Leman F & G
Comparative Assessment

Emerging Recommendations Report


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R01	Issued for review.
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External stakeholders consulted during the Leman F & G Decommissioning Comparative Assessment process:

- National Federation of Fisheries Organisations (NFFO);
- Offshore Petroleum Regulator for Environment and Decommissioning (OPRED);
- Joint Nature Conservation Committee (JNCC);
- Centre for Environment, Fisheries and Aquaculture (CEFAS).

Collectively referred to in this document as “**stakeholder consultees**”.

1. Executive Summary

This document provides a record of the Comparative Assessment (CA) of credible decommissioning options, carried out for the Leman F & G subsea infrastructure. It presents the emerging recommendations for statutory and public consultation in support of the Leman F & G Decommissioning Programmes [1].

The Leman F & G Platforms are two Normally Unattended Installations (NUIs) which support production from the Leman Field. Situated 48km and 51km north-east of Bacton in the Southern North Sea (SNS) area of the U.K. Continental Shelf (UKCS) respectively, production from Leman F & G is exported to the Leman A Complex via subsea pipelines before it is exported to Bacton.

The subsea infrastructure associated with Leman F & G has been subjected to CA in order to determine the optimal solution for decommissioning. This infrastructure includes the 14", 2.7km production pipeline from Leman G to Leman F (PL364); the 20" 4.8km production pipeline from Leman F to Leman A (PL363); the 4" 4.8km power cable from Leman A to Leman F (PL5148); the 4" 2.7km power cable from Leman F to Leman G (PL5147); as well as associated mattresses and grout bags.

The CA has been conducted in accordance with the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) Guidance Notes on Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998 [2].

This CA is submitted by Shell U.K. Limited, registered company number 00140141 (Shell) as operator, on behalf of itself and its co-venturer Esso Exploration and Production UK Limited, registered company number 00207426, both being the recipients of the Section 29 Notices, and throughout this document the terms 'owners', 'we' and 'our' refer to all the co-venturers.

A summary of the recommendations for each scope is presented in Table 1-1 below.

Scope	Scope description	Emerging Recommendation
1	Leman F & G Pipelines PL363 and PL364	Decommission in situ with surface-laid tie-ins removed and ends remediated. This recommendation includes the mattresses at PL5148's crossing of PL363, and PL5147's crossing of PL364
2	Leman F & G Power Cables PL5147 and PL5148	Decommission in situ with surface-laid tie-ins removed and ends remediated
3	LinkLok mattresses at pipeline tie-ins	Total removal. In the event of practical difficulties during detailed engineering or execution, OPRED will be engaged

Table 1-1 – Emerging Recommendations Summary

2. Introduction

2.1. Purpose

The purpose of this report is to present the emerging recommendations from the comparative assessment for the Leman F & G subsea infrastructure in support of the Leman F & G Decommissioning Programmes [1].

The following is included within this document:

- Description of the infrastructure to be decommissioned.
- Description of decommissioning options considered.
- Comparative assessment methodology.
- Emerging recommendations from the comparative assessment.

The decommissioning options for the pipelines and umbilicals have been subjected to a process of comparative assessment in order to determine the optimum method of decommissioning in compliance with the OPRED Guidance Notes [2].

The following pipelines and umbilicals are included in the comparative assessment:

PL Number	Name	Diameter (inch)	Approx. Length (km)
PL363	Leman F Production Pipeline	20	4.8
PL364	Leman G Production Pipeline	14	2.7
PL5147	Leman G Power Cable	4	2.7
PL5148	Leman F Power Cable	4	4.8

Table 2-1 – Pipelines and umbilicals subject to comparative assessment

2.2. Assumptions

Assumptions for the comparative assessment:

- The riser sections of all four lines will be disconnected from the main pipelines and remain in situ within their respective caissons and jacket. These riser sections will be removed with their respective jacket.
- The Leman F & G topsides and jackets will be fully removed

2.3. Regulatory Context

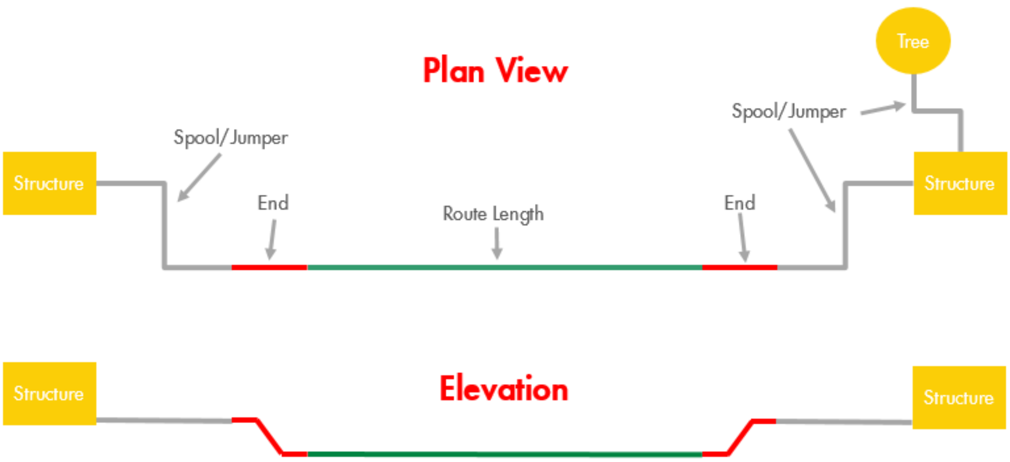
The decommissioning of offshore oil and gas installations and pipelines on the UKCS is regulated through the Petroleum Act 1998, as amended by the Energy Act 2008. The U.K.'s international obligations on decommissioning are governed principally by the 1992 Convention for the Protection of the Marine 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 [2] align with OSPAR Decision 98/3.

Pipelines currently do not fall within the remit of OSPAR Decision 98/3, but it is a requirement of the OPRED Guidance Notes [2] that operators apply the OSPAR framework when assessing pipeline decommissioning options.

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

2.4. General Definitions

The following table specifies the meaning of wording in this report when it is used in a general context to avoid any confusion or doubt.

Wording	Definition for the purposes of this assessment
Pipeline	When pipeline is used in the general text, this should be assumed to mean pipeline in general and may also reference the pipeline system (including spools, cathodic protection etc.), e.g. this can refer to a rigid or flexible pipeline. If a specific pipeline is referenced, then this may also include "rigid" or "flexible" pipeline.
Protection	If protection is referenced this will refer to concrete mattresses and/or grout bags. Any other protection will be specifically referenced.
Route Length / End / Spool / Jumper	A single pipeline / cable is split into 3 different sections for the purpose of this comparative assessment. The route length, which can generally be described as the section of pipe / cable within its trench. The end of a pipeline / cable in general is the section between the trench transition (as the line comes out of a trench) and the tie-in to the structure (including spools). Finally, the spool or jumper which is the section of pipe / cable lain on the seabed and facilitates the tie-in to any structures. The diagram below illustrates the differences between the different sections: 

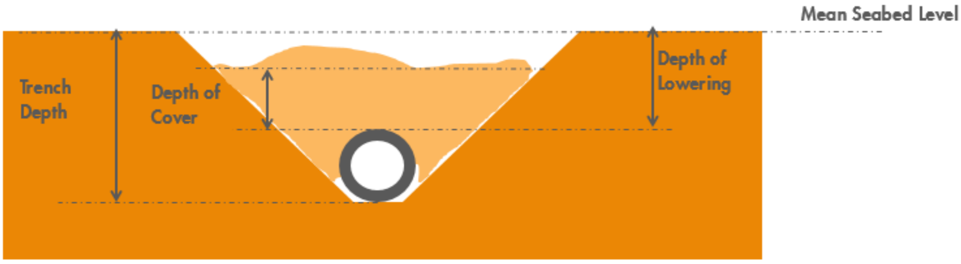
Wording	Definition for the purposes of this assessment
Burial Depth Definitions	Different definitions will be used for different burial depths. The following diagram illustrates the different burial depth definitions: 
Exposure	When an exposure is described this is essentially when the crown of the pipe or cable can be seen. This does not generally mean a hazard.
Reportable Span	A reportable span is a significant span which meets set criteria (FishSAFE criteria) of height above the seabed and span length.
Fluidising	Fluidising is the process of fluidising the seabed to the point where the soil has no inherent strength and hence the pipe or similar will simply fall to the bottom of the trench.

Table 2-2 – General Definitions

2.5. Abbreviations

A&R	Abandonment and recovery	NFFO	National Federation of Fisheries Organisations
AIS	Automatic Identification System	NSTA	North Sea Transition Authority
ALARP	As Low As Reasonably Practicable	NUI	Normally Unattended Installation
BEIS	Department for Business, Energy and Industrial Strategy	OBM	Oil Based Mud
CA	Comparative Assessment	OCNS	Offshore Chemical Notification System
CEFAS	Centre for Environment, Fisheries and Aquaculture Science	OEUK	Offshore Energy UK
DOB	Depth of Burial	OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
DOC	Depth of Cover	OSPAR	Oslo Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
ESDV	Emergency ShutDown Valve	POB	Persons on Board
EUNIS	European Nature Information System	PLONOR	Posing Little Or No Risk
FAR	Fatal Accident Rate	QRA	Quantitative Risk Assessment
FEED	Front End Engineering Design	ROV	Remotely Operated Vehicle
GHG	GreenHouse Gases	SAC	Special Area of Conservation
ICES	International Council for the Exploration of the Sea	SIMOPS	Simultaneous Operations
JNCC	Joint Nature Conservation Committee	SNS	Southern North Sea
LAT	Lowest Astronomical Tide	UKCS	United Kingdom Continental Shelf
MCZ	Marine Conservation Zone		
MoD	Ministry of Defence		
NFFO	National Federation of Fisheries Organisations		
NSTA	North Sea Transition Authority		
NUI	Normally Unattended Installation		
OBM	Oil Based Mud		
OCNS	Offshore Chemical Notification System		

Table 2-3 – Table of Abbreviations

2.6. Field Overview

2.6.1. General

The Leman Gas Field was discovered in December 1965, with production from Leman commencing in 1968. Operation of the Leman Field is split between Shell and Perenco.

The Foxtrot (F) and Golf (G) Platforms are NUIs, with maintenance or well service visits carried out via walk-to-work vessels. Whilst overnight stays are not planned, an Unplanned Overnight Shelter (UOS) is provided on both platforms.

Both facilities are controlled by the Installation Control Centre (ICC) at Bacton and served by a Field Response Team (FRT) sourced from the Leman Complex and/or onshore personnel.

Leman F stands in 35m water depth, approximately 73km north-east of Lowestoft and 48km from Bacton in Block 49/26. Leman G stands in 20m water depth, approximately 75km north-east of Lowestoft and 51km from Bacton in Block 49/26.

Production from Leman G is exported to Leman F via the 2.7km, 14" carbon steel gas export pipeline PL364. Production from both Leman G and Leman F is then exported to the Leman A Complex via the 4.8km 20" carbon steel gas export pipeline PL363. At the Leman A Complex, water is removed and the gas is compressed together with the gas produced by the other Leman platforms and the Corvette Pipeline User Group (CPUG) platforms, before it is exported to Bacton.

Power is provided via cables from Leman AK to Leman F (PL5148), and from Leman F to Leman G (PL5147).

Leman F and G are two satellite NUIs in late life which contribute only a small percentage of the overall production from Shell's Leman assets. Shell has submitted a Cessation of Production (CoP) Report to the North Sea Transition Authority (NSTA) seeking approval to cease production from Leman F and G no earlier than 31 December 2022. The NSTA issued a letter of no objection to these proposals on 29 March 2022.

The topsides and jacket for both Leman F and Leman G will be fully removed as part of the decommissioning scope.

Figure 2-1 provides an overview of the Leman Field layout, with Leman F and Leman G highlighted.

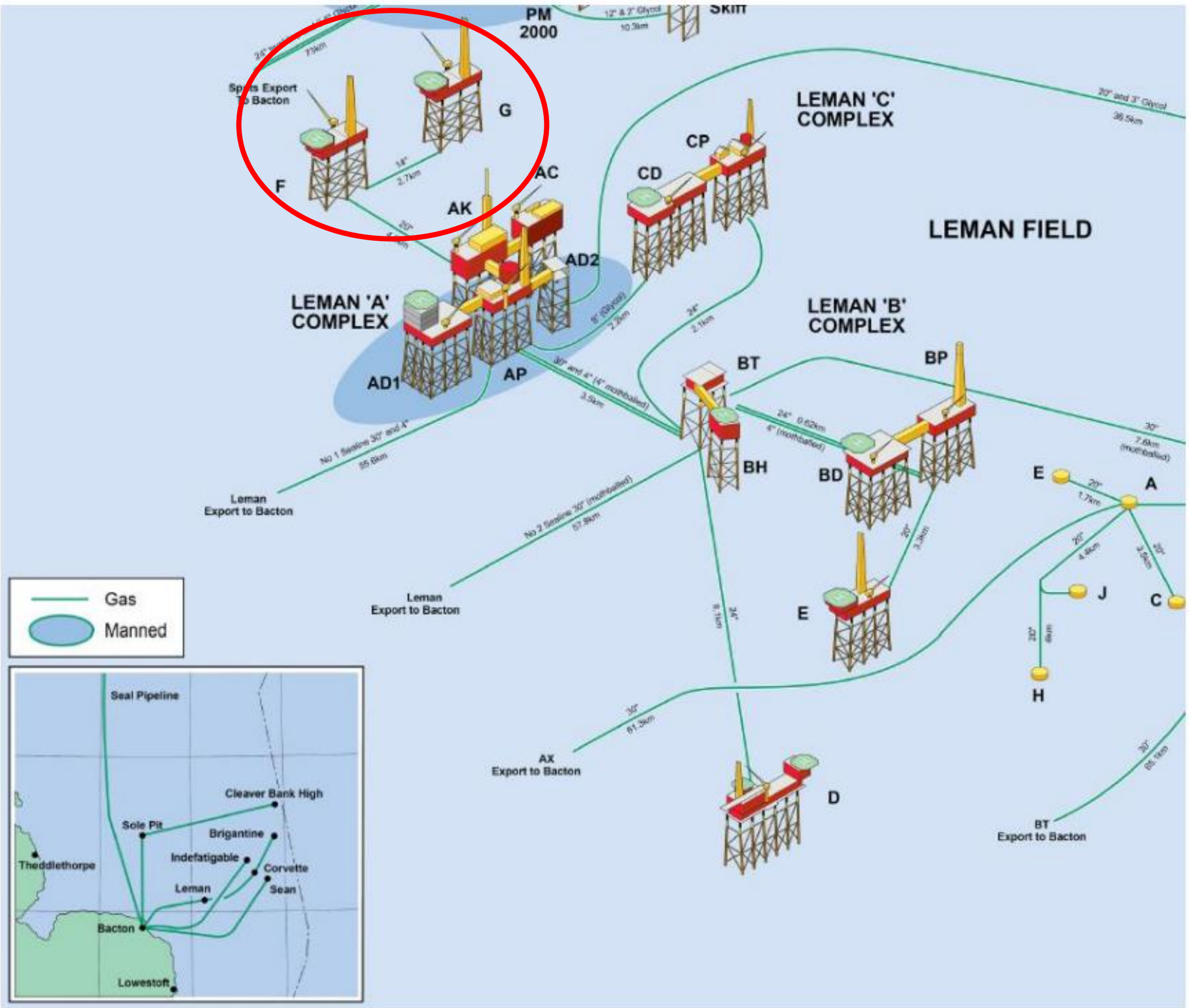


Figure 2-1 – Leman Field Location

2.6.2. Environmental Summary of Leman F & G

Environmental receptors
Physical environment
Leman F and G are located in Block 49/26. The water depth across the surveyed area varies from approximately 20 m below Lowest Astronomical Tide ('LAT') to 49.7 m below LAT.
Conservation interests
Both Leman F and Leman G are located within two protected areas: the North Norfolk Sandbanks and Saturn Reef SAC and the Southern North Sea SAC. The North Norfolk sandbanks are the most extensive example of the offshore linear ridge sandbank type in UK waters. They are a representative functioning example of the Annex I habitat 'Sandbanks which are slightly covered by seawater all the time'. The Southern North Sea SAC has been identified as an area of importance for harbour porpoise, an Annex II species. Other conservation sites that lie within 40 km of Leman platforms are the Haisborough, Hammond and Winterton SAC (10 km SSW), Greater Wash Special Protection Area (SPA) (29 km WSW) and Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) (41 km WSW). The most recent Gardline (2021) habitat assessment survey identified the presence of exposed or subcropping peat and clay largely corresponded with S. spinulosa reefiness, most notably 1 – 1.5 km SE of Leman F, where both were noted in highest density. This suggests that these relatively soft and stable clay and peat outcrop features provide an anchor point from which S. spinulosa can establish a reef, fed by a supply of nearby sand for tube building (Gardline, 2021 [4]). The UK Biodiversity Action Plan (UKBAP) listed priority habitat 'peat and clay exposures with piddocks' has been documented within the broader Leman field, in particular within the Leman A area in a survey carried out in 2019. Patches of peat outcrops and peat clasts were also recorded at Leman F in a survey carried out in 2020. However, no piddocks (clam-like shellfish) or piddock bores were recorded, with the area unlikely to classify as the UKBAP priority habitat.
Marine mammals
Harbour porpoise have been observed and are commonly seen throughout the year within the vicinity of the Leman F and G platforms in variable densities. These sightings peak in the summer months. The density of harbour porpoise in the project area is estimated to be 0.888 animals/km2. Harbour porpoise are Annex II listed species and European Protected Species (EPS). No other cetacean species are likely to be observed in the Leman area. Both grey and harbour seal densities are low (0.4 individuals per 25 km2) across the Leman area due to its distance from shore. Both seal species are Annex II protected species.
Seabed
The seabed around the Leman installations is considered to be made up of largely EUNIS 'Circalittoral mixed sediment' (A5.44) and 'Circalittoral find sand' (A5.25). EUNIS 'Infralittoral fine sand' (A5.23) was found at the shallower stations within the survey area and where S. spinulosa reef were located, EUNIS A5.61 (Sublittoral polychaete worm reefs on sediment) was present. Sediment particle mean diameter identified composed of moderate to well sorted medium sand to gravelly sand. In the Leman G area, the amphipod crustacean was the most abundant and most dominant taxon recorded. The next most abundant taxa were polychaetes and amphipods. The remaining most abundant species identified in the survey included additional polychaetes, urchin, bivalve, crustacean and four amphipods. At Leman F, the most abundant taxon overall were annelids. More than half of the dominant taxa reported within the current survey comprised polychaetes. The annelids found are typically an opportunistic order of bristle worms and are commonly found in the North Sea in a range of sediment types. Actiniaria were highly

abundant throughout the survey; their presence being indicative of a shift to coarser sediments allowing for attachment of these taxa (Fugro, 2020b). The polychaetes found at Leman G, were also present in significant numbers at Leman F . Benthic epifauna are sparse along the pipelines connecting the three Leman platforms with Arthropoda, namely Crustacea, being the most abundant taxonomic group. Annelida, was the second most abundant taxonomic group [5]. These results are to be expected considering the sediment type. Within areas of S. spinulosa reef formations epifauna were observed in lager numbers, with crabs, anemone and hydroids being present. Overall, the epifauna observed was typical of background conditions for SNS.
Fish
Leman F and Leman G are located in an area of high intensity spawning for plaice in the winter months; cod, lemon sole, mackerel, Norway lobster, sprat, whiting and sandeels also use the area for spawning throughout the year. The following species have nursery grounds near the project area: herring, lemon sole, mackerel, Norway lobster, sandeels, sprat, tope shark, and whiting. Aires et al. (2014) provides modelled spatial representations of the predicted distribution of juvenile fish (less than one year old). The modelling indicates the presence of multiple juvenile species in Block 49/26 including: anglerfish, blue whiting, European hake, haddock, herring, mackerel, Norway Pout, plaice, sprat and whiting. The probability of juvenile aggregations across the project area is low for all species (<0.15).
Seabirds
The area surrounding Leman F and G is used by the following species throughout year: sooty shearwater, Manx shearwater, northern gannet, pomarine skua, Arctic skua, great skua, black-legged kittiwake, little gull, great black-backed gull, common gull, lesser black-backed gull, herring gull, sandwich tern, common tern, Arctic tern, guillemot, razorbill and Atlantic puffin . In recent years, there has been an increase in the number of seabirds utilising offshore installations for nesting. Opportunistic species such as kittiwake and herring gull are utilising artificial nest locations and rearing chicks. In some instances, colonies of several hundred birds have established and return each year. Currently there are no birds using the NUI's for nesting, however this situation will be monitored moving forward. The Seabird Oil Sensitivity Index identifies areas at sea where seabirds are likely to be most sensitive to surface pollution. Seabird sensitivity to oil within Block 49/26 varies throughout the year, from low in the summer months (May-September) to extremely high in January and February.
Social receptors
Commercial fisheries
The Southern North Sea sector provides a relatively low contribution to the commercial fishery compared to areas such as the northern North Sea and west of Scotland . In addition, there are fewer key ports located along the east coast of England. The Leman NUIs are situated within ICES Block 35F2 which is an area of moderate fishing activity (targeted by both UK and international vessels). The most frequently used gear type in ICES Rectangle 35F2 is trawls, specifically beam trawls. Both shellfish and demersal species are targeted however, demersal value far exceeds that of shellfish, comprising 3% and 97% respectively of the average landings value from 2016 to 2020, with the dominant species caught including plaice, turbot and sole. Pelagic species have only recorded landings and therefore value within the years 2017 and 2020, however these values are still negligible accounting for <0.01% of the average landings value from 2016 to 2020. Trawling intensity across pipelines is very low; between 0 – 12 trawl passes across the ICES sub-blocks associated with the Leman pipelines per year on average (between 2007 – 2015). AIS vessel tracking data also shows that trawling activity in the vicinity of the Leman pipelines is negligible.

