BRENT DECOMMISSIONING PROJECT

Document Title:	Brent Decommissioning Programmes Environmental Statement
Document No:	BDE-F-GEN-HE-0702-00006

This Environmental Statement has been prepared by DNV GL on behalf of Shell U.K. Limited and Esso Exploration and Production UK Limited, as the Brent Field owners, under the responsibility of the Brent Field owners to provide an Environmental Impact Assessment in support of the Brent Field Decommissioning Programme.

The Brent Field owners agree and endorse the contents of this document.

Brent Field Decommissioning Environmental Statement

Shell U.K. Limited

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Summary:

Shell U.K. Limited (Shell) is presently preparing the *Brent Field Decommissioning Programmes* to decommission the Brent Field.

DNV GL was requested to prepare an Environmental Impact Assessment for the decommissioning of the Brent Field and facilities, based on the technically feasible decommissioning options defined by Shell, the results of which are provided in this Environmental Statement. The key objectives of this report are to set the background, describe the environmental baseline of the project area, identify and assess the potential impacts of the various decommissioning options for the various facilities, and assess the potential impacts of the decommissioning programme of work proposed by Shell.

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ABBREVIATIONS

ABS	Acrylonitrile Butadiene Styrene
AET	Apparent Effects Threshold
AHT	Anchor Handling Tug
ALARP	As Low As Reasonably Practicable
APE	Alkylphenolpolyethoxylates
ARPD	Apparent Redox Potential Discontinuity
AtoN	Aid to Navigation
AWJ	Abrasive Water Jet Cutting
BA	Brent Alpha (Brent A)
BAT	Best Available Technique
BB	Brent Bravo (Brent B)
bbl/day	Barrels per day
BC	Brent Charlie (Brent C)
BD	Brent Delta (Brent D)
BDP	Brent Decommissioning Project
BEIS	Department for Business, Energy and Industrial Strategy (termed BEIS)
BEP	Best Environmental Practice
BS	Brent South
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CCS	Carbon Capture and Storage
CFC	Chlorofluorocarbon
CFP	European Commission's Common Fisheries Policy
CGF	Conductor Guide Frame
CHARM	Chemical Hazard Assessment and Risk Management
CITES	Convention on International Trade in Endangered Species
CODA	Cetacean Offshore Distribution and Abundance in the

	European Atlantic
CoP	Cessation of Production (production shutdown)
CPR	Continuous Plankton Recorder
CRI	Cuttings Re-injection
CSV	Construction Support Vessel
Cu	Copper
DECC	Department of Energy and Climate Change
DEFRA	Department of Environment, Food and Rural Affairs
DPV	Drain Purge Vent
DP	Decommissioning Programme
DP	Dynamic Positioning
DP ROV	Dynamic Positioning Remotely Operated Vehicle
DS	Drilling Shaft
DSV	Diving Support Vessel
DWC	Diamond Wire Cutting
EAC	Ecotoxicological Assessment Criteria
EC	European Commission
E&E	Energy use and gaseous Emissions (referred to as Energy and Emissions)
EEMS	Environmental Emissions Monitoring System
EPDM	Ethylene Propylene Diene Monomer
ERM	Effects Range Medium
EIA	Environmental Impact Assessment
EPS	European Protected Species
ES	Environmental Statement
EUETS	European Union Emissions Trading Scheme
EWC	European Waste Code
FFPV	Flexible Fallpipe Vessel

FLAGS	Far North Liquids and Associated Gas System
FOCI	Feature of Conservation Importance
GBS	Gravity Based Structure
GHG	Greenhouse Gas
GRP	Glass Reinforced Plastic
GWP	Global Warming Potential
GTF	Gas Tight Floor
HAB	Harmful Algal Bloom
Hg	Mercury
HLV	Heavy Lift Vessel
HP	High Pressure
HQ	Hazard Quotient
HSE	Health, Safety and Environment
IMO	International Maritime Organisation
IPPC	Integrated Pollution Prevention and Control
IPR	Interim Pipeline Regime
ISSOW	Shell Integrated Safe System of Work
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LCV	Light Construction Vessel
LoD	Limit of Detection
LP	Low Pressure
LTD	Low Temperature Thermal Desorption
LTFD	Long-Term Field Development project
LWIV	Light Well Intervention Vessel
MAT	Master Application Template
MCZ	Marine Conservation Zone

MMscf	Million standard cubic feet
MNA	Monitored Natural Attenuation
MNR	Marine Nature Reserve
MPA	Marine Protected Area
MSV	Multi Service Vessel
N/A	Not applicable
NCMPA	Nature Conservation Marine Protected Area
ND	No Data
NDT	Non-Destructive Testing
NLGP	Northern Leg Gas Pipeline
NGL	Natural Gas Liquids
Ni	Nickel
nm	nautical mile
NM	Notice to Mariners
NNS	Northern North Sea
NOAA	National Oceanic and Atmospheric Administration
NORM	Naturally Occurring Radioactive Material
OBM	Oil-Based Mud
OCNS	Offshore Chemical Notification Scheme
OIW	Oil in Water content
OPEP	Oil Pollution Emergency Plan
ORP	(Shell Project and Technology) Opportunity and Realisation Process
ORS	(Shell Project and Technology) Opportunity and Realisation Standards
OSI	Organism Sediment Index
OVI	Offshore Vulnerability Index
P&A	Plugging & Abandonment

PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
PDMS	Plant Design Management System
PEC	Predicted Environmental Concentration
PETS	Portal Environmental Tracking System
PGDS	Plate Girder Deck Structure
PLEM	Pipeline End Manifold
PLL	Potential Loss of Life
PNEC	Predicted No-Effect Concentration
PON	Petroleum Operations Notice
POPM	Platform Operating Procedures Manual
PVC	Polyvinyl Chloride
ROV	Remotely Operated Vehicle
ROVSV	Remotely Operated Vehicle Support Vessel
ROTV	Remotely Operated Towed Vehicle
cSAC	candidate Special Area of Conservation
SAC	Special Area of Conservation
SAST	Seabirds at Sea Team
SCANS	Small Cetacean Abundance in the North Sea
SEI	Significant Environmental Impact
SEERAD	Scottish Executive Environment and Rural Affairs Department
Shell	Shell U.K. Limited and Brent Field Partners ExxonMobil
SCI	Sites of Community Importance
SLV	Single Lift Vessel
SOPEP	Ship Oil Pollution Emergency Plan
SPA	Special Protection Area
SPI	Sediment Profile Imaging

SSCV	Semi-Submersible Crane Vessel
SSIV	Subsea Isolation Valve
SSSI	Site of Special Scientific Interest
SUKEP	Shell UK Limited Exploration and Production
TBT	Tributyl tin
TCC	Thermomechanical Cuttings Cleaner
tCO_2	tonnes of carbon dioxide (CO_2)
tCO_2e	tonnes of CO_2 equivalent; a standard unit for measuring global warming potential. Illustrates the impact of a greenhouse gas in terms of the amount of CO_2 that would create the same amount of warming.
TERRC	Teesside Environmental Reclamation and Recycling Centre
TEG	Triethylene glycol
TLB	Tilting Lifting Beam
TLS	Topsides Lifting System
TOP	Top of Pipeline
Tscf	trillion standard cubic feet
THC	Total Hydrocarbon Content (concentration)
TSV	Trenching Support Vessel
UKCPC	United Kingdom Cable Protection Committee
UKCS	United Kingdom Continental Shelf
UKHO	UK Hydrographic Office
UKOOA	United Kingdom Offshore Operators Association
US	Utility Shaft
VASP	Valve Assembly Spool Piece
WBM	Water -Based Mud
WCROV	Work Class Remotely Operated Vehicle
WLGP	Western Leg Gas Pipeline

WONS	Well Operations and Notification System
WoW	Waiting on Weather
WROV	Work-class Remotely Operated Vehicle
Zn	Zinc

GLOSSARY

Acute effect	An adverse effect caused by initial exposure to a hazardous substance, and which will subside after exposure is ceased. A short-term effect.
Anthropogenic	Produced or caused by human activity.
At field operations	This is a term used in DNV GL's Energy & Emission methodology and represents fuel use on the platforms during decommissioning.
Attic oil	The oil trapped or stranded at the very top of the GBS cells because it is above the mouth of the oil export pipe.
AWJ	Abrasive Water Jetting. Uses high-pressure water with entrained abrasive material to cut through steel and other materials.
Ballast	Seawater or a solid to add weight for increased stability.
Baseline Studies/ Survey	A survey of the existing conditions of the environment(s) in which activities or operations will take place, in order to establish the conditions before the project was undertaken.
BEIS	In July 2016, the Department of Energy and Climate Change (DECC) was merged with the Department for Business, Innovation and Skills to create the Department for Business, Energy and Industrial Strategy (BEIS). Some instances of 'DECC' are still used in this report in reference to historical documents.
Benthic	Relating to seabed.
Benthic fauna	Species which live either within the seabed sediment (infauna) or on its surface (epifauna).
Bioaccumulation	The accumulation of a substance within the tissues of an organism. This includes 'bioconcentration' and uptake via the food chain.
Bioavailability	The extent to which a substance can be absorbed into the tissues of organisms.
Bioconcentration	The accumulation of a substance in the tissues of an organism as a result of (e.g.) respiration in an aquatic environment.
Bio-degradation	The break-down of a substance or material by biological activity.
Biodiversity	A measure of the degree of variety of living organisms in a particular ecosystem or region.
Biofouling	The covering of a structure by hard and soft marine growth. This consists of marine fauna native to the North Sea which have opportunistically colonised the hard surfaces of the structures (i.e. jacket or GBS).
Biogenic	Produced by living organisms.
Biogenic reefs	Reefs comprising the living or dead parts of marine organisms.

Biota	Living organisms.
Bq/g	Bequerels per gram (1Bq is one disintegration per second).
Bracing	Structural steel members linking the jacket legs.
Caisson	Cluster of vertical tanks (cells) which collectively constitute the GBS substructure gravity base. They may be used for (e.g.) oil storage or ballasting.
Cellar deck	A term for the fabricated steel structure at Brent C. An integral part of the topsides structure which will be removed during decommissioning.
Cells	Concrete oil storage and settling cells or ballast cells.
Cetacean	Collective name for the group of marine mammals comprising whales, dolphins, and porpoises.
Clay	Sediment grains <3.9 micron in diameter.
Concrete mattress	Concrete mattresses are used to provide protection and/or stability to subsea pipelines and umbilicals. Typically they are made from multiple concrete blocks joined together with polypropylene or Kevlar rope.
Condeep caisson	A make of Gravity Based Structure developed in Norway usually consisting of a base of concrete oil storage tanks (cells). One, three or four of these cells extend upwards as legs to support the topsides. BB and BC are both Condeep caissons.
Conductor	Large-diameter casing set in a well to support the surface formations, and to prevent the sides of the hole from collapsing into the well. They also serve to conduct drilling muds from the bottom of the well to the surface once drilling begins.
Decommissioning	The final phase of project life after an oil and gas field ceases production, and broadly involves the dismantling, removal and disposal of the installations, in compliance with strict national and international legislation.
Demersal	The term for organisms that live on or close to the seabed.
Derogation	An exemption from the requirement to remove the whole of a steel structure or concrete substructure from the seabed.
Diversity	An integrated index of species richness and relative abundance, measured using for example the Shannon-Wiener Diversity Index (H').
Dowel	A vertical steel or concrete pile projecting downwards from the base of a gravity platform, used to restrict horizontal movement of the substructure during installation.

Drawdown	The system and process which maintains a difference in pressure between the fluids inside the cells and the surrounding sea. The cell fluids are kept at a lower pressure and the resultant compression force on the caisson enhances its strength and integrity.
Dredging	Excavation of material performed underwater.
Drill cuttings	Fragments of rock created by the drilling process, and carried to the surface by lubricating fluids. Within the context of this report the material also contains residual drilling mud and other substances, some of which are classed as contaminants.
EIA and ES	Environmental Impact Assessment is a formal process to identify and assess the potential environmental impacts from a proposed development. The Environmental Statement is the report produced as a result of the EIA process.
Emulsion	Stabilised fluid-in-fluid mix.
Environmental aspect	An environmental aspect is an element of an organisation's activities, products or services that can interact with the environment.
Footings	Those parts of a steel installation which are below the highest point of the piles which connect the installation to the seabed.
GBS	Gravity Based Structure(s). Platform substructure (which supports topsides) made from concrete and steel which principally uses its own weight to remain in place (also see skirt). In this report, 'GBS' refers to all three concrete platforms (BB, BC, BD), and also to a singular platform.
GBS cell sediment	An accumulation of solids, water and hydrocarbons in the base of the GBS oil storage cells presumed to have built up over many cycles of filling and emptying during operations. Solids presumed to comprise mainly fine particles produced from the reservoir.
Grout	Cement used to secure conductor tubing or piles on the seabed. Also used for ballast and for pipe joint repairs in the GBS.
Hydrocarbons	Any compound containing only hydrogen and carbon.
ICES Rectangle	International Council for the Exploration of the Seas. An ICES Rectangle is a sea area of 30 minutes latitude by one degree (60 minutes) longitude used internationally to record fisheries statistics such as catch and effort.
Interphase Layer	Stable oil in water emulsion found in the GBS cells, between the attic oil and aqueous phase.
Isomers	Isomers are two or more compounds that have the same molecular formula, but have a different arrangement of atoms.

Jacket	The fixed steel frame substructure that supports the Brent A topsides.
Marine operations	This is a term used in DNV GL's Energy & Emission methodology and represents fuel use by vessels.
MARPOL	International Convention for the Prevention of Pollution from Ships (1973/1978).
Material recycling	This is a term used in DNV GL's Energy & Emission methodology and represents energy used when recycling materials.
Minicell	A 60 m tall cylindrical compartment at the bottom of the utility shaft of the GBS. The gap between the leg wall and the minicell is referred to as the minicell annulus.
MNA	Monitored Natural Attenuation is a remediation technique proposed for use on the GBS cell contents and involves leaving the cell sediment and water *in situ* in the GBS cells and adding nutrients into the cells to enhance degradation of hydrocarbons and other compounds. This is termed MNA.
Modules	Structural units assembled to form the platform topsides.
Neap tide	A tide that occurs when the difference between high and low tide is least.
NORM	Naturally Occurring Radioactive Material is typical of offshore oil and gas operations, and is often found in produced water and can precipitate as an insoluble scale. The production of oil and gas results in the transport of radioactive constituents and accompanying major ions from the oil-bearing formations to the wellhead and to downstream processing and transport facilities. It can also precipitate inside pipework or valves, and is called scale.
Oil-based mud	Oil-based mud (OBM) is a drilling fluid composed of oil as the continuous phase and water in the dispersed phase, along with other additives such as emulsifiers and wetting agents which are used during drilling for lubrication, maintaining pressure and flushing out drill cuttings.
Onshore dismantling and treatment	This is a term used in DNV GL's Energy & Emission methodology and represents the processing of reclaimed materials.
Onshore transport	This is a term used in DNV GL's Energy & Emissions methodology and represents the movement(s) of material(s) onshore e.g. from quay to processing site or from quay to landfill site, and is based on an assumed distance to such sites.
ORP	Shell's Opportunity Realisation Process, part of the sequence of checks and balances in Shell U.K. Limited's decision-making process.
Pelagic	Organisms living in the water column.

Phytoplankton	The collective term for the microscopic plants that drift or float in the water column. Phytoplankton consists mainly of microscopic algae. They are the primary producers in the sea and form the basis of food for all other forms of aquatic life.
Pigging	The act of forcing a device (pig) through a pipeline for the purposes of displacing fluids as well as cleaning out rust, wax, scale and debris.
Piles	Heavy beams of concrete or steel driven into the seabed as a foundation or support for the jacket or subsea structure.
Plate Girder Deck Structure	The Plate Girder Deck Structure (PGDS) is the fabricated steel structure which is an integral part of, and supports, the topsides of Brent B and D, and will be removed during decommissioning.
Pockmarks	Natural craters or depressions in the seabed caused by subsurface fluids (gas and liquids) leaking or venting into the water column.
Polychaete	The class of annelid worms which possess distinct segments.
Produced water	Water produced from the reservoir along with the oil and gas.
Pyrophoric scale	Residual material which may be found on the topsides that can burn or ignite spontaneously when in contact with air, if struck.
Re-mobilisation	With respect to drill cuttings refers to moving the cuttings by whichever means (e.g. dredging).
Replacement of 'lost' materials	This is a term used in DNV GL's Energy & Emission methodology and represents a penalty for not recycling otherwise recyclable materials.
Re-suspension	With respect to drill cuttings refers to material and especially contaminants re-entering the water column when disturbed by natural or man-made forces.
cSAC	Candidate Special Areas of Conservation are sites that have been submitted to the European Commission for consideration as a SAC, but have not been formally designated. The first step in the designation process. See SAC.
SAC	Special Areas of Conservation are sites which have been adopted by the European Commission and are given special protection under the EU Habitats Directive. They provide increased protection to a variety of wild animals, plants and habitats. They are also formally designated by the country in which the site lies.
SCI	Sites of Community Importance are sites that have been adopted by the European Commission as areas for increased environmental protection, however they have not yet been formally designated by the country in which the site lies, the second step in the designation process. See SAC.

Sediment clast	A sedimentary rock composed of fragments, or clasts, of pre-existing rocks or minerals.
Slurry	A thin sloppy mud or cement or, in extended use, any fluid mixture of a pulverized solid with a liquid (usually water), often used as a convenient way of handling solids in bulk.
Spar	A Spar platform is moored to the seabed like Tension Leg Platforms (TLPs); but whereas a TLP has vertical tension tethers, a spar has more conventional mooring lines.
Substructure	See definitions for 'GBS' and 'Jacket'.
Topsides	The topsides are the surface decks of a platform, located on top of the support structure (jacket or GBS), that contain the oil and gas drilling, production and processing equipment, plus helideck and living quarters.
Transient effect	An effect which is temporary and short-lived.
Tri-cells	In BB and BD this is the void in between adjacent storage cells. For BC this is the void between the legs and the caisson structure.
Truss deck	The term for the fabricated steel structure supporting the topsides of Brent A which will be removed during decommissioning.
Umbilical	Cable and tubing-like structure that provides utilities and communication to sub-sea equipment to allow it to be operated.
Vessel spread	The fleet of vessels used for any particular activity or operation.
Water-based mud	Water-based mud is a drilling fluid in which water is the major liquid phase.
Water column	The vertical column of water extending from the sea surface to the seabed.
Wellbore	The wellbore is the openhole or uncased portion of the well.
Zooplankton	The collective term for the animals that float/drift in the water column.

0. NON TECHNICAL SUMMARY

0.1 Introduction

The Brent Field was discovered in 1971 and is one of the largest hydrocarbon accumulations ever discovered in the Northern North Sea (NNS). The operator, Shell U.K. Limited (Shell) is preparing to decommission the Brent Field on behalf of Shell and Brent Field partner Esso Exploration and Production UK Limited (Esso), as the field is reaching the end of its economic life after having been in operation for 40 years.

The Brent Field consists of four platforms (Brent Alpha, Brent Bravo, Brent Charlie and Brent Delta) installed between 1976 and 1978. Three are concrete Gravity Based Structures (GBS) (Brent B, C and D), and one a steel jacket (Brent A), as shown in Figure 0-1. The Brent Decommissioning Project (BDP) will be the largest decommissioning project to date in the UK Continental Shelf (UKCS).

In support of Shell's *Brent Field Decommissioning Programmes*, this Environmental Statement (ES) presents the main findings of the Environmental Impact Assessment (EIA) process carried out by DNV GL for Shell for the decommissioning of the Brent Field in the NNS. This non-technical summary provides an overview of the findings and is a standalone section.

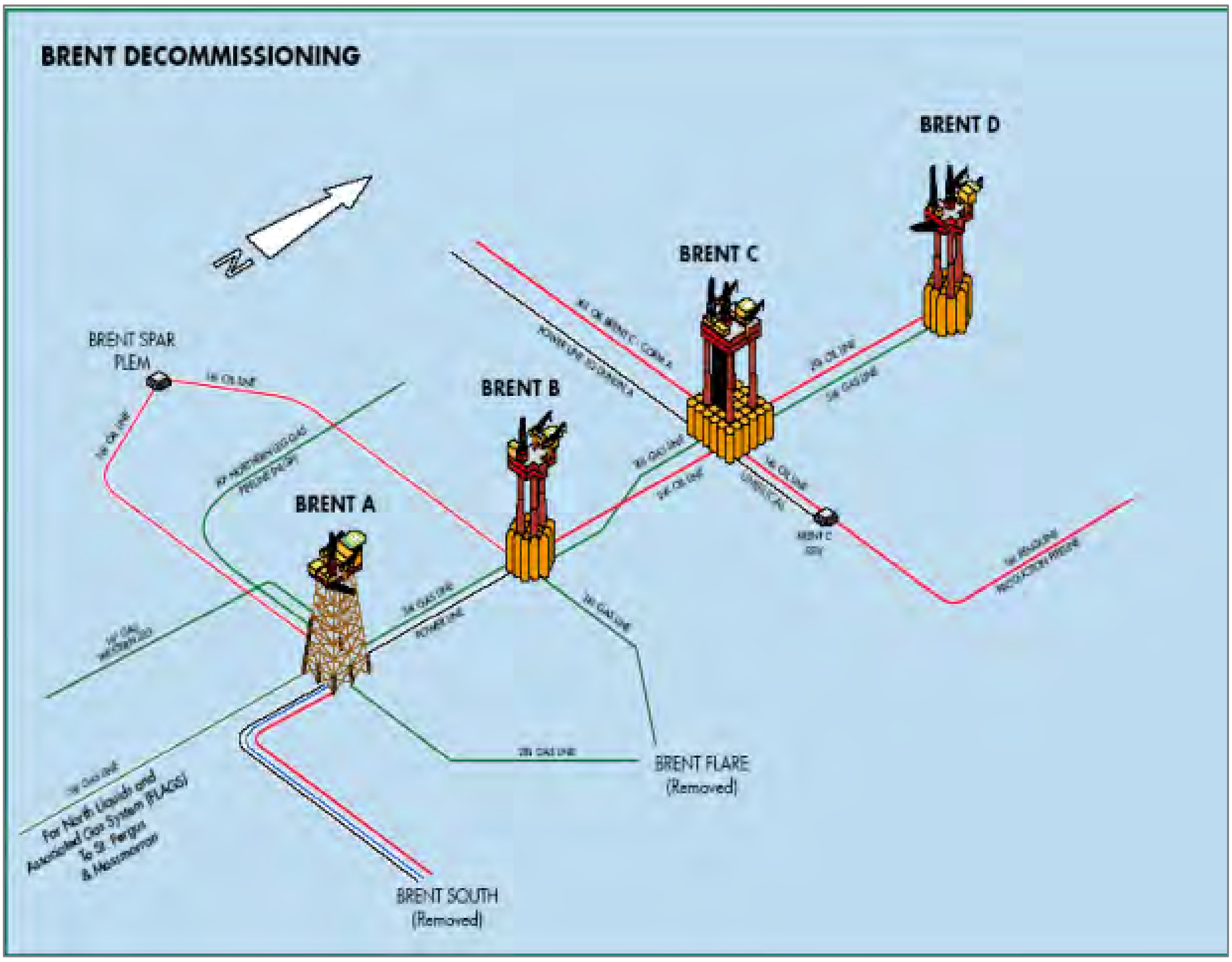
This ES has been prepared by DNV GL in accordance with the Department of Energy and Climate Change (DECC) Guidance Notes for Decommissioning of Offshore Oil and Gas Installations under the Petroleum Act 1998 (as amended by the Energy Act 2008), which requires a decommissioning programme to be supported by an EIA. Shell submitted the *Brent Delta Topsides Decommissioning Programme* to the Department for Business, Energy and Industrial Strategy (BEIS) in June 2015 and will be submitting two further programmes, the *Brent Platforms Decommissioning Programme* and the *Brent Pipelines Decommissioning Programme* (which will be submitted together within one document, the *Brent Field Decommissioning Programmes* document). This single ES provides information and assessments applicable to all three Decommissioning Programmes (including the already approved *Brent Delta Topsides Decommissioning Programme*).

This ES presents:

- a description of the Brent Field facilities, and the current environmental condition of the Brent Field, offshore transport route and onshore dismantling location.
- the results of the EIA process to identify and assess both the potential short and long-term impacts of the technically feasible decommissioning options for the Brent Field facilities after industry standard mitigation has been applied.
- the potential environmental impacts of the decommissioning programme of work proposed by Shell.

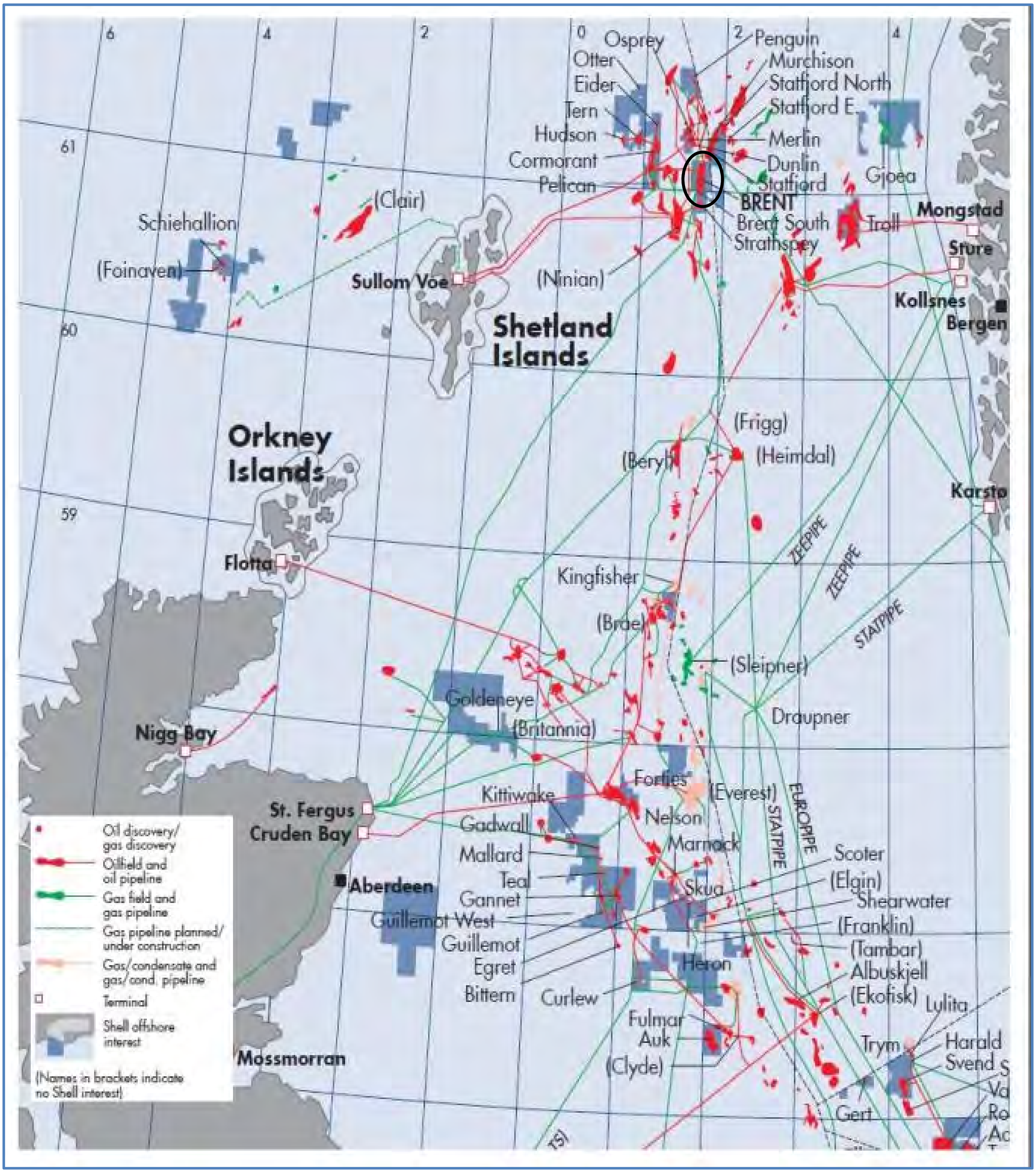
This ES helps inform the decision-making process as well as the Comparative Assessment undertaken by Shell, and summarises the mitigation measures necessary to control impacts.

Figure 0-1: Layout of the Brent Field Platforms



As shown in Figure 0-2, the Brent Field is located in UKCS Block 211/29 in the NNS approximately 136 km north-east of the Shetland Islands, in a water depth of approximately 142 m.

Figure 0-2: Location of Brent Field in relation to Scotland and Norway



0.2 Summary of the Brent Field Facilities

Topsides	Brent Alpha, Bravo, Charlie, Delta
Steel Jacket Substructure	Brent Alpha
3 Gravity Based Structures (GBS)	Brent Bravo, Charlie, Delta
GBS cell contents	Brent Bravo, Charlie, Delta Oily water, attic oil and sediment inside GBS storage cells
GBS drilling leg material	Contents of GBS drilling legs (Brent Bravo, Delta)
GBS minicell annulus material	Contents of GBS minicell annulus (Brent Bravo, Delta)
Drill cuttings	Seabed (Brent Alpha, Bravo, Charlie, Delta and Brent South)
	GBS cell tops GBS tri-cells (Brent Bravo, Delta)
Pipelines	103 km Pipelines, umbilicals and cables Includes Brent South pipelines that remain after the earlier decommissioning of the Brent South Field
	Concrete mattresses
Subsea structures	Brent Spar PLEM (Pipeline End Manifold) and protective cover; Brent Spar protective cover; Brent B SSIV (Subsea Isolation Valve); Brent A umbilical splitter box; VASP (Valve Assembly Spool Piece)
Subsea debris	Grout bags, scaffolding, anchor block, wires
Wells	146 wells throughout the Brent Field

The Brent Field Decommissioning Project comprises the following infrastructure:

Brent Alpha was installed in 1976 and is a fixed steel jacket, secured to the seabed by piles at the base of each of its eight legs. The platform stands in a water depth of 140 m and has an overall height of 162 m.

Brent Bravo was installed in 1975 and is a three-leg concrete Condeep GBS supporting the topsides, each leg being 160 m high, measured from the seabed to the top of the ring beam. The

base consists of 19 reinforced concrete cells 60 m high, arranged in a hexagonal-shaped honeycomb caisson.

Brent Charlie was installed in 1978 and is a four-leg concrete Seatank GBS comprising 36 cells 57 m high, arranged in a 6 x 6 rectangular pattern on the seabed. Four of the cells extend upward as supporting legs, each 164.7 m high (including steel transition pieces), to support the topsides.

Brent Delta is a three-leg concrete Condeep GBS similar to Brent B, installed in 1976. It comprises 19 reinforced concrete cells 58 m high, arranged in a hexagonal-shaped honeycomb caisson which sits on the seabed. Three of the cells extend upward as supporting legs, each 162 m high, measured from the seabed to the top of the ring beam.

The subsea concrete cells ('caissons') of the three GBS are used for different purposes: storage of ballast water and crude oil, separation of crude oil and produced water, and cooling of storage cell contents. The tops of the GBS cells sit approximately 80 m below sea level. The **cell contents** contain large volumes of attic oil, an oil/water interphase layer, water and sediment, as verified by a 2014 sampling project conducted by Shell.

On both Brent B and D, two of the three GBS legs serve as **drilling legs**, while the third leg has a utility function and has a minicell (a 60 m high by 7 m diameter cylinder) located at the bottom of the leg; the gap between the leg wall and the minicell is referred to as the **minicell annulus**. The drilling legs of the Brent B and D GBS contain contaminated drill cuttings and the minicell annulus of Brent B and D contains some oily sludge.

Drill cuttings are present on the seabed at all four platforms, on the tops of the GBS storage cells and within some of the GBS tri-cells. Drill cuttings are also present on the seabed at Brent South, a subsea development that is no longer operational and has been removed. Drill cuttings are rock fragments that were generated by the drill bit during drilling. Fluids called drilling muds were used to lubricate and cool the drill bit, maintain pressure, and to transport cuttings back to the topsides for separation prior to discharge. Drilling muds can be water-based or oil-based fluids. Discharged drill cuttings can still have some proportion of the drilling muds adhering to their surface. Tri-cells are void spaces in between GBS cells, which over time at Brent B and D have accumulated drill cuttings (Brent C has no tri-cell drill cuttings as the tri-cells are not open to sea).

A total of 28 subsea **pipelines,** ranging between 0.3 and 35 km long, will be decommissioned at the Brent Field. These include pipelines used for oil production and gas export, power cables and control umbilicals. Also, concrete mattresses have been installed to protect subsea pipelines and umbilicals, and are present on the sea floor.

Subsea structures (e.g. subsea isolation valves, pipeline end manifolds and valve assembly spools) **and debris** (e.g. grout bags, scaffolding, grating, ladders and wires) are also present on the seabed, around the platforms and on top of the GBS cells.

A total of **146 wells** were drilled throughout the Brent Field at Brent A, Brent B, Brent C, Brent D and Brent South, and will be plugged and abandoned during the decommissioning programme.

Brent D ceased production in December 2011, Brent A and B ceased production in November 2014 and Brent C will continue to produce for the foreseeable future.

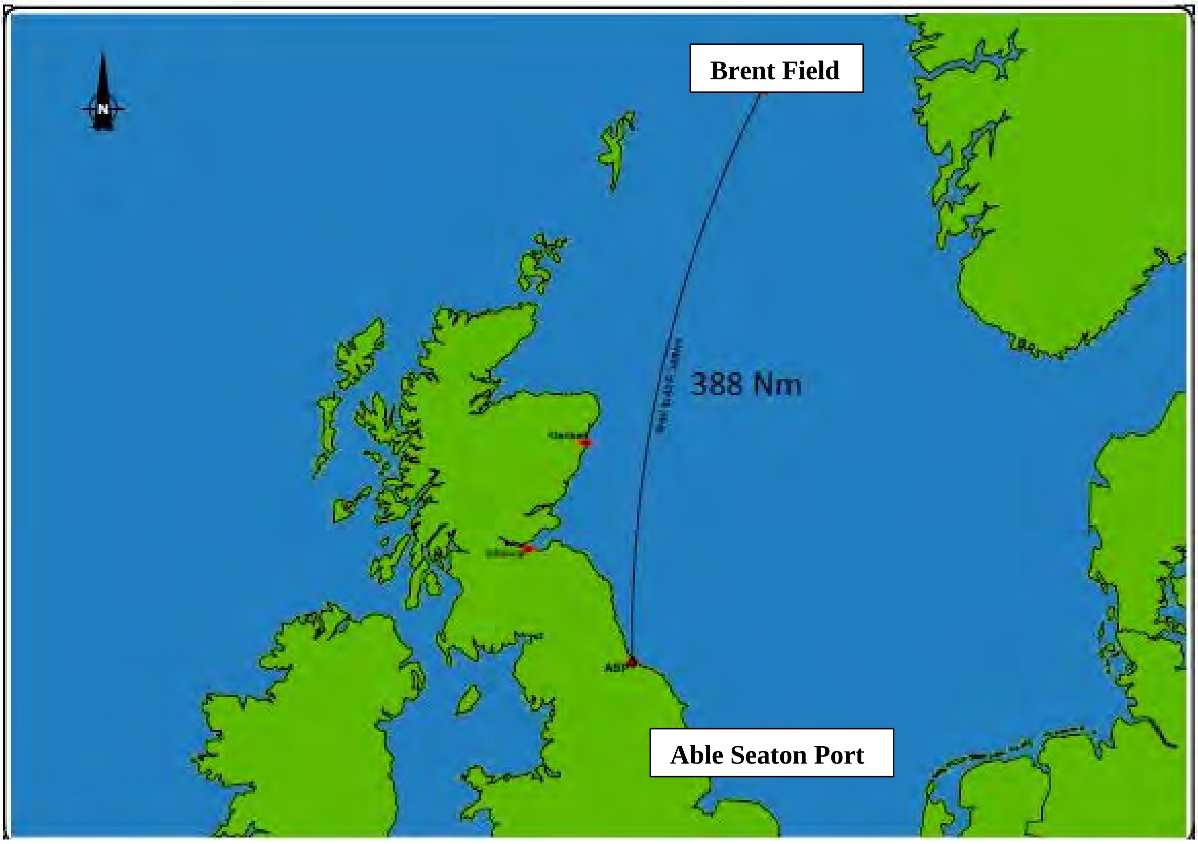
0.3 Environmental Setting

It is important to understand the current status and sensitivities of the environmental areas that could be affected by the decommissioning operations, in order to effectively predict and assess the environmental impacts.

Brent A, B and D topsides and Brent A upper jacket will be transported from the Brent Field to a nearshore location off the north-east coast of England, where they will be transferred from the Single Lift Vessel (SLV) the *'Pioneering Spirit'* to a cargo barge (because the SLV is too large to berth alongside the onshore facility). The transfer location is approximately 5.5 nautical miles, or 10 km, from the mouth of the River Tees. The topsides and upper jacket will then be transported on the cargo barge to the onshore dismantling facility at Able Seaton Port (ASP) in Teesside, operated by Able UK Limited (Able). The transit route is illustrated in Figure 0-3.

The current environmental conditions are briefly described below at the Brent Field, the proposed offshore transit route and transfer location, and at the onshore dismantling facility.

Figure 0-3: Location and Distance from Brent Field to Able Seaton Port



Offshore Environment at the Brent Field Area

The climate in the Brent Field is influenced by the inflow of Atlantic waters, and is characterised by large variations in wind speed and direction, significant cloud and high rainfall. Winds generally come from the south to south-west, are on average between 6-13 m/s, and the area is known for severe gales and storms.

There are no particularly environmentally sensitive habitats close to the Brent Field. The closest environmentally protected areas are the Pobie Bank Reef, a Site of Community Importance (SCI) located approximately 85 km south-west, and the NE Faroe Shetland Channel Marine Protected

Area (MPA) located approximately 110 km to the north-east. There are no designated Special Areas of Conservation (SAC) close to the Brent Field.

Seabed communities in the general area are diverse and abundant, but are not unique to the region. Seabed surveys have identified elevated concentrations of metals and hydrocarbons in the sediment around each Brent Field platform. The elevated concentrations are localised, with elevated THC concentrations extending up to a maximum distance of between 250-800 m, (depending on which platform); adverse effects from other pollutants are restricted to smaller areas. This is typical of North Sea facilities due to the historical discharge of drill cuttings contaminated by residual oil-based (and water-based) drilling fluids. Samples indicate that benthic fauna are affected locally around the platforms, but at more than 800 m from the platforms, benthic communities were indicative of undisturbed conditions.

The Brent Field is a relatively small area located within larger spawning grounds used by cod, haddock, saithe, Norway pout, mackerel, sandeels and blue whiting. The fishing industry in the Brent Field has historically been dominated by the mackerel fishery, which accounted for approximately 76% of the value of the catch over the period 2000-2015, but the mackerel catch has reduced in recent years. The total value of the catch in the Brent area from 2000-2015 was approximately £75 million, with an annual average of less than £5 million.

A number of marine mammal species have been observed in the Brent Field, including harbour porpoises (an Annex II species), white-sided dolphins, minke and killer whales and other species.

Seabirds rely entirely on the marine environment for their survival, and there are approximately twenty-five species of seabird in the UK. The overall vulnerability of seabirds to oil pollution in the Brent Field and surrounding blocks is considered to be 'low', however the months of January, March, July and between September to November show a 'high' seabird vulnerability in some blocks.

Shipping traffic to European ports entering the NNS from the west generally traverse through the Pentland Firth or Fair Isle Channel between the Orkney and Shetland Islands; thus the main shipping routes in the North Sea are predominantly well to the south-west of the Brent Field. Shipping to or from northern Norway, Russia or traffic from Denmark to the Faeroe Islands or vice versa, has the potential to transit closer to the Brent facilities. However, studies estimate the shipping density around the Brent Field to be "Low" in Block 211/29 and surrounding blocks, and assumes that due to the close proximity of other major offshore oil and gas developments, the majority of vessels in the area are likely to be oil and gas support vessels.

Offshore Transit Route and Transfer Location

Some of the Brent facilities will be transported from the Brent Field by SLV to a transfer location 5.5 nautical miles (10 km) from the mouth of the River Tees, off the north-east coast of England where they will be transferred to a cargo barge, and subsequently towed to shore. The proposed route will pass by twelve marine conservation areas and directly through one conservation area, the North East of Farnes Deep Marine Conservation Zone (MCZ), a large area of sub-tidal sand, sediment and mud which is home to a varied seabed ecosystem.

Common seals and grey seals, both listed in Annex II of the EU Habitats Directive, are found in the area (and at the Teesmouth Natural Nature Reserve, adjacent to the ASP facility as discussed below). The average density of seals within a 40 km radius of the ASP facility has been recorded as less than one individual common seal per km^2 and less than five individual grey seals per km^2. The marine operations will take place in a period associated with common seal pupping, and seal

individuals in search of food may be encountered at the transfer location. Dolphins, porpoises and whales have also been observed within a 40 km radius of the proposed transfer location.

The density of shipping traffic along the length of the offshore transit route is highest close to the proposed nearshore transfer location, due to oil and gas support vessels and vessels servicing the Teesside ports and harbours.

The seabed sediments around the transfer location are primarily medium to fine sands or slightly muddy sands. The marine environment from the transfer location to the Tees Estuary at the onshore dismantling location is characterised by a broad range of biological communities including mussel beds, kelp and seaweeds.

Nearshore and Onshore Environment

The ASP facility, located on the north-east coast of England, will be used for the onshore dismantling of the Brent A, B and D topsides and the Brent A upper jacket. The nearest residential property is approximately 1.7 km away, and the site is close to several locally, nationally or internationally significant coastal and onshore conservation areas. These include, but are not limited to, the following:

Table 0-1: Nearshore and Onshore conservation areas close to the ASP Facility

Site Name	Environmental Significance
Seal Sands Site of Special Scientific Interest (SSSI)	Intertidal mudflats. Supports a large population of migratory wildfowl, especially during the winter months.
Tees and Hartlepool Foreshore and Wetlands SSSI	Coastal environment including wetlands, estuarine and maritime sites. Supports internationally significant population of waterfowl and wading birds.
Teesmouth and Cleveland Coast Ramsar Site and Special Protection Area (SPA)	Range of coast habitats. Provides feeding and roosting grounds for internationally significant population of waterfowl.
Teesmouth National Nature Reserve	Comprises dunes, grazing marsh and intertidal mudflats. Supports various bird species. Haul out site for common and grey seals, listed in Annex II of EU Habitats Directive. The only regular breeding colony of common seals on the north-east coast of England.

0.4 Decommissioning Options

Shell examined a number of potential decommissioning options for the Brent Field facilities. The technically feasible decommissioning options included within the scope are listed in Table 0-2 and are described and assessed in this ES.

Table 0-2: Technically Feasible Decommissioning Options for Brent Field Facilities

Facility	Decommissioning Options
Brent A, B, C, D Topsides	Option 1: Complete removal using Single Lift Vessel (SLV)
Brent A upper jacket	Option 1: Removal to approximately -84.5 m below sea level using SLV
Brent A Jacket (footings)	Option 1: Complete removal by SSCV in several pieces, after cutting piles externally Option 2: Complete removal by SSCV in several pieces, after cutting piles internally Option 3: Leave *in situ*
Brent B, C, D GBS	Option 1: Partial removal of legs to -55 m below sea level Option 2: Leave *in situ*
GBS Cell Contents	Option 1: Recover and re-inject into a new remote well Option 2: Recover to shore for treatment Option 3: Leave *in situ* and cap using a mixture of sand and/or gravel Option 4: Leave *in situ* and treat with Monitored Natural Attenuation (MNA) Option 5: Leave *in situ*
GBS Drilling Leg Material	Option 1: Recover and re-inject into a new remote well Option 2: Recover to shore for treatment Option 3: Leave *in situ* and cap Option 4: Leave *in situ* and treat with Monitored Natural Attenuation (MNA) Option 5: Leave *in situ*
GBS Minicell Annulus Material	Option 1: Recover and re-inject into a new remote well Option 2: Recover to shore for treatment Option 3: Leave *in situ* and cap Option 4: Leave *in situ* and treat with Monitored Natural Attenuation (MNA) Option 5: Leave *in situ*
Seabed Drill Cuttings	Option 1: Leave *in situ* for natural degradation
Brent A Seabed Drill Cuttings (only applicable for complete removal of jacket)	Option 1: Dredge, transfer to Brent C topsides, treat and discharge water and solids to sea Option 2. Dredge, transfer to vessel and transport to shore for treatment and disposal Option 3. Dredge, transfer to Brent C topsides, treat & discharge water to sea, solids to shore Option 4. Dredge to vessel and re-inject into a new remote well
GBS Cell Top Drill Cuttings	Option 1: Relocate small amounts by water jetting into the water column Option 2: Dredge, transfer to Brent C topsides, treat and discharge water and solids to sea Option 3: Dredge, transfer to vessel and transport to shore for treatment and disposal Option 4: Dredge, transfer to Brent C topsides; treat & discharge water to sea, solids to shore Option 5: Dredge to vessel and re-inject into a new remote well Option 6: Leave *in situ*
GBS Tri-cell Drill Cuttings (Brent B/ D)	Option 1: Leave *in situ*
Pipelines	Combinations of: • Leave on seabed with or without remediation • Partial or whole trenching of line • Rock dumping of partial or whole section of line • Complete removal and recycle/disposal onshore
Subsea Structures & Debris	Option 1: Complete removal to shore
Subsea Wells	Option 1: Plugging and abandonment of all 146 wells

0.5 EIA Approach

The EIA process has been carried out in two stages: scoping and impact assessment. Environmental scoping identified the potentially significant impacts as a result of the BDP and a Scoping Report was made publicly available in 2011. The scoping exercise provided input to the environmental assessment stage.

The environmental and socioeconomic impact categories evaluated for each decommissioning option in this ES are:

- Onshore Impacts
- Resource Use
- Hazardous Substances
- Waste
- Physical
- Marine and Underwater Noise
- Environmental Risk
- Employment
- Legacy
- Fisheries
- Shipping
- Energy and Emissions

DNV GL's impact assessment is based on an evaluation of:

1. the sensitivity of the receiving environment
2. the scale of effect of the decommissioning activity upon the receiving environment

By combining 1 and 2 in an impact matrix, the overall significance of the impact is predicted.

The assessment generated a large number of impact assessment matrices, which are presented in an appendix to this report. The results of the impact assessment are discussed and summarised in this Environmental Statement.

0.6 Main Impacts from Decommissioning

The main impacts identified are briefly discussed below. Industry standard mitigation and management measures as identified in the report have been taken into account when assessing impacts. Only those impacts considered to be 'small-moderate negative' or worse or 'small moderate positive' or better, are listed in the following tables.

0.6.1 Topsides

As the topsides are required to be removed under OSPAR Decision 98/3, only one decommissioning option is considered, complete removal. Approximately 76,700 tonnes of carbon steel from the four topsides will be brought to shore sequentially and recycled over a period of approximately eight years. The impacts summarised below concern the total impacts that would occur assuming that all four topsides will be decommissioned at the ASP facility, although the contractual details surrounding the dismantling of the Brent C platform are still being finalised (it is anticipated they will follow a similar process to the other Brent topsides).

Option 1: Complete removal

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative onshore impacts as a result of potential dust, noise, visual impact and increased traffic.	Moderate positive impact of recycling 76,700 tonnes of carbon steel.
Moderate negative impact from Energy and Emissions primarily due to offshore marine operations and onshore recycling.	Small-moderate positive employment benefits from offshore and onshore activities

Main negative impacts (small-moderate or worse)	Main positive impacts (small-moderate or better)
Small-moderate negative impact from the large volume of hazardous wastes generated (although there will be no hazardous wastes generated for which the waste management expertise does not already exist).	

0.6.2 Brent A Jacket

Shell has committed to removing the upper jacket in one piece using SLV to approximately -84.5 m below LAT. There are three options for the decommissioning of the jacket footings:

- Option 1: Complete removal by SSCV in several pieces, by digging pits in the seabed to allow the steel piles to be cut *externally* at 3 m below the seabed
- Option 2: Complete removal by SSCV in several pieces, by drilling out the grout in the steel piles so that a machine can be inserted into each pile to cut the pile *internally*
- Option 3: Leave *in situ*

The estimated impacts of decommissioning the Brent A jacket are as follows:

Removal of upper jacket

Main negative impacts (small-moderate or worse)	Main positive impacts (small-moderate or better)
	Small-moderate positive impact of recycling 8,400 tonnes of steel.

Jacket footings Option 1: Complete removal (external cutting of piles)

Main negative impacts (small-moderate or worse)	Main positive impacts (small-moderate or better)
Small-moderate negative onshore impact owing to the significant volumes of material brought onshore that would require handling, deconstruction and transportation.	Small-moderate positive impact of recycling 14,850 tonnes of steel.
Small-moderate negative impact to the marine environment as a result of the excavation of the seabed in order to remove the jacket legs, causing turbulence and potential smothering of organisms. *	

*The effect of removing the drill cutting pile (and any contaminated seabed sediment) at Brent A is covered under 'drill cuttings', so only the excavation of the clean seabed sediment is assessed here. It should be noted that the two impacts will overlap.

Jacket footings Option 2: Complete removal (internal cutting of piles)

Main negative impacts (small-moderate or worse)	Main positive impacts (small-moderate or better)
Small-moderate negative onshore impacts owing to the significant volumes of material brought onshore that would require handling, deconstruction and transportation.	Small-moderate positive impact of recycling 14,850 tonnes of steel.

Jacket footings Option 3: Leave *in situ*

All impacts are estimated to be small or insignificant however further detail is given below.

Comparison of Options

The Brent A upper jacket will be removed, but there are three options for decommissioning the Brent A jacket footings; the differences between the options are summarised below.

Removing the jacket footings under Option 1 would involve significant disturbance of the surrounding drill cuttings and seabed sediment, and would impact the marine environment. As the jacket footings would be removed internally under Option 2, this option is preferable to Option 1 from an environmental perspective because there is significantly less impact to the marine environment. All other impacts would be similar for Options 1 and 2. All impacts for Option 3 (leave *in situ*) would be small or insignificant. However, Option 3 would have no positive impact from the recycling of steel like Options 1 and 2.

Although only considered to have a 'small negative' impact, and hence not included in the table above, one of the main differences between the three options relates to the legacy of leaving behind the Brent A jacket footings in Option 3. This would restrict fishermen for hundreds of years from being able to trawl over the area. It is estimated to be only a small negative impact as there is only one jacket, so the area involved is relatively small, and the Brent Field has a low commercial fishing value. Also, leaving the jacket footings *in situ* would have an environmental benefit as there would be no need to disturb the Brent A seabed drill cuttings. Note that there will be cumulative legacy impacts when considering the jacket in conjunction with GBS.

0.6.3 Gravity Based Structures (GBS)

Two options are considered for the decommissioning of each of the three GBS:

- Partial removal to approximately -55 m below sea level to meet International Maritime Organisation (IMO) requirements (Option 1). This would involve removing the GBS legs, generating approximately 37,917 tonnes of concrete and 9,382 tonnes of reinforced steel in total. The bulk of the GBS would be left *in situ.* The cut leg sections would be brought to shore.
- Leave GBS *in situ* with legs intact (Option 2)

A third option, complete removal by refloat, was examined by Shell in detail but was not found to be technically feasible. Shell concluded that it would take years of work before a refloat could be attempted, however given the technical and safety risks even then it could not be guaranteed that the work could be completed safely and successfully.

The estimated impacts of decommissioning the GBS are as follows:

Option 1: Partial removal of GBS legs

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Moderate negative legacy impact from leaving the three GBS *in situ* due to a combination of long-term legacy impacts to fisheries, the marine environment and shipping.	
Moderate negative onshore impacts as a result of dust, noise, visual impacts and increased traffic from processing recovered materials onshore.	
Small-moderate risk of accidents to the environment, because the offshore removal operations are not straightforward and involve new technologies.	
Large negative impact from Energy and Emissions primarily owing to the large quantities of steel and concrete that are left *in situ*, which incur an energy / CO_2 penalty. Additionally, there is significant energy use due to marine operations.	

Option 2: Leave GBS *in situ*

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Moderate negative legacy impact from leaving the three GBS *in situ* due to a combination of legacy impacts to fisheries, the marine environment and to shipping, including environmental risk from ship collision.	
Large negative impact from Energy and Emissions primarily owing to the large quantities of steel and concrete that are left *in situ*, which incur an energy / CO_2 penalty.	

Comparison of Options

There are some differences between the two decommissioning options for the GBS. Option 1 would involve intervention to partially remove the GBS legs and transport 37,917 tonnes of concrete and 9,382 tonnes of steel to shore, with associated negative onshore impacts, large energy consumption and increased risk of environmental accidents. Option 2 would involve leaving the GBS *in situ*, and would result in moderate negative legacy impacts to shipping, the marine environment and fisheries for hundreds of years. But Option 1 would also present very similar legacy impacts for hundreds of years, as ships would still be unable to pass over the partially removed GBS, because Shell would apply for a continuation of the safety zone to protect fishermen (assuming full compliance with the safety zone).

The main environmental benefit Option 1 has over Option 2 is that removing the GBS legs would mean removing a source of falling debris that could impact the GBS caisson and storage cells. Thus the integrity of the caisson and GBS cells would last longer [83], but for both options the cell contents would still ultimately be released to the marine environment.

In summary, removing the GBS legs would appear to come at a cost to the environment, with increased energy use and onshore nuisance, for limited environmental benefit. Although Option 2 would still present a risk of ship collision with the GBS legs which could potentially result in significant environmental consequences (e.g. due to oil spill), studies suggest that such a major collision is very unlikely with the safety zone (and other mitigation measures) in place, hence the associated environmental risk is small.

0.6.4 GBS Attic Oil

There is only one option for the attic oil and that is to remove it. The estimated impacts are as follows (there are no negative impacts greater than small):

Option 1: Recover attic oil

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
	This option involves recovering approximately 12-14,000 m^3 of attic oil and interphase material from Brent B and D, which will have a beneficial effect as the waste oil will be brought to shore, treated and reused. A small-moderate positive impact is allocated as the oil has volume and value.

0.6.5 GBS Cell Contents

For all options, attic oil and interphase material will be recovered. Five options are considered for the management of the cell contents within the three GBS:

- Option 1: Mobilise to vessel and re-inject into new remote subsea wells
- Option 2: Mobilise and retrieve to vessel, transport to shore for treatment
- Option 3: Cap or Cover *in situ* in the cells using (e.g.) mixture of sand and/or gravel
- Option 4: Leave *in situ* in the cells and treat with MNA
- Option 5: Leave *in situ* in the cells

The estimated impacts of decommissioning the GBS cell contents are as follows:

Option 1: Recover and re-inject

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate physical impact on seabed from vessel anchor pits, drill rig mooring, and drilling activities	Moderate positive employment benefits mainly from offshore activities.
Large negative impact from Energy and Emissions primarily owing to energy use during marine operations.	

Option 2: Recover to shore

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative onshore impacts as a result of dust, noise and increased traffic from processing ~600,000 m^3 of slurry from all three GBS onshore (the cell sediment would be fluidized and hence contain a large quantity of water as well as sediment) plus similar volumes of cell water.	Small-moderate positive employment benefits from offshore and onshore activities
Small-moderate negative waste impacts from treating and disposing of ~600,000 m^3 of slurry from all three GBS plus similar volumes of cell water. Uncertainty over the disposal of dewatered sludge, as natural radioactivity content is currently unknown.	
Moderate negative impact from Energy and Emissions primarily owing to energy use during marine operations and onshore operations.	

Option 3: Leave *in situ* and cap

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative legacy impact on the marine environment based on the analytical results (moderate negative based on the modelling results using pre-cell sampling CSP data). Impacts are expected to be a little lower than Options 4 and 5, because the cell sediment (where most of the contaminant load exists) would be capped, and this cap would provide a further barrier between the sediment and the marine environment when the GBS degrades in the future, thus delaying the release of the cell contents. There are however some uncertainties about the cap effectiveness.	
Moderate negative impact from Energy and Emissions primarily owing to energy use during marine operations.	

Option 4: Leave *in situ* with MNA

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative legacy impact on the marine environment based on the analytical results (moderate negative based on the modelling results using pre-cell sampling CSP data). Impacts are a little lower than Option 5, because nutrients would be introduced into the GBS cells to assist the degradation of contaminants. Hence when the GBS degrade in the future there should be less organic polluting load exposed to the local	

Main negative impacts (small-moderate or worse)	Main positive impacts (small-moderate or better)
environment. However, while the nutrients would be effective to the water phase, they would be less so to the sediment phase because nutrients would only penetrate the sediment to several centimeter's depth, and the sediment, approximately 4 m deep, carries the bulk of the pollutant load.	
Moderate negative impact from Energy and Emissions primarily owing to energy use during marine operations.	

Option 5: Leave *in situ*

Main negative impacts (small-moderate or worse)	Main positive impacts (small-moderate or better)
Small-moderate negative legacy impact on the marine environment based on the analytical results (moderate negative based on the modelling results using pre-cell sampling CSP data). The cell contents would be left *in situ* and there would be no attempt to aid degradation of contaminants or cover the cell sediment. When the GBS degrade in the future, the cell contents would be exposed to the marine environment, and would pollute the local environment (~0.05 km^2 based on analytical results and *static* release) around each platform. Modelling shows that a *dynamic* release of 3,650 m^3 of the cell sediment over a one year period would lead to a larger area of contamination on the seafloor compared to a static release. However, the vast majority of this area would have a sediment thickness of less than 1 mm with a pollution concentration exceeding potential harmful limits. Because of bioturbation mixing, the contaminated sediment would quickly be diluted in the upper part of the seafloor sediment and hence not have any harmful impact on biota. The seafloor with >10 mm contaminated sediment and PEC:PNEC>1 is expected to cause harmful effects on the biota. Dynamic modelling results show that 0.06 km^2 seafloor would have such conditions. This is close to the 0.05 km^2 footprint with potential harmful effects that was derived from the updated static modelling.	

Comparison of Decommissioning Options for Cell Contents

Options 3, 4 and 5 would have negative legacy impacts relating to exposure of the cell contents (in the distant future after degradation of the GBS) and the associated impact on the marine environment ('small-moderate negative' of varying degrees for all three options based on analytical results, 'moderate negative' based on modelling results using pre-cell sampling CSP data). Options 1 and 2 would have a significantly reduced legacy impact because of the removal of the cell contents, but both would involve energy and emissions as a result of activities to retrieve and manage the cell contents, and Option 1 would require a drilling rig for the drilling of new wells. Option 2 would have small-moderate waste management and onshore impacts as a result of the quantities of slurry and wastewater that are brought to shore. Option 1 would have some small-moderate negative physical impacts on the seafloor because of drilling new wells, and due to anchoring and mooring. Conversely there would be a small-moderate positive impact on employment for both Options 1 and 2.

In summary, there would be a fundamental difference between impacts for:

- Options 1 and 2 where activities to remove the cell sediment and hence its legacy impact may result in impacts in other environmental categories (such as energy and emissions), and
- Options 3, 4, 5 where the cell sediment would be left in place (the most significant issue being a negative legacy impact to the marine environment as a result of the localised pollution caused when the cell contents are exposed to the marine environment).

Many of the impacts from Options 1 and 2 occur in different environmental media, take place in different time periods and in some cases different locations than the impacts from Options 3, 4 and 5. In such instances, different stakeholder may take different views about which are more significant.

0.6.6 Material in Drilling Legs and Minicell Annulus

For the materials present within GBS Brent B and D drilling legs and the minicells annulus, 5 decommissioning options are considered:

- Option 1: Mobilise and re-inject in a new remote subsea well away from site
- Option 2: Mobilise and retrieve to vessel and dispose onshore
- Option 3: Cap or cover *in situ* using sand and coarse gravel
- Option 4: Leave *in situ* and improve natural biodegradation by adding chemicals (Monitored Natural Attenuation, MNA)
- Option 5: Leave *in situ* for natural biodegradation

The estimated impacts of decommissioning the GBS drilling leg and minicell annulus material are as follows:

GBS drilling legs Option 1: Mobilise and re-inject

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Moderate negative impact from Energy and Emissions primarily owing to energy use during marine operations.	Small-moderate positive employment benefits mainly from offshore activities.

Except for the impacts listed above for drilling legs Option 1, all impacts are estimated to be small or insignificant for all of the remaining decommissioning options for the drilling legs and minicell annulus. This is because the combined oil load (approximately 66 t) contained within them is only a fraction (less than 1%) of that in the GBS cell sediment. Although there are some fundamental differences between impacts for Options 1 and 2 (remove the material) and Options 3, 4, 5 (leave *in situ*), because the impacts are generally small or insignificant, thus there is little to distinguish between the environmental impact of these decommissioning options.

0.6.7 Drill Cuttings

The options considered in this ES for the decommissioning of the drill cuttings on the seabed, cell tops and in the GBS tri-cells are as follows:

Undisturbed Seabed Drill Cuttings Option 1: Leave *in situ*

Approximately 20,900 m^3 of seabed drill cuttings are present at the Brent Field including Brent South. It is intended to leave these cuttings in place as they fall below the OSPAR Recommendation 2006/5 thresholds. However, if the Brent A jacket footings are fully removed by cutting them externally, the drill cuttings at Brent A will need to be disturbed, therefore four management options for the seabed drill cuttings at Brent A (summarised below) are assessed in this EIA.

Seabed Drill Cuttings at Brent A

Four options are considered for the decommissioning of the drill cuttings on the seabed surrounding the Brent A jacket (see above). These operations will only take place if the jacket

footings are completely removed and are cut externally (Brent A Jacket Footings Option 1), to enable Shell to access and cut the jacket piles.

- Option 1 Complete removal: Dredge, transfer to Brent C topsides and treat and discharge water and solids to sea
- Option 2 Complete removal: Dredge, transfer to vessel and transport slurry to shore for treatment and disposal
- Option 3 Complete removal: Dredge, transfer to Brent C topsides; water treated and discharged to sea, solids to shore
- Option 4 Complete removal: Dredge to vessel and re-inject into a new remote subsea well

Cell Top Drill Cuttings

Updated modelling indicates that the persistence of all of the cell top drill cuttings was far below the OSPAR Recommendation 2006/5 threshold (500 km^2years), but that the Brent C cell top drill cuttings exceed the 10 tonne/year OSPAR Recommendation 2006/5 threshold. As the cell top drill cuttings at Brent B and D have significantly less volume and cover much smaller areas, it is likely that they meet OSPAR thresholds.

Six options are considered for the decommissioning of the drill cuttings on the GBS cell tops, so that access is gained to facilitate management of the cell contents:

- Option 1 Partial removal: Re-locate small amounts locally by water jetting into water column (approximately 60 m^3 in total)
- Option 2 Complete removal: Dredge, transfer to Brent C topsides and treat and discharge water and solids to sea (up to 13,400 m^3)
- Option 3 Complete removal: Dredge, transfer to vessel and transport slurry to shore for treatment and disposal (up to 13,400 m^3)
- Option 4 Complete removal: Dredge, transfer to Brent C topsides; water treated and discharged to sea, solids to shore (up to 13,400 m^3)
- Option 5 Complete removal: Dredge to vessel and re-inject into a new well (up to 13,400 m^3)
- Option 6 Leave Brent C cuttings *in situ* for natural degradation.

Tri-cell Drill Cuttings Option 1: Leave *in situ*

Approximately 26,800 m^3 of drill cuttings may be present inside the Brent B and D GBS tri-cells. These drill cuttings were created during the same drilling operations as the drill cuttings forming the seabed and cell top cuttings piles, and are contaminated by OBM and WBM. As such, Shell considers that any tri-cell drill cuttings should also be assessed under OSPAR Recommendation 2006/5. None of the decommissioning options being assessed will disturb the tri-cell drill cuttings and Shell believes the Brent B and D tri-cell cuttings fall below the oil loss and area persistence thresholds in OSPAR Recommendation 2006/5 just like Brent B and D seabed and cell top drill cuttings; Shell therefore proposes to leave any GBS tri-cell drill cuttings *in situ* for natural degradation.

The estimated impacts of decommissioning the drill cuttings on the seabed, GBS cell tops and in the GBS tri-cells are as follows:

Drill Cuttings – Seabed Option 1: Leave *in situ*

Shell's calculations and modelling studies of the seabed drill cuttings estimate that the seabed cutting piles at each of the five platforms (including Brent South) fall below both OSPAR 2006/5 thresholds; therefore only small localised impacts are expected from leaving the piles *in situ*.

Brent A Seabed Drill Cuttings – Option 1: Dredge, transfer to Brent C topsides and treat and discharge water and solids to sea

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative marine impacts due to exposure of receptors to suspended solids and associated toxic substances as a result of dredging drill cuttings and return of cleaned solids to sea.	

Brent A Seabed Drill Cuttings – Option 2: Dredge, transfer to vessel and transport slurry to shore for treatment and disposal

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative marine impacts due to exposure of receptors to suspended solids and associated toxic substances as a result of dredging drill cuttings.	
Small-moderate negative onshore impacts as a result of dust, noise and increased traffic from processing 80,000 m^3 of slurry onshore.	

Brent A Seabed Drill Cuttings – Option 3: Dredge, transfer to Brent C topsides; water treated and discharged to sea, solids to shore

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative marine impacts due to exposure of receptors to suspended solids and associated toxic substances as a result of dredging drill cuttings.	
Small-moderate negative onshore impacts as a result of dust, noise and increased traffic from processing dewatered slurry onshore. Slightly less impact than Option 2.	

Brent A Seabed Drill Cuttings – Option 4: Dredge to vessel and re-inject into a new well

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative marine impacts due to exposure of receptors to suspended solids and associated toxic substances as a result of dredging drill cuttings. Additional marine impact owing to drilling of a new well.	

Cell Top Drill Cuttings - Option 1: Re-locate small amounts locally by water jetting into water column

All impacts are estimated to be small or insignificant.

Cell Top Drill Cuttings - Option 2: Dredge, transfer to Brent C topsides and treat and discharge water and solids to sea

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative marine impacts due to dredging and the resulting exposure of receptors to suspended solids and associated toxic substances.	

Cell Top Drill Cuttings - Option 3: Dredge, transfer to vessel and transport slurry to shore for treatment and disposal

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative onshore impacts as a result of potential dust, noise and increased traffic from processing 130,000 m^3 dredged slurry onshore.	
Small-moderate negative marine impacts due to dredging and the resulting exposure of receptors to suspended solids and associated toxic substances.	

Cell Top Drill Cuttings – Option 4: Dredge, transfer to Brent C topsides; water treated and discharged to sea, solids to shore

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative onshore impacts as a result of potential dust, noise and increased traffic from processing the dewatered dredged slurry onshore.	
Small-moderate negative marine impacts due to dredging and the resulting exposure of receptors to suspended solids and associated toxic substances.	

Cell Top Drill Cuttings – Option 5: Dredge to vessel and re-inject into a new well

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative marine impacts due to dredging and the resulting exposure of receptors to suspended solids and associated toxic substances. Additional marine impact owing to drilling of a new well.	

Cell Top Drill Cuttings – Option 6: Leave *in situ*

All impacts are estimated to be small or insignificant.

Tri-cell Drill Cuttings - Option 1: Leave *in situ*

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
On degradation of the GBS and subsequent exposure of the tri-cell drill cuttings to the marine environment, similar localised pollution (~0.05 km^2) is expected to that of the exposure of the GBS cell sediment to the marine environment (based on cell sediment analytical results). A small-moderate negative legacy impact to the marine environment is estimated when the GBS degrade in the future, as the volume of tri-cells is substantial and they contain oil. Their release will not induce any measurable effects on the regional level, but when they are exposed to the marine environment on degradation of the GBS, they will pollute the local environment and add to the area persistence. Modelling shows that a dynamic release of 3,650 m^3 of sediment over a one year period will lead to a larger area of contamination on the seafloor compared to a static release. However, the vast majority of this area will have a sediment thickness of less than 1 mm with a pollution concentration exceeding potential harmful limits. Because of bioturbation mixing, the contaminated sediment will quickly be diluted in the upper part of the seafloor sediment and hence not have any harmful impact on biota. The seafloor with >10 mm contaminated sediment and PEC:PNEC>1 is expected to cause harmful effects on the biota. Dynamic modelling results show that 0.06 km^2 seafloor will have such conditions. This is close to the 0.05 km^2 footprint with potential harmful effects that was derived from the updated static modelling.	

Comparison of Decommissioning Options for Drill Cuttings

Shell has demonstrated by calculation and by modelling that the seabed cuttings piles presently fall below both of the thresholds in OSPAR Recommendation 2006/5. It is therefore likely that the long-term presence of these piles would have no significant impacts.

The four options to decommission the seabed drill cuttings at Brent A (if the jacket footings were to be completely removed) would all have similar impacts (‘small-moderate negative’) on the marine environment in the short-term; the impacts would be similar because the volumes of drill cuttings released into the marine environment are similar in all options. Two of the decommissioning options also have potential for onshore impact.

Options 2-5 to decommission the cell top drill cuttings would all have similar impacts (‘small-moderate negative’) on the marine environment in the short-term, because the volumes of drill cuttings dredged are the same (two of these four decommissioning options also have potential for some onshore impact). Options 2-5 would impact local benthic fauna (such as tube worms) that would take some years to recover, but the Brent Field does not contain any unique species, or species of particular conservation interest. Water jetting under Option 1 would have less potential for impact to the marine environment, but this is only because Option 1 involves disturbing a much smaller volume of drill cuttings than Options 2-5. Under Option 6, Brent C cell top cuttings would be left in place for natural degradation, and the environmental impact is evaluated to be ‘small negative’ because the environmental impact is currently local (even though the Brent C cell top cuttings initial yearly loss of oil exceeds the OSPAR recommendation threshold) and this condition is likely to proceed as long as the cuttings are left undisturbed. The cell top drill cuttings at Brent B and D are considered to meet OSPAR thresholds.

Only one option for tri-cell drill cuttings is considered, leave *in situ*, and it is estimated to have a small-moderate negative legacy impact on the marine environment when the GBS degrade in the future.

0.6.8 Pipelines

A total of 28 subsea pipelines are included in the scope of the BDP and will be decommissioned at the end of field life. Shell divided the pipelines into two groups:

- Group 1 Pipelines comprise 14 pipelines, umbilicals and power cables which are 14" or less in diameter, are trenched or surface-laid and exposed on the seabed. For these pipelines there are indications from the DECC Guidance Notes what the accepted decommissioning option should be, and Shell conducted a qualitative assessment to determine the recommended decommissioning option. The impacts of this decommissioning option are assessed in this ES.
- Group 2 Pipelines comprise 14 pipelines larger than 16" in diameter, made of steel, with or without concrete coating, and may be partially rock dumped. There are a number of feasible decommissioning options, and the impacts of each feasible option are assessed in this ES. The results are used by Shell as part of a Comparative Assessment as required by BEIS.

Concrete mattresses are also present at a number of the exposed pipelines to protect them from, for example, fishing trawlers.

Group 1 Pipelines

All impacts are estimated to be small or insignificant.

Group 2 Pipelines

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
When each individual pipeline is considered in isolation, there are a few impacts identified that are greater than small. Most of the larger impacts relate to operations involving pipeline N0501, the largest pipe at 35.9 km long, with onshore and waste management impacts (when N0501 is removed), and marine and/or resource use and/or legacy impacts (when N0501 is trenched, rock dumped or left *in situ*). There are also legacy, resource use and/or marine impacts for other pipes for options involving significant rock dump, a lot of trenching, or that leave pipes *in situ* with little intervention, thus presenting risks to fishing vessels. The options which involve a lot of rock dumping can result in negative marine impacts due to benthic burial and smothering, and legacy impacts to the marine environment due to habitat change, and resource consumption (rock dump). Localised marine impacts are expected where there is significant trenching of pipelines. Removing long sections of pipeline and taking them to shore also has potential hazardous waste management impacts because the presence of mercury and naturally radioactive material in pipelines cannot be discounted (it is difficult to measure before production ceases and pipelines can be physically cut open; if these materials are found to be present they will require strict management).	

0.6.9 Subsea Structures and Debris

As the removal of subsea structures is required under OSPAR Decision 98/3, and the removal of debris required by BEIS, removal is the only decommissioning option considered. Based on subsea survey data, approximately 950 tonnes of steel and 500 tonnes of concrete will be recovered and brought to shore. The steel and concrete will be recycled where possible.

Option 1 – Complete removal

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative effects on the benthic marine environment and marine sediments as the removal of subsea structures and debris causes disturbance of drill cuttings and contaminated sediment. It will only be a localised impact and temporary in character, but will occur in a number of locations.	

0.6.10 Wells

There is only one decommissioning option for wells, plugging and abandonment. An estimated 40,000 tonnes of steel will be recovered and brought to shore from the 146 Brent Field wells, together with oily well fluids. The steel will be recycled where possible.

Option 1: Plugging and Abandonment of Wells

Main negative impacts (small-moderate or worse)	*Main positive impacts (small-moderate or better)*
Small-moderate negative onshore impacts as a result of potential dust, noise and increased traffic from processing 40,000 t of steel and oily well fluids from the plugging and abandonment of the 146 wells.	Moderate positive employment benefits from offshore and onshore decommissioning activities over a period of years.
Large negative impact from Energy and Emissions primarily owing to the energy required offshore to plug and abandon the wells over approximately a decade.	Small-moderate positive waste impact, primarily from recycling 40,000 t steel.

0.7 Cumulative Decommissioning Impacts

The cumulative impacts of decommissioning the Brent Field facilities are assessed on the basis of Shell's proposed programme of work as presented below:

- Remove all four topsides
- Remove the Brent A upper jacket to -84.5 m below LAT
- Leave Brent A jacket footings *in situ*
- Leave all three GBS *in situ* with legs up
- Remove all attic oil in GBS structures
- Leave cell water and cell sediment *in situ* in GBS cells, untreated and uncapped
- Leave material in GBS drilling legs and GBS minicells *in situ*, untreated and uncapped
- Leave seabed drill cuttings *in situ*
- Leave cell top drill cuttings *in situ* (although it is possible that some drill cuttings may have to be disturbed to create new access holes to the cells, to enable attic oil removal)
- Leave tri-cell drill cuttings *in situ*
- Pipelines – approximately 89 km of pipelines will be (or currently are) trenched, 13.5 km will be removed, and 61% of the 1,760 t of concrete mattresses will be removed.
- Remove subsea structures and debris
- Permanent plugging and abandonment of all 146 wells.

The main environmental impacts of Shell's proposed decommissioning programmes are summarised in
Table **0-3**. Only those impacts which are estimated to be 'small-moderate negative' or worse, or 'small-moderate positive' or better, are shown. The assessments have been made on the basis that the mitigation measures detailed in the report are in place.

Table 0-3: Main Impacts of Proposed Programme of Work

Proposed Decommissioning Programme	Main negative impacts	Main positive impacts
Remove all four topsides	Onshore (S/M) Hazardous Substances (S/M) Energy and Emissions (M)	Waste (M) Employment (S/M)
Remove Brent A upper jacket (-84.5 m)		Waste (S/M)
Leave Brent A jacket footings *in situ*		
Leave all three GBS *in situ* with legs up	Legacy (M) Energy and Emissions (L)	
Remove GBS attic oil		Waste (S/M)
Cell water/sediment left *in situ* in the GBS	Legacy (S/M)	
Leave material in GBS drilling legs/minicells *in situ*		
Leave seabed drill cuttings *in situ*		
Displace some cell top drill cuttings to access cells to remove attic oil	Onshore (S/M)* Marine (S/M) *	
Leave tri-cell drill cuttings *in situ*	Legacy (S/M)	
Pipelines – trench/remove/leave *in situ*	Marine (M) Legacy (S/M) Energy and emissions (M) Resource use (S/M)	
Remove subsea structures and debris	Marine (S/M)	
Plug and abandon all 146 wells	Onshore (S/M) Energy and Emissions (L)	Waste (S/M) Employment (M)

L = Large; M = moderate; S/M = Small-moderate.

*Brent C only (table shows impacts assuming disturbance is required, as this has the bigger environmental impact)

Legacy impacts and energy and emissions are prominent for the proposed decommissioning programme. Therefore, an important consideration will be the potential for cumulative impacts in these areas, and these are discussed below. Other cumulative impacts are discussed within the body of the report.

0.7.1 Cumulative Legacy Impacts

The following Brent Field facilities would be left *in situ* under Shell's proposed decommissioning programme:

- Brent A jacket footings
- 3 GBS with legs up
- GBS cell contents
- GBS drilling legs material and GBS minicells material
- Drill cuttings: Seabed, Cell tops, Tri-cells
- Pipelines - approximately 89 km of pipelines will be (or are already) trenched (13.9 km will be removed). Approximately 39% of the concrete mattresses will be left *in situ*.

Legacy impacts have potential for cumulative impacts to the marine environment, shipping and fisheries, and these are considered in turn below. Table 0-4 illustrates which legacy sub-category is impacted by which facility, and highlights how the marine environment has the most potential to be subjected to cumulative impact.

Table 0-4: Facilities with Legacy Impacts

Facility left *in situ*	Size of negative legacy impact	Legacy-impact to marine environment	Legacy- impact to fisheries	Legacy-impact to shipping
GBS	Moderate	Yes	Yes	Yes
Pipelines	Moderate	Yes	Yes	-
Cell contents	Small-moderate	Yes	-	-
Tri-cells	Small-moderate	Yes	-	-
Jacket footings	Small	Yes	Yes	-
Drilling leg/Minicell	Small	Yes	-	-
Drill cuttings: seabed and celltops	Small	Yes	-	-
Wells	Insig-small	Yes	-	-

Legacy – shipping

Due to the requirement to maintain the current 500 m safety zones during and following decommissioning, the GBS will continue to have an impact upon shipping, just as they currently do, with large vessels restricted from passage in this small area for several hundred years. The 500 m safety zones are required to remain in place until the structure no longer projects above the surface of the sea. Then Shell will apply to the regulator for a continuance of the 500 m safety zone; its extended existence will mean ships will continue to be restricted from passage for an indefinite period.

The GBS are the only facility having an impact upon shipping; as such there are no additional cumulative impacts as a result of other facilities left *in situ*.

Legacy - marine environment

Legacy impacts upon the marine environment have been identified individually for:

i. Cell contents
   - ‘Small-moderate negative’ impact to the marine environment upon release of cell contents due to degradation of the GBS.

ii. Drill cuttings
   - ‘Small-moderate negative’ impact to the marine environment upon release of tri-cell drill cuttings due to degradation of the GBS.
   - ‘Small negative’ impact to the marine environment from the drill cuttings if left *in situ* at the seabed and cell tops.

iii. Drilling leg and minicell materials
   - ‘Small negative’ impact to the marine environment due to the exposure of the minicell and drilling leg contents contained within Brent B and D into the water column following degradation of the GBS.

iv. Wells

- ‘Insignificant-small’ negative impact to the marine environment from future seeps, if any, of plugged wells.

v. Jacket Footings

- ‘Small negative’ impact upon the marine environment from the future collapse of the jacket footings.

vi. GBS

- Negative impact to the seabed marine environment due to degradation of three GBS, similar to the localised impact of a large ship wreck on the seafloor.

vii. Pipelines

- ‘Small-moderate negative’ impact owing to approximately 149,000 t of rock dump, which results in habitat change due to the introduction of a hard substrate.

Release of Petroleum Hydrocarbons

Hydrocarbons will be released to the marine environment from items i, ii and iii (and potentially from iv).

Any overlap in the timing of the release of the GBS cell contents, GBS minicell and drilling leg contents, and/or tri-cell drill cuttings is difficult to predict owing to the uncertain nature of the degradation mechanism of the GBS. The degradation has been examined but is not an exact science, and even within an individual GBS, the timing of the release of the above materials is uncertain. It is estimated that the upper GBS leg would remain largely intact for around 150 to 250 years with a steady degradation around water level. Despite significant damage to the cells below due to falling debris (particularly as the GBS ‘legs up’ option was selected for the programme of works), the caisson structure would still likely survive for at least 500 years, after which time loss of containment of the cell contents could occur. It is possible that the GBS cell water and sediments may become partially exposed to the marine environment prior to the tri-cell drill cuttings, which are more protected within the caisson structure.

It should be noted that:

- Although the three GBS will degrade in the same approximate timeframe (in excess of 500 years), there could be decades or even centuries between each GBS being sufficiently degraded for exposure of its contents to the marine environment.
- The distance between the three GBS will limit the potential for contamination overlap. DNV GL’s toxicology study suggests that, based on analytical results, the size of the chemically impacted area (due to static exposure of the cell contents) will be approximately 0.05 km^2 (to a distance of 250 m) at each platform, 1 year after release. The two closest GBS platforms are 2.4 km apart, so there will be no overlap in the impact areas.

But some cumulative legacy impacts to the marine environment will take place, particularly at each GBS due to the combination of the hydrocarbons contained within the cell contents, the minicell and drilling leg contents, and the tri-cells drill cuttings. To help consider the cumulative impact, Table 0-5 estimates the petroleum hydrocarbon loads involved.

Table 0-5: Volumes of Material and Petroleum hydrocarbon loads

	Volume (m^3)	Hydrocarbon load (t)
Cell contents	39,408 (sediment)	11,228*
Tri-cell drill cuttings * **	26,772	4,926**
Drilling leg waste material	4,000	46
Minicell annulus material	500	20

*includes 266 t of oil contained within cell water

**based on maximum concentration

***The seabed and cell top drill cuttings (if left *in situ*) will also, in 500+ years, continue to lose oil to the marine environment; estimated to be less than 10 t (per annum) in total

Approximately 16,000 tonnes of hydrocarbons could therefore become exposed to the marine environment in total for all three GBS. Even though this may not occur for more than 500 years, Shell do not expect significant anoxic biodegradation of the hydrocarbons to have taken place during this period because the sampling exercise indicated a lack of bacteria inside the cells (possibly because all the nutrients and electron acceptor have been consumed).

This is about 2.8 times the quantity of hydrocarbons (5,642 tonnes) estimated to be contained within the seabed and cell top drill cuttings that are currently exposed to the marine environment.

There will be a cumulative legacy impact from the hydrocarbons on the marine environment, and DNV GL considers it to be one of the most important cumulative environmental impacts of the decommissioning programme. The main driver of the impact is the cell contents, as this provides the bulk of the hydrocarbon load, although the tri-cells contribution is also significant, particularly as it is more likely to be released in a dynamic disturbed state and at a higher location than the cell contents. There will be localised pollution to the marine environment around each platform, and although it will naturally degrade over time, this localised pollution will be present for decades, and will affect local benthic fauna. The cumulative contaminated area at Brent B and D has not been modelled but will be similar, but larger, than that predicted in the DNV GL toxicology study for a 'static' cell contents release (0.05 km^2 based on analytical results, to a distance of 250 m), when taking the tri-cells drill cuttings into account. Because the contaminated area will be localised around the platforms, there is not expected to be any measurable effect upon marine or benthic populations/systems. The impact will be smaller at Brent C because the volume of cell contents is smaller and also because there are no tri-cell drill cuttings present.

It is reasonable to assume that a proportion of the hydrocarbons in the GBS may be released in a dynamic disturbed state as a result of GBS degradation (particularly the tri-cells drill cuttings, most of which are located at a higher level than the cell sediment). The likelihood of some disturbed release of material is higher for the 'leave the GBS legs in place' Option 2, where a GBS leg collapse will have more destructive energy to damage the GBS caisson than the GBS legs down option. Although dynamic sediment release scenarios would result in larger areas of the seafloor being contaminated, the vast majority of the area would have a sediment thickness of less than 1 mm, and hence is not expected to have any harmful impact on biota once mixing by bioturbation and biodegradation effects are taken into account.

The existing drill cuttings on the seabed and the cell tops will also be disturbed by the degradation of the GBS, and this will also add to the cumulative impacts described above. If it took approximately 500 years before loss of containment of the cell contents occurred, the

seabed and cell top drill cuttings that are currently exposed on the seabed will have degraded further by between 30-50%, hence they will still retain some hydrocarbons. The future disturbance of the existing drill cuttings is likely to occur in stages as the GBS degrades over time. Modelling of the disturbance of drill cuttings suggests that the disturbance will mainly result in a thin layer less than 1 mm thick, and in such areas there is not expected to have any harmful impact on biota. Regardless, the disturbance of the drill cuttings will add to the cumulative impact described above, but the environmental impact will remain localised (to several hundred metres) around the platforms and will reduce over time, particularly where the sediment is less than 1 cm thick, as aerobic degradation will break down the organic material. The cumulative area with potentially harmful impact due to THC contamination will be similar to what is currently observed on the seafloor around many North Sea oil and gas installations.

Legacy - *fisheries*

Fisheries will be affected by the following facilities left *in situ*.

- Brent A jacket footings: leaving the jacket footings *in situ* will continue to present an obstruction to fishermen, as they do today, for decades and centuries, and is estimated to be a 'small negative' impact.
- GBS: leaving the GBS structures *in situ* will result in a continued occupation of the platform area, thus excluding fisheries interests in this area for an indefinite period. The effect on fisheries is estimated to be 'small negative' because the value of the catch is assumed to only increase (if all the Brent platforms were completely removed) by 0.1% of the projected annual catch of £7 million per year (equates to £7,000 p.a.). The impact may be smaller if the catch is limited by quotas and days at sea, rather than physical access.
- Pipelines - approximately 89 km of pipelines will be (or currently are) trenched and 13.9 km of pipelines will be removed, and these measures will remove legacy impacts to fisheries. No pipelines will remain exposed on the seabed, and there will thus be no spans presenting legacy risks to fishing vessels.

There will be some cumulative impacts as a result of combining the legacy impact of decommissioning the Brent A jacket and GBS, but the overall cumulative effect on fisheries remains similar because the value of the catch in the area is small.

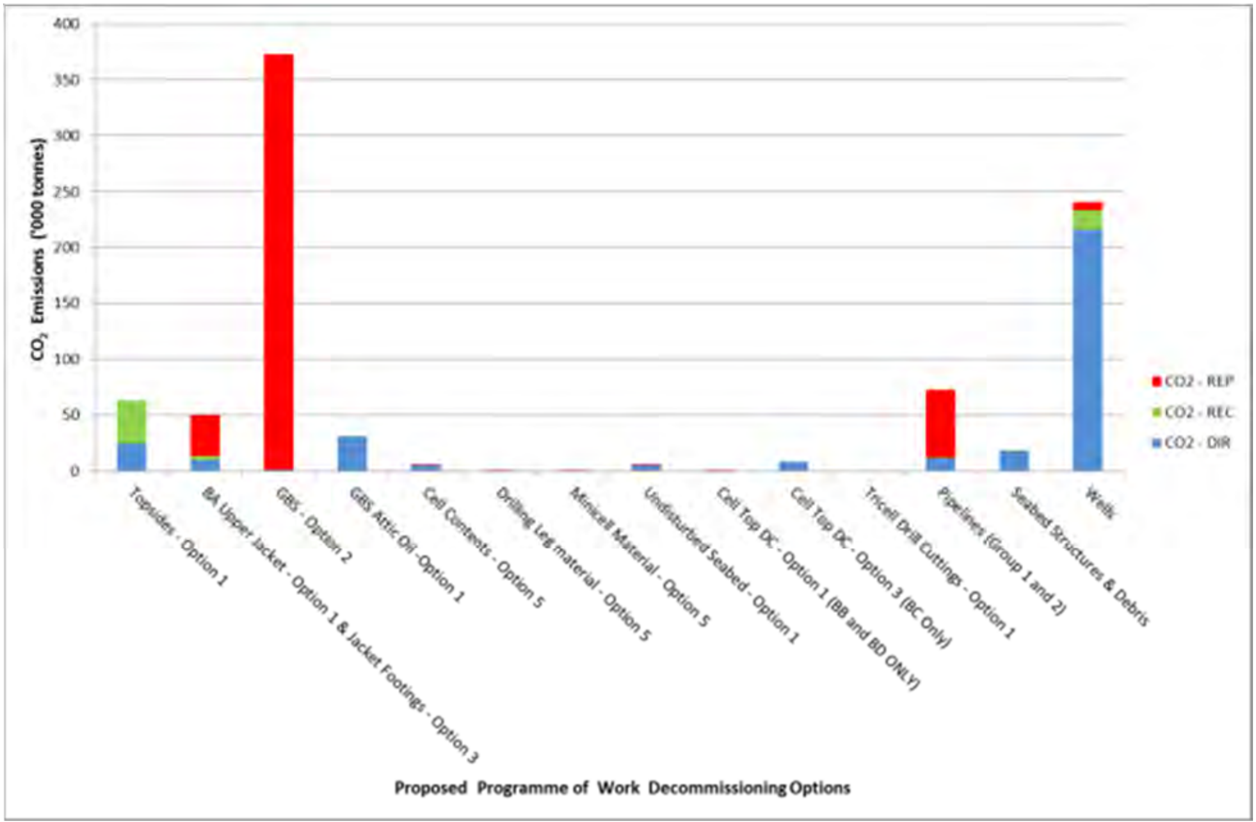
0.7.2 Overall Energy and Emissions

Energy and emissions estimations associated with the various decommissioning options have been estimated and the total CO_2 emissions (direct and indirect) for Shell's proposed programme of work are illustrated in Figure 0-4.

The emissions include offshore material removal, offshore transport, onshore demolition, onshore transport, and the recycling of metals and other materials. In addition, the energy and emissions associated with the replacement of materials (which are either left *in situ* or disposed of to landfill) are taken into account via a penalty. For the purposes of this assessment, it has been assumed that all recyclable materials are recycled.

Figure 0-4 illustrates how the plugging and abandonment of the wells and the decommissioning of the GBS (due to a penalty) are the main contributors to the total CO_2 emissions.

Figure 0-4: Comparison of CO_2 Emissions for Proposed Programme of Work



KEY:

CO_2 REP: A theoretical mass of CO_2 emissions equivalent to the total emissions arising from the production of new material from virgin materials (e.g. 1 tonne of steel), where an otherwise recyclable decommissioned material is disposed of and not recycled/re-used.

CO_2 REC: CO_2 emissions due to the energy consumed by recycling/melting down metal

CO_2 DIR: CO_2 emissions due to direct energy consumption for the option (fuel, electricity)

0.8 Conclusions

This Environmental Statement examines the environmental and socioeconomic impacts of the decommissioning options for the Brent Field facilities, and helps ensure that environmental considerations are incorporated within Shell's planning and decision making.

It is important to understand the current status and sensitivities of the environmental areas that could be affected by decommissioning, in order to effectively predict and assess the environmental impacts of the proposed decommissioning options. Most decommissioning operations will take place at the Brent Field, and there are no particularly environmentally sensitive habitats nearby. Seabed communities in the general area are diverse and abundant, but are not unique. Seabed surveys have identified elevated concentrations of metals and hydrocarbons in the sediment around each Brent Field platform, and samples indicate that benthic fauna are affected locally around the platforms. This is typical of North Sea oil and gas facilities due to the historical discharge of drill cuttings contaminated by residual oil-based drilling fluids.

The Brent Field comprises a large number of facilities (topsides, jacket, GBS, cell contents, drill cuttings, pipelines, subsea structures, wells), and there are a number of different decommissioning options under consideration (leave *in situ*, partially remove, complete removal etc.). Each decommissioning option has been broken down into activities/end points, which are then evaluated against a range of environmental and socioeconomic categories (onshore, resource use, hazardous substances, waste, physical, marine, environmental risk from accidents, employment, legacy, fisheries, shipping, energy and emissions) to identify the environmental impacts.

It was found that although decommissioning options can be conducted without causing significant environmental or socioeconomic impacts, some fundamental differences were identified between the impacts of the decommissioning options, particularly between:

- those options involving leaving structures *in situ* (resulting in some legacy impacts to the marine environment, fishermen and shipping); and
- those options to remove structures (resulting in very different impacts e.g. onshore impacts and energy and emissions, although these negative impacts are somewhat counterbalanced by the positive impact of employment and by recycling useful materials such as steel).

These are very different types of impacts, and comparing one type of environmental impact against another is not a straightforward task. Any comparison will always be open to challenge by interested and affected parties, who may only be interested in one particular environmental or socio-economic category. A specific issue of interest to one group of stakeholders (e.g. the removal of the jacket footings may be considered positive by fishermen) may be considered negatively by another group (e.g. residents living adjacent to the recycling facility where the recovered steel is transported).

The environmental impact findings were used to inform the Comparative Assessment conducted by Shell which balanced the technical, costs, safety, environmental and societal aspects in helping to identify the proposed programme of work for the Brent Field facilities in Shell's decommissioning programme.

This report then focusses on the proposed programme of work, and found the following impacts to be the most prominent:

- legacy impacts – primarily from leaving the GBS, the cell contents and the tri-cell drill cuttings *in situ*. Plus the legacy impact resulting from 149,000 t of rock dump during pipeline decommissioning (long-term change to marine habitat).
- onshore impacts – mainly from onshore handling of waste from four topsides and the P&A of wells.
- marine impacts – mainly from trenching pipelines and removing subsea structures and debris.
- energy and emissions - mainly from the decommissioning of the topsides, pipelines, the P&A of wells, and an emissions penalty for leaving the GBS *in situ.*

Even these most prominent impacts have been found to be short-term in nature, or restricted to causing localised or limited impacts.

Cumulative impacts are subsequently further examined to explore the possible synergy effects when considering all the facilities together (e.g. the impacts at the three GBS in conjunction with the impacts at the jacket). The potential for cumulative impacts was found to be limited owing to:

- the distance between the platforms; there is approximately 11 kilometres between Brent A and Brent D, and impacts are localised.
- the long length of the decommissioning programme. Because it will be a phased decommissioning approach and works will take place over a period of 10 years, the operational cumulative environmental impacts will in most instances be similar to the impacts estimated for the individual facilities, and are thus considered to be manageable, albeit simply extended over a longer period of time.

Perhaps the cumulative impact of interest to many stakeholders is the cumulative impact to the marine environment upon exposure (in the distant future following degradation of the GBS) of the GBS cell contents, tri-cell drill cuttings and material in the drilling legs and minicell annulus. Any overlap in the timing of the release of these materials is very difficult to predict owing to the uncertain nature of GBS degradation, but an estimated total of approximately 16,000 tonnes of petroleum hydrocarbons could become exposed (not at the same time) to the marine environment for all three GBS. There will be a cumulative legacy impact on the marine environment, with localised pollution to the marine environment around Brent B, C and D platforms, which will be present for decades and will affect local benthic fauna (such as tube worms), just as the local benthic fauna are currently impacted by the presence of the historical drill cuttings. The cumulative area affected, including due to the disturbance of the existing seabed and cell top drill cuttings by the degradation of the GBS, is predicted to extend at each platform to several hundred metres. Because the contaminated area will be localised around the platforms, there is not expected to be any measurable effect upon marine or benthic populations/systems. The impact is not insignificant, but it is localised, and over time the seabed will recover via natural biodegradation, particularly where the sediment is less than 1 cm thick, as aerobic degradation will break down the organic material.

It is concluded that decommissioning can be undertaken without causing any significant environmental or socioeconomic impacts, provided that the proposed mitigation and management measures are implemented. Industry best practice mitigation measures will be applied by Shell, will be managed within Shell’s established Environmental Management System, and are detailed within this report to help ensure all impacts are managed.

1. INTRODUCTION

On behalf of the owners Shell U.K. Limited (Shell) and Brent Field Partner Esso Exploration and Production UK Limited (Esso), the operator Shell is presently preparing the *Brent Platforms Decommissioning Programmes* [1] to decommission the Brent Field. This will be the largest decommissioning project in the UK sector of the North Sea to date.

There are three Decommissioning Programmes for the Brent Field. The *Brent Delta Topsides Decommissioning Programme* was submitted to the Department for Business, Energy and Industrial Strategy (BEIS) in June 2015[1], and Shell will submit two further programmes, the *Brent Platforms Decommissioning Programme* and the *Brent Pipelines Decommissioning Programme* (which will be submitted within one document). This single Environmental Statement (ES) presents the main findings of the Environmental Impact Assessment (EIA) process carried out by DNV GL for Shell for the decommissioning of the whole Brent Field and provides information and assessments applicable to all three Decommissioning Programmes.

This ES has been prepared by DNV GL in accordance with the Department of Energy and Climate Change (DECC) Guidance Notes for Decommissioning of Offshore Oil and Gas Installations under the Petroleum Act 1998 (as amended by the Energy Act 2008), which requires a decommissioning programme to be supported by an EIA.

1.1 Background

The Brent Field, discovered in 1971, is one of the largest hydrocarbon accumulations in the Northern North Sea (NNS) and is reaching the end of its economic life after having been in operation for 35 years.

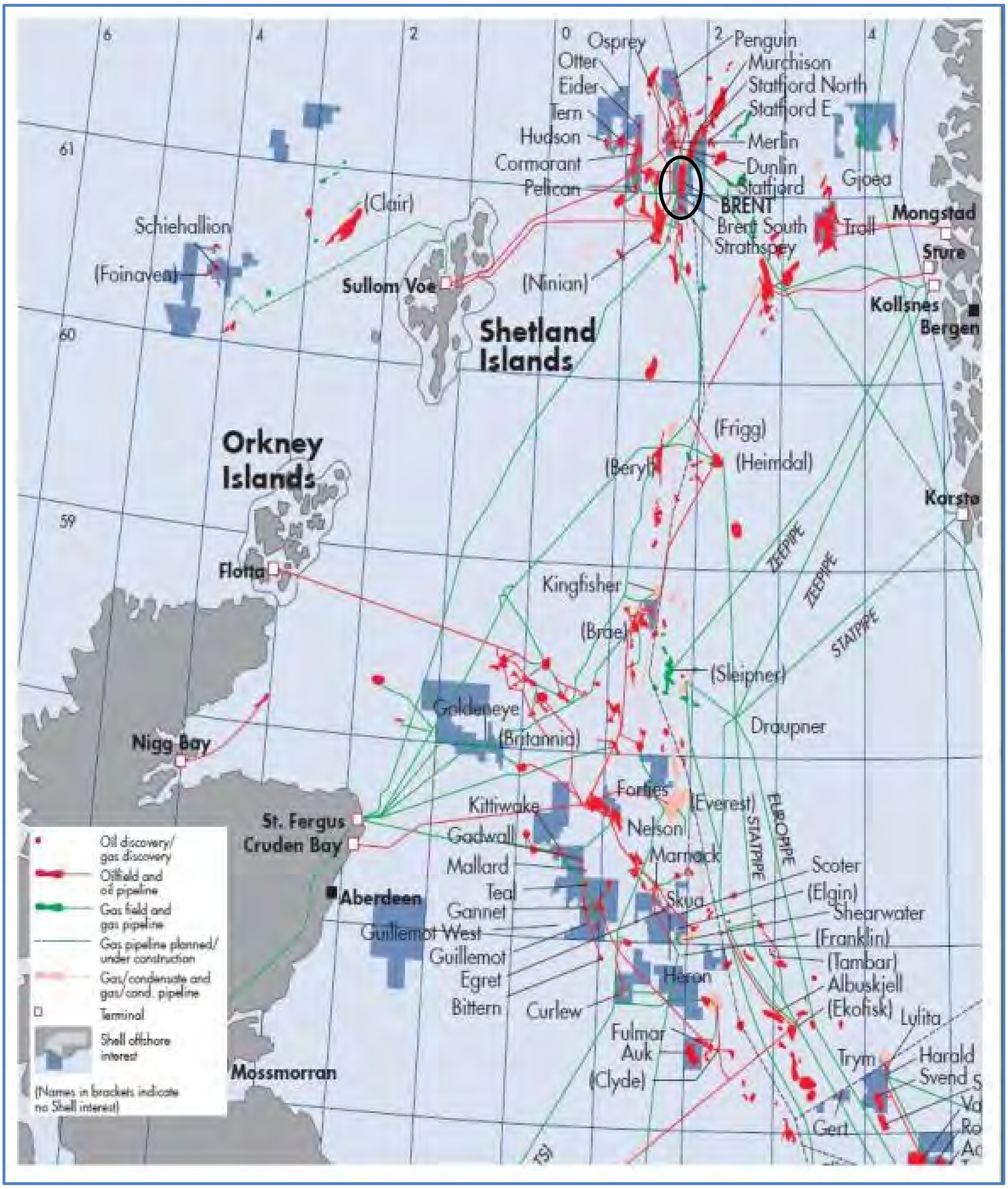
The Brent Field has four oil and gas producing platforms (Brent Alpha, Brent Bravo, Brent Charlie and Brent Delta). These are hereafter referred to as Brent A, Brent B, Brent C and Brent D. They are located in UKCS Block 211/29 in the NNS, approximately 180 km north-east of the Shetland Islands.

Brent D cessation of production (CoP) was in December 2011, and Brent A and B CoP were in Nov 2014. Brent C is still in operation and CoP is expected around 2019. A table listing the entire associated Brent Field infrastructure is found in Section 1.3.

The Brent Field is surrounded by other oil and gas developments as illustrated in Figure 1-1. Interconnecting pipelines, umbilicals and power cables link the Brent platforms with other NNS infrastructure. Oil is transported by pipeline through the Brent system via Cormorant Alpha platform to the onshore terminal at Sullom Voe in the Shetland Islands. Gas and Natural Gas Liquids (NGLs) are transported to the St. Fergus Gas Terminal via the FLAGS (Far North Liquids and Associated Gas System) pipeline.

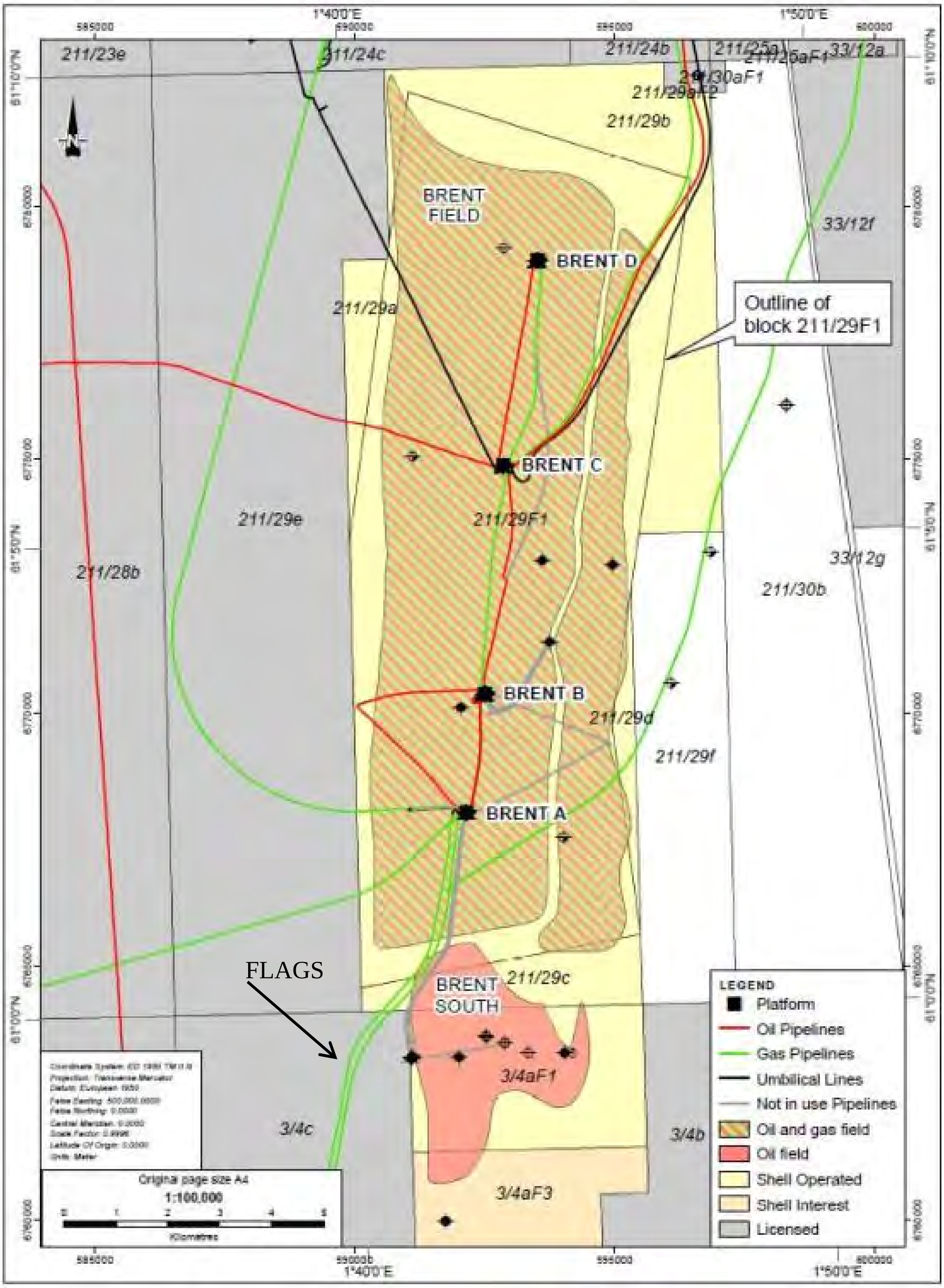
[1] In July 2016, the Department of Energy and Climate Change (DECC) was merged with the Department for Business, Innovation and Skills to create the Department for Business, Energy and Industrial Strategy (BEIS). Some instances of 'DECC' are still used in this report in reference to historical documents.

Figure 1-1: Brent Field Location Map



A closer view of Block 211/29 is shown in Figure 1-2. Brent South, also shown in the figure, was a subsea development located about 5 km south of Brent A, and is no longer operational and has been removed. The Brent South drill cuttings pile that remains is included within the scope of this study, as are the pipelines from Brent A to Brent South.

Figure 1-2: Brent Field and Platforms



1.2 Objective of the EIA Process

Decommissioning of offshore oil and gas facilities can have short-term and long-term impacts on the environment and on society. Environmental impacts can result from the hydrocarbons contained within the facilities and other issues such as hazardous substances, waste production and energy consumption. Long-term societal impacts to fishing and shipping are possible due to restrictions caused by any oil and gas facilities that are left in the sea. Impacts onshore are possible due to onshore dismantling activities creating dust, noise and traffic.

It is therefore important to carry out an EIA to ensure that environmental and social impacts are identified so that they can be managed effectively.

DNV GL was contracted by Shell to conduct an EIA for the decommissioning of the Brent Field. This ES presents the findings of the EIA, and includes:

- a description of the Brent Field installations
- a summary of the current environmental setting offshore at the Brent Field, the offshore transport route, transfer location and onshore dismantling facility
- a description and assessment of the potential environmental and social impacts of the technically feasible decommissioning options recommended by Shell and of the programme of work Shell is proposing to carry out
- discussion of the potentially significant issues, the associated mitigating measures and the residual impacts

1.3 Scope

The facilities examined in this ES are listed in Table 1-1 and described in Section 2. All stages of the decommissioning process are assessed, namely removal operations, transport, onshore recovery/dismantling, breakdown and final use/disposal. If the decommissioning option involves leaving facilities *in situ*, then the legacy impact of doing so is assessed.

Table 1-1: Summary of Brent Field EIA Scope

Topsides	Brent Alpha, Bravo, Charlie, Delta
Steel Jacket Substructure	Brent Alpha
3 Gravity Based Structures (GBS)	Brent Bravo, Charlie, Delta
GBS cell contents	Brent Bravo, Charlie, Delta Oily water, attic oil and sediment inside GBS storage cells
GBS drilling leg material	Contents of GBS drilling legs and minicell annulus (Brent Bravo, Delta)
GBS minicell annulus material	Contents of GBS minicell annulus (Brent Bravo, Delta)
Drill cuttings	Seabed (Brent Alpha, Bravo, Charlie, Delta and Brent South)
	GBS cell tops GBS tri-cells (Brent Bravo, Delta)
Pipelines	Pipelines, umbilicals and cables Brent South pipelines that remain after the earlier decommissioning of the Brent South Field
	Concrete mattresses
Subsea structures	Brent Spar PLEM (Pipeline End Manifold) and Brent Spar protective cover; Brent B SSIV (Subsea Isolation Valve); Brent A umbilical splitter box; VASP (Valve Assembly Spool Piece)
Subsea debris	Grout bags, scaffolding, anchor block, wires
Wells	146 wells throughout the Brent Field

For each of the facilities listed in Table 1-1, Shell has identified one or more decommissioning options; the technically feasible options for each facility are examined in this ES. Further decommissioning options were considered as part of the overall process by Shell, but due to various technical, feasibility or safety reasons were excluded from assessment. The decommissioning options are summarised in Section 7 and discussed in further detail in each of the respective facility chapters, as well as in Shell's Technical Documents.

1.4 Supporting Studies

A significant amount of data, information and studies were commissioned by Shell and reviewed by DNV GL to support the Brent Field Decommissioning Programmes. Approximately 130

studies are referenced in this ES; some of the key studies reviewed and used in this environmental assessment include environmental baseline studies, debris and habitat surveys, modelling of the GBS cell contents, modelling of the drill cuttings, and data on material inventories for the Brent Field.

1.5 Layout of Environmental Statement

The structure of this Environmental Statement is as follows:

Section	Description
Non-Technical Summary	Presents a summary of the entire Environmental Statement, including a description of the Brent Field and facilities, the environmental baseline, and the main findings of the EIA process.
Section 1: Introduction	Introduction to the Brent Field and the scope and objectives of the EIA.
Section 2: The Brent Field Facilities	Summarises the Brent Field facilities and the inventory of materials
Section 3: Regulatory Requirements	Outlines the environmental legislation relevant to this study
Section 4: Shell Company Standards and Procedures	Describes Shell's company requirements and Environmental Management
Section 5: EIA Methodology	Describes the EIA approach used in this study
Section 6: Environmental Setting	Describes the current environmental baseline for the Brent Field
Section 7: Decommissioning Options	Summarises the technically feasible decommissioning options for the Brent Field.
Section 8: Topsides	Provides a description of facilities, inventory of materials, proposed programme of work and significant impacts, mitigation and management measures and residual risks.
Section 9: Brent Alpha Jacket	Provides a description of facilities, inventory of materials, available options, Shell's proposed programme of work, significant impacts, mitigation and management measures and residual risks.
Section 10: GBS	Provides a description of facilities, inventory of materials, available options, Shell's proposed programme of work, significant impacts, mitigation and management measures and residual risks.
Section 11: GBS Cell Contents	Provides a description of facilities, inventory of materials, available options, Shell's proposed programme of work, significant impacts, mitigation and management measures and residual risks.
Section 12: GBS Drilling Legs and Minicell Material	Provides a description of facilities, inventory of materials, available options, Shell's proposed programme of work, significant impacts, mitigation and management measures and residual risks.
Section 13: Drill Cuttings	Provides a description of facilities, inventory of materials, available options, Shell's proposed programme of work, significant impacts, mitigation and management measures and residual risks.
Section 14: Pipelines	Provides a description of facilities, inventory of materials, available options, Shell's proposed programme of work, significant impacts, mitigation and management measures and residual risks.
Section 15: Subsea	Provides a description of facilities, inventory of materials, proposed programme of

Section	Description
Structures and Debris	work and significant impacts, mitigation and management measures and residual risks.
Section 16: Wells	Provides a description of facilities, inventory of materials, proposed programme of work and significant impacts, mitigation and management measures and residual risks.
Section 17: Cumulative Impacts of Proposed Decommissioning Options	Discusses cumulative impacts as a result of decommissioning activities
Section 18: Monitoring, Mitigation and Maintenance of Remains	Describes Shell's monitoring and mitigation plans
Section 19: Conclusions	Summarises the conclusions of the ES
Section 20: References	Provides all references used in this ES
Appendices	• Appendix 1: Environmental Impact Assessment Matrices • Appendix 2: Energy Categorisation of Decommissioning Options • Appendix 3: Summary of Environmental Underwater Noise Analysis to support the Brent Field Environmental Statement • Appendix 4: Inventory of Brent Field Subsea Pipelines • Appendix 5: Brent Field Debris Survey Findings • Appendix 6: Cumulative Impact Matrices by Environmental Media
Additional DNV GL Supporting Studies	Other reports produced by DNV GL in support of this ES include: • DNV GL, Energy Use and Gaseous Emissions Report for the Shell Brent Decommissioning EIA, Shell Report No.: BDE-F-GEN-HE-0702-00011 [2] • DNV GL, Environmental Noise Analysis for the Brent Field Decommissioning EIA, Shell Report No.: BDE-F-GEN-HE-0702-00010 [3] • DNV GL, Gravity Based Cell Contents Environmental Risk Report, Shell Report No.: BDE-F-GBS-HE-0709-00016 [94]

2. THE BRENT FIELD FACILITIES

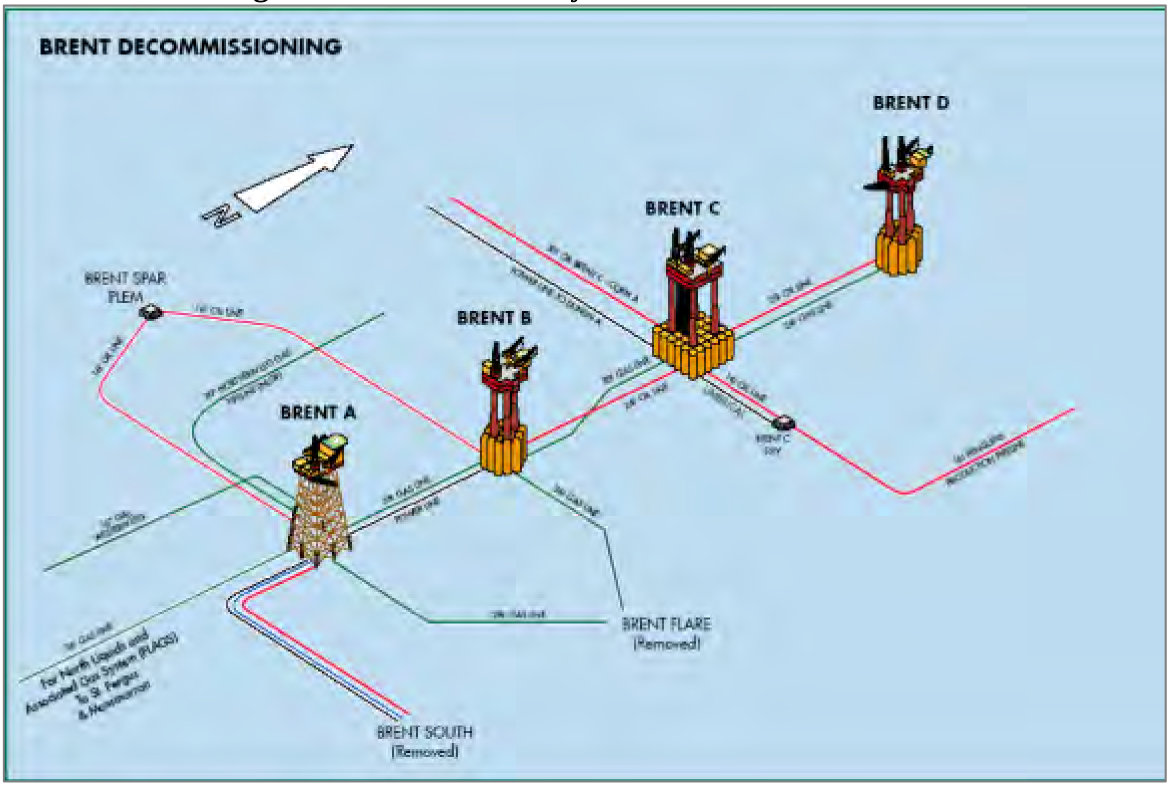
The Brent Field consists of four oil and gas producing platforms. The four Brent Field platforms are located in a water depth of approximately 142 m in UKCS Block 211/29 in the NNS, approximately 136 km north-east of the Shetland Islands, 11 km from the UK/Norway median line and 150 km from the Norwegian coast. The coordinates for each of the platforms are listed in Table 2-1, the field layout in Figure 2 and the field location in relation to Scotland and Norway is shown in Figure 2.

Table 2-1: Coordinates of the Brent Field Platforms

Site	North	East	Distance between platforms
Brent A	61° 02' 05.6"	01° 42' 19.5"	BA to BB: 2.4km
Brent B	61° 03' 21"	01° 42' 47.2"	BB to BC: 4.5km
Brent C	61° 05' 46"	01° 43' 18.6"	BC to BD: 4.1km
Brent D	61° 07' 56.6"	01° 44' 10.1"	

Three of the platforms are concrete GBS (Brent B, C and D) and the fourth a steel jacket (Brent A). Each platform consists of the installation substructure (GBS or jacket) as well as the topsides, which sit above the sea surface and contain the drilling, production and accommodation modules.

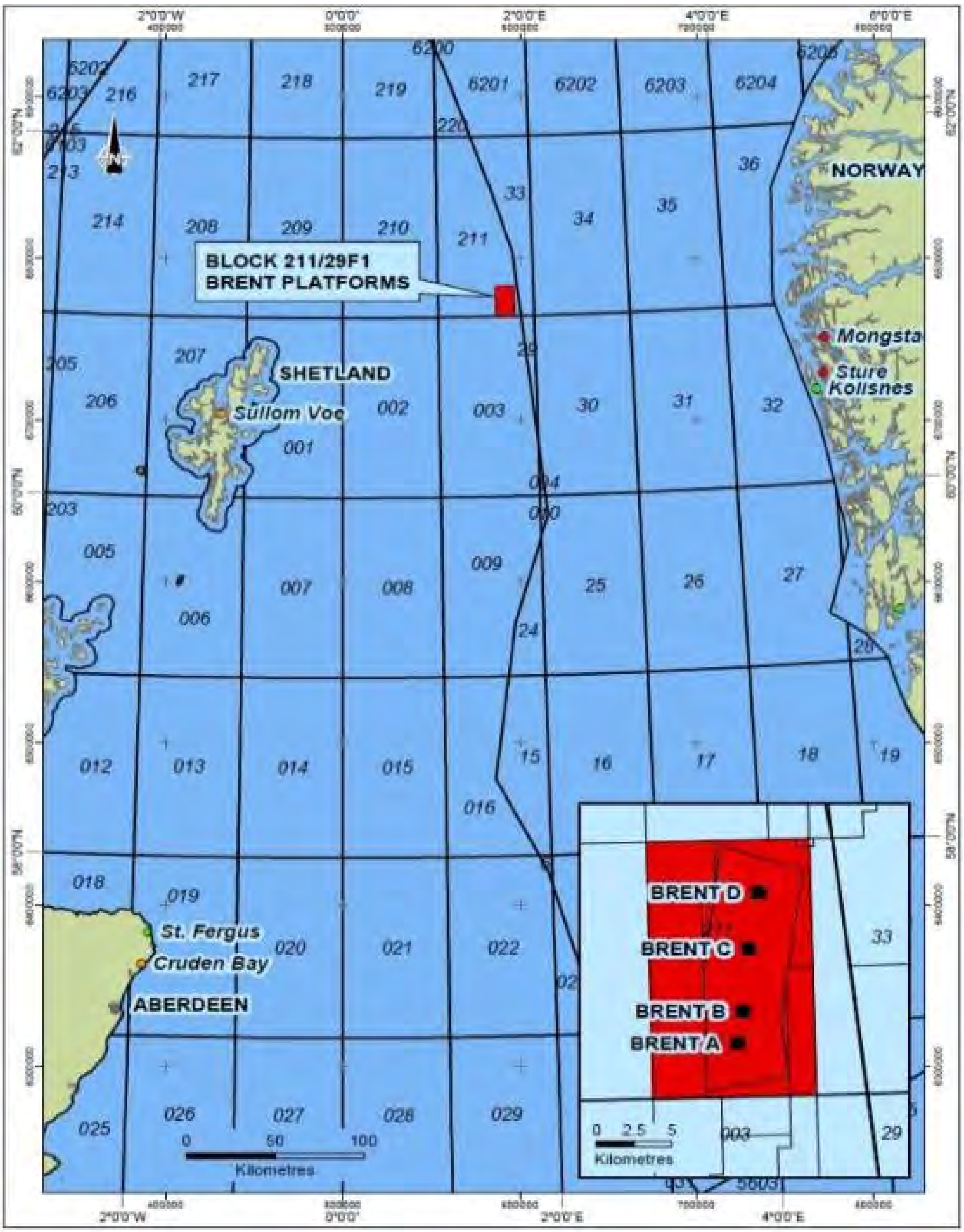
Figure 2-1: Schematic Layout of the Brent Platforms



Note: The above figure is a general schematic of the Brent Field and does not show the full extent of the pipeline systems which fall within the scope of this ES.

Brent South was a subsea development located about 5 km south of Brent A but is no longer operational.

Figure 2-2: Location of UKCS Blocks containing the Brent Field in Relation to Scotland and Norway



The Brent Field facilities are summarised below and an overview of the total weights and volumes of the Brent Field facilities is provided in Table 2-2. A more detailed description of all of the facilities is presented in Sections 8 - 16.

Brent A was installed in 1976 and consists of topsides supported by a fixed steel jacket, standing on the seabed in a water depth of approximately 140 m (overall height 162 m). It is secured to the seabed by piles at the base of each of its eight legs. The jacket footprint at the

seabed is approximately 77 m long by 75 m wide forming a base area of 5,775 m^2. Brent A ceased production in November 2014.

Brent B was installed in 1975 and is a three-leg concrete Condeep GBS supporting the topsides, each leg is 160 m high measured from the seabed to the top of the ring beam. The base consists of 19 reinforced concrete cells 60 m high, arranged in a hexagonal-shaped honeycomb caisson. The total substructure base area is 8,920 m^2. Brent B ceased production in November 2014.

Brent C was installed in 1978 and is a four-leg concrete Seatank GBS comprising 36 cells, each 57 m high, arranged in a 6 x 6 rectangular pattern on the seabed. Four of the cells extend upward as supporting legs, each 149 m high, on top of which there is a 15.7 m long steel extension piece to support the topsides. The total substructure base area is 8,281 m^2. Brent C will continue to produce for the foreseeable future.

Brent D is a three-leg concrete Condeep GBS similar to Brent B, installed in 1976. It comprises 19 reinforced concrete cells 58 m high, arranged in a hexagonal-shaped honeycomb caisson which sits on the seabed. Three of the cells extend upward as supporting legs, each 162 m high, measured from the seabed to the top of the ring beam. The total substructure base area is 8,920 m^2. Brent D ceased production in December 2011.

The subsea concrete cells (‘caissons’) of the three GBS are used for different purposes: storage of ballast water and crude oil, separation of crude oil and produced water, and cooling of storage cell contents. The tops of the GBS cells sit approximately 80 m below sea level. The **cell contents** consist of significant volumes of attic oil, an oil/water interphase layer, water and sediment, as verified by a successful cell sampling project conducted by Shell in 2014.

In addition at Brent B and D, the **drilling legs** contain some contaminated drill cuttings **and** the **minicell annuli** contain some oily sludge.

Drill cuttings are present on the seabed at all four platforms and at Brent South, on the tops of the three GBS storage cells and are present within some of the GBS tri-cells. Drill cuttings are rock fragments that were generated by the drill bit during drilling. Fluids called drilling muds are used to lubricate and cool the drill bit, maintain pressure, and to transport cuttings back to the topsides for separation prior to discharge. Drilling muds can be water-based or oil-based fluids. Discharged drill cuttings can still have some proportion of the drilling muds adhering to their surface. Tri-cells are void spaces in between GBS cells, which over time at Brent B and D may have accumulated drill cuttings (Brent C has no tri-cell drill cuttings as the tri-cells are not open to sea).

A total of 28 subsea **pipelines** ranging between 0.3 and 35 km long are included in the BDP and all will be decommissioned. These comprise rigid pipelines, flexible flowlines and risers, umbilicals and power cables, most of which are no longer in use. These lines have historically been used for oil production, gas export or control umbilicals. Concrete mattresses have been installed to protect subsea pipelines and umbilicals, and are also present on the sea floor.

Subsea structures (e.g. subsea isolation valves, pipeline end manifolds and valve assembly spools) and **debris** (e.g. grout bags, scaffolding, grating, ladders and wires) are also present on the sea floor, around the platforms and on the tops of the GBS cells.

All of the **wells** (146 in total) throughout the Brent Field will be plugged and abandoned.

Table 2-2: Summary of Estimated Weights and Volumes of Brent Field Facilities

	Topsides weight (t)	Brent A jacket weight (t)	GBS	GBS Cell Contents[9]					Seabed drill cuttings (m^3)	GBS Drill Cuttings		Subsea structures and debris (t)	Pipelines (t)	Wells (t)
			GBS weight (t)	GBS minicells (m^3)	GBS drilling leg contents (m^3)	Attic oil (m^3)	Cell water (m^3)	Cell sediment (m^3)		Cell top drill cuttings (m^3)	Tri-cell drill cuttings[5] (m^3)			
Brent A	15,051	31,453	-	-	-	-	-	-	6,300	-	-	-	-	-
Brent B	23,627	-	345,266[2]	250[3]	2,000[4]	0	163,840	17,280	5,300	1,887	12,039	-	-	-
Brent C	30,409	-	297,321	-	-	11,116	311,667	6,035	4,922	7,735	-	-	-	-
Brent D	24,186	-	331,138[2]	250[3]	2,000[4]	800	163,040	17,280	2,230	3,790	14,733	-	-	-
Brent South	-	-	-	-	-	-	-	-	2,166	-	-	-	-	-
Total	**93,273**	**31,453**[1]	**973,725**	**500**	**4,000**	**11,916**	**638,547**	**40,595**	**20,918**	**13,412**	**26,772**	**Steel: 941** **Grout: 485**	**Steel: 25,129** **Concrete: 23,658**[6]	**Steel: 39,740**[7] **Concrete: 1,500**[8]
Oil Content (t)	-	-	-	20 t	46 t	11,916 m^3	261 t	7,194 t	1,694 t	3,948 t	4,926 t	-	-	-

[1] Includes conductors, anodes, grout and marine growth

[2] Includes sand ballast

[3] Value used during data reconciliation based upon measured range 135-270 m^3

[4] Based on average drilling leg waste volumes of 500 m^3 in Brent D East leg, 1,500 m^3 in Brent D West leg. Excludes volume of (clean) top hole drill cuttings in each leg

[5] Volumes provided are an estimate of the maximum that Shell believes might be present

[6] Includes concrete mattresses

[7] Includes tubings, casing, conductors, platform wellheads and xmas tree

[8] Includes concrete from conductors

[9] Volumes shown were calculated prior to the GBS cell sampling exercise. Cell sediment initially assumed 11% oil content, density 1.611 (Table 11-4); Cell water initially assumed average 409 mg/l oil content (Table 11-15).

3. REGULATORY REQUIREMENTS

The Brent Field Decommissioning Programmes will be subject to the requirements of international treaties, UK and EU legislation, and Shell company requirements. These are discussed in turn below.

3.1 International Framework

In making decisions regarding the disposal of decommissioned offshore facilities, the UK authorities are obliged to consider certain international conventions and guidelines such as:

- The OSPAR Convention, the current legal instrument guiding international cooperation on the protection of the marine environment of the Northeast Atlantic. Work under the Convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Union.
- International Maritime Organisation (IMO) guidelines. IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships.

Relevant decisions, recommendations and guidelines are described below.

3.1.1 OSPAR Decision 98/3

OSPAR Decision 98/3 [4] mandates that offshore facilities are re-used, recycled or finally disposed of on land. In certain circumstances derogations from this decision can be sought, however the following facilities must be removed and returned to shore for re-use, recycling or disposal:

- The topsides of all offshore platforms
- All steel substructure jackets weighing 10,000 tonnes or less
- Subsea structures (including drilling templates, production manifolds, wellheads and risers)

Although there is a presumption that offshore installations will be removed entirely, the OSPAR Decision also recognises that there may be difficulty in removing some very large structures such as:

- Footings of large steel jackets weighing more than 10,000 tonnes (excluding topsides). ‘Footings’ are defined by OSPAR as those parts of a steel installation which are below the highest point of the piles which connect the installation to the seabed or, in the case of an installation constructed without piling, form the foundation of the installation and contain amounts of cement grouting similar to those found in piled installations. The definition also includes those parts of a steel installation which are so closely connected to the 'footings' as to present major engineering problems in severing them.
- Concrete Gravity Based Structures (GBS).
- Exceptional circumstances, for example, where for safety or technical reasons, it can be demonstrated that structural deterioration or damage would make removal of the installation impossible.

As a result, exceptions to the requirement for complete removal and disposal of disused offshore installations, known as ‘derogations’, can be granted.

Derogation is an exemption from the requirement to remove the whole of a steel structure or concrete substructure from the seabed, and is considered on an individual basis. It is presumed by the Regulator that all structures will be removed entirely, however an exception (derogation) requires that any proposal for an alternative approach must demonstrate that there are significant reasons why an alternative option to reuse, recycling or onshore disposal is preferable.

OSPAR 98/3 states that a summary of disposal options must be collated in an assessment, comprehensive enough to allow for a logical and justifiable Comparative Assessment of the disposal options. The Comparative Assessment should demonstrate a balanced judgement of technical and engineering aspects, safety, marine impacts, environmental emissions and energy use, use of natural resources, physical impacts, and societal and economic impacts. Where it is considered that an option involves a high level of safety or environmental risk, it may be ruled out without further consideration. Table 3-1 and corresponding footnotes are sourced from the DECC Guidance Notes on Decommissioning [5] (discussed further in Section 3.2). The table shows the possible disposal options which may be considered for various categories of offshore installations located on the UKCS, as per OSPAR requirements:

Table 3-1: Possible Disposal Options for Various Categories of Offshore Installations [5]

Installation (excluding topsides)	Weight (tonnes)	Complete Removal to Land	Partial Removal to Land	Leave Wholly in Place	Re-use	Disposal at Sea
Fixed Steel	<10,000	Yes	No	No	Yes(3)	No
Fixed Steel	>10,000	Yes	Yes(1)(2)	No	Yes(3)	No
GBS	Any	Yes	Yes(2)	Yes	Yes	Yes(4)
Floating	Any	Yes	No	No	Yes	No
Subsea				No	Yes	No

(1) Only the 'footings' or part of the 'footings' may be left in place.

(2) Minimum water clearance of -55 m LAT required above any partially removed installation not projecting above sea surface.

(3) The placement of materials on the seabed for a purpose other than that for which it was originally intended is covered by the OSPAR Guidelines on Artificial Reefs in relation to Living Marine Resources of June 1999 (OSPAR Reference: Agreement 1999-13)

(4) Although the disposal of the substructure of a concrete installation at a deep-water site is an option this must be considered against UK Government announcements at the time of the OSPAR Decision when Ministers stated that there would be no toppling and no local or remote dumping of offshore installations.

Pipelines are not covered by OSPAR Decision 98/3, and there are no international guidelines on their decommissioning. See Section 3.2 for national legislation relating to pipeline decommissioning.

3.1.2 OSPAR Recommendation 2006/5

OSPAR Recommendation 2006/5 [6] outlines the approach for the management of historic drill cuttings piles offshore, with the purpose of reducing the impacts of pollution by oil and/or other substances to a level that is not significant.

> Drill cuttings are fragments of rock created by the drilling process, and carried to the surface by lubricating fluids. The material also contains residual drilling mud and other substances, some of which are contaminants.

Two threshold values are defined by OSPAR:

- Rate of oil loss to water column: 10 tonnes/year (this is understood to include all mechanisms that result in oil loss from the cuttings pile, including surface loss, diffusion, erosion and bio-turbation)
- Persistence over the area of contaminated seabed[2]: 500 km^2yr

The cuttings pile management regime is then divided into two stages, namely:

- **Stage 1** requires the initial screening of all cuttings piles within 2 years of the Recommendation taking effect (30 June 2006)
- **Stage 2** requires a Best Available Technique (BAT) and/or Best Environmental Practice (BEP) assessment and should, where applicable, be carried out within a timeframe determined in Stage 1

The **Stage 1** screening is an assessment of the two OSPAR threshold values above. The rate of oil loss from the cuttings pile to the water column over time should be compared to the threshold of 10 tonnes per year. The persistence of the cuttings pile should be assessed based on the area of seabed where the concentration of oil in the sediment remains above 50 mg/kg compared to the threshold of 500 km^2yr. If both the rate of oil loss and the area persistence are below the threshold levels and no other discharges have contaminated the cuttings pile, under the Recommendation no further action is necessary and the cuttings pile may be left *in situ* to degrade naturally.

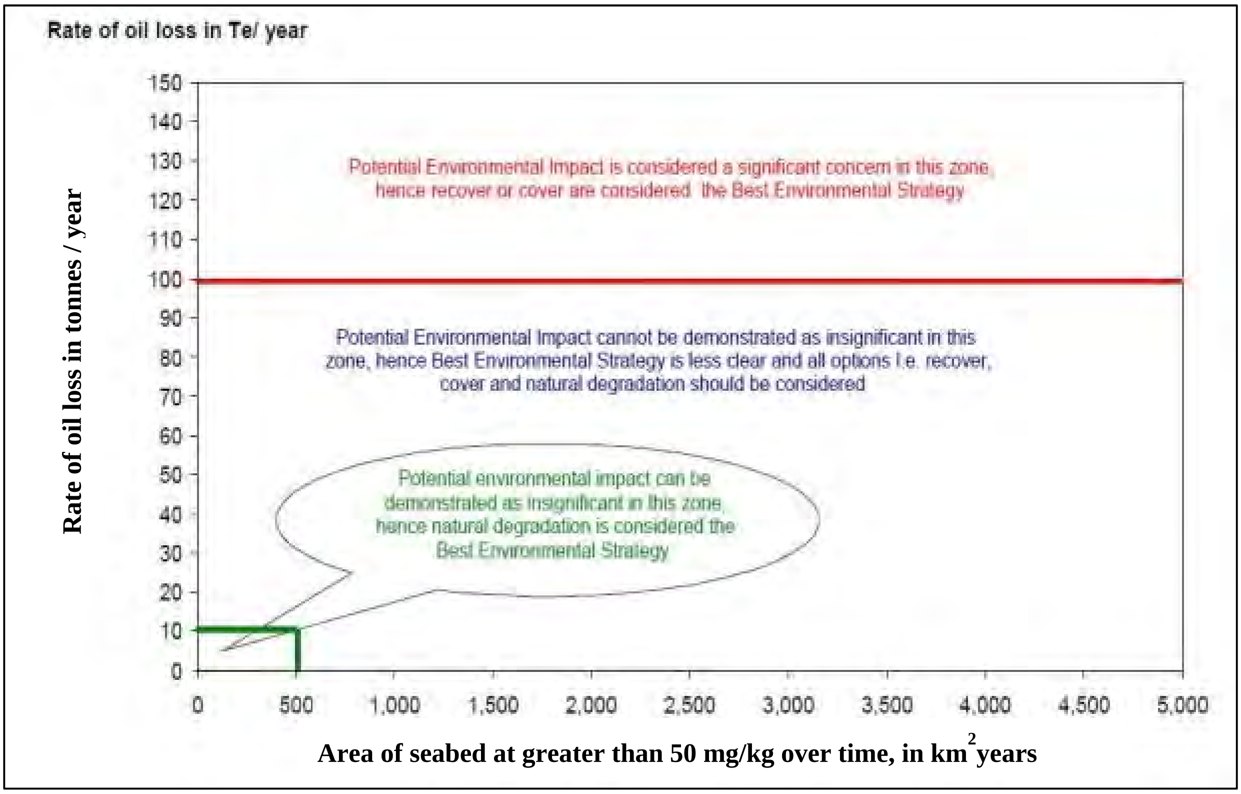
If either the rate of oil loss or the area persistence is assessed to be above the OSPAR threshold levels, a **Stage 2** assessment should be initiated with a BAT/BEP study for the cuttings pile. This study should characterise the cuttings pile, review the impacts and provide a Comparative Assessment to determine BAT/BEP, taking into account the rate of oil loss, the persistence over the area of contaminated seabed and the timing of the decommissioning of the associated installation.

The UKOOA (United Kingdom Offshore Operators Association) JIP (Joint Industry Project) on Drill Cuttings [7] was the basis for the OSPAR Recommendation 2006/5 and forms part of the Norwegian Oil and Gas Association (NOG, formerly OLF) Guideline for Characterisation of Offshore Drill Cuttings Piles [8]. Figure 3-1 illustrates the UKOOA ‘best environmental

[2] A persistence of 500 km^2yr could mean an area of 1 km^2 is contaminated for 500 years, or an area of 500 km^2 is contaminated for one year.

strategy' for drill cuttings management and for environmental significance. The UKOOA JIP concludes that only cuttings piles having an oil loss above 100 tonnes per year need to be recovered or covered (whichever is shown to be the best environmental strategy). Less loss of oil (<100 tonnes per year) implies that the 'best environmental strategy' is less clear and all options for decommissioning should be considered (including recover, cover and natural degradation). Oil loss <10 tonnes/year and with persistence of <500 km^{2}years means that the potential environmental impact of the drill cuttings is insignificant and the piles can be left *in situ* for natural degradation.

Figure 3-1: Likely Best Environmental Strategy for Drill Cuttings Pile Management [7]



3.1.3 IMO Guidelines

In 1989 the International Maritime Organisation (IMO) adopted Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone [9] ('The IMO Guidelines') for the purpose of promoting safety of navigation and to prevent any potential effects on the marine environment. The guidelines are advisory in nature and not formally binding. The IMO Guidelines recommend a case-by-case evaluation to determine whether a redundant offshore installation should be left wholly or partly on the seabed, taking into consideration the effects on navigation and the marine environment, costs, risks, safety and technical feasibility.

According to the IMO Guidelines, if the coastal state determines that an installation will be partly removed to below the sea surface and will not be re-used (e.g. as an artificial reef), an unobstructed water column of at least 55 m to the sea surface (Lowest Astronomical Tide LAT) should be provided.

In addition, the IMO Guidelines stipulate that the coastal state is responsible for ensuring that those installations not entirely removed are indicated on nautical charts and properly marked

with navigational aids. Any disused installation that projects above the sea surface should be adequately maintained. The purpose of the IMO's maintenance recommendation is to ensure preservation of the navigation aids, thereby promoting maritime safety.

3.2 UK and EU Regulations and Guidance

3.2.1 Legislation

Petroleum Act 1998

The Petroleum Act 1998 (as amended by the Energy Act 2008 Part III Chapter 3) sets out requirements for undertaking decommissioning of offshore oil and gas installations and pipelines, including preparation and submission of a decommissioning programme before decommissioning can take place. Although there is currently no statutory requirement to undertake an EIA at the decommissioning stage, a decommissioning programme will nevertheless need to be supported by an EIA. The EIA regulations require that an ES is submitted for all new developments and this must consider the long-term impacts of the field development including the impacts arising from decommissioning.

The Petroleum Act 1998 provides the UK framework for the orderly decommissioning of pipelines.

The Petroleum Act 1998 (Part IV) also outlines the long-term obligations in respect to abandoned wells. This requirement will be met by confirmation that abandonment has been carried out in accordance with the Oil & Gas UK Guidelines for the Suspension and Abandonment of Wells [10] and that an application will be submitted in support of any works that are to be carried out.

The Offshore Petroleum Production and Pipelines (Assessment of Environmental Effects) (Amendment) Regulations 2007

These regulations implement for offshore oil and gas operations in the UK the requirements of *EC Directive 85/337/EEC on The Assessment of the Effects of Certain Public and Private Projects on the Environment* (as amended by Directives 97/11/EC and 2003/35/EC), hereafter referred to as the **EIA Directive**.

Other Relevant Environmental Legislation

The management, handling and recycling/disposal of materials onshore must comply with all applicable onshore environmental legislation. In the UK this includes the **Environment Protection Act 1990 Part II**, which sets out waste management and disposal requirements, (including Duty of Care), the **Hazardous Waste Directive (91/689/EEC)** (implemented in the UK by **The Hazardous Waste (England and Wales) Regulations 2005**), and the **Controlled Waste (England and Wales) Regulations 2012**. In Scotland, the **Controlled Waste Regulations 1992**, **The Special Waste Regulations 1996**, and the **Special Waste Amendment (Scotland) Regulations 2004** apply. In certain circumstances additional authorisation under the **Radioactive Substances Act 1993** may be necessary for anybody who receives radioactive waste for disposal.

The carriage, loading, unloading and storage of all classes of dangerous substances in port areas is governed by the **Dangerous Substances in Harbour Areas Regulations 1987** (as amended).

The Offshore Chemical Regulations 2002 (as amended 2011) control the use and discharge of chemicals during the decommissioning of an offshore installation, pipeline or during well suspension/abandonment. The Operator will need to apply to BEIS via their new environmental

permitting system, the Portal Environmental Tracking System (PETS). Previously permits were split into several 'PONs' (Petroleum Operations Notice), but these have now been replaced by the PETS system which seeks to integrate all applications into one Master Application Template (MAT).

The Marine and Coastal Access Act 2009 (MCAA) controls marine activities and puts in place a system for improved management and protection of the marine and coastal environment. Operators require a license for all decommissioning activities and for any deposits, removals or seabed disturbance resulting from decommissioning.

The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 prohibit the discharge of oil into the sea from an offshore installation or pipeline, except under authority of a permit. Operators are required to make provision for the removal and recycling of oil recovered during decommissioning, but it is possible to apply for a permit for the discharge or reinjection of certain types and quantities of oil.

The **Offshore Combustion Installations (Prevention and Control of Pollution) Regulations 2001** (as amended) implement the Council Directive 96/61/EC **Integrated Pollution Prevention and Control** (IPPC) **Directive** for offshore combustion installations. Under the regulations a permit is required if the aggregated thermal capacity of the combustion equipment on an installation exceeds 50 MW. Such permits are issued for the operational phase only. Following Cessation of Production (CoP) and decommissioning, the installation is no longer subject to the controls and the operator is required to surrender the permit.

Under the **Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) Regulations 1998** operators of offshore oil and gas installations and pipelines are responsible for preparing and submitting an Oil Pollution Emergency Plan (OPEP) to BEIS. The OPEP should cover all activities with a risk of a hydrocarbon spill, including decommissioning activities.

The **Greenhouse Gases Emission Trading Scheme (ETS) Regulations 2003** implement the **EU Emissions Trading Scheme** (EUETS) in the UK. Under the regulations, operators are required to apply to BEIS for a permit covering the emission of CO_2 if the aggregated thermal capacity of the combustion equipment on an installation exceeds 20 MW. Such permits are issued prior to decommissioning and must be surrendered when the aggregated thermal capacity falls below the threshold.

EC Directive 92/43/EEC 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora (more commonly termed the Habitats Directive) and **EC Directive 2009/147/EC 2009 on the Conservation of Wild Birds** (more commonly termed the Wild Birds Directive) are implemented offshore by the **Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001**. The regulations aim to protect and ensure the biodiversity of certain habitats, areas and species by designating protected sites termed Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). In addition, **CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora)** is an international agreement which aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. An EIA for a decommissioning programme is required to identify any habitats and species relevant to the study area which are protected under the regulations, and to demonstrate that the protected sites are not significantly affected by the decommissioning programme. But the regulations do not apply to artificial habitats created by the offshore infrastructure, and it is not necessary to justify the removal of structures colonised by protected or rare species.

3.2.2 Guidance Notes

The Department for Business, Energy and Industrial Strategy (BEIS) is the competent authority for the decommissioning of UK offshore oil and gas installations and pipelines. Guidance notes were prepared by DECC (now BEIS) in 2011 to those engaged in preparing decommissioning programmes: *Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998* (Version 6, 2011) [hereafter referred to as the **DECC Guidance Notes on Decommissioning**] [5].

The Petroleum Act 1998 provides the framework for the orderly decommissioning of pipelines, while the DECC Guidance Notes on Decommissioning require that a Comparative Assessment be completed, where all feasible decommissioning options for pipelines, including their re-use, are considered and compared.

Additional to the OSPAR requirements as set out earlier in Section 3.1.1, the DECC Guidance Notes on Decommissioning state that appropriate surveys should be undertaken to identify and recover any debris located on the seabed which has arisen from the decommissioning operation or from past development and production activity. The area to be covered is a minimum of 500 m around each platform and along a corridor 200 m wide centred on each pipeline [5].

4. SHELL COMPANY STANDARDS AND PROCEDURES

4.1 Introduction

In addition to being subject to the requirements of UK and EU legislation, international treaties and agreements, Shell has company requirements, guidelines and standards that also need to be complied with.

The Brent Decommissioning Project will be managed within the boundaries set by the Shell Control Framework (SCF). The SCF is the single overall control framework that applies to all Shell companies. Figure 4-1 illustrates the key components comprising Group Manuals, Standards and Procedures which are accessible via Shell's Business Management System (BMS).

Figure 4-1: Shell Control Framework

4.2 Shell HSSE & SP Control Framework

Shell's HSSE & SP Control Framework (Health, Safety, Security, Environment and Social Performance) defines and communicates Shell Group HSSE & SP requirements, and is shown in Figure 4-2. It came into force in January 2009 (updated Nov 2016) and is a component of the SCF. It contains a set of mandatory standards that define high level HSSE and SP principles and expectations. The HSSE & SP Control Framework contains eleven manuals for the Group-wide HSSE & SP risk and process areas. The manuals include all of the HSSE and SP requirements such as Shell's industry-first biodiversity standard. The Control Framework includes supporting documents such as mandatory specifications and glossary terms, and non-mandatory assurance protocols and guides.

The Environmental section of the HSSE Control Framework is made up of nine sections:

1. Biodiversity,
2. Flaring and Venting,
3. Greenhouse Gas and Energy Management,
4. Ozone Depleting Substances,
5. Soil and Groundwater,

6. Sulphur Oxides (SO_x) and Nitrogen Oxides (NO_x),
7. Volatile Organic Compounds (VOC),
8. Waste, and
9. Water in the Environment

HSSE Control Framework gap analyses are completed at significant stages of the BDP against the assurance protocols for these nine areas.

