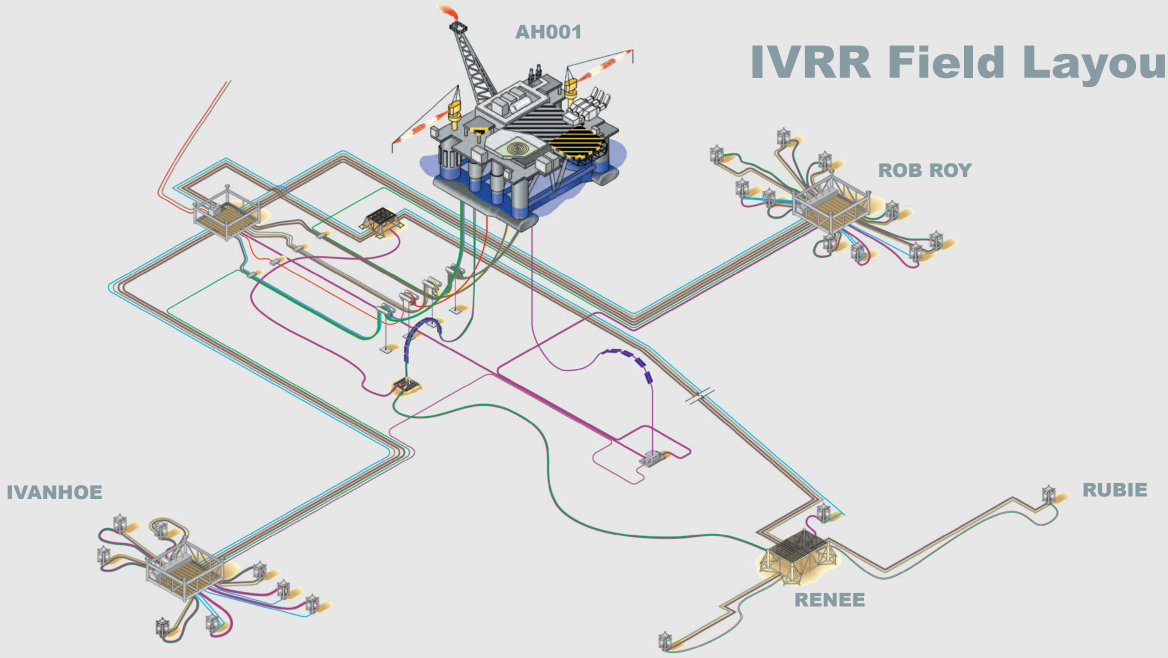
# Ivanhoe and Rob Roy Fields Decommissioning Programmes

## Close-Out Report

IVRR Field Layout

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## Abbreviations

| | |
|---|---|
| BAT/BEP | Best Available Technique and Best Environmental Practice |
| BOP | Blowout Preventer |
| CSV | Construction Support Vessel |
| CU | Control Umbilical |
| CUBS | Control Umbilical Base Structure |
| DECC | Department of Energy and Climate Change |
| DP | Decommissioning Programme |
| DSV | Diving Support Vessel |
| DUBS | Dynamic Umbilical Base Structure |
| EEMS | Environmental Emissions Monitoring System |
| EMT | Environmental Management Team |
| FDP | Field Decommissioning Programmes |
| FFFA | Fife, Fergus, Flora and Angus |
| FPF | Floating Production Facility |
| FPV | Fall Pipe Vessel |
| Hess | Hess Limited |
| HMR | High Magnesium Resistance |
| IVPM | Ivanhoe Production Manifold |
| IVRR | Ivanhoe and Rob Roy |
| JNCC | Joint Nature Conservation Committee |
| LWIV | Light Well Intervention Vessel |
| MBES | Multi-Beam Echo Sounder |
| MCAA | Marine and Coastal Access Act |
| NORM | Naturally Occurring Radioactive Material |
| OBM | Oil Base Mud |
| PAH | Poly-Aromatic Hydrocarbon |
| RBM | Riser Base Manifold |
| ROTV | Remotely Operated Towed Vehicle |
| ROV | Remotely Operated Vehicle |
| RRC | Riser Release Connector |
| RRPM | Rob Roy Production Manifold |
| SFF | Scottish Fisheries Federation |
| SSCV | Semi Submersible Crane Vessel |
| THC | Total Hydrocarbon |
| UKCS | United Kingdom Continental Shelf |
| WBM | Water Base Mud |

