Shell U.K. Limited

Brent Delta Topside Decommissioning
Close-Out Report
INTERIM

Frontispiece: Brent Delta Topside in 2013.

Shell Report Number: BDE-D-TOP-AA-6945-00001

6th Aug 2018

Contents

1 EXECUTIVE SUMMARY

1.1 Close-out Report

In accordance with the *Petroleum Act 1998* and the *BEIS Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998*, the owners as Section 29 Notice holders sought approval from the Department for Business, Energy and Industrial Strategy (BEIS) via a Decommissioning Programme (DP) to decommission the Brent Delta topside by removing it completely and returning it to shore for recycling and disposal. The *Brent Delta Topside Decommissioning Programme* was approved on 3rd July 2015.

This document is an interim close-out report for the decommissioning of the Brent Delta topside (Table 1), which was removed in April 2017. It is submitted by the co-venturers Shell U.K. Limited and Esso Exploration and Production UK Limited.

As outlined in the DP, this interim close out report covers the offshore programme of work to cut, lift and remove the Brent Delta topside and fit the caps and Aids to Navigation on top of the legs of the gravity based structure (GBS). A final close out report will be submitted within four months of the completion of all the onshore operations to dismantle, recycle and dispose of the topside. The reports will describe the programmes of work that were actually performed and in particular explain the reasons for any variations from the planned programmes.

1.2 Brent Delta Decommissioning

Brent Delta ceased production on 31st December 2011 after nearly 40 years of production. Shell started planning the complex engineering process of decommissioning Brent Delta in 2006.

After detailed technical and engineering studies it was decided to remove the Brent Delta topside using the new single lift vessel (SLV) *Pioneering Spirit* commissioned by Excalibur AS (part of the Allseas Group) (Figure 1). The Brent Delta topside was removed on 28th of April 2017 and transported to the Able Seaton Port (ASP) facility at Teesside in May 2017, which is operated by Able UK Limited (Able), where, at the time of writing, it is being dismantled (Table 2).

Figure 1. The SLV *Pioneering Spirit* with the Cargo Barge *Iron Lady*.

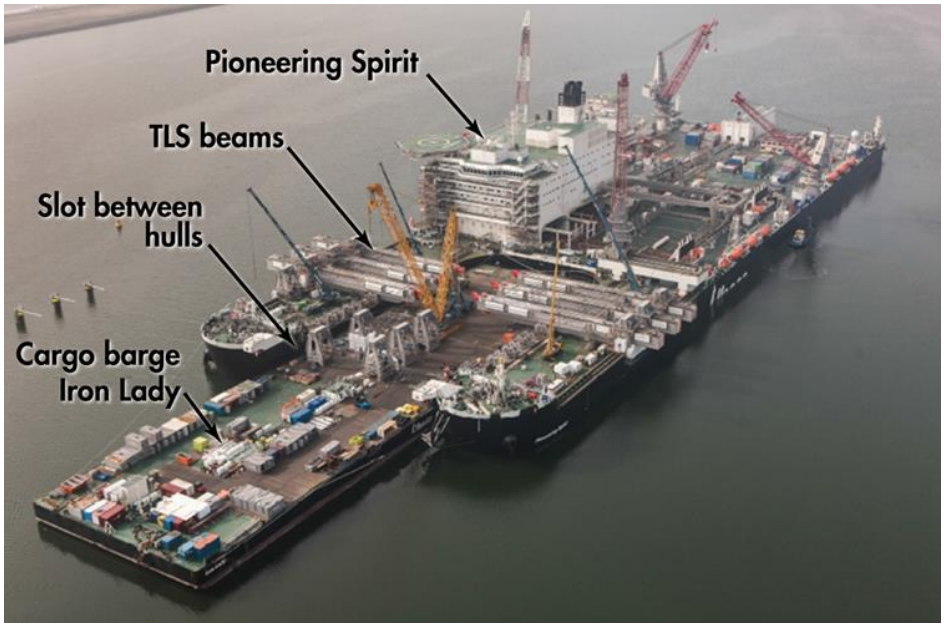


Table 1. Overview of Decommissioned Installation

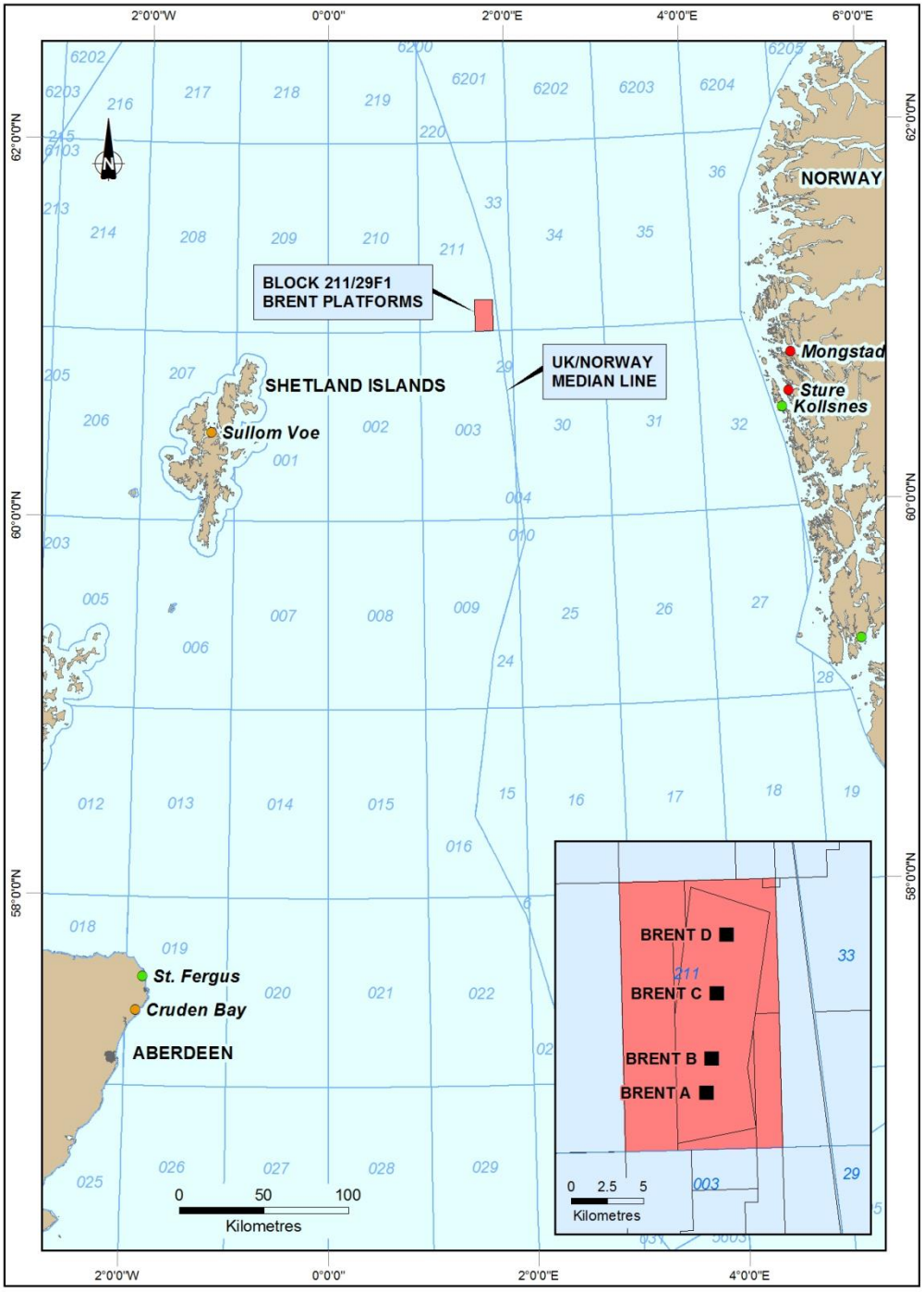
Installation Being Decommissioned			
Field name		Quad/Block	
BRENT FIELD		UKCS Block 211/29	
Surface Installation			
Total Number	Type	Location	Weight
1	Brent Delta Topside	61° 07′ 56.6″N 01° 44′ 10.1″ E	23,727 tonnes
Production Type	Water Depth (m)	Distance from nearest UK coastline (km)	Distance to median line (if less than 5km)
Gas and oil	142	136	N/A
Equity Interest (%) of the Owners			
Shell U.K. Limited		50	
Esso Exploration and Production UK Limited		50	

Table 2. Summary of Programme of Work.

Summary of Executed Decommissioning Programme		
Selected Option	Reason for Selection	Execution of Decommissioning Solution
1. Brent Delta Topside		
Complete removal, onshore dismantling, recycling and disposal.	Complies with requirements of OSPAR Decision 98/3 relating to topsides.	The Brent Delta topside has been removed in one piece by a SLV, transferred to a barge at a near-shore site and back-loaded to the ASP facility at Teesside. Some equipment may be re-used but the majority of material will be recycled. Non-recyclable material will be disposed of to landfill.
2. Brent Delta Wells		
Plug and Abandon.	Meets BEIS regulatory requirements.	All the Brent Delta wells have been plugged and abandoned in accordance with the Oil & Gas UK *Guidelines for the Suspension and Abandonment of Wells*. PON5/PON15 applications under the relevant regulations were submitted and approved.
3. Brent Delta Interdependencies		
There were no alternative uses for the Brent Delta platform and in line with the approved Final Field Development Plan (FFDP), BEIS confirmed that it could be decommissioned. Neither the platform wells nor any equipment or facility on the topside were needed to complete any technically feasible options for decommissioning the Brent Delta GBS or for managing the materials in the oil storage cells, drilling legs and minicell annulus. The two pipelines to the adjacent platform Brent Charlie were emptied and flushed before the Brent Delta topside was removed.		

Figure 2 shows the location of the Brent Field and Brent Delta in relation to the other Brent platforms. The removal of the Brent Delta topside by the SLV and its transportation to shore had no effects on, or any implications for, any other facility either within or beyond the Brent Field.

Figure 2. Location of the Brent Field and the Brent Delta platform.



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2 ORGANISATION OF THE WORK

2.1 Project Management and Verification

The project was managed in accordance with applicable regulatory requirements and to Shell's Global Project Management standards. It was led by an experienced Shell Project Director with sub-project managers, project engineers and support functions including, but not limited, to Health, Safety and Environment (HSE), Quality, and Project Services. The project was divided into a series of sub-projects and tendered to the open market as appropriate. Synergies were sought with other Shell project activities (and in principle other decommissioning activities) where they made economic and business sense.

2.2 Main Contractors and their Role

2.2.1 Decommissioning Services Contract

At that time, Shell concluded that there was a net economic advantage to be gained by tendering the Decommissioning Services Contract (DSC) scope as a dedicated contract. The DSC contract was awarded to PSN (Aberdeen) Ltd and started on 1st August 2010.

