in accordance with the process described in Section 4.

Full details of the RAG analysis and scoring for each scope can be found in the appendices of this document.

5.3 Assumptions

The CA was conducted taking into account the following assumptions:

- There will be no use of explosives in any decommissioning options for Gaupe;
- The project will ensure “diving activities are minimised wherever possible” in accordance with the HSSE and Asset Integrity Management Strategy [10];
- All pipelines and umbilicals will, where practicable, be cleaned of hydrocarbons and chemicals to a level of cleanliness demonstrating ALARP;

- Safety risks have been scored on a credible / reasonable basis rather than worst case scenario;
- Decommissioning plans for the Gaupe Field were part of the wider Armada Hub Decommissioning Plans, first within BG Group and later Shell U.K. The Armada Hub Decommissioning Project was suspended in June 2017 following the announcement of the proposed divestment of Shell U.K's interest in the Armada Hub to Chrysaor Holdings Limited and the latter's intention to postpone cessation of production from the Armada Hub assets indefinitely. Gaupe Field owners are A/S Norske Shell (60% and operator) and Lundin Energy Norway AS (40%). A/S Norske Shell is responsible for responding to the UK Government's Section 29 notice and producing a Decommissioning Programme and associated underpinning deliverables for the Gaupe infrastructure in the UKCS. In the development of the Gaupe Standalone deliverables, the project will rely on and reference previous Gaupe decisions taken and underpinning studies/consultations completed while preparing the pre-draft Armada Hub Decommissioning Programme. Readers of this document may therefore find a mixed use of references to "Gaupe Standalone" or "Armada Hub" documents as appropriate.

Type	Component Type / As-Laid Condition	Applicable Armada Items	Total removal by reverse reeling	Total removal by cut-and-lift	Backfill existing trench	Leave *in situ*	Leave *in situ* with exposed ends rock-covered	Leave *in situ* with exposed ends buried	Leave *in situ* with exposed ends cut and removed
A1	Trenched and buried pipelines	Gaupe North 8”/12” pipeline (PL2781) Gaupe South 8”/12” pipeline (PL2782)					✓	✓	✓
A2	Trenched and natural backfill	Gaupe North umbilical (PLU2784) Gaupe South umbilical (PLU2785)	✓		✓		✓	✓	✓

Table 9 – Gaupe CA Scopes and Options

6.0 COMPARATIVE ASSESSMENT

6.1 Type A1 – Trenched and Buried Pipelines

Type A1 consists of the following pipelines:

- PL2781 - Gaupe North 8” / 12” pipeline
- PL2782 – Gaupe South 8” / 12” pipeline

The scope is summarised in Figure 8 - overleaf.

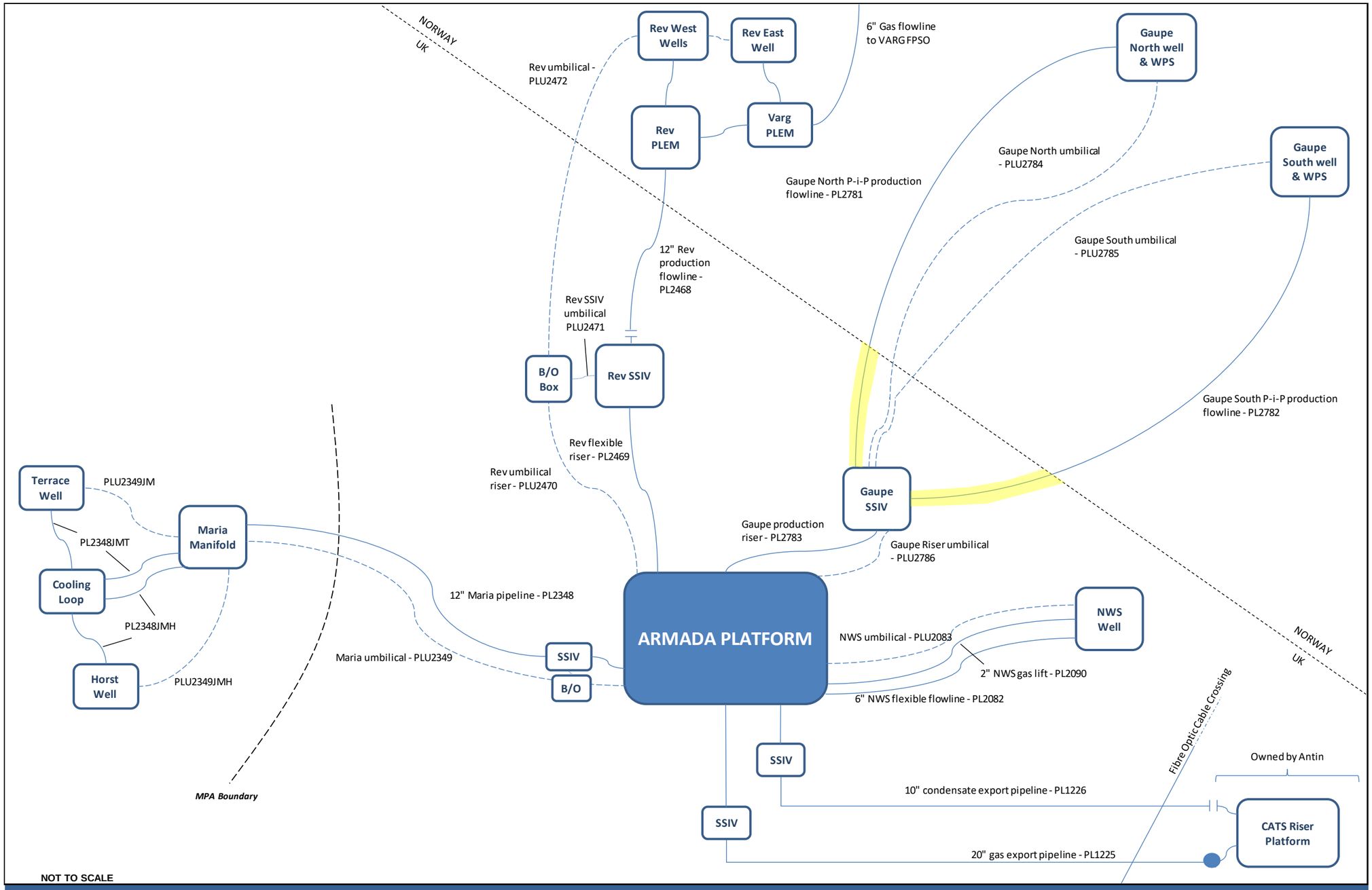
Each pipeline can be summarised as follows:

PL2781 – Gaupe North

- 7.453km long, 8”/12” pipe-in-pipe production pipeline from the Gaupe North wellhead in the Norwegian sector to the Gaupe SSIV commingling manifold within the Armada 500m safety zone
- Trenched and buried
- Only the pipeline within the UK Sector is considered, from approximately KP 3.2 to KP 7.5
- There are 3 areas of rock cover within the UK sector, an example of which is shown in Figure 9:
    - KP 3.914 to KP 3.919 (5m)
    - KP 5.961 to KP 6.045 (84m)
    - KP 6.459 to KP 6.600 (141m)
- At the SSIV manifold, there is 65m of surface laid pipeline then a 50m transition section before the pipeline achieves full 1.8m burial depth. These areas are included in the CA.
- The production jumper between the surface laid section and the SSIV manifold, as well as all concrete mattresses covering the surface laid section and transition section will be removed.

PL2782 – Gaupe South

- 7.119km long, 8”/12” pipe-in-pipe production pipeline from the Gaupe South wellhead in the Norwegian sector to the Gaupe SSIV commingling manifold within the Armada 500m safety zone
- Trenched and buried
- Only the pipeline within the UK Sector is considered, from approximately KP 1.9 to KP 7.1



Gaupe Comparative Assessment Groups

Type	Description	Infrastructure included	Options to be assessed
A1	Trenched and buried pipelines	PL2781, PL2782	Leave in situ with ends rock-covered; Leave in situ with ends buried; Leave in situ with ends removed
A2	Trenched and natural backfill umbilicals	PLU2784, PLU2785	Total removal by reverse reeling; Backfill trench; Leave in situ with ends rock-covered; Leave in situ with ends buried; Leave in situ with ends removed

Figure 8 – Type A1 Scope Schematic

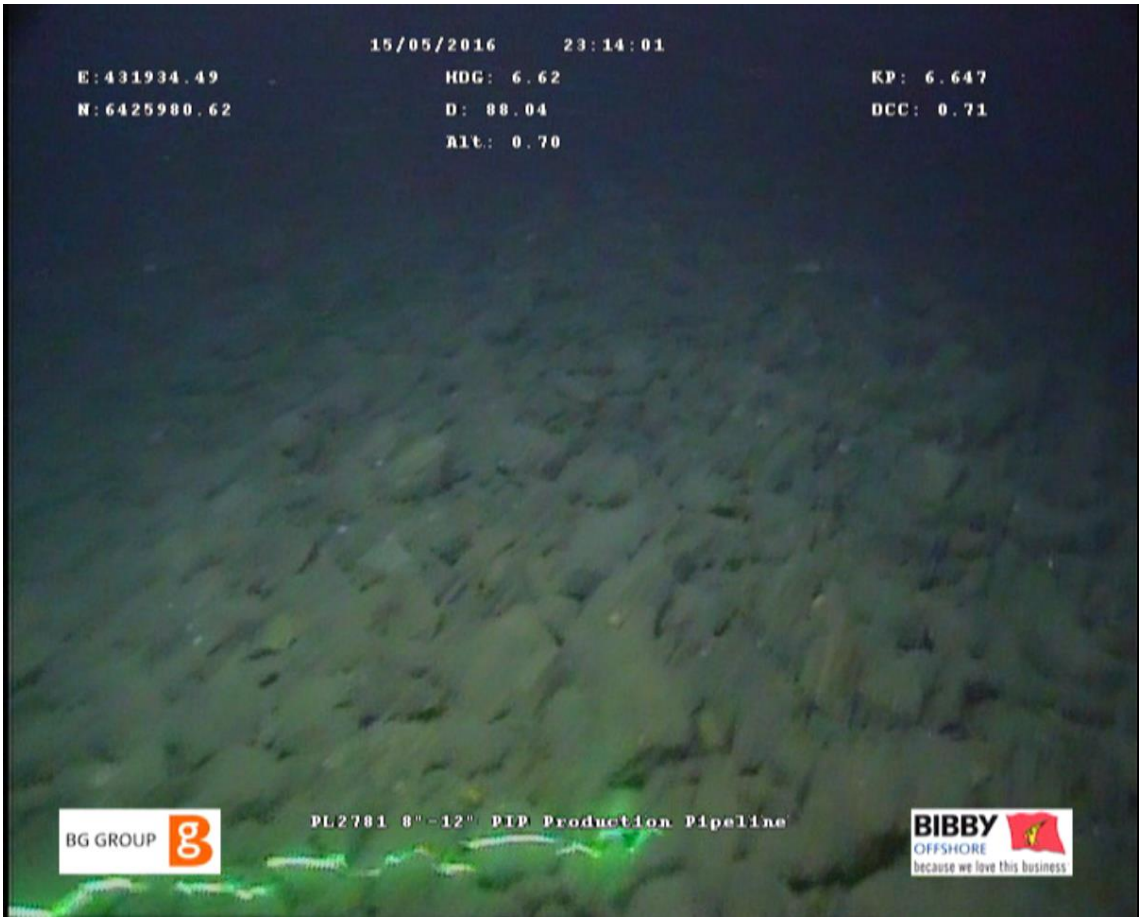


Figure 9 – Example of Rock-Covered Area (PL2781)

- There are 5 areas of rock cover within the UK sector:
    - KP 2.289 to KP 2.293 (4m)
    - KP 5.533 to KP 5.666 (133m)
    - KP 5.729 to KP 5.744 (15m)
    - KP 5.788 to KP 5.793 (5m)
    - KP 6.048 to KP 6.148 (100m)
- At the SSIV manifold, there is 65m of surface laid pipeline then a 50m transition section before the pipeline achieves full 1.8m burial depth. These areas are included in the CA.
- The production jumper between the surface laid section and the SSIV manifold, as well as all concrete mattresses covering the surface laid section and transition section will be removed.