Other sea users
Shipping activity within Block 49/26 is considered to be high overall (OGA, 2016). Although within the immediate Leman area, fishing activity is relatively low. There are multiple surface installations within 40 km of Leman F and Leman G; the closest to both being Leman AD1 platform operated by Shell (3 km WSW from Leman F and 5 km ESE from Leman G). The nearest active cable is located 22 km ENE of the Leman platforms. There are some historic cables in the vicinity of the project location – though disused, sections of these cables may remain on the seabed. Block 49/26 does not lie within training ranges that are areas of concern to the MoD (OGA, 2019). There are no renewable energy sites within 40 km of the project area. The nearest wreck is located approximately 4 km ENE of the project area and is classified as non-dangerous.
Onshore communities
Per the Environmental Appraisal scoping, there are no Onshore Communities sensitivities identified that would be impacted by the Leman F & G Decommissioning scope.

2.6.3. Leman F & G Field Infrastructure

Leman F & G are NUIs, tied-back to Shell UK's Leman A Platform with the following pipelines and umbilicals.

PARAMETER	Leman F Production Pipeline	Leman F Power Cable	Leman G Production Pipeline	Leman G Power Cable
S# / PL#	S0410 / PL363	S0806 / PL5148	S0412 / PL364	S0805 / PL5147
Diameter	20"	4"	14"	4"
Wall Thickness	17.48mm	N/A	14.27mm	N/A
Material	Carbon Steel	N/A	Carbon Steel	N/A
Length	4.8km	4.8km	2.7km	2.7km
Service	Gas production	Power supply	Gas production	Power supply
Current Contents	Hydrocarbon	N/A	Hydrocarbon	N/A
Coatings	Concrete, neoprene at risers	N/A	Concrete, neoprene at risers	N/A
Offshore Crossings	See below	See below	See below	See below

Table 2-4 –Pipelines and Cables Summary

PL363 is a 20" carbon steel pipeline transporting gas condensate from Leman Foxtrot to the Leman AK hub. The pipeline consists of:

- ~36m riser section through the Leman F jacket
- ~36m tie-in spool between the Leman F riser and main pipeline
- ~4800m main pipeline
- ~36m tie-in spool between the main pipeline and Leman AK riser
- ~36m riser section through the Leman AK jacket

The battery limits for PL363 are the two 20” riser Emergency Shutdown Valve (ESDV) at the top of each riser.

The pipeline was trenched and buried on installation, to a target depth of 1.8m. Historic depth-of-cover data was provided at the CA Workshop and is shown in Appendix A: Pipeline Burial Depth Summary.

The riser sections of the pipeline are neoprene coated, with the main length of the pipeline protected by a ~40mm concrete coating and reinforcement mesh.

PL5148 (S0806) is a flexible umbilical providing power from Leman AK to Leman F. The umbilical is approximately 4.8km long, has an outside diameter of 273mm and consists of:

- 100mm 6.6kV subsea cable
- 3-off power conductors
- 12-off twisted and individual screened signal pairs
- Double counter-wound layer of galvanised armour wiring
- Outer sheaving

The battery limits for the umbilical are the 250mm Sch80 ANSI flanges at the top of each j-tube at Leman F and Leman AK.

The umbilical was trenched and buried on installation, to a target depth of circa 1.0m. Historic depth-of-cover data was provided in the CA Workshop and is shown in Appendix A: Pipeline Burial Depth Summary.

PL364 is a 14” carbon steel pipeline transporting gas condensate from Leman Golf to Leman Foxtrot. The pipeline consists of:

- ~39m riser section through the Leman G jacket;
- ~12m tie-in spool between the Leman G riser and the main pipeline;
- ~2500m main pipeline;
- ~12m tie-in spool between the main pipeline and the Leman F riser;
- ~39m riser section through the Leman F jacket.

The battery limits for PL364 are the two 14” riser Emergency Shutdown Valve (ESDV) at the top of each riser.

The pipeline was trenched and buried on installation, to a target depth of 1.8m. Historic depth-of-cover data was provided at the CA Workshop and is shown in Appendix A: Pipeline Burial Depth Summary.

The riser sections of the pipeline are neoprene coated, with the main length of the pipeline protected by a ~92mm concrete coating and reinforcement mesh.

PL5147 (S0805) is a flexible umbilical providing power from Leman F to Leman G. The umbilical is approximately 2.7km long, has an outside diameter of 273mm and consists of:

- 100mm 6.6kV subsea cable
- 3-off power conductors
- 12-off twisted and individual screened signal pairs
- Double counter-wound layer of galvanised armour wiring
- Outer sheaving

The battery limits for the umbilical are the 250mm Sch80 ANSI flanges at the top of each j-tube at Leman F and Leman G.

The umbilical was trenched and buried on installation, to a target depth of circa 1.0m. Historic depth-of-cover data was provided in the CA Workshop and is shown in Appendix A: Pipeline Burial Depth Summary.

There are no third-party crossings associated with the Leman F & G pipelines and cables. However, the lines do cross each other as follows:

- Approximately 320m from the Leman A Platform and within its 500m exclusion zone, PL5148 crosses over PL363. The crossing is protected by mattresses and is, according to the latest survey data, fully buried.
- Approximately 20m from the Leman F Platform and within its 500m exclusion zone, PL5147 crosses over PL363. The crossing is supported by a rollerbridge (3.2m x 2.2m x 2.3m, weighing 13.2Te) and, according to the latest survey data, is proud of the seabed.
- Approximately 340m from the Leman G Platform and within its 500m exclusion zone, PL5147 crosses over PL364. The crossing is protected by mattresses and is, according to the latest survey data, fully buried.

Figure 2-2 provides an overview of the subsea layout for Leman F & G pipelines and cables, overlaid with the 2021 survey data indicating the presence and density of the *S. spinulosa* reef and sandeel habitat.

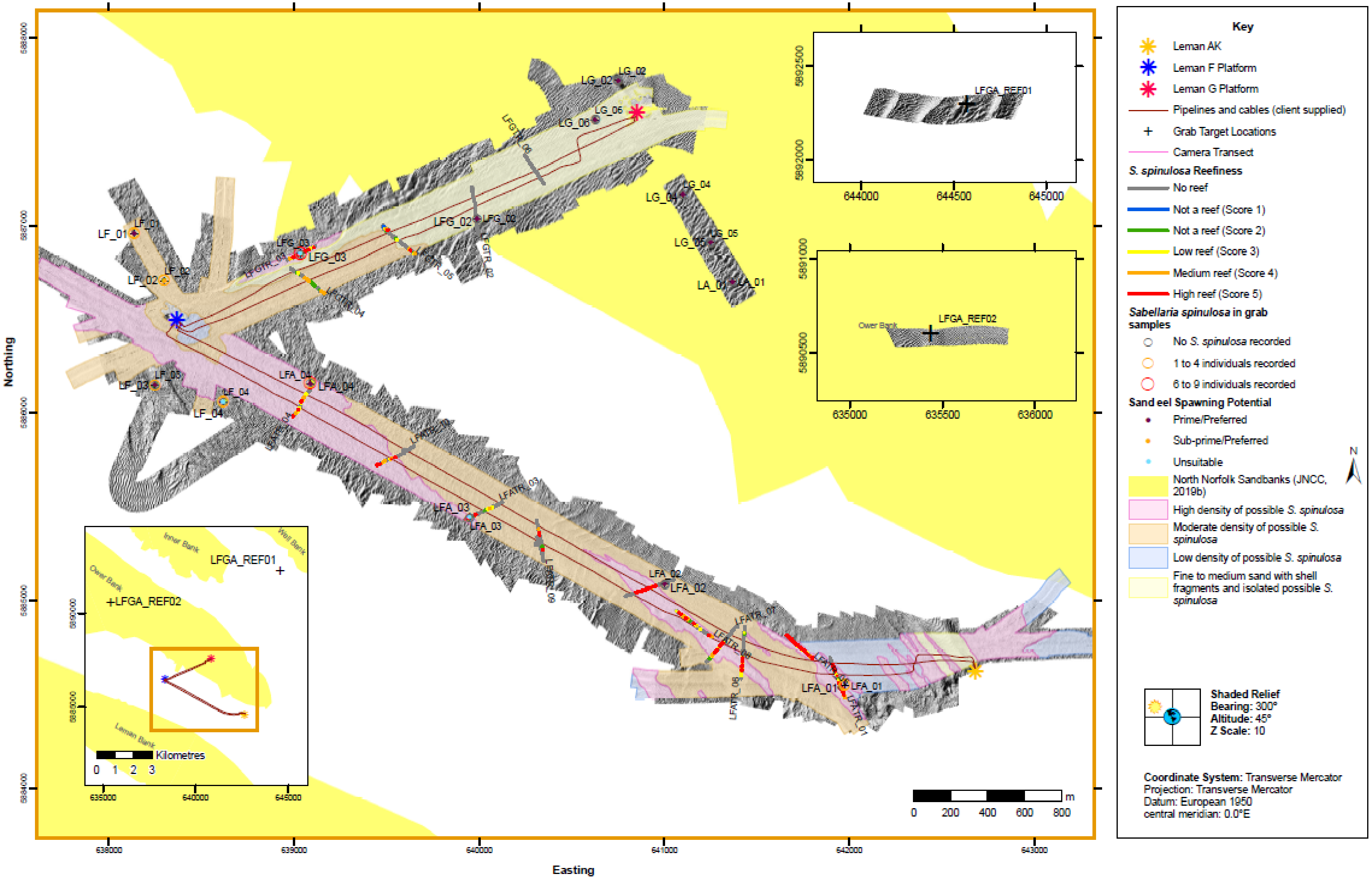


Figure 2-2 – Leman F & G Layout, Overlaid with reef density and sandeel habitat

2.6.3.1. Mattresses, Grout Bags and Stabilisation Features

Prior to installing the tie-in spools between the main pipelines (PL363 and PL364) and the four risers at Leman AK (one riser), Leman F (two risers) and Leman G (one riser), Shell installed seabed stabilisation mattresses. These consist of a number of Linklok mattresses shackled together to form a stable surface on which the tie-in spools were to be laid. Each Linklok mattress is 10m x 2.5m x 0.15m, weighing approximately 11.4 Te (in air). The mattresses were installed in pairs, before being shackled together subsea into larger surfaces up to 40m long. The mattresses consist of polyethylene segments cast on a synthetic rope network and filled with high density concrete mix.

Further, a number of frond mattresses were installed alongside and over the surface-laid sections of tie-in spools to mitigate against pipeline scouring.

There are 3 crossings of note containing various stabilisation features:

- PL363 is crossed by PL5148 (S0806, Leman AK to F Power Cable) approximately 320m from the Leman AK Platform, within its 500m safety zone. The crossing consists of a bitumen and frond matts – PL363 is buried at this location.
- PL363 is crossed by PL5147, (S0805, Leman F to G Power Cable) approximately 20m from the Leman F Platform, within its 500m safety zone. The crossing consists of a rollerbridge (3.2x2.2x2.3m) installed over PL363.
- PL364 is crossed by PL5147 (S0805, Leman F to G Power Cable) approximately 340m from the Leman G Platform, within its 500m safety zone. The crossing consists of bitumen and frond matts – PL364 is buried at this location

Grout bags have been installed in conjunction with the mattress arrangements and at specific locations to support the tie-in spools and mitigate against pipeline scouring.

The only known area of rock dump associated with the pipelines and cables is installed at the Leman G tie-in flange to mitigate against pipeline scouring. The volume is unknown at this stage and so is conservatively estimated at 100Te.

All the mattresses installed in association with the Leman F & G pipelines and cables have become buried beneath the seabed sediment. The latest available survey of the lines was unable to identify the location of any mattress along the pipeline route.

The integrity of the mattresses is unknown. Installed in 1986, the Linklok mattresses were shackled together subsea to form large stable 'platforms' on which to lay the tie-in spools. In the intervening 35 years, marine growth and significant seabed sediment deposits have buried the mattresses and tie-in spools.

3. Comparative Assessment Process

3.1. General Process Description

The comparative assessment process was performed in accordance with the OPRED Decommissioning Guidance Notes [2] and guidance was used from the OEUK pipeline Comparative Assessment Guidelines [3].

The following sections present the comparative assessment methodology used for each of the Leman F & G scopes, however a summary of the process used is as follows:

- Scoping of subsea infrastructure to be decommissioned and inventory mapping.
- Decommissioning assessment criteria and sub-criteria.
- Decommissioning options to be considered.
- Screening workshop to initially agree the decommissioning options to take further and any grouping to be considered.
- Selection of groups with similar circumstances, to be assessed as a scope group.
- Traffic light assessment.

Stakeholder engagement and multi-disciplinary reviews have formed an important part of the comparative assessment process.

3.2. Scoping and Inventory Mapping

The initial phase of the comparative assessment process was to identify the scope to be decommissioned and map the inventory which requires decommissioning. This is summarised in section 2.6.3.

3.3. Criteria and Sub-Criteria

The next step in the comparative assessment process is to agree the criteria and sub-criteria to be used. Table 3-1 presents the selected criteria and sub-criteria, which was used to assess each option for decommissioning during the comparative assessment process. The criteria are in line with those recommended in the OEUK comparative assessment guidelines [3], with the following exceptions as shown in Table 3-1 below:

- the impact of operations and legacy impact of operations and legacy impact sub-criteria which have been adapted in line with internal lessons learned.
- following the internal screening workshop, it was decided that the sub-criterion *Energy, Emissions, Resource Consumption* will be separated into two separate sub-criteria for *Energy and Resource Consumption* and an individual item for *Emissions*. This allows Shell to align with the NSTA's Stewardship Expectation 11 and specifically the requirement to "ensure[ing] that GHG emissions reduction is considered throughout the entire oil and gas lifecycle". Estimated emissions were quantified for presentation at the CA Workshop

Criteria	Sub-Criteria	Applicable to	Applicable When	Factors	Potential Sources of data
Safety	**Project risk to personnel – Offshore**	Project team offshore, project vessels crew, diving teams, supply boat crew, heli-ops, survey vessels crew	During execution phase of the project including any subsequent monitoring surveys	Type of activity Number of personnel involved & project duration. Number of crew changes (helicopter transfers) Number of vessels involved & SIMOP activity Numbers, durations and depth that divers are anticipated to work. Any unique or unusual handling or access activities required of personnel.	Decommissioning methodology for each option; vessel study; diving study; etc Coarse QRA data based on POB / exposure, durations and activity Fatal Accident Rate (FAR). Industry data will be used to derive the probability of loss of life.
	Project risk to other users of the sea	Navigational safety of all other users of the sea, fishing vessels, commercial transport vessels, military vessels	During execution phase of the project including any subsequent monitoring surveys	Likelihood of incursion into project exclusion zone by other users of the sea Number and type of transits by project vessels to and from the project work site	Fishing study on anticipated activity in area of activity Other vessels movements review, stakeholder engagement
	Operational risk to personnel – Onshore	Onshore dismantling and disposal sites personnel; extent of materials transfers/ handling on land	During execution phase of the project, through to final disposal of recovered materials	Extent of dismantling required & hazardous material handling anticipated. Numbers of road transfers from dismantling yard to final disposal site.	Decommissioning methodology for each option, considering volume and type of material to be returned to shore Coarse QRA data based on POB / exposure, durations and activity Fatal Accident Rate (FAR)
	Potential for a high consequence event	Project team offshore and onshore; project vessels; diving teams; supply boat crew; heli-ops; survey vessels; onshore dismantling and disposal sites personnel	During execution phase of the project including any subsequent monitoring surveys	Decommissioning philosophy; potential for dropped object over a live pipeline; degree of difficulty anticipated in onshore dismantling	Decommissioning methodology for each option; vessel study; diving study; etc
	Residual risk to other users of the sea	Fishing vessels, fishermen, supply boat crews, military vessel crews, commercial vessel crew and passengers, other users of the sea	Following completion of the Decommissioning project and residual / ongoing impact in perpetuity	Extent of facility / equipment / pipeline left in situ on completion of the project and its likelihood to form a future hazard; likelihood for further deterioration; predicted future fishing activity; proximity of retained facilities to main transport routes	Decommissioning methodology for each option, focussing on volume and type of infrastructure to be left in situ; fishing navigational safety study on anticipated activity in area(s) where infrastructure is decommissioned in situ; assessment(s) of degradation for infrastructure left in situ; stakeholder engagement
Environmental	**Impact of operations**	Environmental impact to the marine environment, nearshore areas and onshore caused by project activities	During execution phase of the project from mobilisation of vessels to the end of project activities at the waste processing / disposal site (does not include landfill and long-term storage impacts) For rock placement, trenching and dredging any seabed disturbance is included here, depending on area of	Associated planned discharges; marine noise; seabed disturbance, including seabed footprint (area), sediment suspension and contaminated sediment including drill cuttings; protected habitat and species in nearshore, marine and onshore areas – conservation objectives, their presence, impacts, distance from activities; waste processing	Asset knowledge, decommissioning methodologies, Environmental Baseline Survey, Habitat Survey, Waste Inventory, Environmental Appraisal Report, project schedule, collision assessment, predicted discharges to sea, historic events

Criteria	Sub-Criteria	Applicable to	Applicable When	Factors	Potential Sources of data
			impact – changes to habitat and species are covered in Legacy Impact.		
	Energy and resource consumption	Project activities from vessel mobilisation to the final destination of waste, including the energy penalty for leaving recyclable material in field. Includes vessel mobilisation, demobilisation, waiting on weather, post-decommissioning monitoring surveys.	During execution phase of the project from mobilisation of vessels to the end of project activities at the waste processing / disposal site (does not include landfill and long-term storage impacts) Not recovering and recycling the installations material will require that raw material and energy will be consumed to replace the materials which would have been recycled if the structure had been brought onshore	Number and type of vessels; duration of vessel activities; tasks vessels are fulfilling; vessel station keeping approach Energy required to replace recyclable materials not recovered for recycle of re-use Helicopter trips are not to be included as impact is marginal.	Energy and emissions assessment, undertaken per Institute of Petroleum: Guidelines for the Calculation of Estimates of Energy Use and Gaseous Emissions in the Decommissioning of Offshore Structures
	Emissions	Project activities from vessel mobilisation to the final destination of waste, including the emissions penalty for leaving recyclable material in field. Includes vessel mobilisation, demobilisation, waiting on weather, post-decommissioning monitoring surveys.	During execution phase of the project from mobilisation of vessels to the end of project activities at the waste processing / disposal site (does not include landfill and long-term storage impacts) Not recovering and recycling the installations material will require that raw material and energy will be consumed to replace the materials which would have been recycled if the structure had been brought onshore	Number and type of vessels; duration of vessel activities; tasks vessels are fulfilling; vessel station keeping approach Emissions required to replace recyclable materials not recovered for recycle of re-use Helicopter trips are not to be included as impact is marginal.	Energy and emissions assessment, undertaken per Institute of Petroleum: Guidelines for the Calculation of Estimates of Energy Use and Gaseous Emissions in the Decommissioning of Offshore Structures
	Legacy Impact	Ongoing long term environmental impact and benefit caused by materials left in place or long-term waste storage / landfill	Following completion of the Decommissioning project and residual / ongoing impact For rock placement, trenching and dredging any changes to habitat and species are included here - seabed disturbance is included in Impact of Operations, depending on area of impact.	Waste disposal including onshore landfill and long-term waste storage; habitat alteration and long-term changes in species composition; physical and chemical degradation of products left on the seabed (make and content of material like wax, chemicals, plastic and concrete, steel, debris). CA will be conducted with assumption that reasonable endeavours are used to clean the infrastructure.	Decommissioning methodology for each option, focussing on volume and type of infrastructure to be left in situ; Environmental Baseline Survey; Habitat Survey; Waste Inventory
Technical	**Risk of major project failure** Cost and Schedule overruns. Ease of recovery from excursion.	Overall Project	From project select phase through to completion, including monitoring surveys and ultimate disposal of materials returned to shore.	Maturity of scope definition, confidence level that project will proceed as foreseen; ability to recover from unplanned events which could impact completion of the project as planned;	Decommissioning methodology for each option, concept / pre-FEED study, lessons learned from industry