The primary aim of the DSC was to support the topsides engineering-down activities with the objective to shut down and make safe the platforms once they reached Cessation of Production (CoP). As such, the contractor was expected to deliver the following Post-CoP scopes of work: -

- Platform maintenance (i.e. life support, utilities, fabric integrity).
- System decommissioning (i.e. cleaning, support to operations).
- Modifications (i.e. minor Change Proposals, design and installation of temporary equipment).
- Module separations (i.e. isolation, segregations).

2.2.2 Offshore Removals Contract

The offshore removals contract was awarded to Excalibur AS (part of the Allseas Group) in 2013. Allseas were tasked with completing design work and engineering to ensure the topside was suitable for the single lift, as well as providing the interface between the single lift vessel and the disposal yard. The scope of the contract included the following:

- Single lift design engineering and project management.
- Leg cutting design and execution.
- Lift of structure using *Pioneering Spirit*.
- Transport to barge transfer location.
- Load in at disposal yard from barge.

2.2.3 Onshore Dismantling Contract

The onshore dismantling and recycling contract was awarded to Able UK in 2013. The Onshore Disposal scope comprised the following:

- Provision of a suitable quayside facility and laydown area to receive the topside.
- Provision of facilities, equipment and personnel to safely dismantle the topside.
- Re-use and/or recycling of materials, with a target of at least 97%.
- Disposal of debris in accordance with statutory requirements.

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3 DESCRIPTION OF THE BRENT DELTA TOPSIDE

3.1 Introduction

The topside of Brent Delta was supported by a concrete GBS with three legs (two for drilling, one for utilities) that extend upwards from the cluster of 19 concrete cells (Figure 3). All the topside modules and equipment were located on a plate girder deck structure (PGDS) (Figure 4), which was mated to the tops of the concrete legs by steel transition pieces. The transition pieces were part of the PGDS and they met the tops of the legs at the ring beam (Figure 4). During original construction, the PGDS, fitted with some topside modules, was floated over the GBS and attached to it at a near shore deep water site before the GBS was towed offshore, and the remaining modules were lifted into place after the GBS had been ballasted down in the Brent Field.

As defined in the Brent Delta Topside DP, the Brent Delta topside is "the whole of the structure located above the ring beams at the top of the concrete legs and including the steel transition pieces."

The topside weighed 23,727 tonnes and comprised three main levels – the PGDS, the Module Deck and the Drilling Deck (Figure 4). Together these decks housed the modules, facilities and equipment for oil and gas drilling, production and processing, and for the accommodation, safety and welfare of the platform's personnel. Figure 5 shows the heights of the different topside levels in relation to the cut line.

Figure 3. Brent Delta GBS with Topside.

Figure 4 The Three Main Levels of the Brent Delta Topside.

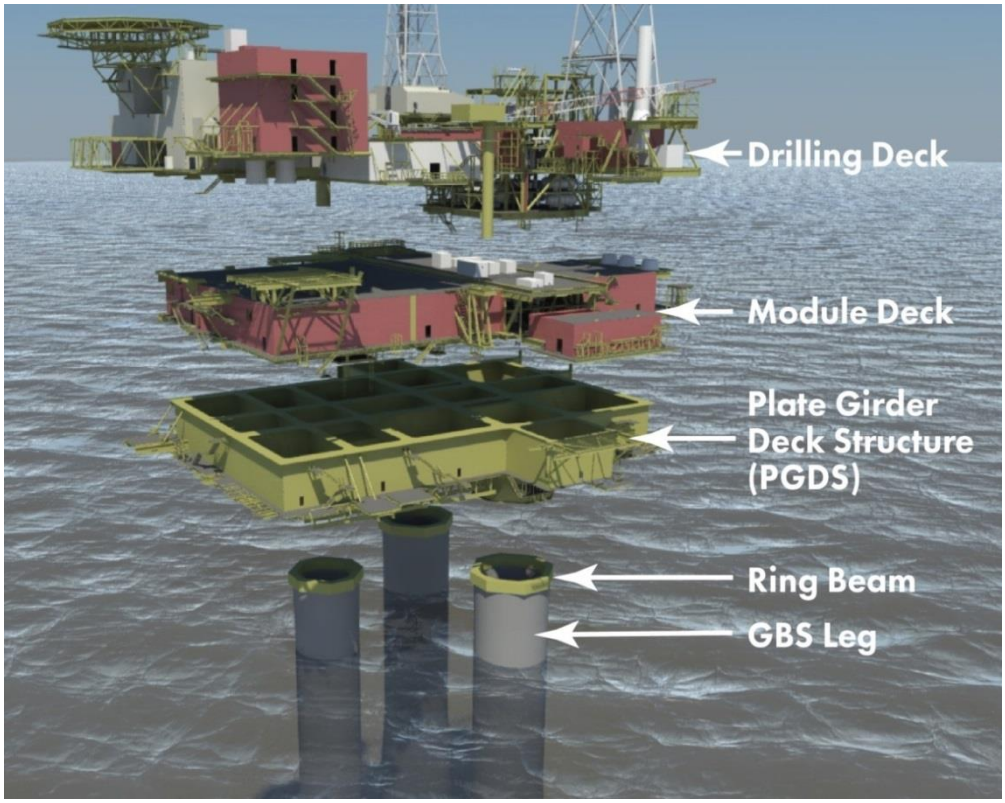
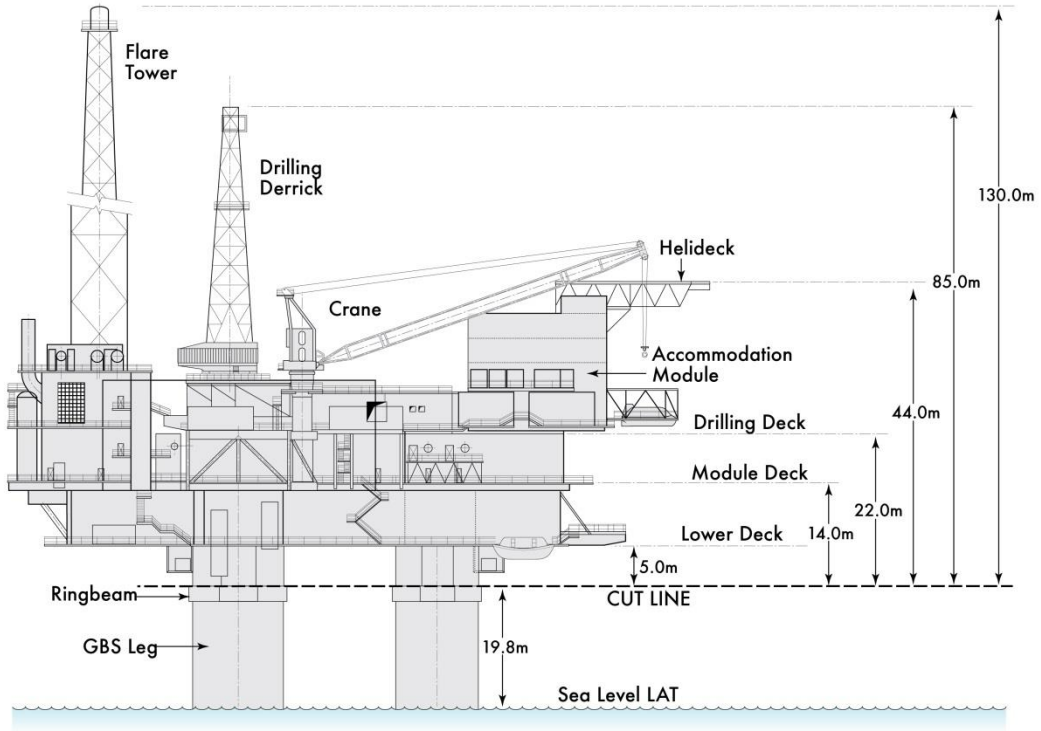


Figure 5. Brent Delta Topside, Heights of the Main Deck Levels and Components.



Note: All the height measurements above the cut line have been rounded to the nearest metre.

3.2 Main features

The Brent Delta topside housed the following modules and systems:

- Accommodation and helideck. Comprised the accommodation, laundry, catering, and recreation facilities for the crew. Helicopter landing and fuelling facilities were located on the roof of this module.
- Drilling derrick and support. Comprised equipment for the drilling and maintenance of oil and gas wells, including the drilling rig, an electrical generation package and facilities for the bulk storage, handling, preparation and pumping of drilling fluids.
- Utilities. Comprised the firewater and safety systems, water purifying equipment, chemical storage and pumping, potable water bulk storage and pumping, hot water boilers, electrical switchboards, workshop facilities, and diesel fuel storage and pumping.
- Oil and Gas production process modules. Contained all of the vessels and equipment used to separate the well fluid into its three main components – oil, gas and produced water – and transfer these individual streams to the export pipelines, other areas of the platform or for disposal via the oil storage cells as produced water.
- Water injection module. Contained the equipment used to filter and treat raw seawater so that it could be pumped down-hole to enhance production by augmenting the natural pressure of the reservoir.
- Power generation modules. Contained the electrical generators, transformers, switchboards and associated equipment. The generators were powered by turbines fuelled by gas from the production process. After cessation of production CoP, Brent Delta was powered exclusively by diesel generators.
- Wellhead modules. Contained the equipment and control valves that regulated the flow of oil and gas from each of the individual wells. The individual flow lines were combined via a manifold system which in turn supplied the oil and gas processing equipment. The modules also contained the water injection wellhead equipment which, when in use, received high pressure treated water from the water injection module and routed it to the dedicated water injection wells and down into the reservoir.
- Flare tower. The tower supported the flare, which was designed to vent and burn any surplus hydrocarbon gas that might pose safety risks to platform personnel and process systems. Following cessation of production (CoP) and removal of the hydrocarbon inventory, the flare was only used for cold-venting.
- Drainage systems. The drains on the Brent Delta platform were divided into those serving hazardous areas, non-hazardous areas and living quarters. They were used to manage permitted discharges to sea through the use of oil/water separators.

3.3 Final Inventory of Materials

Table 3 provides an inventory of the materials that were estimated to be present in or on the Brent Delta topside when it was removed. Together, carbon steel and stainless steel accounted for approximately 90% of the mass of the topside. Section 4.5 summarises how the topside were prepared for removal.

Please note that in Table 3 the columns "Disposal Method" and "Actual Amount" will be completed in the final close out report.

Table 3. Brent Delta Topside Estimated Inventory of Materials.