6.1.1 Type A1 Comparative Assessment Results

Leave *in situ* with the exposed ends cut-and-removed is the emerging recommendation for the Type A1 scope, based on the scoring of the comparative assessment process.

	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
Overall scoring:	0.19	0.20	0.25
Overall ranking:	3.0	2.0	1.0

For ten of the fourteen sub-criteria there was deemed to be no significant difference between the three options. For each of the remaining four sub-criteria, the 'leave *in situ* with exposed ends cut-and-removed' option was scored higher than the other two options.

For full detail on the scoring refer to Appendix 3.

Sensitivity check – equal weighting

Reverting to equal weighting has no influence on the result as 'leave *in situ* with exposed ends cut and removed' remains the best option.

	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
Overall scoring:	0.21	0.19	0.26
Overall ranking:	2.0	3.0	1.0

Sensitivity check – excluding cost

Cost was not scored for this scope as it was not a differentiating factor, therefore there is no change to the scoring from removing *cost* as a sub-criterion.

Sensitivity check – use of divers

Assuming that subsea intervention activities would be performed by divers rather than ROV has no impact on the result of the CA as 'leave *in situ* with exposed ends cut and removed" remains the emerging recommendation.

	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
Overall scoring:	0.27	0.28	0.31
Overall ranking:	3.0	2.0	1.0

6.2 Type A2 – Umbilicals trenched with natural backfill

Type A2 consists of the following umbilicals:

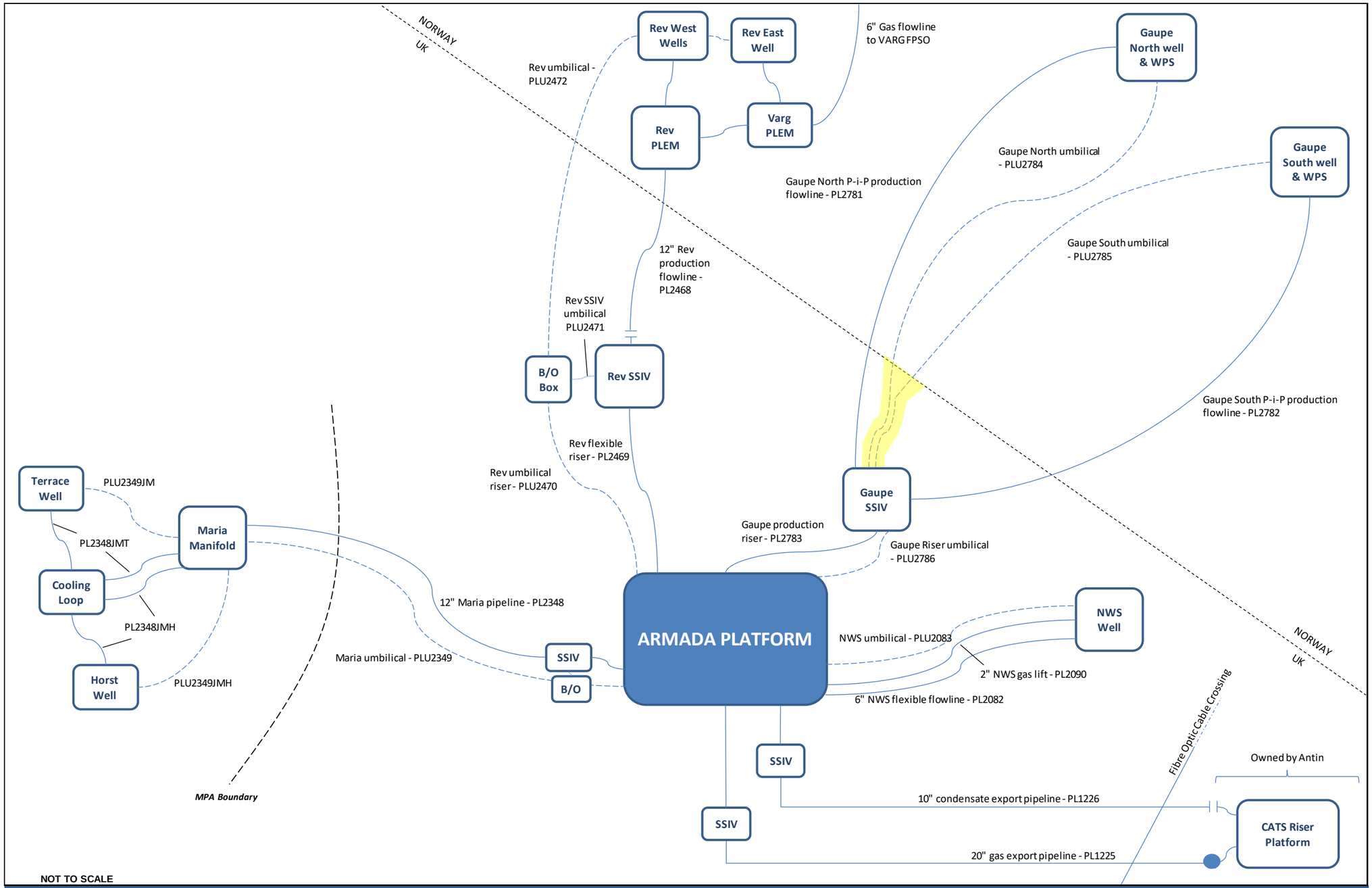
- PLU2784 - Gaupe North Umbilical
- PLU2785 – Gaupe South Umbilical

The scope is summarised in Figure 10 overleaf.

Each umbilical can be summarised as follows:

PLU2784 – Gaupe North Umbilical

- 7.642km long, 139.4mm OD static Electro-Hydraulic Control (EHC) umbilical
- Trenched and allowed to backfill naturally
- Only the umbilical within the UK Sector is considered, from approximately KP 3.2 to KP 7.5. From approximately KP 5.5, both the Gaupe North and Gaupe South umbilicals are laid in the same pre-cut trench.
- There are no areas of rock cover within the UK sector
- At the SSIV manifold, there is 50m transition section as the umbilical exits the trench before a 135m surface laid section which crosses the Gaupe North flexible production jumper and connects to the SSIV manifold. Mattresses cover both the transition and surface laid sections. These sections are included within the CA.
- The SSIV manifold and all mattresses are to be removed.