Criteria	Sub-Criteria	Applicable to	Applicable When	Factors	Potential Sources of data
				extent of potential re-engineering that may be required and its impact if strategy goes wrong	
	Technology demands, Availability / Track Record	Overall Project	From project select phase through to completion, including monitoring surveys and ultimate disposal of materials returned to shore.	Extent of new or emerging technology proposed by the option; extent of application of existing technology to different uses; extent that the approach has been completed before	Decommissioning methodology for each option, concept / pre-FEED study, lessons learned from industry
Societal	**Commercial impact to fisheries**	Impacts from both the decommissioning operations and the end-points on the present commercial fisheries in and around the field	During and following completion of the Decommissioning project and residual / ongoing impact	Residual impact on fishing areas: • If exclusion zones are to be retained where equipment or materials are left in-situ • If fishing habitats are inhibited as a result of the decommissioning methods adopted	Fishing study on anticipated activity in area of activity; decommissioning methodology for each option focussing on volume and type of infrastructure to be left in situ; vessel study; publicly available data; stakeholder engagement
	Socio-economic impact on communities and amenities	The impact from any near shore and onshore operations and end-points (dismantling, transporting, treating, recycling, land filling) on the health, well-being, standard of living, structure or coherence of communities or amenities. E.g. business or jobs creation, job loss, increase in noise, dust or odour pollution during the process which has a negative impact on communities, increased traffic disruption due to extra-large transport loads.	During and following completion of the Decommissioning project and residual / on-going impact	May be positive or negative; jobs created; establishment of track record; improvements to roads and quaysides; use of limited landfill resource	Decommissioning methodology for each option; publicly available data; stakeholder engagement
Economic	**Cost**	Overall Project	Full decommissioning project cost including future monitoring surveys and proposed remediation, if required	Actual cost estimates are not to be included in the CA report, but a normalised scale can be produced to indicate the comparison between each option	Cost and schedule estimates
	Cost Risk / Uncertainty	Overall Project	Project execution phase and ongoing cost liability (surveys and potential remedial action)	Uncertainty in estimates prepared, potential for / risk of growth through the project, risk will be greater with a larger number of unknowns and where activities are weather sensitive	Risk and opportunity register

Table 3-1 – Comparative Assessment Criteria and Sub-Criteria

3.4. Decommissioning Options and Initial Screening Workshop

3.4.1. Decommissioning Options

The options available for decommissioning have been considered and were assessed as part of the initial screening process to assess each option's feasibility. The options for decommissioning being assessed are shown in Section 4.

3.4.2. Initial Screening Workshop

An initial screening workshop was held where internal experts and third-party contractors were consulted to assess the technical feasibility and practicality of each of the decommissioning options relating to each scope. The initial screening workshop also identified which scopes displayed similar characteristics and could therefore be grouped and assessed together.

Guidance on assessment parameters against the five Comparative Assessment criteria was agreed at the initial screening workshop. The assessment criteria parameters are provided in Appendix B – CA Assessment Guidance. These parameters were developed from Appendix A of the Oil and Gas UK Guidelines for Comparative Assessment in Decommissioning Programmes [3], with amendments as noted in Section 3.3.

3.5. Comparative Assessment Workshops

A Comparative Assessment (CA) workshop was held on 22 March 2022, including licence partners and stakeholder consultees to inform the emerging recommendations. During the CA workshop, the scopes were presented to and discussed with the attendees detailing the circumstances associated with each item of infrastructure, the credible options identified, and the impacts against the fifteen CA sub-criteria. The decommissioning recommendations were presented for discussion with the stakeholders in attendance.

3.6. Traffic-light assessment

The assessment of each credible option against the fifteen CA sub-criteria is provided in Section 5, using a simple traffic-light system. An example of the traffic-lighting is shown in Table 3-2 below.

		Option Category	Leave In-Situ	Remediate	Remove
		Include Option for Screening?	☑ Option 1	☑ Option 2	☑ Option 5
Criteria	Ref	Sub Criteria	Option 1: Leave In-Situ (Do Nothing)	Option 2: Leave In-situ (Remediate with Rock Cover Above Seabed)	Option 5: Full Removal
Safety	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 even			
	5	Residual risk to other users of the sea			

Table 3-2 – Example Traffic Lighting

Each option can be scored as the following for each sub-criterion:

- Green – comparatively preferable to other options
- Amber – moderately less preferable in comparison to other options scored green, or moderately more preferable than other options scored red
- Red – comparatively less preferable to other options
- Grey – no score applied to all options for this sub-criterion as there is no significant difference between any of the options

Note that scores are assigned in comparison to the other credible options available only. A ‘red’ result, for example, does not necessarily mean that an option is unacceptable or has been ruled out, only that it is not preferable for the associated sub-criterion in comparison to the other options.

Note that cost may only be a determining factor when all other criteria emerge as equal.

4. Decommissioning Options

A brief discussion of the decommissioning options is presented below, which will cover the high-level options of pipeline removal, re-use, remediation and leave in-situ.

4.1.1. Re-use

No opportunities have been identified to re-use any of the Leman F & G subsea pipelines, spools, cables or jumpers.

4.1.2. Removal

4.1.2.1. Cut and lift

The cut and lift method to date has been the most commonly used method to remove pipelines. The method requires the pipeline to be un-trenched and water flooded. The pipeline will then be cut into sections of approximately 24m in length by a Remotely Operated Vehicle (ROV), deployed from an ROV Support Vessel (ROVSV), using hydraulic shears and then recovered by a vessel using a hydraulic lifting beam ready for transport to shore and disposal. A simplified schematic of the cut and lift process is shown in **Error! Reference source not found.**. Other cutting methods are available, however for the purposes of this CA and based on Shell's experience with decommissioning projects to date, it has been assumed that cuts will most likely be performed by hydraulic shears.

Error! Reference source not found. indicates that cut sections of the pipeline are transferred to a second vessel, i.e. a supply boat, for transit to shore. Shell assumes the use of a supply boat to support the removal of pipelines longer than 3.5km. As it is assumed that PL363 (4.8km) and PL364 (2.7km) will be recovered in a single campaign, it is assumed that a support vessel will be utilised throughout.

The cut and lift method can be used for the entire pipeline removal or localised sections, such as spools or spans.

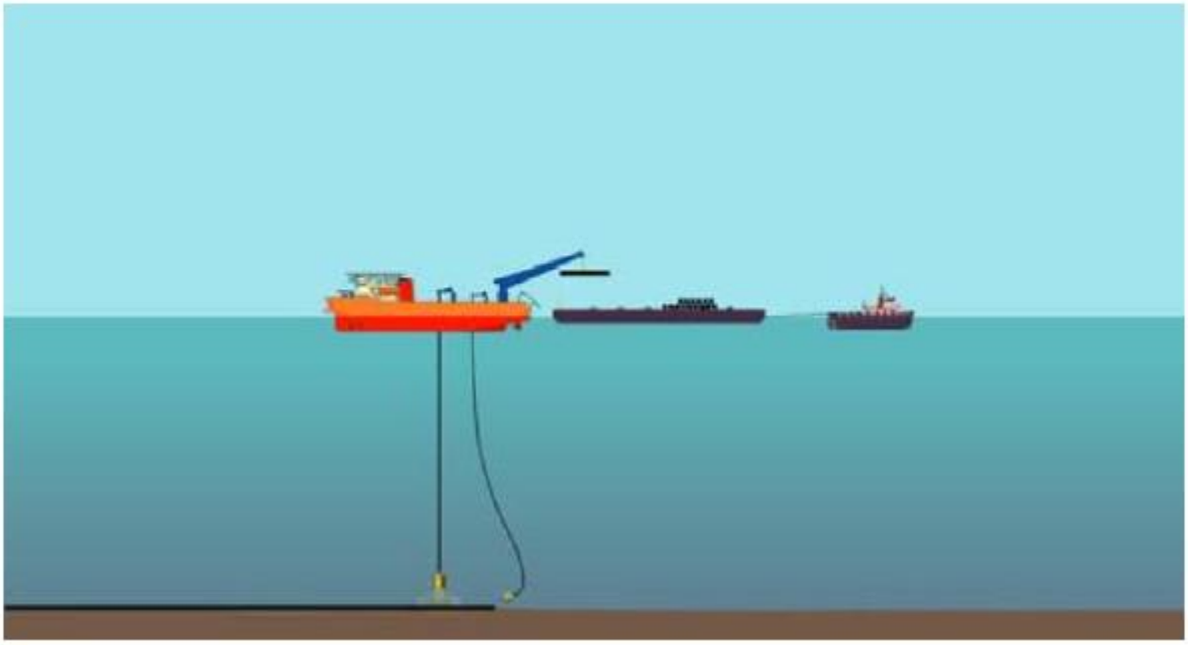


Figure 4-1 – Cut and Lift Pipeline Removal Illustration

4.1.2.2. Reverse Reel

Reverse reeling has previously been performed on flexible pipelines and cables, however there is very little, if any, experience of the reverse reeling of a complete rigid pipeline. Further, reverse reeling of a concrete coated pipeline is not considered a credible option for PL363 and PL364 but may be considered for the Leman power cables PL5147 and PL5148.

To reverse reel pipelines and cables, they would potentially need to be un-trenched and de-watered to reduce the submerged unit weight. The pipeline ends would then need to be cut or disconnected allowing the reeling vessel to connect to the pipeline end and recover the end using the A&R (abandonment and recovery) winch until the tensioner could grip the pipeline and proceed to pull it on to the vessel. The pipeline or cable would then need to be connected to the main reel, so that the vessel could proceed to reel on. Once reeling is complete, the pipeline would be transported to shore on the reel for disposal or recycling.

4.1.2.3. Reverse S-lay

Both Leman AK to F (PL363) and Leman F to G (PL364) pipelines were installed from the BAR 420 pipelay barge using the S-lay technique.

Reverse S-lay is a potentially feasible option to recover pipelines, however there is very limited experience using this technique and a detailed study and trials would need to be performed prior to committing to this method. Reverse S-lay is the reversal of the common S-lay installation technique, which generally consists of a pipeline lay vessel or barge equipped with a stinger and tensioner where the line pipe is welded together on the vessel, prior to being laid onto the seabed, controlled by the applied tension to the pipeline.

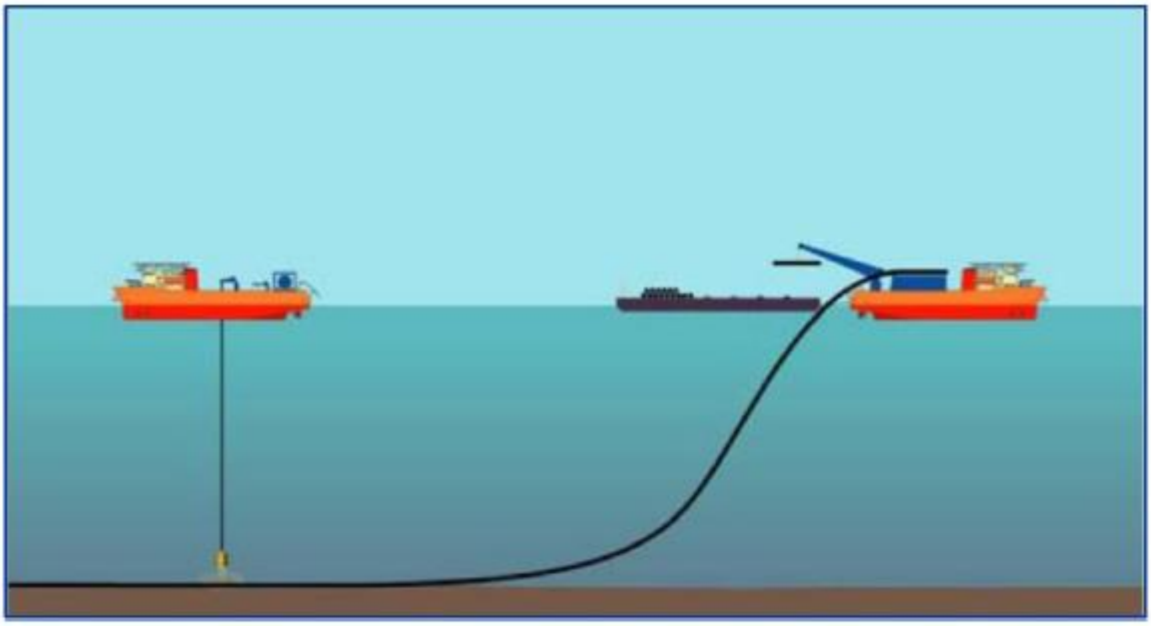


Figure 4-2 – Reverse S-lay Illustration

For the removal process the tensioner would be used to recover the pipeline from the seabed and then cut to manageable lengths on the vessel for transport back to shore.

The pipeline would need to be un-trenched to perform this method of recovery. In addition, it would be prudent to dewater the pipeline (air filled or nitrogen purged) to reduce the equivalent weight and hence reduce the required tension. A summary of the reverse S-lay methodology is summarised in **Error! Reference source not found.**.

The presence of concrete coating on both PL363 and PL364 introduces significant safety risk for reverse S-lay and it is therefore not considered a credible option.

4.1.3. Decommission In-situ

4.1.3.1. Pipelines (No remediation)

This option consists of decommissioning the pipeline or cable in-situ with no further remediation; however the pipeline ends will be cut at each end, with the ends requiring some form of protection - either cut and buried or cut and rock covered.

4.1.3.2. Pipelines (Re-trench)

Re-trenching is an option for pipelines subject to increased risk from snagging or becoming unstable (e.g. buoyant pipelines or free spanning pipelines) due to a reduction in the burial depth or cover. The retrenching of a pipeline can be performed by a jet trencher, plough or mass flow excavator. Re-trenching on areas with remedial rock may not be possible as it would require the rock to be removed prior to trenching – this is uncertain and dependent on the volume and type of rock deposited on each line.

4.1.3.3. Localised Cut and Lift

For localised exposures or areas of low cover, localised cut and lift operations can be used, which would be executed in a similar manner to that shown in Section 4.1.2.1.

Localised cut and lift would require some remediation of the pipeline ends that are left in situ, either by remedial rock cover or burial.

4.1.3.4. Pipelines (Remedial Rock Cover)

Remedial rock cover involves either blanket or locally placing rock at specific locations to increase the cover to the pipeline to reduce the risk of snagging or affecting other users of the sea. Base case assumption for installing new rock cover is to use a fall pipe vessel, as shown in **Error! Reference source not found.**.

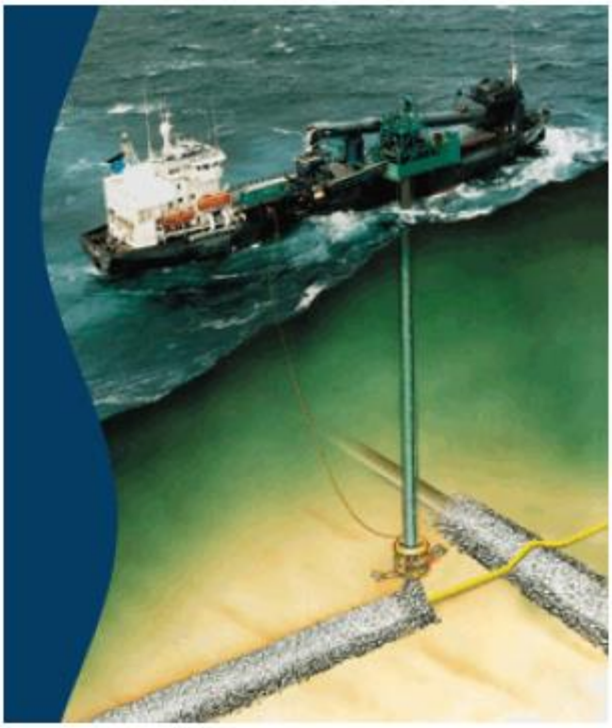


Figure 4-3 – Remedial Rock Cover Installation Illustration

Rock dump quantities should be assumed as:

- Leman F and Leman G Power Cables (PL5147 and PL5148)
  - 10 Te per end
  - 10 Te per metre of remedial rock cover required
- 14" Leman G to Leman F production pipeline (PL364)
  - 15 Te per end
  - 15 Te per metre of remedial rock cover required
- 20" Leman F to Leman G production pipeline (PL363)
  - 20 Te per end
  - 20 Te per metre of remedial rock cover required

4.1.3.5. Mattress Recovery

The mattresses and grout bags associated with the Leman F & G pipelines and cables were installed in 1986. Due to the age of this infrastructure and concerns regarding its integrity, any scope to remove and recover mattresses is likely to be executed using a multi-purpose subsea grab, deployed from a Construction Support Vessel. Use of a subsea grab will also avoid any chance of an ROV becoming entangled in the mattresses, which can be a risk with fronded mattresses or Leman's LinkLok mattresses, shackled together into large platforms.

Durations of mattress recovery using the subsea grab are assumed to be similar to those for individual ROV recovery.

5. Comparative Assessment Results

5.1. Initial Decommissioning Options Screening and Grouping

A number of stakeholder engagements took place during the initial screening phase to further understand and clarify each stakeholder's concerns and views regarding the decommissioning of the Leman F & G subsea infrastructure. Details of stakeholder engagement can be found in Section 1.4.2 of the Leman F & G Environmental Appraisal [6].

Internal workshops to screen the options were held by Shell in 2021 and 2022, utilising information from both internal and external survey data gathered over the life of the field. The workshops enabled the project team to identify and define credible options for each scope, assessing what data gaps existed for each option and defining whether any studies were required to inform the comparative assessment workshop.

During the initial screening workshop, the credible options for each scope was assessed against the five CA criteria identified in Section 3.3 and the pipelines and cables were grouped, where applicable, for the purposes of the comparative assessment workshop. A summary of the grouping and options identified for each scope is shown in Table 5-1.

Details of the conclusions for each scope and group are contained within the following sections.

Scope	Description	Decommissioning Options
1	Leman F & G Pipelines PL363 and PL364	Total removal – assumed cut-and-lift ~~Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover mitigated with rock cover~~ ~~Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover removed by cut-and-lift~~ Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover remediated by re-trenching Decommission *in situ* with surface-laid tie-ins removed and ends remediated
2	Leman F & G Cables PL5147 and PL5148	Total removal – assumed reverse reel-lay ~~Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover mitigated with rock cover~~ ~~Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover removed by cut-and-lift~~ Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover remediated by re-trenching Decommission *in situ* with surface-laid tie-ins removed and ends remediated
3	Linklok mattresses at pipeline tie-ins	~~Disconnect the tie-in spools at the pipeline tie-in flange, remove the tie-in spools and decommission all LinkLok mattresses *in situ*~~ ~~Blanket rock-cover the tie-in spools and associated LinkLok mattresses without disconnecting from the main pipeline routes, decommissioning all infrastructure *in situ*~~ Disconnect the tie-in spools at the pipeline tie-in flange and remove both the tie-in spools and all LinkLok mattresses supporting the tie-ins

Table 5-1 – Summary of Decommissioning Options and Grouping

Notes:

Options with a strikethrough (e.g. ~~Decommission in-situ~~) were deselected during initial screening.