Brent Delta Topside, estimated inventory of materials					
Material	Unit	Estimated Amount	Notes	Disposal Method	Actual Amount
ABS	Tonnes	2	Plastic pipes		
Alloy steel	Tonnes	555	Pipework, pumps		
Aluminium	Tonnes	65	Anodes, engines		
Asbestos (total)	Tonnes	10	Insulation, gaskets		
Batteries	Tonnes	31	Various battery sets		
Butyl rubber	Tonnes	2	O-ring seals		
Carbon steel	Tonnes	19,781	Structural steel, equipment		
Ceramics (all types)	Tonnes	5	White ware		
Chartex/fire protection	Tonnes	80	Penetrations		
Copper	Tonnes	84	Pipes, cables, transformers		
Copper nickel alloys	Tonnes	309	Pipe valves, pumps		
Cork	Tonnes	2	Lifebuoys		
Cotton	Tonnes	6	Bedding		
Cutting residues	Tonnes	12	Drill cuttings		
EPDM	Tonnes	11	Cables		
Ethylene/Polypropylene	Tonnes	85	Cables		
Fire foam	m^3	20	Firefighting systems		
Fluorescent tubes	Number	3,446	Lighting		
Formica	Tonnes	2	Living areas		
Glass	Tonnes	5	Living areas		
GRP	Tonnes	20	Replaced floor grids		

Brent Delta Topside, estimated inventory of materials concluded					
Material	Unit	Amount	Notes	Disposal Method	Actual amount
Hydrocarbons	Tonnes	<1	Residual hydrocarbons in dead-legs		
Inconel/nimonics	Tonnes	13	Generators		
Insulation	Tonnes	104	Structures, pipes		
Iron (cast)	Tonnes	3	Weights		
Lead	Tonnes	11	Batteries		
LSA scale	Tonnes	69	Pipework, vessels		
Neoprene	Tonnes	5	Various		
Ni-resist	Tonnes	10	Pump valves		
Nylon	Tonnes	10	Electrical equipment, ropes		
Paint	Tonnes	899	Paint on structured steel		
Pb-210	MBq	117	LSA scale		
Plastics	Tonnes	5	Floor coverings		
PVC	Tonnes	61	Cable covering		
Radium (Ra-226)	MBq	711	LSA scale		
Radium (Ra-228)	MBq	476	LSA scale		
Rubber	Tonnes	20	Floor coverings		
Stainless steel	Tonnes	1,371	Pipes and vessels		
Titanium	Tonnes	31	Pipes and machines		
Wood	Tonnes	7	Accommodation		
Zinc	Tonnes	499	Anodes, paint, galvanising		
Approx. Total Weight	Tonnes	24,186			

4 PREPARATION OF TOPSIDE FOR REMOVAL

4.1 Introduction

The decommissioning of Brent Delta involved ground-breaking and innovative engineering work leading up to the largest-ever marine lift in the North Sea. The SLV method was selected by Shell after analysing several studies to determine the best method of removal.

The marine warranty surveyor DNV-GL (formerly Noble-Denton) reviewed and accepted all relevant calculations, specifications, procedures and marine spread for the programmes of work for removal, transportation and load-in, such that a Certificate of Approval was provided to assure Shell's insurers that the marine activities were ready to proceed safely. Bureau Veritas provided an independent verification of platform modifications of Safety Critical Elements (SCE) that affected the Dismantlement Safety Case.

The technical requirements for which compliance was demonstrated included:

- Lloyd's Register Class requirements for Dynamic Positioning Class 3 Standard and appropriate redundancy concept for DP system.
- Robustness against Single Point Failures of Ballast, Power Management, Dynamic Positioning and Lifting System Failures.
- Application of Two Compartment Damage Stability Standard.
- Strengthening of Topside such that the Support Structure is Robust against Worst Combination of Loads Corresponding to Failure of a single Lifting Point.

4.2 Plug and Abandonment of Wells

Before the topside was removed, all of Brent Delta's 40 wells[1] were plugged and made safe. This programme of work was performed in accordance with the *Oil and Gas UK Guidelines for the Suspension and Abandonment of Wells*, and was completed in June 2014.

4.3 Removal of conductors and pipework

The topside was linked to the GBS by pipework in the utility leg and by conductors in the two drilling legs. Most connections were severed at approximately 16m above the height of the lowest astronomical tide (LAT), that is, slightly below the 19.8m LAT height at which the concrete legs were cut. Other connections were cut at a lower level but all were cut above the seabed. The upper parts of the conductors were retrieved as part of the wells P&A programme and recycled onshore. This allowed a scaffold work-platform to be installed inside the top of each leg for the deployment of the diamond wire cutting (DWC) equipment to cut the legs.

In addition to the items removed from inside the legs, four of the external caissons were cut and removed to ensure they did not interfere with vessel operations.

[1] There were 48 well slots on Delta but 8 were conductor only.

4.4 Preparation for Lift

Structural preparations for the removal of the Brent Delta topside started in the summer of 2014.

To allow the lifting beams of the SLV to make secure contact with the topside, and to ensure that the topside was strong enough to be lifted in this way, eight specifically- designed steel lift points ("cruciforms"), weighing between 15 tonnes and 20 tonnes each, were welded in to place on the underside of the deck in the summer of 2015 (Figure 6 and Figure 7). This was an extremely complicated programme of work which required a large amount of scaffold access and the installation of underdeck runway beams to allow the lift points to be installed. The installation of the underdeck runway beams required the removal of some of the underdeck fixtures and fittings. After the lift points had been installed, sections of the runway beams were removed and laser surveys were performed to provide Allseas with the exact positions of the lift points.

Figure 6. A Cruciform Strengthening Beam being Lifted into Place on Brent Delta.

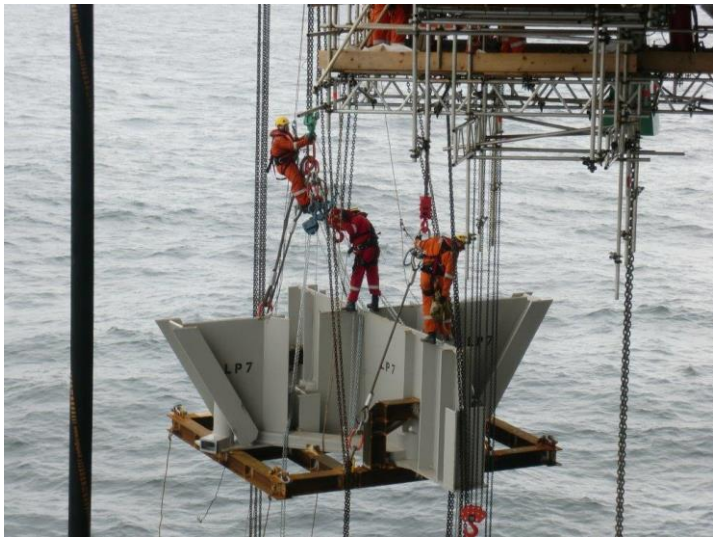


Figure 7. A Cruciform Strengthening Beam in Place under the PGDS on Brent Delta.

The topside required strengthening with additional steel in order to bear the forces that would be exerted during removal. A significant number of steel doubler plates were welded in place on the primary steel bulkheads of the Module Support Frame (MSF); this required the removal of some local obstructions.

Clearance zones were created in each of the legs to allow personnel to access the area to cut the legs, and to ensure that the DWC would not snag or break on any internal components. A variety of cables and pipes,

H-VAC ducts, access stairs and a lift shaft were removed in the utility leg. In the drilling legs, all of the pipework around the cut zone was removed.

Before cutting the legs, steel "shear restraints" were fitted inside each leg at the cut zone, to ensure that the cut legs did not move in the interval between cutting the legs in the summer of 2016 and lifting the topside in the summer of 2017. To permit the shear restraints to be fixed securely in place, the concrete surface at the top of the concrete ring beam on the inside of each leg was cleared of obstructions. The shear restraints were pre-fabricated in sections; each section was installed and bolted to the concrete and shim plates were fitted between each section (Figure 8 and Figure 9). Once the complete ring was in place, the gap between steel and concrete was filled with grout.

Figure 8. Shear Restraint being Assembled Dry Onshore.

Figure 9. Shear Restraint Fitted Inside a Leg on Brent Delta.

Allseas also identified 4 modules on the Module Deck where additional strengthening was required to the main steelwork. Again, some removal of local obstructions was required before the stiffeners could be welded in place.

Lastly, Module Sea Fastening was carried out on 19 modules and packages that were supported on either the MSF or the module below. This required sea fastening plates to be welded between the modules and their supporting structure; the derrick was also secured.

The design reports for the under-deck strengthening and the Dismantlement Safety Case were accepted by the UK Health and Safety Executive (UK HSE) in 2016, well in advance of the 2017 lift. The whole structure was checked for loose or damaged items and components, and these were either repaired or removed.

4.5 Cleaning of topside process facilities before removal

The topside process systems were drained, purged, and vented (and in some cases also flushed), as appropriate, to ensure no pockets of hydrocarbon liquid or gas were present before the topside was removed. Additional vents were created at selected locations in the topside process system to ensure that they were not recharged from any trapped inventories, and drained systems were left open to the atmosphere to allow free-venting to occur so that gases did not build up.

It was known that residual material may have accumulated in 'dead legs' (such as the bends of pipes) but large quantities were not expected to be present; by virtue of their location such residual materials were not likely to escape during lifting or transportation.

Due to the possibility of needing to re-man the topside briefly before the lift, a small volume of diesel was left on the platform; the tonnage and location were included in the final inventory in the *Brent Materials Inventory Technical Note*. Any potential leak sources that were created in the preparation for the removal of the topside were managed through each individual work-pack associated with each project scope.

An overview of the tanks and vessels that were cleaned was provided to Able and it was made clear that all other tanks and vessels should be sampled before dismantlement. The majority of lubricating ('lube') oils were removed and shipped to shore for disposal before the removal of the topside, but oils within sealed systems were left because (i) they were present in only small quantities and, (ii) their removal would have involved breaking open systems which could have damaged the equipment and resulted in it being scrapped instead of reused. As the volumes involved were small and the systems remain closed there was a very small risk of spillage.

During the topside preparation scopes, all drains within the modules were flushed, plugged and capped. Drains outside the modules were retro-jetted and left open to sea to stop rain water gathering. Brent Delta had two drain tanks; one was cleaned and dismantled, and the other was emptied and left isolated.

Any liquids present on the topside were collected in drip trays and bunds. The remaining chemicals were containerised and oils were transferred to tote tanks (transportable containers) before being shipped to shore for disposal (except for the chemicals/oils required for maintaining the equipment for a possible re-manning; these oils were secured in a bunded container).

Following CoP in December 2011, fifteen of the sixteen oil storage cells in the GBS had been emptied of bulk oil and therefore contained attic oil and interphase material, water and cell sediment. The remaining oil storage cell contained approximately 5,000m^3 of produced oil and emulsion. Any oil derived from topside cleaning was routed into this cell for temporary storage. On completion of the topside cleaning operations a final oil export run was undertaken in July 2015, to ensure that as much oil and emulsion as possible was removed from this cell before the topside was lifted.