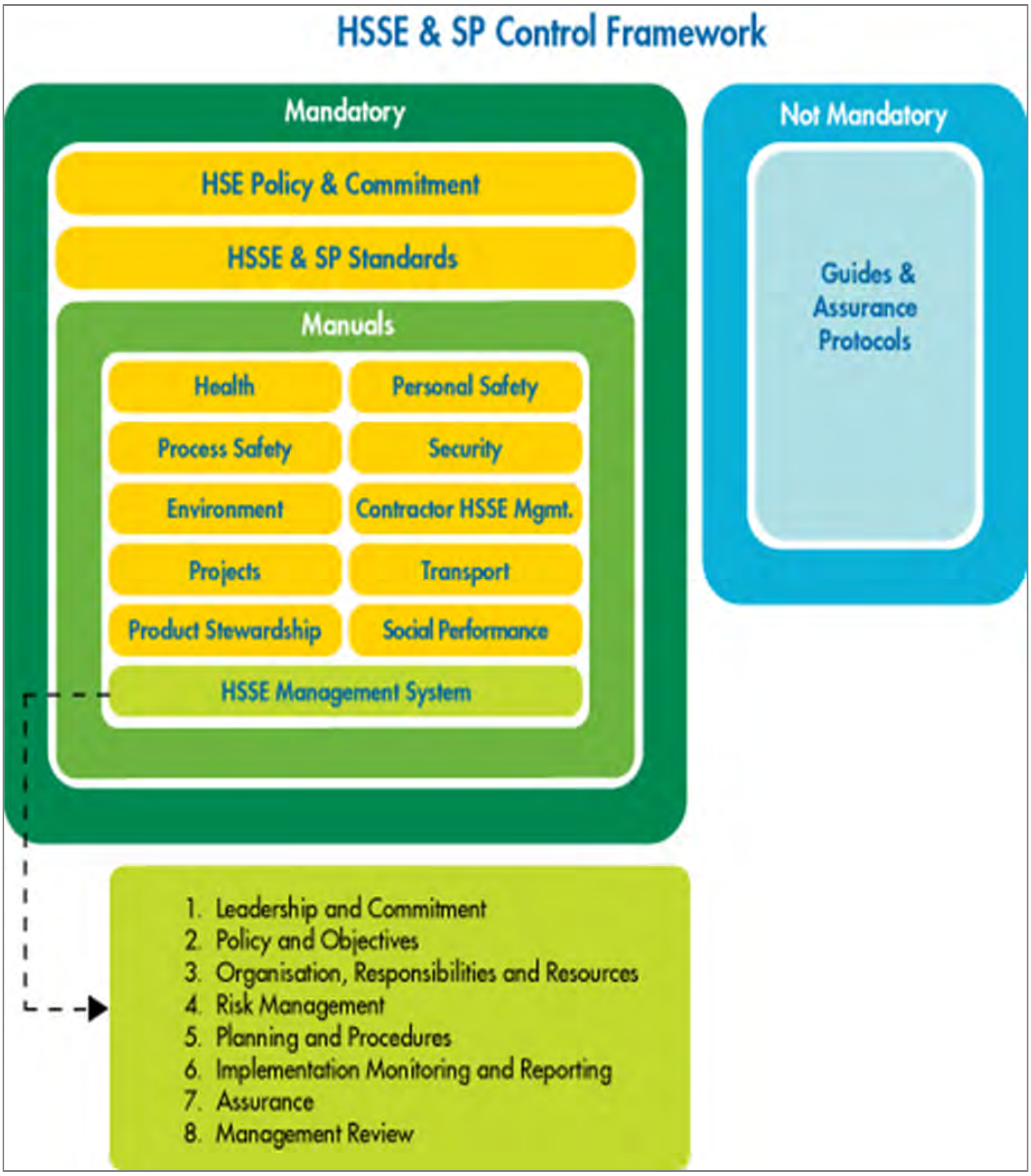
4.3 HSE in the Opportunity Realisation Process (ORP)

As well as checks against the HSSE Control Framework, various steps of the project will require identification and management of environmental risks as part of the Shell's Opportunity Realisation Process (ORP), governed by the Opportunity and Realisation Standards (ORS). The ORS sets out the mandatory rules, provides a practical approach for managing and delivering projects and requires certain HSSE actions/outputs at each stage of the project, which includes (but are not limited to):

- HSSE & SP Hazards and Effects Register
- HSE Management Plan
- As Low As Reasonably Practicable (ALARP) Demonstration Report
- Greenhouse Gas (GHG) and Energy Management
- Social Performance Plan
- Impact Assessment

The majority of the sub-projects within the BDP will have as a minimum an HSSE & SP Hazards and Effects register, which will include actions required to reduce the identified risks, and a HSSE Activity Plan.

Figure 4-2: Shell HSSE & SP Control Framework



4.4 Environmental Management

Shell has developed and implemented an Environmental Management System (EMS) across all the Shell UK businesses through the HSSE & SP Framework. The EMS provides a framework for a systematic approach to identifying and managing the environmental risks associated with Shell's operations, covering all activities that are used in the exploration, production and processing of hydrocarbons in the UK. The EMS is independently certified to IS014001: 2004 standard, and meets the requirements of OSPAR Recommendation 2003/5 which promotes EMS within the offshore industry. Shell's HSSE & SP framework has been integrated into Shell's

BMS and therefore there will be consistency between the ISO 14001:2004 standard and Shell Group requirements. Environmental protection is considered at all stages of the lifecycle of Shell's oil and gas facilities.

4.4.1 Policy

Assets and Functions in the UK operate under the UK HSSE & SP Policy which is fully aligned with the Shell Group HSE Commitment and Policy. In addition to the HSSE & SP Policy, Shell is governed by General Business Principles, signed by the Chief Executive, Principle 5 of which states:

> '*Shell companies have a systematic approach to health, safety, security and environmental management in order to achieve continuous performance improvement. To this end, Shell companies manage these matters as critical business activities, set standards and targets for improvement, and measure, appraise and report performance externally. We continually look for ways to reduce the environmental impact of our operations, products and services'.*

Shell UK Limited's HSSE & SP Policy is shown in Figure 4-3. This Policy sets the direction and objectives of environmental management, and is applicable to all activities related to the Brent Decommissioning Project.

Figure 4-3: Shell U.K. Limited HSSE & SP Policy

SHELL COMMITMENT AND POLICY ON HEALTH, SECURITY, SAFETY, THE ENVIRONMENT AND SOCIAL PERFORMANCE

COMMITMENT

In Shell we are all committed to:

- Pursue the goal of no harm to people;
- Protect the environment;
- Use material and energy efficiently to provide our products and services;
- Respect our neighbours and contribute to the societies in which we operate;
- Develop energy resources, products and services consistent with these aims;
- Publicly report on our performance;
- Play a leading role in promoting best practice in our industries;
- Manage HSSE & SP matters as any other critical business activity; and
- Promote a culture in which all Shell employees share this commitment.

In this way we aim to have an HSSE & SP performance we can be proud of, to earn the confidence of customers, shareholders and society at large, to be a good neighbour and to contribute to sustainable development.

POLICY

Every Shell Company:

- Has a systematic approach to HSSE & SP management designed to ensure compliance with the law and to achieve continuous performance improvement;
- Sets targets for improvement and measures, appraises and reports performance;
- Requires contractors to manage HSSE & SP in line with this policy;
- Requires joint ventures under its operational control to apply this policy, and uses its influence to promote it in its other ventures;
- Engages effectively with neighbours and impacted communities; and
- Includes HSSE & SP performance in the appraisal of staff and rewards accordingly.

Ben van Beurden
Chief Executive Officer

Originally published in March 1997 and updated by the Executive Committee December 2009.

General Disclaimer: The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate entities. In this Policy the expression "Shell" is sometimes used for convenience where references are made to companies within the Shell group or to the group in general. Likewise, the words "we", "us" and "our" are also used to refer to Shell companies in general or those who work for them. These expressions are also used where no useful purpose is served by identifying specific companies.

4.4.2 Planning

All Brent Decommissioning Project activities will be managed in accordance with SCF together with supporting manuals, standards and procedures accessed via the BMS. The potential environmental aspects of the activities have been assessed and appropriate controls will be in place to ensure that these do not lead to adverse impacts on the environment.

The Shell U.K. Limited Policy on HSSE & SP contains a commitment to compliance with environmental legislation and other requirements (e.g. Oil & Gas UK guidelines). These include Shell Group requirements, which set targets and require reporting of performance for Shell Group companies.

Shell promotes compliance and continuous improvement in performance by establishing appropriate environmental objectives and targets within an annual HSE Plan. The Brent Decommissioning Project will be designed to comply with Shell's overall environmental objectives and targets of Shell.

4.4.3 Implementation and Operation

The general responsibilities for health, safety and environmental protection are specified in Shell's policy (which is issued to all staff and contractors). As contractor companies undertake many of Shell's activities, the management of HSSE protection by contractors is an important area for Shell. All contractors are required to fulfil defined standards in HSSE management before they work with Shell, and their performance in this area is monitored and reviewed. Shell has a Compliance and Verification Group that carries out audits and second party checks. Shell also has HSSE Interface Documents with contractors, and contractor audits are carried out. This ensures that the competence and standards of contractors are checked. Specific HSSE responsibilities for the Brent Decommissioning Project will be set out in the Interface Document between Shell and the main Contractors.

Shell provides training to ensure that personnel are competent to carry out their activities and where there are specific responsibilities for environmental protection specific training is provided. Contractor companies are expected to provide an equivalent level of training and this is verified at the tender stage of projects. Contractor competency, ensuring that the correct training and relevant qualifications have been achieved, is verified during the assessment of tender documents.

Communication on environmental issues takes place primarily via line managers and supervisors. In addition, Shell has a comprehensive system of committees, meetings and publications that ensure the flow of information between all parts of the organisation. Environmental Specialists are available to provide advice to management and operations on environmental matters. Communication with the authorities and interested parties is also an important part of Shell's approach to environmental management, and external consultations take place during the environmental assessment stage of the project.

The main Shell environmental documents are sign-posted in the BMS and its supporting documents. Shell specifies certain operational controls that are to be implemented throughout the company. The main controls related to the Brent Decommissioning Project are referenced at relevant points within this ES.

Shell maintains operational controls on its activities through procedures, work instructions, physical controls, maintenance and training of personnel or combinations of these. Where

required, activities are carried out in accordance with the appropriate procedures and these and other requirements are also communicated to third party contractors and suppliers.

A system for emergency preparedness and response is maintained by Shell to ensure that the correct action is taken in the event of an incident or accident that could affect the environment. There are arrangements covering the Brent Decommissioning Project activities, and in particular oil spill or release contingency planning arrangements [11].

4.4.3.1 Oil Pollution Emergency Plan

A BEIS approved Oil Pollution Emergency Plan (OPEP) for the Brent Field system (including Penguin) is in place which is in accordance with the Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) Regulations 1998 and the Offshore Installations (Emergency Pollution Control) Regulations 2002. The Brent Field System and Associated Pipelines Offshore OPEP (3149-010) details the response strategy to worst case scenarios including a complete release of Brent B cell contents. The response strategy incorporates areas such as transboundary arrangements, the resources available (onshore and offshore) to deal with releases, dispersants available on the standby vessel, and membership of Oil Spill Response Limited (OSRL).

Within the Brent Field OPEP, Shell recognises three tiers, or categories, of oil spill incidents. A Tier 1 spill is for smaller spills, the response to which is normally undertaken from the resources at the Field System under the command of the OIM. When these resources are insufficient to counteract the oil spill, Tier 2 and/or Tier 3 resources can be sought via the onshore Emergency Response Team. Examples of these additional resources include the use of air surveillance, assessing if dispersant is required or utilising an emergency response team depending on the spill size. All these details and step by step guides including a Bonn Agreement Oil Appearance Colour Code Sheen Assessment table are detailed in the Brent Field System and Associated Pipelines Offshore OPEP (3149-010).

As the Brent Field OPEP worst case scenarios are based on operational platforms which will have a higher crude oil quantity than non-operational platforms, possible releases due to decommissioning activities are appropriately covered under the OPEP. In addition when new decommissioning activities are planned, the Brent Field OPEP is updated to include the appropriate actions and approved by BEIS before the activity takes place.

4.4.4 Checking

Monitoring is essential for the measurement of performance and effecting new measures and targets for continual improvement. Performance is measured to satisfy both regulatory requirements including compliance with environmental consents, as well to identify progress/fulfilment of project objectives and commitments. Measuring performance involves monitoring of waste, emissions, effluents and chemical discharges.

Commitment to continuous improvement in environmental performance underpins the Shell BMS. The Company monitors a range of environmental performance indicators and these are used to set improvement targets for important emissions and discharges that are considered to be significant. Proposed activities and operations are reviewed against these targets, enabling technical and operational controls to be identified and implemented.

Emissions and discharges associated with the Brent Decommissioning Project will be monitored as part of Shell's environmental measurement and monitoring programmes. Results will be used

to review the environmental performance of the facilities, take appropriate corrective actions and apply these to future operations and activities.

Performance reports are provided to the authorities, via the Environmental Emissions Monitoring Scheme (EEMS) and to the Shell Group as required. These requirements are identified in this ES.

Environmental considerations are integrated into audit programmes that address all aspects of Shell's business. Project reviews and installation audits and inspections conducted by Shell, the regulatory authorities and Verification Bodies, help to ensure that standards are being maintained and corrective action is taken where necessary.

4.4.5 Management Review

The leadership teams throughout Shell carry out regular reviews of the SCF and BMS. The reviews take into account any relevant matters including the findings of audits, non-conformances and environmental performance and the output of these feed into the HSSE Improvement Plans. HSSE & SP Management System and its individual elements are reviewed on a regular basis to assess the effectiveness and adequacy of the management system in delivering the policy and objectives and driving continual improvement. During the planning and operational phases of the Brent Decommissioning Project, the Project Director is responsible for ensuring that the BMS and its supporting manuals, standards and procedures are applied to all activities.

4.4.6 Brent Decommissioning Project HSSE Plan and Environmental Commitments

A Brent Decommissioning Project HSSE & SP Activity Plan has been developed which outlines how HSSE issues are managed and how Shell's HSSE policies and BMS requirements are implemented effectively throughout the project. The HSSE Plan will apply to all work carried out on the Brent project be it onshore within offices or construction sites, or offshore on vessels.

The register of environmental commitments for the Brent Decommissioning Project are compiled and incorporated into the Brent Decommissioning Project HSSE & SP Activity Plan. The commitments are driven by Shell's environmental policy objectives, taking into account lessons learned both in UK upstream operations and business wide. The commitments provide direction for the project, to comply with environmental legislation, and meet environmental performance targets in accordance with Shell Group requirements throughout each phase of the Brent Decommissioning Project.

The environmental risks that are identified during the HSSE Control Framework checks, the ORP stages and under the EMS of the project and sub-projects are managed through the creation of risk registers, procedures and Work Instructions. While the Brent platforms are undergoing preparation for decommissioning there are several procedures and work instructions in place to ensure environmental aspects are managed during the platform's ongoing operation and maintenance; examples of these procedures include (but are not limited to):

- Brent platforms POPMs (Platform Operating Procedures Manual) which will include details on how to manage oil in water overboard, flaring, venting and chemical management
- Offshore Waste Disposal Procedures Manual - Northern North Sea and Central North Sea
- Offshore Oil Pollution Emergency Plan - Brent Field System (includes Penguins)

- Shell UIE UK Radiation Local Rules
- Standard Methods – Includes details on the correct methodology for sampling oil in water analysis as per permit requirements
- Bunkering of diesel from a supply vessel (SUKEP-71.WI.75.01)
- Handling and storage of hazardous substances (SUKEP-71.WI.20.62)
- Monitor and control oily discharges to sea (SUKEP-71.WI.20.60)

In preparation for decommissioning the major engineering activities/changes to be made on the platform will be detailed in a workpack. The workpack preparation includes a Safety and Environmental screening exercise, the actions from which will be closed out before work begins. Workpacks with possible environmental aspects are also reviewed by a Shell environmental specialist to ensure that all environmental risks have been identified and are being managed.

4.4.7 Contractor Interface

Contactors undertake a number of activities with Shell. Contactor competency is reviewed first at the tendering stage where checks are made as to whether contactors have received the level of training required and have the relevant qualifications. Shell Upstream International Europe has a Standard for Contractor HSSE management which provides a framework for:

- Defining key roles and responsibilities
- Assessing HSSE risks and contractor capability
- Managing of the contract
- Analysing and improving contractor HSSE performance

Once contactors have been identified HSSE interface documents are set up between Shell and their contractors to ensure that Shell UK Ltd.'s HSSE & SP policy is effectively communicated and implemented. These interface documents are held by the relevant HSSE manager, agreed by all parties and periodically reviewed. An assurance programme, including a comprehensive plan of environmental audits is in place to monitor contractor competence and standards with regards HSSE management and effective delivery of Shell's HSSE policy objectives.

5. EIA METHODOLOGY

This section describes the EIA process followed in producing this Environmental Statement, and then provides more detailed descriptions of the main stages of the process.

5.1 General DNV GL EIA Approach

Table 5-1 provides an overview of the EIA process, and includes comments specific to this Brent Field Decommissioning ES.

Table 5-1: EIA Stages

Stage	Description	Section in this report
Screening	Screening involves determining whether or not a proposed project requires detailed assessment in an EIA. In accordance with the DECC Guidance Notes on Decommissioning the Brent Field Decommissioning Programmes require an EIA.	-
Scoping	Scoping of the EIA allows the project to identify the issues and impacts to be addressed. DNV GL finalised a Scoping Report in May 2011 that was made available to the public.	5.2.1
Project Description	The ES should include a description of the project including size, location, timetable, nature.	2, 7
Analysis of Alternative Options	The project should consider alternative options, and include environmental considerations in the decision-making process.	8 – 15
Environmental Baseline Review	The collection of environmental baseline data from literature and field measurements; and may also include discussions with relevant local authorities, and other stakeholders.	6
Legislative Review	A review of local, regional, national and international environmental legislation that could affect the proposed project.	3
Impact Assessment	Prediction of the environmental impacts associated with the project, and comparison against relevant criteria.	8 – 15
Impact Mitigation	Development of controls that can be used to mitigate significant or uncertain impacts. Mitigation measures may require redesign of elements of the project.	8 – 15
Environmental Management Plan	Development of mitigation measures into a management plan.	Refer to Shell DP
Environmental Monitoring Programme	Development of an environmental monitoring programme to verify that estimated impacts are as predicted.	17
Reporting	Reporting of the EIA process, via an Environmental Statement (ES) which clearly and impartially documents the impacts of the project, the proposed mitigation measures and the significance of the effects. The ES must be suitable for describing the project to the general public, stakeholders and decision-makers.	This report
Review	Review of ES by regulator to determine if the report is a satisfactory assessment of the project, and contains the information required for decision-making.	BEIS
Project Implementation	Regular environmental monitoring reviews should take place. Significant deviations from expectation may require retrofitting/modification of the project as well as more consultation with the authorities and interested and affected parties.	Shell

Throughout the EIA process, DNV GL liaised with the Shell Project Team to understand the condition of the facilities, the possible decommissioning options and how these options could be executed. DNV GL made Shell aware of the significance of potential impacts being identified by providing regular feedback so that, where necessary and feasible, project plans could be amended.

The scope of DNV GL's work for the BDP includes all stages up to and including 'Reporting'. The regulator (BEIS) and Shell are responsible for the 'Review' and 'Project Implementation' stages, respectively.

5.2 Specific Methodologies

This sub-section describes two of the main EIA stages mentioned in the table above:

- Scoping methodology
- Impact assessment methodology
  - DNV GL impact assessment matrix
  - Energy and emissions methodology
  - Assessment of legacy impacts

5.2.1 Environmental Scoping

The objective of the scoping exercise was to identify the potential impacts to be examined within the EIA. An outline of the environmental scoping approach and output is presented below.

5.2.1.1 Approach to Environmental Scoping

The methodology used in the scoping process was based on the *European Commission (EC) Guidance on EIA Scoping June 2001* [12], which provides a structured and recognised approach to identifying significant impacts from the project. The EC guidance can be found at the following site:

http://ec.europa.eu/environment/eia/eia-guidelines/g-scoping-full-text.pdf

Using the EC Guidance on EIA Scoping and checklists, a structured discussion was held for each facility to evaluate the impacts of the decommissioning options. The Scoping Checklist in the EC Guidance is in two parts:

1. The first part of the Scoping Checklist provides a list of possible project characteristics which could give rise to environmental effects. The user is prompted to first consider whether the project is expected to involve any of the activities or features listed in the checklist and to answer with:

   - yes - if the activity is likely to occur.
   - no - if the activity is not expected to occur.
   - ? - if it is uncertain whether the activity will occur or not.

   If the answer to any question is 'Yes' or '?', the user then considers which characteristics of the surrounding environment could be affected by that activity and the results are entered in the checklist. If the answer is 'No', this is recorded and is not considered any further.

2. For the second part of the checklist, consideration is given as to whether an impact is likely to be significant. DNV GL used the *EC Guidance Checklist of Criteria for Evaluating the Significance of Environmental Effects* as a workshop prompt, but experience and expertise were the main tools in evaluating the potential significance of environmental effects.

5.2.1.2 Scoping Workshop

In May 2010, an internal DNV GL scoping workshop was held in Stavanger, Norway and was attended by a multidisciplinary team of DNV GL environmental personnel (Shell were not involved in the workshop). The purpose of the scoping workshop and subsequent Scoping Report was to identify potential environmental impacts associated with Shell's proposed decommissioning options.

Environmental baseline documents and background information on the facilities were reviewed and summarised to provide the context for the workshop.

For increased quality assurance, DNV GL compared the findings of the scoping workshop against findings from similar previous EIA studies of offshore decommissioning projects. Also, DNV GL ensured that input from Shell stakeholders was captured.

The potentially significant impacts identified during the workshop are presented in the *DNV GL Environmental Scoping Report for Brent Field Decommissioning EIA, Rev 5, 24 May 2011*[13], which is available on Shell's website at the following link.

http://s05.static-shell.com/content/dam/shell-new/local/country/gbr/downloads/pdf/upstream/brent-field-scoping-report.pdf

The output from the scoping workshop was used to inform DNV GL's environmental assessment. Any modifications to the decommissioning options following publication of the scoping report have been taking into consideration in this ES.

5.2.2 DNV GL EIA Methodology

The following subsections describe DNV GL's EIA methodology.

The Brent Field comprises a large number of facilities (topsides, jacket, GBS, cell contents, drill cuttings, pipelines, subsea structures), and there are a number of different decommissioning options under consideration (leave *in situ*, partially remove, complete removal etc.), and each decommissioning option needs to be evaluated against a range of environmental and socioeconomic categories, shown in Table 5-6. This results in a large number of impact assessment matrices (Appendix 1).

> The intention of the proposed methodology is not to assess all impacts in detail. The main objective is to seek to distinguish the important environmental impacts from those that are less important, so that focus can then be given to those issues considered to have greatest potential for impact, such that decision-making is facilitated and differences between decommissioning options are highlighted.

After DNV GL assessed the environmental impact of all the decommissioning options, Shell used the output to feed into a ‘Comparative Assessment’ to help select a preferred decommissioning option based on a number of factors including technical, safety, environmental and economic. Then DNV GL focussed more specifically on the decommissioning options selected by Shell.

The significance of the impact for a particular decommissioning activity is dependent on two considerations:

1. the ecological value/sensitivity of the receiving environment (this is allocated after consideration of the environmental setting, see Section 8), and
2. the scale of the effect of the impact resulting from the activity

The two are combined to provide an assessment of the environmental impact of the activity.

The following modelling and calculations have been performed to support the EIA process to help predict the scale of effect. Existing criteria have been used where available (e.g. OSPAR thresholds for drill cuttings).

- Underwater noise modelling
- Modelling of the exposure of cell water and sediment to the marine environment
- Modelling of the releases to the marine environment from dredging and mass flow excavation of drill cuttings
- Calculations to estimate CO_2, NO_x and SO_x emissions

The impact is evaluated qualitatively in some cases. In some instances, there are no criteria available, and in these cases DNV GL made internal professional judgement, for example by comparison against benchmarks.

5.2.2.1 Description of impact assessment stages

There are three stages in the EIA methodology developed by DNV GL, as follows:

1. General description of the receiving environment

The value or sensitivity of an area or environmental receptor is evaluated based on information in the Environmental Setting (see Section 6). The value or sensitivity may be categorized in two ways:

Conservation / ecological value: A resource having a high conservation value is considered more important to protect than a resource with a lower conservation value. Further, a high conservation value often reflects a high scientific importance due to high abundance on a local/regional scale and/or rarity on a regional/global scale.

Economic value: Economic value is reflected, for example, by annual fisheries income, or the value of materials (e.g., recycled steel) brought to shore.

An example of both ecological value and economic value is given in Table 5-2.

Table 5-2: Example of the Value of Natural Resources or Fisheries

Value	Status and interest of conservation	Economic value of demersal fisheries per ICES rectangle per annum
Low value	Not a protected area	Less than £500,000
Medium value	Protected or proposed/considered for protection + of interest nationally	Between £500,000 and £2 million
High value	Protected or proposed/considered for protection + of interest internationally	Greater than £2 million

It is possible that a receptor may have a low conservation value but a high economic value; in this instance, the value selected should relate to that which is potentially impacted by the effect.

2. Scale of effect

The scale of effect from the decommissioning activity upon the environment should, as far as possible, be based on scientific documentation. The scale of the effect is then evaluated, ranging from high negative to high positive.

Several criteria can be used to assess the scale of effect (the criteria used are dependent on the effect under consideration, hence they will differ from one issue to another, and all the criteria will not be applicable for all the aspects):

- *Classification of substances*. Formalized criteria for classification of substances as dangerous for the environment have been adopted in the European Union (Directive 67/548/EEC). Detailed specific criteria for the aquatic environment have been elaborated based on:
    - Acute toxicity
    - Biodegradability
    - Bioaccumulation
- *Magnitude*. This is a measure of the extent to which the activity affects the receptor (e.g. area of seabed affected, percentage of receptors affected, quantity of pollutant released etc.).
- *Permanence*. This defines whether an exposure is temporary or permanent, and should be seen only as a measure of the temporal status of the effect.
    - No change / not applicable
    - Temporary
    - Permanent
- *Cumulative*. This is a measure of whether the effect will have a single direct impact, whether there will be a cumulative effect over time or a synergistic effect with other impacts.
    - No change / not applicable
    - Non-cumulative / single
    - Cumulative
    - Synergistic

- *Recovery time.* Emissions and other sources of impacts may cause many types of ecological effects, on many different organisational levels (e.g., tissue, organ, individual, population, community). It is a general scientific opinion that in order to classify the effects as significant they must be measurable at the population or community level [14]. Further, the parameter recovery time is widely adopted as a general and overall parameter that is appropriate for classification of the significance of ecological effects.

Table 5-3 below provides examples of the criteria used when assessing the scale of effects for relevant activities of the Brent Decommissioning Project. The criteria are project specific and are not intended to be precise, but were used to help differentiate between the numerous decommissioning options, such that focus could then be given to the more significant impacts. In many cases the thresholds in the table are arbitrary (in the absence of regulatory thresholds).

Table 5-3: Examples of criteria for evaluating 'Scale of effect'

High positive	• Recycling of more than 100,000 t of material with value • Creation of more than 9,000 man-years employment
Medium positive	• Recycling between 45,000-100,000 t of material with value • Creation of between 3,000-9,000 man-years employment
Low-medium positive	• Recycling of between 7,000-45,000 t of material with value • Creation of between 400-3,000 man-years employment
Low-none	• Less than above or below • No legacy impact
Low-medium negative	• Significant volumes of solid materials (7,000-45,000t steel) come onshore for dismantling; operations last for months/year • Large volumes of slurry (10,000-80,000t) or dewatered sludge (1,000-8,000t) wastes arrive onshore for processing and subsequent onward road transport • Smothering or polluting small areas (~100 m^2) of non-unique marine receptors, including some lethal effects, from e.g. anchor damage, dredging. Reversible impact. • Minor temporary disturbance to receptors due to underwater noise • Free passage restricted to ships and/or fishermen for indefinite period due to continued existence of safety zones at one location • Localised long term impact from drill cuttings (that satisfy OSPAR) left *in situ*
Medium negative	• Large volumes of solid materials (e.g. 45,000-100,000t steel) come onshore for dismantling; operations last for years • Large volumes of slurry (80,000-600,000t) or dewatered sludge (8,000-60,000t) wastes arrive onshore for processing and subsequent onward road transport • Smothering or polluting areas (~1 hectare) of non–unique benthic environment; reversible impact. Rock dumping similar areas. • Dredging ~12,000m^3, or water jetting up to 1,000 m^3, of non-unique seabed area containing drill cuttings • Free passage restricted to ships and/or fishermen for indefinite period due to continued existence of safety zones at several locations
High negative	• Very large volumes of materials (more than 100,000t steel) come onshore for dismantling; operations last for years • Very large volumes of slurry (more than 600,000t) or sludge (60,000t) wastes arrive onshore for processing and onward transport • Dredging ~ 30,000m^3 of non-unique seabed areas containing drill cuttings • Smothering or polluting areas (>1km^2) of non-unique environment; reversible impact. Rock dumping similar areas. • Free passage restricted to ships and/or fishermen for indefinite period due to continued existence of safety zones covering 10's of square kilometres.

Decommissioning activities are assessed for each environmental category for each facility. The relevant criteria are applied and the overall scale of effect is presented per facility per category, with focus on the most important drivers.

When assessing the scale of effect, DNV GL (i) identified ‘standard’ mitigation measures that would normally be applied by the oil and gas industry to the type of activities or operations undertaken in the decommissioning programme; and (ii) confirmed that Shell and their contractors would apply these standard measures, when planning or executing the various stages of the work both offshore and onshore.

3. Determination of overall impact for each environmental and socioeconomic category

By combining 1) and 2) in the impact matrix found in Table 5-5 and Figure 5-1, the overall significance of the impact can be predicted. The scale of effect is represented on the left vertical axis of the figure and can range from ‘high negative’ through ‘low’ to ‘high positive’. The sensitivity of the receiving environment is represented on the top horizontal axis and can range from ‘low’ to ‘high’.

Combining the two produces a defined area as shown on Figure 5-1. This indicates the magnitude of the impact, as defined on the right vertical axis. The magnitude of the impact can range from ‘very large negative’ to ‘very large positive’. A ‘small-moderate negative’ or ‘moderate negative’ impact may require additional mitigation to minimise residual impacts further; a ‘large negative’ impact will require additional mitigation to minimise residual impacts. The categorisation of impacts is provided in Table 5-4 to help provide additional understanding to the assessment.

Table 5-4: Categorisation of Impacts [1]

Large negative[2]	A significant and unacceptable impact that may affect regional populations, ecosystems or local populations of high value environmental receptors. Additional mitigation is necessary.
Moderate negative[2]	A local impact which will occur over a larger area or over a greater time period than impacts categorised as ‘small-moderate’ negative. Additional mitigation may be recommended to minimise residual impacts further.
Small-moderate negative[2]	A local impact which will occur over a larger area or over a greater time period than impacts categorised as ‘small’ negative. Additional mitigation may be recommended to minimise residual impacts further.
Small negative[3]	A minor localised and reversible impact which will typically be reversible in less than one year.
Insignificant / No impact[3]	An impact with negligible effect, or no effect. It may result in changes to the environment or local populations that are indistinguishable from natural variations that occur from time to time, which are fully reversible and have no long-term detrimental effects on local populations or ecosystems.
Positive	An impact that provides some beneficial effect (as a result of, for example, recycling steel or generating employment).

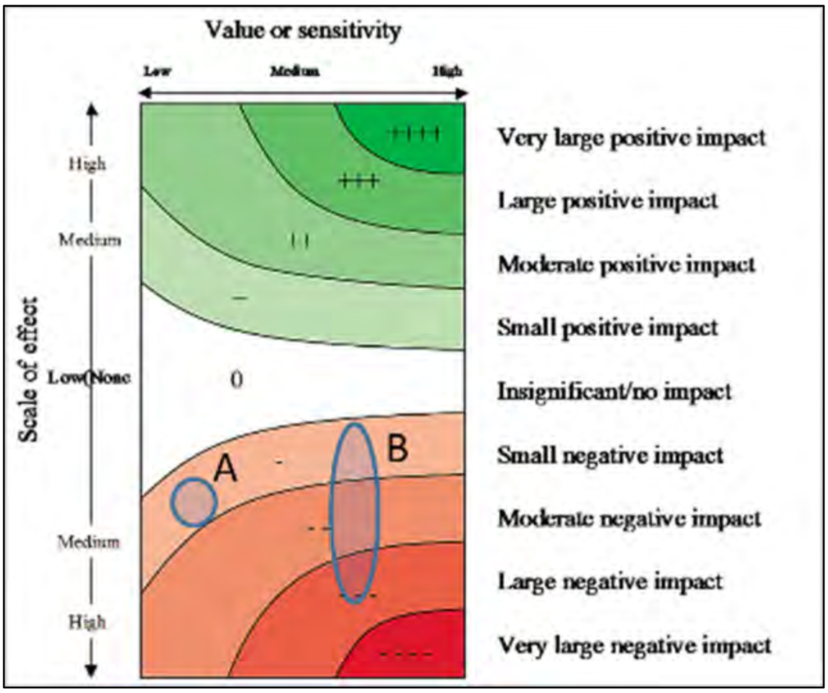
Note:

1. E&E categories are not described here but in Table 5-7
2. Impact categories larger than ‘small’, as well as being presented in Appendix 1, are presented and discussed further within the body of this ES, as they are the main contributors to environmental impact. The same is true for positive impacts.
3. These impact categories are presented only in Appendix 1 as they are not the main contributors to environmental impact. The mitigation measures necessary to control them to small negative or less are captured.

Table 5-5: Example Impact Assessment Matrix

<table>
<tr><td colspan="2">Facility and decommissioning activity
Consequence evaluation for: (Socioeconomic and Environmental category e.g. Marine)</td></tr>
<tr><td colspan="2">1. General description of the receiving environment (situation and characteristics)</td></tr>
<tr><td colspan="2">Describe the basis for evaluating value or sensitivity of an area. What are the facts, literature sources or statements this is based upon. Indicate further factors considered more important than others in arriving at this conclusion.
Evaluation of the value:
Low Medium High
|----------|----------|
X</td></tr>
<tr><td>2. Description of the scale of effect</td><td>3. Total (environmental) impact</td></tr>
<tr><td>Describe the scientific information and data the assessment is based on. Describe further how it is interpreted in this context. What has been given highest priority, and why?
Document the reasons for the conclusions.
Evaluation of scale of effect:
High neg. Medium neg. Low/none Medium pos. High positive.
|--------------|-----------------|---------------|------------------|
X</td><td>Combine 1) and 2) in the impact matrix. The total impact can then be identified, and stated here.
The impact can range from ‘very large negative’ to ‘very large positive’.</td></tr>
</table>

Figure 5-1: Example Impact Assessment Matrix



Point A = low uncertainty.

Point B = high uncertainty in the scale of effect, low uncertainty of sensitivity of receiving environment.

It is worth noting that:

- The same scale of effect may give a different impact depending on the value or sensitivity of the recipient/environment.
- The size of the circle signifies the uncertainty in the assessment of the impact. In the example above, Point A has a small negative impact and a relatively low level of uncertainty, as indicated by the small circle. The value or sensitivity (x-axis) is well defined, and the scale of effect (y-axis) is robust. By contrast, Point B represents a relative higher level of uncertainty, as although the value or sensitivity (x-axis) is well defined, there is a high level of uncertainty on the scale of effect (y-axis), which is shown as an elongated circle with the scale of effect ranging from 'low' to 'high'. The resulting overall impact ranges from 'small negative' to 'large negative'. Detailed planning of activities, substantial knowledge, and robust methodologies and procedures can contribute to a reduced level of uncertainty in the assessment of impacts.

5.2.2.2 Socioeconomic and Environmental Impact Categories

Table 5-6 describes what is covered within each impact category and explains the boundaries between categories as established by DNV GL to help ensure there is no double-counting when conducting the impact assessment. The impact categories include both environmental (e.g. marine, waste management) and socioeconomic categories (where consideration is given to the potential impact on the fishing and shipping industries, as well as the generation of employment). Decommissioning EIAs typically cover both categories.

Table 5-6: Description of Socio-economic and Environmental Impact Categories

Category	Description
Onshore Impacts	Onshore Impacts assess onshore impacts occurring from operations as a result of the decommissioning project such as traffic, noise, odour, dust, light and visual impacts. Coastal impacts adjacent to and resulting from, the onshore site are also included. Impacts that relate to both 'Physical' and 'Onshore Impacts' are covered under 'Onshore Impacts'. Waste management impacts onshore are assessed under 'Waste'.
Resource Use	Resource Use covers the use of materials (e.g. grillage or steel material used on platform upgrades to facilitate decommissioning). Energy use and air emissions are covered under 'Energy and Emissions'.
Hazardous Substances	Hazardous Substances covers the assessment of the handling and removal of hazardous materials present at the facilities (e.g. hydrocarbons, chemicals, asbestos, Naturally Occurring Radioactive Material NORM), or the use of hazardous materials as part of the decommissioning process (e.g. sodium nitrate). Impacts resulting from the disturbance of drill cuttings (seabed and cell top) are covered under 'Marine'. Impacts from recovering cell sediment (Options 1 and 2) are captured within other matrices ('Onshore', 'Waste management', 'Environmental risk of accidents').
Waste	The waste assessment is based on the non-hazardous material inventories for the Brent Field, and includes materials such as concrete and steel. Any hazardous materials encountered during decommissioning of the topsides are covered under 'Hazardous Substances'. Wastewater onshore is captured within 'Onshore Impacts'. Long-term waste impacts due to landfilling are covered within this category.
Physical	Physical impacts cover the offshore activities related to the decommissioning activities and relate to physical changes to the structure or substructure of the seabed as a result of the decommissioning project such as anchor pits and dredging activities. Impacts that relate to both the 'Physical' and 'Onshore Impacts' are covered under 'Onshore Impacts'. Impacts to the marine biological environment (e.g. biota, and fish) are covered under 'Marine'. Long-term impacts such as habitat

Category	Description
	change (e.g. due to rock dump) are covered under legacy.
Marine (includes underwater noise)	Marine is an assessment of impacts to the marine biological environment including benthic organisms, fish, shellfish, plankton, seabirds and marine mammals. Long-term impacts to the marine environment are assessed under 'Legacy' impacts. 'Underwater Noise' impacts on marine mammals and fish (from e.g. cutting of structures in the sea) were assessed individually and assessment results have been incorporated within the 'Marine' impacts matrices. Onshore noise nuisance is covered within 'Onshore' impacts.
Environmental Risk from Accidents	Environmental Risk from Accidents qualitatively assesses the risk to the environment from potential accidents during the decommissioning activities. The consequences from such accidents are expected to be reversible, usually delaying the schedule of the decommissioning activities. However, some failures will have the potential to impact the environment through operations (e.g. lifting) resulting in spillages of oil or chemicals (from vessels or broken pipelines) or misplaced disposal (dropped module). This is not an environmental risk assessment, and considers environmental risks from accidents only in a broad sense.
Employment	Employment assesses potential impacts to employment resulting from decommissioning activities to both onshore and offshore workforce as well as from vessels activity.
Legacy	Legacy assesses the long-term (legacy) impacts (physical and chemical) of all decommissioning activities and of leaving structures *in situ* in the sea (to eventually degrade over hundreds of years). This is an all-encompassing assessment which looks at overall long-term impacts to all environmental categories (apart from landfilling, which is captured in the 'Waste' category) and is particularly relevant for long term impacts to fisheries, the marine environment and to shipping.
Fisheries	The fisheries assessment of impacts to the fishing industry as a result of decommissioning activities considers operations such as increased marine operations and traffic affecting fishing vessels. The current state of the commercial fishing industry in the area is used as the environmental baseline. Long-term impacts as a result of leaving structures *in situ* are assessed under 'Legacy'.
Shipping	Impacts to shipping and shipping lanes resulting from operational decommissioning activities are assessed in this category. Proximity of shipping routes to the Brent platforms and ship frequency is considered, as well as projected use of decommissioning vessels. Long-term impacts to shipping as a result of leaving structures *in situ* are assessed under 'Legacy'.
Energy and Emissions (E&E)	Energy and Emissions estimates the energy use and gaseous emissions (CO_2, NO_x, SO_x) associated with the various decommissioning options. This comprises E&E from preparatory work through to material removal, offshore transport, onshore demolition, onshore transport, and the recycling of metals and other materials. In addition, the E&E associated with the replacement of 'lost' materials (materials which are either left *in situ* or disposed of to landfill and thus not recycled) is taken into account. See Section 5.2.3 for further detail.

5.2.2.3 Calibration of Impact Assessment Findings

The DNV GL project team met on two occasions (before delivery of the ES Revisions 2 and 3) for two internal 'calibration meetings' to present their draft impact assessment results, and to reach consensus. This helped minimise the element of subjectivity in the assessment, and to calibrate the findings.

The DNV GL team consisted of degree qualified engineers, scientists and environmental professionals with more than 130 years cumulative professional experience and knowledge in EIA, environmental sciences, marine biology, chemical engineering, drill cuttings, decommissioning and underwater noise. Shell had no involvement in these calibration exercises.

5.2.3 Energy and Emissions Estimation Methodology

To support the EIA, DNV GL produced an *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016*, which details the approach taken, the assumptions made, and the results.

This section briefly describes the methodology for estimating the energy and emissions associated with the various decommissioning options.

5.2.3.1 Energy and Carbon Dioxide

Energy use and carbon emissions are important indicators in the evaluation of the environmental impact of the decommissioning and disposal of ageing offshore installations. Carbon dioxide (CO_2) emissions produced when consuming energy (from non-renewable fuel) are the main global contributor to greenhouse gas emissions, which cause climate change.

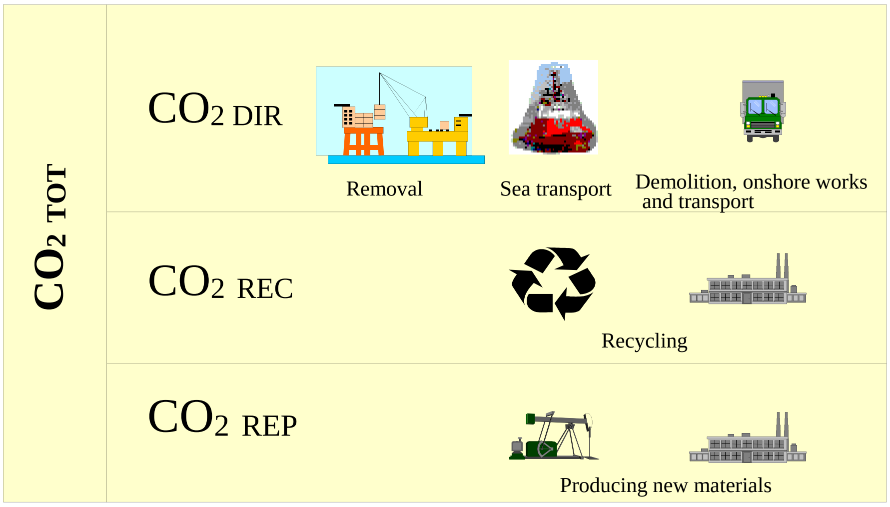
There are various ways of accounting for energy and carbon, and a wide range of input data may be used. The method adopted for this assessment is recommended as an international standard by the Institute of Petroleum [15], and was developed by DNV GL and BMT Cordah. The IoP method is based on a lifecycle approach, and offers a 'standard' way of performing the Energy & Emissions calculations. The guideline includes tables of emissions and energy factors that are now widely used in decommissioning assessments. This allows different decommissioning options to be compared in a broader perspective, and also allows for valid comparison between decommissioning programmes from different operators.

Figure 5-2 illustrates the scope of the calculation adopted in this assessment. Energy and emissions for each facility and decommissioning option were considered from the following six sources:

- *At field operations:* fuel use on the platforms/flotel during decommissioning
- *Marine operations:* fuel use by vessels
- *Onshore dismantling and treatment:* the processing of reclaimed materials onshore
- *Onshore transport:* fuel used per tonne of material transported to a processing site
- *Material recycling:* energy used to recycle materials
- *Replacement of 'lost' materials:* penalty for not recycling otherwise recyclable materials

The energy and emissions associated with the replacement of 'lost' materials (materials which are either left *in situ* or disposed of to landfill and thus not recycled), is based on generic data for mining, transportation and smelting, for example. The calculations are based on data such as durations and vessel type provided by the Institute of Petroleum [15]. For the purposes of this assessment, it is assumed that all recyclable materials are recycled.

Figure 5-2: Scope of Energy / Carbon Calculations [16]



'**Total Carbon Impact**' ($CO_{2\ TOT}$) for each decommissioning option is represented by the following formula:

$$CO_{2\ TOT} = CO_{2\ DIR} + CO_{2\ REC} + CO_{2\ REP}$$

$CO_{2\ TOT}$ = Total CO_2 impact from a global perspective

$CO_{2\ DIR}$ = CO_2 emissions due to direct energy consumption for the option (fuel, electricity)

$CO_{2\ REC}$ = CO_2 emissions due to the energy consumed by recycling/melting down metal

$CO_{2\ REP}$ = A theoretical mass of CO_2 emissions equivalent to the total emissions arising from the production of new material from virgin materials (e.g. 1 tonne of steel), where an otherwise recyclable decommissioned material is disposed of and not recycled/re-used.

The energy calculations were made for all the decommissioning options identified by Shell.

In terms of recycling "value", metals are the most important, with steel the dominant material for the BDP. Any concrete that is brought onshore is not recycled within a closed loop system, but is processed onshore and used as filling material in roads (for example, as a substitute for other filling materials). Within this methodology, concrete therefore has no "recycling energy" associated with it (but its re-use is covered under 'resource utilisation'). The energy and emissions calculations for recycling do not include concrete waste; instead this is included in "direct emissions" which consists of crushing and local transport. It is considered that the significance of energy and emissions impact of concrete processing (i.e. crushing) would be limited in comparison to steel.

The 'energy impact key' outlined in Table 5-7 has been used to categorise the energy impact and consumption of the different decommissioning alternatives (ranging from no impact to very large negative impact). It is important to note that this key was developed to evaluate significant differences between alternative options and to rank the alternatives in relative terms. The 'impact' output is not definitive and would be different if set in a different context. For example,

an energy impact defined as 'large negative' using this key might be 'insignificant' when compared against national energy consumption.

Table 5-7: Energy Impact Key [17]

Reference Unit	Energy Impact Categories				
	None/ Insignificant	Small Negative*	Small – Moderate Negative*	Moderate Negative	Large Negative
Energy (Million GJ)	<0.1	0.1-0.8	0.8-1	1-3	3-6
Energy Equivalent (Cars run in one year)	<2,500	2,500-20,000	20,000-25,000	25,000-75,000	75,000-150,000

*These energy categories have been modified slightly because the original key did not have a 'small-moderate negative' category

For comparison, the 2011 annual emissions from the Brent platforms were approximately 376,000 tCO_2e [18]. Approximately 6 million GJ of energy were consumed in 2011, which would be deemed (via Table 5-7) as a 'large negative' impact.

5.2.3.2 NO_x and SO_x Emissions to Atmosphere

Atmospheric emissions are also quantified using the Institute of Petroleum's Guidance [15]. The main emission components assessed were nitrogen oxides (NO_x) and sulphur dioxide (SO_2). Since these atmospheric emissions are not global but are local or regional in their impact potential, their environmental impact depends on the discharge location. There is also significant geographical difference in tolerance to emissions of NO_x and SO_2, related to the nature of soil and water, biota composition, and present and historical exposure to the pollutants.

NO_x forms part of the exhaust from combustion processes (e.g. ship engines and smelters for recycling metals). Emissions of nitrogen oxides (NO and NO_2) react chemically with humidity and water in the air, transforming them mainly to nitric acid ($HNO_3 \rightarrow H^+ + NO_3^-$), which will fall as acidic precipitation (acid rain). NO_x is known to cause adverse effects on vegetation and fauna, and may contribute to respiratory complaints in humans. These effects arise since NO_x contributes to the generation of acid rain, the creation of ground-level ozone, over-fertilisation and direct nitrogen precipitation. In offshore decommissioning and disposal, the vessel operations are the main source of NO_x. The majority of these operations will be offshore, and so the local effects are less relevant than when occurring onshore. The magnitude of NO_x emissions from such operations is likely to be small when compared with other offshore operations and national emission figures.

Similarly, SO_2 will also react with humidity and create acid rain. The dominant effects of acidification from SO_2 are the acidification of lakes, changes in vegetation (e.g. the disappearance of vulnerable species such as heather, peat bog-areas and lichen and moss), and the corrosion of materials (buildings, monuments etc.). With regard to offshore decommissioning SO_2 is relevant in operations involving the combustion of oil or diesel.

No assessment has been made of NO_x and SO_2 effects on specific environmental receptors, and as such NO_x and SO_2 impacts are described in terms of total quantitative emissions. This

establishes the relative differences between decommissioning options, independent of the location where emissions subsequently occur.

5.2.3.3 Global Warming Potential

Carbon dioxide, methane (CH_4) and nitrous oxide (N_2O) are the main contributors to Global Warming Potential (GWP) from man-induced sources, with the relative factor 1:21:310. In offshore petroleum activities, methane emissions are important in (e.g.) cold venting, flaring and fugitive releases during operations but such emissions are not relevant here. In decommissioning the main source of methane is from diesel engines, and the relative contribution is very low (0.0328 kg/t diesel compared with 3,200 kg/t diesel for CO_2 [19]. For nitrous oxide the emission factor from diesel engines is typically 0.22 kg/t diesel. In CO_2 equivalents, the GHG emissions from diesel engines in decommissioning hence will contribute with 97.9 % for CO_2, 2.1 % for N_2O and 0.02 % for CH_4. The uncertainty in E&E calculations are often in the range of 30-40% [17] mainly due to uncertainties in duration of operations, wait on weather etc. Methane and nitrous oxide emissions are hence not calculated because, although they have very high global warming potential, the operations involved in decommissioning will result in only very small methane and nitrous oxide emissions. The contribution of such emissions to the global warming potential of all greenhouse gas emissions from the BDP is considered to be insignificant.

5.2.4 Assessing Legacy Impacts

Many of the topics explored in this ES are not uncommon, such as waste generation and energy consumption, and they occur as decommissioning operations proceed. However, decommissioning the Brent Field also involves topics that are not ‘standard’, such as the legacy, or long-term, impact of leaving some of the Brent Field facilities in the sea. The following sub-sections discuss legacy impacts in more detail.

5.2.4.1 GBS and jacket

The OSPAR 98/3 legislation permits GBS and jacket footings to remain *in situ* provided it is satisfactorily demonstrated via a Comparative Assessment that an alternative option is preferable to reuse or recycling or final disposal on land [4]. A Comparative Assessment of alternatives is required for derogation, and would include an assessment of the potentially significant risk of accidents from moving, dismantling and disposal of the large structures). In the Comparative Assessment of alternatives, the environmental issues relating to leaving the GBS and jacket *in situ* need to be taken into account. Such an assessment should include:

- The social impacts relating to hazards and obstacles to fishing, both in the short-term and in the long-term after degradation of the structures
- Other environmental issues relating to the degradation of structures, such as impacts relating to the exposure of GBS contents to the marine environment (if left *in situ*)
- The need for adequate maintenance and long-term monitoring of the *in situ* structures
- The long-term liabilities

The considerations above have been taken into account in this ES.

5.2.4.2 Drill cuttings

The requirements of OSPAR Recommendation 2006/5 have been taken into account in this ES (as described in Section 3.1.2).

5.2.4.3 Pipelines

Pipelines are not covered by OSPAR Decision 98/3, but a framework for the orderly decommissioning of offshore pipelines is provided by the Petroleum Act 1998.

DECC Guidance Notes on Decommissioning state that all feasible decommissioning options for pipelines should be considered and a Comparative Assessment made. The Comparative Assessment should include, for example, the long-term issues of leaving the pipelines *in situ*, and the physical impacts on seabed habitats and fauna as a result of dredging, rock dumping, trenching, etc.

Any decision to leave pipelines *in situ* should have regard to their likely long-term deterioration and the possible future effects on the marine environment (i.e. legacy effects), that includes the potential future impacts upon fisheries (a key impact is often fishing gear interactions).

These considerations have been taken into account in this ES.

6. ENVIRONMENTAL SETTING

6.1 Introduction

Decommissioning the Brent Field facilities will involve operations offshore at the Brent Field, but also nearshore and onshore at the Able Seaton Port (ASP) facility in Teesside, on the north-east coast of England. The ASP facility is an onshore dismantling facility operated by Able UK Limited (Able).

In order to understand the environmental setting for the BDP, this section describes the environmental status of the following areas:

- The offshore project area at the Brent Field (Sections 6.2 - 6.8)
- The offshore transit route that will be taken by a SLV to transport some of the facilities from the Brent Field to a nearshore transfer location (Section 6.9)
- The nearshore transfer location where some of the Brent facilities (e.g. topsides) will be transferred from the SLV to a cargo barge for transportation to shore (Section 6.9)
- The onshore dismantling site and the surrounding environment, both onshore and nearshore (Section 6.10)

A significant amount of work has been conducted by Shell and its consultants in assessing the environmental baseline of the Brent Field, and this work is summarised in this section and has been reproduced in some instances. A report by BMT Cordah, *Brent Decommissioning Project Environmental Setting including Brent Field, Transportation Route, Transfer Area and Onshore Destination* 2015 [20] provides a detailed summary of the offshore and natural environment at the Brent Field and surrounding areas, the proposed transfer route from the Brent Field to the onshore dismantling facility, and the area surrounding the nearshore transfer location, and this report is used as the basis for this Section. Several additional studies and data have been used by DNV GL and these are introduced and referenced throughout.

This section is set out as follows:

1. Offshore physical and chemical environment at the Brent Field: covering meteorology, oceanography, marine sediment composition, drill cuttings, subsea debris
2. Offshore natural resources: covering benthic fauna, coral, fish, shellfish, marine mammals and birds
3. Fisheries activity
4. Oil and gas infrastructure surrounding the Brent Field
5. Shipping in the vicinity of the Brent Field
6. Wrecks, military activities and subsea cables
7. Environmental setting of offshore transit route and transfer location
8. Description and environmental setting of onshore dismantling facility

6.2 Offshore Physical and Chemical Environment at the Brent Field

Subsections 6.2.16.2.1, 6.2.2, 6.2.3.1 and 6.2.3.2 draw on the 2015 BMT Cordah report [20], which includes information from other earlier studies. These subsections describe the offshore

physical and chemical environment at the Brent Field. The UKCS blocks covered in the scope of these reports and thus in the following sections are Block 211/29: the Brent platforms, Blocks 211/29, 211/28, 211/27 and 211/26: the Brent C to Cormorant Pipeline, and Block 3/4a: the Brent South subsea facilities.

6.2.1 Meteorology

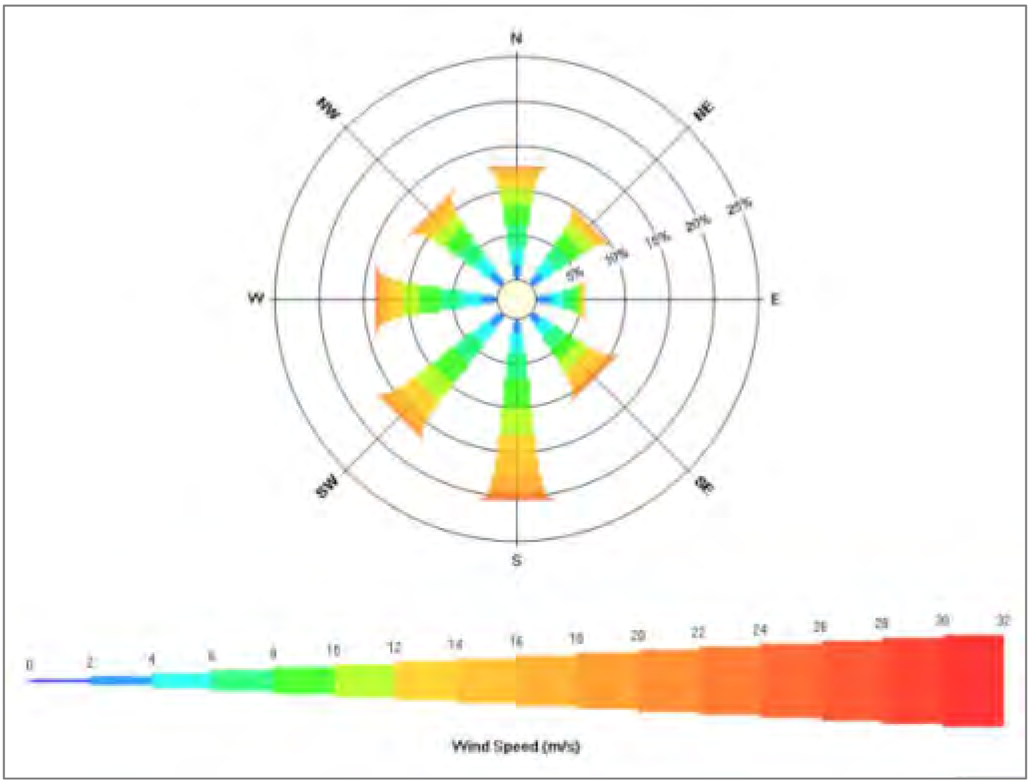
The North Sea is situated in temperate latitudes with a climate that is strongly influenced by an inflow of oceanic water from the Atlantic Ocean, and by a large-scale westerly air circulation which frequently contains low-pressure systems. The North Sea climate is characterised by large variations in wind direction and speed, significant amounts of cloud cover, and relatively high precipitation.

Weather patterns in the NNS, including the area around Block 211/29, are highly variable throughout the year, although there are seasonal trends in both wind speed and direction. Winds in this region of the North Sea are most frequently from south to south-westerly directions, as indicated in Figure 6-1.

Predominant wind speeds throughout the year are equivalent to moderate to strong breezes (approximately 6-13 m/s). Winds speeds greater than 28m/s mainly occur during the winter months (September to March), and no dominant wind direction is observed. Wind speeds during the summer months (May to August) are generally lower, ranging between 5-14 m/s, and the dominant wind direction originates mainly from the south and south-west.

Visibility was measured on Brent B; the likelihood of visibility of less than 1km from Brent B was found to be approximately 1.0%.

Figure 6-1: **Annual Mean Wind Rose at 10 m above Sea Level for the Brent Field Area [20]**



6.2.2 Oceanography

6.2.2.1 Seabed Topography

Seabed topography is important in relation to the circulation and vertical mixing of the water masses. The rectangular basin of the North Sea is relatively shallow (30-200 m), with a shelving topography north to south and a deep trough, the Norwegian Trench (around 700 m depth), on its north-east margin.

Water depths around the Brent platforms range from 138 m Lowest Astronomical Tide (LAT) to 145 m LAT. The average seabed gradient is less than 0.1^{o}.

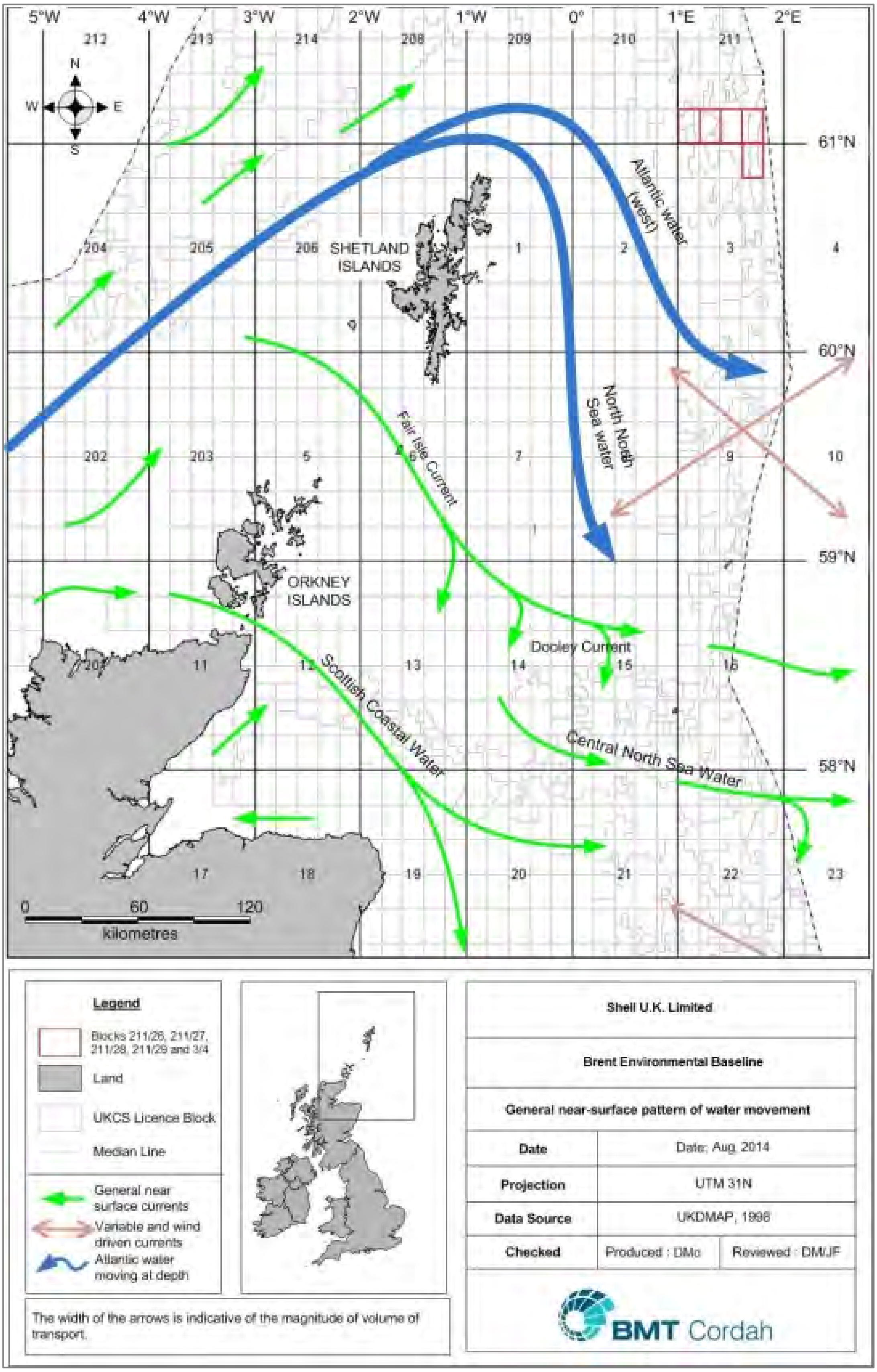
6.2.2.2 Water Masses

Several different water masses have been classified in the North Sea, based on temperature and salinity distributions or on residual current patterns or stratification. The circulation and distribution of these water masses are important in determining the biological productivity, transportation and concentration of plankton and fish larvae, as well as the distribution and circulation of potential contaminants.

The major water masses in the North Sea are shown in Figure 6-2, and are classified as Atlantic water, Scottish Coastal water, NNS water, Norwegian Coastal water, Central North Sea water, Southern North Sea water, Jutland coastal water and Channel water. The Brent Field is located in area influenced by the NNS water mass.

Fronts or frontal zones mark boundaries between water masses, including tidally-mixed and stratified areas, of which there are numerous such areas in the North Sea. Fronts may restrict horizontal dispersion and are often associated with increased biological productivity.

Figure 6-2: General Near-surface Water Circulation around the Brent Field Area [20]



6.2.2.3 Currents

Currents in the NNS are illustrated in Figure 6-2, and are largely affected by an inflow of Atlantic water around the north of the Shetland Islands. The currents follow the 200m depth contour to the north of the Shetland Islands, before passing southwards towards the western edge of the Norwegian Trench.

The Norwegian Coastal Current, which flows predominantly along the Norwegian coast, constitutes the only outflow from the North Sea and balances the various inputs of water to the North Sea.

Circulation in the North Sea is driven by a combination of winds, tidal forcing and topographically-steered inflows. Maximum surface tidal streams vary from 0.25 to 0.5 m/s over most of the NNS, and are in excess of 1.0 m/s around the Orkney and Shetland Islands. Average tidal currents at the Brent Field range from 0.1 m/s (neap tides) to 0.2 m/s (spring tides). The prevailing seabed currents around Brent run in a north-south direction.

The severe gales and storms that can commonly occur in this area result in variable, wind-driven surface currents and oscillatory currents at the seabed.

Anatec has summarised a wave height exceedance curve for the Brent Field, showing that the frequency of the wave height exceeding 5 m is 11.2% [21].

6.2.2.4 Temperature and salinity

Water masses in most of the North Sea are vertically well-mixed, and water temperature remains uniform through the water column during winter months, with an average of 7.75°C at the sea surface and 7.25°C at the seabed. During spring, as solar heat input increases, a thermocline (a pronounced vertical temperature gradient) develops, which separates the warmer, lighter surface layers (average of 13.5°C) from the colder, heavier, deeper layers of the water column (average of 8°C).

In the open waters of the North Sea, seasonal changes in sea surface salinity are comparatively small, with surface salinity approximately 35 parts per thousand.

6.2.3 Marine Sediment

6.2.3.1 Sediment Composition

The nature of the local seabed sediments plays an important role in determining the composition, diversity and abundance of benthic flora and fauna. Seabed sediments provide habitats and a food source for benthic fauna which, in turn, are preyed upon by other species such as fish and shellfish. See Section 6.3.2 for further description of benthic fauna.

Seabed sediments over the majority of the North Sea are sand or mud, or a mixture of the two. Data on broad scale sediment distribution indicates that the area around Block 211/29 is dominated by sand.

Sediments at the Brent Field consist of moderately well sorted, fine to very fine sands, which contain a relatively low proportion of organic matter and coarse material, with moderate amounts of fine and shelly material. The 2006 Gardline Geosurvey debris and habitat surveys involved seabed surveys of 15 km x 4 km covering the Brent Field and the four platforms [22]. The surveys indicate that the area is predominantly sand, with occasional clay exposure. There are also some scattered cobbles and boulders up to 0.4 m in height, in increasing frequency in the northerly direction. In addition, evidence of boulders and sediment clasts (rock fragments)

dropped during anchor pull out are found throughout the Brent Field, and in areas of frequent clay exposure are found to be more numerous. The seabed debris found during the survey is described in Section 15.3.2.

Sediment characteristics have an influence on heavy metal content, because finer sediments and sediments with a high organic content tend to exhibit higher concentrations of metals and hydrocarbons. Organic matter can also adsorb heavy metals and hydrocarbons, transporting them into the sediments. Brent Field sediments, however, consist predominantly of well sorted fine sands with only a low proportion of silt / clay and organic matter as discussed above. This implies that generally the sediments at the Brent Field are not characteristic of those prone to adsorbing hydrocarbons or heavy metals.

6.2.3.2 Marine Sediment and Drill Cuttings Characteristics

The main source of heavy metal and hydrocarbon inputs from offshore oil and gas activities is the historical discharge of drill cuttings contaminated with drilling muds. Drill cuttings are rock fragments that were generated by the drill bit during drilling, and were historically contaminated with drilling mud which was used to lubricate and cool the drill bit, maintain pressure, and to transport cuttings back to the topside for separation prior to discharge. Shell has historically used both oil-based mud (OBM) and water based mud (WBM) drilling fluids.

OBM is a drilling fluid composed of oil, water and other additives such as emulsifiers and wetting agents which is used during drilling for lubrication, maintaining pressure and flushing out drill cuttings. OBM was traditionally used until a ban on its discharge to the marine environment was imposed by PARCOM in 1992. WBM is a drilling fluid in which water is the major liquid phase.

The discharge of OBM drill cuttings was allowed until the introduction of PARCOM Decision 92/2 which prohibited the discharge of untreated cuttings contaminated with OBM. Shell ceased the discharge of OBM contaminated cuttings in 1998 but following the introduction of new technologies Shell began the discharge of OBM contaminated cuttings in line with OSPAR 2000/3 which superseded the PARCOM decision.

Early environmental surveys of the Brent Field from 1977-1995 measured the metal and hydrocarbon contamination of sediments. These surveys found that elevated concentrations of contamination were mainly localised and decreased with increasing distance from each of the platforms, in a pattern typical of that found around other North Sea installations. Sediment metal concentrations declined markedly between 200-500 m from the discharge point, and with the exception of barium, returned to near reference station concentrations at a distance of 1,000 m. Barium, not a parameter of great toxicological concern, remained elevated at distances between 2,500-5,000 m because of high proportions of residual barite associated with drilling muds discharged with the cuttings. Diesel and low toxicity base oils, used in earlier drilling operations, were evident in sediments closer to the platforms cuttings piles.

More recent surveys have been conducted to define the current environmental status of the marine sediment and drill cutting piles, as described below.

6.2.3.3 Brent Field Seabed Surveys

In 2007, Gardline Environmental conducted environmental surveys at each of the Brent platforms and at Brent South [23, 24]. Details of these surveys are discussed by platform in Sections 6.2.3.4 to 6.2.3.8.

The surveys covered the area on and around the drill cuttings piles as well as distances between 500-2,500 m away from the platforms. Reference stations included in the survey were located up to 19,000 m away from the platforms.

The purpose of the Gardline surveys was to establish baseline information for the OSPAR Stage 1 screening of the Brent Field drill cuttings piles (see Section 3.1.2). In addition, the surveys aimed to establish the current environmental condition of the areas surrounding the platforms and to assess the degree of sediment contamination at different distances from the cuttings piles. The survey results do not predict future conditions.

The general protocol described in OLF '*Guidelines for Characterisation of Offshore Drill Cutting Piles*' [8] was also used to establish the survey and sampling regime for the cuttings piles. The surveys assessed the volume and physical characteristics of the seabed drill cuttings piles, concentrations of contaminants in the cuttings piles and the composition of the benthic community in order to determine if any correlations could be made between the physical, chemical and biological effects of the cuttings piles on the local marine environment.

The survey consisted of grab samples of drill cuttings and marine sediment collected in a cruciform pattern around each platform.[3] Further samples were collected within the drill cuttings pile (piston core samples, box samples, core samples).

> There are several different methods of collecting sediment samples. As well as the standard **grab sample**, a sample can be collected by a **piston corer,** which is a gravity corer dropped from height and uses a trigger system. **A box corer** contains a box that takes a large sample when lowered to the seabed by a wire, and the box corer pushes into the seabed under its own weight. **ROV core samples** involve the use of a device operable by manipulator arms on a Remotely Operated Vehicle (ROV).

Note that these methods only sample the near-surface parts of the drill cuttings piles, not the deeper sediments at the bottom of the piles. Shell have reviewed the historical drilling records for the Brent Field. These show a pattern in the use of drilling muds across the Brent wells: WBMs were used in the upper sections of the wells, with OBMs used only in the deeper well sections and/or the sidetrack wells. This means that during the drilling of each well, first WBM contaminated drill cuttings and then OBM cuttings would have been discharged, creating alternating layers of WBM and OBM contaminated drill cuttings through the drill cuttings piles. The pre-decommissioning surveys completed by Shell have, to date, only sampled the upper layers of the historic drill cuttings piles; however, given the depths achieved during this sampling and the evidence provided by the drilling records, Shell believe these upper samples to be representative of the character of the whole drill cuttings pile.

[3] Note: Gardline Environmental quote platform measurement distances as taken from the centre point of the Brent platforms.

Additionally, fauna samples were collected from selected locations (see Section 6.3.2).

The sampling locations are listed in Table 6-1, and the physical and chemical parameters analysed are shown in Table 6-2.

Shell commissioned a further pre-decommissioning survey in 2015. Although the results are still being reviewed by Shell, Shell advise that initial indications of the 2015 survey data for Brent D suggest that total hydrocarbon concentrations have continued to decrease from levels found in previous surveys (note some analytical techniques were revised between 2007 and 2015 and are not always directly comparable to the previous techniques used). Analysis of the heavy metal concentrations in the field do not clearly show a continuing decrease in levels compared with earlier surveys though the greater concentrations continue to be found closer to the platform. The 2015 data also show a continuing recovery of the seabed communities at the stations close to the platform with an increase in secondary colonising taxa and hydrocarbon intolerant species when compared with the early (1986) results.

Table 6-1: Summary of Sampling Locations at Brent Field (including Brent South) [23]

Station	Brent A	Brent B	Brent C	Brent D	Brent South
	Approximate Distance and Direction from Brent A	Approximate Distance and Direction from Brent B	Approximate Distance and Direction from Brent C	Approximate Distance and Direction from Brent D	Approximate Distance and Direction from Brent South
GR1	1,000 SSE[1]	1,000m NW[1]	1,000 NW[1]	1,000m NW	1,000m SSE[1]
GR2	500m SSE	500m NW	500m NW	500m NW	520m SSE[1]
GR3	250m SSE	250m NW	250m NW	250m NW	275m SSE[1]
GR4	100m SE	100m NNW	100m NNW	100m NW	125m SSE[1]
GR5	1,000 E[1]	300m ESE	225m SSW	330m SSE	1,000m ENE[1]
GR6	600m E[1]	500m SSE	475m SSE	520m SSE	500m ENE[1]
GR7	75m ESE	800m SSE[1]	820m SSE[1]	800m SSE	250m ENE[1]
GR8	350m E	1,200m SSE[1]	1,200m SSE[1]	1,200m SSE	100m ENE[1]
GR9	1,000m N[1]	1,000 NE[2]	1,000m NE[1]	1,000m NE	870m NNW[1]
GR10	450 NNW	500m NE	500m NE	500m NE	475m NNW[1]
GR11	250m NW	250m NE	250m NE	250m NE	250m NW[1]
GR12	150m N	100m NE	100m NE	100m NE	150m WNW[1]
GR13	1,000m W[1]	100m SSW	100m WSW	100m SSW	1,000m WSW[1]
GR14	800m W[1]	250m SW	250m SW	250m SW	520m WSW[1]
GR15	200m W	500m SW	500m SW	500m SW	280m WSW[1]
GR16	100m WSW	1,000m SW[1]	1,000m SW[1]	1,000m SW	100m SW[1]
GR17	2,500m SSE[1]	2,500m SSE[1]	2,500m SSE[1]	2,500m SSE[1]	Not required
GC1	59m SSE[1]	68m ESE[1]	76m SSE[1]	70m S	5m WNW[1]
BC1	57m SSE[1]	68m SE[1]	77m SSE[1]	67m S	25m WSW[1]
BC2	55m SSE[1]	68m ESE[1]	83m SSE[1]	69m S	14m E[1]
BC3	57m SE[1]	70m ESE[1]	91m SSE[1]	63m NW	21m E[1]
ROV1	16m SSW[1]	Not required	32m SE[1]	32m SW	Not required
ROV2	Not required	Not required	40m SE[1]	25m WSW	Not required
REF1	14,700m NNW	12,700m NNW	9,000m NW	7,000m WNW	19,100m NNW
REF2	7,000m SE	8,600m SSE	12,500m SSE	16,200m SSE	6,000m E

GC: Piston core BC: Box core GR: Day grab Ref: Reference

[1] No SPI (Sediment Profile Imagery) images obtained.

Green highlight: Stations where fauna samples were taken.

Gardline Environmental quote platform measurement distances as taken from the centre point of the Brent platforms.

Table 6-2: Gardline Sampling Analysis Parameters

Grab Samples Analysis	Piston Core Sample Analysis
Particle size	Particle size
Total Hydrocarbon Content (THC)	Total Hydrocarbon Content (THC)
Polycyclic Aromatic Hydrocarbon (PAH)	Polycyclic Aromatic Hydrocarbon (PAH)
Alkylphenolpolyethoxylates (APE)	Alkylphenolpolyethoxylates (APE)
Polychlorinated Biphenyls (PCB)	Polychlorinated Biphenyls (PCB)
Metals	Metals
Radioactivity	Radioactivity
N-alkanes	Shear strength
Organic tin	Water content
	Leach rate

After collecting and analysing the samples from each of the drill cuttings piles, assessment criteria were used by Gardline [23] to interpret the analytical results. These criteria are described below and are referenced in Sections 6.2.3.4 to 6.2.3.8.

- Significant Environmental Impact (SEI): The SEI threshold for THC is 50mg/kg; therefore a cuttings pile having a THC value below 50 mg/kg is not considered to have any SEI. Adverse effects to macrofauna are generally observed at sediment THC above 50 mg/kg.
- Ecotoxicological Assessment Criteria (EAC): The EAC are OSPAR criteria for trace metals, PCB, PAH, TBT and some organochlorine pesticides [25], and is the concentration below which no harm to the environment or biota is expected. It should be noted that these criteria should be used to identify potential areas of concern and to prioritise substances of concern, and are not a firm standard.
- Effects Range Medium (ERM) and Effects Range Low (ERL) criteria were developed by the National Oceanic and Atmospheric Administration (NOAA), and are considered the best estimates of potential toxicity of PAHs in marine sediments. The ERL and ERM values for total PAH concentration in sediments are 4.022 mg/kg and 44.792 mg/kg, respectively. Toxic effects are rarely observed if concentrations are below the ERL. Concentrations greater than the ERL, but less than the ERM represent a range in which effects would occasionally occur, and concentrations greater than the ERM represent a range within which effects could frequently be expected.
- Apparent Effects Threshold (AET) criteria were developed by NOAA, and represent the concentration above which adverse biological impacts would always be expected due to exposure to one contaminant. Adverse impacts are also known to occur, however, at concentrations below the AET.
- Background concentration: 10 mg/kg of oil is considered the natural background concentration in North Sea sediment and was established by UKOOA in the 2000 Drill Cutting Initiative Research & Development Programme [26].

6.2.3.4 Brent A Survey of Drill Cuttings and Marine Sediment

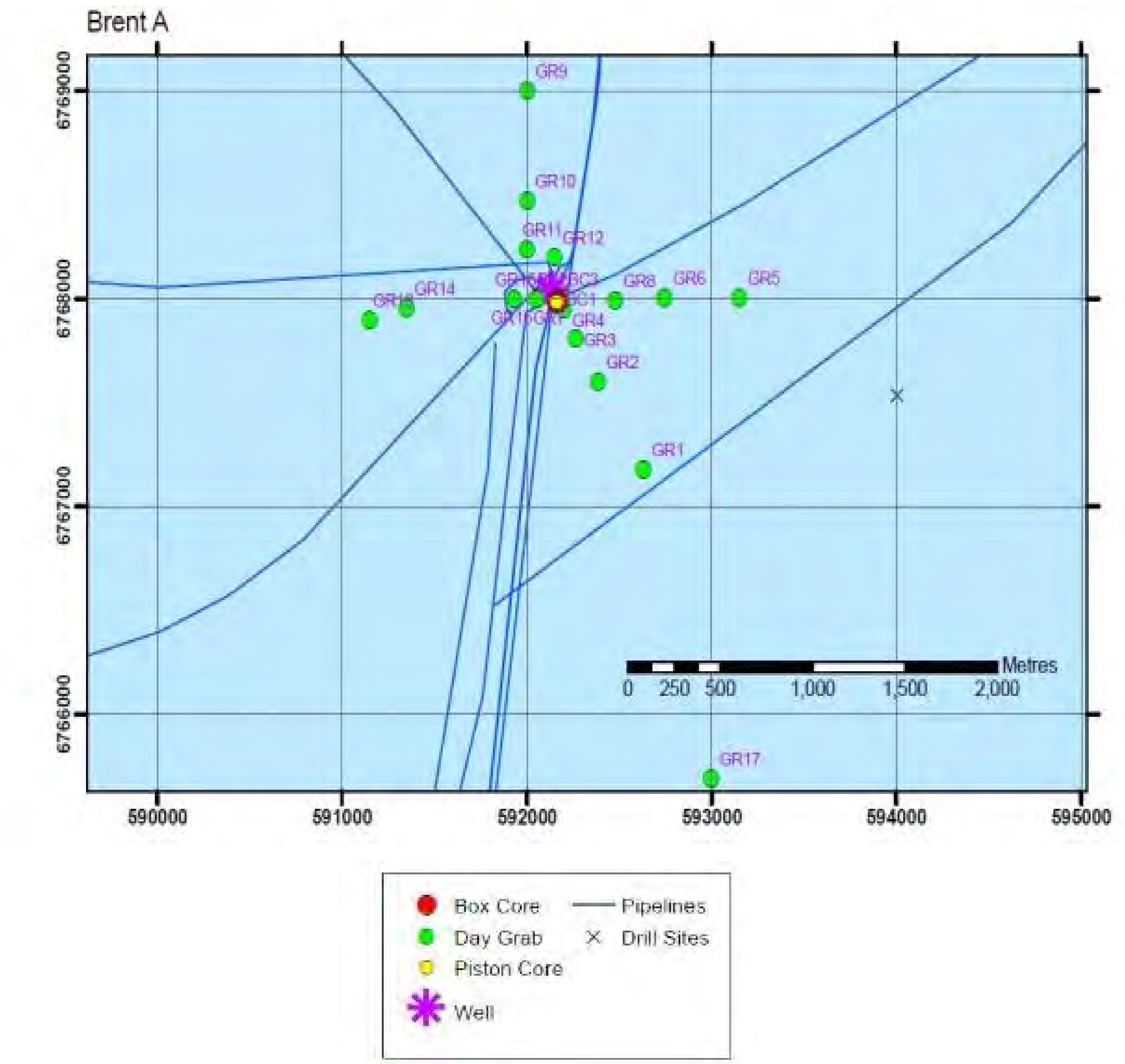
At the Brent A the following samples were collected (see Figure 6-3):

- 17 grab samples of drill cuttings and marine sediment were collected in a cruciform pattern centred around the Brent A platform.
- Within the drill cuttings pile, one piston core and three box samples were collected.
- In addition to this, one ROV core sample was collected underneath the Brent A platform.

Samples were also collected from two reference stations in the wider Brent Field area (these are the same reference stations for Brent A, B, C, D and South).

It should be noted that only the near-surface parts of the drill cuttings piles were sampled, not the deeper sediments at the bottom of the piles, which could contain higher contaminant concentrations.

Figure 6-3: Sampling Locations for Brent A Survey [23]



The results for Brent A are briefly discussed below and are summarised in Table 6-3 (the fauna results are discussed in Section 6.3.2):

- Fine particulates (silt and clay, < 0.063 mm) dominate the cutting piles.
- THC exceeds the SEI threshold (50 mg/kg THC) up to 800 m west of Brent A. The SEI boundary extends beyond the physical cuttings pile observed from the available data. Note that the drill cuttings still meet the OSPAR Stage 1 screening criteria (for persistence and oil loss) under Recommendation 2006/5 (see Section 3.1.20 and Section 13 for further detail).
- For all stations greater than 1 km from Brent A, the THC ranged from 23-33 mg/kg; this includes the two reference stations located several kilometres from Brent A and is slightly above the North Sea background concentration of 10 mg/kg, but lower than the SEI threshold.
- The impacted area due to PAH exceeding the OSPAR EAC, ERM or AET is restricted to localised areas less than 100 m from the Brent A platform.
- Concentrations of As, Cd, Cu, Pb, Zn exceed the OSPAR EAC in most samples up to 100 m from Brent A, and Zn exceeds the OSPAR EAC in one sample at 200 m W; toxicological impacts on the faunal community is therefore expected.
- APE and PCB concentrations are below the Limit of Detection (LoD).
- Organic tin exceeded the OSPAR EAC at one station at 150 m N; remaining samples are below the LOD.
- The vast majority of gross alpha and beta radioactive values were near, or below, the LoD, suggesting an absence of any notable radioactivity.

In summary, the sampling results show elevated THC concentrations in seabed drill cuttings to a maximum distance of 800 m from Brent A. These concentrations can have adverse effects on macrofauna. Adverse effects from other pollutants such as metals are contained within a smaller area, less than 200 m from the Brent A platform.

Table 6-3: Summary of Brent A Survey Results [23]

Location	Station	Sediment	Hydrocarbons	Metals	Fauna
Northern Transect (heading towards Brent A)					
1,000m N	GR9	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrations decreasing to Reference Station levels.	ND
450m NNW	GR10		THC decreasing to background concentration. Some biodegraded diesel present		Communities of high species diversity consistent with undisturbed conditions
250m NW	GR11		THC>50µg g^{-1}		
150m N	GR12			Cu, Pb and Zn above OSPAR EAC	ND
SSE Transect (heading away from Brent A)					
55m SSE	BC2	Predominance of fines	THC>50µg g^{-1}	As, Cd, Cu, Pb and Zn above OSPAR EAC	ND
57m SSE	BC1				ND
57m SE	BC3				ND
59m SSE	GC1				ND
100m SSE	GR4				Faunal community stressed. High abundance of opportunistic species
250m SSE	GR3	Sediment composition consistent with reference stations		Concentrations decreasing to Reference Station levels	Communities of high species diversity consistent with undisturbed conditions
500m SSE	GR2		THC decreasing to background concentration. Some biodegraded diesel present		
1,000m SSE	GR1				
2,500m SSE	GR17		THC consistent with reference stations		
Western Transect (heading toward Brent A)					
1,000m W	GR13	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrations decreasing to Reference Station levels	ND
800m W	GR14		GC trace consistent with North Sea background		ND
200m W	GR15	Predominance of fines	THC>50µg g^{-1}		Communities of high species diversity consistent with undisturbed conditions
100m WSW	GR16			As, Cd, Cu, and Zinc above OSPAR EAC	ND
16m SSE	ROV1	ND		Pb above OSPAR EAC	ND
Eastern Transect (heading away from Brent A)					
75m ESE	GR7	Predominance of fines	THC>50µg g^{-1}	As, Cd, Cu, Pb and Zinc above OSPAR EAC	ND
350m E	GR8	Sediment composition consistent with reference stations	THC decreasing to background concentration. Some biodegraded diesel present	Concentrations decreasing to Reference Station levels	Communities of high species diversity consistent with undisturbed conditions
600m E	GR6				ND
1,000m E	GR5		THC consistent with reference stations		ND

ND indicates no data

6.2.3.5 Brent B Survey of Drill Cuttings and Marine Sediment

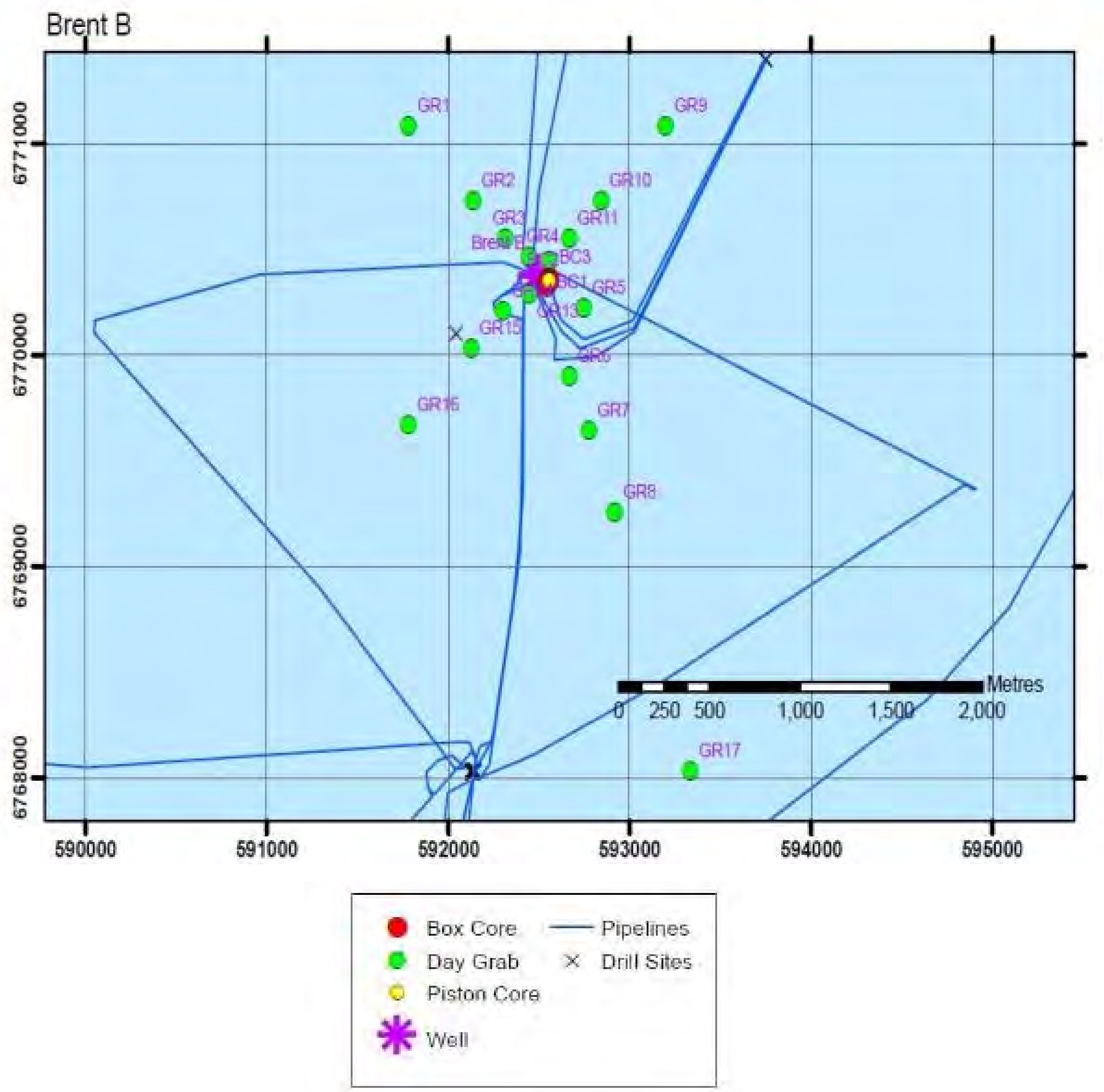
The following samples were collected (see Figure 6-4):

- 17 grab samples of drill cuttings and marine sediment were collected in a cruciform pattern around the Brent B platform.
- Within the drill cuttings pile, one piston core and three box samples were collected.
- There was not a sufficient drill cuttings volume at the centre of Brent B GBS between the platform legs to collect a ROV core sample.

Samples were also collected from two reference stations in the wider Brent Field area (these are the same for Brent A, B, C, D and South).

It should be noted that only the near-surface parts of the drill cuttings piles were sampled, not the deeper sediments at the bottom of the piles, which could contain higher contaminant concentrations.

Figure 6-4: Sampling Locations for Brent B Survey [23]



The results for Brent B are briefly discussed below and are summarised in Table 6-4 (the fauna results are discussed in Section 6.3.2):

- Fine particulates (silt and clay, < 0.063mm) dominate the cutting piles.
- THC exceeds the SEI threshold up to 500 m SSE/SW/NE of Brent B. The SEI boundary extends beyond the physical cuttings pile observed from the available data. Note that drill cuttings still meet the OSPAR Stage 1 criteria (for persistence and oil loss) under OSPAR Recommendation 2006/5 (see Section 3.1.2).
- For all stations greater than 1 km from Brent B, the THC ranged from 23-30 mg/kg; this includes the two reference stations located several kilometres from Brent B and is slightly above the North Sea background concentration of 10 mg/kg but lower than the SEI threshold.
- The impacted area due to PAH exceeding the OSPAR EAC, ERM or AET is restricted to localised areas less than 100 m from the Brent B platform.
- Concentrations of As, Cd, Cu, Pb, Zn exceed the OSPAR EAC in most samples up to 100 m from Brent B, and some impact on the faunal community is therefore expected within this area.
- APE and organic tin levels are below the LoD.
- PCB concentrations meet criteria except for an isolated sample exceeding the OSPAR EAC at 500 m.
- The vast majority of gross alpha and beta radioactive values were near, or below, the LoD, suggesting an absence of any notable radioactivity.

In summary, the sampling results show elevated THC concentrations in seabed drill cuttings to a maximum distance of 500 m from Brent B. These concentrations can have adverse effects on macrofauna. Adverse effects from other pollutants such as metals and PAH are contained within a smaller area (up to 100 m from the platform) while one isolated sample of PCB exceeded criteria at 500 m from the Brent B platform.

Table 6-4: Summary of Brent B Survey Results [23]

Location	Station	Sediment	Hydrocarbons	Metals	Fauna
NW Transect (heading towards Brent B)					
1,000m NW	GR1	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrations decreasing to Reference Station levels	ND
500m NW	GR2		THC decreasing to background concentration. Some biodegraded diesel present		Communities of high species diversity consistent with undisturbed conditions
250m NW	GR3				
100m NNW	GR4		THC >50µg g^{-1}	As, Cu, Pb, Zn above OSPAR EAC	ND
Southern Transect (heading away from Brent B)					
68m ESE	GC1	Predominance of fines	THC >50µg g^{-1}	As, Cd, Cu, Pb, Zn above OSPAR EAC	ND
68m SE	BC1				ND
68m ESE	BC2			As, Cu, Pb, Zn above OSPAR EAC	ND
70m ESE	BC3				ND
300m ESE	GR5	Sediment composition consistent with reference stations		Concentrations decreasing to Reference Station levels	Communities of high species diversity consistent with undisturbed conditions
500m SSE	GR6		THC decreasing to background concentration. Some biodegraded diesel present		
800m SSE	GR7		THC consistent with reference stations		
1,200m SSE	GR8				
2,500m SSE	GR17				
SW Transect (heading towards Brent B)					
1,000m SW	GR16	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrations decreasing to Reference Station levels	ND
500m SW	GR15		THC decreasing to background concentration. Some biodegraded diesel present		ND
250m SW	GR14		THC >50µg g^{-1}		Communities of high species diversity consistent with undisturbed conditions
100m SSW	GR13			As, Cu, Pb, Zn above OSPAR EAC	ND
NE Transect (heading away from Brent B)					
100m NE	GR12	Sediment composition consistent with reference stations	THC >50µg g^{-1}	As, Cu, Pb, Zn above OSPAR EAC	ND
250m NE	GR11			Concentrations decreasing to Reference Station levels	Slightly disturbed community but diversity consistent with other stations
500m NE	GR10		THC decreasing to background concentration. Some biodegraded diesel present		ND
1,000m NE	GR9		THC consistent with reference stations		ND

ND indicates no data

6.2.3.6 Brent C Survey of Drill Cuttings and Marine Sediment

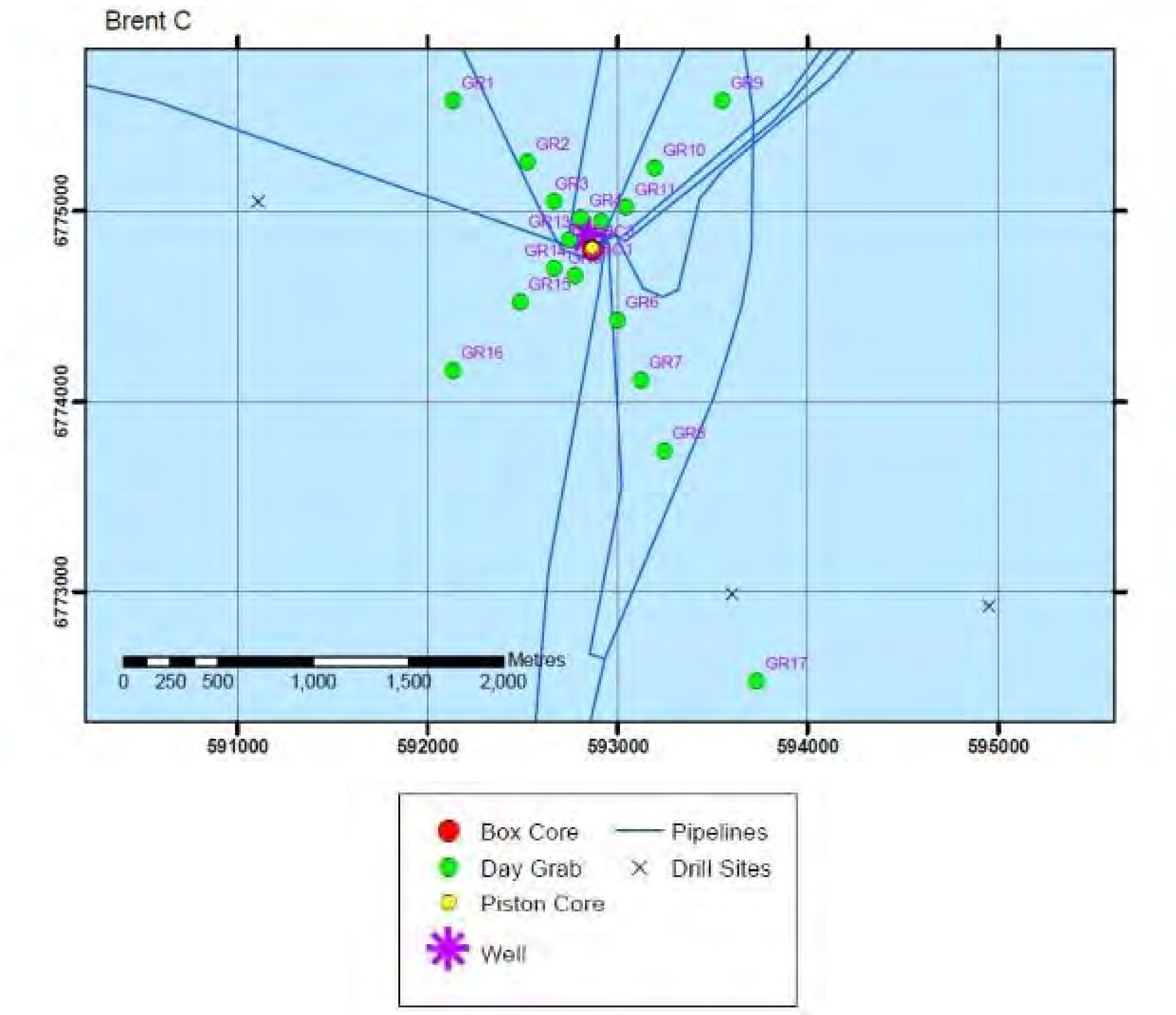
At the Brent C platform the following samples were collected (see Figure 6-5):

- 17 grab samples of drill cuttings and marine sediment were collected in a cruciform pattern around the Brent C platform.
- Within the drill cuttings pile, one piston core and three box samples were collected.
- In addition to this, one ROV core sample was collected at Brent C.

Samples were also collected from two reference stations in the wider Brent Field area (these are the same for Brent A, B, C, D and South).

It should be noted that only the near-surface parts of the drill cuttings piles were sampled, not the deeper sediments at the bottom of the piles, which could contain higher contaminant concentrations.

Figure 6-5: Sampling Locations for Brent C Survey [23]



The results for Brent C are discussed below and summarised in Table 6-5 (fauna results are discussed in Section 6.3.2):

- Fine particulates (silt and clay, < 0.063 mm) dominate the cutting piles.
- THC exceeds the SEI threshold up to 500 m NW/SW of Brent C. The SEI boundary extends beyond the physical cuttings pile observed from the available data. Note that the drill cuttings still meet the OSPAR Stage 1 screening criteria (for persistence and oil loss) under OSPAR Recommendation 2006/5 (see Section 3.1.2).
- For all stations greater than 1 km from Brent C, the THC ranged from 22-35 mg/kg; this includes the two reference stations located several kilometres from Brent C and is slightly above the North Sea background concentration of 10 mg/kg but lower than the SEI threshold.
- The impacted area due to PAH exceeding the OSPAR EAC, ERM or AET is restricted to localised areas less than 100 m from the Brent C platform.
- Concentrations of As, Cd, Cu, Pb, Zn exceed the OSPAR EAC in most samples up to 100 m from Brent C, and Pb exceeds the OSPAR EAC in one sample at 250 m W; toxicological impact on the faunal community is therefore expected within this area.
- APE and organic tin levels are below LoD.
- PCB concentrations meet criteria except for an isolated sample which exceeds the OSPAR EAC at 83 m.
- The vast majority of gross alpha and beta radioactive values were near, or below, the LoD, suggesting an absence of any notable radioactivity.

In summary, the sampling results show elevated THC concentrations in seabed drill cuttings to a distance of 500 m from Brent C. These concentrations can have adverse effects on macrofauna. Adverse effects from other pollutants such as metals are contained within a smaller area, less than 250 m from the Brent C platform.

Table 6-5: Summary of Brent C Survey Results [23]

Location	Station	Sediment	Hydrocarbons	Metals	Fauna
NW Transect (heading towards Brent C)					
1,000m NW	GR1	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrate decreasing to Reference Station levels	ND
500m NW	GR2		THC decreasing to background concentration. Some biodegraded diesel present		Communities high species diversity consistent with undisturbed conditions
250m NW	GR3			Pb above OSPAR EAC	
100m NNW	GR4		THC >50µg g^{-1}	As, Cu, Pb, Zn above OSPAR EAC	ND
SSE Transect (heading away from Brent C)					
32m SE	ROV(5)	Predominance of fines	THC >50µg g^{-1}	Cd, Pb and Zn above OSPAR EAC	ND
40m SE	ROV(15)			Pb and Zn above OSPAR EAC	ND
76m SSE	GC1			As, Cd, Cu, Pb and Zn above OSPAR EAC	ND
77m SSE	BC1				ND
83m SSE	BC2	NA due to oil content			ND
91m SSE	BC3	Predominance of fines			ND
225m SSW	GR5	Sediment composition consistent with reference stations	THC decreasing to background concentration. Some biodegraded diesel present	Concentrations decreasing to Reference Station levels	Communities of high species diversity consistent with undisturbed conditions
475m SSE	GR6				
820m SSE	GR7		THC consistent with reference stations		
1,200m SSE	GR8				
2,500m SSE	GR17			Concentration consistent with Reference Station levels	
SW Transect (heading towards Brent C)					
1,000m SW	GR16	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrations decreasing to Reference Station levels	ND
500m SW	GR15		THC decreasing to background concentration. Some biodegraded diesel present		ND
250m SW	GR14		THC >50µg g^{-1}		High species diversity consistent with undisturbed conditions
100m WSW	GR13			As, Cu, Pb, Zn above OSPAR EAC	ND
NE Transect (heading away from Brent C)					
100m NE	GR12	Sediment composition consistent with reference stations	THC >50µg g^{-1}	As, Cu, Pb, Zn above OSPAR EAC	ND
250m NE	GR11		THC decreasing to background concentration. Some biodegraded diesel present	Concentrations decreasing to Reference Station levels	High species diversity consistent with undisturbed conditions
500m NE	GR10				ND
					ND
1,000m NE	GR9		THC consistent with reference stations		

ND indicates no data

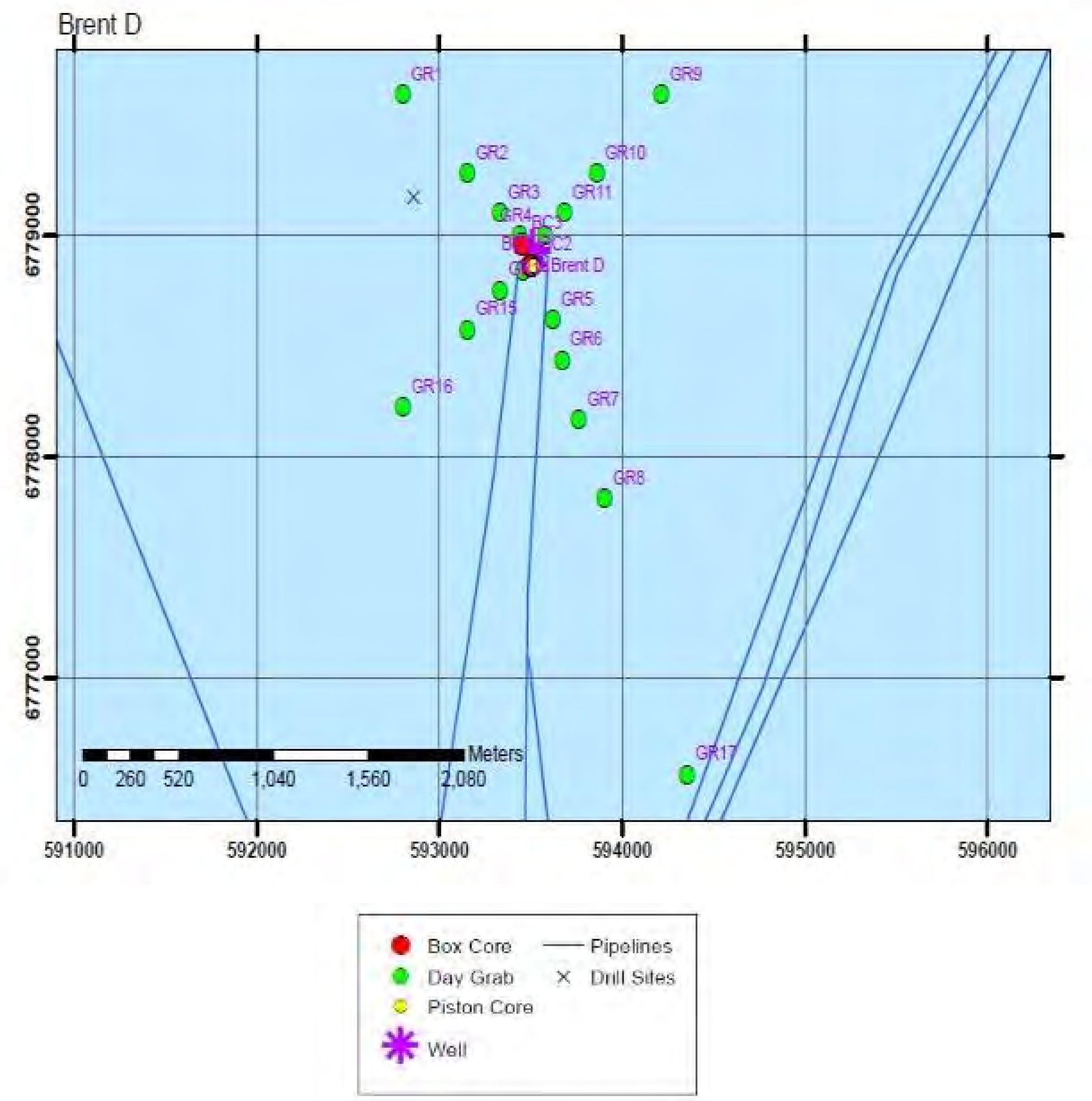
6.2.3.7 Brent D Survey of Drill cuttings and Marine Sediment

At the Brent D platform the following samples were collected (see Figure 6-6):

- 17 grab samples of drill cuttings and marine sediment were collected in a cruciform pattern around the Brent D platform.
- Within the drill cuttings pile, one piston core sample and three box samples were collected together with one ROV core sample on the cell top.

It should be noted that only the near-surface parts of the drill cuttings piles were sampled, not the deeper sediments at the bottom of the piles, which could contain higher contaminant concentrations.

Figure 6-6: Sampling Locations for Brent D Survey [24]



The results for Brent D are discussed below and summarised in Table 6-6 (fauna results are discussed in Section 6.3.2):

- Increasing fines (silt and clay, < 0.063 mm) with proximity to centre; fine particles dominate the cutting piles.
- THC exceeds the SEI threshold within the cuttings pile and up to 250 m from the Brent D platform. The SEI boundary extends beyond the physical cuttings pile observed from the available data. Note that the drill cuttings still meet the OSPAR Stage 1 screening criteria (for persistence and loss) under OSPAR Recommendation 2006/5 (see Section 3.1.2).
- For all stations greater than 1 km from Brent D the THC ranges from 20-30 mg/kg; this includes the two reference stations located several kilometres from Brent D and is slightly above the North Sea background concentration of 10 mg/kg but lower than the SEI threshold.
- PAH exceeds the OSPAR EAC or ERM threshold for all samples within 100 m of Brent D (with potential significant impact within this 100 m).
- At stations within contamination zone, there is additional evidence that a wide variety of drilling fluids were used over the lifetime of the platform (i.e. unresolved complex mixture of hydrocarbons).
- Concentrations of As, Cd, Cu, Pb and Zn, exceed the OSPAR EAC criteria at several stations up to 100 m from Brent D, and Pb exceeds the OSPAR EAC in one sample at 250 m NE. This is expected to have a toxicological impact upon the faunal community.
- APEs and organic tins were below the LoD.
- PCBs were below the LoD for all stations except GR14, which exceeds reported background data for the region.
- The vast majority of gross alpha and beta radioactive values were near or below the LoD, suggesting an absence of any notable radioactivity.

In summary, the sampling results show elevated THC concentrations in seabed drill cuttings to a distance of 250 m from Brent D. These concentrations can have adverse effects on macrofauna. Adverse effects from other pollutants are possible up to 250 m.

Table 6-6: Summary of Brent D Survey Results [24]

Location	Station	Sediment	Hydrocarbons	Metals	Fauna
NW Transect (heading towards Brent D)					
1,000m NW	GR1	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrations decreasing to Reference Station levels	ND
500m NW	GR2		THC decreasing to background concentration. Some biodegraded diesel and LTOBM		Communities of high species diversity consistent with undisturbed conditions
250m NW	GR3		THC >50µg g^{-1}		
100m NW	GR4	Predominance of fines		As, Cd, Cu, Pb and Zn above OSPAR EAC	ND
63m NW	BC3				ND
SSE Transect (heading away from Brent D)					
67m S	BC1	Predominance of fines	THC >50µg g^{-1}	As, Cd, Cu, Pb and Zn above OSPAR EAC	ND
69m S	BC2				ND
70m S	GC1	Coarse cuttings			ND
330m SSE	GR5	Sediment composition consistent with reference stations		Concentration decreasing to Reference Station levels	Communities of high species diversity consistent with undisturbed conditions
520m SSE	GR6		THC decreasing to background concentration. Some biodegraded diesel and LTOBM/		
800m SSE	GR7				
1200m SSE	GR8				
2500m SSE	GR17		THC consistent with reference stations		
SW Transect (heading towards Brent D)					
1,000m SW	GR16	Sediment composition consistent with reference stations	THC decreasing to background concentration. Some biodegraded diesel and LTOBM	Concentrations decreasing to Reference Station levels	ND
500m SW	GR15				ND
250m SW	GR14				Communities of high species diversity consistent with undisturbed conditions
100m SSW	GR13		THC >50µg g^{-1}	Cu, Pb, Zn above OSPAR EAC	ND
32m SW	ROV1(4)	NA		Pb, and Zn above OSPAR EAC	ND
25m WSW	ROV1(11)	NA		Cu and Pb above OSPAR EAC	ND
NE Transect (heading away from Brent D)					
100m NE	GR12	Predominance of fines	THC >50µg g^{-1}	As, Cd, Cu, Pb and Zn above OSPAR EAC	ND
250m NE	GR11	Sediment composition consistent with reference stations			Slightly lower diversity and evenness due to high number of the Polychaeta *Paramphinome jefferysii*
500m NE	GR10		THC consistent with reference stations	Pb, above OSPAR EAC	ND
1,000m NE	GR9			Concentrations decreasing to Reference Station levels	ND

ND indicates no data

6.2.3.8 Brent South Survey of Drill Cuttings and Marine Sediment

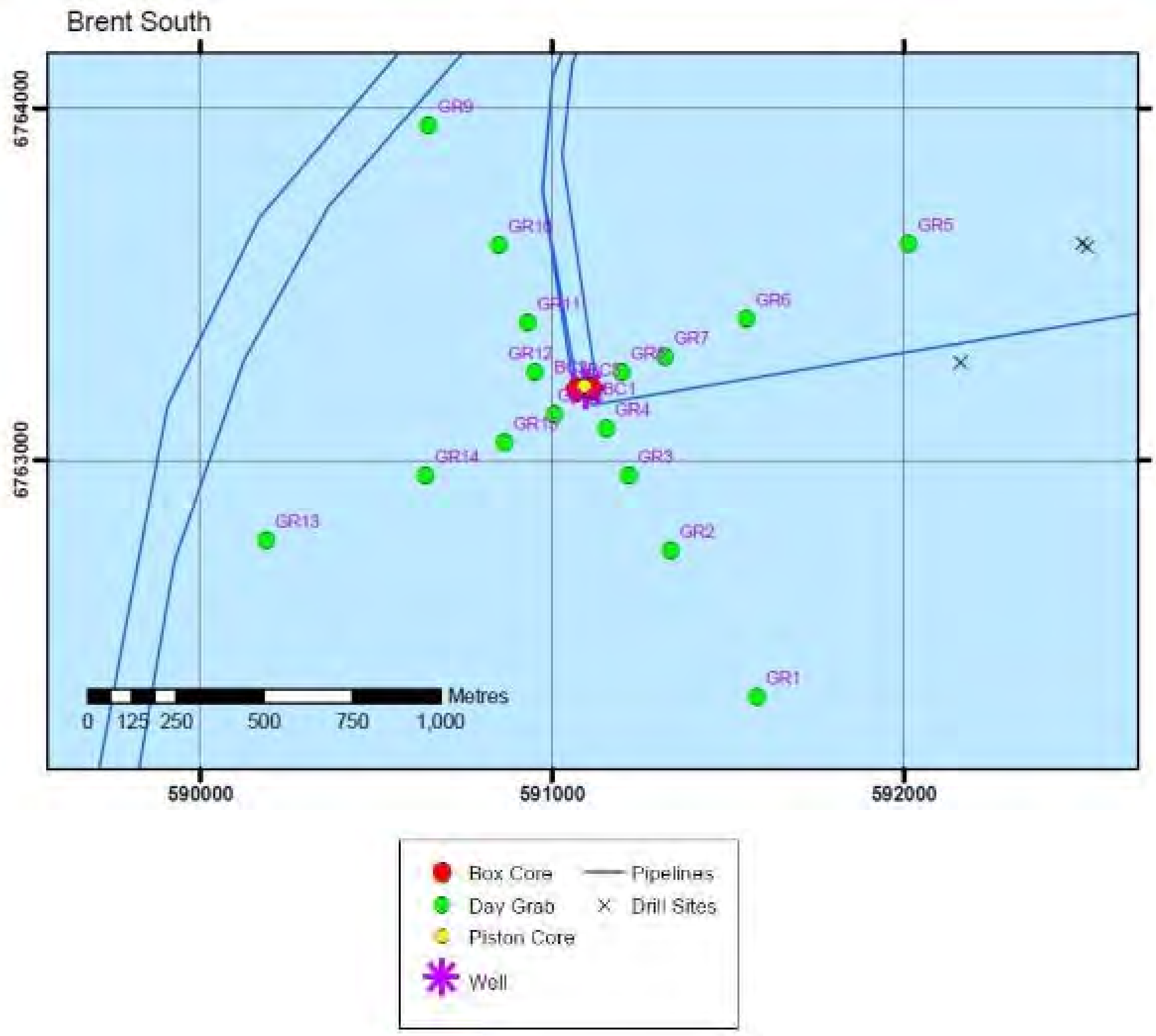
At Brent South the following samples were collected (see Figure 6-7):

- 16 grab samples of drill cuttings and marine sediment were collected in a cruciform pattern around the Brent South platform.
- Within the drill cuttings pile, one piston core and three box samples were collected.

Samples were also collected from two reference stations in the wider Brent Field area (these are the same for Brent A, B, C, D and South).

It should be noted that only the near-surface parts of the drill cuttings piles were sampled, not the deeper sediments at the bottom of the piles, which could contain higher contaminant concentrations.

Figure 6-7: Sampling Locations for Brent South Survey [23]



The results for Brent South are briefly discussed below and are summarised in Table 6-7 (noting that the fauna results are discussed in Section 6.3.2):

- Fine particulates (silt and clay, < 0.063 mm) dominate the cutting piles.
- THC exceeds the SEI threshold up to 280 m WSW of Brent South. The SEI boundary extends beyond the physical cuttings pile observed from the available data. Note that the drill cuttings still meet the OSPAR Stage 1 criteria (for persistence and loss) under OSPAR Recommendation 2006/5 (see Section 3.1.2).
- For all stations greater than 600 m from Brent South the THC ranged from 22-35 mg/kg, this includes the two reference stations located several kilometres from Brent South and is slightly above the North Sea background concentration of 10 mg/kg but below the SEI threshold.
- None of the samples from Brent South indicated PAH concentrations in excess of their associated criteria (OSPAR EAC, ERM or AET).
- Concentrations of As and Pb exceed the OSPAR EAC up to 21 m E of Brent South; adverse impact on the faunal community is therefore expected in this limited area.
- APE, organic tin and PCB levels are all below the LoD.
- The vast majority of gross alpha and beta radioactive values were near or below the LoD, suggesting an absence of any notable radioactivity.

In summary, the sampling results show elevated THC concentrations in seabed drill cuttings to a distance of 280 m from Brent South. These concentrations can have adverse effects on macrofauna. Adverse effects from other pollutants are restricted to a smaller area (less than 21 m from the platform).

Table 6-7: Summary of Brent South Survey Results [23]

Location	Station	Sediment	Hydrocarbons	Metals	Fauna
NW Transect (heading towards Brent South)					
870m NNW	GR9	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrations decreasing to Reference Station levels	ND
475m NNW	GR10				Communities of high species diversity consistent with undisturbed conditions
250m NW	GR11		THC decreasing to background concentration. Some LAO-SBM		
150m WNW	GR12				ND
5m WNW	GC1	Predominance of fines	THC decreasing to background concentration. Some fresh diesel	Pb above OSPAR EAC in MID sample	ND
SSE Transect (heading away from Brent South)					
125m SSE	GR4	Sediment composition consistent with reference stations	THC >50µg g^{-1}	Cd, and Pb above OSPAR EAC	Communities of high species diversity. Some pollution tolerant species present
275m SSE	GR3		THC decreasing to background concentration. Some LAO-SBM	Concentrations decreasing to Reference Station levels	Communities of high species diversity consistent with undisturbed conditions
520m SSE	GR2		THC consistent with reference stations		
1,000m SSE	GR1			Concentration consistent with Reference Station levels	
WSW Transect (heading towards Brent South)					
1,000m WSW	GR13	Sediment composition consistent with reference stations	THC consistent with reference stations	Concentrations decreasing to Reference Station levels	ND
520m WSW	GR14				ND
280m WSW	GR15		THC decreasing to background concentration. Some LAO-SBM		
100m SW	GR16		THC >50µg g^{-1}		ND
25m WSW	BC1		Surface THC >50µg g^{-1}		ND
ENE Transect (heading away from Brent South)					
14m E	BC2	Predominance of fines	THC >50µg g^{-1}	As and Pb above OSPAR EAC	ND
21m E	BC3				ND
100m ENE	GR8	Sediment composition consistent with reference stations		Concentrations decreasing to Reference Station levels	Communities of high species diversity. Some pollution tolerant species present
250m ENE	GR7		THC consistent with reference stations		Communities of high species diversity consistent with undisturbed conditions
500m ENE	GR6				ND
1,000m ENE	GR5				ND

ND indicates no data

6.2.3.9 Sediment Profile Imaging Survey

A Sediment Profile Imagery (SPI) survey of the seafloor on the Brent Field was conducted by Aqua-Fact in June 2007 [27]. A total of 50 stations were sampled on the seafloor of the Brent Field using a SPI camera system. These were made up of 10 stations on Brent A, 11 stations on Brent B, 11 stations on Brent C, 16 stations on Brent D and two reference stations. The aim of the survey was to document the environmental conditions of the seabed at each of the stations.

The profile images captured were analysed for some or all of the following:

- Sediment type (measured in the upper 5 cm sediment layer)
- Prism penetration depth (providing an indication of relative sediment compaction)
- Sediment boundary roughness (indicating the degree of physical disturbance or biotic activity at the sediment-water boundary)
- Mud clasts
- Apparent Redox Potential Discontinuity (ARPD) depth (assessing the depth of oxygenated sediment on the bottom)
- The presence of sedimentary gas
- Various parameters related to the faunal community (discussed in Section 6.3.2)

The key conclusions from the survey were:

- Fine to mediums sands with a variable fraction of shell material are characteristic of the seafloor in the survey area. Stations sampled in the centre of each of the four platforms exhibit the most impacts on habitat, with impacts decreasing with distance away from the platforms. An example location and Sediment Profile Image from Brent A is shown in Figure 6-8.

Figure 6-8: Example Sediment Location and Sediment Profile Image from Brent A [27]

- Deposits of coarse sediments were found to the west of site centre on Brent B, surrounding the site centre on Brent C and at stations more than 200 m from Brent D
- At all four platforms, deposits of fine grained hypoxic/anoxic mud/silt were observed under a layer of fine sand
- The following fauna were recorded in moderate numbers in the Brent Field survey area: juvenile urchins, tusk shells, hermit crabs and parchment tube worms
- The habitat quality recorded at the non-central sites at the Brent platforms was comparable to the habitat quality at the two reference stations

6.3 Natural Resources in Brent Field Area

The subsections below draw on the 2015 BMT Cordah Report [20], which references information from other earlier studies, and describe the natural resources (flora and fauna) found offshore at the Brent Field.

6.3.1 Habitat

Many offshore, coastal and onshore habitats are designated as conservation areas for their importance in protecting various plant and animal species, marine and coastal habitats and onshore environments. These jurisdictions are assigned under various national and international agreements. A description of the offshore conservation areas in proximity to the Brent Field are provided below. Descriptions of conservation areas for coastal and onshore environments (relevant for the proposed offshore transit route, transfer location and onshore dismantling facility) are provided in Sections 6.9.3 and 6.10.3).

In relation to the area closely surrounding the Brent Field, the findings from the Gardline Geosurvey's debris and habitat survey conducted in July and August 2006 [22] indicate that no environmentally sensitive habitats were identified within the survey area (15 km x 4 km covering the Brent Field and the four platforms). In addition, no pockmarks or naturally occurring reef structures were identified within the survey area during the study.

6.3.1.1 Offshore conservation areas close to the Brent Field

Marine Special Areas of Conservation (SAC)

As noted in Section 3.2, the UK Government (under the direction of JNCC and DEFRA) has jurisdiction under the Habitats Directive to propose offshore areas to be designated as Special Areas of Conservation (SACs) or Sites of Community Importance (SCI), to protect habitat or specific species of European importance. In UK offshore waters there are currently 19 SACs and SCIs and one candidate SAC (cSAC), Hatton Bank. In UK offshore waters, four habitats from the Habitats Directive are under consideration to be identified as SACs; these are shown in Table 6-8. Additionally, SACs can be designated to protect four species under Annex II of the Habitats Directive: grey seal, harbour seal, bottlenose dolphin and harbour porpoise (see Section 6.3.7). A site remains a cSAC until formally designated as a SAC, following approval as a SCI by the European Commission. The closest SCI to the Brent Field is 85 km away, the Pobie Bank Reef, described in Table 6-8.

Table 6-8: Summary of Annex I Habitats considered for SAC Selection in UK Waters

Annex I habitats considered for SAC selection in UK offshore waters
Sandbanks: sandy sediments which are slightly covered by seawater all the time, typically at depths of less than 20 m. As the Brent Field is in a water depth of approximately 140 m, it is outside the area where sandbanks occur.
Reefs (bedrock, biogenic and stony) • Bedrock reefs – made from continuous outcroppings of bedrock which may be of various topographical shape • Stony reefs – these consist of aggregations of boulders and cobbles which may have some finer sediments in interstitial spaces • Biogenic reefs – formed by cold water corals (e.g. *Lophelia pertusa,* see Section 6.3.3) and *Sabellaria spinulosa* Reef habitats, including bedrock and stony reef habitats, are scarce in the North Sea. No reefs were

	Annex I habitats considered for SAC selection in UK offshore waters
	identified during the Brent debris and habitat survey [22]. The closest reef habitat is the Pobie Bank Reef; a SCI located approximately 85 km south-west of the Brent Field and is considered an SCI due to its extensive community of encrusting and robust sponges and bryozoans.
	Submarine structures made by leaking gases are complex structures consisting of rocks, pavements and pillars up to 4 m high and are formed by the oxidation of gases, mainly methane which causes sandstone to aggregate. The seabed sediments within the Brent Field are not found to be conducive to the formation of these structures.
	Submerged or partially submerged sea caves – there are no known examples in the NNS.

Marine Protected Areas (MPA):

In addition, there are national designations (under the Marine and Coastal Access Act 2009) denoting a Marine Protected Area (MPA) in the UKCS, which could include nationally important conservation areas for marine wildlife, habitats and geology. JNCC are responsible for their identification in the UK. These include Marine Conservation Zones (MCZs) in England and Wales, and Nature Conservation Marine Protected Areas (NCMPAs) in Scotland. There are currently fifty designated MCZs, twenty-three of which were designated in January 2016 (another phase will be designated in 2018). There are also thirty designated NCMPAs offshore Scotland.

The closest MPA to the Brent Field is the NE Faroe Shetland Channel NCMPA, located approximately 110 km to the north-west. This site features deep-sea sponge aggregations, offshore deep-sea muds, offshore sub-tidal sands and gravels, continental slope and features of geological importance. Marine protected areas relevant to the offshore transit route and transfer location are described in Section 6.9.1.

6.3.2 Benthic Fauna

Benthic fauna are species that live either within the seabed sediment (infauna) or on its surface (epifauna).

Benthic fauna are typically divided into various categories, principally according to size. The largest are the megafauna, which comprise animals usually living on the seabed, and are large enough to be seen in bottom photographs and caught by trawl. Macrofauna are typically greater than 0.5 mm in size [28], whereas meiofauna comprise the smaller animals between 45-500 µm that typically live in the interstitial spaces in the seabed sediment.

Colonisation of sediments by different species is largely dependent on the type of sediment and sediment characteristics. Both physical and biological factors are important in determining species abundance and distribution, including seabed depth, water movements, water masses, salinity, temperature, food supply and available oxygen.

Benthic communities in this region of the NNS are diverse and abundant, and include species typical of the deep water and soft fine sediments of the North Sea. There do not appear to be any benthic species listed for their conservation value in this part of the NNS.

Data from benthic surveys around the Brent Field indicate that characteristic infaunal species associated with this region of the North Sea include the polychaete *Owenia fusiformis* (tube worm), *Thyasira spp* (bivalve mollusc) and *Myriochele spp*. (polychaete worm).

The benthic communities around the Brent Field were analysed as part of environmental surveys carried out in 1990 and 1994. Analysis of these historic data indicated that the benthic fauna was affected up to a few hundred metres from the Brent platforms with a zone of slight benthic disturbance extending 500 m to 800 m from the platform. Stations more than 800 m from the Brent A platform showed diverse benthic communities indicative of undisturbed conditions, typical of the East Shetland Basin. The benthic infauna around Brent D beyond the immediate area of contamination is expected to consist of a typical North Sea infauna.

The most recent surveys by Gardline in 2007 [23,24] included an analysis of the benthic communities. Benthic sampling was conducted as follows:

- 18 samples from 9 stations were collected for macrofaunal analysis at each of the four Brent platforms and at Brent South, making a total of 90 samples
- Samples were also collected from 2 reference stations for each platform in the wider Brent Field area

The results from the macrofaunal analysis are as follows:

- The macrofauna analysis at each of the Brent Field platforms showed that impacts of contamination and ecological effects are evident, although conclusive statements cannot be made because macrofauna was not collected from every station.
- Significant evidence of contamination exists particularly at 100 m SE of the Brent A platform.
- The faunal community appeared to be relatively uniform between stations, and no significant difference was identified between the 150-500 m and >500 m zones.
- At Brent D significant correlations were evident between the macrofaunal community and distance from the platform. However without additional sampling, no further conclusions were drawn and this correlation cannot be applied to other survey stations.
- None of the species identified were of statutory conservation significance, in accordance with the EU Habitats Directive.

In addition to the above, the SPI survey (see Section 6.2.3.9) conducted by Aqua-Fact in June 2007 [27], investigated the following at the Brent Field locations:

- Infaunal successional stage (qualifying the type of animals living in the bottom)
- Organism Sediment Index (OSI) which integrates the information gained from other parameters measured into a single index, which is indicative of the health status of the location
- Benthic Habitat Quality index
- Additional biological parameters (e.g. epifauna, infaunal burrows and tubes)

The conclusions from the SPI survey, related to the faunal community, are summarised below.

- Based on an analysis of the SPI and surface images taken during the survey, heavily impacted habitat is found in the group of stations clustered around the centre of each of the four sites surveyed (Brent A – D) with generally mature healthy habitat found beyond this (taking Brent A as an example with heavily impacted, low quality habitat appearing up to 100-200 m from the Brent A centre with relatively good quality habitat found at the stations lying beyond these).
- Deposits of fine grained hypoxic/anoxic mud/silt were noted underlying a layer of fine sand on Brent A, B and D.

- Moderate numbers of fauna were recorded on the Brent sites. Of particular note were numerous juvenile urchins (*Echinus acutus*), tusk shells (*Scaphopoda*), hermit crabs (*Eupaguridae*) and parchment tube worms (*Chaetopteridae*).
- The habitat showing least impact was visually recorded at stations furthest from the platform centres and approaches what could be considered ambient for the surrounding area.

6.3.3 Coral

The cold-water coral *Lophelia pertusa* can form large dome-shaped growths on offshore platforms. It is protected under CITES (Convention on International Trade in Endangered Species) and reefs formed by *L. pertusa* are candidates for allocation as SACs under the EC Habitats Directive (92/43/EEC). In addition, the 1998 adoption of a new Annex to the OSPAR Convention (1992 Convention for the Protection of the Marine Environment of the North East Atlantic) offers the opportunity to protect important deep water or offshore habitats and species, such as *L. pertusa*. Protection offered to *L. pertusa* may have implications for fouling removal measures and this may require evaluation should growth on platforms be shown to include *L. pertusa*. Current opinion from conservation bodies suggests that *L. pertusa* on North Sea installations is an artefact resulting from the presence of man-made structures in the sea, and so the colonies are not of significant conservation interest.

However, it is noted that the DECC Guidance Notes on Decommissioning state that, as with all marine species, if there is a significant growth of coral the potential impact of the operations on these species should be assessed in the EIA process. BEIS also state that if the coral is present and the installation upon which it is located is to be returned to shore it will be necessary to discuss the requirements with DEFRA (Department of Environment, Food and Rural Affairs), in relation to CITES.

The findings from a 2008 study by BMT Cordah [29] on the evaluation of the extent of colonisation of *L. pertusa* and marine growth on the Brent D facility are summarised below. The scope of the study was to review existing ROV survey footage of Brent D, assess the extent of marine growth, and describe the colonisation and physical extent of *L. pertusa* on the platform.

- A total of 199 *L. pertusa* colonies were identified on the platform. 142 (71%) of these colonies were recorded on pipework and 57 (29%) on concrete. All observations were recorded at depths greater than 67m, with the maximum number of colonies observed in the depth zone 130-150 m.
- The results indicate that the marine fouling community and composition on Brent D were typical of that found on large platforms in the North Sea. Approximately 460 tonnes (wet weight) of marine growth (not all of it is *L. pertusa*) were estimated to be growing on the concrete structure of the platform.

Just over half (54%) of the Brent D subsea concrete structure was assessed from the survey footage available. The results showed that the greatest weight of marine growth (89 tonnes) occurs in depth zone 100-110 m and the least weight (6 tonnes) occurs in the depth zone 50-60 m.

6.3.4 Plankton

The planktonic community is composed of a range of microscopic plants (phytoplankton) and animals (zooplankton). The majority of the phytoplankton occurs in the upper 20 m of the water column, known as the photic zone, where there is sufficient light for photosynthesis.

These organisms form the basis of marine ecosystem food webs and many species such as fish, birds and cetaceans, are dependent upon them. The composition, distribution and abundance of

plankton vary throughout the year, and directly influence the movement and distribution of other marine species. Plankton populations are influenced by physical parameters such as temperature, salinity, nutrient levels, light penetration, water movements in the area and the local presence of benthic species.

Phytoplankton generally encompasses a wide range of unicellular organisms. The most common phytoplankton groups are the diatoms, dinoflagellates and the smaller flagellates and together they are responsible for the majority of the primary production of the North Sea. The phytoplankton community in the NNS is dominated by the dinoflagellate genus *Ceratium spp*., including species such as, *C. fusus, C. furca and C. tripos*. Phytoplankton in the area generally exhibit an increase in productivity between May and August before a decline in November. Plankton in the North Atlantic and North Sea has been monitored using the Continuous Plankton Recorder (CPR) over the last 70 years, and the results of this programme have shown an increase in the dinoflagellates, with a gradual decrease in the diatom species.

Zooplankton is composed of a wide variety of multicellular herbivorous and carnivorous organisms, ranging in size from microscopic larval life stages of fish and copepods to large jellyfish. The larger zooplankton (or megaplankton) includes the euphausiids (krill), thaliacea (salps and doloids), siphonophores and medusae (jellyfish). Important groups include the larvae of starfish and sea urchins (echinoderms), crabs and lobsters (decapods), and several fish species.

The principal organisms which constitute the zooplankton in the NNS comprise the neritic (coastal) and intermediate (mixed water) species, although there is an introduction of oceanic species via an inflow of Atlantic waters, such as *Salpa fusiformis*, *Calanus finmarchicus* and *Metridia lucen* throughout the summer and late autumn. Zooplankton species in the NNS are dominated by the *Calanus* sp. Krill is abundant throughout the North Sea and is a primary food source for some fish and whales.

In the North Sea, a bloom of phytoplankton occurs every spring, often followed by a smaller bloom in the autumn. Blooms can also occur at other times of year under certain circumstances.

Planktonic organisms are potentially vulnerable to accidental oil spills and chemical discharges, although they may be able to recover quickly from localised pollution incidents through the continual exchange of individuals with surrounding waters and short reproductive cycles. Secondary effects to organisms which depend on plankton as a food source, such as some commercial fish species and marine mammals, could be affected by a change in the distribution or abundance of plankton communities. There is also the possible bioaccumulation of pollutants ingested by plankton.

6.3.5 Fish and Shellfish

A total of 224 species of fish have been recorded in the North Sea, but it is estimated that fewer than 20 species constitute over 95% of the total fish biomass. Fish are an important food source for seabirds, marine mammals and other fish species.

Fish species can be broadly classified as:

- **Pelagic species** which occur in shoals swimming in mid-water, typically making extensive seasonal movements or migrations between sea areas. Pelagic species include herring, mackerel, blue whiting and sprat
- **Demersal species** which live on or near the seabed and include cod, haddock, plaice, sandeel, sole, and whiting

- **Shellfish species**, comprising demersal (bottom-dwelling) molluscs and crustaceans, such as shrimps, crabs, *Nephrops norvegicus* (Norway lobster), mussels and scallops

There are several ways in which offshore decommissioning activities may impact fish populations, both in positive and negative ways. These can include underwater noise impacts from operations, and exposure to drill cuttings, hydrocarbon and chemical discharges. Fish are also known to congregate around offshore platforms and the platforms and pipelines may provide a habitat for some species.

Fish are most vulnerable to disturbance and pollution during the egg and juvenile stages of their lifecycle. The Brent Field is located within spawning and nursery grounds used by several species which are shown in Table 6-9.

All of these fish species typically have pelagic eggs that are released into the water column to be fertilised. Demersal species are particularly vulnerable to any sediment disruption. Pelagic spawners are generally not as vulnerable in terms of activities that disturb the seabed.

Table 6-9: Spawning and Nursery Times of Fish in the Vicinity of the Brent Field [20,30]

Species	J	F	M	A	M	J	J	A	S	O	N	D
Anglerfish												
Blue whiting												
Cod		*	*									
European hake												
Haddock		*	*	*								
Herring												
Ling												
Mackerel												
Norway pout		*	*									
Saithe	*	*										
Sandeel												
Spurdog												
Whiting												

Spawning period | * Peak spawning period | Nursery/Juveniles

Note: Nursery cells highlighted in light blue indicate these fish species using the area around the Brent Field as rearing grounds. White cells indicate no spawning or nursery grounds.

For many fish species, spawning grounds are dynamic features of fish life history and are rarely fixed in one location from year to year. Fish may also spawn earlier or later in the season in response to environmental conditions. Therefore, the information on the fish spawning areas represents the widest known distribution, based on current knowledge. Spawning times represent the generally accepted maximum duration of spawning.

In the early stage of the fish lifecycle, many species occupy discrete areas, either in the water column or on the seabed, where opportunities for feeding and for protection from predators are greatest. Juvenile fish can often be found in nursery areas together with slightly older individuals, and occasionally adults. The locations of these nursery grounds can change from year to year depending on factors such as water temperature or the availability of food. It is therefore difficult to define the limits of nurseries precisely, and similarly with spawning locations. Figure 6-9 provides an indication of the likely positions of spawning concentrations and illustrates the widest known distribution.

Nursery grounds are used throughout the year, potentially making it impossible to avoid an operational period coinciding with the presence of juvenile fish. Nursery grounds are shown in Figure 6-10 and Figure 6-11.

Figure 6-9: Fish Spawning Areas in the Vicinity of the Brent Field [20]

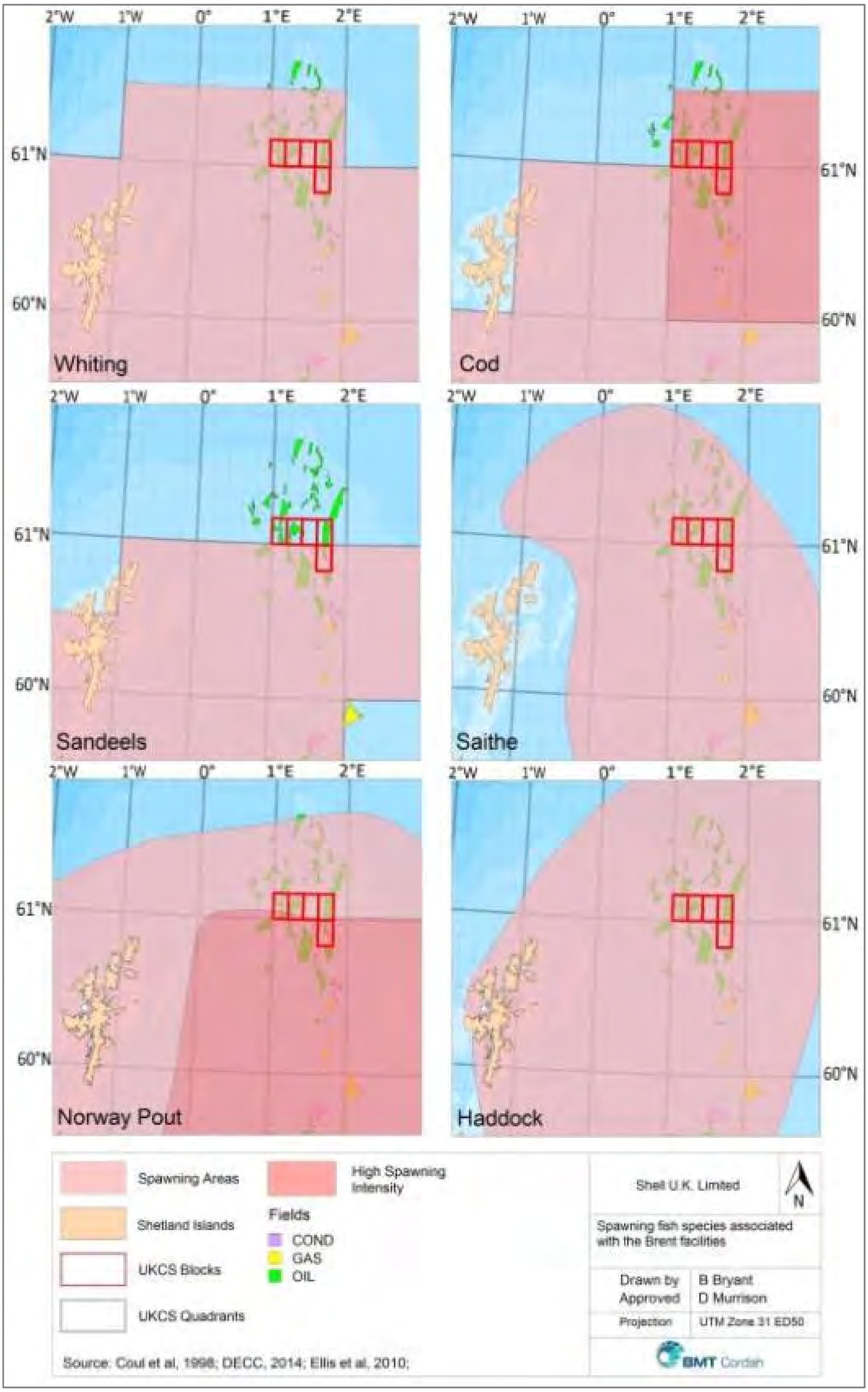


Figure 6-10: Fish Nursery Areas in the Vicinity of the Brent Field [20]

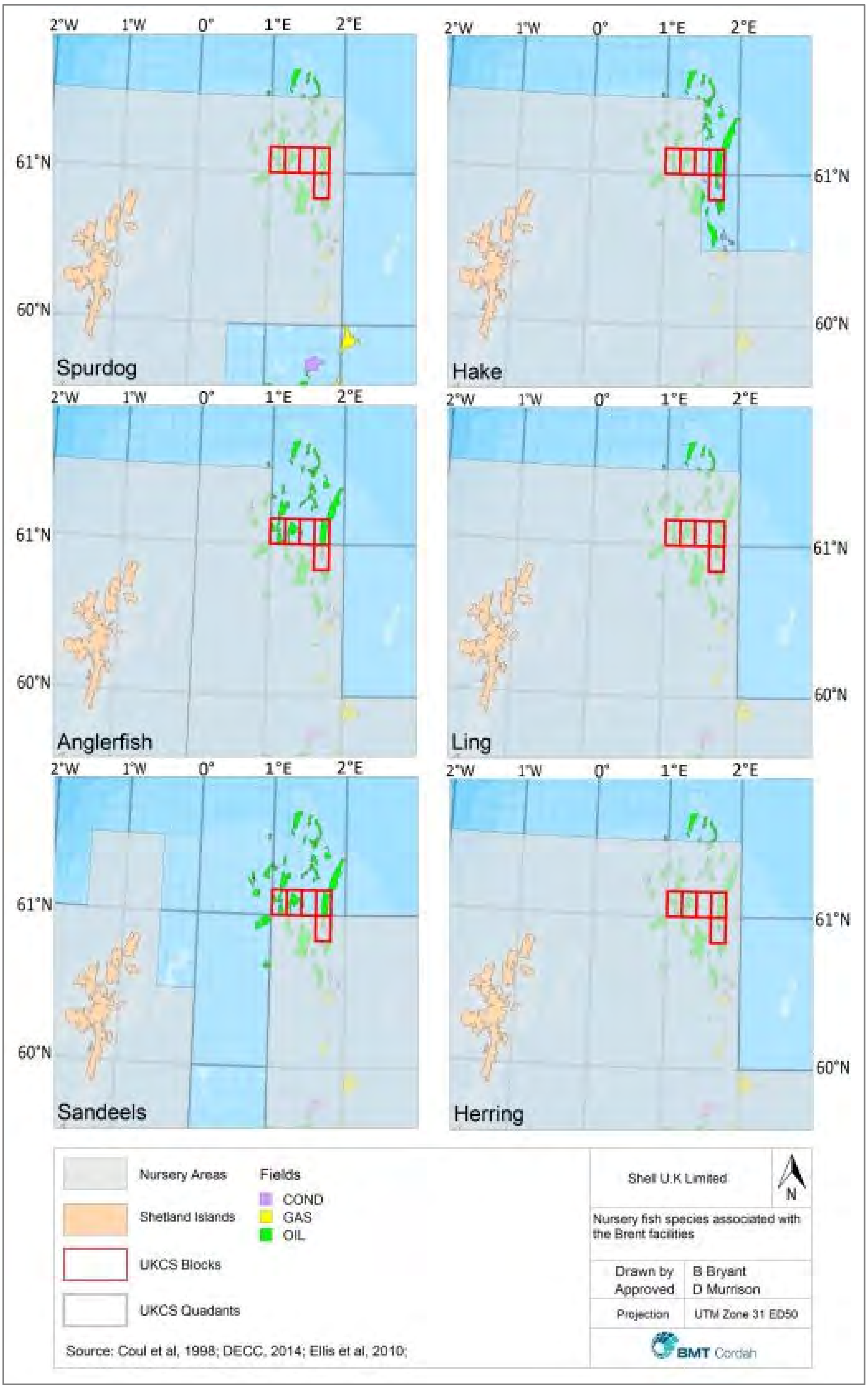
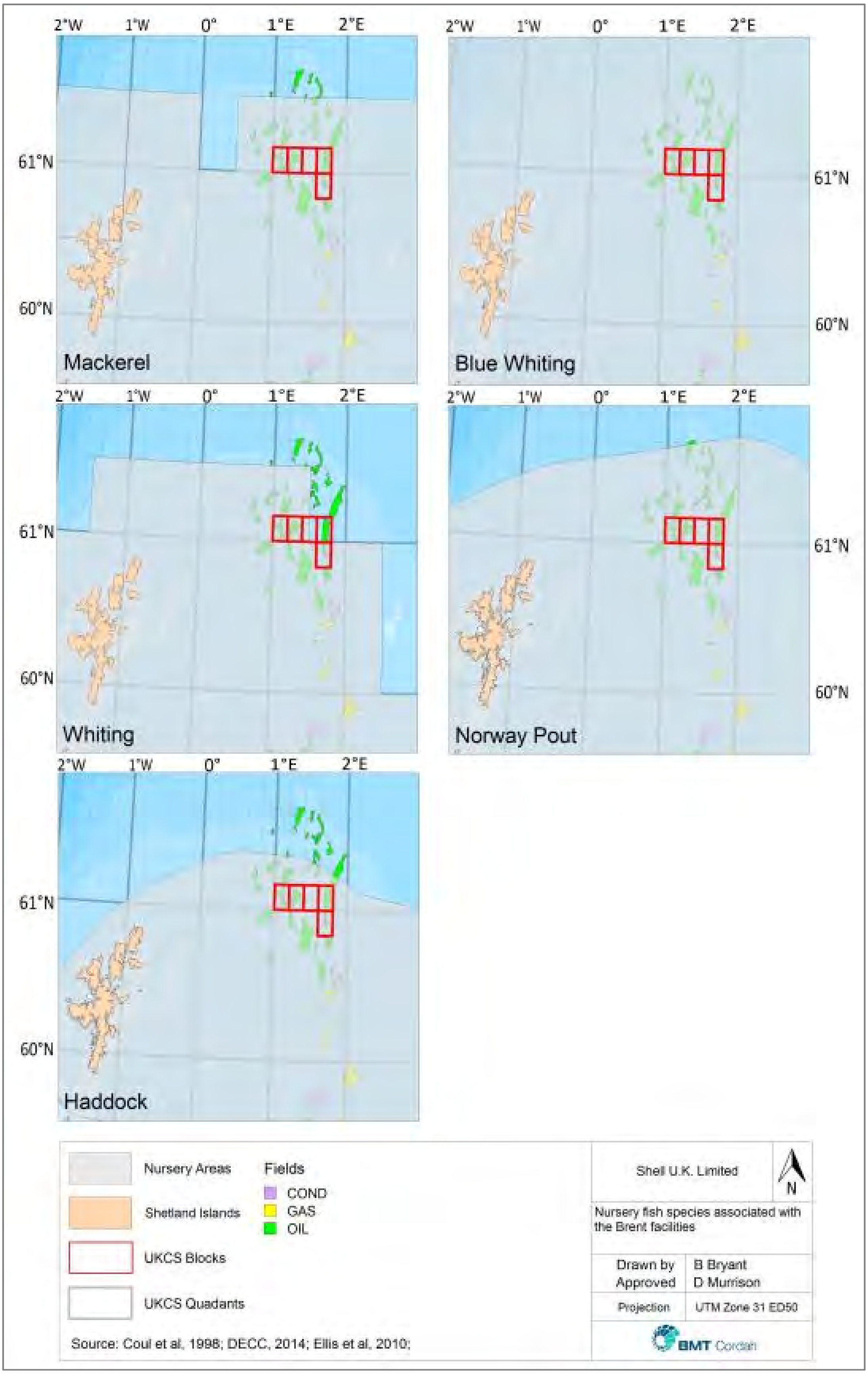


Figure 6-11: Fish Nursery Areas in the Vicinity of the Brent Field [20]



6.3.6 Seabirds

Seabirds comprise those species of bird that depend wholly or mainly on the marine environment for their survival. Internationally important numbers of several species of seabird breed around the coastal margin of the North Sea and depend on offshore areas for their food supply and, for much of the year, their habitat.