5.2. Scope 1 – Leman F and G Pipelines, PL363 and PL364

This scope covered the pipeline lengths, excluding riser sections, of the following:

- PL363 – 4.8km-long, 20" carbon steel, concrete-coated production pipeline from Leman F to Leman AK
- PL364 – 2.7km-long, 14" carbon steel, concrete-coated production pipeline from Leman G to Leman F

Three credible options were identified and presented for scoring at the workshop:

- Total removal by cut-and-lift
- Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover remediated by re-trenching Decommission *in situ* with surface-laid tie-ins removed and ends remediated

Two options had been 'screened out' during Shell's internal screening assessment and were not presented for scoring at the workshop. They were:

- Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover mitigated with rock cover
- Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover removed by cut-and-lift

These options were screened out as they would both introduce significant volumes of new hard substrate in comparison to remedial trenching – either through blanket rock cover, or by several areas of spot rock that would be required to protect the ends of the pipeline where sections of low cover had been cut and removed. Placement of hard substrate not only smothers the habitats in the area, which consist of Annex I biogenic reefs, but also replaces the type of seabed that would be supportive of the growth of the biogenic reefs (sandy). As the Leman F and G pipeline routes are within the North Norfolk Sandbanks and Saturn Reef Special Area of Conservation (SAC), which aims to recover and maintain the Annex I habitat within the SAC, the use of additional rock in this manner was considered to be against the SAC's objectives and therefore an unacceptable environmental impact in comparison with the option to remediate through retrenching.

Note that additional rock cover may be required during the decommissioning of Leman F & G, i.e. to protect the cut ends of pipelines and cables, where no viable alternative is available. However, any rock placement will be minimised to end remediation and will be assessed in the context of current seabed movement in the local area prior to installation.

The remaining three options were presented and scored by the CA Workshop attendees. The scores are presented in Figure 5-1. Following scoring of all sub-criteria, the workshop attendees agreed that the emerging recommendation from the CA was to **decommission the pipelines in situ, with the surface-laid tie-ins removed and ends remediated.**

Detail on how each score was derived is provided below.

Criteria	Ref	Sub Criteria	Option 1: Decom In-Situ (Remove ends only)	Option 2: Decom In-situ and remediate by re-trenching	Option 3: Total removal by cut and lift
Safety	1	Project risk to personnel - Offshore	g	g	a
	2	Project risk to other users of the sea	b	b	b
	3	Project risk to personnel - Onshore	g	g	a
	4	Potential of a high consequence even	b	b	b
	5	Residual risk to other users of the sea	a	g	a
Environment	6	Marine impact of operations	g	r	r
	7	Energy, resource consumption	b	b	b
	8	Emissions	b	b	b
	9	Impact of marine end points (legacy impact)	g	a	a
Technical	10	Risk of major project failure	b	b	b
	11	Technology demands / track record	b	b	b
Societal	12	Commercial impact on fisheries	g	g	a
	13	Socio-economic impact on communities and	b	b	b
Economic	14	Cost	g	g	a
	15	Cost risk and uncertainty	a	a	a

Figure 5-1 – Scope 1 scoring table

Key for colour-blind readers: g – green; a – amber; r – red; b – blank / grey indicating no significant difference between options

Safety

- **Project risk to personnel offshore** – it was noted that the option to *remove by cut-and-lift* has the highest risk due to extended vessel time in the field and the high number of lifts, noting that the integrity of the pipeline's concrete-coating is uncertain and will represent a dropped object risk during recovery. However, it was noted that the increased risk is not sufficient to justify a 'red' score and hence 'amber' was deemed appropriate. The options to *decommission in situ* and *remediate by re-trenching* were considered to be standard, comparatively low-risk options and therefore scored 'green'.
- **Project risk to other users of the sea** – although the option for *total removal* has more execution scope outside the 500m zones compared to the other options, it was noted that there is very little fishing in the area and so this should not be considered a significant differentiator. Therefore, each option would be scored 'green' and, as there is no significant difference between each option, all options were scored 'grey'
- **Project risk to personnel onshore** – the option for *total removal* would result in hundreds of pipe sections with concrete-coating being offloaded at a quay and transported to a dismantling yard for recycling. Similar to *project risk to personnel offshore*, this is not considered significant enough to be scored 'red' and hence 'amber' was deemed appropriate. The options to *decommission in situ* and *remediate by re-trenching* would not result in the same volumes of waste and so were scored 'green'
- **Potential of high consequence event** – as there are no large lifts or crossings over live pipelines associated with any of the options, the attendees at the workshop considered there to be no significant difference between any of the options and so all options were scored 'grey'
- **Residual risk to other users of the sea** – it was noted that both the option to *decommission in situ* and the option for *total removal* would present a greater legacy risk to other users of the sea, i.e. the fishing industry, than the option to *remediate by re-trenching – decommissioning in situ* will include some sections of pipeline which are not buried to a depth-of-cover exceeding 0.6m; whilst, per engagement with the NFFO ahead of the CA Workshop, *total removal* of a concrete-coated pipeline may leave sections of the coating as snagging risks on the seabed after removal. It was noted, however, that post-decommissioning debris clearance and seabed clearance surveys, including a future monitoring campaign to be agreed with OPRED, would endeavour to mitigate these risks for both options.
  Shell has contracted Xodus to conduct third-party studies in support of the CA, including a risk assessment of the pipelines and cables considering the infrastructure's burial status; the seabed profile and mobility; and fishing activity in the area. It was noted that Xodus' study indicated that the risk of decommissioning the pipelines in situ was very low and that the option to *decommission in situ* would not be executing any work that could potentially increase this risk. Details of this risk assessment were presented to attendees at the CA Workshop.
  It was therefore agreed at the workshop that, whilst the option to *remediate by re-trenching* scored 'green', neither of the other two options represented a significant enough risk to be scored 'red' and therefore both *decommission in situ* and *total removal* were scored 'amber'.

Environment

- **Marine impact of operations** – it was noted that the pipeline routes traverse an Annex I habitat within the North Norfolk Sandbanks and Saturn Reefs Special Area of Conservation. Survey data has indicated a healthy *sabellaria spinulosa* biogenic reef, with moderate to high density, particularly between Leman AK and Leman F, and towards the Leman F end of the Leman F to Leman G pipeline. These habitats are considered critical habitat within Shell. It was highlighted during the CA that the identified reefs in this area are the remnants of the Saturn Reef, after which the SAC is named. Previous surveys

at Leman F and Alpha indicate that the extend of the reef does go beyond the Leman F and Alpha platforms.
The options of *total removal* and *remediate by re-trenching* would create significant disturbance to this environment – both from immediate seabed disturbance and then subsequent smothering from the sediment that has been dispersed by the execution activities. This would be directly against the conservation objectives of the SAC.
The option to *decommission in situ* would have very little impact on the Annex I habitat and was therefore scored 'green'; whilst *total removal* and *remediate by re-trenching* were scored 'red' due to their much greater impact upon the habitat.

- **Energy and resource consumption** – based on Shell's experience with decommissioning projects at other UKCS fields and using industry norms, quantified estimates of energy and resource consumption were presented for each option. Although *total removal* had the highest values, followed by *remediate by re-trenching* and then *decommission in situ*, it was agreed at the workshop that none of the options incurred significant impacts and therefore there was considered to be no significant difference between any of the options and so all options were scored 'grey'.
- **Emissions** – the decision was taken during Shell's internal screening workshop to consider *emissions* as a separate sub-criterion to align with the North Sea Transition Authority's Stewardship Expectation 11 and specifically the requirement to "ensure[ing] that GHG emissions reduction is considered throughout the entire oil and gas lifecycle". Therefore, quantified emissions data for each option was presented during the workshop. These figures were derived from vessel duration estimates based on Shell's decommissioning experience and industry norms for emissions from vessel activity and steel manufacturing. Although *total removal* had the highest values, followed by *remediate by re-trenching* and then *decommission in situ*, it was agreed at the workshop that none of the options incurred significant impacts when put in terms of offshore oil and gas emissions and therefore there was considered to be no significant difference between any of the options and so all options were scored 'grey'
- **Impact of marine end points (legacy impact)** – the CA assessment criteria provided for the workshop included guidance that any inert material left within the seabed, i.e. decommissioned *in situ*, would constitute an 'amber' scoring. Feedback from JNCC during the workshop indicated that this is not a logical driver for 'negative impact' as inert material within the seabed does not pose any risk to the environment. It was agreed that Shell would revise its CA criteria going forward and that, for the purposes of the Leman F & G CA, this specific piece of guidance would be discounted.
It was noted that options which include significant amounts of additional rock cover, and therefore present the greatest long-term impact to the marine environment, were screened out during Shell's internal screening exercise.
JNCC noted that the options for *total removal* and *remediate by re-trenching* would effectively "reset" the immediate marine environment's recovery to zero and introduce a risk that it may never recover. The likelihood of this risk occurring was not considered significant enough to merit a 'red' score. Therefore, the options for *total removal* and *remediate by re-trenching* were scored 'amber'; whilst *decommission in situ* was scored 'green' as it does not include this 'resetting' impact.

Technical

- **Risk of major project failure** and **Technology demands / track record –** each of the options would be executed using well-understood methodologies with a track record of successful use across the UKCS. Whilst it was noted that the pipelines' concrete-coating may make *total removal* or *remediate by re-trenching* more difficult, this was considered to present a cost risk only and would be captured with the *Cost* criterion. Therefore, to avoid any double-counting, there was considered to be no significant difference between any of the options and so all options were scored 'grey' for both sub-criteria.

Societal

- **Commercial impact on fisheries –** it was noted that, whilst fishing activity in this area is currently very low, that does not preclude the possibility of future fishing activity increasing. Following pre-workshop feedback from the NFFO, it was noted that *total removal* could result in the dispersion of debris from the pipelines' concrete-coating. This could present an impediment or delay to fishing activity as concrete sections become snagged in fishing nets. However, it was noted that post-decommissioning debris sweeps and seabed clearance surveys, as well as future monitoring surveys, should mitigate this risk.
  Therefore, the option for *total removal* was scored 'amber' and the options for *decommission in situ* and *remediate by re-trenching*, which do not carry this potential for dispersing concrete debris, were scored 'green'
- **Socio-economic impact on communities and fisheries –** it was agreed that the scope of Leman F & G decommissioning is relatively small and that all waste returned, even for the *total removal* option, would be managed within existing supply chains. Therefore, the impacts to communities, both positive and negative, is relatively minor for all options. There was considered to be no significant difference between any of the options and so all options were scored 'grey'.

Economic

- **Cost –** it should be noted that *cost* may only be a differentiating factor where all other criteria are considered equal. Normalised, quantified costs were presented for each option. These figures were derived from vessel duration estimates based on Shell's decommissioning experience and internal Shell norms for vessel costs.
  Whilst it was noted that *total removal* has the highest cost, Shell advised that the total cost was not considered significant enough to merit a 'red' score. Therefore, *total removal* was scored 'amber' and the lower costs for *decommission in situ* and *remediate by re-trenching* were scored 'green'
- **Cost risk and uncertainty –** it was noted that each option carried an element of cost risk.
  As previously noted, *total removal* may result in the pipelines' concrete-coating being dispersed across the pipeline route following cut-and-lift activities. Whilst Shell's estimates for this option included additional debris clearance activities to account for this, the risk that this duration would be exceeded should be noted.
  The options for *remediate by re-trenching* and *total removal* would each carry the risk of additional future monitoring surveys and potential mitigation activities. Feedback from OPRED during the workshop advised that future monitoring requirements could be extensive, both in terms of frequency and total number of surveys.
  To reflect that these risks exist for each option, all options were scored 'amber'.

5.3. Scope 2 – Leman F & G Cables PL5147 and PL5148

This scope covered the cable lengths, excluding riser sections, of the following:

- PL5148 – 4.8km-long, power cable from Leman F to Leman G
- PL5147 – 2.7km-long, power cable from Leman AK to Leman F

Three credible options were identified and presented for scoring at the workshop:

- Total removal by reverse reel
- Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover remediated by re-trenching Decommission *in situ* with surface-laid tie-ins removed and ends remediated.

Two options had been 'screened out' during Shell's internal screening assessment and were not presented for scoring at the workshop. They were:

- Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover mitigated by rock cover
- Decommission *in situ* with surface-laid tie-ins removed and ends remediated; with areas of insufficient depth-of-cover removed by cut-and-lift

These options were screened out as they would both introduce significant volumes of new hard substrate in comparison to remedial trenching – either through blanket rock cover, or by several areas of spot rock that would be required to protect the ends of the cable where sections of low cover had been cut and removed. Placement of hard substrate not only smothers the habitats in the area, which consist of Annex I biogenic reefs, but also replaces the type of seabed that would be supportive of the growth of the biogenic reefs (sandy). As the Leman F and G cable routes are within the North Norfolk Sandbanks and Saturn Reef Special Area of Conservation (SAC), which aims to recover and maintain the Annex I habitat within the SAC, the use of additional rock in this manner was considered to be against the SAC's objectives and therefore an unacceptable environmental impact in comparison with the option to remediate through retrenching.

Note that additional rock cover may be required during the decommissioning of Leman F & G, i.e. to protect the cut ends of pipelines and cables, where no viable alternative is available. However, any rock placement will be minimised to end remediation and will be assessed in the context of current seabed movement in the local area prior to installation

The remaining three options were presented and scored by the CA Workshop attendees. The scores are presented in Figure 5-2.

Following scoring of all sub-criteria, the workshop attendees agreed that the emerging recommendation from the CA was to **decommission the cables in situ, with surface-laid tie-ins removed and ends remediated**.

Detail on how each score was derived is provided below. The scoring from Scope 1 was used as a baseline – as the lines are within ~50m of each other the circumstances are the same. The options were assessed to identify differences when considering cables rather than concrete-coated pipelines.

Criteria	Ref	Sub Criteria	Option 1: Decom In-Situ (Remove ends only)	Option 2: Decom In-situ and remediate by re-trenching	Option 3: Removal by reverse reel-lay
Safety	1	Project risk to personnel - Offshore	g	g	g
	2	Project risk to other users of the sea	b	b	b
	3	Project risk to personnel - Onshore	g	g	a
	4	Potential of a high consequence even	b	b	b
	5	Residual risk to other users of the sea	a	g	g
Environment	6	Marine impact of operations	g	r	r
	7	Energy, resource consumption	b	b	b
	8	Emissions	b	b	b
	9	Impact of marine end points (legacy impact)	g	a	a
Technical	10	Risk of major project failure	b	b	b
	11	Technology demands / track record	b	b	b
Societal	12	Commercial impact on fisheries	b	b	b
	13	Socio-economic impact on communities and	b	b	b
Economic	14	Cost	g	a	a
	15	Cost risk and uncertainty	a	a	g

Figure 5-2 – Scope 2 scoring table

Key for colour-blind readers: g – green; a – amber; r – red; b – blank / grey indicating no significant difference between options

Safety

- **Project risk to personnel** offshore – it was noted that the option to *remove by reverse reeling* has the highest risk due to extended vessel time in the field. However, as opposed to Scope 1, it was noted that the increased risk is not sufficient to justify a 'red' or 'amber' score. The options to *decommission in situ* and *remediate by re-trenching* were considered to be standard, comparatively low-risk options and therefore all options were scored 'green'.
- **Project risk to other users of the sea** – although the option for *total removal* has more execution scope outside the 500m zones compared to the other options, it was noted that there is very little fishing in the area and so this should not be considered a significant differentiator. Therefore, each option would be scored 'green' and, as there is no significant difference between each option, all options were scored 'grey'
- **Project risk to personnel onshore** – the option for *total removal* would include a notable quayside lift to transfer the reel(s) and then onshore dismantling to split each cable into shorter sections for recycling / disposal. However, this is not considered significant enough to be scored 'red' and hence 'amber' was deemed appropriate. The options to *decommission in situ* and *remediate by re-trenching* would not result in the same volumes of waste and so were scored 'green'
- **Potential of high consequence event** – as there are no large lifts or crossings over live pipelines associated with any of the options, the attendees at the workshop considered there to be no significant difference between any of the options and so all options were scored 'grey'
- **Residual risk to other users of the sea** – it was noted that the option to *decommission in situ* would present a greater legacy risk to other users of the sea, i.e. the fishing industry, than the options for *remediate by re-trenching* or *total removal – decommissioning in situ* will include some sections of cable which are not buried to a depth-of-cover exceeding 0.6m. It was noted, however, that post-decommissioning seabed clearance surveys, including a future monitoring campaign to be agreed with OPRED, would mitigate these risks.
  Shell has contracted Xodus to conduct third-party studies in support of the CA, including a risk assessment of the pipelines and cables considering the infrastructure's burial status; the seabed profile and mobility; and fishing activity in the area. It was noted that Xodus' study indicated that the risk of decommissioning the cables in situ was very low and that the option to *decommission in situ* would not be executing any work that could potentially increase this risk. Details of this risk assessment were presented to attendees at the CA Workshop.
  It was therefore agreed at the workshop that, whilst the options to *remediate by re-trenching* and *total removal* scored 'green', the residual risk did not represent a significant enough risk to be scored 'red' and therefore *decommission in situ* was scored 'amber'.

Environment

- **Marine impact of operations** – it was noted that the cable routes traverse an Annex I habitat within the North Norfolk Sandbanks and Saturn Reefs Special Area of Conservation and the Southern North Sea Special Area of Conservation. Survey data has indicated a healthy *sabellaria spinulosa* biogenic reef, with moderate to high density, particularly between Leman AK and Leman F, and towards the Leman F end of the Leman F to Leman G cable. These habitats are considered critical habitat within Shell. It was highlighted during the CA that the identified reefs in this area are the remnants of the Saturn Reef, after which the SAC is named. Previous surveys at Leman F and Alpha indicate that the extend of the reef does go beyond the Leman F and Alpha platforms.
  The options of *total removal* and *remediate by re-trenching* would create significant disturbance to this environment – both from immediate seabed disturbance and then subsequent smothering from the

sediment that has been dispersed by the execution activities. This would be directly against the conservation objectives of the SAC.
The option to *decommission in situ* would have very little impact on the Annex I habitat and was therefore scored 'green'; whilst *total removal* and *remediate by re-trenching* were scored 'red' due to their much greater impact upon the habitat.

- **Energy and resource consumption** – based on Shell's experience with decommissioning projects at other UKCS fields and using industry norms, quantified estimates of energy and resource consumption were presented for each option. Although *remediate by re-trenching* had the highest values, followed by *total removal* and then *decommission in situ*, it was agreed at the workshop that none of the options incurred significant impacts and therefore there was considered to be no significant difference between any of the options and so all options were scored 'grey'
- **Emissions** – the decision was taken during Shell's internal screening workshop to consider *emissions* as a separate sub-criterion to align with the North Sea Transition Authority's Stewardship Expectation 11 and specifically the requirement to "ensure[ing] that GHG emissions reduction is considered throughout the entire oil and gas lifecycle". Therefore, quantified emissions data for each option was presented during the workshop. These figures were derived from vessel duration estimates based on Shell's decommissioning experience and industry norms for emissions from vessel activity and steel manufacturing. Although *remediate by re-trenching* had the highest values, followed by *total removal* and then *decommission in situ*, it was agreed at the workshop that none of the options incurred significant impacts and therefore there was considered to be no significant difference between any of the options and so all options were scored 'grey'
- **Impact of marine end points (legacy impact)** – the CA assessment criteria provided for the workshop included guidance that any inert material left within the seabed, i.e. decommissioned *in situ*, would constitute an 'amber' scoring. Feedback from JNCC during the workshop indicated that this is not a logical driver for 'negative impact' as inert material within the seabed does not pose any risk to the environment. It was agreed that Shell would revise its CA criteria going forward and that, for the purposes of the Leman F & G CA, this specific piece of guidance would be discounted.
It was noted that options which include significant amounts of additional rock cover, and therefore present the greatest long-term impact to the marine environment, were screened out during Shell's internal screening exercise.
JNCC noted that the options for *total removal* and *remediate by re-trenching* would effectively "reset" the immediate marine environment's recovery to zero and introduce a risk that it may never recover. The likelihood of this risk occurring was not considered significant enough to merit a 'red' score. Therefore, the options for *total removal* and *remediate by re-trenching* were scored 'amber'; whilst *decommission in situ* was scored 'green' as it does not include this 'resetting' impact.

Technical

- **Risk of major project failure** and **Technology demands / track record –** each of the options would be executed using well-understood methodologies with a track record of successful use across the UKCS. Therefore, there was considered to be no significant difference between any of the options and so all options were scored 'grey' for both sub-criteria.