Gaupe Comparative Assessment Groups

Type	Description	Infrastructure included	Options to be assessed
A1	Trenched and buried pipelines	PL2781, PL2782	Leave in situ with ends rock-covered; Leave in situ with ends buried; Leave in situ with ends removed
A2	Trenched and natural backfill umbilicals	PLU2784, PLU2785	Total removal by reverse reeling; Backfill trench; Leave in situ with ends rock-covered; Leave in situ with ends buried; Leave in situ with ends removed

Figure 10 – Type A2 Scope Schematic

PLU2785 – Gaupe South Umbilical

- 7.335km long, 139.4mm OD static Electro-Hydraulic Control (EHC) umbilical
- Trenched and allowed to backfill naturally
- Only the pipeline within the UK Sector is considered, from approximately KP 1.9 to KP 7.1. From approximately KP 5.0, both the Gaupe North and Gaupe South umbilicals are laid in the same pre-cut trench.
- There are no areas of rock cover within the UK sector
- At the SSIV manifold, there is 50m transition section as the umbilical exits the trench before a 135m surface laid section which crosses the Gaupe North flexible production jumper and connects to the SSIV manifold. Mattresses cover both the transition and surface laid sections. These sections are included within the CA.
- The SSIV manifold and all mattresses are to be removed.

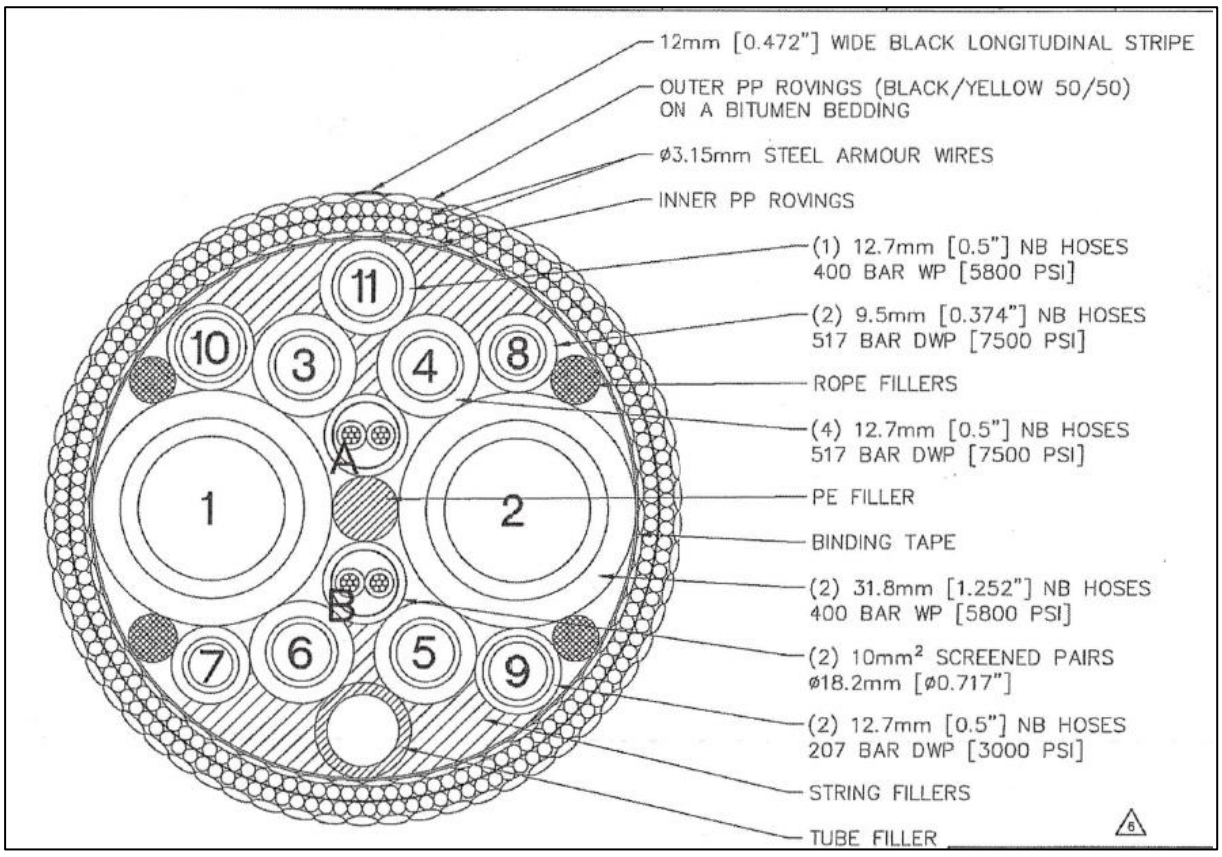


Figure 11 – Cross-section of Gaupe North and South umbilical

6.2.1 Type A2 Comparative Assessment Results

Leave *in situ* with the exposed ends cut and removed is the emerging recommendation for the Type A2 scope, based on the scoring of the comparative assessment process.

	Total removal by reverse reeling	Trench and bury full length	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
Overall scoring:	0.32	0.36	0.35	0.38	0.38
Overall ranking:	5.0	3.0	4.0	1.0	1.0

As the 'leave *in situ* with exposed ends buried' and 'leave *in situ* with exposed ends cut and removed' options were scored equally, the latter option would allow the project to conduct decommissioning of the A2 scope in a 'campaign approach' scope A1.

For eight of the fourteen sub-criteria, there was deemed to be no significant difference between the five options. In five of the remaining six sub-criteria, 'leave *in situ* with exposed ends cut and removed' was assessed to be the best, or equal best, of the five options. *Impact on marine end points (legacy)* is the only sub-criterion where 'leave *in situ* with exposed ends cut and removed' was scored lower than another available option, in this case 'total removal'.

For full detail on the scoring refer to Appendix 4.

Sensitivity check – equal weighting

Reverting to equal weighting results has no influence on the final result with 'leave *in situ* with exposed ends cut and removed' remaining as the emerging recommendation.