Twenty-five species of seabird in six families breed in the UK. In addition, many other non-breeding species can occur regularly in the seas around the UK at various times throughout the year. Each year over seven million seabirds breed in the UK. In general, offshore areas contain peak numbers of seabirds following the breeding season and through winter, with birds tending to forage closer to coastal breeding colonies in spring and early summer. Seabird prey varies from zooplankton to small fish.

Seabirds which breed regularly in the UK and around mainland North Sea coastlines include:

- Four species of petrel: fulmar (*Fulmarus glacialis)*, Manx shearwater (*Puffinus puffinus*), storm petrel (*Hydrobates pelagicus*) and Leach's petrel (*Oceanodroma leucorhoa*)
- Two species of cormorant: cormorant (*Phalacrocorax carbo*) and shag (*Phalacrocorax aristotelis*)
- Northern gannet (*Morus bassanus*)
- Two species of skua: great skua (*Catharacta skua*) and Arctic skua (*Stercorarius parasiticus*)
- Six species of gull: herring gull (*Larus argentatus*), common gull (*Larus canus*), black-headed gull (*Larus ridibundus*), lesser black-backed gull (*Larus fuscus*), great black-backed gull (*Larus marinus*) and kittiwake (*Rissa tridactyla*)
- Five species of tern: Sandwich tern (*Sterna sandvicensis*), roseate tern (*Sterna dougallii*), common tern (*Sterna hirundo*), Arctic tern (*Sterna paradisaea*) and little tern (*Sterna albifrons*)
- Four species of auk: guillemot (*Uria aalge*), razorbill (*Alca torda*), black guillemot (*Cepphus grylle*) and puffin (*Fratercula arctica*)

Seabirds are not normally affected by routine offshore oil and gas operations. However, in the event of an oil spill, birds are vulnerable to oiling from surface oil by:

- Direct mortality. Oil soaks into the plumage and destroys insulation and buoyancy causing hypothermia, starvation and drowning. Oiled birds spend more time preening and less time foraging.
- Oil ingested when seabirds attempt to clean their oiled plumage, and when they feed on oil-contaminated food, can be toxic. This can significantly affect survival and reproduction. Even lightly oiled adult birds may transfer oil to eggs when incubating, thereby reducing hatching success.
- The vulnerability of seabirds to oil spills varies with species and time of year with peaks in late summer after breeding when the birds disperse into the North Sea, and during the winter with the arrival of over-wintering birds. In addition, birds that feed, swim and dive on the sea surface are more vulnerable, such as:
  - Auks, diving ducks, many terns and gulls (feed throughout the year)
  - Some ducks, grebes and divers (feed for a part of the year)

- Cormorants and gannets (solitary species)
- Guillemots, razorbills and puffins moult their flight feathers after the breeding season (July-August) and are unable to fly for 2-7 weeks. They spend this flightless period at sea, where they are safe from terrestrial predators and are considered to be the most vulnerable to oil pollution.
- The fulmar and gulls, due to their aerial habits as well as their large populations and widespread distribution are considered the least vulnerable to oil pollution.

The JNCC (Joint Nature Conservation Committee) Seabirds at Sea Team (SAST) has developed an index to assess the vulnerability of bird species to the threat of oil pollution. This Offshore Vulnerability Index (OVI) is derived by taking account of the following four factors:

- The amount of time spent on the water
- Total biogeographic population
- Reliance on the marine environment; and
- Potential rate of recovery

The overall vulnerability of seabirds to oil pollution in the Brent Field (Block 211/29 and surrounding blocks) is shown in the JNCC block-specific vulnerability data (Table 6-10) and is "low". The months of January, March, July and between September to November show a "high" seasonal vulnerability of seabirds in some specific blocks.

Table 6-10: Vulnerability of Seabirds to Oil Pollution in the Brent Field Area [20]

Block	J	F	M	A	M	J	J	A	S	O	N	D	All
211/29	3	3	4	4	4	4	2	4	3	3	2	4	4
211/23	3	3	2	4	3	4	2	4	3	2	2	4	4
211/24	3	3	4	4	3	4	2	4	3	3	2	4	4
211/25	3	3	4	4	3	4	2	4	3	3	2	4	4
211/28	3	3	2	4	4	4	2	4	3	2	2	4	4
211/30	3	3	4	4	4	4	2	4	3	3	2	4	4
3/3	2	3	2	3	4	4	2	4	2	2	2	3	4
3/4	3	3	4	3	4	4	2	4	3	3	2	3	4
3/5	3	3	4	3	4	4	2	4	3	3	2	3	4

KEY		
	1	Very High Vulnerability
	2	High Vulnerability
	3	Moderate Vulnerability
	4	Low Vulnerability
		No data

6.3.7 Marine Mammals

Marine mammals include whales, dolphins and porpoises (cetaceans) and seals (pinnipeds). Marine mammals can be impacted by offshore oil and gas activities and are potentially vulnerable to underwater noise, injury from collisions with vessels, oil spills and chemical discharges, and any effects on the availability of prey.

6.3.7.1 Annex II Species

As discussion in Section 6.3.1, the following marine mammals are listed in Annex II (species requiring designation of SAC) of the Habitats Directive. Of these four species, only the harbour porpoise has been recorded in the Brent Field. Low numbers of porpoises have been recorded in the vicinity of the Brent Field in February, from April to September, and in December (as shown in Table 6-12).

	Species Listed in Annex II
	Grey seal
	Harbour seal
	Bottlenose dolphin
	Harbour porpoise

However, at this time, no offshore SACs have been designated for these species. An on-going study by the JNCC is examining whether any SACs for grey or common seals may be identified in offshore waters (currently only coastal SACs have been identified for these species) [31]. In addition, only coastal SACs have been identified for the bottlenose dolphin, and a recent study by the JNCC [32] has determined that no suitable SACs in UK offshore waters can be identified for the bottlenose dolphin. An SCI in Northern Ireland has been identified to protect the harbour porpoise, however there have currently been no SACs identified in the UK for harbour porpoises as a qualifying feature.

6.3.7.2 Cetaceans

All cetacean species are listed in Annex IV of the European Commission Habitats Directive (92/43/EEC), which protects them from any deliberate disturbance, particularly during the periods of breeding and migration.

Numerous species of cetacean are widely distributed in the North Sea and are recorded throughout the year, and more than 20 cetacean species have been recorded in UK waters. Cetaceans can be divided into two main subgroups as shown in Table 6-11.

Table 6-11: Subgroups of Cetaceans

Cetacean	Species	Feeding Method
Baleen (Mysticeti)	• Fin, sei, minke and humpback whales	Feed by sieving water through a series of baleen plates
Toothed (Odontoceti)	• Sperm whale (the largest) • Medium-sized whales: long-finned pilot and killer whales) • Smaller species: Risso's, white-sided, white-beaked, common and striped dolphins, harbour porpoise and bottlenose dolphin	Have teeth for prey capture

Cetacean distribution may be influenced by a variety of natural factors such as water masses, fronts, eddies, upwellings, currents, water temperature, salinity and length of day. A major factor likely to influence cetacean distribution is the availability of prey, mainly fish, plankton and cephalopods.

Harbour porpoise, killer whale, minke whale, sperm whale, white beaked dolphin and white-sided dolphin are the main marine mammals seen in the vicinity of the Brent Field; with harbour porpoises and white-sided dolphins recorded in Quadrant 211. The majority of sightings of cetaceans have occurred from May to August. A few sightings of harbour porpoise, sperm whale and white-beaked dolphins have also occurred during the autumn and winter. Table 6-12 provides seasonal data on the densities of cetacean species found in the Brent Field area and surrounding quadrants. Further information on the distribution and abundance of each species is given in the text that follows.

Table 6-12: Seasonal Sightings of Cetaceans in Vicinity of Brent Field [20]

Species	J	F	M	A	M	J	J	A	S	O	N	D
Harbour porpoise		L		L	L	L	L	L	L			L
Killer whale					M	M		L				
Minke whale					L		L					
Sperm whale					L	L	L	L	L	L		
White-beaked dolphin		M	M			L	L					
Atlantic white-sided dolphin					L	L						

KEY	
	No animals / no data
VH	0.01-0.09 animals/km
H	0.10-0.19 animals/km
M	0.20-0.49 animals/km
L	>0.5 animals/km
(green)	Sightings within Quadrants 211 and 3
(blue)	Sightings within surrounding Quadrants

Note: Quadrant 211 and surrounding quadrants. As marine mammals are wide ranging, Quadrant 211 and surrounding quadrants are used as a reference to get an indication of their potential presence in the area.

Harbour porpoise (*Phocoena phocoena*)

Harbour porpoises are the most common cetacean in UK waters and are present in the NNS throughout the year. Harbour porpoises have been recorded in low numbers in February, from April to September, and in December. The northern and central areas of the North Sea appear to

be important areas for harbour porpoises, especially in summer. Although the harbour porpoise is generally described as a coastal species, there have also been sightings in deep offshore waters.

Killer whales (*Orcinus orca*)

Killer whales have been observed in UK waters off northern and western Scotland throughout the year. Between Shetland and Norway, the species has been recorded regularly from November to March. No overall population estimates exist for killer whales in the Northeast Atlantic or UK waters.

Minke whales (*Balaenoptera acutorostrata*)

Minke whales occur throughout the central and NNS, particularly during the summer months. In the North Sea, minke whales appear to move into the North Sea at the beginning of May and are present throughout the summer until October. The summer abundance of minke whales in North Sea areas was estimated during the SCANS II 2005 survey, and minke whales were recorded throughout the North Sea, west of Britain and Ireland and on the Celtic Shelf. The northern part of the central North Sea saw the highest density. Approximately 17,500 animals were estimated, with approximately 3,700 animals in the north and central North Sea.

Sperm whales (*Physeter macrocephalus*)

Sperm whales are widely distributed in deep waters to the north and west of Scotland, and have been recorded regularly in waters around the Orkney and Shetland Islands, with sightings and strandings reported in most months. From a 2007 Cetacean Offshore Distribution and Abundance in the European Atlantic (CODA) survey of offshore European waters, numbers may exceed 2,000 animals.

White-beaked dolphins (*Lagenorhynchus albirostris*)

White-beaked dolphins are distributed over the continental shelf. In the North Sea they tend to be more numerous within about 200 nm (nautical miles) of the Scottish and north-eastern English coasts. They are present throughout the year in the North Sea, with most sightings recorded between June and October (Table 6-12). Moderate numbers have been recorded in February, March and September, with low numbers observed in June and July. Estimates of population from the SCANS II 2005 survey area were approximately 25,000 animals, within approximately 9,500 animals in the north and central North Sea.

The Atlantic white-sided dolphin (*Lagenorhynchus acutus*)

The Atlantic white-sided dolphin is primarily an offshore species, and has been recorded during a number of surveys in the NNS, especially during summer. It shares most of its range with the white-beaked dolphin, but in the eastern North Atlantic it has a mainly offshore distribution and is regularly sighted in the waters north and west of Shetland.

6.3.7.3 Pinnipeds

There are two species of pinnipeds (seals) which reside in UK waters, the common or harbour seal, and the grey seal. Both of these species breed in the UK, with harbour seals pupping in June and July and grey seals pupping between October and December.

Common or harbour seals (*Phoca vitulina*)

The common (or harbour) seal is found in all coastal waters around the North Sea. Estimated numbers of harbour seals in the UK are approximately 28,000 animals, derived from aerial surveys between 1996 and 2006. The majority (85%) are found in Scotland. During the pupping

season (June/July) and the moulting season (August/September), these seals will spend more time ashore than at other times of the year. Their distribution at sea is constrained by their need to return periodically to land.

Grey seals (*Halichoerus grypus*)

Grey seals are found across the North Atlantic and the Baltic Sea. The Northeast Atlantic is home to approximately half of the world population, with approximately 40% of the grey seals occurring in the UK. The best estimate of grey seal population size in UK waters is approximately 130,000, with growth of around 2.5% per annum. Approximately 70,000 seals are associated with breeding colonies in the North Sea, and over 90% of the UK population breed in Scotland. Most of the population will be on land from October to December for pupping, and again from February to March for their annual moult. Grey seal foraging movements are either long distance trips from one haul-out site to another or local repeated trips to discrete offshore areas.

6.3.8 Marine Reptiles

This subsection draws on a report by the JNCC (2000) [33].

Five species of marine turtle have been recorded in UK waters. Of these five, only the leatherback turtle *(Dermochelys coriacea)* is considered a regular member of UK marine fauna, and has been recorded annually by the JNCC since the 1950's. Sightings are concentrated to the west and south of Ireland, south-west England and the west coast of Scotland, Orkney and Shetland, with far fewer recorded sightings from the North Sea coasts of England and east Scotland. A total of 451 leatherback sitings have been recorded, with most sightings made in August and 95% of all sightings reported between June and October.

6.4 Fisheries Activity in Brent Field Area

This section describes the current understanding of the fishing industry offshore at the Brent Field, and is based on statistical data from the International Council for the Exploration of the Seas (ICES), provided by Marine Scotland and summarised in reports by Mackay Consultants in 2011 and 2014 [34,35] and BMT Cordah [20].

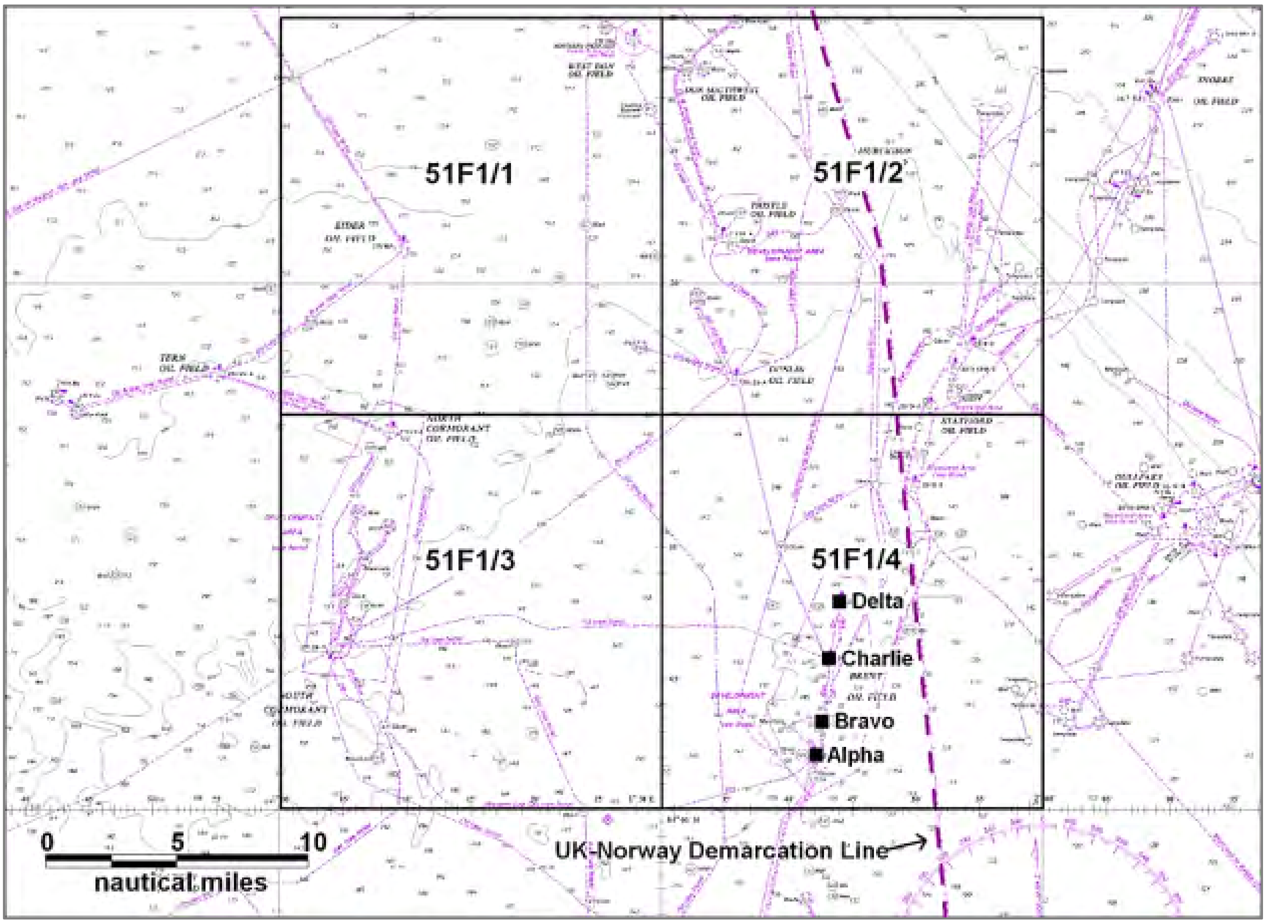
These studies provide the latest data as well as recent historic trends with regards to fishing activity in ICES rectangle 51F1, which corresponds to the Brent Field (see Figure 6-12). For management purposes, ICES collates fisheries information for individual rectangles, or geographic areas, measuring 30 nm by 30 nm, which equates to approximately 3,080 km^2.

Historical fishing statistics have been summarised for the following:

- Fishing effort: a measure of the time spent travelling to fishing grounds as well as the time spent fishing
- Weight (tonnes) and financial value (£) of catch
- Overall value: financial yield per ICES rectangle represented as a scale from low to high, which can be used as a method of expressing commercial sensitivity [20]

This summary represents the latest appreciation of the commercial fisheries around the Brent Field.

Figure 6-12: Location of Brent Field in relation to ICES Rectangle 51F1 Divided into Four Quadrants [38]



The Petroleum Act 1987 regulates the interaction between fishing and the offshore oil and gas industry, and includes automatic safety zones around all offshore installations and compensation for loss of access / damage to fishing gear. The safety zone extends to 500 m from each platform (an area of 785,400 m^2 per Brent platform), and it is an offence for an unauthorised vessel to enter a safety zone except under special circumstances. The combined total safety zone for the four Brent platforms is approximately 3.1 km^2 (approximately 0.1% of ICES rectangle 51F1). A safety zone is required to stay in place during the decommissioning period and can only cease when the structure no longer projects above the surface of the sea [36]. Shell will clarify any doubt about the continuation of a safety zone beyond this period during decommissioning work with the regulator. Shell intends to apply for an extension to the safety zone.

The total value of the catch in rectangle 51F1 over the period 2000-2015 was approximately £75 million, with an annual average of less than £5 million, as shown in Table 6-13. Approximately 115,000 tonnes of catch were reported between the same years, with an annual average of approximately 7,000 tonnes. However, there have been substantial year-to-year fluctuations in the weight and value of the catch, mainly because of the impact of the European Commission’s Common Fisheries Policy (CFP). The CFP aims to foster a dynamic EU fishing industry while ensuring that the industry is sustainable and fish stocks are conserved. In terms of value, for example, the total has fluctuated from approximately £556,000 in 2012 to £11.4 million in 2008.

The figures in Table 6-13 also show that the total catch (in terms of weight and value) during the last five years is much lower than the preceding decade [34]. For example, the average weight of catch for the period 2000-2010 is approximately 9,900 tonnes, while for the period 2011-2015 the average weight is approximately 1,200 tonnes. The same can be said for value: comparing the average of approximately £6,300,000 (2000-2010) to £1,200,000 (2011-2015).

It should be noted that these data reflect historic fluctuations in fisheries ecosystems and may not be representative of future statistics.

Table 6-13: Summary of Reported Catches in Rectangle 51F1 for the Period 2000-2015 [20, 34, 37][1]

Year	Days Effort (Fished)	Live Weight (Tonnes)	Value (£)
2000	1,142	22,602	9,625,166
2001	1,311	16,278	8,908,296
2002	1,090	19,287	10,757,250
2003	840	13,236	6,695,900
2004	458	10,120	6,958,058
2005	233	1,307	1,026,564
2006	182	4,018	3,200,928
2007	223	7,157	5,374,435
2008	237	10,826	11,400,099
2009	233	3,207	3,753,504
2010	158	1,036	1,119,618
2011	117	490	740,786
2012	90	361	556,236
2013	182	1,094	1,422,491
2014	100	2,067	1,748,346
2015[2]	102	1,933	1,562,931
Total	**6,700**	**115,000**	**74,850,600**

[1] This includes both UK and foreign vessels having access rights (working under EU Common Fisheries Policy).

[2] 2015 data are provisional statistics from Marine Scotland.

Fishing in rectangle 51F1 was historically dominated by the mackerel fishery (a pelagic species), which accounted for 76% of the value of the catch over the period 2000-2015 and 84% of the weight, shown in Table 6-14. Demersal species including haddock, cod, saithe, monkfish and whiting accounted for the remaining value/weight. Although the mackerel fishery represents 84% of the catch weight, the UK mackerel quota can usually be caught in only a few weeks. Therefore the majority of the fishing effort, or particularly the number of days fished, has been by the whitefish fleet [35].

In the period 2010-2013, no mackerel were reported to be caught in rectangle 51F1. This reflects the changing nature of the mackerel fishery resulting from a northwards migration of the stock. Since the early 2000's, catches of mackerel in this area have declined as the focus of this fishery has shifted elsewhere [35]. A small mackerel catch was reported in 2014 and 2015, with a total of approximately 2,700 tonnes [37]. This represents only 3% of the overall mackerel catch from 2000-2015 (summarised in Table 6-14).

Table 6-14: Comparison of Weight and Value of Mackerel Catch to other Species in ICES Rectangle 51F1 for the Period 2000-2015 [34,37][1]

Species	Weight (tonnes)	Percentage of Total	Value (£)	Percentage of Total
Mackerel	95,715	84%	56,068,843	76%
Other (demersal species)	18,195	16%	17,866,031	24%
Total Value	**113,910**	**100**	**73,934,870**	**100**

[1]2015 data are provisional statistics from Marine Scotland.

In 2012, the 'relative effort' in kWdays (kWdays are the days at sea multiplied by the power of the vessel in kilowatts at the voyage landing date) was 'low' for demersal species, with no recorded data for pelagic species as listed in Table 6-15. Additionally there was no recorded data for shellfish; however, the same gear type used for demersal species has been used to fish for shellfish, therefore the fishing effort for shellfish is recorded under demersal fishing effort.

Table 6-15: Relative Fishing Effort in ICES Rectangle 51F1 for 2012 [20]

Effort (kWdays)	
Species	**ICES rectangle 51F1**
Demersal	"Low" [20,000 – 100,000]
Pelagic	No data
Shellfish	No data*

* kWdays for shellfish are included within the demersal effort due to the gear type used

According to the Marine Scotland website [37], the value of demersal species caught in rectangle 51F1 in 2014 was approximately £0.95 million, representing a 'moderate' value. The value of pelagic species caught in rectangle 51F1 in 2014 was approximately £0.79 million, and the value of shellfish species was approximately £220, or a 'low' value. These categories are somewhat arbitrary and should only be used as an indication of the sensitivity of an area.

Projections of future mackerel fishery in the Brent area by Mackay indicate the value of the mackerel fishery to be similar to the annual average from 2006-2009 in rectangle 51F1 of approximately £5 million [35].

In contrast the scientific evidence suggests that many of the key white fish (e.g. cod, haddock, and whiting) stocks have been over-fished and that more action is required to enable them to recover to sustainable levels. A good example of that is the current Cod Recovery Plan. On the assumption that some of these policies will be successful it is reasonable to expect higher future

demersal/whitefish catches in 51F1, although they may continue to be controlled by the total allowable catches [35].

The future projection of demersal fishery by Mackay is an annual average value of approximately £2 million. Combining both the mackerel and demersal values gives an overall annual average of £7 million. This is similar to the 2000-2009 average of just under £6.8 million [35].

No significant increase in fishing effort or the number of vessels or fishermen is expected. Technological improvements in the industry are anticipated, and at the present time there is also substantial spare capacity in the industry, notably the pelagic fleet [35].

The number of fishing vessels registered in Scotland and the variation over the period 1999-2009 is summarised in Table 6-16. The number of fishermen in Scotland over the period 2002-2009 is included in Table 6-17.

Table 6-16: Number of Fishing Vessels Registered in Scotland (over 10m length) [34]

Year	Number	Changes
1999	979	-
2000	949	-30
2001	944	-5
2002	828	-116
2003	749	-79
2004	730	-19
2005	719	-11
2006	706	-13
2007	697	-9
2008	713	+16
2009	691	-22

Table 6-17: Number of Fishermen in Scotland [34]

Year	Number	Changes
2002	5,707	-
2003	5,276	-431
2004	5,275	-1
2005	5,155	-120
2006	5,205	+50
2007	5,424	+219
2008	5,448	+24
2009	5,409	-39

It can be seen from the above tables that:

- The number of vessels (over 10 m in length) in 2009 was about 30% less than in 1999. There was a decrease every year during that period with the exception of a small increase in 2008.
- There have been significant improvements in catching technology in recent years, the result being that a given catch quota can be caught with less effort and, eventually, fewer vessels. That is evident from the mackerel fishery because some of the Scottish pelagic fleet now only fish for a few weeks of the year in order to catch their specific quotas.

6.5 Oil and Gas Infrastructure Surrounding the Brent Field

The Brent Field is located within an area of major offshore oil and gas development and infrastructure. There are several UKCS oil and gas field developments adjacent to the Brent Field, the closest being the Norwegian Statfjord Field, as follows:

- Statfjord (3 km), Murchison (24 km) and Dunlin (10 km) to the north
- Cormorant (28 km) and Hutton (13 km) to the west.
- Lyell (24 km) and Ninian (14 km) to the south-west
- Strathspey (0.5 km) and Alwyn (14 km) to the south

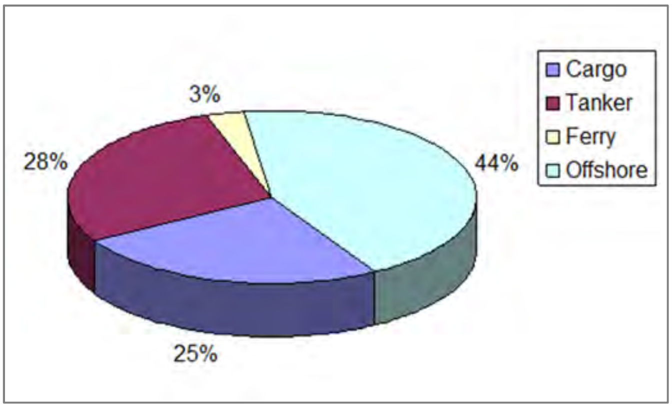
6.6 Shipping in the Vicinity of the Brent Field

Shipping traffic to European ports entering the NNS from the west generally traverse through the Pentland Firth or Fair Isle Channel between the Orkney and Shetland Islands, therefore the main shipping routes in the North Sea are predominantly to the south-west of the Brent Field.

Shipping to or from northern Norway, Russia or traffic from Denmark to the Faeroe Islands or vice versa, have the potential to transit closer towards the Brent Field. A study by BMT Cordah [20] recorded 0.5 to 10 vessels per day using 4 shipping lanes located in the area around Block 211/29, which consisted of shuttle tankers and offshore supply and standby vessels, suggesting that there is limited international shipping traffic in the Brent area.

A more recent study performed by Anatec [21] has evaluated the shipping routeing pattern and found that there are 24 shipping routes trafficked by an estimated 686 ships per year passing within 10 nm of the Brent B, C and D locations. This corresponds to an average of 1 to 2 vessels per day. The majority of vessels passing in the vicinity of the Brent Field are offshore support vessels in the range of 1,500 – 5,000 dead weight tonne (DWT) and tankers in the size range > 40,000 DWT. Brent Field supply and operations vessels are excluded from this data as it is assumed this activity will stop once decommissioning starts. The overall breakdown of traffic by vessel type is presented in Figure 6-13.

Figure 6-13: Vessel Type Distribution within 10 nm of the Brent Platforms



Fishing vessel activity in ICES rectangle 51F1 was studied by Anatec in 2014 [38], and occurs an average of 180 days per year from 2005 to 2011 (April and May are the busiest months). This equates to a rough average of one fishing vessel every other day in the vicinity of the Brent platforms travelling at relatively slow speeds of under 5 knots.

6.7 Wrecks, Military Activities and Subsea Cables near the Brent Field

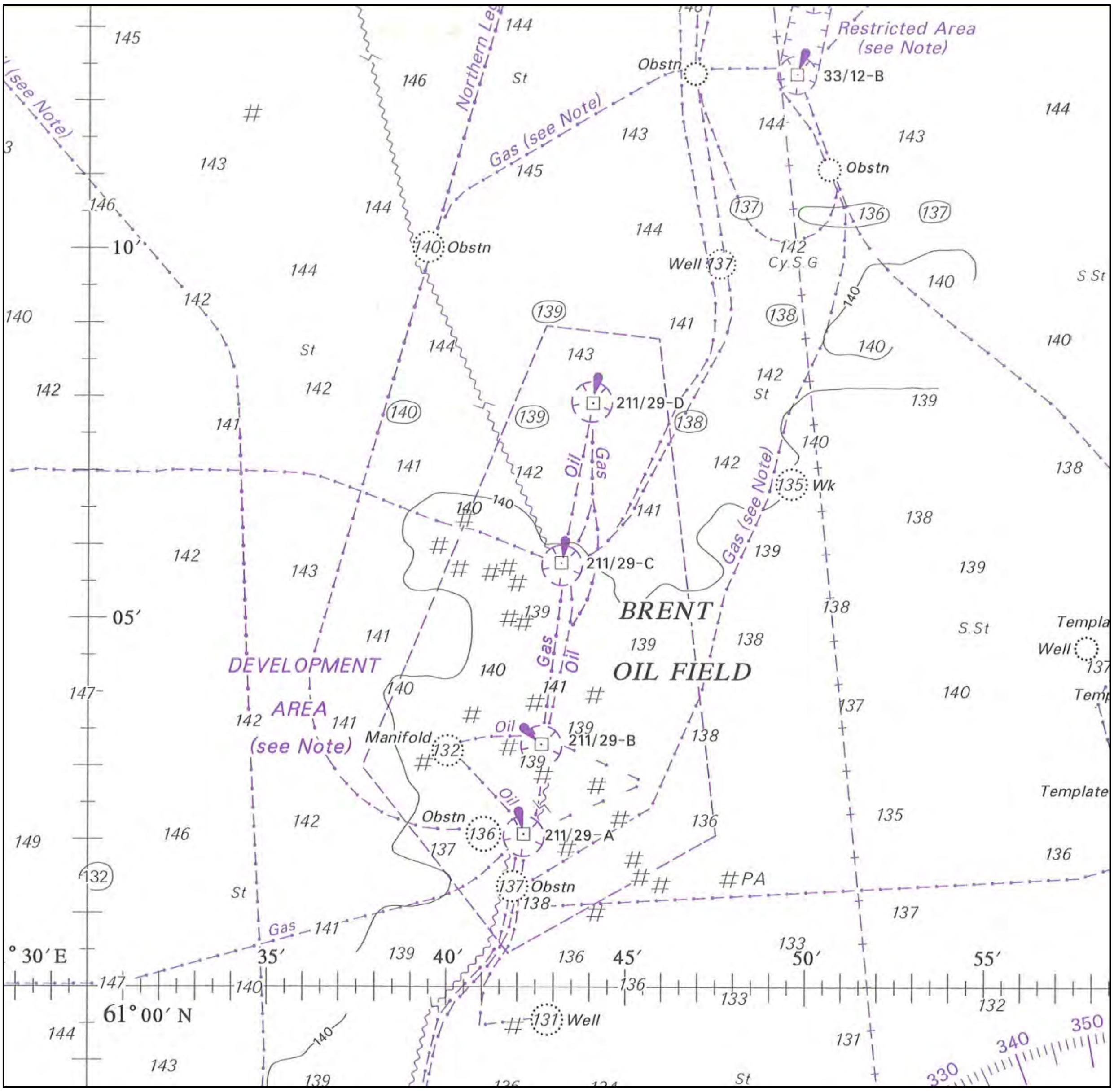
6.7.1 Wrecks

A total of three obstructions in the Brent Field are marked on Admiralty Charts (in Figure 6-14), with a shallowest known depth of 132 m (west of 211/29-B), 136 m (west of 211/29-A) and 137 m (south of 211/29-A), and they pose no risk to shipping.

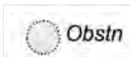
Also within the Brent Field (shown in Figure 6-14 as 'development area'), some 15 remains of wrecks, or other foul areas, are identifiable which while considered non-dangerous to navigation (owing to the water depth), should be avoided by anchoring vessels or trawling activities. A foul area is defined by the International Hydrographic Organisation as an area of numerous unchartered dangers to navigation.

Therefore apart from the platforms themselves, there are no charted obstructions on the seabed within the Brent Field that would pose a risk to navigation.

Figure 6-14: Extract from Admiralty Chart showing Brent Field and Surrounding Area[4]



#: Foul ground, non-dangerous to navigation but to avoid by vessels anchoring, trawling etc.

 Obstruction of least known depth

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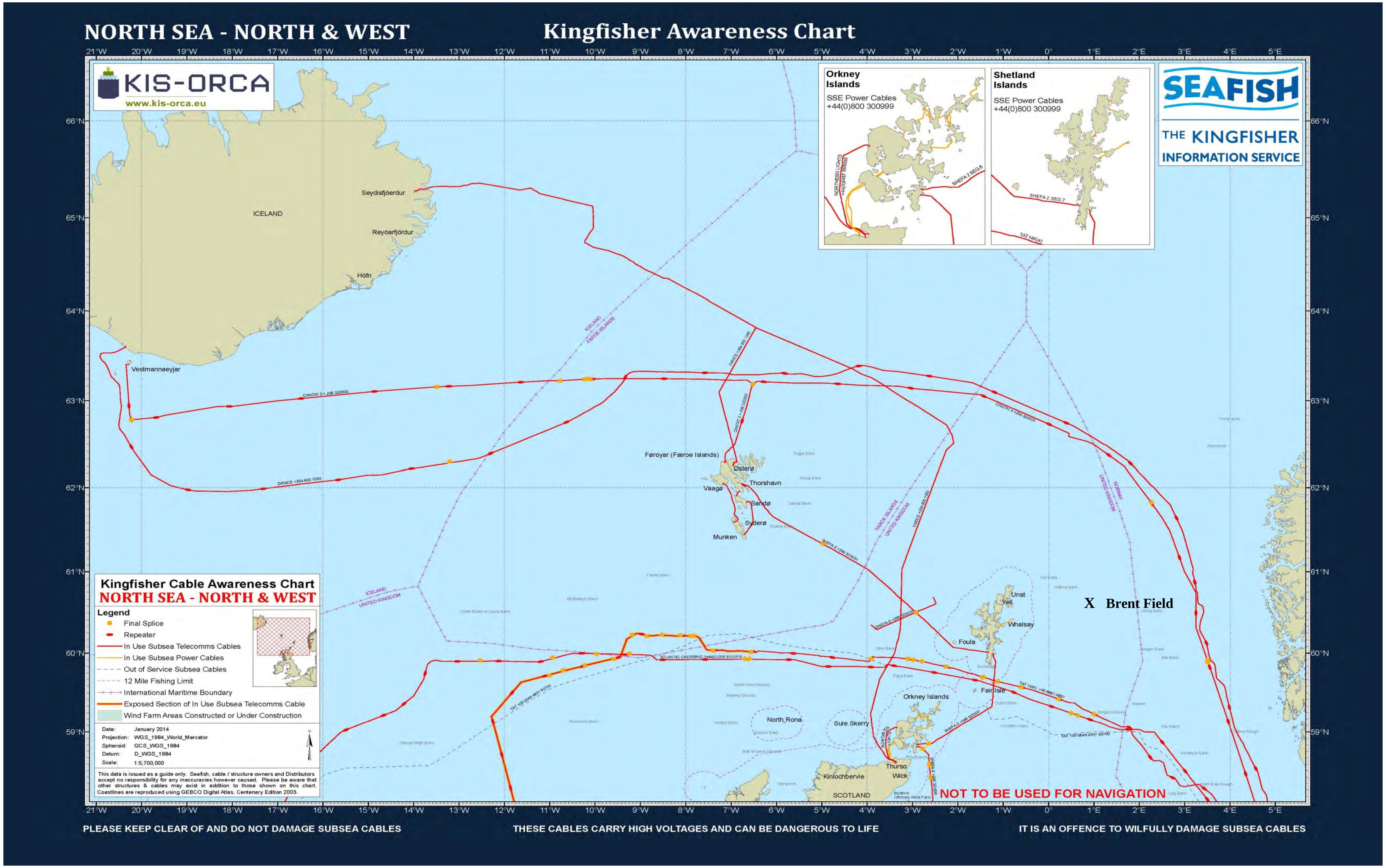
6.7.2 Military Activities

There are no identified areas dedicated for military activities in the vicinity of the Brent platforms.

6.7.3 Subsea Cables

Other than those associated with Brent operations, there are no known subsea cables in the vicinity of the Brent Field. The Kingfisher Information Service [39] has produced guidelines of the locations of subsea cables based on information from the UK Cable Protection Committee (UKCPC). According to Figure 6-15, the closest subsea cable lies to the east in Norwegian waters, approximately 70 km from Brent.

Figure 6-15: Kingfisher Cable Awareness Chart for the North Sea – North and West [40]



6.8 Summary of Environmental Sensitivities in the Vicinity of the Brent Field

The preceding sections have summarised the offshore project area at the Brent Field after approximately 40 years of operations, including:

- Offshore physical and chemical environment at the Brent Field: covering meteorology, oceanography, marine sediment composition, drill cuttings, subsea debris
- Offshore natural resources: covering benthic fauna, coral, fish, shellfish, marine mammals and birds
- Fisheries activity
- Oil and gas infrastructure surrounding the Brent Field
- Shipping in the vicinity of the Brent Field
- Wrecks, military activities and subsea cables

Table 6-18 provides a summary of the most important environmental sensitivities in the area surrounding the Brent Field offshore over the course of a year.

Table 6-18: Summary of Environmental Sensitivities in the Vicinity of the Brent Field

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Habitats Directive: Annex I Habitats There are no known Annex I habitats in the Brent facilities area.											
Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Habitats Directive: Annex II Species Of the four Annex II species, only the harbour porpoise has been sighted in the Brent facilities area, with low abundance in February, from April to September and in December (UKDMAP, 1998).											
Low	Moderate	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate
Benthic Fauna Benthic communities in the Brent facilities area are similar to those found throughout a large surrounding area of the NNS.											
Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Plankton The plankton in the Brent facilities area is typical of the NNS. Peak productivity occurs in spring and summer.											
Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Finfish and Shellfish The Brent facilities are located in spawning grounds for cod (Jan to April), haddock (Feb to May), Norway pout (Jan to April), saithe (Jan to April), sandeel (Nov to Feb) and whiting (Feb to June), and within nursery grounds for anglerfish, blue whiting, European hake, haddock, herring, ling, mackerel, Norway pout, sandeel, spur dog and whiting (throughout the year) (Coull *et al*., 1998; Ellis *et al*., 2010).											
Very High	Very High	Very High	Very High	High	Moderate	Moderate	Moderate	Moderate	Moderate	High	High
Marine Mammals The main marine mammal species occurring in the Brent facilities area are harbour porpoise, killer whale, minke whale, sperm whale, white beaked dolphin and white-sided dolphin. The majority of sightings have taken place during the spring and summer (Reid *et al*., 2003; UKDMAP, 1998).											
Moderate	Moderate	High	High	High	High	High	High	High	Moderate	Moderate	Moderate
Seabirds Seabird vulnerability to oil pollution in the Brent facilities area and surrounding blocks is "high" in January, March, July and between September to November. The overall vulnerability of seabirds to oil pollution in the Brent area is "low" (JNCC, 1999).											
High	Moderate	High	Moderate	Moderate	Low	High	Low	High	High	High	Moderate
Fisheries The relative value of demersal species in the Brent facilities area is "moderate", while the relative value for shellfish species is "low". Relative fishing effort for demersal species is "low" (BMT 2015, Marine Scotland, 2015).											
Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Shipping Shipping density in the Brent facilities area ranges from "low" to "very low" density (DECC, 2014).											
Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

KEY:
- Very High sensitivity
- High sensitivity
- Moderate sensitivity
- Low sensitivity
- Not surveyed/ No data

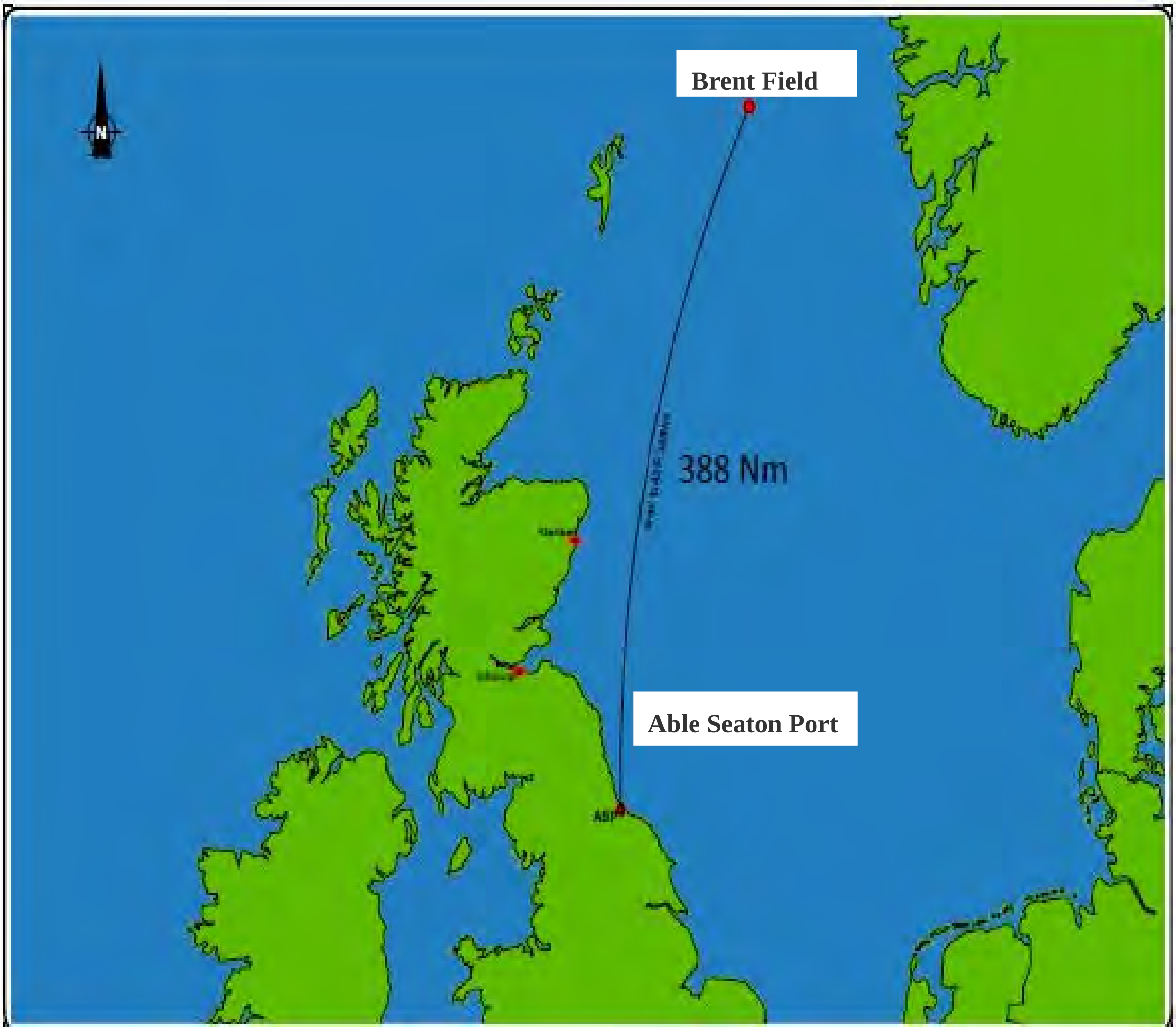
6.9 Environmental Setting along Transit Route and Transfer Location

The subsections below draw on a report by BMT Cordah (2015) [20], which references information from other earlier studies, and describes the proposed offshore transit route and transfer location.

Able has been awarded the contract to dismantle the Brent A topsides and jacket, and the Brent B and D topsides at their ASP facility at Teesside, on the north-east coast of England. The details surrounding the dismantling of the Brent C platform are being finalised, although it is anticipated this will follow a similar process to the other Brent topsides. The location and contracts for the dismantling and disposal of the remaining Brent Field facilities have not yet been decided.

The topsides and jacket will be transported by SLV to a location 15 nm from the mouth of the River Tees, off the north-east coast of England, at a water depth of 35m. The topsides will be transferred from the SLV to a cargo barge, and subsequently transported to the ASP facility. The whole journey is less than 400 nm, as illustrated in Figure 6-16.

Figure 6-16: Distance and Tow Route from Brent Field to ASP Facility



6.9.1 Offshore Infrastructure in the vicinity of the Transit Route and Transfer Location

After leaving the Brent Field, the proposed offshore transit route passes through UKCS Blocks 3/4 and 3/8 where the Ninian South platform and pipelines, Strathsprey subsea infrastructure, North Alwyn platform and numerous other subsea wells, pipelines, umbilicals and power cables are located (Figure 6-17).

Moving south into the Central North Sea, the offshore transit route passes through UKCS Blocks 15/17, 15/18, 15/22, 15/27, 21/1 and 21/2. These areas contain many oil and gas developments such as the Piper Bravo, Saltire, Scott, Galley and Buchan offshore platforms and facilities, as well as numerous other subsea wells, pipelines, umbilicals and power cables.

As shown in Figure 6-18, the closest surface infrastructure to the transfer location is Teesside Windfarm, located approximately 2 km to the south-east of the proposed transfer location. Subsurface infrastructure is also illustrated in the figure, and includes numerous pipelines, umbilicals, power cables and subsea wrecks. The route from the transfer location to the ASP facility would cross over the Ekofisk 2/4J to Teesside pipeline.

Figure 6-17: Offshore Infrastructure close to the Transit Route [20]

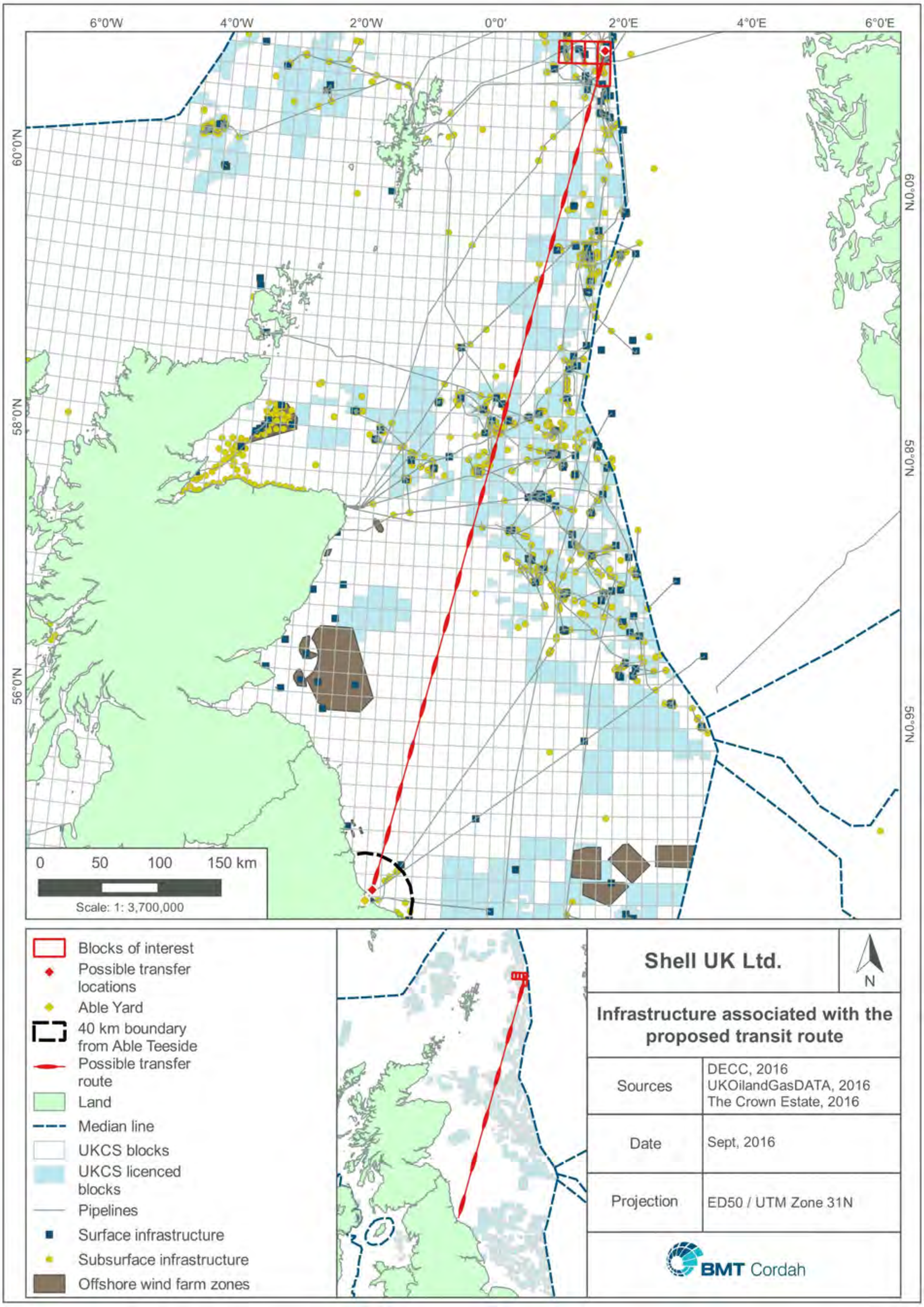
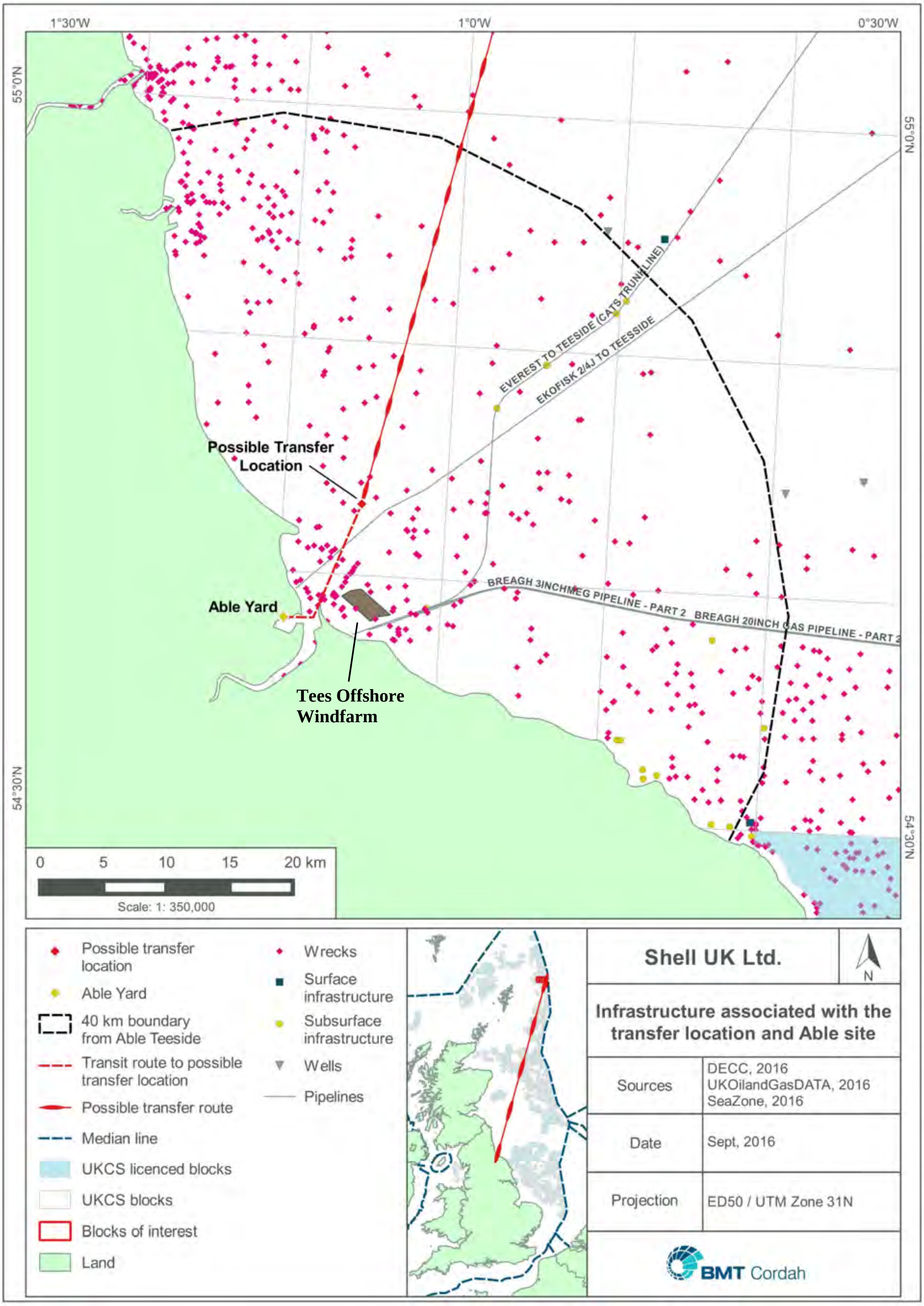


Figure 6-18: Offshore Infrastructure close to the Transfer Location [20]

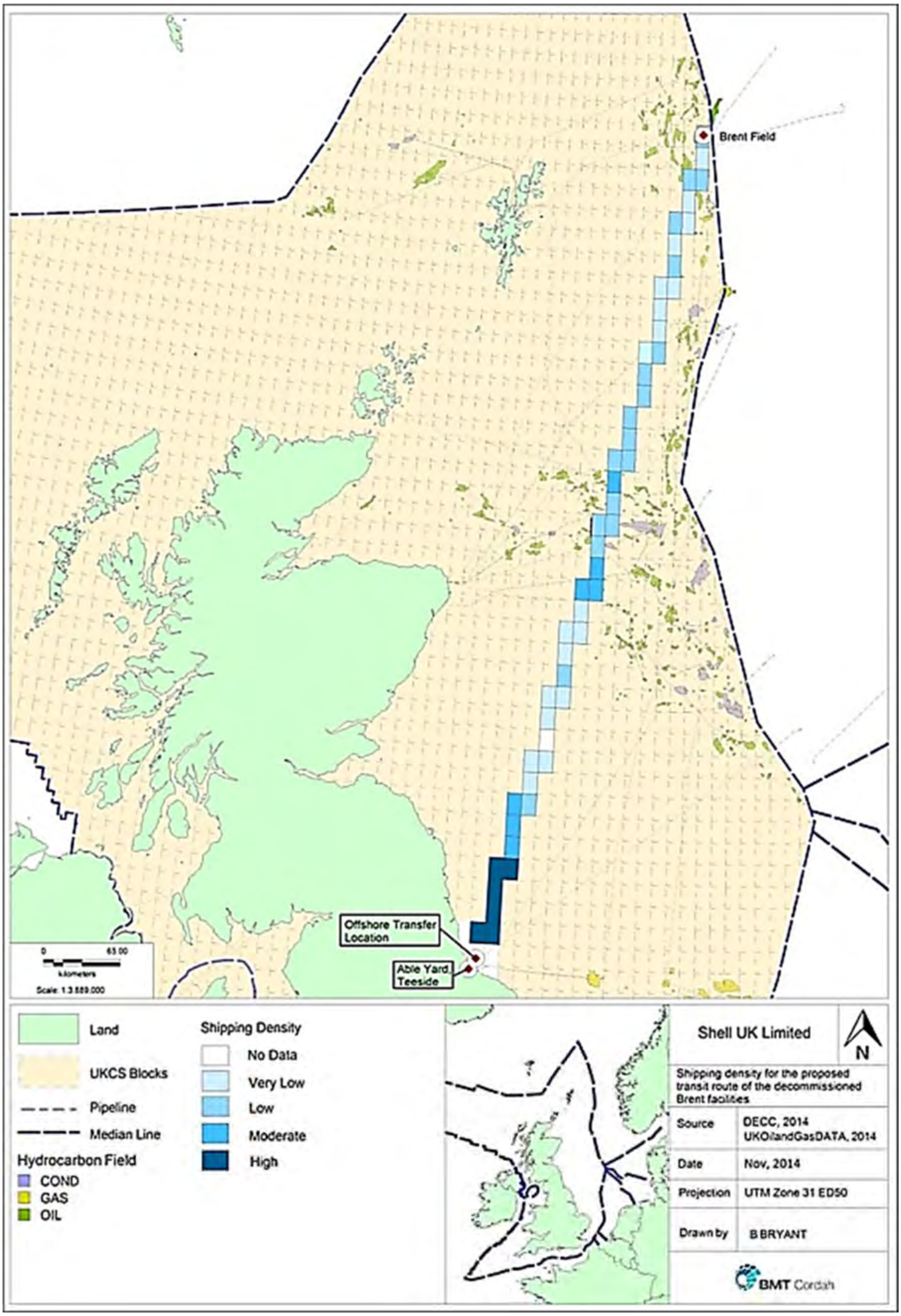


6.9.2 Shipping in the vicinity of Transit Route and Transfer Location

The estimated shipping density along the proposed offshore transit route and transfer location has been studied by BMT Cordah [20], and is illustrated in Figure 6-19. Shipping density along the route ranges from 'Very Low' to 'High'. It is highest close to the proposed nearshore transfer location, and is likely to be associated with oil and gas support vessels and vessels servicing the Teesside ports and harbours. A moderate shipping density is observed in the CNS, where given the high concentration of oil and gas developments, the majority of vessels found in this area are likely to be oil and gas support vessels.

The Tees Harbour Master provided input when determining the transfer location, which is located outside the shipping approach lanes for both the Tees and Hartlepool Marina.

Figure 6-19: Expected Shipping Densities in Relation to the Proposed Offshore Transit Route [20]



6.9.3 Offshore Conservation Areas in Relation to Transit Route and Transfer Location

Figure 6-20 illustrates the offshore conservation areas in proximity to the proposed transit route from the Brent Field to the ASP facility. The proposed route will pass by twelve marine conservation areas and one recommended MPA and directly through one conservation area, the North-East of Farnes Deep MCZ. These nearest conservation areas are summarised in Table 6-19. Note that definitions of marine conservation areas are provided in Section 6.3.1.1.

The **North-East of Farnes Deep MCZ** is located 55 km offshore from the Northumberland coast and protects a large area (492 km^2) of subtidal sand, sediment and mud. The varied sediment creates a dynamic environment home to a varied ecosystem, with a total of approximately 410 infaunal and 39 epifaunal taxa recorded during a 2012 survey by the JNCC [41]. Twenty eight individual Ocean quahog (*Arctica islandica*), a species designated as a Feature of Conservation Importance (FOCI), were recorded. Sea pens and evidence of burrowing fauna were also observed during the 2012 study.

Other offshore protected areas found within 25 km of the proposed transit route are Farnes East MCZ (an important habitat for seabirds, white-beaked dolphins, nephrops and seapens) and Coquet to St Mary’s MCZ (an important habitat for birds, seals and crustaceans).

Figure 6-20: Offshore Conservation Areas close to the Proposed Transit Route [20]

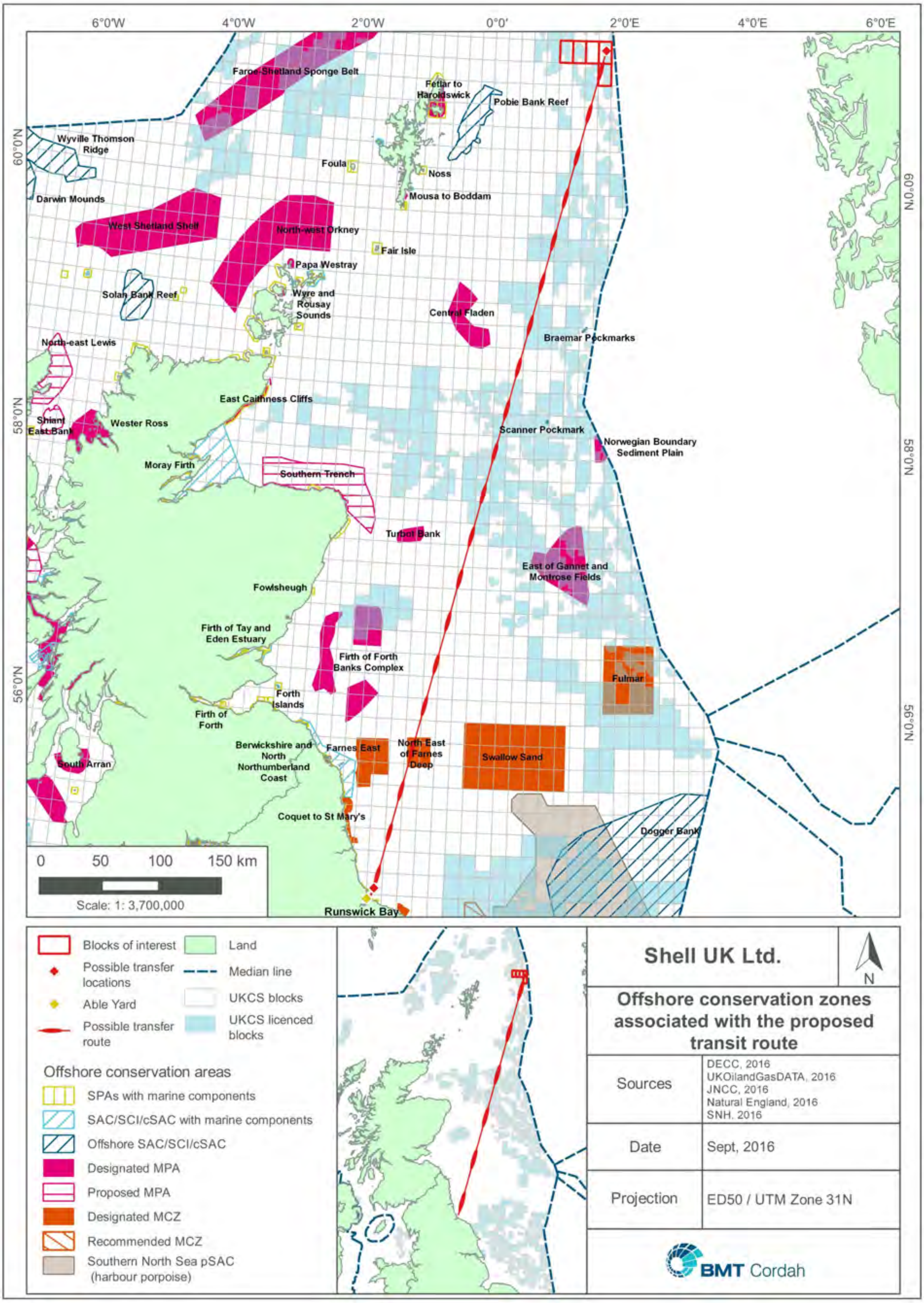


Table 6-19: Offshore Conservation Areas close to the Proposed Transit Route [20]

Designation	Description
Pobie Bank Reef SCI	This area is considered as an SCI due to the presence of an extensive community of encrusting and robust sponges and bryozoans.
Central Fladen MPA	This area was designated to protect seapens and burrowing megafauna that depend on burrowed mud habitat. The tall seapen is rare in UK waters, but they can be found near this MPA.
Braemar Pockmarks SAC	The pockmarks are a series of crater-like depressions on the sea floor, two of which contain the Annex I habitat "Submarine structures made by leaking gases".
Scanner Pockmark SAC	The pockmark is a large seabed depression in the NNS which contains large blocks of the Annex I habitat "Submarine structures made by leaking gases".
Norwegian Boundary Sediment Plain MPA	This sandy sediment plain area located far offshore to the east of Scotland in relatively shallow waters has been designated for the protection of the ocean quahog.
East of Gannet and Montrose Fields MPA	This MPA lies within a shallow sediment plain to the south-east of Scotland. The sandy seabed is an ideal home for ocean quahog. The southern part of the MPA includes one of very few examples of deep-sea mud on the continental shelf in the North Sea. Diverse communities of animals may be found here, such as sea urchins, sea cucumbers, worms and molluscs.
Turbot Bank MPA	This is an important habitat area for sandeel, the primary food species of many larger fish and marine mammals.
Southern Trench proposed MPA	This proposed MPA consists of a large undersea valley and is an example of an enclosed glacial seabed basin, important for understanding regional ice sheet drainage patterns. The deep shelf is a potential nursery area for certain fish species. Burrowed mud and minke whales have been found in the Southern Trench, and are protected features.
Firth of Forth Banks Complex MPA	This area is made up of three small designated areas west of the transit route. It was designated to conserve ocean quahog populations, offshore subtidal sands and gravels, and shelf banks. It encompasses a feature called the Wee Bankie, an area of unusual seabed, formed from underwater glacial ridges from the last Ice Age.
Swallow Sand MCZ	This area was to protect the sandy, gravelly sediment habitats found within its boundaries. It is one of the deepest areas in the North Sea and one of the largest MCZs covering an area of 4,746 km^2. The western region of this MCZ is home to the Swallow Hole, a glacial tunnel valley that supports many commercial fish species, including sprat and mackerel.
Farnes East MCZ	Farnes East became a designated MCZ in 2016. It is an important foraging area for seabirds and one of the few sites in the North Sea to include mud sediment, an important habitat for Nephrops and blonde and red seapens. Farnes Deeps, a glacial feature in this area, is a regular site for foraging and breeding white-beaked dolphins.
Coquet to St Mary's MCZ	Coquet to St Mary's became a designated MCZ in 2016. This area includes Coquet Island, an important breeding ground for seabirds and foraging and breeding grey seal habitat, and St. Mary's Island, home to rocky reefs and crustaceans. Additionally, it supports 90% of the UK roseate tern population. Marine mammals sighted in this area include harbour porpoise, grey seals, minke, orca and humpback whales.
Runswick Bay MCZ	Runswick Bay became a designated MCZ in 2016. This area provides spawning and nursery grounds for many fish, including herring, sprat, cod, whiting, and plaice. Harbour porpoises are frequent visitors of this area.

6.10 Nearshore and Onshore Environmental Setting

The ASP facility was selected because it meets Shell's technical requirements, it has a large onshore capacity, it has a successful track record in dealing with large offshore structures including a range of hazardous and non-hazardous materials, and Able will secure all of the necessary permits and licenses to perform decommissioning and waste management operations by the time decommissioning commences.

The ASP facility is certified to ISO 9001:2008 (Quality Management System), ISO 14001:2004 (Environmental Management System), OSHAS 18001:2007 (Health and Safety Management System), and ISO 30000 (Ship Recycling Management System).

In addition, the nearby Seaton Meadows Landfill, also operated by Able, has an Environmental Permit in place under the Environmental Permitting (England and Wales) Regulations 2010, which accepts the following types of waste:

- Non-hazardous and inert waste
- Asbestos waste and construction material containing asbestos
- Stable, non-reactive hazardous waste

Therefore, there will be no need to transport much of the waste through the local communities. Shell has set a target of 97% for re-use and recycling of materials.

Figure 6-21 shows an aerial photograph of the ASP facility.

Figure 6-21: Aerial Photograph of ASP Facility

6.10.1 Site Description

The ASP facility is located on the north-east coast of England, on the Seaton Channel off the River Tees, Hartlepool and covers an area of 126 acres including a 25 acre deep-water basin/dry dock and 306 m of quay frontage. The site is situated in a sheltered channel, and the conditions enable the site to receive large offshore structures which can be manoeuvred to the quayside.

Much of the area surrounding the site is industrial; the site is adjacent to Hartlepool Nuclear Power Station and close to Huntsman Dioxide chemical plant, sewage works, industrial estates and oil storage depots.

The nearest residential area to the site is approximately 1.7 km away, Seaton Carew, a small seaside resort in Hartlepool, as marked on Figure 6-26 to Figure 6-28 with a red X. It is understood that this community may expand in the future, which could decrease this distance to approximately 1.5 km. The red outlined area outlined on the figures represents the approximate boundaries of the ASP facility.

The ASP facility also includes the Teesside Environmental Reclamation and Recycling Centre (TERRC) and is within 0.2 km of the Seaton Meadows hazardous waste landfill. The facility is capable of processing up to 300,000 tonnes of offshore structures per year. The quayside facilities are shown in Figure 6-22.

Figure 6-22: Quayside Facilities at Able Seaton Port

To accommodate the Brent topsides and Brent A jacket, Quay 6 at the ASP facility is being strengthened. A new grounding pad is also being constructed within the existing dry dock facility shown in Figure 6-23. This will allow the cargo barge carrying the Brent structure (discussed further in Section 8.5.3) to enter the ASP facility and subsequently transfer the structure from the barge to the designated dismantling area on the quay. Able are constructing these facilities as part of ongoing expansion work and these activities will be completed prior to receipt of the decommissioned Brent facilities; they are not considered to be specifically part of the BDP and are therefore outside the scope of this ES.

Figure 6-23: Existing Dry Dock at the ASP Facility

6.10.2 Seabed Sediment

6.10.2.1 Sediment composition

The 2015 environmental baseline report by BMT Cordah [20] examined the seabed environment within 40 km of the onshore site. The sediments are categorised and illustrated in Figure 6-24, and described in Table 6-20.

The seabed sediments along the later stages of the proposed transit route to the transfer location are dominated by A5.2 sublittoral sand, as is the proposed offshore transfer location, which is characterised by clean medium to fine sands or non-cohesive slightly muddy sands on open coasts, offshore or in estuaries and marine inlets.

Seabed sediments along the proposed route from the offshore transfer location to the onshore dismantling facility at Teesside range from A4.2 Atlantic and Mediterranean moderate energy circalittoral rock just south of the transfer location to A3.1 Atlantic and Mediterranean high energy infralittoral rock at the entrance of the Tees Estuary. Sediments within the Tees Estuary are expected to be A3.3 Atlantic and Mediterranean low energy infralittoral rock.

Figure 6-24: Sediment Habitat Types associated with the Transfer Location and the Final Onshore Destination [20]

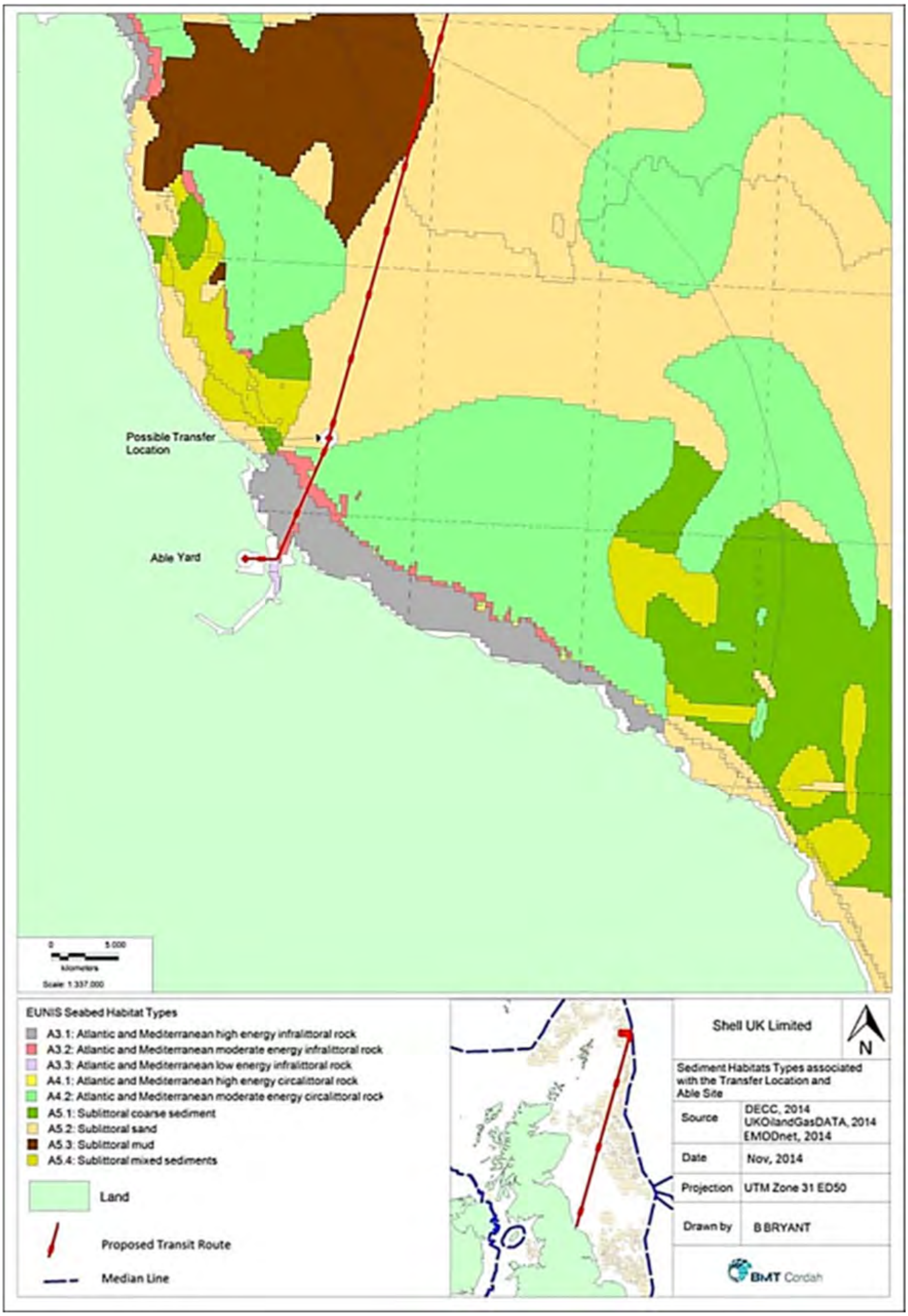


Table 6-20: Sediment Types Expected along Proposed Route from Offshore Transfer Location to ASP Facility [20]

Seabed habitat type (Figure 7.7)		Description
Nearshore transfer location ↓	A5.2 Sublittoral sand	• Clean medium to fine sands or non-cohesive slightly muddy sands on open coasts, offshore or in estuaries and marine inlets. • This habitat is often subject to a degree of wave action or tidal currents which restrict the silt and clay content to less than 15%. • The sediment habitat is characterised by a range of taxa including polychaetes, bivalve molluscs and amphipod crustacean.
	A4.2 Atlantic and Mediterranean moderate energy circalittoral rock	• Mainly occurs on exposed to moderately wave-exposed circalittoral bedrock and boulders, subject to moderately strong and weak tidal streams. • This habitat type contains a broad range of biological subtypes, from echinoderms and crustose communities (A4.21) to *Sabellaria* reefs (A4.22) and circalittoral mussel beds (A4.24).
	A3.2 Atlantic and Mediterranean moderate energy infralittoral rock	• Predominantly moderately wave-exposed bedrock and boulders, subject to moderately strong to weak tidal streams. • On the bedrock and stable boulders there is typically a narrow band of kelp *Laminaria digitata* in the sublittoral fringe which lies above a *Laminaria hyperborea* forest and park. • Associated with the kelp are communities of seaweeds, predominantly reds and including a greater variety of more delicate filamentous types than found on more exposed coasts (cf. A3.11).
	A3.1 Atlantic and Mediterranean high energy infralittoral rock	• Rocky habitats in the infralittoral zone are subject to exposed to extremely exposed wave action, or strong tidal streams. • The rock typically supports a community of kelp *Laminaria hyperborea* with foliose seaweeds and animals, the latter tending to become more prominent in areas of strongest water movement. • The water depth to which the kelp extends varies according to water clarity, exceptionally reaching 45 m. • The sublittoral fringe is characterised by dabberlocks *Alaria esculenta*.
Tees Estuary Able Yard	A3.3 Atlantic and Mediterranean low energy infralittoral rock	• This habitat type occurs in wave and tide-sheltered conditions, supporting silty communities with *Laminaria hyperborea* and/ or *Laminaria saccharina* (A3.31). • Associated seaweeds are typically silt-tolerant and include a high proportion of delicate filamentous types. • In turbid-water estuarine areas, the kelp and seaweeds (A3.32) may be replaced by animal-dominated communities (A3.36) whilst stable hard substrata in lagoons support distinctive communities (A3.34).

6.10.2.2 Sediment quality

Table 6-21 summarises the results of three marine sediment samples taken from areas in the rough proximity of the offshore transfer location. Sampling locations are shown in Figure 6-25. These samples have been collected by CEFAS with the aim of assisting regulators with sediment dredging disposal applications [42].

The sample results have been used to determine if there is likely to be any contamination present at the offshore transfer location, as there is no specific data available. The samples are compared against CEFAS Action Levels I and II which are defined as:

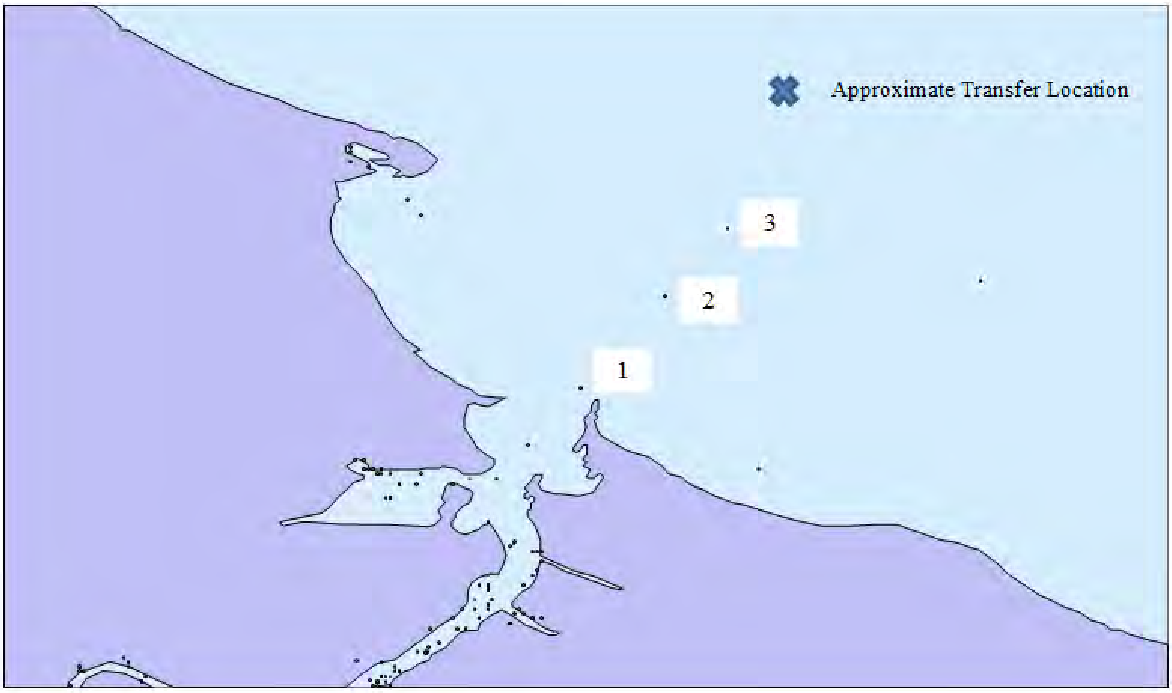
- Action Level I: Contaminant levels in dredged material below Level I are generally considered to be of no concern
- Action Level II: Contaminant levels in dredged material above Level II are generally considered unsuitable for sea disposal
- Dredged material showing contamination between Action Levels I and II requires further consideration and testing

As can be seen from the results, concentrations of the tested parameters for all three samples are below Action Level I, and are therefore not contaminated (although it should be noted that organic parameters have not been analysed).

Table 6-21: Results of CEFAS Marine Sediment Sampling [42]

	Point 1	Point 2	Point 3	CEFAS Action Level I (ppm)	CEFAS Action Level II (ppm)
Sample Date	2005	2005	2009		
Distance Offshore	Adjacent to shore	2 miles	3.5 miles	-	-
Sample type (ppm)					
Arsenic	7.8	13	10	20	100
Cadmium	0.013	0.06	0.05	0.4	5
Chromium	5.5	15	11	40	400
Copper	12	8.4	4.4	40	400
Lead	28	28	26	50	500
Mercury	0.01	0.01	0.02	0.3	3
Nickel	14	11	7.1	20	200
TBT	0.001	0.001	No data	0.1	1
Zinc	72	58	40	130	800

Figure 6-25: Location of CEFAS Marine Sediment Samples



6.10.3 Conservation Areas and Sensitive Receptors close to Nearshore and Onshore Operations

The ASP facility is located in close proximity to several locally, nationally or internationally significant coastal and onshore conservation areas.

6.10.3.1 Conservation areas

The following describes the categories of coastal conservation areas.

Ramsar sites are areas of internationally important wetland, and are designated under the Convention of Wetlands of International Importance adopted in Ramsar, Iran, and implemented in the UK by the JNCC. In the selection of Ramsar sites in the UK, the emphasis is on selecting sites of importance to waterfowl; consequently many Ramsar sites are also SPAs (defined below). There are currently 67 designated and two proposed sites in England.

Special Protection Areas (SPAs) are international designations under the European Habitats and Birds Directives to protect areas which support large populations of birds, and are implemented in the UK by the JNCC. These sites can be either a coastal or onshore environment. There are currently 107 SPAs with marine components.

Site of Special Scientific Interest (SSSI) is a national designation representing a protected area, primarily land based but some sites extend below the low level water mark. SSSIs are legally protected under the Wildlife and Countryside Act 1981, and designated by Natural England. These sites are designated to protect the country’s best wildlife and geological sites and are sometimes internationally significant. There are over 4,100 SSSIs in England.

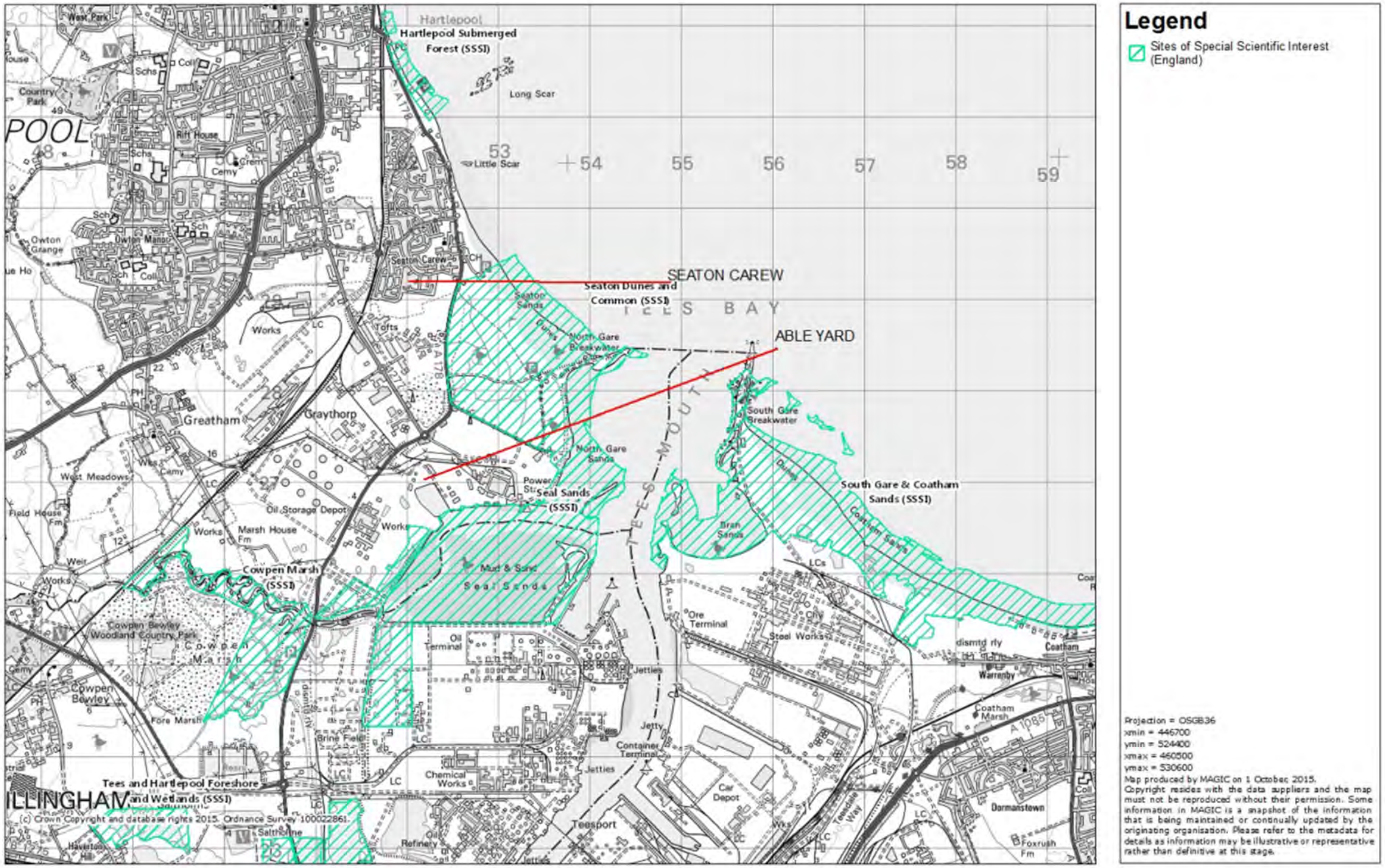
In addition, **Local and National Nature Reserves (LNR, NNR)** can also be defined, and are protected areas as they can contain important wildlife or geology of local or national interest.

The conservation areas surrounding the onshore site are described in Table 6-22 and shown in Figure 6-26.

Table 6-22: Summary of Coastal and Onshore Conservation Areas Surrounding the ASP Facility [43,44,45,46,47,48,49,50,51,52]

Site Name	Approximate Distance to ASP Facility	Environmental Significance
Seal Sands SSSI	Adjacent to site	This site consists of an extensive area of intertidal mudflats. These are of ornithological significance and attract large numbers of migratory wildfowl (approximately 4,000) and wading birds (approximately 24,000), especially during the winter months. There are several internationally significant species of bird which feed on the mudflats of Seal Sands, including the shelduck (approximately 3,200), knot (approximately 10,000) and redshank (approximately 1,000). Several other bird species including: mallard, teal, wigeon, diving duck, dunlin, oystercatcher, ringed plover, curlew, bar-tailed godwit, lapwing, grey plover and turnstone are also observed. When the mudflats are at high tide, the adjacent areas of reclaimed land with shallow lagoons and sand dunes serve as important roosting sites. Despite the name, seal populations and haul out sites are not a reason for the designation of this SSSI. Seal Sands SSSI is shown in Figure 6-26.
Tees and Hartlepool Foreshore & Wetlands SSSI	Adjacent to site	The Tees and Hartlepool Foreshore & Wetlands SSSI comprises seven distinct areas spread over approximately 600 acres. The section of this SSSI relevant to the BDP is an area of approximately 65 acres of coastal environment including wetlands, estuarine and maritime sites which abut the ASP facility to the south-west. This area supports an internationally significant population of wildfowl and wading birds on the Tees Estuary. Nationally important numbers of purple sandpiper, sanderling and shoveler are observed to be supported by the overall SSSI during winter. Redshank, curlew, teal and shelduck have been shown to feed and roost in the area of the SSSI adjacent to the onshore APS facility. This site is shown in Figure 6-26.
Teesmouth and Cleveland Coast Ramsar Site and Special Protection Area (SPA)	Adjacent to site	This site encompasses the same areas as the Tees and Hartlepool Foreshore & Wetlands SSSI, Seal Sands SSSI and Cowpen Marsh SSSI, and has a total area of approximately 3,000 acres. It is significant due to its range of coastal habitats which provide an area for feeding and roosting of internationally important numbers of waterfowl. These are described in further detail above. This SPA is designated in part to protect the Annex I species: the Little tern and the Sandwich tern. From April to August, Little terns breed on the beaches along the Teesmouth and Cleveland Coast. From October to March this SPA provides feeding and roosting land for more than 20,000 waterfowl. The area is used regularly by more than 1% of the biogeographic population of certain migratory species such as the knot, redshank and the ringed plover. Additionally, this SPA is home to nationally important populations of cormorant, shelduck, teal, shoveler, ringed plover and sanderling. The Teesmouth and Cleveland Coast SPA have the same boundaries as the Ramsar site as both were selected to protect the conservation of waterfowl. These sites are shown in Figure 6-27.
Teesmouth National Nature Reserve (NNR)	Adjacent to site	This site covers approximately 865 acres of coastal reserve, split into two main sections: North Gare and Seal Sands. North Gare is the hatched area shown in lime green to the north of ASP facility in Figure 6-28, and comprises dunes and grazing marsh. Bird species such as lapwings, curlew, short-eared owls, skylarks and meadow pipits are known to inhabit and breed in this area. Common and grey seals haul out on the sandbanks at low tide. This is the only regular breeding colony of common seals on the north-east coast of England. A description of Seal Sands SSSI is given above.
Seaton Dunes and Common SSSI and Local Nature Reserve (LNR)	0.5 km NE	The Seaton Dunes and Common SSSI encompass an area of approximately 260 acres, shown in Figure 6-26, and are of significance for its flora, fauna and bird life. Many types of flora are present including marram grass, sea lyme grass, sand couch and sea rocket. The nationally rare rush-leaved fescue, sea couch, sea buckthorn, and common spotted and marsh orchids are also observed on the dunes. Two nationally rare species of beetle exist here, *Hydnobius perrisi* and *Philonthus atratus* as well as the rare spider *Silometopus incurvatus*. Additionally, these dunes have significance in their provision of winter feeding grounds and roosting sites for several species of wading birds including sanderling, knot, ringed plover, turnstone, oystercatcher, dunlin and grey plover. Approximately 6% (600 birds) of the western European population of sanderling and 3% (10,000 birds) of the western European population of knot feed and roost within this area. This Seaton Dunes and Common LNR is represented as the top half of the SSSI, shown as the hatched area in teal in Figure 6-28.
Cowpen Marsh SSSI	1 km SW	This site is shown in Figure 6-26 and forms part of the Teesmouth Flats and Marshes and is an integral part of Tees Estuary, a site of international significance for overwintering shore birds. Migratory wildfowl and wading birds use its large saltmarsh and adjacent coastal grazing marshes and mudflats as a wintering location. The saltmarsh is dominated by common saltmarsh grass with sea aster. Additionally, species such as red fescue, sea plantain, sea arrowgrass, greater sea-spurry, sea milkwort and sea-lavender are found. The coastal grazing marsh comprises semi-improved neutral grassland with flora such as common bent, Yorkshire-fog, red fescue, tufted hairgrass, creeping bent, floating sweet-grass and marsh foxtail. Some brackish flora is also present. Together these two areas provide an important habitat for large numbers of roosting and feeding migratory wildfowl and wading birds. An estimated 1,000 birds have been recorded in the winter months, including wigeon, teal, curlew, redshank, bar-tailed godwit, lapwing, golden plover and dunlin. The species mallard, teal, moorhen, coot, redshank, snipe, lapwing, reedbunting and yellow wagtail are found to breed in the grazing marsh.
South Gare & Coatham Sands SSSI	1.8 km E	This site is shown in Figure 6-26 and forms part of the Teesmouth Flats and Marshes. It is significant for its flora, fauna and bird life and includes a variety of habitats including intertidal mud and sand, sand dunes, saltmarsh and freshwater marsh which have developed since the 1860’s with the construction of the South Gare breakwater with tipped slag. Marram grass, lyme grass (one of the largest continuous stands in Britain), and sea-couch grass are found on the sand dunes. Additionally, large populations of northern marsh orchid, early marsh orchid, fragrant orchid, yellow wort, lesser centaury, knotted hedge parsley, carline thistle, strawberry clover and rush-leaved fescue are also present on the dunes. Plants in the saltmarsh include sea wormwood, lesser sea spurrey, lax-flowered sea lavender, sea purslane, smallest hare’s ear and parsley water dropwort. Several species of butterfly, uncommon beetles (*Broscus cephalotes* and *Enochrus quadripunctatus*) and the rare spiders *Silometopus incurvatus* and *Dysdera crocata* are also present. An internationally significant number of sanderling (approximately 8% of the western European population, or 1,200 birds) is found on the intertidal areas along Coatham Sands. In addition the mud and sand-flats provide an important winter feeding habitat for bar-tailed godwit, curlew, redshank, dunlin and grey plover. The intertidal areas, breakwater and mussel beds are used by knots as feeding areas, with peak counts of 6,000 birds (approximately 2% of the western European population).
Hartlepool Submerged Forest SSSI	4 km N	The Hartlepool Submerged Forest SSSI comprises an area of approximately 50 acres and is shown in Figure 6-26. This site is of significance due to its evidence for Flandrian sea-level changes in eastern England, a geological period dating from 12,000 years ago at the end of the last glacial period to the present day. The site exhibits a sequence of inorganic and organic deposits including a peat bed in the intertidal area. Studies of the deposits have found pollen molluscs and archaeological remains which have been used to understand the pattern of sea-level change in eastern England over the last 5,000 years.

Figure 6-26: MAGIC Map[5] Showing SSSI Designations Surrounding the ASP Facility



[5] The MAGIC (Multi-Agency Geographic Information for the Countryside/Coast) website provides geographical and environmental information across Great Britain. The MAGIC partners are: DEFRA, English Heritage, Natural England, Environmental Agency, Forestry Commission and the MMO.

Figure 6-27: MAGIC Map Showing Location of RAMSAR and Special Protection Areas Surrounding the ASP Facility

Figure 6-28: MAGIC Map Showing Nature Reserves Surrounding the ASP Facility

Additionally, and as mentioned in Table 6-8, sandbanks and reefs are two Annex I habitats in consideration for SAC selection under the Habitats Directive. Sandbanks and reefs within a 40 km radius of the ASP facility have been mapped by BMT Cordah [20]. These sites are considered “potential” Annex I habitats because the JNCC believe, from the best available evidence, that Annex I sandbanks and reefs might be present. Figure 6-29 and Figure 6-30 illustrate these potential Annex I areas.

Figure 6-29: Potential Annex I Sandbanks in relation to Proposed Transfer Location and Onshore Destination [20]

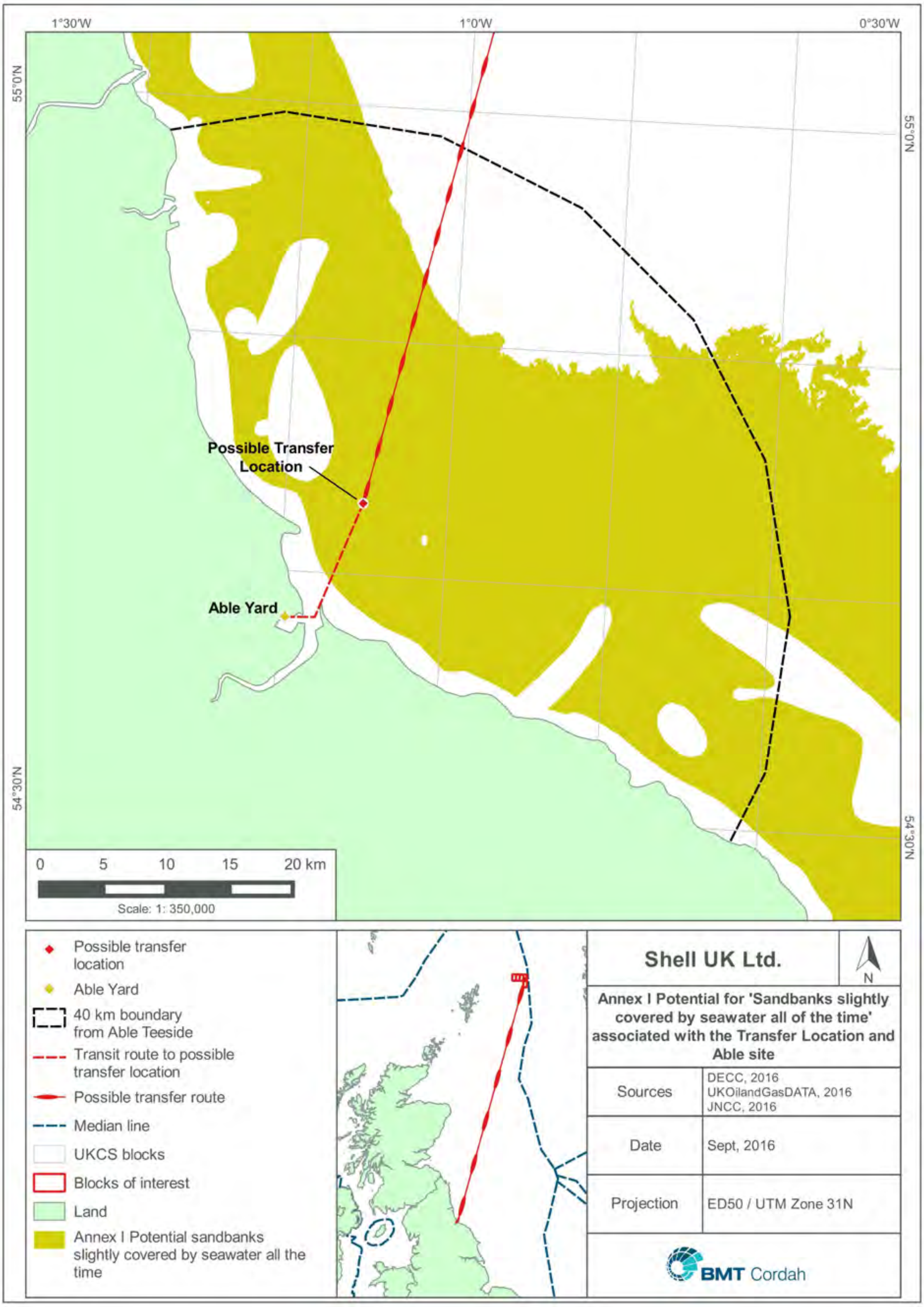
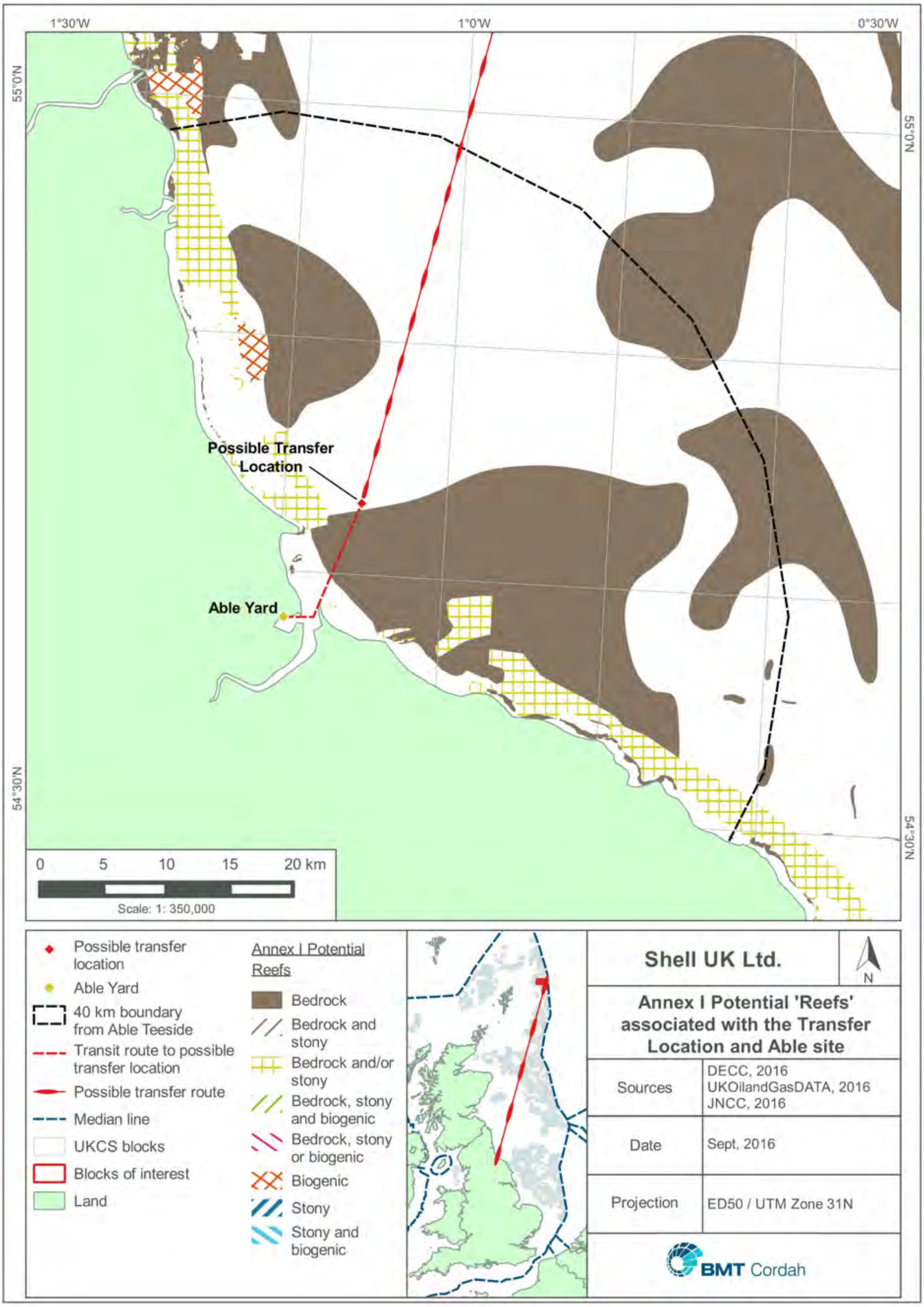


Figure 6-30: Potential Annex I Reefs in relation to Proposed Transfer Location and Onshore Destination [20]



6.10.3.2 Annex II: Protected species

Seals

Grey and common seals are listed in Annex II of the Habitats Directive, and are classified as European Protected Species (EPS) under Schedule 3 of these regulations. It is considered an offence to disturb, kill or injure these species.

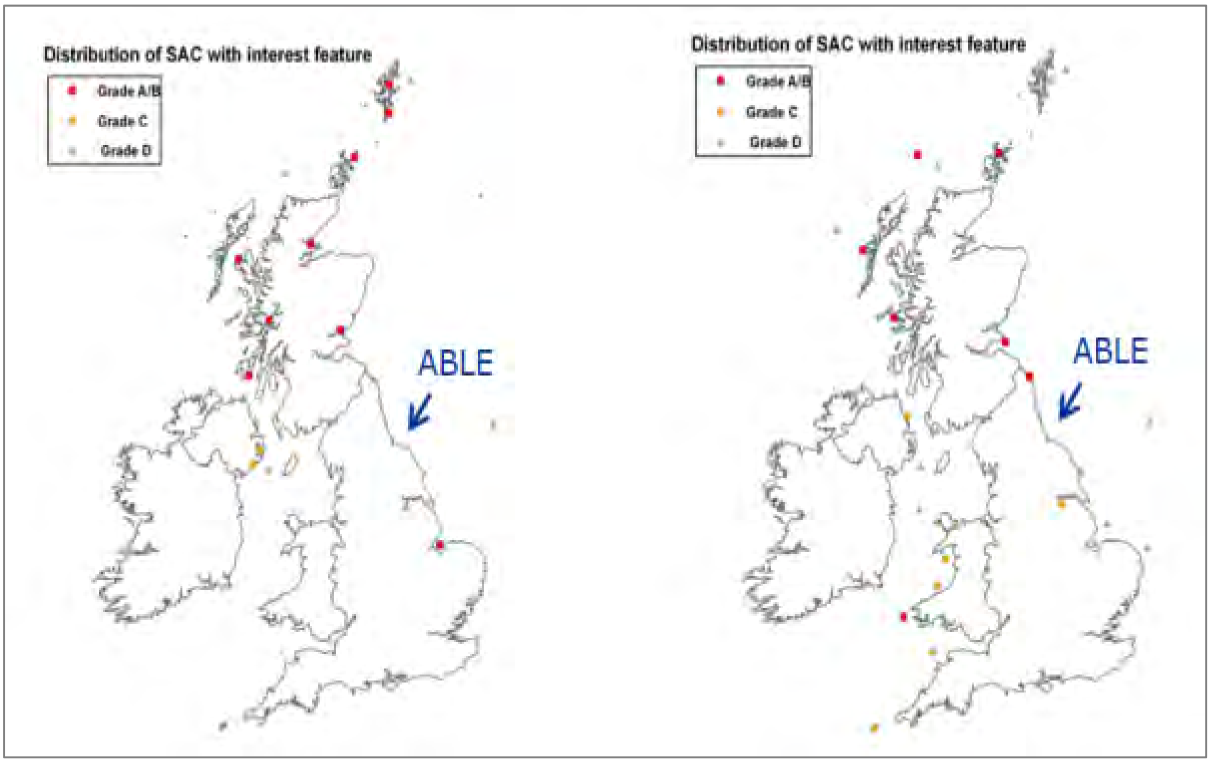
Figure 6-32 and Figure 6-33 illustrate the average densities of grey and common seals nearshore. The density of seals within a 40 km radius of the onshore decommissioning ASP facility have been recorded as less than one individual common seal per km^2 and less than five individual grey seals per km^2 [20].

Both common seals and grey seals are found at the Teesmouth NNR (Figure 6-28) but it is only the common seal that breeds at Seal Sands (Figure 6-26). As grey seal pups do not enter the water for weeks after birth, they require nurseries that are above the high-water mark. This is not possible at Seal Sands as the mudflats are inundated by the tide [53]. The pupping season of common seals is from June to July and the moulting season from August into September. During these times, the common seal spends more time ashore than at other times of the year. For grey seals, most of the population is on land from October to December for pupping, and again from February to March for their annual moult. Given this information, seal densities at the offshore transfer location are likely to be higher during the pupping and moulting seasons compared to other times of the year. The marine operations will take place in a period associated with common seal pupping, and seal individuals in search of food may be encountered at the transfer location.

Since 2008, there has been an increasing concern over the number of seal carcases (mainly grey seals and adult female harbour seals) found at various locations along the UK coastline. There appears to be some correlation between the seals' breeding season and the number of seal deaths recorded. In some months the victims are predominantly common seals. These deaths are more often associated with haul out sites. The fatal wounds observed on the seals are consistent with a single, smooth-edged cut starting at the head and spiralling around the body. The neat edge to the wound initially suggested the effects of a blade with a smooth edge applied with considerable force, while the spiral shape is consistent with the rotation about the longitudinal axis of the animals. Expert opinion initially suggested these injuries were consistent with those one might expect to see if seals were drawn through a ducted propeller, for example those used by vessels with Dynamic Positioning (DP) capability. However, JNCC have more recently stated that there is now incontrovertible evidence that corkscrew injuries can be caused by grey seal predation on young seals and seal pups. Based on the latest information it is considered very likely that the use of vessels with ducted propellers may not pose any increased risk to seals over and above normal shipping activities and therefore extensive mitigation measures and monitoring may not be necessary in this regard, although all possible care should be taken in the vicinity of major seal breeding and haul-out sites to avoid collisions.

Although both types of seal are present at Seal Sands, the area is not designated as a SAC. The nearest grey and common seal SAC areas to the ASP facility are located some distance away (approximately 60 nautical miles) as shown in Figure 6-31.

Figure 6-31: Distribution of Common Seal SACs (left) and Grey Seal SACs (right) around the UK [54][6]



Dolphins, porpoises and whales are also designated as EPS and are protected under the Habitats Directive. All three types of mammals have been sighted in the nearshore waters of the Tees Estuary, as well as within a 40 km radius of the proposed transfer location. The following observations have been made of these marine mammals in the nearshore area:

- Harbour porpoises: observed in low numbers apart from July when numbers are high
- White-beaked dolphins: observed throughout the year with very high numbers in June to medium numbers in September
- White-sided dolphins: observed in low numbers from September to April.

[6] **Grade A:** Outstanding examples of the feature in a European context.
Grade B: Excellent examples of the feature, significantly above the threshold for SSSI/ASSI notification but of somewhat lower value than Grade A sites.
Grade C: Examples of the feature which are of at least national importance (i.e. usually above the threshold for SSSI/ASSI notification on terrestrial sites) but not significantly above this. These features are not the primary reason for SACs being selected.
Grade D: Features of below SSSI quality occurring on SACs. These are non-qualifying features ("non-significant presence"), indicated by a letter D, but this is not a formal global grade.

Figure 6-32: Average Density of Common Seals near Proposed Offshore Transfer Location and Onshore Destination [20]

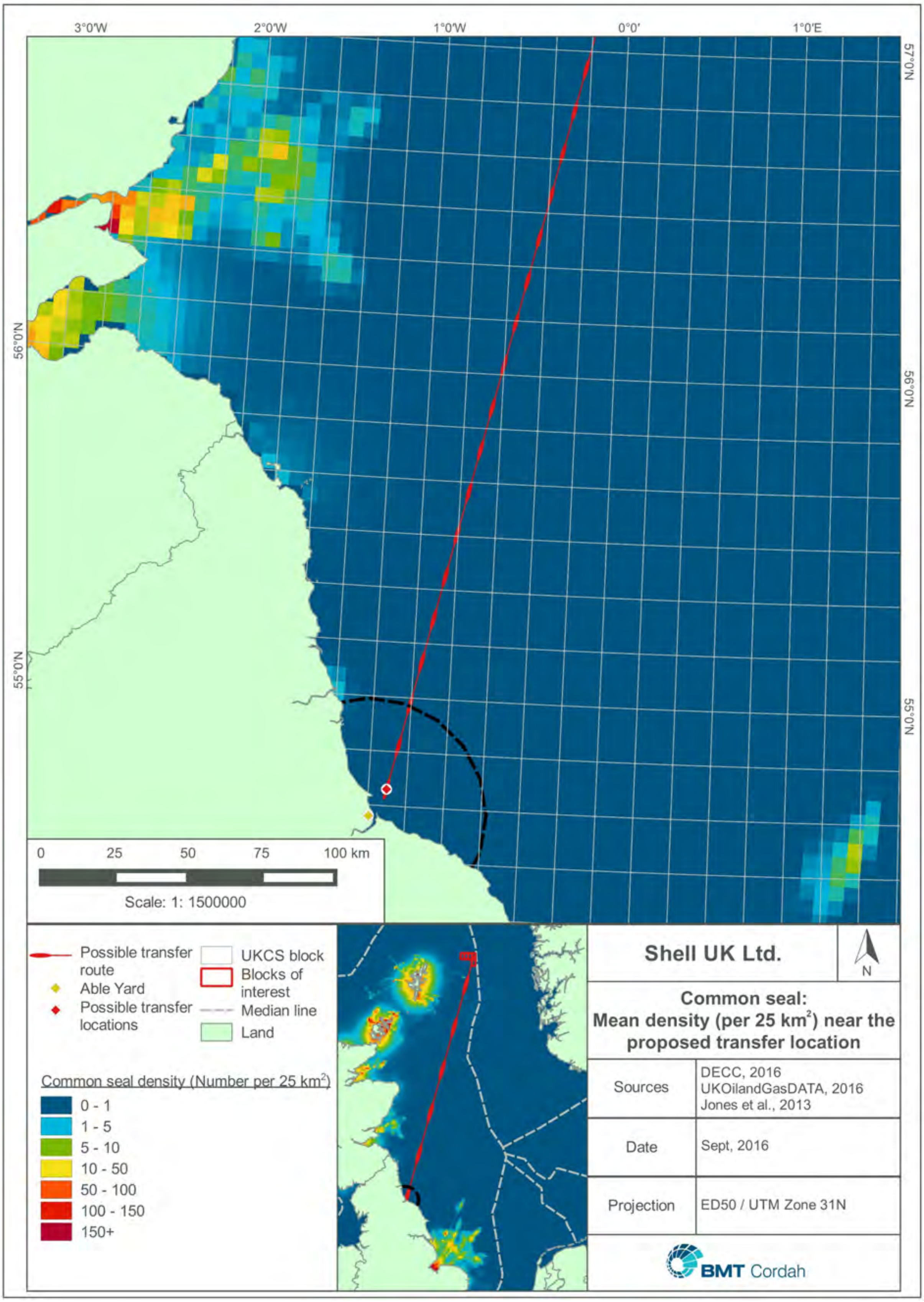
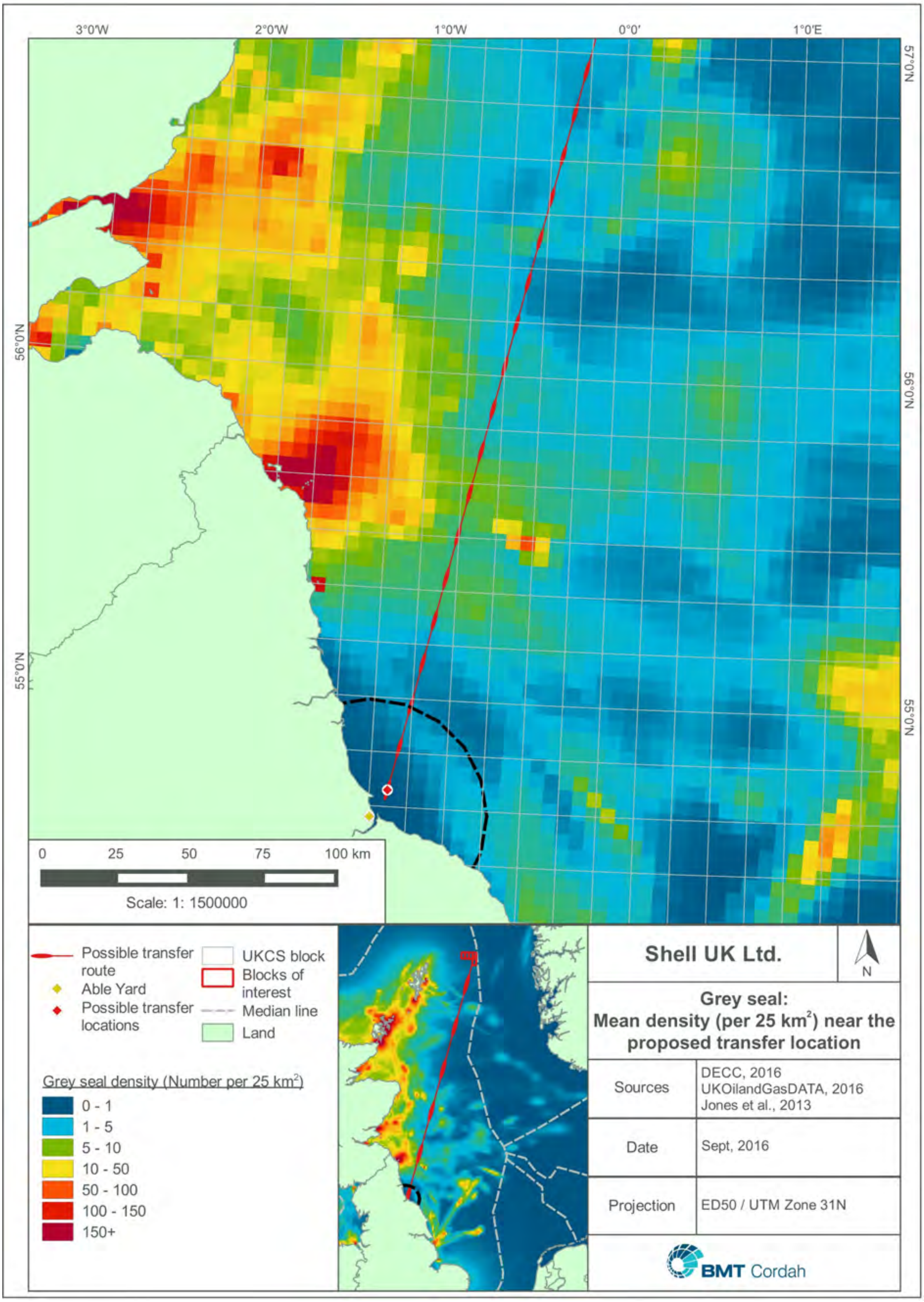


Figure 6-33: Average Density of Grey Seals near Proposed Offshore Transfer Location and Onshore Destination [20]



7. DECOMMISSIONING OPTIONS

For each of the facilities, Shell identified decommissioning options to be examined in the EIA as presented in Table 7-1.

For many of the facilities, additional decommissioning options were examined by Shell but are not assessed in this ES because they were discarded by Shell due to feasibility or safety reasons (for example) as discussed in the individual facilities sections. The decommissioning options presented in Table 7-1 represent the technically feasible decommissioning options.

The table colouring for the different options signifies the following:

Complete Removal
Partial Removal
Leave in Place

Each decommissioning option is discussed in detail in Sections 8 - 16.

Table 7-1: Summary of Decommissioning Options for the Brent Field Facilities

Topsides	**COMPLETE REMOVAL** **Option 1.** Remove in one piece using SLV				
Brent A Upper Jacket	**COMPLETE REMOVAL** **Option 1**. Remove in one piece to approx. -84.5 m LAT using SLV				
Brent A Jacket Footings	**COMPLETE REMOVAL** **Option 1.** Complete removal by Semi-Submersible Crane Vessel (SSCV) in several pieces, after cutting the piles externally	**COMPLETE REMOVAL** **Option 2.** Complete removal by SSCV in several pieces, after cutting the piles internally	**LEAVE IN PLACE** **Option 3.** Leave *in situ*		
Brent B, C, D GBS (after removal of topsides)	**PARTIAL REMOVAL** **Option 1.** Remove legs in single piece to give -55 m clear water depth below LAT	**LEAVE IN PLACE** **Option 2.** Leave *in situ*			
GBS Attic Oil and Interphase Material	**COMPLETE REMOVAL** **Option 1.** Recover to shore				
GBS Cell Contents	**COMPLETE REMOVAL** **Option 1.** Mobilise and retrieve to vessel and re-inject to new remote subsea wells	**COMPLETE REMOVAL** **Option 2.** Mobilise and retrieve to vessel and treat and dispose onshore	**LEAVE IN PLACE** **Option 3.** Cap or cover *in situ* using sand and gravel	**LEAVE IN PLACE** **Option 4.** Leave *in situ* and enhance natural biodegradation by adding chemicals (Monitored Natural Attenuation MNA)	**LEAVE IN PLACE** **Option 5.** Leave *in situ*
GBS Drilling Leg Material **GBS Minicell Annulus Material**	**COMPLETE REMOVAL** **Option 1.** Mobilise and re-inject in a new remote subsea well	**COMPLETE REMOVAL** **Option 2.** Mobilise and retrieve to vessel and treat and dispose onshore	**LEAVE IN PLACE** **Option 3.** Cap or cover *in situ*	**LEAVE IN PLACE** **Option 4.** Leave *in situ* and enhance natural biodegradation by adding chemicals (Monitored Natural Attenuation MNA)	**LEAVE IN PLACE** **Option 5.** Leave *in situ*
Drill Cuttings Seabed	**LEAVE IN PLACE** **Option 1.** Leave *in situ*				
Brent A Seabed Drill Cuttings (options only applicable for complete removal of Brent A jacket footings Option 1)	**COMPLETE REMOVAL** **Option 1.** Dredge, transfer to Brent C topsides and treat and discharge water and solids to sea	**COMPLETE REMOVAL** **Option 2.** Dredge, transfer to vessel and transport slurry to shore for treatment and disposal	**COMPLETE REMOVAL** **Option 3.** Dredge to vessel, transfer to Brent C topsides; water treated and discharged to sea, solids to shore for treatment and disposal	**COMPLETE REMOVAL** **Option 4.** Dredge to vessel and re-inject into new wells	
Drill Cuttings GBS Cell Tops	**PARTIAL REMOVAL** **Option 1.** Re-locate small amounts locally by water jetting into water column	**COMPLETE REMOVAL** **Option 2**. Dredge, transfer to Brent C topsides and treat and discharge water and solids to sea	**COMPLETE REMOVAL** **Option 3.** Dredge, transfer to vessel and transport slurry to shore for treatment and disposal	**COMPLETE REMOVAL** **Option 4.** Dredge to vessel, transfer to Brent C topsides; water treated and discharged to sea, solids to shore for treatment and disposal **Option 5.** Dredge to vessel and re-inject into a new well	**LEAVE IN PLACE** **Option 6.** Leave Brent C cuttings *in situ* for natural degradation
Drill Cuttings GBS Tri-cells Brent B, D	**LEAVE IN PLACE** **Option 1.** Leave *in situ*				
Pipelines and Umbilicals Group 1 including concrete mattresses Pipelines are split into 2 groups for the purposes of this EIA	**LEAVE IN PLACE** **Option 1**: Leave in existing trench/rock dump and rock dump ends	**COMPLETE REMOVAL** **Option 2**: Remove the whole line by cut and lift.	**Option 3**: Remove the whole line by reeling.		
Pipelines and Umbilicals Group 2 including concrete mattresses Pipelines are split into 2 groups for the purposes of this EIA	**LEAVE IN PLACE** **Option 1:** Leave *in situ* with no further remediation **Option 2**: Leave tied-in at platforms and trench non-platform ends	**LEAVE IN PLACE** **Option 3**: Leave tied-in at platforms and rock dump non-platform end **Option 4**: Trench and backfill whole length **Option 5**: Rock dump whole length	**COMPLETE REMOVAL** **Option 6**: Recover whole length by cut and lift **Option 7**: Recover whole length by reverse S lay (single joint)	**LEAVE IN PLACE** **Option 8**: Trench and backfill shallow-trenched sections + isolated rock dump (N0501) **Option 9**: Rock dump all shallow-trenched sections (N0501)	
Subsea Structures and Debris	**COMPLETE REMOVAL** **Option 1.** Recover to shore				
Wells	**LEAVE IN PLACE** **Option 1.** Plugging and abandonment				

8. TOPSIDES

8.1 Introduction

This section describes the topsides, the inventory of materials and the proposed programme of work to decommission the topsides. The main anticipated environmental impacts of decommissioning are discussed. The necessary management and mitigation measures to control the impacts are summarised, and measures are recommended to further reduce residual impacts where appropriate. The Technical Document for Decommissioning the Brent Platform Topsides [55] has been used as the basis for Sections 8.2, 8.3 and 8.4.

8.2 Description of Facilities

All four platforms at the Brent Field have topsides.

> The topsides are the surface decks of a platform that contain the oil and gas drilling, production and processing equipment, plus helideck and living quarters.

The Brent Field topsides contain the following main modules:

- **Accommodation and helideck**
- **Drilling derrick** - contains equipment and storage facilities for the drilling and maintenance of oil and gas wells.
- **Utilities** - contains water purifying equipment, chemical/diesel/potable water storage and pumping, boilers, switchboards and workshop.
- **Oil and gas production process modules** - contains the equipment required for separation of the oil well fluids into its three main components (oil, gas and produced water) and transfer of these products to export lines, other areas of the platform or disposal.
- **Water injection module** - contains the water injection equipment required for the enhanced recovery of hydrocarbons from the reservoir. No water injection has been operated in the Brent Field since the mid to late 1990s.
- **Power generation modules** - contains gas turbine generators which have sufficient capacity to power the whole of the platforms with electrical power. There are also sub main generators and emergency generators.
- **Wellhead modules** - contain the equipment and control valves to regulate the flow of oil and gas from each of the individual wells.
- **Flare tower/boom** – this is a structure designed to burn off any hydrocarbon gas that may pose safety risks to platform personnel and process systems.
- **Drainage systems –** drains on a platform are usually divided into those serving hazardous areas, non-hazardous areas and living quarters. Drains are used to manage discharges to sea through the use of oil/water separators and/or centrifugal pumps.

Decreasing reservoir pressures across the Brent B, C and D fields prompted Shell in 1995 to redevelop all three platforms for low pressure operations (Long-Term Field Development LTFD project). This project modified the topsides equipment and converted the oil processing trains to oil and gas processing trains. Brent A was not converted to low pressure operations.

8.2.1 Brent A Topsides

Brent A topsides and the upper jacket are shown in Figure 8-1. The Brent A jacket is defined as all of the steel structure below the level of the truss deck. The topsides comprise the truss deck, the module deck and the drilling deck located at the top.

The Brent A jacket was installed in 1976 with production start-up in 1978. Brent A was designed to produce up to 110,000 bbl/day of crude oil from two production trains of four-stage separation each. Although Brent A was not redeveloped during the LTFD project in the 1990s, the project did decommission the Brent A processing facilities, and Brent A then produced directly into the production train at Brent B, where fluids were processed, separated and exported to shore. Much of the decommissioned plant is still in place on the Brent A topsides (such as the utilities, water injection, oil and gas processing and power generation equipment). CoP at Brent A was in November 2014.

8.2.2 Brent B Topsides

Brent B topsides and the GBS upper legs are shown in Figure 8-2. The three legs of Brent B GBS connect to the plate girder deck structure (PGDS), the fabricated steel structure which is an integral part of, and supports, the topsides. The topsides comprise the PGDS, the module deck and the drilling deck located at the top.

Oil production at Brent B began in 1976 and peaked in the period 1984 to 1985. Oil production averaged at approximately 73,000 bbl/day, and total annual gas production averaged 800 MMscf/day. The LTFD project in the 1990s involved the addition of major new process modules to the Brent B topsides, but much of the decommissioned topsides modules still remain in place, such as separators, fuel gas facilities, flare knock-out drum and pig handling area. CoP at Brent B was in November 2014.

8.2.3 Brent C Topsides

The four legs of Brent C GBS connect to the cellar deck, a fabricated steel structure and integral part of the topsides structure which will be removed during decommissioning. The topsides modules consist of the cellar deck, module deck and weather deck located at the top. Brent C topsides and GBS are shown in Figure 8-3.

Oil production at Brent C began in 1976 and peaked in the period 1983 to 1986, with a yearly average of approximately 400,000 bbl/day. Since then, oil production has steadily declined.

The LTFD project in the 1990s involved the addition of many new modules to the Brent C topsides, however similar to Brent B, some of the decommissioned topsides modules remain in place such as separators, fuel gas facilities, generator and oil export facilities.

8.2.4 Brent D Topsides

Brent D topsides and the upper GBS legs are shown in Figure 8-4. Similar to Brent B, the three legs of Brent D GBS connect to the PGDS, a fabricated steel structure that is an integral part of, and supports, the topsides. The topsides modules comprise the PGDS, module deck and drilling deck located at the top.

Brent D was installed in 1976 with production start-up in 1977. The LTFD project in the 1990s involved the addition of many new modules to the Brent D topsides, however similar to Brent B and C, some of the decommissioned topsides modules remain in place. CoP at Brent D was in December 2011.

Figure 8-1: Brent A Topsides General Configuration

Figure 8-2: Brent B Topsides General Configuration

Figure 8-3: Brent C Topsides General Configuration

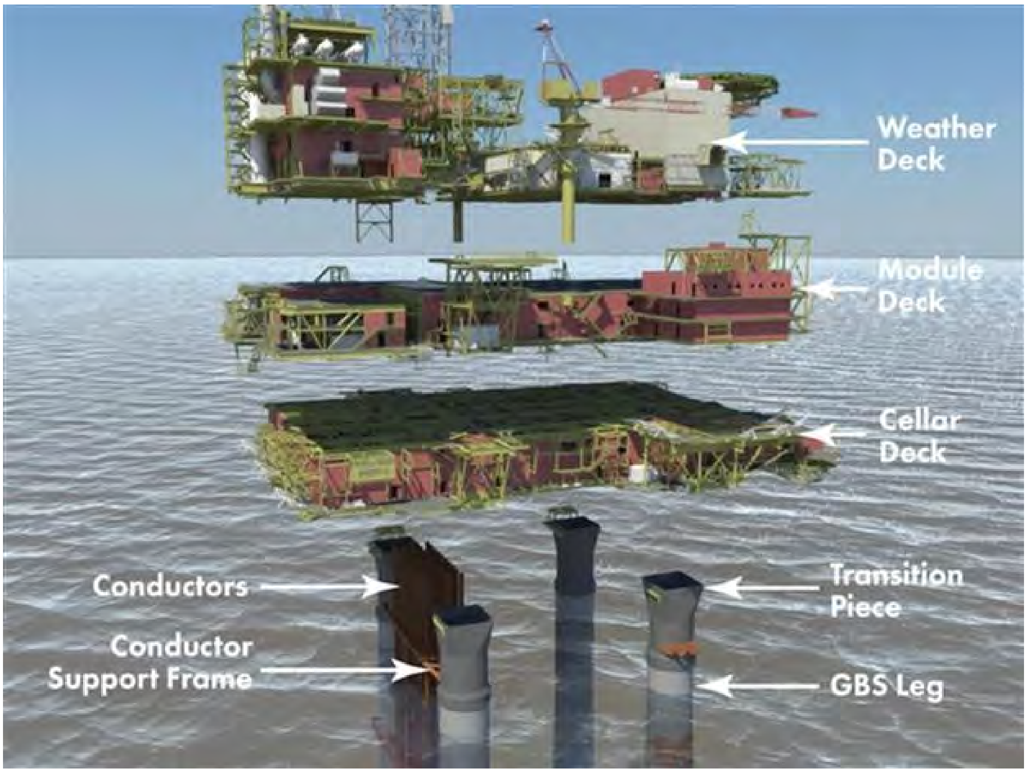


Figure 8-4: Brent D Topsides General Configuration

8.3 Inventory of Materials

This section provides information on the materials likely to be present in the topsides at the time of decommissioning. Most information has been sourced from the Sigma3 Provisional Materials Inventory study [56] commissioned by Shell, with updated information provided by Shell's Technical Document [55].

8.3.1 Total Inventory of Brent Field Topsides

The total inventory of materials for all four topsides is summarised in Table 8-1.

By far the biggest contributor to the total topsides weight is carbon steel, with approximately 76,700 tonnes at the four platforms, plus additional smaller volumes of alloy and stainless steel. The vast majority of steel will be recycled during decommissioning.

Table 8-1: Brent A, B, C and D Topsides Material Inventory [55]

Material	Unit	Brent A	Brent B	Brent C	Brent D	Notes
ABS (Acrylonitrile Butadiene Styrene)	tonnes	2	2	2	2	Plastic pipes
Alloy steel	tonnes	216	285	329	555	Pipework, pumps
Aluminium	tonnes	419	15	15	65	Anodes, engines
Asbestos (total)	tonnes	4	9	9	10	Insulation, gaskets
Batteries	tonnes	28	16	36	31	Various battery sets
Butyl rubber	tonnes	2	2	2	2	O-ring seals
Carbon steel	tonnes	11,921	19,572	25,448	19,781	Structural steel, equipment
Ceramics (all types)	tonnes	5	5	122	5	White ware
Chartex/fire protection	tonnes	27	103	<1	80	Penetrations
Copper	tonnes	107	222	281	84	Pipes, cables, transformers
Copper nickel alloys	tonnes	67	174	229	309	Pipe-valves, pumps
Cork	tonnes	2	2	2	2	Lifebuoys.
Cotton	tonnes	2	5	5	6	Bedding
Cutting residues	tonnes	12	12	12	12	Drill cuttings
EPDM (Ethylene Propylene Diene Monomer)	tonnes	23	5	23	11	Cables
Ethylene / Polypropylene	tonnes	72	46	120	85	Cables
Fire foam	m^3	20	20	20	20	Firefighting systems
Fluorescent tubes	nos.	1,396	2,984	3,116	3,446	Lighting
Formica	tonnes	2	2	2	2	Living areas
Glass	tonnes	5	5	5	5	Living areas

Material	Unit	Brent A	Brent B	Brent C	Brent D	Notes
GRP (Glass Reinforced Plastic)	tonnes	7	21	16	20	Replaced floor grids
Inconel / nimonics	tonnes	6	13	13	13	Generators
Insulation	tonnes	31	99	83	104	Structures, pipes
Iron (cast)	tonnes	3	3	3	3	Weights
Lead	tonnes	11	6	13	11	Batteries
Neoprene	tonnes	5	5	5	5	Various
Ni-resist	tonnes	10	10	10	10	Pump valves
Nylon	tonnes	10	10	10	10	Electrical equipment, rope
Paint	tonnes	930	961	899	899	Paint on structural steel
Plastics	tonnes	4	3	4	5	Floor coverings
PVC (Polyvinyl Chloride)	tonnes	32	19	65	61	Cable covering
Rubber	tonnes	20	20	20	20	Floor coverings
Scale with NORM activity in topside pipes/ valves/ pumps	tonnes	22*	43*	323**	69*	(Pb-210, Rd-226, Rd-228)
Scale sand & sludge with NORM activity in topside vessels	tonnes	150***	225***	240***	30***	(Pb-210, Rd-226, Rd-228)
Stainless steel	tonnes	459	1,349	1,732	1,371	Pipes and vessels
Titanium	tonnes	28	31	32	31	Pipes and machines
Wood	tonnes	20	20	20	7	Accommodation
Zinc	Tonnes	537	532	519	499	Anodes, paint, galvanising
Total Weight of Materials	**Tonnes**	**15,051**	**23,627**	**30,409**	**24,186**	**93,272**

*>10Bq/g **>5 but <10 Bq/g ***<5 Bq/g

The Brent Field platforms use a variety of topsides chemicals for controlling reservoir conditions, during oil recovery and during processing of the oil and gas. After Cessation of Production (CoP) process trains will have been drained, purged and vented (DPV) to ensure that no pockets of hydrocarbon liquid, gas, chemicals or contaminants remain on the topsides before they are removed. Chemicals stocks and fuel will have been run down, bulk fluids removed and drains drained and vented. All drilling muds and chemicals will be removed prior to decommissioning.

8.3.2 Hazardous Substances

Hazardous materials that remain on the topsides as the topsides cease operation and are decommissioned become hazardous waste. Waste is considered hazardous if it (or the material or substances it contains) are harmful to humans or the environment [57].

A description of some of these hazardous substances is given in the paragraphs below and the inventory of hazardous materials for each of the four topsides is summarised in Table 8-2.

A description of the topsides cleaning and preparation process prior to topsides removal is given in Section 8.5.1 and the impact assessment of the removal of the remaining hazardous substances is provided in Section 8.6.2.

8.3.2.1 Asbestos

Asbestos is a fire resistant material and is present on the Brent Field topsides. However, uncertainty remains as to the exact quantities. Asbestos is typically present on offshore installations, and although it presents a significant issue for decommissioning due to its hazardous nature and will require further assessment and professional management, the expertise to manage asbestos waste is widely available.

8.3.2.2 Batteries

There are a large number of batteries on the Brent platforms in both large centralised supplies and small-scale supplies in individual items such as back-up un-interruptible power supplies for safety-critical systems. Batteries may contain a range of heavy metals (including cadmium and lead) and potentially environmentally harmful chemicals.

8.3.2.3 Cables

In addition to potentially large quantities of copper, additive chemicals in the cable insulation can make up 50% of the PVC weight, which will need consideration for dismantling and waste management.

8.3.2.4 Diesel

Diesel fuel is used for routine operations on the Brent Field platforms and also to power emergency electricity supplies and firefighting systems. Due to the large quantities stored, attention must be given to its management upon decommissioning.

Diesel will be required up until the start of removal operations, and assuming that all the tanks at CoP are run to 5% of nominal total capacity, the possible volumes of residual diesel remaining would be approximately 10–30 tonnes per platform. More activities will take place between CoP and dismantlement such that this volume may increase (as fuel gas will no longer be available and the platform will become more reliant on bunkering). Regardless, all diesel storage tanks would be DPV prior to the start of decommissioning, resulting in significantly smaller volumes of diesel requiring management.

8.3.2.5 Fluorescent tubes

There are a significant number of fluorescent tubes on the Brent Field topsides, which also pose a hazard as a source of mercury (Hg).

8.3.2.6 Halons

Halons are a wide range of halogenated organic compounds used in fire extinguishing systems and as refrigerants. Because of their significant threat to the ozone layer, their manufacture and use is governed under a number of Protocols and EU Directives. The more hazardous isomers have now been replaced by other halons which pose a smaller hazard to the ozone layer, although still requiring careful management. All of the halons once used on the Brent platforms fire systems have been removed and replaced either with water-based foams or fine water spray.

8.3.2.7 Heli-fuel

Heli-fuel is stored in tanks close to the heli-deck and will continue to be used almost until the topsides are removed. Shortly before each planned lift, heli-fuel will be run down to volumes that are as low as practical and the equipment will be isolated. Once onshore, all tanks and pipelines will be flushed and purged before dismantling begins.

8.3.2.8 Hydrocarbon residues

At CoP, residues of hydrocarbons will remain in piping. The residues will vary from traces of hydrocarbon gases, films and pools of liquid oil, or solid deposits of waxes. The DPV operations are designed to minimise the volumes of residual hydrocarbons.

8.3.2.9 Lubricating oil

The Brent platforms comprise many pumps, motors and other rotating machinery which use lubricating oils.

8.3.2.10 Mercury (Hg)

Mercury from formation fluids can be deposited into oil and gas process pipelines and vessels of platforms, and may occur:

- In the free state, as a surface film, which once identified can be managed relatively easily.
- Combined and within the fabric of the steel pipes and vessels, which is more problematic to manage.

Potential sources of mercury have not currently been studied in depth on the topsides. Shell does not have any sampling data from any Brent topside to indicate if mercury is present, although Shell has identified those parts of the process system where it is most likely to be found. From a health and safety point of view, Shell considers it best to keep the process systems intact until the topside is delivered to shore, and then perform carefully planned and controlled surveys and intrusive sampling to determine if mercury is present. Once the topsides are onshore they will be carefully surveyed and detailed plans finalised for dismantling and the removal and disposal of wastes.

8.3.2.11 NORM

Naturally Occurring Radioactive Material (NORM) is found in produced water and is typical of offshore oil and gas operations. Production of oil and gas results in the transportation of radioactive constituents and accompanying major ions from the oil-bearing formations to the wellhead and to downstream processing and transport facilities. NORM can precipitate inside pipework or valves as an insoluble scale. There is uncertainty in the weight of NORM scale present on the topsides; however it is assumed that there is NORM in the closed drain system. This can only be quantified once accessible.

As part of the materials inventory, Shell commissioned ARPS [58], Shell’s Radiation Protection Advisors, to estimate (based on the past six years of NORM data from the Brent Field) NORM scale build-up in pipework and in vessels. The study identified scale with activity levels above the limits set in the Rare Earths Exemption Order [59] and is therefore subject to disposal under the Environmental Permitting Regulations 2010 as amended for England and Wales [60]. NORM with activities below 5 Bq/g may be disposed of according to the Rare Earths Exemption.

Shell's topsides materials inventory (Table 8-1) is based on currently available information and estimates that the majority of the NORM scale identified in the topsides vessels of all four platforms (645 tonnes) is <5 Bq/g and hence not considered radioactive for disposal purposes. Approximately 134 tonnes of scale with NORM activity in the topsides pipes, valves and pumps is above 10 Bq/g, and the remaining 323 tonnes of scale sits between 5 Bq/g and 10 Bq/g. A description of how this waste will be handled is provided in Section 8.6.2.

Due to the issues surrounding NORM, from the worker protection, environmental and public standpoints, NORM continues to be subject to significant scrutiny within the industry and by regulators and stakeholders. As such, NORM must be treated in accordance with national legislation as described above. Once the Brent topsides arrive onshore, more detailed NORM surveys will be conducted, and the contaminated materials identified will be removed to Able's dedicated reception facility for decontamination and cleaning. NORM waste will be disposed of in line with the OGP Guidelines for the Management of NORM [61] depending on the activity of the waste.

8.3.2.12 Paint

Paint coatings are applied externally and internally, mostly for protection against corrosion. The types and quantities of paints will influence their management upon decommissioning, and the risks and extent to which they can be recycled. While the main reported paints are zinc primers and epoxies there are other potentially hazardous paints which include lead chromate paints, isocyanate paints and anti-fouling paints containing tribuytl tin (TBT). Work has been conducted to identify lead-based paint locations on the platforms and this information will be provided to the onshore contractor.

8.3.2.13 PCBs

Although they are no longer used offshore there may be residues of PCBs in some transformers. PCBs are resistant to biodegradation and therefore persistent in the environment. Under electrical and thermal stress, PCBs can break down to form dioxins that are also persistent but much more toxic.

8.3.2.14 Smoke detectors

Smoke detectors contain small amounts of heavy metals (such as lead (Pb), zinc (Zn), tin (Sn) and copper (Cu)) and smaller more exotic metals in the components themselves. These are standard materials as covered by the Waste Electrical Equipment Directive. Ionisation smoke detectors use a small radioactive source and require specialist handling.

8.3.2.15 Topside chemicals

Bulk chemicals are used in oil and gas recovery and processing, including methanol, Triethylene Glycol (TEG), corrosion inhibitor, anti-scale chemicals, oxygen scavenger (ammonium bisulphite), demulsifier, anti-foam, hydrogen sulphide scavenger, biocide, foams used in the firefighting systems, and diatomaceous earth used in water injection filter pre-coat systems.

Most of these chemicals are delivered to the platforms in 2.7 m^3 Intermediate Bulk Containers (IBCs). It is planned that they will all be run down at CoP, all bulk chemicals will be removed prior to decommissioning, and that only minimal volumes/residues will be present on the topsides when they are lifted off.

8.3.2.16 Summary of total inventory of hazardous materials

The total inventory of the hazardous materials found on the Brent Field topsides is summarised in Table 8-2. The potential impact from managing these materials is assessed in Sections 8.6.2 and 8.6.3.

Table 8-2: Topsides Hazardous Materials Inventory [55]

Material	Unit	Brent A	Brent B	Brent C	Brent D	Notes
Asbestos (total)	tonnes	4	9	9	10	Insulation, gaskets
Batteries	tonnes	28	16	36	31	Various battery sets
Cutting residues	tonnes	12	12	12	12	Cuttings
EPDM	tonnes	23	5	23	11	Cables
Ethylene / Polypropylene	tonnes	72	46	120	85	Cables
Fire foam	m^3	20	20	20	20	Firefighting systems
Fluorescent tubes	nos.	1,396	2,984	3,116	3,446	Lighting
Insulation	tonnes	31	99	83	104	Structures, pipes
Lead	tonnes	11	6	13	11	Batteries
Paint (topsides)	tonnes	930	961	899	899	Paint on structural steel
Scale with NORM activity in topside pipes/ valves/ pumps	tonnes	22*	43*	323**	69*	(Pb-210, Rd-226, Rd-228)
Scale sand & sludge with NORM activity in topside vessels	tonnes	150***	225***	240***	30***	(Pb-210, Rd-226, Rd-228)
Zinc	tonnes	537	532	519	499	Anodes, paint, galvanizing

*>10Bq/g **>5 but <10 Bq/g ***<5 Bq/g

Note: Process trains will have been DPV to ensure that no pockets of hydrocarbons remain. Chemical stocks will have been run down and bulk fluids removed. Hence, only residues of these substances will be present on the topsides at the point of removal.

8.4 Available Decommissioning Options

In accordance with OSPAR Decision 98/3 [4] and the DECC Guidance Notes on Decommissioning [5], only one option for the management of the topsides was considered: to remove all four topsides completely and return them to shore for re-use, recycling or disposal.