Societal

- **Commercial impact on fisheries –** in contrast to the assessment for Scope 1, it is anticipated that *total removal* would not create significant debris that would pose an impediment to fishing. Therefore, there was not considered to be any significant difference between the options and so all options were scored 'grey'.

- **Socio-economic impact on communities and fisheries –** it was agreed that the scope of Leman F & G decommissioning is relatively small and that all waste returned, even for the *total removal* option, would be managed within existing supply chains. Therefore, the impacts to communities, both positive and negative, is relatively minor for all options. There was considered to be no significant difference between any of the options and so all options were scored 'grey'.

Economic

- **Cost –** it should be noted that *cost* may only be a differentiating factor where all other criteria are considered equal. Normalised, quantified costs were presented for each option. These figures were derived from vessel duration estimates based on Shell's decommissioning experience and internal Shell norms for vessel costs.
  Whilst it was noted that *remediate by re-trenching* has the highest cost, closely followed by *total removal*, Shell advised that the total cost was not considered significant enough to merit a 'red' score. Therefore, *remediate by re-trenching* and *total removal* were scored 'amber' and the lower costs for *decommission in situ* were scored 'green'
- **Cost risk and uncertainty –** In contrast to Scope 1, *total removal* is not expected to create significant debris and so the cost risk regarding debris clearance activities does not apply to Scope 2. In addition, Shell's vessel estimates include an assumption that the cables will be deburied prior to removal, removing the risk that pulling the cables through the seabed sediment fails and would require an additional vessel mobilisation.
  The options for *remediate by re-trenching* and *total removal* would each carry the risk of additional future monitoring surveys and potential mitigation activities. Feedback from OPRED during the workshop advised that future monitoring requirements could be extensive, both in terms of frequency and total number of surveys.
  To reflect that these risks exist for each option, the options for *remediate by re-trenching* and *decommission in situ* were scored 'amber'. The option for *total removal* was deemed to carry little cost risk and scored 'green'.

5.4. Scope 3 – Leman F & G LinkLok Stabilisation Mattresses

The latest survey, executed in 2020, indicated that all mattresses associated with the Leman F and G pipelines and cables (PL363, PL364, PL5147, PL5148) are currently buried. However, the depth-of-cover above each mattress is not known.

The mattresses within this scope are the LinkLok stabilisation mattresses installed to support the pipeline tie-ins at Leman AK, Leman F and Leman G. Mattresses at the cable and pipeline crossing are included within Scope 1. Details of types and numbers of mattresses in Scope 3 are as follows:

- Associated with Leman F pipeline PL363
    - Tie-in to Leman AK
        - 14.5No 10m x 2.5m x 0.15m 11.4Te LinkLok mattresses, underneath PL363 tie-in spool
        - 2No large grout supports beneath PL363 tie-in
            - 0.5m x 1.3m x 2.3m, 1.8Te each
        - 12No 500kg grout bags supporting PL363 tie-in
    - Tie-in to Leman F
        - 15.5No 10m x 2.5m x 0.15m 11.4Te LinkLok mattresses, underneath PL363 tie-in spool
        - 2No large grout supports beneath PL363 tie-in
            - 0.75m x 1.5m x 1.5m 2Te
            - 0.5m x 1.3m x 2.3m, 1.8Te
- Associated with Leman G pipeline PL364
    - Tie-in to Leman F
        - 8No 10m x 2.5m x 0.15m 11.4Te LinkLok mattresses, underneath PL364 tie-in spool
            - Note 5No additional LinkLok matts are shared with PL363 and not recorded here
        - 3No large grout supports beneath PL364 tie-in
            - 1No - 0.5m x 2m x 1.5m, 1.6Te
            - 2No – 0.5m x 1.3m x 2.3m, 1.8Te each
    - Tie-in to Leman G
        - 11No 10m x 2.5m x 0.15m 11.4Te LinkLok mattresses underneath PL364 tie-in spool
        - 2No large grout supports beneath PL364 tie-in
            - 0.75m x 1.4m x 2.5m, 2.8Te each

Internal screening of the decommissioning options for the mattresses was inconclusive, and further discussion with the stakeholders present at the CA Workshop aligned on the requirement for additional study work to be completed to inform the decision. Three credible options were identified by the stakeholders at the CA Workshop:

1. Disconnect the tie-in spools at the pipeline tie-in flange, shown in blue in Figure 5-3 for the tie-in at Leman A, remove the tie-in spools and decommission all LinkLok mattresses *in situ*
2. Blanket rock cover the tie-in spools and associated LinkLok mattresses without disconnecting from the main pipeline routes, decommissioning all infrastructure *in situ*
3. Disconnect the tie-in spools at the pipeline tie-in flange, shown in blue in Figure 5-3 for the tie-in at Leman A, and remove both the tie-in spools and all LinkLok mattresses supporting the tie-ins

The orange highlight in Figure 5-3 indicates the riser tie-in flange and the downstream disconnection point. The riser sections inboard of the orange highlight will be removed with the jacket.

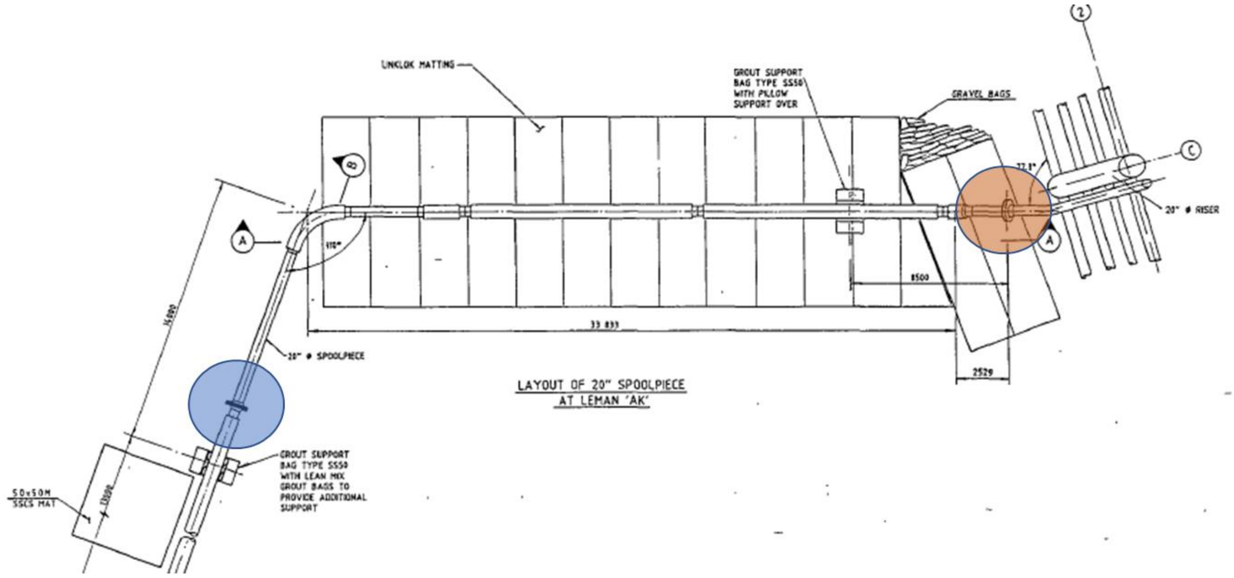


Figure 5-3 – Scope 3 disconnection options at Leman A

Following the CA Workshop, Shell has undertaken additional assessment of these options including the development of a third-party study into the long-term impact of plastic degradation, ref LDFG-XOD-E-HE-7180-00003.

The *Leman Plastic Degradation Study* [7] produced by Xodus concludes the following:

> "This study shows that the degradation of concrete mattresses into microplastics, and leaching of plasticisers, have real potential to degrade marine habitats, and to manifest in lethal and sublethal impacts to marine organisms. These impacts can be mitigated by removal and appropriate disposal onshore. In the scenario that no other environmental, safety or technical concerns were present, the best environmental option would be to remove the mattresses to prevent their long-term degradation and the release of up to approximately 16 tonnes of microplastics. Although removal could result in an immediate release of microplastics, given the mattresses are buried and are expected to be in good condition it is expected that the quantities of microplastic released on lifting would be minor compared to those if the mattresses are left in situ."

At the CA Workshop, the option to decommission both the tie-in spools and mattresses *in situ*, and to install blanket rock cover to prevent the infrastructure presenting a snagging risk was suggested by the stakeholders present. This option has been assessed by Shell. However, blanket rock cover would be directly in opposition to the conservation objectives of the North Norfolk and Saturn Reef SAC, within which the platforms are located. The initial installation of the rock berms would have a similar footprint to any dredging activities required to remove the mattresses (circa 1800m^2) and cause sediment dispersion over a wide area. Further, the introduction of new hard substrate would have a detrimental long-term impact on the habitat. Lastly, the plastic components of the mattresses would remain *in situ* and, should they become unburied over time, present a risk of degradation into microplastics. This option therefore has no short-term environmental benefit over full removal but has additional long-term environmental impact and risk. Therefore, it was discounted from further consideration.

The tie-in spools at each platform were installed on top of the LinkLok mattresses. The CA for Scope 1 concluded that these tie-in spools will be removed, and the main pipeline routes decommissioned *in situ*. As-found surveys may identify the opportunity to remove a shorter section of tie-in spool., however the current proposal is that each spool will be removed between their respective pipeline tie-in flanges and riser tie-in flanges. The assumed sections for removal are highlighted in yellow in Figure 5-4 to Figure 5-7.

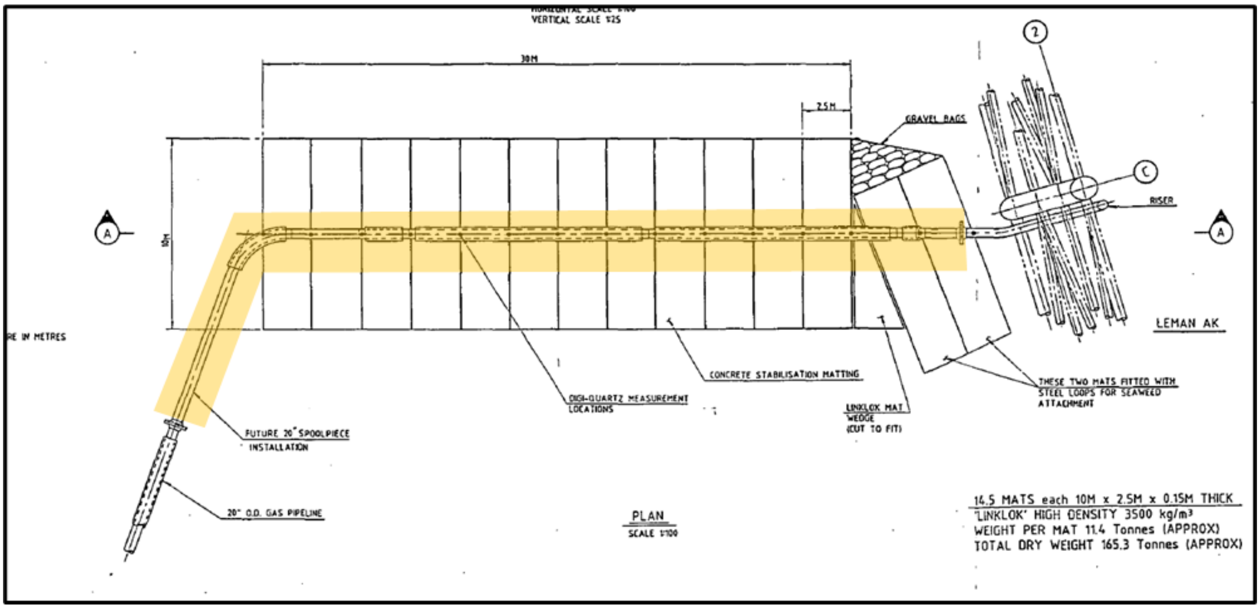


Figure 5-4 – Assumed PL363 spool removal at Leman F

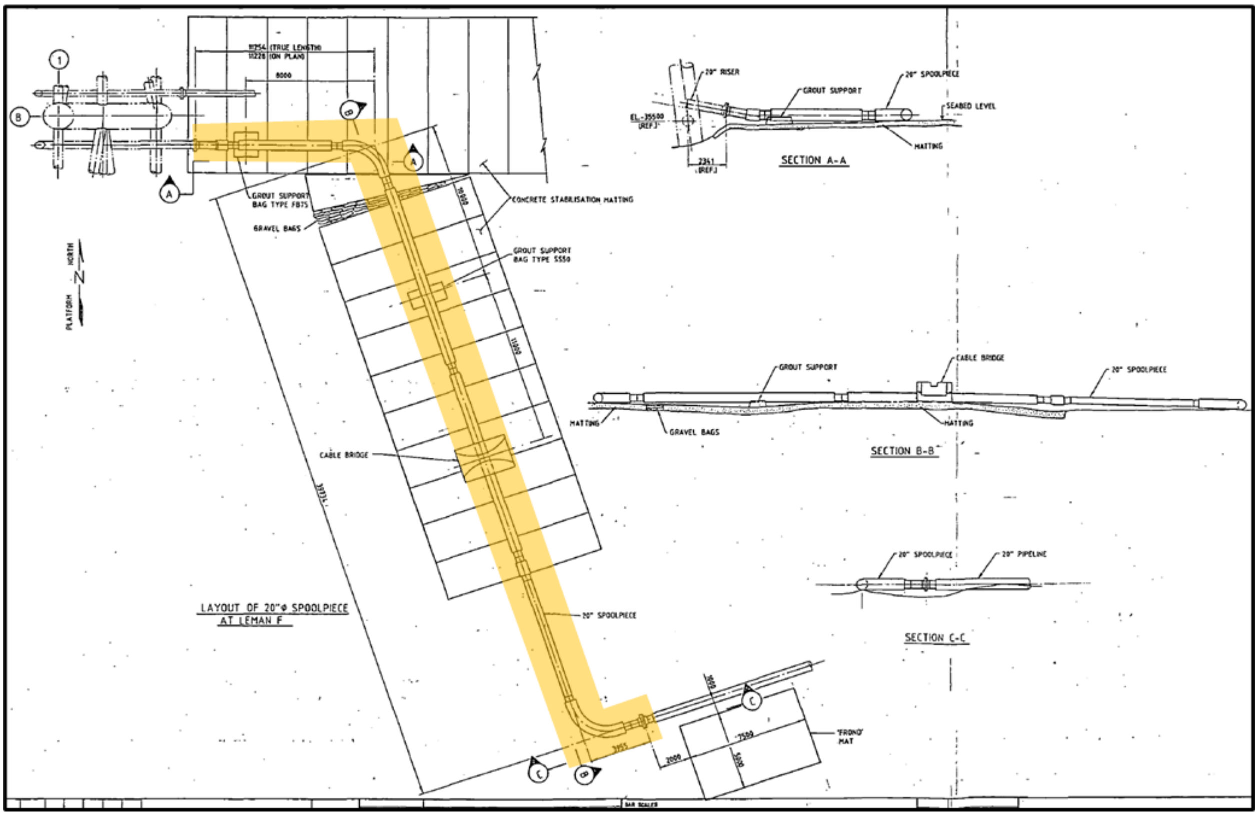


Figure 5-5 – Assumed PL363 spool removal at Leman F

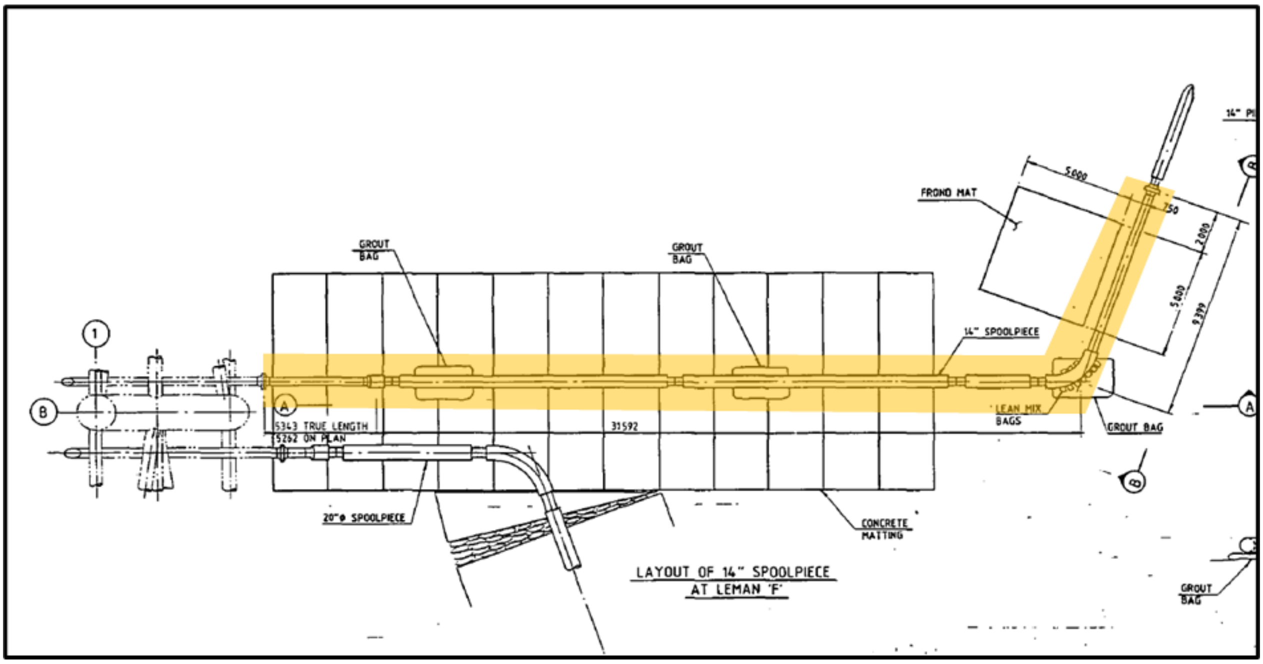


Figure 5-6 – Assumed PL364 spool removal at Leman F

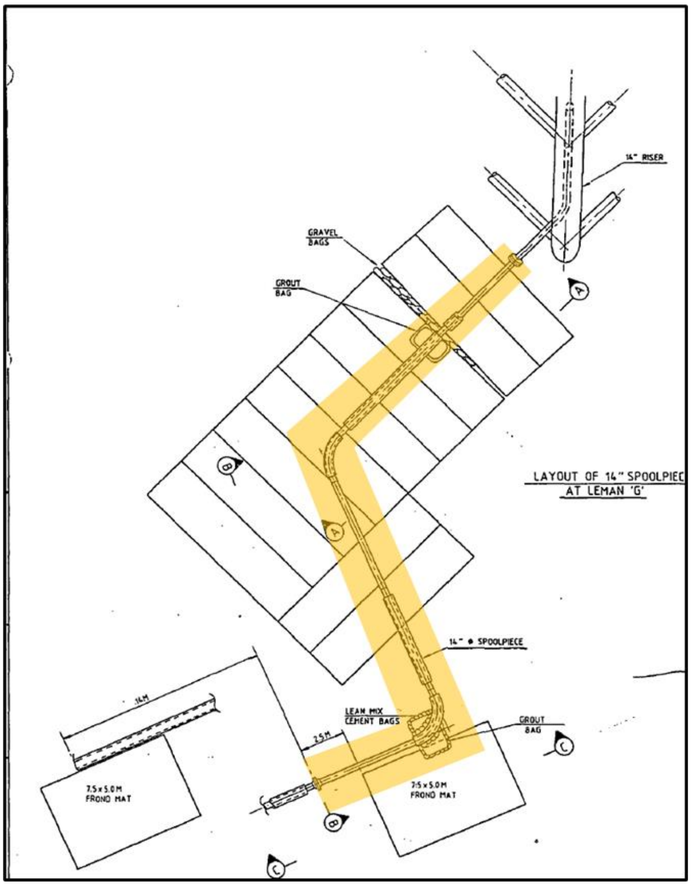


Figure 5-7 – Assumed PL364 spool removal at Leman G

To allow sufficient access for cutting and lifting these spools, subsea excavation will be required. This is typically performed by a mass flow excavator. When preparing permits for mass flow excavation, Shell estimates that the seabed will be disturbed along a corridor of 2m width and 1m depth. It is probable that this act of deburying and removing the pipeline spools will also uncover the mattresses, or at least part thereof.