4.6 Cutting the legs

The topside was fixed to the top of the legs by 5.5m long steel transition pieces located at +19.8m LAT, just above the ring beam at the top of the concrete legs (Figure 10).

In order to separate the topside, a DWC machine was deployed inside the legs to cut through the grout and the bolts that secured the transition pieces to the ring beams (Figure 11). To make the cuts, holes were drilled at intervals around the wall of the leg so that the wire of the DWC could be passed out and round a section of the leg wall (Figure 12). All of this work was carried out from the scaffold platform inside the top of each leg but personnel had to use rope access on the outside faces of the legs to pass the diamond wire back through the holes to create the wire loop. As each section of leg was cut, steel corner plates were fitted to the shear restraints and these provided the means of holding the topside securely in place once the leg was fully cut.

The topside remained stable and in place on top of the legs by a combination of its great weight, friction between the cut ends of the transition pieces and the tops of the ring beam, and the shear restraining supports.

Figure 10. Location of the Cut Line at the Top of the Concrete Leg.

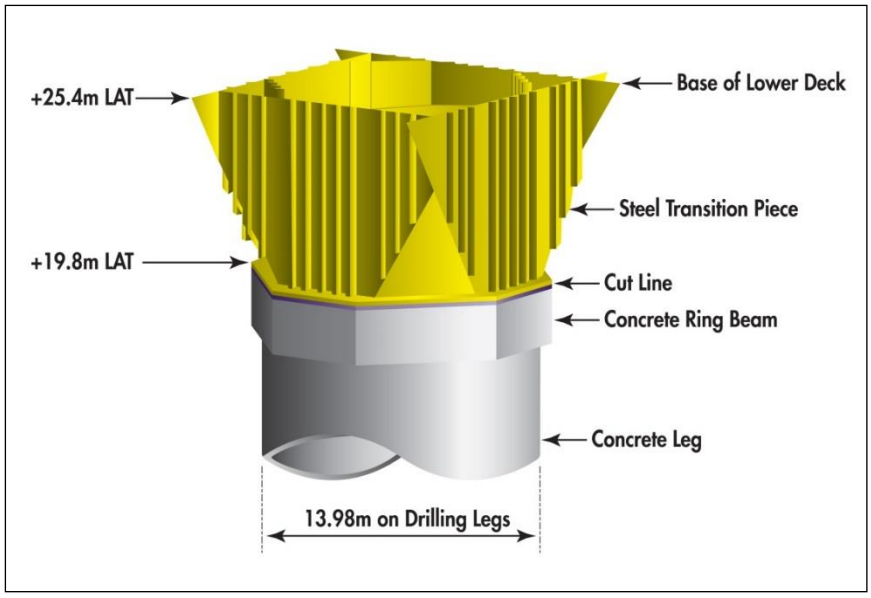


Figure 11. Cross-section through the Top of a Leg and Ring Beam.

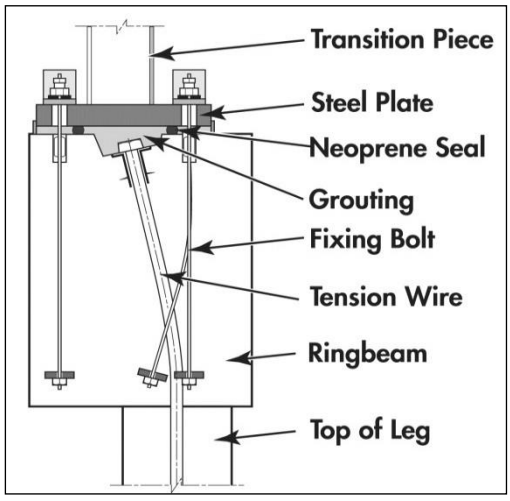
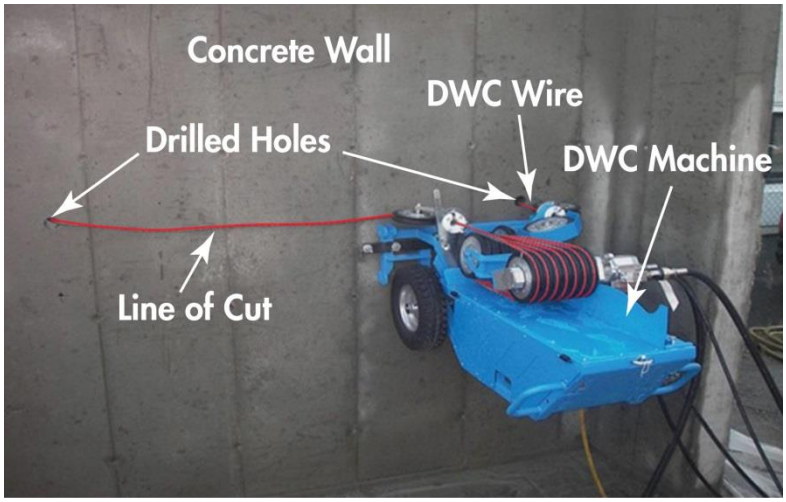


Figure 12. Using a Diamond Wire Cutting Machine on Concrete.



4.7 Removal of Attic Oil

When Brent Delta was in production, the 16 GBS cells were used to store oil prior to export. In preparation for CoP and subsequent decommissioning, the final amounts of crude oil were exported from the cells and replaced by seawater. Because of the shape of the cell domes, however, and the configuration of the oil export line inside the domes of the Brent Delta cells, a small volume of crude oil and emulsion remained trapped in the upper domes of the cells and could not be removed by the platform export system. This material, which amounts to about 50m^3 in each cell, is referred to as "attic oil" (Figure 13 and Figure 14).

Shell has undertaken to remove this material and take it to shore for treatment, recycling or disposal as appropriate. A recovery programme has been started, in which attic oil from three individual cells was transferred into a single holding cell in preparation for pumping to a tanker for transportation to shore. Some of this work was undertaken from the topside before the lift in 2017. The rest of the work will be performed from a vessel and does not require the topside to be in place. The outcome of the attic oil removal programme will be described in the close-out report for the Brent Field DP.

Figure 13. The Materials in a Brent Delta GBS Storage Cell at CoP.

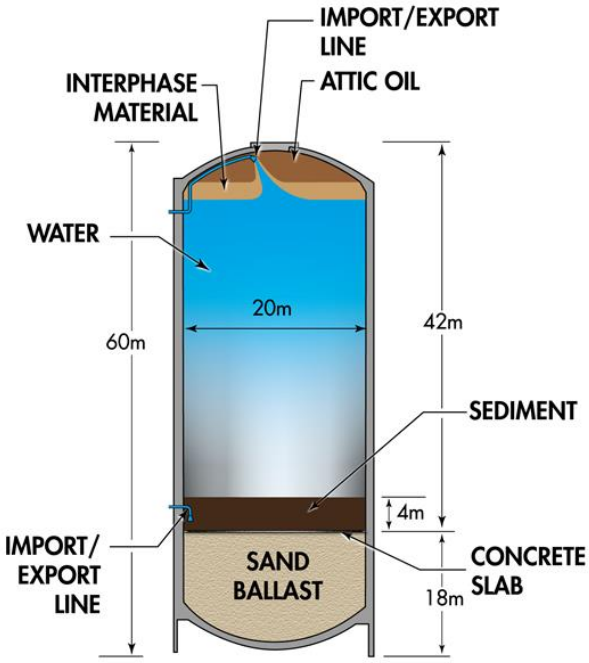
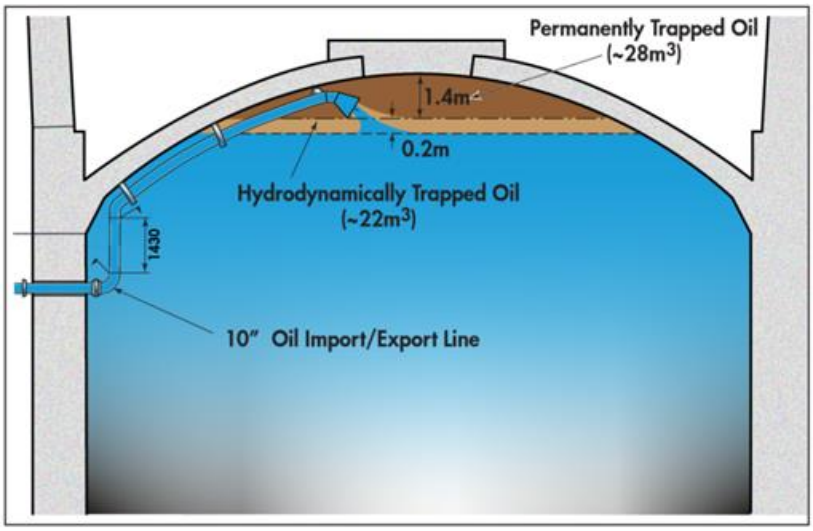


Figure 14. Schematic Diagram of the Attic Oil in a Storage Cell on Brent Delta.



4.8 Unmanned Period

On completion of the preparatory phase, the platform was left unmanned for approximately 9 months. Interim navigation aids were fitted to the platform to warn vessels, and an obstruction light was fitted to the top of the flare to warn aircraft. Both these aids were powered by solar-panels and batteries that were fitted on the topside before they were unmanned.

The state of the topside was monitored until the lifting programme to ensure that it remained in a condition suitable for lifting and did not deteriorate. Monitoring was undertaken in several ways. After the legs had been cut, a motion-monitoring device was fitted to the legs to measure the movement of the topside over the winter. The existing sensor in the utility leg monitored the water level to ensure that it stayed within a pre-determined range in order to maintain the integrity of the GBS structure.

Once the Brent Delta platform had been unmanned, a visual survey using a 'Cyberhawk' aerial drone took place in July 2016 to record the condition of the platform before the onset of winter. A second survey was performed in March 2017, before the start of the topside removal programme. This survey covered the same pre-programmed flight path as the first survey, and was used to undertake a visual check for deterioration, damage and the presence of loose components or items of equipment.