The bulk of the topsides will be recycled onshore. Shell has not identified any commercially viable alternative use for the topsides. They are more than 35 years old and Shell has not received any expressions of interest from third parties wanting to use them in their entirety. Some sub-components or items of equipment could be re-used, but there are unlikely to be many opportunities because of the age and obsolescence of much of the equipment.

8.5 Description of Proposed Programme of Work

The option assessed for decommissioning the topsides is:

COMPLETE REMOVAL
Option 1. Complete removal in one piece using SLV

There are several elements to the proposed programme of work to remove the topsides by SLV:

- Preparation
- Offshore removal of topsides by SLV and transportation
- Transfer from SLV to cargo barge, and then transportation to shore
- Onshore dismantling and disposal.

These are discussed in turn below.

8.5.1 Cleaning and Preparation

Because the topsides will be removed as one unit using an SLV, less preparatory work will be required offshore than would be required if the topsides was to be removed in several modules using a Heavy Lift Vessel (HLV). The use of an SLV will result in reduced safety risks and lower likelihood of accidental environmental impacts offshore.

Shell will conduct a DPV programme to ensure that no pockets of mobile contaminants from equipment, pipework or vessels remain on the topsides, and to ensure that the topsides are safe for transportation. The main locations where there are hazardous materials and chemicals which might pose a risk to the environment are the well engineering package and the topside production process systems.

The activities below occur before and up to CoP, and are outside the scope of this ES because they are preparatory works. But the impact assessment of the decommissioning of the drained, purged and vented systems is part of the scope.

- Stocks of chemicals on the platforms will be run-down to the essential minimum amounts. The focus will be on reducing the inventories of chemicals used in production such as H_2S scavenger, corrosion inhibitor, anti-foam chemical, oxygen scavenger, Monoethylene glycol, triethylene glycol and biocide.
- Any chemicals remaining after the pre-CoP run-down period will be transferred to tote tanks and shipped to shore for reuse, recycling or disposal, along with any remaining lube oils present in open systems such as tanks and machine pipework. The main sources of lube oils will be the turbine generators and large pump/motor/gearbox assemblies. Lube oils within closed systems will be left due to their small quantities (removal would involve breaking open systems which could cause damage to equipment causing it to be scrapped instead of reused).
- Before CoP, a DPV programme will be conducted and repeated as required until the systems are certifiably within limits for the safe breaking of containment (that is cutting of a pipe or breaking into a vessel). All drained systems will be left open to the atmosphere to allow free-venting to occur so that gases do not build up. As necessary, vents and drains will be created at appropriate locations in systems to prevent recharging of the topsides process systems from any trapped inventories. Tanks and vessels will be

drained of all free-flowing liquids. Where this is not possible for operational reasons, the quantities and locations will be clearly recorded for the disposal contractor e.g. final diesel inventory. Where practical, tanks and vessels will be sampled, and the results of such analyses incorporated into the materials inventory, which will be issued to Able. Shell will put in place a procedure to monitor all potential leak sources that are created as a result of preparing the topside for removal; each potential source will be monitored for a specified period of time to prove that it is safe.

The acceptable level of cleanliness of the equipment or systems will be dependent on the particular system, and guidance on cleanliness will be produced on a system-by-system basis. Appropriate levels of cleanliness will be further defined during the detailed engineering phase, before the start of any work.

Once the cleaning programme has been completed, the topside process system will be purged with nitrogen and the gas cold vented via the flare system to ensure no pockets of hydrocarbon gas are present. Residual material may accumulate in dead legs, for example in the bends of pipes but large quantities are not expected. Even after successful cleaning operations it is still possible that both hazardous and non-hazardous material will be present in parts of the topsides, for example in the separators, and such information will be passed to the onshore contractor. The topsides will not be hydrocarbon-free when removed, and it is possible that residual material may accumulate in areas such as ‘dead legs’.

Shell will implement “positive isolation” to prevent any remaining hydrocarbons from migrating between systems and areas of the platform. This means that at important locations, pipework/systems will be severed and blanked-off, creating a physical gap between components. Additional controlled drain and vent points will also be installed to enable bleed-off and monitoring of any accumulations of gas or fluid. The topsides processes will be monitored to ensure risks to the environment are managed. Drain points will be connected via a flexible hose and valve to a collecting tray. Appropriate sections of the drains will be closed and monitored daily until no fluids are discharged when the valves are opened. Any liquids collected in the trays will be transferred to tote tanks (transportable containers) and shipped to shore for disposal.

The attic oil and interphase material in the GBS cells below the topsides will be removed and taken to shore for treatment and disposal; Shell proposes to do this in two phases. Firstly, a small (3.5” diameter) access hole will be drilled in each cell and temporary flexible pipelines will be laid across the tops of the cells so that the attic oil and interphase material from all the cells can be collected into a single receptor cell; the fluid extracted will be replaced by water from the receptor cell. The access hole to each cell will be closed after the attic oil and interphase material has been extracted. Secondly, the oil amalgamated in the receptor cell will either be exported via the existing oil pipeline before the removal of the topside (or pumped to a vessel after the removal of the topside) and taken to shore for recycling. As this material is pumped out from the receptor cell it will be replaced by raw seawater. In both cases, these pumping operations will keep the cell fully flooded and will not have any detrimental effect on the structural integrity of the cells or the GBS caisson.

Some hazardous substances will remain on the topsides until they reach the shore, such as asbestos and NORM. For such materials, it is not imperative that the topsides is decontaminated offshore, only that it is left in a safe condition and labelled. The following scope shall apply to NORM contaminated process equipment:

- NORM-contaminated vessels, pipe work, valves and bridles that remain in place on the platform will not be cleaned/decontaminated offshore, but labelled in accordance with duty of care and Shell Local Rules.
- All contaminated material found loose inside equipment and adjacent to breaks of containment will be removed. Material that adheres to internal walls shall not necessarily be removed.
- Valves and spools removed for access, physical isolation, or topsides separation purposes shall either be decontaminated offshore or sent onshore in compliance with the Shell Local Rules.

Before lifting the topsides, obstructions will be removed (e.g. the conductors will be severed slightly below the cut height on the concrete legs, and the upper parts of the conductors returned to shore for recycling). And structural components will be reinforced to withstand the structural stresses expected during lift and transfer. All pipework and hoses that might be sources of spills to the environment will be capped-off, and loose objects that may pose a risk to personnel, the vessel or the substructure will be secured.

8.5.2 Offshore Removal of Topsides by SLV and Transportation

The topsides will be removed by a purpose-built SLV, the '*Pioneering Spirit*' which is capable of removing the entire topside in one lift (Figure 8-5). The SLV is capable of lifting topsides of up to 48,000 tonnes. The description below summarises Shell's proposed generic programme of work for removing all four topsides by SLV, while the illustrations show a GBS platform topside. Although programme details will vary from installation to installation, the four topsides are not so different that unique programmes have to be devised for each one. One of the main differences is Brent A topsides which is supported by a jacket not a GBS; the Brent A jacket will require a specially-designed lifting arrangement.

Figure 8-5: Photograph of the *Pioneering Spirit SLV*

The platform legs will be cut by a specialist cutting contractor using Diamond Wire Cutting (DWC) equipment before the SLV enters the Brent Field. The SLV will then be positioned in the field using an advanced DP system so that the GBS legs fit into the SLV slot (the gap between the two SLV hulls), as shown in Figure 8-6. The SLV DP system consists of twelve

5.5 MW thrusters, six located at the aft and six at the two bows (three each). All thrusters are non-retractable, fixed pitch, variable speed, azimuth type. The speed and azimuth controls are located in the same space as the thrusters.

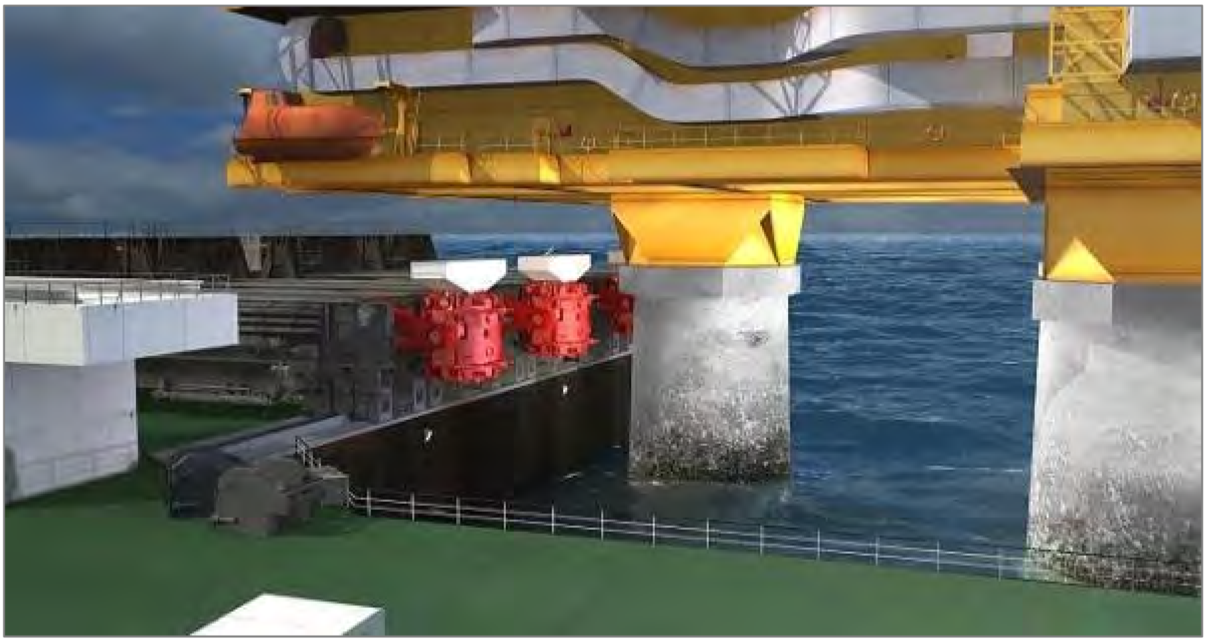
The SLV Topside Lift System (TLS) beams will be fully retracted during this stage to provide the maximum clearance between the SLV and the platform while manoeuvring.

Figure 8-6*:* SLV Aligning with a GBS

Once the SLV is positioned correctly, the 16 TLS beams (which are coupled as 8 'fork lift units' by purpose-built 'yokes' as shown in Figure 8-7) will be extended to position for the lift of the topsides (Figure 8-8) at predetermined lift points under the topsides. The yoke structures fit the prepared lift points on the underside of the topsides support structure.

Figure 8-7: Illustration of a TLS Beam and Yoke Structure

Figure 8-8: Sliding the TLS Beam into Place



Once positioned correctly, the SLV will be deballasted to the necessary height to connect the TLS system to the underside of the topsides support structure. Gradually the SLV will be further deballasted until almost all of the weight of the topside is transferred onto the SLV (Figure 8-8 and Figure 8-9). The final lift will take place in less than one minute by a combination of all the yokes simultaneously pushing up, and the SLV deballasting, to lift the topside clear of the GBS legs.

The SLV will then move away from the substructure, lock the TLS beams, and close the connection beam between the two bow sections of the SLV. Transportation of the topsides away from the platform area is shown in Figure 8-10.

Figure 8-9: Deballasting the SLV

Figure 8-10: Preparing for Transportation

Once the topsides have been secured to the SLV, the vessel cranes will fit concrete caps (each weighing about 300 tonnes) onto the GBS legs above sea level. One of the caps will be pre-fitted with an Aid to Navigation (AtoN), which will be fully functional before the SLV leaves the field. If the AtoN is not fitted immediately, as a contingency the GBS substructures will be patrolled by a guard vessel until such time as the AtoN is installed and commissioned. The

installation of the concrete caps and AtoN would be installed whether GBS Option 1 or 2 was selected, and are part of the topsides programme of work. As the upper jacket will be removed, no concrete caps or AtoN will be fitted to the Brent A jacket.

An AtoN would be fitted to one leg of each GBS, and on the Condeeps this would probably be the utility leg. It is likely that two support structures would be installed on the leg so that a second, new system could be fitted (by helicopter) before the original system was removed for repair or replacement. According to the International Association of Lighthouse Authorities, the minimum requirement for an AtoN is the provision of light, but there are optional extras that can be incorporated, including an Automatic Identification System (AIS) transmitter and a Racon unit (a radar transponder).

On the Condeeps, the utility leg is tall enough to ensure that the AtoN would be clear of wave action. For Brent C there is a complication in that the top of the permanent (concrete) part of the legs is only about 7 m above LAT. This means that one of the legs on Brent C would have to be extended by approximately 22 m so that the AtoN would not be vulnerable to North Sea storms. It is likely that either Leg C3 or Leg C4 would be chosen to support the AtoN; these legs are more heavily reinforced and pre-stressed than either C1 or C2 because they were designed to support the conductor guide frames.

The materials and resources required offshore for the installation of concrete caps and AtoN on the GBS are summarised in Table 8-3, based on best available data from Shell.

Table 8-3: Materials Required for Installation of GBS Concrete Caps and Aid to Navigation

Material Required	Estimated Mass (tonnes)			
	Brent B	Brent C	Brent D	Total
New concrete	900	1200	900	3,000
New steel	30	20	30	80
Aid to Navigation Support Structure (steel)	5	50	5	60
Aid to Navigation (electronics and steel)	2	2	2	6

The SLV will then proceed to Teesside, about 388 nautical miles (719 km) away. The topsides will be considered as cargo in this phase of the project, and if they contain any hazardous materials that are subject to special permitting requirements they will be itemised in the vessel's cargo manifest and will be labelled, monitored and handled as required.

As part of the topsides programme of work, all of the significant external steel from the three GBS (approximately 2,150 tonnes) would also be removed after the topsides had been removed, regardless of which GBS decommissioning option is selected (see Sections 10.5.1 and 10.5.2).

8.5.3 Transfer from SLV to Cargo Barge and then to Onshore Facility

The SLV is too large to enter the onshore facility, so the topsides will be transferred onto a cargo barge at a nearshore site 5.5 nm from the mouth of the River Tees, off the north-east coast of England.

The transfer operation will take an estimated 36-48 hours, during which time the SLV vessel will be held in position through the use of its DP system. To help facilitate a safe transfer, the operations will be conducted during good weather and metocean conditions.

The hull connection beam will be opened and the mechanical lock of the TLS beams undone, and the cargo barge manoeuvred into the slot between the bows using pre-rigged mooring wires from the SLV. The SLV will be gradually ballasted-down until the whole weight of the topsides is taken by the cargo barge. The TLS forklift units will then be fully retracted.

At high tide the cargo barge will be towed to the ASP facility by four harbour tugs (see Figure 8-12) operating on DP azimuthal thrusters (although the majority of the time the tugs will be working moored to the barge).

Figure 8-11 Approximate Transfer Location

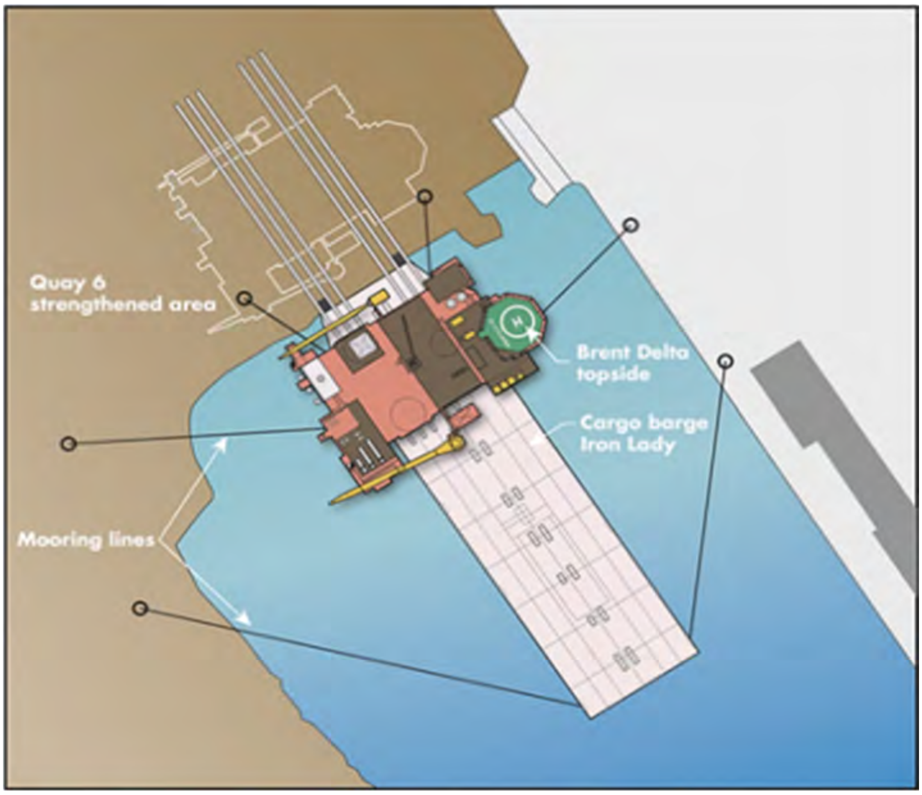
Note: The X denotes the approximate location of the transfer site, which is centred on 54°44.0’ N, 01°06.0’ W.

Figure 8-12: Harbour Tug

Source: DNV GL Database

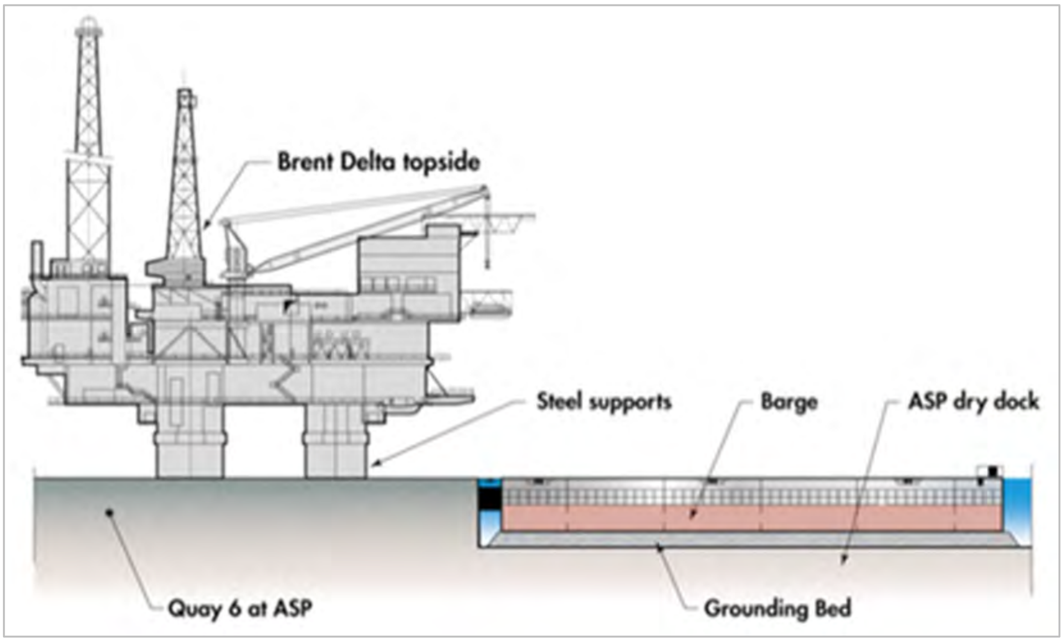
At the ASP facility, the cargo barge will be moored with its stern to the quayside, as shown in Figure 8-13.

Figure 8-13: Skidding Topside from Cargo Barge onto Quayside at ASP Facility



The barge will be ballasted-down so that it rests on a prepared grounding pad (see Section 6.10.1), such that the barge deck is at the correct height for skidding the topsides to the quayside. The topsides will be slid from the barge onto prepared support structures (stillages) in the onshore dismantling area (Figure 8-14).

Figure 8-14: Mooring/skidding arrangement for load-in of topsides to the quayside



8.5.4 Onshore Dismantling and Disposal

After the topside is safely positioned, access will be arranged and surveys will be completed to determine if the topsides have suffered any structural damage during transportation.

Before any work begins, Able will carry out a series of additional inspections, surveys and risk assessments including:

- Demolition and Refurbishment Asbestos Survey
- Hazardous Waste Survey
- Non-Hazardous Waste Survey
- Hazardous Waste Inventory
- Photographic Survey
- Stored Energy Report
- Gas Survey
- NORM Survey

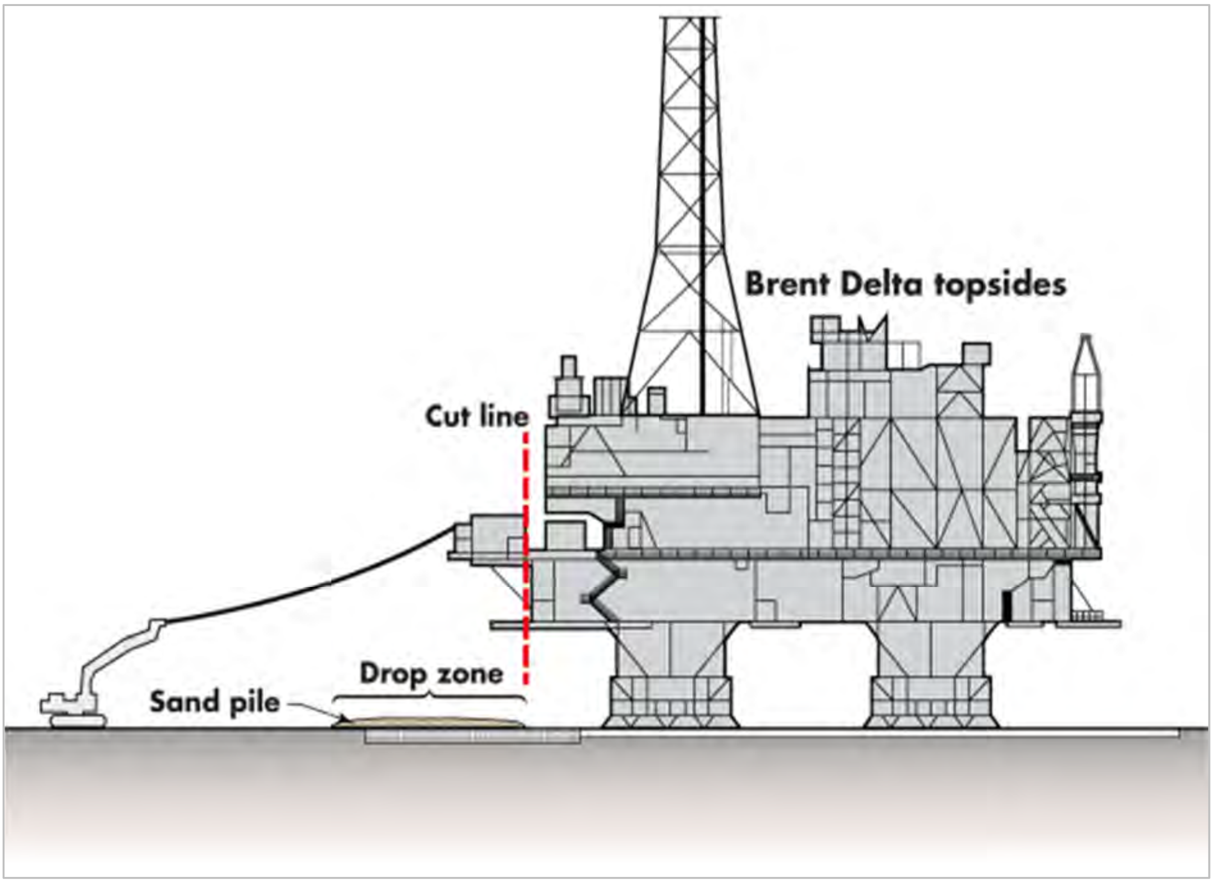
The surveys and inspections will help to ensure it is safe for the work to begin, to identify and quantify any hazardous substances and to identify areas requiring any special safety precautions. The onshore inspection will include checks for pyrophoric scale, which can ignite spontaneously in air and is sometimes found in sulphur containing systems such as those handling oil and naptha (its presence has not been confirmed). Any recommendations arising from the surveys and inspections will be implemented and agreed before work begins.

Following the surveys and inspections, all hazardous waste material identified (such as asbestos, NORM, and hydrocarbon residues) will be removed from the topsides, stored and processed to allow dismantling of the topside structure to commence. After all hazardous materials have been removed from an area; a team will remove architectural items, soft

furnishings and other non-structural equipment. Wherever possible, items for reuse will also be removed at this time, before demolition begins.

The proposed programme of demolition involves quickly reducing the height of the topsides by cutting it into sections from the top downwards, and pulling sections to the ground using wire ropes. In this ‘cut and pull’ method, the internal and external walls will be partially cut then attached by wire ropes to a large vehicle on the ground (for example an excavator), as shown in Figure 8-15. This will then slowly move away, forcing the section to part from the topsides and fall in a controlled manner into the designated drop zone. A thick bed of sand will be laid around the topsides to absorb the shock of these falling sections and reduce noise and vibration.

Figure 8-15: Dismantling of Topsides



Once on the ground, the topsides will be safer and easier to dismantle, and a number of different hot and cold cutting techniques will be used, such as excavator fitted with hydraulic cutting shears or ripper blades, diamond wire cutters, hand-held abrasive cutting tools, oxy-propane burners and saws.

This procedure will be repeated until the topside is dismantled.

An exclusion zone will be set up around the work area before any demolition begins, as shown in Figure 8-16.

Figure 8-16: Plan of Exclusion Zone around Topsides

The storage area at the onshore facility is 5 hectares of concrete hard-standing that is fully lined and surrounded with a drainage ditch system connected to an oil interceptor. Any liquid wastes or rainwater run-off from the topsides will be collected in the cut-off drain and passed through the oil interceptor before exiting into the main site drainage.

Most of the material leaving the site (mainly steel) will be transported by ship from the quay or will be transported by local train, rather than by road transport.

Hazardous materials for disposal will be managed according to the Hazardous Waste Regulations which require that hazardous waste consignment notes accompany each hazardous waste. The consignment note details the waste quantity and type, the European Waste Code (EWC) identification and the hazard code, the disposal location, and enables cradle to grave tracking.

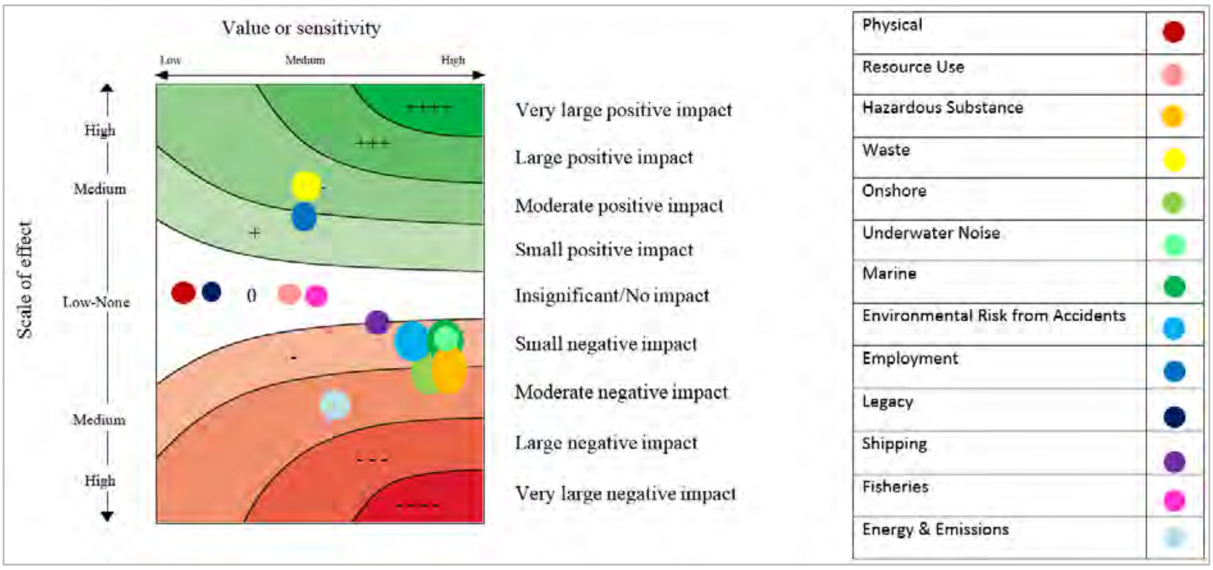
8.6 Significant Impacts of Proposed Programme of Work

This assessment considers the total impacts that would occur from decommissioning all four topsides. The assessment assumes that all four topsides will be decommissioned at the ASP facility, although the contractual details surrounding the dismantling of the Brent C platform are still being finalised (it is anticipated they will follow a similar process to the other Brent topsides). Note also that the Brent D topside was the subject of a separate DP (with a separate EIA) and thus the information on Brent D topside presented within this ES document is for completeness and to enable the assessment of cumulative impacts.

Appendix 1 documents the environmental assessment of all environmental categories. This section provides a summary of the most important impact assessment matrices from Appendix 1, discussing only the most significant impacts identified (those with either 'small-moderate negative' impacts or worse, or 'small-moderate positive' impacts or better).

As shown in Figure 8-17, the significant impacts identified are for onshore, hazardous substances, waste management, employment and energy and emissions. Estimated impacts are considered small or insignificant for all other categories.

Figure 8-17: Topsides Option 1 – Complete Removal



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact)
- The Energy and Emissions impact has been sourced from: DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

8.6.1 Onshore Impacts

The overall onshore impact as a result of topsides decommissioning is estimated to be **'small-moderate negative'** owing to the large quantities of material that will come onshore that will require handling, deconstruction and transportation.

8.6.1.1 Noise, dust and traffic impact

The dismantling of the four topsides will generate large quantities of material, including approximately 76,700 tonnes of carbon steel, plus 2,150 t of external steel. Onshore decommissioning operations can have 'nuisance' impacts on residents and disturb other sensitive receptors in the local area such as birds, and decommissioning will take a significant

period of time (an estimate of one year per topside, spread over 8 years). Potential impacts include:

- Dust and noise emissions from increased traffic, both on and offsite:
    - Traffic can sometimes cause problems to local residents living close to industrial sites, but traffic should not be a major issue to residents at this onshore site because most of the material leaving the site (steel) will be shipped out of the site from the quay or will be transported via local train. Also there are no residents located close to the site, and traffic onsite is limited to 10 mph.
- Dust and noise from deconstruction activities (e.g. lifting and cutting):
    - One of the main sources of noise will occur during the forced toppling of topsides sections as described in Section 8.5.4, but this is mitigated by a thick bed of sand to absorb the shock and reduce noise and vibration. Aside from toppling, noise from Brent deconstruction activities will be associated with activities such as lifting, cutting and material handling.
    - Sources of dust include the concrete crusher and the thick layer of sand; Able inspect and damp down with water in dry windy weather.
    - The nearest residential receptor sensitive to noise and dust is located 1 km away, far enough to not be of any great concern. The ASP facility is large, and most of the decommissioning operations will take place within the heart of the facility, even further from the nearest residential receptors. DNV GL has been informed there have been no complaints to site from any residents regarding such issues for several years, and the site is understood to have a good relationship with the environmental regulator.
    - There are sensitive habitats located very close to the site that are important for birds, and these have potential to be disturbed by noise. The Teesmouth and Cleveland Coast SPA are designated to protect breeding, passage and wintering populations of birds. The dismantling site is located opposite Seal Sands, one of the largest areas of intertidal mudflats on England's north-east coast (see Section 6.10.3). These mudflats are of great ornithological importance attracting large numbers of migratory wildfowl and wading birds especially during the winter months [20]. According to a study carried out at the University of York [62], little tern, sandwich tern, redshank and knot are typical species to be found at the North Gare and Seal Sands. In 2012 a comprehensive review of international research was summarised in the preparation of the management plan for Lista Beaches in Norway. The study found that the species most sensitive to disturbance were larger species often found in open areas: cormorants, divers, swans, geese, ducks, birds of prey, wading birds gulls and terns. Several studies indicated that birds to some extent can adapt to disturbances, but there were also studies showing that such habituation does not occur [63].
    - There are indications that animals generally show greater tolerance for mechanical noise compared to biological threat factors such as predators or humans [64]. It has been suggested that waterbirds habituate to disturbance, in time becoming less responsive to the activity [65]. Distance is also a key factor; birds are more likely to be flushed (disturbed and fly off) when the activity is close, but are less responsive in the water where they are rarely flushed regardless of the activity [66].
    - Onshore dismantling activities will take 12 months for each topside, spread over approximately 8 years for the four topsides, and will be conducted more than 500 m away from the nearest sensitive bird area. General deconstruction work is not

expected to result in a noise level which differs greatly from previous activities at the ASP facility and surrounding industry. It is accordingly reasonable to assume that birds have become accustomed to “normal” background noise from adjacent industry, but it cannot be excluded that sudden noise from dismantling activities/transport may result in a local and temporary displacement of bird individuals from adjacent feeding grounds. Permanent effects are however not considered significant as the facility is surrounded by large areas of alternative feeding grounds. Negative impacts on birds are accordingly considered small.

- Able has established a working relationship, and sits on a regular forum, with Natural England, RSPB and the Hartlepool Council that meets every quarter to discuss current activities, to ensure that any concerns are being addressed. The main concern usually relates to noise from piling, and the ASP facility has specific operational restrictions on piling during certain times of day (when birds and seals come to feed) and is only permitted in certain areas away from the quayside (to avoid noise levels close to the quayside). Note: there will be no onsite piling or use of explosives during the decommissioning of the topsides.

The ASP facility is licensed to receive decommissioning wastes and the dismantling operations will be carried out under responsible management and control, with all necessary permits and consents (as discussed in Section 6.10 and 6.10.1). The mitigation measures and controls as discussed above will be in place to minimise impacts. Previous experience of major decommissioning projects in the North Sea demonstrates that the impact potential to local communities can be effectively controlled and mitigated [67].

8.6.1.2 Visual impacts

There will be extended periods of visual impact owing to the large size of the topsides (the drilling and flare towers reach 84 m and 130 m, respectively) and because they will be received in one piece. The topsides will, on arrival at the ASP facility, present a view for miles, before the visual impact gradually decreases as dismantling progresses and the topsides are brought down to the ground over a period of about 12 months. The topsides are likely to be seen from parts of Hartlepool, the nearest densely populated area, located 1.5 miles away, although the Seaton Meadows landfill site will obstruct some views.

The topsides will be dismantled in series, so there will be four periods, each approximately 12 months long, spread over an estimated 8 years, where the topsides will present a visual impact over a wide area. Given that the ASP facility is an established industrial facility, has been operating for years and has often presented similar industrial visual impacts to receptors (the site is often working with very large industrial structures from the oil and gas, wind or marine sectors, such as during the decommissioning of the North West Hutton platform), and considering that the visual impacts will be temporary, and that the site is located next to a nuclear power station, the anticipated visual impacts will be reduced, as receptors will have become accustomed to such views. There have been no complaints in the past received by the site from receptors about visual impacts.

Literature suggests that birds may also be affected by sudden large visual impressions, which they may perceive as a threat [63]. If the situation is more constant (e.g. a permanent installation), birds will generally adapt to the situation and become habituated (Follestad 2012). For a yard activity going on for years it is hence considered unlikely that the visual impression of the topsides located at the ASP facility will cause any measurable impact to birds, especially as the topsides will be located more than 500 m away during the deconstruction.

8.6.1.3 Expansion of onshore facility

As described in Section 6.10.1, a new grounding pad is being constructed at the ASP facility as part of ongoing expansion work, and Quay 6 is being strengthened to accommodate the topsides. These activities will be completed prior to receipt of the decommissioned Brent facilities they are not considered specifically part of the Brent Decommissioning Project and are therefore outside the scope of this ES.

8.6.1.4 Summary

Decommissioning the topsides onshore is estimated to have a ‘small-moderate negative’ impact upon local receptors owing to a combination of potential noise, dust, traffic and visual impacts upon local residents and birds that could occur over a significant period of time as a result of the large volumes of topsides materials that will come to shore. Considered individually, the different types of onshore impacts described above are small. However when considered together, and bearing in mind the sensitive nature and proximity of the SPA, and the significant length of time the decommissioning activities take, the overall impact is higher. However, the impacts are manageable and the necessary controls will be in place to ensure that impacts are minimised.

8.6.2 Hazardous Substances

Hazardous wastes are estimated to have a **‘small-moderate negative’** impact owing to the combination of the factors described below. Impacts from the non-hazardous wastes generated during decommissioning are captured under the ‘Waste management’ category.

8.6.2.1 Large volumes of hazardous waste

There are a number of hazardous substances present on the topsides, and they are typical of the materials and wastes generated from offshore production operations. They include residual hydrocarbons, NORM and chemicals in process plant and drains, and other hazardous wastes such as asbestos. When the facilities cease production and are decommissioned, these materials become hazardous waste.

Prior to commencement of their removal, the topsides will be cleaned by means of a DPV programme for topsides piping, vessels, tanks and other receptacles. This will ensure that no pockets of hydrocarbon liquid, gas, chemicals or contaminants remain on the topsides. As part of this programme, all vessels will be drained of free-flowing liquid. It is planned as part of the physical isolation of the production facilities to install high points, low points and dead legs. This is to enable all hydrocarbons which could not be drained during the DPV to be removed, monitored and proven. DPV is not part of the scope of this ES as DPV is part of the preparatory works; only the potential for impact of the residual hazardous wastes after DPV is considered.

Decommissioning the topsides will still generate significant quantities of hazardous waste, but there are no hazardous materials present which are not typical of offshore platforms and no hazardous wastes will be generated for which the waste management expertise, and treatment and disposal options, do not exist.

There will be some impacts relating to:

- Hazardous wastes such as asbestos, which will require disposal to a licensed landfill having been identified, removed, sealed, packed and labelled by a licensed hazardous waste management contractor. The asbestos waste (and other hazardous wastes) will

consume landfill space and leachate will require treatment, but only licensed contractors and disposal facilities will be used (Seaton Meadows Landfill), and operations will be in line with permit conditions.

- Some hazardous wastes may require incineration (e.g. chemicals, possibly NORM contaminated waste that contains hydrocarbons). These wastes will be treated and disposed of in line with legislative requirements, but will result in emissions to atmosphere (in accordance with permit conditions).
- NORM is typical of offshore oil and gas operations, is often found in produced water and can precipitate as an insoluble scale on the topsides inside some of the process plant, valves and pipework. Shell commissioned ARPS [58] to estimate the NORM scale build-up in topsides pipework, vessels and pumps, as described in Section 8.3.2.11. Scale with NORM activities above the limits set in the Rare Earths Exemption Order [59] is subject to disposal under the Environmental Permitting Regulations 2010 as amended for England and Wales [60].

  Current information estimates that most of the NORM waste identified in the topsides vessels of all four platform (645 tonnes) is <5 Bq/g and hence not considered radioactive for disposal purposes. Approximately 134 tonnes of scale attached to topsides pipework, valves and pumps is above 10Bq/g and hence must be treated as radioactive waste and disposed of at a permitted site. The remaining 323 tonnes is <10Bq/g but >5Bq/g, hence should either be disposed of at a permitted site for acceptance as radioactive waste or to a non-permitted site where a radiological risk assessment has been completed to demonstrate exposure to public and workers is below 300μSv and 1mSv dose respectively.

  Once the topsides arrive at the ASP facility, a more detailed NORM survey will be conducted, and the contaminated materials identified will be removed to a dedicated reception area for decontamination and cleaning. NORM waste will be disposed of in line with industry guidance [61] depending on the activity of the waste. Common methods of NORM disposal currently used in the oil and gas industry include landfill, incineration and dedicated waste facilities such as subsurface salt cavern disposal.
- If there is significant mercury within the topside process equipment (this is difficult to measure before production ceases and units can be physically cut open), this has the potential to contaminate dust at the onshore dismantling facility, and spread mercury which could become a concern if not managed robustly. An assessment and a management plan will be required as discussed below and in Section 8.7.

8.6.2.2 Uncertainties

There are some uncertainties relating to the hazardous wastes present on the topsides:

- NORM waste is present on the topsides and quantities and activity levels have been estimated but there remain some uncertainties. An appropriate survey will be undertaken onshore.
- The current asbestos inventory suggests 40 tonnes of asbestos is present on the topsides. By comparison the Norwegian Frigg platforms had 441 tonnes of asbestos. There is some uncertainty about the Brent asbestos inventory as it is not possible to safely access all areas of the topside until it is brought onshore. A full survey will be undertaken onshore to assess the quantity of asbestos present on the topside prior to dismantling.
- The presence of Pyrophoric Scale (FeS) on the topsides has not been confirmed. An inspection of the topsides will be conducted once they are brought to shore which will

include a survey for any presence of pyrophoric scale, such that the management plan can be implemented if necessary.

- The quantity of mercury in the topsides process equipment (if present) is difficult to measure before production ceases and plant can be physically cut open. Surveys and intrusive sampling will be undertaken to determine if mercury is present once the topsides arrive onshore. Detailed plans will then be finalised for dismantling and the removal and disposal of the wastes to ensure that mercury is managed robustly. This is discussed further in Section 8.7.

8.6.2.3 Summary

In summary, hazardous wastes from decommissioning the topsides are estimated to have a 'small-moderate negative' impact primarily owing to the nature, and the large volumes, of the hazardous waste that will be generated and which will require handling and treatment. The assessment reflects the current uncertainty about the exact volumes of mercury, asbestos and NORM wastes, and the potential presence of pyrophoric scale.
In practice, the impact of the planned management of hazardous waste may be less, even 'insignificant'. Able will employ strict, detailed procedures to ensure fully compliant waste management practices at the ASP facility, perform auditing to control these processes, and as applicable implement further mitigation measures. However, this assessment acknowledges that the reality of waste management and segregation of complex wastes on a site is sometimes not entirely in compliance with all procedures. Small fractions of contaminated material can unintentionally be disposed of incorrectly, with contaminants potentially being released to the environment, with a small associated impact.

8.6.3 Waste Management

The overall waste impact as a result of the removal and decommissioning of the topsides is estimated to be **'moderate positive'**, owing mainly to the large quantity of steel that will be recycled. Hazardous materials present on the topsides are covered in the Hazardous Substances category.

8.6.3.1 Steel recycling

Approximately 76,700 tonnes of carbon steel (plus 2,150 t of external steel), as well as smaller volumes of alloy and stainless steel will be recoverable from the four topsides and will be recycled. Steel constitutes the bulk of the material present on the topsides and is valuable. The recycling of this material therefore dominates the positive impact allocated to this waste management category.

8.6.3.2 Other materials

Dismantling the four topsides will generate considerable amounts of other non-hazardous waste materials, including approximately 515 tonnes of aluminium, 16 tonnes of brass, bronze and tin, concrete, 70 tonnes of wood, 20 tonnes of glass, and 190 tonnes of plastic and rubber. Further details can be found in Section 8.3.1.

These materials will either be recycled or disposed of as waste. Previous experience of major decommissioning projects in the North Sea demonstrates that the environmental impact can be effectively controlled and mitigated [67].

It is assumed that local and national regulations will be applied to ensure that the environmental impact arising from the disposal of non-recyclable materials is minimised. Much of the non-hazardous material from this process is, however, recyclable, which will

thus minimise the volume of waste going to landfill. There is a minimum target of 97% for re-use and recycling of materials brought onshore for the BDP [55].

8.6.3.3 Summary

In summary, decommissioning the topsides is estimated to have a 'moderate positive' impact primarily because of the large quantities of steel that will be generated and recycled.

To put this into a national context, in the UK in 2013 approximately 4.7 million tonnes of steel scrap was exported and approximately 4 million tonnes of steel scrap was consumed for steelmaking [68]. Although 76,700 tonnes of carbon steel from the four topsides represents only a small fraction of this national quantity, the decommissioning of the Brent Field topsides is still likely to be one of the biggest individual contributors of recycled steel in the UK over the duration of the project.

8.6.4 Employment

The overall employment benefit as a result of decommissioning the four Brent Field topsides is estimated to be **'small-moderate positive'**.

Shell commissioned an independent report to estimate the employment generated by the BDP. As part of this study, a factor was derived for the Brent project of £250,000 per new job per year. This factor was then applied by Shell to estimate the man-years generated for each decommissioning option. Shell estimates that the removal of the topsides will generate approximately 1,030 man-years of work.

Although this number is small when considered within a wider context (the UK oil and gas industry is estimated to employ 330,000 people [69]), 1,030 man-years is still considered a 'small-moderate positive' benefit in recent times of relatively high unemployment in the UK oil and gas sector.

8.6.5 Energy and Emissions

Decommissioning each topside will take approximately 12 months, and the four topsides will take eight years to decommission, and will involve significant energy consumption. DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use as a result of decommissioning the four topsides. Comparing this against the energy impact categories in Table 5-7, the impact from energy use is considered to be **'moderate negative'**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

Table 8-4 shows the total energy and emissions resulting from decommissioning all four topsides by SLV, having applied the industry guidelines for such calculations [15].

Table 8-4: Total Energy and Emissions for Removing and Recycling the Topsides

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	0	0	0	0
Marine operations	254,958	19,423	527	284
Onshore dismantling	43,511	3,200	71	3
Onshore transport	21,340	1,570	35	1
New Material[3]	-	-	-	-
Sum	*319,809*	*24,193*	*633*	*288*
Recycling				
Material recycling	837,199	38,852	135	407
Sum	*837,199*	*38,852*	*135*	*407*
Material Replacement				
Materials not recycled	42,125	-	-	-
Total	**1,199,133**	**63,045**	**768**	**695**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option.
[3] No data were available for the manufacture of new materials.

8.6.5.1 Energy consumption and CO_2 emissions

Energy is required offshore (marine vessels and field operations), onshore (dismantling and transport) and for material recycling. Additionally an energy penalty has been applied for replacement of materials that are not recycled (see Section 5.2.3).

The material inventory and vessel durations used within the energy and emissions calculations are included in DNV GL's *Energy Use and Gaseous Emissions Report* [2].

There are no 'at field' operations (decommissioning operations occurring at the Brent Field, such as power generation, or flotel for accommodation of personnel).

Marine vessels will be used for the removal of the four topsides. The removal of each topside will be by SLV. The topside will be transferred from the SLV to a cargo barge nearshore and will then be towed to the ASP facility.

Onshore operations will include the dismantling of topsides, the transportation of materials, and the operation of recycling facilities. As the majority of materials on the topsides are recycled, the emissions for the replacement of topsides (CO_{2REP}) are negligible.

In total, the energy demand for removing and recycling the four topsides is estimated to be approximately 1.2 million GJ, based on the contributions of different operations. The total CO_2 emissions ($CO_{2\ TOT}$) from these operations are estimated to be approximately 63,000 tonnes, of which the largest contribution (62%) comes from recycling operations.

8.6.5.2 Emissions of NO_x and SO_2 to atmosphere

The majority of the gaseous emissions generated during the removal of the topsides are likely to be quickly dispersed as they will be released offshore and over the long duration of the decommissioning works. As such, it is anticipated that the concentrations of NO_x and SO_2 will be relatively low at any given location and at any given time. Onshore emissions (mainly

from recycling the steel) will be within the permit conditions of recycling facilities. As such emissions of NO_x and SO_2 are considered to be smaller contributors to the environmental impact than CO_2 emissions. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

8.6.5.3 Summary

The overall environmental impact from Energy and Emissions as a result of decommissioning the four Brent Field topsides is estimated to be 'moderate negative' owing primarily to the energy consumed and CO_2 emitted during steel recycling, and owing to the length of the decommissioning operations (approximately eight years). Emissions of NO_x and SO_2 are considered a small contributor to this impact. The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put this into another context, the total CO_2 emissions from the removal of the topsides is estimated to be 3% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70].

8.7 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that the following mitigation and management measures are in place. Table 8-5 also highlights the residual impacts as described in Section 8.6 and Appendix 1.

Table 8-5: Summary of Mitigation and Management Measures of Proposed Programme of Work

Environmental Category	Mitigation Measures	Residual Impact
Onshore Impacts	• Prior to removal, the topsides will undergo a DPV programme to ensure that no pockets of hydrocarbon liquid or gas remain, thus reducing the amount of material brought to shore for processing and disposal. • The ASP facility will be responsibly managed. The ASP facility is licensed to perform decommissioning and waste management operations (including hazardous wastes), and the topsides dismantling will be carried out within these conditions. • The ASP dismantling facility is accredited to ISO 9001:2008 (Quality Management System), ISO 14001:2004 (Environmental Management System), OSHAS 18001:2007 (Health and Safety Management System), and ISO 30000 (Ship Recycling Management System). • Able will continue their working relationship with Natural England, RSPB and the Hartlepool Council. • Onshore controls to minimise environmental impacts where necessary, including: ▪ Dust control using, for example, sweeping vehicles, water sprays, speed limits onsite and cleaning of traffic wheels leaving site where necessary. ▪ A thick bed of sand is used to control noise and vibration during dismantling of topsides. ▪ Appropriate environmental monitoring regime. ▪ The majority of material leaving the site, predominantly steel, will be sent by ship or rail. ▪ The dismantling operations will take place more than 500 m away from the Teesmouth and Cleveland Coast SPA, an important area for birds. ▪ No piling will be done onshore as part of the BDP, to restrict noise impacts. • Independent auditing of onshore operations to help ensure regulatory limits are satisfied.	Small-moderate negative
Resource Use	No mitigation measures necessary, few resources used apart from fuel (see Energy and Emissions category)	Insignificant-small
Hazardous Substances	• Hazardous waste will be managed in accordance with all legislative requirements, both offshore and onshore. • The removal of topsides by SLV means that most of the removal and management of hazardous substances will be performed onshore, a safer environment than offshore. • Hazardous materials on the platform will be handled as per Shell's Handling and Storage of Hazardous Substances procedure SUKEP-71.WI.20.62. If shipped to shore, hazardous wastes will be managed in accordance with Shell's Offshore Waste Disposal Procedures manual, and the International Maritime Dangerous Goods (IMDG) Code. • Shell will only use registered hazardous waste management contractors for handling and managing hazardous wastes. Wastes will be tracked and logged from offshore to final recycling/disposal onshore, with hazardous waste consignment notes completed and kept for a minimum of three years. Hazardous waste management procedures will be followed. • Shell will monitor and audit practices. • Able will conduct more detailed surveys onshore of hazardous materials present on the topsides, including asbestos, pyrophoric scale, mercury and NORM. Following surveys, specific plans will be updated and implemented to manage all hazardous wastes in line with legislative requirements and good practice. NORM will be managed in line with OGP Guidelines for the management of NORM in the oil and gas industry [61]. Shell will monitor the UK NORM disposal routes to ensure they are capable of handling NORM waste arising from the decommissioning programme. • Shell will, through a process of risk-based interface arrangements with the onshore disposal site ensure adequate surveying assessment of the topsides to identify substances hazardous to health for any and all instances and activities whereby mercury could be found within the topsides, either in process equipment, or through dismantlement processes. If mercury is found by way of mitigation the following additional activities would be initiated through the agreed interfacing arrangements with Shell's disposals contractor: ▪ Operational and HSE support to the initial surveying of the topsides upon arrival onshore ▪ Participation in an ongoing audit schedule which includes specialist support where required (Occupational Hygienist, HSE Advisor) ▪ Sharing of relevant Shell standards & procedures (as per interface arrangements and documentation) ▪ Spaces or equipment contaminated with mercury will be marked and unauthorised access prohibited. Specialist contractors will be engaged to remove any steel impregnated with mercury and will be disposed of by a Specialist Waste Management Contractor. If recycling or reclamation is not possible, mercury-contaminated steel will be disposed of by burial at an approved, secure landfill. ▪ Periodically sample dust onsite and analyse for mercury, and take appropriate actions (e.g. use of dust collecting vehicles) if dust is found to be contaminated.	Small-moderate negative
Waste	• Shell will have representatives onsite and will establish a plan for monitoring and auditing the waste management contractor, and will implement the plan. Shell will ensure the contractor acts in accordance with duty of care, other legal requirements and contract conditions. Shell will review Able waste management documentation and procedures. • Able has a 97% target for recycling set in the contract to help optimize waste management. • The nearby Seaton Meadows Landfill, also operated by Able, is permitted and will be operated in accordance with conditions.	Moderate positive

Environmental Category	Mitigation Measures	Residual Impact
Physical	The SLV and other vessels will not use anchors, and will operate on DP, therefore minimizing any potential physical damage to the seabed from anchor pits.	No impact
Marine (includes underwater noise)	• The SLV and other vessels will not use anchors, and will operate on DP, therefore minimising any potential damage to the benthic environment from anchor pits. • Following a detailed risk assessment and discussion with stakeholders such as Natural England, Shell will consider establishing a Seal Corkscrew Injury Monitoring Scheme, to include the use of marine mammal observers and seal scarers during the 48-hr period of near-shore operations when the SLV is stationary and held in position using DP thrusters, as well as the use of tugs without ducted propellers during transport through the channel. • Shell will sample the marine sediment at the nearshore transfer location to confirm that it is not contaminated (inorganic or organic parameters will be analysed). Shell will collect benthic samples to confirm there is no protected fauna present at the transfer location. • Movement of vessels during decommissioning operations will generally be local, and vessels will have a ballast water management plan that follows IMO guidelines [71].	Small negative
Environmental Risk from Accidents	• Prior to removing the topside, a DPV programme will take place to ensure that no pockets of hydrocarbon liquid or gas remain; this will minimize the risk of pollution from a potential environmental spill. • The topside will be strengthened to allow single lift to be undertaken safely. • Before the topside is removed a test lift will be undertaken and sea trials subjected to third party marine warranty services. • The SLV lift operations will have been subjected to HAZID and HAZOP, and any necessary actions taken to satisfy all parties that the lift, transport and transfer of the topsides will be safe. • SLV fuel tanks are surrounded by 3 m of ballast water (in effect double-skinned) • Shell will undertake a safety assessment of the towing route and transfer location to ensure collision risk is minimised. • Modelling of the forces exerted on the topsides during transfer and transit operations has been conducted by Shell, and satisfactorily demonstrates the lift to have a very low likelihood of failure. • Operations will take place in good weather. • Manoeuvring of vessels at the Brent Field and the nearshore transfer site will be controlled and at low speeds. • Operations will be carried out under an approved Dismantlement Safety Case, to be approved by the HSE. • A BEIS approved Oil Pollution Emergency Plan (OPEP) for the Brent Field system is in place. The *Pioneering Spirit* Ship SOPEP, approved by the Maritime and Coastguard Agency (MCA), will be in place. The SOPEP will be reviewed by Shell when in place to ensure that the response strategy and control mechanisms are robust. A bridging document between Shell and AllSeas will be developed. • Shell will put systems in place to minimise the potential for accidents, such as visual checks of the integrity of hoses and tanks, and checking connections before bunkering via (e.g.) a leak test. • A guard vessel may be in place during removal of the topsides. • The UK Coastguard as well as the Teesmouth Harbour Master will be notified of the decommissioning operations in order to provide advance warning to other ocean-going or harbour vessels operating in the area.	Small negative
Employment	Positive impact	Small-moderate positive
Legacy	No impact	No impact
Fisheries	• Majority of operations will take place within 500 m safety zone of the platforms. • Shell will liaise with the fisheries agency to provide advance warning of vessel movements resulting from decommissioning activities, both by the SLV and support vessels.	Insignificant
Shipping	• Once the topsides have been secured to the SLV, the vessel cranes will fit concrete caps onto the GBS legs; one of the caps will be pre-fitted with an automatic AtoN, which will be fully functional before the SLV leaves the field. If the AtoN is not fitted immediately, a guard vessel will be stationed near the GBS as a contingency until it has been fitted. The 500 m radius safety zone will remain in force. Shell will notify the UK Hydrographic Office of the changed status of the remaining GBS structures and Notices to Mariners will be issued. • The SLV offshore transit route will be carefully planned and managed. • The UK Coastguard as well as the Teesmouth Harbour Master will be fully notified of the decommissioning operations in order to provide advance warning to other ocean-going or harbour vessels operating in the area.	Insignificant-small negative
Energy & Emissions	• The SLV will use marine diesel in line with MARPOL North Sea Special Area requirements [72], to reduce SO_x emissions. • Vessel speeds will be managed to minimise fuel consumption. • To increase efficiency, combustion equipment on vessels will be maintained in accordance with manufacturers' recommendations.	Moderate negative

9. BRENT ALPHA JACKET

9.1 Introduction

This section describes the Brent A jacket, the inventory of materials and the decommissioning options. The main anticipated environmental impacts of the decommissioning options are discussed and compared. The necessary management and mitigation measures to control the impacts of Shell's proposed programme of work are summarised, and measures are recommended to further reduce residual impacts where appropriate. The Technical Document for Decommissioning the Brent Alpha Jacket [73] has been used as the basis for Sections 9.2 - 9.4.

9.2 Description of Facilities

The Brent A jacket was installed in 1976. The jacket is defined as all of the steel structure below the level of the truss deck. The truss deck is part of the topsides structure and will be removed when the topsides are lifted off. Figure 9-1 shows the main features of the jacket structure.

Brent A sits in a water depth of approximately 140 m, and the jacket has an overall height of approximately 162 m. On the seabed, the area enclosed by the base of the jacket (footprint) is 77 m by 75 m, or 5,775 m^2.

The jacket comprises eight tubular steel legs and is fixed to the seabed by 32 piles (long hollow steel pipes). There are four piles on each of the eight legs. The piles are external on five jacket legs and internal on the three pontoon legs. During installation of the jacket, the pontoon legs were air-filled to enable the jacket to be floated out to location. Through controlled ballasting and venting of compartments, the jacket was rotated vertically to sit on the seabed and all the ballast tanks were flooded to maximise stability. Following this, the internal piles in the pontoon legs were driven into the seabed to a depth of between 24-35 m, and the piles were filled with cement grout to secure the jacket structure and increase its on-bottom stability. Figure 9-2 shows these structural features. After installation, all of the jacket legs and bracings below -45.7 m LAT were flooded with seawater. External well conductors rise through the jacket towards the topsides wellbay, and are supported within five horizontal guide-frames positioned down through the jacket. After the removal of the Brent A topsides the conductors will still be present in the jacket. The removal of the conductors (either partially or completely) will be part of the jacket programme of work.

The present total weight of the Brent A jacket and anodes (in air), including the piles and their grout, is estimated to be 25,834 tonnes excluding conductors (31,453 tonnes including conductors and associated grout/marine growth).

The Brent A jacket is not protected by any anti-corrosion or anti-fouling paint coatings. Similar to most other platforms on the UKCS, the submerged parts of the jacket support structure are covered in a considerable amount of hard and soft marine growth (or biofouling), consisting of marine fauna and flora native to the North Sea which have opportunistically colonised the hard surfaces of the jacket. Marine fauna in the Brent Field are discussed in detail in Section 6.3.2 and 6.3.3. The occurrence of these species does not prevent or hinder either partial or complete removal of the jacket.

No part of the Brent A jacket has ever been used for the storage or processing of oil, gas or chemicals.

The FLAGS pipeline runs under Brent A and contains high pressure hydrocarbon gas. The decommissioning of the Brent A platform will not commence until the section of FLAGS pipeline underneath the facility has been isolated and is no longer in operation.

Figure 9-1: Brent A Jacket General Configuration

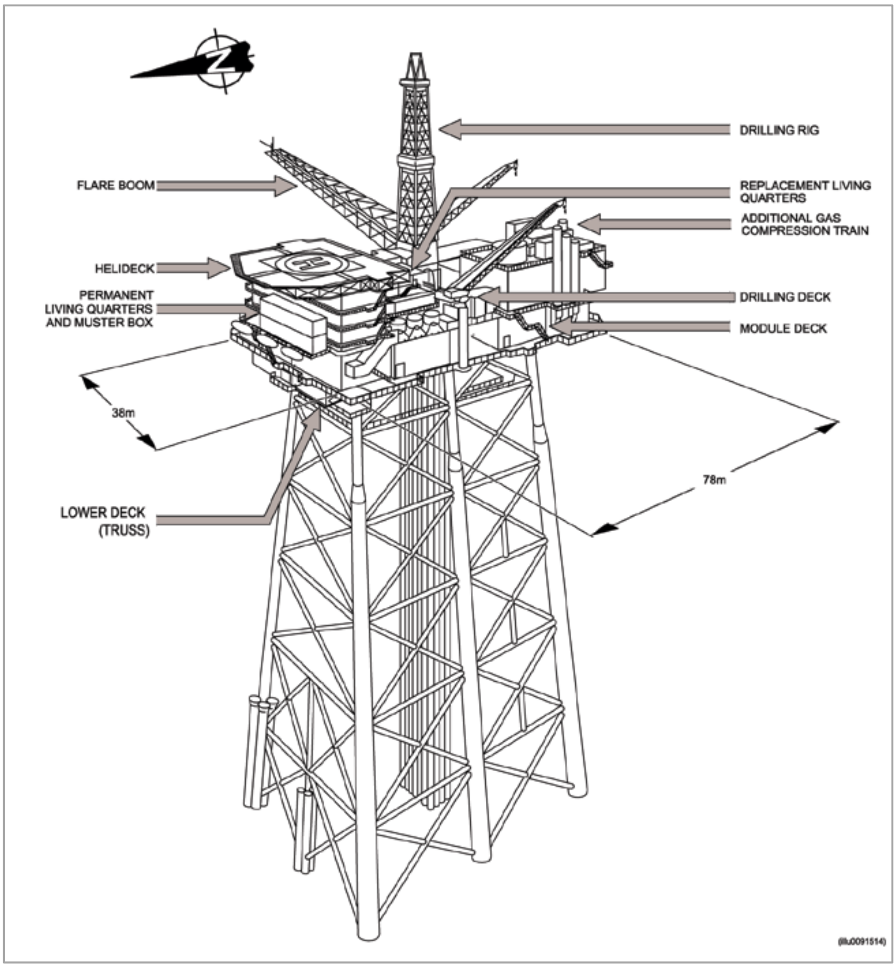
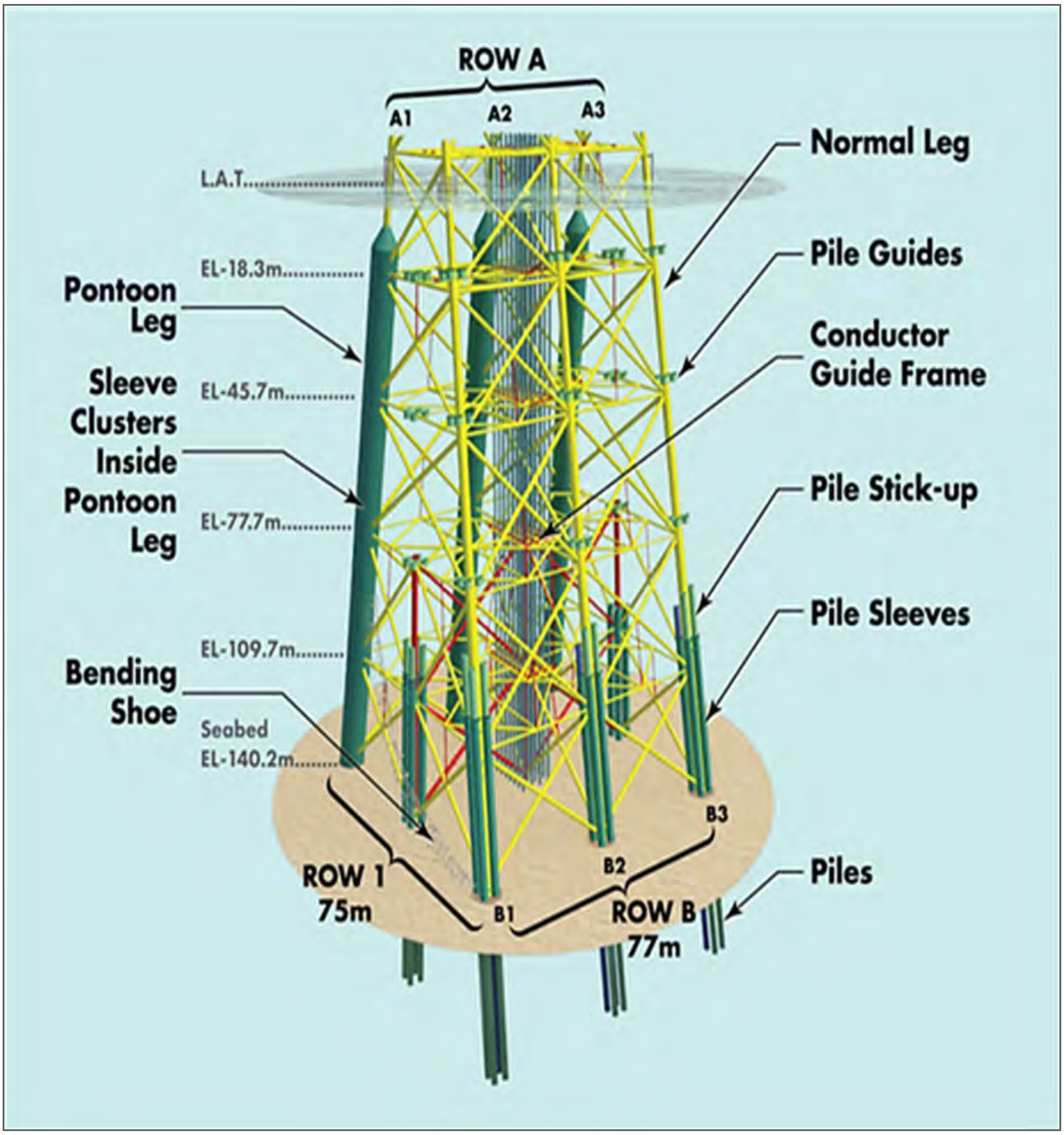


Figure 9-2: Brent A Jacket Legs and Footings [73]



9.3 Inventory of Materials

The materials inventory showing the estimated mass of materials on the Brent A jacket is given in Table 9-1.

Table 9-1: Brent A Jacket Materials Inventory

	Material and Estimated Mass (tonnes)				
Item or Component	**Steel**	**Cementitious Grout**	**Marine Growth**	**Aluminium or Zinc**	**Total**
Jacket	14,813	0	2,120	0	16,933
Conductors (28)	4,285	720	614	0	5,619
Piles (32)	4,161	0	0	0	4,161
Grout in piles (incl. below seabed level)	0	4,484	0	0	4,484
Anodes	0	0	0	256	256
Total	**23,259**	**5,204**	**2,734**	**256**	**31,453**

Note: The masses in this table are for the jacket, piles and conductors down to 3 m below the seabed, the presumed depth for cutting if the whole jacket were to be removed.

9.4 Available Decommissioning Options

The installed weight of the Brent A jacket (without conductors or any marine growth) is estimated to be 23,714 tonnes. Under OSPAR Decision 98/3, exceptions ('derogations') to the requirement for complete removal and recovery of steel jackets heavier than 10,000 tonnes may be granted provided that:

- Only the jacket footings (or partial footings) are left in place
- A minimum water clearance of -55 m LAT is provided as per IMO requirements, to allow ships to pass above jacket footings
- Any alternative approach, such as partial removal, is demonstrated to be preferable via a Comparative Assessment

Shell screened a wide range of possible re-use options for Brent A, including Carbon Capture and Storage (CCS) but concluded that none of the options were both technically and economically feasible. Shell also examined complete and partial removal of the jacket using added buoyancy and concluded that neither option was technically feasible. In addition, Shell considered complete removal of the jacket in one piece by SLV and concluded that, from a technical feasibility point of view, there were too many unresolved issues and risks to warrant further investigation. Shell concluded that the jacket could only be removed in pieces, and that an obvious major cut line on the jacket would be at -84.5 m LAT, separating the upper jacket from the footings.

All available decommissioning options for the Brent A jacket are discussed in further detail in Shell's Technical Document for Decommissioning the Brent Alpha Jacket [73], as is discussion regarding derogation.

9.4.1 Upper Jacket

Subsequent to screening studies on options for the jacket, Shell has committed to removing the upper jacket in one piece at -84.5 m LAT, and has contracted AllSeas Group SA to

remove it using the SLV *Pioneering Spirit*. The potential impacts of this programme of work are described in Section 9.7.1. As Shell has committed to removing the upper jacket, it is not subject to a Comparative Assessment under OSPAR 98/3.

The option assessed in this ES for decommissioning the Brent A upper jacket is:

Brent A Upper Jacket	**COMPLETE REMOVAL**
	Option 1. Removal in one piece to approx. -84.5m LAT using SLV.

9.4.2 Jacket Footings

There are decommissioning options for the footings. Shell examined if the footings could be removed by a SLV in a single piece and concluded that this is not technically viable. Consequently, the footings would have to be cut into sections and lifted in pieces to the surface. Shell decided that there are two ways in which this could be done:

- By digging pits in the seabed to allow the steel piles to be cut externally at -3 m below the seabed by DWC, or
- Drilling out the grout in the steel piles so that an Abrasive Water Jetting (AWJ) machine could be inserted into each pile to cut the pile internally.

In both cases the jacket legs would then be cut free from the rest of the footings by cutting the bracings with mechanical shears, DWC or AWJ as appropriate and lifted by the crane of a Semi-Submersible Crane Vessel (SSCV) onto a cargo barge for transportation back to shore.

In both cases the lower parts of the conductors (assuming they had been cut at -84.5 m LAT and removed as part of the removal programme for the upper jacket) would have to be removed as part of any programme to remove the footings. The lower parts of the conductors could not be lifted away with the parts of the footings, they would be removed separately.

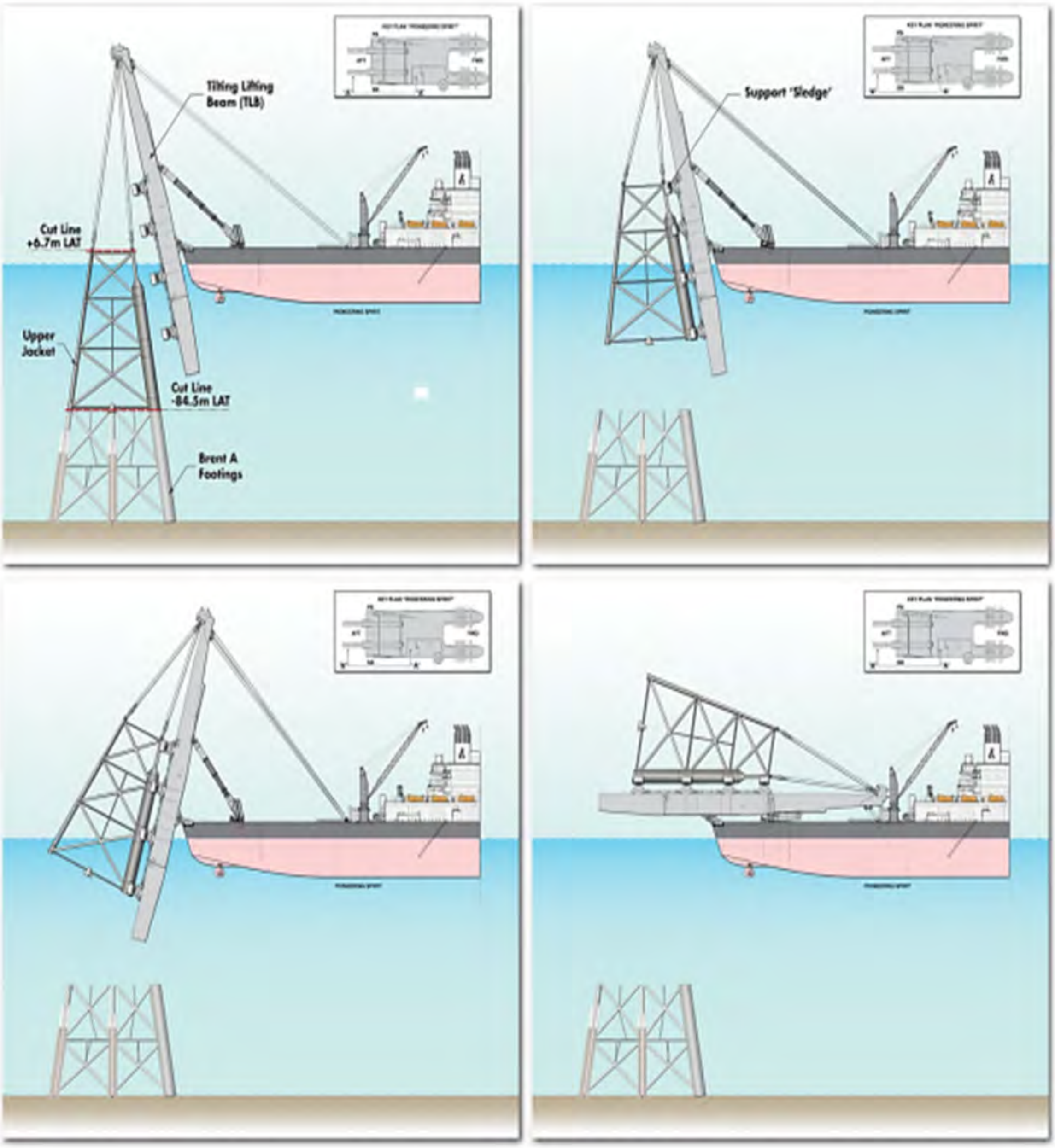
Subsequently, Shell has performed a Comparative Assessment on the jacket footings, which weigh approximately 21,340 tonnes (including the lower parts of the conductors), and for which there are three decommissioning options assessed in this ES:

	COMPLETE REMOVAL	**COMPLETE REMOVAL**	**LEAVE IN PLACE**
Brent A Jacket Footings	**Option 1.** Complete removal by SSCV in several pieces, after cuttings the piles externally	**Option 2.** Complete removal by SSCV in several pieces, after cutting the piles internally	**Option 3.** Leave *in situ.*

9.5 Description of Proposed Programme of Work to Remove the Brent A Upper Jacket by SLV

Removal of the Brent A upper jacket will be undertaken using the SLV *'Pioneering Spirit'*, which is described in Section 8.5.2. The upper part of the jacket will be severed from the jacket footings by cutting at a depth of -84.5 m LAT. The upper part of the jacket will then be removed by the SLV in a single lift (see Figure 9-3) and taken to shore for dismantling and recycling, as described in more detail below.

Figure 9-3: Lifting the Upper Brent A Jacket by SLV



9.5.1 Preparation

After removing the topsides, two temporary 63 tonne working platforms will be fitted to the top of the jacket by a Construction Support Vessel (CSV) to provide safe platforms for preparatory work, and to fit the lifting points. If there is a time period between the removal of the topsides and the removal of the upper jacket, Shell will fit an AtoN on the jacket, and submit appropriate navigation information to the UK Hydrographic Office (UKHO) so that Notices to Mariners (NM) can be issued.

The following preparatory activities will take place prior to the removal of the upper jacket, after removal of the topsides:

- Local cleaning for hole drilling (e.g. insertion of lift anchors for removal, leg inspection holes)
- Local cleaning for cutting tool clamping (depending on marine growth levels, this may not be necessary)
- Clearance created for cutting tools by removal of obstructions such as:
  - External piping close to the leg/pontoon wall will be removed with DWC, AWJ or shears and mechanical grinders as appropriate
  - Small obstructions and anodes which are in the way of underwater cutting will be removed using AWJ techniques
- Major appurtenances removed will be lifted to the surface by crane.

9.5.2 Removal of Conductors

The conductors will be removed down to approximately -84.5 m below LAT. The conductors will be freed from within their guide-frames by the removal of external repair clamps where fitted, and then will be lifted in sections complete with casing and tubing strings.

In the season before the upper jacket is removed, a HLV supported by a Remotely Operated Vehicle Support Vessel (ROVSV), will cut the 13 3/8” and 20” casings and the 30” conductor using AWJ. The casings will be pinned to the conductor, and the 91 m long 158 tonne conductor and casings will be removed in a single lift. The conductors will be sea-fastened on a cargo barge and taken to shore for dismantling and recycling. In total, an estimated 2,576 tonnes of steel from the conductors will be taken to shore.

9.5.3 Cutting and Lifting

The upper jacket will be separated from the footings by cutting it at a depth of about -84.5 m below LAT. This will require a total of thirty nine cuts comprising the three 7 m diameter pontoon legs in Row A, the three large legs on Row B, the two legs on Row AB, and thirty-one vertical and vertical diagonal bracings. It is estimated that in good weather the cutting programme will take about 17 days.

Underwater cutting will be conducted using a DWC system deployed by ROVs from a Diving Support Vessel (DSV) (Figure 9-4) or CSV, probably operating on DP; it is not envisaged that divers will be needed. All the cuts will be significantly above the seabed so the drill cuttings will not be disturbed. The use of underwater explosives is not planned (if they were required as a contingency, Shell will consult with BEIS on their use and follow the JNCC Guidelines on minimising acoustic disturbance to marine mammals [74]).

Figure 9-4: Diving Support Vessel (DSV)

Source: DNV GL Database

Before the final cuts are made, new specially-designed lifting trunnions will be inserted and welded inside the open tops of the four corner legs. The SLV will then move into position at the platform using DP. The crane lifting strops will be attached to the lifting trunnions and the slack taken up. When the final cuts are made, the upper part of the jacket will be lifted clear by the SLV jacket lift system (JLS, a pulley system controlled by winches on the deck of the SLV) attached to the top of the Tilting Lifting Beam (TLB). In this way, the jacket will be carefully aligned and laid against tailor-made carrying cradles on the TLB, specifically designed to accommodate the jacket's shape and transfer its weight onto the TLB.

Once the jacket is on the TLB, the TLB will be rotated back onto the deck of the SLV so that the jacket is lying horizontally. The jacket will then be pulled further inboard by lifting wires and will be secured to the SLV. From beginning the final cuts to completing the sea-fastening of the jacket on board the SLV, this whole process is estimated to take 18 hours.

The decommissioning options for the jacket footings left *in situ* are described in Section 9.6.

9.5.4 Transportation and Backloading

The SLV will then travel to a nearshore transfer site which is a circular area of 2.78 km in diameter. The centre of this area (54°44.0'N, 01°06.0'W) is approximately 5.5 nautical miles from the mouth of the River Tees and approximately 3 nautical miles from the nearest coastline (The Headland at Hartlepool) and has a water depth of approximately 35 m. During a period of suitable good weather the upper jacket will be skidded from the SLV to a large cargo barge in an operation taking approximately 12 hours; the barge will be moored against the SLV which will operate on DP. Such a transfer is necessary because there is insufficient depth of water in the Tees Estuary to allow the SLV to berth alongside the quay at the ASP facility. The cargo barge is 200 m long and 51.6 m wide and has been designed by AllSeas for use in a variety of installation and decommissioning operations.

After the jacket has been sea-fastened it will take approximately 8 hours for tugs to tow the barge to the ASP facility. The barge will be moored to the quayside and ballasted so that it rests firmly on the new, strengthened cargo barge grounding pad on the river bed next to the quay. The jacket will be skidded off the barge in an operation lasting approximately 12 hours.

9.5.5 Onshore Dismantling and Recycling

Shell has contracted Able to receive, dismantle and recycle the upper jacket. This will take place at their ASP facility at Teesside, which is fully licensed to receive, handle and dispose of the range of materials that will be present on the jacket. See Section 6.10.1 for more details.

Including the upper parts of the conductors, approximately 8,400 tonnes of steel and 100 tonnes of aluminium-zinc anodes will be returned to shore and recycled. Since the upper jacket comprises predominantly steel, it is anticipated that about 84% of the recovered total mass of material will be recycled (the remaining 16% being marine growth).

Table 9-2: Removal of Upper Jacket by SLV

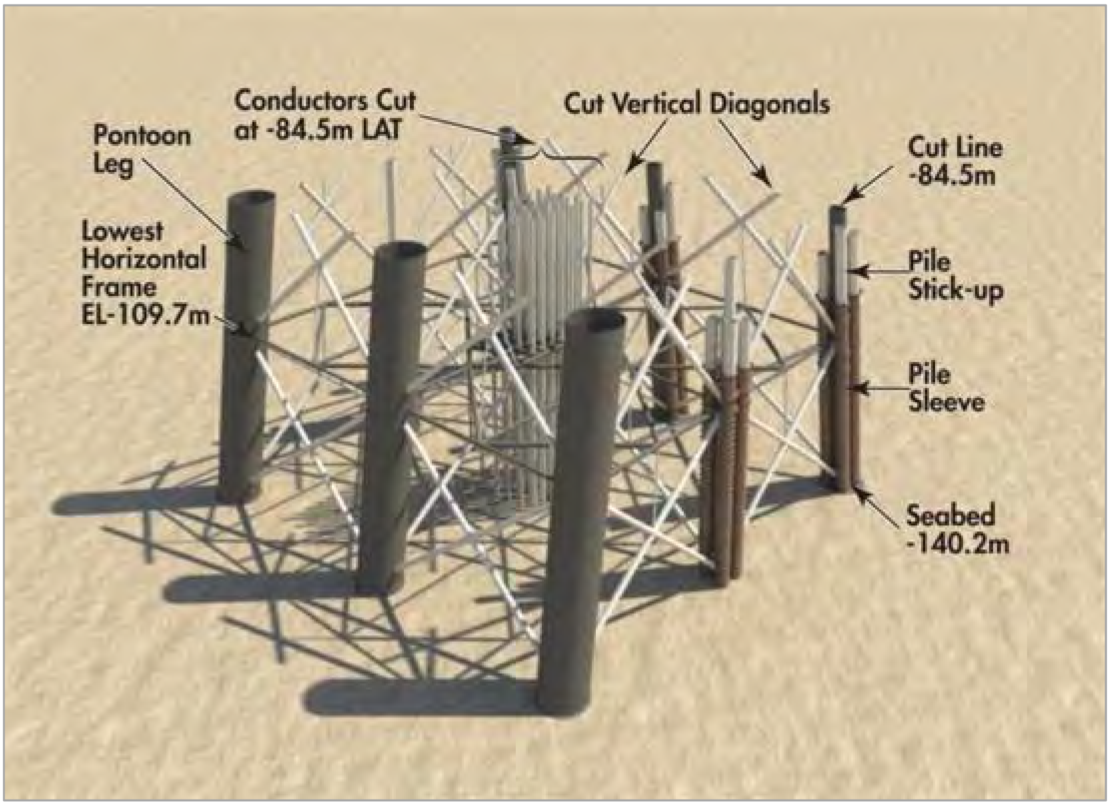
	Material and Estimated Mass to be Removed (tonnes)				
Item or Component	**Steel**	**Cementitious Grout**	**Marine Growth**	**Aluminium or Zinc**	**Total**
Jacket	5,835	0	1,232	0	7,168
Piles (32)	0	0	0	0	0
Pile grout	0	0	0	0	0
Conductors (28)	2,576	0	369	0	2,945
Anodes	0	0	0	101	101
Total	**8,411**	**0**	**1,601**	**101**	**10,113**

Marine growth on the jacket will be removed onshore and disposed to landfill. The jacket will then be dismantled, probably using hydraulic shears and cranes, although some ‘hot cutting’ (oxy-acetylene cutting) may be required. The aim of the programme of work will be to reduce the height of the structure as quickly as possible so that component parts are bought down to ground level where they can more easily and safely be cut into small pieces ready for recycling. Once started, this process will take approximately 4-6 months, but the intact jacket section may sit in the yard until Able starts this operation.

9.6 Description of Technically Feasible Decommissioning Options for the Jacket Footings

This section describes the technically feasible options for the removal of the Brent A jacket footings, which is a candidate for derogation under OSPAR 98/3. The starting condition for all of these options is that the topside and upper jacket (with upper conductors) would have been removed, leaving the footings as shown in Figure 9-5.

Figure 9-5: Condition of Jacket Footings after Removal of Upper Jacket to -84.5 m [73]



9.6.1 Option 1: Complete Removal of Footings by SSCV in Several Pieces, after Cutting the Piles Externally

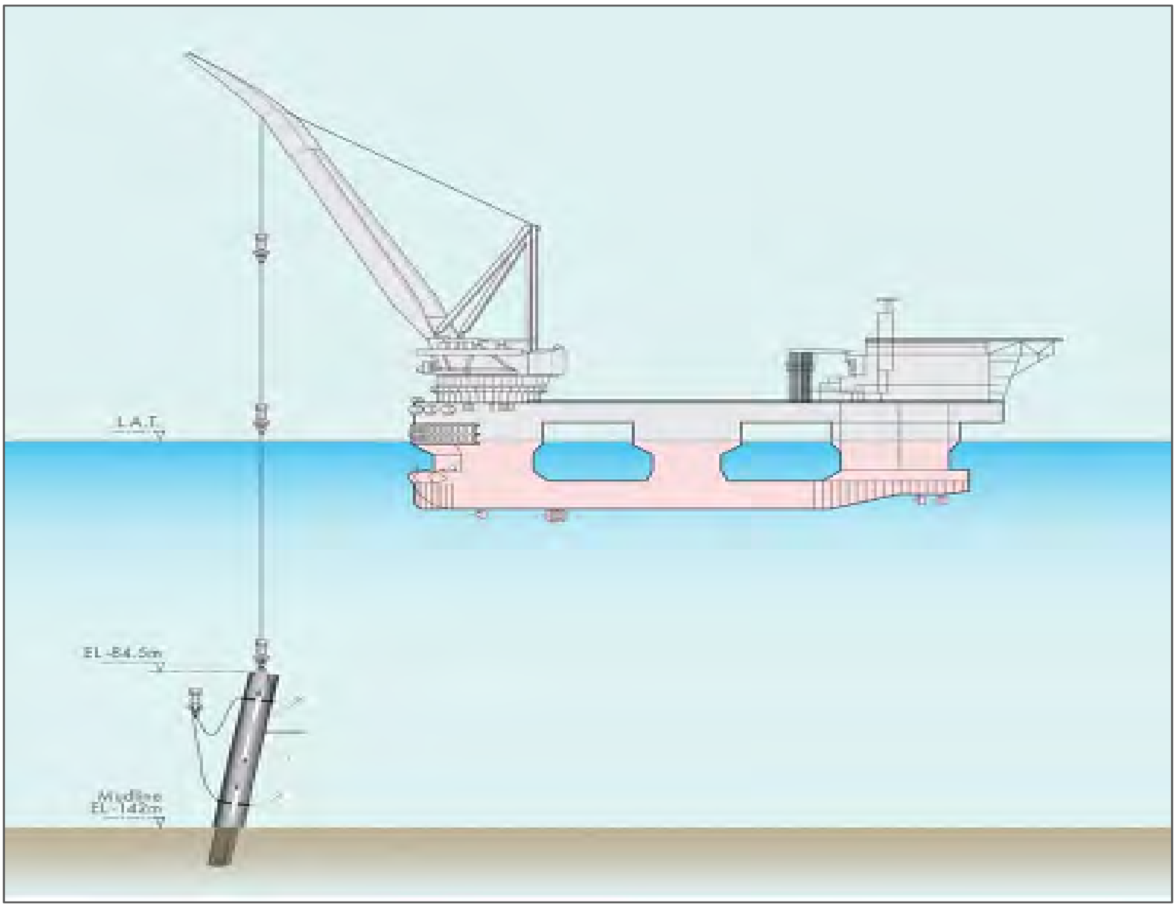
9.6.1.1 Overview

Under Option 1, the Brent A jacket footings would be removed by SSCV after cutting the piles externally. This programme of work would begin by cutting out and removing the lowest conductor guide frame, and then removing the lower parts of the conductors. The majority of the drill cuttings pile would then be removed in order to dig pits around each leg (see Section 13.5.2).

The seabed would then be excavated around each leg in turn to about -4 m depth, and a DWC would be used to cut the piles to -3 m below the seabed. The weight of the disconnected leg would then be taken on the crane of the SSCV while the bracings linking the jacket leg to the footings are severed. The detached leg section would be lifted by an SSCV (see Figure 9-6), secured on the deck of a cargo barge and returned to shore for dismantling and recycling. This operation would be repeated for each of the legs and the spoil from excavated pits would be used to back-fill the preceding pit to provide the required 3 m burial of the cut ends of the piles. After all the footings sections had been removed and the last pit back-filled, the former

site of the Brent A jacket would be left clear of all platform components. In good weather, it would take approximately 9 months to cut and remove the Brent A jacket footings in this way.

Figure 9-6: Lifting Sections of the Brent A Jacket Footings Using an SSCV



9.6.1.2 Removal of conductors and guide frame

The first part of this programme of work would be to cut and remove the conductors and guide frame using a ROVSV with a suitable crane capacity and approximately 120 m^2 deck space for the AWJC, DWC, guillotine shears and associated cutting spreads. It is unlikely that individual lifts would be more than 100 tonnes each and operations would likely be completed in one month.

The upper conductors would have been cut at -84.5 m LAT and removed together with the upper jacket. This might leave the 13 3/8" casing in place below the cut line, in addition to the 20" casing, and in such circumstances the 13 3/8" casing would have to be cut at about -4 m below the seabed and removed, in order to create access for the internal AWJ to cut the approximately 60 m long sections of 20" casing and 30" conductor. It is noted that the annuli between the 20" casings and 30" conductors might be grouted to some height above the seabed, and together these 60 m lengths of grouted conductor and casing would weigh approximately 80 tonnes each. Typically, the AWJ cutter would be deployed from an ROVSV capable of both cutting and lifting the casings and conductors, which would be loaded onto a cargo barge and taken to shore for recycling.

9.6.1.3 Removal of drill cuttings pile

The majority of the drill cuttings pile would be removed by dredging in order to dig a pit around each leg, resulting in the removal of approximately 6,500 m³ of drill cuttings (see Section 13.5.2). Even if the central portion of the drill cuttings pile was unaffected by the creation of the access pits, the surrounding pits would leave a tall and probably unstable inner core that might be further disturbed by the removal of the lower parts of the conductors, a necessary precursor to the removal of the footings. This part of the cuttings pile would therefore also have to be removed, either because it would be likely to slump into the pits or because it posed unacceptable technical and safety risks to the deployment of the DWC.

Shell has assumed that the upper 25 cm of natural seabed sediment beneath the drill cuttings pile is contaminated with hydrocarbons and other contaminants from the drill cuttings, and that consequently an additional 1,425 m³ of sediment would have to be removed and treated along with the cuttings themselves. The total volume of contaminated material that would have to be removed would therefore be approximately 7, 925 m^3. The deeper, clean layers of natural sediment from the access pits (estimated volume 23,750 m^3) could be displaced to a nearby location on the seabed, as described below.

9.6.1.4 Excavating the access pit

A pit would have to be excavated around each of the eight jacket legs to gain access for cutting the piles. Shell calculates that to provide the necessary level working area around each of the legs (which vary in diameter from 1.8 m to 7.3 m), the pits would be approximately 4 m deep and 42 m in diameter. Excluding the historic drill cuttings pile, this would result in the excavation of approximately 25,175 m³ of natural seabed sediment. If the lower parts of the conductors had been cut internally by AWJ no excavation would be required around the conductors. However, because of the dimensions and close grouping of the pits (Figure 9-7), the excavation of the pits would essentially entail the removal of a 4 m thick layer of seabed sediment from within the whole footprint of the footings, and approximately 20 m beyond as illustrated.

For the soil conditions found in the Brent Field, the established method of excavating this amount of seabed would be to use a track-mounted subsea dredger (Figure 9-8), such as the “Scanmachine™” supported by an ROV-guided “Scandredge™” for the more restrictive areas. These machines break up the seabed and dredge by means of venturi suction technology using seawater, and this allows large amounts of soil, gravel and sand to be easily moved to an adjacent location on the seabed. This equipment has been used successfully for about 10 years and equipment failures are rare. Depending on schedule and structural stability, it may be possible to excavate one leg and deposit the spoil into a previous hole in order to re-establish a 3 m deep layer of seabed sediment over the tops of the cut steel piles.

Figure 9-7: Size and Location of Seabed Pits for Cutting the Jacket Piles

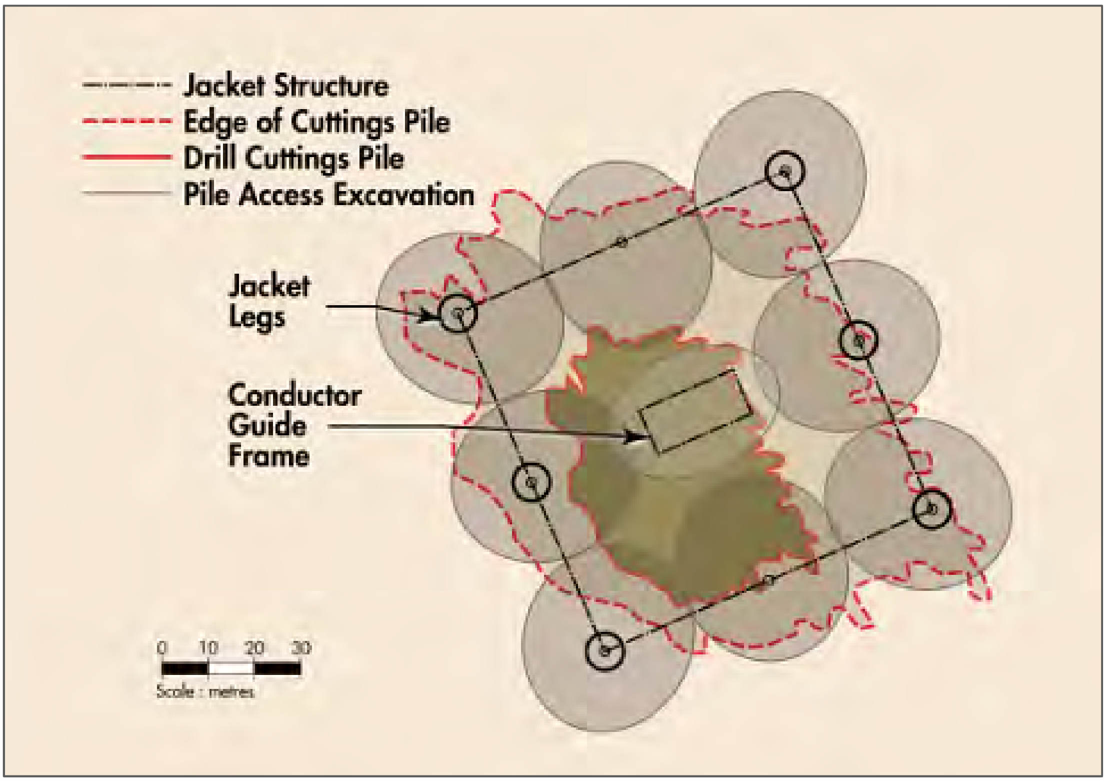


Figure 9-8: Using a Subsea Dredger to Excavate a Pit

9.6.1.5 Cutting steel piles externally

Once the pit is excavated, the ROV-guided DWC would be deployed at the base of the pit and clamped onto the pile just below the proposed cut elevation. On completion of the cut, the diamond wire would be on the opposite side of the pile from the main body of the DWC. The ROV would therefore have to cut the wire to free the DWC, which would then be re-covered, fitted with a new wire and redeployed on the next pile. The pile cutting operation would take approximately seven hours per pile.

Both the dredging system and the DWC system could be deployed from the SSCV used to cut and lift the footings sections. Although the two operations of excavation and cutting could be performed simultaneously, excavation around one leg would have to be completed before pile-cutting could begin. These operations would also have to be coordinated with the cutting and lifting of the footings sections.

9.6.1.6 Cutting and removing the sections of footings

Each of the eight jacket legs and its associated sections of horizontal and vertical diagonal bracings would be lifted as single units by an SSCV (Figure 9-6). These would be removed in a phased programme of work (comprising sequences of excavation, pile-cutting, and lifting). It is not envisaged that divers would be needed during any of this work. If the piles were cut externally by DWC, it is assumed that the upper part of each pile (to be removed with the section of leg) would remain firmly fixed in the pile sleeve by the pile annulus grout and would therefore not have to be pinned in place to prevent detachment during lifting.

It is likely that the bracings would be severed using one of three methods: DWC, AWJ or mechanical shears, depending on their size and location. The final choice of equipment and the exact sequence in which the bracings would be cut would be decided during any detailed FEED study.

This would result in the lifting of approximately 10-14 sections of footings, with weights ranging from approximately 1,000 to 3,000 tonnes.

9.6.1.7 Transportation to shore, recycling and disposal

The severed footings sections would be positioned onto specially designed and prepared grillage on a cargo barge and sea-fastened for the tow to shore. In addition to the 105 tonne guide frame, approximately 18,561 tonnes of material (plus the lower sections of the conductors and associated marine growth and grout) would be returned to shore and would likely be skidded off the cargo barge onto a quayside. Marine growth would be removed and disposed of to landfill, anodes would be removed for recycling, steel would be cut into sections for transportation to a steel smelting and recycling facility, and concrete grout would be separated as far as practicable from the legs, piles and pile sleeves, and would likely be recycled as in-fill for construction projects.

9.6.1.8 Final condition of the Brent A site

Each pit would be at least partially back-filled using the spoil from the next pit, and it is likely that over time they would be further filled by seabed sediment moved by natural seabed currents and occasional storm waves. At the former site of Brent A, no part of the jacket footings would remain visible; the cut ends of the piles, conductors and casings would be approximately -3 m below the restored level of the natural seabed. An area with a radius of 500 m centred on the former site of the footings would be swept to ensure that it was free of debris derived from offshore oil & gas operations that might pose a snagging risk to bottom-towed fishing gear.

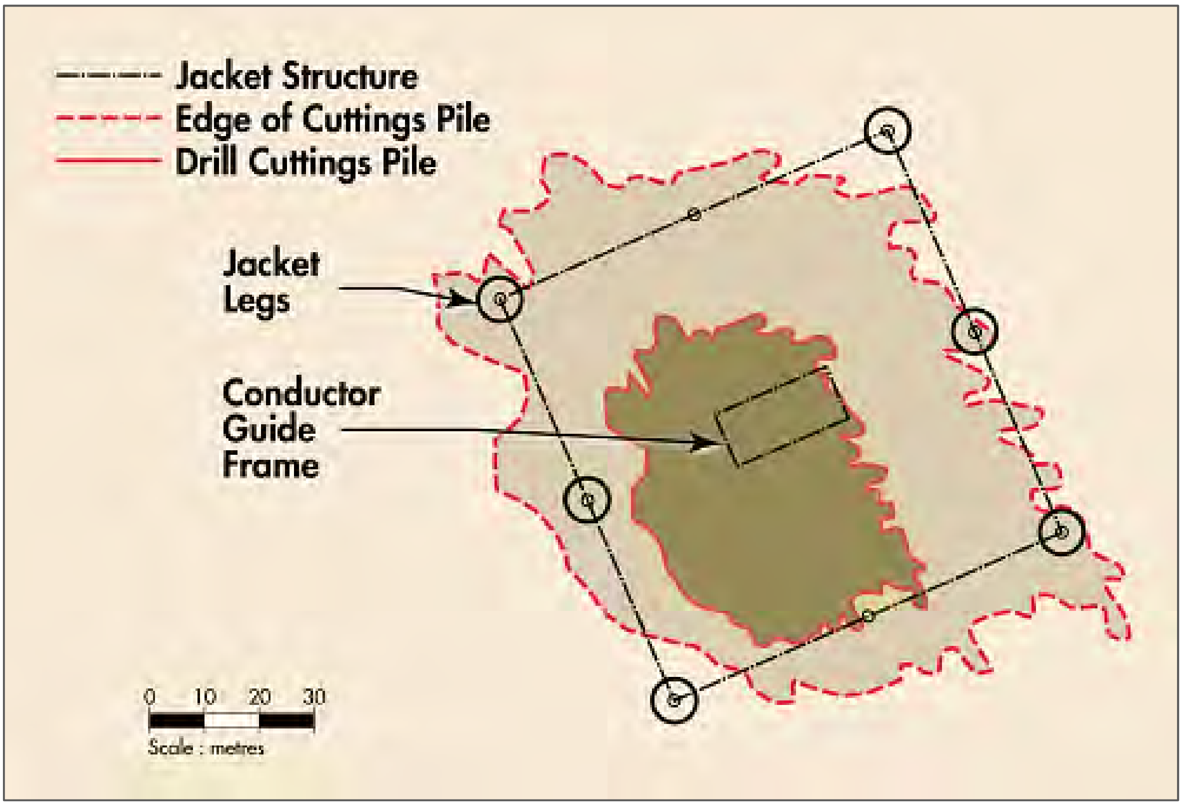
9.6.2 Option 2: Complete Removal of Footings by SSCV in Several Pieces, after Cutting the Piles Internally

9.6.2.1 Overview

Under Option 2, the Brent A jacket footings would be removed by SSCV after cutting the piles internally. This programme of work would begin by cutting out and removing the lowest conductor guide frame, and then removing the lower parts of the conductors.

The grout inside each pile would then be removed by drilling and an AWJ deployed inside the piles to cut them to -3 m below the seabed. The weight of the disconnected leg would be taken on the crane of the SSCV while the horizontal and vertical-diagonal bracings linking the leg to the footings are severed. The detached leg section would be lifted by the SSCV (Figure 9-6), secured on the deck of a cargo barge and returned to shore for dismantling and recycling. The former site of the Brent A jacket would be left clear of all platform components. In good weather, the footings could be removed in approximately four months.

Figure 9-9: Brent A Jacket Footings Option 2: Removal with Internal Pile-Cutting



9.6.2.2 Removal of conductors and guide frame

The conductors and guide frame would be removed in the same way as for Option 1 (see Section 9.6.1.2).

9.6.2.3 Removal of pile-bore grout

To cut each pile internally, most of the grout would have to be removed so that the internal cutting system (AWJ) could be inserted far enough to cut the pile 3 m below the seabed.

There are currently two methods under consideration for grout removal. The first method is based on an existing tool for removing soil plugs by drilling/milling; this has been

successfully used to remove grout from within similar sized piles. The drill string is similar to conventional drilling and driven from a surface vessel. It would take approximately 48 hours to drill out each pile or a total of about 69 days for all the Brent A jacket piles. The second method is based on a high pressure water jetting technology which has been used to remove grout from smaller piles. The high pressure water jetting system would be operated from the surface support vessel via an umbilical, and it is estimated that grout could be removed at a rate of approximately 5 m^3/hr, or a total of about 28 days for all the Brent A jacket piles. Grout would be returned to shore and reused.

However, in both methods grout removal would not be a single continuous operation. The legs would be severed and then removed from the seabed in sequence.

Shell has decided that the most appropriate system to use for the purpose of performing a Comparative Assessment of options is the drilling method.

It is possible that the grout in the annulus between the pile and the sleeve grout would fail as a result of the physical disturbance caused by either of these methods. This would loosen the piles and they might have to be pinned in place before the sections of footings are lifted.

9.6.2.4 Cutting steel piles internally

A bespoke AWJ cutting system would be lowered to the specified elevation inside the pile and stabilised in the centre. Once the cut had been completed the tool would be recovered and prepared for the next pile. It is estimated that it would take approximately twelve hours per pile to complete this sequence of operations.

9.6.2.5 Cutting, removing and transporting the sections of footings

The method for cutting the footings into sections, lifting them to the surface and transporting them to shore would be the same as that described for Option 1 (see Sections 9.6.1.6 and 9.6.1.7). In total approximately 10-14 sections would be lifted.

The removal out of the pile bore grout would reduce the total mass of the footings returned to shore to approximately 15,250 tonnes (excluding the lower conductors and casings).

9.6.2.6 Final condition of the Brent A site

This description of the final condition of the Brent A site ignores the presence of the seabed cuttings piles and associated embedded debris. The condition and long-term fate of the Brent A drill cuttings pile is described in Section 13.6.1.2.

Instead of an area partially disturbed with back-filled seabed at the former location of each leg (see Section 9.6.1.8) as would be the case for Option 1, it is likely that there would be a small depression marking the base of each leg, and small indentations where the approximately 3 m long buried parts of both the cut piles and the cut conductors had been extracted from the sediment as the sections of footings were lifted clear of the seabed. An area with a radius of 500 m centred on the former site of the footings would be swept to ensure that it was free of debris derived from offshore oil & gas operations that might pose a snagging risk to bottom-towed fishing gear.

9.6.3 Option 3: Leave *in situ*

9.6.3.1 Overview

After the removal of the upper jacket by SLV (Section 9.5), the footings would be left in place (see Figure 9-5). The lower parts of the conductors would be left in place secured within the conductor guide frame at -109.7 m. The 20” and 13 3/8” casings would remain inside the conductors, with some or all of the annuli filled with grout.

An area with a radius of 500 m centred on the footings would be swept to ensure that it was free of debris derived from offshore oil & gas operations that might pose a snagging risk to bottom-towed fishing gear. After the debris sweep, no further activities would take place on or around the jacket footings.

The jacket footings would corrode and progressively collapse over a period of 30-500 years, as described below.

9.6.3.2 Long-term fate of footings

Shell examined what might happen to the Brent A jacket footings if they were left *in situ*, as described within Shell’s Technical Document for Decommissioning the Brent Alpha Jacket [73]. The study considered the physical and chemical processes that would degrade the footings after removal of the upper jacket, to determine how long the footings might survive. The study findings are relevant only for assessing the impact of Option 3, leave jacket footings *in situ*.

The steel in the members, legs and piles of the footings varies in thickness from 17.4 mm to 47.6 mm. Corrosion of the steel jacket structure would start after approximately twenty years, following full use of the remaining anodes. In the well-oxygenated cool waters of the Brent Field, a single-sided corrosion rate of between 0.1 - 0.3 mm per year might be experienced. After removal of the topsides and upper jacket, the stresses on the footings would be reduced, and Shell estimates that at least 50% of the wall thickness of members would need to be corroded away before the member is likely to fail under normal conditions. Later, as the steel walls of legs and members are increasingly pierced by localised corrosion, oxygenated seawater would access the interior of legs and members, and the inside face would also begin to corrode.

Based on the above, and by considering which jacket components might be critical for initiating or promoting the onset of the progressive collapse of the jacket, Shell estimated the longevity of different parts of the jacket, as follows:

- The thinner, lighter bracings of the jacket are likely to fail and fall from the jacket structure after approximately 30-40 years, and land on the seabed or the Brent A drill cuttings pile.
- The main legs, nodes and pontoon legs would last much longer, even after the loss of the structural support provided by the lighter members, and it might take up to 250 years before the main legs start to collapse. The presence of grout around and in the internal piles of the pontoon legs is expected to increase their longevity. Internal piles in the pontoon legs may only start to corrode when the pontoon legs are extensively perforated due to corrosion, and the layer of grout surrounding the internal pile sleeves has degraded significantly, such that oxygenated seawater reached the (outside) of the piles.
- Finally, after perhaps 250 years, Shell predicts that only the hollow steel piles (25.4 mm thick) and the bases of the large diameter pontoon legs (containing the internal piles and

grout) would remain upright on the seabed. All other material would have fallen onto the seabed and the drill cuttings pile, and would be present as a mass of corroded steel and broken grout. Parts of the foundation piles may remain protruding from the seabed for more than 500 years, depending on the stabilising effects of the grout.

9.7 Significant Impacts of Decommissioning Options

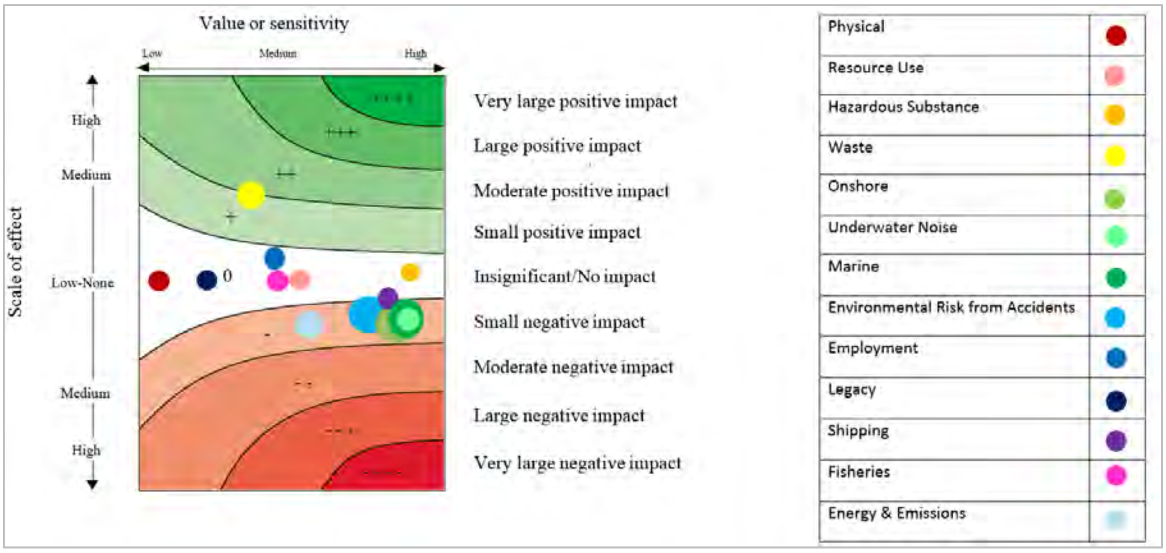
Appendix 1 documents the assessment of environmental impacts for all categories for the decommissioning options. This section provides a summary of the Appendix 1 impact assessment matrices, discussing only the most significant impacts identified (those with either 'small-moderate negative' impacts or worse, or 'small-moderate positive' impacts or better).

9.7.1 Removal of Brent A Upper Jacket by SLV

This assessment considers the impacts that will occur from removing the Brent A upper jacket in one piece by SLV to approximately -84.5 m below LAT.

As shown in Figure 9-10 the most significant impact identified is in the waste management category. Estimated impacts are considered small or insignificant for all other categories. Please refer to Appendix 1 for details of the impact assessments for these categories.

Figure 9-10: Removal of Brent A Upper Jacket Option 1



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

9.7.1.1 Waste Management

The overall waste impact as a result of the removal and decommissioning of the upper jacket is estimated to be **'small-moderate positive**'. This category takes into account any non-hazardous materials existing on the jacket. Hazardous materials present on the jacket are covered in the 'hazardous substances' category.

9.7.1.1.1 Steel recycling

The major waste stream generated from the removal of the Brent A upper jacket is the significant quantity of steel. Approximately 8,400 tonnes of steel (approximately 36% of all the steel in the jacket, conductors and piles to -3 m) will be recovered for recycling, which

has a positive impact (although this is significantly less than the quantity of steel from the topsides that will be recycled).

9.7.1.1.2 Other materials

An estimated 1,600 tonnes of marine growth is attached to the upper jacket and upper parts of the conductors, and will require management onshore. The ASP site is large, and residents are located a considerable distance away, so odour impacts are not anticipated. Odour at the site boundary should be monitored periodically to confirm that there is no impact. The marine growth will be disposed of at a suitable licensed landfill site.

9.7.1.1.3 Summary

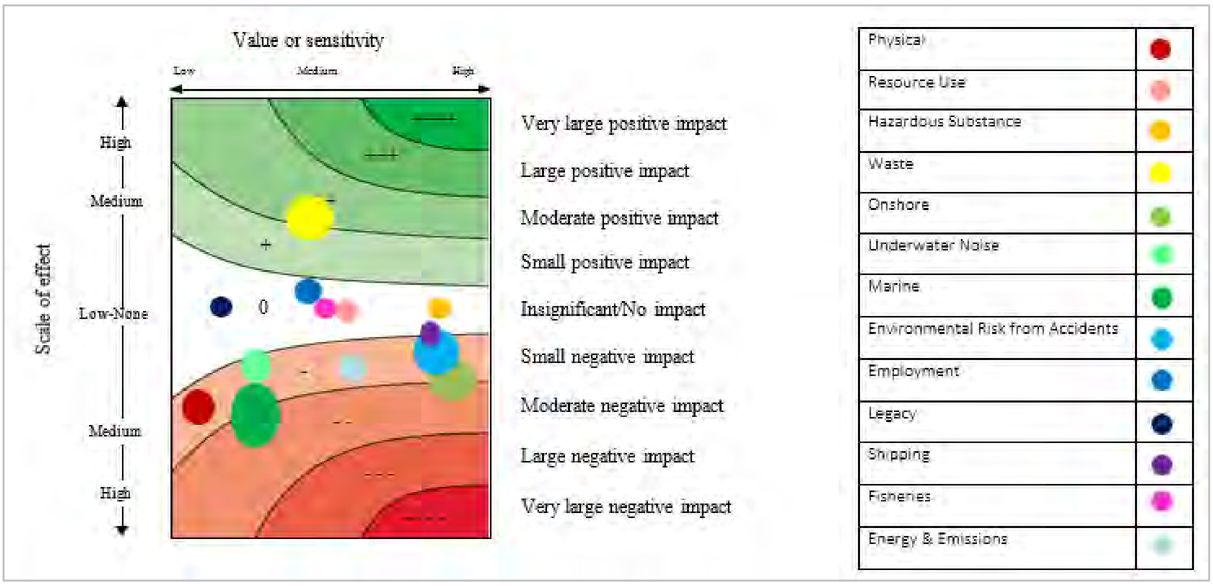
In summary, the removal of the Brent A upper jacket is estimated to have a 'small-moderate positive' impact with regards to waste primarily because of the significant quantity of steel that will be recycled. This represents the bulk of the material present on the jacket and is valuable material, dominating the impact allocated to this waste management category.

To put the volume of steel recycled into a national context, in the UK in 2013 approximately 4.7 million tonnes of steel scrap was exported and approximately 4 million tonnes of steel scrap was consumed for steelmaking [75]. Although 8,400 tonnes of carbon steel from the upper jacket represents only a small fraction of this national quantity, the decommissioning of the Brent jacket will still likely be a significant individual contributor of recycled steel in the UK.

9.7.2 Brent A Jacket Footings Option 1: Complete Removal by SSCV in Several Pieces after Cutting the Piles Externally

As shown in Figure 9-11, the significant impacts identified are in the onshore, marine and waste management categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 9-11: Brent A Jacket Footings Option 1: Complete Removal by SSCV in Several Pieces after Cutting the Piles Externally



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

9.7.2.1 Onshore Impacts

The overall onshore impact as a result of the complete removal and decommissioning of the Brent A jacket footings under Option 1 is estimated to be **'small-moderate negative'** owing to the significant volumes of material brought onshore that would require handling, deconstruction and transportation.

9.7.2.1.1 Noise, dust, odour and traffic impact

Complete removal of the jacket footings would generate significant quantities of materials, including approximately 14,850 tonnes of steel (from the jacket, piles and lower conductors), 5,200 tonnes of cementitious grout (from the piles and lower conductors), 1,130 tonnes of marine growth and 155 tonnes of metal anodes. The sections of footings would be brought onshore to the ASP facility for dismantling, recovery and disposal. Onshore decommissioning operations can have 'nuisance' impacts on residents and disturb other sensitive receptors in the local area such as birds for a significant period of time. The time required for dismantling the jacket footings under Option 1 is estimated to be less than one year. Potential impacts include:

- Dust and noise emissions from increased traffic, both onsite and offsite:
  - Traffic can sometimes cause problems to local residents living close to industrial sites, but traffic should not be a big issue to residents at this onshore site because most of the material leaving the site (steel) would be shipped out of the site from the quay or would be transported via local train. Also there are no residents located close to the site, and traffic is limited to 10 mph.
- Dust and noise emissions from deconstruction of jacket and management of solid grout:
  - Noise from deconstruction activities would be associated with deconstruction activities such as lifting, cutting and material handling.
  - Sources of dust include the concrete crusher and the thick layer of sand; Able inspect and damp down with water in dry windy weather.
  - The nearest residential receptor sensitive to noise and dust is located 1 km away, far enough to not be of any great concern. The ASP facility is large, and most of the decommissioning operations would take place within the heart of the facility, even further from the nearest residential receptors. DNV GL has been informed there have been no complaints to site from any residents regarding such issues for several years, and the site is understood to have a good relationship with the environmental regulator.
  - There are sensitive habitats located very close to the site that are important for birds, and these have potential to be disturbed by noise. The Teesmouth and Cleveland Coast SPA are designated to protect breeding, passage and wintering populations of birds. The dismantling site is located opposite Seal Sands, one of the largest areas of intertidal mudflats on England's north-east coast (see Section 6.10.3). These mudflats are of great ornithological importance attracting large numbers of migratory wildfowl and wading birds especially during the winter months [20]. According to a study carried out at the University of York [62], little tern, sandwich tern, redshank and knot are typical species to be found at the North Gare and Seal Sands. As part of the preparation of the management plan for Lista Beaches in Norway, a comprehensive review of international research was summarised in 2012. The study found that the species most sensitive to disturbance were larger species often found in open areas: cormorants, divers, swans, geese,

ducks, birds of prey, wading birds gulls and terns. Several studies indicated that birds to some extent can adapt to disturbances, but there were also studies showing that such habituation does not occur [63].

- There are indications that animals generally show greater tolerance for mechanical noise compared to biological threat factors such as predators or humans [64]. It has been suggested that waterbirds habituate to disturbance, in time becoming less responsive to the activity [65]. Distance is also a key factor; birds are more likely to be flushed when the activity is close, but are less responsive in the water where they are rarely flushed regardless of the activity [66].
- The onshore dismantling activities for the jacket footings would take less than one year and be conducted more than 500 meters away from nearest sensitive bird area. General deconstruction work is not expected to result in a noise level which differs greatly from previous activities at the ASP facility and surrounding industry. It is accordingly reasonable to assume that birds have become accustomed to “normal” background noise from adjacent industry, but it cannot be excluded that sudden noise from dismantling activities/transport may result in a local and temporary displacement of bird individuals from adjacent feeding grounds. Permanent effects are however not considered significant as the facility is surrounded by large areas of alternative feeding grounds. Negative impacts on birds are accordingly considered small.
- Able has established a working relationship, and sits on a regular forum, with Natural England, RSPB and the Hartlepool Council. The forum meets every quarter to discuss current activities and to ensure that any concerns are being addressed. The main concern usually relates to noise from piling. The ASP facility has specific operational restrictions on piling during certain times of day (when birds and seals come to feed) and piling is only permitted in certain areas away from the quayside (to avoid noise levels close to the quayside). Note: there will be no onsite piling or use of explosives during the BDP.

The ASP facility is licensed to receive decommissioning wastes and the dismantling operations would be carried out under responsible management and control, with all necessary permits and consents. The mitigation measures and controls as discussed above would be in place to minimise impacts. Previous experience from the execution of major decommissioning projects in the North Sea demonstrates that the potential impact on local communities can be effectively controlled and mitigated [67].

9.7.2.1.2 Odour impacts

Marine growth removal from the jacket footings may result in odour emissions onshore. The extent would depend on the amount of marine growth, temperature, air exposure time, drying and the efficiency of disposal methods. At the ASP facility, the marine growth is likely to be left to dry until it drops off the jacket sections. Birds might eat some of the marine growth but residues would be disposed to landfill. As it is a big onshore facility, the smell is likely to be limited onsite. If the onshore dismantling facility had a local population in the immediate vicinity some small impacts might be anticipated though of limited duration [67]. However, the nearest residential receiver is located more than 1 km away, so no significant problems are anticipated. The amount of marine growth on the footings that would be taken to shore under Option 1 is estimated to be 1,130 tonnes.

9.7.2.1.3 Visual Impacts

There would unlikely to be any significant visual impact during the decommissioning of the jacket footings as they are received broken down into sections. Also, the ASP facility is an established industrial facility that has been operating for years and often presents industrial visual impacts to receptors (the site is often working with very large industrial structures from the oil and gas, wind or marine sectors, such as during the decommissioning of the North West Hutton platform).

9.7.2.1.4 Expansion of onshore facility

As described in Section 6.10.1, a new grounding pad is being constructed at the ASP facility as part of ongoing expansion work. Additionally, Quay 6 is being strengthened to accommodate the topsides and upper jacket. Whilst these activities would be completed prior to receipt of decommissioned Brent facilities they are not considered specifically part of the Brent Decommissioning Project and are therefore outside the scope of this ES.

9.7.2.1.5 Summary

In summary, the overall onshore impact as a result of the complete removal of the Brent A jacket footings under Option 1 is estimated to be 'small-moderate negative', owing to the combination of noise, dust, odour and traffic impacts upon local residents and birds that would occur for less than one year. Considered individually, these different types of impacts are small but when considered together, and bearing in mind the sensitive nature and proximity of the SPA, and the length of time the decommissioning activities take, the overall impact is higher. However, the impacts are manageable and the necessary onshore mitigation controls would be in place to ensure that impacts are minimised. All dismantling operations would be carried out under all necessary permits and consents to ensure that impacts are minimised.

9.7.2.2 Marine

The overall impact to the marine environment as a result of decommissioning the jacket footings under Option 1 is estimated to be **'small-moderate negative'**.

One of the potential risks to the marine environment from removing the jacket footings under Option 1 would be from the disturbance of drill cuttings and seabed sediment to enable the jacket piles to be cut externally. The effect of removing the drill cuttings pile at Brent A is covered under 'drill cuttings', so only the excavation of the natural seabed sediment is assessed here (although it should be noted that the two impacts would combine).

After dredging the entire Brent A drill cuttings pile, the clean seabed sediment would be excavated around the legs to expose the jacket footings, to enable cutting the piles approximately 3 m below the sea floor. A pit would have to be excavated around each leg in turn to gain access for cutting the piles; Shell estimates that each pit would be approximately 4 m deep and 42 m in diameter. This would result in the excavation of some 25,175 m^3 of natural seabed sediment in total and essentially the removal of a 4 m thick layer of the seabed sediment from within the whole footprint of the jacket. Shell assumes that the first 25 cm of this seabed sediment is contaminated by the drill cuttings, and would remove this portion (approximately 1,425 m^3) with the drill cuttings above it when dredging. The remaining 23,750 m^3 of clean natural seabed sediment would be dredged from around each leg in turn, and Shell assumes that the material from one pit would be deposited in the previous pit to back-fill it. At the end of the operations to expose the piles and then cut them externally, all

the pits would have been more or less back-filled with natural sediment to provide the necessary 3 m cover over the cut ends of the piles.

This disturbance of seabed could lead to ‘small-moderate negative’ impact on the marine environment owing to turbulence and the smothering of organisms. The turbidity (small particles in the water phase) is known to cover the breathing functions (gill and skin) and feeding functions of local organisms. The re-located sediment would settle in the local environment and smother the benthos over a hectare or two. These effects however are not considered of major significance because there are no species identified in the area which are of statutory conservation interest (the communities comprise tube worms and molluscs, which are not unique in nature). However the area disturbed is not insignificant and would take years to recover, so a small-moderate negative impact is allocated. The long-term impact of the excavated hole is addressed in ‘Legacy’.

9.7.2.3 Waste Management

The overall waste impact as a result of the removal and decommissioning of the Brent A jacket footings under Option 1 is estimated to be **‘small-moderate positive’**. The ‘waste’ category takes into account the non-hazardous materials on the jacket. Hazardous materials are covered in the ‘Hazardous Substances’ category.

9.7.2.3.1 Steel Recycling

The major waste stream generated from the complete removal of the Brent A jacket footings is steel. Under Option 1, approximately 14,850 tonnes of steel would be recovered for recycling, which has a positive impact (although this is significantly less than the quantity of steel from topsides - more than 80,000 tonnes - that would be recycled).

9.7.2.3.2 Other materials

A significant quantity of approximately 5,200 tonnes of grout (from the piles and from the conductors and their casings) would also be removed and brought to shore. Waste grout has significantly less value than steel. The intention is that some of this grout would be re-used after crushing (e.g. as bottoming for roads, harbours or quays), although this may not be practical in all instances. Based on industrial experience, grout can be recycled as filling material depending on contamination level and local recycling options [76]. Therefore, for the purposes of this assessment it is assumed that most of the grout would be re-used; if this is not the case, the impact would become more negative.

An estimated 1,130 tonnes of marine growth would be present on the footings and lower parts of the conductors, and would require management onshore. The ASP site is large, and residents are located a considerable distance away, so odour impacts are not anticipated. Odour at the site boundary should be monitored periodically to confirm that there is no impact. Marine growth would be removed at the ASP facility and disposed of at a suitable licensed landfill site.

Lastly, approximately 155 tonnes of zinc and aluminium in anodes would be recycled, and this would have an additional positive environmental impact.

9.7.2.3.3 Summary

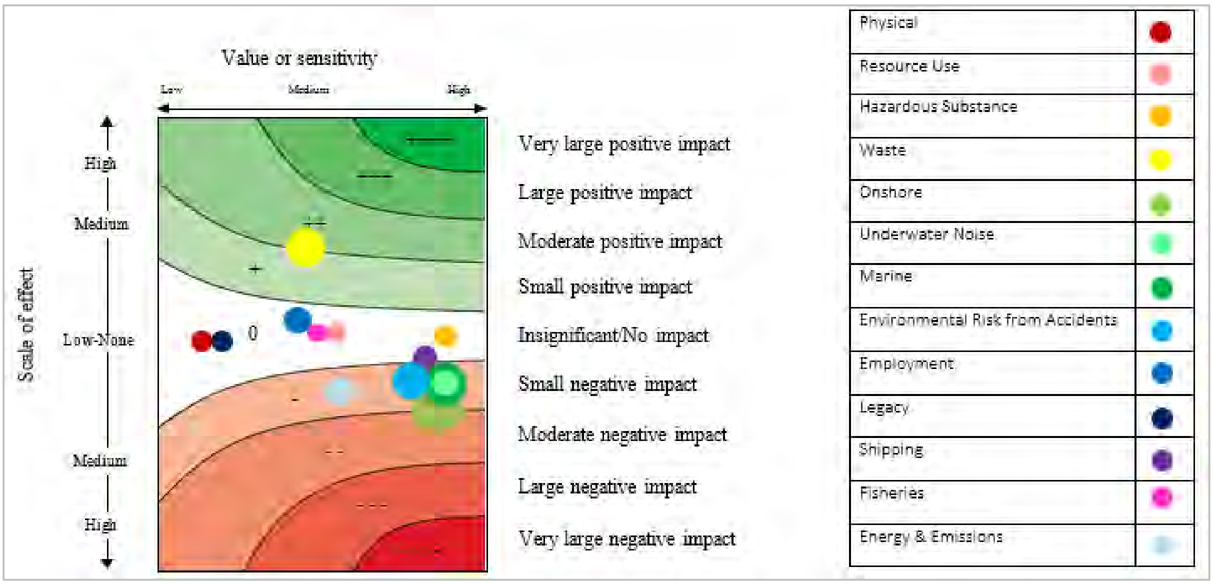
Although there are some significant positive impacts from Option 1 (from the recycling of steel), this significant positive impact is offset by the lower ‘value’ of the waste grout generated, and by the quantities of marine growth generated. Overall it is estimated that the

waste impact from the removal of the jacket footings under Option 1 is 'small-moderate positive' provided there is a local market for re-using some of the grout. Although 14,850 tonnes of carbon steel represents only a small fraction of the national quantity of steel recycled, the decommissioning of the Brent jacket is still likely to be a big individual contributor of recycled steel in the UK.

9.7.3 Brent A Jacket Footings Option 2: Complete Removal by SSCV in Several Pieces after Cutting the Piles Internally

As shown in Figure 9-12, the significant impacts identified are in the onshore and waste management categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 9-12: Brent A Jacket Footings Option 2: Complete Removal by SSCV in Several Pieces after Cutting the Piles Internally



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

9.7.3.1 Onshore Impacts

The decommissioned Brent A jacket footings would be brought onshore to the ASP facility under Option 2. The potential onshore impacts would be very similar to those described for Brent A jacket footings Option 1 (see Section 9.7.2.1), and would include odour (from marine growth), noise, dust and vibration, and increased traffic nuisance. The impact is estimated to be **'small-moderate negative'** owing to the significant volumes of materials brought onshore that would require handling, deconstruction and transportation.

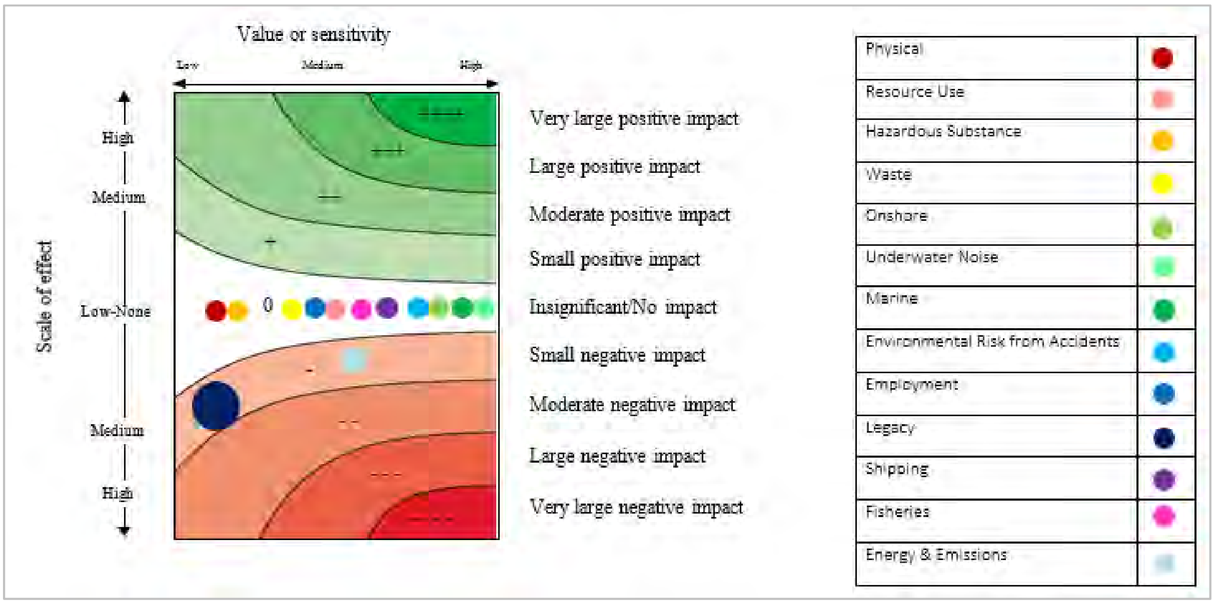
9.7.3.2 Waste Management

This option involves the removal of the Brent A jacket footings and would generate the same volumes of waste as Brent A jacket footings Option 1 (see Section 9.7.2.3). Although there are some significant positive impacts (from recycling steel), this significant positive impact is reduced by the lower value of grout, and by the quantities of marine growth requiring disposal. Overall it is considered that impacts are **'small-moderate positive'** provided the Able yard is capable of re-using the grout in the local market.

9.7.4 Brent A Jacket Footings Option 3: leave *in situ*

As shown in Figure 9-13, all impacts for Option 3 are considered small or insignificant. Of particular interest may be the small negative legacy impact upon fisheries and the marine environment resulting from leaving the jacket footings in place, and Appendix 1 provides further details.

Figure 9-13: Brent A Jacket Footings Option 3: Leave *in situ*



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

9.8 Comparison of Options for Decommissioning of Brent A Jacket

The Brent A upper jacket will be removed, but there are three options for decommissioning the Brent A jacket footings; the differences between the options are summarised below:

- All impacts are small or insignificant for Option 3 (leave *in situ*). However, Option 3 has no positive impacts like Options 1 and 2 (where the recovered steel is recycled).
- Removing jacket footings (Option 1) would involve significant disturbance of the surrounding drill cuttings and seabed sediment, and would impact the marine environment. Jacket footings Option 2 is preferable to Option 1 from an environmental perspective because there would be significantly less impact to the marine environment (excavation pits are not required to access the jacket piles). Otherwise the two options have very similar impacts (‘small-moderate positive’ waste management impact and ‘small-moderate negative’ impact onshore).
- In the ‘legacy’ category, Options 1 and 2 contrast with Option 3, where there is a ‘small negative’ legacy impact upon fisheries if jacket footings are left in place which disappears if the jacket footings are completely removed (beneficial to fisheries).
- It is also interesting to note from DNV GL’s *Energy Use and Gaseous Emissions Report* [2] that there is no ‘energy’ benefit from leaving the jacket footings *in situ*, because the savings in energy by not undertaking recovery activities is exceeded by the energy ‘penalty’ of leaving useful steel materials *in situ* and not recovering them.

9.9 Significant Impacts of Proposed Programme of Work

Shell's proposed programme of work is to remove the upper jacket and leave the jacket footings *in situ* (Option 3). Recovery of the upper jacket will result in 8,400 tonnes of steel being returned to shore and this will have a positive impact as it will be recycled. There are no negative impacts greater than 'small negative' for the proposed programme of work for the Brent A jacket.

9.10 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that mitigation and management measures are in place. Table 9-3 below details these measures for the proposed option to decommission the Brent A jacket and highlights the residual impacts described in Section 9.7 and Appendix 1.

Table 9-3: Summary of Mitigation and Management Measures for Proposed Programme of Work

Environmental Category	Mitigation Measures	Residual Impact
Onshore Impacts	• The ASP facility will be responsibly managed. The ASP facility is licensed to perform decommissioning and waste management operations (including hazardous wastes), and the jacket dismantling will be carried out within these conditions. • The ASP dismantling facility is accredited to ISO 9001:2008 (Quality Management System), ISO 14001:2004 (Environmental Management System), OSHAS 18001:2007 (Health and Safety Management System), and ISO 30000 (Ship Recycling Management System). • Able will continue their working relationship with Natural England, RSPB and the Hartlepool Council. • Onshore controls to minimise environmental impacts where necessary, including: ▪ Dust control using, for example, sweeping vehicles, water sprays, speed limits onsite and cleaning of traffic wheels leaving site where necessary. ▪ A thick bed of sand will be used as necessary for particular operations to cut and drop large/heavy sections of the jacket to control noise and vibration. ▪ Appropriate environmental monitoring and management regime; regime should include periodic monitoring of odour (from marine growth) at site boundary. ▪ The majority of material leaving the site, predominantly steel, will be sent by ship or rail. ▪ The dismantling operations will take place more than 500 m away from the Teesmouth and Cleveland Coast SPA, an important area for birds. ▪ No piling will be done onshore as part of the BDP, to restrict noise impacts. • Independent auditing of onshore operations to help ensure regulatory limits are satisfied.	Small-moderate negative
Resource Use	No mitigation measures necessary, few resources used apart from fuel (see Energy and Emissions category)	Insignificant-small negative
Hazardous Substances	There are no significant hazardous substances used in this option. Hazardous waste will be managed in accordance with all legislative requirements, both offshore and onshore.	Insignificant
Waste	• Shell will have representatives onsite and will establish a plan for monitoring and auditing the waste management contractor, and will implement the plan. Shell will ensure the contractor acts in accordance with duty of care, other legal requirements and contract conditions. Shell will review Able waste management documentation and procedures. • Able has a 97% target for recycling (steel) set in the contract to help optimize waste management. • The nearby Seaton Meadows Landfill, also operated by Able, is permitted and will be operated in accordance with conditions. • The ASP site is large, and residents are located a considerable distance away, so odour impacts are not anticipated. Regardless, odour at the site boundary will be monitored periodically to confirm that there is no impact. The marine growth will be disposed of at a suitable licensed landfill site.	Small-moderate positive
Physical	The SLV and vessels will not use anchors, and will operate on DP, therefore minimising any potential physical damage to the seabed from anchor pits.	Insignificant
Marine (includes underwater noise)	• The SLV and other vessels will not use anchors, and will operate on DP, therefore minimising any potential damage to the benthic environment from, for example, anchor pits. • Following a detailed risk assessment and discussion with stakeholders such as Natural England, Shell will consider establishing a Seal Corkscrew Injury Monitoring Scheme, to include the use of marine mammal observers and seal scarers during the 48-hr period of near-shore operations when the SLV is stationary and held in position using DP thrusters, as well as the use of tugs without ducted propellers during transport through the channel. • Shell will sample the marine sediment at the nearshore transfer location to confirm that it is not contaminated (inorganic or organic parameters will be analysed). Shell will collect benthic samples to confirm there is no protected fauna present at the transfer location. • Movement of vessels during decommissioning operations will generally be local, and vessels will have a ballast water management plan which will follow IMO guidelines [71].	Small negative
Environmental Risk from Accidents	• Before the jacket is removed a test lift will be undertaken by the SLV and sea trials subjected to third party marine warranty services. • The SLV lift operations will have been subjected to HAZID and HAZOP, and any necessary actions taken to satisfy all parties that the lift, transport and transfer of the jacket will be safe.	Small negative

Environmental Category	Mitigation Measures	Residual Impact
	• Shell will undertake a safety assessment of the towing route to ensure collision risk is minimised. • Examination of the forces exerted on the jacket during transfer and transit operations will be conducted by Shell, to satisfactorily demonstrate the lift to have a very low likelihood of failure. • Jacket pieces will be secured on the vessel by sea-fastening. • Operations will take place in good weather. • Operations will be carried out under an approved Dismantlement Safety Case, to be approved by the HSE. • A BEIS approved Oil Pollution Emergency Plan (OPEP) for the Brent Field system will be in place. The *Pioneering Spirit* Ship SOPEP, approved by the Maritime and Coastguard Agency (MCA), will be in place. The SOPEP will be reviewed by Shell when in place to ensure that the response strategy and control mechanisms are robust. • A guard vessel may be in place during removal of the jacket. • The UK Coastguard as well as the Teesmouth Harbour Master will be notified of the decommissioning operations in order to provide advance warning to other ocean-going or harbour vessels operating in the area.	
Employment	Insignificant employment generated.	Insignificant
Legacy	See Monitoring and Maintenance of Remains, Section 17.	Small negative
Fisheries	• Majority of operations will be within 500 m safety zone. • Shell will liaise with the fisheries agency to provide advance warning of vessel movements resulting from decommissioning activities, both by the SLV and support vessels.	Insignificant
Shipping	• Majority of operations will be within 500 m safety zone. • Shell will notify the UK Hydrographic Office of the changed status of the remaining jacket structure and Notices to Mariners will be issued. • The SLV offshore transit route will be carefully planned and managed. • The UK Coastguard as well as the Teesmouth Harbour Master will be fully notified of the decommissioning operations in order to provide advance warning to other ocean-going or harbour vessels operating in the area.	Insignificant-small negative
Energy & Emissions	• The SLV will use marine diesel in line with MARPOL North Sea Special Area requirements [72], to reduce SO_x emissions. • Vessel speeds will be managed to minimise fuel consumption. • To increase efficiency, combustion equipment on vessels will be maintained in accordance with manufacturers' recommendations.	Small negative

10. GRAVITY BASED STRUCTURES (GBS)

10.1 Introduction

This section describes the GBS, the inventory of materials and the decommissioning options. The main anticipated environmental impacts of the decommissioning options are discussed and compared. The necessary management and mitigation measures to control the impacts of Shell's proposed programme of work are summarised, and measures are recommended to further reduce residual impacts where appropriate. The Technical Document for Decommissioning the Brent Gravity Based Structures [77] has been used as the basis for Sections 10.2 - 10.4 and 10.5.

10.2 Description of Facilities

Three of the four platforms at the Brent Field are a GBS (Brent B, C and D). Brent B and D are 3-legged "Condeep" design, and Brent C a 4-legged "SeaTank" design.

> A GBS is the large, heavy platform substructure (which supports the topsides) made from concrete reinforced with steel, and which principally uses its own weight to remain in place on the seabed.

The two Condeep GBS, Brent B and D, are almost identical in design therefore they are described together, with any significant differences noted. Brent C, the SeaTank GBS has many similarities to Brent B and D; however it also has some important differences and is described separately. Table 10-1 highlights the main design features, as well as the differences in design, of each GBS.

Table 10-1: GBS Design Features [77]

Aspect	Brent B	Brent C	Brent D
GBS design-type	Condeep	SeaTank	Condeep
Year of installation	1975	1978	1976
Water depth (m)	140-142	140-142	140-142
Maximum height above LAT (m)	19.7	6.8	19.8
Total GBS mass excl. water ballast incl sand ballast (t)	345,266	297,322	331,138
Total mass of sand ballast in caisson (t)	124,901	0	101,228
Area of base caisson (m^2)	8,920	8,281	8,920
Number of legs	3	4	3
Height of legs from seabed to top of ring beam (m)	160	149	162
External diameter of legs (m)	12.2 – 21	8.8 – 15	12.2, 14-21
Thickness of leg walls (m)	0.55 – 1.15	0.4 – 0.9	0.55 - 1.15
Number of conductors inside legs (Condeeps)	38	-	48
Number of external conductors penetrating caisson	N/A	40	N/A
Number of cells	19	36	19
Number of cells used for oil storage during operation	16	10	16
Total oil storage capacity (barrels)	1,100,000	600,000	1,100,000
Number of cells with water only	0	22	0
Height of cells (m)	60	57	58
Dimensions of oil storage cells (m)	18.54m dia	13 x 13m	18.54m dia
Number of Tri-cells	22	16	22

Note: Brent B and Brent D GBS use the terms Utility Shaft and Drilling Legs, while Brent C legs are referred to as Columns. For the purposes of consistency in this report, the term used is “legs”.

10.2.1 Brent Bravo and Delta

The Brent B platform [78] was designed and installed in 1975, and the Brent D platform [79] in 1976 by the Condeep Group. Representative diagrams are shown in shown in Figure 10-1 and Figure 10-2. The installations stand on the seabed in a water depth of approximately 140 m, and the legs have a total height of 160 m and 162 m, respectively. The total mass of Brent B and D (excluding water ballast but including sand ballast) is approximately 345,300 tonnes and 331,100 tonnes, respectively.

Lateral movement of Brent B and D is prevented by vertical steel skirts that penetrate several metres into the seabed. The base substructure of the GBS is called the caisson and consists of a number of cells.

The caisson is a cluster of vertical tanks (cells) which collectively constitute the GBS substructure gravity base. They may be used for oil storage or ballasting during operations.

Both GBS have a base of 19 reinforced concrete cells arranged in a hexagonal-shaped honeycomb caisson, approximately 60 m high. Three of the cells form the leg bases which connect to the PGDS, the fabricated steel structure which supports the topsides. The remaining 16 cells have historically been used for oil storage. Two of the legs were used for drilling (“drilling legs”) and house the conductors. The third leg is a utility leg, which provides a link between the topsides and the storage cells.

The 16 storage cells are closed by domed caps, and are partially filled with sand ballast. When the Brent B and D GBS were first installed, the primary function of the cells was to store oil. The cells have also historically been used for separation. The storage cells operate in a completely flooded condition and each of the Condeep GBS can store up to 1,100,000 barrels (approximately 144,700 tonnes) of oil.

During the cycles of filling and emptying the oil storage cells, a layer of oily residue called “cell sediment” has accumulated at the bottom of the cells as a result of normal operations. This is discussed in detail in Section 11.2.

Triangular spaces, called “tri-cells” exist where the circular cell walls touch. The tri-cells run for the whole height of the cells, are partially open to sea at the top and closed at the bottom. Further discussion of tri-cells is found in Section 13.2.3.

There are a number of pipelines connected to Brent B and D, which are discussed in Section 14.