Although the integrity of the mattresses is uncertain, there are no known impediments which would prevent removal should they be uncovered whilst deburying and then removing the tie-in spools. The proposed total removal of both the spools and mattresses is therefore aligned with the OPRED Guidance Notes which state that “it is expected that… all related stabilisation features such as mattresses… should be considered for removal with the aim to achieve a clear seabed and for disposal onshore”. In the event that practical difficulties are encountered, either during detailed engineering or execution, and full removal is no longer an ALARP solution, OPRED will be engaged to discuss mitigation options.

6. References

Table 6-1 – Supporting Documents

Ref	Document Number	Title
[1]	LDFG-PT-S-AA-8203-00001	Leman F & G Decommissioning Programmes
[2]	N/A	OPRED GUIDANCE NOTES - Decommissioning of Offshore Oil and Gas Installations and Pipelines November 2018
[3]	N/A	Oil and Gas UK Guidelines for Comparative Assessment in Decommissioning Programmes, Issue 1 October 2015
[4]	Gardline Report 11594 Vol 1	Pipeline Pre-decommissioning & Habitat Assessment: Leman Alpha to Leman Foxtrot & Leman Foxtrot to Leman Golf. Debris Clearance and Environmental Habitat Assessment
[5]	ED-2021-003	Gardline Pipeline pre-decommissioning & Habitat Assessment: Leman Alpha to Leman Foxtrot & Leman Foxtrot to Leman Golf. Habitat Assessment Report
[6]	LDFG-XOD-E-HE-7180-00001	Xodus: Leman F & G Decommissioning - Environmental Appraisal
[7]	LDFG-XOD-E-HE-7180-00003	Xodus: Leman F & G Decommissioning – Plastics Degradation Study

7. Appendix A: Pipeline Burial Depth Summary

7.1. General

The burial depth of the pipelines and umbilicals is important information when considering leaving pipelines or umbilicals in-situ or removal. The historical survey data for the Leman F & G pipelines and cables has been assessed to determine the burial depth. Shell contracted Xodus to complete a risk assessment of each pipeline and cable with the scope of the Leman F & G Decommissioning Programmes. This risk assessment considered the burial status of each line, the historical fishing intensity in the vicinity of each line and the seabed mobility in the area.

The following sections present graphical summaries of the Leman F & G pipeline data.

7.2. Pipeline Burial Depth Definition

Generally, there are two definitions for burial depth; depth of lowering and depth of cover, which are both illustrated in Figure 7-1 below. The depth of cover is the conventional definition of burial depth, which is the depth of backfill or rock on top of the pipeline or cable. The depth of lowering is the depth of the top of the pipeline or cable below the natural mean seabed level. The natural mean seabed level is identified ignoring any berms to the sides of the trench.

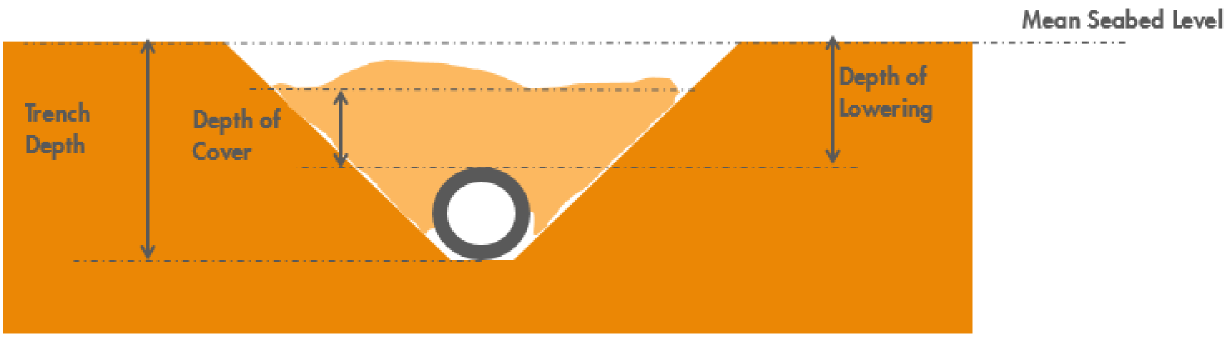


Figure 7-1 – Burial depth definition

Shell has contracted Xodus to supplement historical depth-of-cover survey results with data on fishing activity and seabed mobility to produce a risk assessment for decommissioning each line *in situ*.

The graphics below provide the following for each line:

- Depth-of-cover line graph providing the results from historical surveys
- Spannogram indicating where each line is buried, is exposed or is in freespan
- The output from the Xodus risk assessment.

A brief explanatory note is provided for each line.

On the completion of decommissioning activities, Shell will perform a depth-of-cover survey for the full length of each line being decommissioned *in situ*. The results of these surveys will be presented to OPRED in a similar linear graph format as part of the Close Out Report.

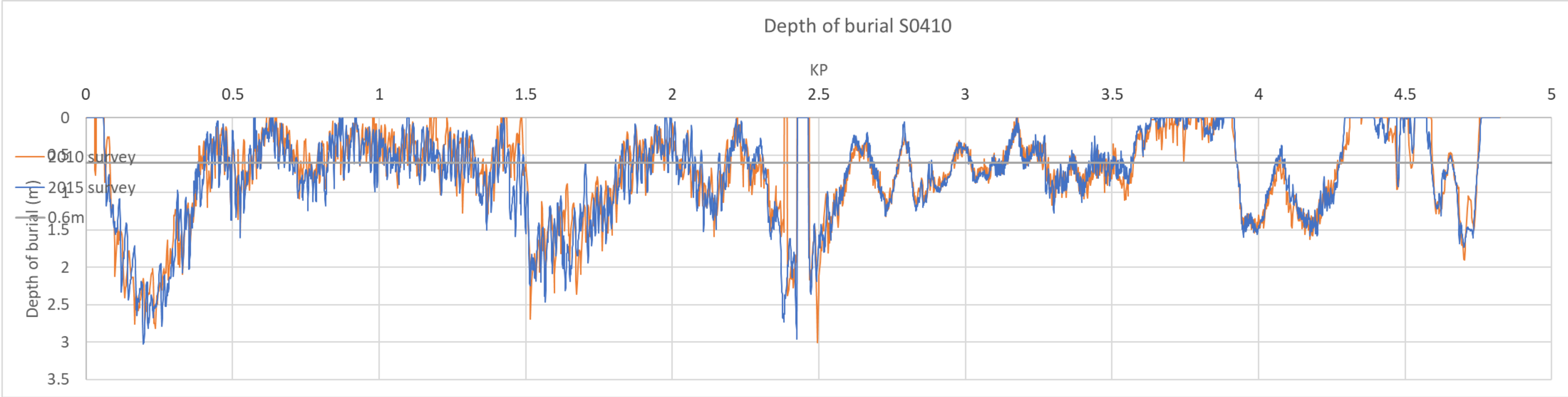


Figure 7-2 – Leman F Production Pipeline Depth of Cover (S0410 / PL363)

Figure 7-2 shows the survey results from the 2010 and 2015 depth-of-cover surveys for PL363. The orange line indicate the depth-of-cover results from the 2010 survey; the blue line the results from the 2015 survey.

Figure 7-3 shows the spanogram for PL363 – historical side-scan sonar survey results incorporating surveys in 2010, 2012, 2014, 2016, 2018 and 2020. A key is provided on the left of the drawing – where the pipeline is coloured green, the line is buried; where it is coloured red it is in freespan; and where it is coloured blue the line has been inspected but the result is uncertain. Note that the red indicates that the pipeline is in freespan but not that the span is of the height and length to be classified as recordable within the Kingfisher definition of a span.

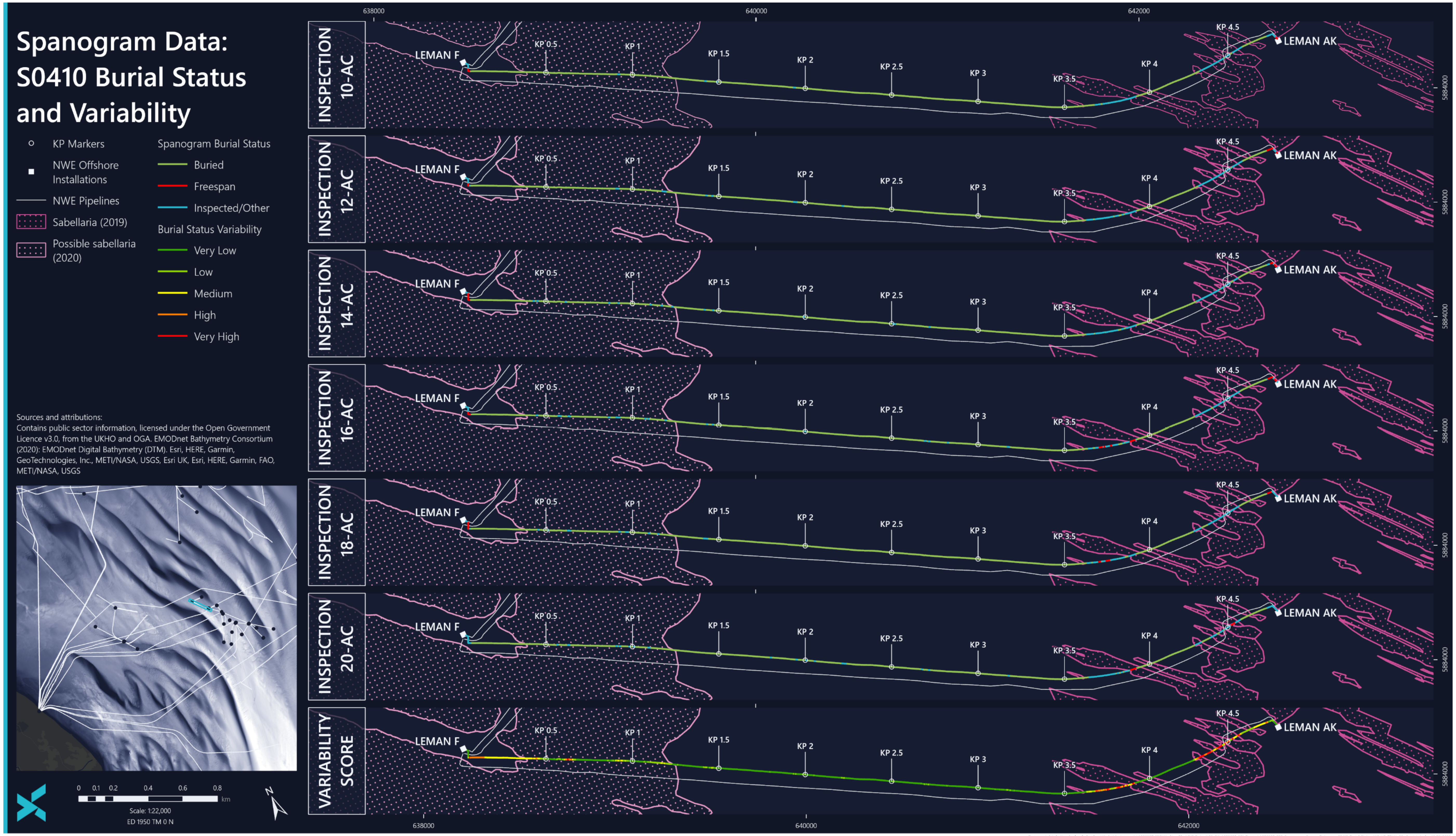


Figure 7-3 – Leman F Production Pipeline Historical Spanogram Results (S0410 / PL363)

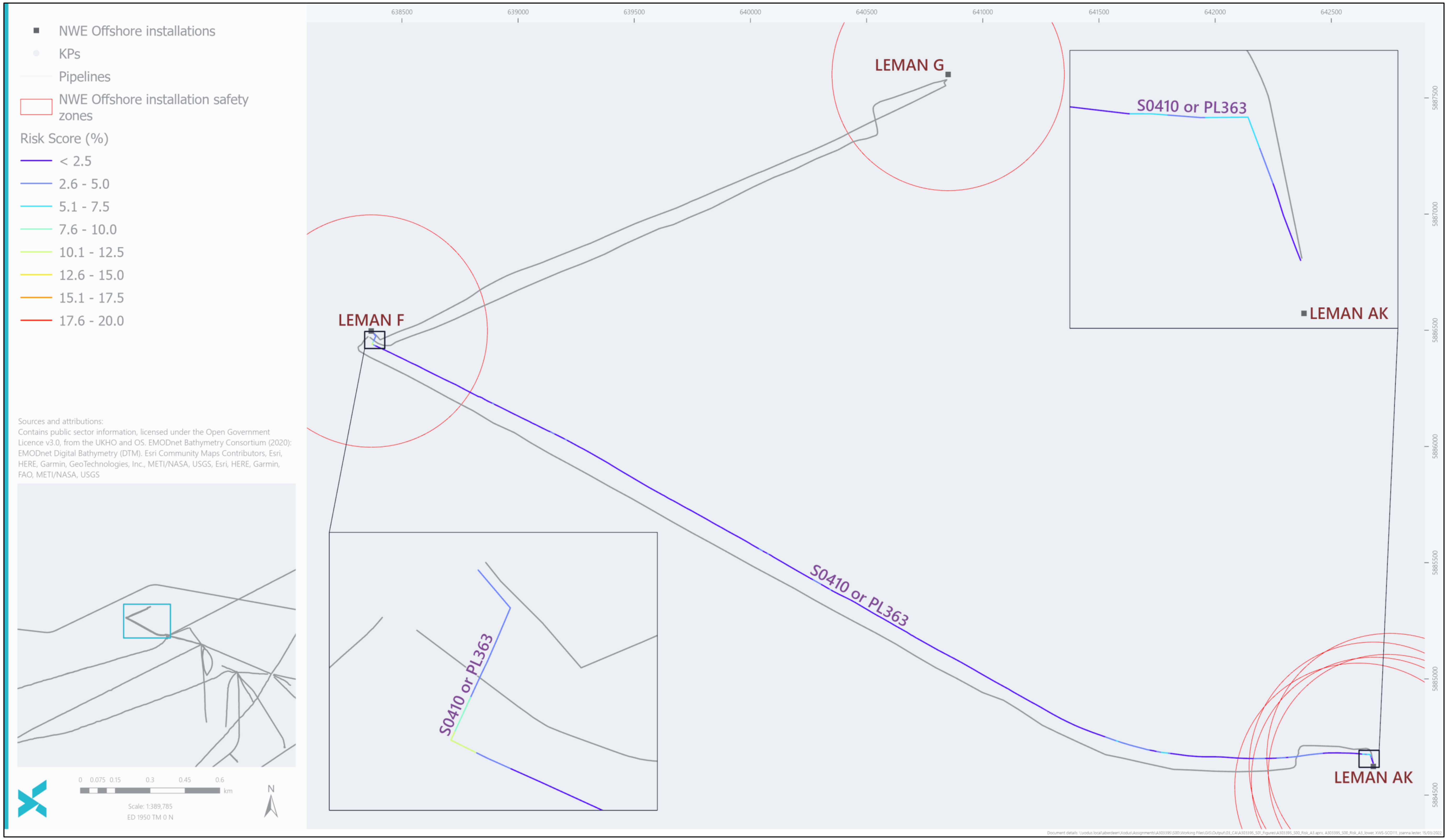


Figure 7-4 – Leman F Production Pipeline Risk Assessment (S0410 / PL363)

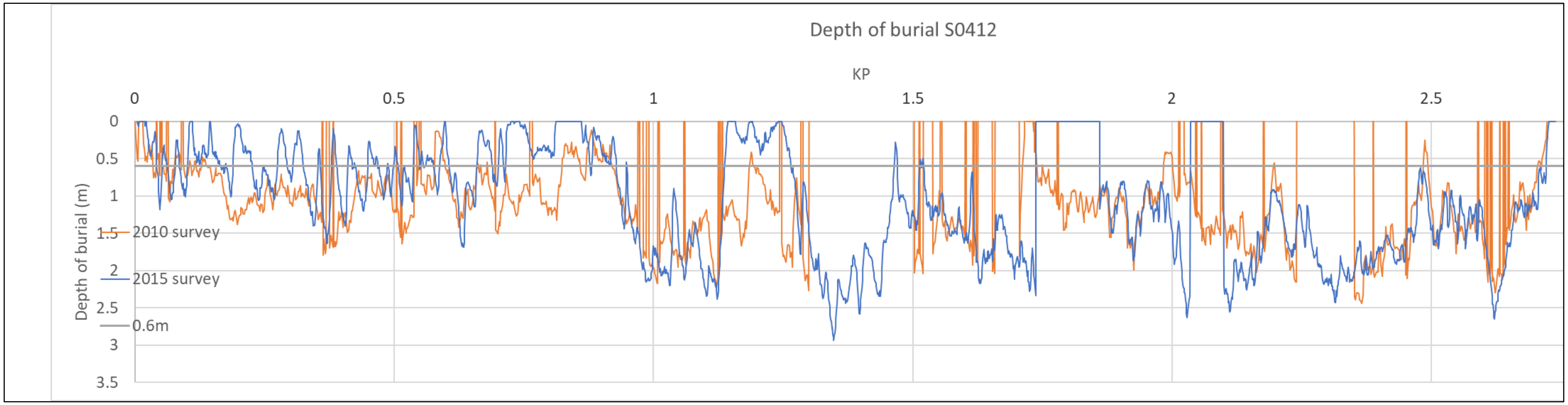


Figure 7-5 – Leman G Production Pipeline Depth of Cover (S0412 / PL364)

Figure 7-5 shows the survey results from the 2010 and 2015 depth-of-cover surveys for PL364. The orange line indicate the depth-of-cover results from the 2010 survey; the blue line the results from the 2015 survey.

Figure 7-6 shows the spanogram for PL364 – historical side-scan sonar survey results incorporating surveys in 2010, 2012, 2014, 2016, 2018 and 2020. A key is provided on the left of the drawing – where the pipeline is coloured green, the line is buried; where it is coloured red it is in freespan; and where it is coloured blue the line has been inspected but the result is uncertain. Note that the red indicates that the pipeline is in freespan but not that the span is of the height and length to be classified as recordable within the Kingfisher definition of a span.