5 REMOVAL AND LOAD-IN OF TOPSIDE

5.1 Lifting the topside

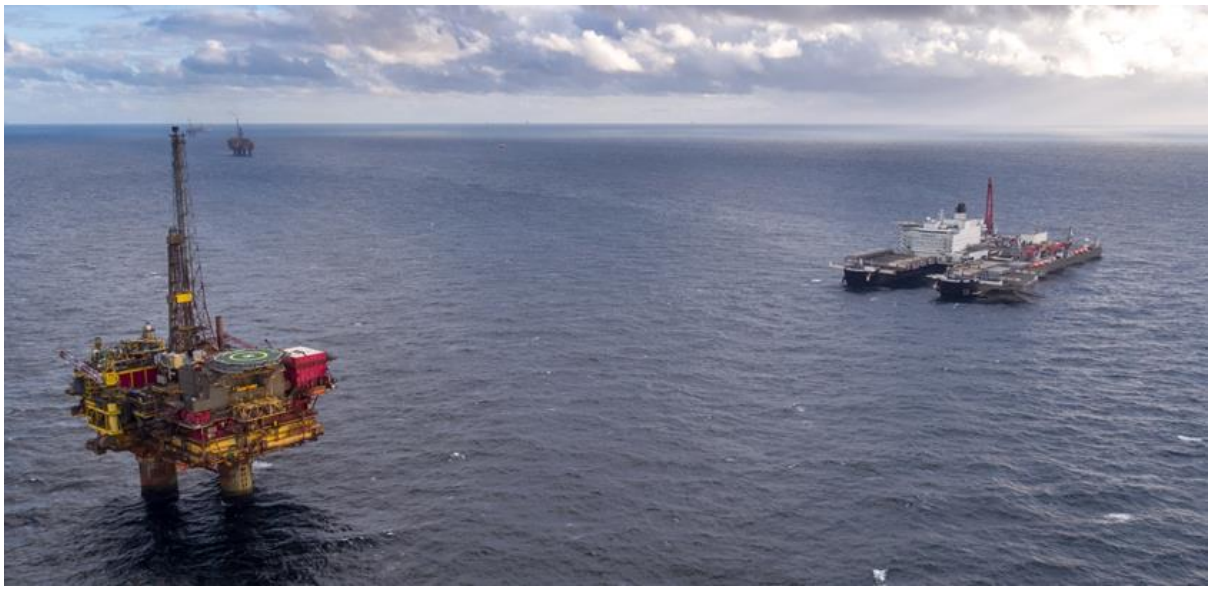
The Brent Delta topside was lifted from the GBS as a single piece by the SLV *Pioneering Spirit*, in an operation that took about 2 days. The SLV mobilized from the Alexia harbour in Rottterdam on April 25th 2017, and sailed directly from Rotterdam to the Brent Field. On April 28th 2017 the vessel entered the Delta 500m safety zone and proceeded to lift the topside. Table 4 provides information on the durations of the various phases of the operation to remove the Brent Delta topside.

Considerable effort was made to mitigate the likelihood of the Brent Delta topside toppling during removal, transportation or back-loading. In 2016 the vessel performed a series of trial lifts using part of a redundant platform weighing 5,000 tonnes as a test facility. Allseas also used the *Pioneering Spirit* in 2016 to lift the topside of the Yme platform[2], which weighed approximately 13,000 tonnes. Together, these two activities provided further assurance that any unforeseen issues in design, systems or operating procedures had been identified and resolved before the Brent Delta topside was lifted in 2017.

Topside removal operations took place during a suitable 'weather window' which was clearly defined by the maximum limits for sea state and wind speed. Before finally committing to the operation, a detailed weather forecast was obtained by the Metocean engineer based on the vessel to determine whether the weather conditions would be within the design limits for the lift and a safe voyage to a predetermined safe-harbour location afterwards.

After completing pre-operational checks on the dynamic positioning (DP), ballast and lift systems, the vessel was granted formal approval from Shell and the Marine Warranty Surveyor to enter the 500m safety zone and begin operations (Figure 15).

Figure 15. The SLV *Pioneering Spirit* aligning with the Brent Delta platform.



The vessel was accurately positioned so that the GBS legs fitted into the vessel's slot (Figure 16); the clearance between the vessel's hull and the platform substructure was sufficient to allow for some movement of the vessel. The beams of the Topside Lifting System (TLS) were fully retracted to provide the maximum clearance between the SLV and the substructure when manoeuvring. Positioning was achieved by using a

[2] Yme is a platform in the Norwegian sector of the North Sea, operated by Talisman Energy Norge AS.

combination of the *Pioneering Spirit's* advanced DP system, a global reference system and a local reference system fitted on the platform substructure during the preparatory phase.

Figure 16. TLS Beams Extending from both Hulls of the *Pioneering Spirit*, Brent Delta, April 2017.

The SLV was stationed beneath the topside and the 16 large beams of the TLS (paired into 8 fork-lift units) were positioned under the prepared lift points on the underside of the PGDS (Figure 17). Each fork-lift unit was fitted with a yoke (lifting pad) that fitted on to one of the topside lifting points and was kept positively in touch with the topside by a hydraulic system that compensated for the movement of the vessel.

When all of the beams and yokes were in place, the SLV was progressively deballasted so that it took nearly all of the topside weight. The final lift to take the topside clear of the top of the legs was accomplished in less than one minute by a combination of a hydraulically-actuated upward thrust of the yokes and some fast deballasting of the SLV (Figure 18).

Once clear of the legs further deballasting took place in order to create clearance of the underside of the lifting arms and the GBS tops to allow the vessel to move away from the GBS legs. Once the vessel was clear of the GBS legs, the hull connection beam was closed and the vessel was ballasted to its transit draft and all the X, Y and Z drives of the lifting arms were placed into sea-fastening mode ready for transit (Figure 19).

Figure 17. Lifting the Brent Delta topside using the SLV *Pioneering Spirit*.

Figure 18. Brent Delta Topside Lifted Clear of GBS legs, April 2017.

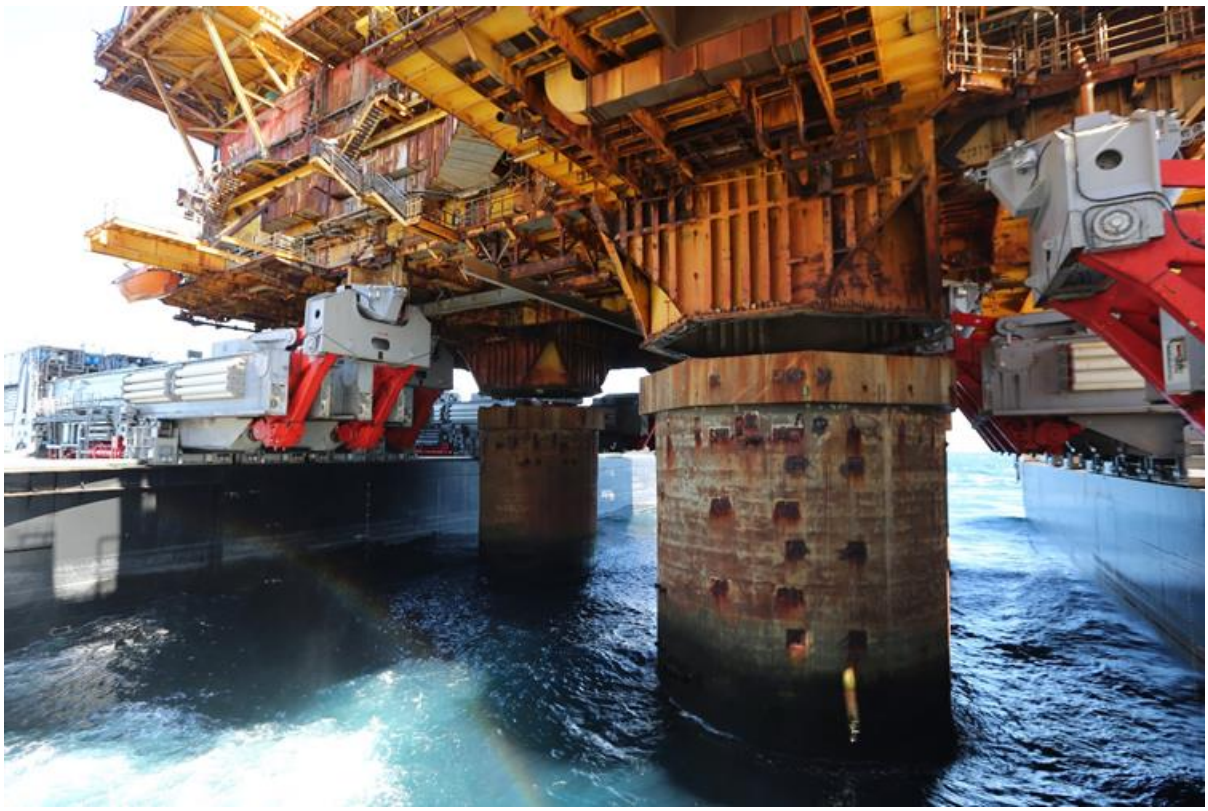


Figure 19. Preparing Brent Delta Topside for Transportation, April 2017.

5.2 Fitting navigation aids and condition of the Brent Delta GBS after removal of topside

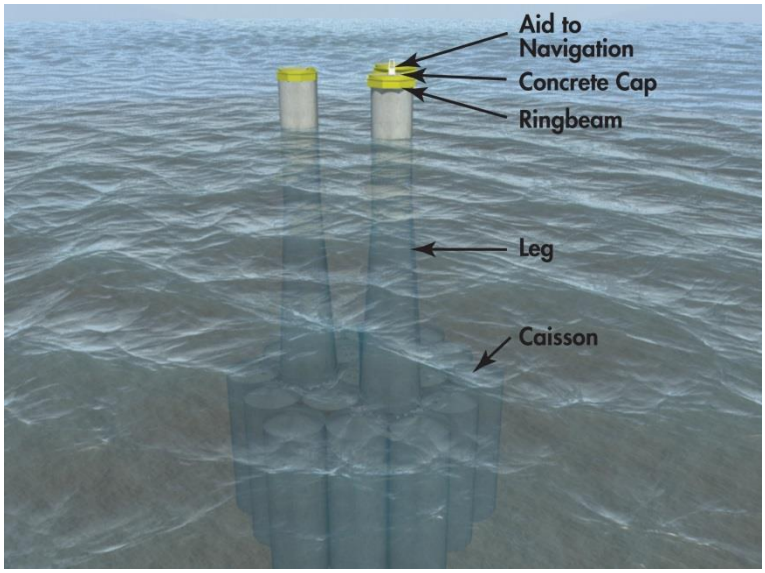
The GBS has been left with all three legs protruding 19.8m above the sea. The attainment of this condition does not pre-judge the outcome of the proposals for the decommissioning of the Brent Delta GBS, as described in the *Brent Field DP* and the *Brent Bravo, Charlie and Delta GBS Decommissioning Technical Document*.

After securing the topside on the SLV, the vessel was repositioned so that its cranes could fit concrete caps onto the open end of each leg. The caps on the two drilling-legs weighed approximately 270 tonnes and the cap on the smaller utility-leg weighed 240 tonnes; this cap was also pre-fitted with Aids to Navigation (AtoN) (Figure 20). The AtoN is designed to operate remotely and be maintained/changed-out by helicopter or vessel without any need for personnel to be put on to the leg. Figure 21 shows the condition of the three protruding legs of the Brent Deltas substructure after the removal of the topside and the fitting of the concrete caps. The existing 500m radius safety zone around the Brent Delta GBS remains in place.