# 1 Introduction

The Hess operated Ivanhoe and Rob Roy fields are situated in Block 15/21 in the northern North Sea. These fields formed the Ivanhoe and Rob Roy (IVRR) development and previously produced hydrocarbons to the *AH001* Floating Production Facility (FPF), before production ceased and the FPF was moved off site in summer 2009. The fields were suspended whilst full field decommissioning and well abandonment operations were undertaken.

Following approval of the IVRR Field Decommissioning Programme (DP; ADP-011), Hess carried out full field decommissioning activities on behalf of the IVRR Joint Venture partnership. The operations are now complete with the subsea infrastructure, including all wellheads, removed.

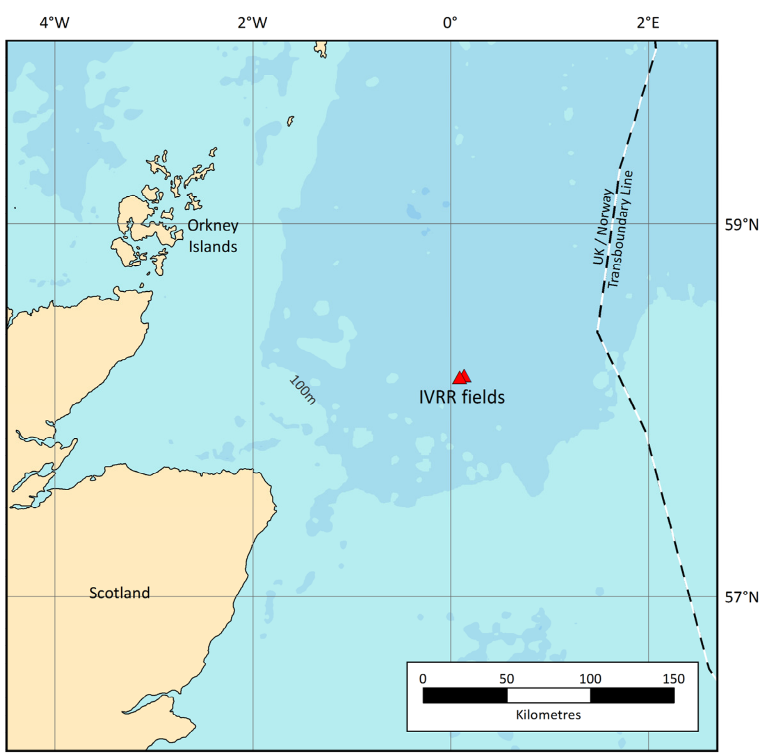
The scope of this document is to report the outcome of the decommissioning operations for the IVRR fields, including pipelines, seabed infrastructure, wellheads and other items, as defined in the IVRR DP. The close out report documents how key stages of decommissioning were achieved, discusses significant variations from the approved DP and provides information on managing related legacy issues for future activities in the area. This is supported by the data acquired from environmental sampling and other surveys, along with a summary of costs incurred by the execution of decommissioning. Measures taken to manage any potential risks arising from the decommissioning operations and remaining features (“legacies”) are described at relevant junctures throughout the report.

# 2 Background

## 2.1 Field history

The IVRR development consisted of the Ivanhoe and Rob Roy fields. The IVRR development was located in Block 15/21 of the United Kingdom Continental Shelf (UKCS), approximately 193 km northeast of Aberdeen and in an average water depth of 140 m (Figure 2.1). The Ivanhoe and Rob Roy fields lie approximately 3 km apart, and were both tied back to the *AH001* FPF in the centre. All wells were located in Block 15/21a, with the exception of the Hamish satellite production well associated with Rob Roy which lay in Block 15/21b.