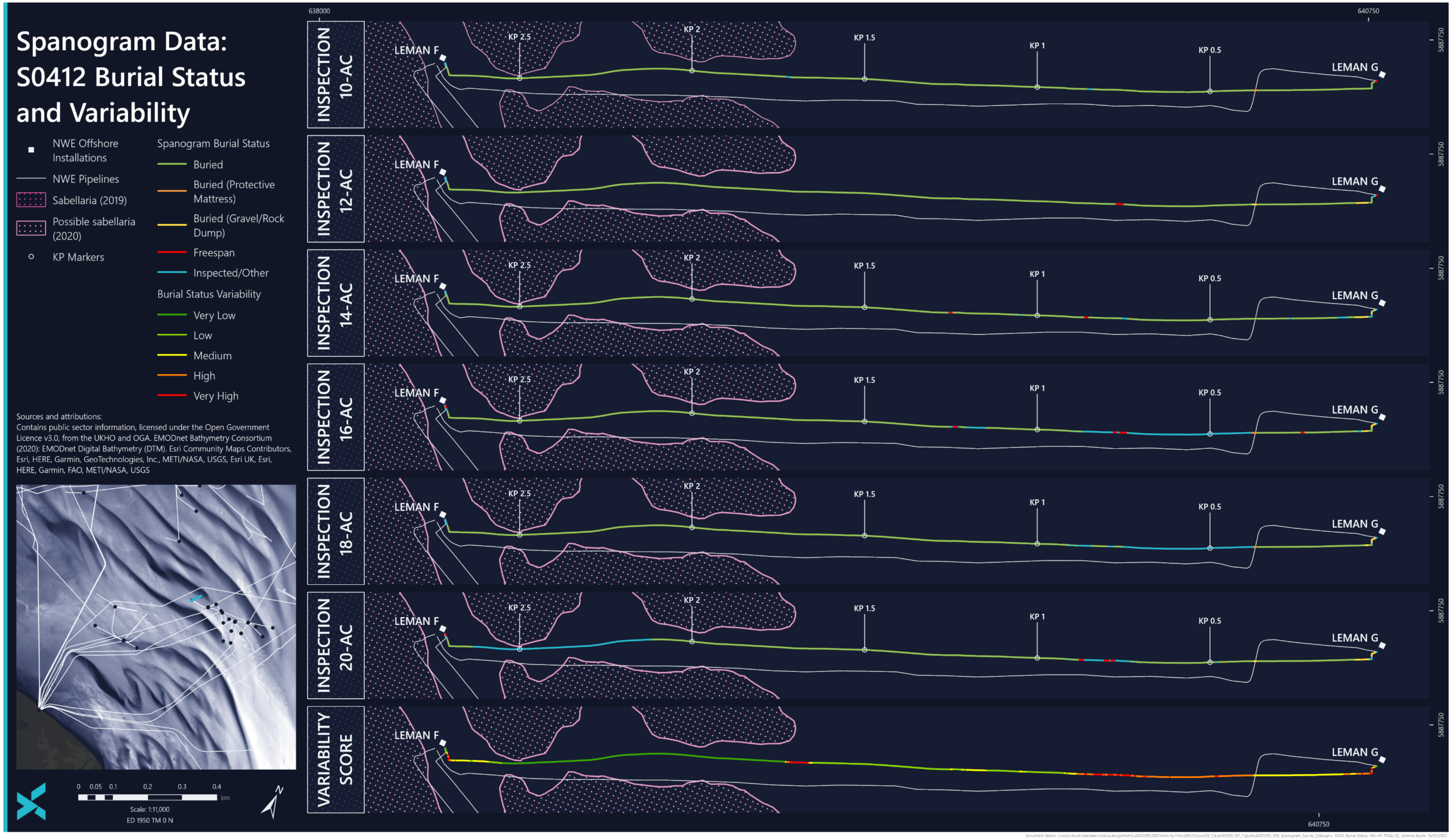


Figure 7-6 – Leman G Production Pipeline Historical Spanogram Results (S0412 / PL364)

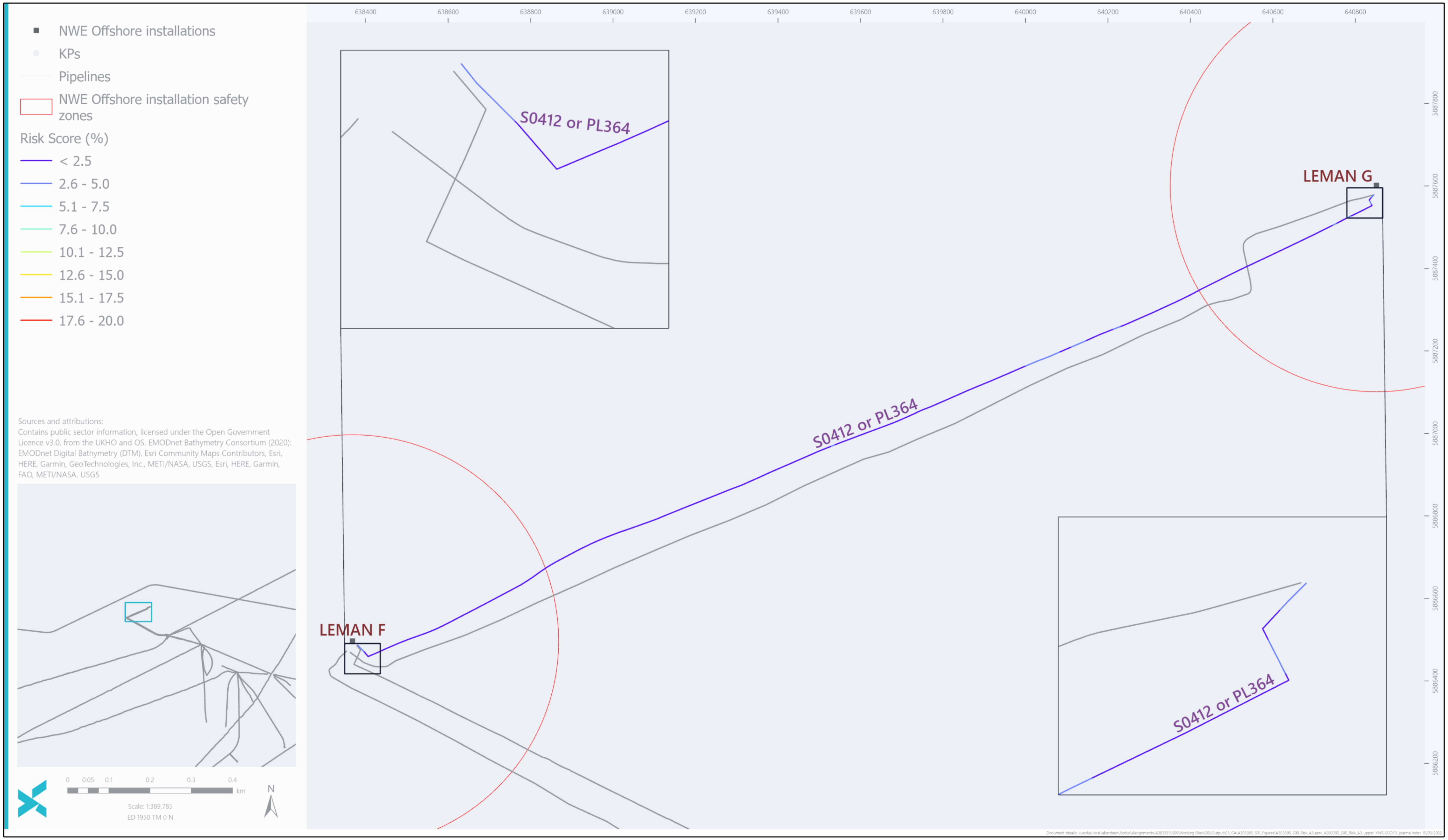


Figure 7-7 – Leman G Production Pipeline Risk Assessment (S0412 / PL364)

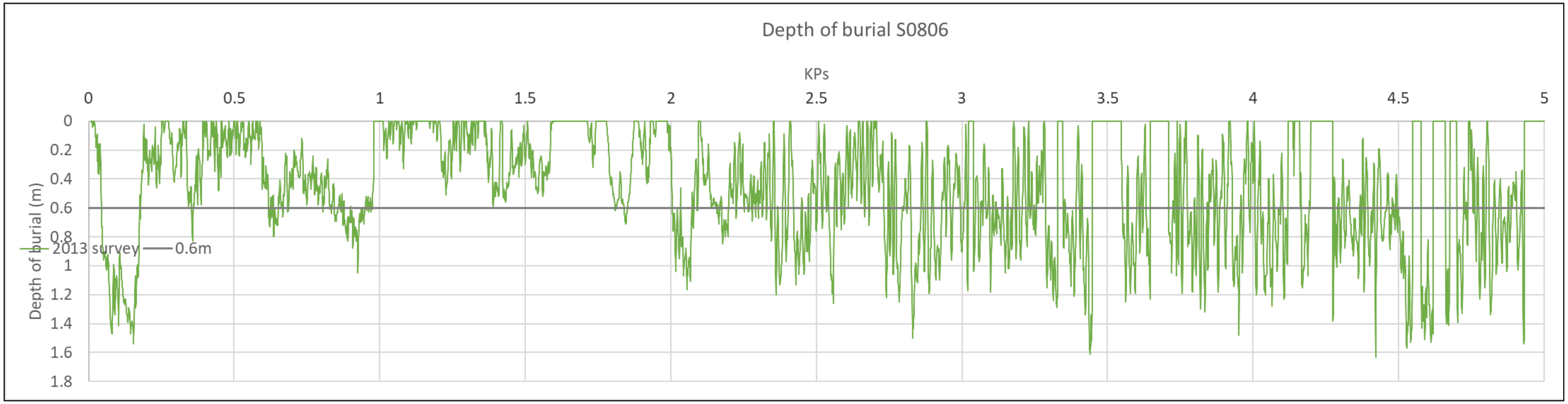


Figure 7-8 – Leman F Power Cable Depth of Cover (S0806 / PL5148)

Figure 7-8 shows the survey results from the 2013 depth-of-cover survey for PL5148. The green line indicate the depth-of-cover results.

Figure 7-9 shows the spanogram for PL5148 – historical side-scan sonar survey results incorporating surveys in 1995, 1996, 1997, 2002, 2013 and 2020. A key is provided on the left of the drawing – where the cable is coloured green, the line is buried; where it is coloured red it is in freespan; and where it is coloured blue the line has been inspected but the result is uncertain. Note that the red indicates that the cable is in freespan but not that the span is of the height and length to be classified as recordable within the Kingfisher definition of a span.

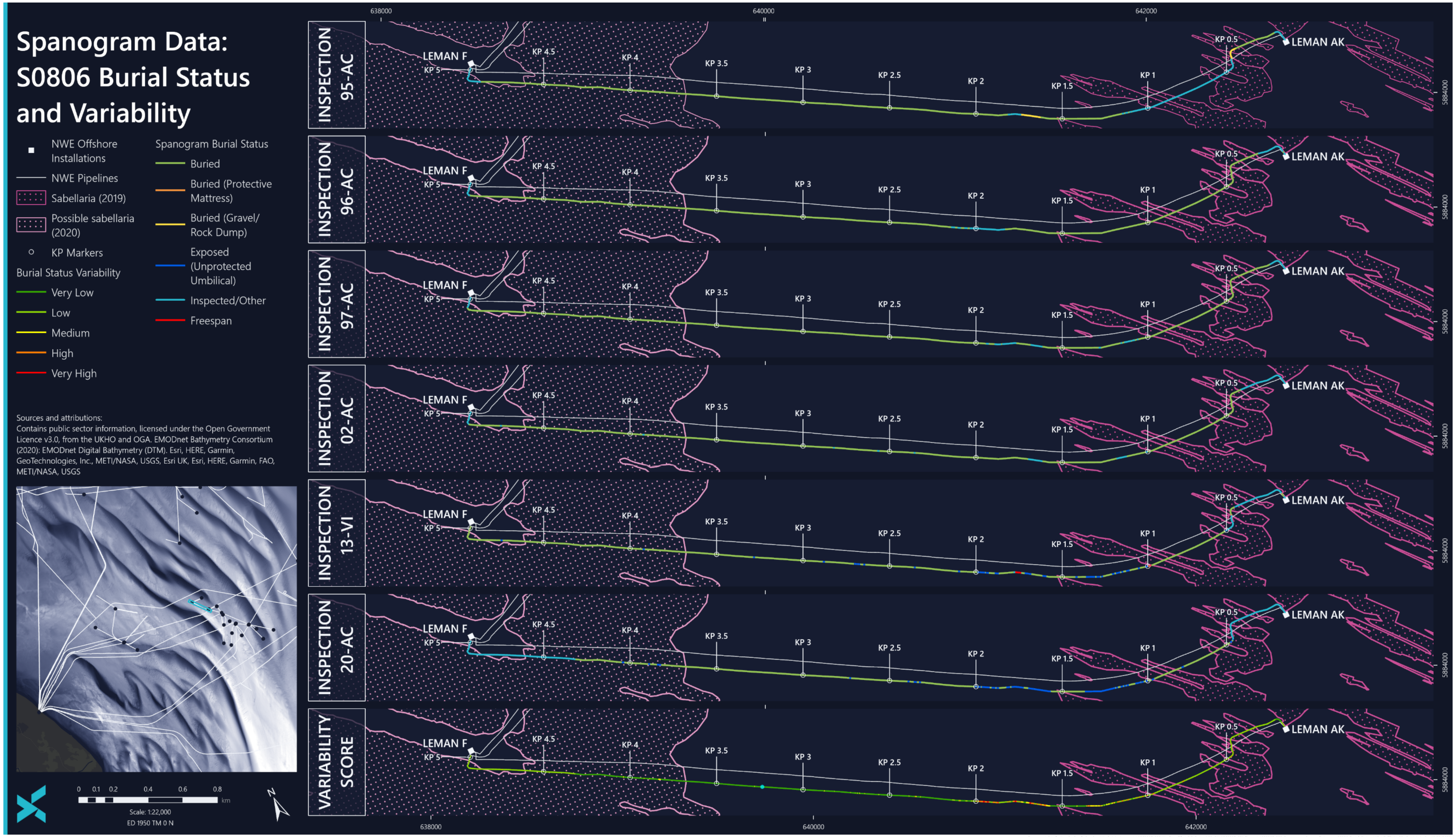


Figure 7-9 – Leman F Power Cable Historical Spanogram Results (S0806 / PL5148)

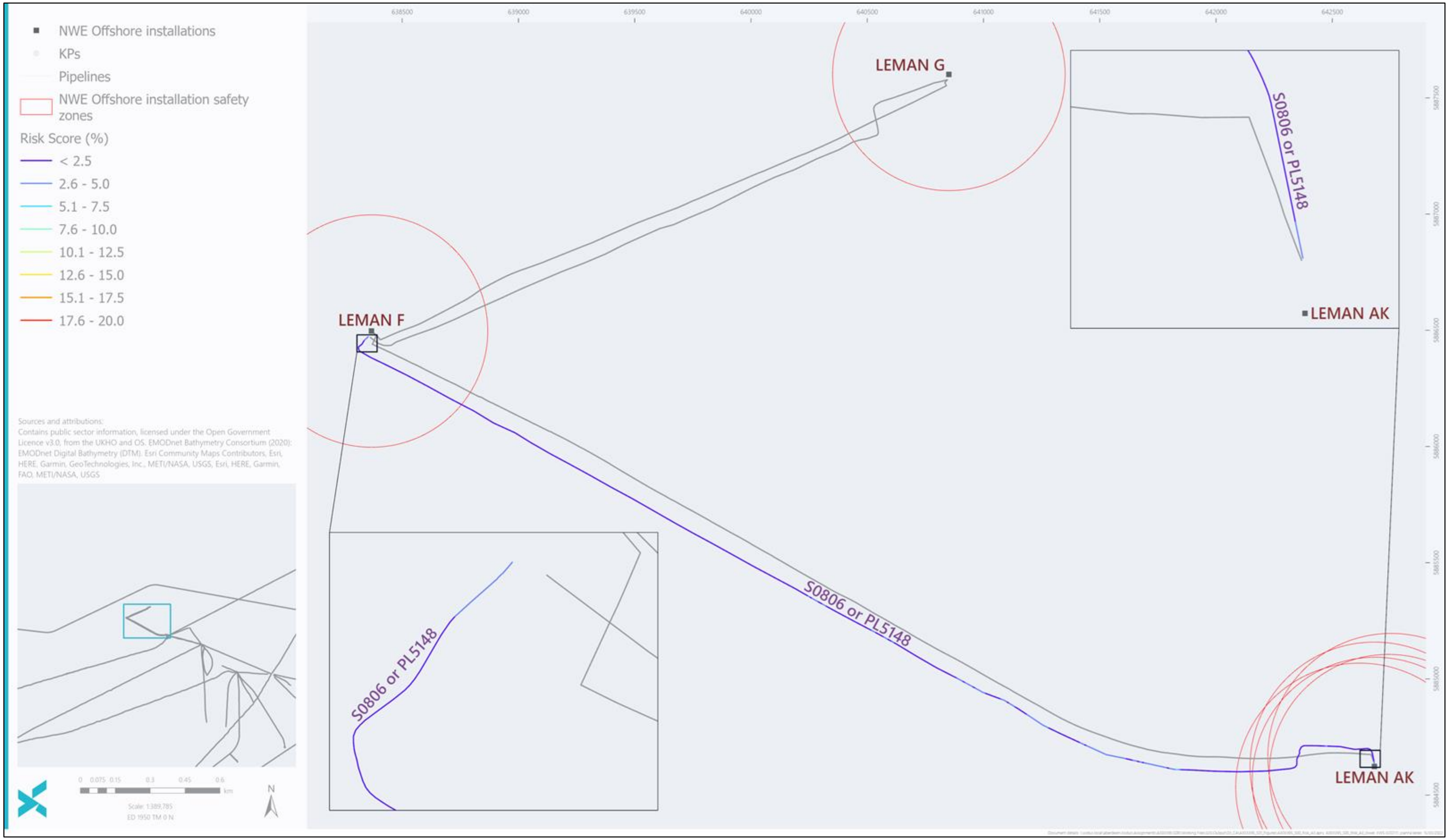


Figure 7-10 – Leman F Power Cable Risk Assessment (S0806/ PL5148)

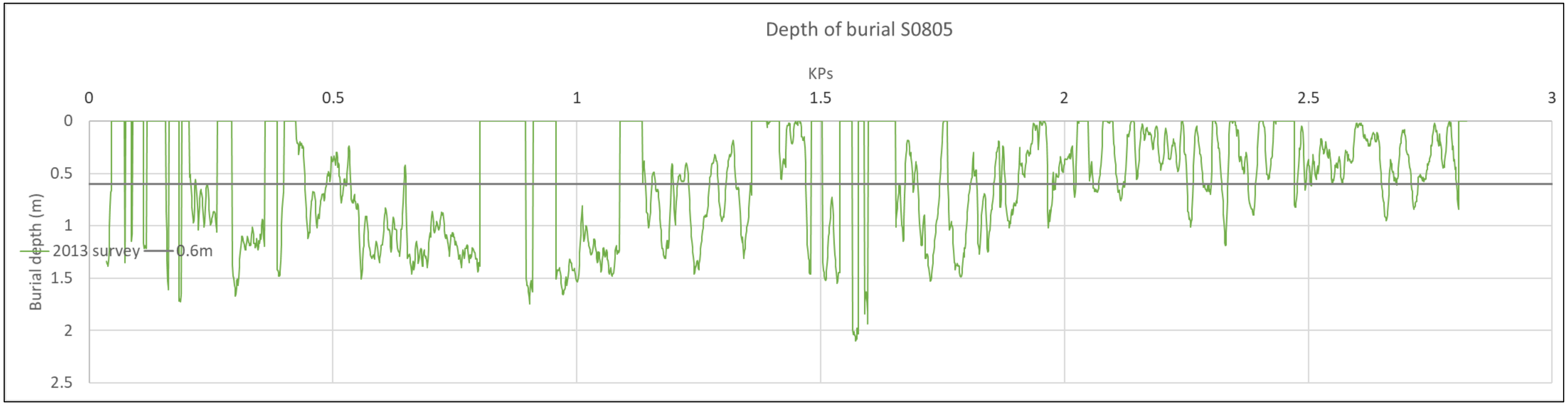


Figure 7-11 – Leman G Power Cable Depth of Cover (S0805 / PL5147)

Figure 7-11 shows the survey results from the 2013 depth-of-cover survey for PL5147. The green line indicate the depth-of-cover results from the survey.

Figure 7-12 shows the spanogram for PL5147 – historical side-scan sonar survey results incorporating surveys in 1995, 1996, 1997, 2002, 2013 and 2020. A key is provided on the left of the drawing – where the pipeline is coloured green, the line is buried; where it is coloured red it is in freespan; and where it is coloured blue the line has been inspected but the result is uncertain. Note that the red indicates that the pipeline is in freespan but not that the span is of the height and length to be classified as recordable within the Kingfisher definition of a span.