	Total removal by reverse reeling	Trench and bury full length	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
Overall scoring:	0.24	0.28	0.29	0.31	0.31
Overall ranking:	5.0	4.0	3.0	1.0	1.0

Sensitivity check – excluding cost

Cost was not scored for this scope as it was not a differentiating factor; therefore there is no change to the scoring from removing cost as a sub-criterion.

Sensitivity check – use of divers

Assuming that subsea intervention activities would be performed by divers rather than ROV has no impact on the result of the CA. With 'leave *in situ* with exposed ends buried' achieving a score of just 0.01 higher than 'leave *in situ* with exposed ends cut and removed", there is assessed to be no significant difference between the two options and the latter remains the emerging recommendation.

	Total removal by reverse reeling	Trench and bury full length	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
Overall scoring:	0.32	0.34	0.35	0.38	0.37
Overall ranking:	5.0	4.0	3.0	1.0	2.0

7.0 REFERENCES

[1]	Draft Decommissioning Programme, GAUPD-PT-S-AA-7180-00001
[2]	Environmental Impact Assessment Report, GP50-BGNO-S-RA-0001
[3]	OPRED Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998, Version 6 March 2011
[4]	BG Decommissioning Comparative Assessment Guideline, BG-GL-PM-PM-040
[5]	Armada Hub Decommissioning Project Comparative Assessment Procedure, BG-ARMD-25-35-00002
[6]	Armada Decommissioning Technology Report (Genesis), BG-ARMD-25-40-00001
[7]	Armada Decommissioning HSSE and Asset Integrity Management Strategy, BG-ARMD-HS-SY-00001
[8]	Armada Hub Decommissioning Project CA Framing Workshop Report, BG-ARMD-50-40-00002
[9]	Oil and Gas UK Guidelines for Comparative Assessment in Decommissioning Programmes, October 2015
[10]	BG HSSE and Asset Integrity Management Strategy, BG-ARMD-HS-SY-00001

APPENDIX 1
ABBREVIATIONS/DEFINITIONS

A&C	Atlantic and Cromarty (fields)
ALARP	As Low As Reasonably Practicable
Bbls/d	Barrels (or equivalent) per day
BEIS	Department of Business, Energy and Industrial Strategy (formerly DECC)
CA	Comparative Assessment
CATS	Central Area Transmission System
CHARM	Chemical Hazard and Risk Management
Cooler	Subsea structure containing piping loops in order to reduce temperature of process fluids from the well
CoP	Cessation of Production
CRA	Corrosion Resistant Alloy
CSV	Construction Support Vessel
DECC	Department of Energy and Climate Change (now BEIS)
DOL	Depth of Lowering
DSV	Dive Support Vessel
EHC	Electro-Hydraulic Control
FEED	Front End Engineering Design
FLAGS	Far North Liquids and Associated Gas System
Future Tee	A branched connection designed to allow future tie-ins to a pipeline
HSSE	Health, Safety, Security and Environment
IPR	Interim Pipeline Regime
JNCC	Joint Nature Conservation Committee
J-Tube	A structural tube housing an umbilical or flexible pipeline from seabed to platform topsides
KP	Kilometre Point
Mmscfd	Million standard cubic feet of gas per day
MEG	Monoethylene Glycol
MPA	Marine Protected Area
NCS	Norwegian Continental Shelf
OCNS	Offshore Chemical Notification Scheme

OD	Outside Diameter
OGA	Oil and Gas Authority
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
PLEM	Pipeline End Manifold
PLET	Pipeline End Termination
PLL	Potential Loss of Life
PLONOR	Poses Little Or No Risk (to the marine environment)
ROV	Remote Operated Vehicle
ROVSV	Remote Operated Vehicle Support Vessel
SAGE	Scottish Area Gas Evacuation
SFF	Scottish Fishermen's Federation
SIMOPS	Simultaneous Operations
ToP	Top of Pipe
Tree	Assembly of valves, spools, instruments and fittings attached to the wellhead in order to control or isolate production from the well
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
Umbilical	Single flexible pipe / tube containing various steel and/or thermoplastic tubes and hoses to deliver electro-hydraulic control and chemical consumables from the platform topsides to subsea structures and wells.
UTA	Umbilical Termination Assembly
VAF	Value Assurance Framework (BG internal project gate system)
WAGES	Western Area Gas Evacuation
WROV	Work-class Remote Operated Vehicle

APPENDIX 2
COMPARATIVE ASSESSMENT CRITERIA

The scopes of each sub-criterion and examples applied to the comparison assessment were adopted from Appendix A of the Oil and Gas UK *Guidelines for Comparative Assessment in Decommissioning Programmes* [9]; with the exception of the assessment criteria for the "Impact on Marine End Points (legacy impact)" and "Environmental Impact on marine end-points (legacy)" sub-criteria. When conducting the Red / Amber / Green analysis of these sub-criteria, the project assumed alternative assessment criteria which would allow for a viable comparison based on the particular circumstances of the project.

The assessment criteria for these two sub-criteria are contained in the table overleaf.

Sub-Criteria	Applicable to	Applicable when	Factors	Most Preferred	Moderate	Least Preferred
Environmental - Marine Impact of Operations	Marine environmental impact caused by: Project Vessels, Supply Boats, Survey vessels	During execution phase of project including any subsequent monitoring surveys	Number and type of vessels and duration on station. Tasks vessels are fulfilling. Vessel station keeping approach. Likelihood of spills, discharges, noise.	Spill of diesel fuel <300te No incremental discharge to sea anticipated. No significant disturbance to sensitive seabed habitat / species anticipated Small vessel size and numbers anticipated and activity leading to only minor increase in noise above existing baseline. Discharge poses little environmental risk	Spill of diesel fuel >300te Minor sensitive seabed habitat / species disturbance resulting from removal operations Maximum 2 additional vessels on DP, some intermittent noise associated with vessels and helicopters for duration of project. Discharge with potential to cause harm	Spill of crude Increased risk potential vessel collisions. Increased corridor of seabed disturbance. Continuous noise from vessels (on DP) and helicopter activities. Large vessel size and noise above existing baseline. Explosive techniques adopted for cutting. Discharge of persistent or toxic material
Environmental - Impact on marine end-points (legacy)	Ongoing long term Marine environmental impact caused by materials left in place.	Following completion of the Decommissioning project and residual / ongoing impact	Extent of and composition of materials left in-situ to deteriorate into marine environment longer term. Function of extent of cleanliness of materials left in-situ. Predicted persistence of materials left in-situ.	Materials left on seabed biodegrade or exhibit low toxicity	Materials left on seabed are inert and clean	Materials left on seabed are toxic and persistent