**Figure 2.1 Location of the IVRR fields**



The Joint Venture partners in the IVRR development are Hess Limited (Hess) and Endeavour Energy UK Limited (Endeavour). Hess operated the development on behalf of the Joint Venture partners, with the licence ownership spilt 76.55% to Hess and 23.45% to Endeavour. Development drilling was undertaken in the fields between 1987 and 1990. Oil production from the IVRR development commenced in 1989 and the FPF operated at the development for 20 years, processing fluids produced from the Endeavour owned Renee and Rubie fields (R-Block fields) as well as IVRR. A total of 210 mm bbl of oil was produced from the IVRR development over its life span.

## 2.2 Cessation of production

Annual oil production from the IVRR development had fallen below 100,000 bbls by 2007. As Joint Venture partners, Hess and Endeavour explored all options for continuing production from the fields using the *AH001* FPF, but concluded that no option was economically viable. The potential for redeveloping oil and gas reserves in the vicinity of the Ivanhoe, Rob Roy and Hamish fields was also evaluated. Hess decided not to pursue the redevelopment of these fields, but Endeavour wished to maintain the option subject to further studies. In December 2008, Hess and Endeavour agreed to suspend production and Hess proposed their plans for the removal of *AH001* and the safe suspension of the development to the Department of Energy and Climate Change (DECC). DECC agreed to these plans in March 2009, advising that Endeavour had been given two years, with a possible extension of two further years, to investigate redevelopment opportunities. Field production then ceased in March 2009 with the fields suspended in such a way as to allow possible redevelopment in the future. In April 2012, Endeavour confirmed that they did not wish to pursue redevelopment of the IVRR fields.

## 2.3 Summary of the decommissioning programmes

The work to decommission the IVRR development was conducted in phases. Phase 1, consisting of suspension of the development and removal of the *AH001* FPF from the development, was completed in 2009. Phase 2, comprising preparatory work for full decommissioning and including the removal of some items from the seabed, was completed in 2011. These phases of work, both of which were agreed with DECC before operations began, took place whilst the fields were suspended pending the investigation of potential redevelopment opportunities. Once it was confirmed that redevelopment would not be pursued, planning for the full decommissioning operations (Phase 3) was allowed to commence.

The Decommissioning Programmes (DP) for the Ivanhoe, Rob Roy and Hamish fields (ADP-011) were prepared by Hess Ltd on behalf of the Joint Venture, and submitted to DECC for approval in early 2013. Approval was granted on 28 February 2013 and full field decommissioning operations commenced immediately thereafter. A summary of the individual phases, associated objectives and how these were achieved is provided below.

### Phase 1

The first phase of decommissioning was undertaken in 2009. It began with cessation of production from IVRR (and R-Block fields) on 6 March 2009. Thereafter the field subsea infrastructure was flushed clean of hydrocarbon residues and left filled with inhibited seawater. After flushing, the risers and umbilicals were disconnected from the FPF and then laid on the seabed, with the mid water arches left in the water column. The *AH001* FPF subsequently left the 500 m safety zone and was towed away from the fields on 15 July 2009, before being sold to Petrofac.

### Phase 2

The primary objective of the second phase was to undertake the preparatory work that would facilitate later full decommissioning operations, depending on the decision regarding future redevelopment. To commence this phase of decommissioning, and to facilitate the future monitoring of any environmental impacts related to the operations, a pre-decommissioning environmental baseline survey was carried out in August 2010. Preliminary recovery operations were then undertaken, including the removal of the mid water arches and their gravity bases. Any potential pressure sources were isolated from the subsea infrastructure, with the infield flowlines disconnected from the production manifolds and the jumpers disconnected from the wells and removed to surface. The FPF mooring system was also recovered in December 2011. These operations were carried out with the agreement of DECC, based on the provision that these activities would not prejudice the scope of final decommissioning options or the potential for future redevelopment.

#### Phase 3

The DP for the Ivanhoe, Rob Roy and Hamish Fields, detailing removal of the installation, pipelines and other structures and also well abandonment, were prepared by Hess Ltd on behalf of the Joint Venture. The resultant document (ADP-011) was submitted to DECC for approval on 11 February 2013 and approval granted on 28 February 2013.