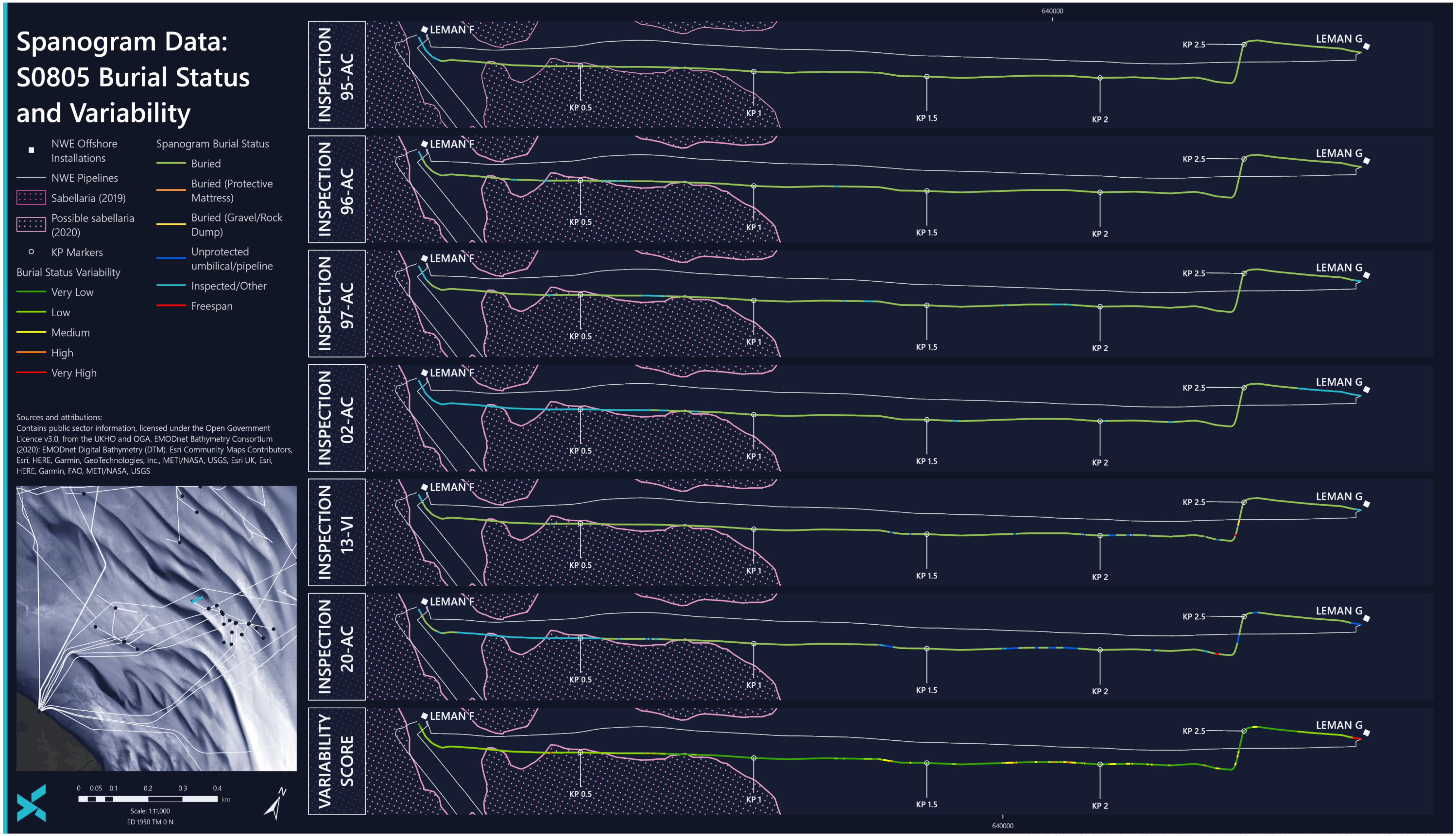


Figure 7-12 – Leman G Power Cable Historical Spanogram Results (S0805 / PL5147)

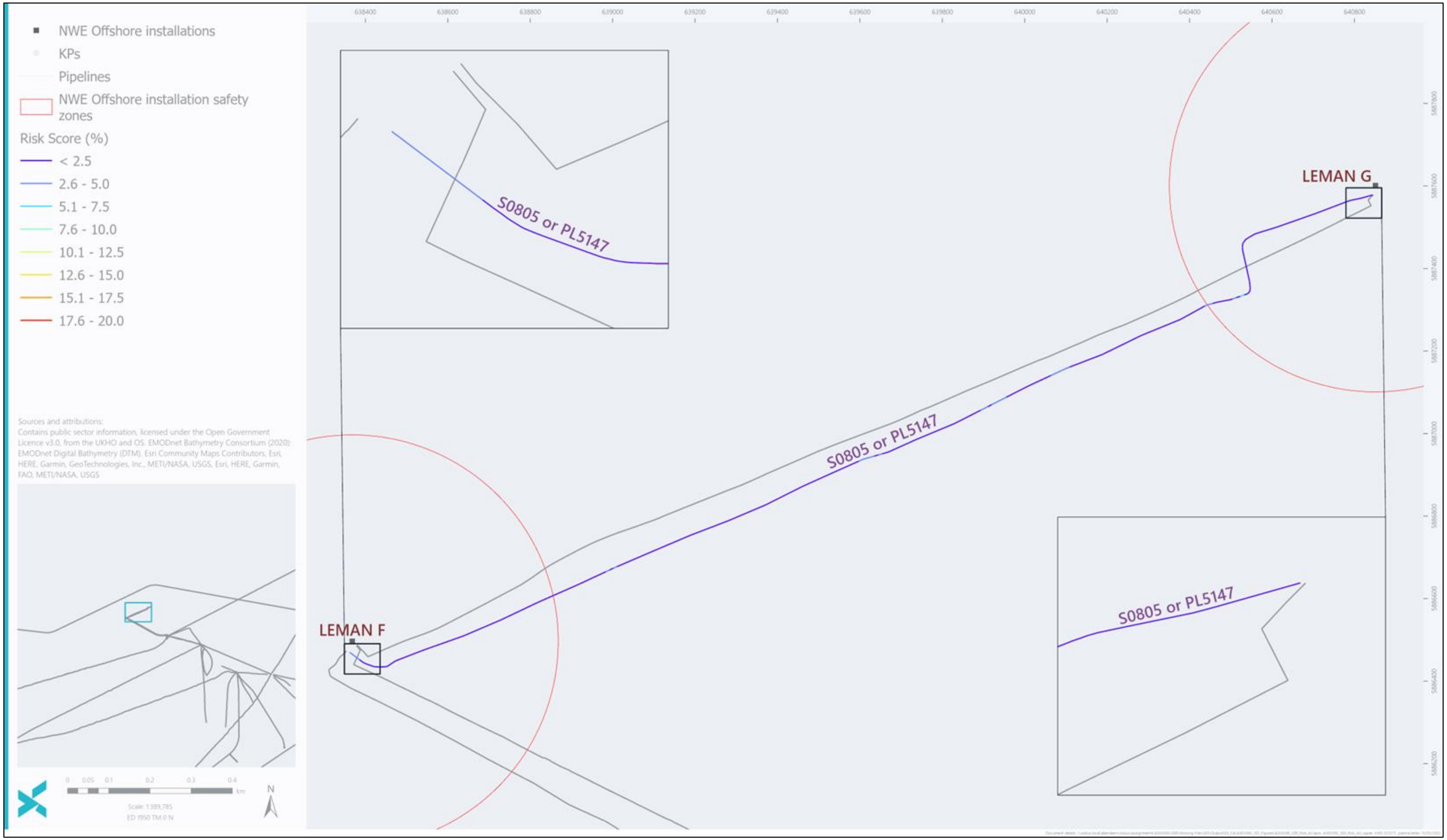


Figure 7-13 – Leman G Power Cable Risk Assessment (S0805 / PL5147)

8. Appendix B – CA Assessment Guidance

Criteria	Sub-Criteria	Applicable to	Applicable When	Green	Amber	Red
Safety	Project risk to personnel – Offshore	Project team offshore, project vessels crew, diving teams, supply boat crew, heli-ops, survey vessels crew	During execution phase of the project including any subsequent monitoring surveys	Minimal preparatory activity to be completed prior to start of removal activity. No underdeck / overside working. Minimal materials handling on deck or barge during removal. Minimal diver activity.	Some preparatory activity to be completed prior to start of removal activity – but straight forward. Limited underdeck / overside working. Some materials handling activity on deck or barge during removal – but straight forward. Increased diver activity for short intervals and for less than 25% project duration.	High level of preparatory activity to be completed prior to start of removal activity. Significant underdeck / overside working. Multiple materials handling activity on deck or barge during removal. Extended diver activity throughout entire project phase.
	Project risk to other users of the sea	All other users of the sea, fishing vessels, commercial transport vessels, military vessels	During execution phase of the project including any subsequent monitoring surveys	Minimal project activity outside existing exclusion zone. Minimal additional vessels transits to and from shore.	Moderate project activity outside existing exclusion zones but for short durations. Some additional vessel transits to and from shore of significant sized vessels. No complex transits.	Significant project activity outside existing exclusions zones but for most of project duration. Some complex transits to shore.
	Operational risk to personnel – Onshore	Onshore dismantling and disposal sites personnel; extent of materials transfers/ handling on land	During execution phase of the project, through to final disposal of recovered materials	Medium sized / volume of structures returned as waste - moderate dismantling required onshore, minimal work at height. Minimal contaminated materials to be returned, capable of being processed in existing facilities without additional specialist equipment or treatment.	Large size / volume of structures returned as waste – more dismantling required onshore, some working at height possible. Some contaminated materials may be returned, may require some additional specialist equipment or treatment.	Significant sized or awkward shaped structures returned as waste – significant working at height required, significant and complex dismantling and materials handling activities required. Significant volumes of contaminated materials handling and clean up anticipated; or requires onerous levels of additional specialist equipment / treatment.
	Potential for a high consequence event	Project team offshore and onshore; project vessels; diving teams; supply boat crew; heli-ops; survey vessels; onshore dismantling and disposal sites personnel	During execution phase of the project including any subsequent monitoring surveys	Short vessel campaign (summer campaign); low level vessel SIMOPS; minimal helicopter crew changes anticipated; few lifting operations; all straightforward and not over live plant.	Prolonged vessel campaigns; some vessel SIMOPS; helicopter crew changes possible; some lifting operations; recovered structures lifted onto vessels for backload but not over live plant.	Extensive vessel campaigns; multiple mob / demob; multiple vessel SIMOPS; helicopter crew changes likely; major lifting operations, some very large lifts; possible lifts of structures over live trunk lines.
	Residual risk to other users of the sea	Fishing vessels, fishermen, supply boat crews, military vessel crews, commercial vessel crew and passengers, other users of the sea	Following completion of the Decommissioning project and residual / ongoing impact in perpetuity	None anticipated as clear seabed on completion of project, all material left in situ is adequately trenched or buried below mean seabed level.	Some materials which are proud of mean seabed level / not trenched or buried but are otherwise protected, i.e. rock-covered or present minimal risk of snagging due to their inherent structure (e.g. large diameter trunklines). Other mitigations in place (retention of exclusion zones).	Material left in situ is proud of the seabed and not protected by rock-cover and could represent a future snagging risk; mitigation available is limited to marking on admiralty charts. Material left in situ would require significant future monitoring and / or future mitigation measures.
Environmental	Impact of operations	Environmental impact to the marine environment, nearshore areas and onshore caused by project activities	During execution phase of the project from mobilisation of vessels to the end of project activities at the waste processing / disposal site (does not include landfill and long-term storage impacts) For rock placement, trenching and dredging any seabed disturbance is	No associated discharges*[1]; No behavioural disturbance to any marine mammals; Area of disturbance equal or less than area disturbed during installation and/or operations; No disturbance to drill cuttings accumulation*[2];	Non-SUB, GOLD or E/PLONOR chemicals discharges*[1]; Temporary changes to behaviour of any marine mammals i.e. temporary move away from the area; Area of disturbance is up to two times bigger than the area disturbed during installation and / or operation;	Any other chemical discharges*[1] (other than in Amber) e.g. SILVER, OCNS A-C or no longer CEFAS registered; Permanent damage / change to behaviour of any mammals (i.e. move away permanently and / or permanent damage to hearing); Area of disturbance more than two times bigger than the area disturbed during installation and / or operations;

Criteria	Sub-Criteria	Applicable to	Applicable When	Green	Amber	Red
			included here, depending on area of impact – changes to habitat and species are covered in Legacy Impact.	Extend of the sediment resuspension equal or less than the extent caused during operations and/or installation; No protected / sensitive species and or habitats affected; Onshore processing can be completed by existing facilities without additional specialist equipment / treatment*4	Less than half the volume of the drill cuttings deposits*2 will be disturbed; Extent of the sediment resuspension is up to two times bigger than during operation and/or installation; Presence of protected / sensitive species and/or habitats identified and confirmed by a survey*3; Onshore processing requires moderate levels of specialist equipment / treatment, additional qualified personnel, etc	AND Greater than half the volume of the drill cuttings will be disturbed; AND Sediment resuspension is more than twice than during operation and/or installation; Presence of designated protected species and/or habitats*3; Onshore processing requires onerous or offsite levels of specialist equipment / treatment
	Energy and resource consumption	Project activities from vessel mobilisation to the final destination of waste, including the energy penalty for leaving recyclable material in field. Includes vessel mobilisation, demobilisation, waiting on weather, post-decommissioning monitoring surveys.	During execution phase of the project from mobilisation of vessels to the end of project activities at the waste processing / disposal site (does not include landfill and long-term storage impacts) Not recovering and recycling the installations material will require that raw material and energy will be consumed to replace the materials which would have been recycled if the structure had been brought onshore	Short duration and/or small number of vessels during decommissioning operation and future monitoring; Small volume of material left in situ	Moderate duration and number of vessels during decommissioning operation and future monitoring; Moderate volume of material left in situ	Significant duration and number of vessels required for operations and future monitoring; Significant volume of material left in situ
	Emissions	Project activities from vessel mobilisation to the final destination of waste, including the emissions penalty for leaving recyclable material in field. Includes vessel mobilisation, demobilisation, waiting on weather, post-decommissioning monitoring surveys.	During execution phase of the project from mobilisation of vessels to the end of project activities at the waste processing / disposal site (does not include landfill and long-term storage impacts) Not recovering and recycling the installations material will require that raw material and energy will be consumed to replace the materials which would have been recycled if the structure had been brought onshore	Can be quantified using assumptions for vessel types and duration for each option; quantified using Institute of Petroleum: Guidelines for the Calculation of Estimates of Energy Use and Gaseous Emissions in the Decommissioning of Offshore Structures Low emissions	Can be quantified using assumptions for vessel types and duration for each option; quantified using Institute of Petroleum: Guidelines for the Calculation of Estimates of Energy Use and Gaseous Emissions in the Decommissioning of Offshore Structures Moderate emissions	Can be quantified using assumptions for vessel types and duration for each option; quantified using Institute of Petroleum: Guidelines for the Calculation of Estimates of Energy Use and Gaseous Emissions in the Decommissioning of Offshore Structures High emissions
	Legacy impact	Ongoing long term environmental impact caused by materials left in place or long-term waste storage / landfill	Following completion of the Decommissioning project and residual / ongoing impact For rock placement, trenching and dredging any changes to habitat and species are included here - seabed disturbance is included in Impact of	Minor volumes of material to landfill; No hazardous waste requiring long-term storage; No change to habitat or species composition (introduction of no new materials); No material left ON the seabed; and / or inert material left IN the seabed (trenched or buried)	Moderate volumes of material to landfill; Non-hazardous waste requires disposal (landfill) OR Small amount of hazardous waste requiring treatment and / or long term-storage; Possible / temporary alteration of species composition due to habitat alteration with recovery and recolonization of the area by original species;	Majority of recovered material destined for landfill; Majority of hazardous waste long-term storage; Permanent habitat alteration with permanent changes in species composition; Material left ON or IN the seabed containing contaminated material that

Criteria	Sub-Criteria	Applicable to	Applicable When	Green	Amber	Red
			Operations, depending on area of impact.		Inert material left ON the seabed; or contaminated material left IN the seabed posing no significant threat to the environment *5	poses a significant long term threat to the environment*6
Technical	Risk of major project failure	Overall Project	From project select phase through to completion, including monitoring surveys and ultimate disposal of materials returned to shore.	High level of confidence that schedule slippage can be accommodated within the contingency and float in the plan; high level of confidence that cost increases can be accommodated by contingency UAP budget allocation; slippage to schedule and growth in cost anticipated is small; assets and equipment are immediately available to facilitate recovery and stabilise the situation after an incident; speed of recovery is anticipated to be swift; limited impact on planned campaign schedule is anticipated as remaining planned activities can continue in the interim.	Less confidence in cost and schedule, however moderate level of delay and cost overrun is anticipated as worst case; assets and equipment are available in a reasonable timeframe from onshore to stabilise the situation after an incident; speed of recovery is anticipated to be longer due to some re-engineering of activities being required; considerable impact on the planned campaign schedule is anticipated, as remaining planned activities cannot continue in the interim.	Significant delays are possible if upsets occur pushing removals phase into a separate season and increased cost overrun possible; re-engineering required to develop procedures and identify assets and equipment to stabilise the situation after an incident; speed of recovery is anticipated to be slow due to re-engineering and procurement of new equipment; significant impact on the entire project schedule and company reputation.
	Technology demands, Availability / Track Record	Overall Project	From project select phase through to completion, including monitoring surveys and ultimate disposal of materials returned to shore.	The proposed concept has been successfully implemented in the past; technological feasibility of the concept is beyond doubt; industry and expert opinion consistently concludes that the proposed solution is technically robust and complies with existing legislation; vessels and most supporting equipment are industry-standard with good track record of successful operation with no new marine asset construction required; some minor supporting equipment may require investment to aid development or proof of use as planned, however it is anticipated that this can be completed successfully ahead of the project schedule; the supply chain is generally readily available in the present market; project schedule is reasonable and equipment availability is within project timetable.	The proposed concept has been seriously considered for several directly comparable assets in the past but has not yet been used; technological feasibility of the concept requires some additional engineering development; expert opinion is united in confidence that the proposed solution is generally technically sound and complies with existing legislation; some vessels require some investment to aid minor development, however there is widespread confidence within the industry that this shall be completed successfully; more supporting equipment requires early investment to aid development, however it is anticipated that this will be completed successfully ahead of the project schedule; the supply chain requires some engagement to meet project requirements; project schedule can be managed to suit equipment availability within the overall project timetable.	The proposed concept is not mature; technological feasibility of the concept requires considerable engineering to prove; there is some doubt within the industry and expert opinion is divided on whether the proposed solution is technically sound and can comply with existing legislation; vessel require investment to aid their development and construction; other supporting equipment requires investment to aid development; there is uncertainty within the industry that this will be completed successfully ahead of the project schedule; the supply chain requires development; project schedule is tight but may be managed to suit equipment availability.
Societal	Commercial impact to fisheries	Impacts from both the decommissioning operations and the end-points on the present commercial fisheries in and around the field	During and following completion of the Decommissioning project and residual / ongoing impact	The status of the area / site post-decommissioning will have no effect on commercial fisheries.	The status of the area / site post-decommissioning results in small areas of fishing ground or water column becoming inaccessible to fishing and is lost to fishing over prolonged period.	The status of the area / site post-decommissioning results in larger areas of fishing ground or water column becoming inaccessible to fishing and is lost to fishing over a prolonged period.

Criteria	Sub-Criteria	Applicable to	Applicable When	Green	Amber	Red
	Socio-economic impact on communities and amenities	The impact from any near shore and onshore operations and end-points (dismantling, transporting, treating, recycling, land filling) on the health, well-being, standard of living, structure or coherence of communities or amenities. E.g. business or jobs creation, increase in noise, dust or odour pollution during the process which has a negative impact on communities, increased traffic disruption due to extra-large transport loads.	During and following completion of the Decommissioning project and residual / on-going impact	No or minor negative impact: short-term (<6 months) impact on local communities causing potential minor nuisance from some aspects of the operations, but would cease and revert to previous condition on completion of specific short term operations. Short-term (<6 months) impact on local amenities for some or all of the operations, but would cease and revert to previous condition on completion of operations, without the need for mitigation. Positive impact: new business or long term employment created, extends beyond duration of the operation by more than 1 year. Permanent road and other infrastructure improvements created.	Some negative impact on local communities, leading some actual deterioration in quality of life, deterioration would exist while actual operations were being carried out but would essentially cease as soon as operations were completed and quickly revert to pre-operation condition; some impact on local amenities, leading to some actual deterioration in amenities; deterioration would exist whilst actual operations were being carried out. Some mitigation / remedial work would be required when operations were completed to restore amenities to pre-operational condition. Short term and local positive impact on communities as localised increased job prospects created for duration of the operation. No permanent positive impact on amenities anticipated.	Significant and long-term (>1 year) negative impact on local communities leading to noticeable deterioration in quality of life during the operations. Anticipated this would persist for a period of 6 months to 1 year after actual operations had ceased. Significant and long-term (>1 year) impact on local amenities, leading to noticeable deterioration during the operations. Mitigation / remedial work would be required when operations were completed to restore amenities to pre-operational condition. No positive impact on communities or amenities. Existing businesses and infrastructure can accommodate operations.
Economic	Cost	Overall Project	Full decommissioning project cost including future monitoring surveys and proposed remediation, if required	Lowest cost option	-	Highest cost option
	Cost Risk / Uncertainty	Overall Project	Project execution phase and ongoing cost liability (surveys and potential remedial action)	Scope reasonably defined and understood; estimate developed using recognised and validated estimating tools; validated cost basis industry norms from similar work already carried out.	Some uncertainty / information gaps in parts of the scope and / or equipment used; estimate developed using recognised and validated estimating tools; validated cost basis using industry norms, some information gaps in norms due to costs of new or emerging equipment rates not being available.	Uncertainty in many areas of the scope and in equipment used; OOM estimate only developed; significant information gaps in norms due to costs of new / emerging equipment rates not being available.