Figure 10-1: Brent B General Configuration

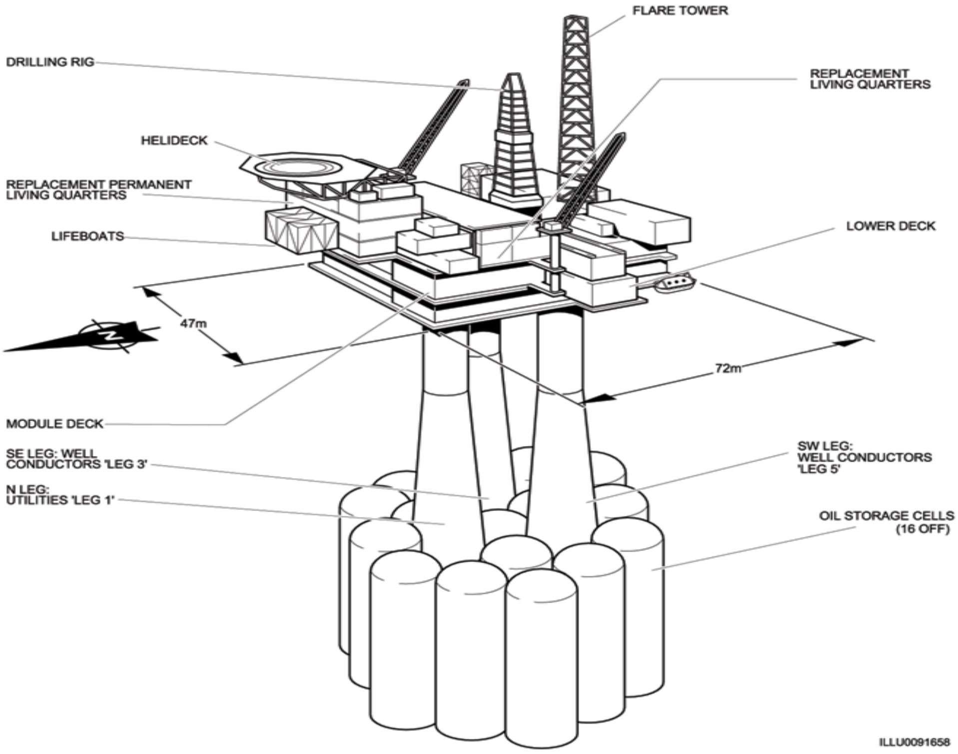
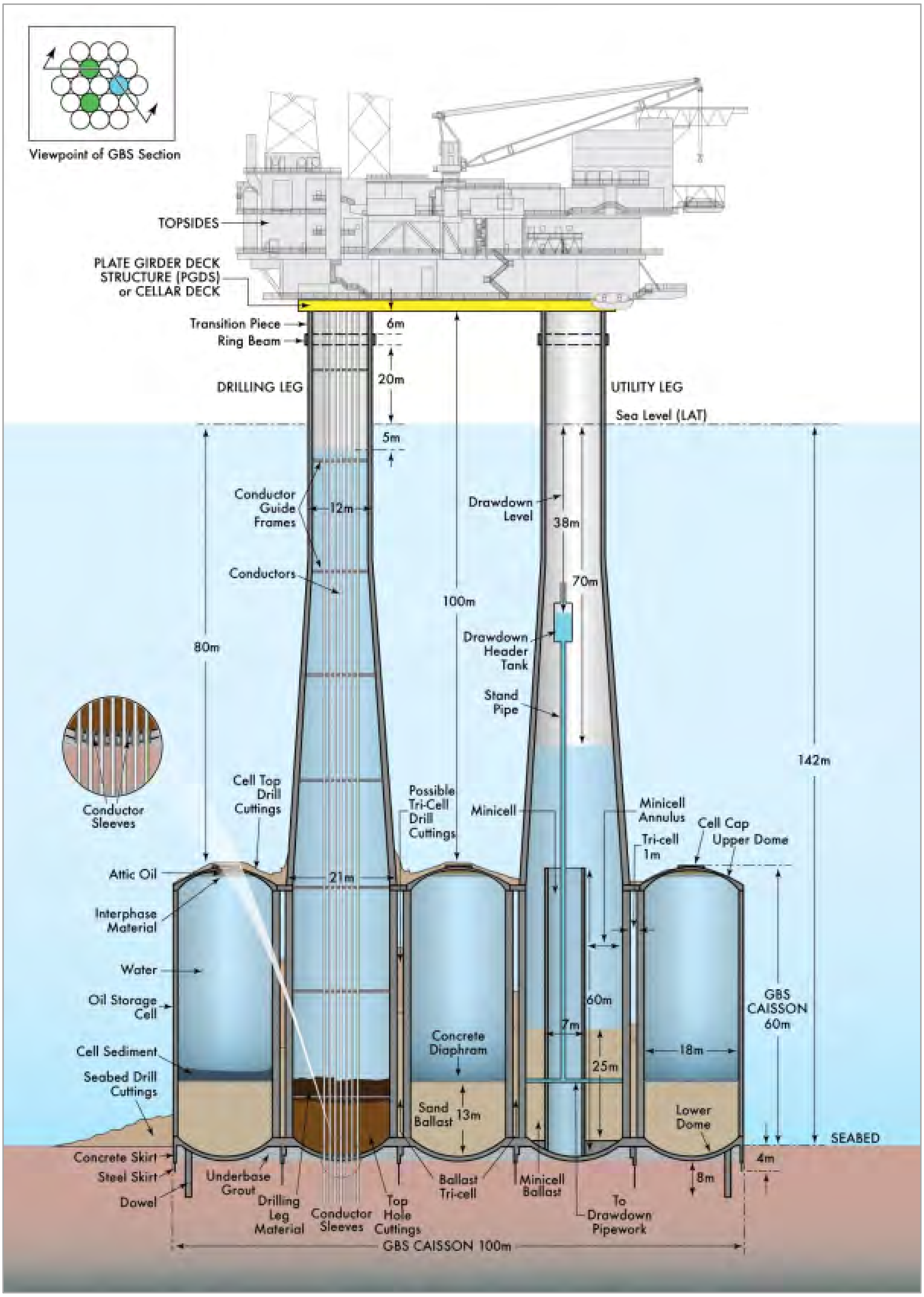


Figure 10-2: Brent B GBS



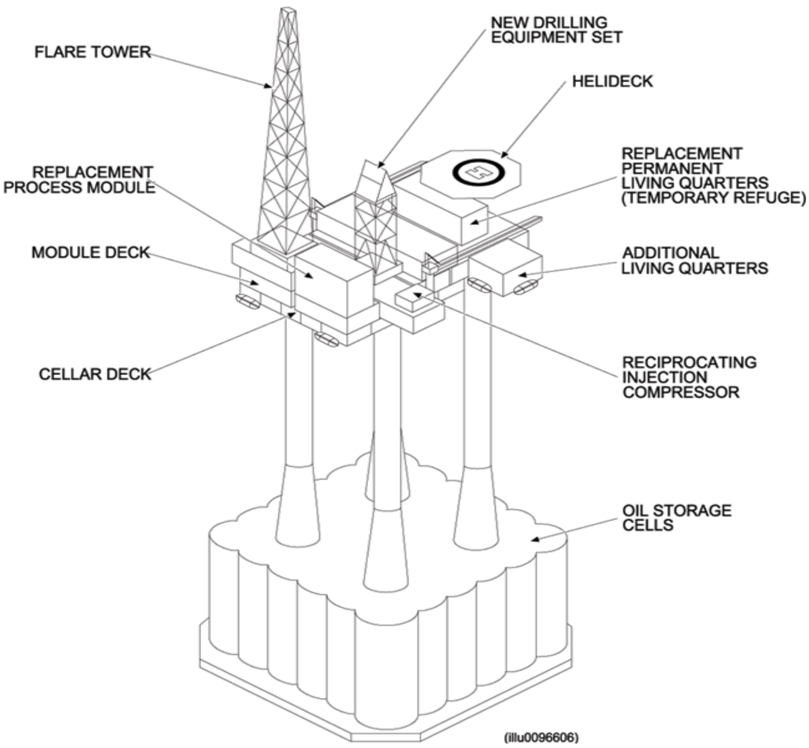
10.2.2 Brent Charlie

The Brent C platform [80] was designed by SeaTank and was installed in 1978. It is a 4-legged concrete GBS installation (Figure 10-3) and sits on the seabed in a water depth of approximately 140 m. The concrete legs are 149 m high (from the seabed to the top of the ring beam) and also have steel transition pieces on top, which means the topsides are more than 20m above sea level. The total mass of Brent C (excluding water ballast) is approximately 297,300 tonnes; Brent C has no sand ballast.

Brent C has a square base of 36 reinforced concrete cells (collectively called the caisson), which rest on a base slab. The cells are approximately 57 m high, extending from the seabed to the height of the caisson. The top of each cell is closed by a trapezoidal roof. Four of the cells are the leg bases, which connect to the cellar deck, a fabricated steel structure and integral part of the topsides structure which will be removed during decommissioning. The remaining 32 cells were historically used for oil storage, ballast and conductor cells.

The primary function of 10 of the Brent C GBS inner cells was to store, separate and process oil and they operated in a flooded condition. The 20 peripheral cells were used for conducting cooling water. Brent C has a total oil storage capacity of 600,000 barrels (approximately 78,900 tonnes) of oil. See Section 11.2 for further detail on cell contents. There are also a number of pipelines connected to Brent C, which are discussed in Section 14.

Figure 10-3: Brent C General Configuration



10.3 Inventory of Materials

The inventory of materials for the three Brent GBS is summarised in Table 10-2. This is the inventory of the GBS after removal of the topsides, before the fitting of the concrete caps and before the fitting of the steel extension piece on Brent C.

Table 10-2: GBS Inventory of Materials

Summary of Materials	Estimated Mass (tonnes)		
	Brent B	Brent C	Brent D
Steel in reinforced concrete	37,768	38,594	39,457
Concrete in reinforced concrete	178,048	258,285	184,733
Sand Ballast	124,901	0	101,228
Other steel incl. conductors	4,475	0	5,653
Other (assume <1% Steel mass):			
Aluminium	0.2	0.2	0.2
Cadmium	0.1	0.1	0.1
Copper	0.6	0.5	0.5
Glass Reinforced Plastic (GRP):			
GRP (as installed)	44	413	40
Post-installation	29	28	26
Plastics	0.2	0.2	0.2
Rubber	0.4	0.4	0.4
Total GBS Mass	**345,266**	**297,322**	**331,138**
Total GBS mass (excl sand ballast)	**220,365**	**297,322**	**229,910**

Note 1 Volume of GBS cell contents (water and sediment) not included in the above table; see Section 11.3.
Note 2 Volume of tri-cell drill cuttings not included in the above table; see Section 13.3.

10.4 Available Decommissioning Options

10.4.1 Alternative Uses

Shell screened a range of possible re-use options for the Brent GBS, described in the *Brent Platforms Decommissioning Programmes* [1]. Shell has not identified any opportunities for the continued use of any of the Brent GBS platforms for the production or export of oil or gas. Neither the platforms nor the field are suitable for use in CCS programmes. All other possible non-oil and gas uses for the platforms at their present locations or other sites are technically infeasible and/or economically unviable. Shell has therefore concluded that the Brent GBS platforms must be decommissioned.

10.4.2 Complete removal of GBS

OSPAR Decision 98/3 requires that GBS are removed, but also recognizes the difficulty in taking away these very large structures. Derogation may therefore be granted if the assessment shows that there are significant reasons why sea disposal or leaving the installation in place is preferable to re-use or recycling and final disposal on land [5]. Further, if an option such as complete removal involves intolerable safety risks or environmental impacts, it may be ruled out without further consideration.

Section 10.4.2.1 discusses the complete removal of the GBS by dismantling offshore, while Section 10.4.2.2 discusses the complete removal of the GBS by refloat, which was not considered a feasible option for the reasons described below. Section 10.4.3 describes the available options for decommissioning the GBS that are examined in this ES.

10.4.2.1 Complete Removal of GBS by Dismantling offshore

Shell also considered the feasibility of dismantling the GBS offshore. After the topsides are removed it might be possible to dismantle the GBS *in situ* in a long programme of offshore underwater demolition, cutting and lifting. In such a 'piece-small' dismantling programme the structure would be taken apart in its present location offshore by breaking it up into a very large number of small pieces that could be lifted by conventional cranes and loaded onto cargo barges for transportation to shore. For the GBS this would mean creating and moving thousands of tonnes of concrete rubble embedded with reinforced steel. This process has never been attempted offshore on concrete structures as big as the Brent GBS and would require extensive subsea work by divers and ROVs, HLVs and an extraordinary amount of offshore and onshore handling of small pieces of reinforced concrete. Shell estimates that it would take at least a decade to dismantle and remove all three Brent GBS using this process, and that the associated levels of safety risk to project personnel would be considerably greater than the maximum levels generally deemed acceptable by the UKCS oil and gas industry. As a result of this high-level analysis and the effort and safety risks of such a programme, Shell has ruled out this option.

10.4.2.2 Complete Removal of GBS by Refloat

Although the GBS were not designed to be refloated, the only realistic way to remove them would be to carry out a reverse of the installation process and take them to shore for dismantling and recycling. Shell has completed numerous technical and engineering studies to examine in detail how this might be achieved, to assess how the important technical challenges could be overcome, and to assess and quantify the risks associated with refloat and the likelihood of success. The conclusion of the various investigations is that the removal of the whole of any of the Brent GBS by refloat is not technically feasible.

For a successful refloat, certain vital procedures would have to be completed and certain conditions or states of the GBS achieved. Although there are differences in the detailed programme for each GBS, the following main steps must be completed successfully for each structure:

1. Sealing all existing and potential leaks so that the GBS can be made buoyant.
2. Ensuring that the GBS caisson and cells are strong enough to withstand the refloat process.
3. Installing equipment to control the ascent of the GBS and ensure it remains vertical.

4. Reducing the weight of the GBS so that it will float, and with the necessary freeboard for nearshore dismantling.
5. Making the GBS buoyant by displacing all the water in cells and legs with gas.
6. Breaking the suction between the GBS and the seabed by injecting water below the base.
7. Towing the GBS to a deepwater nearshore site, and keeping it afloat for about 18 months while the legs and upper caisson are dismantled.
8. Building a new dry dock, and towing the base of the caisson into the dock for set down and final dismantling.

Several of the operations would require the use of pipework that was installed during GBS installation. These systems were often embedded in the concrete of the GBS while it was being constructed and were not designed (or required) to remain operable for 35 years: they will now have deteriorated completely and would have to be replaced. Shell estimates that it would take many years of design, installation and testing before the GBS could be ready to attempt a refloat; this would include dangerous and difficult work in the utility legs and minicells, and work at the base of the drilling legs and under the caisson.

Using data from GL Noble Denton and others, Shell carried out a detailed technical and environmental risk study with the Danish consultants COWI [81] to quantify the likelihood of 'technical project failure' in the GBS refloating operations. In the oil and gas industry it is generally accepted that no project or procedure would be contemplated if, at the outset, the likelihood of failure was estimated to be greater than 1 in 1,000. The COWI work showed that for the Brent GBS, given all the uncertainties about their condition and the ability to float them and keep them afloat, the best estimates of project failure at the beginning of the operations were Bravo 7.4%, Charlie 3.6% and Delta 6.8% [81]. These are an order of magnitude higher than would generally be accepted in the industry.

Shell therefore concluded that it is not tenable to consider refloating any of the Brent GBS; years of work would have to be completed successfully before any refloat could be attempted, and even then there would not be any guarantee that refloat could be completed successfully. Accordingly, the refloat option was not taken forward into a full Comparative Assessment.

10.4.3 Available Decommissioning Options

There are two decommissioning options assessed in this ES for the Brent GBS:

PARTIAL REMOVAL	LEAVE IN PLACE
Option 1. Remove legs as a single piece, to give at least -55 m clear water depth below LAT.	**Option 2.** Leave *in situ*.

Given the agreed programme of work for the removal of the GBS topsides, the practical starting condition for both GBS decommissioning options would be that the whole topside (including the PGDS/Cellar Deck) would have been removed in a single piece by the SLV and taken to shore for dismantling and recycling. Regardless of which option is adopted for the decommissioning of the GBS, Shell will have completed a programme of isolation and clearance at each level of the utility legs of Brent B and D before the topsides are removed. The following interdependent systems in the utility leg would be systematically isolated and

disconnected from the associated pipework at each elevation: service water system, produced water system including drawdown, instrument air system, power generation system, oil export and rundown systems, open hazardous drains system, P&A cold vent and hazardous closed drains systems, fire water pumps and firemain, and miscellaneous items (platform utilities and instrument / electrical cabling). The upper sections of the Brent B and D conductors will have been cut (mainly at approximately +16 m LAT, just below the cut line) and removed as part of the topsides programme of work.

In addition, after the removal of the topside, Shell will have removed the external conductors and the guide-frames on Brent C down to the top of the cell top drill cuttings pile which is approximately 11 m high. This will be undertaken as a separate scope of work (for the purposes of this ES it is captured in Section 16), and may happen some time after the topside has been removed, and will be completed regardless of which option is chosen for the decommissioning of Brent C GBS.

For Option 1, Shell gave some consideration to disposal of the GBS legs on the seafloor. Although the DECC Guidance Notes indicate that the concrete installation (after the topsides have been removed) may remain in place or be disposed of at deep-water licensed site [5], disposal at a deepwater site "must be considered against the UK Government announcements at the time of the OSPAR Decision when Ministers stated that there would be no toppling and no local or remote dumping of offshore installations" [4]. Accordingly, Shell did not formally investigate the placement of GBS legs on the seafloor.

Further detail regarding available decommissioning options for the GBS are found in Shell's Technical Document for Decommissioning the Brent Gravity Based Structures [77].

10.5 Description of Technically Feasible Decommissioning Options

10.5.1 Option 1: Remove GBS legs down to -55 m water depth

As part of the topsides removal programme, the topsides and any support structures would have been removed. All the significant external steel, approximately 2,150 tonnes, would be removed after the removal of the topsides and would form part of the topsides programme of work (see Section 8.5.2) and not the GBS programme of work.

An SSCV would be used to remove the conductors. On Brent B and D the conductors that partially remain (after removing the topsides) would be removed down to at least -55 m below LAT, while on Brent C the external conductors would be removed down to the top of the cell top drill cuttings pile (in a separate programme of work, see Section 16). The majority of steel fittings and other equipment and facilities in the legs would otherwise be left in place.

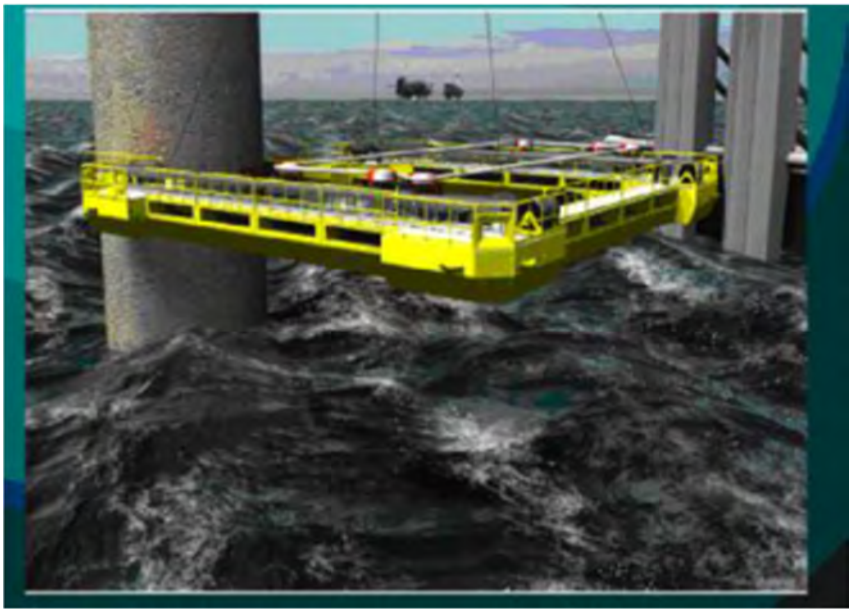
The feasibility of removing the legs from the Brent GBS was studied by Shell for each structure. After an initial screening, more detailed studies were undertaken to identify the main components of the marine operations. Critical elements were then examined in more detail to understand whether removal of the legs was feasible. As a result of these studies the methods described below would be used to remove the legs.

The removal of the legs would involve cutting the legs, transporting them to shore, dismantling them and then recycling or disposing of the resultant waste streams. The programme of work for cutting, lifting and transporting the legs to shore requires relatively

calm sea states. In the technical risk assessment the main concerns were related to obtaining the sea states required.

Each leg of the GBS would be cut horizontally using a purpose-designed and built DWC system (see Figure 10-4). The steel hardware and structures inside the leg would be cut at the same time, as part of this process.

Figure 10-4: Installation of DWC Machine on GBS Leg [82]



In the case of the two Condeep GBS, each leg would be removed in a single section approximately 75 m long and would not be supported or restrained while being cut, requiring calm sea conditions. The point of no return would be reached when 50% of the leg diameter had been cut. In order to avoid the complication of using leg restraints the final stages of the cutting operation would have to be performed in extremely calm sea states. On Brent B the weight of each leg above the 55 m clearance level is approximately 4,900 tonnes, giving a total of 14,700 tonnes for all three legs. On Brent D each leg is slightly heavier at about 5,700 tonnes, giving a total of approximately 17,100 tonnes. These weights exclude the weight of the concrete caps, which would also be removed.

For Brent C, the procedure would be similar except that the legs of Brent C are lighter and more slender than Brent B and D, and thus would have to be restrained. Currently, the best approach considered by Shell would be to use tension wires back to the tops of the GBS cells to increase the virtual weight and stabilise the legs. However, there are understood to be complexities in this procedure which leave some doubts as to whether this is achievable. The weight of each leg of Brent C above the 55 m clearance level is approximately 2,500 tonnes, giving a total of 10,000 tonnes for all four legs (these weights exclude the weight of the concrete caps and the Brent C steel transition piece, which would also be removed). Each leg would be removed in a single section approximately 62 m long.

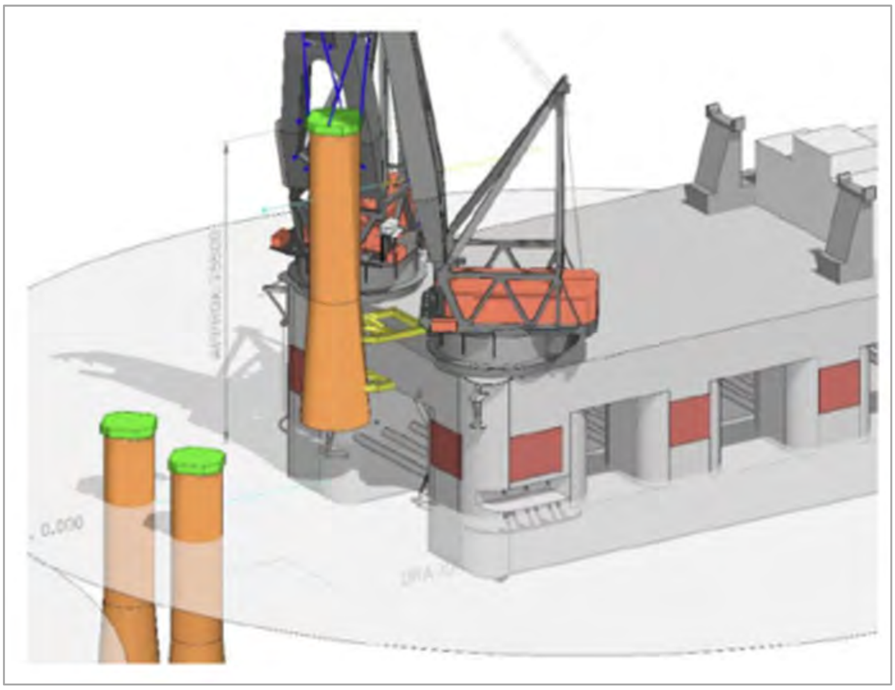
For all three GBS, Shell has determined that the best way to lift each leg would be by attaching lifting wires near the bottom of the legs by means of steel hooks, and running the wires vertically up to a spreader bar at the top.

After each leg section had been fully cut, the lifting wires would be fitted and the spreader bar would be connected to both of the cranes of an SSCV and lifted away (see Figure 10-5). Studies have shown that the Condeep legs would not be strong enough to be transported in a horizontal orientation. Consequently, each leg would have to be transported to shore suspended from the cranes of a large SSCV and secured in a purpose-built steel cradle attached to the stern of the SSCV. This would require the manufacture of one new 500 tonne steel frame which could be used for all legs at all three GBS platforms.

On arrival at the onshore dismantling site the SSCV would lower the cut leg onto a weight-distributing platform on the quayside. Suspended from the SSCV crane, the leg could then be tilted and toppled in a controlled operation so that it lay horizontally on the quayside, to facilitate dismantling. Alternatively, depending on the profile of the cut end, the leg could be secured in a vertical position, perhaps stabilised by the attachment of hydraulic pads at the base. The leg could then be grouted and fixed to the platform on the quay, and dismantled in a 'piece-small' operation. Working from scaffolding erected around the leg, the internal steel work would be removed and the leg cut into sections by conventional dismantling equipment. These sections would then be lifted off by a mobile crane for recycling. Once the leg had been safely set down on the quayside, the SSCV would return to the Brent Field to recover the next leg.

An SSCV operator has agreed in principle that this programme of work would be viable.

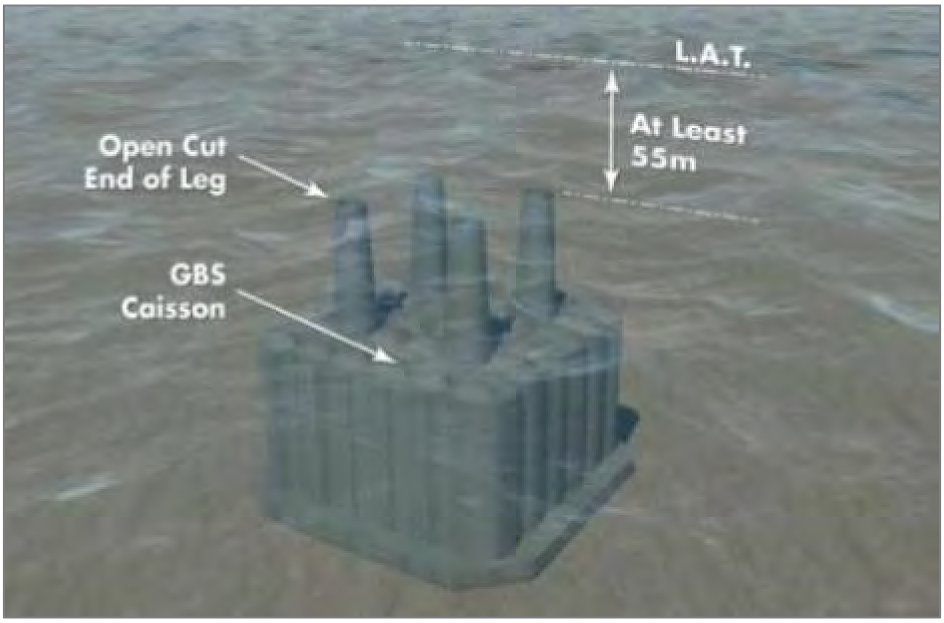
Figure 10-5: Transportation of Cut GBS Leg by SSCV [82]



After the partial removal of the legs, the remaining leg "stubs" left in place above the caisson on Brent B, C and D would be, respectively, approximately 28 m, 31 m and 32 m high above the tops of the cells. The legs would not be capped but would be left open to the sea.

Figure 10-6 gives an artist's impression of the condition of Brent C on completion of the partial removal option.

Figure 10-6: Brent C after Completion of Option 1



The mass of materials left *in situ* in Option 1 are summarised in Table 10-3.

Table 10-3: Option 1 Mass of GBS Remaining *in situ* after Partial Leg Removal

Summary of Mass Remaining *in situ* (legs down)[1]	Estimated Mass (tonnes)		
	Brent B	Brent C	Brent D
Concrete only	149,500	245,540	156,220
Grout (Underbase)	6,710	5,530	7,780
Grout (Post install clamps/ systems)	170	170	130
Steel	30,560	34,890	31,900
Sand Ballast	138,910	0	112,180
Other (assume <1% Steel mass):			
Aluminium	0.1	0.1	0.1
Cadmium	0.0	0.0	0.0
Copper	0.4	0.4	0.4
Glass Reinforced Plastic (GRP)			
GRP (Part of original system)	45	360	39
Post-installation (new pipes etc.)	20	20	20
Plastics	0.1	0.1	0.1
Rubber	0.3	0.3	0.3
Total GBS Mass Remaining *in situ* (legs down)	326,000	286,000	308,000

[1] GBS cell contents & Tri-cell drill cuttings are not included; they are covered in Sections 11 and 13

Table 10-4 summarises the resources required for decommissioning the GBS under Option 1.

Table 10-4: Materials Required for GBS Option 1

	Estimated Mass (tonnes)			
	Brent B	Brent C	Brent D	Total
Lifting and Cutting Equipment				
Fabricate slings and spreader bar, lifting attachments and platform (steel)	500	500	500	1,500
Manufacture new DWC frame (steel)	50	50	50	150
Manufacture new 10mm diamond wire, 210m/leg (steel)	630	920	630	2,180
Mooring points and anchor wires (steel)	100	100	100	300
Steel frame for securing and transporting legs				500

* This table is based on best available data from Shell.

10.5.2 Option 2: Leave GBS *in situ*

As part of the topsides removal programme, the topsides and any support structures would have been removed and pre-fabricated concrete caps, each weighing about 300 tonnes, would have been fitted to the tops of the legs above sea level. All the significant external steel (2,150 tonnes) would be removed after the removal of the topsides (see Section 8.5.2) and would not form part of the GBS programme of work. The majority of steel fittings and other equipment and facilities inside the legs and caisson would be left in place.

The upper parts of the internal conductors inside the Brent B and D drilling legs would have been cut to allow separation of the topsides, and some of them would have been partially removed down to different heights in the utility legs. The majority of internal conductors will be left in place, however, extending to a height of about 16 m in the drilling leg, just below the cut line for separating the topsides. As stated above, the external conductors and the associated conductor guide frames on Brent C would have been removed down to the top of the cell top drill cuttings pile (at approximately -72 m LAT), and this will be done in a separate programme of work (see Section 16).

An AtoN would be fitted to one leg of each GBS. This is also part of the topsides programme of work, see Section 8.5.2. Figure 10-7 shows the Brent C GBS on completion of Option 2.

In summary, after the successful completion of the topsides removal (and the fitting of leg caps and navaids that will be undertaken as part of the topsides programme), the GBS option ‘leave in place’ requires no further offshore or onshore operational activities. The GBS would be subject to a future structural and environmental monitoring programme to be agreed by Shell with BEIS (see Section 18).

Figure 10-7: Brent C after Completion of Option 2

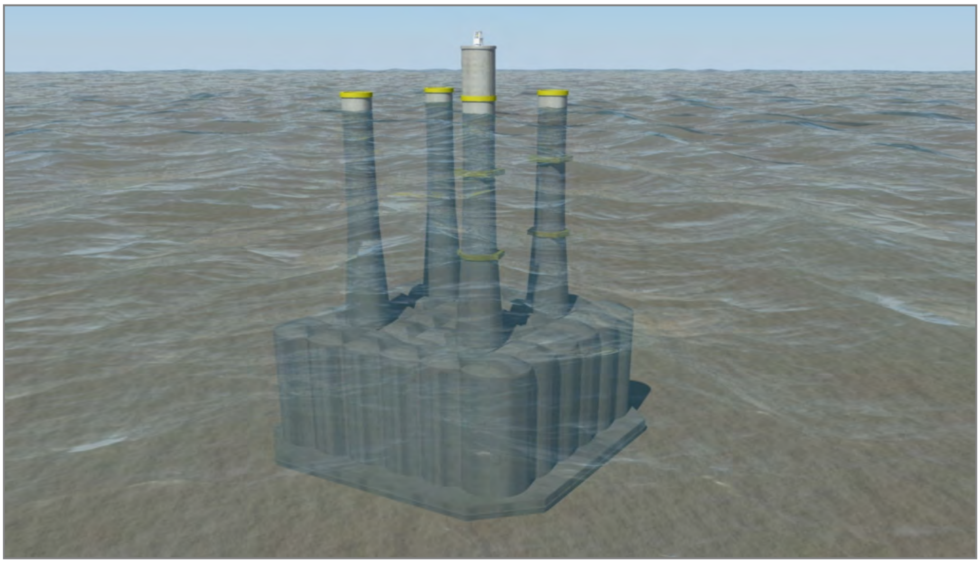


Table 10-5 summarises the masses of materials left *in situ* on the three GBS under Option 2.

Table 10-5: Summary of Option 2 Mass of GBS Remaining *in situ* (including GBS legs)

Summary of Mass Remaining *in situ* (including legs)[1]	Estimated Mass (tonnes)		
	Brent B	Brent C	Brent D
Concrete only	160,870	253,490	169,160
Grout (Underbase)	6,710	5,530	7,780
Grout (Post Install Clamps and Systems)	170	170	130
Steel	34,030	37,600	36,130
Sand Ballast	138,900	0	112,180
Other (assume <1% Steel mass):			
Aluminium	0.2	0.2	0.2
Cadmium	0.1	0.1	0.1
Copper	0.5	0.5	0.5
Glass Reinforced Plastic (GRP)			
GRP (Part of original systems)	40	410	40
Post-installation (new pipes, grating, etc.)	30	30	30
Plastics	0.2	0.2	0.2
Rubber	0.4	0.4	0.4
Total GBS Mass Remaining *in situ*	341,000	297,000	325,000

[1]GBS cell contents & Tri-cell drill cuttings are not included; they are covered in Sections 11 and 13

10.6 Significant Impacts of Decommissioning Options

Appendix 1 documents the assessment of environmental impacts for all categories for the decommissioning options. This section provides a summary of the impact assessment matrices from Appendix 1, discussing only the most significant impacts identified (those with either 'small-moderate negative' impacts or worse, or 'small-moderate positive' impacts or better).

The assessments consider the total impacts that would occur from decommissioning all three GBS. The impacts of the GBS cell contents are discussed in Section 11. The impacts of the GBS tri-cell drill cuttings are discussed in Section 13.6.13.

10.6.1 Information to Support Environmental Assessment

This section summarises studies that have been conducted to support the assessment of the GBS decommissioning.

10.6.1.1 Degradation of the GBS

A study has been conducted by Atkins [83] to assess what might happen to the GBS if left *in situ* with the legs in place; the study was, used to inform Shell's decision-making process.

The study assessed the structural integrity of the legs and whether they would be able to withstand an extreme winter storm. This included an examination of degradation and fatigue effects. Subsequently, leg collapse and caisson damage scenarios were examined in more detail, considering their effects on the longevity of the legs as well as the GBS structure as a whole. The study aimed to identify the possible degradation mechanisms and the size of objects that could fall from the legs as they deteriorate. With this information, an estimate of the resulting energy impact was made. An evaluation of the loss of leg sections from the splash zone and how this might affect the environmental forces that the legs experience was also made. The study culminated in the development of three potential degradation and collapse scenarios.

The most likely scenario is the collapse of the upper section of one or more legs around the splash zone as a result of concrete and steel degradation mechanisms, as well as due to the effects of repeated impact from waves and sea currents.

It is estimated that the upper leg(s) would remain visible and largely intact for around 150 to 250 years with a steady degradation around water level. Despite significant damage to the cells below due to falling debris, the caisson structure would still likely survive for at least 500 years, after which time loss of containment could occur [84]. If the GBS legs deteriorate to below sea level, their condition may not satisfy current IMO requirements (i.e. maintaining a 55 m clear and navigable water depth below sea surface) which could lead to the need for remedial work. Once the upper section of a leg collapses, it is estimated that the remaining parts of the legs could remain for a period in excess of 500 years.

If the GBS legs are partially removed, the structural integrity of the caisson is expected to last much longer, resulting in a life expectancy in excess of 500 years before loss of containment might occur [84]. This is because leg loads are much less and the risk of legs collapsing onto the caisson is lower.

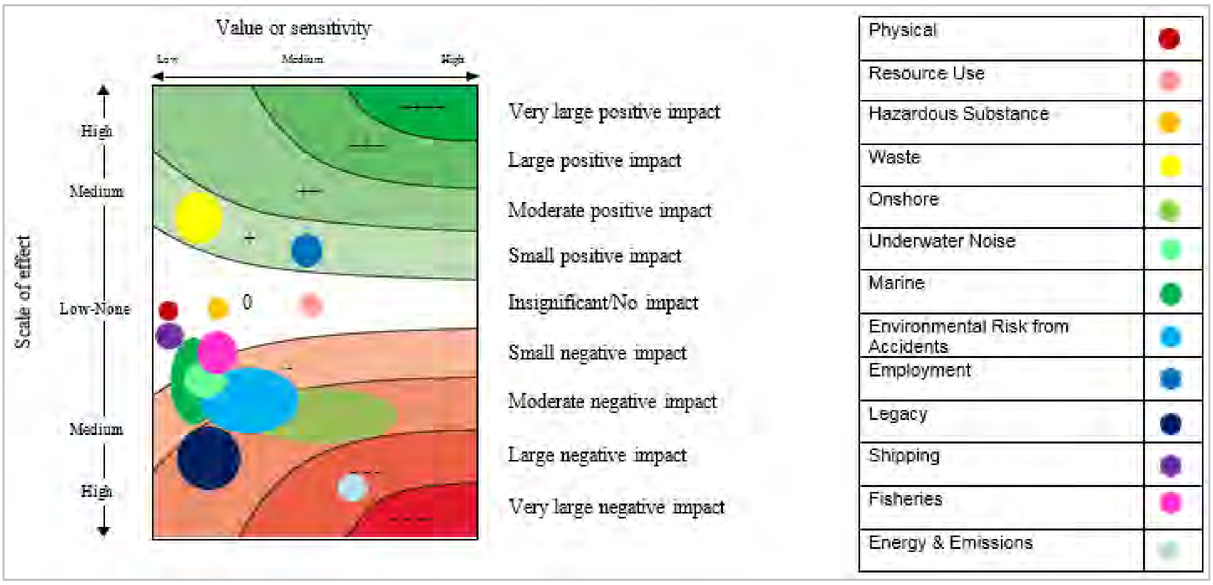
Seismic risk from earthquakes in the North Sea is low, and consequently seismic effects are not expected to reduce the life expectancy of the caisson structure, estimated to be at least 500 years as discussed above [84].

10.6.2 Option 1: Partial Removal

Option 1 involves the partial removal of the legs from the three GBS, comprising approximately 37,917 tonnes of concrete (approximately 6% of the total GBS concrete), and 9,382 tonnes of reinforced steel (approximately 8% of the total reinforced steel). The vast majority of the three GBS would be left *in situ*.

As shown in Figure 10-8, the significant impacts identified are in the onshore, environmental risk, legacy, and energy and emissions categories. Impacts are considered small or insignificant for all other categories.

Figure 10-8: Brent B, C, D GBS Option 1: Partial Removal



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

10.6.2.1 Onshore Impacts

The overall onshore impact as a result of the GBS decommissioning activities under Option 1 is '**moderate negative**' owing to the large quantities of material that would come onshore and require handling, deconstruction and transportation. At this time the location of the onshore dismantling facility is not known, and the assessment incorporates this uncertainty.

10.6.2.1.1 Noise, dust and traffic impact

The dismantling of the GBS legs (including the concrete caps and the Brent C steel transition piece) from the three platforms would generate large quantities of material, including approximately 37,917 tonnes of concrete and 9,382 tonnes of steel, plus 4,502 tonnes of steel from the Brent B and D upper conductors. The legs would be brought to shore for dismantling, recovery and disposal. Onshore decommissioning operations can have 'nuisance' impacts on residents in the local area for a significant period of time. Potential impacts can be significant [86], and can include:

- Dust emissions from deconstruction of legs and crushing of concrete
- Dust and noise emissions from increased traffic, both onsite and offsite
- Noise from deconstruction activities (e.g. lifting, cutting and crushing).

Dust emissions can significantly impact local populations, and mitigation measures would be put in place to control these impacts. Impacts can also result from increased onshore traffic nuisance, and good planning and timing of operations would be necessary. Noise impacts are possible from dismantling operations and crushing of concrete from the legs, and noise abatement measures may be necessary to minimise the extent of these impacts.

These issues would require strict control to avoid significantly impacting communities located within the immediate vicinity of the onshore deconstruction location. Shell would only use onshore facilities that are licensed to receive decommissioning wastes and the dismantling operations would be carried out under responsible management and control, with all necessary permits and consents. As such it is anticipated that mitigation measures and strict onshore process controls would be in place to minimise these risks. Previous experience of major decommissioning projects in the North Sea demonstrates that the impact potential to local communities can be effectively controlled and mitigated [67], however large concrete offshore structures have never been taken to shore for deconstruction.

10.6.2.1.2 Visual Impacts

The GBS legs would either be dismantled in a horizontal or vertical position on the quayside, depending on the cut profile of the leg. If the legs are dismantled vertically, they would be grouted and fixed to the platform on the quay, and dismantled in a 'piece-small' operation to cut the legs into sections, using a mobile crane to lift the sections away for recycling. If dismantled vertically, there would be a period of visual impact owing to the size of legs. Any visual impacts would depend on the exact location of the onshore dismantling facility and the proximity of local populations. Given that the selected onshore dismantling location would be an established industrial facility, any visual impacts should be lessened. In addition, any visual impact will reduce as the legs are dismantled.

10.6.2.1.3 Odour impacts

Marine growth removed onshore from the GBS legs could result in odour, the extent depending on the amount of marine growth, temperature, air exposure time, drying and the efficiency of disposal methods. If the onshore dismantling facility has a local population in the immediate vicinity some small impacts might be anticipated though of limited duration [67].

10.6.2.1.4 Summary

In summary, partially removing the GBS legs under Option 1 is estimated to have a 'moderate negative' onshore impact on local residents owing to the combination of noise, dust, odour, traffic and potential visual impacts upon local residents that could occur over a significant period of time as a result of the large volumes of materials that would come to shore. Only licensed facilities would be used, and strict controls may be necessary to ensure impacts are managed effectively. When the onshore site is selected, the impact should be re-evaluated, as there is currently some uncertainty without this information.

10.6.2.2 Environmental Risk from Accidents

The overall impact of environmental risks from accidents as a result of the removal of the GBS legs under Option 1 is estimated to be **'small-moderate negative'.**

10.6.2.2.1 Environmental risks from operations

No party to date is believed to have cut (underwater) concrete legs of this size and diameter. The cut GBS legs would be towed to shore in the air, suspended from the two cranes on the stern of the SSCV, and secured onto a purpose-built steel cradle. The steel cradle would be built with a solid steel base, serving to prevent any loose debris from falling out of the GBS legs and into the sea. Once the GBS leg is safely deposited on the quayside, the SSCV would return to the Brent Field to collect the next leg; each GBS leg would be transported individually.

This presents a potential increase in technical risk of failure. Due to the increased technical risk of failure, there is an associated potential increase in environmental risk from dropped GBS legs (e.g. onto the GBS cells, seabed, seabed drill cuttings or pipelines) which could impact the marine environment.

However, as the Brent Field would no longer be in production during decommissioning, there would be no live pipes operating in the field, so the main environmental risks would likely be from potential damage to the GBS caisson and dispersion of seabed drill cuttings resulting from a dropped GBS leg during lifting operations [81]. The consequence of a subsequent release of cell contents would be localised pollution as discussed in detail in the cell contents chapter (Section 11). Dropping a GBS leg onto the seabed could cause pollution from localised dispersion of seabed drill cuttings and could also result in localised damage to the benthic environment and cause habitat change, the consequence of which would be similar to that described in Section 10.6.3.1.2. There is also the risk of dropping the GBS legs near shore in a more sensitive environment, however as the GBS legs do not contain any hydrocarbon material the impact would be mainly restricted to physical habitat change and benthic smothering unless a live third party pipe is damaged. Environmental risks should be re-evaluated when the onshore site is decided if Option 1 is selected.

10.6.2.2.2 Other environmental risks

Potential environmental accidents for Option 1 include dropped object scenarios and collision of vessels resulting in spillages. Such events present lower risks than those presented by the above operations, but still require effective management and control.

10.6.2.2.3 Summary

In summary, it is estimated that partially removing the GBS legs under Option 1 presents a 'small-moderate negative' impact in the 'environmental risks from accidents' category, primarily because it involves new technology and novel operations. If this option is selected it is recommended that a more detailed environmental risk analysis is carried out to ensure all appropriate management measures are identified and implemented. Also, when the onshore site is selected, the risk should be re-evaluated as the site may be located close to a sensitive environment.

10.6.2.3 Legacy

The overall legacy impact as a result of partially removing the GBS under Option 1 is estimated to be '**moderate negative'.** Option 1 would have similar long-term effects on the marine environment as Option 2 (a localised benthic impact and habitat change) and presents similar restrictions to fisheries (refer to Section 10.6.3.1.1) and there remains a legacy impact to shipping because although the legs would be cut to -55 m below sea level such that ships

can safely pass over, Shell would apply for a continuation of the safety zone (to protect fishing vessels as described below).

This is because Option 1 would present an increased risk of fishing gear snagging on the GBS legs that remain underwater, because the GBS legs are no longer visible to fishing vessels. A study conducted by Anatec [21] assessed the effect of removing the safety zone immediately after decommissioning and this increased the risk of fatality due to fishing gear snagging on leg stubs by 54%. Shell would thus apply to the regulator for a continuance of the 500 m safety zone for Option 1 after decommissioning is complete, and this would restrict fisheries to the area for an indefinite period of time, with a small but long-term associated socioeconomic impact as discussed further in Section 10.6.3.1.1 (this ES does not assess the risk of human fatalities, whether from ships or fishing vessels, but does consider socioeconomic impacts). This would also restrict the passage of ships.

Note: the exposure of any GBS cell contents to the water column is assessed in Section 11.7. If the upper parts of the GBS legs are removed, the risk of the caisson suffering accidental damage is lower (because the GBS legs are the weakest part of the GBS structure) and therefore the GBS cells would be expected to remain intact for longer.

10.6.2.4 Energy and Emissions

DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use as a result of decommissioning all three GBS under Option 1. Comparing this against the energy impact categories in Table 5-7, the impact from energy use is considered to be **'large negative'**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

The energy and emissions for Option 1 are presented in Table 10-6 to Table 10-8 for each GBS individually, while the cumulative results are shown in Table 10-9.

Table 10-6: Energy and Emissions from Partial Removal of Brent B GBS Option 1

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations	-	-	-	-
Marine operations	447,129	35,753	897	546
Onshore dismantling	9,045	665	15	1
Onshore transport	4,444	327	7	0
Concrete demolition	1,146	0	0	0
New materials	17,500	1,375	2	3
Sum	*479,264*	*38,120*	*921*	*550*
Recycling				
Material recycling	*48,084*	*2,176*	*8*	*19*
Material Replacement				
Materials not recycled	*1,120,157*	*108,658*	*90*	*64*
Total	**1,647,505**	**148,954**	**1,019**	**633**

Table 10-7: Energy and Emissions from Partial Removal of Brent C GBS Option 1

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations	-	-	-	-
Marine operations	232,376	18,390	489	260
Onshore dismantling	6,350	467	10	0
Onshore transport	3,120	229	5	0
Concrete demolition	871	0	0	0
New material	52,500	4,125	6	8
Sum	*295,217*	*23,211*	*510*	*269*
Recycling				
Material recycling	*26,600*	*1,200*	*4*	*11*
Material Replacement				
Materials not recycled	*1,190,599*	*118,469*	*90*	*63*
Total	**1,512,416**	**142,884**	**605**	**343**

[1] Operations categories are defined in Section 5.2.3.

Table 10-8: Energy and Emissions from Partial Removal of Brent D GBS Option 1

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	473,925	37,920	1,043	581
Onshore dismantling	10,507	773	17	1
Onshore transport	5,162	380	8	0
Concrete demolition	1,319	0	0	0
New material	17,500	1,375	2	3
Sum	*508,413*	*40,448*	*1,070*	*585*
Recycling				
Material recycling	*57,215*	*2,590*	*10*	*23*
Material Replacement				
Material not recycled	*1,173,331*	*113,688*	*95*	*67*
Total	**1,738,959**	**156,726**	**1,175**	**675**

Table 10-9: Total Energy and Emissions from Partial Removal of all 3 GBS: Option 1

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	1,153,430	92,063	2,429	1,387
Onshore dismantling	25,902	1,905	42	2
Onshore transport	12,726	936	21	1
Concrete demolition	3,336	0	0	0
New material	87,500	6,875	10	14
Sum	*1,282,894*	*101,779*	*2,502*	*1,403*
Recycling				
Material recycling	131,899	5,970	22	53
Material Replacement				
Materials not recycled	3,484,087	340,815	275	194
Total	**4,898,880**	**448,564**	**2,799**	**1,650**

[1] Operations categories are defined in Section 5.2.3.

[2]No at field operations for this option

10.6.2.4.1 Energy consumption and CO_2 emissions

Energy is required offshore (marine vessels and field operations), onshore (dismantling and transport) and for material recycling. Additionally an energy penalty is applied for replacement of materials that are not recycled (see Section 5.2.3).

The partial removal of the GBS legs would involve extensive use of marine vessels. The main activities would include the removal of the upper conductors and the cutting and lifting of the legs. Both of these operations would be conducted by an SSCV, ROVSV, tug and barge. The SSCV would also likely be the vessel used for all other supporting activities and equipment such as ROVs and DWC equipment. The vessel durations used within the energy and emissions calculations are included in DNV GL's *Energy Use and Gaseous Emissions Report* [2].

The energy demand required to remove all three GBS legs is estimated to be about 4.9 million GJ based on the contributions from different operations. The total CO_2 emissions ($CO_{2\ TOT}$) from these operations would be approximately 450,000 tonnes, of which the largest contribution would come from materials left *in situ* (76%). The majority of materials would be left *in situ* under this decommissioning option.

10.6.2.4.2 Emissions of NO_x and SO_2 to atmosphere

The majority of the gaseous emissions of NO_x and SO_x generated are likely to be quickly dispersed as they would be released offshore, and are considered to be smaller contributors to the environmental impact than the more significant CO_2 emissions discussed above. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

10.6.2.4.3 Summary

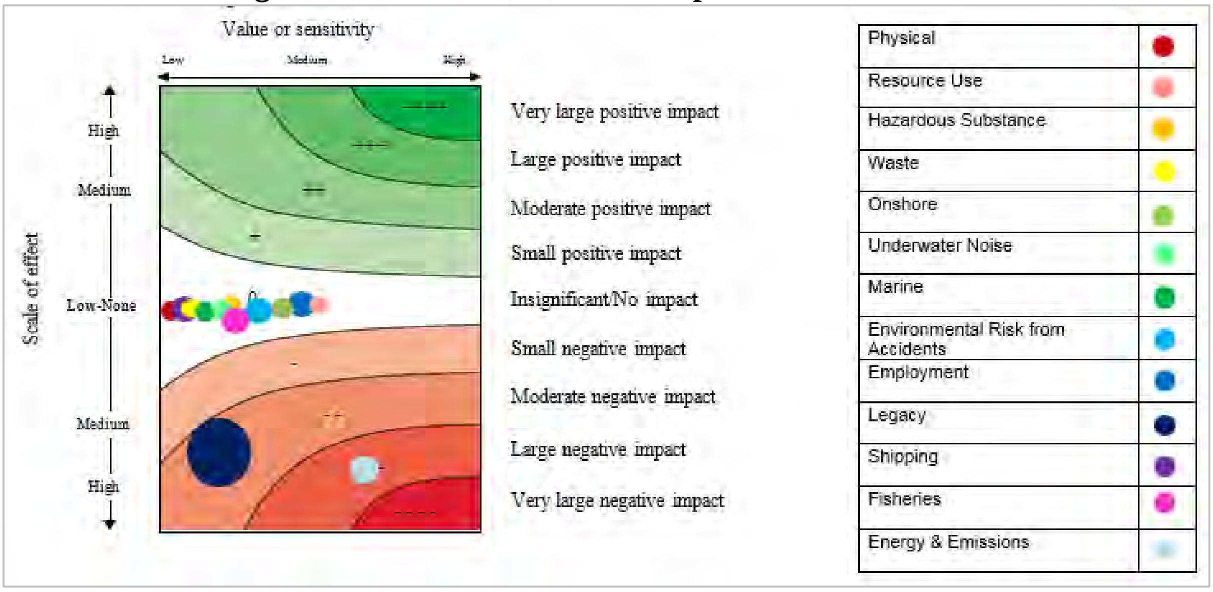
The overall environmental impact from Energy and Emissions as a result of decommissioning all three GBS under Option 1 is estimated to be 'large negative' owing primarily to the energy/CO_2 penalty applied due to the large quantity of steel (~114,600 tonnes) and concrete (~586,000 tonnes) that are left *in situ* in conjunction with the significant energy used during marine operations. The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put this into another context, the total CO_2 emissions for Option 1 are estimated to be 18.5% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70].

10.6.3 Option 2: Leave *in situ*

Under this option, the three GBS would be left *in situ*.

As shown in Figure 10-9, the significant impacts identified are in the legacy and energy and emissions categories. Estimated impacts are considered small or insignificant for all other categories. As preparatory activities such as the installation of concrete caps for the GBS legs and the installation of Navaids are within the topsides programme of work, there are no short-term operational impacts for the leave *in situ* option.

Figure 10-9: Brent B, C, D GBS Option 2: Leave *in situ*



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

10.6.3.1 Legacy

The overall legacy impact as a result of leaving the three GBS *in situ* under Option 2 is estimated to be **'moderate negative'** due to a combination of the following legacy impacts to fisheries, the marine environment and to shipping.

10.6.3.1.1 Legacy - *fisheries*

If it is assumed that in the future fisheries would be comparable to the present, the effect on fisheries as a result of leaving the GBS structures *in situ* is estimated to be small because if the Brent facilities were completely removed, the value of the catch is assumed (by comparing the increase in available acreage versus the block size) to only increase by 0.1% of the projected annual catch of £7 million per year, which would be only approximately £7,000 per year [35].[7] However, the current safety zone in the Brent area affects trawling fisheries more. This is because trawl vessels have to begin deflection manoeuvres very early to avoid moving into the safety zone, which implies that an area larger than the actual safety zone is unavailable to trawlers. Leaving the GBS structures *in situ* would, in the long-term perspective, imply a continued occupation of the area for an indefinite period into the future.

In accordance with UK regulations, the 500 m safety zones must remain in place until the structure no longer projects above the sea surface. The structures would also be clearly marked on navigation charts, and the lights and navigational aids would be clearly be visible to fishermen. Therefore, the risk of snagging trawl gear in the short-term (0-250 years) will be very low. Snagging risk would be introduced as the GBS legs degrade below water level (after several hundred years) and are no longer be visible, when the risk of collision and

[7] The impact may be smaller if the catch is limited by quotas and days at sea, rather than physical access.

snagging fishing gear increases. At this time, Shell would apply for a continuation of the safety zones, and assuming this is granted it would prevent fishing vessels from entering the area. This would result in small (but long-term) socioeconomic impact (the commercial fishing value of the area is low). Anatec [21] recommend considering keeping the safety zone in place until the GBS legs no longer pose a snagging hazard risk to fishing vessels, and this is likely to take approximately 1,000 years. Note: this ES does not assess the risk of human fatalities, whether from ships or fishing vessels, but does consider associated socioeconomic impacts.

10.6.3.1.2 Legacy - *marine*

There are two elements which account for the impact to the marine environment, as discussed in turn below. For both elements it should be noted that the benthic fauna impacted are typical of the region, are diverse and abundant, and there do not appear to be any species of particular conservation concern (see Section 6.3.2).

The GBS substructures would degrade over several hundred years, and would constitute an object with a hard-bottom effect for local organisms. Ultimately, it would become a hard reef-like structure on the seabed, attracting the settlement of hard-bottom species of organisms such as corals, anemones and hydrozoa (accepting that concrete is less attractive than steel to such species). This constitutes a change in the natural environment where the debris falls away from the GBS, similar to the effect of a large ship wreck on the seafloor. The Norwegian Institute of Marine Research has however noted [85] that after 35 years of operation, installations become part of the ecosystem. It is therefore their opinion that leaving concrete substructures in place would not significantly harm the fish resources or other marine fauna. That is also the view taken in a study conducted for the Norwegian regulator [86].

Additionally, the degrading GBS would at irregular periods disturb the seabed sediments as they degrade, causing turbulence of seabed sediment, which would settle locally on the seabed. This is anticipated to impact local benthic fauna.

The impact to the marine environment from exposure of the cell contents after GBS degradation is assessed separately in Section 11.7.1.

10.6.3.1.3 Legacy - *shipping*

Due to the continued requirement for safety zones around each GBS, large vessels would be restricted (as they are currently) from passage in the Brent area for several hundred years (until eventual degradation of the GBS legs), thereby preventing full use of the area. There is also some ensuing risk of ship collision and this could result in a large environmental accident (although ship navigation is likely to become more effective in the future at preventing collisions due to improvements in technology over time). Note: this ES does not assess the risk of human fatalities, whether from ships or fishing vessels, but does consider socioeconomic impacts (as a result of excluding ships, for example) and also environmental risks due to accidents.

The existing 500 m radius safety zone centered on each platform would remain in force while any part of the structure is visible above sea level. At the time that the platform is taken below sea level, or when a residual structure degrades below sea level, Shell would apply to the regulator for a continuance of the 500 m safety zone (to reduce risks to shipping and fishing vessels). The continued existence of this zone, the marking of the new status for the

four platforms on Admiralty charts, the issuing of Notices to Mariners, and the inclusion of all platforms on the Fishsafe system as well as formal notifications to the UK Hydrographic Office and the Maritime and Coastguard agency would all ensure that other users of the sea are notified and fully aware of the presence and condition of any residual platform material that remains within the field.

Thus the risk of a shipping accident would be managed but there would thus be a continued small socioeconomic impact due to continued restrictions to ship passage in the area for many hundreds of years, just as today.

Also, although the safety zone would remain in place, Option 2 would continue to present some risk of ship collision with the GBS legs, and this could potentially result in a major accident with associated environmental consequences. An analysis of the possibility of a major collision with the GBS legs was conducted [21] which estimated the risks to be low; a collision with a Brent structure could result in ten or more fatalities once every 1.1 million years (the basic accident frequency is 1 in 11,000 years; a major accident with 10 or more fatalities estimated as 1% of that). Although the study was safety-focussed, such a major collision could also potentially result in significant environmental consequences (e.g. oil spill). As such an event is very unlikely, the environmental risk is small. It is acknowledged that such risk estimates have significant levels of uncertainty, but the results are also very low. Measures would be put in place to ensure long-term environmental risks are managed appropriately (see Table 10-14).

10.6.3.1.4 Summary

In summary, leaving the GBS *in situ* under Option 2 is estimated to have a 'moderate negative' impact due to a combination of the long-term legacy impacts to the marine environment (change of local habitat), exclusion of fisheries interests and restrictions to the passage of ships.

Note that leaving the steel fittings and equipment (e.g. pipes, ladders) inside the GBS legs if they are left *in situ* may make it more difficult to cut and remove partially collapsed legs in the future, if or when it becomes necessary, because cutting through corroded and deteriorated steel fittings may prove difficult. But the pipework and architecture in the legs is sound and secure at present. If at a later date the legs are to be partially removed, studies have shown that a 2 m by 2 m "window" could be cut in the side of each GBS leg to allow the internals to be severed if necessary by ROV. Shell does not plan to remove the steel fittings and equipment at this time.

10.6.3.2 Energy and Emissions

DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use as a result of decommissioning all three GBS under Option 2. Comparing this against the energy impact categories in Table 5-7, the impact from energy use is considered to be **'large negative'**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

The energy and emissions for Option 1 are presented in Table 10-10 to Table 10-12 for each GBS individually, while in Table 10-13 shows the total energy and emissions as a result of leaving all three GBS *in situ*.

Table 10-10: Energy and Emissions from Brent B GBS Option 2: Leave *in situ*

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	4,655	343	7	2
Onshore dismantling	-	-	-	-
Onshore transport	-	-	-	-
Concrete demolition	-	-	-	-
Sum	*4,655*	*343*	*7*	*2*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	1,248,982	120,909	101	72
Total	**1,253,773**	**121,252**	**108**	**74**

Table 10-11: Energy and Emissions from Brent C GBS Option 2: Leave *in situ*

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	4,655	343	7	2
Onshore dismantling	-	-	-	-
Onshore transport	-	-	-	-
Concrete demolition	-	-	-	-
New materials	-	-	-	-
Sum	*4,655*	*343*	*7*	*2*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	1,233,263	122,753	93	66
Total	**1,237,918**	**123,096**	**100**	**68**

[1] Operations categories are defined in Section 5.2.3.

[2]No at field operations for this option

Table 10-12: Energy and Emissions from Brent D GBS Option 2: Leave *in situ*

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	4,655	343	7	2
Onshore dismantling	-	-	-	-
Onshore transport	-	-	-	-
Concrete demolition	-	-	-	-
New material	-	-	-	-
Sum	*4,655*	*343*	*7*	*2*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Material not recycled	*1,328,522*	*128,417*	*108*	*77*
Total	**1,333,177**	**128,760**	**115**	**79**

Table 10-13: Total Energy and Emissions from all 3 GBS in Option 2: Leave *in situ*

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations	-	-	-	-
Marine operations	13,965	1,029	21	6
Onshore dismantling	-	-	-	-
Onshore transport	-	-	-	-
Concrete demolition	-	-	-	-
New material	-	-	-	-
Sum	*13,965*	*1,029*	*21*	*6*
Recycling				
Material recycling	-	-	-	-
Replacement				
Materials not recycled	3,810,767	372,079	302	215
Total	**3,824,732**	**373,108**	**323**	**221**

[1] Operations categories are defined in Section 5.2.3.

[2]No at field operations for this option

10.6.3.2.1 Energy consumption and CO_2 emissions

The energy demand for leaving the Brent B, C and D GBS *in situ* is estimated to be about 3.8 million GJ. The total CO_2 emissions ($CO_{2\ TOT}$) from these operations would be about 373,100 tonnes, in which by far the largest contribution is from replacing materials left *in situ* (372,079 tonnes, or 99.7% of total CO_2 emissions). This is due to the large volumes of steel (~126,000 tonnes) and concrete (~624,000 tonnes) left *in situ.*

10.6.3.2.2 Emissions of NO_x and SO_2 to atmosphere

The majority of the gaseous emissions of NO_x and SO_x generated are likely to be quickly dispersed as they would be released offshore, and are therefore considered to be smaller contributors to the environmental impact than the more significant CO_2 emissions. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

10.6.3.2.3 Summary

The overall environmental impact from Energy and Emissions as a result of decommissioning the three GBS under Option 2 is estimated to be 'large negative' owing primarily to the energy/CO_2 penalty applied due to the large quantity of steel (125,947 tonnes) and concrete (624,066 tonnes) that are left *in situ.* The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put this into another context, the total CO_2 emissions for Option 2 are estimated to be 15% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70].

10.6.4 Comparison of Options for GBS Decommissioning

There are some differences between the two decommissioning options for the GBS.

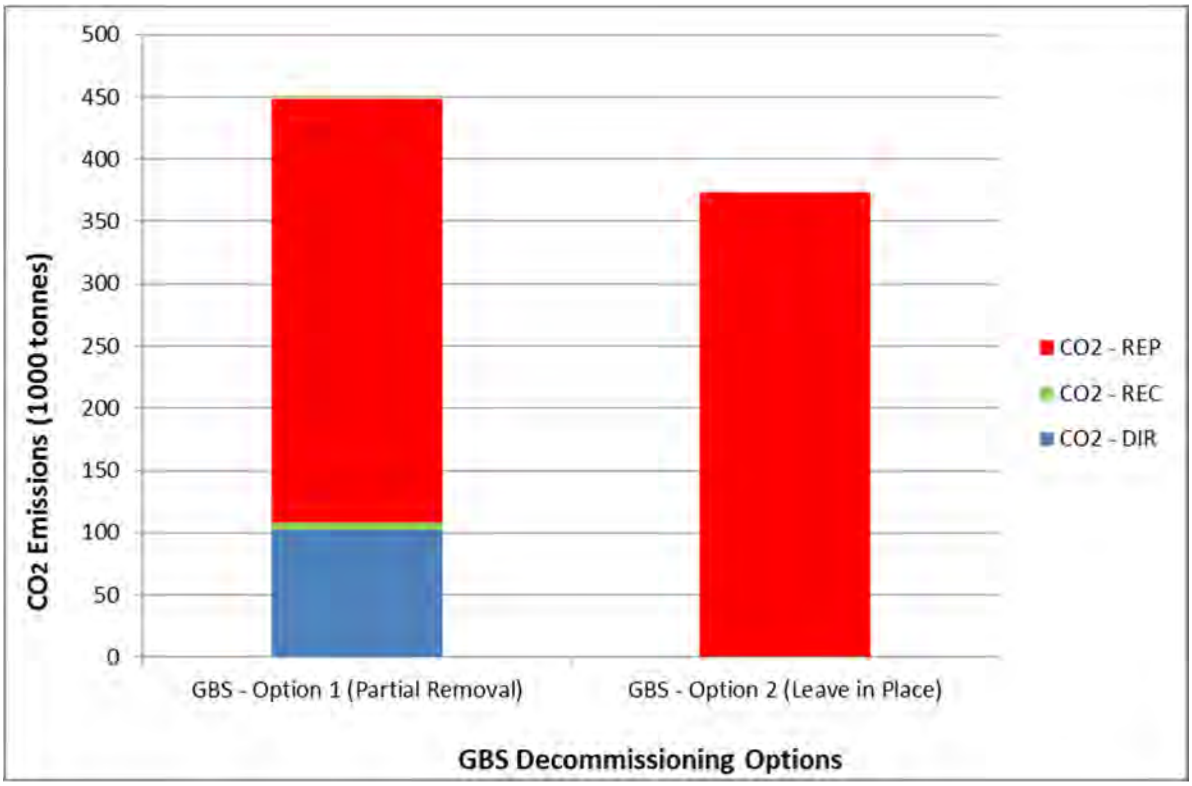
Option 1 involves intervention to partially remove the GBS legs (including the concrete caps and the Brent C steel transition piece) and transport 37,917 tonnes of reinforced concrete and 9,382 tonnes of steel to shore (together with the Brent B and D upper conductors, weighing 4,502 tonnes), with associated negative onshore impacts, large energy consumption and increased risk of environmental accidents. Option 2 involves leaving the GBS *in situ*, and results in moderate negative legacy impacts to shipping, the marine environment and fisheries for hundreds of years. But Option 1 also presents very similar legacy impacts for hundreds of years, as ships would still be unable to pass over the partially removed GBS, because Shell would apply for a continuation of the safety zone to protect fishermen.

The only environmental benefit Option 1 has over Option 2 is that removing the GBS legs means removing a source of falling debris that could impact the GBS caisson and storage cells. Thus the integrity of the caisson and GBS cells would last longer [83], but for both options the cell contents would still ultimately be released to the marine environment.

In summary, removing the GBS legs comes at a cost to the environment, with increased energy use, risk of environmental accidents and onshore nuisance, for limited environmental benefit. For both Options 1 or 2, sufficient mitigation measures would be applied to manage impacts effectively.

Figure 10-10 compares the total CO_2 emissions for the options to decommission the GBS. Option 2: Leave *in situ* has lower CO_2 emissions compared to Option 1: Partial removal.

Figure 10-10: Comparison of CO_2 Emissions for the Options to Decommission the GBS



10.7 Significant Impacts of Proposed Programme of Work

Shell's proposed option for decommissioning the GBS is Option 2, leave *in situ*. The key impact for this option is the '**moderate negative**' impact resulting from the combination of legacy impacts to fisheries, the marine environment and to shipping. The impacts are described in Section 10.6.2 and will require management as described below.

10.8 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that mitigation and management measures are in place. Table 10-14 details these measures for the proposed option to decommission the GBS and highlights the residual impacts as described in Section 10.6 and Appendix 1.

Table 10-14: Summary of Mitigation and Management Measures for Proposed Programme of Work

Environmental Category	Mitigation Measures	Residual Impact
Onshore Impacts	There will be no onshore operations	No impact
Resource Use	No resources will be used (the manufacture of the concrete caps and Aid to Navigation is taken into account in Topsides).	No impact
Hazardous Substances	No hazardous substances will be used	No impact
Waste	There will be no waste generated	No impact
Physical	No physical impacts	No impact
Marine (includes underwater noise)	No marine or underwater noise impacts	No impact
Environmental Risk from Accidents	There are no offshore operations and therefore no environmental risk (the installation of the concrete caps and Aid to Navigation is taken into account in Topsides).	No impact
Employment	Insignificant employment generated.	Insignificant
Legacy	• Adequate monitoring and maintenance of the GBS structure, as described in Section 18. • Maintain the 500 m safety zones around the platforms as long as required by BEIS. BEIS require the safety zone to stay in place while the structure projects above the sea surface. Shell will apply to BEIS for a continuance of the 500 m safety zone owing to the increased risk of snagging fishing gear once the GBS legs have degraded and are no longer visible and due to the increased risks to shipping. In accordance with the Marine and Coastal Access Act 2009, the Marine Scotland Act 2010 and OSPAR requirements, Shell will maintain the navigational aids on the GBS structures to ensure continued safety of navigation. Whilst the GBS legs remain above sea level, the AtoN will have a light, and will also transmit a suitable AIS position code so that the structure appears on modern navigation surveillance systems. It may also have a radio beacon or racon installed so that it makes a clear return on primary radar. When GBS legs start to degrade, it will be particularly important to maintain the navigational aids. When they degrade, and it is clear that the legs can no longer support the AtoN, Shell will discuss and agree with BEIS a suitable alternative warning device. Under present legislation it is likely that this will be a tethered buoy, with appropriate lighting. Additionally, the substructures will be properly marked on navigational charts to mitigate any potential risks for ship collision. Note that the installation of these items are part of the topsides programme of work, however their long-term maintenance and monitoring will fall under the GBS monitoring programme. To assist fishermen, the subsea structure will be identified and recorded in the UK "FishSAFE" programme (www.fishsafe.eu), a computerized system providing fishermen with information about obstructions or hazards in fishing grounds. Fishing vessels fitted with the "FishSAFE" equipment receive a visual and audible alarm when they come within 6 nautical miles of an identified obstacle. • Shell will organize the marking of the new status of the Brent platforms on Admiralty Charts, the issuing of Notices to Mariners, and formal notifications to the UK Hydrographic Office and the Maritime and Coastguard Agency. This will help ensure that users of the sea are notified and aware of the presence and condition of any residual platform material that remains at the Brent Field. • Shell will perform 4 structural monitoring surveys, at 50, 150, 250 and 350 years post-decommissioning. • Shell will conduct periodic reviews following decommissioning to monitor if the vessel activity changes are in-line with Anatec study predictions [21]. This includes a check for and follow-up of any safety zone infringements at the locations to ensure vessels continue to comply with the safety zones, even without the ERRV at the field to enforce them.	Moderate negative
Fisheries	There will be no marine operations	No impact
Shipping	There will be no marine operations	No impact
Energy & Emissions	There will be no marine operations	Large negative

11. GBS CELL CONTENTS

11.1 Introduction

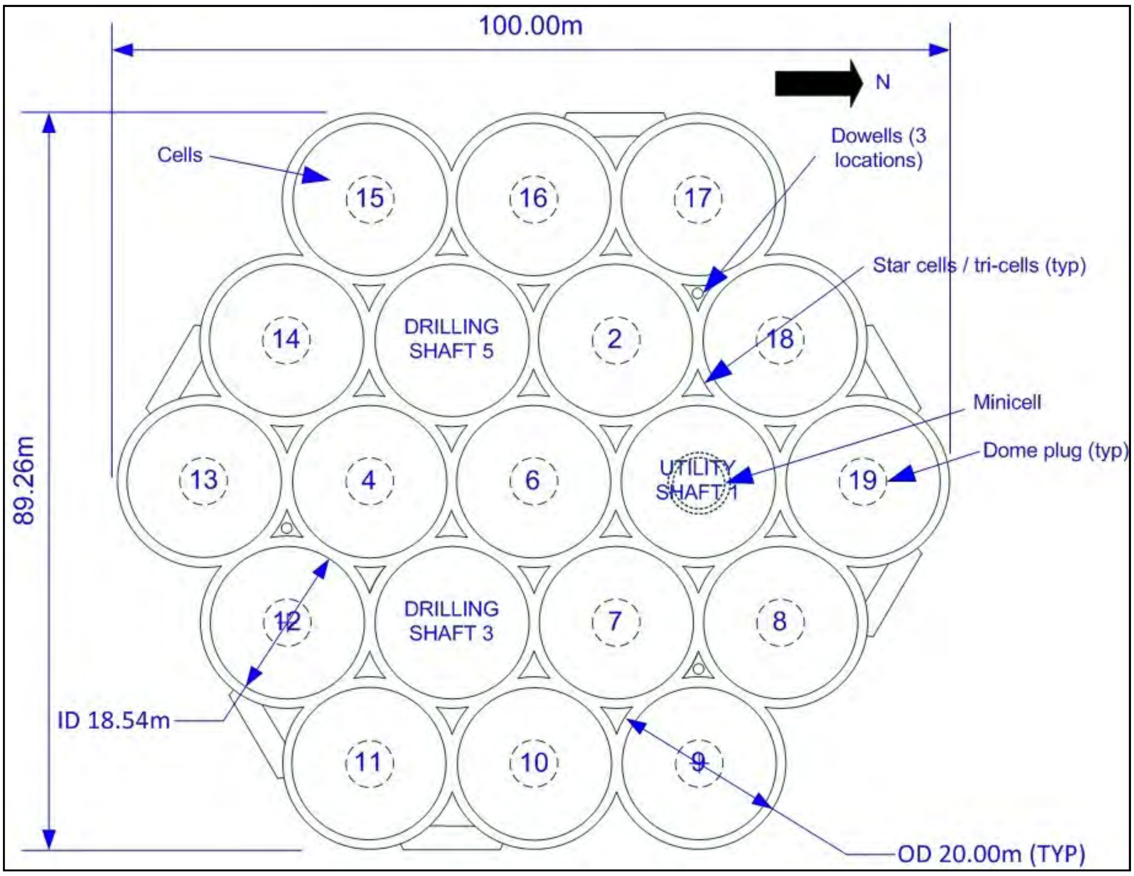
This section describes the GBS cell contents, the inventory of materials and the decommissioning options. The main anticipated environmental impacts of the decommissioning options are discussed and compared. The necessary management and mitigation measures to control the impacts of Shell's proposed programme of work are summarised, and measures are recommended to further reduce residual impacts where appropriate. The Technical Document the Brent GBS Contents Decommissioning [87] has been used as the basis for much of Sections 11.2 - 11.6.

11.2 Description of GBS Cell Contents

Brent B, C and D GBS are substantial concrete structures. The GBS cells were used for either the storage of crude oil, ballast water or produced water from the oil and gas operations; as a result some of the cells will contain residual hydrocarbons at the time of decommissioning.

As described in Section 10.2, the Brent B and D caissons are similar and consist of a concrete substructure with 19 cylindrical cells, 3 of which form the supporting legs while the remaining 16 were used for oil storage (Figure 11-1). One storage cell on both Brent B and D was designed and used for bulk diesel storage but converted to oil storage through the mid-1990s, and afterwards Brent B and D had only crude oil filled cells.

Figure 11-1: Arrangement of Cells in Brent D GBS Caisson [87]



Brent C GBS consists of 36 square shaped cells used for different functions, and has a slightly different configuration to Brent B and D (as discussed in Section 10.2). The inner storage cells were used for storage of hydrocarbons (including two cells that were initially filled with diesel and later stored various waste fluids). The 20 peripheral cells (shown in blue in Figure 11-2) were not designed for storing oil but for conducting cooling water around the inner storage cells. Fluids (mainly produced water) are exchanged between some of the peripheral cells and some of the inner storage cells via a 24” standpipe. However, it is believed that there may be some oil trapped in these peripheral cells due to overfilling the active storage cells on a number of occasions. Studies have also indicated a possibility of sediment in three of the peripheral cells (B11, B16, and B22) due to failure of the standpipes allowing ingress of solids into the adjacent peripheral cell. Neither of these instances has been confirmed.

Figure 11-2: Layout of Brent C Storage Cells [88]

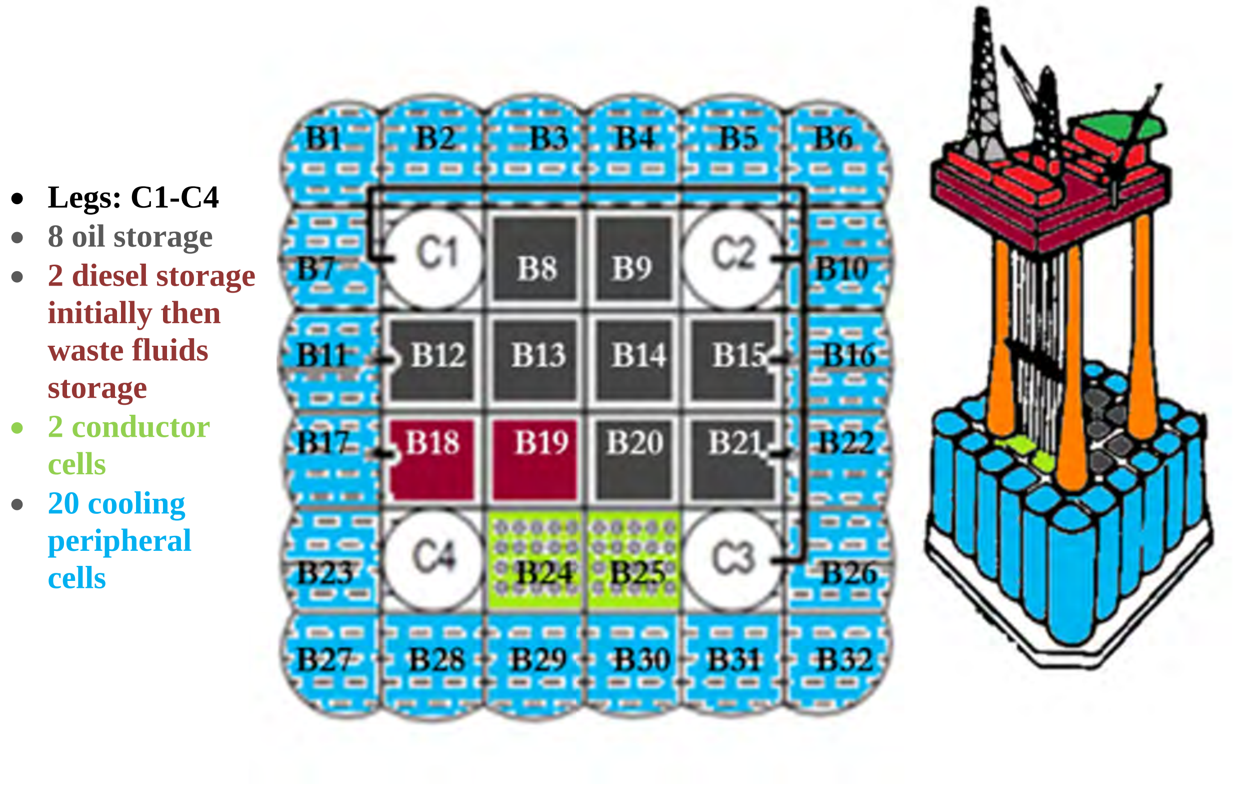


Table 11-1 outlines the main features of the GBS cells. The cells of the three GBS have a total storage capacity (excluding the volume occupied by ballast materials, the legs and other spaces not used for the production of hydrocarbons) of 691,058 m^3.

Table 11-1: Total Available Storage Capacity of Brent GBS Cells [87]

Parameter	Brent B	Brent C	Brent D
Inner diameter of cell (m)	18.54	13.1 by 13.1 m	18.54
Base area of cell (m^2)	270	172	270
Number of cells	19	36	19
Number of cells used for legs	3	4	3
Cells used for storage of crude oil	16	8	16
Cells used for storage of diesel	1	2	1
Cells only used for water cooling	0	22*	0
Total storage capacity (m^3)**	181,120	328, 818	181,120

*20 peripheral cooling cells plus 2 conductor cooling cells
**Excludes tri-cells and ballast

The substances currently present in the GBS cells, pipework and associated structures will include:

- Crude oil and its range of constituent hydrocarbons
- Refined petroleum products that were stored as a fuel for engines and turbine power plant
- Produced water (used as cooling water)
- Ballast water – essentially seawater present in the storage cells
- Ballast sand in base of the storage cells, covered with a slab of concrete
- Emulsions: sediments at the bottom of the cells essentially mixture of oil, produced water and solid particles

It has been difficult to sample the cell contents because the tops of the Brent GBS cells are approximately 80 m below sea level, and 'drawdown' (see below) must be maintained during sampling activities while the platform topsides are in place.

Drawdown is the system and process which maintains a difference in pressure between the fluids inside the cells and the surrounding sea. The cell fluids are kept at a lower pressure and the resultant compression force on the caisson enhances its strength and integrity.

As such the volume and physical and chemical characteristics of sediment was originally estimated from analogous samples, calculations and modelling. This information is described in Sections 11.2.1 and 11.2.2. In 2015, samples were collected of the cell sediment from three of Brent D cells and this is described in Section 11.2.3. This ES makes use of both the estimations and the sampling results.

11.2.1 Predictions of Cell Contents and Chemistry

A desk-based chemical assessment of the Brent D cell contents was performed by URS Group in 2010 [89], which aimed to characterise the chemistry of the materials within the Brent D GBS storage cells at CoP. A summary of this study is given in this subsection.

The characterisation of the chemistry of materials in the GBS cells draws from the analysis of a number of samples [93] that were collected (oil, interphase and water from the storage cells and sediment from the topside separators) and which are discussed further in Section 11.7.1. The study is based on a number of assumptions which are described on the following pages.

The aim of the desktop study was to characterise the chemical composition and physical properties of the various phases of cell contents, to provide the basis for a conceptual model of the cell contents to be developed. This enabled an assessment to be conducted of the decommissioning options.

The GBS cells are believed to contain the following different phases or layers of material:

- Attic oil: a small volume of oil (30 to 50 m^3) trapped at the top of each cell. Attic oil is not likely to be present on Brent B
- Interphase material: a viscous emulsion of oil and water that has accumulated at the junction of the attic oil phase and the water phase
- Water phase: a large volume of water comprising produced water and seawater
- Cell sediment: sand and mineral particles coated with a film of oil that settled out from the crude oil while it was being stored, to form a layer on the cell base
- A layer of organic deposits on the cell walls as a result of microbial activity and the accumulation of waxes, asphaltenes and other oil-derived materials

The URS study was based on the following information and assumptions:

- The oil phase was characterised from information provided by Shell [89], including samples taken from within the GBS cells of Brent D, supplemented by analyses of Brent oil samples
- The aqueous phase was characterised from information provided by Shell, including samples taken from within the GBS cells of Brent B and Brent D
- No direct data are available for the sediment phase but sediment samples have been collected and analysed from:
  - the topside separators at Brent
  - Brent crude storage tank at Sullom Voe terminal
  - inside Brent Spar, which stored oil for export from the Brent Field

  The sediment is likely to be a mixture of: produced sand, organic material, solids from the closed drainage system (e.g. shot from blasting operations), corrosion products/scale, oil and wax, water, H_2S and traces of production chemicals.

The main chemical characteristics of the various phases on the Brent D GBS storage cells, and the potential changes following CoP are estimated to be [89]:

- The chemistry of all phases of the cell is likely to be dominated by the presence of elevated concentrations of petroleum hydrocarbons, that may result in any microflora present rapidly depleting any available oxygen and nitrate
- This may result in the formation of hydrogen sulphide, with a dissolved phase concentration of approximately 1,000 mg/l predicted. Even though this is within the solubility limits there is potential for localised break out which may result in gas cap formation

- Following CoP there may be a predicted fall in temperature from 25°C to sea temperature (5-8°C)
- The attic oil may largely retain the characteristics of crude oil. If oil remains after CoP then its viscosity could increase, this could result in increased deposition of wax on the inner surface of the cell, and the precipitation of asphaltenes in the wax
- The interphase layer (oil in water emulsion) may have hydrocarbons concentrations of 200 mg/l
- Within the aqueous phase, lower concentrations of oil-related constituents may be encountered. More soluble alcohols and aldehydes are anticipated, as well as organic acids in high concentrations
- The sediment phase is likely to be a chemically heterogeneous material. Concentrations of hydrocarbons may be in the order of 100,000 mg/kg (i.e. 10%) and BTEX (Benzene, Toluene, Ethylbenzene, and Xylene) in the 1,000's mg/kg, with organic acids in similar proportions. Following CoP, the sediment may continue to provide an on-going source of hydrocarbons for microbial degradation (however there is believed to be a lack of bacteria inside the cells, possibly because all the nutrients and electron acceptors have been consumed). There is significant potential for methane formation posed by the mass of hydrocarbons present. Concentrations of PCBs and chlorinated solvents may be present (anticipated to be <5 mg/kg wet weight of chlorinated solvents and <1 mg/kg PCBs).

The existing data set compiled from previous analytical measurements (well heads, topside separator, produced water, export line, storage cells) was then used by Shell to estimate the potential concentrations of various chemicals that could be present in the cell sediment or cell water (see Section 11.7.1.1). These concentrations were then increased by 20% and used as input parameters to a series of initial modelling reports which investigated possible release scenarios and environmental impacts of the release of the cell contents. The concentrations were later increased three-fold and modelling scenario 14 rerun with these updated concentrations. Finally, the modelling scenarios were re-run with the data gained from the successful recovery of samples from the Brent Delta cells (see Section 11.2.3). The BMT modelling reports are discussed further in Section 11.7.1.

11.2.2 Predictions of Sediment Level in Cells

As part of the Brent D decommissioning project scope, various studies have been commissioned by Shell to try to predict the quantity of sediment in the GBS storage cells, including:

- Snaith, 1997 [90]
- Sigma 3, 2007 [91]
- Aker Kvaerner, 2007 [92]

In 2008 Shell [93] analysed and reviewed these studies and discussed their assumptions, shortcomings and merits. Based on this information as well as production history, chemical use, fluid analysis and certain assumptions taken from data on sediment found in Brent Spar and at another platform in the North Sea, a further estimate was made by Shell of the cell sediment height. The study estimated that between 0.29 m to 0.35 m of sediment is likely to

be present in the cells, considerably less than previous estimates. This was because the earlier studies made significant assumptions that could affect the estimates.

The cell sediment heights estimated in the various studies are summarised in Table 11-2.

Table 11-2: Estimated Sediment Heights

Report	Level Sediment Height Estimate (m)	Upper Sediment Height Estimate (m)
Snaith 1997	4.17	6.67
Sigma 3(basis 1) 2007*	As Snaith	As Snaith
Sigma 3 (basis 2) 2007**	16.67	33.33
Aker Kvaerner 2008	2	6
Shell report 2008	0.29	0.35

*Basis 1: Directly based on Snaith report
**Basis 2: Based on sand flow rate, % of sand dropping out of cells and density of sand particles

The estimate by Sigma 3 (basis 2) has been discounted as the results indicate heights of sand and sediment that are not compatible with operation records. Such a high level of sand would have blocked the water ballast line located at the bottom of cells and permanently prevented fluid circulation, and no such event has been recorded. If this estimate is discarded, the estimated height of sediment varies from 0.3 m to 6.7 m. Given this range, Shell took 4 m as a working assumption for the height of sediment in all the oil storage cells, and used this for the engineering of the remediation options for all three GBS platforms. In reality, however, Shell expects that the actual height of sediment will vary from one cell to another. As increased sand production was expected towards the end of the production phase, various cells have been taken out of service permanently or for extended periods of time. This could have resulted in different levels of sediment accumulation in the Brent D and Brent B storage cells.

In 2011 Shell examined several potential exposure scenarios of the cell contents to the marine environment. The report [88] outlined the parameters to be used in a modelling exercise (this report as well as modelling of cell contents release is described in Section 11.7.1). A 4 m sediment height was assumed by Shell as described above within the oil storage cells, and was used as the initial basis in DNV GL's *Impact Assessment of the Exposure of Brent Field GBS Cell Contents to the Marine Environment* [94] (Section 11.7.1.3).

11.2.3 Cell Sampling on Brent Delta

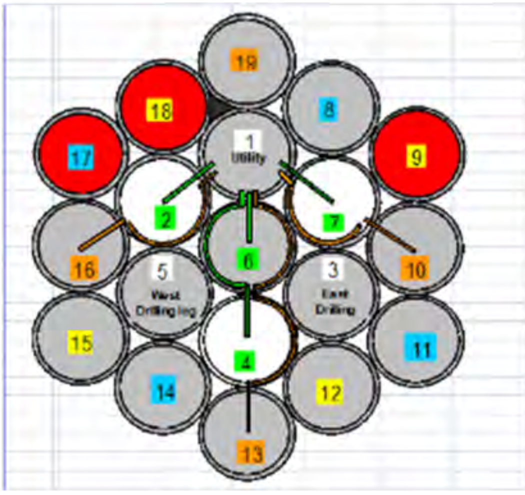
As described earlier, the Brent Decommissioning Project was able to derive from operational records and existing data, a set of assumptions to describe the cell contents. These assumptions were used to develop an initial set of remediation concepts. However, Shell also recognised the need to validate these assumptions by comparing against actual measurements. A sub-project was subsequently launched to develop the necessary equipment in order to carry out a cell content sampling operation on the Brent D platform.

During the initial phase of engineering development, it emerged that the scope of the sampling and surveys had to be balanced out against the corresponding technical challenges in order to keep the offshore execution within pragmatic boundaries. After this phase, the objectives of this sub-project were set as follows:

- to collect fluid samples (oil and water) and sediment samples
- to launch a 3D sonar device to obtain the sediment surface topography and identify the depth and thickness of the sediment

Three storage cells (9, 17 and 18 as shown on Figure 11-3 below) on Brent D were selected for access mainly because of their favourable location with respect to the topside cranes which were required to deploy the equipment from the topside.

Figure 11-3: Location of the Storage Cells on Brent D selected for Access (9, 17 and 18)

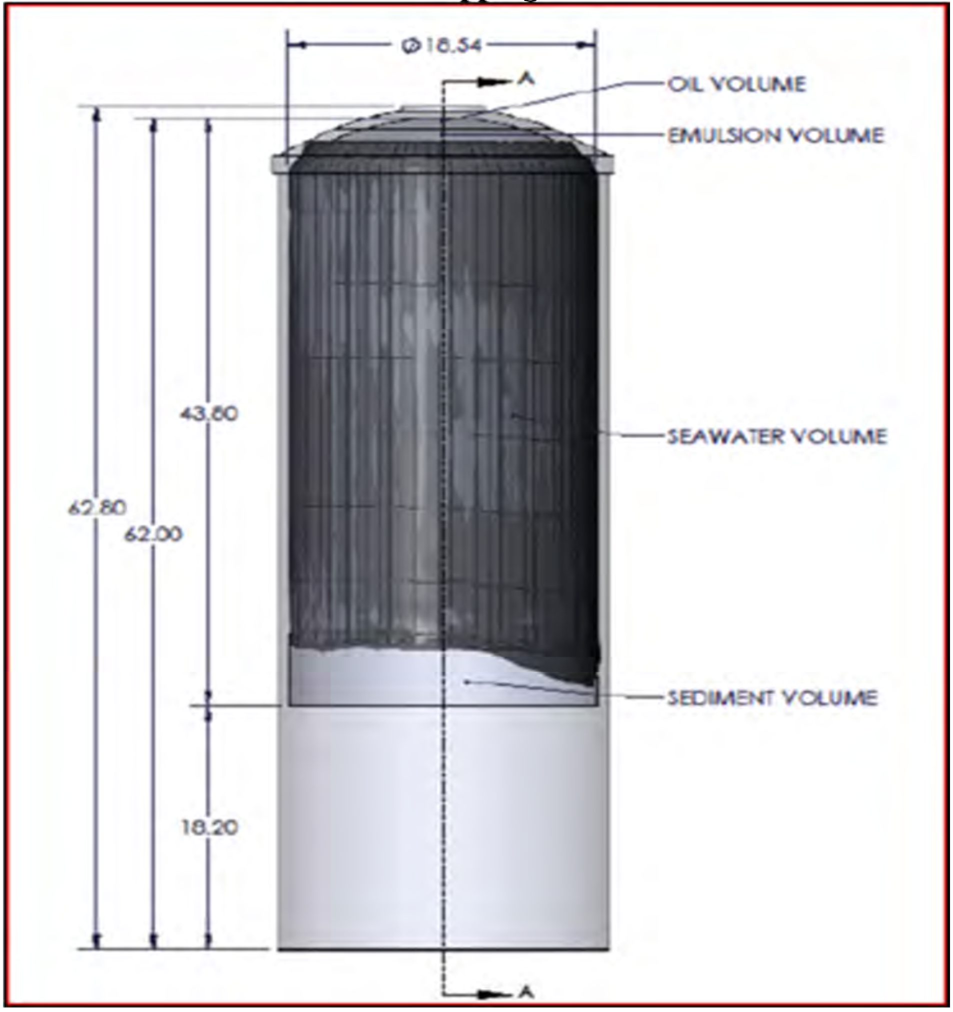


The 3D Sonar survey confirmed the presence of a sediment layer at the bottom of all three storage cells and the presence of a remaining hydrocarbon inventory at the top of the water column. The processing of the sonar profiles enabled calculations of the sediment and hydrocarbon volumes in each of the three cells. The average sediment volume of 1,044 m^3 is very close to the assumption of 1,080 m^3 derived during earlier engineering studies prior to cell sampling.

Table 11-3: Calculated Sediment Volumes in Brent D Cells based on Sonar Profile Measurement

	Cell 9	Cell 7	Cell 18	Average
Sediment Volume (m^3)	852	1,185	1,095	1,044 +/- 150 (vs. assumption of 1,080)
Average Sediment thickness (m)	3.1	4.4	4.1	3.9

Figure 11-4: Surface Topography of Sediment in Cell 18 derived from 3D Sonar Mapping



The sediment samples collected during the operation were sent to a 3rd party laboratory (SGS UK Ltd.) for analysis. The recovery, storage and handover of the samples were witnessed by an independent 3rd party controller (BV).

Samples from the same cell and same location were co-mingled to provide sufficient volume to carry-out the planned analytical program. The comparisons between the initial assumptions and the results obtained on the sediment and water samples are presented in Table 11-4 and Table 11-5 below:

Table 11-4: Comparison between the Initial Assumptions and the Measurements made of the Sediment Samples Collected from Cells 9, 17 and 18

Platform	Brent D Initial Modelling Assumptions	Brent D Modelling Assumptions (Scenario 14)	Cell sampling (CSP) Data (average result of duplicate)			
			Cell 9	Cell 17	Cell 18	Average
Shear strength (Pa)			***43.8***	***124***	***80.5***	***82.8***
density (specific gravity)	Oil: 0.859	Oil: 0.859	0.806	0.817	N/A	0.812
	Solids: 2.650	Solids: 2.65	2.28	2.72	2.65	2.55
	Water: 1.021	Water: 1.021				
	bulk density: 1.611	bulk density: 1.611	1.25	2.09	2.15	1.83
Cell sediment material	% oil/organics: 28	% oil/organics: 28	38.8	22.1	13.2	24.7
Proportions (% volume)	% water: 33	% water: 33	38.5	51.3	56.5	48.8
	% sediment: 39	% sediment: 39	22.7	26.6	30.2	26.5
Chemical Name	**Initial Concentration (mg/kg)**	**Concentration (mg/kg)**				
Mercury	4.16	12.5	0.3	0.086	0.07	0.15
Copper	1,118	3,355	43.1	82	1.65	42.25
Zinc	2,028	6,084	54.4	170	28.5	84.3
Naphthalene	301	904	56	18	16.5	30.2
Benzo(a)pyrene	172	515	0.55	0.2	0.3	0.4
Phenanthrene	913	2,740	27	14.5	1.4	14.3
Benzene	1,010	3,031	***1,165***	***1,200***	1,000	***1,122***
Total PCBs	0.12	0.36	<0.001	<0.001	<0.001	<0.001
THC	110,000	330,000	***134,000***	***167,500***	***156,360***	***152,620***
Tributyl Tin	0.26	0.77	<0.001	<0.001	<0.001	<0.001
Phenols	82.7	248	1.65	79.35	***158.5***	79.8

Numbers highlighted in ***bold italics*** are those CSP measurements that are higher than the initial assumptions (but lower than the revised concentrations in scenario 14, where concentrations of the contaminants were three times greater than initial assumptions).

Note that some free oil was identified inside the gravity corer on top of the sediment core, and it is possible that this oil may have been released from the sediment as a result of the sediment samples undergoing pressure reduction (alternatively it could have been attic oil which leaked into the sample vessel during the sampling exercise). As the free oil was not analysed, Shell commissioned additional modelling using the OSCAR model that examined the release of free oil from the sediment, to determine if the resulting oil volumes on the sea surface and in the water column could present any environmental risk (see 11.7.7.1.2).

Table 11-5: Comparison between the Initial Assumptions and the Measurements made of the Water Samples Collected from Cells 9, 17 and 18

Chemical Name	Initial Assumed Concentration (mg/l)	Measured concentration (mg/l)		
		Cell 9	Cell 17	Cell 18
Mercury	0.0022	0.0019	***0.0032***	0.00079
Copper	0.33	<0.162	<0.016	<0.016
Zinc	2.568	<1.4	<1.2	<1.2
Naphthalene	0.496	0.035	0.036	0.0058
Benzo(a)pyrene	0.052	<0.002	0.0005	<0.0001
Phenanthrene	0.198	<0.002	0.024	0.003
Benzene	112.8	4.92	7.25	1.6
Total PCBs	0.012	<0.0001	<0.0001	<0.0001
THC	503	30	***1,081***	139
Tributyl Tin	0.00008	<0.001	<0.0002	<0.001
Phenols	0.474	<0.3	0.412	0.37
Organic Acids	876	8.55	8.125	100

Numbers highlighted in ***bold italics*** are those measurements that are higher than the initial assumptions

It can be seen in the above tables that for most parameters (although not all), the initial assumptions greatly overestimated the chemical concentrations detected in the cell contents. For example, Benzo(a)pyrene, PCB and Phenanthrene concentrations are orders of magnitude lower than initial assumptions (between 60-500 times lower). This is discussed further in Section 11.7.1.3.

11.3 Inventory of Materials

The inventory of materials for the GBS cell contents is given in Table 11-6. All of the below volumes are estimates from Shell and have been summarised for this report.

Table 11-6: Estimated GBS Cell Content Volumes post Cell Sampling Project [88]*

Content	Origin	Brent B (m^3)	Brent C (m^3)	Brent D (m^3)***
Attic Oil	Oil trapped at top of cells	0**	11,116	960-2,880
Water	Produced, ballast and drainage water	164,416	311,667	161,536 -163,456
Sediment	Water-in-oil emulsion in inorganic & organic particles	16,704	6,035	16,704

* Brent B and D have been amended based on the cell sampling results, whereas Brent C volumes have remained as assumed.

** Shell believes attic oil is only present on Brent C and D. On Brent B, the exit to the oil export pipe is flush with the top of the cell dome; hence potentially there is no trapped oil there. However, recent operational evidence suggests the presence of a residual hydrocarbon emulsion in some of the cells. At the time of writing, an estimate of this volume cannot be determined, so it has been excluded from all DNV GL assessments.

***The sonar probe struggled to find the interface between the water and interphase material, hence ranges are given.

11.4 Available Decommissioning Options

11.4.1 Attic Oil and Interphase Material

It is believed that the attic oil (the volume of oil trapped above the exit to the export pipe inside the cells) is only present on Brent C and D. On Brent B, the exit to the oil export pipe is flush with the top of the cell dome; hence potentially there is no trapped oil there. However, interphase material (this is between the attic oil phase and underlying aqueous phase and consists of emulsified oil droplets) may have been left inside some of the storage cells (the quantity of interphase material is unknown). BEIS expect that attic oil and interphase material will be removed during decommissioning.

Shell has committed to removing the attic oil and interphase material from every cell as far as practical and hence, this scope of work does not serve to differentiate any of the cell contents options.

The current method preferred for recovering the remaining oil and interphase material on Brent D following CoP is to create a new subsea access point on top of the cells and pump out the mobile hydrocarbons from the cells into a chosen collection cell. The base case is to do so while topsides are still in place to take advantage of the additional barrier provided by drawdown. Once collected into a single cell, the mobile hydrocarbons will then likely be transferred direct from the cell to a vessel for onshore treatment and disposal. The optimisation concept to utilise the platform export system is still under consideration for Brent B and C.

The method could be applied similarly for all three GBS; however alternative options may be applied as follows:

- On Brent B there is the potential to use existing pipework to recover the remaining hydrocarbons instead of the creation of a new subsea access point.
- On Brent C the attic oil and interphase material could be recovered using the 2” vent lines (small vents provided to release air when the platform was installed, which may still be open).

These alternative options to recover the attic oil at Brent B and C would reduce the need to disturb the cell top drill cuttings in order to gain access to the cells at these platforms. However, these alternative options would only be pursued if the cell contents are left in place, as there would then be no need to access the cells on Brent B and C via a subsea access point. There is some uncertainty over the feasibility of these alternatives due to the unknown integrity of some of the pipework.

In all cases the recovered fluids would be recycled or disposed of in an appropriate location.

11.4.2 GBS Cell Water and Sediments

Numerous engineering solutions were considered by Shell for managing or remediating the cell contents. These are listed in Table 11-7.

Table 11-7: Possible Solutions for the Management of Cell Contents [87]

Main treatment location		Description of the concept
In situ Treatment		Biological degradation of hydrocarbons in water and sediment Chemical degradation of hydrocarbons in water and sediment Solvent extraction of hydrocarbons in water and sediment Capping of sediment layer
Onshore		Dewatering of slurry then Low Thermal Desorption treatment of solids
Offshore Treatment	Topsides	Incineration Injection of retrieved sediment and water slurry in existing platform well Dewatering of retrieved slurry and treatment of solids onshore Dewatering of slurry, treatment of solids by Low Thermal Desorption on topsides
	Vessel	Injection of retrieved slurry into new wells

These options were reduced by Shell to five technically feasible options (see Section 11.6) by examining the combination of access, retrieval, transportation, treatment and disposal programmes that would be required for each one. Further detail on the full engineering assessments of each of these long-list options can be found in Shell's Technical Document for the Brent GBS Contents Decommissioning [87].

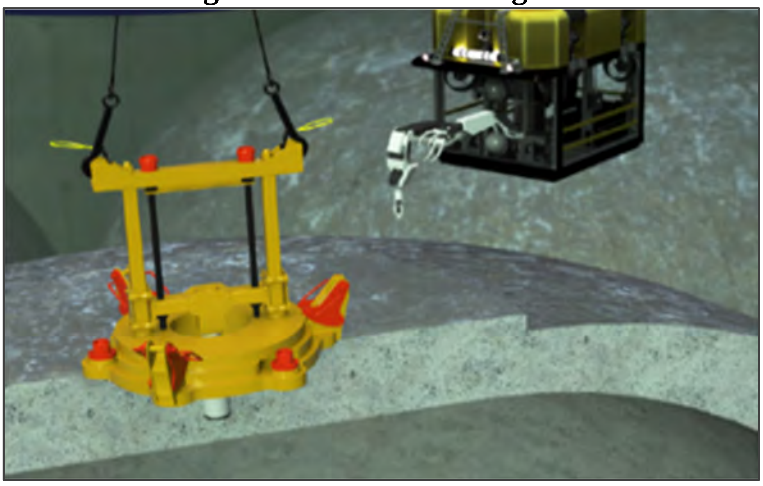
11.5 Description of Proposed Programme of work to remove Attic Oil

The option assessed in this ES for decommissioning the Attic Oil is:

GBS Attic Oil	COMPLETE REMOVAL
	Option 1. Recover to shore.

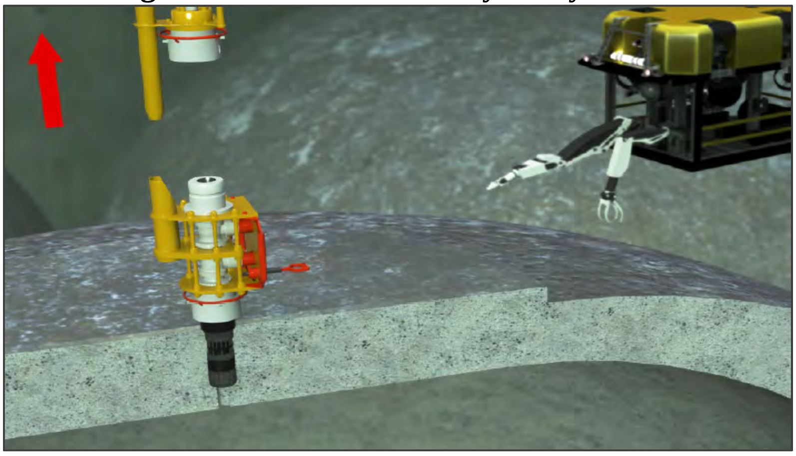
A diameter of approximately 3m will be cleared of debris in the centre of the cell top using a platform based ROV. A location plate will then be installed and a core drill tool guided/latched into position (see Figure 11-5) to enable the core drill to penetrate 575 mm into the cell cap concrete. The core will be caught and retrieved within the drill bit.

Figure 11-5: Core drilling tool



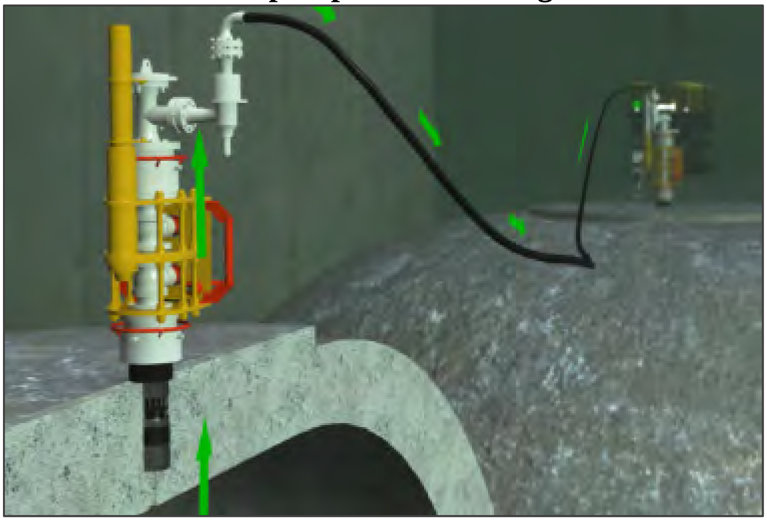
An anchor hub and valve block assembly will then be installed to enable the remaining core to be drilled through with an 86 mm core drill bit. The valves are closed and the drilling tool recovered to surface leaving the cell with a new subsea access point (Figure 11-6).

Figure 11-6: Valve assembly ready for use



A pump tool is attached to the valve block on the donor cell and the ROV connects a transfer hose onto the pump tool and routes it across to the connector on the nominated collection cell. The pump is then used to transfer the mobile hydrocarbons out of the donor cell (Figure 11-7). A window in the pump tool allows visual and UV monitoring of what is flowing from the cell and a conductivity sensor is also incorporated to assist in determining when the transfer is complete. It may be necessary to inject chemicals (e.g. wax solvent) to make it easier to pump the attic oil.

Figure 11-7: ROV monitors pumped fluid through a window in the pump

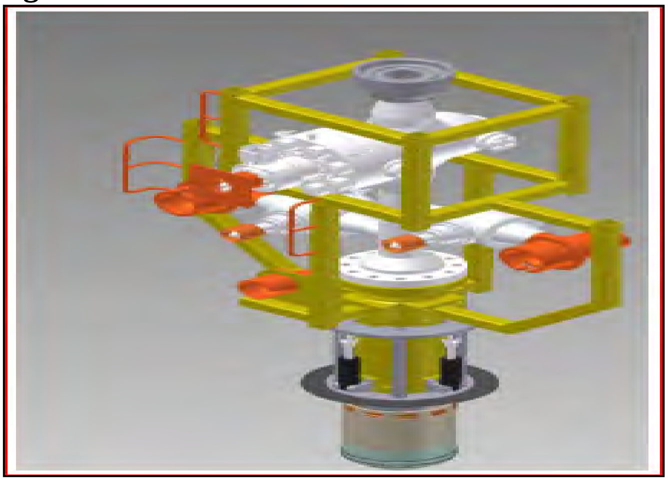


The isolation valves are closed, the hose flushed with sea water into the storage cell, disconnected and the pump tool recovered. Once access to the cell is no longer required, a retrievable mechanical plug is set through the valve block into the anchor hub. Once tested the valve block is removed to surface and a debris cap locked onto the anchor hub (Figure 11-8).

Figure 11-8: Install debris cap

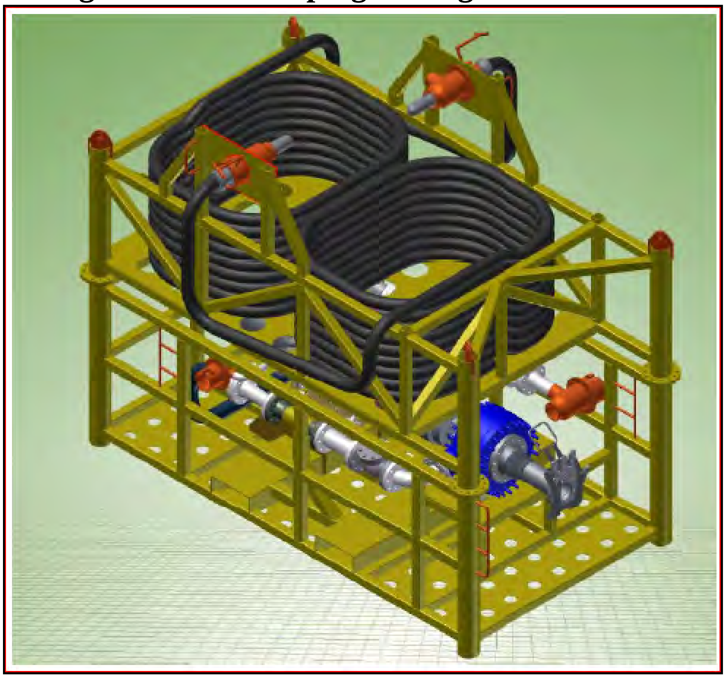
After the topside has been removed, a vessel based operation will be launched to recover the oil and interphase material stored in one of the storage cell. In order to re-connect to that cell, a steel baseplate will be installed on the flat part of the top of the cell. A drilling stack will be lowered onto the baseplate from a vessel and used to drill a 7-9" (approximately 0.2 m) hole through the concrete structure. In order to extract fluids from the storage cells a fluid head module (Figure 11-9) will be deployed subsea and attached to the baseplate by a subsea connector.

Figure 11-9: Schematic of the Fluid Head Module



A subsea pumping and agitation module (Figure 11-10) will be installed on the seabed adjacent to the GBS in a location selected to minimise seabed and drill cuttings disturbance, and to minimise the risk of dropped objects onto the cells. This module is designed to inject chemicals such as H_2S scavengers in order to reduce the H_2S concentration within the fluids pumped back to the vessel. An ROV will be used to connect a fluid suction jumper between the pumping module and the cell top.

Figure 11-10: Pumping and Agitation Module



Once the system is installed and connected to the vessel the attic oil and interphase material will be pumped onto the vessel while H_2S scavenger (approximately 680 m^3 for 3 GBS) is injected and subsequently recovered with the fluids. Due to deck storage requirements the vessel will be able to work on four cells consecutively and will then need to return to port to offload the recovered fluids and re-load with H_2S scavenger before returning to the platform.

Following recovery, the attic oil will be reused or recycled, depending on its characteristics and composition. During the extraction of the fluids from the storage cell, seawater will be let in through the decommissioned drawdown system in order to compensate for the volume extracted. At the end of the recovery process, the valve on the baseplate at the top of the storage cell will be left closed.

11.6 Description of Technically Feasible Decommissioning Options for GBS Cell Water and Sediment

Five options are considered in this ES for the management of the GBS cell contents:

COMPLETE REMOVAL	COMPLETE REMOVAL	LEAVE IN PLACE AND CAP	LEAVE IN PLACE WITH MNA	LEAVE IN PLACE
Option 1. Mobilise and retrieve to vessel and re-inject into new remote subsea wells away from site.	**Option 2.** Mobilise and retrieve to vessel and dispose onshore.	**Option 3.** Cap or cover *in situ* in the cells using sand and coarse gravel.	**Option 4.** Leave *in situ* in the cells and improve natural biodegradation by adding chemicals. Monitored Natural Attenuation, MNA.	**Option 5.** Leave *in situ* in the cells for natural biodegradation.

The following resources would be required.

Table 11-8: Resource Use Required for all Options

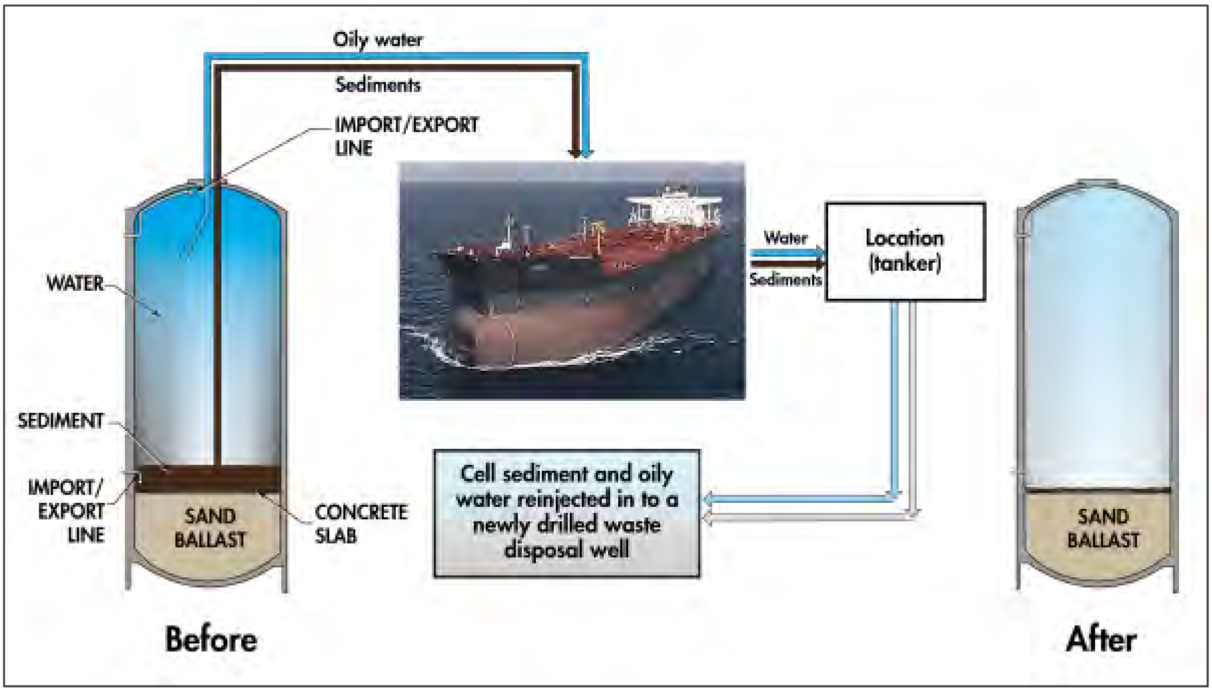
	Option 1: Recover and Re-inject	Option 2: Remove to Shore	Option 3: Leave in Place and Cap	Option 4: Leave in Place with MNA	Option 5: Leave in Place
Steel (tonnes)	2600	705	615	600	0
Water H_2S scavenger (m^3)	9,700	9,700	9,700	9,700	0
Capping agent (m^3)	0	0	11,800	0	0
Structural agent (m^3)	0	0	19,600	0	0
Nutrient water phase (t)	0	0	3,500-5,500	3,500-5,500	0
Nutrient sediment (t)	0	0	0	6,900-10,900	0

Note: The above figures represent the total estimated amount of materials required for all three GBS.

11.6.1.1 Option 1: Recover and re-inject

As shown in Figure 11-11, Option 1 would involve recovery of the cell contents to a vessel and disposal by injecting them into new purpose-drilled wells within the Brent Field.

Figure 11-11: Graphic of GBS Cell Contents Option 1 [Shell 2016]



Three or four new subsea wells would be drilled away from the platforms to accommodate the retrieved slurry from the cells. These would be drilled by a semi-submersible drilling unit held on location (possibly by anchors). Options for using existing Brent wells were examined and not found to be technically feasible [87].

If necessary, the cells would be dosed with H_2S scavenger to reduce the H_2S concentration in the fluids returning to the vessel. The water phase (approximately 640,000 m^3 for all 3 GBS) would first be pumped out through the small access hole previously used for removal of the

attic oil and interphase material and then replaced with seawater through the ballast lines. A CSV would be deployed to create a large access hole (~5 m) on the cell tops by cutting a hole using abrasive water-jet cutting, and lifting and removing the cut concrete section using the vessel crane. The concrete section would be recovered on deck for onshore disposal. Suitable arrangements, such as a fabrication of a steel lid, would be made to prevent the water phase from escaping to sea.

Once the large subsea access hole has been created a dredging tool, either ROV mounted dredger or crawler, would be lowered into the storage cell by the vessel crane. The dredging tool used would fluidise the sediment with the water pumped through the nozzle, subsequently recovering a large quantity of water as well as sediment. Based on the volume of the sediment the likely total volume of slurry for all three GBS would be approximately 600,000 m^3. A Discflo pump, installed on top of the cell or on the seabed, would be used to pump the slurry from the cell to the deck of the CSV. It is estimated that it may take approximately 8 days to remove all the sediment from one of the GBS oil storage cells.

The slurry would be transferred by floating hose to a tanker for temporary storage and then be transported by the tanker to the selected injection well location elsewhere in the Brent Field. The remaining empty cells would be fitted with steel lids.

A Light Well Intervention Vessel (LWIV) would be used for injecting the slurry. The tanker would connect to the LWIV via floating hose and slowly transfer the slurry as the injection process is carried out taking approximately 6 days per cell. The tanker would be stationed on DP or on anchors whilst loading. This may require the installation of an offshore loading buoy during transfer from the CSV to the tanker, and then from the tanker to the LWIV. On the LWIV a small buffer tank would allow adjustments to be made to the chemistry of the slurry before it is injected. Chemicals such as viscosifier, O_2 scavenger and H_2S scavenger may need to be added before the slurry is pumped down the well.

It is likely that the subsea wells would require work-overs once the sediment from each platform had been injected, and allowances for such activities have been made in the plan. Once all the waste from all three platforms had been re-injected the wells would be plugged and abandoned by the LWIV or the MODU.

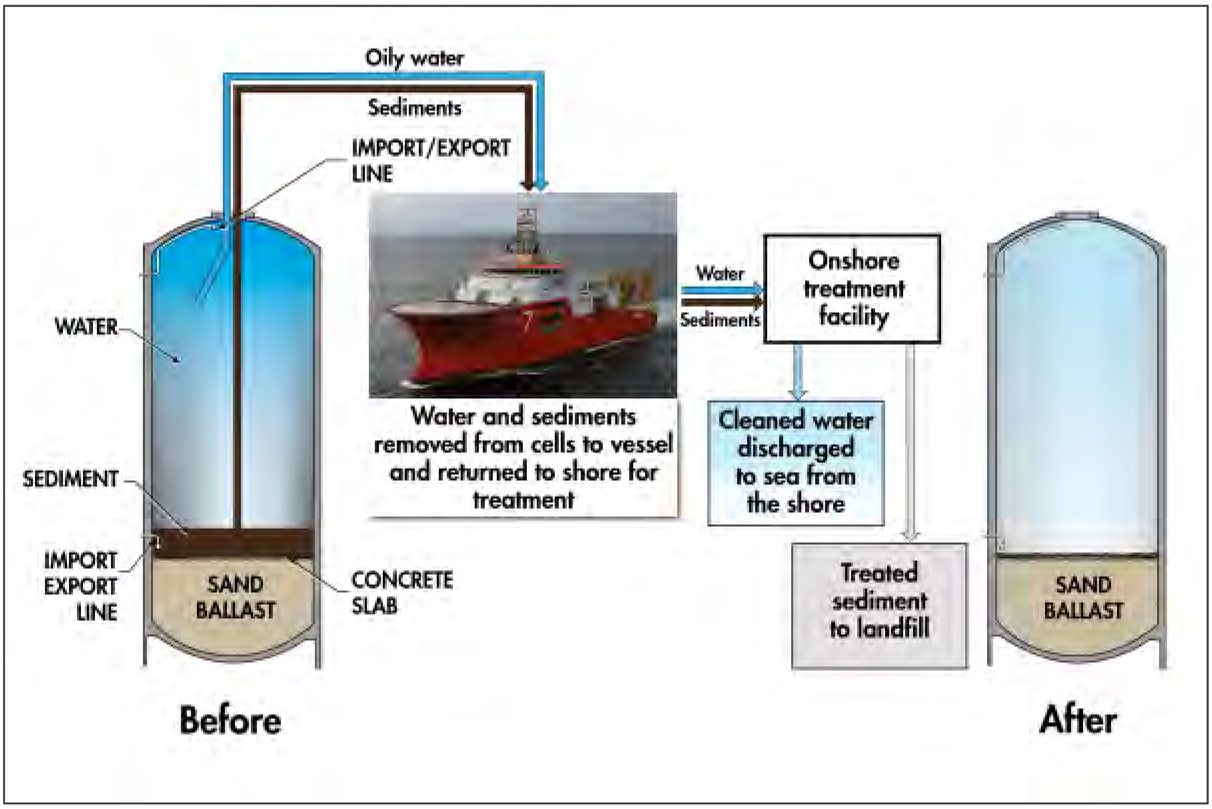
Table 11-9: Chemicals used in GBS Cell Contents Option 1

	Brent B	Brent C	Brent D
Water H_2S scavenger (m^3)	4,000	1,700	4,000

11.6.1.2 Option 2: Recover to shore for treatment

Option 2 would involve recovering the cell contents to a vessel and transporting them to shore for treatment and disposal (Figure 11-12).

Figure 11-12: Graphic of GBS Cell Contents Option 2 [Shell 2016]



If necessary, the cells would be dosed with H_2S scavenger to reduce the H_2S concentration in the fluids returning to the vessel. The water phase (approximately 640,000 m^3 for all 3 GBS) would first be pumped out through the small access hole previously used for removal of the attic oil and interphase material and then replaced with seawater through the ballast lines. A CSV would be deployed to create a large access hole (~5 m) on the cell tops by cutting a hole using abrasive water-jet cutting, and lifting and removing the cut concrete section using the vessel crane. The concrete section would be recovered on deck for onshore disposal. Suitable arrangements, such as a fabrication of a steel lid, would be made to prevent the water phase from escaping to sea.

Once the large subsea access hole has been created, a dredging tool, either an ROV mounted dredger or crawler, would be lowered into the storage cell by the vessel crane. The dredging tool used would fluidise the sediment with the water pumped through the nozzle, subsequently recovering a large quantity of water as well as sediment. Based on the volume of the sediment the likely total volume of slurry for all three GBS would be approximately 600,000 m^3. A Discflo pump, installed on top of the cell or on the seabed, would be used to pump the slurry from the cell to the deck of the CSV. It is estimated that it may take approximately 8 days to remove all the sediment from one of the GBS oil storage cells.

The slurry would be transferred by floating hose to a tanker for temporary storage and then be transported by the tanker to a UK port close to a suitable treatment facility. The remaining empty cells would be left open to sea.

At the reception site the oil, water and solids would be separated. The water would be treated at the site and discharged to sea under appropriate permit conditions.

The dewatered solids may require further treatment, such as thermal desorption or incineration, prior to disposal at a suitable landfill site, depending on their exact composition.

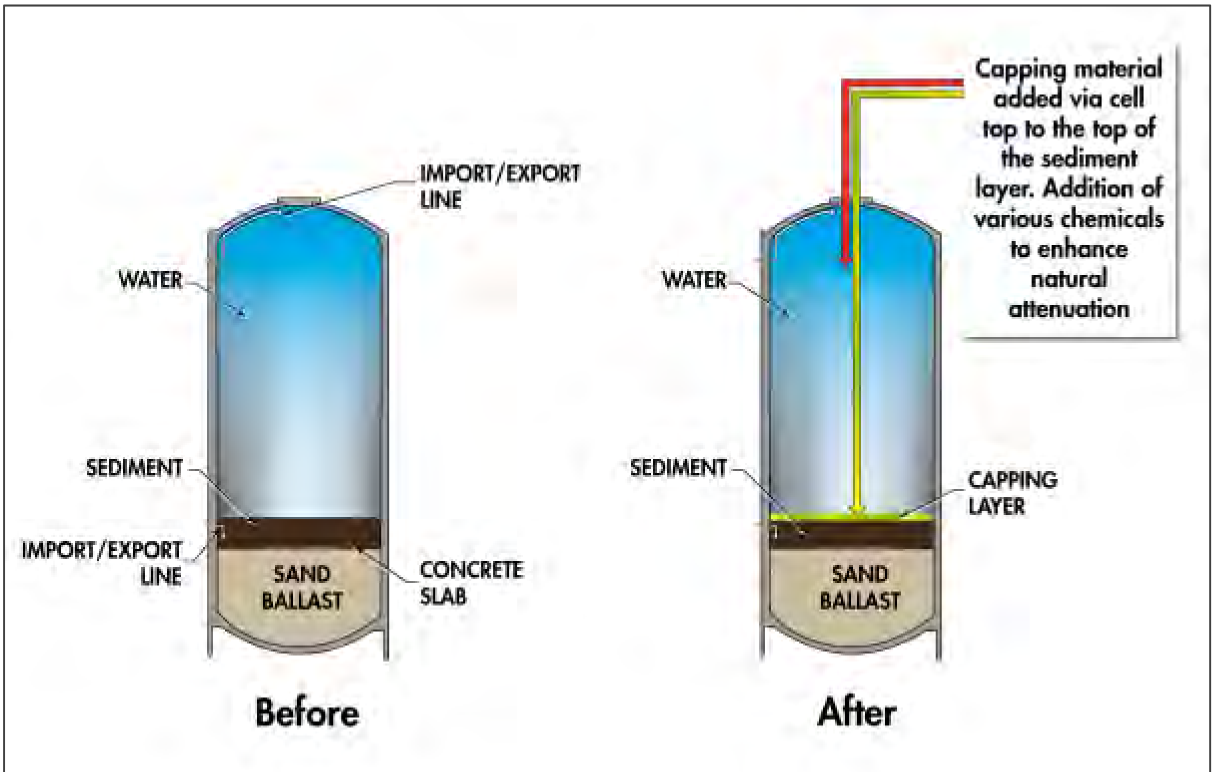
Table 11-10: Chemicals used in GBS Cell Contents Option 2

	Brent B	Brent C	Brent D
Water H_2S scavenger (m^3)	4,000	1,700	4,000

11.6.1.3 Option 3: Leave in place and cap

In Option 3, the cell sediments would be left in place and capped *in situ*. The capping layer would help minimise diffusion of the sediment into the water phase (and later into the sea) and also provide some mechanical protection to the sediment layer from falling debris/collapsing cell domes and walls (Figure 11-13).

Figure 11-13: Graphic of GBS Cell Contents Option 3 [Shell 2016]



The preferred capping agent is sand but as the top layer of sediment may exhibit a low bearing capacity, coarse gravel will be initially injected into the cell to act as a structural agent. The sand would then be deployed on top of the gravel/sediment mixture. Both the sand and gravel would be deployed through the subsea access hole created to remove the attic oil. A capping agent injection tool would be deployed from a MSV and used to inject the sand or gravel to cover the sediment with a layer around 1m thick. The capping agent would be injected using a carrier fluid. The volume of capping agent would vary between cells but it is estimated that a volume of approximately 11,800 m^3 for three GBS would be required. In addition to this volume, a volume of approximately 19,600 m^3 of structural agent (three GBS) would need to be injected in order to provide the necessary bearing capacity. The total volume of material to be injected in the three GBS would therefore be 31,400 m^3. The

displaced water would be recovered onto the vessel and either transported to shore for treatment and disposal or treated offshore prior to overboard discharge. Once the capping material is installed, a sonar mapping tool would be used to confirm that the sediment was fully covered to a suitable thickness. The work would be done in two phases: once the structural agent has been put in place, the access will be closed and time given for the particles to re-settle before injecting the capping agent.

The water remaining in the cells would be treated *in situ* using bio-stimulation or Monitored Natural Attenuation (MNA). This would involve the application of nutrients and electron acceptors into the cells to promote the biological degradation of hydrocarbons in the water phase. MNA would not have any effect on non-biodegradable contaminants such as heavy metals or NORM in the cell water or sediment.

The chemicals would be injected through the access hole using the capping agent injection tool and a subsea pumping unit.

MNA of the water phase would require subsequent visits to monitor effectiveness of the administered treatment. Chemicals that would be used in the treatment of cell contents under Option 3 are shown in Table 11-11.

Table 11-11: Chemicals used in GBS Cell Contents Option 3

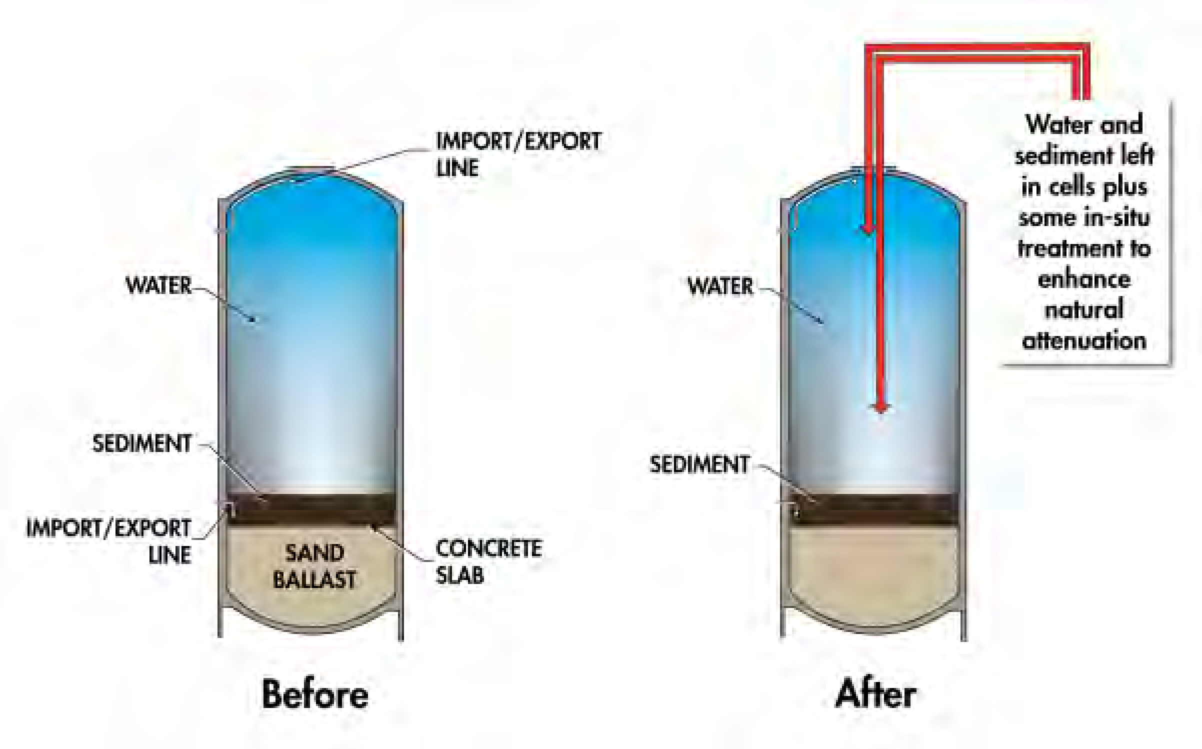
	Brent B	Brent C	Brent D
Structural agent (m^3)	8,000	3,600	8,000
Capping agent (m^3)	4,800	2,200	4,800
Water H_2S scavenger (m^3)	4,000	1,700	4,000
Calcium Nitrate $Ca(NO_3)_2$ (m^3)	800-1,300	1,525-2,450	800-1,300
Sodium Hexametaphosphate $Na(PO_3)_6$ (m^3)	80-112	150-215	80-112

In the long term, over hundreds of years, the structure would deteriorate and break-up (see Section 10.6.1), with exposure of the residual cell contents to the surrounding environment. The objective of this remediation concept is to reduce the dispersion of sediment during the final stage of the collapse of the concrete structure by providing a mechanical cover on top of the sediment and to reduce the leaching of contaminant into the water phase sitting above the sediment deposit.

11.6.1.4 Option 4: Leave in place with MNA

In Option 4, a set of chemicals would be injected into the cells to promote *in situ* natural biodegradation of the hydrocarbons, a process also referred to as Monitored Natural Attenuation or bio-stimulation. The selected process is based on stimulating nitrate reduction under anaerobic conditions. Two chemicals have been identified to bring the required amount of nitrate and phosphate into the water phase. The biological degradation is expected to promote hydrocarbon reduction in the water phase, the top 20-30 cm surface layer of cell sediment (sediment is 4 m deep) and on the surface of the deposit on the cell walls. MNA would not have any effect on non-biodegradable contaminants such as heavy metals or NORM in the cell water or sediment.

Figure 11-14: Graphic of GBS Cell Contents Option 4 [Shell 2016]



The cells would be accessed using the subsea access point created for the removal of the attic oil and interphase material. The bulk of water would be treated *in situ* using MNA. The chemicals would be injected using an injection tool connected to a subsea pumping unit. The current plan accounts for two injection campaigns.

The cell contents would be treated by the injection of chemicals (calcium nitrate $Ca(NO_3)_2$ and sodium hexametaphosphate $Na(PO_3)_6$) in the water column above the cell sediment. A certain amount of mixing will be provided for the water phase through the injection process but no mixing of the sediment would be generated. It is anticipated that the chemicals added would not diffuse very far into the sediment (20-30 cm). Therefore, the biological processes would stop at depths greater than 30 cm due to the lack of nutrients and electron acceptors.

The volume of chemicals required for each of the GBS is estimated in Table 11-12.

Table 11-12: Chemicals used in GBS Cell Contents Option 4

	Brent B	Brent C	Brent D
Water H_2S scavenger (m^3)	4,000	1,700	4,000
Nutrient water phase (t)	880-1,400	1,700-2,660	880-1,400
Nutrient sediment (t)	1,760-2,800	3,350-5,320	1,760-2,800

This dose of chemicals is designed to sustain the biological process in order to degrade the hydrocarbon within the water as well as within the top layer of the sediment (top 20 to 30 cm), but would also aim to treat any of the hydrocarbons which might eventually leach from the sediments. Following injection of the chemicals the access hole would be left closed (i.e. valve left shut) but not plugged.

Any fluid displaced, due to the introduction of volumes of nutrients into the cells, would be recovered to the surface vessel via the annulus between the inner and outer pipes. Once on the vessel, it would be collected and transported onshore for treatment and disposal or treated offshore prior to overboard discharge.

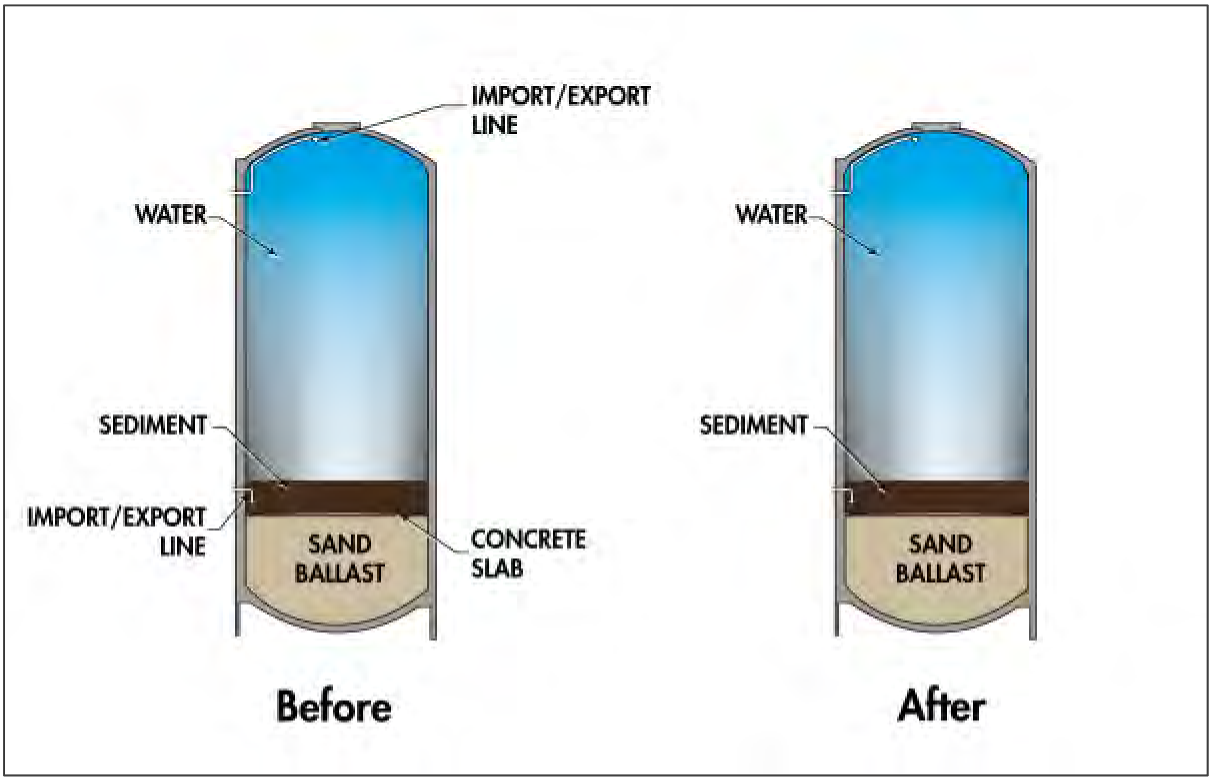
MNA would require subsequent visits to monitor the effectiveness of the administered treatment on the cell sediments. Sampling surveys would be performed periodically to check on the status of the water phase and sediments, and the attenuation in the Brent GBS storage cells.

In the longer term, over hundreds of years, the structure would deteriorate and break-up (see Section 10.6.1), with exposure of the residual cell contents to the surrounding environment. The objective of this remediation concept is to reduce as much as possible the hydrocarbon content within the water phase and the top layer of sediment prior to the collapse of the concrete structure in order to minimize the dispersion of contaminants into the marine environment.

11.6.1.5 Option 5: Leave in place

In Option 5, the cell sediments and water would be left in place untreated (Figure 11-15).

Figure 11-15: Graphic of GBS Cell Contents Option 5 [Shell 2016]



In the longer term, over hundreds of years, the structure would eventually deteriorate and break-up, exposing the cell contents to the surrounding environment, as described in Section 10.6.1.

11.7 Significant Impacts of Decommissioning Options

Appendix 1 documents the assessment of environmental impacts for all categories for the options to decommission the GBS cell contents. This section provides a summary of the Appendix 1 impact assessment matrices, discussing only the most significant impacts identified (those with either ‘small-moderate negative’ impacts or worse, or ‘small-moderate positive’ impacts or better).

The impact assessment considers the total impacts that would result from decommissioning the cell contents at all three GBS. The attic oil and interphase material will be removed and recovered for all options and as a result are not differentiators between options.

11.7.1 Information to Support Environmental Assessment

This section summarises studies that have been conducted to support the assessment of GBS cell contents.

If the GBS are left *in situ* to degrade naturally, the GBS cell contents will ultimately, in hundreds of years’ time, become exposed to the local marine environment as the GBS break up and deteriorate. The results of a study examining the structural integrity of the GBS legs and caisson and eventual collapse of the structure is summarised in Section 10.6.1.

To try to predict the impact of the exposure of the cell contents to the marine environment, desk studies and modelling has been conducted by Shell and several consultants and samples have been collected by Shell. DNV GL has interpreted the results of these studies, which are summarised in the following sub-sections.

11.7.1.1 Studies to estimate cell content parameters for initial modelling work

To assess the potential environmental impact of exposure of the cell contents to the marine environment, a 2011 Shell study [88] considered a range of release scenarios. The amounts of water and sediment that might be exposed to the marine environment were estimated to produce a range of six release scenarios, which formed the basis for modelling work conducted by BMT Cordah [95]. The cell water and sediment parameters used in the modelling are detailed in the following subsections.

Produced water and cell water chemical analyses

Chemical analyses have been conducted by Shell [88] on Brent B, C and D produced water, as well as on Brent B and D cell water, to understand the quality of the cell water.

For each compound analysed, the highest value plus 20% (as a contingency factor) was established as a modelling parameter by Shell and later used in BMT’s environmental modelling study [95] to predict the potential contaminant concentrations in the surrounding environment should cell water be released to the environment following GBS degradation.

Table 11-13 shows the analysis of water samples taken from the three platforms and the resulting values when 20% is added.

Table 11-13: GBS Cell Water Analysis in mg/l [88]

Compound (mg/l)	Brent B Cell Water		Brent C Produced Water		Brent D Cell Water		Brent D Utility Leg		Brent D West Drilling Leg		Brent D Max Highest +20% value
	Highest	+20%	Highest	+20%	Highest	+20%	Highest	+20%	Highest	+20%	
Mercury	0.002	0.002	0.002	0.002	0.001	0.001	0.0004	0.0005	0.001	0.002	0.002
Copper	0.003	0.004	1.2	1.44	0.04	0.05	0.017	0.02	0.28	0.33	0.33
Zinc	0.045	0.055	0.144	0.173	0.90	1.08	1.6	1.9	2.1	2.57	2.57
Naphthalene	0.276	0.331	0.217	0.260	0.413	0.496	0	0	0	0	0.496
Benzo(a)pyrene	0.0002	0.0002	0.002	0.002	0.043	0.052	0.001	0.002	0.0001	0.0001	0.052
Phenanthrene	0.037	0.044	0.011	0.013	0.165	0.198	0.067	0.08	0.0001	0.0001	0.198
Benzene	0.047	0.056	29	34.8	94	112.8	0.1	0.12	0.1	0.12	112.8
Total PCBs	0.42	0.504	Assume 0.504		0	0	0.01	0.012	0.01	0.012	0.012
H_2S	1,000	1,200	1,000	1,200	1,000	1,200	1,000	1,200	1,000	1,200	1,200
THC	466	559	137	164	419	503	32	38	2	3	503
Tributyl Tin	0.00002	0.00002	0.00008 (assume)		0.00002	0.00002	0.00007	0.00008	0.00001	0.00001	0.00008
Trichlorobenzene	0.05	0.06	Assume 0.06		Not measured		0.002	0.0024	0.002	0.0024	0.0024
Total Phenols	0.74	0.89	3.84	4.6	0.39	0.47	0.002	0.002	0.005	0.006	0.47
Organic Acids	684	821	383	438	730	876	Not measured		Not measured		876

Sediment chemical analyses

For all GBS, a 4 m sediment height was assumed by Shell [88] at the base of the oil storage tanks above the sand ballast, as discussed in Section 11.2.2 and illustrated in Figure 11-4. For Brent C, 1 m of sediment within the connected, adjacent, peripheral water coolant cells was also assumed.

No sediment samples have been collected at the base of the GBS storage cells at the time that modelling was initially performed. The sediment concentrations used to model the sediment release from the GBS were based on the highest values from the analysis of sand collected from the test separator on Brent C and the sediment collected in the base of the Brent D minicell annulus and west drilling leg. Similar to the cell water analysis, these values, plus 20% (as a contingency factor) were established as modelling parameters by Shell and used in BMT's initial modelling [95] to predict the potential contaminant concentrations in the environment should cell sediment be exposed following GBS degradation. The sediment chemical analyses at Brent C and D are detailed in Table 11-14. The samples were analysed for these contaminants because of their potentially harmful ecological effects.

Table 11-14: Sediment Chemical Analysis at Brent C and D [88]

Compound	Brent C Test Separator		Brent D Utility Leg		Brent D West Drilling Leg		Maximum Highest +20% Value
	Highest Conc	+20%	Highest Conc	+20%	Highest Conc	+20%	
Mercury (mg/kg)	1.66	1.99	3.47	4.16	0	0	4.16
Copper (mg/kg)	137	164.4	932	1,118	120	144	1,118
Zinc (mg/kg)	313	375.6	12.3	14.76	1,690	2,028	2,028
Naphthalene (mg/kg)	251	301	1.3	1.6	0.35	0.42	301
Benzo(a)pyrene (mg/kg)	143	172	1	1.2	0.04	0.04	172
Phenanthrene (mg/kg)	761	913	2.9	3.5	0.77	0.92	913
Benzene (mg/kg)	842	1,010	0.2	0.24	0.2	0.24	1,010
Total PCBs (mg/kg)	0.0002	0.0002	0.1	0.12	0.0002	0.0002	0.12
H_2S(mg/kg)	5,000	6,000	5,000	6,000	5,000	6,000	6,000
THC (mg/kg)	38,983	46,780	91,011	110,000	11,594	13,913	110,000
Tributyl Tin (mg/kg)	0.006	0.007	0.21	0.26	0.001	0.001	0.26
Trichlorobenzene (mg/kg)	0.1	0.12	0.1	0.12	0.1	0.12	0.12
Total Phenols (mg/kg)	67.9	82.7	9.2	11	6.1	7.3	82.7
Organic Acids (mg/kg)	Not Measured						

Summary of cell water and cell sediment concentrations

Table 11-15 summarises the selected cell water and cell sediment concentrations (as described above) in Shell's numerical modelling study [88] and later used in BMT's environmental modelling study [95]. The attic oil at the top of the storage cells will be removed prior to decommissioning, and was thus not modelled.

Table 11-15: Compounds and Concentrations Modelled [88]

Compound	Water (mg/l)			Sediment* (mg/kg)	$PNEC_{water}$ (mg/l)	$PNEC_{sediment}$ (mg/kg)	Potential Ecological Effects
	Brent B	Brent C	Brent D				
Mercury	0.002	0.002	0.002	4.16	0.0018	0.13	Toxic to aquatic organisms, can cause long-term damage to environment
Copper	0.004	1.44	0.33	1,118	0.0048	18.7	Bioavailable, potential to yield toxic effects.
Zinc	0.055	0.173	2.57	2,028	0.09	124	In aquatic systems bioaccumulates in plants and animals.
Naphthalene	0.331	0.26	0.496	301	0.668	0.35	Very toxic to aquatic organisms, may cause long-term harm
Benzo(a)pyrene	0.0002	0.0024	0.052	172	0.00009	0.089	Carcinogen/mutagen. Very toxic, may cause long-term damage
Phenanthrene	0.044	0.013	0.198	913	0.0077	0.087	Harmful
Benzene	0.056	34.8	112.8	1,010	0.5	NA	Carcinogen, highly toxic to

Compound	Water (mg/l)			Sediment* (mg/kg)	$PNEC_{water}$ (mg/l)	$PNEC_{sediment}$ (mg/kg)	Potential Ecological Effects
	Brent B	Brent C	Brent D				
							aquatic organisms.
Total PCBs	0.504	0.504	0.012	0.12	0.00014	0.022	Accumulates with adverse effect on marine environment
H_2S	1,200	1,200	1,200	6,000	0.012	NA	Highly toxic to aquatic life
THC	559	164	503	110,000	0.1	50	Toxic at high concentration
Tributyl Tin	0.00002	0.00008	0.00008	0.26	0.00042	0.015	Very toxic, may cause long-term adverse effects to aquatic organisms
Trichlorobenzene	0.06	0.06	0.0024	0.12	0.16	0.19	Toxic to aquatic life
Total Phenols	0.89	4.6	0.47	82.7	0.58	0.42	Biodegradable, hazardous to waters
Organic Acids	821	438	876	Not Measured	NA	NA	Mildly toxic to aquatic organisms, high concentration in water

*Worst case modelling scenario (modelling scenario 14) for cell sediment conservatively assumed three times greater than the concentrations detailed in this table

11.7.1.2 BMT Cordah Modelling

BMT conducted several modelling studies [95] on behalf of Shell to try to estimate the chemical concentration gradients resulting from the exposure to the water column of the 14 contaminants (listed in Table 11-15) thought to be contained within the GBS cell water (101,900 m^3 exposure scenario from 1 GBS) and cell sediment (12,960 m^3 exposure scenario from 1 GBS), following degradation of the GBS caissons. As mentioned in the previous sections, modelling of the cell contents, and in particular, the cell sediment was carried out in a number of stages: the initial modelling scenarios assumed a starting THC of 110,000mg/kg for the cell sediment based upon evidence from surrogate samples taken from other areas of the Brent Delta platform, including a 20% increase in concentration as a contingency and sediment volumes of 3,000 and 6,000m^3. A second set of modelling then increased the starting concentrations of the cell sediment by three-fold, including THC from 110,000 to 330,000mg/kg in a particular modelling scenario 14, which also assumed an increased sediment volume of 12,960 m^3. (Finally, the cell sediment modelling was later revised on the basis of the CSP results, see Table 11-4 and Section 11.7.1.3).