Table 10 – CA RAG Scoring Guidance adapted from OGUK Guidance Notes

APPENDIX 3
SCOPE A1, TRENCHED AND BURIED PIPELINES – SCORING DETAILS

Decommissioning Options identified

At the Initial Framing Workshop, four feasible options were identified for this scope:

- Total removal by reverse reeling
- Leave *in situ* and rock cover the exposed ends
- Leave *in situ* and bury the exposed ends
- Leave *in situ* and cut-and-remove the exposed ends

Full details of these options can be found in the Technology Report [6].

Red / Amber / Green Analysis

Type A1 - Trenched and buried pipelines		Options to be assessed			
		Total Removal	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
Criteria	**Sub-Criteria**				
Safety	Project Risk to Personnel - Offshore	Extended duration in field, large number of lifts	Short duration of low-risk activities in field	Short duration of low-risk activities in field	Short duration but lifting activities comparatively slightly more risky than rock cover or burying
	Project risk to other users of the sea	Significant duration of activity outside existing exclusion zones	All project activity within existing exclusion zones	All project activity within existing exclusion zones	All project activity within existing exclusion zones
	Project risk to personnel - onshore	Significant number of lifts for material returned to shore	No material returned to shore, routine rock loading activity	No material returned to shore, routine plough loading activity	Very small volume of material returned to shore
	Potential of a high consequence event	Prolonged vessel campaign, some SIMOPS possible	Very short vessel campaign	Very short vessel campaign	Very short vessel campaign
	Residual risk to other users of the sea	All options leave the seabed safe and clear of any snagging risks, whether the pipelines are removed or remain in their buried condition			
Environmental	Marine impact of operations	Mass flow excavator to be used to uncover pipelines, thereby spreading the sedminent over a wide footprint	Some noise disturbance from rock cover operation	Some seabed disturbance from burying activities	Lower noise from operations than rock cover, lower seabed disturbance than burying
	Energy, emissions, resource consumption	Highest emissions by a significant margin	Low emissions, broadly comparable to burying or removing ends	Low emissions, broadly comparable to rock covering or removing ends	Low emissions, broadly comparable to burying or rock covering ends
	Impact of marine end points (legacy)	No material left, clean seabed	JNCC preference for no new rock cover	Material left on seabed is inert and clean	Material left on seabed is inert and clean
Technical	Risk of major project failure	Reeling / cut-and-lift technically more challenging, more weather exposure	High confidence that schedule slippage can be accomodated within contingency	High confidence that schedule slippage can be accomodated within contingency	High confidence that schedule slippage can be accomodated within contingency
	Technology demands / track record	Gaupe pipe-in-pipe lines - llimited precedence for reverse reeling	Technologically feasible, proven track record	Technologically feasible, proven track record	Technologically feasible, proven track record
Societal	Commercial impact on fisheries	All options leave the seabed safe and clear of any snagging risks, whether the pipelines are removed or remain in their buried condition - therefore there is no anticipated impact on commercial fishing in the area			
	Socio-economic impact on communities and amenities	Jobs from steel returned for recycling	Negligible positive or negative impact to communities		
Economic	Cost	Highest cost by a significant margin	Significantly lower cost than total removal, broadly comparable with burying or removing the ends	Significantly lower cost than total removal, broadly comparable with rock covering or removing the ends	Significantly lower cost than total removal, broadly comparable with burying or rock covering the ends
	Cost risk and uncertainty	All estimates have been conducted using the same methodology and are as robust as each other			

Following the RAG Analysis, the *total removal* option was excluded due to the number of "red" results. This option was deemed to be sub-optimal on the basis of *risk to personnel (offshore); risk to other users of the sea; marine impact of operations, energy, emissions; resource consumption* and *cost.* This conclusion is supported by Section 10.6 of the OPRED Guidance Notes [3] which states that pipelines which are "adequately buried or trenched and which are not subject to development of spans and are expected to remain so" may be candidates for in-situ decommissioning.

Therefore, three options were taken forward to scoring:

- Leave *in situ* with exposed ends rock-covered
- Leave *in situ* with exposed ends buried
- Leave *in situ* with exposed ends cut-and-removed

Option Scoring

Safety

The Safety criterion is split into five-sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

The Safety sub-criteria for Type A1 were scored thus:

Ref.	Attribute	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
1	Project risk to personnel - Offshore	-	-	-
2	Project risk to other users of the sea	-	-	-
3	Project risk to personnel - Onshore	-	-	-
4	Potential of a high consequence event	-	-	-
5	Residual risk to other users of the sea	0.8	1.0	1.0

Coarse Potential Loss of Life (PLL) data was prepared to inform the *Project risk to personnel – Offshore* and *Residual risk to other users of the sea* sub-criteria but all were assessed qualitatively.

For four of the five sub-criteria (*Project risk to personnel – offshore; Project risk to other users of the sea; Project risk to personnel – Onshore; Potential for a high consequence event*) there was deemed to be no significant difference between the three options and so no score was applied, effectively removing these sub-criteria from the CA.

Due to the small legacy risk of the resulting rock berm becoming disturbed over time and exposing the cut end of the pipeline, the 'leave *in situ* with exposed ends rock-covered' option was assessed to have a slightly lower score for *residual risk to other users of the sea*.

Environment

The Environment criterion is split into three sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

The Environment sub-criteria for Type A1 were scored thus:

Ref.	Attribute	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
6	Marine impact of operations	0.6	0.6	0.8
7	Energy, emissions, resource consumption	-	-	-
8	Impact of marine end points (legacy impact)	0.6	0.8	1.0

The *energy, emissions, resources consumption* sub-criterion was assessed quantitatively in accordance with the Institute of Petroleum Guidelines (IoP 2000) cited by Oil and Gas UK in its guidelines of comparative assessment as a recognised source of data to support emissions calculations [9]. The *marine impact of operations* and *impact of marine end points (legacy impact)* sub-criteria were assessed qualitatively.