The proposed decommissioning of the Brent Delta GBS itself is included in the *Brent Field Decommissioning Programmes document*.

Figure 20. Fitting the Concrete Caps and AtoN to the Brent Delta GBS Legs, April 2017.

Figure 21. Condition of the Brent Delta GBS after removal of the topside



5.3 Transportation to near shore transfer site

The topside was carried on the SLV (Figure 22) to the estuary of the River Tees which is some 388 nautical miles from the Brent Field. The SLV proceeded under her own power and this voyage took about 50 hours (Table 4). Operational procedures, based on acceptable accelerations and subsequent loads in the structure determined the vessel's maximum speed in different sea conditions.

The topside was considered 'cargo' in this phase of the project and because it contained some hazardous materials that were subject to special permitting requirements, these materials were itemised in the vessel's cargo manifest and all necessary permits and consents were obtained for the carriage and movement of these materials. The removal and transportation of LSA scale, for example, was in accordance with the Radioactive Substances Act (RSA) 1993. All sealed radioactive sources, for example in instruments and

gauges, were transported in accordance with the International Maritime Dangerous Goods (IMDG) Code 2011 which is mandatory under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).

Shell worked closely with the appropriate Regulators and local Marine/Harbour authorities to ensure that all the contingency plans were in place before removing the topside in 2016. Emergency response plans were in place for the removal and transportation activities including a Brent Field System Oil Pollution Emergency Plan (OPEP) incorporating a contract for specialist response services through Oil Spill Response Limited (OSRL). Once the topside was secured on the SLV, the emergency response reverted to the vessel's Shipboard Oil Pollution Emergency Plan (SOPEP). A bridging document was in place between Shell and Allseas to confirm all of the responsibilities and response arrangements. The OPEP in place for the Brent Field, has been updated to reflect the lift and legs left in place.

Well before the lift Shell, Allseas, Able, the Marine Warranty Surveyor and Harbour Master performed a detailed Marine Hazard Identification (HAZID) exercise for the transfer, tow-in and load-in of the Brent Delta topside. This was informed by the knowledge that was gained from the transfers and load-ins that were performed in and around Teesside over the last few years. Shell also undertook an Environmental Societal and Health Impact Assessment (ESHIA), bearing in mind the inventory of materials that would be present on the topside when it was ready to be removed. The Delta Dismantlement Safety Case, detailing the management of the remaining offshore Major Accident Hazards (MAH), was issued and approved, along with the associated environmental Department for Business, Energy and Industrial Strategy BEIS permits.

Figure 22. Brent Delta Topside en route to Teesside on SLV *Pioneering Spirit*, April 2017.

5.4 Transfer of topside from SLV to ASP facility

There was insufficient water depth at the ASP facility for the *Pioneering Spirit* to moor alongside the quay. The Brent Delta topside was therefore transferred to Quay 6 of the ASP facility using the Allseas' cargo barge, the *Iron Lady*, which is approximately 200m long and 50m wide (Figure 23).The *Iron Lady* was mobilised from Rotterdam port and was towed directly to the transfer site by tugs. Prior to sailing, the barge was fitted with grillage beams, sections of skid beams on top of the grillage beams, pre-installed skidding equipment (Skid Shoes, Push/Pull units and Teflon pads) and three steel "Support Stools". These Support Stool structures (weighing approximately 500 tonnes each) are designed to transfer the loads of topside into the barge structure; they were designed for the removal of both the Brent Delta and the Brent Bravo topsides.

Figure 23. The cargo barge *Iron Lady* during construction.

The topside was transferred to the cargo barge *Iron Lady* at a designated nearshore transfer site which is a circular area of 2.78km diameter centred on 54°44.0' N, 01°06.0' W. The centre of this area is approximately 5.5 nm from the mouth of the River Tees and approximately 3 nm from the nearest coastline (The Headland at Hartlepool), and has a water depth of approximately 35m (Figure 24). Transfer operations were conducted during very specific weather and Metocean conditions.

At the transfer site, the hull connection beam was opened and the mechanical lock (sea fastening) of the TLS beams was undone. The barge was then manoeuvred into the slot using tugs and pre-rigged mooring wires from the SLV (Figure 25). The transfer was performed by ballasting the SLV and deballasting of the cargo barge so that the short steel leg transition pieces below the PGDS engaged with the Support Stools, and the whole topside weight was subsequently transferred to the barge (Figure 26).

The ballasting and deballasting of the *Pioneering Spirit* and the barge were carefully controlled and coordinated to ensure that both vessels stayed horizontal and level. Load monitors on the TLS beams confirmed that the load had been successfully transferred. The TLS forklift units were then fully retracted to create maximum clearance for the barge to be towed out of the slot. Upon completion of this operation, the *Pioneering Spirit* demobilized back to the Netherlands in preparation for its next project.

Figure 24. Location of the transfer site off the River Tees.

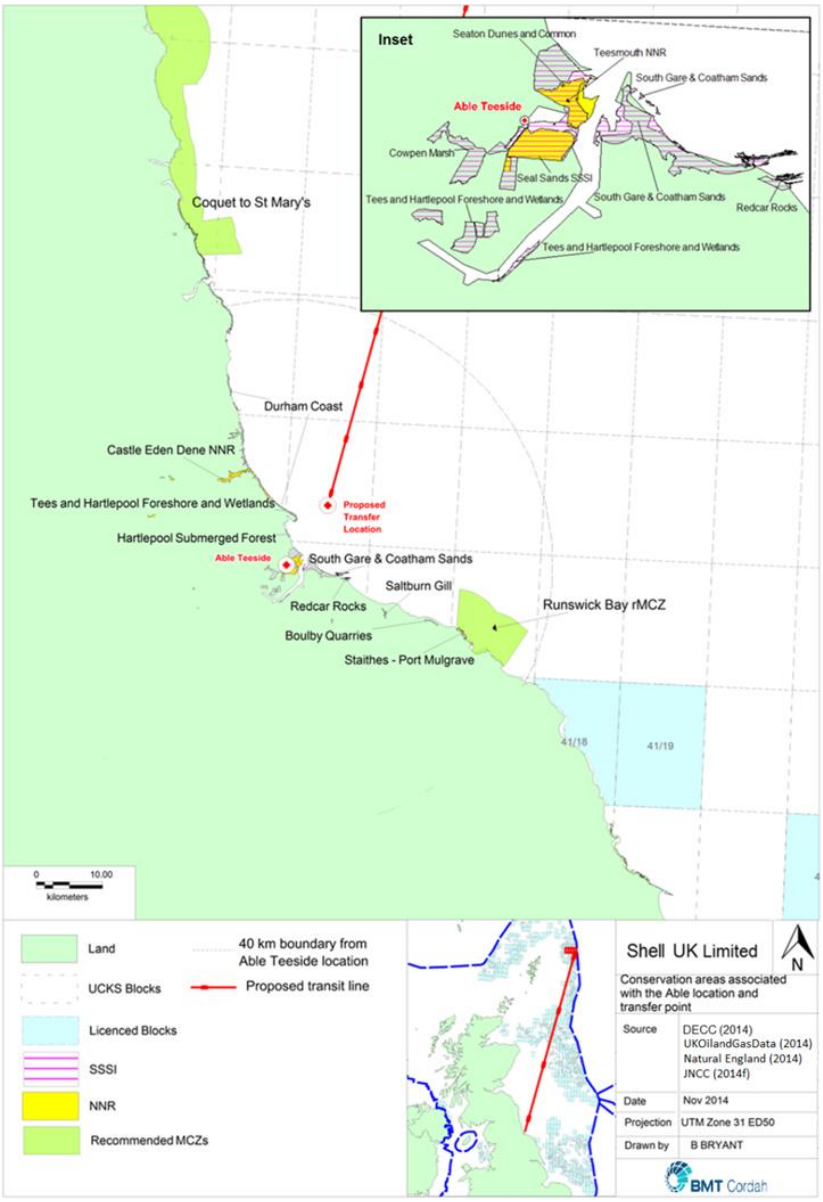


Figure 25. Inserting the *Iron Lady* into the Pioneering Spirit at Nearshore Site, May 2017.

Figure 26. Transferring the Brent Delta topside from the Pioneering Spirit to the Iron Lady.

The barge was towed by four tugs to Quay 6 of the ASP facility. The timing of this operation was determined by the tide as the barge required a high tide to enter the Seaton Channel and into the dock at Quay 6. The barge was first towed to the 'Turning Circle' in the River Tees, where it was more sheltered from the sea whilst waiting for optimum tide conditions for the final part of the tow through the Seaton Channel to the ASP facility. At the ASP facility it was moored with its stern to the quayside and then carefully ballasted until it rested on the pre-installed grounding pad (Figure 27 and Figure 28). Ballasting control was also used to ensure that the barge remained on the grounding bed during tidal changes and load transfer from the barge to the quay.

At the ASP facility, the contractor Mammoet fitted skid beams from the quay, across the quay wall and onto the barge. To ensure that the tracks were level, the skid beams were shimmed and grout was installed underneath them. These metal skid beam tracks are fitted with Teflon blocks, and the bases of the skid shoes are stainless steel. With the addition of a lubricant this combination of Teflon and stainless steel has a very low friction, allowing heavy loads to be moved with limited force. The skidding operation therefore comprised many hundreds of small movements in which Skid Shoes lifted the support stools and the topside vertically and the Push-Pull Units skidded the topside laterally. The push-pull hydraulic cylinder expanded by about 1m, and pushed the load along the track by gripping the skid tracks. After each stroke the cylinder was retracted, locked onto the next section of skid track and the skidding process repeated. The various cylinders were grouped hydraulically to synchronise all their movements during the skidding operations, and each stroke was verified by software to control the operation. In this way, the approximately 25,500 tonnes topside and Support Stools was skidded approximately 160m from the barge to its planned dismantling location on Quay 6. Figure 29 shows the skid rails with their Teflon pads and the large rusty-brown support stools beneath each of the cut legs. The skidding operation was completed in one day, on May 7th 2017 (Figure 30).

Table 4 presents a record of the durations of each of the main phases of the topside removal programme, from the SLV entering the Field to the skidding of the topside onto Quay 6 at the ASP facility.

Figure 27. Indicative mooring arrangement for load-in of Delta Topside to Quay 6 of the ASP facility.