The scenarios modelled by BMT are conservative in that:

- they assume that the volume of cell contents are released instantaneously to the environment (i.e. the release event itself was not modelled). In terms of volume, this is a conservative modelling scenario as it is unlikely that such a large proportion of the GBS cell sediment would instantaneously be exposed to the marine environment, sitting as a pile on the seabed, unprotected by any remains of the GBS. The more realistic exposure scenario is gradual but increasing exposure of the cell contents as the cell dome collapses and the cell walls begin to fail. Some of the collapsed GBS is likely to fall onto the cell sediment and partially reduce its exposure to the environment.
- All environmental fate and effect modelling involves uncertainty, so it is also for the models and impact assessments applied in this EIA. Some uncertainties are related to model input parameters, like contamination concentrations, currents, water temperature, etc. These uncertainties can be handled by running the models with varying input

parameters, or take a cautious approach and run the model with conservative input parameters. Other uncertainties are model inherent and cannot be varied, and these are handled by taking a conservative approach. Thus, BMT and DNV GL have applied a cautious approach in modelling the GBS cell water and sediment release. The results from the modelling are considered to be conservative, though sufficient for assessing the potential impact from a release of GBS cell water and sediment.

- They assume that none of the contaminants in the cell water or cell sediment adsorb onto the organic matter in the water column and sediment or bioaccumulate. As such, whatever is released to the environment is assumed to remain bioavailable.
- Scenario 14 initially assumes very high initial concentrations of cell sediment contaminants (three times greater than the concentrations originally modelled (Table 11-15), which equates, for THC, to approximately twice the average value measured during cell sampling in the CSP, see 11.7.1.3).
- Toxicity limits for PNEC are conservatively derived. The toxicity results for the most sensitive tested organism are used for each environmental compartment. In addition, a contingency factor, normally ranging from 10 – 1000, is applied to make the PNEC limit more robust.
- PNEC is derived from toxicity test using the most toxic state of the substances, as for instance for mercury where methylmercury has been applied.
- The initial modelling simulated continuous spreading of substances without any degradation. And when degradation is included, the applied half-lives are in the conservative range of the identified degradation rates.

Refinement of the above assumptions is likely to show that the predicted impact is overstated by these results.

Conversely:

- The total volume of cell water in a GBS is greater than that modelled, as is the (predicted) total volume of cell sediment in Brent B and D (Brent C is lower).
- The modelling considered the release from only one GBS.
- The modelling scenarios did not account for some possible disturbance of cell sediment due to impact from falling pieces of concrete and debris during GBS degradation (see Section 11.7.1.4 for discussion of ‘dynamic release’).

11.7.1.3 Cell sampling on Brent D

The modelling studies described above were initially based on desk studies, operational records and assumptions. There was a need to collect and analyse cell content samples to validate this initial work. The cell sampling work on Brent D is described in Section 11.2.3. For most parameters, the initial assumptions were found to overestimate the chemical concentrations in the cell contents.

It should be noted that sampling was very difficult to do, and samples were only collected in three of the Brent D GBS cells, and only of the top 0.5 m of sediment (the average sediment thickness is 3.1 to 4.4 m deep). There is no guarantee that the samples are representative of all GBS cell contents.

11.7.1.4 DNV GL Toxicology Study

Based on BMT's modelling results, DNV GL conducted a toxicology study titled *Impact Assessment of the Exposure of Brent Field GBS Cell Contents to the Marine Environment* [94] that assessed the environmental impact of the 14 contaminants for both the cell water and cell sediment release. DNV GL's assessment compared BMT modelling results for predicted environmental concentrations (PEC) against predicted no effect concentrations (PNEC) based on water regulatory criteria for cell water release and based on sediment quality guidance or regulatory criteria for cell sediment release. The results showed that PEC exceeded the PNEC for many contaminants; hence an environmental impact for these scenarios is predicted.

The results of BMT's modelling work and DNV GL's toxicology study are used primarily to assess the legacy impacts to the marine environment of the different decommissioning options, as discussed in the sections below.

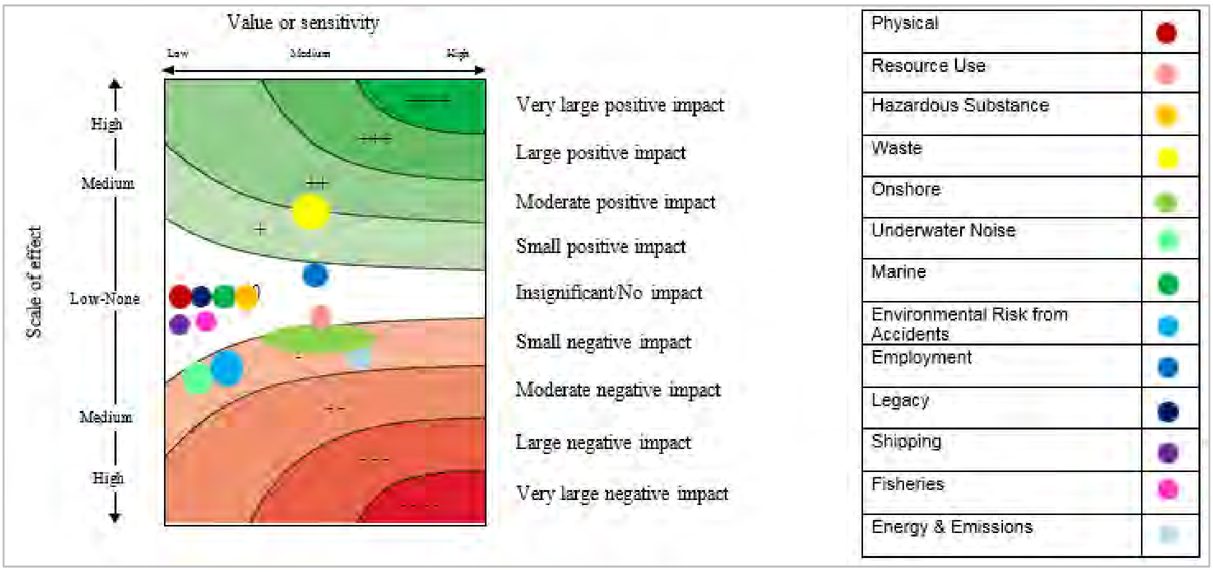
It should be noted that the DNV GL toxicology study was written in two phases:

- the initial assessment was based on 14 contaminants modelled by BMT Cordah, with concentrations and inventory estimated by Shell (as described above in Sections 11.7.1.1 and 11.7.1.2). The modelling was deliberately conservative, assuming, for example, instantaneous release of contaminants, high initial chemical concentrations, and no removal of the organic constituents by biodegradation.
- the updated assessment was based on measured concentrations of the same contaminants from samples taken inside different cells of the GBS at Brent D (as described above in Section 11.7.1.3). In addition, two new substances (octylphenol and nonylphenol) were incorporated into the assessment. Consideration was also given to the possible change to microbiological fauna as a result of a cell sediment release. This stage also included revised modelling results to show the effects of:
  - biodegradation of hydrocarbons and hydrogen sulphide
  - varying particle density
  - dynamic sediment release from height (e.g. due to disturbance of cell sediment by falling pieces of concrete), rather than static release. Additional modelling was conducted with variations of the cell sediment release scenarios (dynamic release versus static release). Of the dynamic release modelling scenarios commissioned by Shell, DNV GL examined the scenario that released 10 m^3/day for 1 year (3,650 m^3 of sediment), representing a significant amount of cell sediment to be fully re-suspended in the water column for dispersion around the platform (~21% of Brent B or Brent D cell sediment, or ~60% of Brent C cell sediment) as that gave the biggest seabed impact of the various dynamic release scenarios. The new modelling results show that although dynamic sediment release scenarios would result in larger areas of the seafloor being contaminated (the PEC:PNEC>1 covers much wider areas), approximately 97% of this area has a sediment thickness of less than 1 mm, and hence is not expected to have any harmful impact on biota once mixing by bioturbation has been taken into account. The seafloor with >10 mm contaminated sediment and PEC:PNEC>1 is expected to cause harmful effects on the biota. Dynamic modelling results show that 0.06 km^2 seafloor would have such conditions. This is close to the 0.05 km^2 footprint with potential harmful effects that was derived from the updated static modelling.

11.7.2 Removal of Attic Oil (all options)

Approximately 12-14,000 m^3 of attic oil would be recovered from the GBS and returned to shore, treated and the oil recovered. As shown in Figure 11-16, the most significant impact identified is in the waste category. Estimated impacts are considered small or insignificant for all other categories.

Figure 11-16: GBS Attic Oil Option 1: Recover to shore



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- The Energy and Emissions impact has been sourced from: DNV GL, *Energy and Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

11.7.2.1 Waste Management

The beneficial effect of recovering the attic oil under Option 1 is estimated to be **'small-moderate positive'**.

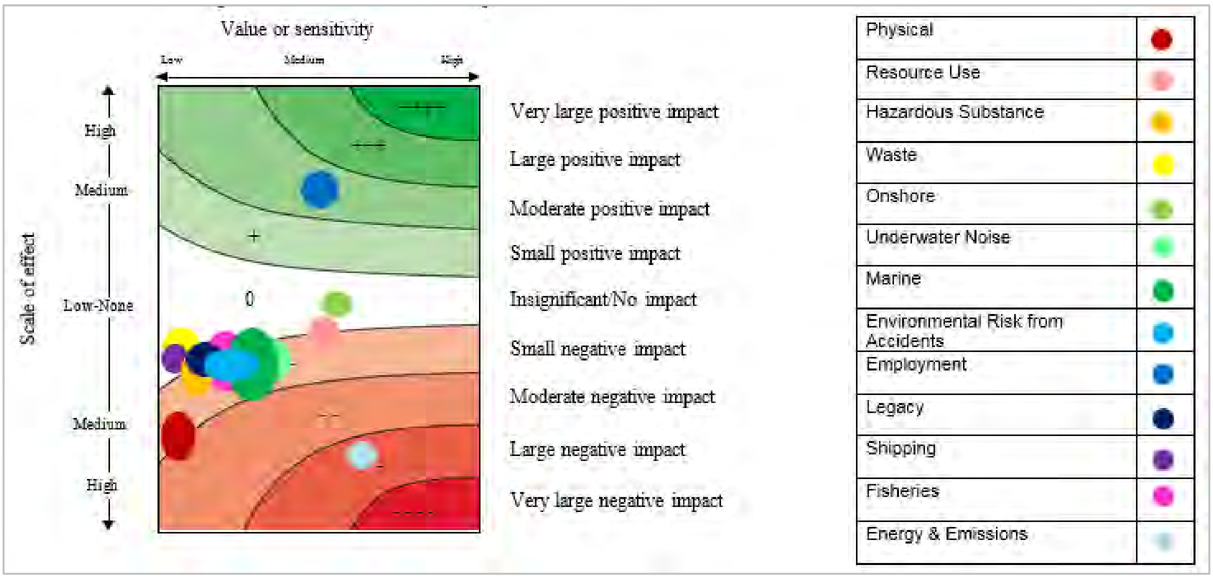
This option involves recovering approximately 12-14,000 m^3 of attic oil and interphase material from Brent B and D and this will have a positive effect as the waste oil will be brought to shore, treated and reused. A 'small-moderate positive' impact is allocated as the oil has volume and value.

11.7.3 Option 1: Recover and re-inject

Under Option 1, the GBS cell contents would be recovered to a vessel and re-injected into new remote subsea wells away from the platform, drilled specifically for this purpose. Re-injection removes the main legacy issue presented if the cell contents are left in place.

As shown in Figure 11-17 the most significant impacts identified are in the physical, employment and energy and emissions categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 11-17: GBS Cell Contents Option 1: Recover and Re-inject



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

11.7.3.1 Physical

The overall physical impact as a result of GBS cell content decommissioning activities under Option 1 is estimated to be **'small-moderate negative'**.

Under Option 1, vessels such as DSVs and drilling rigs may operate using anchors, which can cause local disturbances on the seabed as a result of anchor pits. However, the Gardline Debris Geosurvey conducted in 2006 [22] identified evidence of extensive trawling and anchoring activity in the form of trawl scars, anchor pull-out pits and scars throughout the survey area. No pockmarks were identified, and all seabed depressions were attributed to anchoring or construction activity.

The overall physical impact from Option 1 is estimated to be 'small-moderate negative' because of the combination of physical effects related to:

- Vessel anchor pits: each anchor could be approximately 5-6 m wide and 3-4 m high.
- Drilling of 4 new offshore wells: the drilling rig mooring arrangement would typically require 6-8 anchors placed 1-1.5 km away with mooring chains in between.
- Drilling activities would produce WBM top-hole cuttings that could disperse and settle with a 1-10 mm thick layer, within 150 m from the discharge point. Any WBM cuttings discharged overboard would result in dispersion over a large area [96]. Any possible OBM cuttings would be returned to shore and treated.

11.7.3.2 Employment

The overall impact on employment as a result of GBS cell content decommissioning activities under Option 1 is estimated to be **'moderate positive'**.

Shell commissioned an independent report to estimate the employment generated by the BDP. As part of this study, a factor was derived for the Brent project of £250,000 per new job

per year. This factor was then applied by Shell to estimate the man-years generated for each decommissioning option. Shell estimates that GBS cell contents Option 1 would generate 6,035 man-years of work. This option generates the highest level of employment of the technically feasible options considered in this EIA.

Although this number is relatively small when considered within a wider context (the UK oil and gas industry is estimated to employ 330,000 people [69]), 6,035 man years is still considered a ‘moderate positive’ benefit in recent times of relatively high unemployment in the UK oil and gas sector.

11.7.3.3 Energy & Emissions

DNV GL’s *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use as a result of decommissioning the cell contents at all three GBS under Option 1. Comparing this against the energy impact categories in Table 5-7, the impact from energy use is considered to be **‘large negative’**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

Table 11-16 to Table 11-18 show the energy and emissions for Option 1 ‘recover and re-inject’ cell contents into new remote subsea wells for each individual GBS, while Table 11-9 shows the total energy and emissions for all three GBS.

Table 11-16: Energy and Emissions from Brent B Option 1: ‘Recover and Re-inject’

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations	-	-	-	-
Marine operations	1,453,764	107,489	2,345	1,110
Onshore dismantling/ treatment	-	-	-	-
New material	30,333	2,383	3	5
Sum	*1,484,097*	*109,872*	*2,348*	*1,115*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	22,100	2,346[2]	2	1
Total	**1,506,197**	**112,218**	**2,350**	**1,116**

[1] Operations categories are defined in Section 5.2.3.
[2] This includes oil (in sediments), which is not recovered and a CO_2 emissions penalty is applied for ‘lost’ oil

Table 11-17: Energy and Emissions from Brent C Option 1: 'Recover and Re-inject'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	1,152,400	85,235	1,877	745
Onshore dismantling and treatment	-	-	-	-
Onshore disposal	-	-	-	-
New material	30,333	2,383	3	5
Sum	*1,182,733*	*87,618*	*1,880*	*749*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	*22,100*	*2,131*	*2*	*1*
Total	**1,204,833**	**89,749**	**1,882**	**751**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3] This includes oil (in sediments), which is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

Table 11-18: Energy and Emissions from Brent D Option 1: 'Recover and Re-inject'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	1,455,574	107,627	1,571	1,110
Onshore dismantling and treatment	-	-	-	-
Onshore disposal	-	-	-	-
New material	30,333	2,383	3	5
Sum	*1,485,907*	*110,010*	*1,575*	*1,115*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	22,100	2,346[3]	2	1
Total	**1,508,007**	**112,356**	**1,577**	**1,116**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3] This includes oil (in sediments), which is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

Table 11-19: Total Energy and Emissions for all 3 GBS Cell Contents in Option 1: 'Recover and Re-inject'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	4,061,737	300,350	5,793	2,965
Onshore dismantling	-	-	-	-
Onshore disposal	-	-	-	-
New material	91,000	7,150	10	14
Sum	*4,152,737*	*307,500*	*5,803*	*2,979*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	66,300	6,822[3]	6	4
Total	**4,219,037**	**314,322**	**5,809**	**2,984**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3] This includes oil (in sediments), which is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

11.7.3.3.1 Energy consumption and CO_2 emissions

Under Option 1, GBS cell contents would be recovered to a vessel and re-injected into several newly drilled wells. The majority of emissions are expected from the marine vessels such as the DSV, LCV, pipelay vessel, supply vessel, mid-range tanker and drilling rig. There would be energy required to manufacture new materials such as steel for drilling wells. The calculations also include an energy and emissions 'penalty' for the loss of oil within the cell sediments that would not be recovered and for loss of material such as steel.

The vessel durations used within the energy and emissions calculations are included in DNV GL's *Energy Use and Gaseous Emissions Report* [2]. The total energy demand for recovering the sediment (into slurry form) and injecting to newly drilled wells for all three GBS is estimated to be 4.2 million GJ, primarily as a result of marine operations. The total CO_2 emissions ($CO_{2\ TOT}$) for all three GBS would be approximately 314,300 tonnes.

11.7.3.3.2 Emissions of NO_x and SO_2 to atmosphere

The majority of the gaseous emissions of NO_x and SO_x generated are likely to be quickly dispersed as they would be released offshore, and are therefore considered to be smaller contributors to the environmental impact than the more significant CO_2 emissions. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

11.7.3.3.3 Summary

The overall environmental impact of Energy and Emissions as a result of decommissioning the cell contents at all three GBS under Option 1 is estimated to be 'large negative', owing primarily to significant energy used during marine operations. The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put this into another context, the total

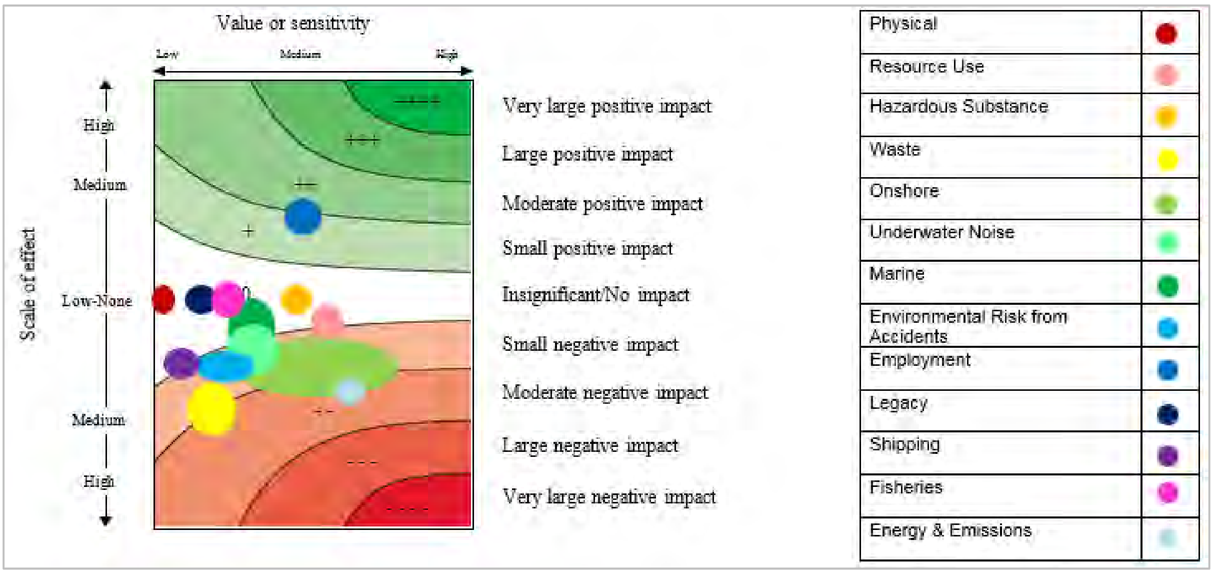
CO_2 emissions for Option 1 are approximately 13% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70].

11.7.4 Option 2: Recover to shore for treatment

Under Option 2, the GBS cell contents would be recovered to a vessel and transported to shore for treatment and disposal.

As shown in Figure 11-13, the significant impacts identified are in the onshore, waste, employment and energy and emissions categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 11-18: GBS Cell Contents Option 2: Recover to Shore for Treatment



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

11.7.4.1 Onshore Impacts

The overall onshore impact as a result of GBS cell content decommissioning activities under Option 2 is estimated to be '**small-moderate negative**' owing to the large quantities of material that would come onshore for handling, treatment and transportation. At this time the location of the onshore dismantling facility is not known, and the assessment incorporates this uncertainty.

11.7.4.1.1 Noise and dust

The recovery of the cell contents from the three GBS would generate large quantities of material that come to shore:

- Approximately 600,000 m^3 of cell content slurry
- Approximately 640,000 m^3 of cell water

The material brought to shore would be liquid which requires treatment and then transport offsite. For Option 2, there is no dismantling or deconstructing activities required onsite like

those necessary for the topsides, jacket and GBS, so noise and dust are unlikely to be the main concern. Regardless, noise and dust can result from increased traffic onsite and this would require management.

11.7.4.1.2 Traffic

Increased traffic onshore can result in nuisance to residents in the local area (and beyond) for a significant period of time, and good planning and timing of operations would be necessary. The large volumes of material coming onshore would, after treatment onsite, require significant quantities of materials to be transported offsite for recycling or recovery (waste oil) or to landfill (dewatered slurry).

It is assumed that the slurry would be dewatered at the onshore facility, such that only a small proportion of the slurry (the sludge resulting from dewatering) would need transporting on the external road network. Regardless, a significant number of journeys would still be required. The level of nuisance caused would depend on the transport infrastructure and the proximity of residents. The wastewater is assumed to be treated and discharged to sea under appropriate permit conditions.

11.7.4.1.3 Summary

In summary, Option 2 is estimated to have a ‘small-moderate negative’ impact onshore owing primarily to the increased traffic generated and consequent potential nuisance impacts upon local residents. Strict controls may be necessary to ensure impacts are managed effectively. When the onshore site is selected, the impact should be re-evaluated. Shell would only use onshore facilities that are licensed to receive decommissioning wastes and operations onshore would be carried out under responsible management and control, with all necessary permits and consents. As such it is anticipated that mitigation measures and strict onshore process controls would be in place to minimise these impacts. Previous experience of major decommissioning projects in the North Sea demonstrates that the impact potential to local communities can be effectively controlled and mitigated [67].

11.7.4.2 Waste

The impact in the waste category as a result of GBS cell content decommissioning activities under Option 2 is estimated to be **‘small-moderate negative’** owing to the large volumes of waste that would be generated and need management, the need to transport this waste to shore, treat the wastewater and dispose of the residual sludge to a dedicated landfill site.

From the three GBS, approximately 600,000 m^3 of slurry waste would be generated, in addition to 640,000 of cell wastewater, and transported to shore for treatment at a licensed onshore facility. Treated wastewater would be discharged to sea and residual sludge and solids sent to landfill. Disposal to landfill is likely to be the order of 40,000 tonnes.

There is some uncertainty about the composition of the slurry, and the dewatered solid waste may contain some NORM, and this would need to be taken into account when selecting the landfill site, as the sludge may require further treatment prior to disposal at a suitable landfill site, depending on the exact composition. If this option was selected, Shell should check capacity of landfills to accommodate NORM waste volumes.

11.7.4.3 Employment

The overall impact on employment as a result of GBS cell content decommissioning activities under Option 2 is estimated to be **‘small-moderate positive’**.

Shell commissioned an independent report to estimate the employment generated by the BDP. As part of this study, a factor was derived for the Brent project of £250,000 per new job per year. This factor was then applied by Shell to estimate the man-years generated for each decommissioning option. Shell estimates that GBS cell contents Option 2 would generate 1,410 man-years of work.

Although this number is small when considered within a wider context (the UK oil and gas industry is estimated to employ 330,000 people [69]), 1,410 man years is still considered a 'small-moderate positive' benefit in recent times of relatively high unemployment in the UK oil and gas sector.

11.7.4.4 Energy & Emissions

DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use as a result of decommissioning the cell contents at all three GBS under Option 2. Comparing this against the energy impact categories in Table 5-7, the impact from energy use is considered to be **'moderate negative'**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

Table 11-20 to Table 11-22 show the energy and emissions for GBS cell contents Option 2 for each GBS, while Table 11-23 shows the total energy and emissions for all three GBS.

Table 11-20: Energy and Emissions from Brent B Option 2: 'Recover to Shore for Treatment'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_x	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	365,186	26,936	559	169
Onshore treatment [3]	19,847	1,460	32	1
Onshore transport to disposal[4]	2,469	182	4	0
New material	-	-	-	-
Sum	*387,502*	*28,577*	*595*	*171*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	-	-	-	-
Total	**387,502**	**28,577**	**595**	**171**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3,4]The cell contents slurry brought onshore is dewatered, treated in low thermal desorption unit and transported offsite. This is accounted for in direct emissions onshore treatment, transport and disposal.

Table 11-21: Energy and Emissions from Brent C Option 2: 'Recover to Shore for Treatment'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	256,781	18,940	393	119
Onshore treatment [3]	7,129	524	12	0
Onshore transport to disposal[4]	887	65	1	0
New material	-	-	-	-
Sum	*264,797*	*19,529*	*406*	*120*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	-	-	-	-
Total	**264,797**	**19,529**	**406**	**120**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3,4]The cell contents slurry brought onshore is dewatered, treated in low thermal desorption unit and transported offsite. This is accounted for in direct emissions onshore treatment, transport and disposal.

Table 11-22: Energy and Emissions from Brent D Option 2: 'Recover to Shore for Treatment'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	365,186	26,936	559	169
Onshore treatment [3]	19,847	1,460	32	1
Onshore transport to disposal[4]	2,469	182	4	0
New material	-	-	-	-
Sum	*387,502*	*28,577*	*595*	*171*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	-	-	-	-
Total	**387,502**	**28,577**	**595**	**171**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3,4]The cell contents slurry brought onshore is dewatered, treated in low thermal desorption unit and transported offsite. This is accounted for in direct emissions onshore treatment, transport and disposal.

Table 11-23: Total Energy and Emissions from all 3 GBS Cell Contents in Option 2: 'Recover to Shore for Treatment'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	987,154	72,811	1,512	458
Onshore treatment [3]	46,823	3,444	76	3
Onshore transport to disposal[4]	5,824	428	9	0
New material	-	-	-	-
Sum	*1,039,800*	*76,683*	*1,597*	*461*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	-	-	-	-
Total	**1,039,800**	**76,683**	**1,597**	**461**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3,4]The cell contents slurry brought onshore is dewatered, treated in low thermal desorption unit and transported offsite. This is accounted for in direct emissions onshore treatment, transport and disposal.

11.7.4.4.1 Energy consumption and CO_2 emissions

Under Option 2, the cell contents would be recovered to a vessel and treated onshore. This would involve a mid-range tanker, DSV and LCV. The majority of emissions are from marine operations for the transportation of the sediment slurry to shore. The energy and emissions 'penalty' for the loss of oil within the cell sediments that would not be recovered (left in place) does not apply to Option 2.

The tanker fuel consumption data as reported by the Institute of Petroleum Guidelines [15] are applicable for the tankers of dead weight between 500 to 3,000 DWT. The vessel durations used within the energy and emissions calculations are included in DNV GL's *Energy Use and Gaseous Emissions Report* [2].

The total energy demand for recovering the sediment (in slurry form) from all three GBS and bringing it to shore for treatment is estimated to be 1 million GJ based on contributions from marine operations and onshore activities including dewatering the slurry onshore, treating the residue by low thermal desorption, and disposal. The total CO_2 emissions ($CO_{2\ TOT}$) from the operations at all three GBS would be about 77,000 tonnes of which the largest contribution would come from marine operations (72,800 tonnes, or 95% of total CO_2 emissions).

11.7.4.4.2 Emissions of NO_x and SO_2 to atmosphere

The majority of the gaseous emissions of NO_x and SO_x generated are likely to be quickly dispersed as they would be released offshore, and are therefore considered to be smaller contributors to the environmental impact than the more significant CO_2 emissions. Onshore emissions would be in line with permits. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

11.7.4.4.3 Summary

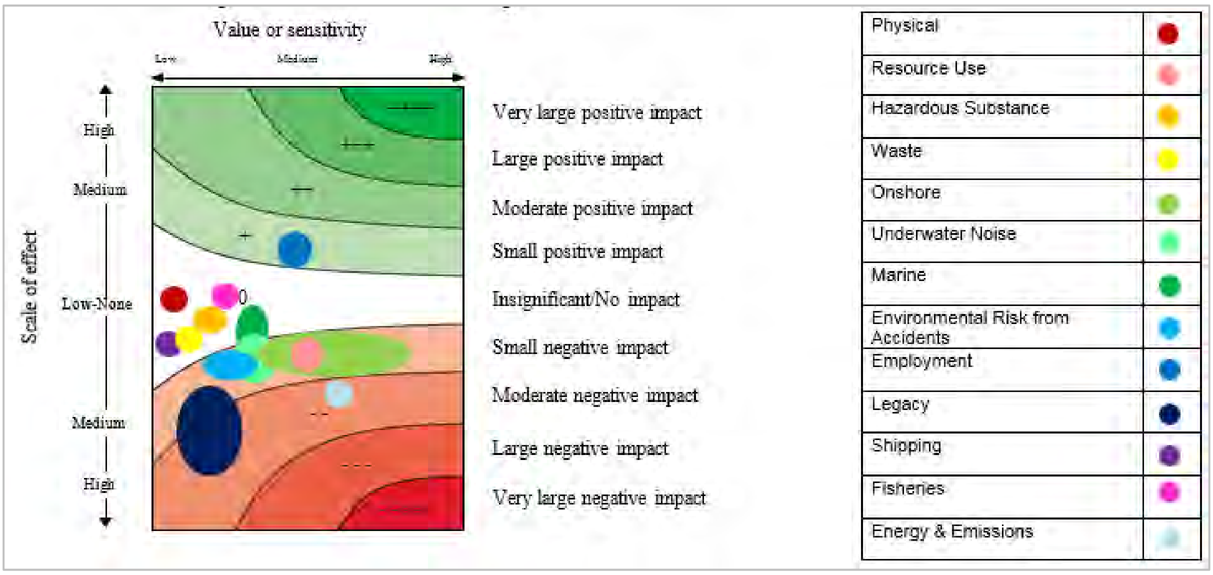
The overall environmental impact of Energy and Emissions as a result of decommissioning the cell contents at all three GBS under Option 2 is estimated to be 'moderate negative', owing primarily to the energy used during marine operations. The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put this into another context, the total CO_2 emissions for Option 2 are approximately 3% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70].

11.7.5 Option 3: Leave *in situ* and cap

Under Option 3, the GBS cell contents would be left *in situ* and capped (to help prevent diffusion of the sediment contaminants into the cell water phase, and later to the sea). The cell contents would remain in place until the GBS eventually degrade and the cell contents become exposed to the marine environment. The capping layer would restrict sediment exposure to some degree depending on the integrity of the capping layer at that future time.

As shown in Figure 11-19 the most significant impact identified are in the legacy and energy and emissions categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 11-19: GBS Cell Contents Option 3: Leave *in situ* and Cap



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact)
- Energy and Emissions data has been sourced from DNV GL's *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

11.7.5.1 Legacy

The overall legacy impact as a result of GBS cell content decommissioning activities under Option 3 is estimated to be **'small-moderate negative'** based on the analytical results shown in Table 11-4 ('moderate negative' based on the modelling results using the increased concentrations in modelling scenario 14).

The legacy impacts under Option 3 are estimated to be slightly less negative than Options 4 and 5, because the capping or covering of cell sediment would limit future exposure to the external marine environment, hence the scenario modelled by BMT (in which a large proportion of the total cell sediment from a single GBS appears on the seabed) would not be realised. As such, lower concentrations of contaminants would be expected in the local marine environment, and thus there would be a smaller impact, albeit the impact may take place over a longer time period. However, there would still be some environmental impact because:

- Biodegradation of the sediment would be limited by the cap; hence the cell sediment under the cap would remain contaminated over time and not degrade in part, as it would under Option 4.
- Some of the cell sediment would still ultimately be exposed to the marine environment after the cap deteriorates, albeit this would likely take place gradually as the cap degrades, and over a longer period of time.
- The effectiveness of the cap is uncertain. Also, the cap would be disturbed during caisson degradation and collapse, reducing the effectiveness of the cap to contain the cell sediment.

The reader should refer to Option 5 for more details on the interpretation of the BMT modelling and DNV GL toxicology report.

11.7.5.2 Energy & Emissions

DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use as a result of decommissioning the cell contents at all three GBS under Option 3. Comparing this against the energy impact categories in Table 5-7, the impact from energy use is considered to be **'moderate negative'**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

Table 11-24 to Table 11-26 show the energy and emissions for GBS cell contents Option 3 for each individual GBS, while Table 11-27 shows the total energy and emissions for all three GBS.

Table 11-24: Energy and Emissions from Brent B GBS Cell Contents Option 3: 'Leave *in situ* and Cap'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	421,044	31,056	645	195
Onshore treatment	-	-	-	-
Sum	*421,044*	*31,056*	*645*	*195*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	*ND*	*335*[2]	*ND*	*ND*
Total	**421,044**	**31,391**	**645**	**195**

[1] Operations categories are defined in Section 5.2.3.
[2] Oil (in sediments) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

Table 11-25: Energy and Emissions from Brent C GBS Cell Contents Option 3: 'Leave *in situ* and Cap'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	322,474	23,785	494	150
Onshore treatment	-	-	-	-
Onshore transport to disposal	-	-	-	-
New material	-	-	-	-
Sum	*322,474*	*23,785*	*494*	*150*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	*ND*	*120*[3]	*ND*	*ND*
Total	**322,474**	**23,905**	**494**	**150**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3] Oil (in sediments) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

Table 11-26: Energy and Emissions from Brent D GBS Cell Contents Option 3: 'Leave *in situ* and Cap'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	415,204	30,625	636	193
Onshore treatment	-	-	-	-
Onshore transport to disposal	-	-	-	-
New material	-	-	-	-
Sum	*415,204*	*30,625*	*636*	*193*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	*ND*	*335*[3]	*ND*	*ND*
Total	**415,204**	**30,960**	**636**	**193**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3] Oil (in sediments) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

Table 11-27: Total Energy and Emissions for all 3 GBS Cell Contents Option 3: 'Leave *in situ* and Cap'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	1,158,722	85,466	1,774	538
Onshore treatment	-	-	-	-
New Material	-	-	-	-
Sum	*1,158,722*	*85,466*	*1,774*	*538*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	*ND*	*790*[3]	*ND*	*ND*
Total	**1,158,722**	**86,256**	**1,774**	**538**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3] Oil (in sediments) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

11.7.5.2.1 Energy consumption and CO_2 emissions

Under Option 3, the GBS cell contents would be left *in situ* and capped. Almost all emissions are from marine operations and would involve a DSV, LWIW, supply vessel, ROVSV and survey vessel. The calculations also include an energy and emissions 'penalty' for the loss of oil within the cell sediments that would not be recovered. Emissions do not include for production of capping material. The vessel durations used within the energy and emissions calculations are included in DNV GL's *Energy Use and Gaseous Emissions Report* [2].

The total energy demand for leaving the sediment *in situ* and capping from all three GBS is estimated to be approximately 1.2 million GJ based mainly on contributions from marine operations. The total CO_2 emissions ($CO_{2\ TOT}$) from the operations at all three GBS would be about 86,200 tonnes of which 99% would come from marine operations.

11.7.5.2.2 Emissions of NO_x and SO_2 to atmosphere

The majority of the gaseous emissions of NO_X and SO_X generated are likely to be quickly dispersed as they would be released offshore, and are therefore considered to be smaller contributors to the environmental impact than the more significant CO_2 emissions. Onshore emissions would be in line with permits. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

11.7.5.2.3 Summary

The overall environmental impact of Energy and Emissions as a result of decommissioning the cell contents at all three GBS under Option 3 is estimated to be 'moderate negative', owing primarily to significant energy used during marine operations. The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put this into another context, the

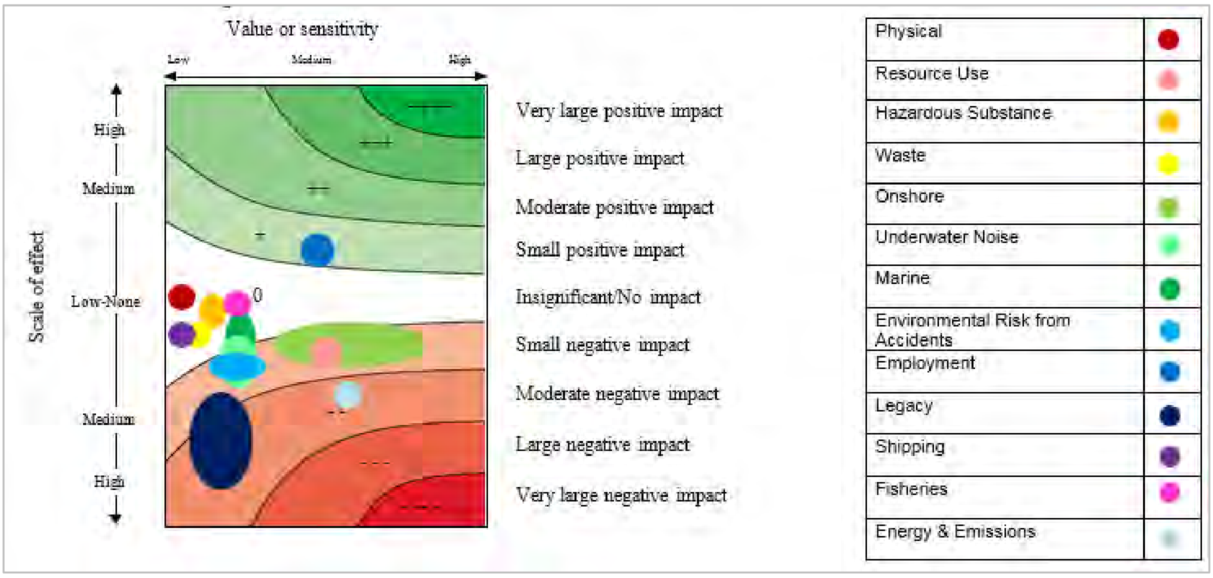
total CO_2 emissions for Option 3 are approximately 4% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70].

11.7.6 Option 4: Leave *in situ* with MNA

Under Option 4, the GBS cell contents would be left *in situ* with MNA. The cell contents would remain *in situ* until the GBS eventually degrade and the cell contents become exposed to the marine environment.

As shown in Figure 11-20, the most significant impacts identified are in the legacy and energy and emissions categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 11-20: GBS Cell Contents Option 4: Leave *in situ* with MNA



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-13, 2016.

11.7.6.1 Legacy

The overall negative environmental legacy impact as a result of GBS cell content decommissioning activities under Option 4 is estimated to be **'small-moderate negative'** based on the analytical results detailed in Table 11-4 ('moderate negative' based on the modelling results using the increased concentrations in modelling scenario 14).

The legacy impacts under Option 4 are estimated to be similar to, but a little lower than Option 5, because the use of MNA would speed up the rate of oil degradation in the cell water and also, to a limited extent, in the upper levels of the cell sediment. Oil degradation in the sediment would be limited by the depth to which the attenuation chemicals diffuse, which is anticipated to be the top 20-30 cm [97]. As the vast majority of the pollutant load is located within the cell sediment, the benefit would be limited (because the sediment height is believed to be about 4 m). It should also be noted that the treatment would only be effective for biodegradable components, and not for pollutants such as heavy metals.

The reader should refer to Option 5, which provides more details on the reasoning behind the assessment of the legacy impact.

11.7.6.2 Energy & Emissions

DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use as a result of decommissioning the cell contents at all three GBS under Option 4. Comparing this against the energy impact categories in Table 5-7, the impact from energy use is considered to be **'moderate negative'**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

Table 11-28 to Table 11-30 show the energy and emissions Option 4, for each individual GBS, while Table 11-31 shows the total energy and emissions for all three GBS.

Table 11-28: Energy and Emissions from Brent B GBS Cell Contents Option 4: 'Leave *in situ* with MNA'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations	-	-	-	-
Marine operations	524,850	38,712	804	244
Onshore treatment	-	-	-	-
Onshore transport to disposal	-	-	-	-
New material	-	-	-	-
Sum	*524,850*	*38,712*	*804*	*244*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	ND	335[2]	ND	ND
Total	**524,850**	**39,047**	**804**	**244**

[1] Operations categories are defined in Section 5.2.3.
[3] Oil (in sediments) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

Table 11-29: Energy and Emissions from Brent C GBS Cell Contents Option 4: 'Leave *in situ* with MNA'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations	-	-	-	-
Marine operations	386,241	28,489	591	179
Onshore treatment	-	-	-	-
New material	-	-	-	-
Sum	*386,241*	*28,489*	*591*	*179*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	ND	120[2]	ND	ND
Total	**386,241**	**28,609**	**591**	**179**

[1] Operations categories are defined in Section 5.2.3.
[2] Oil (in sediments) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

Table 11-30: Energy and Emissions from Brent D GBS Cell Contents Option 4: 'Leave *in situ* with MNA'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	523,514	38,614	802	243
Onshore treatment	-	-	-	-
Onshore transport to disposal	-	-	-	-
New material	-	-	-	-
Sum	*523,514*	*38,614*	*802*	*243*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	ND	335[3]	ND	ND
Total	**523,514**	**38,949**	**802**	**243**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3] Oil (in sediments) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

Table 11-31: Total Energy and Emissions from all 3 GBS Cell Contents Option 4: 'Leave *in situ* with MNA'

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	1,434,605	105,815	2,197	666
Onshore treatment	-	-	-	-
Onshore transport to disposal	-	-	-	-
New material	-	-	-	-
Sum	*1,434,605*	*105,815*	*2,197*	*666*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	ND	790[3]	ND	ND
Total	**1,434,605**	**106,605**	**2,197**	**666**

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations for this option
[3] Oil (in sediments) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil

11.7.6.2.1 Energy consumption and CO_2 emissions

Decommissioning of the GBS cell contents by leaving them *in situ* with MNA under Option 4 would require marine vessels including a DSV, LCV, LWI and supply and survey vessel. Marine vessels would be used for creating access to the cells and further seabed

environmental surveys (although emissions due to environmental surveys would be low considering the short duration of operations). In addition, marine vessels would be used for transportation of nutrients from shore for use in the MNA process. Calculations include an energy and emissions 'penalty' for the loss of oil within the cell sediments that would not be recovered. Emissions do not include for production of nutrients for MNA treatment.

The vessel durations used within the energy and emissions calculations are included in DNV GL's *Energy Use and Gaseous Emissions Report* [2]. There are no onshore operations.

The total energy demand for leaving the cell contents at all three GBS *in situ* with MNA is estimated to be more than 1.4 million GJ. The total CO_2 emissions ($CO_{2\ TOT}$) from the operations at all three GBS would be about 106,600 tonnes, which is almost entirely from marine operations.

11.7.6.2.2 Emissions of NO_x and SO_2 to atmosphere

The vast majority of the gaseous emissions of NO_x and SO_x generated are likely to be quickly dispersed as they would be released offshore, and are therefore considered to be smaller contributors to the environmental impact than the more significant CO_2 emissions. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

11.7.6.2.3 Summary

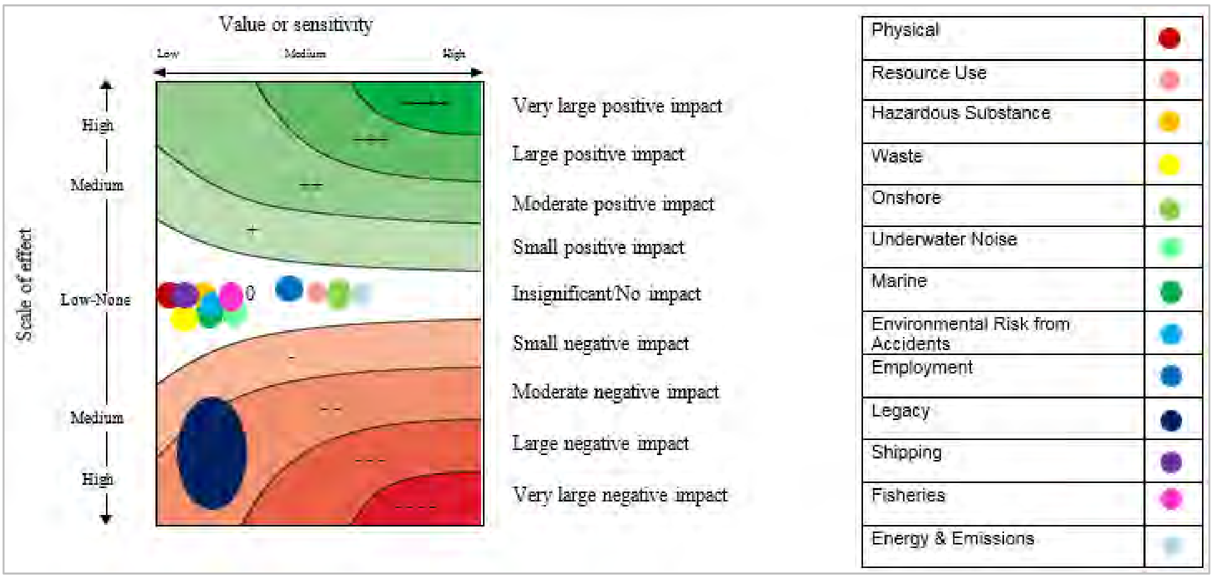
The overall environmental impact of Energy and Emissions as a result of decommissioning the cell contents at all three GBS under Option 4 is estimated to be 'moderate negative', owing primarily to significant energy used during marine operations. The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put this into another context, the total CO_2 emissions for Option 4 are approximately 4% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70].

11.7.7 Option 5: Leave *in situ*

Under Option 5, the GBS cell contents would be left *in situ* in the GBS cells to degrade naturally. They would remain *in situ* until the GBS eventually degrade and the cell contents become exposed to the marine environment.

As shown in Figure 11-21, the most significant impact identified is in the legacy category. Estimated impacts are considered small or insignificant for all other categories.

Figure 11-21: GBS Cell Contents Option 5: Leave *in situ*



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

11.7.7.1 Legacy

The BMT modelling studies [95] and the DNV GL toxicology study [94], as described earlier in Section 11.7.1, examined a number of scenarios of the exposure of cell contents to the marine environment, including a major release of cell contents from one GBS.

The overall legacy impact as a result of GBS cell content decommissioning activities under Option 5 is estimated to be **'small-moderate negative'** based on the analytical results detailed in Table 11-4 ('moderate negative' based on the increased concentrations in modelling scenario 14), due to the contributing factors discussed below.

11.7.7.1.1 Initial Assessment of worst case impacts to the marine environment

Cell water

For the impact of a worst case (i.e. greatest cell water release of the modelled scenarios) 101,900 m^3 cell water release from 1 GBS viewed in isolation, DNV GL considers that:

- Taking into account the instability of hydrogen sulphide in alkaline environments such as seawater (pH 8.2), and that most of the H_2S would be dissociated and hence non-toxic to marine organisms [98] the acute impact (i.e. the impact that occurs shortly after exposure to the toxin) from this toxic substance would likely be minor.
- The modelled impacts from copper, zinc and benzene also appear overly conservative because complexation of metals (dissolved metal cations are very reactive [99]) and biodegradation of benzene (which has a short half-life of 12 hours [100]) have not been considered. Hence acute impacts are expected to be localised, short duration and minor.
- Released amounts of bioaccumulating substances, mainly PCBs (1.2 kg released in the worst case scenario) and mercury (0.2 kg released in the worst case scenario) are too small to represent a threat to higher trophic levels (organisms near the top of the food chain) via bioaccumulation.

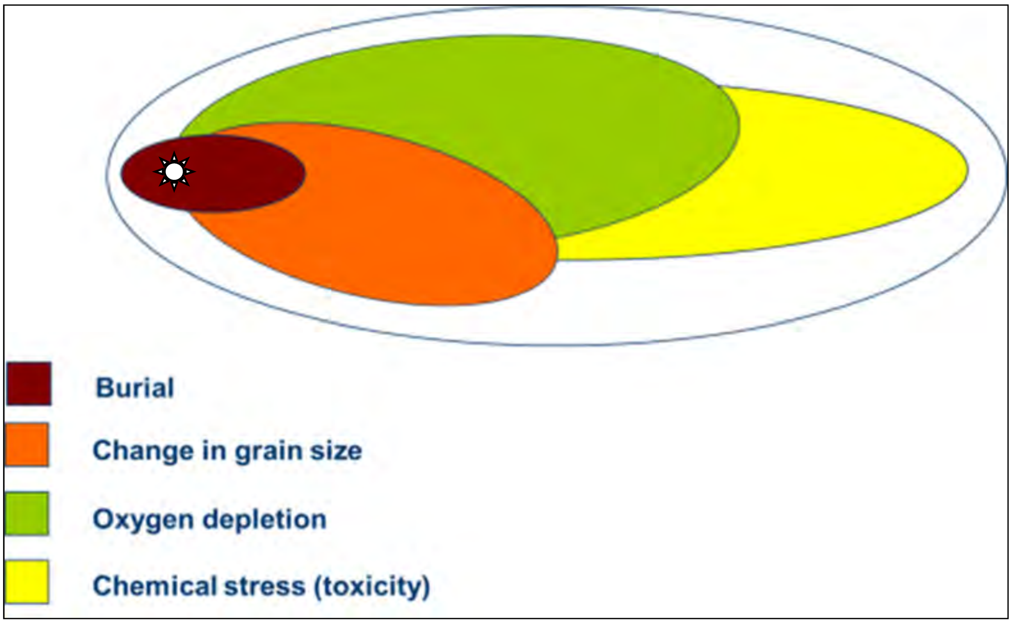
- In summary, DNV GL considers the predicted environmental impact following a worst case release of 101,900 m^3 of contaminated cell water to be limited to significant transient effects close to the release point. The size of the impacted area is not large enough to be measurable on the regional level of water column resources.

Cell sediment

For the impact of a worst case (i.e. greatest cell sediment volume release of the modelled scenarios, scenario 14, which corresponds to a release of sediment containing THC concentrations of 33%, much greater than the maximum THC concentration measured by CSP of 17.5%) 12,960 m^3 cell sediment release from 1 GBS viewed in isolation, DNV GL considers that:

- Modelling results predict the highest impact related to a worst case cell sediment release comes from the hydrocarbons (THC, naphthalene, phenanthrene and benzo[a]pyrene), with predicted impact areas ranging between 0.6-1.7 km^2.
- Worst case results are for phenanthrene. The chemically impacted seabed area as a result of a worst case release event is predicted to be a maximum area of 1.7 km^2 and to extend to a maximum distance of up to 2 km from the platform 10 years after release (without considering biodegradation).
- The impacts from non-chemical stressors including smothering, grain size alteration and oxygen depletion have not been modelled but it is known from studies on drilling discharges [101] that such physical stressors have a smaller footprint than chemical stressors such as hydrocarbons. This is shown in Figure 11-22 where the discharge point is represented as a white marker.

Figure 11-22: Comparison of Physical Footprint and Chemical Stressors for Drilling Discharges [101].



Note: this is a conceptual figure and is not specific to the Brent Field

- Released sediments exceeding a thickness of 1 cm are predicted only for a very small distance (36 m from release point after 10 years). Although the modelling has not

included biodegradation (and consequently the impacted area continues to grow over the entire modelling period of 1,000 years), in reality the biodegradation rates of most of the hydrocarbons released are expected to be relatively quick based on the modelled prediction that the cell sediment would form thin layers (<1 cm) on the seabed. Thin layers (<1 cm) of contaminated sediments and efficient oxygenation of deep water promote biodegradation of all organic substances, and it is known that the study area is well aerated [102]. It is estimated that the advancing front of hydrocarbon-contaminated sediments with time, due to the erosion effect, would be counteracted by biodegradation and consequently that the impacted area would not expand significantly with time.

- For more complex hydrocarbons (particularly benzo[a]pyrene), biodegradation would be slow, and possibly take decades before non-toxic sediment concentrations are achieved. The impacted seabed area (0.6 km^2 after 10 years) is nevertheless too small to have an effect on the regional benthic fauna.
- A potential concern from a cell sediment release is from bioaccumulating and prioritised substances (substances that might merit action under OSPAR due to their persistency, potential to bioaccumulate and toxicity) which may give rise to delayed toxic effects in higher trophic levels. The major portion of released mercury would accumulate in sediments where it would become susceptible to methylation and subsequent release to the water column. The rate of methylmercury release has not been modelled, however the released amount of mercury (261 kg in a worst case scenario) is not considered sufficient to have any measurable effects in higher trophic levels including humans. Benzo[a]pyrene is modelled to be released in significant amounts in a worst case scenario (10.7 tonnes); however metabolism of this substance in vertebrates such as fish would hinder bioaccumulation in higher trophic levels. Furthermore, benzo[a]pyrene has limited mobility and would largely remain adsorbed to the seabed sediments.

Combined release

A combined release of cell water and sediment would not significantly alter the total risk from the assessed substances. The amount of bioaccumulating and persistent substances released with cell water and likely to accumulate in marine sediments, is small compared to what would be released with cell sediments. Release of hydrocarbons from sediment to the water column would be slow and the impact on water column resources (such as fish) would be very local.

11.7.7.1.2 Updated Assessment

Analytical results of samples collected from Brent D

Analytical results of cell water and cell sediment samples (Table 11-4) show that, with the exception of THC and mercury in cell water, the actual concentrations of contaminants inside the GBS cells are lower than estimated and assessed, in many cases significantly lower.

As a result, in the assessment which uses the CSP sample data, the THC in cell water and sediments represent the largest potential impact from a major release of GBS cell content.

- The modelled impact reaches up to 17 km from the discharge point, lasting for up to 173 hours as a result of a worst case cell water release (Scenario D using the single highest THC measurement of 1,380 mg/l). A significant portion of the oil released with cell water is predicted to reach the sea surface where it could potentially impact seabirds, but assessment shows the (credible case) risk to seabirds to be negligible, and similarly that the environmental consequences for coastal habitats are negligible.

- The modelled impact from highest measured THC concentration in a release of 12,960 m^3 of sediments (17,500 mg/kg THC, Scenario 14) after 1 year reaches 250 m from the discharge point (impact area 0.05 km^2), a much smaller impact than predicted in the initial worst case studies. The modelling assumes that the volume of cell contents is released instantaneously to the environment. This is a conservative assumption as it is unlikely that such a large proportion (~75%) of the GBS cell sediment at Brent B and D would instantaneously be exposed to the marine environment, sitting as a pile on the seabed, unprotected by any remains of the GBS. The more realistic exposure scenario is gradual but increasing exposure of the cell contents as the cell dome collapses and the cell walls begin to fail. Some of the collapsed GBS is likely to fall onto the cell sediment and partially reduce its exposure to the environment. Conversely, the cell sediment volumes in both Brent B and D GBS are greater than that modelled (Brent C is lower).
- And a release of free oil from the sediment would result in oil volumes on the sea surface and in the water column that present an insignificant environmental risk, as the oil would degrade close to the release point.

Modified physical and biogradation input parameters

Updated modelling results with biodegradation of oil compounds and hydrogen sulphide (H_2S) built-in, show that for a worst case cell water release, toxic effects of H_2S are predicted to last for 56 hours. For a cell sediment release, new modelling results predict that the seafloor area impacted over a long period (decades) by toxic THC concentrations would be limited to contaminated sediments above a certain thickness (~1 cm), and hence close to the GBS.

Additional modelling was conducted with variations of the cell sediment release scenarios (dynamic release versus static release). Of the dynamic release modelling scenarios commissioned by Shell, DNV GL examined the scenario that released 10 m^3/day for 1 year (3,650 m^3 of sediment), representing a significant amount of cell sediment to be fully re-suspended in the water column for dispersion around the platform (~21% of Brent B or Brent D cell sediment, or ~60% of Brent C cell sediment) as that gave the biggest seabed impact. The new modelling results show that although dynamic sediment release scenarios would result in larger areas of the seafloor being contaminated (the PEC:PNEC>1 covers much wider areas), approximately 97% of this area has a sediment thickness of less than 1 mm, and hence is not expected to have any harmful impact on biota once mixing by bioturbation has been taken into account. The seafloor with >10 mm contaminated sediment and PEC:PNEC>1 is expected to cause harmful effects on the biota. Dynamic modelling results show that 0.06 km^2 seafloor would have such conditions. This is close to the 0.05 km^2 footprint with potential harmful effects that was derived from the updated static modelling.

The nature of the future exposure of the cell sediment to the marine environment is uncertain. If two such dynamic releases occurred at different times within (e.g.) a 10 year period at the same platform (e.g. Brent B or Brent D), the impact would be similar (but extended in time) because the 1 mm thickness would degrade quickly (within a year or two). Two such dynamic release events (of 3,650 m^3/year) would represent nearly half of the cell sediment present at Brent B or Brent D.

Microbiological Assessment

The potential for change in the microbiological fauna as a result of a cell sediment release was also examined. DNV GL consider it likely that the number of hydrocarbon-utilizing

microorganisms in sediments, and their proportion in the heterotrophic community, would increase locally as a response to the instantaneous release of polluted cell content. It is further considered that bacterial communities in sediments at the Brent Field would exhibit higher biodegradation rates than communities with no history of hydrocarbon contamination due to exposure from drill cutting piles. A bacterial community structure similar to pre-spill may be expected in sediments, and the exposed area is expected to gradually be recolonized by biological communities within year(s). Negative long term impacts are accordingly not expected.

11.7.7.1.3 Conclusions

In conclusion, based on modelling results and using estimates of released substance concentrations, a major release of cell water and sediment from a GBS would pollute the local marine environment but is not expected to induce any measurable effects at the regional level. Effects on water column resources would be restricted to acute and transient effects close to the release point. A major cell sediment release would result in an impacted area around each platform that is a comparable to the area already impacted around each platform by the historic drill cuttings (although this impacted area would have significantly decreased in size by the time cell contents are released). The released amounts of persistent, bioaccumulating and toxic substances (PCBs, organic mercury, TBT, and to some extent benzo[a]pyrene) have the potential to biomagnify in marine food webs in theory, but DNV GL's assessment concludes that the environmental impact would be small owing to the relatively small amounts of bioaccumulating substances involved, so is not expected to induce any measurable effects at the regional level.

It should be noted that there are three GBS that contain cell water and cell sediment, all of which would become exposed to the marine environment (probably at different times) in the long-term future if they are left *in situ*. The cumulative impact from all three GBS (based on modelling results, see Section 17.6) would be increased localised pollution and short-term acute effects (but most likely at different times), but there continues to be no expected measurable effects on the regional level. There would be some increased potential to biomagnify in marine food webs in theory, but because the environmental impact remains small in nature owing to the relatively small amounts of bioaccumulating substances involved, this is unlikely to have any measurable effects in higher trophic levels including humans.

DNV GL has also reviewed the literature on interacting effects from co-exposure to relevant contaminants. THC and hydrogen sulphide (H_2S) account for the vast amount of assessed contaminants released with cell water (99 %) and cell sediment (97 %). Hydrogen sulphide is unstable in alkaline and oxidized environments and interacting effects involving this substance are therefore considered unlikely. Potential interacting effects would therefore be limited to hydrocarbons, which have a common or similar mode of action once taken up by an organism, and can act jointly to produce combination effects. Based on this, DNV GL concludes that no significant interacting effects from co-exposure to relevant contaminants would occur other than additive toxicity.

Impact to the marine environment could also result from NORM contamination present in any sediment that is exposed to the environment. A study by ARPS [103] analysed the impact of a release of sediment containing NORM to the ocean floor. Both a fast release (lasting one year) and gradual release (lasting 250 years) were modelled using the UK Health Protection Agency assessment model. Results showed the maximum dose (to adults, children

or infants) to be extremely low, approximately 5 microSv/y or less. Hence the radiological impact of the release of sediment contaminated with NORM would be very small to human health. In relation to impact upon the environment, the NORM levels of between 2-20 Bq in the sediment (based on a Brent Spar sediment sample) are typical of produced water in the North Sea oil and gas industry and would mostly only affect some sediment-dwelling organisms in the vicinity of the deteriorated GBS (for further discussion of NORM, see Section 8.3.2.11).

Please refer to DNV GL's toxicology study [94] for more details.

11.8 Comparison of Options for Decommissioning of Cell Contents

Some negative but manageable environmental impacts have been identified for all options.

Options 3, 4 and 5 have negative legacy impacts relating to exposure of the cell contents (in the distant future after degradation of the GBS) and the associated impact upon the marine environment ('small-moderate negative' of varying degrees for all three options based on analytical results, 'moderate negative' based on modelling results using the increased concentrations). Options 1 and 2 have much improved legacy impacts, but Option 1 involves significant fuel consumption as a result of activities to retrieve and manage the cell contents. In addition, Option 2 has 'small-moderate negative' waste management and onshore impacts as a result of the large quantities of slurry that would be brought to shore. Option 1 has some 'small-moderate negative' physical impacts on the seabed because of drilling new wells and from vessel anchoring. There is conversely a 'moderate positive' and 'small-moderate positive' impact on employment for both Options 1 and 2, respectively.

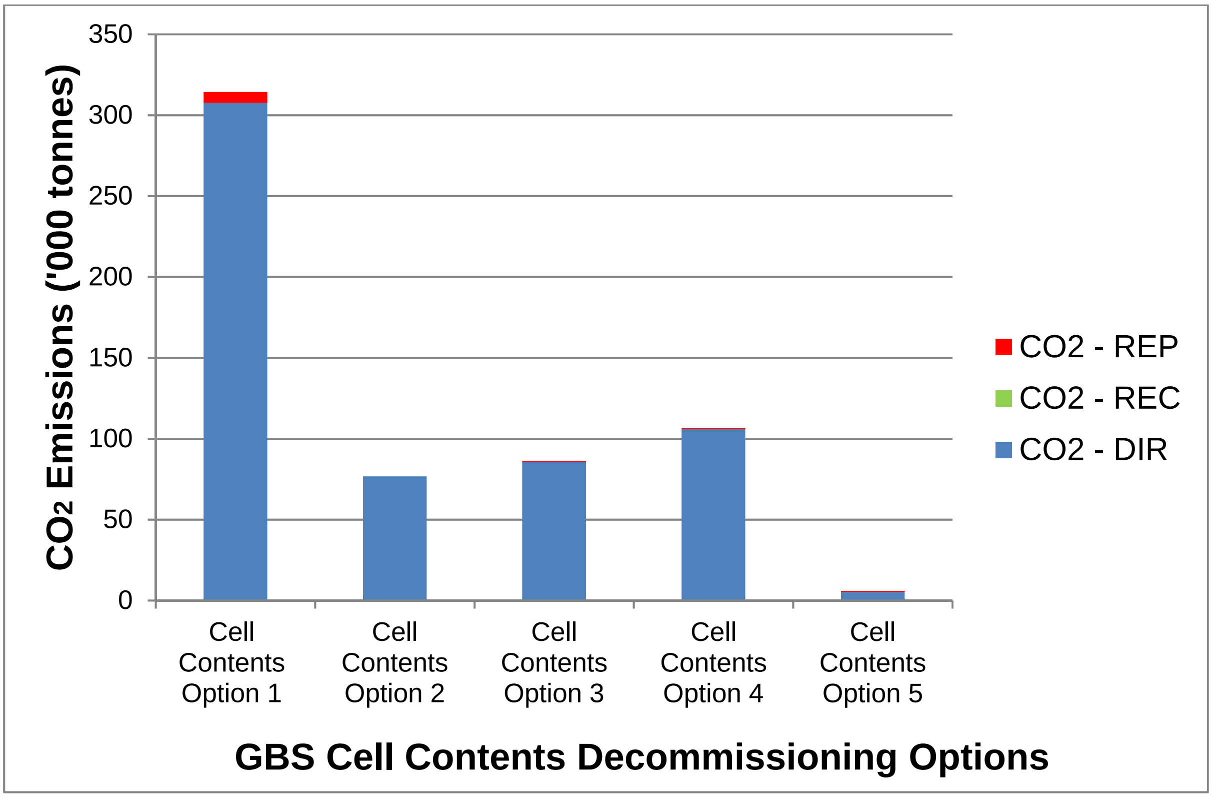
In summary, there is a fundamental difference between impacts for:

- Options 3, 4 and 5 where the cell contents are left in place (the key issue being the negative legacy impact to the marine environment as a result of the local pollution caused when the cell contents are exposed to the marine environment); and
- Options 1 and 2, where the legacy issue is addressed in the main but the decommissioning activities to remove the cell sediment result in other environmental impacts (in categories such as onshore, waste, physical and energy and emissions).

Many of the impacts from Options 1 and 2 occur in different environmental media, take place in different time periods and in some cases different locations than the impacts from Options 3, 4 and 5. In such instances, different stakeholder may take different views about which are the more significant. A specific issue of interest to one group of stakeholders may be viewed conversely by another group. It could be argued that legacy impacts should be given greater emphasis because of their long-term nature and the uncertainties involved in predicting the future.

Figure 11-23 illustrates the CO_2 emissions for the five cell contents decommissioning options. Option 1 would produce the most emissions, Option 5 the least.

Figure 11-23: Comparison of CO_2 Emissions for the Options to Decommission the GBS Cell Contents



11.9 Significant Impacts of Proposed Programme of Work

Shell's proposed decommissioning option for the GBS attic oil is to remove the entire volume (between 12-14,000 m^3) from Brent B and D to shore; this will have a positive effect as the waste oil will be treated and reused.

Shell's proposed decommissioning option for the GBS cell contents is Option 5: leave *in situ* for natural degradation. The key negative impact identified for this option is the localised pollution that will occur after the degradation of the GBS when the cell contents become exposed to the marine environment.

Impacts are discussed in detail in Section 11.7.7 and are only briefly summarised here. The release of cell water and sediment will impact the local environment but is not expected to induce any measurable effects at the regional level. Effects on water column resources would be restricted to acute and transient effects close to the release point. A major static sediment release would result in an impacted seabed area of approximately 0.05 km^2 around each platform, up to a distance of approximately 250 m (based on analytical results detailed in Table 11-4). Although dynamic (disturbed) sediment releases would result in larger areas of the seafloor where PEC:PNEC>1, the vast majority of the area would have a sediment thickness of less than 1 mm, and hence is not expected to have any harmful impact on biota once mixing by bioturbation has been taken into account.

Released sediments exceeding a thickness of 1 cm are predicted for only a very small distance for a major static release of the cell sediment (~36 m from release point after 10 years based on the worst case initial modelling for static exposure), or ~ 175 m from release point after 1 year if a significant proportion of it is released dynamically at 20 m height. Although the initial modelling did not include biodegradation (and consequently the impacted area continued to grow over the entire modelling period of 1,000 years), the updated modelling shows that in reality the biodegradation rates of most of the hydrocarbons released are expected to be relatively quick, based on the modelled prediction that the cell sediment will mainly form thin layers (<1 cm) on the seabed. For more complex hydrocarbons (particularly benzo[a]pyrene), biodegradation will be slow, and possibly decades before non-toxic sediment concentrations are achieved, but analytical results suggest concentrations of these complex hydrocarbons is much lower than initial worst case assumptions. The impacted seabed area is nevertheless too small to have an effect on the regional benthic fauna.

The released amounts of persistent, bioaccumulating and toxic substances (PCBs, organic mercury, TBT, and to some extent benzo[a]pyrene) have the potential to biomagnify in marine food webs in theory, but modelling results show that environmental impact is localised owing to the relatively small amounts of bioaccumulating substances involved [94].

11.10 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that mitigation and management measures are in place. Table 11-32 details these measures for the proposed option to decommission the GBS cell contents and attic oil and highlights the residual impacts as described in Section 11.7 and Appendix 1.

Table 11-32: Summary of Mitigation and Management Measures for Proposed Programme of Work*

Environmental Category	Mitigation Measures	Residual Impact
Onshore Impacts	• Cell contents will be left *in situ* and therefore there are no onshore impacts • 12-14,000 m^3 of attic oil/interphase material will be recovered and taken to shore for treatment and potential re-use. The onshore site is currently not known, but Shell will ensure it is responsibly managed, is licensed to perform waste management operations, and that operations will be carried out within the licence conditions. • Shell will audit onshore operations, including offsite road transport of oil, for management of attic oil to ensure regulatory limits are met.	Small negative
Resource Use	There are few resources used	Insignificant-small negative
Hazardous Substances	• Some chemicals may be used during the removal of attic oil. However none of these chemicals would be released to the environment unless there was an accident (see ERA category below). • There are no hazardous substances used for cell contents Option 5.	No impact
Waste	• Cell contents will be left *in situ* and therefore there is no waste generated • 12-14,000 m^3 of attic oil and interphase material will be recovered, treated and reused (a positive impact)	Small-moderate positive
Physical	During the removal of attic oil, vessels working offshore will not use anchors and will operate on DP, therefore there will be no physical impacts. There are no operations for cell contents Option 5, hence no physical impact.	Insignificant
Marine (includes underwater noise)	There are some marine operations to remove the attic oil, but vessels will operate on DP, preventing impacts to the benthic environment from anchor pits.	Insignificant
Environmental Risk from Accidents	• Shell will identify and manage the environmental barriers of operations to remove and handle attic oil/interphase material. • Shell will develop and implement an attic oil recovery procedure that includes pressure/leak testing equipment prior to use. In addition, an ROV will be on station to provide real time video link during the operations. Should any concerns be raised, or anything unexpected happen, the procedure then calls for a sequence of isolations, flush and purge before operations can continue. • Attic oil transfer operations will be in compliance with permit conditions • A BEIS approved Oil Pollution Emergency Plan (OPEP) for the Brent Field system is in place. SOPEP for vessels, approved by the Maritime and Coastguard Agency (MCA), will be in place. • Operations will take place in good weather where practical. • Manoeuvring of vessels both at the Brent Field and nearshore will be controlled and at low speeds.	Small negative
Employment	There is little employment generated	Insignificant
Legacy	• Attic oil will be removed, hence no legacy impact. • Shell will monitor and maintain the GBS structures and monitor the surrounding environment as described in Section 18. • Shell will undertake appropriate actions if, after GBS degradation, environmental monitoring (for example, sediment analysis, benthic fauna samples) shows impacts to be more significant than predicted by modelling and desk studies. Specific remedial actions would need to be engineered to respond to the actual situation.	Small-moderate negative
Fisheries	There are few marine operations and most operations will take place within the 500 m safety zone.	Insignificant
Shipping	There are few marine operations and most operations will take place within the 500 m safety zone.	Insignificant
Energy & Emissions	There are very few operations	Small negative

*This table covers mitigation measures for both attic oil Option 1 and cell contents Option 5; the residual impact shown is the largest impact of the two.

12. GBS DRILLING LEGS AND MINICELL MATERIAL

12.1 Introduction

This section describes the material contained within the GBS drilling legs and minicells, the inventory of materials and the decommissioning options. The main anticipated environmental impacts of decommissioning are discussed and compared. The necessary management and mitigation measures to control the impacts of Shell's proposed programme of work are summarised, and measures are recommended to further reduce residual impacts where appropriate. The Technical Document the Brent GBS Contents Decommissioning [87] has been used as the basis for Sections 11.212.2 - 12.4.

12.2 Description of Materials in GBS Drilling Legs and Minicell

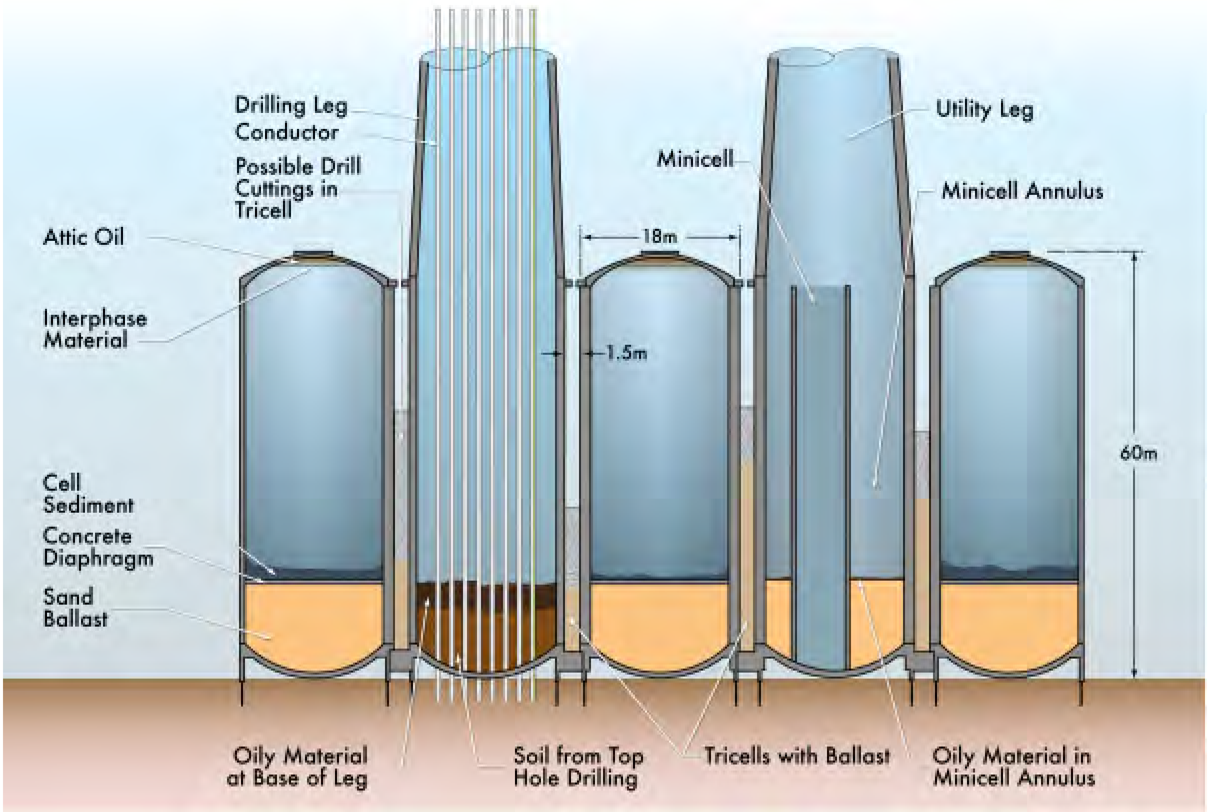
On both Brent B and D, two of the three GBS legs serve as drilling legs. On Brent B, the drilling legs are closed to the sea, and operate with the water level inside the legs kept at 5 m below LAT. The drilling legs on Brent D are open to the sea.

Within both Brent B and D GBS, a minicell (a 60 m high by 7 m diameter cylinder) is found at the bottom of the utility leg. The minicell provides a means of gaining access to several systems such as the water ballast, without having to dewater the utility legs to the point of structural instability. The gap between the leg wall and the minicell is referred to as the minicell annulus. There is no man access down to the minicell annulus as it is kept flooded at all times.

The drilling legs of Brent D GBS contain some contaminated drill cuttings, and the minicell annulus of Brent D GBS contains some oily sludge. Samples have been collected from Brent D drilling legs and minicell annulus to confirm the existence of this material. As Brent B has many similar features to Brent D and has undergone similar operations over time, Shell believe that similar waste is likely to exist at Brent B. Therefore for the purposes of this assessment, DNV GL assumes that the mass of oily contents in the drilling legs and minicell at Brent B are comparable to that of Brent D.

Figure 12-1 shows the location of these materials within a GBS drilling leg and minicell at Brent B or D. Brent C has external conductors and thus has no drilling legs or minicell.

Figure 12-1: Location of Materials within GBS Drilling Leg and Minicell [88]



12.2.1 Material in Drilling Legs

The material accumulated at the bottom of the Brent D drilling legs is believed to originate from:

- Uncontaminated top hole cuttings that entered the drilling leg through the annulus between the conductor and the conductor sleeve at the bottom of the leg during the installation of the conductors.
- Historical spillage of OBM from the drill floor.

Based on surveying and detailed general arrangement calculations, the volume of sediment in each of the drilling legs is estimated [87] as follows:

In the East drilling leg the sediment/water interface lies between 1.7 - 4.9 m above the base of the leg, equating to a volume in the range 112 - 835 m^3, with an average of 474 m^3. The gradient of concentration identified on the sediment core shows that the thickness of the contaminated sediment layer is less than 1 m, however for any removal options the whole sediment layer has been considered. Therefore a contaminated sediment volume of 500 m^3 is assumed, and this sits above the (clean) top hole cuttings.

In the West drilling leg the sediment/water interface lies between 5.9 - 8.9 m above the base of the leg, equating to a volume in the range 1,083 - 1,827 m^3, with an average of 1,455 m^3. Assuming that the volume of clean cuttings in the West leg should be similar to that in the East, this leaves an approximate thickness of potentially contaminated material of 2 - 5 m.

However, assuming the whole sediment layer is to be recovered, a total volume of 1,500 m^3 contaminated sediment is assumed, and this sits above the (clean) top hole drill cuttings.

The sediment elevations in the drilling legs are shown in Figure 12-2 and Figure 12-3**.**

Figure 12-2: Sediment Elevations in East Drilling Leg

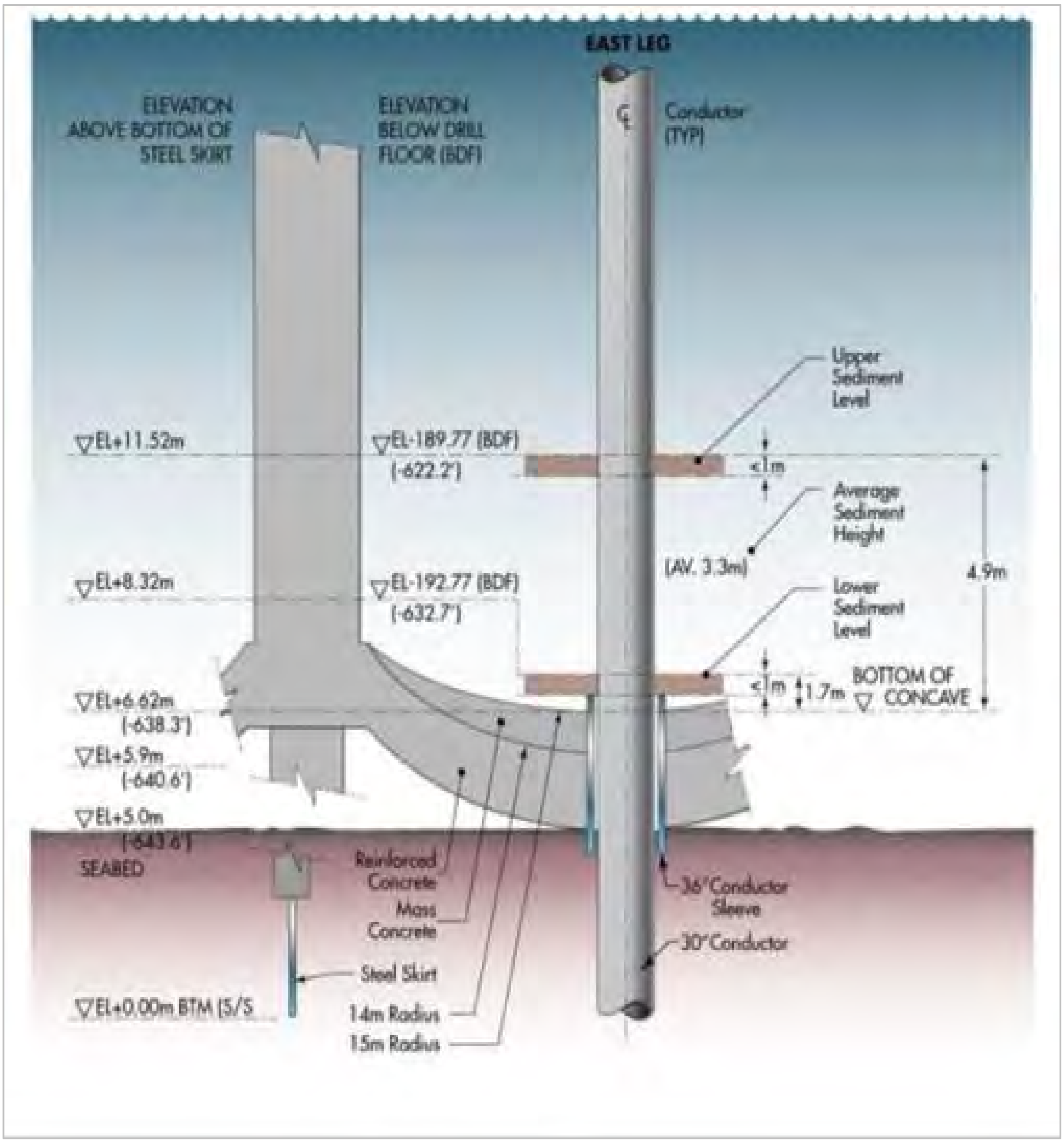
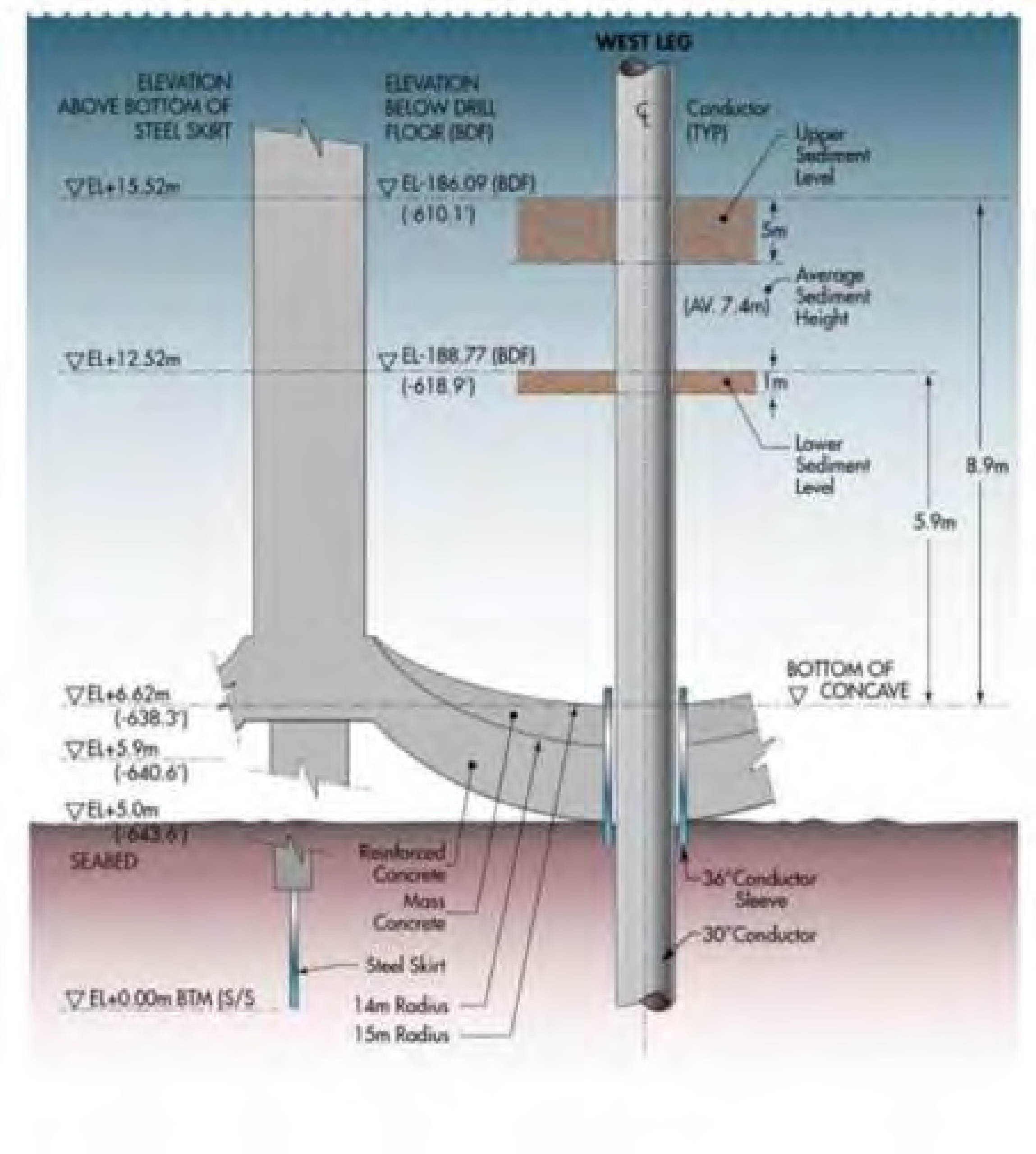


Figure 12-3: Sediment Elevations in West Drilling Leg



The key contaminants identified in the samples collected were the total amount of hydrocarbons (1.2% THC) and elevated concentrations of heavy metals (Cu, Zn, Pb). The samples are similar in composition to the samples collected from the surface of the seabed drill cuttings pile (Section 13.2.1). The presence of hydrocarbons is indicative of historic leakages, while the presence of heavy metal contamination (copper, lead, zinc) suggests corrosion of steelwork inside the drilling leg; most likely the conductors, guide frames and anodes for which the cathodic protection no longer works.

Table 12-1: Analysis of Sediment Composition within Brent D Drilling Leg [87]

Sampling Area	West Leg (001)	West Leg (002)
Density (kg/m^3)	1,384	1,259
THC (mg/kg)	11,575	11,594
BTEX (mg/kg)	0.3	0.3
PCB (µg/kg)	0.18	<0.1
TBT (µg/kg)	<1	<1
Chlorobenzene (mg/kg)	0.2	0.7
Tri-chlorobenzene (mg/kg)	<0.1	<0.1
NORM (Bq/g) Ra-226	<0.056	<0.047
Heavy Metals (mg/kg)		
Cadmium (Cd)	9	6
Chromium (Cr)	56	47
Copper (Cu)	120	89
Iron (Fe)	35,800	33,100
Arsenic (As)	17	17
Mercury (Hg)	0.108	0.109
Nickel (Ni)	23	24
Lead (Pb)	253	160
Zinc (Zi)	1,690	1,150
Total PAH (∑16) µg/kg	1,746	2,499

Water samples were also collected from inside the Brent D drilling legs in 2009 and 2010 The sample results (Table 12-2) show contamination with heavy metals (Cu, Hg, Ni, Zn), again probably owing to corrosion of steelwork inside the drilling leg. The right-hand column represents the average concentration measured in Brent Field produced water discharge, and is used as a comparison against the sampling results.

Table 12-2: Analysis of Water Composition within Brent D Drilling Leg

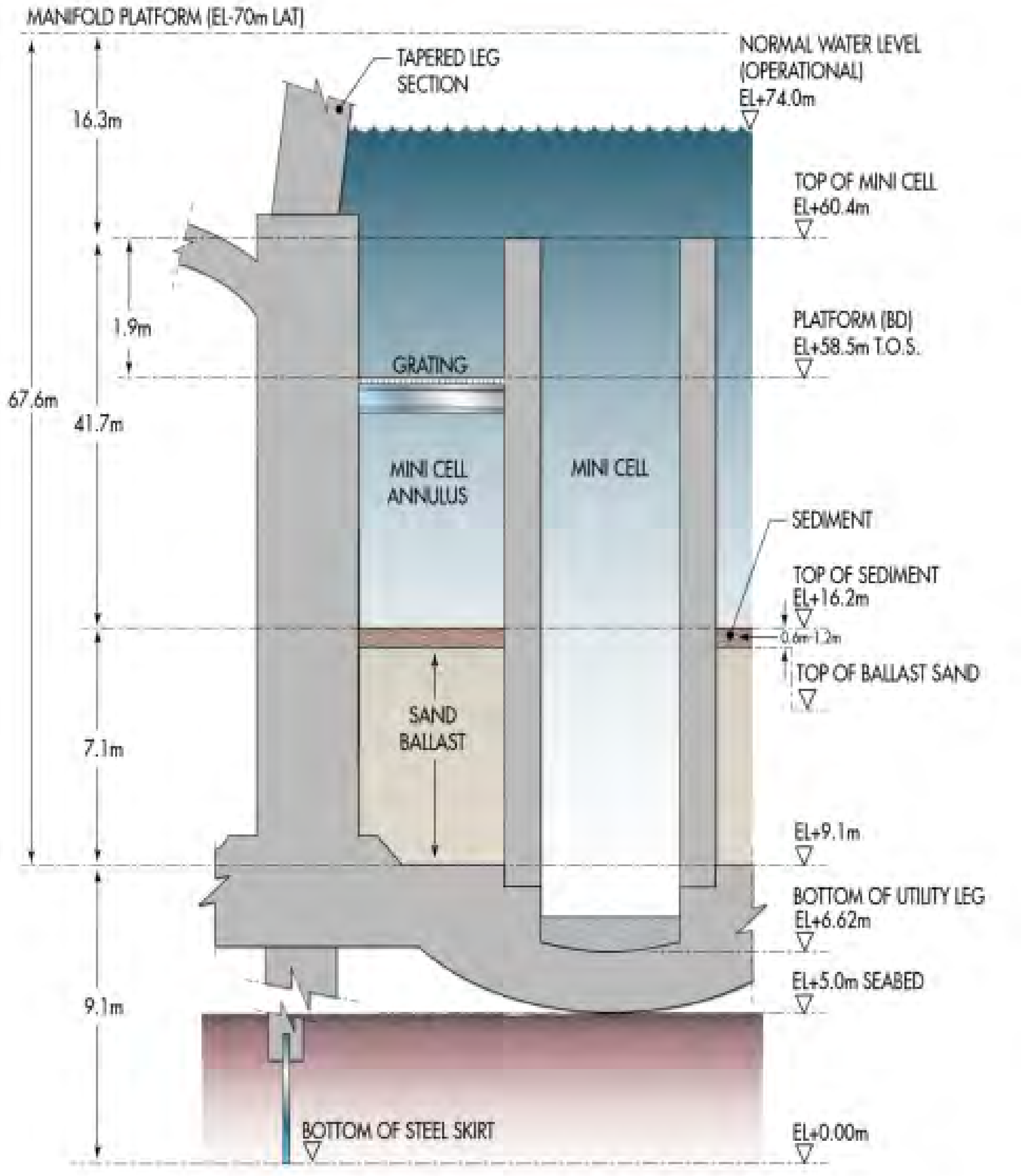
Sampling Area	West Leg (2009)	West Leg (2010)	Produced Water Average
Density (kg/m³)	1,026	1,027	ND
OIW (mg/l)	0.22	2.4	18
TSS (mg/l)	2.13	68.4	ND
BTEX (mg/l)	<0.1	<0.1	26.2
PCB (µg/l)	ND	<10	ND
TBT (µg/l)	ND	<0.01	ND
Tri-chlorobenzene (mg/l)	ND	<0.002	ND
NORM (Bq/g)			
Radium - 226	ND	<0.0022	0.000032
Lead - 210	ND	<0.020	0.00047
Actium - 228	ND	<0.00048	0.00011
Heavy Metals (µg/l)			
Cadmium (Cd)	0.2	10.2	19
Chromium (Cr)	<2	7.81	26
Copper (Cu)	<1	275	100
Arsenic (As)	1.21	11.3	76
Mercury (Hg)	<0.06	1.87	0.61
Nickel (Ni)	3.64	49.1	33
Lead (Pb)	2.03	18.3	31
Zinc (Zi)	21.9	2,140	43
Total PAH (∑16) µg/l	0.5	<0.1	10

ND indicates no data (not measured)

12.2.2 Material in Minicells

During maintenance work in the 1990s on Brent D, contaminated material was found in the minicell. This was moved from the minicell into the minicell annulus to allow maintenance work to continue. It is unclear where this material originated from but samples indicate it is contaminated with hydrocarbons including PAH and BTEX as well as traces of TBT. The material appears to lie on top of the 7.1 m thick layer of ballast sand. A sampling program carried out in 2010 [87] determined that the thickness of the contaminated layer ranges from 0.6 - to 1.2 m (equating to volumes of approximately 135 – 270 m^3). The sediment elevations in the minicell annulus are shown in Figure 12-4.

Figure 12-4: Sediment Elevation in Minicell



The analytical results of sediment samples from contaminated material in the minicell are presented in Table 12-3.

Table 12-3: Analysis of Sediment Composition within Brent D Minicell Annulus

Samples (Intertek numbers)	001-00B	002-00C	003-00B	004-00	010-00
Density (kg/m^3	1,360	1,035	1,273	1,425	1,287
THC (mg/kg)	17,403	745	83,283	66,967	91,011
BTEX (mg/kg)	<0.2	<0.2	<0.2	<0.2	<0.2
PCB (µg/kg)	<100	<100	<100	<100	<100
TBT (µg/kg)	ND	3	ND	ND	213**
Chlorobenzene (mg/kg)	ND	<0.1	ND	ND	<0.1
Tri-chlorobenzene (mg/kg)	ND	<0.1	ND	ND	<0.1
NORM (Bq/g) Ra-226	<0.1	<0.17	<0.13	<0.22	<0.20
Heavy Metals (mg/kg)					
Cadmium (Cd)	20	1.88	34	57	33
Chromium (Cr)	62	81	120	161	81
Copper (Cu)	571	61	498	932	270
Iron (Fe)	46,200	7,320	60,300	106,000	35,900
Arsenic (As)	47	5.07	17.8	31.7	20.1
Mercury (Hg)	1.48	<0.21	1.31	3.47	2.07
Nickel (Ni)	38	<0.1	63	77	28
Lead (Pb)	189	26.4	86	137	95
Zinc (Zi)	4,460	628	8,770	12,300	7,650
Total PAH (∑14) µg/kg	51,588	8,126	69,890	119,689	44,292

ND indicates no data due to limited volume sample.

The water phase in the minicell and the minicell annulus was also sampled in 2010, and the overall volume of water was estimated to be approximately 11,000 m^3: 8,740 m^3 from the minicell annulus and 2,230 m^3 from the minicell itself. The results from the sampling exercise are presented in Table 12-4. The right-hand column represents the average concentration measured in Brent Field produced water discharge, and is used as a comparison against the sampling results.

Table 12-4: Analysis of Water Composition within Brent D Minicell and Minicell Annulus

Chemical Analysis	Minicell	Minicell Annulus	PW average
OIW mg/1	<1	32.1	30
Total PCB mg/1	<0.01	<0.01	Not measured
Total Alkylated Phenols (mg/1)	<0.0001	0.0018	1.29
Heavy Metals			
(As) Arsenic (µg/1)	0.81	1.33	76
(Cd) Cadmium (µg/1)	8.77	0.74	19
(Cr) Chromium (µg/1)	1.48	3.64	26
(Cu) Copper (µg/1)	17	10.7	100
(Hg) Mercury (µg/1)	0.41	0.15	0.61
(Ni) Nickel (µg/1)	26.9	7.47	33
(Pb) Lead (µg/1)	2.43	3.37	31
(Zn) Zinc (µg/1)	1,595	202	43
PAH (µg/1)	124.8	9	10
NPD (µg/1)	156.4	177.8	240
BTEX (mg/1)	<0.1	<0.1	26.2
Tin-Organic			
Dibutyltin (ng/1)	<10	34	Not measured
Tributyltin (ng/1)	<10	66	Not measured
Triphenyltin (ng/1)	<10	89	Not measured
NORM (Bq/g)			
Radium – 266	<0.0026	<0.0024	0.000032
Lead – 210	<0.0086	<0.0021	0.00047
Actium - 228	<0.00057	<0.00067	0.00011

12.3 Inventory of Materials

The inventory of materials for the GBS drilling legs and minicell is given in Table 12-5 based on estimates from Shell.

Table 12-5: Estimated Volume of Material in GBS Drilling Legs and Minicell[1] [87]

	Brent B	Brent C	Brent D
Volume of oily material in drilling legs (m^3)	2,000[2]	0	2,000
Volume of oily material in minicells (m^3)	135-270	0	135-270

[1]Volumes of material in Brent B drilling leg and minicell area are based on Brent D sampling results.
[2]Excludes volume of (clean) top hole cuttings

12.4 Description of Technically Feasible Decommissioning Options

Five options are considered in this ES for the management of the material in the GBS drilling legs and minicell annulus:

COMPLETE REMOVAL*	COMPLETE REMOVAL*	LEAVE IN PLACE AND CAP*	LEAVE IN PLACE WITH MNA*	LEAVE IN PLACE
Option 1. Mobilise and re-inject in a new remote subsea well.	**Option 2.** Mobilise and retrieve to vessel and treat and dispose onshore.	**Option 3.** Cap or cover *in situ*.	**Option 4.** Leave *in situ* and improve natural biodegradation (Monitored Natural Attenuation, MNA).	**Option 5.** Leave *in situ* for natural biodegradation.

*For these decommissioning options for the drilling leg material at Brent B, there are two sub-options: a. Brent B topsides in place, and b. after removal of Brent B topsides

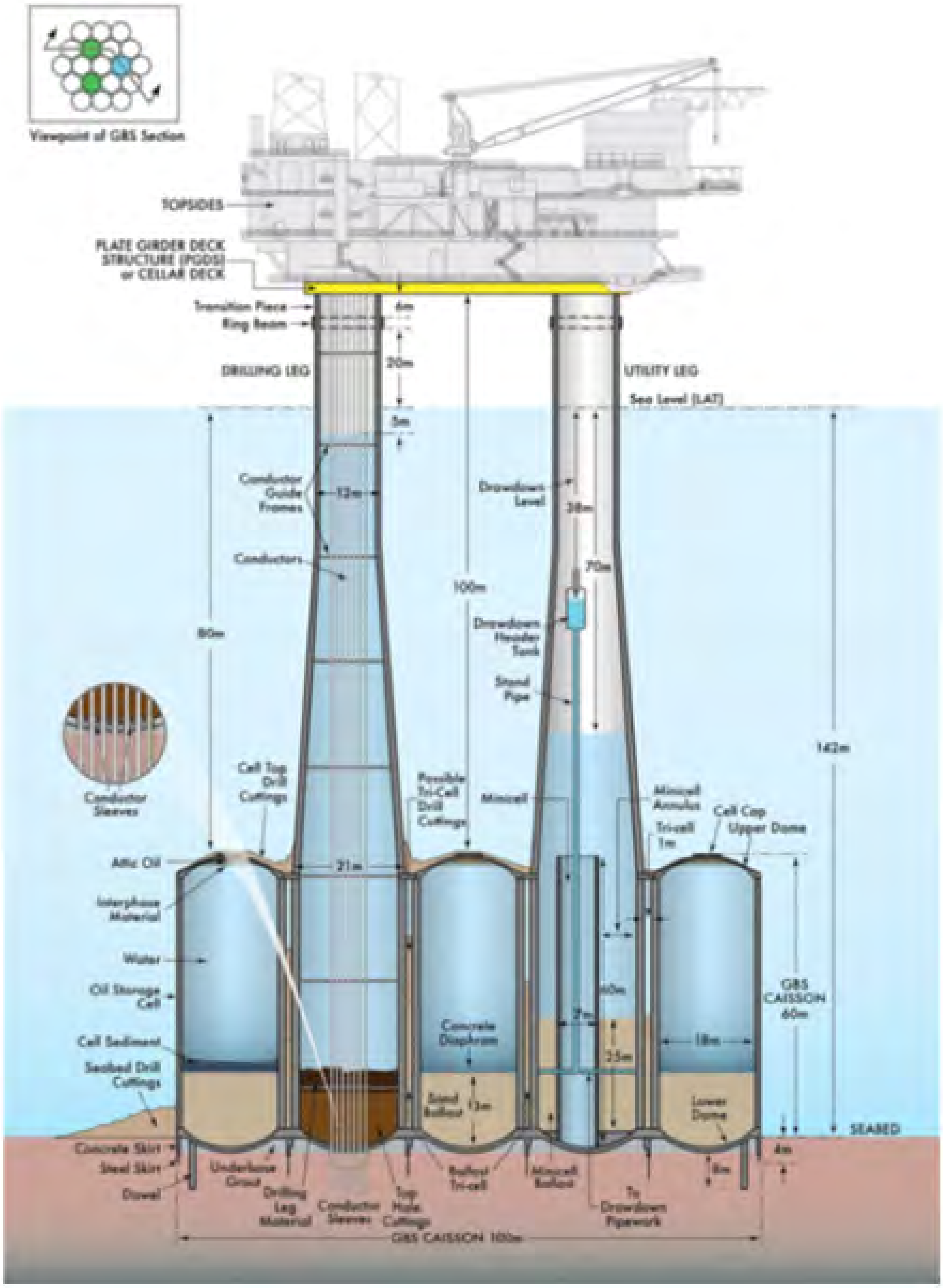
There are numerous similarities between the options for the drilling legs and minicell annulus. In order to keep this section as simple as possible it is arranged specifically covering drilling legs and minicell annulus as separate locations (referencing the similarities where applicable). Each sub-section covers the proposed sediment management with topsides in place as the base case and differences in the case of post topsides removal. It is envisaged that after topsides removal, facilities and access to the legs will be provided from a suitable SSCV.

This section covers the management of materials between the bottom of the drilling legs and minicell annulus to either topsides or surface vessels. This applies to the recovery of materials and onward transportation, treatment and disposal or the deployment and distribution of capping material or biostimulation nutrients injected into the sediment.

It is important to understand the relationship between the bottom of the drilling leg, the minicell annulus and the storage cells, and Figure 12-5 shows a typical section through the Brent B GBS. The drilling legs and utility legs of both Brent B and D are flooded, but to different levels.

An assessment of the schedule and risks will need to be considered when selecting the decommissioning options to be carried forward including the proposed installation of protective caps to the legs post topsides removal. If the sediment recovery / treatment operation is to be carried out after cap installation the caps will need to be temporarily removed with alternative Navaids provided.

Figure 12-5: General Section through Brent B GBS Drilling Legs and Minicell Annulus



12.4.1 Material in GBS Drilling Legs

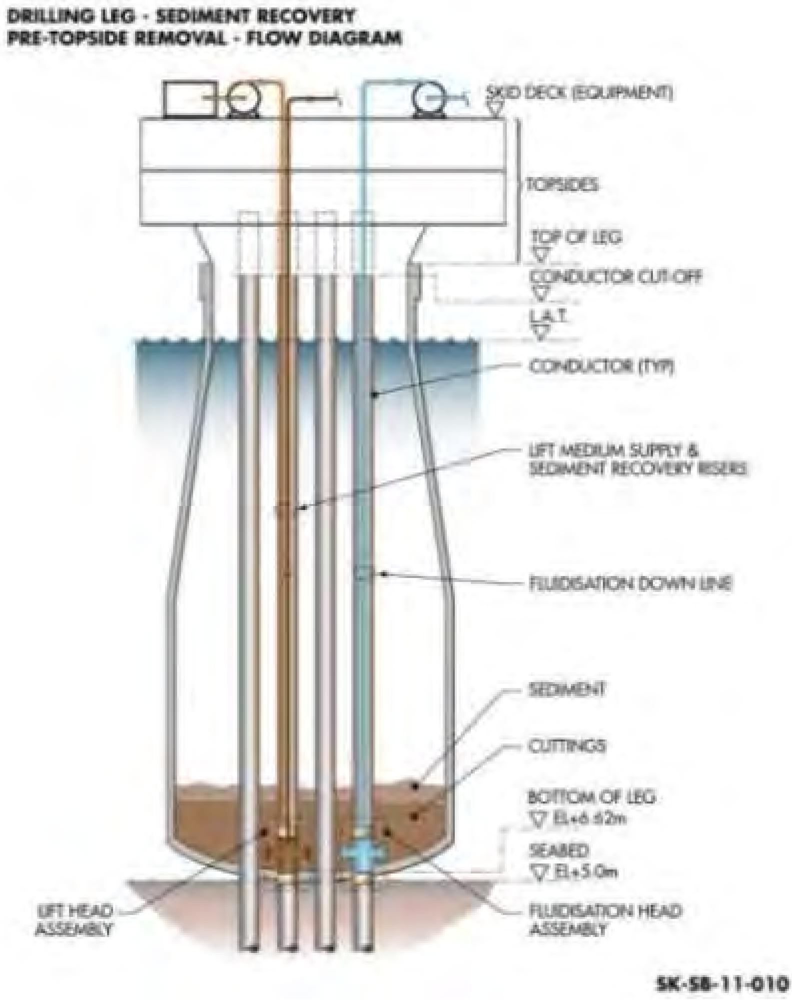
12.4.1.1 Option 1: Recover and reinject

Topsides in place (Brent B only)

Option 1 requires the sediment to be recovered from the bottom of the drilling leg. The drill cuttings and sediment will be fluidised in order to allow the material to be lifted to the topsides for pre-processing and transportation to a new remote injection well. Separating the clean sediment from the drill cuttings is not deemed feasible due to the remote access which is only really available via the drilling conductors. This process is illustrated in Figure 12-6.

For the purpose of this study the surface equipment would be located on the skid deck, therefore the lift requirement is in the region of 183 m.

Figure 12-6: Flow Diagram of Sediment Recovery System with Topsides in Place



Access to the sediment would be achieved via the conductors. The inner drill strings would be removed and the conductors would be perforated using AWJ equipment deployed from the topsides. Once the conductors have been perforated the fluidisation and lift heads can be deployed. The sediment would be fluidised by injecting high pressure seawater via multiple conductors located around the periphery of the leg and recover the material via a single, more central conductor.

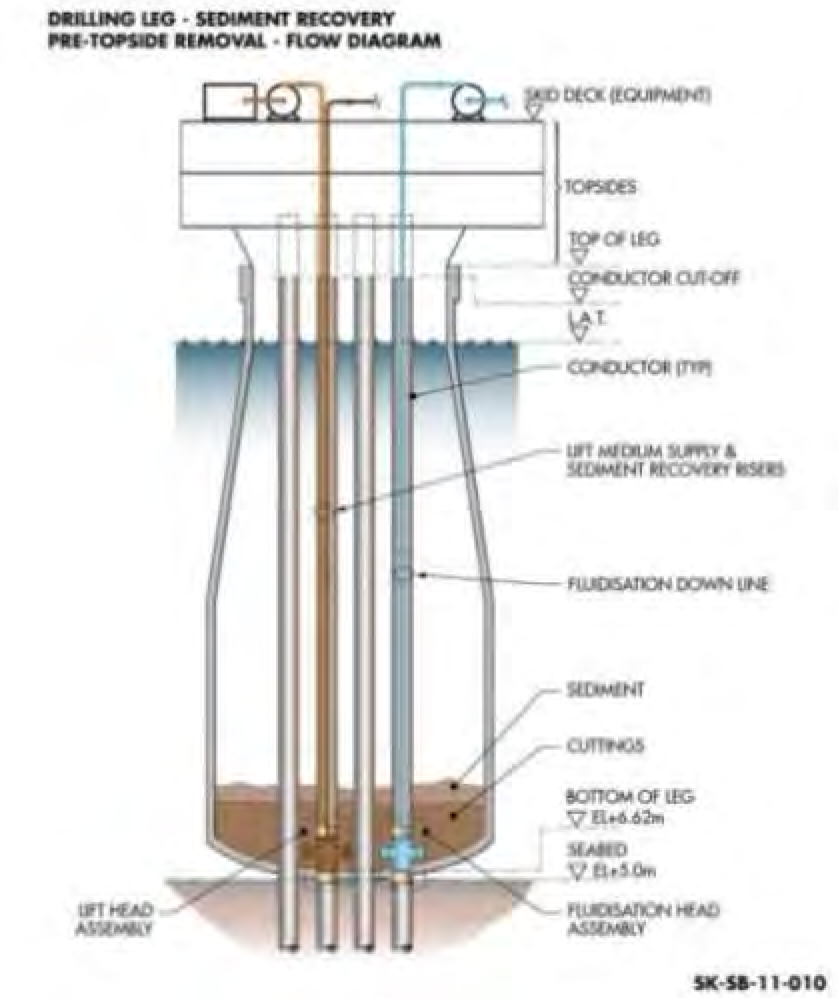
Once recovered to the topsides, the total volume of the water content would be reduced by approximately 50% prior to being transferred via tanker to a well injection vessel. It is envisaged that the well injection vessel will be a LWIV and will therefore not have the facilities to reduce the liquid volume. The removed liquid would be treated through a water polishing package installed on the topside.

Post topsides removal

The post topsides removal option is similar to the above with the obvious exceptions. In this case the services previously provided from the topsides would be provided from an SSCV equipped with a suitable work-over platform to provide access over the top of the leg. The work-over platform would also have to be suitable to perform the drill casing cutting and recovery operations; the main equipment, pumps and treatment packages would be located on the main vessel.

Dewatering would be performed on a MSV with suitable treatment packages. The remaining sediment and liquid would be transferred via tanker to the LWIV for injection in the new remote well, followed by the re-injection of the separated water (50% by volume).

Figure 12-7: Flow Diagram of Sediment Recovery System with Topsides Removed



The drilling legs contain a number of conductors and the challenge is to access the bottom of the legs; there is no personnel access down the flooded (to LAT) drilling legs therefore any work to recover the sediment has to be by remote methods.

The programme of work for each drilling leg would comprise:

1. Drill a remote injection well
2. Remove concrete caps (post topside removal only)
3. Locate a work-over platform over the leg, from an SSCV (post topside removal only)
4. Cut and recover the necessary sections of casings
5. Mill holes in bases of conductors
6. Place packers below each of the holes
7. Insert flexible down line and fluidisation head into the conductors to deliver fluidisation fluid to sand ballast layer.
8. Place packers above these units in the conductors.
9. Mill hole in the base of the single selected recovery conductor.
10. Place venture suction head and line in this conductor.
11. Place packer above this suction head.
12. Install a fluidisation pumping package and a recovery pumping package
13. Install a dewatering package (pre topside removal only)
14. Pump up the slurry, using a 6” hose with minimum of 1 cm/sec flowrate to prevent drop-out**,**
15. Dewater by 50% and discharge treated water to sea (pre topside removal only)
16. Pump slurry to tanker. Floating hose, tanker on DP near platform using 12” hose.
17. Decommission topside packages (pre topside removal only)
18. Remove work over platform and replace leg caps (post topside removal only)
19. Transport by tanker to remote well.
20. Locate LWIV on well.
21. Dewater slurry by 50% (post topside removal only)
22. Store excess water in tanker (post topside removal only)
23. Pump slurry from tanker to LWIV via floating hose
24. Inject slurry down hole.
25. Inject excess water down hole (post topside removal only)
26. P&A injection well

12.4.1.2 Option 2: Recover to shore for treatment

Recovery of the material to the surface is the same as described for Option 1 (tasks 2 to 18 above). The programme of work for each drilling leg for Option 2 would additionally comprise:

- Transport by tanker to shore.
- Pump slurry to holding tanks onshore, using 12” hose at 1cm/hour.
- Dewater slurry to 10% water (if topsides is in place then slurry is dewatered to 50% offshore and then down to 10% onshore; if post topsides removal, all dewatering is onshore). Discharge treated water.
- Treat slurry through Low-temperature Thermal Desorption. Treatment rate of 5m3 /hour
- Transport dry inert solids to landfill site. Assume in 25 tonne lorry-loads with a round trip of 200 km to a licenced site
- Collect recovered oil and re-use.

12.4.1.3 Option 3: Leave in place and cap

Option 3 requires the material to be left in place and to be capped with a suitable agent such as Bentonite in order to help minimise migration of the contaminated material into the marine environment.

The 13 3/8” and 18 5/8" casings within the conductors would be removed and the conductors perforated, sealed and used to distribute the capping agent and allow it to settle onto the top of the sediment. This will require the development of the conductor perforation tooling sealing systems as for Options 1 and 2. The sealing of the conductors is envisaged to utilise packers which will result in only small volumes of the conductor being injected with the capping material and therefore maintaining the required flow rate.

The sediment layer in the drilling legs could be neither flat nor level, and this would have to be taken into account when estimating the volume of capping agent required to achieve the desired sealing barrier. It may be necessary to modify the capping agent to provide a structural element, i.e. another material to provide surface strength to support the capping agent.

The programme of work for each drilling leg would comprise:

1. Remove the concrete caps (post topside removal only).
2. Locate a work-over platform over the leg, from an SSCV (post topside removal only).
3. Cut and recover the necessary sections of casings
4. Mill a series of perforations in selected conductors above the level of the material to be covered.
5. Place packers below each set of holes.
6. Insert flexible down line inside the conductors
7. Place packers above the perforation
8. Install a capping carrier fluid pumping package on the skid deck.
9. Pump the capping agent down the line into the conductor and out through the perforations using a 6” hose with minimum of 1cm/sec flowrate to prevent drop-out.
10. Launch a 3D sonar in between the conductors to verify that the surface is adequately covered by the capping agent
11. Decommission the pumping package; leave the lines in place inside the conductors.
12. Remove work-over platform and replace leg caps (post topside removal only)

12.4.1.4 Option 4: Leave in place with MNA

The nutrients and bacteria required to promote the degradation of the hydrocarbons in the sediment would be introduced through one or more perforations in selected conductors. The technical issues associated with accessing the conductors, cutting perforations, and packing the conductors would all be the same as for Options 1-3. An additional study would be required to determine the optimal number and location of perforations in order to ensure that the bio-stimulation materials were properly distributed throughout the sediment. It is noted that the efficacy of such a remediation option is not assured, particularly in a situation where the sediment cannot be oxygenated or agitated.

Tasks 1 to 7 detailed under Option 3 are also required for Option 4. The programme of work for each drilling leg for Option 4 would additionally involve:

- Install a bio-stimulation capping carrier fluid pumping package on the skid deck or work-over platform.
- Pump the bio-stimulation fluid/agent down the line into the conductor and out through the perforations. If 3”-4” hose with minimum of 1 cm/sec flowrate to prevent drop-out.
- Decommission the pumping package; leave the lines in place inside the conductors.
- Install temporary monitoring equipment
- Remove work-over platform and replace leg caps (post topside removal only)

The progress of the biological process must be monitored. In general, this is done through physical sampling of both the contaminated materials and water phase. Whilst this can be readily achieved with the topsides in place, it would become extremely onerous after the topsides removal. Therefore, *in situ* remote monitoring equipment would need to be developed and installed prior to the removal of the temporary deck.

12.4.1.5 Option 5: Leave *in situ*

In Option 5 the material in the drilling legs would be left *in situ* to degrade naturally as the structure itself degrades over hundreds of years. The location of these materials makes their immediate release into the marine environment during the collapse of the concrete structure highly unlikely. As a consequence, no specific fate modelling has been carried out by Shell to predict the dispersion into the marine environment.

12.4.2 Material in GBS Minicell Annulus

12.4.2.1 Option 1: Recover and reinject

There are no existing pipes or down-lines in the minicell annulus that are suitable for the recovery of the sediment or the deployment of the capping material. For any of Options 1-4, new risers and down-lines would therefore need to be installed following the creation of a new access into the leg, at an elevation just above the tops of the cells. To reach the sediment in the annulus, however, the down-lines would have to pass through new penetrations at EL+70.5 m and ROV access would have to be gained to the platform around the minicell annulus at approx. EL+ 58.5 m.

The programme of work would comprise:

1. Drill new remote injection well.
2. Clear drill cuttings at the base of the leg
3. Install working platform for divers
4. Drill and install chemical anchors
5. Install drilling stack and drill 4 pre-holes
6. Install support frame
7. Install DWC tool
8. Cut new 3 m x 2 m hole in side of utility leg, by DWC.
9. Lift away the whole section of cut concrete.
10. Use work-class ROV (WCROV) to enter leg and create access for deployment of venture hoses into minicell annulus waste and sand ballast.
11. Use DWC system on WCROV to cut steel as necessary.
12. Connect hoses to large MSV or similar on DP near legs.
13. Slurrify all contents of minicell annulus and pump to surface (loading buoy).
14. Pump slurry to tanker. If 12” hose at 1 cm/hour.

15. Transport by tanker to remote well.
16. Locate LWIV on well.
17. Dewater slurry on tanker and store excess water.
18. Pump slurry from tanker to LWIV.
19. Inject slurry down hole.
20. Inject excess water from tanker down hole.
21. P&A injection well.
22. Remove hose(s) from the utility leg. Leave hole open.

12.4.2.2 Option 2: Recover to shore for treatment

Regardless of timing the slurry would be brought onshore as waste regulations would prohibit the discharge of liquids and/or solids. The methodology for recovery of the material to the surface is the same as described for Option 1, so steps 2-14 above apply. The programme of work for Option 2 would additionally involve:

- Transport by tanker to shore
- Pump slurry to holding tanks onshore, using 12” hose at 1 cm/hour
- Dewater slurry to 10% water and discharge treated water
- Treat slurry through Low-temperature Thermal Desorption unit at 5 m^3 /hour
- Transport dry inert solids to landfill site.
- Collect recovered oil and re-use
- Remove hose(s) from utility leg; leave hole open

12.4.2.3 Option 3: Leave in place and cap

Option 3 requires the material to be left in place and to be capped with a suitable agent such as bentonite and/or sand in order to help minimise migration of the contaminated material into the marine environment and provide a barrier. It may be necessary to modify the capping agent to provide a structural element, i.e. another material, to provide surface strength to support the capping agent.

The methodology for generating access to pump material to the top surface within the minicell annulus is the same as described for Option 1, steps 2-9. The programme of work for Option 3 would additionally involve:

- Use work-class ROV to enter leg and create access for deployment of one or more new hoses onto top of minicell annulus waste and sand ballast
- Use DWC system on WROV to cut steel as necessary
- Install a capping carrier fluid pumping package on the MSV
- Pump the capping agent down the hose and out onto the minicell annulus material. If 6” hose with minimum of 1cm/sec flowrate to prevent drop-out
- Decommission the pumping package; remove the hose(s) from the utility leg
- Remove hose(s); leave hole open

12.4.2.4 Option 4: Leave in place with MNA

The nutrients and bacteria required to promote the degradation of the hydrocarbons in the sediment would be introduced through the flexible risers and down-lines. The technical issues associated with installing the risers and down-lines would be the same as for Options 1-3. Additional study would be required to determine the optimal number and location of down-

lines in order to ensure that the bio-stimulation materials were properly distributed throughout the sediment. It is noted that the efficacy of such a remediation option is not assured, particularly in a situation where the sediment cannot be oxygenated or agitated.

The methodology for generating access to pump material to the top surface within the mini cell annulus is the same as described for Option 1, steps 2-9. The programme of work for Option 4 would additionally involve:

- Use work-class ROV to enter leg and create access for deployment of one or more new hoses into minicell annulus material
- Use DWC system on WROV to cut steel as necessary
- Install a bio-stimulation carrier fluid pumping package on the MSV
- Pump the bio-stimulation fluid/agent down the hoses into the minicell annulus material. If 3”-4” hose with minimum of 1cm/sec flowrate to prevent drop-out
- Decommission the pumping package; leave the lines in place inside the utility leg
- Remove the hose(s); leave the hole open

12.4.2.5 Option 5: Leave *in situ*

In Option 5 the material in the minicell annulus would be left in place to degrade naturally as the structure itself degrades over hundreds of years. The location of these materials makes their immediate release into the marine environment during the collapse of the concrete structure highly unlikely. As a consequence, no specific fate modelling has been carried out by Shell to predict the dispersion into the marine environment.

12.5 Significant Impacts of Decommissioning Options

Appendix 1 documents the assessment of all environmental categories for all of the decommissioning options. This section provides a summary of the Appendix 1 impact assessment matrices, discussing only the most significant impacts identified (those with either ‘small-moderate negative’ impacts or worse, or ‘small-moderate positive’ impacts or better).

12.5.1 Information to Support Environmental Assessment

As described in Sections 12.2.1 and 12.2.2, contaminated drill cuttings and oily sludge are thought to be contained within the drilling legs and minicell annuli of both Brent B and D and would be exposed after degradation of the GBS, with the potential to pollute the marine environment.
The exposure of such materials to the marine environment has not been modelled. However, as shown in Table 12-6, the volumes and oil loads within the minicell annuli and drilling leg materials are much smaller than those in the GBS cell sediment (the release of which has been modelled). The total oil load within the minicell annuli and drilling legs material is, in total, less than 1% of the total oil load within the cell sediment.

Also, it is likely that much of the minicell and drilling leg contents would actually be prevented from entering the marine environment because they are located within the depths of the GBS such that when the GBS disintegrates, the wastes may remain buried under the GBS remains. The wastes are located on the bases of the drilling legs, near the centre of the caisson, so there are at least three concrete cell walls between the wastes and the marine environment.

Taking these factors into account, only localised pollution to the marine environment would result if the materials were left *in situ* and ultimately exposed to the marine environment, and the impact would be much less than that modelled for a cell sediment release.

Table 12-6: Comparison of Estimated Volume of Contaminated Materials and Hydrocarbon concentrations at Brent Field

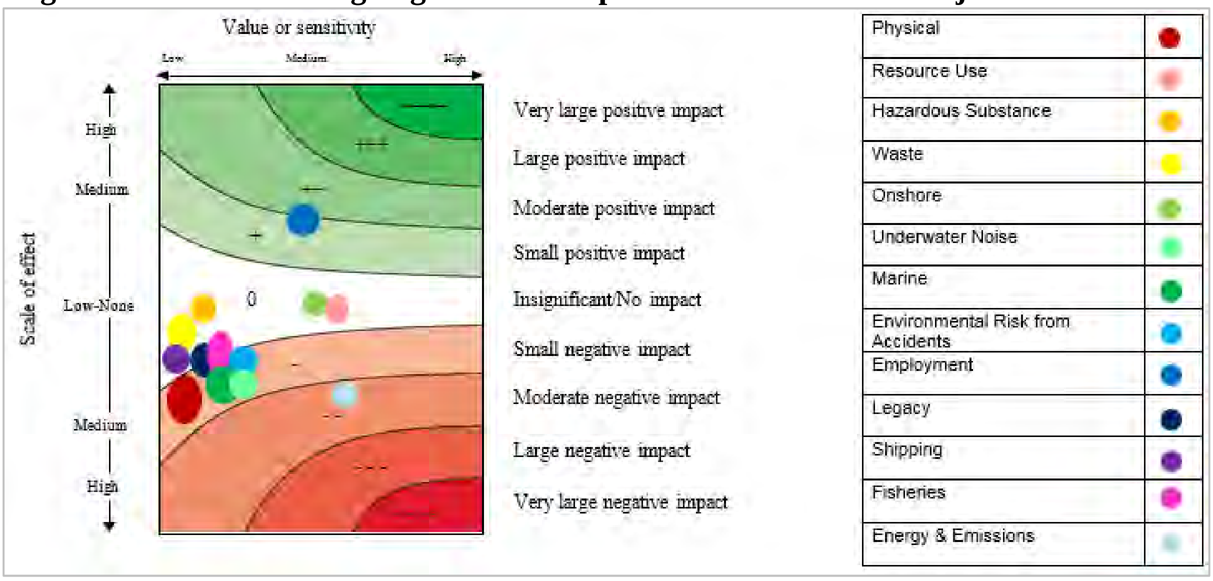
	Waste at bottom of all minicell annulus	Cuttings at bottom of all drilling legs	GBS cell sediment total
Contaminated materials Brent (m^3)	500*	4,000**	~39,400
TPH (%)	5%	1.2%	15%***
Petroleum Hydrocarbon load (m^3)	25	56	~13,000
Proportion of oil load compared against Cell sediment oil load	~0.2%	~0.4%	-

* Value used during data reconciliation based upon measured range 135-270m^3
**Based upon average sediment volumes of 500m^3 in East leg and 1500m^3 in west leg
***Concentration by weight

12.5.2 Significant Impacts from GBS Drilling Legs Decommissioning Options

As shown in Figure 12-8 the most significant impacts identified for Option 1 are in the employment and energy and emissions categories. Estimated impacts are considered small or insignificant for all other environmental categories.

Figure 12-8: GBS Drilling Legs Material Option 1: Remove and re-inject into new well



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

12.5.2.1 Employment

The overall impact on employment as a result of GBS drilling leg decommissioning activities under Option 1b is estimated to be **'small-moderate positive'**.

Shell commissioned an independent report to estimate the employment generated by the BDP. As part of this study, a factor was derived for the Brent project of £250,000 per new job per year. This factor was then applied by Shell to estimate the man-years generated for each decommissioning option. Shell estimates that GBS drilling legs Option 1b will generate 1,219 man-years of work.

Although this number is small when considered within a wider context (the UK oil and gas industry is estimated to employ 330,000 people [69]), 1,219 man years is still considered a 'small-moderate positive' benefit in recent times of relatively high unemployment in the UK oil and gas sector. It should be noted that only 223 man-years are estimated for Option 1a, an 'insignificant' impact.

12.5.2.2 Energy and Emissions

Figure 12-8 shows the most significant impact identified in Option 1 (1b, post-topsides removal) to be energy and emissions. DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use as a result of decommissioning the drilling legs material in Option 1b (post-topsides removal). Comparing this against the energy impact categories in Table 5-7, the impact from energy use is estimated to be **'moderate negative'** when considering Brent B and D GBS together. Table 12-7 details the energy and emissions for Option 1.

Table 12-7: Energy and Emissions from Brent B and D GBS Drilling Leg Option 1b: 'Recover and Re-inject' (combined totals)

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	-	-	-	-
Marine operations	1,387,210	103,572	2,385	672
Onshore treatment and transport to disposal	-	-	-	-
Onshore transport to recycling	-	-	-	-
New Material	-	-	-	-
Sum	*1,387,210*	*103,572*	*2,385*	*672*
Recycling				
Material recycling	-	-	-	-
Material Replacement				
Materials not recycled	ND	5[3]	-	-
Total	1,387,210	103,576	2,385	672

[1] Operations categories are defined in Section 5.2.3.
[2] No at field operations, onshore dismantling, treatment or disposal for this option
[3] Oil (in drilling legs waste material) is not recovered and a CO_2 emissions penalty is applied for 'lost' oil.

Under Option 1b, the material in the Brent B and D GBS drilling legs would be recovered to a vessel and re-injected into new remote subsea wells. The total energy demand from operations is estimated to be approximately 1.4 million GJ. The vast majority of CO_2 emissions (approximately 103,600 tonnes) are direct emissions from marine vessels (99.9%) such as the HLV, LWI, and ROVSV, supply vessel, mid-range tanker and drilling rig. There is also a small energy and emissions 'penalty' applied for the loss of oil (5 tonnes) within the drilling legs that would not be recovered. There are no onshore operations.

The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put this into another context, the total CO_2 emissions for Option 1b are approximately 4% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70].

See DNV GL's *Energy Use and Gaseous Emissions Report* [2] for further information.

For Options 2-5, the estimated impacts are considered small or insignificant for all environmental categories, as shown in Figure 12-9 to Figure 12-12.

Figure 12-9: GBS Drilling Legs Material Option 2: Remove and process onshore

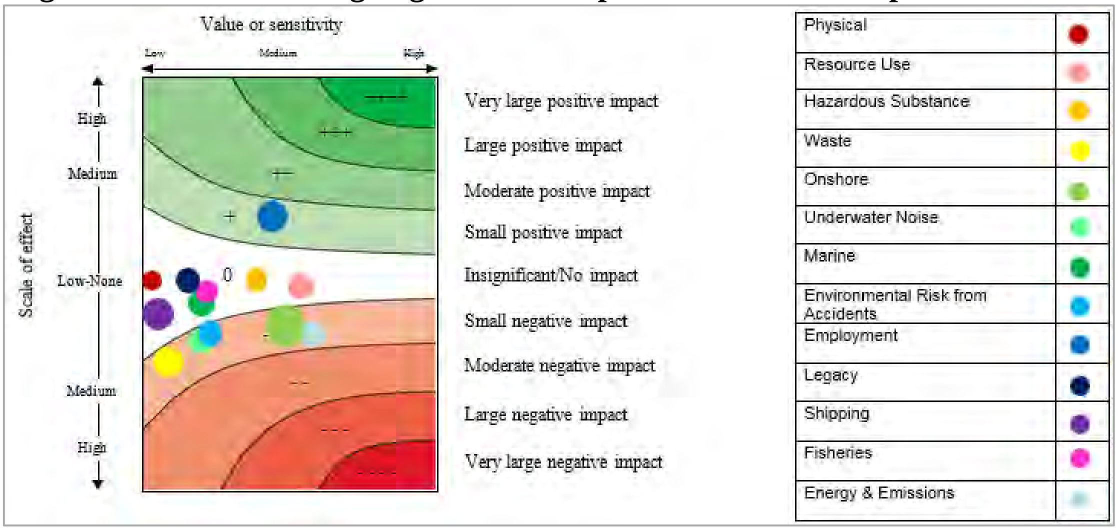


Figure 12-10: GBS Drilling Legs Material Option 3: Leave in place capped

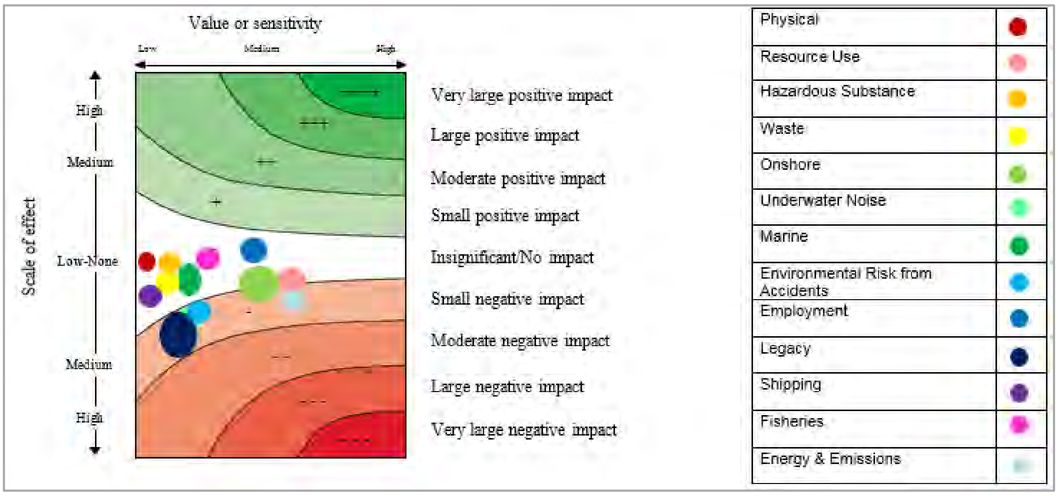


Figure 12-11: GBS Drilling Legs Material Option 4: Bio-stimulation *in situ*

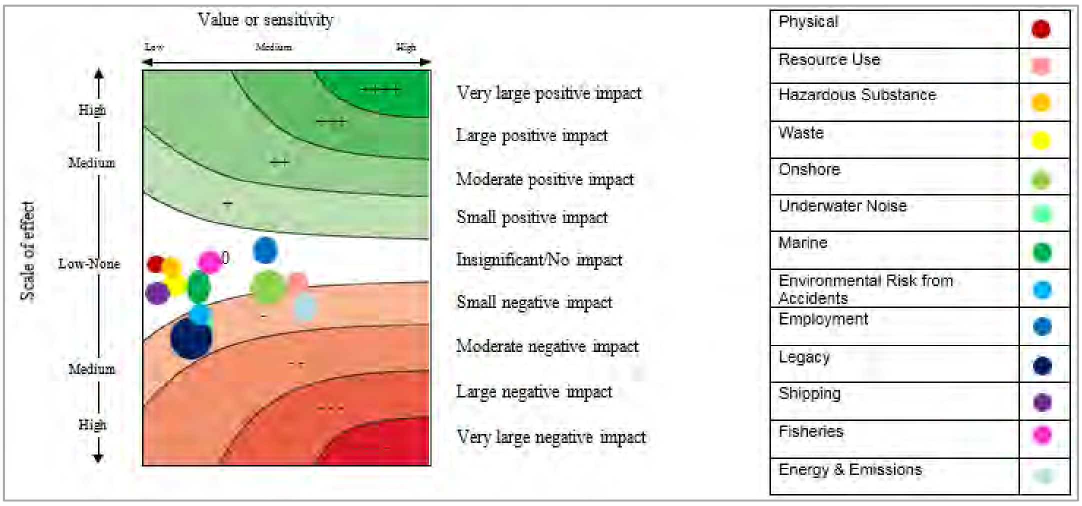
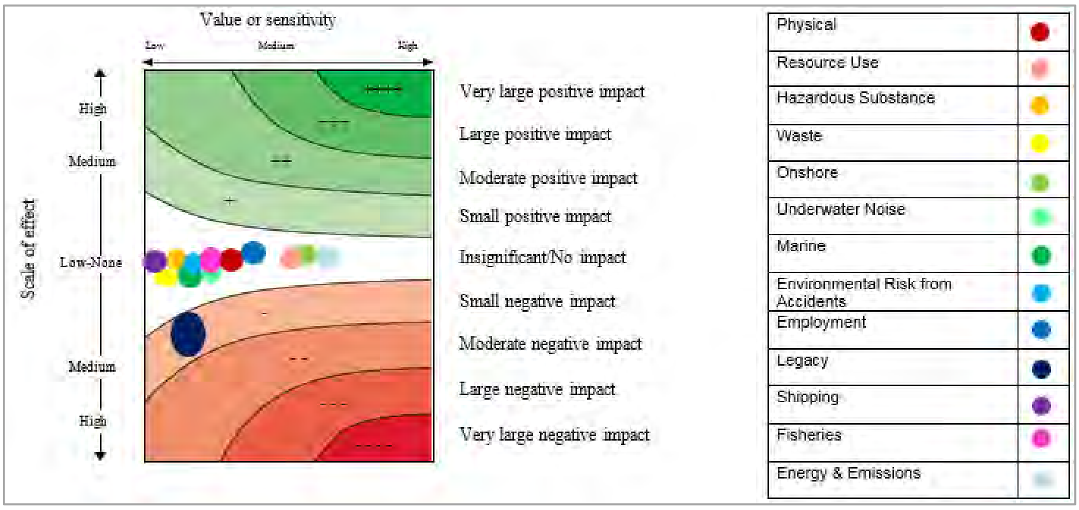


Figure 12-12: GBS Drilling Legs Material Option 5: Leave in place



Note to above Figures 12-9 to 12-12:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, November 2016.

12.5.3 Significant Impacts from GBS Minicell Decommissioning Options

As shown in Figure 12-13 to Figure 12-17, estimated impacts are considered small or insignificant for all environmental categories for Options 1-5.

Figure 12-13: GBS Minicell Annulus Material Option 1: Remove and re-inject to well

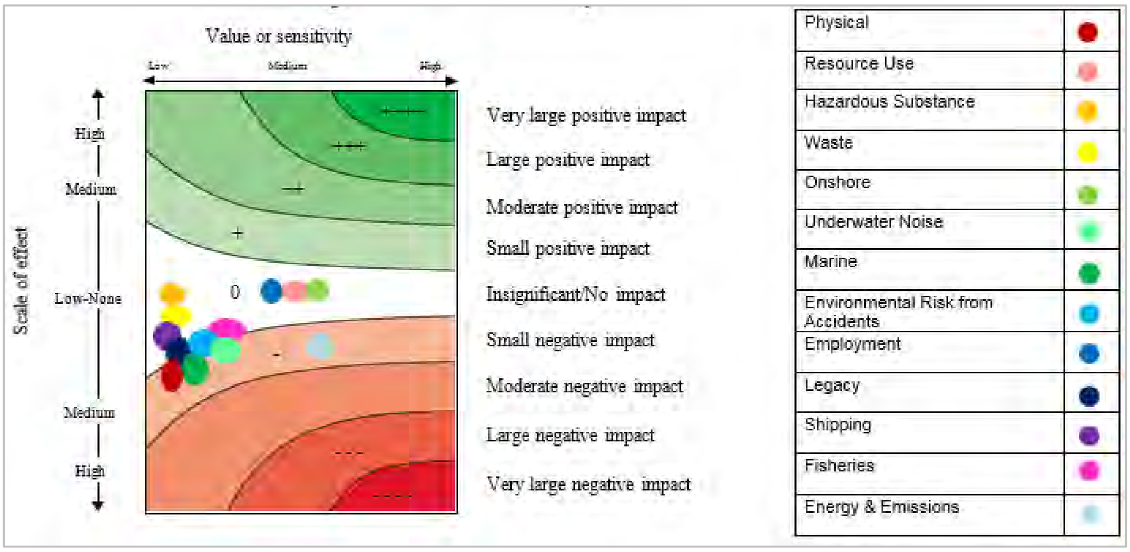


Figure 12-14: GBS Minicell Annulus Material Option 2: Remove and process onshore

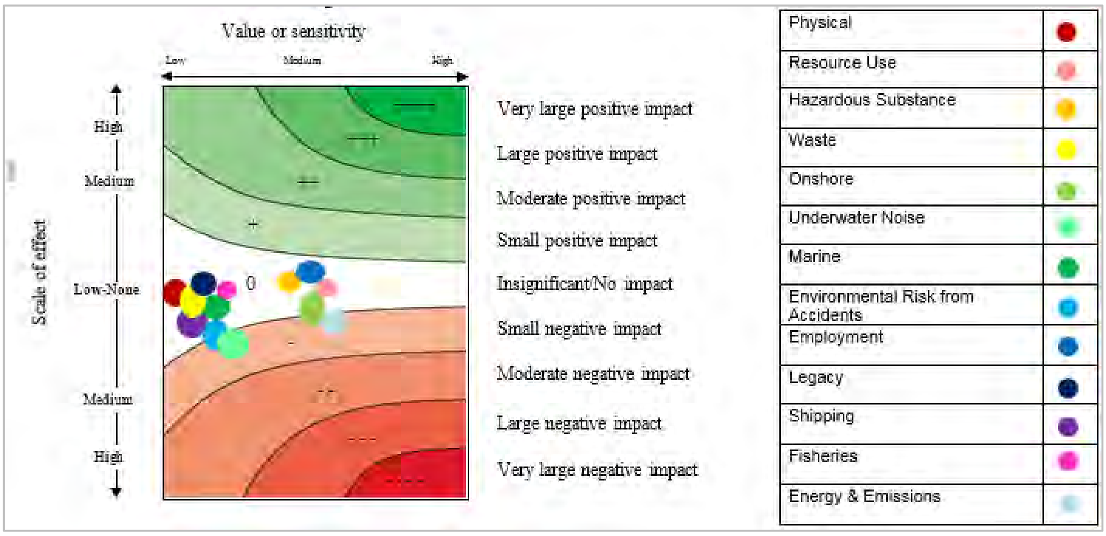


Figure 12-15: GBS Minicell Annulus Material Option 3: Leave in place capped

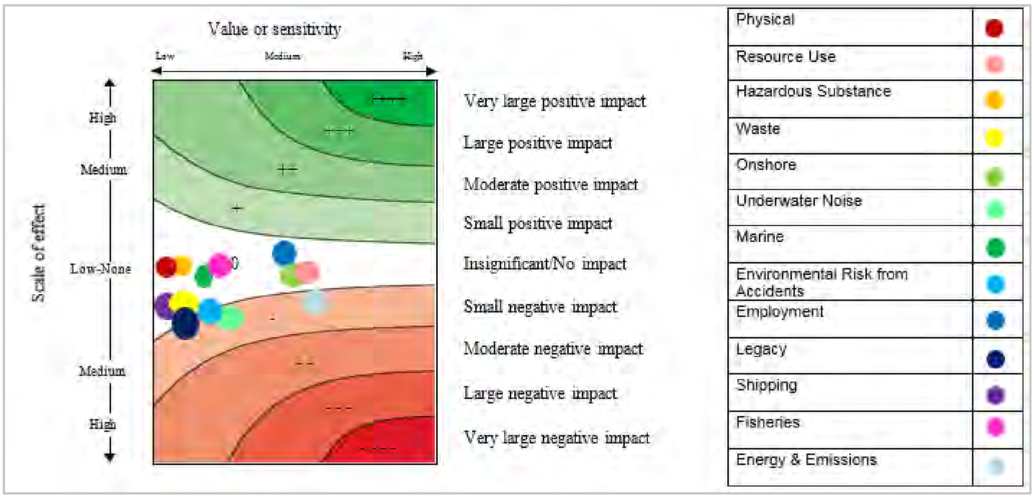


Figure 12-16: GBS Minicell Annulus Material Option 4: Bio-stimulation *in situ*

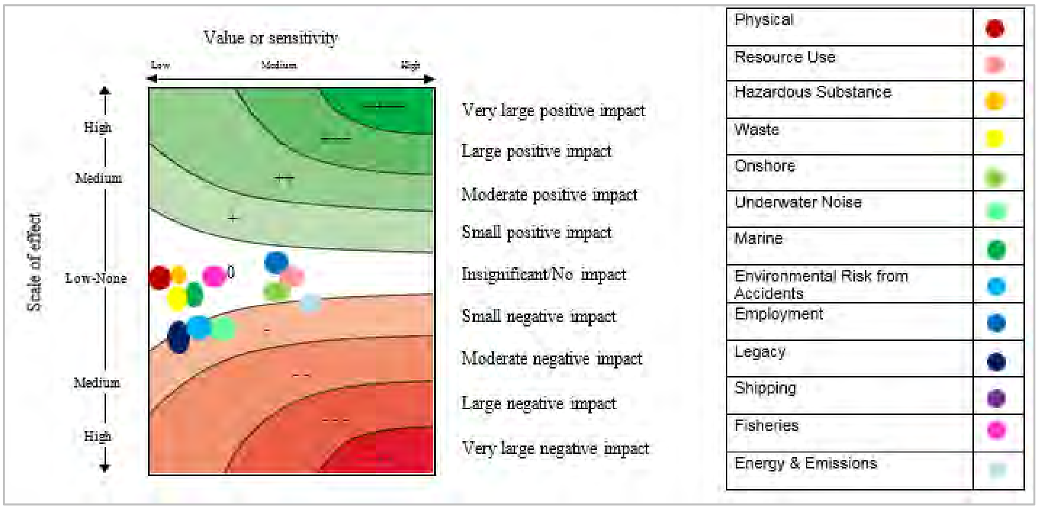
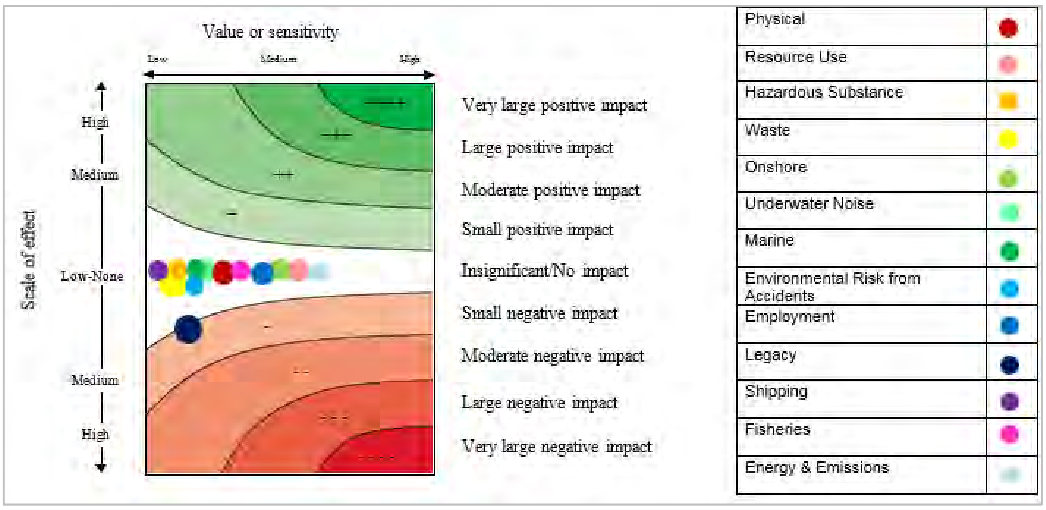


Figure 12-17: GBS Minicell Annulus Material Option 5: Leave in place



Note to above Figures 12-13 to 12-17:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

12.6 Comparison of Options for Decommissioning of the GBS Drilling Legs and Minicells

The five options to decommission the GBS drilling leg material are the same as the decommissioning options for the materials in the minicell annuli. All environmental impacts are estimated to be small or insignificant for all of the decommissioning options (apart from energy and emissions for Drilling legs Option 1b). This is because the volumes of the contaminated materials involved, and the oil load contained within them, are only a fraction (less than 1%) of those for the GBS cell sediment. Although there are some fundamental differences between impacts for Options 1 and 2 (remove the material) and Options 3, 4, 5 (leave *in situ*), almost all the impacts are small or insignificant, thus there is little to distinguish between the environmental impact of these decommissioning options.

There are also some minor differences in environmental impact between decommissioning operations for the Brent B drilling legs material conducted with the Brent B topsides in place and post-topside removal. If the Brent B topsides had been removed, services which would previously have been provided from the Brent B topsides would need to be provided from an SSCV equipped with a suitable work-over platform to provide access over the top of the GBS leg. The differences in environmental impact are minor.