As the CA was originally conducted as part of the wider Armada Hub Decommissioning Project, the total emissions were calculated together with those associated with the decommissioning of two pipelines now outwith the scope of this report. The results in that case were that no significant difference existed between the three options available.

The results including the two Armada Hub lines were: total emissions output for the 'leave *in situ* with exposed ends rock-covered' option was 9,790 tonnes CO_2; for 'leave *in situ* with exposed ends buried' the estimate was 10,637 tonnes CO_2; for 'leave *in situ* with exposed ends cut and removed' it was 9,921 tonnes CO_2.

Removing the two Armada Hub lines reduces the impact to:

- Leave *in situ* with exposed ends rock-covered 9,463 te
- Leave *in situ* with exposed ends buried 9,775 te
- Leave *in situ* with exposed ends cut-and-removed 9,476 te

Each of these results achieves the same score on the scale provided by the CA Procedure (Table 13, [5]). Therefore, there is still no significant difference between the three options and no score has been applied, effectively removing this sub-criterion from the CA.

The scores for the *marine impact of operations* sub-criterion were driven by the following factors:

- Leave *in situ* with exposed ends rock-covered – the additional species recovery time caused by the addition of rock;
- Leave *in situ* with exposed ends buried – the likelihood that trenching within vicinity of Armada would bring contaminated soil to the seabed;
- Leave *in situ* with exposed ends cut-and-removed – vessels operating outside the 500m safety zone at Armada, although it was noted that this would be marginal.

The scores for *impact of marine end points (legacy)* were driven by the following factors:

- Leave *in situ* with exposed ends rock-covered – the addition of a relatively small volume of new substrate;
- Leave *in situ* with exposed ends buried – this option would leave some material *in situ*, although buried and unlikely to come out of burial;
- Leave *in situ* with exposed ends cut-and-removed – all material would be removed therefore there is no legacy impact.

Technical

The Technical criterion is split into two sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

The Technical sub-criteria for Type A1 were scored thus:

Ref.	Attribute	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
9	Risk of major project failure	1.0	0.6	1.0
10	Technology demands / track record	-	-	-

Both sub-criteria were assessed qualitatively.

The 'leave *in situ* with exposed ends buried' option was assessed to have a higher level of *risk of major project failure* due to the proximity of other pipelines and umbilicals around the Armada Complex, potentially making burial difficult to achieve.

All options were considered to be standard industry practice and the techniques proposed have a proven track record. Therefore, it was assessed that there is no significant difference between the three options for *technology demands / track record* and so no score was applied, effectively removing this sub-criterion from the CA.

Societal

The Societal criterion is split into two sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

The Societal sub-criteria for Type A1 were scored thus:

Ref.	Attribute	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
11	Commercial impact on fisheries	-	-	-
12	Socio-economic impact on communities and amenities	-	-	-

Both sub-criteria were assessed qualitatively.

For both sub-criteria, there was assessed to be no significant difference between the three options and so no score was applied, effectively removing these sub-criteria from the CA.

Economic

The Economic criterion is split into two sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

The Economic sub-criteria for Type A1 were scored thus:

Ref.	Attribute	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
13	Cost	-	-	-
14	Cost risk and uncertainty	-	-	-

A cost estimate was produced for each option and used to assess the *Cost* sub-criterion quantitatively. The *cost risk and uncertainty* sub-criterion was assessed qualitatively.

For both sub-criteria, there was assessed to be no significant difference between the three options and so no score was applied, effectively removing these sub-criteria from the CA.

APPENDIX 4
SCOPE A2, TRENCHED UMBILICALS WITH NATURAL BACKFILL – SCORING DETAILS

Decommissioning Options identified

At the Initial Framing Workshop, five feasible options were identified for this scope:

- Total removal by reverse reeling
- Backfill the existing trench
- Leave *in situ* and rock cover the exposed ends
- Leave *in situ* and bury the exposed ends
- Leave *in situ* and cut-and-remove the exposed ends

Full details of these options can be found in the Technology Report [6].

Red / Amber / Green Analysis

The Red / Amber / Green analysis did not result in any of the five options being excluded and all five were carried forward to the scoring workshops.

Type A2 - Trenched and natural backfill		Options to be assessed				
Criteria	**Sub-Criteria**	Total Removal	Backfill existing trench	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
Safety	Project Risk to Personnel - Offshore	More vessels required in field, longer duration	Base case is that ends will be removed	Short duration of low-risk activities in field	Short duration of low-risk activities in field	Short duration of offshore lifting activities
	Project risk to other users of the sea	Moderate level of activity outside safety zone	Very short duration outside the safety zone	All project activity within existing exclusion zones	All project activity within existing exclusion zones	All project activity within existing exclusion zones
	Project risk to personnel - onshore	Significant number of lifts for material returned to shore	No material returned to shore, routine rock loading activity	No material returned to shore, routine rock loading activity	No material returned to shore, routine rock loading activity	Very small volume of material returned to shore
	Potential of a high consequence event	All relatively short campaigns, no lifts over live plant or pipelines				
	Residual risk to other users of the sea	Clear seabed	Clear seabed, material buried	Material buried but not to same depth as comprehensively as "backfill full length"	Material buried but not to same depth as comprehensively as "backfill full length"	Material buried but not to same depth as comprehensively as "backfill full length"
Environmental	Marine impact of operations	All options were considered to be "amber" due to anticipated discharge of small volumes of chemical to sea				
	Energy, emissions, resource consumption	Moderate emissions	Moderate emissions	Lowest emissions	Moderate emissions	Lowest emissions
	Impact of marine end points (legacy)	No material left, clean seabed	Material left in trench is inert and clean	JNCC preference for no new rock cover	Material left in trench is inert and clean	Material left in trench is inert and clean
Technical	Risk of major project failure	Risk of damaging umbilical during re-reeling, therefore potential for large schedule impact	High confidence that schedule slippage can be accomodated within contingency	High confidence that schedule slippage can be accomodated within contingency	High confidence that schedule slippage can be accomodated within contingency	High confidence that schedule slippage can be accomodated within contingency
	Technology demands / track record	All options are technically feasible with a proven track record				
Societal	Commercial impact on fisheries	All options leave the seabed safe and clear of any snagging risks, therefore there is no anticipated impact on commercial fishing in the area				
	Socio-economic impact on communities and amenities	Negligible positive or negative impact to communities				