The activities required for full field decommissioning commenced in February 2013 and were completed in November 2015. These activities encompassed the removal of all infrastructure on the seabed, including all exposed lengths of flowlines, but with the exception of a number of deteriorated concrete mattresses. The twenty IVRR production and water injection wells were also fully abandoned during this phase. As operations came to an end, a post decommissioning environmental survey was carried out to monitor against the characteristics recorded during the pre-decommissioning survey.

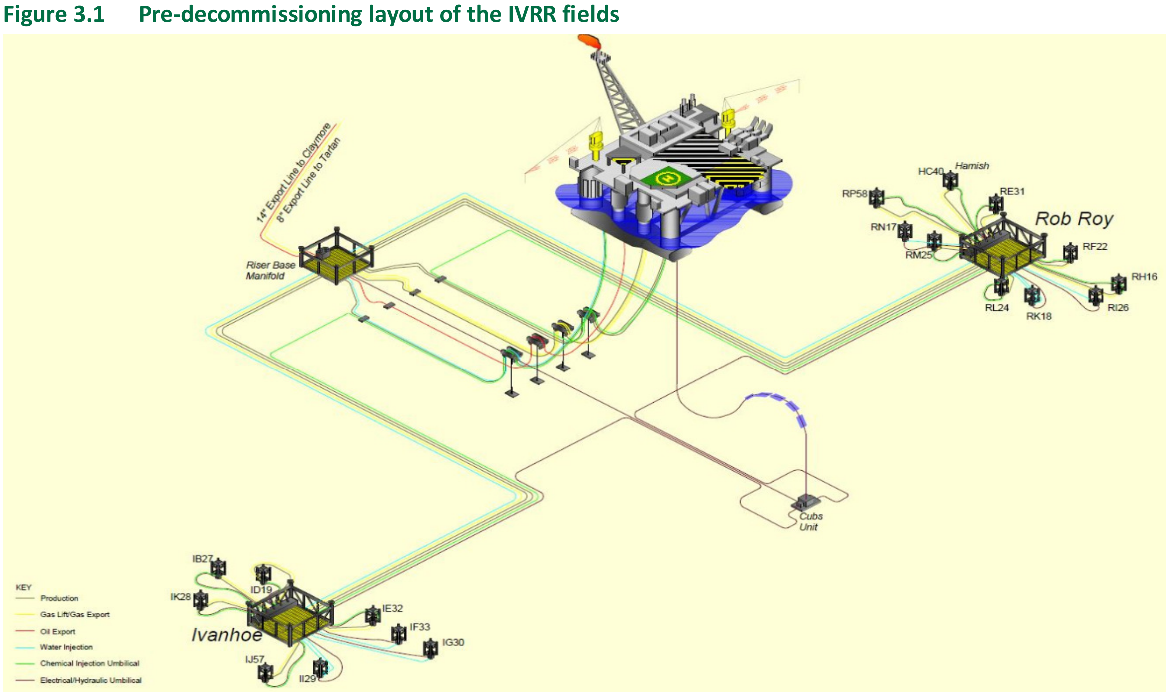
# 3 Decommissioning of field infrastructure

## 3.1 Pre decommissioning status of fields

#### Production installation and mooring system

Production from IVRR was achieved through the *AH001* FPF, which was moored centrally between the Ivanhoe and Rob Roy fields (Figure 3.1). The *AH001* FPF was jointly owned by Hess and Endeavour, and operated by Aker Solutions as Duty Holder. This FPF was moored to the seabed with a series of 12 mooring chains arranged in pairs around the facility. The mooring chains were attached to steel piles, each of which was submerged into the seabed sediments with the top of the pile at least 10 m below the seabed surface.

**Figure 3.1 Pre-decommissioning layout of the IVRR fields**




In addition to these mooring piles, two of the mooring piles and attached chains required for any mobile drilling rig visiting the Ivanhoe and Rob Roy wells were permanently piled into the seabed (four piles in total). This was done to avoid any conflict between the respective anchor patterns of the *AH001* and the temporary drilling rig, while also simplifying the mooring process for any such mobile drilling rig. One of these moorings was decommissioned when the flowline connecting the R-Block fields was put in place in 1998 as it obstructed the flowline route. At that time, the chain was cut beneath and seabed and the pile left in place, replaced by a 50 tonne drag embedment anchor and associated chain.