12.7 Significant Impacts of Proposed Programme of Work

Shell's proposed decommissioning option for both the GBS drilling leg and minicell annulus material is Option 5: leave *in situ* for natural degradation. The key negative impact identified for Option 5 is the legacy impact from localised pollution that will occur after the degradation of the GBS when the drilling leg and minicell material is exposed to the marine environment. However, as discussed in 12.5.1, the minicell and drilling leg material volumes are much smaller than the volumes of GBS cell sediment, and contain much less oily content than the cell sediment. Also, as the material is located within the structure of the GBS, it is likely that much of the minicell and drilling leg contents would actually be restricted from entering the marine environment. It is envisaged that as the GBS disintegrates much of the wastes may remain buried under the GBS. Taking these factors into account, the legacy impact from leaving the drilling leg and minicell material *in situ* is estimated to be 'small negative'.

12.8 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that mitigation and management measures are in place. Table 12-8 details these measures for the proposed options to decommission the GBS drilling legs and minicell and highlights the residual impacts described in Section 12.7 and Appendix 1.

Table 12-8: Summary of Mitigation and Management Measures for Proposed Programme of Work

Environmental Category	Mitigation Measures	Residual Impact
Onshore Impacts	No onshore impacts	No impact
Resource Use	There are few resources used	No impact
Hazardous Substances	There are no hazardous substances used	No impact
Waste	There are no wastes produced	No impact
Physical	There are no physical impacts	No impact
Marine (includes underwater noise)	There are no marine impacts	Insignificant
Environmental Risk from Accidents	There are few operations therefore little environmental risk	Insignificant
Employment	There is no employment generated	No impact
Legacy	• After decommissioning Shell will discuss and agree with BEIS a long-term monitoring programme for the GBS structures and the surrounding environment. • Shell will discuss and agree with the regulator any appropriate actions if, after GBS degradation, environmental monitoring (for example, sediment analysis, benthic fauna samples) shows impacts to be more significant than predicted by modelling and desk studies. Specific remedial actions would need to be engineered to respond to the actual situation.	Small negative*
Fisheries	There are very few marine operations	Insignificant
Shipping	There are very few marine operations	Insignificant
Energy and Emissions	There are very few operations	No impact

*Insignificant-small negative for material in minicells

13. DRILL CUTTINGS

13.1 Introduction

This section describes the drill cuttings (seabed, cell top and tri-cells), the inventory of materials and the decommissioning options. The main anticipated environmental impacts of the decommissioning options are discussed and compared. The necessary management and mitigation measures to control the impacts of Shell's proposed programme of work are summarised, and measures are recommended to further reduce residual impacts where appropriate. The Technical Document for Decommissioning the Brent Field Drill Cuttings [104] has been used as the basis for Sections 13.2 - 13.5.

13.2 Description of Facilities

Drill cuttings are present on the sea floor, on the tops of the GBS cells, and within the Brent B and D GBS tri-cells. Drill cuttings are rock fragments that were generated by the drill bit during drilling. The cuttings were historically contaminated with drilling mud which was used to lubricate and cool the drill bit, maintain pressure, and to transport cuttings back to the topsides for separation prior to discharge.

There is a significant amount of drill cuttings at the Brent Field. Brent D has the greatest estimated volume of drill cuttings when considering seabed, cell top and tri-cell drill cuttings added together. Individually, Brent A has the greatest volume of seabed drill cuttings; Brent C has the greatest volume of cell top drill cuttings, and Brent D the greatest assumed volume of tri-cell drill cuttings. These data are presented collectively in the Inventory of Materials (Table 13-1) by area and volume for each Brent platform, and are a culmination of information produced from different reports by Gardline [105] and Shell [104].

13.2.1 Seabed Drill Cuttings

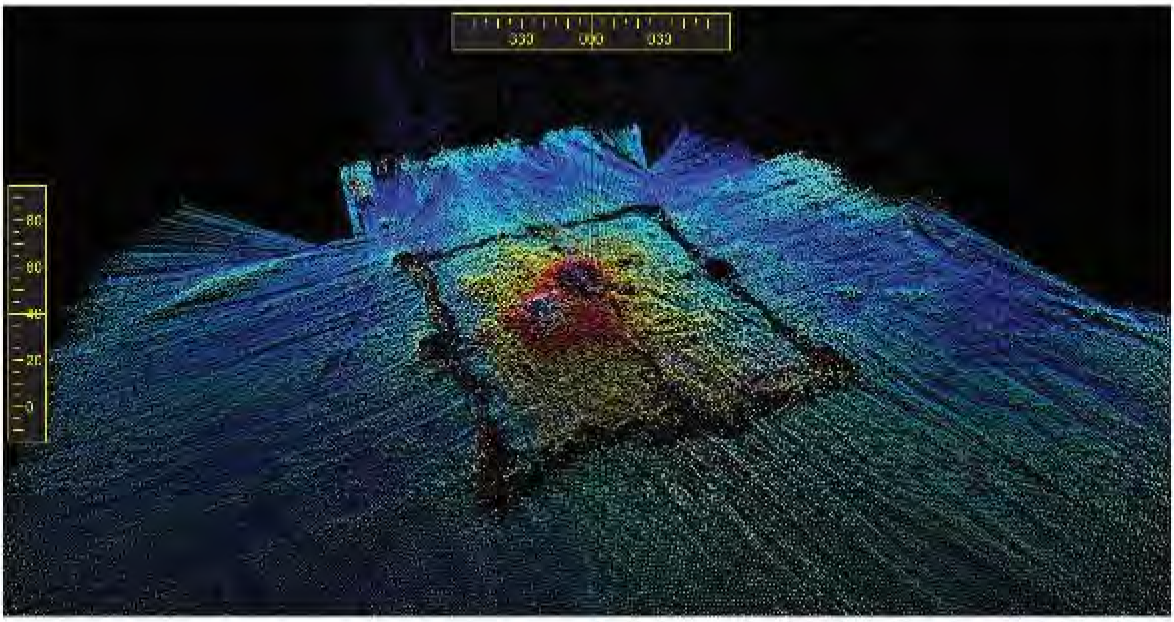
A number of surveys were conducted to examine the physical nature of the seabed and cell top drill cuttings piles at the Brent Facilities, and summarised by Xodus in 2007 [104]. A Remotely Operated Vehicle (ROV) with Multi Beam Echo Sounder (MBES) travelled along defined lines and the collected data was used to create topography charts and volume calculations. The footprints of the drill cutting piles were found to vary in size, depending on the platform. Shell's Plant Design Management System (PDMS) reassessed the results of the MBES seabed survey, and was used to bring together modelled data of the GBS and cuttings piles to calculate a residual volume, as summarised in Table 13-1.

The maximum thickness of the seabed drill cutting piles varies between 3-11 m, depending on the platform. The bulk of drill cuttings are located close to the platforms (within 50-100 m) but the seabed drill cuttings are spread over a wider area. Based on topography measurements (via MBES survey) the largest seabed area covered with drill cuttings is found at Brent A (approximately 8,880 m^2), shown in Figure 13-1. In total, approximately 20,900 m^3 of seabed drill cuttings (including Brent S) have been estimated at the Brent Field.

13.2.1.1 Brent A seabed drill cuttings

The 2007 MBES survey established that the Brent A seabed cuttings pile extends for 95 m in a platform N-S direction and 120 m across in an E-W direction (an area of 8,880 m^2) and that the maximum height of the drill cuttings pile above the reference level is 4 m. When the MBES survey data was imported and analysed in the Shell PDMS the MBES estimated volume of 6,506 m^3 was revised to 6,300 m^3.

Figure 13-1: 3D Image of Brent A Seabed Drill Cuttings]



13.2.1.2 Brent B seabed drill cuttings

According to the MBES survey data, the main accumulation of seabed drill cuttings at Brent B has occurred below the subsea discharge chute against the wall of GBS cell 11. The cell wall has provided a support structure for the deposited cuttings resulting in a maximum pile height of 11 m. The physical cuttings pile at Brent B was estimated by the MBES survey to cover an area of seabed of 3,414 m^2 and after processing of the MBES data in the PDMS system, the volume has been calculated to be 5,300 m^3.

13.2.1.3 Brent C seabed drill cuttings

The MBES survey indicated the greatest volume of seabed drill cuttings at Brent C has accumulated at the south-east side of the platform under the discharge chute, with the largest accumulation adjacent to GBS cell 31. The maximum height of the drill cuttings was estimated to be 9.5 m above the reference level, against the cell wall and the area covered was estimated to be 3,143 m^2. The PDMS estimate of the volume of the cuttings pile is 4,922 m^3.

13.2.1.4 Brent D seabed drill cuttings

Brent D has two drill cuttings discharge chutes and so the main accumulations of seabed drill cuttings are below these points, against GBS cells 14 and 16 at which the maximum heights recorded were approximately 10 m and 7 m respectively. The calculated area covered by the drill cuttings from the MBES survey is 1,632 m^2 and the PDMS calculated volume is 2,230 m^3.

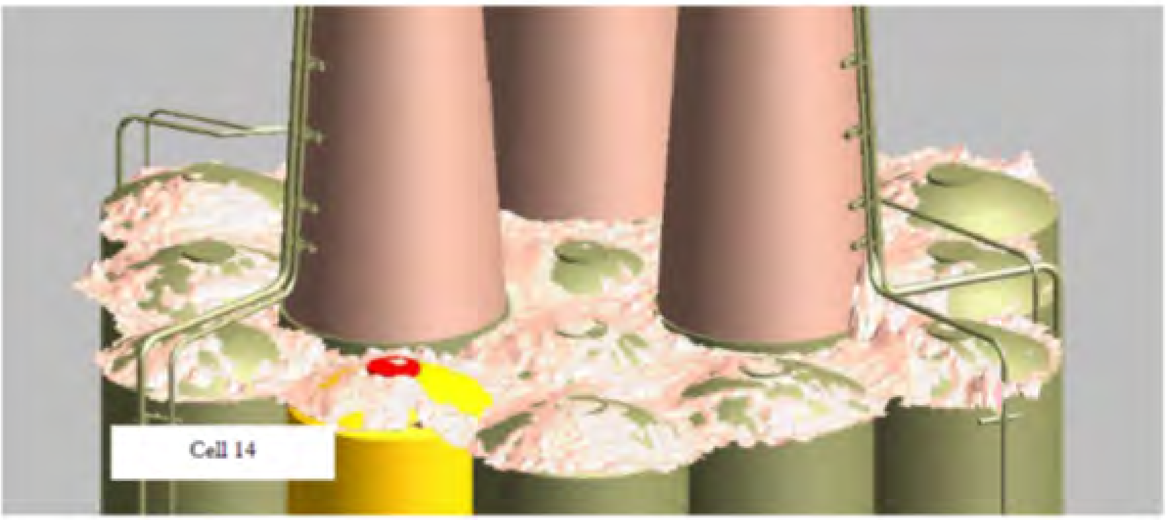
13.2.2 Cell Top Drill Cuttings

As with the MBES seabed survey data, the volume estimates from the 2007 MBES cell top survey were reassessed by Shell using PDMS. Cell top drill cuttings volumes for the three GBS are shown in Table 13-1. PDMS modelled images of each platform are also shown below. Debris and scaffolding were also identified on the cell tops of the three GBS.

13.2.2.1 Brent B cell top drill cuttings

The MBES survey calculated that the maximum height of the cell top drill cuttings pile was 3 m above the top of the GBS cell wall and that the cuttings pile had an area of 673 m^3. The PDMS estimate of the volume of the drill cuttings pile is 1,887 m^3 (Figure 13-2).

Figure 13-2: Brent B Cell Top Drill Cuttings PDMS Model



13.2.2.2 Brent C cell top drill cuttings

Brent C (Figure 13-3) has the largest amount of cell top drill cuttings, with a total volume of about 7,735 m^3 based on the PDMS review of the MBES survey data. The area covered was calculated to be 2,148 m^2. The conductors on Brent C are external, unlike Brent B and Brent D where the conductors are contained within the drilling legs; as a result, the conductors have supported the drill cuttings pile, with a maximum height of 11 m above the top of the vertical GBS cell wall. In Figure 13-4 the spiky peaks in the centre are the conductors. Debris and scaffolding were also identified on the cell tops of the three GBS.

Additionally, a survey was conducted by Gardline in 2012 [105] at Brent C to determine the chemical composition of the cell top cuttings pile. To do this, samples were taken from three pile depths (shallow, medium and deep) using an ROV and ROV support vessel. Results from the survey drew no conclusions regarding contamination surrounding the wider area of the platform; however the results suggest that due to the immobile nature of the cuttings pile, elevated concentrations of hydrocarbons and metals are confined within the cuttings pile on the cell tops and an approximate 100 m area surrounding the platform.

Figure 13-3: Brent C Cell Top Drill Cuttings PDMS Model

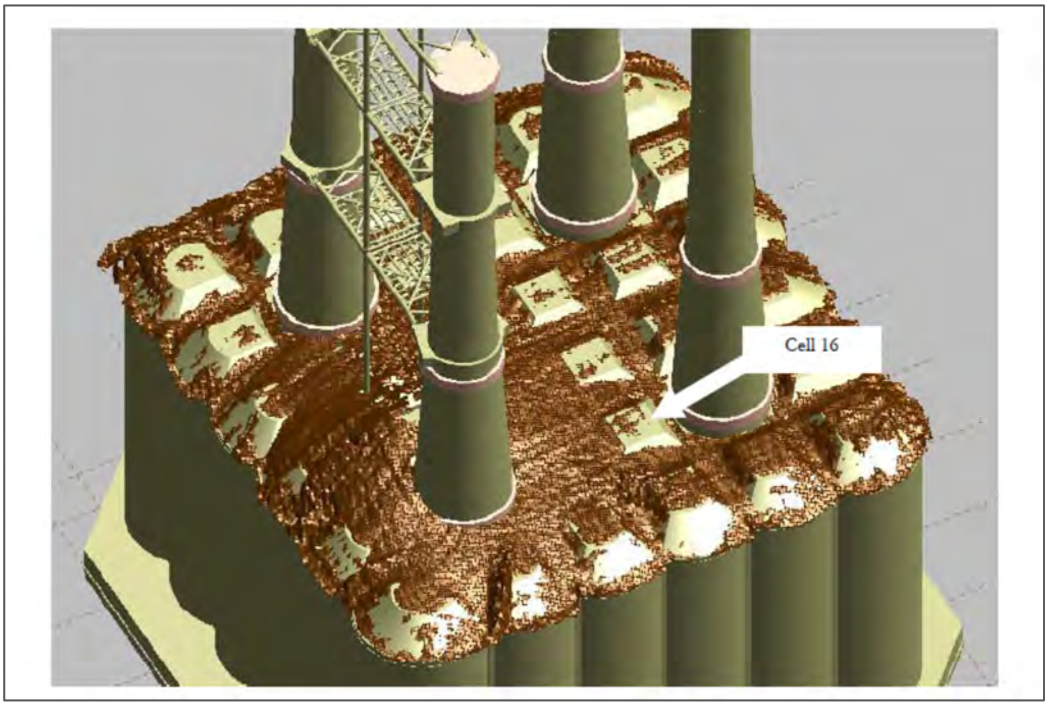
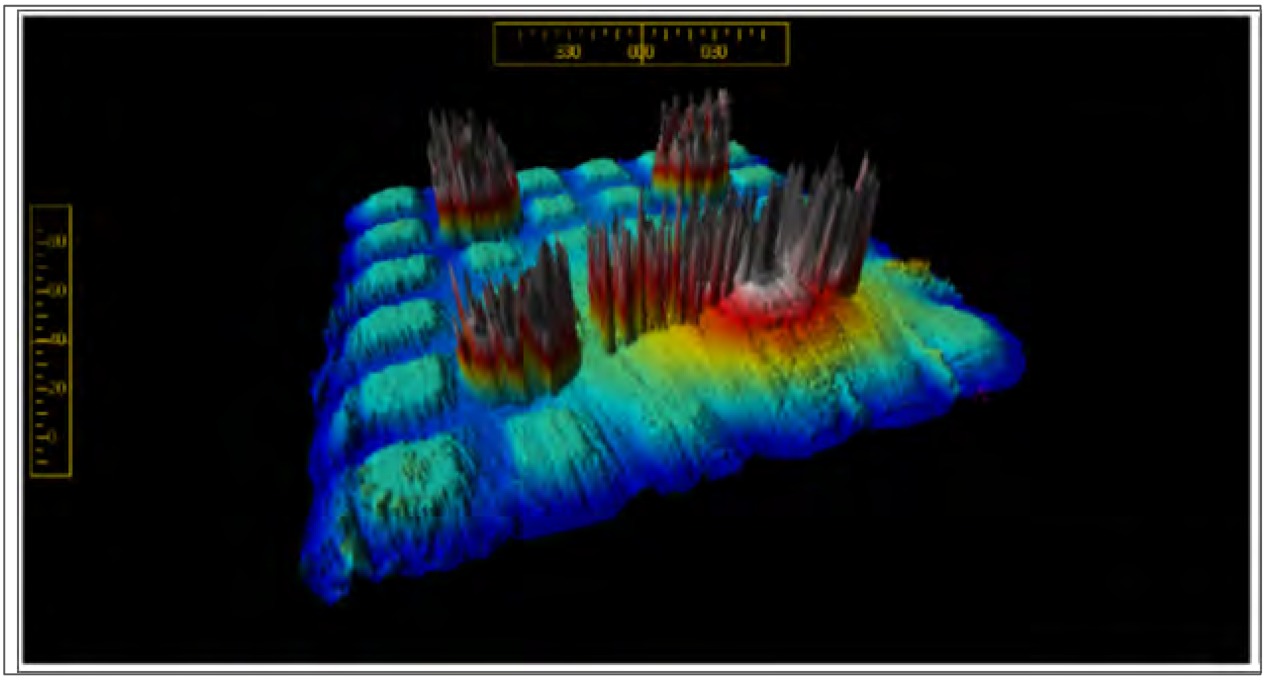


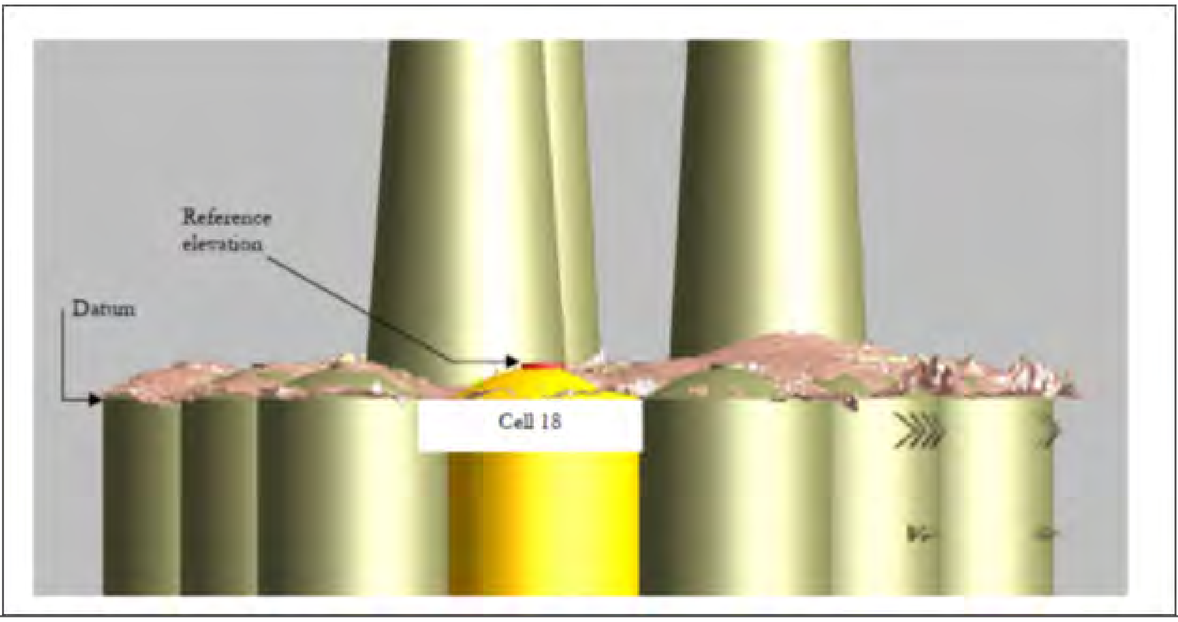
Figure 13-4: 3D Image of Brent C Cell Top Drill Cuttings



13.2.2.3 Brent D cell top drill cuttings

The PDMS evaluation of the 2007 MBES survey data calculated a volume of 798 m^3 for the Brent D cell top drill cuttings pile, covering an area of 234 m^2 with a maximum pile height above the top cell wall of 6.8 m, shown in Figure 13-5. Work to clear the cell caps on Brent D in 2015 allowed an ROV video survey to be completed. It was noted that only small volumes of drill cuttings were present on the cell caps; the video did not allow a quantification of the volume of drill cuttings within the cell valleys. All assessments have therefore been made using the 3,790 m^3 volume.

Figure 13-5: Brent D Cell Top Drill Cuttings PDMS Model



13.2.3 GBS Tri-cell Drill Cuttings

OBM-contaminated drill cuttings are present inside the tri-cells of two of the three GBS (as illustrated in Figure 13-6).

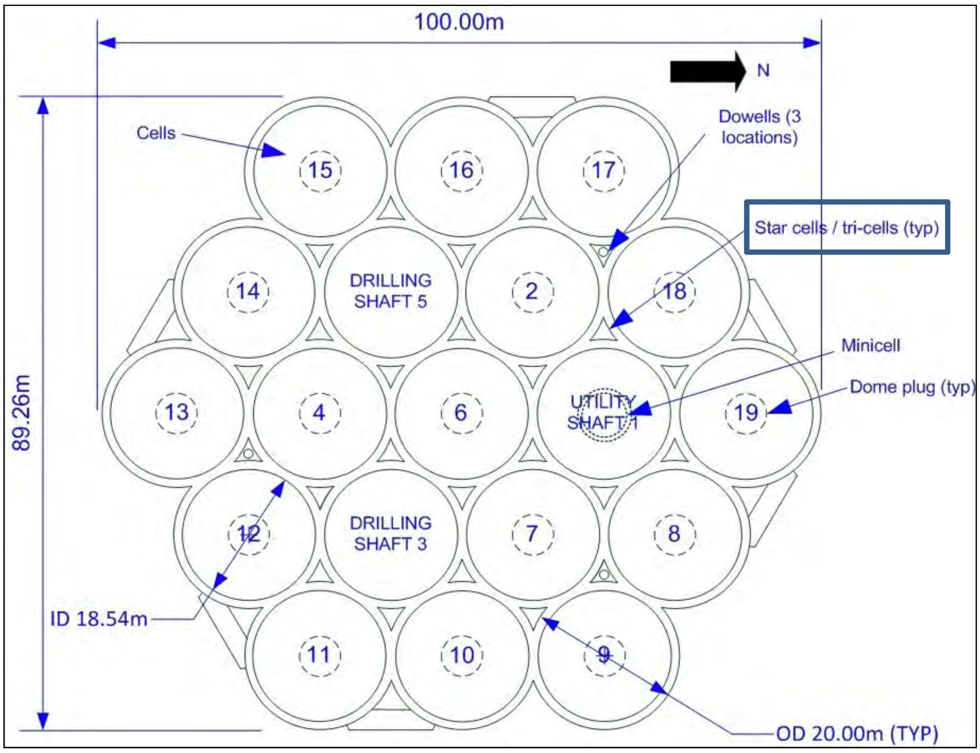
On Brent B and D, there are triangular gaps in between adjacent storage cells, known as tri-cells. The sides of the 'triangle' are approximately 5.8 m long. On Brent C, the tri-cells are the gap between the round GBS legs and the rectangular caisson structure.

The configuration of the Condeep GBS storage cells of the Brent B and Brent D caissons have resulted in gaps between adjacent storage cells, known as tri-cells. The tri-cells of the Brent B and D GBS run the full height of the GBS caisson, approximately 61 m. Because all of the tri-cells at Brent B and D have been open throughout the life of the Brent Field, they have become filled with some drill cuttings, natural sediment and small items of debris.

In 2015, video surveys of the Brent D cell-top were carried out to identify which tri-cells could be accessed with sampling equipment to confirm the presence or absence of drill cuttings. It was found that some of the tri-cell openings were occluded by drill cuttings or other debris such that the sampling equipment could not be deployed. The presence of drill cuttings in some of the other tri-cells could not be visually confirmed, indicating that either drill cuttings were not present or they were present but at a level too far below the opening to be reached by either the camera or the sampling equipment. Ultimately, only one tri-cell could be sampled and two core samples were recovered for analysis.

In contrast, the Brent C tri-cells, which are situated between the walls of the cells and the legs are not open to sea and therefore no drill cuttings can be present.

Figure 13-6: Configuration of Brent B and D GBS Tri-Cells



As is shown in the inventory of materials in Table 13-1, it is estimated (by calculation) that a total volume of approximately 26,800 m^3 of drill cuttings may be present in the GBS tri-cells at Brent B and D, which is larger than the total volume of drill cuttings present on the seabed. The estimated tri-cell volumes are maximum values derived by Shell from a simple mass balance of the total volumes of cuttings known to have been discharged at Brent, the mapped volumes present on the seabed and cell tops, and the volumes estimated in the drilling legs.

At present, the drill cuttings in the tri-cells are not exposed to the seabed and in places only partially exposed to the marine environment at the top of the tri-cells. However, the drill cuttings in the tri-cells will become exposed (to some extent) to the marine environment after eventual degradation of the GBS. This legacy impact is discussed later in this section.

13.3 Inventory of Materials

The inventory of materials for the Brent Field drill cuttings on the seabed, GBS cell tops and tri-cells is given in Table 13-1.

Table 13-1: Drill Cuttings Area and Volumes

Asset	Seabed		Cell Tops		Tri-cells	Total Area	Total Volume (Seabed, Cell top and Tri-cells) (m^3)
	Area (m^2)	Volume (m^3)	Area (m^2)	Volume (m^3)	Assumed Volume (m^3)	Seabed and Cell Tops (m^2)	
Brent A	8,880	6,300	0	0	0	8,880	6,300
Brent B	3,414	5,300	673	1,887	12,039	4,087	19,226
Brent C	3,143	4,922	2,148	7,735	0	5,291	12,657
Brent D	1,632	2,230	234	3,790	14,733	1,866	20,753
Brent South	1,620	2,166	0	0	0	1,620	2,166
Total	**18,690**	**20,918**	**3,055**	**13,412**	**26,772**	**21,744**	**61,102**

* Volume and area of drill cuttings based on topography measurements and calculations

The estimated oil loads contained within the drill cuttings are detailed within Section 13.6.1.3.

13.4 Available Decommissioning Options

13.4.1 Drill Cuttings on Seabed

The decision as to whether or not a drill cuttings pile can be left in place depends on the persistence of the cuttings pile and the rate of oil loss to the water column (OSPAR Recommendation 2006/5 [6]), as described more fully in in Section 3.1.2.

Shell conducted laboratory assessments of the leaching potential of the hydrocarbons from the drill cuttings. These studies were used to model the fate of the piles. It was concluded that at present the five seabed drill cuttings piles fall below both of the OSPAR 2006/5 thresholds (see Section 13.6.1). Therefore, as the piles are not likely to have a significant negative impact, the option considered is to leave the drill cutting piles in place for natural degradation.

However, to completely remove the Brent A jacket footings, excavation around the jacket footings and piles is necessary in order to sever the piles securing the jacket to the seabed and to remove the jacket footings (Brent A jacket footings Option 1). This would inevitably disturb the drill cuttings pile at Brent A, the largest seabed drill cuttings pile in the Brent Field. The drill cuttings could be removed by dredging and the dredged material could be treated offshore, onshore or re-injected down a well. Each of these alternative decommissioning options is considered.

13.4.2 Drill Cuttings GBS Cell Tops

Based on updated sampling of cuttings and modelling at Brent C cell top, the loss of oil exceeds the 10 tonne OSPAR threshold in the worst case scenario. Drill cuttings are also found on the cell tops at both Brent B and Brent D, but with significantly less volume and over much smaller areas, hence it is likely that these cell tops cuttings satisfy the OSPAR 2006/5 thresholds.

Removal of attic oil (where present) and, if selected, remediation of the GBS cell contents may require clear access to some of the GBS cell caps on top of the cells (clear access may not be necessary to facilitate recovery of the attic oil on Brent C because the oil fill line may be reinstated). Some cuttings may need to be cleared prior to commencing cell access activities. Also, clearance of debris on the cell tops may disturb cell top drill cuttings; this is assessed in Section 15.

The cell top drill cuttings could be partially removed by water jetting or by dredging. Dredged material could be treated offshore, onshore or re-injected down a well. Each of these alternative decommissioning options is considered.

13.4.3 Drill Cuttings in GBS Tri-cells

Approximately 26,800 m^3 of drill cuttings may be present inside the Brent B and D GBS tri-cells. These drill cuttings were created during the same drilling operations as the drill cuttings forming the seabed and cell top cuttings piles, and are contaminated by OBM. As such, Shell considers that any tri-cell drill cuttings should also be assessed under OSPAR Recommendation 2006/5. None of the decommissioning options for other Brent facilities will disturb the tri-cell cuttings and Shell believes, as discussed in further detail in [104], the Brent B and D tri-cell cuttings fall below the oil loss and area persistence thresholds in OSPAR Recommendation 2006/5, just like Brent B and D seabed and cell top drill cuttings. Shell therefore proposes to leave any GBS tri-cell drill cuttings *in situ* for natural degradation.

Natural degradation of the cutting piles will be limited as the tri-cells are enclosed within the GBS structure and not exposed to the marine environment except at the top. Tri-cell drill cuttings will ultimately become exposed to the marine environment after the GBS degrades.

13.5 Description of Technically Feasible Decommissioning Options

The options below are considered in this ES for the decommissioning of the drill cuttings on the seabed, GBS cell tops and GBS tri-cells. Shell are aware that under the current legislation, the re-injection of historic drill cuttings is not permissible. However, re-injection of (albeit newly drilled) drill cuttings does occur in the North Sea and the technology is available. It is therefore a technically feasible option and has been included in the CAs for the drill cuttings for completeness.

Undisturbed Drill Cuttings Seabed	**LEAVE IN PLACE**
	Option 1. Leave *in situ*, for natural degradation.

Brent A Seabed Drill Cuttings*	**PARTIAL REMOVAL**	**COMPLETE REMOVAL**	**COMPLETE REMOVAL**	**COMPLETE REMOVAL**
	Option 1. Dredge, transfer to Brent C topsides to treat and discharge treated water and solids to sea.	**Option 2.** Dredge, transfer to vessel and transport slurry to shore for treatment and disposal.	**Option 3.** Dredge, transfer to Brent C topsides, dewater and discharge treated water to sea, solids to shore.	**Option 4.** Dredge, transfer to vessel and re-inject into a new remote well.

*These decommissioning options are only applicable for the complete removal of the Brent A jacket footings Option 1. Leaving the Brent A seabed drill cuttings in place is assessed in this ES within "Undisturbed Drill Cuttings Seabed Option 1" (in Shell's Comparative Assessment it is referred to as Brent A Seabed Drill Cuttings Option 5).

Drill Cuttings **GBS Cell Tops**	**PARTIAL REMOVAL ***	**COMPLETE REMOVAL**	**COMPLETE REMOVAL**	**COMPLETE REMOVAL**	**COMPLETE REMOVAL**	**LEAVE IN PLACE ****
	Option 1. Re-locate small amounts locally by water jetting into water column.	**Option 2.** Dredge, transfer to Brent C topsides to treat and discharge treated water and solids to sea.	**Option 3.** Dredge, transfer to vessel and transport slurry to shore for treatment and disposal.	**Option 4.** Dredge, transfer to Brent C topsides, dewater and discharge treated water to sea, solids to shore.	**Option 5.** Dredge, transfer to vessel and re-inject into a new remote well.	**Option 6.** Leave Brent C cuttings *in situ* for natural degradation.

*Option 1 applies only to the cell top drill cuttings on Brent B and D. The drill cuttings on Brent C are mostly located against the external conductors and water jetting small volumes might destabilise the cuttings.
**Only applies to BC. The exceedance of the 10 tonnes p.a. of oil OSPAR limit at Brent C triggers a requirement for a comparative assessment of drill cuttings management options, including leave in place.

Drill Cuttings GBS Tri-cells Brent B and D	**LEAVE IN PLACE**
	Option 1. Leave *in situ*.

13.5.1 Undisturbed Drill Cuttings Seabed

13.5.1.1 Option 1: Leave *in situ*, for natural degradation.

Natural degradation *in situ* would involve leaving the seabed drill cuttings piles in their present location to allow them to break down via natural processes (i.e. bio-degradation by marine organisms and erosion by sea currents or storms will slowly reduce the volume of hydrocarbons in the cuttings pile). This option would involve no activities. Over time the pile volume would decrease. A monitoring programme may be required to periodically check that the cutting pile volumes remain stable and that there is no significant impact on the surrounding area.

13.5.2 Drill Cuttings Brent A Seabed

The recommended option for the management of the Brent A seabed drill cuttings pile is leave in place, as the pile falls below the OSPAR 2006/5 thresholds. If the Brent A seabed drill cuttings pile had to be displaced in order to retrieve the jacket footings there would be four decommissioning options which are summarised in the subsections below.

13.5.2.1 Option 1: Dredge Brent A seabed drill cuttings, treat on Brent C topsides and discharge treated water and solids to sea

An ROV-operated dredging unit would be deployed onto the Brent A seabed drill cuttings pile and would initially lift the cuttings to the vessel controlling the operation (e.g. ROVSV). It is estimated that in total 8,000 m^3 of cuttings and contaminated sediments would be removed. A significant volume of sea water would be sucked up together with the cuttings, creating a slurry. The slurry would be transferred from the ROVSV via a floating hose to a tanker and transported to the Brent C platform where the tanker would transfer the slurry in batches to a topside processing unit, again via a floating hose. As the cuttings to water ratio in the dredging operation is estimated to be 1:10, the amount of slurry generated would be approximately 80,000 m^3.

The slurry would be dewatered using shakers and centrifuges on Brent C and the water cleaned to meet regulatory requirements before discharge to sea. A Thermomechanical Cuttings Cleaner (TCC) on the topside would process the solids and remove the hydrocarbons which would be shipped to shore. The treated solids would end up as an inert white powder that would be discharged back to sea. Any recovered hydrocarbons will be shipped back to shore for use as fuel by a third party. All stages of treatment would involve sampling and testing procedures to ensure that the process and any discharges meet Shell and regulatory requirements.

13.5.2.2 Option 2: Dredge Brent A seabed drill cuttings and transport slurry to shore for treatment and disposal

As per Option 1, an ROV-operated dredging unit would be deployed onto the Brent A seabed drill cuttings pile and would lift the slurry to the vessel controlling the operation (e.g. ROVSV) and then on to a hydrocarbon-rated tanker. It is estimated that in total about 8,000 m^3 of cuttings and contaminated sediments would be removed. As the cuttings to water ratio in the dredging operation is estimated to be 1:10, the amount of slurry generated would be approximately 80,000 m^3.

The slurry would be transported to shore for treatment. Once onshore, the slurry would be dewatered and the treated water discharged according to legislative requirements. The solids would be put through thermal processing to recover any residual hydrocarbons. The waste drill cutting solids would be sent to landfill and any recovered hydrocarbons would be used as fuel by a third party.

13.5.2.3 Option 3: Dredge Brent A seabed drill cuttings, transfer to Brent C topsides, dewater and discharge treated water to sea, solids to shore for treatment

An ROV-operated dredging unit would be deployed onto the Brent A seabed drill cuttings pile and would transfer the cuttings to the vessel controlling the operation (e.g. ROVSV) and then on to the containment vessel (tanker) as described in Option 1. The volume of slurry created would be approximately 80,000 m^3.

The slurry would be dewatered on the Brent C topsides and the cleaned water discharged offshore before the wet solids would be transported in a similar containment vessel (tanker) to an onshore processing facility for final cleaning and hydrocarbon removal. The cleaned cuttings would then be disposed of to landfill and any recovered hydrocarbons would be used as fuel by a third party. This option is similar to the processing of "new" cuttings today, i.e. those created and captured during the drilling of a new well.

13.5.2.4 Option 4: Dredge Brent A seabed drill cuttings, transfer to vessel and re-inject into a new remote well

An ROV-operated dredging unit would be deployed onto the Brent A seabed drill cuttings pile and would recover the drill cuttings and contaminated seabed sediments as described in Options 1-3. The slurry (approximately 80,000 m^3) would be transferred via an ROVSV to a containment vessel (tanker) for transportation to a new remote well for re-injection. The vessel would then stay at the disposal well site, sending batches of slurry to an LWIV for treatment/preparation before it is injected. Any excess water from the vessel could be treated offshore and disposed, or taken to shore for treatment. A permit will be required for re-injection.

13.5.3 Drill Cuttings GBS Cell Tops

The cell caps on Brent B and D are 5 m in diameter and have 1.2 m thick reinforced concrete caps. Brent C cells have a flat top and four sided pyramid domes, 4.75 in height with a 6.5 m sided top surface. Drill cuttings are found on the cell caps to varying degrees and these must be partially or fully cleaned prior to commencing cell access activities. In addition, debris across the cell top area must be collected in accordance with OSPAR Decision 98/3 and the DECC Guidance Notes on Decommissioning (this is assessed in Section 15).

The use of water jetting to partially remove cell top drill cuttings is Option 1. Options 2-5 assume, as a worst case, that the entire volume of the cell top cuttings piles would be dredged, as shown in Table 13-2 below. In reality, the volumes recovered might be smaller. For example, if only some of the GBS cells had to be accessed to reach the cell contents, or the equipment for the cell access operation can be deployed on areas of the cell tops relatively clear of cuttings, less of the cuttings pile would need to be recovered.

Table 13-2: Volume of Drill Cuttings Removed for Options 2-5 [104]

	Brent B	Brent C	Brent D
Volume of drill cuttings to be removed (m^3)	1,887	7,735	3,790

13.5.3.1 Option 1: Relocate small amounts locally by water jetting

GBS cell top drill cuttings would be displaced by means of Work-class Remotely Operated Vehicle (WROV) mounted high-pressure (HP) water jetting equipment. A small amount of drill cuttings would be displaced from the Brent B and Brent D GBS cell tops into peripheral areas and into the water column in order to clear access for cell remediation activities.

The quantities of material to be displaced from Brent B and D by water jetting under Option 1 are shown in Table 13-3. Option 1 applies only to the cell top drill cuttings on Brent B and D; the drill cuttings on Brent C are mostly located against the external conductors and water jetting small volumes might destabilise the cuttings.

Table 13-3: Option 1 Volume of Drill Cuttings Displaced

Option 1	Brent B	Brent D
Volume of drill cuttings to be displaced (m^3)	40	20

13.5.3.2 Option 2: Dredge cell top cuttings, transfer to Brent C topsides to treat slurry and discharge treated water and solids to sea

An ROV-operated dredging unit would be deployed onto the cell tops and would collect the drill cuttings, generating approximately 134,000 m^3 of slurry for all three GBS. The slurry would be handled in the same manner as described in Section 13.5.2.1.

13.5.3.3 Option 3: Dredge cell top cuttings, transfer to vessel and transport to shore for treatment and disposal

An ROV-operated dredging unit would be deployed onto the cell tops and would collect the drill cuttings, generating approximately 134,000 m^3 of slurry for all three GBS. The slurry would be handled in the same manner as described in Section 13.5.2.2.

13.5.3.4 Option 4: Dredge cell top cuttings, transfer to Brent C topsides, dewater and discharge treated water to sea, transport solids to shore

An ROV-operated dredging unit would be deployed onto the cell tops and would collect the drill cuttings, generating approximately 134,000 m^3 of slurry for all three GBS. The slurry would be handled in the same manner as described in Section 13.5.2.3.

13.5.3.5 Option 5: Dredge cell top cuttings, transfer to vessel and re-inject into a new remote well

An ROV-operated dredging unit would be deployed onto the cell tops and would collect the drill cuttings, generating approximately 134,000 m^3 of slurry for all three GBS. The slurry would be handled in the same manner as described in Section 13.5.2.4.

13.5.3.6 Option 6: leave *in situ*

Natural degradation *in situ* would involve leaving the Brent C cell top drill cuttings in their present location to allow them to break down via natural processes (i.e. bio-degradation by marine organisms and erosion by sea currents or storms will slowly reduce the volume of hydrocarbons in the cuttings pile). This option would involve no activities. Over time the cuttings volume would decrease. A monitoring programme may be required to periodically check that the cutting pile volumes remain stable and that there is no significant impact on the surrounding area.

13.5.4 Drill Cuttings GBS Tri-cells

Option 1: Leave *in situ*

Shell considers that the tri-cell drill cuttings at Brent B and D fall within the OSPAR 2006/5 thresholds (just like Brent B and D seabed and cell top drill cuttings) and thus intend to leave them *in situ.*

13.6 Significant Impacts of Decommissioning Options

Appendix 1 documents the assessment of all environmental categories for the decommissioning options. Section 13.6.1 describes the studies that have been conducted to support the assessment. Sections 13.6.2 - 13.6.13 provide a summary of the Appendix 1 impact assessment matrices, discussing only the most significant impacts identified (those with either 'small-moderate negative' impacts or worse, or 'small-moderate positive' impacts or better).

13.6.1 Information to Support Environmental Assessment

This sub-section provides information used to support DNV GL's assessment of the drill cuttings decommissioning options.

For the assessment of effects on the marine environment, BMT has modelled the long-term fate of the cuttings piles if they are left undisturbed [106]. In addition the spreading of particles and associated contaminants and the extent to which the environment will be influenced from disturbance of the piles have also been modelled by BMT [107].

In assessing legacy impacts, the most relevant issue is the future fate of the cuttings piles either left undisturbed (or partially removed) compared against the OSPAR 2006/5 thresholds. The results of the BMT long-term fate modelling are presented as the physical and chemical persistence of the cuttings piles. Physical persistence predicts the long-term fate of the cuttings pile in terms of changes in volume, resulting from natural environmental changes. Chemical persistence is modelled in terms of the rate of oil loss from the cuttings piles (in tonnes of oil/year).

13.6.1.1 Impacts on the Marine Environment

At present, the Brent drill cuttings piles are relatively stable, both on the seabed and on the cell tops. Natural erosion and degradation of hydrocarbons should reduce the size and contamination of the piles over time. The seabed pile at Brent A jacket is likely to be less protected against forces from water movements, compared to the seabed cuttings adjacent to the GBS.

Based on the surveys of the seabed adjacent to the Brent installations [23, 24], the faunal community composition is influenced by the discharged cuttings. Opportunistic and contaminant-tolerant species dominate close to the installations compared to further away. This is similar to other offshore installations [108]. Over time, conditions should improve together with the degradation of the piles.

Hence, for the option to leave the piles undisturbed *in situ*, the effect on the marine environment has been assessed as small (this is discussed further in Section 13.6.3.1).

However, some of the cuttings piles will need to be totally or partially removed to perform some of the Brent Field decommissioning options. Such operations will result in disturbance and dispersion of contaminated cuttings. The contaminants pose a risk to marine organisms (mainly during operations) and seabed fauna (after settlement of the solids on the seabed). In addition the particles may smother the seabed fauna and influence the local sediment particle size composition, which could influence the faunal community composition.

The disturbance of the cuttings was modelled by BMT [107]. Three piles/scenarios were selected:

1. The Brent A seabed pile; 630 m^3 was lost to sea during 45 seconds disturbance (similar to a possible effect from over trawling).
2. The Brent C seabed pile; heavily contaminated and protected by the GBS, 493 m^3 was lost to sea during 45 seconds disturbance (similar to a possible effect from over trawling).

3. The Brent C cell top pile; a total volume of 7,753 m^3, whereof 775 m^3 was lost to sea during 65 days of suction dredging operations.

There are uncertainties involved in such modelling, but the modelling results will be indicative of the outcome. More information and results from different model scenarios/runs are available in the BMT reports.

The Brent A seabed pile and the Brent C cell top pile are the largest, hence the modelling should be relevant, although it should be noted that the modelled scenarios do not directly correlate with all of Shell's drill cuttings decommissioning options examined in this ES (for example, dredging of the seabed piles, or water jetting the cell top cuttings were not modelled).

BMT modelled the impact of human disturbance on the distribution and spreading of particles and associated contaminants and their effect on marine organisms in the water and seabed. In the water column, groups with variable tolerance to THC were examined (fish, algae, water column/zooplankton and crustaceans). On the seabed, the distribution of THC level was modelled. The concentration of THC was compared with the dose that was considered to give an environmental effect. Hence the volume or area where the concentration was higher than the organisms' tolerance (i.e. the Predicted Environmental Concentration, PEC, was higher than Predicted No Effect Concentration, PNEC) was predicted.

In addition, the thickness of the settled cuttings material on the seabed and the loss of oil from the settled cuttings in a 1, 5 and 10 year perspective after the disturbance of the cuttings were also modelled.

The disturbance of the Brent C seabed cuttings pile was predicted to give the largest time average exposure to hydrocarbons; however the highest water column volume with maximum hydrocarbon concentration was predicted for the disturbance of the Brent C cell top cuttings. In the 2015 BMT modelling [107] the PNEC was set to 0.1 mg THC/l for the most sensitive species (water column, zooplankton and crustaceans). Hence these results represent the worst effect scenarios.

Effects on the water column and zooplankton from the dredging of the Brent C cell top cuttings (PEC:PNEC is $\geq$ 1) were observed up to a maximum distance of 4.2 km from the dredging location [107]. The water volume exposed to PEC:PNEC $\geq$ 1 from cell top dredging (for water column and zooplankton) was about 1.3 million m^3 [107], and the duration of such concentrations was approximately 1,000 hours.

The distribution of the released cuttings on the seabed was found to be largest for the Brent C cell top cuttings modelling scenario; this is logical because the cuttings were released approximately 60 m above the seabed, resulting in a thinner layer and larger dispersal on the seabed compared to seabed release. BMT's modelling of the impact of dredging 7,753m^3 of the Brent C cell top cuttings pile [107] assumes that about 10% of the dredged volume would be released to sea (~775 m^3) during the 65 day operation. The seabed area with predicted effects of THC on the fauna (PEC:PNEC $\geq$ 1) was 15.9 km^2 [107] compared to a disturbance of 217,500 m^2 and 322,500 m^2 for the Brent A and Brent C seabed cuttings respectively. The cuttings from the cell tops generated a layer less than 1 cm thick (the average and the maximum thickness of re-deposited cuttings is 0.2 and 6 mm respectively). An area of 33 km^2 was influenced by sedimentation, but re-deposition with a layer thickness > 1 mm covered a much smaller area of about 0.07 km^2. For comparison, the modelling of disturbance at the Brent C seabed pile resulted in a maximum 0.5 m layer.

Benthic fauna is affected by the settling of particles and contaminants, but how significant this will be depends on the amount of re-sedimentation and the concentration of contaminants. This is likely to be most significant close to the site and reduce as the distance increases (as modelled [107]).

Benthic fauna have different capabilities and tolerance to overcome such conditions. In general, marine benthic fauna have a good capability of settling into available habitats. The timescale for re-colonisation will be very dependent on the local environmental conditions, not least the sediment composition at the Brent Field. Some species tolerate poor conditions better than others and may settle within months.

13.6.1.2 Legacy Impacts

The OSPAR 2006/5 Recommendation requires offshore operators to assess the rate of oil loss and the persistence of the seabed area contaminated with oil-based cuttings.

The fate of the Brent Field cuttings piles against the OSPAR 2006/5 thresholds has been modelled for the Brent A and C seabed piles, Brent C cell top and the combination of Brent C seabed and cell top cuttings [106,107]. The fate of the cuttings piles has been modelled for both undisturbed piles (left *in situ*) and for the cuttings after disturbance by dredging. The modelling allows the OSPAR thresholds to be quantitatively assessed. There are uncertainties involved in such modelling, but the modelling results will be indicative of the outcome. Additional information and results from different model scenarios/runs are available in the BMT reports.

The main modelled scenarios for the Brent Field were selected to cover the worst case for seabed and cell top drill cuttings. They consist of three scenarios where the cuttings were disturbed [107], as described in section 13.6.1.1.

Also, long-term fate modelling of the same piles was performed (and of Brent C seabed and cell top cuttings combined) if they were left undisturbed [106].

Persistence

The modelling indicated that the persistence of the piles was far below the OSPAR 2006/5 threshold (500 km^2years).

The settled cuttings released during disturbance (dredging/removal) of the cuttings had a very low persistence. For the disturbed Brent A seabed cuttings the final area-persistence of the released cuttings was modelled to end with a value of between 0.02-0.15 km^2years in 10 years' time.

For the dispersed Brent C seabed cuttings (after dredging/removal of the pile) the model reached a final area persistence of between 0.04-0.11 km^2years after 100 years. The released cuttings from the cell top were dispersed so widely they did not generate the layer >1 cm thick required for the modelling (i.e. there was no cutting pile to predict the persistence).

Table 13-4 presents the main results from the long-term fate modelling of undisturbed cuttings. It includes the present situation (year 1) and forecasts the future. The predicted final persistence after 1,000 years was highest (5.5 km^2years) for the combination of Brent C seabed and cell top cuttings. The lowest end point (2.4 km^2years) was predicted for the Brent C seabed cuttings pile (this seabed pile covers a smaller area than the Brent A pile). The physical persistence of the piles was about 50-70% of the original size after 1,000 years of degradation. Hence the persistence should increase further into the future.

Table 13-4: Long-term fate modelling of persistence of Brent A and C drill cuttings piles [106]

	Area persistence (km^2years)					
	Year 1	Year 50	Year 100	Year 250	Year 500	Year 1,000
Brent A Seabed	0.01	0.3–0.5	0.5–0.8	0.8–1.5	1.2–2.2	1.7–3.0
Brent C Seabed	0.01	0.1–0.2	0.3	0.6 – 0.7	1.2 – 1.3	2.2–2.4
Brent C Cell top	0.01	0.3	0.5	1.0 – 1.1	1.8-1.9	3.0-3.1
Brent C Combined	0.01	0.4	0.7–0.8	1.7–1.8	3.0–3.2	5.3–5.5

Loss of oil

Based on updated sampling of cuttings and modelling at Brent C cell top, the loss of oil exceeds the 10 tonnes/year OSPAR threshold in the worst case scenario. Drill cuttings are also found on the cell tops at both Brent B and Brent D, but with significantly less volume and over much smaller areas, hence it is likely that these cell tops cuttings satisfy the OSPAR 2006/5 thresholds.

BMT modelled both the conditions of the cuttings after the piles had been dredged (assuming 10 % of the cuttings were released to the water column and re-settled on the seabed), and the situation where the cuttings piles were left undisturbed [106,107]. The scenarios modelled were the same as for modelling persistence (see above). Similar to the results for persistence, the loss of oil from dispersed Brent C cell top cuttings could not be modelled because the settled layer was too thin.

For the disturbed cuttings the loss of oil was highest one year after the dredging, with the Brent C seabed cuttings loss between 2.1-5.7 tonnes/year of oil and the Brent A 1.7-4.6 tonnes. After 10 years the loss of oil was reduced to 0.3-0.4 and 0.001-0.01 respectively.

The loss of oil from the undisturbed piles in the long-term fate modelling indicated the highest numbers (10.0-16.1 tonnes/year) from the Brent C combined cuttings. Also the cell top cuttings alone exceeded (9.7-13.6 tonnes loss of oil) the OSPAR limit (although it should be noted that the modelling was conservative, having been based on the maximum cell top THC concentration measured and high erosion from the surface layer of the pile). The OSPAR loss of oil threshold should be satisfied within the next 11-30 years for the Brent C combined cuttings (the range reflects the variation in surface loss rate and assumed starting THC concentration).

The Brent C seabed cuttings had the lowest loss of oil (0.3-2.5 tonnes/year) at the present conditions. The loss of oil was predicted to greatly reduce over the years and at 1,000 years it was less than 1 tonnes/year. Table 13-5 presents the main results of oil loss from the piles during the long-term modelling.

Table 13-5: Long-term fate modelling of oil loss from Brent A and C drill cuttings piles [106]

	Rate of Oil Loss (tonnes/year)					
	Year 1	Year 50	Year 100	Year 250	Year 500	Year 1,000
Brent A Seabed	0.4–3.8	0.0–1.4	0.0–1.1	0.0–0.6	0.0–0.3	0.0–0.1
Brent C Seabed	0.3–2.5	0.2–1.3	0.2–1.1	0.1–0.8	0.1–0.5	0.0–0.2
Brent C Cell top	9.7-13.6	6.4-6.6	4.9-5.1	2.9-3.0	1.6-1.7	0.7-0.7
Brent C Combined	10.0-16.1	6.7-7.9	5.2-6.2	3.1-3.8	1.7-2.1	0.7-0.8

Other contaminants within the drill cuttings

The environmental effect of the heavy metals contained within the drill cuttings is not likely to be significant and is of less concern compared to the organic pollutants. The heavy metals have low availability to organisms and to the water column, but stay relatively inert in the sediment. After the degradation of the organic pollutants, the remaining heavy metals concentrations are likely to have small toxicity effects on the local seabed fauna community [108].

13.6.1.3 Amount of oil in drill cuttings

An estimate of the THC present in the seabed and cell top drill cuttings is presented in Table 13-6. The cuttings piles at Brent are heterogeneous both in the vertical and horizontal directions, which is consistent with variations in cuttings piles elsewhere. The calculations are based on the average percentage of THC content and should only be used as a rough estimate of the oil load that may be present in the cuttings.

The drill cuttings at Brent C are estimated to contain approximately 3,400 tonnes of oil, while Brent B and Brent D drill cuttings contain approximately 730 and 1,200 tonnes of oil respectively. Brent South had the lowest oil content volume of approximately 22 tonnes. It is important to note that the oil content is not likely free phase oil but hydrocarbons which are strongly bound to the cuttings particles and which will mainly stay adhered to the particles if disturbed.

Table 13-6: Average amount of oil estimated in Seabed and Cell Top Drill Cuttings

Facility	Total volume m^3 of cuttings	Total tonnes of dry cuttings	Average THC (%)	Approximate tonnes of oil
Brent A (seabed)	6,300	12,600	2.5	315
Brent A (Cell top)	-	-	-	-
Brent A (Total)				**315**
Brent B (seabed)	5,300	10,600	5.1	541
Brent B (Cell top)	1,887	3,774	No data	193*
Brent B (Total)				**734**
Brent C (seabed)	4,922	9,844	6.3	620
Brent C (Cell top)	7,735	15,470	17.8	2,754
Brent C (Total)				**3,374**
Brent D (seabed)	2,230	4,460	4.4	196
Brent D (Cell top)	3,790	7,580	13.2**	1001
Brent D (Total)				**1,197**
Brent South (seabed)	2,166	4,332	0.5	22
Brent South (Cell top)	-	-	-	-
Brent South (Total)				**22**
Sub-total (seabed and cell tops)				**5,642*** **
Tri-cells	26,772	53,544	9.2****	**4,926**
TOTAL	61,102	122,204		**10,568**

Note 1: There are no cell top drill cuttings at Brent A or Brent South.
Note 2: A density of 2 has been used to convert volume into tonnes (dry weight).
* With no data for cell-top THC value, the Brent B seabed average THC was used to estimate the Brent B celltop oil content
** The THC concentration used is conservative (the sum of minimum concentration 4.9% and maximum 8.3%)
*** 1,694 t oil in seabed drill cuttings, 3,948 t in cell top drill cuttings
**** maximum value from a limited number of samples

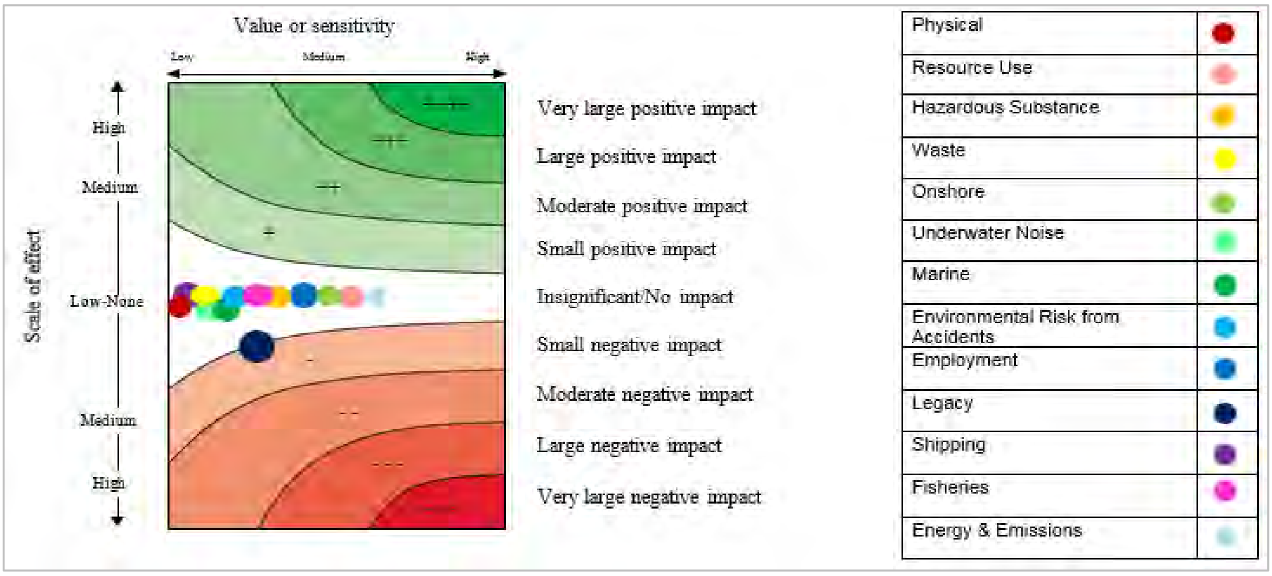
13.6.2 Seabed Drill Cuttings Option 1: Leave *in situ*

Under Option 1, the Brent Field seabed drill cuttings at all four platforms and Brent South will be left *in situ* to degrade naturally.

As shown in Figure 13-8, estimated impacts are considered small or insignificant for all categories.

The long-term impact upon the marine environment within the legacy category is considered 'small negative' because at present the seabed drill cuttings piles fall below both of the OSPAR 2006/5 thresholds (as just discussed in Section 13.6.1 and described in Section 3.1.2). The long-term effect of falling debris from degraded structures disturbing the drill cutting piles is covered in Appendix 1 (Brent A jacket) and Sections 10.6.1, 10.6.2 and 10.6.3 (GBS).

Figure 13-7: Seabed Drill Cuttings Option 1: Leave *in situ*



Note:

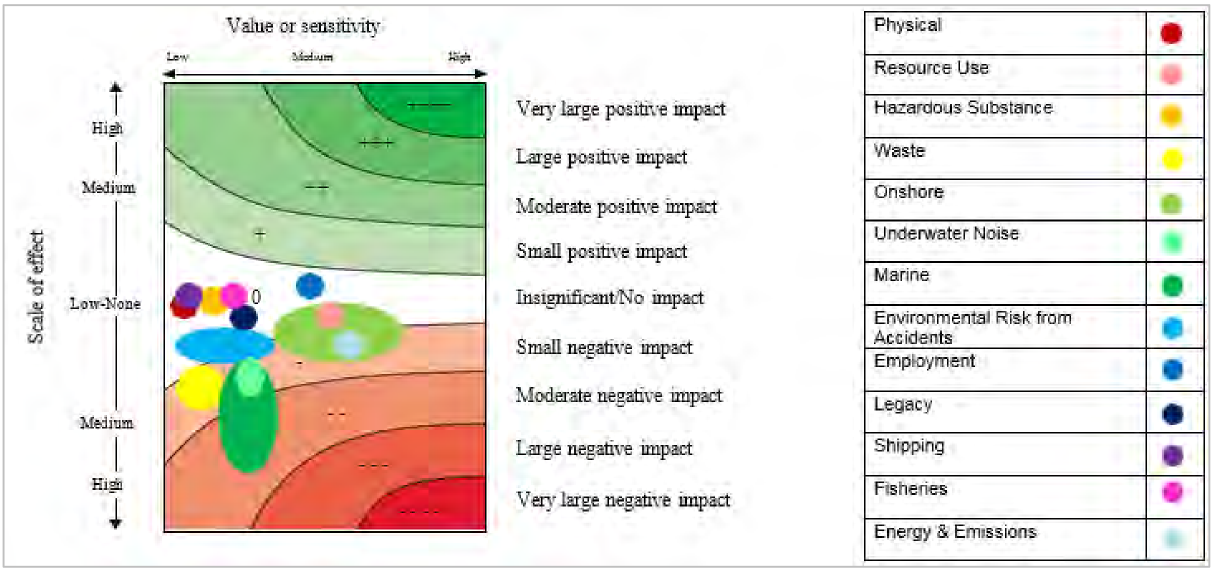
- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- The Energy and Emissions impact has been sourced from: DNV GL, *Energy and Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

13.6.3 Brent A seabed drill cuttings Option 1: Dredge, treat on Brent C topsides and discharge treated water and solids to sea

This option involves dredging the seabed drill cuttings at Brent A, and treating them on the Brent C topsides before discharging treated water and inert solids back to sea.

As shown in Figure 13-8, the most significant impact identified is in the marine category. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-8: Brent A Seabed Drill Cuttings Option 1: Dredge and Treat on Topsides



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

13.6.3.1 Marine

The overall impact upon the marine environment from Option 1 is estimated to be **'small-moderate negative'**.

In order to enable the complete removal of the Brent A jacket, drill cuttings and contaminated seabed surrounding the piles would require removal. Under Option 1, the drill cuttings would be removed by suction dredger and pumped onto a vessel for storage prior to being pumped for processing on the Brent C topsides.

Approximately 80,000 m^3 of slurry would be recovered which includes:

- 6,300 m^3 of seabed drill cuttings, together with seawater = 63,000 m^3 slurry
- 1,425 m^3 of contaminated seabed, together with seawater = 14,250 m^3 slurry

The seawater would be separated and processed to below the regulatory oil in water limits and discharged to sea. Solid drill cuttings would be treated via thermal desorption into a powder, to 0.3-0.5 % oil by weight (below the OSPAR standard of 1.0 % oil by weight [109]) and discharged to sea. Recovered oil would be sent to shore for recycling.

BMT modelled the impact of human disturbances on the Brent A and C seabed cuttings pile [107]. For the Brent A cuttings pile, a volume of 630 m^3 of solids was modelled dispersed

into the water above the cuttings pile during a 45 second long period (similar to possible effect from over trawling). The concentrations of pollutants and dispersion and re-settlement of the 630 m^3 of cuttings were estimated. A similar model was run for the Brent C seabed cuttings recovery. In this case 493 m^3 was dispersed into the water column. The results were in general comparable to the Alpha cuttings dispersion.

In addition, the effects of dredging the Brent C cell top cuttings (7,753 m^3) over 65 days was modelled by BMT [107]. The cuttings were modelling with a 10 % loss to the water column (approximately 775 m^3). In this scenario the cuttings were released into the water column at the level of the Brent C cell tops, approximately 60 m above the seabed. The results indicated a wide distribution of the particles and a very thin layer settled on the seabed (average 0.2 mm).

The results for the Brent A seabed cuttings dispersal indicated that 96 % of the solids settled within a relatively limited distance from the pile. In total 2.8 km^2 of the seabed was influenced by settling particles from the dredging, but only 95,000 m^2 had a sedimentation of more than 1 mm. A seabed area of 217,500 m^2 measured an initial THC concentration which corresponded to the threshold for negative impacts on the benthic faunal community (i.e. PEC:PNEC exceeded 1).

In the water column the concentration of contaminants in the cuttings were modelled to exceed thresholds for various marine life in 12,337,500 m^3 of water and to a maximum distance of 5.2 km. The duration of such concentrations in the water column was less than an hour.

In addition to the impacts from dredging the drill cuttings, dredging the top level of the seabed sediment would also release some contamination to the marine environment and is likely to increase the impact, although the volume and contamination of the seabed sediment is less than the drill cuttings.

The dredging activities would temporarily result in increased turbidity. The particles may influence the breathing functions (gill and skin) and feeding functions of local organisms. The effect would be relatively localised provided normal mitigation measures are adopted, such as good operational procedures and the use of best available and well maintained equipment to give the lowest spreading potential. It is recommended to monitor and document the situation and “footprint” within the area.

The polluted water and sediment from the dredging operation would be treated to remove the key contaminant (oil) before discharge to prevent any subsequent significant effects on organisms living in the water column. The remaining concentrations of other substances in the treated water should be monitored to ensure that emissions are within any necessary conditions. The discharge of cleaned water from the treatment of slurry is assessed to have a limited effect on the marine organisms.

The treated solids discharged from the platform would settle on the seabed, but the impacts of this scenario were not included in the BMT modelling. The smallest particles may float for a longer period before they settle on the seabed. This would be similar to the settling of drill cuttings that are dispersed during dredging operations, but may result in an add-on effect due to smothering, for example. If the treated solids are discharged close to the sea surface they would be widely dispersed before they settle, but locally they can add on to the effects from sedimentation of particles from the dredging operation. The local sedimentation would increase if the treated solids are discharged close to the seabed. Even if this material does not

contain much oil, the smothering of the seabed can influence the benthic faunal community. The effect on the seabed from treated solids would mainly be smothering of the fauna and possibly some influence on the particle size distribution in the top sediment. Benthic fauna are generally adapted to sediment characteristic fluctuations along the seabed and the effects from inert cuttings/sediment disposal would be local and associated with highest sedimentation rates.

As discussed in section 13.6.1.1, benthic fauna would be impacted by the settling of particles and contaminants, and this is likely to be most significant close to the site (as modelled, [106]). In general, marine benthic fauna are capable of settling into available habitats and re-colonising. After a year or two several species may be present and a community of opportunistic species may develop. Over a 4-10 year period, the fauna composition may have recovered into a community of normal or low disturbance [108].

If possible, operations should be done during a period with the lowest abundance of vulnerable resources in the water column (such as fish eggs or larvae). With reference to the environmental baseline data in Section 6, if practical, operations should preferably be between mid-September to mid-December when the lowest concentrations of fish eggs and larvae are present in the water column. For benthic fauna, seasonal variations are less significant. The overall impact of Option 1 on the marine environment is estimated to be 'small-moderate negative'. This impact would combine with the marine impact from the subsequent seabed excavation (jacket Option 2).

In the long-term, drill cuttings removal would have some positive effect on the local marine environment as the majority of hydrocarbon contaminated material would be removed.

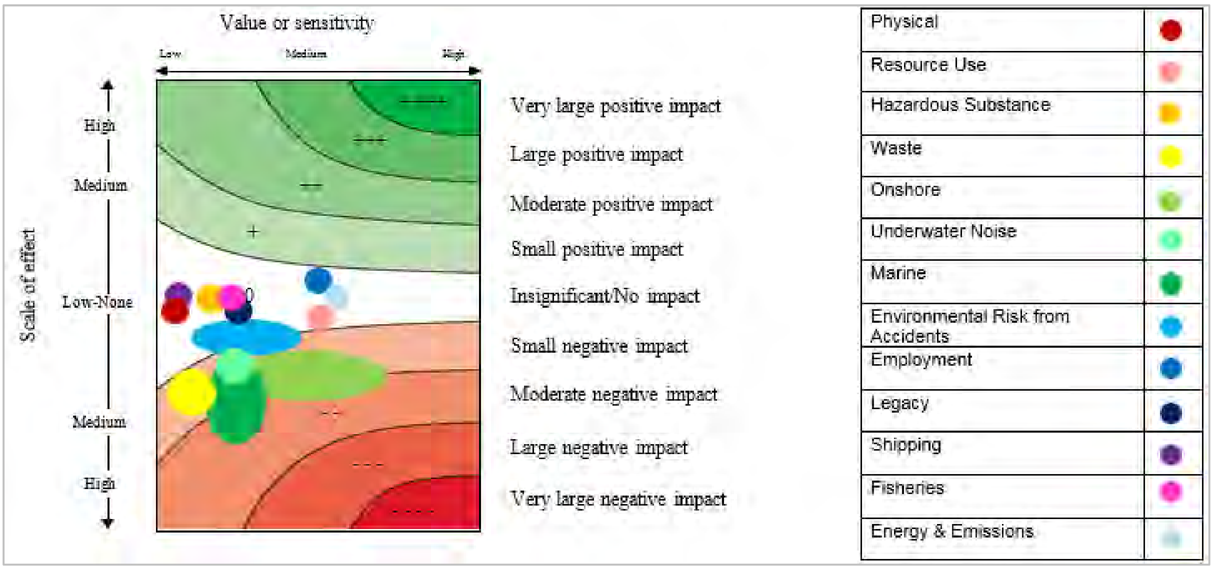
A 'small negative' impact is anticipated from underwater noise generated during the dredging and removal process (see Appendix 3 for a summary of DNV GL's environmental underwater noise analysis).

13.6.4 Brent A seabed drill cuttings Option 2: Dredge and transport to shore for treatment and disposal

This option involves dredging the seabed drill cuttings at Brent A and transporting them to shore for treatment and disposal.

As shown in Figure 13-9, the significant impacts identified are in the marine and onshore categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-9: Brent A Seabed Drill Cuttings Option 2: Dredge and Treat Onshore



Note:

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13.6.4.1 Marine

The overall impact upon the marine environment from Option 2 is estimated to be **'small-moderate negative'**.

As with Option 1, the drill cuttings would be removed by suction dredger and pumped onto a vessel. The total volume of 80,000 m^3 of slurry would then be transported to shore via shuttle tanker for treatment.

Similar to Option 1, the dredging activities would cause some of the sediments to be re-suspended and released to the marine environment, with resulting re-settling of contaminated solids and temporarily increased turbidity.

However, as all processing activities would be completed onshore under Option 2, there would be no offshore discharge of treated water or solids to sea. Therefore the impact to the local marine environment would be comparable, but slightly less than for Option 1; the impact is estimated to be 'small-moderate negative'.

A 'small negative' impact is anticipated from underwater noise generated during the dredging and removal process (see Appendix 3 for a summary of DNV GL's environmental underwater noise analysis).

13.6.4.2 Onshore

The overall onshore impact from Option 2 is estimated to be **'small-moderate negative'**.

In Option 2, approximately 80,000 m^3 of slurry (dredged drill cuttings material) would be transported to shore for treatment. It is assumed that the slurry would be held in holding tanks onshore where the slurry would settle. This would be dewatered onsite (reduced to approximately 15,000 m^3 sludge); water would be treated and returned to sea or sewer in accordance with permit conditions. The 15,000 m^3 thick sludge would be transported offsite (approximately 800 trips) and further dewatered and then treated by thermal desorption. The

cleaned processed powder would be deposited at a licensed landfill site in accordance with permit conditions. The recovered oil (~500 t) would be recycled.

The most significant onshore impact is considered to be the transport of thickened sludge out of the onshore site; an estimated 800 trips (road tanker) would be required. This can have some nuisance impact upon the local area, the extent of which is very dependent on the location. A traffic management plan may need to be developed to mitigate impacts. It is currently not known if the thermal desorption processes would be located at the onshore location. If so, this would reduce the volumes of materials requiring transport offsite by 50% as the excess water contained within the cuttings slurry would be removed onsite. All activities would be undertaken under responsible management and control and in line with permit conditions

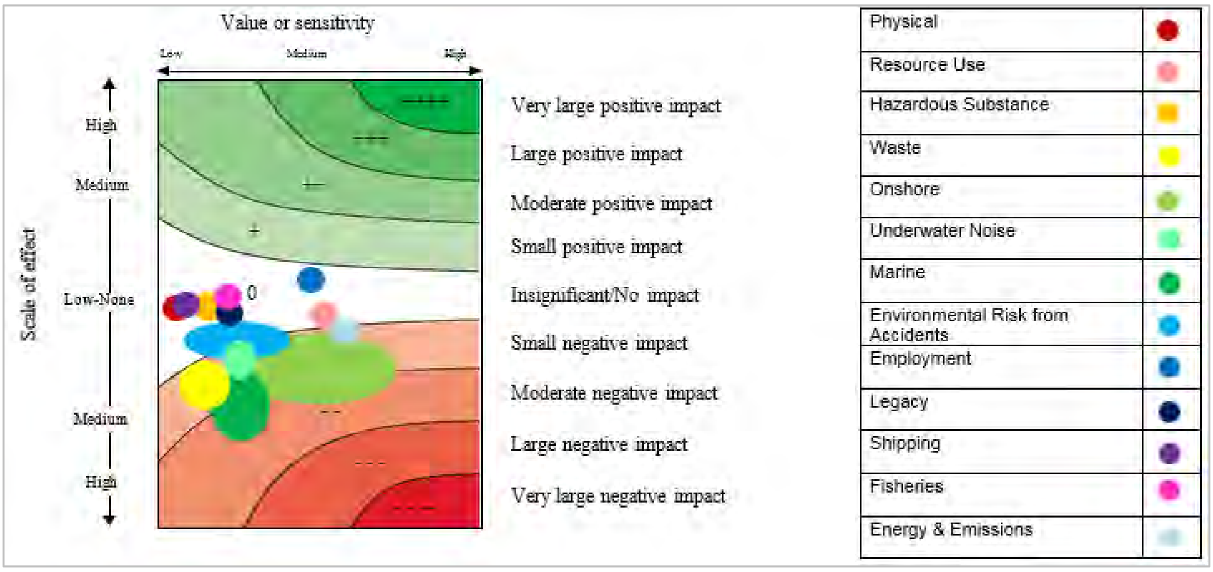
A 'small–moderate negative' impact is anticipated from onshore impacts related to increased traffic, noise, waste, odour, wastewater and nuisance impacts related to handling and treating 80,000 m^3 of slurry (containing less than 1% oil) onshore, a sizeable volume.

13.6.5 Brent A seabed drill cuttings Option 3: Dredge, dewater on Brent C topsides and discharge treated water to sea, solids to shore

This option involves dredging the seabed drill cuttings at Brent A, transferring them to Brent C topsides for dewatering, discharging the clean water to sea and transporting the dewatered solids to shore for further treatment and disposal.

As shown in Figure 13-10, the significant impacts identified are in the marine and onshore categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-10: Brent A Seabed Drill Cuttings Option 3: Dredge, Dewater on Brent C Topsides and Discharge Treated Water to Sea, Transfer Solids to Shore



Note:

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13.6.5.1 Marine

The overall impact upon the marine environment from Option 3 is estimated to be **'small-moderate negative'**.

As with Option 1, the drill cuttings would be removed by suction dredger and lift pump onto a vessel. The total volume of 80,000 m^3 of slurry would then be transferred to the Brent C topsides for separation. Once separated, the seawater would be treated to the regulatory oil in water limits, and discharged to sea. Separated solids would then be transported to shore for treatment.

Similar to Options 1 and 2, the dredging activities would cause some of the sediments to be re-suspended and released to the marine environment, with resulting temporarily increased turbidity and re-settlement of contaminated solids. The dispersion of contaminated particles into the sea would locally have impact on marine organisms. However, as the processing of cuttings solids would be completed onshore under Option 3, there would be no offshore discharge from platform of solids to sea (only treated water would be returned to sea). The remaining concentrations of substances in the treated water should also be monitored to further ensure the water emissions discharged are within any necessary conditions.

The impact to the local marine environment would be comparable, but slightly less than for Option 1; the impact is estimated to be 'small-moderate negative'.

A 'small negative' impact is anticipated from underwater noise generated during the dredging and removal process.

13.6.5.2 Onshore

The overall onshore impact from Option 3 is estimated to be **'small-moderate negative'**.

As with Option 1 and 2, this option involves dredging 8,000 m^3 of seabed drill cuttings and sediment around Brent A jacket. The resulting 80,000 m^3 of slurry is then dewatered offshore on the Brent C topsides, and the resulting thickened sludge (approximately 10,000 m^3) is transported by shuttle tanker to shore for treatment.

It is assumed that onshore the 10,000 m^3 of thickened sludge would be transported offsite and thereafter treated by thermal desorption and the cleaned solids deposited at licensed landfill site in accordance with permit conditions. The recovered oil (~500 tonnes) would be recycled and all activities would be undertaken under responsible management and control and in line with permit conditions.

The most significant onshore impact would be from the transport of solids/oil out of the onshore site; an estimated 580 trips may be required. This can have some nuisance impact upon the local area, the extent of which is very dependent on the location. A traffic management plan may need to be developed to mitigate impacts. Also, it is currently not known if the thermal desorption processes would be located on the onshore location. If so, this would reduce the volumes of materials requiring transport offsite by 50% as the excess water contained within the solids would be removed onsite.

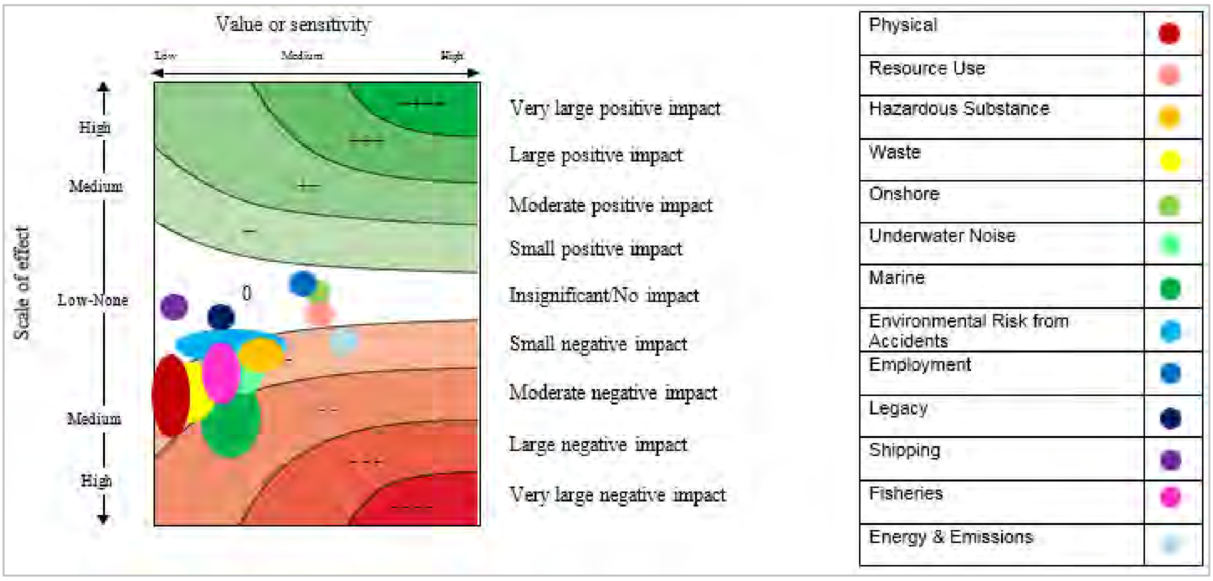
This impact is a little lower than Option 2, because less material is received and managed onsite, but Option 3 is considered as 'small-moderate negative' because the transport of the thickened sludge offsite still retains potential to impact upon local communities, and the volume transported offsite is similar, albeit smaller, to Option 2.

13.6.6 Brent A seabed drill cuttings Option 4: Dredge, transfer to vessel and re-inject into new well

This option involves dredging the seabed drill cuttings at Brent A and transferring them to a new well and re-injecting the slurry downhole.

As shown in Figure 13-11, the most significant impact identified is in the marine category. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-11: Brent A Seabed Drill Cuttings Option 4: Dredge and Re-inject into new Well



Note:

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13.6.6.1 Marine

The overall impact upon the marine environment from Option 4 is estimated to be **'small-moderate negative'**.

Under Option 4, a new remote subsea well would be drilled for Cuttings Re-injection (CRI). In addition to drilling the well, the rig must stay on location and have process equipment available to treat the slurry before it can be injected.

The total volume of 80,000 m^3 of slurry would be transported to the new well for processing prior to injection.

There is potential for impact to the marine environment from the two elements of the process under Option 5:

- Dredging, and
- Drilling of an injection well

Similar to the other options, the dredging activities for removal of drill cuttings would cause some of the sediments to be re-suspended. No offshore discharge of cuttings is expected, as the cuttings slurry would be injected downhole.

There could be some localised disturbance to the local marine environment during drilling and completion of the well, including physical disturbance. Drilling and injection activities would be subject to a permit but would still produce drill cuttings that would settle on the seabed, and result in some localised impact. Chemicals would also be added to the slurry for injection purposes, but there should not be any impact from the use of chemicals upon the marine environment as they should remain within the newly drilled well. Planned discharges, if any, would be subject to a discharge permit application.

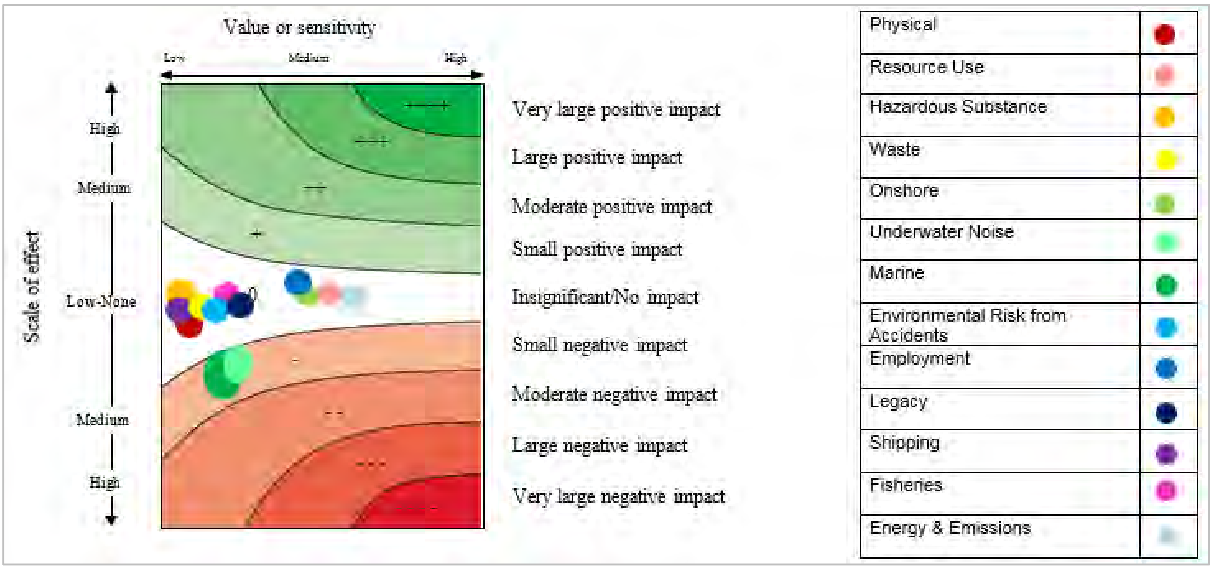
The overall impact to the local marine environment is still estimated to be 'small-moderate negative' due to drilling activities and localised impacts during dredging activities, as marine impacts would be temporary and localised.

A 'small negative' impact is anticipated from underwater noise generated during the well drilling, dredging and cuttings removal process.

13.6.7 Cell Top Drill Cuttings Option 1: Partial Removal by Water Jetting

Under Option 1, only a small volume (approximately 60 m^3 in total) of the cell top drill cuttings would be relocated to the cell top valleys and into the water column by water jetting. As shown in Figure 13-12, there are no impacts larger than small or insignificant.

Figure 13-12: Cell Top Drill Cuttings Option 1: Relocate by Water Jetting



Note:

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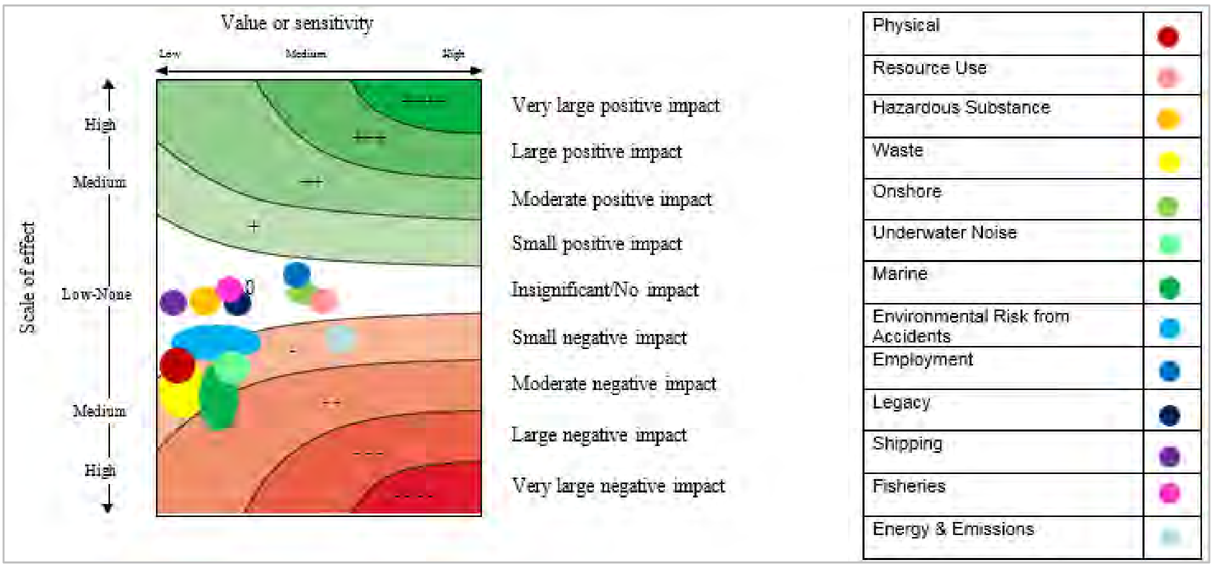
13.6.8 Cell Top Drill Cuttings Option 2: Dredge and Transfer to Brent C Topsides for Treatment Offshore

This option involves removing all of the cell top drill cuttings at Brent B, C and D (13,400 m^3) by dredging, and treating them on the Brent C topsides before discharging treated water and inert solids back to sea.

As shown in Figure 13-13, the most significant impact identified is in the marine category. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-13: Cell Top Drill Cuttings Option 2: Dredge and Treat on Brent C Topsides



Note:

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13.6.8.1 Marine

The overall impact upon the marine environment of Option 2 is estimated to be **'small-moderate negative'**.

The drill cuttings on top of the GBS cell tops may need to be removed in order to provide sufficient working space for subsequent operations. The drill cuttings would be removed in this option by dredging and transfer to the Brent C topsides for treatment. The total quantity of material to be dredged across the Brent B and D cell tops is approximately 1,900 m^3 and 3,800 m^3 respectively. For Brent C, the cell tops volume is estimated to be approximately 7,700 m^3. A large amount of polluted drill cuttings slurry would be generated offshore for treatment on the Brent C topsides. In total the 13,400 m^3 of cuttings may generate approximately 134,000 m^3 of cuttings and contaminated water (slurry). About 10 % of the dredged volume (cuttings) is assumed to be released to the water column during the dredging.

BMT's modelling of the impact of dredging 7,753m^3 of the Brent C cell top cuttings pile [107] assumes that about 10% of the dredged volume would be released to sea (~775 m^3) during the 65 day operation. An area of 33 km^2 was influenced by sedimentation, but re-deposition with a layer thickness > 1 mm would cover a much smaller area of about 71,425 m^2 (0.07 km^2) and the average and the maximum thickness of re-deposited cuttings is 0.2 and 6 mm respectively. The modelled area with Predicted Environmental Effect Concentrations of THC with PEC >PNEC is 15.9 km^2 as a result of the operations.

In the water column the concentration of contaminants in the cuttings was modelled to exceed the thresholds for total water column/zooplankton in 1.3 million m^3 of water and to a maximum distance of 4.2 km. The duration of such concentrations (i.e. PEC:PNEC exceeding 1) in the water column was approximately 1,000 hours.

Note: these modelling results represent data from operations at Brent C; similar but lower impacts would also occur at Brent B and D as the volume dredged is lower.

The dredging would cause some sediment to be re-suspended at all three locations, with resulting turbidity. The particles can affect the breathing functions (gill and skin) and feeding functions of local organisms. The effect would be relatively localised provided normal mitigation measures are adopted.

As discussed for Option 1, benthic fauna would be impacted by the settling of particles and contaminants. But in general, marine benthic fauna are capable of settling into available habitats and re-colonising. After a year or two several species may be present and a community of opportunistic species may develop. Over a 4-10 year period, the fauna composition may have recovered into a community of normal or low disturbance [108].

The polluted water and sediment from dredging is treated on the topsides before discharge to prevent any subsequent significant effects on the water column living organisms from oil. The remaining concentrations of other substances in the treated water should be monitored to further ensure the emissions discharged are within any necessary restrictions.

The treated solids discharged from the topsides would settle to the seabed; however their distribution and impact were not included in BMT’s modeling. The dispersion of these particles is likely to be significant if they are released at the sea surface level and less if they are released at the seabed. The effect would be similar to the settling of cuttings that are dispersed during dredging operations, but may result in an add-on effect. The effect on the seabed would mainly be smothering of the fauna and possibly some influence on the particle size distribution in the top sediment. Since the discharged cuttings are cleaned there should be insignificant effects from remaining pollutants.

The benthic faunal community is generally adapted to sediment fluctuation along the seabed and the effects from inert cuttings disposal would be local and associated with highest sedimentation rates. The benthic community would gradually adapt to the environmental conditions, hence the impact would mainly be temporary.

The overall impact of Option 2 on the marine environment is considered to be ‘small-moderate negative’ in the short-term. The impact would be relatively localised provided normal mitigation measures are adopted such as good operational procedures and use of best available and well maintained equipment to give the lowest spreading potential. It is recommended to monitor and document the situation and “footprint” within the area.

Note that the operations would have some positive effect on the local environment in the long-term as contaminated drill cuttings would be removed from the environment.

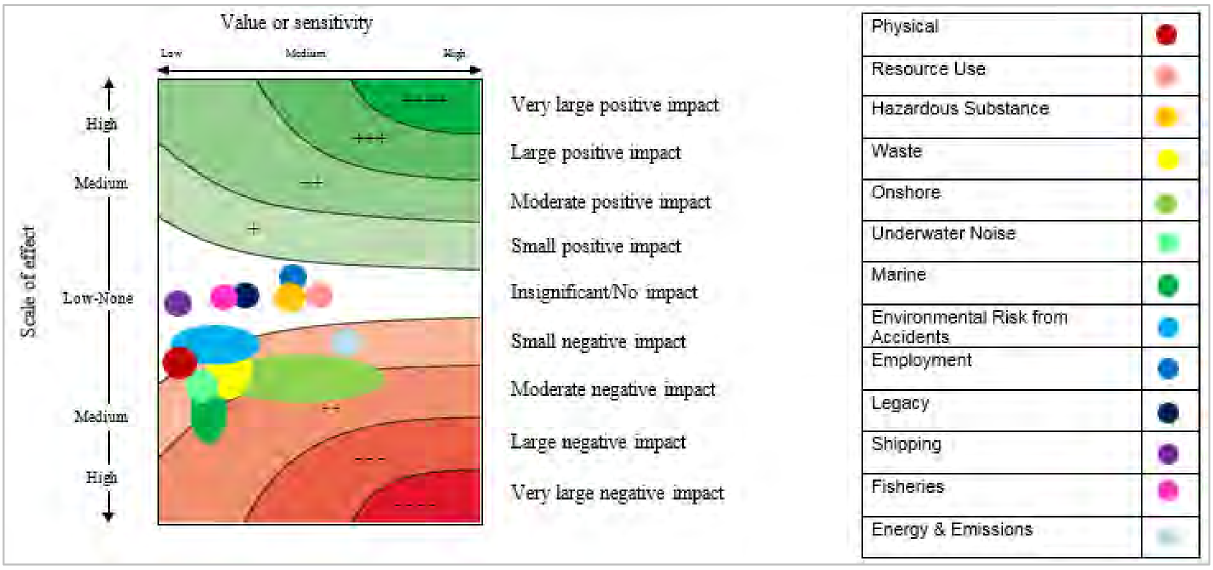
A ‘small negative’ impact is anticipated from noise generated during the dredging process.

13.6.9 Cell Top Drill Cuttings Option 3: Dredge and Transfer to Vessel for Treatment Onshore

This option involves removing all of the cell top drill cuttings at Brent B, C and D (13,400 m^3) by dredging and transporting the slurry to shore for treatment.

As shown in Figure 13-14 the significant impacts identified are in the onshore and marine categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-14: Cell Top Drill Cuttings Option 3: Transfer to Onshore



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact)
- For Energy and Emissions impact, please refer to DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

13.6.9.1 Marine

The overall impact upon the marine environment from Option 3 is estimated to be **'small-moderate negative'**.

The drill cuttings would be dredged from the GBS cell tops at Brent B, C and D, and the marine impacts are expected to be similar to Option 2 from the release of cuttings during dredging.

Some drill cuttings would be dispersed into the water and settle on the seabed during dredging operations. This has the potential to influence water column organisms as well as the local seabed fauna. However, under Option 3 there would be no offshore discharge of treated water or solids as the slurry would be transported to shore for treatment. Hence the impact to the local marine environment would be slightly less than for Option 2.

13.6.9.2 Onshore

The overall onshore impact from Option 3 is estimated to be **'small-moderate negative'**.

As with Option 2, this option involves removing all of the cell top drill cuttings at Brent B, C and D (13,400 m^3) by dredging. In Option 3, all of the dilute slurry generated (approximately 134,000 m^3) would be transported to shore for treatment.

The slurry would settle onshore in holding tanks and then be dewatered onsite (reduced to an estimated 25,000 m^3 of sludge). The separated water would be treated and returned to sea or sewer in accordance with permit conditions. The 25,000 m^3 of thickened sludge would be transported offsite (estimated 1,350 trips) and further dewatered before treatment by thermal desorption. The cleaned processed powder would be deposited at a licensed landfill site in accordance with permit conditions (this would involve further transport to landfill but of a smaller volume of material). The recovered oil (~500 tonnes) would be recycled.

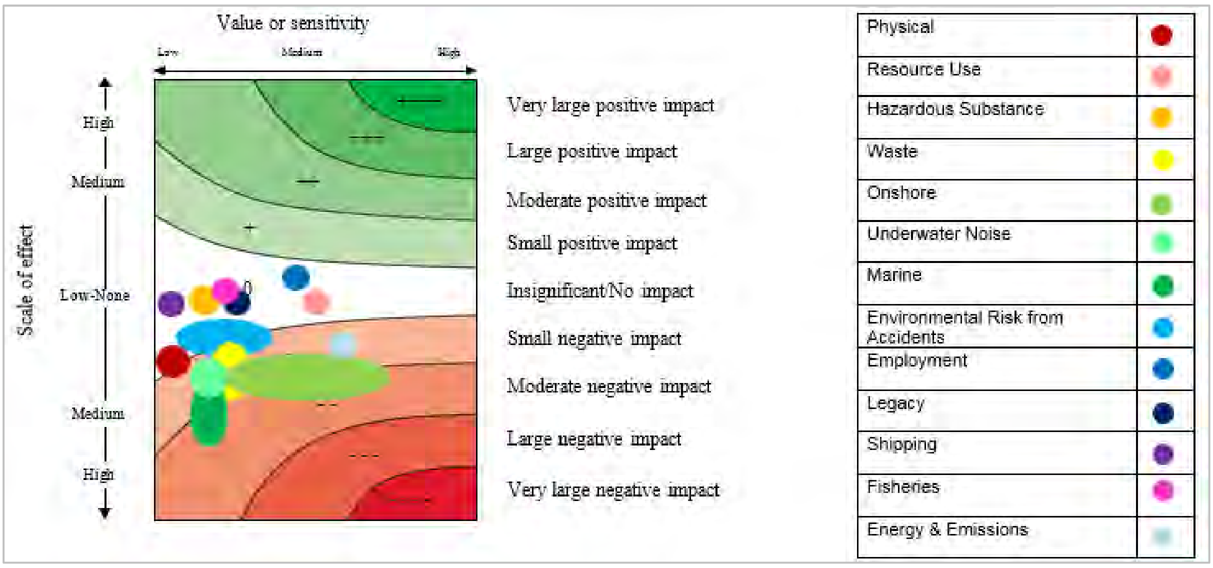
A 'small–moderate negative' impact is anticipated for Option 3 due to the transport of slurry out of the onshore site and along local roads (1,350 trips), this can have some nuisance impact upon the local area, the extent of which is very dependent on the location. A traffic management plan may need to be developed to mitigate impacts. It is currently not known if the thermal desorption process would be located at the onshore location. If so, this would reduce the volumes of materials requiring transport offsite. It is assumed that all activities would be undertaken under responsible management and control and in line with permit conditions.

13.6.10 Cell Top Drill Cuttings Option 4: Dredge, dewater from Brent C topsides, return solids to shore

This option involves removing all of the cell top drill cuttings at Brent B, C and D (13,400 m^3) by dredging, transferring the cuttings to the Brent C topsides for dewatering and transporting the solids to shore for treatment.

As shown in Figure 13-15 the significant impacts identified are in the onshore and marine categories. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-15: Cell Top Drill Cuttings Option 4: Transfer Solids Onshore



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact)
- Energy and Emissions data has been sourced from DNV GL's *Energy and Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

13.6.10.1 Marine

The impact to the local marine environment from a release during dredging would be similar to Option 2, and is estimated to be **'small-moderate negative'**.

As with Option 2, the drill cuttings would be removed by suction dredger and lifted onto a vessel. The slurry would then be transferred to the Brent C topsides for separation. Once separated, the liquid would be treated to less than the regulatory oil in water limits, and discharged to sea. Separated solids would be transported to shore for treatment.

The same volume of material would be dredged as in Options 2 and 3. The dredging would cause some of the sediments to be re-suspended and released to the marine environment, with resulting turbidity. The particles may affect the breathing functions (gill and skin) and feeding functions of local organisms. The effect would be relatively localised provided normal mitigation measures are adopted such as good operational procedures and the use of best available and well maintained equipment to give the lowest spreading potential. It is recommended to monitor and document the situation and "footprint" within the area.

However, as the processing of cuttings solids would be completed onshore under Option 4, there would be no offshore discharge of treated solids to sea (only treated water would be returned to sea). The non-hydrocarbon substances in the treated water should be monitored to further ensure the emissions discharged are within any necessary conditions.

A 'small negative' impact is anticipated from underwater noise generated during the dredging and removal process.

13.6.10.2 Onshore

The overall onshore impact from Option 3 is estimated to be **'small-moderate negative'**.

As with Option 2 and 3, this option involves removing all of the cell top drill cuttings at Brent B, C and D (13,400 m^3) by dredging. In Option 4, the slurry would be dewatered on the Brent C topsides and the solids returned to shore for treatment.

The thickened sludge (estimated 15,000 m^3) would be transported offsite (approximately 970 trips) and further dewatered and then treated by thermal desorption. Transporting the sludge out of the onshore site and along local roads can have some nuisance impact upon the local area, the extent of which is very dependent on the location. A traffic management plan may need to be developed to mitigate impacts.

The cleaned processed powder would be deposited at a licensed landfill site in accordance with permit conditions (this would involve further transport, but of a smaller volume). The recovered oil (~500 tonnes) would be recycled.

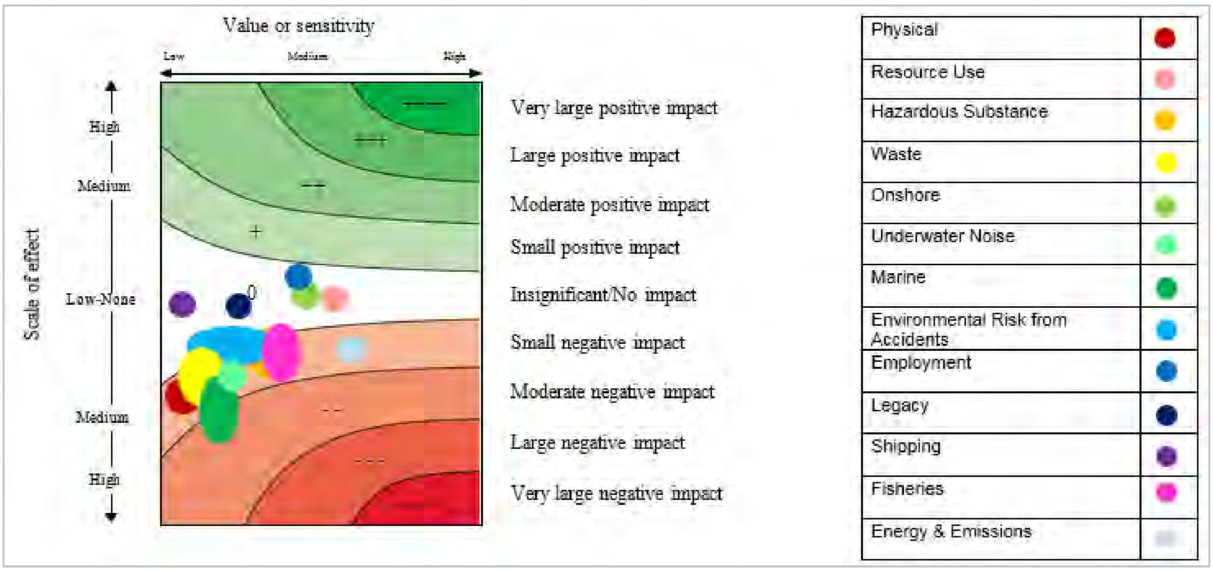
A 'small–moderate negative' impact is anticipated for Option 4, similar (but slightly lower) to the onshore impacts for Option 3. It is assumed that all activities would be undertaken under responsible management and control and in line with permit conditions.

13.6.11 Cell Top Drill Cuttings Option 5: Dredge to a vessel and transport to a newly drilled remote well for cuttings re-injection

Under Option 5, a new subsea well would be drilled for Cuttings Re-injection (CRI). As with the other options, the same volume of cell top drill cuttings would be removed by suction dredger and pumped onto a vessel. The slurry would then be transported to the new well for processing prior to injection.

As shown in Figure 13-16 the most significant impact identified is in the marine category. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-16: Cell Top Drill Cuttings Option 5: Dredge and Re-inject



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

13.6.11.1 Marine

The overall impact upon the marine environment from Option 5 is estimated to be **'small-moderate negative'**.

There is potential for impact to the marine environment from two elements of the process under Option 5:

- Dredging, and
- Drilling of a new well

Similar to the other options, the dredging activities for removal of drill cuttings would cause some of the sediments to be re-suspended. The water body would temporarily be influenced by particles and associated contaminants and the seabed by the settled solids. The effect would be relatively localised provided normal mitigation measures are adopted, as per previous matrix.

There could be some localised disturbance to the local marine environment during drilling and completion of the well, including physical disturbance. Drilling activities would be subject to a permit but would still produce drill cuttings that would settle on the seabed, and

result in some localised impact. Chemicals would also be added to the slurry for injection purposes, but there should not be any impact from the use of chemicals upon the marine environment as they should remain within the newly drilled well. Planned discharges from the drilling would be subject to a discharge permit application.

The overall impact is estimated to be 'small-moderate negative', as marine impacts would be temporary and localised. A 'small negative' impact is anticipated from underwater noise generated during the well drilling, dredging and cuttings removal process.

13.6.12 Cell Top Drill Cuttings Option 6: Leave *in situ*

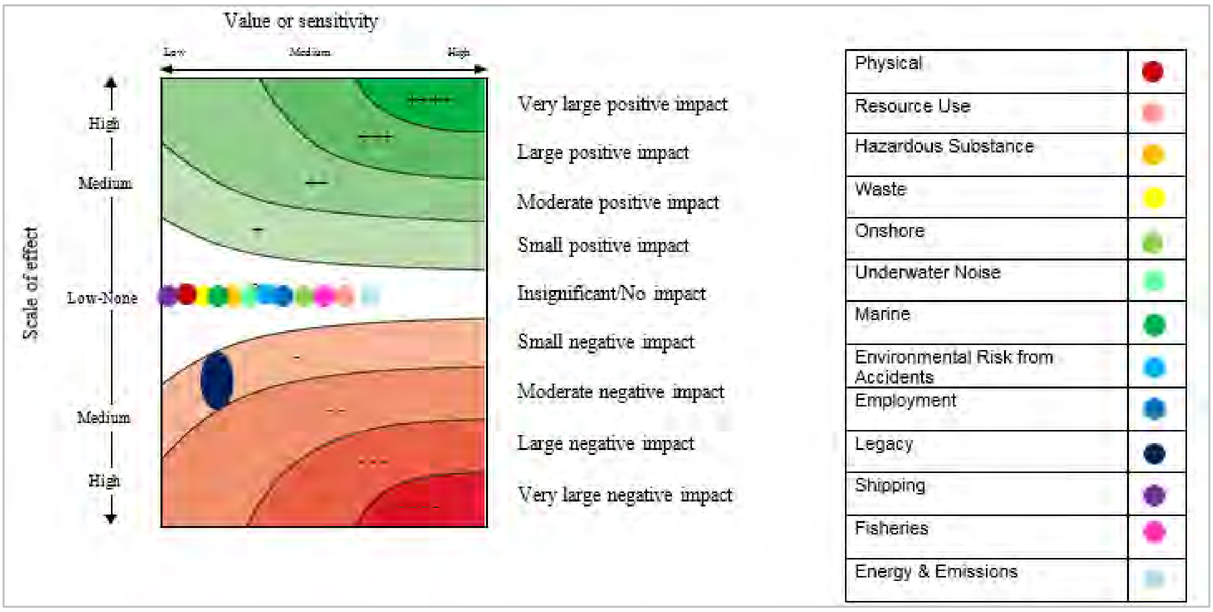
Under Option 6, the Brent C cell top cuttings would be left in place for natural degradation. The cuttings would be subjected to degradation and erosion similar to the cuttings at seabed. The water movement may be stronger at the cell tops compared to at the seabed and this can result in more rapid erosion.

Based on the Brent C cell top cuttings sampling and analyses in 2011, the loss of oil and persistence of the cuttings has been re-modelled [106]. The modelling indicates that the initial yearly loss of oil exceeds the OSPAR recommendation threshold, but the persistence is far less than the 500 km^2years. The OSPAR loss of oil threshold should be satisfied within the next 11-30 years for the Brent C combined cuttings.

Even though one of the OSPAR thresholds is exceeded, based on the current knowledge, the environmental impact from the cell top cuttings is local and no major effects have been identified. The environmental impact is evaluated to be '**small negative**'. There is limited benthic fauna on the cell tops, and although some oil may leak into the water column and migrate upwards, it is very unlikely to generate any slicks on the sea surface that have any potential for impacts to marine life (seabirds). This condition is likely to proceed as long as the cuttings are left undisturbed.

Regardless, the exceedance of the 10 tonnes of oil threshold triggers a requirement for a comparative assessment of drill cuttings management options, and this is performed by Shell within the Comparative Assessment (into which the environmental findings from this ES are input). Further discussions with stakeholders during the decommissioning process about the exceedance of the OSPAR threshold may necessitate further examination of this issue, and this uncertainty is reflected by the elongated bubble in Figure 13-17.

Figure 13-17: Cell Top Drill Cuttings Option 6: leave *in situ*

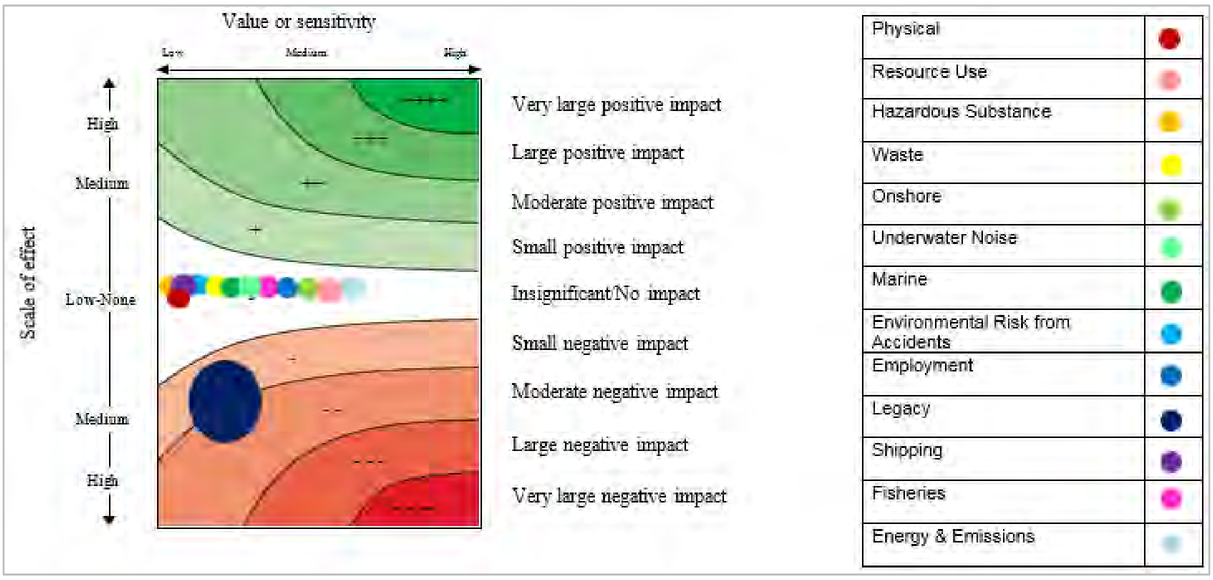


- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

13.6.13 Tri-cell Drill Cuttings Option 1: Leave *in situ*

This option involves leaving the tri-cell drill cuttings *in situ* in the triangular gaps in between GBS adjacent storage cells. Approximately 26,800 m^3 of tri-cell drill cuttings are estimated to exist in Brent B and D GBS (Brent C has no tri-cells). As shown in Figure 13-18, the most significant impact identified is in the legacy category. Estimated impacts are considered small or insignificant for all other categories.

Figure 13-18: Tri-Cell Drill Cuttings Option 1 Leave *in situ*



- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

13.6.13.1 Legacy

The overall legacy impact as a result of leaving the drill cuttings in the tri-cells *in situ* under Option 1 is estimated to be **'small-moderate negative'**.

The drill cuttings in the tri-cells are considered by Shell to be an extension of the cell top drill cuttings and hence fall under OSPAR 2006/5. Shell believes the Brent B and D tri-cell cuttings fall below the oil loss and area persistence thresholds in OSPAR Recommendation 2006/5 [116], just like Brent B and D seabed and cell top drill cuttings; Shell therefore proposes to leave any GBS tri-cell drill cuttings *in situ* for natural degradation.

In the short to medium-term, the tri-cell drill cuttings are expected to remain covered by the GBS cell top drill cuttings, or have only a limited area exposed to the water column. Hence there will be an insignificant impact until the GBS degrade over time and the tri-cell drill cuttings become exposed to the marine environment some hundred years or more into the future.

The tri-cell drill cuttings will ultimately become exposed to the sea when the GBS degrade, at this time the impact should be similar (i.e. localised pollution) as for the GBS cell contents (if left *in situ*), but possibly a little less because:

- The limited sampling of the tri-cell cuttings conducted to date suggests the maximum concentration of oil in the tri-cells is 9.2%. The impact of the cell sediment release is based on 17.5% oil content (for the updated modelling based on sampling results).
- The volume of tri-cell drill cuttings predicted to be in Brent B and D (approximately 26,800 m^3) is less than the volume of GBS cell sediment at Brent B and D (approximately 34,560 m^3), and tri-cell drill cuttings are not present at Brent C, where cell sediment is also present.
- Considered together, the two above points suggest the total oil load within the tri-cell cuttings is less than half of that contained within the cell sediment.
- As the tri-cell drill cuttings are contained internally in the GBS, they are only likely to be exposed to the marine environment in gradual amounts over a period of time, as more than one wall needs to be breached for them to become exposed. Some of the tri-cell cuttings may be 'entombed' within the GBS as they degrade.

Conversely, some of the tri-cell cuttings may be exposed to the marine environment in a dynamic (disturbed) state and released at a higher level above the seafloor, and will thus travel further, albeit they would be more dispersed. No modelling has been conducted by Shell of the exposure of the tri-cell drill cuttings to the marine environment, and as such DNV GL used other modelling results to predict the impact. Of the dynamic release cell sediment modelling scenarios commissioned by Shell, DNV GL examined the scenario that released 10 m^3/day for 1 year at a height of 20 metres above the sea floor (3,650 m^3 cell sediment), representing a significant amount of tri-cells drill cuttings to be fully re-suspended in the water column for dispersion around the platform (~27% of the volume of tri-cell drill cuttings at a platform) as that gave the biggest impact of the scenarios modelled. The cell sediment dynamic modelling results show that the majority of the contaminated seafloor will have a sediment thickness of less than 1 mm with a pollution concentration exceeding potential harmful limits. Because of bioturbation mixing, the contaminated sediment will quickly be diluted in the upper part of the seafloor sediment and hence not have any harmful impact on biota [94]. The seafloor with >10 mm contaminated sediment and PEC:PNEC>1 is expected to cause harmful effects on the biota. Dynamic modelling results show that 0.06

km^2 seafloor will have such conditions. This is close to the 0.05 km^2 footprint with potential harmful effects that was derived from the updated static modelling.

However, a portion of the tri-cell drill cuttings may be released higher than 20 m above the sea floor. Modelling results of the dynamic disturbance of dredging 7,753 of Brent C cell top drill cuttings (in which 775 m^3 is released to the marine environment, a volume similar to the amount of cuttings in one tri-cell) over 65 days, [107] 60 m above the seafloor show (as described in Section 13.6.1.1) that the vast majority of the cuttings is widespread and resettles on the seafloor as a thin layer, less than 1 mm thick and these areas will not harm biota once mixing by bioturbation is taken into account. The maximum thickness was 6 mm.

The nature of the future exposure of the tri-cell drill cuttings to the marine environment is uncertain. If two dynamic releases occurred at different times within (e.g.) a 10 year period, the impact would be similar (but extended in time) because the 1 mm thickness would degrade quickly (within a year or two). Two such dynamic release events (of 3,650 m^3/year) would represent more than half of the tri-cell drill cuttings at one platform. In addition to biodegradation, it would also be diluted as a result of mixing with cleaner sediment because of bioturbation.

As described in the legacy assessment of GBS cell sediment (Option 5 – Leave *in situ*), the modelling results show that, based on analytical results (Table 11-4), a major static release of cell sediment from the GBS will pollute the local benthic environment to a distance of approximately 250 m from each platform but is not expected to induce any measurable effects on regional benthic fauna. Therefore, when the drill cuttings in the tri-cells are exposed to the marine environment upon degradation of the GBS, they would similarly pollute the local environment and add to the area persistence.

As such, the overall legacy impact as a result of tri-cell drill cuttings Option 1 is estimated to be 'small-moderate negative'. The environmental impact would be similar in nature to that currently experienced at the Brent Field as a consequence of the presence of the historical seabed and cell top drill cuttings, because the oil load contained within the tri-cell drill cuttings is similar (see 0), and they were also released from height.

The cumulative impacts from the combined exposure to the marine environment of the tri-cell cuttings and cell contents is discussed in the ES Cumulative Impacts sections (Section 17.6.1).

13.7 Comparison of Options for Decommissioning of the Brent Field Drill Cuttings

Only one option is considered for the management of the seabed drill cuttings, leave *in situ*. No impacts have been identified for this option that are greater than 'small negative', because at present the OSPAR 2006/5 criteria are satisfied.

The four options for Brent A seabed drill cuttings have similar impacts because they all involve dredging the same volume of drill cuttings. Options 2, 3 and 4 present some benefit to the marine environment over Option 1 in that treated solids (with oil removed) would not be returned to sea, but this is not considered a major distinguishing factor. Also, conversely, Options 2 and 3 have potential to result in onshore impacts, while Option 4 would require drilling new wells.

There are six options for the cell top drill cuttings, but Options 2, 3, 4 and 5 all have similar marine impacts because they all involve dredging the same volume of drill cuttings. Option 1

uses a very different technology (water jetting) to Options 2, 3, 4 and 5 (dredging) to manage the cell top drill cuttings, but Option 1 involves managing a much smaller volume of drill cuttings (containing oil) to the marine environment than Options 2, 3, 4 and 5, and so has a lower impact. Options 2, 3, 4 and 5 would result in small-moderate negative impact to the local marine environment, mainly to benthic fauna (such as tube worms), that would take some years to recover. But the Brent Field does not contain any unique species, or species of particular conservation interest. Options 3, 4 and 5 present some benefit to the marine environment over Option 2 in that treated solids (with oil removed) would not be returned to sea, but this is not considered a major distinguishing factor. Also, conversely, Options 3 and 4 have potential to result in onshore impacts, while Option 5 would require drilling new wells. What is clear is that the bigger the volume of cell top drill cuttings that requires removal, the more dredging should be considered as the mechanism for removal rather than water jetting, because dredging releases far less suspended particulates to the marine environment than water jetting for a given volume of cuttings handled. Under Option 6, the cell top cuttings would be left in place for natural degradation, and the environmental impact is evaluated to be 'small negative' because their current environmental impact is local (even though the Brent C cell top cuttings initial yearly loss of oil exceeds the OSPAR recommendation threshold, while the persistence is far less than the 500 km^2years) and this condition is likely to proceed as long as the cuttings are left undisturbed. The cell top drill cuttings at Brent B and D are considered to meet OSPAR thresholds.

With regard to the substantial quantity of tri-cell drill cuttings presumed to be located within the GBS tri-cells, there is currently only one management option and that is to leave *in situ.* The most significant impact for tri-cell drill cuttings relates to legacy, as the drill cuttings would only be significantly exposed to the marine environment when the GBS deteriorate.

13.8 Significant Impacts of Proposed Programme of Work

Shell's proposed decommissioning options for drill cuttings are:

- Seabed drill cuttings – Option 1, leave *in situ*. No significant impacts (Shell proposes to partially remove the Brent A jacket, so the Brent A seabed drill cuttings will also be left *in situ*).
- Cell top drill cuttings:
  - Brent B and D: in the event that the drill cuttings have to be disturbed a little to create new small diameter access holes, the proposed option is Option 1 (water jet). This will only have a small impact on the environment as described earlier in this section.
  - The proposed option for Brent C is Option 6, leave *in situ,* which will have a small impact on the marine environment. It is only if new access points are required does Option 3 (Dredge and return slurry to shore) become necessary.
- Tri-cell drill cuttings – Option 1, leave *in situ*: small-moderate negative legacy impact on the local marine environment after GBS degradation.

13.9 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that mitigation and management measures are in place. Table 13-7 details these measures for the proposed options to decommission the drill cuttings and highlights the residual impacts described in Section 13.6 and Appendix 1.

Table 13-7: Summary of Mitigation and Management Measures for Proposed Programme of Work

Environmental Category	Mitigation Measures*	Residual Impact
Onshore Impacts	The following is applicable for cell top drill cuttings Option 3 only; all other drill cutting management options in the proposed programme of works have no onshore impact: • A large volume of dilute drill cuttings slurry will come to shore for treatment. The onshore site is currently not known, but Shell will ensure it is responsibly managed, is licensed to perform such waste management operations, and that operations will be carried out within the licence conditions. • Shell will audit onshore operations to ensure regulatory limits are met. • A traffic management plan will be developed to mitigate impacts from a large number of lorry trips offsite.	Small-moderate negative (Cell top drill cuttings Opt 3)
Resource Use	There are few resources used	Insignificant
Hazardous Substances	There are very few hazardous substances used; they will be managed in accordance with relevant legislative requirements	|Insignificant
Waste	The following is applicable for cell top drill cuttings Option 3 only; all other drill cutting management options in the proposed programme of works will generate no waste: • The large volume of slurry waste will be dewatered onshore to minimise the quantity of waste that goes to landfill. • A licensed landfill site will be used and operations will be carried out within license conditions. • Shell will audit waste management to ensure duty of care and all other waste management requirements are satisfied.	Small negative (Cell top drill cuttings Op 3)
Physical	There are few physical impacts	Insignificant-small negative (Cell top drill cuttings Opt 3)
Marine (includes underwater noise)	The following is applicable for cell top drill cuttings Options 1 and 3 only; all other drill cutting management options in the proposed programme of works have insignificant marine impact. • Shell will obtain all necessary permits from the regulator before commencing dredging or water jetting operations • Shell will encourage use of low disturbance-type tools to minimise the generation of turbulence • Shell should consider conducting environmental monitoring during operations (and Shell will monitor the remains as described in Section 18). Environmental monitoring might include turbidity measurement, sediment traps, passive sampler devices, samples of the seabed prior and after the dredging etc. Such data collection will contribute to increased knowledge about the subject and to document the footprint/impact of increased turbidity and the spreading/settlement of the cuttings particles. • Shell will audit the dredging to ensure good practice is followed to minimise disturbance to the marine environment • Shell will use dredging (rather than water jetting) as the preferred approach if large volumes of cell top drill cuttings are required to be removed or displaced • Shell will conduct operations, where practical, in a period with lowest abundance of vulnerable resources (e.g. fish eggs or larvae) in the water column.	Small-moderate negative (Cell top drill cuttings Opt 3)
Environmental Risk from Accidents	The following is applicable for cell top drill cuttings Option 3 only; all other drill cutting management options in the proposed programme of works have insignificant risk. • Dredging will dilute slurry to less than 1%. oil content. • A BEIS approved Oil Pollution Emergency Plan (OPEP) for the Brent Field system is in place. • Strict operational procedures will be in place for removal operations and periods of high seabird vulnerability will be avoided, where practical. • Operations will take place in good weather.	Insignificant-small negative (Cell top drill cuttings Opt 3)
Employment	There is insignificant employment generated	Insignificant
Legacy	The following is applicable only for tri-cell drill cuttings Option 1; all other drill cutting management options in the proposed programme of works will have smaller/no legacy impact: • Shell will monitor as described in Section 18 • Shell will undertake appropriate actions if, after GBS degradation, environmental monitoring (for example, sediment analysis, benthic fauna samples) shows impacts to be more significant than predicted by desk studies. Specific remedial actions would need to be engineered to respond to the actual situation.	Small-moderate negative (Tri-cell drill cuttings)
Fisheries	There are few marine operations and marine operations will mainly be conducted within the 500 m zone.	Insignificant
Shipping	There are few marine operations and marine operations will mainly be conducted within the 500 m zone.	Insignificant
Energy and Emissions	• Marine diesel will be used in line with MARPOL North Sea Special Area requirements [72], to reduce SO_x emissions. • Vessel speeds will be managed to minimise fuel consumption. • To increase efficiency, combustion equipment on vessels will be maintained in accordance with manufacturers' recommendations.	Small negative

*This mitigation table assumes (worst case) that the Brent B and D cell top drill cuttings have to be disturbed a little to create new small diameter access holes, and that new access points are required at Brent C cell tops such that dredging of cell top drill cuttings is necessary.

14. PIPELINES

14.1 Introduction

This section describes the pipelines, the inventory of materials and the decommissioning options. The main anticipated environmental impacts of the decommissioning options and the proposed programme of work are discussed. The necessary management and mitigation measures to control the impacts of Shell's proposed programme of work are summarised, and measures are recommended to further reduce residual impacts where appropriate. The Technical Document for Decommissioning the Brent Field Pipelines has been used as the basis for Sections 14.2-14.5 [110].

14.2 Description of Facilities

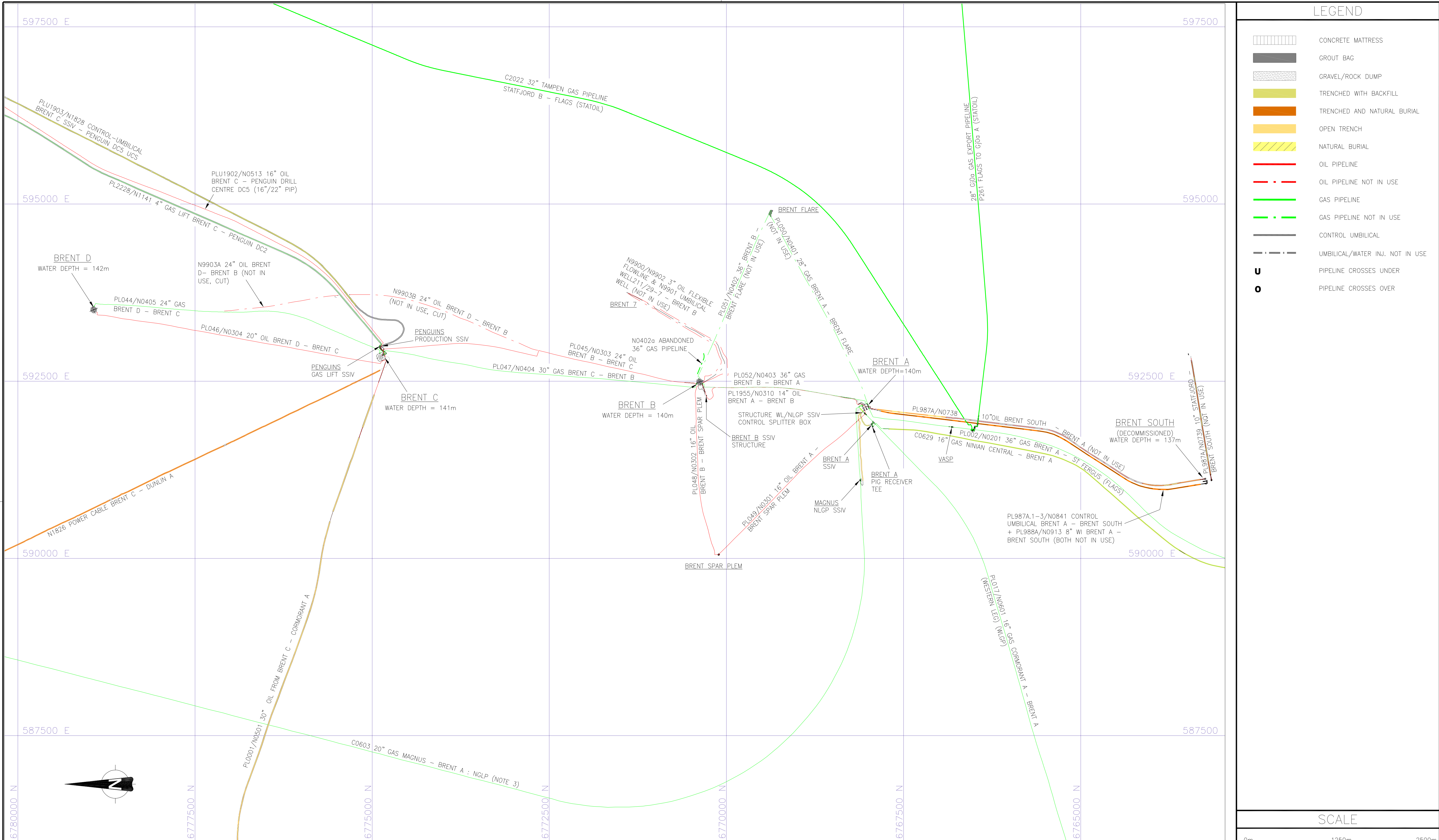
A total of 28 subsea pipelines are included in the BDP and will be decommissioned at the end of field life. The types of pipelines being decommissioned include rigid pipelines, flexible flow lines and risers, umbilicals and power cables. There are also concrete mattresses and rock cover in some locations to protect subsea pipelines and umbilicals.

The pipelines included in the scope of this study are shown in Table 14-1 and illustrated in Figure 14-1. Most pipelines have both a Shell reference number and a BEIS reference number. The Shell reference numbers are used in the sections that follow.

Table 14-1: Brent System Pipelines, Umbilicals and Power Cable

BEIS Pipe No.	Shell Pipe No	Service	From	To	Size (inch)	Length (km)
PL002	N0201	Gas Export	Brent A	VASP	36	1.3
PL049	N0301	Oil Export (now drains line)	Brent A	Brent Spar PLEM	16	2.8
PL048	N0302	Oil Export (now drains line)	Brent B	Brent Spar PLEM	16	2.3
PL045	N0303	Oil Production	Brent B	Brent C	24	4.6
PL046	N0304	Oil Production	Brent D	Brent C	20	4
PL1955	N0310	Oil Production	Brent A	Brent B SSIV	14	2.3
PL1955	N0311	Oil Production	Brent B SSIV	Brent B	12	0.27
PL050	N0401	Flare Gas (Disused and in IPR)	Brent A	Brent Flare Location	28	3
PL051	N0402	Flare Gas (Disused and in IPR)	Brent B	Brent Flare Location	36	2.6
PL052	N0403	Gas Export	Brent B	Brent A	36	2.3
PL047	N0404	Gas Export	Brent C	Brent B	30	4.4
PL044	N0405	Gas Export	Brent D	Brent C	24	4.2
PL001	N0501	Oil Export	Brent C	Cormorant A	30	35.9
PL017	N0601	Gas Import	Brent A SSIV on WLGP	Brent A	16	0.4
PL987A	N0738	Oil Production (Disused and in IPR)	Brent S	Brent A	10	5
PL987A	N0739	Oil Production (Disused and in IPR)	Brent S	Statfjord DC	10	1.8
PL987A 1-3	N0841	Umbilical (Disused and in IPR)	Brent A	Brent S	5	5.3
PL988A	N0913	Water injection (Disused and in IPR)	Brent A	Brent S	8	5
None	N9900	Oil Production (Disused and in IPR)	Well 211/29-7	Brent B	4	2.1
None	N9902	Oil Production (Disused and in IPR)	Well 211/29-7	Brent B	4	2.3
None	N1844	Power Cable	Brent B	Brent A	5	2.9
None	N2801	Control Umbilical	Brent B	Brent B SSIV	2.5	0.4
None	N9901	Control/Chemical Umbilical (Disused and in IPR)	Brent B	Well 211/29-7	4	2.2
None	N0830	SSIV Control Umbilical	Brent A	WLGP SSIV	4	0.5
None	N9903A	Oil Production (Disused and in IPR)	N0405 Midline Tie-in	N0513 Pipeline Crossing	24	1.7
None	N9903B	Oil Production (Disused and in IPR)	N0513 Pipe Crossing	N0303 Midline Tie-in	24	2.9
PL050	N0952	Flushing jumper (Disused and in IPR)	Brent A Flare Line	Brent B Flare Line	8	0.03
PL051	N0402a	Abandoned during construction	Brent B	n/a	36	0.147

Figure 14-1: Layout of Pipelines at Brent Field (within the scope of this ES)



BRENT FIELD PRE-DECOMMISSIONING SUBSEA FIELD LAYOUT

SCALE: 1:25000

REFERENCE DRAWINGS.	DRAWING No.
PRE DECOM INTER P/FORM PIPELINES BC-BD	BDE-F-SUB-UA-4024-00014-001
PRE DECOM INTER P/FORM PIPELINES BB-BC	BDE-F-SUB-UA-4024-00015-001
PRE DECOM INTER P/FORM PIPELINES BA-BB	BDE-F-SUB-UA-4024-00016-001
PRE DECOM INTER P/FORM PIPELINES BS-BA	BDE-F-SUB-UA-4024-00017-001
PRE DECOM OIL EXPORT PIPELINE BC-CA SHT. 1	BDE-F-SUB-UA-4024-00018-001
PRE DECOM OIL EXPORT PIPELINE BC-CA SHT. 2	BDE-F-SUB-UA-4024-00018-002

NOTES:

1. UNLESS SHOWN, ANODE SKIDS, GROUT BAGS AND SEA BED DEBRIS HAVE BEEN OMITTED FOR CLARITY.

REV	DATE	DESCRIPTION	DRAWN	CHK or TECH REP	DES ENG.	APP'D
A02	10.11.16	REVISED. APPROVED FOR DESIGN	TB	DM	KB	JB
A01	26/03/13	APPROVED FOR DESIGN	RP	ADS	JI	AR
R01	27.02.13	ISSUED FOR REVIEW / IDC	ADS	AH	JI	AR

SIEP SHELL INTERNATIONAL EXPLORATION AND PRODUCTION B.V.- EP PROJECTS

BRENT DECOMMISSIONING PROJECT
SUBSEA FACILITIES
BRENT FIELD PRE DECOMMISSIONING
SUBSEA FIELD LAYOUT

DRG No. BDE-F-SUB-UA-4024-00020-001 REV. A02

THIS DOCUMENT ORIGINATED IN U.K. THIS DOCUMENT HAS AN ECCN OF EAR99

The decommissioning of the Brent platforms will be phased and so some pipelines will need to be reconfigured to maintain export routes from the Brent system until CoP. The following three pipelines and three control umbilicals connect to Brent A and must be re-configured before Brent A is decommissioned:

- The Northern Leg Gas Pipeline (NLGP) from Magnus (PL164/C0603)
- The Western Leg Gas Pipeline (WLGP) from Cormorant "A" (PL017/N0601)
- The FLAGS line from Brent B (PL 2 / N0201)
- The WLGP SSIV control umbilical N0830
- The NLGP SSIV control umbilical C0815
- The redundant former NLGP SSIV control umbilical C0801

These will be addressed through the Brent Bypass Project. The environmental impacts of the Brent Bypass Project are not considered in this ES. In addition, redundant lines belonging to third parties, and lines related to the Penguin Field, are not considered.

Prior to decommissioning it is assumed that the pigging and flushing of the subsea pipelines (to clean the pipelines and remove hydrocarbons and other contaminants such as wax) will have been undertaken. These operations are not within the scope of this ES.

14.3 Materials Inventory

The pipeline materials are summarised in Table 14-2, with more detail for each pipeline provided in Appendix 4. The table details more than 99% of the pipeline weights; the proportion and breakdown of materials within the remaining 1% is unknown.

Table 14-2: Total Materials Inventory for Pipeline Groups

	Group 1* (Qualitative)	Group 2* (Quantitative)	Total
Total weight of steel in pipeline (t)	2,071	23,058	25,129
Total weight of concrete in pipeline (t)	66	21,830	21,896
Total weight of protective coatings & plastics in pipeline (t)	287	1,226	1,513
Total weight of concrete mats (t)	1,040	722	1,762
Total weight (t)	3,464	46,836	50,300 **

*Group 1 and 2 pipelines described in Section 14.4.
**Additionally there are approximately 92 t of anodes in the field, plus approximately 16,000 t of existing rock dump.

14.4 Available Decommissioning Options

DECC Guidance Notes on Decommissioning state that all feasible decommissioning options should be considered and that comparative assessments are used to inform the selection of the recommended option. Each pipeline is to be assessed based on the alternative options available, and taking account of factors including burial status (i.e. trenching, spanning, exposure, presence of rock dump), and the characteristics of the pipeline (diameter, length, type etc.).

There are 28 pipelines within the scope of the BDP, and Shell divided them into two groups: Group 1 (Qualitative) and Group 2 (Quantitative), as follows:

- **Group 1** Pipelines comprise 14 pipelines, umbilicals and power cables which are 14" or less in diameter, are trenched or surface-laid and exposed on the seabed. For these

pipelines there are indications from DECC Guidance Notes what the accepted decommissioning option should be, and Shell conducted a qualitative assessment to determine the recommended decommissioning option. The impacts of this option are assessed in this ES.

- **Group 2** comprise 14 pipelines larger than 16" in diameter, made of steel, with or without concrete coating, and may be partially rock dumped. There are a number of feasible decommissioning options, and the impacts of each feasible option are assessed in this ES. The results are used by Shell as part of a Comparative Assessment as required by BEIS.

The Group 1 and Group 2 pipelines are presented in the Table 14-3. Most pipelines have both a BEIS reference number and a Shell reference number for identification purposes.

Concrete mattresses are placed over some of the exposed pipelines to protect them from, e.g., fishing trawlers. Some mattresses are covered by existing rock dump, some pipelines are covered by rock dump without mattresses. See Appendix 4 for data on concrete mattresses.

Rock dumping is used to support, cover, stabilise and protect subsea pipelines which are potentially exposed to external damage.

Table 14-3: Group 1 and Group 2 pipelines within the Brent Field ES

Group 1 (Qualitative) Pipelines		Group 2 (Quantitative) Pipelines	
BEIS Pipe No.	Shell Pipe No.	BEIS Pipe No.	Shell Pipe No.
PL1955	N0310	PL002	N0201
PL1955	N0311	PL049	N0301
PL051	N0402a	PL048	N0302
PL987A	N0738	PL045	N0303
PL987A	N0739	PL046	N0304
None	N0830	PL050	N0401
PL987A 1-3	N0841	PL051	N0402
PL988A	N0913	PL052	N0403
PL050	N0952	PL047	N0404
None	N1844	PL044	N0405
None	N2801	PL001	N0501
None	N9900	PL017	N0601
None	N9901	None	N9903A
None	N9902	None	N9903B

Further information on the pipelines is available in the Shell Technical Document for pipelines and in Appendix 4.

14.5 Technically Feasible Decommissioning Options

Group 1 (Qualitative) Decommissioning Options

The options for decommissioning the pipelines (and umbilicals) in Group 1 that are considered in this ES are summarised in Table 14-4.

For the purpose of the assessment the Group 1 pipelines were categorised into the three subgroups indicated in the table based on the decommissioning option that applies. The assessment of impact was made at the subgroup level (not individual pipelines). The exception to this is for energy and emissions where each pipeline was considered individually.

Table 14-4: Group 1 Decommissioning Options and Assessment Subgroups

	LEAVE IN PLACE	COMPLETE REMOVAL	
Option	**Option 1**: Leave in existing trench with minor rock dump over exposed flanges. Leave N0952 under existing rock dump.	**Option 2**: Remove the whole line by cut and lift. Recycle/dispose onshore.	**Option 3**: Remove the whole line by reeling. Recycle/ dispose onshore.
Assessment Subgroup	Subgroup 1A	Subgroup 1B	Subgroup 1C
Pipelines	N0738 N0739 N0913 N0841 N0952	N9900 N9901 N9902 N0402a	N0310 N0311 N1844 N2801 N0830

Group 2 (Quantitative) Decommissioning Options

The decommissioning options assessed for the Group 2 pipelines are shown in Table 14-5.

Table 14-5: Group 2 Decommissioning Options

LEAVE IN PLACE			COMPLETE REMOVAL	LEAVE IN PLACE
Option 1: Leave *in situ* with no further remediation **Option 2**: Leave tied-in at platforms and trench non-platform end	**Option 3**: Leave tied-in at platforms and rock dump non-platform end **Option 4**: Trench and backfill whole length.	**Option 5:** Rock dump whole length.	**Option 6**: Recover whole length by cut and lift. **Option 7**: Recover whole length by reverse S lay (single joint)	**Option 8:** Trench and backfill shallow-trenched sections + isolated rock dump (N0501) **Option 9**: Rock dump all shallow-trenched sections (N0501)

The description of each option is as follows:

Options 1: Leave *in situ* with no further remediation. This option only applies to those pipelines which are currently tied in to platforms at both ends. In this option it is assumed that the ends would remain tied in to derogated structures so no remediation would be required to make the pipeline ends safe for other users of the sea.

Option 2: Leave tied-in at the platforms and trench and backfill the non-platform end. In Option 2, the pipelines would be largely left on the seabed with one end left tied-in to the GBS (or the jacket at Brent A). There would be no rectification work on the platform closing spans, where present. At non-platform ends, where the pipeline is connected to a subsea structure (which will all be removed), pipeline tie-in spools would be cut and removed and the ends trenched and backfilled.

Option 3: Leave tied-in at the platform, rock dump the non-platform end. In Option 3, the pipelines would remain on the seabed with one end tied-in to the GBS (or the jacket at Brent A). At non-platform locations, the pipeline tie-in spools would be cut and removed and the ends rock dumped to a length of 30m.

Option 4: Trench and backfill the whole length of the pipeline. In Option 4, the pipelines would be disconnected from the platforms and any subsea infrastructure, but would require extensive remedial work to achieve a suitable status for decommissioning. Option 4 would involve cutting out and recovering the pipeline tie-in spools, then trenching and backfilling the whole of the remaining pipeline. Shell will trench the pipeline ends to a depth of 0.6m to Top Of Pipeline (TOP), however, it is recognised that this may not be possible along the whole pipeline length, particularly in the Brent area where the soil conditions are very variable. Should any problems be encountered with achieving a 0.6m depth of trench to TOP, Shell would consult with BEIS regarding the options for appropriate remediation. For two pipelines (PL050/N0401 and PL051/N0402) which are covered at the non-platform (Brent Flare) end by existing rock dump, a small amount of rock would be deposited to cover the cut end of the pipeline. This is because trenching equipment cannot be deployed immediately next to existing rock dump.

Option 5: Rock dump the whole length of the pipeline. In Option 5, the pipeline tie-in spools at the platforms and other subsea facilities would be cut and removed, and the whole length of the pipeline would be rock dumped to a minimum depth of 0.5m over the top of the pipeline to mitigate the snagging hazards from the ends and long-term pipeline degradation.

Option 6: Remove the whole length of the pipeline by cut and lift. In Option 6, the pipelines would be fully removed by subsea cutting and lifting the pipeline sections to the surface, transferring to a vessel for transport to shore, and recycling or disposal accordingly. For some pipelines which are already covered by existing rock dump, a small amount of rock would be deposited to cover the cut end of the pipeline. This is because cutting equipment cannot be deployed immediately next to existing rock dump.

Option 8: Trench and backfill the shallow-trenched sections and isolated rock dump. Option 8 only applies to pipeline N0501, which is very long and has been trenched to varying degrees along its route, with some sections of the pipeline protruding partially or completely above the surrounding seabed. Under Option 8, many of these sections would be rectified by trench and backfill to achieve a depth of trench of 0.6m below mean seabed level, while

sections which cannot be trenched would be rock dumped to a minimum rock depth of 0.5m to mitigate against snagging hazards.

Option 9: Rock dump all the shallow-trenched sections. Option 9 only applies to pipeline N0501. Where the pipeline currently protrudes above the mean seabed or is not trenched to 0.6m or more to TOP, it would be rock dumped to achieve 0.5m of rock cover to top of pipe, to mitigate snagging hazards from the ends and long-term degradation.

As with Group 1, the pipelines in Group 2 have been categorised in subgroups to aid the assessment process. This was based upon the pipeline length, size, location and the feasible decommissioning options. The subgroups essentially contain 'similar' pipelines in terms of the criteria above. The pipeline groups and subgroups are presented in Table 14-6, including the criteria used to create the groups.

As with Group 1, the assessment of impact has been made at the subgroup level. The exception to this is for energy and emissions where each pipeline was considered individually.

Table 14-6: Group 2 Assessment Subgroups

Subgroup	2A	2B	2C	2D	2E
Subgroup Criteria	< 3km length > 16 inch diameter Decommission by 6 options	> 3 km length > 16 inch diameter Decommission by 5 options	Long pipeline > 30km 30 inch diameter Decommission by 5 options	Short pipeline <1km 16 inch diameter Decommission by 4 options	< 3km length 24 inch diameter Decommission by 5 options
Pipelines	N0201 N0301 N0302	N0303 N0304 N0401 N0402 N0403 N0404 N0405	N0501 (only)	N0601 (only)	N9903A N9903B
Decom Options	Group 2 – Options 2,3,4,5,6,7	Group 2 – Options 1,4,5,6,7	Group 2 – Options 1, 6, 7, 8, 9	Group 2 – Options 2,3,5,6	Group 2 – Options 1,4,5,6,7

14.5.1 Cleaning of Pipelines prior to Decommissioning

Prior to decommissioning, oil pipelines will be cleaned using a mixture of seawater flushes and mechanical pigging runs. If cleaning operations are inefficient the project may consider the use of chemicals to assist in the removal of, for example, waxy deposits. When repeated sampling of the flush water indicates a plateau of oil in water concentrations has been reached, Shell will confirm with BEIS that cleaning operations can stop and the pipeline can be deemed to be clean. Any solids will be captured and returned to shore for further cleaning and disposal.

Gas pipelines will be cleaned by flushing. No heavy deposits are expected in these pipelines and so it is believed that flushing will successfully remove any free hydrocarbons from the pipeline. As with the oil pipelines, samples will be taken and when no further improvement in

oil in water levels are found, a report will be made to BEIS to confirm that cleaning operations can be stopped.

Umbilicals will be flushed before being severed and then capped prior to recovery.

Those pipelines which are to be recovered will be left flooded with treated seawater to protect the integrity of the pipelines until decommissioning can begin. Those pipelines which are to be left *in situ* will probably be left filled with untreated seawater as there will be no requirement to maintain the pipeline integrity. Should any pipeline be taken out of use prior to the approval of the Decommissioning Programmes, Shell will clean them as described above but leave them filled with inhibited seawater regardless of the recommended option from the CA. This will ensure that if Shell are later directed to remove a pipeline which was intended to be decommissioned *in situ*, the pipeline integrity will have been maintained. All operations will be completed under appropriate permits.

Flushing and cleaning take place prior to the start of decommissioning and it is assumed that it results in pipelines that are clean and ready for decommissioning. Flushing and cleaning are not covered within this EIA, but are assessed under the existing permitting regime.

14.6 Significant Impacts of Decommissioning Options

Appendix 1 documents the assessment of all environmental categories for the decommissioning options. Sections 14.6.1 to 14.6.2.5 provide a summary of the Appendix 1 impact assessment matrices, discussing only the most significant impacts (those with either ‘small-moderate negative’ impacts or worse, or ‘small-moderate positive’ impacts or better).

14.6.1 Group 1 Pipelines

Group 1 pipelines (see Section 14.5) are either left in existing trenches (with exposed ends cut and recovered) or completely removed by cut and lift or reeling. Table 14-7 shows the Group 1 pipelines materials inventory and the proportion of material recovered.

Table 14-7: Group 1 Pipelines Material Inventory and Recovery

Material	Inventory (tonnes)	Recovered (tonnes)	% Recovered
Steel	2,071	649	31
Concrete (including mattresses)	1,106	429	39
Protective coatings and plastics	287	139	48
Total	3,464	1,217	35%

Given the relatively small materials inventory and quantities recovered, there are no environmental impacts from decommissioning Group 1 pipelines with either ‘small-moderate negative’ impacts or worse, or ‘small-moderate positive’ impacts or better, as can be seen in Figure 14-2 to Figure 14-4. Impacts are considered small or insignificant for all categories.