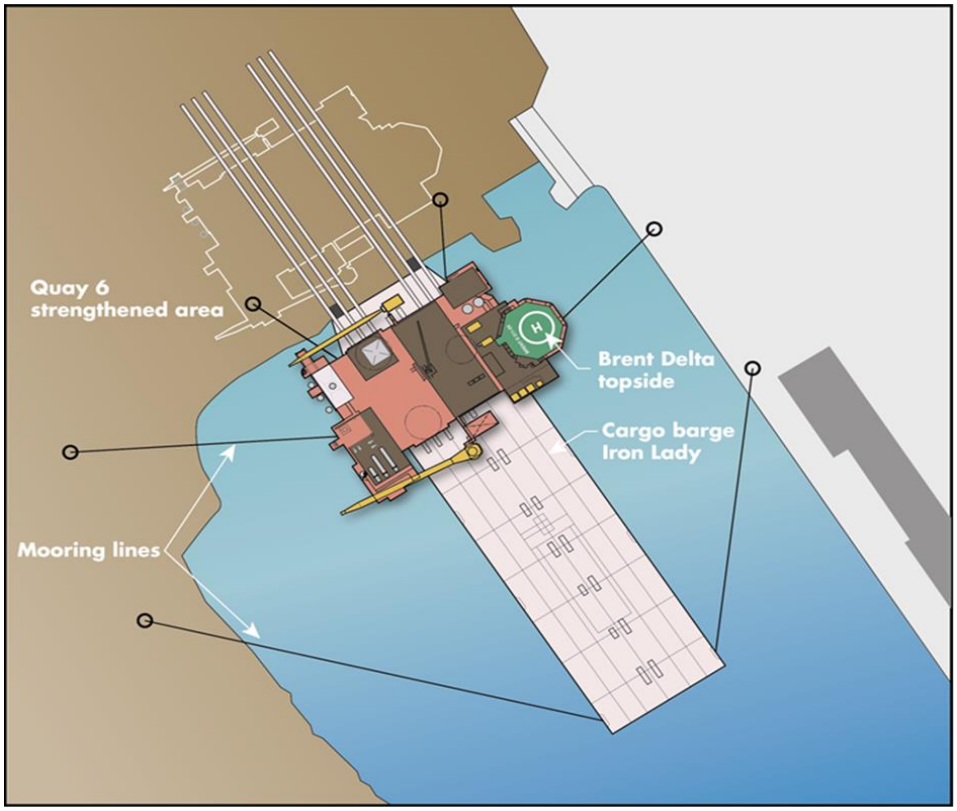


Figure 28. Skidding the Brent Delta topside from cargo barge to Quay 6 at the ASP facility.

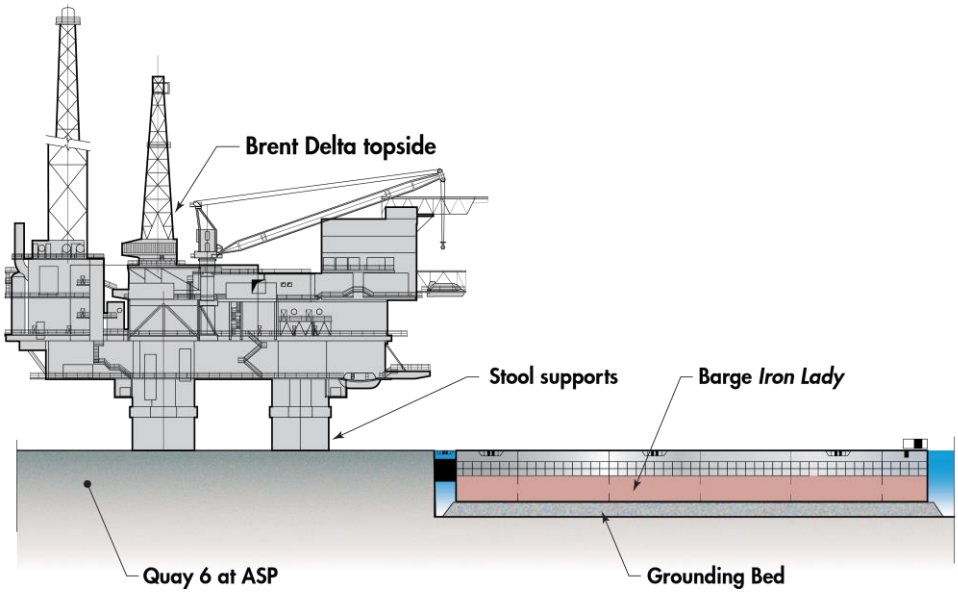


Figure 29. Brent Delta Topside on Skid Shoes and Skid Rail, May 2017

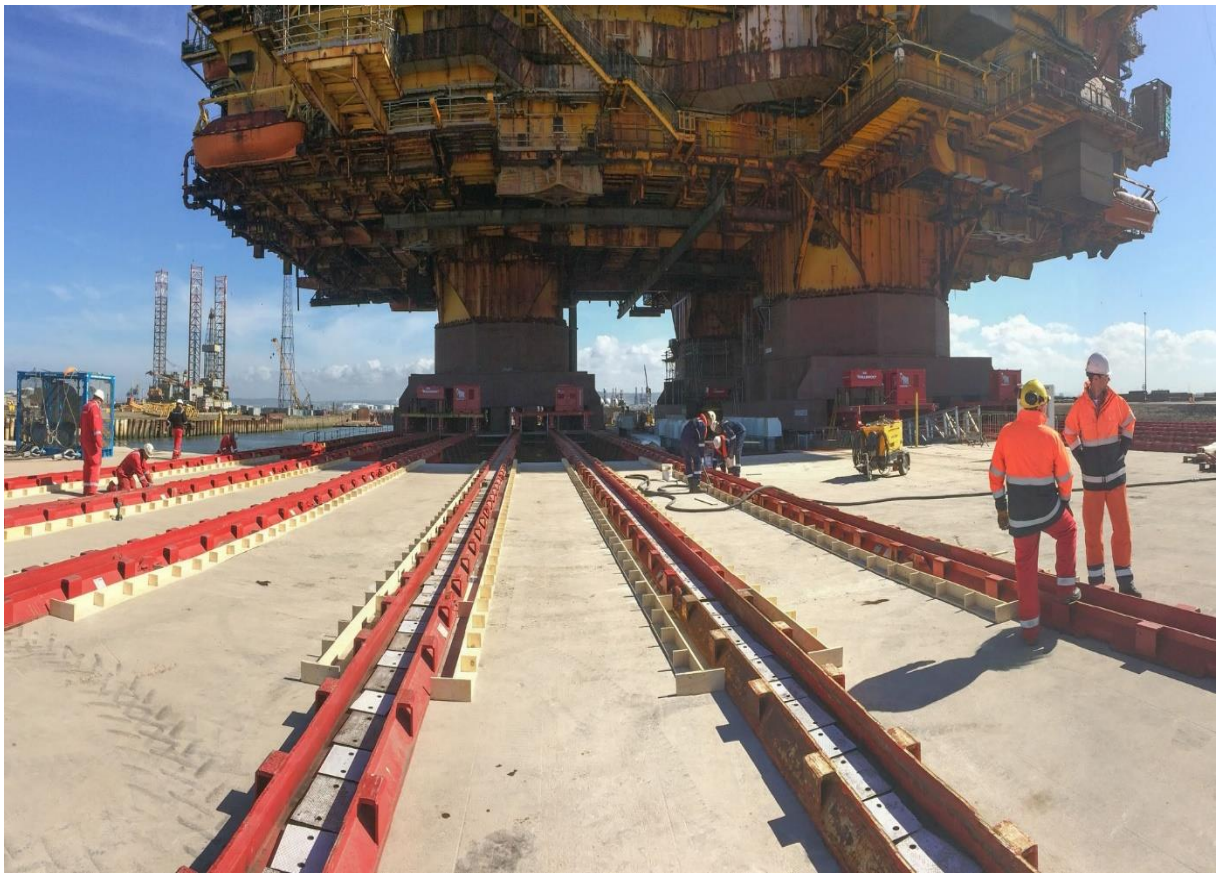


Figure 30. Brent Delta Topside Skidded onto Quay 6 ASP Facility Teesside, May 2017.

Table 4. Summary Data for Brent Delta Topside Lift, 2017.

Aspect	Data
Estimated weight of Brent Delta topside	24,200 tonnes
Measured weight of Brent Delta topside	23,727 tonnes
Time taken to fix all lifting beams, after entering 500m zone	8 hours 56 mins
Time taken from start of deballasting until ready for fast lift	1 hour 35 mins
Duration of fast lift	15 seconds
Initial clearance above leg tops after fast lift	1.5m
Time taken to complete deballasting	5 hours 19 mins
Maximum sea-state during lifting operations	2.1m Hs
Time taken to fit three concrete caps	8 hours 28 mins
Total time in the Brent Field	31 hours 48 mins
Time taken to travel to nearshore transfer site	50 hours 12 mins
Average speed en route to Teesside	7.8 knots
Time taken to transfer topside to cargo barge	16 hours 21 mins
Time taken to transport up river on cargo barge	10 hours, incl waiting on tide
Time taken to skid topside from cargo barge to quay 6 at ASP facility	10 hours

6 POST-TOPSIDE REMOVAL ACTIVITIES

6.1 Information to 3rd Party Users of the Area

After the removal of the topside; the GBS was entered into the FishSAFE programme of electronic warning, the UKHO and MCA were notified, and a Notice to Mariners was issued so that other users of the sea could amend their charts. The AtoN that has been fitted was approved by the UKHO and the UK Coastguard.

6.2 Monitoring and Maintenance

Since the removal of the Brent Delta topside and installation of the AtoN, and ahead of BEIS' decision on whether to approve the *Brent Field DP*, Shell have initiated an agreed interim programme of monitoring and maintenance to ensure that the AtoN on Brent Delta remain in working order. The variation of the Consent to Locate permit has been approved by BEIS. Weekly checks are being carried out by the standby vessel as agreed with BEIS. Until the remaining Brent facilities are decommissioned, it is most likely that this will be achieved by visual monitoring from the other Brent platforms, the Brent Field standby vessel and other vessels operating in the Field. The AtoN will be replaced every 4-5 years or on failure. A monitoring contract has been established with Compower, the supplier of the unit, which allows failures of the system to be detected via GSM or satellite communications. The AtoN is dual-redundant to maximise availability.

If the AtoN has a single failure which is identified by the monitoring procedures, depending on the severity of the failure, the spare unit located at Shell's storage base in Aberdeen will be mobilised and exchanged for the faulty unit. The faulty unit will be brought back to shore for repair and will be retained as the back-up unit for the installed AtoN in the field.

6.3 Post-topside removal debris clearance and verification

The programme to remove the Brent Delta topside by SLV did not result in the deposition of any debris on the seabed at Brent Delta.

The existing debris on the top of the Brent Delta GBS cells and on the seabed around the GBS will be removed in one or more 'campaigns' which will be performed across the whole Brent Field once all the platforms and pipelines have been decommissioned.