Option Scoring

Safety

The Safety criterion is split into five-sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

The Safety sub-criteria for Type A2 were scored thus:

Ref.	Attribute	Total removal by reverse reeling	Trench and bury full length	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
1	Project risk to personnel - Offshore	0.6	1.0	1.0	1.0	1.0
2	Project risk to other users of the sea	-	-	-	-	-
3	Project risk to personnel - Onshore	0.8	1.0	1.0	1.0	1.0
4	Potential of a high consequence event	-	-	-	-	-
5	Residual risk to other users of the sea	1.0	1.0	0.8	1.0	1.0

Coarse Potential Loss of Life (PLL) data was prepared to inform the *Project risk to personnel – Offshore* and *Residual risk to other users of the sea* sub-criteria but all were assessed qualitatively.

For two of the five sub-criteria (*Project risk to other users of the sea; Potential for a high consequence event*) there was deemed to be no significant difference between the five options and so no score was applied, effectively removing these sub-criteria from the CA.

During reverse reeling, there would be a risk to personnel on the backdeck of the reeling vessel from the chemicals that would be recovered with the umbilical. This results in a higher risk and lower score in the *project risk to personnel – offshore* sub-criterion.

Similarly, reverse reeling would include a risk to onshore personnel during load-in and recycling from chemicals recovered with the umbilical. This results in a higher risk and lower score in the *project risk to personnel – onshore* sub-criterion.

Although any additional rock-cover would be the subject of over-trawlability trials at the conclusion of decommissioning activities, the presence of a cut-end above the seabed surface may present a future snagging risk to fishing vessels should the rock-berm be disturbed in future. Therefore, 'leave *in situ* with exposed ends rock-covered' was scored lower in the *residual risk to other users of the sea* sub-criterion.

Environment

The Environment criterion is split into three sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

The Environment sub-criteria for Type A2 were scored thus:

Ref.	Attribute	Total removal by reverse reeling	Trench and bury full length	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
6	Marine impact of operations	0.6	0.6	0.6	0.8	0.8
7	Energy, emissions, resource consumption	-	-	-	-	-
8	Impact of marine end points (legacy impact)	1.0	0.6	0.6	0.6	0.6

The *energy, emissions, resources consumption* sub-criterion was assessed quantitatively in accordance with the Institute of Petroleum Guidelines (IoP 2000) cited by Oil and Gas UK in its guidelines of comparative assessment as a recognised source of data to support emissions calculations [9]. The *marine impact of operations* and *impact of marine end points (legacy impact)* sub-criteria were assessed qualitatively.

Total emissions for each option were estimated as follows:

- Total removal by reverse reeling 1000te CO_2
- Trench and bury 1175te CO_2
- Leave *in situ* with ends rock-covered 475te CO_2
- Leave *in situ* with ends trenched 965te CO_2
- Leave *in situ* with ends removed 557te CO_2

Each of these results achieves the same score on the scale provided by the CA Procedure (Table 13, [5]). Therefore, there was deemed to be no significant difference between the five options and no score was applied, effectively removing this sub-criterion from the CA.

The scores for the *marine impact of operations* sub-criterion were driven by the following factors:

- All options would require some vessel activity outside the 500m exclusion zone at Armada;
- Total removal would require significant seabed disturbance from the mass flow excavation required to debury the umbilical before recovery;
- Backfilling the existing trench would result in seabed disturbance along a corridor approximately 30m wide for the length of the umbilicals;
- Leave *in situ* with additional rock-cover on the ends would result in prolonged recovery time for the marine environment from the introduction of new substrate;

For the 'total removal' option there is no legacy impact on the marine environment, all other options include the umbilical being decommissioned *in situ* and the chemical contents seeping out over time, which drives a lower score for the *impact on marine end points (legacy)* sub-criterion.

Technical

The Technical criterion is split into two sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

The Technical sub-criteria for Type A2 were scored thus:

Ref.	Attribute	Total removal by reverse reeling	Trench and bury full length	Leave in situ with exposed ends rock-covered	Leave in situ with exposed ends buried	Leave in situ with exposed ends cut and removed
9	Risk of major project failure	0.4	0.8	1.0	1.0	1.0
10	Technology demands / track record	-	-	-	-	-

Both sub-criteria were assessed qualitatively.

A subsea contractor has indicated they would consider reverse reeling unfeasible if it proves impossible to flush the umbilical of all chemicals, in particular the methanol. Reeling the umbilical with the chemicals still in the cores would present an unacceptable HSE risk to the contractor and an alternative removal method would be required. This results in the lower score for 'total removal' against the *risk of major project failure* sub-criterion.

Back-filling carries the risk that acceptable depth-of-burial is not achieved along the full length of the umbilicals, requiring additional remediation such as rock-cover and an additional vessel to be mobilised. This results in a slightly lower score for the backfilling option against the *risk of major project failure* sub-criterion.

All options were considered to be standard industry practice and the techniques proposed have a proven track record. Therefore, it was assessed that there is no significant difference between the five options for *technology demands / track record* and so no score was applied, effectively removing this sub-criterion from the CA.

Societal

The Societal criterion is split into two sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

Both sub-criteria were assessed qualitatively.

For both sub-criteria, there was assessed to be no significant difference between the five options and so no score was applied, effectively removing these sub-criteria from the CA.

Economic

The Economic criterion is split into two sub-criteria which were individually assessed and scored according to the scales provided in the CA Procedure [5].

A cost estimate was produced for each option and used to assess the *Cost* sub-criterion quantitatively. The *cost risk and uncertainty* sub-criterion was assessed qualitatively.

For both sub-criteria, there was assessed to be no significant difference between the five options and so no score was applied, effectively removing these sub-criteria from the CA.