Figure 14-2: Pipelines Subgroup 1A

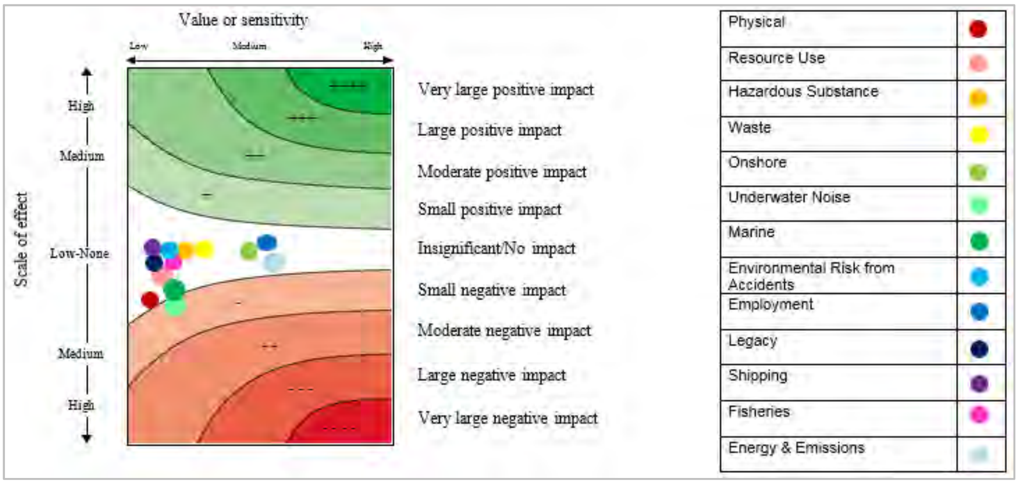


Figure 14-3: Pipelines Subgroup 1B

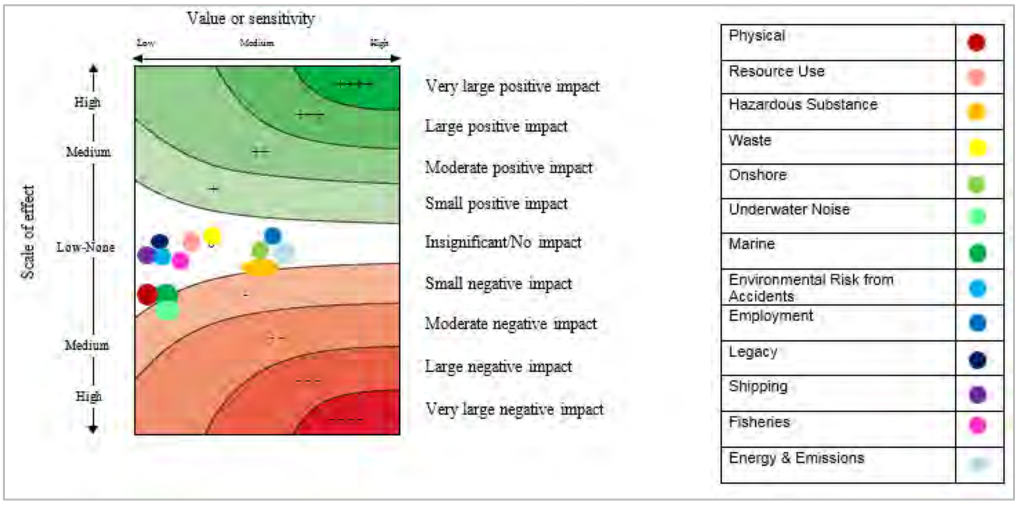
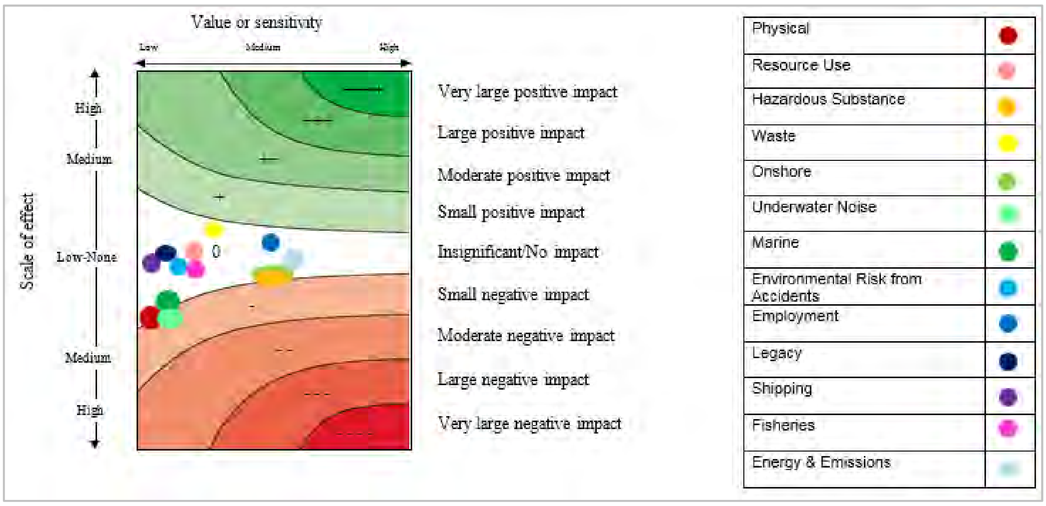


Figure 14-4: Pipelines Subgroup 1C



- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact)
- The Energy and Emissions impact has been sourced from: DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3 November 2016.

14.6.2 Group 2 Pipelines

Table 14-9 summarises the impact assessment for the Group 2 pipelines described in Section 14.5 (it was not practical to produce a cumulative matrix for pipelines because there are many pipelines and many decommissioning options). The more significant impacts identified are in the following environmental categories: onshore, resource use, waste management, marine and legacy, and these are discussed further in Sections 14.6.2.1 to 14.6.2.5. Impacts are considered small or insignificant for all other categories.

The impact key in Table 14-8 is used to characterise the level of environmental impact. The colours of the key have been transposed from the impact matrices in Appendix 1.

Table 14-8: Impact Key

Impact Key	
(dark green)	Moderate Positive
(green)	Small - Moderate Positive
(yellow-green)	Small Positive
(pale green)	Insignificant - Small Positive
(white)	Insignificant, No Impact
(pale orange)	Insignificant - Small Negative
(light orange)	Small Negative
(orange)	Small - Moderate Negative
(dark orange)	Moderate Negative

Table 14-9: Group 2 Pipelines Summary of Impact Assessment

Sub Group	Option	Onshore	Resource Use	Hazardous Substances	Waste	Physical	Marine	Underwater Noise	Environmental Risk	Employment	Legacy	Fisheries	Shipping
2A	2	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Insig - no impact	Insig - no impact	Small - mod negative	Insig - no impact	Insig - no impact
	3	Insig - no impact	Insig - no impact	Insig - no impact	Insignificant	Insig - no impact	Insig - no impact	Small negative	Insig - no impact	Insig - no impact	Small - mod negative	Insig - no impact	Insig - no impact
	4	Insig - no impact	Insig - no impact	Insig - no impact	Insignificant	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact
	5	Insig - no impact	Small - mod neg	Insig - no impact	Insignificant	Insig - no impact	Small - mod negative	Small negative	Insig - no impact	Insig - no impact	Small - mod negative	Insig - no impact	Insig - no impact
	6	insig - Small negative	Insig - no impact	Insig - small neg	Insig - small positive	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Insig - small neg	Insig - small neg
	7	insig - Small negative	Insig - no impact	Insig - small neg	Insig - small positive	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Insig - small neg	Insig - small neg
2B	1	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Moderate negative	Insig - no impact	Insig - no impact
	4	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insignif - no impact	Insig - small neg	Insig - small neg
	5	Insig - no impact	Moderate negative	Insig - no impact	Insig - no impact	Insig - no impact	Moderate negative	Small negative	Insig - no impact	Insig - no impact	Moderate negative	Insig - small neg	Insig - small neg
	6	Small negative	Insig - no impact	Small negative	Small positive	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Small negative
	7	Small negative	Insig - no impact	Small negative	Small positive	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Small negative
2C	1	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Moderate negative	Insig - no impact	Insig - no impact
	6	Small - mod neg	Insig - no impact	Small negative	Small - mod positive	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Small negative
	7	Small - mod neg	Insig - no impact	Small negative	Small - mod positive	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Small negative
	8	Insig - no impact	Small - mod neg	Insig - no impact	Insig - no impact	Small negative	Moderate negative	Small negative	Insig - no impact	Insig - no impact	Small - mod neg	Insig - small neg	Insig - small neg
	9	Insig - no impact	Moderate negative	Insig - no impact	Insig - no impact	Insig - no impact	Moderate negative	Small negative	Insig - no impact	Insig - no impact	Moderate negative	Insig - small neg	Insig - small neg
2D	2	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Insig - no impact	Insig - no impact	Insig - small neg	Insig - no impact	Insig - no impact
	3	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Insig - no impact	Insig - no impact	Insig - small neg	Insig - no impact	Insig - no impact
	5	Insig - no impact	Insig - small neg	Insig - no impact	Insig - no impact	Insig - no impact	Insig - small neg	Small negative	Insig - no impact	Insig - no impact	Insig - small neg	Insig - no impact	Insig - no impact
	6	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - small neg	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact
2E	1	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Insig - no impact	Insig - no impact
	4	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact
	5	Insig - no impact	Small - mod neg	Insig - no impact	Insig - no impact	Insig - no impact	Small - mod neg	Small negative	Insig - no impact	Insig - no impact	Small - mod neg	Insig - no impact	Insig - no impact
	6	Insig - no impact	Insig - no impact	Insig - small neg	Insig - no impact	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact
	7	Insig - no impact	Insig - no impact	Insig - small neg	Insig - no impact	Small negative	Small negative	Small negative	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact	Insig - no impact

14.6.2.1 Onshore Impacts

The onshore dismantling location for pipelines has not yet been selected. Recovered pipelines and materials will be taken onshore to licensed waste management sites for dismantling and recycling. The assessment below is based on the potential impacts in terms of a 'generic' processing site or facility.

Table 14-10 presents the maximum and minimum masses of material to be recovered from Group 2 pipelines under the different options. It can be seen that the mass of material recovered varies widely depending on the options selected and may range from 88% of the entire inventory (maximum recovery options), through to almost no recovery (minimum recovery options).

Table 14-10: Maximum and Minimum Material Recovery for Group 2 Pipelines

Subgroup	Inventory (tonnes, mainly steel and concrete)	Maximum Recovery		Minimum Recovery	
		Recovered (tonnes)	% Recovered	Recovered (tonnes)	% Recovered
2A	2,735	2,638	96	275	1
2B	16,065	15,735	98	0	0
2C	25,752	20,553	80	0	0
2D	151	151	100	8	5
2E	2,222	2,222	100	0	0
Total	46,925	41,299	8	283	0.6

Given the total mass of materials recovered, the worst case onshore impacts of processing materials from Group 2 pipelines are estimated to be **'small-moderate negative'** as a result of the associated noise, dust and traffic impacts related to the onshore management of these volumes of material, if the maximum mass is recovered. If the minimum mass is recovered, then the decommissioning of Group 2 pipelines will have an 'insignificant' impact. It is assumed that the onshore sites will operate in accordance with license conditions and will take appropriate steps to limit the exposure of site personnel.

14.6.2.2 Resource Use

Resources used for pipeline decommissioning include rock dump. Although the rock used is an unlimited resource, the quarry industry is a demanding business with associated impacts on the environment. Hence, using this resource in a project contributes indirectly to the overall impact from exploiting the resource and is included in this impact assessment on a generic basis.

Rock dumping does not apply to all options; the options which would use the largest volumes are:

- Subgroup 2A – Option 5 would result in the largest impact as approximately 109,000 tonnes of rock would be required; this is estimated to have a **'small-moderate negative'** impact.
- Subgroup 2B – Option 5 would result in the largest impact as approximately 430,000 tonnes of rock would be required; this is estimated to have a **'moderate negative'** impact.

- Subgroup 2C – Option 9 would result in the largest impact as approximately 489,000 tonnes of rock would be required; this is estimated to have a **'moderate negative'** impact.
- Subgroup 2E – Option 5 would result in the largest impact as approximately 78,000 tonnes of rock would be required; this is estimated to have a **'small-moderate negative**' impact.

Subgroup 2D options would only require negligible volumes of rock dump.

14.6.2.3 Waste Management

Some of the options for decommissioning of Group 2 pipelines would result in steel, concrete, marine growth, and other pipeline coating materials being recovered. The recovered pipelines and materials would be taken to licensed sites for dismantling and recycling. The location of these sites is currently unknown.

Table 14-10 presents the material inventory for Group 2 pipelines, and the masses recovered. This includes the 'maximum recovery' (the sum of each pipeline option recovering the most material) and the 'minimum recovery' (the sum of each pipeline option recovering the least material). This includes the recovery of concrete mattresses by speed-loader and lifting basket.

The mass of material recovered varies widely depending on the options selected and may range from almost the entire inventory (maximum recovery options), through to almost no recovery (minimum recovery options).

It is anticipated that high proportions of recovered pipeline steel would be recycled. Plastic pipes, umbilicals, and power cables would be broken down into their constituent materials by mechanical processes; with plastics and metals being recycled where possible. It may not be possible or cost-effective to disassemble complex pipes, pipes-in-pipes and umbilicals. Where materials cannot be reused or recycled, as a last resort they would be disposed of through a licensed landfill site. During the decommissioning of other North Sea facilities, 82 % was reuse/recycled [67].

If the minimum mass is recovered, then the decommissioning of Group 2 pipelines is estimated to have an 'insignificant' impact in terms of waste management. If the maximum mass is recovered the decommissioning of Group 2 pipelines is estimated to have a **'small-moderate positive'** impact due to the value of recovered steel.

14.6.2.4 Marine

Marine impacts (e.g. damage to benthic fauna) from decommissioning Group 2 pipelines could result from disturbance of the seabed sediments, seabed habitat and drill cuttings and from rock dumping. Noise generated by vessels and decommissioning operations can also impact the marine environment. The actual impacts would depend on the decommissioning options selected, although no habitats of conservation interest would be affected by any of the options at Brent Field.

From some decommissioning options (e.g. trenching), the disturbance of the surface sediment and associated benthic communities would be temporary, and seabed communities would adapt to the change in the environment and recover without any permanent adverse effects. Any disturbance would have a temporary impact through sediment disturbance, suspension and re-deposition. It may be necessary to disturb some of the drill cuttings piles as part of decommissioning operations, and this would impact the local seabed. The options that involve

rock dumping would result in benthic burial and smothering, a long term impact, the significance of which depends on the options selected and area involved.

The impact of the pipeline subgroups that would present small-moderate impacts or greater are summarised below. They mainly relate to rock dumping, which would result in benthic burial and smothering within the rock dump area.

- Subgroup 2A: Rock dumping in Option 5 (rock dump whole length) would cover the entire 6.4 km of pipelines in subgroup 2A with approximately 109,000 t of rock dump, causing a **'small-moderate negative'** impact.
- Subgroup 2B: Rock dumping in Option 5 (rock dump whole length) would cover the entire 25 km of pipelines in subgroup 2B with approximately 430,000 t of rock dump, causing a **'moderate negative'** impact.
- Subgroup 2C: The rock dump in Option 9 (rock dump all shallow trenched sections) involves approximately 490,000 t of rock dump, causing a **'moderate negative'** impact. The combination of rock dump (approximately 147,000 t) and trenching in Option 8 is also considered to cause a **'moderate negative'** impact to the marine environment.
- Subgroup 2E: The rock dump in Option 5 (rock dump whole length) would cover the entire 4.6 km of pipelines in subgroup 2E with approximately 78,000 t of rock dump, causing a **'small-moderate negative**' impact.

14.6.2.5 Legacy

The legacy impacts of pipelines consider the potential long-term impact to the marine environment and long term commercial impacts to fisheries, and do not attempt to address any aspects related to safety. The legacy impact of Group 2 pipelines would depend on the decommissioning options selected.

The main legacy impact to the marine environment would be from the long-term change in habitat of the seabed area as a result of rock dumping. This is generally considered to have a negative impact in terms of conservation (although it could be argued that there are some positives in that new species would populate the rock dump, and this may increase the diversity of species present). The subgroups and options that would have the highest legacy impacts due to rock dumping are presented in Table 14-11; impacts could reach **'moderate negative'** depending on the decommissioning option chosen.

Table 14-11: Main legacy impacts from rock dumping

Subgroup	Option	Rock dump (t)	Impact
2A	5	108,800	Small-moderate negative
2B	5	430,300	Moderate negative
2C	9	489,300	Moderate negative
2E	5	78,200	Small-moderate negative

Also, the pipelines will degrade over time. Anti-corrosion pipeline coatings act as a barrier to decay, but over long periods of time the pipelines left *in situ* would deteriorate and eventually breakup. Analysis by Atkins [111] indicates that the process of deterioration of rigid steel pipelines may take from 220 to 600 years. The deterioration of flexible lines may take significantly longer due to use of plastics which degrade very slowly in the marine environment [112]. Since the pipes will be cleaned and flushed prior to decommissioning, no contaminants would be released into the marine environment after pipe breakdown, apart from any potential residual contaminants, which could have negligible local effect.

In relation to *fishing*, the purpose of the protective rock dump is both to protect the pipeline and to ensure that fishing gear would not be impeded if it travels across the buried pipelines and umbilicals or any material that remains when the pipelines and umbilicals eventually corrode and collapse. However, rock dumping can present long-term problems to industrial trawlers because they drag a small meshed trawl net along the seabed (other types of trawl nets stay above the seabed so are not impacted). Sharp rocks can potentially damage the industrial trawl net [113]. Furthermore, if rocks are collected by the trawl net they can damage the catch and ultimately damage pumping equipment when the catch is pumped into the processing line [114]. However, industrial trawling is only relevant for shrimp, sand eel and Norway pout, and thus not very relevant in the Brent area where more than 90% of the fish caught are mackerel, cod and haddock. So the long-term impact to industrial trawlers (demersal) from rock dump is estimated to be small, particularly as final overtrawling of this area would be conducted as part of the main overtrawling program following completion of decommissioning operations.

There are also a number of decommissioning options (Options 1, 2 and 3) which would leave the pipes exposed (including numerous pipe spans), which can also result in commercial impact on fisheries if the associated safety risks inhibit fisheries activities. The decommissioning options that have the largest such legacy risks (ranging from **‘small-moderate negative’** to **‘moderate negative’**) include subgroup 2A Options 2 and 3, subgroup 2B Option 1 and subgroup 2C Option 1. Since these pipelines will be decommissioned *in situ*, they will be subject to a suitable monitoring programme as agreed with BEIS, to account for changes in pipeline stability and any increased risk to sea users, but residual risks remain.

14.7 Significant Impacts of Proposed Programme of Work

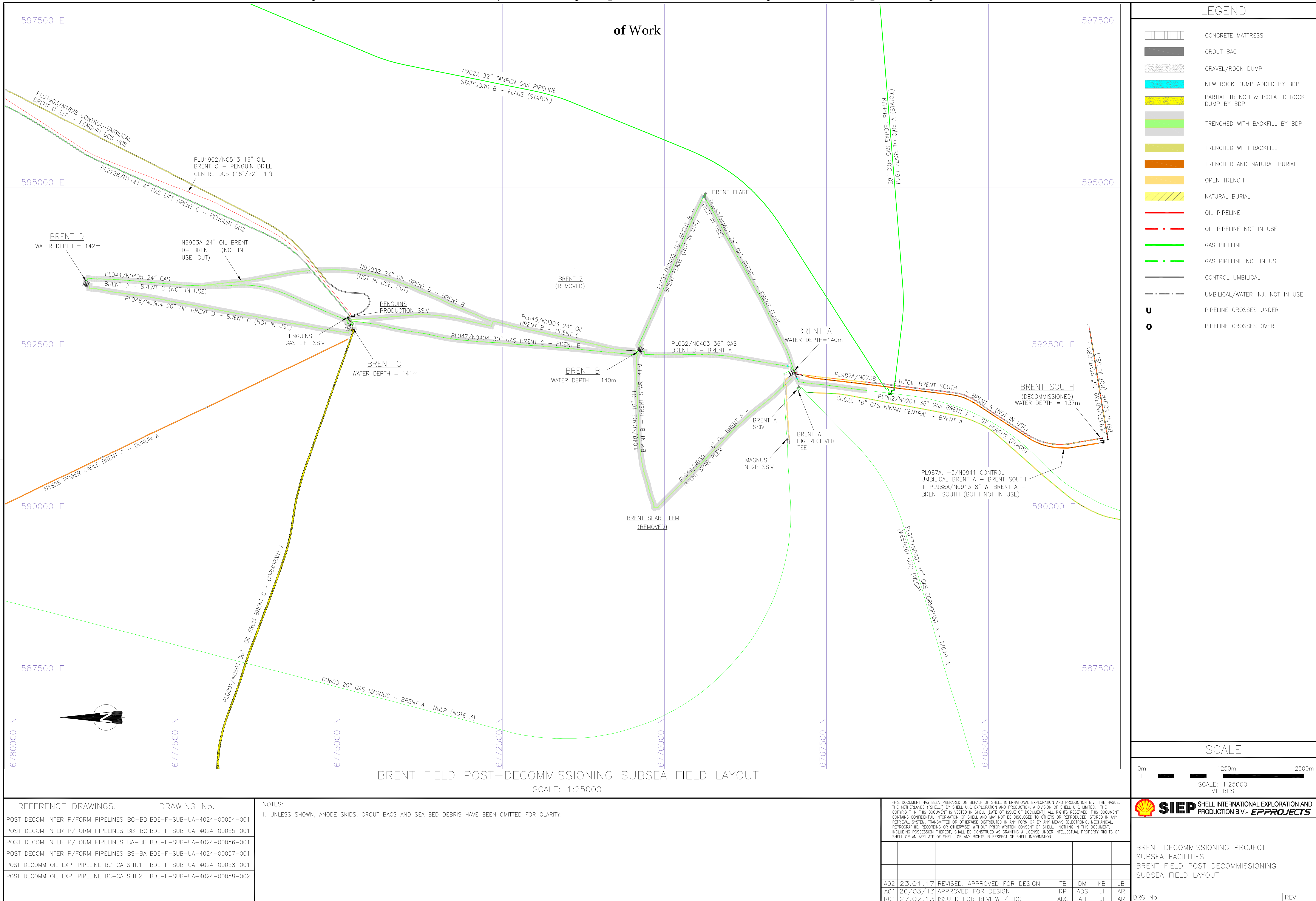
14.7.1 Proposed programme of work

Shell's proposed programme of work is as shown in Table 14-12. Out of a total weight of 50,300 t of pipelines materials and concrete mattresses, 2,910 t of material will be removed and 47,392 t will be left in the field. All of the pipelines that will be left in the field will be (or are already) trenched or under rock dump. Shell will remove the concrete mattresses that are associated with the pipelines (and subsea structures) that will be removed/trenched where appropriate; this accounts for about 61% of the 1,760 t of concrete mattresses.

Table 14-12: Proposed Programme of Work

Group 1 Pipelines			Group 2 Pipelines		
BEIS Pipe No.	**Shell Pipe No.**	**Proposed Option**	**BEIS Pipe No.**	**Shell Pipe No**	**Proposed Option**
PL1955	N0310	Remove by reverse reeling **(Option 7)**	PL002	N0201	Trench and backfill whole length (**Option 4**)
PL1955	N0311	Remove by reverse reeling **(Option 7)**	PL049	N0301	Trench and backfill whole length (**Option 4**)
PL051	N0402a	Remove by cut and lift **(Option 6)**	PL048	N0302	Trench and backfill whole length (**Option 4**)
PL987A	N0738	Leave in trench and rock dump ends **(Option 3)**	PL045	N0303	Trench and backfill whole length (**Option 4**)
PL987A	N0739	Leave in trench and rock dump ends **(Option 3)**	PL046	N0304	Trench and backfill whole length (**Option 4**)
None	N0830	Remove by reverse reeling **(Option 7)**	PL050	N0401	Trench and backfill whole length (**Option 4**)
PL987A 1-7	N0841	Leave in trench and rock dump ends **(Option 3)**	PL051	N0402	Trench and backfill whole length (**Option 4**)
PL988A	N0913	Leave in trench and rock dump ends **(Option 3)**	PL052	N0403	Trench and backfill whole length (**Option 4**)
PL050	N0952	Leave *in situ* under rock dump with no further remediation **(Option 1)**	PL047	N0404	Trench and backfill whole length (**Option 4**)
None	N1844	Remove by reverse reeling **(Option 7)**	PL044	N0405	Trench and backfill whole length (**Option 4**)
None	N2801	Remove by reverse reeling **(Option 7)**	PL001	N0501	Partial trench and backfill with isolated rock dump (**Option 8**)
None	N9900	Remove by cut and lift **(Option 6)**	PL017	N0601	Recover whole length by cut and lift (**Option 6**)
None	N9901	Remove by cut and lift **(Option 6)**	None	N9903A	Trench and backfill whole length (**Option 4**)
None	N9902	Remove by cut and lift **(Option 6)**	None	N9903B	Trench and backfill whole length (**Option 4**)

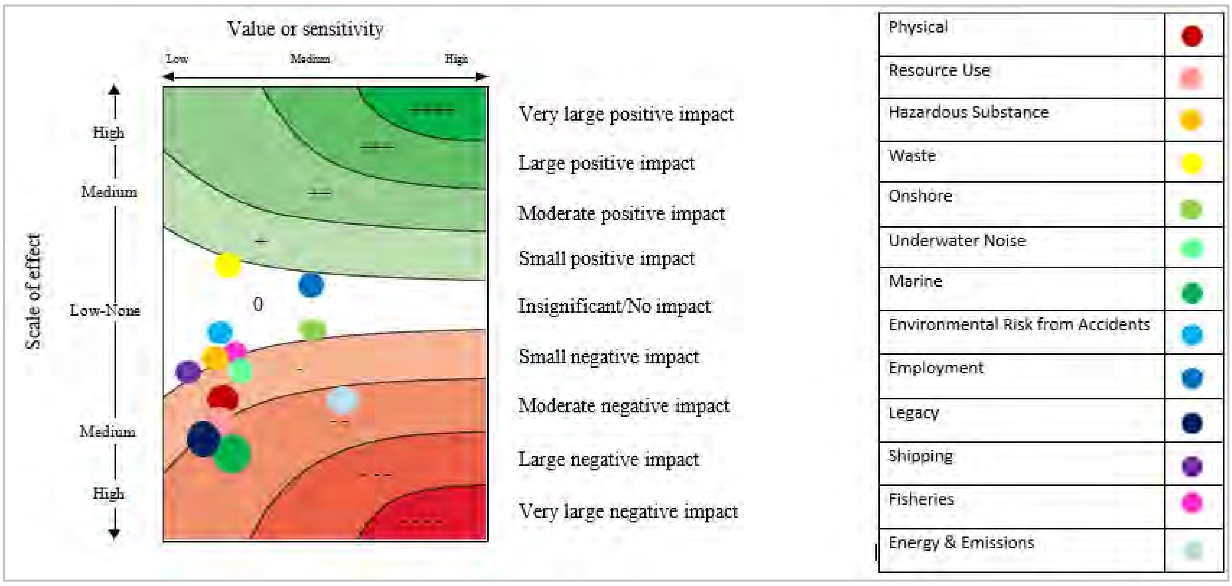
Figure 14-5: Brent Field Sub-sea layout following completion of Decommissioning based on the proposed Programme of Work



14.7.2 Significant Impacts of Proposed Programme of Work

Appendix 1 documents the assessment of all environmental categories to decommission the Brent Field pipelines. The following sub-section discusses only the most significant impacts that have been identified (those with either 'small-moderate negative' impacts or worse, or 'small-moderate positive' impacts or better). As shown in Figure 14-6, the most significant impact for the proposed decommissioning programme for pipelines are in the 'marine', 'legacy', 'energy and emissions' and 'resource use' categories. Impacts are considered small or insignificant for all other categories.

Figure 14-6: Impact of Pipelines Proposed Decommissioning Programme (Groups 1 & 2)



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact)
- The Energy and Emissions impact has been sourced from: DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

14.7.2.1 Marine

Decommissioning the pipelines would result in marine impacts due to the disturbance of benthic fauna and habitats from operations such as cut and lift, reverse lay, trenching and rock dumping, and from disturbance due to noise generated by vessels and operations such as cutting.

Marine impacts that will result from the pipeline programme of works are generally small impacts for pipelines viewed in isolation (except for pipeline N0501) because:

- the total rock dump for the pipeline programme of works, excluding N0501, is only approximately 2,000 t, a small volume
- decommissioning cut and lift/reverse reeling operations would disturb the sediments and benthic communities along the pipeline length for a few metres on either side of the 13.9 km pipelines removed (6.75 km of pipelines from subgroup 1B, 6.8 km from subgroup 1C and 0.4 km from subgroup 2D). But the combined impact to the marine environment of operations would be small, as it is temporary and reversible, and because seabed

disturbance due to cut and lift/reverse reeling is much less than disturbance due to trench and backfill.

The main driver of marine impact is the decommissioning of the N0501 pipeline. N0501 is a long and large diameter pipeline (35.9 km, 30 inch diameter), is trenched to varying degrees along its route but is mostly exposed on the sea bed, and has a high frequency of spanning, including two FishSAFE spans (>10 m long, 0.8 m high). The decommissioning option selected (Option 8) would involve trenching and backfilling to achieve a depth of trench of 0.6 m below the mean seabed level, while remaining short isolated sections which cannot be trenched would be rock dumped to mitigate against snagging hazards.

The disturbance caused by trenching would temporarily affect the surface layers of the seabed and associated benthic communities along the length of the pipeline, to a distance of several metres on either side of the pipeline. Sediment would be released into suspension and re-deposited. Generally, seabed communities would adapt to the change in the environment and recover without any permanent adverse effects. The exception is when there is rock dumping (~147,000 t), as this would cause a permanent change in the seabed habitat and the type of species present (see 'legacy'). But rock dumping also has direct marine impacts during operations as it will damage/smother any existing benthic fauna along the footprint of the rock dump. It should be noted that the benthic community in the area is diverse and abundant and does not appear to contain any species of particular conservation concern.

Trenching of the other 16 smaller pipelines (cumulative length approximately 53 km) would add to the localized marine impacts from sediment disturbance. And it may be necessary to disturb some of the drill cuttings piles as part of these pipeline decommissioning operations, but such operations would be restricted to small areas and only result in localised impacts. Where a pipeline section is heavily covered in drill cuttings, agreement with BEIS may be sought to leave certain small pipeline lengths *in situ* in order to minimise disturbance of the drill cuttings. There will also be a small noise disturbance impact because decommissioning will involve marine operations for a period of time in the area [3].

Viewed together, the cumulative impact on the marine environment from the proposed programme of works to decommission the pipelines is considered to be **'moderate negative'**, primarily from the decommissioning of pipeline N0501 owing to the combination of rock dumping and trenching, in combination with the effects from trenching the other 16 smaller pipelines.

14.7.2.2 Legacy

Of the 28 pipelines (which have a combined length of approximately 103 km):

- 10 will be removed by cut and lift or reverse reel (combined length removed is approximately 13.9 km)
- 1 will be left *in situ* under rock dump (0.03 km)
- 17 will be (or currently are) trenched, some with isolated rock dump (approximately 89 km).

Decommissioned pipelines can present long term legacy impacts to the marine environment and long term commercial impacts to fisheries, as discussed below.

- The main legacy impact to the *marine* environment would be from rock dumping approximately 149,000 t (~99% of which is for pipeline N0501). Rock dumping is

generally considered to have a negative impact due to the long-term change in habitat of the seabed area as a result (although it could be argued that there are some positives in that new species would populate the rock dump, and this may increase the diversity of species present).

- Also, the pipelines that are left behind will degrade over time. Anti-corrosion pipeline coatings act as a barrier to decay, but over long periods of time the pipelines left *in situ* would deteriorate and eventually breakup. Analysis by Atkins [111] indicates that the process of deterioration of rigid steel pipelines may take from 220 to 600 years. The deterioration of flexible lines may take significantly longer due to use of plastics which degrade very slowly in the marine environment [115]. Since the pipes will be cleaned and flushed prior to decommissioning, no contaminants would be released into the marine environment after pipe breakdown, apart from any potential residual contaminants, which would have negligible local effect.
- In relation to *fishing*, rock dumping can present long-term problems to industrial trawlers because they drag a small meshed trawl net along the seabed (other types of trawl nets stay above the seabed so are not impacted). However, the long-term impact to industrial trawlers (demersal) from rock dump is estimated to be small for the reasons described in section 14.6.2.5, particularly as final overtrawling of this area would be conducted as part of the main overtrawling program following completion of decommissioning operations.
- All current pipeline spans will disappear, as all pipelines will be trenched, rock dumped or removed. After decommissioning there will be no exposed pipes on the seabed, thus there will be no commercial legacy impact on fisheries, provided that pipes remain trenched over time.

In summary, a **'small-moderate negative'** impact is allocated, primarily as a consequence of the rock dumping for pipeline N0501, and the associated change to the marine habitat. Although the benthic community in the area is diverse and abundant and does not appear to contain any species of particular conservation concern, the rock dump area involved is significant.

14.7.2.3 Resource Use

The decommissioning of pipelines will involve rock dumping, with few other resources used. Fuel consumption from onshore and offshore decommissioning activities is captured within the 'Energy and Emissions' category and not within 'Resource Use'.

Approximately 149,000 t of rock dump will be necessary for the pipeline programme of works, the vast majority (an estimated 146,800 t) being required for one pipeline, N0501.

Although the rock used is an unlimited resource, the quarry industry is a demanding business with associated impacts on the environment. Hence, using this resource in a project contributes indirectly to the overall impact from exploiting the resource and is included in this impact assessment on a generic basis. A **'small-moderate negative'** impact is allocated.

14.7.2.4 Energy and Emissions

Energy will be required to decommission the large number of pipelines in the Brent Field, and DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimates the overall energy use. Comparing this against the energy impact categories in Table 5-7, the impact from energy use

is considered to be **'moderate negative'**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

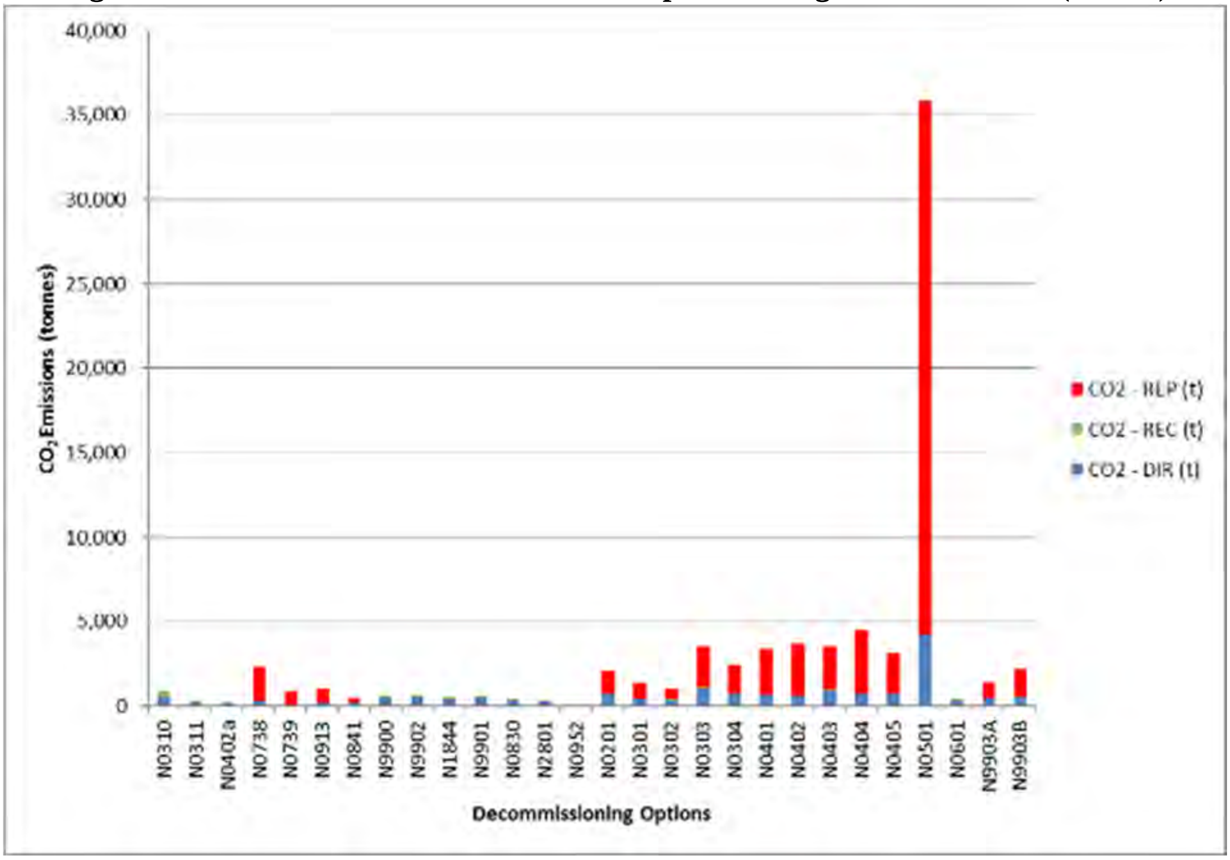
Table 14-13 summarises the energy and emissions for Shell's proposed programme of works for the pipelines, having applied the industry guidelines for such calculations [15]. Nearly half of the CO_2 emissions are derived from one pipeline, N0501, as shown in Figure 14-7, because line N0501 is the largest and longest pipeline (30 inch diameter, 36 km long).

Table 14-13: Energy and Emissions from Pipelines Programme of Work

Pipeline	Method	Energy (GJ)	Total CO_2 (tonnes)	Emissions to Atmosphere (tonnes)				
				CO_2 - DIR	CO_2 - REC	CO_2 - REP	NO_x	SO_x
Group 1								
N0310	Reverse reel	12,558	916	522	394	-	12	10
N0311	Reverse reel	3,247	235	201	34	-	4	3
N0402a	Cut & lift	2,924	166	135	31	-	3	2
N0738	Leave in trench	31,369	2,266	263	0	2,003	7	4
N0739	Leave in trench	11,811	845	126	-	719	3	2
N0913	Leave in trench	13,217	1,122	285	0	838	7	5
N0841	Leave in trench	12,493	444	192	0	252	4	3
N9900	Cut & lift	7,875	613	532	81	-	11	9
N9902	Cut & lift	7,875	645	564	81	-	12	10
N1844	Reverse reel	5,652	515	391	123	-	8	7
N9901	Cut & lift	7,707	624	554	71	0	12	9
N0830	Reverse reel	4,942	378	361	17	-	7	6
N2801	Reverse reel	3,755	280	276	4	-	6	5
N0952	Leave in rock dump	460	34	34	-	-	1	1
Group 2								
N0201	Option 4	25,963	2,073	693	38	1,342	16	6
N0301	Option 4	17,883	1,355	432	6	917	10	3
N0302	Option 4	14,042	1,052	373	7	672	8	3
N0303	Option 4	46,361	3,571	1,042	27	2,502	24	8
N0304	Option 4	32,109	2,445	737	9	1,699	17	6
N0401	Option 4	43,366	3,405	641	8	2,756	16	6
N0402	Option 4	45,256	3,645	590	11	3,045	15	6
N0403	Option 4	43,078	3,577	943	23	2,611	22	8
N0404	Option 4	56,584	4,502	713	19	3,770	19	7
N0405	Option 4	39,767	3,083	723	14	2,346	17	6
N0501	Option 8	461,192	35,837	4,163	23	31,651	102	44
N0601	Option 6	5,481	389	368	21	0	8	2
N9903A	Option 4	18,471	1,429	447	0	982	10	3
N9903B	Option 4	28,073	2,185	509	0	1,676	12	4
TOTAL		**1,003,511**	**77,631**	**16,810**	**1,042**	**59,781**	**393**	**188**

Option 4	Trench and backfill whole pipeline
Option 6	Remove by cut and lift
Option 8	Partial trench and backfill with isolated rock dump

Figure 14-7: Source of CO_2 Emissions for Pipelines Programme of Work (tonnes)



14.7.2.4.1 Energy consumption and CO_2 emissions

Energy is required offshore (e.g. marine vessels) and onshore for material recycling. Additionally an energy penalty is applied for replacement of pipelines that are left behind (see Section 5.2.3), and most emissions come from this because the majority of the pipelines will be left *in situ*. The material inventory and vessel durations used within the energy and emissions calculations are included in DNV GL's *Energy Use and Gaseous Emissions Report* [2].

In total, the energy demand for decommissioning the pipelines is estimated to be approximately 1 million GJ, based on the contributions of different operations. The total CO_2 emissions ($CO_{2\ TOT}$) from these operations are estimated to be approximately 77,600 tonnes, of which the largest contribution (77%) is a penalty.

14.7.2.4.2 Emissions of NO_x and SO_2 to atmosphere

The majority of the gaseous emissions generated during the decommissioning of the pipelines are likely to be quickly dispersed as they will mainly be released offshore and over the duration of the decommissioning works. As such, it is anticipated that the concentrations of NO_x and SO_2 will be relatively low at any given location and at any given time. Onshore emissions (mainly from recycling the steel) will be within the permit conditions of recycling facilities. As such emissions of NO_x and SO_2 are considered to be smaller contributors to the environmental impact than CO_2 emissions. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

14.7.2.4.3 Summary

The overall environmental impact from Energy and Emissions as a result of decommissioning the pipelines is estimated to be 'moderate negative' owing primarily to the penalty applied for leaving many of the pipelines behind. Emissions of NO_x and SO_2 are considered a small contributor to this impact. CO_2 emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the works. To put into another context, the total CO_2 emissions from decommissioning the pipelines is only approximately 3% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [116].

14.8 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that mitigation and management measures are in place. Table 14-14 details these measures for the proposed programme of works to decommission the pipelines, and highlights the residual impacts described in Appendix 1.

Table 14-14: Summary of Mitigation and Management Measures for Proposed Programme of Work

Environmental Category	Mitigation Measures	Residual Impact
Onshore Impacts	Only applicable for decommissioning options that involve recovery of pipelines and result in onshore operations: • Only approximately 3,000 t of steel, concrete and plastics will be recovered to shore, a small amount. The onshore site is currently not known, but Shell will ensure it is responsibly managed, is licensed to perform such waste management operations, and that operations will be carried out within the licence conditions. • Shell will audit onshore operations to ensure regulatory limits are met	Insignificant
Resource Use	There are few resources used apart from ~149,000 t of rock for dumping, the vast majority for N0501. Shell shall minimise the quantities of rock used by trenching where possible.	Small-moderate negative
Hazardous Substances	• Onshore site selected will be licensed and experienced in dealing with hazardous wastes • There are few hazardous substances used or wastes produced. Hazardous substances and wastes will be managed in accordance with all legislative requirements and good practice (e.g. OGP Guidelines for the management of NORM in the oil and gas industry [61]), both offshore and onshore. • There remains some uncertainty about the presence of NORM and mercury within pipelines. Shell will conduct further studies to better understand the NORM and mercury content within pipelines, and will develop and implement a specific management plan to manage risks from the materials brought to shore. • Shell will monitor the UK NORM disposal routes to ensure they are capable of handling NORM waste arising. • If mercury is present within pipelines, the onshore site will periodically sample dust onsite and analyse for mercury, and take appropriate actions (e.g. use of dust collecting vehicles) if dust is found to be contaminated.	|Insignificant-small negative
Waste	The volume of waste generated from the proposed programme of work for pipelines is ~3,000 t, which is relatively small. Regardless, Shell will audit waste management to ensure duty of care and all other waste management requirements are satisfied. Recovered steel will be recycled, as will concrete where practicable.	Insignificant-small positive
Physical	Trenched pipelines will be backfilled, and Shell shall minimise the quantities of rock used for N0501, by trenching where possible	Small negative
Marine (includes underwater noise)	• Pipelines will be subject to a DPV programme prior to the start of decommissioning to ensure that no pockets of hydrocarbon liquid or gas remain • Shell will obtain all necessary permits from the regulator before commencing operations • Shell will encourage use of low disturbance-type tools to minimise the generation of turbulence. For example, low disturbance trenching methods will be used where practical (e.g. mechanical ploughing rather than water-jet based systems), particularly in areas contaminated by drill cuttings. • There will be only one underwater cutting operation taking place at any one time • Shell will minimise the quantities of rock dump by trenching where possible. • Shell will conduct operations, where practical, in periods with low abundance of vulnerable resources (e.g. fish eggs or larvae) in the water column. • Pipelines decommissioned *in situ* will be subject to a monitoring programme agreed with BEIS and in consultation with other Government Departments. A post-decommissioning survey will be conducted when all offshore work has been completed, and all debris is removed. Shell propose to conduct a second post-decommissioning survey after a period of five years. Structural surveys will be conducted for pipelines left *in situ*, using a risk-based approach to target monitoring, and appropriate actions taken.	Moderate negative
Environmental Risk from Accidents	• Pipelines will be subject to a DPV programme prior to the start of decommissioning to ensure that no pockets of hydrocarbon liquid or gas remain; this will minimize the risk of pollution from a potential environmental spill. • Ship SOPEP, approved by the MCA, will be in place, and will be reviewed by Shell to ensure that the response strategy and control mechanisms are robust. • The UK Coastguard and the Harbour Master will be notified of the decommissioning operations in order to provide advance warning to other ocean-going or harbour vessels operating in the area.	Insignificant
Employment	There is little employment generated	Insignificant
Legacy	• Survey to document that all (trenched or rock dumped) pipelines are covered to specification • Final overtrawl of decommissioned areas to demonstrate there is no problem for fishing vessels • Shell will monitor pipelines left *in situ* as described in Section 18 • Should any FishSAFE spans be identified, these will be submitted to FishSAFE as appropriate	Small-moderate negative
Fisheries	Shell will liaise with the fisheries agency to provide advance warning of vessel movements resulting from decommissioning activities	Insignificant-small negative
Shipping	The UK Coastguard and the Harbour Master will be notified of the decommissioning operations in order to provide advance warning to other ocean-going or harbour vessels operating in the area.	Insignificant-small negative
Energy & Emissions	• Vessel speeds will be managed to minimise fuel consumption. • To increase efficiency, combustion equipment on vessels will be maintained in accordance with manufacturers' recommendations. • Marine diesel will be used in line with MARPOL North Sea Special Area requirements [72], to reduce SO_x emissions.	Moderate negative

15. SUBSEA STRUCTURES AND DEBRIS

15.1 Introduction

This section describes the Brent Field subsea structures and subsea debris at the Brent Field, provides an inventory of materials, and explains how they will be decommissioned. The main anticipated environmental impacts of the decommissioning activities are discussed. The necessary management and mitigation measures to control the impacts are summarised, and measures are recommended to further reduce residual impacts where appropriate. The Technical Document for Decommissioning the Brent Field Pipelines has been used as the basis for Sections 15.2-15.5 [110].

15.2 Description of facilities

15.2.1 Subsea Structures

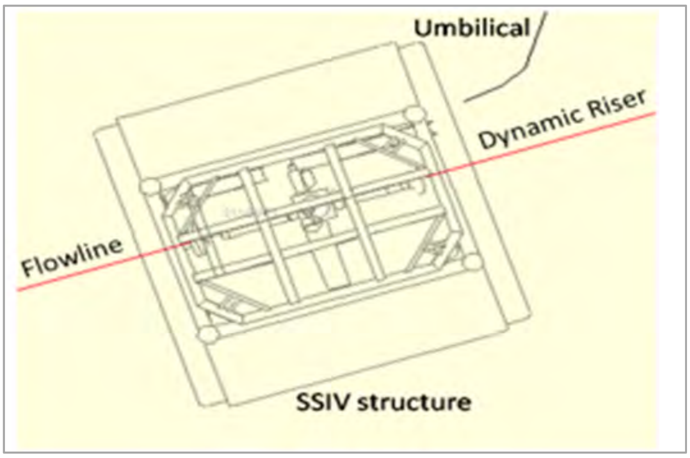
The subsea structures that will be decommissioned are described in Table 15-1 and shown in Figure 15-1 to Figure 15-4.

Table 15-1: Subsea Structures

Structure	Dimensions	Method of attachment to the seabed	Location
Brent B Subsea Intervention Valve (SSIV) (Figure 15-1)	7.5m x 7.5m x 3 m high	Gravity (held under its own weight plus additional ballast chests).	150 m WSW of Brent B
Brent Spar pipeline end manifold (PLEM) and associated protection structure (Figure 15-2)	10 m x 6 m x 2.4 m high	PLEM is secured by gravity (held under its own weight plus weight of additional grout ballast). Protection structure is secured by 2 piles driven into the seabed.	2.4 km W of Brent B and 2.9 km NW of Brent A
Brent A splitter box (Figure 15-3)	4 m x 4 m x 3 m high	Secured by 2 piles driven into the seabed.	50 m NW of Brent A
Valve Assembly Spool Piece (VASP) (Figure 15-4)	16.4 x 4.3 m x 3.4 m high	Gravity (held under its own weight).	1.2 km SW of Brent A

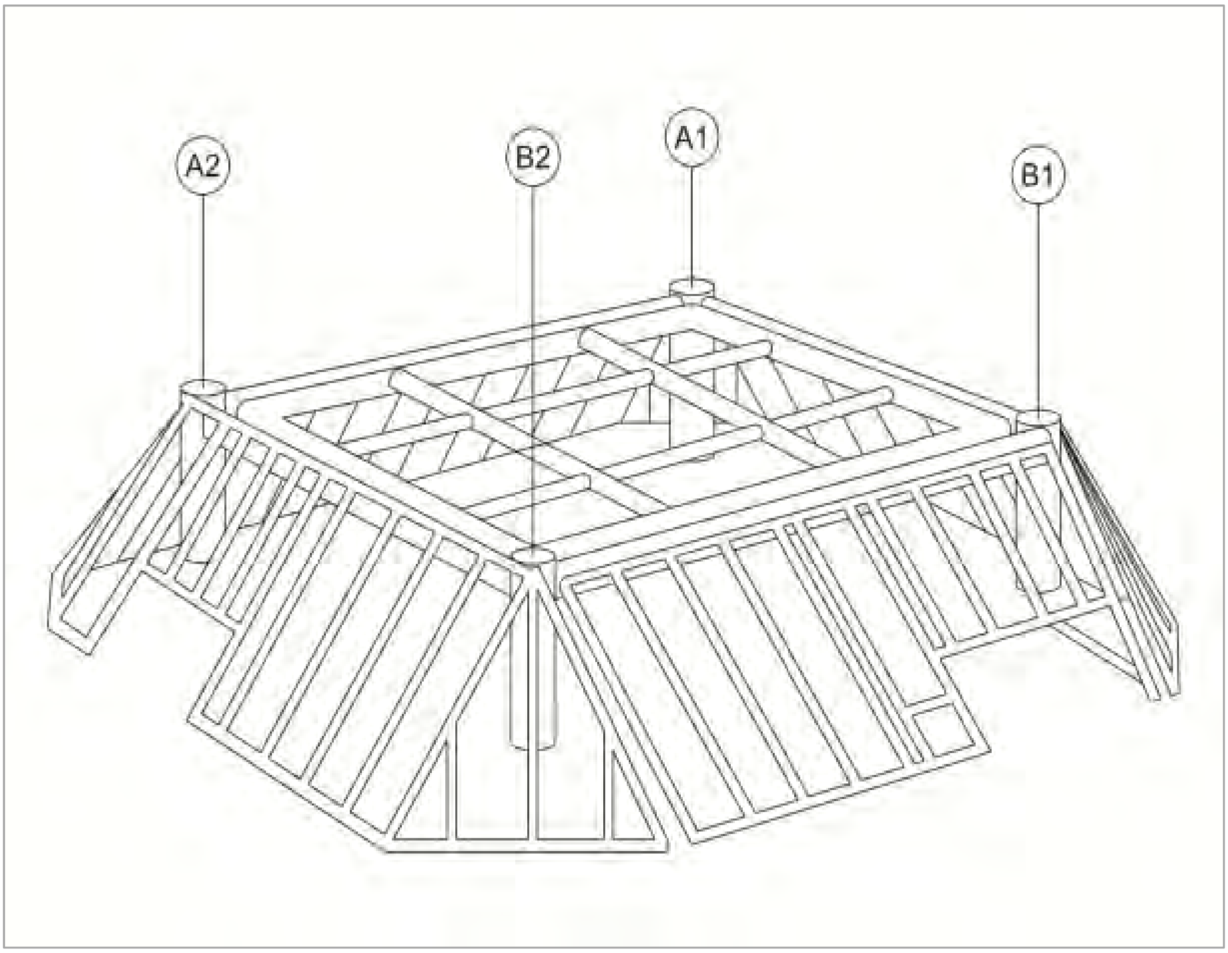
The Brent B SSIV (see Figure 15-1) is constructed of steel tube and sections with a mudmat foundation upon which ballast chests are placed to secure it to the seabed.

Figure 15-1: Brent B SSIV



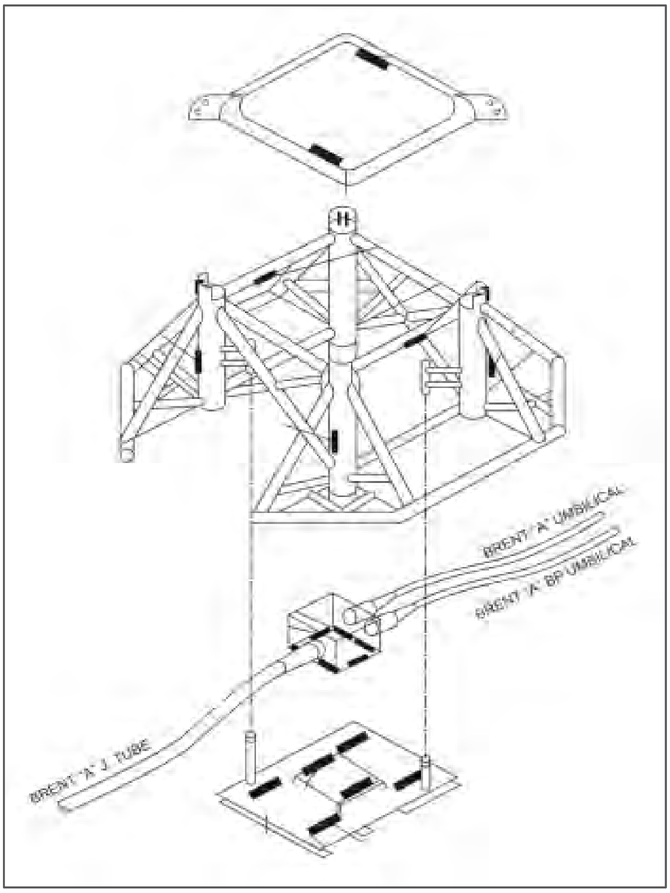
The Brent Spar PLEM (Figure 15-2) is constructed from steel section and plate. The PLEM protection cover consists of a central rectangular structure complete with roof panel which fits over the PLEM. It is piled (diameter not known) to the seabed through 2 vertical corner members. There are four sloping panels which will be removed to allow access to the central structure and piles.

Figure 15-2: Brent Spar PLEM



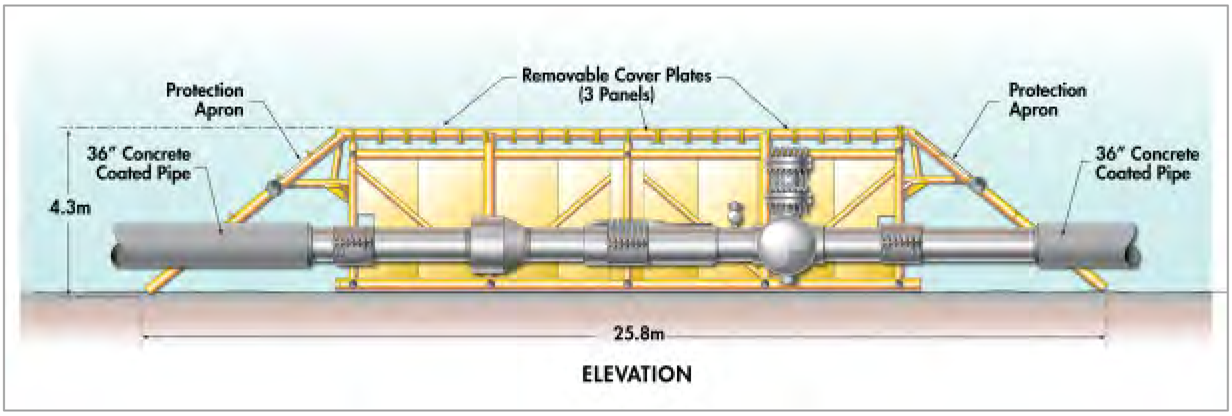
The Brent A splitter box (Figure 15-3) was installed to house and protect the Brent A SSIV umbilical splitter assembly and is comprised of three sections; the base, the main structure and the roof panel. The structure is piled into the seabed using two piles at either end, which are driven 3.6 m into the seabed.

Figure 15-3: Brent A Splitter Box



The VASP (Figure 15-4) forms part of the FLAGS pipeline (Far North Liquids and Associated Gas System). It consists of an inner rectangular structure constructed of steel tubes and sections.

Figure 15-4: VASP



The material weights and volumes have been estimated for the Brent subsea structures and are presented in Section 15.3.1.

15.2.2 Subsea Debris

Subsea debris consists of items such as scaffolding, grout bags, grating, ladders, wires and other dropped objects. Some of these items are lying on the seabed around the platforms and others are sitting on top of the GBS cell caissons at Brent B, C and D.

A seabed debris survey was conducted by Gardline Geosurvey [22] in 2006, with a survey area measuring 15 km x 4 km covering the Brent Field and the four platforms. The survey outputs for each platform are summarised in Table 15-2 (this survey also included a habitat survey as discussed in Section 6.3.1) and illustrated in Appendix 5.

Table 15-2: Debris Recorded around the Brent Platforms during the Seabed Survey [22]

Location	Survey Area	Seabed Sediments	Seabed Obstructions
Brent A	1.6 km x 1.6 km	Predominantly sand, occasional clay exposure, scattered cobbles/boulders (up to 0.4m high)	Occasional items of debris (some linear items up to 40 m long), numerous scaffolding poles up to a distance 188 m from Brent A, boulders and sediment clasts dropped during anchor pull-out, seabed scars and Brent A SSIV
Brent B	1.6 km x 1.6 km	Predominantly sand, occasional clay exposure, scattered cobbles/boulders (up to 0.4m high)	Debris, wires/chains, numerous scaffolding poles around platform up to a distance of 182 m, boulders and sediment clasts dropped during anchor pull-out, seabed scars and Brent B SSIV. Anchor block (3.6 m high with 200 m of chain) east of platform.
Brent C	1.6 km x 1.6 km	Predominantly sand, occasional clay exposure, scattered cobbles/boulders (up to 0.4m high)	Occasional objects up to 1.3 m high, cable, abandoned pipe, numerous scaffolding poles up to 204 m from platform centre, boulders and sediment clasts dropped during anchor pull-out, and seabed scars.
Brent D	1.6 km x 1.6 km	Predominantly sand, occasional clay exposure, scattered cobbles/boulders (up to 0.4m high)	Occasional objects less than 0.8 m high, wire/chain, numerous scaffolding poles up to 194 m from platform, two discarded mattresses, boulders and sediment clasts dropped during anchor pull-out, and seabed scars

The material weights and volumes have been estimated for the Brent subsea debris and are presented in Section 15.3.2.

A debris survey was also conducted to evaluate the debris sitting on top of the GBS cell caissons at Brent B, C and D [104]; the results are presented in Table 15-3.

Table 15-3: GBS Cell Top Debris Survey [104]

Location	Cells Top Observations
Brent B	• Significant quantity of scaffolding debris across 40% of the cell top areas, mainly appearing as individual scaffold poles of varying lengths. • Large items of debris, including two complete riser fender structures, several large sections of pipe, some clamps and larger scaffolding assemblies. • Accumulations of drill cuttings/mud within the valleys between the cell top domes. The majority of the debris is free from the drill cuttings.
Brent C	• A large, almost complete scaffolding tower on the cell top. • Drill cuttings are present. The cuttings to the south of the cell caisson have become compacted and may have solidified.
Brent D	• Mainly scaffolding/other small metal items. A skip and other containers may be present. • Most, but perhaps not all of the debris is clear of drill cuttings. Although there is a greater volume of cuttings on this cell top than Brent B, the cuttings have mostly accumulated in the cell valleys.

15.3 Inventory of Materials

15.3.1 Subsea structures

The material weights and volumes of the subsea structures have been estimated and are presented in Table 15-4.

Table 15-4: Subsea Structures Materials Inventory

Subsea Structure	Material	Weight in air (tonnes)
Brent B SSIV	Steel	99.1
	Grout*	2.0
Brent SPAR PLEM	Steel	63.8
	Grout*	188.5
Brent SPAR PLEM Protection Structure	Steel	100
Brent A Splitter Box	Steel	30
VASP	Steel	132.8

*Grout was pumped into the structures to act as ballast

Note that there is also a well guide frame at the abandoned Brent 7 well to recover, however as Shell have no record of the mass, it is excluded from the above table.

15.3.2 Subsea Debris

The material weights and volumes have been estimated for the Brent debris and grout bags on the seabed and are presented in Table 15-5. The ‘non-scaffolding’ category debris comprises mostly metallic items, such as grating, ladders, pipe and wires, and therefore it has been assumed that the material is primarily steel and will be recycled.

Table 15-5: Seabed Debris Materials Inventory [117]

Location	Debris Type	Material	Steel Weight in air (tonnes)	Grout Weight in air (tonnes)	Steel Volume (m^3)	Grout Volume (m^3)
Brent A	Scaffolding	Steel	54		6.8	
	Non-scaffolding	Steel	55		7.0	
	Grout bags	Grout		9		5.9
Brent B	Scaffolding	Steel	67		8.5	
	Non-scaffolding	Steel	69		8.8	
	Anchor block	Concrete		200		125.0
	Grout bags	Grout		25		15.5
Brent C	Scaffolding	Steel	54		6.8	
	Non-scaffolding	Steel	55		7.0	
	Grout bags	Grout		19		11.6
Brent D	Scaffolding	Steel	53		6.8	
	Non-scaffolding	Steel	24		3.1	
	Grout bags	Grout		41		25.7
Pipeline corridor	General	Steel	84		10.8	
Total			**515**	**294**	**66**	**184**

Debris is also present on the Brent B, C and D cell tops as described in the previous sub-section, but no specific material weights and volumes are available.

15.4 Available Decommissioning Options

In accordance with OSPAR Decision 98/3[4] and the DECC Guidance Notes on Decommissioning [5], the only option for all subsea structures (other than pipelines) is to remove them completely. BEIS treats the subsea structures as "installations" and requires their complete removal to shore and subsequent recycling.

The DECC Guidance Notes on Decommissioning state that appropriate surveys should be undertaken to identify and recover any debris located on the seabed which has arisen from the decommissioning operation or from past development and production activity. The area to be covered is a minimum of 500 m around each platform and along a corridor 200 m wide centred on each pipeline [5]. If any debris elsewhere is identified to belong to Brent, it will also require removal.

15.5 Description of proposed programme of work

15.5.1 Subsea structures

The recovery of subsea structures will be done using a ROVSV and DSV. The detailed programme of work will be finalised with the selected removals contractor but it is envisaged that the structures will be transferred to subsea baskets, cradles or grillages for lifting to the vessel decks. All recovered material will be transported to shore for recycling or disposal.

15.5.1.1 Brent Bravo SSIV

Initially the SSIV protection structures (mattresses and grout bags) will be removed to a temporary wet storage area (underwater storage in a cradle or on the seabed). It is possible that wet storage will not be required but this will be dependent on the finalised removal schedule. The ballast chests will then be lifted followed by the SSIV structure. The Brent B SSIV is located 150 m from the Brent B platform, outside the cuttings pile but within an area of marine sediment with elevated oil content [22]. Excavation or dredging may be required to allow substructure jetting, to reduce or remove the suction effect between the mudmat and the seabed, and to enable removal of the SSIV and recovery to a vessel.

15.5.1.2 Brent Spar PLEM and protection structure

Initially the external protection structures (mattresses, grout bags, glass reinforced plastic (GRP) tunnel and support stools) will be relocated to a temporary wet storage area, in a cradle or on the seabed. It is possible that wet storage will not be required but this will be dependent on the finalised removal schedule. The sloping side panels will be removed and recovered. The piles securing the Brent PLEM protection structure will be excavated to enable them to be severed 3 m below the level of the seabed. This will involve the displacement of approximately 70 – 90 m^3 of clean seabed sediment adjacent to each of the piles to allow access for ROV and DWC equipment. The PLEM and protection structure will then be recovered to a vessel.

15.5.1.3 Brent Alpha splitter box

It may be necessary to remove any sediment build up around or within the structure using excavation equipment. The piles securing the splitter box will be cut and excavated. The splitter box is located 50 m from the Brent A platform [22]. The volume of seabed sediment that will need to be displaced is unknown but is likely to be similar to the volume required to remove the PLEM. The splitter box will then be transferred in sections to subsea baskets, cradles or grillages for removal and recovery to a vessel.

15.5.1.4 VASP

Initially the SSIV protection structures (mattresses and grout bags) will be removed to a temporary wet storage area, in a cradle or on the seabed. It is possible that wet storage will not be required but this will be dependent on the finalised removal schedule.

The recovery of the VASP is expected to be by lifting the separate sections to subsea cradles for recovery to a vessel. As the structure is partially buried major excavation will be required to allow access for removal. It is expected there will be some sediment build up within the plated side of the structure.

15.5.2 Debris

Recovery of debris will be done using a crawler ROV and/ or a WROV where possible (some debris items such as the fenders on Bravo celltop, are too big to be removed by WROV). The

material, including 3,756 grout bags (25 kg each) associated with the pipelines and subsea structures, is to be fully recovered where visible and removed to shore (apart from the grout bags associated with pipelines that will be left *in situ)*. All steel will be recycled and the intention is that recovered grout will be used as a filling material in construction where possible, or re-used in some other capacity.

Over time the cutting piles will erode and may expose sections of debris not visible at the time of decommissioning. As Shell is responsible for the debris in perpetuity, risk based monitoring (to be agreed with BEIS) will capture the ongoing status of the piles and any changes that may result in further mitigation being necessary.

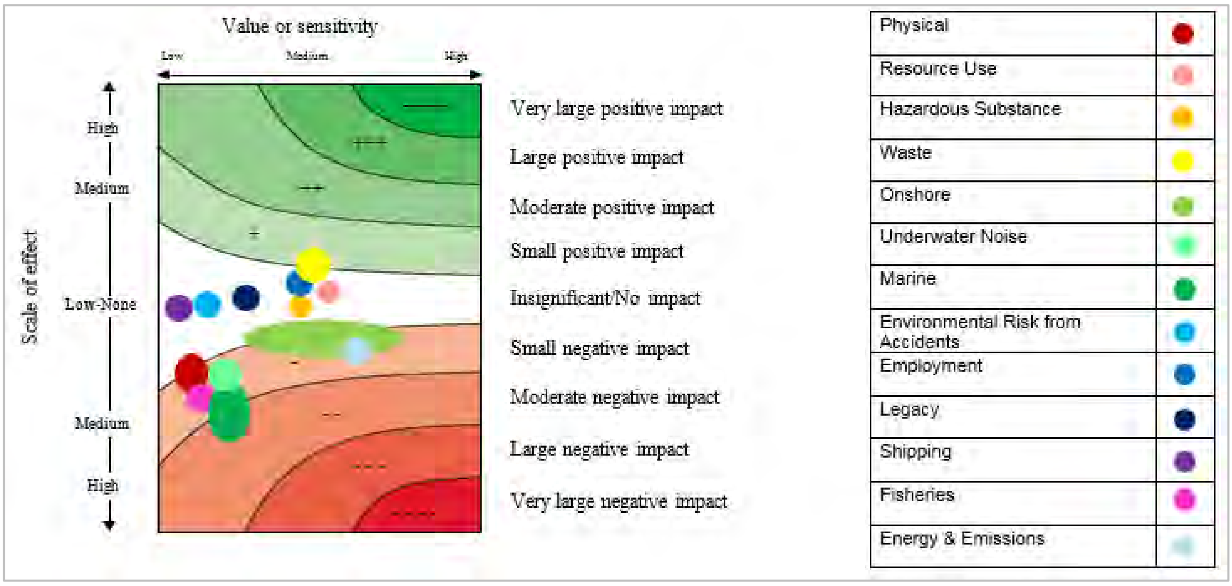
15.6 Significant impacts of proposed programme of work

Appendix 1 documents the assessment of all environmental categories. This section provides a summary of the Appendix 1 impact assessment matrices, discussing only the most significant impacts identified (those with either 'small-moderate negative' impacts or worse, or 'small-moderate positive' impacts or better).

As shown in Figure 15-5, the most significant impact identified is in the marine category. Estimated impacts are considered small or insignificant for all other categories.

The assessments concern the total impacts that will occur from decommissioning all the subsea structures and debris in the Brent Field.

Figure 15-5: Subsea Structures and Debris Option 1: Complete Removal



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-13, 2016.

15.6.1 Marine

Removal of subsea structures and debris involves marine operations for a period of time in the area. The removal of seabed structures and debris will have a '**small-moderate negative**' impact on the marine environment owing to a combination of a number of factors:

15.6.1.1 Disturbance of marine sediment

The removal of seabed structures and debris will cause disturbance of marine sediments and this may affect the local benthic communities. It should be noted that no benthic species have been identified in the Brent Field which are of statutory conservation interest (the communities identified include tube worms and molluscs, which are not unique in nature; see Section 6.3 for more details).

In practice, the removal will cause sediments to be re-suspended, and will create some turbidity. This turbidity is known to cover the breathing functions (gill and skin) and feeding functions of local organisms. This will however be of a local (limited to within tens of metres from activities) and temporary character (lasting only as long as the removal of seabed structures and debris).

There will be a number of areas where there is only a little disturbance as the numerous small items of debris (e.g. scaffold poles) distributed throughout the Brent Field are recovered. These small disturbed areas are expected to biologically recover within months as a result of natural sediment infilling and through migration of adjacent communities [118]. The sediment at Brent Field is predominantly sand, and such areas have the quickest recovery rates following disturbance [118]. Areas with larger disturbance (e.g. excavation to cut piles connecting subsea equipment to the sea floor) will take longer to recover.

15.6.1.2 Disturbance of drill cutting piles

Some of the debris (e.g. scaffold poles) is located close to the platforms, and on the GBS cell tops, and recovery will therefore likely cause some disturbance of the drill cuttings. Shell have agreed with BEIS that debris covered in cuttings will be cut as close to the cuttings as possible to minimise disturbance.

Removal activities will cause sediments to be re-suspended and will create turbidity (and will additionally release a small quantity of hydrocarbons contained within the drill cuttings). This this will affect the local benthic communities. It should be noted that no benthic species have been identified in the Brent Field that are of statutory conservation interest (the communities identified include tube worms and molluscs, which are not unique in nature; see Section 6.3 for details).

Removal operations should be performed in a cautious way (by use of low disturbance tools and equipment where practical) to minimise release of contaminants to the surrounding water masses and impact upon the local benthic communities. Again, the impact upon benthic communities will be local (limited to within tens of metres from activities) and temporary (lasting only as long as the removal of seabed structures and debris), as above. The impact on water column resources is expected to be lower than on benthic fauna because the oil contamination is strongly bound to the drill cuttings sediment, so there is low potential for leaching. Also, any organic contaminants (such as small oil particles) that do enter the water column will disperse, dilute and be subject to natural degradation [119].

Although heavy metal concentrations in sediments exceed the OSPAR EAC up to 100m from the Brent platforms, there is generally detected no straight correlation between such concentration and effects on benthic fauna [120], as other factors such as oxygen availability and organic load may be as important; hence it is not possible to predict level of impact based on heavy metal concentrations alone. The environmental baseline of the Brent Field (Section 6.3.2) shows there is currently some benthic faunal disturbance but only locally.

There will be a number of areas where there is only a little disturbance as the numerous small items of debris (e.g. scaffold poles) located in the drill cutting piles are recovered, and these small disturbed areas are expected to biologically recover within months. Areas with larger disturbance will take longer to recover, possibly years.

15.6.1.3 Removal of *Lophelia* Colonies

Fouling of subsea structures by *Lophelia* may have occurred in some instances and these will be affected by decommissioning activities. But current opinion from conservation bodies suggests that *Lophelia* on North Sea installations is an artefact resulting from the presence of man-made structures in the sea, and so the colonies are not of significant conservation interest. The idea of turning seabed structures into artificial reefs has been studied by Mackay, but “no positive effects” were foreseen [35]. Hence the removal of *Lophelia* is not considered a significant impact to the marine environment.

15.6.1.4 Summary

In summary, removing the subsea structures and debris is estimated to have a ‘small-moderate negative’ impact to the marine environment, primarily as a result of the impact to benthic communities from removal activities that disturb the marine sediment and the drill cuttings. The impact will be localised and temporary but will occur in a number of locations, therefore activities should be performed cautiously to minimise disturbance (see Table 15-6). It should be noted that the benthic fauna impacted are typical of the region, are diverse and abundant, and do not appear to contain any species of particular conservation concern (see Section 6.3.2).

15.7 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that mitigation and management measures are in place. Table 15-6 details these measures for the proposed option to decommission the subsea structures and debris and highlights the residual impacts described in Section 14.6 and Appendix 1.

Table 15-6: Summary of Mitigation and Management Measures for Proposed Programme of Work

Environmental Category	Mitigation Measures	Residual Impact
Onshore Impacts	Shell will ensure that the onshore facility selected will be responsibly managed, and will be licensed to perform decommissioning and waste management operations, and that operations will be carried out within these conditions.	Small negative
Resource Use	There are few resources used apart from fuel (covered in Energy and Emissions category)	No impact
Hazardous Substances	• Although they will have been flushed prior to decommissioning, some of the subsea structures (SSIV, PLEM, VASP) may contain residual hazardous substances such as NORM or Hg, but these will be quantified once the structures are brought to shore and examined internally. • Hazardous substances and wastes identified (if any) will be managed in accordance with all legislative requirements and good practice (e.g. OGP Guidelines for the management of NORM in the oil and gas industry [61]) and onshore site selected will be licensed and experienced in dealing with hazardous wastes. • Shell will develop and implement a specific management plan to manage risks from the materials brought to shore. Shell will monitor the UK NORM disposal routes to ensure they are capable of handling any NORM waste arising.	Insignificant
Waste	• Approximately 1,000 tonnes of steel will be recovered for recycling. • Approximately 500 tonnes of grout will be recovered, and the intention is to recycle. Shell will, once the onshore dismantling location is known, ensure research into local concrete re-use markets is performed to increase the likelihood of re-use of grout. Shell will examine possible contract conditions with the waste management contractor to help facilitate recycling/re-use of waste grout recovered. Contract conditions could, e.g., require an evaluation to be made by the waste contractor for the best environmental solution. • Shell will visit onshore site, will establish a plan for monitoring and auditing the waste management contractor, and will implement the plan. Shell will ensure the contractor acts in accordance with duty of care, other legal requirements and contract conditions. Shell will review waste management documentation and procedures.	Insignificant-small positive
Physical	Vessels performing decommissioning operations will not use anchors, and will operate on DP, therefore minimising any potential physical damage to the seabed from anchor pits.	Small negative
Marine (includes underwater noise)	• The removal process will be performed in a cautious way to minimise disturbance/dispersion of particles and release of associated contaminants to the surrounding water masses, by use of 'low-disturbance' type tools and equipment (and by avoiding the use of water jetting devices) where possible. Contract conditions that encourage such practices will be developed by Shell. • Any discharges will be subject to a discharge permit. • Noise levels of underwater cutting operations will be confirmed once the contractor is selected, to ensure the cutting equipment selected is aligned with assumptions made within the noise modelling study. • Movement of vessels resulting from decommissioning operations will be local, vessels will have a ballast water management plan and will follow IMO guidelines on ballast water management [71].	Small-moderate negative
Environmental Risk from Accidents	The activity level is low, as is the environmental risk.	Insignificant
Employment	Employment generated is insignificant	Insignificant
Legacy	The subsea structures will be completely removed as will all visible debris. Over time the cutting piles will erode and may expose sections of debris not visible at the time of decommissioning. As Shell is responsible for the debris in perpetuity, risk-based monitoring (to be agreed with BEIS) will capture the ongoing status of the piles and any changes that may result in further mitigation.	Insignificant
Fisheries	• Any ditches/berms created in the seabed when removing subsea structures and debris will be backfilled as part of the operation if they are considered hazardous to fishermen. • If wet storage takes place in areas outside the Safety Zones, mitigation may be required and this will require liaison with fishermen to agree details. Mitigation could involve a boat to warn fishermen or a temporary buoy in relevant areas. Also, Shell will ensure that wet storage will not take place in any drill cutting piles.	Small negative
Shipping	There is insignificant impact on shipping	Insignificant
Energy & Emissions	Vessel speeds will be managed to minimise fuel consumption. To increase efficiency, combustion equipment on vessels will be maintained in accordance with manufacturers' recommendations.	Small negative

16. WELLS

16.1 Introduction

This section describes the Brent Field wells, the inventory of materials and the proposed programme of work for well abandonment. The main environmental impacts of plugging and abandonment (P&A) of the wells are discussed, the necessary management and mitigation measures to control the impacts are summarised, and measures are recommended to further reduce residual impacts where appropriate.

Well abandonment activities are covered by a separate permitting and approval process, however as an integral part of the BDP, the main impacts of the Brent well abandonment programme have been examined and assessed in this ES.

16.2 Description of Facilities

A total of 146 wells were drilled throughout the Brent Field at Brent A, Brent B, Brent C, Brent D and Brent South.

A well is a boring into the ground that is designed to bring petroleum hydrocarbons to the surface, or to allow fluids or gas to be pumped into or out of a reservoir to assist in hydrocarbon production, or to provide a disposal route for produced water or drill cuttings.

The well slots are connected to the platform topsides via steel conductors, which contain the well casing strings and completion tubing.

Casing is steel pipe that is cemented into place during the construction of a well to provide wellbore stability and prevent the well from collapsing, to prevent formation fluids from entering the wellbore and to isolate geological formations.

Completion tubing or production tubing is a steel tubular run into the well to allow the production of reservoir fluids or the injection of fluids or chemicals into the reservoir.

The Brent Field wells consist of a number of production wells, water injection wells, gas lift production wells, enhanced voidage (EV) water production wells and cuttings reinjection (CRI) wells as summarised in Table 16-1.

Table 16-1: Number and Type of Brent Field Wells

	Producer	Gas Lift Producer	EV Water Producer	Gas Injection	Water Injection	Cuttings Reinjection (CRI)	Total
Brent A	15	8	-	-	4	1	28
Brent B	8	19	6	2	1	1	37
Brent C	5	26	2	-	5	-	38
Brent D	5	24	2	1	5	3	40
Brent South	2	-	-	-	1	-	3
Total							**146**

The well P&A campaign for the Brent Field commenced in 2004 with the abandonment of the three Brent South wells, which produced to Brent A. Well P&A activities on the remaining Brent Field wells commenced in November 2008 beginning with the wells at Brent D. The P&A campaign on Brent D was completed in 2014 and the P&A of the remaining wells at Brent A, Brent B and Brent C will continue and is projected to be completed by the early 2020s.

16.3 Inventory of Materials

The estimated inventory of materials that will be recovered during the P&A campaign at Brent A, Brent B, Brent C and Brent D is shown in Table 16-2. Approximately 40,000 tonnes of steel will be recovered in total.

Table 16-2: Inventory of Materials

Summary of Materials	Mass of Materials (tonnes)			
	Brent A	Brent B	Brent C	Brent D
Steel tubing	2,100	2,800	3,000	3,000
Steel casing	3,640	4,940	5,200	5,200
Steel from conductor	2,000	1,900	2,000	2,400
Platform wellheads (Steel)	140	190	190	200
Xmas trees (Steel)	160	220	220	240
NORM scale from tubulars*	1.8	2.5	3.3	2.5

*The quantity of scale with NORM activity is estimated based on Shell historical data from cleaning well tubulars at Brent A and Brent C. The activity of the scale exceeds 10 Bq/g so must be treated as radioactive waste and disposed of at a permitted site. The quantity of scale at Brent B and Brent D is assumed to be the average of quantities at Brent A/Brent C.

For the purposes of this ES, the removal of the Brent C conductors is considered together with the wells. The Brent C conductors will be removed down to the cell tops. There is some marine growth present on the Brent C conductors.

16.4 Available Decommissioning Options

The 146 Brent Field wells will be P&A in accordance with the DECC Guidance Notes on Decommissioning [5], the Oil & Gas UK Guidelines for the Suspension & Abandonment of Wells [10] and Shell's group standards. There are no opportunities or other options available for the wells.

Shell has developed a Global Wells Abandonment Manual with supporting material, which in conjunction with the Oil and Gas UK Guidelines, have been used to develop a Well Abandonment Philosophy for Brent. Shell's aim is to ensure the wells are made safe in such a way that any risk of unplanned hydrocarbon release from the well to the surface is reduced to as low as reasonably practicable (ALARP). The Well Abandonment Philosophy will be updated during the course of the work, incorporating learnings and latest industry technology developments.

16.5 Description of Proposed Programme of Work

Only one option is considered in this ES for the decommissioning of the wells:

Leave in Place
Option 1. Plugging and Abandonment (P&A) of wells

The P&A of all of the Brent platform wells will be undertaken using existing drilling facilities on each platform, with no mobile drilling units required, and will be undertaken prior to any preparation or removal of topsides facilities. Platform generators will provide power for the operations and use a maximum of 10 tonnes of fuel per day for well abandonment activities, in addition to daily running requirements for the platforms.

Brent well abandonment will be achieved in line with an approved Brent Field Abandonment Philosophy, and by the establishment of formation isolations (barriers) such that the risk of any unplanned hydrocarbons from the wells to the surface is reduced to ALARP.

After recovering the production tubing, the barriers will be placed in the well, set in pairs, with each barrier consisting of several hundred feet of cement. Once the barriers have been tested and their integrity assured, the remaining steel casing sections will be cut and recovered at an approved depth below the platform topside. Casing will be cut using standard mechanical cutting techniques. Some explosives may be required to perforate or cut the production tubing or perforate casings, following standard oilfield procedures.

For certain wells it may be necessary to mill and under-ream a window in the casing to restore the annulus seal to ensure the well integrity is suitable for abandonment. This may generate a small quantity of metal swarf and drill cuttings. Any metal swarf generated will be recovered to the rig and contained and shipped to shore for treatment and disposal. Cuttings will be shipped to shore for treatment and disposal.

When the casings are cut, the remaining fluids in the well will be displaced using inhibited seawater (seawater which has been treated with chemicals such as hydrogen sulphide (H_2S) scavengers, biocide etc), or milling fluid consisting of polymers and inhibited seawater, and weighted with barite. It is expected that displaced annular fluids (fluids remaining between the wellbore and the steel casing, or remaining between casing strings, from drilling operations) are likely to be mainly WBM, but some OBM may be encountered (estimated to be

approximately 25-80 m^3/well). Up to approximately 11,500 m^3 of these fluids (and associated seawater/milling fluids) will be shipped to shore for treatment and disposal.

All recovered Xmas trees, production tubing, casings and wellheads will be removed from the topsides and taken to shore for recycling. In preparation for the cutting and removal of the remaining conductors, some of the fluids remaining in the conductors (~120ft) will be circulated out and contained, then shipped to shore for appropriate treatment and disposal in compliance with the relevant permits. The remainder of the fluids will be left in the conductors.

All chemical use and discharge for the well abandonment operations are subject to control under the Offshore Chemical Notification Scheme (OCNS) and the Offshore Chemical Regulations, 2002 (as amended). Consent for Abandonment of each well will be sought from BEIS through the Well Operations and Notification System (WONS).

All planned and contingency chemical use and discharge will be detailed on the relevant Chemical Permit Application and any planned discharge of oil will be detailed on the relevant Oil Discharge Permit application under the Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended). The actual use and discharge of all chemicals, including cement, during well abandonment operations will be reported to BEIS through the EEMS (Environmental Emissions Monitoring System) reporting system.

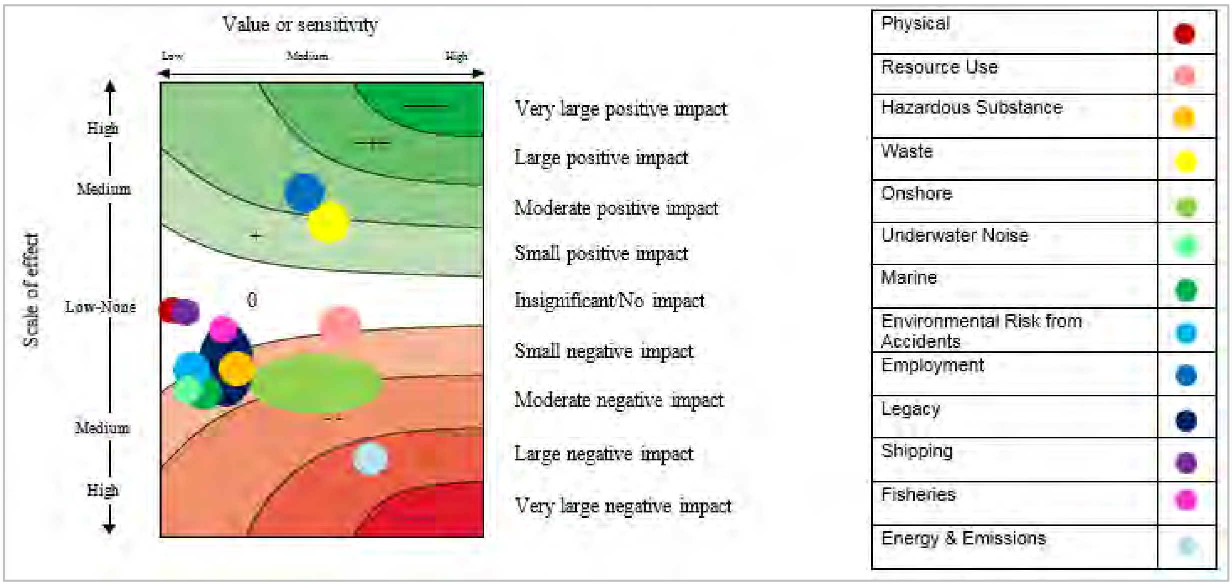
16.6 Significant Impacts of Proposed Programme of Work

Appendix 1 documents the assessment of all environmental categories. This section provides a summary of the most important impact assessment matrices from Appendix 1, discussing only the most significant impacts identified (those with either 'small-moderate negative' impacts or worse, or 'small-moderate positive' impacts or better).

As shown in Figure 16-1 the significant impacts identified are for onshore, waste, employment and energy and emissions. Estimated impacts are considered small or insignificant for all other categories. There is some uncertainty and public concern regarding potential weeps and seeps from abandoned wells in the long term, but as the amount of hydrocarbons released in such events are typically small, and because there will be a post-decommissioning survey, it was allocated a small negative impact in the legacy category.

The assessments concern the total impacts that will occur from P&A of the 146 wells.

Figure 16-1: Wells Option 1 – Plugging and Abandonment



Note:

- Some impact points have been moved slightly on the x-axis to facilitate visibility (without changing the impact).
- Energy and emissions data has been sourced from DNV GL, *Energy Use and Gaseous Emissions Report for the Brent Field Decommissioning EIA*, Rev 5, DNV GL Report No.: 187KVXJ-3, 2016.

16.6.1 Onshore Impacts

The overall onshore impact as a result of P&A of wells is estimated to be **'small-moderate negative'** owing to the large quantities of material that will come onshore that will require handling, deconstruction and transportation. The onshore dismantling facility is currently not known, so the assessment described below reflects the uncertainty of the environmental sensitivity of the site.

The P&A of wells will generate large quantities of material, including approximately 40,000 tonnes of steel and (potentially) an estimated 11,500 m^3 of OBM/ WBM fluids.

When brought onshore, the OBM/WBM fluids will be settled or dewatered/centrifuged at an onshore facility, such that only a small proportion of the fluids (the resulting solids sludge) will need transporting on the external road network to landfill. Regardless, a significant number of journeys may still be required to transport the materials offsite. The level of nuisance caused will depend on the transport infrastructure and the proximity of residents. The wastewater will be treated in an effluent treatment plant and then discharged to sea under appropriate permit conditions. Oil will be sent for recycling.

Onshore decommissioning operations can have 'nuisance' impacts on residents and other receptors in the local area for a significant period of time (~a decade) during the dismantling of the material. Impacts can include:

- Dust and noise emissions from increased traffic.
- Dust and noise from deconstruction activities (e.g. lifting, cutting etc.)

These issues will require control to avoid significant impact. The onshore facility will be licensed to receive decommissioning wastes and the dismantling operations will be carried out

under responsible management and control, with all necessary permits and consents. As such it is anticipated that mitigation measures and onshore process controls will be in place to minimise these impacts. Previous experience of major decommissioning projects in the North Sea demonstrates that the impact potential to local communities can be effectively controlled and mitigated [67].

In summary, P&A of the wells is estimated to have a 'small-moderate negative' impact onshore upon local receptors primarily owing to a combination of potential noise, dust, and traffic impacts upon local residents that may occur over a significant period of time as a result of the large volumes of wells materials that will come to shore. Measures will be necessary to ensure impacts are managed and minimised.

16.6.2 Waste Management

The overall waste impact as a result of the P&A of the wells is **'small-moderate positive'**, owing mainly to the large quantity of steel that will be recycled. Hazardous materials present on the wells are covered in the Hazardous Substances category.

16.6.2.1 Steel recycling

Approximately 40,000 tonnes of steel is recoverable (tubings, casings and conductors) from the 146 wells that will come onshore and be recycled. This represents the bulk of the material present and is valuable material, dominating the impact allocated to this waste management category.

16.6.2.2 Other materials

P&A of the wells will generate amounts of other non-hazardous waste materials (e.g. concrete, and marine growth from conductors), which will either be recycled, reused (concrete) or disposed of as waste. Previous experience of major decommissioning projects in the North Sea demonstrates that the impact potential can be effectively controlled and mitigated [67].

Although an onshore dismantling site has not yet been chosen by Shell, it has been assumed that local and national regulations will be applied as well as stringent contractor selection to ensure that the environmental impact arising from the disposal of non-recyclable materials is minimised. Much of the non-hazardous materials from this process are, however, recyclable, which will thus minimise the volume of waste going to landfill.

16.6.2.3 Summary

In summary, decommissioning the wells is estimated to have a 'small -moderate positive' waste impact primarily because of the large quantities of steel that will be generated and recycled.

16.6.3 Employment

The overall employment benefit as a result of the P&A of wells is estimated to be **'moderate positive'**.

Shell commissioned an independent report to estimate the employment generated by the BDP. As part of this study, a factor was derived for the Brent project of £250,000 per new job per year. This factor was then applied by Shell to estimate the man-years generated for each decommissioning option. Shell estimates that the P&A of wells will generate 3,841 man-years

of work. This option generates the second highest level of employment of the technically feasible options considered in this EIA.

Although this number is relatively small when considered within a wider context (the UK oil and gas industry is estimated to employ 330,000 people [69]), 3,841 man years is still considered a 'moderate positive' benefit in recent times of relatively high unemployment in the UK oil and gas sector.

16.6.4 Energy and Emissions

DNV GL's *Energy Use and Gaseous Emissions Report* [2] estimate the overall energy use as a result of decommissioning all of the Brent Field wells. Comparing this against the energy impact categories in Table 5-7, the impact from energy use is considered to be **'large negative'**, owing to the combination of the factors described below. Energy impacts for all facilities are summarised in Appendix 2.

It is estimated that P&A of the 146 wells will take another 4-5 years to complete. The campaign will involve significant energy consumption owing to the large number of wells. Table 16-3 shows the total estimated energy consumption and emissions resulting from decommissioning the wells.

Table 16-3: Total Energy and Emissions for P&A of Wells

Operations[1]	Energy (GJ)	Emissions to Atmosphere (tonnes)		
		CO_2	NO_X	SO_2
Direct				
At field operations[2]	2,792,880	205,416	4,536	181
New material	41,890	7,558	6	2
Onshore dismantling	30,872	2,271	50	2
Onshore transport	13,556	997	22	1
Sum	*2,879,198*	*216,242*	*4,614*	*186*
Recycling				
Material recycling	377,530	17,088	64	151
Material Replacement				
Materials not recycled	41,890	7,558	6	2
Total	**3,298,618**	**240,888**	**4,683**	**340**

[1] Operations categories are defined in Section 5.2.3.
[2]At field operations factor not used as data was available for diesel generator used on platform for P&A activity.

16.6.4.1 Energy consumption and CO_2 emissions

Energy is required offshore (field operations), onshore (dismantling and transport) and for material recycling. Additionally an energy penalty has been applied for replacement of materials that are not recycled (see Section 5.2.3).

All the recovered material from the wells will be transferred from the platform to vessels that are part of the platform operational vessels and not designated specifically to this activity.

At field operations (i.e. those operations occurring at the Brent Field for decommissioning, excluding vessel transit) include power generation (diesel) for abandonment activities and these represent the bulk of energy consumption. There will no flotel operations for

accommodation of personnel. Onshore operations will include the dismantling of recovered material, treatment, the transportation of materials, and the operation of recycling facilities.

The energy demand for P&A of the wells is estimated to be approximately 3.3 million GJ, based on the contributions of different operations. The total CO_2 emissions ($CO_{2\ TOT}$) from these operations are estimated to be approximately 241,000 tonnes, of which the largest contribution comes from direct operations, with power generation at platforms the main contributor. As the majority of the material recovered from the wells is recycled, the emissions for the replacement of material (CO_{2REP}) is small (3%).

16.6.4.2 Emissions of NO_x and SO_2 to atmosphere

The majority of the gaseous emissions generated during the P&A of wells are likely to be quickly dispersed as they will be released offshore and over the long duration of the decommissioning works. As such, it is anticipated that the concentrations of NO_x and SO_2 will be relatively low at any given location and at any given time. Onshore emissions (mainly from recycling the steel) are small and will be within permit conditions of recycling facilities. As such emissions of NO_x and SO_2 are considered to be smaller contributors to the environmental impact than CO_2 emissions. Please refer to DNV GL's *Energy Use and Gaseous Emissions Report* [2] for more details.

16.6.4.3 Summary

The overall environmental impact from Energy and Emissions as a result of decommissioning all of the Brent Field wells is estimated to be 'large negative' owing primarily to the energy consumed and CO_2 emitted by diesel generator operations on platforms during P&A activities, that will have taken place over a decade. Emissions of NO_x and SO_2 are considered to be a small contributor to this impact.

The emissions are important when considered within the context of current concerns about climate change, but are necessary to undertake the decommissioning option. To put the emissions into another context, the total CO_2 emissions for the P&A campaign are approximately 10% of Shell U.K.'s 2013 upstream GHG emissions (CO_2 equivalent) [70]. However, it is still a significant quantity of energy, and it is recommended that control measures are put in place to minimise fuel use (see Section 16.7).

16.7 Mitigation, Management and Residual Impacts of Proposed Programme of Work

The assessments detailed earlier have been made on the basis that mitigation and management measures are in place. Table 16-4 details these measures for the proposed option to decommission the wells and highlights the residual impacts as described in Section 15.6 and Appendix 1.

Table 16-4: Summary of Mitigation and Management Measures for Proposed Programme of Work

Environmental Category	Mitigation Measures	Residual Impact
Onshore Impacts	• Shell will only use onshore facilities licensed to receive decommissioning wastes and will ensure onshore operations are carried out under all necessary permits and consents. • Shell will ensure onshore controls are in place to minimise environmental impacts, including: o Dust control via sweeping vehicles, water sprays, speed limits onsite and cleaning of traffic wheels leaving site o Appropriate monitoring regime o Limits on when certain operations can take place if necessary o Planning of traffic routes offsite to ensure nuisance to residential areas is minimised.	Small-moderate negative
Resource Use	Shell will only use chemical additives that are inert or low toxicity, and are typical of platform operational inventories. They will be specified in the well abandonment application.	Insignificant-small
Hazardous Substances	• Hazardous waste will be managed in accordance with all legislative requirements, both offshore and onshore. Shell will only use registered hazardous waste management contractors for handling and managing hazardous wastes. Wastes will be tracked and logged from offshore to final recycling/disposal onshore, with hazardous waste consignment notes completed and kept for a minimum of three years. Hazardous waste management procedures will be followed. • The P&A of the wells will be controlled via BEIS's Offshore Environmental Permitting System, under which Shell will apply for all the necessary chemical permits. P&A operations requiring the use of chemicals will be covered by well intervention chemical permits with no planned discharges to sea. All mud and cementing chemicals are subject to control under the Offshore Chemical Notification Scheme (OCNS) and the Offshore Chemical (Pollution Prevention and Control) Regulations, 2002 (as amended). The majority of chemicals selected are category E or low RQ chemicals that were selected to minimise hazards to the marine environment. There will be no chemicals used which are not typical of offshore industrial platforms and with which specialised contractors are not familiar. • NORM: Impact on the environment will be controlled by having an appropriate NORM waste management plan offshore, and by ensuring that the onshore waste contractor has a regulated plan for the identification, removal and disposal of NORM scale. NORM will be managed in line with OGP Guidelines for the management of NORM in the oil and gas industry [61]. Shell will monitor the UK NORM disposal routes to ensure they are capable of handling NORM waste arising from the decommissioning programme. • Well Fluids: Any OBM (oily waste) will be contained and returned to shore for management and disposal, in accordance with relevant permits. • Shell will monitor and audit practices both on and offshore.	Small negative
Waste	Most of the waste generated (e.g. steel) will have a positive impact as it will be recycled. But there will also be other wastes which require management (such as marine growth, mud). Shell will establish a plan for monitoring and auditing the waste management contractor, and will implement the plan. Shell will ensure the contractor acts in accordance with duty of care, other legal requirements and contract conditions. Shell will review waste management documentation and procedures.	Small-moderate positive
Physical	Vessels performing decommissioning operations will not use anchors, and all P&A will be from existing platforms, therefore minimising any potential physical damage to the seabed from anchor pits.	Insignificant
Marine (includes underwater noise)	• Any fluids discharged (e.g. WBM) will be under a chemical permit. Shell will check to ensure any products discharged are within their permitted allowances and free of oil. If taken to shore, fluids will be treated and wastewater discharged to sea under a permit, and oil will be recycled. • Shell will use a hydrophone to measure the underwater noise on the first use of explosives during P&A of wells. Shell will then develop a plan to manage the noise if appropriate.	Small negative
Environmental Risk from Accidents	• Environmental risk from accidents associated with plugging and abandonment of wells will be lower than those experienced during the drilling of the wells due to low pressure and low flow rate. The P&A activity is a well-defined risk assessed process. There remains an inherent risk of accidental release but it is low as activities are part of a closed loop system (via platform). • Procedures, systems and training will be in place to mitigate the chance of a spill occurring and to ensure a rapid response to any such event. A BEIS approved Oil Pollution Emergency Plan (OPEP) for the Brent Field system is in place. • Shell intend not to discharge to sea during P&A operations, but if necessary all activities will be permitted via necessary well permits.	Insignificant-small negative
Employment	Positive impact	Moderate positive
Legacy	• P&A will be achieved in line with an approved Brent Field Abandonment Philosophy and by formation isolations (barriers) such that the risk of any unplanned hydrocarbons being released from the wells is reduced to ALARP. Permanent cement barriers will be installed in pairs, with each barrier consisting of several hundred feet of cement. This will isolate the wells from the reservoir. • After P&A, Shell will perform a post P&A monitoring of the abandoned wells to ensure that the reservoir has been isolated. If any biogenic shallow 'weeps and seeps' are detected then any decisions for risk mitigation will be based on ALARP. • Shell commit to implementing future P&A procedures that come out of the current ongoing industry studies to reduce risk of seeps, where appropriate.	Insignificant-small negative
Fisheries	The majority of operations will be conducted from within the 500 m safety zone.	Insignificant-small
Shipping	The majority of operations will be conducted from within the 500 m safety zone.	Insignificant
Energy & Emissions	Shell will implement appropriate control measures to minimise fuel use during decommissioning of the wells, with particular focus on the use of energy efficient platform generators.	Large negative

17. CUMULATIVE IMPACTS OF PROPOSED DECOMMISSIONING PROGRAMME

17.1 Introduction

The impact assessment matrices in Appendix 1 provide the detail of the environmental assessment of the various decommissioning options for the Brent Field. The key environmental issues are then summarised and discussed in Sections 8 - 16 for each facility.

This assessment was conducted, thus far, by consideration of the impacts from decommissioning ‘groups’ of facilities at the Brent Field (e.g. the impact of decommissioning four topsides together). However, impacts also need to be viewed:

a) the interaction of impacts between facilities (e.g. the environmental impact of decommissioning three GBS considered together with the impact of decommissioning four topsides) to provide a view of the overall cumulative impacts of the BDP.

b) cumulatively i.e. consider whether there is any overlap between the impacts (e.g. from decommissioning four topsides) in the different environmental categories (marine, onshore, resource use, hazardous waste etc.).

Because there are so many facilities and numerous decommissioning options for many of the facilities, it is very difficult to consider the cumulative environmental impacts of decommissioning all the Brent Field facilities until the final decommissioning strategies are decided, as the permutations are numerous.

Shell’s proposed decommissioning programme is presented below; it is not in chronological order. Discussion of the potential cumulative impacts is made based on this programme:

- Remove all four topsides
- Remove the Brent A upper jacket to -84.5 m below LAT
- Leave Brent A jacket footings *in situ*
- Leave all three GBS *in situ* with legs up
- Remove all attic oil in GBS structures
- Leave cell water and cell sediment *in situ* in GBS cells, untreated and uncapped
- Leave material in GBS drilling legs and GBS minicells *in situ*, untreated and uncapped
- Leave seabed drill cuttings *in situ*
- Leave cell top drill cuttings *in situ* (although it is possible that some drill cuttings may have to be disturbed to create new access holes to the cells, to enable attic oil removal)
- Leave tri-cell drill cuttings *in situ*
- Pipelines – approximately 89 km of pipelines will be (or currently are) trenched and 13.5 km will be removed. 61% of the 1,760 t of concrete mattresses will be removed.
- Remove subsea structures and debris
- Permanent plugging and abandonment of all 146 wells

Post-decommissioning monitoring is considered within the decommissioning operations of each facility.

17.2 Significant Impacts of Proposed Decommissioning Programme

For the proposed decommissioning programme described above, the main environmental impacts for grouped facilities are identified in Table 17-1. Only those impacts which are estimated to be 'small-moderate negative' or worse, or 'small-moderate positive' or better, are shown (although all impacts are considered). Assessment has been made on the basis that the mitigation and management measures detailed in Sections 8-16 are in place. Cumulative impacts are discussed in Section 17.6.

Table 17-1: Main Environmental Impacts of Proposed Programme of Work

Proposed Decommissioning Programme	Main negative impacts	Main positive impacts
Remove all four topsides	Onshore (S/M) Hazardous Substances (S/M) Energy and Emissions (M)	Waste (M) Employment (S/M)
Remove Brent A upper jacket (-84.5 m)		Waste (S/M)
Leave Brent A jacket footings *in situ*		
Leave all three GBS *in situ* with legs up	Legacy (M) Energy and Emissions (L)	
Remove GBS attic oil		Waste (S/M)
Cell water/sediment left *in situ* in the GBS	Legacy (S/M)	
Leave material in GBS drilling legs/minicells *in situ*		
Leave seabed drill cuttings *in situ*		
Displace some cell top drill cuttings to access cells to remove attic oil	Onshore (S/M)* Marine (S/M) *	
Leave tri-cell drill cuttings *in situ*	Legacy (S/M)	
Pipelines – trench/remove/leave *in situ*	Marine (M) Legacy (S/M) Energy and emissions (M) Resource use (S/M)	
Remove subsea structures and debris	Marine (S/M)	
Plug and abandon all 146 wells	Onshore (S/M) Energy and Emissions (L)	Waste (S/M) Employment (M)

L = Large; M = moderate; S/M = Small-moderate.

*Brent C only (table shows impacts assuming disturbance is required, as this has the bigger environmental impact)

As shown in Table 17-1, legacy impacts and energy and emissions are the two most prominent negative impact categories in Shell's proposed decommissioning programme. Important considerations will therefore be:

- the potential for cumulative legacy impacts (to the marine environment, to shipping and to fisheries) resulting from the different facilities that will remain *in situ*
- the energy efficiency of the decommissioning operations

Marine and Onshore are the next most prominent negative impact categories with potential for cumulative impacts. All these issues are discussed in Section 17.6. Resource use and Hazardous substances are only identified once each in the table, hence these impact categories have much less potential for cumulative impact.

To facilitate the discussion of cumulative impacts, two sets of combined impact matrices have been developed:

- One set combines the estimated environmental impacts of the twelve environmental categories, and places them on a single impact matrix for each decommissioning option. This shows pictorially the range of impacts for a single decommissioning option. These figures are presented throughout Sections 8-16.
- A second set draws on the same results but presents them differently. The estimated impacts are combined for each decommissioning option, and placed on a single matrix, one matrix for each of the twelve environmental categories. This shows pictorially how the range of impacts for a single environmental category differs by facility (for the proposed programme of work). These are presented in Appendix 6.

It should be noted that the impacts presented in the matrices do not necessarily take place at the same time, so should be interpreted carefully. To understand better how these significant environmental impacts may interact or overlap, the schedule of Shell's decommissioning programme also needs to be considered.

17.3 Schedule of Decommissioning Programme

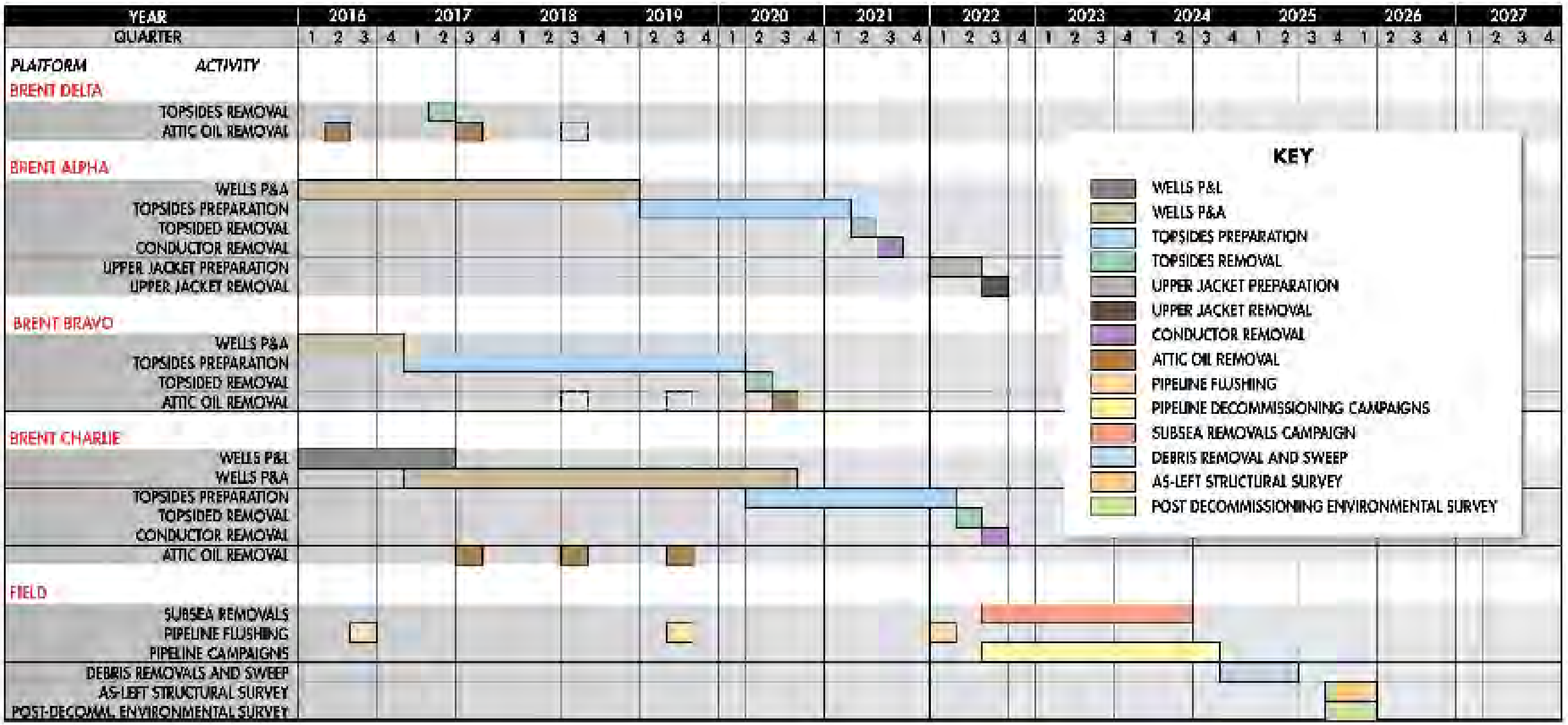
The current (draft) schedule of the Brent Decommissioning Programmes is shown in Figure 17-1, and shows that decommissioning will take approximately ten years to complete.

17.4 Interactions between Decommissioning Activities during BDP

Figure 17-1 shows that although activities will be conducted at different platforms at different periods during the 10 year decommissioning programme, there are often periods of overlapping activities at two, and sometimes three or four, platforms. But concentrating on the key impacts identified in Table 17-1, DNV GL considers that one of the main potential areas for cumulative impact is legacy, which will occur in a later time period than that shown in the above schedule. There is potential for interaction of legacy impacts to fisheries, shipping and to the marine environment due to the different facilities that will remain *in situ*, and this is examined in Section 17.6.1.

Energy and emissions, marine and onshore impacts are the other environmental categories where there is most potential for cumulative impact (as described in Section 17.2), and these are examined in Section 17.6.

Figure 17-1: Brent Decommissioning Programme



17.5 Interactions between the BDP and other Activities

The main environmental impacts identified in Table 17-1 are legacy, marine, onshore impacts and energy and emissions. The potential interaction of the BDP with other activities are considered below.

- There is potential for interaction between the BDP and other activities in the NNS with respect to cumulative *legacy* impacts, as a result of the facilities that will remain in the sea both at Brent Field and maybe also at other nearby decommissioning locations in the future. However, since the BDP legacy impacts are considered to be relatively local impacts (see below), this overlap should not be significant since the distance to the nearest other facilities, such as the Statfjord Field or Strathspey subsea facilities, is several kilometres.
- It is possible that the onshore yard(s) handling BDP wastes could be awarded contracts to handle major waste streams from other projects unrelated to the BDP, and this will result in cumulative *onshore/waste* impacts. However, the onshore yard(s) will still need to work within the licence conditions, which will help manage any potential cumulative impacts.
- The more significant *marine* impacts highlighted in Table 17-1 result from cell top drill cuttings displacement, pipeline decommissioning (primarily from the combination of rock dumping and trenching pipeline N0501) and subsea structures and debris recovery. These are all localised impacts (as detailed within the assessment chapters) that are restricted to the Brent Field or the pipeline N0501 corridor, and so interaction with other activities is unlikely.

17.6 Cumulative Impacts

In order to provide a view of the overall cumulative impacts of the BDP, this section seeks to address two types of cumulative impacts:

- Consider whether there is any overlap in impacts in the different environmental categories (marine, onshore, resource use, hazardous waste etc.)
- The interaction of impacts between facilities (e.g. consider impacts at the three GBS in conjunction with impacts at the jacket).

In relation to the first point, many of the environmental categories are very different in nature and do not inter-relate (e.g. hazardous substances and energy and emissions). Also, there is no overlap between impacts that take place on land (e.g. onshore impacts) and those impacts that take place offshore (e.g. marine impacts), while some impacts are 'spread' between onshore and offshore (e.g. resource use, energy and emissions, employment, environmental risk). Areas where cumulative impacts could potentially occur include:

- Short-term offshore operational cumulative impacts between marine, physical and underwater noise. But of these categories, only the marine category is a main contributor to the environmental impact (see Table 17-1); physical and underwater noise impacts are small for the programme of works (see Appendix 6). Hence cumulative impacts in these areas are considered to remain manageable.
- Legacy impacts to the marine environment overlapping with operational marine impacts. But legacy impacts are not expected to be realised for hundreds of years, while operational marine impacts will typically recover within a few years. There will be no overlap.

In relation to the second point, and as detailed earlier in this section, facilities will not all be decommissioned at the same time; it will be a phased decommissioning approach and the works will take place over a period of 10 years. Hence the (short-term) negative cumulative environmental impacts will in most instances be similar to the impacts estimated for the individual facilities, and are thus considered to be manageable, albeit simply extended over a longer period of time. However, the following comments can be made:

- There are periods of overlapping activities at two and sometimes three platforms, and this has potential for cumulative impacts onshore as a result of materials brought to shore (e.g. from dismantling of the jacket and topsides, and the P&A of wells). Provided the onshore controls are applied as recommended within this report, and independently monitored and audited, DNV GL considers impacts to remain 'small-moderate negative' and to be more of a nuisance, and of a temporary nature (albeit covering a number of years), than a significant environmental impact. Note also that if Shell utilises one onshore location to handle wastes generated as part of the BDP, this can be beneficial because it can help in developing a solid and improving operating partnership with the contractor during the long programme.
- There is potential for cumulative short-term impacts to the marine environment from operations to:
  - Remove subsea structures and debris
  - Displace cell top drill cuttings for access to cells to remove attic oil
  - Trench and rock dump pipeline N0501

  Individually, these operations will impact the marine environment, primarily as a result of the localised impact upon the benthic communities from activities that disturb the marine sediment and drill cuttings, as described in the assessment chapters. Although it should be noted that the benthic fauna impacted are typical of the region, are diverse and abundant, and do not appear to contain any species of particular conservation concern.

  But these three decommissioning operations will take place at different times and (mostly) different locations, hence cumulative impacts to the marine environment will remain localised and reversible (apart from the rock dump, which has a more permanent localised impact, as previously described). Shell will conduct operations, where practical, in periods with low abundance of vulnerable resources (e.g. fish eggs or larvae) in the water column, to help minimise impacts.

- Energy and emissions are additive when several facilities are considered together (see Section 17.6.2).

- There will be some positive impacts. The main positive impacts (waste recycling and employment) are additive when considering facilities in combination. Some of these decommissioning solutions can also give positive synergy effects: e.g. leaving the GBS *in situ* enables the seabed drill cuttings (and some cell top drill cuttings) to be left *in situ* (this is considered the best solution for the drill cuttings, and which would not be possible if the GBS were removed).

Additionally, it should be noted that there is some distance between the Brent platforms as shown in Table 17-2: approximately 11 kilometres between Brent A and Brent D, with Brent B and C located in between. As many of the impacts identified are localised, the cumulative effects again can be considered manageable, as there will be little overlap between platforms.

Table 17-2: Distance between Platforms

Platforms	Distance between Platforms
BA to BB	2.4 km
BB to BC	4.5 km
BC to BD	4.1 km
BA to BS	4.9 km

Cumulative *legacy* impacts will occur in a very different timeframe and are discussed below.

17.6.1 Cumulative Legacy Impacts

The following Brent Field facilities would be left in place under Shell's proposed decommissioning programme:

- Brent A jacket footings
- 3 GBS with legs up
- GBS cell contents
- GBS drilling legs material and GBS minicells material
- Drill cuttings: Seabed, Cell tops (assume for worst case legacy discussion, that they are left *in situ*), Tri-cells
- Pipelines - approximately 89 km of pipelines will be (or are already) trenched, and 13.9 km will be removed. Most concrete mattresses will be removed.

Legacy impacts have potential for cumulative impacts to the marine environment, shipping and fisheries, and these are considered in turn below. Table 17-3 illustrates which legacy sub-category is impacted by which facility, and highlights how the marine environment has the most potential to be subjected to cumulative impact.

Table 17-3: Facilities with Legacy Impacts

Facility left *in situ*	Size of negative legacy impact	Legacy-impact to marine environment	Legacy- impact to fisheries	Legacy-impact to shipping
GBS	Moderate	Yes	Yes	Yes
Pipelines	Moderate	Yes	Yes	-
Cell contents	Small-moderate	Yes	-	-
Tri-cells	Small-moderate	Yes	-	-
Jacket footings	Small	Yes	Yes	-
Drilling leg/Minicell	Small	Yes	-	-
Drill cuttings: seabed and celltops	Small	Yes	-	-
Wells	Insig-small	Yes	-	-

17.6.1.1 Legacy - *shipping*

Due to the requirement to maintain the current 500 m safety zones during and following decommissioning, the GBS will continue to have an impact upon shipping, just as they currently do, with large vessels restricted from passage in this small area for several hundred years. The 500 m safety zones are required to remain in place until the structure no longer projects above the surface of the sea. Then Shell will apply to the regulator for a continuance of the 500m safety zone; its extended existence will mean ships will continue to be restricted from passage for an indefinite period.

The GBS are the only facility having an impact upon shipping; as such there are no additional cumulative impacts as a result of other facilities left *in situ*.

17.6.1.2 Legacy - *marine environment*

Legacy impacts upon the marine environment have been identified individually for:

i. Cell contents
   a. ‘Small-moderate negative’ impact to the marine environment upon release of cell contents due to degradation of the GBS.

ii. Drill cuttings
   a. ‘Small-moderate negative’ impact to the marine environment upon release of tri-cell drill cuttings due to degradation of the GBS.
   b. ‘Small negative’ impact to the marine environment from the drill cuttings if left *in situ* at the seabed and cell tops.

iii. Drilling leg and minicell materials
   a. ‘Small negative’ impact to the marine environment due to the exposure of the minicell and drilling leg contents contained within Brent B and D into the water column following degradation of the GBS.

iv. Wells
   a. ‘Insignificant-small’ negative impact to the marine environment from future seeps, if any, of plugged wells.

v. Jacket Footings
   a. ‘Small negative’ impact upon the marine environment from the future collapse of the jacket footings.

vi. GBS
   a. Negative impact to the seabed marine environment due to degradation of three GBS, similar to the localised impact of a large ship wreck on the seafloor.

vii. Pipelines
   a. ‘Small-moderate negative’ impact owing to approximately 149,000 t of rock dump, which results in habitat change due to the introduction of a hard substrate.

Release of Petroleum Hydrocarbons

Hydrocarbons will be released to the marine environment from items i, ii and iii (and potentially from iv).

Any overlap in the timing of the release of the GBS cell contents, GBS minicell and drilling leg contents, and/or tri-cell drill cuttings is difficult to predict owing to the uncertain nature of the degradation mechanism of the GBS (see Section 10.6.1.1). The degradation has been examined but is not an exact science, and even within an individual GBS, the timing of the release of the above materials is uncertain. It is estimated that the upper GBS leg would remain largely intact for around 150 to 250 years with a steady degradation around water level. Despite significant damage to the cells below due to falling debris (particularly as the GBS legs up option was selected for the programme of works), the caisson structure would still likely survive for at least 500 years, after which time loss of containment of the cell contents could occur. It is possible that the GBS cell water and sediments may become partially exposed to the marine environment prior to the tri-cell drill cuttings, which are more protected within the caisson structure.

It should be noted that:

- Although the three GBS will degrade in the same approximate timeframe (in excess of 500 years), there could be decades or even centuries between each GBS being sufficiently degraded for exposure of its contents to the marine environment.
- The distance between the three GBS will limit the potential for contamination overlap. DNV GL's toxicology study [94] suggests that, based on analytical results (Table 11-4), the size of the chemically impacted area (due to a major static exposure of the cell contents) will be approximately 0.05 km^2 (to a distance of 250 m) at each platform, 1 year after release. The two closest GBS platforms are 2.4 km apart, so there will be no overlap in the impact areas.

But some cumulative legacy impacts to the marine environment will take place, particularly at each GBS due to the combination of the hydrocarbons contained within the cell contents, the minicell and drilling leg contents, and the tri-cells drill cuttings. To help consider the cumulative impact, Table 17-4 estimates the petroleum hydrocarbon loads involved.

Table 17-4: Volumes of Material and Petroleum hydrocarbon loads

	Volume (m^3)	Hydrocarbon load (t)
Cell contents	39,408 (sediment)	11,228*
Tri-cell drill cuttings***	26,772	4,926**
Drilling leg waste material	4,000	46
Minicell annulus material	500	20

*includes 266 t of oil contained within cell water

**based on maximum concentration

***The seabed and cell top drill cuttings (if left *in situ*) will also, in 500+ years, continue to lose oil to the marine environment; estimated to be less than 10 t (per annum) in total, based on Table 13-5.

Approximately 16,000 tonnes of hydrocarbons could therefore become exposed to the marine environment in total for all three GBS. Even though this may not occur for more than 500

years, Shell do not expect significant anoxic biodegradation of the hydrocarbons to have taken place during this period because the sampling exercise indicated a lack of bacteria inside the cells (possibly because all the nutrients and electron acceptor have been consumed).

This is about 2.8 times the quantity of hydrocarbons (5,642 tonnes) estimated to be contained within the seabed and cell top drill cuttings that are currently exposed to the marine environment (see Section 13.6.1).

There will be a cumulative legacy impact from the hydrocarbons on the marine environment, and DNV GL considers it to be one of the most important cumulative environmental impacts of the decommissioning programme. The main driver of the impact is the cell contents, as this provides the bulk of the hydrocarbon load, although the tri-cells contribution is also significant, particularly as it is more likely to be released in a dynamic disturbed state and at a higher location than the cell contents. There will be localised pollution to the marine environment around each platform, and although it will naturally degrade over time, this localised pollution will be present for decades, and will affect local benthic fauna. The cumulative contaminated area at Brent B and D has not been modelled but will be similar, but larger, than that predicted in the DNV GL toxicology study for a major 'static' cell contents release (0.05 km^2 based on analytical results, to a distance of 250 m), when taking the tri-cells drill cuttings into account. Because the contaminated area will be localised around the platforms, there is not expected to be any measurable effect upon marine or benthic populations/systems. The impact will be smaller at Brent C because the volume of cell contents is smaller and also because there are no tri-cell drill cuttings present.

It is reasonable to assume that a proportion of the hydrocarbons in the GBS may be released in a dynamic disturbed state as a result of GBS degradation (particularly the tri-cells drill cuttings, most of which are located at a higher level than the cell sediment, see Figure 10-2). The likelihood of some disturbed release of material is higher for the 'leave the GBS legs in place' Option 2, where a GBS leg collapse will have more destructive energy to damage the GBS caisson than the GBS legs down option. Although dynamic sediment release scenarios would result in larger areas of the seafloor being contaminated (modelling has shown that the PEC:PNEC>1 covers much wider areas), the vast majority of the areas have a sediment thickness of less than 1 mm, and hence are not expected to have any harmful impact on biota once mixing by bioturbation and biodegradation effects are taken into account.

The existing drill cuttings on the seabed and the cell tops will also be disturbed by the degradation of the GBS, and this will also add to the cumulative impacts described above. If it took approximately 500 years before loss of containment of the cell contents occured, the seabed and cell top drill cuttings that are currently exposed on the seabed will have degraded further by between 30-50% [106], hence they will still retain some hydrocarbons. The future disturbance of the existing drill cuttings is likely to occur in stages as the GBS degrades over time, and the impacts are likely to be similar to those discussed in Section 13.6.1.1, which describes the modelling of the disturbance of the drill cuttings [107] from various activities such as trawling and dredging, with between 493 m^3 and 775 m^3 of drill cuttings released into the water column. The distribution of the released cuttings on the seabed was largest for the release of 775 m^3 of Brent C cell top cuttings (this is logical because the cuttings were released at the cell tops approximately 60 m above the seabed, resulting in a thinner layer and larger dispersal on the seabed compared to seabed release). The cuttings from the cell tops generated a layer less than 1 cm thick (the average and the maximum thickness of re-deposited cuttings is

0.2 and 6 mm respectively), and re-deposition with a layer thickness of more than 1 mm was restricted to an area of about 0.07 km^2. Where the sediment thickness is less than 1 mm, there is not expected to have any harmful impact on biota. Regardless, the disturbance of the drill cuttings will add to the cumulative impact described above, but the environmental impact will remain localised (to several hundred metres) around the platforms and will reduce over time, particularly where the sediment is less than 1 cm thick, as aerobic degradation will break down the organic material. The cumulative area with potentially harmful impact due to THC contamination will be similar to what is currently observed on the seafloor around many North Sea oil and gas installations.

All the above impacts, when they occur in ~500 years' time (after the GBS degrade), will overlap with the (future) seabed environmental baseline conditions. However, although the existing seabed drill cuttings will still be causing some localised environmental stress around the platforms at that time (in 500 years' time the THC in the piles are estimated to have further degraded by between 30-50%), the current THC contamination of the seabed at distance from the platforms is expected to have recovered significantly owing to degradation over time. So the overlap is not expected to provide additional cumulative impact of significance to that discussed in the paragraphs above.

Habitat change

There will also be cumulative habitat change resulting from the degradation of three GBS and the collapse of the jacket footings, which will add to the habitat change caused by the 147,000 tonnes of rock dump planned during the programme of works. But the impact on the sea bed at the jacket and GBS after degradation will be similar to the current situation, with the footprint only expected to expand a little further owing to the spreading of degraded and corroded items that have fallen.

Each will be a localised impact, and each will occur in distinct areas that do not overlap. The cumulative area involved is approximately 0.1 km^2, which is not much larger than the habitat change resulting from the pipelines when considered in isolation. Hence the cumulative impact is similar to the pipelines impact considered in isolation (main contributor is rock dumping at Pipeline N0501).

17.6.1.3 Legacy - *fisheries*

Fisheries will be affected by the following facilities left *in situ*.

- Brent A jacket footings: leaving the jacket footings *in situ* will continue to present an obstruction to fishermen, as they do today, for decades and centuries, and is estimated to be a 'small negative' impact, as described in Section 9.7.4.
- GBS: leaving the GBS structures *in situ* will result in a continued occupation of the platform area, thus excluding fisheries interests in this area for an indefinite period. The effect on fisheries is estimated to be 'small negative' because the value of the catch is assumed to only increase (if all the Brent platforms were completely removed) by 0.1% of the projected annual catch of £7 million per year (equates to £7,000 p.a.). The impact may be smaller if the catch is limited by quotas and days at sea, rather than physical access. The risk of snagging of trawl gear is low because GBS legs will be clearly visible to fishermen,

although risks will increase upon degradation of the GBS legs to below sea level after an estimated 150-250 years.

- Pipelines - approximately 89 km of pipelines will be (or currently are) trenched and 13.9 km of pipelines will be removed, and these measures will remove legacy impacts to fisheries. No pipelines will remain exposed on the seabed, and there will thus be no spans presenting legacy risks to fishing vessels.

There will be some cumulative impacts as a result of combining the legacy impact of decommissioning the Brent A jacket and GBS, but the overall cumulative effect on fisheries remains similar because the value of the catch in the area is small.

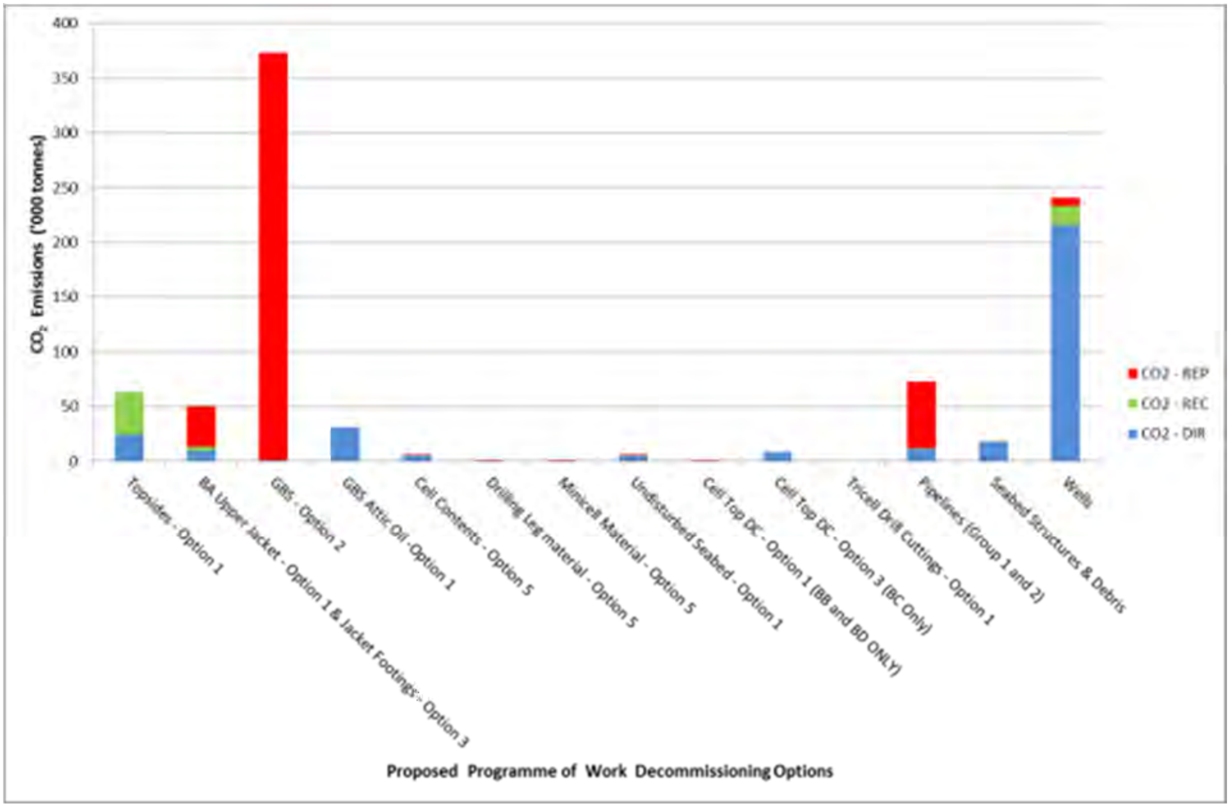
17.6.2 Overall Energy and Emissions

Energy and emissions estimations associated with the various decommissioning options are presented in detail in DNV GL's *Energy Use and Gaseous Emissions Report* [2].

Emissions come from material removal, offshore vessels, onshore demolition, onshore transport, and the recycling of metals and other materials. In addition, the energy and emissions associated with the replacement of recyclable materials (which are either left *in situ* or disposed of to landfill) are taken into account.

The total CO_2 emissions (direct and indirect) for Shell's proposed programme of work are illustrated in Figure 17-2 which shows that the decommissioning of the GBS (due to the emissions penalty) and the P&A of wells are the main contributors to the total CO_2 emissions. The energy and emissions for the programme of works will emit a total of approximately 870,000 tonnes of CO_2, only 38% of which are direct. Most of the direct emissions come from plugging and abandoning the wells, which highlights the benefit of trying to ensure energy efficient platform generators are used during the long campaign.

Figure 17-2: Comparison of CO_2 Emissions for Proposed Programme of Work



17.7 Additional Mitigation Measures to address cumulative impacts

The following additional measures to those previously discussed are identified to address the cumulative impacts of the proposed programme of works.

17.7.1 Marine

If more than one underwater cutting operation is required at any one time in the Brent Field during decommissioning operations, underwater noise modelling should be conducted to demonstrate that there will be no significant impact. DNV GL is unaware of underwater noise source data for DWC or commercial AWJ, so conservative values are believed to have been used in the noise modelling study in this ES (see Appendix 3); it would be beneficial to obtain more accurate estimates of the affected ranges and measurements of underwater noise levels emitted from the selected cutting equipment.

17.7.2 Environmental Accidents

Environmental risk has been considered at a high level in this ES. A more detailed environmental risk assessment will be conducted now that the draft programme of works is defined.

18. MONITORING, MITIGATION AND MAINTENANCE OF REMAINS

This section discusses the environmental and structural surveys proposed by Shell for the Brent Field and for the structures that remain in the sea after decommissioning. Environmental monitoring of the decommissioning operations has been previously discussed within Sections 08-16 of this report.

18.1 Inventory of Materials that will remain in the Sea

Based on Shell's proposed programme of work, the facilities listed in Table 18-1 will remain in the sea after the decommissioning of the Brent Field is complete.

Table 18-1: Approximate Inventory of Materials Remaining in the Sea following Decommissioning

Brent Field Facility	Approximate quantities of materials left in the sea
Brent A jacket footings	9,700 tonnes steel
	4,700 tonnes grout
	850 tonnes marine growth
	160 tonnes anodes
Three GBS	583,500 tonnes concrete
	251,000 tonnes sand ballast
	34,000 tonnes steel
	20,500 tonnes grout
Contents of GBS drilling legs and minicell annulus	8,580 m^3
GBS cell contents	638,500 m^3 cell water
	40,595 m^3 cell sediment
Seabed drill cuttings	20,918 m^3
Cell top drill cuttings	13,412 m^3
Tri-cell drill cuttings	26,800 m^3 (maximum estimate)
Pipelines left in place (mostly trenched, some rock dump)	47,392 tonnes of pipelines (steel, concrete, protective coating and concrete mattresses)
Rock dump added	149,000 t rock dump during decommissioning (plus existing Brent Field rock dump footprint of approximately 10,000 m^2)

18.2 Overview of Structural and Environmental Survey Programme

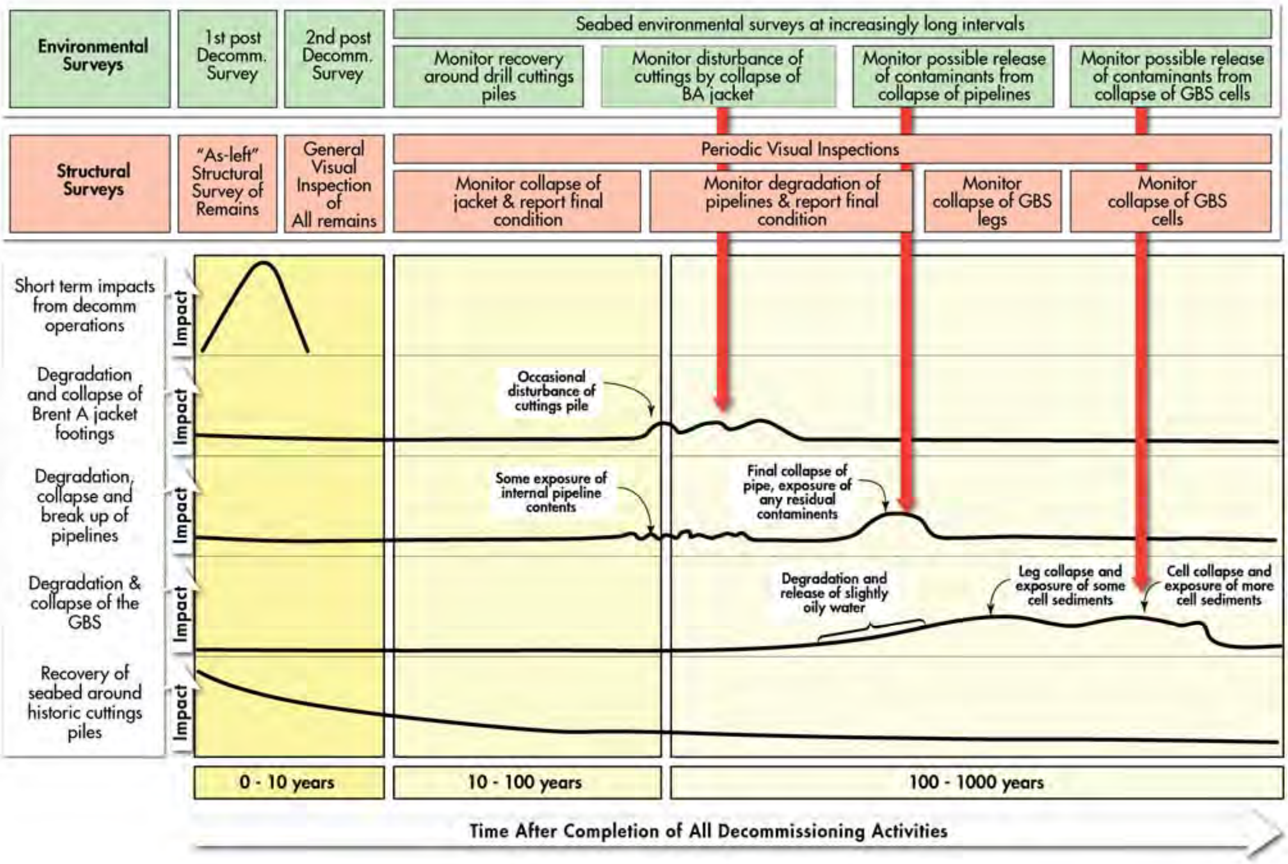
Shell's proposed survey programmes are designed to monitor two things, environmental effects and the physical degradation and collapse of remains.

Some surveys will take place in the near future, while some will occur in the medium and long-term, depending on the longevity and integrity of the different facilities left to degrade in

the sea (such as jacket footings, pipelines, or GBS). These surveys are discussed in the following sections.

The Shell schematic presented below shows the relative timescales of impacts of offshore operations, and some of the long-term consequences of leaving material on the seabed.

Figure 18-1: Schematic of Timescales of Impacts from Offshore Operations



Over time the cutting piles will erode and may expose sections of debris not visible at the time of decommissioning. As Shell is responsible for the debris in perpetuity, risk based monitoring (to be agreed with BEIS) will capture the ongoing status of the piles and any changes that may result in the need for further mitigation.

18.3 Pre-decommissioning Environmental Surveys

Shell commissioned a pre-decommissioning environmental survey in 2007 [23,24] to provide information for this ES and Shell's Comparative Assessments. Shell recently carried out another survey at the Brent Field in 2015 and are currently reviewing the results.

Together, the data from these surveys will provide a detailed assessment of the status of the seabed around each site before offshore decommissioning operations begin. It will also show a time-series of changes in the concentrations of oil and other contaminants, and in the character of the benthic community, on the seabed immediately adjacent to and within the historic cuttings piles.

18.4 Post-decommissioning Environmental Surveys

Shell will conduct a post-decommissioning environmental survey when all offshore decommissioning work has been completed, debris removed, and the debris sweep successfully carried out. It is planned that the survey would re-visit all the stations sampled in the two pre-decommissioning environmental surveys mentioned above, to obtain a directly comparable set of data which would allow Shell to determine if the offshore decommissioning operations had any significant impacts on the local environment.

Shell intends to carry out a second post-decommissioning environmental survey about 5 years after the first, again re-visiting the previous sampling stations. This would be the fourth environmental survey in a time series of comprehensive and comparable environmental surveys, and should provide a good assessment of the extent of any perturbation caused by the offshore operations, as well as more data on the general character and health of the seabed in the Brent Field. This series of surveys will also provide more data on how the seabed around the platforms is or is not recovering from the impact of the historic discharge of drill cuttings.

If the post-decommissioning surveys show that there have been impacts from Shell's operations, Shell will continue the environmental surveys at about 5-year intervals until either the seabed has returned to its pre-decommissioning state, or until there is a clear trend showing that recovery is taking place and will occur within a reasonable time-scale.

Thereafter, Shell will discuss the need for further environmental surveys with the regulator, BEIS. As Figure 18-1 shows, once the seabed has recovered from any operational impacts, it is unlikely to experience any further significant impact either from residual contaminants in remains, or from the physical presence of degraded remains, for many years. Future environmental surveys therefore should be targeted at anticipated milestones in the slow degradation of the remains, when there will be a heightened risk that some residual contaminants could become exposed to the environment.

18.5 Structural Survey of Brent Field Remains

Shell will conduct an 'as left' detailed structural survey to record the condition of all facilities that are left in the sea after decommissioning. The post-decommissioning as-left structural survey will provide detailed information on the Brent A footings, the Brent B, C and D GBS, and all sections of pipeline that may be left *in situ*.

Shell discussions with BEIS on suitable long-term monitoring programmes are at an early stage and will be informed by the findings of the proposed surveys. When informed by these surveys, Shell will enter into discussions with BEIS to plan and agree the content and frequency of a cost-effective risk-based long-term structural monitoring programme. Any agreed programme of work offshore on or near the seabed would be subject to permit under the prevailing legislation (e.g. currently MCAA).

Shell is responsible in perpetuity for all structures and materials permitted to remain on the seabed on completion of the BDP. These structures will only slowly degrade, and it is unlikely that any noticeable structural degradation would occur in the first few decades. Shell's programme of post-decommissioning structural monitoring therefore needs to be targeted and 'risk-based'. Rather than repetitive, unproductive surveys, Shell proposes to minimise the risks to the environment and to other users of the sea that may occur as structures deteriorate by

leaving the remains in a good structural condition. This means, for example, removing light-weight components such as external piping and caissons.

19. CONCLUSIONS

This Environmental Statement examines the environmental and socioeconomic impacts of the decommissioning options for the Brent Field facilities, and helps ensure that environmental considerations are incorporated within Shell's planning and decision making.

It is important to understand the current status and sensitivities of the environmental areas that could be affected by decommissioning, in order to effectively predict and assess the environmental impacts of the proposed decommissioning options. Most decommissioning operations will take place at the Brent Field, and there are no particularly environmentally sensitive habitats nearby. Seabed communities in the general area are diverse and abundant, but are not unique. Seabed surveys have identified elevated concentrations of metals and hydrocarbons in the sediment around each Brent Field platform, and samples indicate that benthic fauna are affected locally around the platforms. This is typical of North Sea oil and gas facilities due to the historical discharge of drill cuttings contaminated by residual oil-based drilling fluids.

The Brent Field comprises a large number of facilities (topsides, jacket, GBS, cell contents, drill cuttings, pipelines, subsea structures, wells), and there are a number of different decommissioning options under consideration (leave *in situ*, partially remove, complete removal etc.). Each decommissioning option has been broken down into activities/end points, which are then evaluated against a range of environmental and socioeconomic categories (onshore, resource use, hazardous substances, waste, physical, marine, environmental risk from accidents, employment, legacy, fisheries, shipping, energy and emissions) to identify the environmental impacts.

It was found that although decommissioning options can be conducted without causing significant environmental or socioeconomic impacts, some fundamental differences were identified between the impacts of the decommissioning options, particularly between:

- those options involving leaving structures *in situ* (resulting in some legacy impacts to the marine environment, fishermen and shipping); and
- those options to remove structures (resulting in very different impacts e.g. onshore impacts and energy and emissions, although these negative impacts are somewhat counterbalanced by the positive impact of employment and by recycling useful materials such as steel).

These are very different types of impacts, and comparing one type of environmental impact against another is not a straightforward task. Any comparison will always be open to challenge by interested and affected parties, who may only be interested in one particular environmental or socio-economic category. A specific issue of interest to one group of stakeholders (e.g. the removal of the jacket footings may be considered positive by fishermen) may be considered negatively by another group (e.g. residents living adjacent to the recycling facility where the recovered steel is transported).

The environmental impact findings were used to inform the Comparative Assessment conducted by Shell which balanced the technical, costs, safety, environmental and societal aspects in helping to identify the proposed programme of work for the Brent Field facilities in Shell's decommissioning programme.

This report then focusses on the proposed programme of work, and found the following impacts to be the most prominent:

- legacy impacts – primarily from leaving the GBS, the cell contents and the tri-cells drill cuttings *in situ*. Plus the legacy impacts resulting from 149,000 tonnes of rock dump during pipeline decommissioning (long term change to marine habitat).
- onshore impacts – mainly from onshore handling of waste from four topsides and the P&A of wells.
- marine impacts – mainly from trenching pipelines and removing subsea structures and debris.
- energy and emissions - mainly from the decommissioning of the topsides, pipelines, the P&A of wells, and an emissions penalty for leaving GBS *in situ*.

Even these most prominent impacts are short-term in nature, or restricted to causing localised or limited impacts.

Cumulative impacts are subsequently further examined to explore the possible synergy effects when considering all the facilities together (e.g. the impacts at the three GBS in conjunction with the impacts at the jacket). The potential for cumulative impacts is limited owing to:

- the distance between the platforms (there is approximately 11 kilometres between Brent A and Brent D)
- the long length of the decommissioning programme. Because it will be a phased decommissioning approach and works will take place over a period of 10 years, the operational cumulative environmental impacts will in most instances be similar to the impacts estimated for the individual facilities, and are thus considered to be manageable, albeit simply extended over a longer period of time.

Perhaps the cumulative impact of interest to many stakeholders is the cumulative impact to the marine environment upon exposure (in the distant future following degradation of the GBS) of the GBS cell contents, tri-cell drill cuttings and material in the drilling legs and minicell annulus. Any overlap in the timing of the release of these materials is very difficult to predict owing to the uncertain nature of GBS degradation, but an estimated total of approximately 16,000 tonnes of petroleum hydrocarbons could become exposed (not at the same time) to the marine environment for all three GBS. There will be a cumulative legacy impact on the marine environment, with localised pollution to the marine environment around Brent B, C and D platforms, which will be present for decades and will affect local benthic fauna (such as tube worms), just as the local benthic fauna are currently impacted by the presence of the historical drill cuttings. The cumulative area affected, including due to the disturbance of the existing seabed and cell top drill cuttings by the degradation of the GBS, is predicted to extend at each platform to several hundred metres. Because the contaminated area will be localised around the platforms, there is not expected to be any measurable effect upon marine or benthic populations/systems. The impact is not insignificant, but it is localised, and over time the seabed will recover via natural biodegradation, particularly where the sediment is less than 1 cm thick, as aerobic degradation will break down the organic material.

It is concluded that decommissioning can be undertaken without causing any significant environmental or socioeconomic impacts, provided that the proposed mitigation and

management measures are implemented. Industry best practice mitigation measures will be applied by Shell, will be managed within Shell's established Environmental Management System, and are detailed within this report to help ensure all impacts are managed.

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