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7 SAFETY AND ENVIRONMENTAL PERFORMANCE

7.1 Technical Safety

In terms of major accident hazards (MAHs), associated safety critical elements (SCEs) and performance standards (PSs) the transition from an offshore installation in production mode through Cessation of Production (CoP), dismantlement and eventually post-dismantlement required strategic safety case revisions to ensure that the document reflected changing installation status. Most of the revisions did not require submission to the Health and Safety Executive (HSE) as they did not constitute a 'Material Change', as defined in the offshore safety case regulations. However, the work associated with cell sampling did require a 'Material Change' submission which was accepted by the HSE. The significant change during this transition from production to dismantlement, in terms of MAHs, was the elimination of the gross hydrocarbon inventory as this represented about 50% of the MAH profile on a production installation.

7.2 Occupational Safety

The introduction by Shell of the 'Safety' project, which focused on a drive towards a fully integrated team approach (onshore/offshore), as well as the introduction of 'Mindsafety', helped improve safety performance. Shell's 'Safety Project' took inputs from various sources through surveys as they embarked on their mind safety journey. It included the notion that the right environment to decommission had to be created and that this investment in turn would encourage a positive response from the workforce. By creating the right environment and driving compliance, maintenance programmes and platform integrity, improvements were seen in safety performance and downtime was improved.

This early investment put in place good foundations which were built upon and gave a strong enough base to meet the challenges which come from the human, engineering, and dynamic aspects of decommissioning, as well as those from the more obvious surroundings themselves.

Shell achieved a positive change in safety culture by taking ownership offshore and driving an improved safety performance. This was particularly evident during the last 7 months of work on Delta before the platform was unmanned which saw the busiest and most complex period of work completed injury free.

During the project, the decision to move from reverse engineering to single lift also provided an important risk benefit. Reverse engineering requires significant offshore man-hours to deconstruct the facility in order to separate the modules for a heavy lift campaign to systematically and sequentially remove and transfer them onshore. It also involves additional flying and marine risks to support the activity, and thereby exposes personnel to offshore occupational and logistical hazards. Conversely, the single lift methodology largely eliminates the need for module segregation, greatly reduces the overall lifting offshore and considerably simplifies the offshore work scope, which in turn reduces the risk factors described above. In this context the single lift approach was considered to provide an overall risk that was as low as is reasonably practicable (ALARP).

Lifting, transportation and offloading were all achieved in 2017 without any occupational safety incidents.

7.3 Comparison with assumptions in the Environmental Impact Assessment

The lifting, transportation, transfer and off-loading of the Brent Delta topside were all performed without any environmental incidents or accidents.

There were no reports of dropped objects, or of any releases of fuel or other liquid contaminants to sea either from the topside or from the vessel spread.

There were no reports of any interactions with marine mammals at the transfer site or during the short tow in the River Tees.

Given the fact that this Brent Delta topside lift was the first such large lift by the SLV *Pioneering Spirit*, the operations were conducted in a timely and efficient manner, and vessel usage was kept to a minimum commensurate with the safe performance of novel lifting operations and the prevailing weather and tidal conditions.

8 SCHEDULE

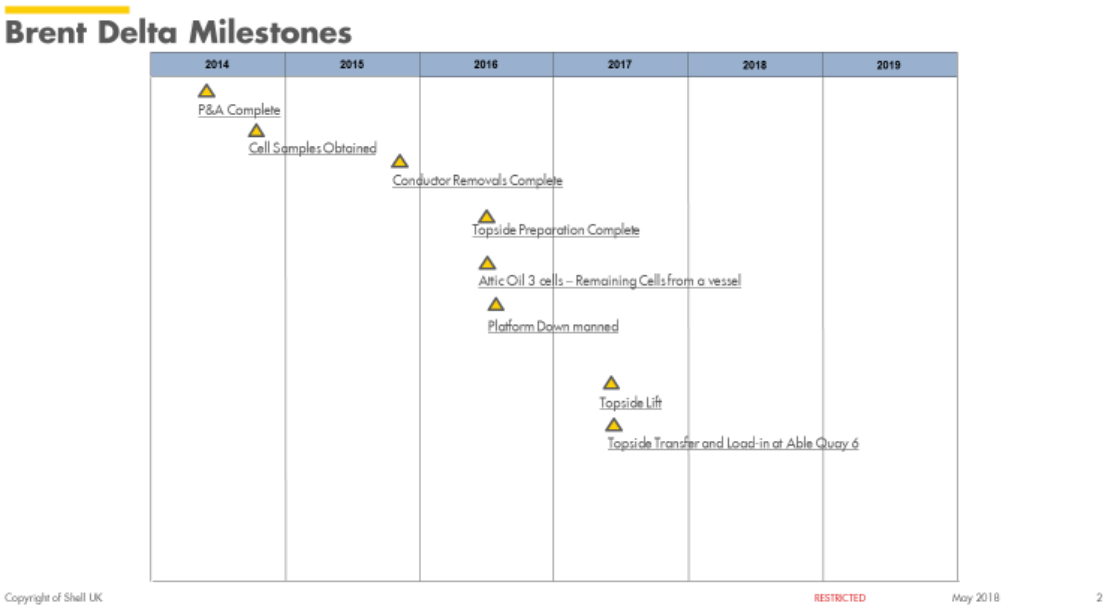
8.1 Schedule

As outlined in the Brent Delta Topside Decommissioning Programme, the Brent Delta topside was due to be removed and placed on Quay 6 at the ASP facility in the summer of 2016.

The *Pioneering Spirit* was still being commissioned in the summer of 2016 due to later than planned completion of the lifting arms, and this ultimately led to the topside being removed in the summer of 2017.

It is anticipated that once dismantling begins it will take approximately 18 months to completely dismantle and dispose of the Brent Delta topside. Figure 31 shows the actual schedule for the decommissioning and removal of the Brent Delta topside.

Figure 31. Summary of Schedule for Decommissioning the Brent Delta Topside.



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9 COST SUMMARY

9.1 Estimate vs Final Cost

An estimate of the overall cost of the programme of work to remove and recycle the Brent Delta topside was provided separately to BEIS before the submission of the Brent Delta Topside DP.

The actual cost of the work, up to the load-in of the Brent Delta topside, has been provided separately to BEIS.

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10 LESSONS LEARNED

10.1 Summary of Lessons Learned

In advance of the removal of the Brent Delta topside by SLV, the owners prepared the installation for CoP, completed a programme to plug and make safe the wells, rendered the topside hydrocarbons-free, and prepared the topside for removal.

The Lessons Learned from this multi-faceted programme of work over approximately 10 years are summarised below.

Project-wide Planning

- Decommissioning needs to be considered early in the EOFL phase, i.e. before CoP
- Lack of planning is likely to erode overall Asset value; early planning is likely to enhance Asset value
- A focus on Abex may highlight the need for early Asset investment
- Transition into the Decommissioning phase is likely to be just as challenging (if not more so) than production
- Start early - CoP is often triggered by an unplanned event – Be Ready!
    - Reduces some risk and ~20% maintenance hours but utility reliability is crucial; e.g. of cranes, power, safety systems
    - Prioritise decommissioning work appropriately pre-CoP: it's a major opportunity to get into a project mindset
- Early strategic decisions will have a major impact to overall decommissioning costs
- Hydrocarbon-free is a more significant milestone than CoP; achieving this milestone can lead to a reduction in maintenance costs of up to 50%.
- A new risk profile means different ways of working
- Engage the market in decommissioning solutions: Continually monitor market conditions to optimise: early input from supply chain
- Organisation Design / People / Skills Planning: improve collaboration between Project / Operations / Wells
- Focus on down-manning, a milestone that has a significant effect on cost and offshore exposure.

Cost-savings

- Typically, over 40% of the decommissioning costs on manned installations are associated with the P&A of platform wells.
- Recognise the hierarchy of value drivers – least to most valuable
    - Wireline P&L before P&A
    - Wireline P&L concurrent with P&A
    - Commence P&A before CoP
- New ways of working are driving down costs (Well P&A) and duration (post-CoP Opex)
    - Individual wells - appropriate P&A barrier philosophy
    - Suitable platform focus

- POB - Integrated rig and asset crew
- Application of new technology/techniques
- Conductor recovery using the platform crane proved to be much cheaper than using the rig.

Work-scopes

- Freeze engineering solution at the right time; a mindset of continuous improvement preserves value
- Flexible execution:
    - Project led, but construction driven
    - Multiple work fronts available for fall back work
    - Flexibility as demand changes, capability to manage/adapt
    - Offshore integration – Platform Services under Project
    - Reduced & simplified interfaces: rapid decision making

APPENDIX 1. TERMS AND ABBREVIATIONS

Abbreviation	Explanation
Abex	Abandonment Expenditure
Able	Able UK Limited
ABS	Acrylonitrile butadiene styrene
ALARP	As Low As Reasonably Practicable
ASP	Able Seaton Port
AtoN	Aids to Navigation
BEIS	Business, Energy and Industrial Strategy
Bq	Becquerel, the SI unit measuring the activity of a quantity of radioactive material
CoP	Cessation of Production
DECC	Department of Energy and Climate Change
DP	Decommissioning Programme
DSC	Decommissioning Services Contract
DWC	Diamond Wire Cutting
DyP	Dynamic Positioning
EIA	Environmental Impact Assessment
EOFL	End of Field Life
EPDM	Ethylene propylene diene monomer (a type of rubber)
ESHIA	Environmental, Societal, Health Impact Assessment
FFPD	Final Field Development Plan
FishSAFE	An electronic means of alerting vessels to the proximity of a structure in the sea.
GBS	Gravity Base Structure
GRP	Glass-reinforced plastic
HAZID	Hazard Identification
HFO	Heavy Fuel Oil
HSE	Health, Safety and Environment
HVAC	Heating, Ventilation, Air-Conditioning
IMDG	International Maritime Dangerous Goods
km	Kilometre
LAT	Lowest Astronomical Tide
LSA	Low Specific Activity (scale)
m	metre
MAH	Major Accident Hazard
MBq	MegaBecquerel, one million (10^6) Becquerels
MCA	Maritime and Coastguard Agency
MSF	Module Support Frame
nm	Nautical miles
OPEP	Oil Pollution Emergency Plan
OPEX	Operating Expenditure
OSPAR	Oslo Paris Commission
OSRL	Oil Spill Response Limited
P&A	Plug and Abandon
P&L	Plug and Lubricate
Pb	Lead
PGDS	Plate Girder Deck Structure
POB	Persons on Board

Abbreviation	Explanation
PON	Petroleum Operations Notice
PVC	Polyvinylchloride
Ra	Radium
RSA	Radioactive Substances Act 1993.
SCE	Safety Critical Element
SLV	Single Lift Vessel
SOPEP	Shipboard Oil Pollution Emergency Plan
STASCO	Shell Trading and Shipping Company
t	Tonne (1,000kg)
TLS	Topside Lifting System
UKCS	United Kingdom Continental Shelf
UKHO	United Kingdom Hydrographic Office
UK HSE	Health and Safety Executive

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