### Infield manifolds

The wellheads for each field were grouped around field-specific production manifolds; the Ivanhoe Production Manifold (IVPM) and the Rob Roy Production Manifold (RRPM). Connected by a series of flexible production and injection jumpers, the IVPM collected the produced fluids from the Ivanhoe wells and distributed the necessary injection water and lift gas to these wells. Situated approximately 1.7 km southwest of the central location, this manifold was a large steel structure, approximately 7.7 m high and with a 16.0 x 15.6 m base. Similarly, the RRPM received the production fluids from the Rob Roy and Hamish wells, and served as the distribution point for the water injection and gas lift required to maintain production. This manifold was a large rectangular steel structure, approximately 20 x 16.8 x 8 m.

Both field production manifolds were connected to a central Riser Base Manifold (RBM), as described below, which routed production to the *AH001* FPF via flexible risers (Figure 3.1). It also acted as a distribution point for the export pipelines to the Claymore and Tartan platforms. The RBM had a base of 14 x 13.3 m and was approximately 6.6 m high. These three manifolds were each secured into the seabed by four steel piles, with each pile measuring approximately 30" in diameter. The piles were buried to a depth of between 4.2 and 6.3 m.

### Infield flowlines and protective structures

As introduced above, a series of flexible jumpers connected the Ivanhoe wells to the IVPM (Table 3.1). An 8" production flowline (PL547) and a 5" production/test flowline (PL548) transported hydrocarbons from these wells to the *AH001* FPF. Gas for lift purposes was transported via a 4" flowline (PL549) to the IVPM for distribution to the wells. Water injection was provided to the Ivanhoe field via an 8" line (PL550), alongside a chemical injection line (PL551). These lines all ran from the IVPM to the RBM, situated near the former *AH001* location.

Similarly, two 8" production flowlines (PL515 and PL516) and a 5" production/test flowline (PL517) transported hydrocarbons from the Rob Roy wells to the associated production manifold and onto the production facility. Gas and water were transported via a 4" line (PL518) and an 8" (PL519) line respectively, alongside a chemical injection line (PL520). As with the equivalent Ivanhoe flowlines, these lines all ran between the RRPM and the RBM (Figure 3.1).

Routed from the RBM, the IVRR flexible riser system carried produced fluids, gas lift, water injection and control fluids to and from the FPF itself. A total of ten flexible risers were connected to the *AH001* FPF. The risers were supported in the water column by buoyant mid water arches, with each arch tethered to the seabed by a concrete gravity base (Figure 3.1).

All infield flowlines were laid in the surface of the seabed, with some sections covered with flexible concrete mattresses for protection. Each of these mattresses was constructed from individual concrete blocks measuring approximately 35 x 30 x 25 cm, and the individual concrete blocks within each mattress were held together with lengths of wire rope (older 'Armorflex' design) or polypropylene run through cast holes in each.

### Other infield structures

The IVRR development required a number of other articles of seabed infrastructure to facilitate production. The Control Umbilical Base Structure (CUBS) unit, a steel structure, around 1.2 m high with a 7 x 4 m base, was located approximately 400 m southeast of the RBM (Figure 3.1). It provided electrical and hydraulic control of the wells and manifolds, via three static umbilicals. One control umbilical (CU1) ran between the CUBS unit and the RBM, while a further two (CU2 and CU3) ran between the CUBS and the Ivanhoe and Rob Roy manifolds respectively (Figure 3.1). Also, a transponder tripod (2 $m^2$) and associated concrete piles (1.7 $m^2$ each) were located on the seabed approximately 50 m northwest of the CUBS unit.

The Dynamic Umbilical Base Structure (DUBS) unit was a piece of seabed infrastructure designed to provide hydraulic and chemical control to the wells and manifolds located in the Endeavour R-Block fields. It was a steel structure of around 5.4 x 5.4 x 1.8 m and weighed 25 tonnes. It was based on a metal plate filled with concrete which sank into the seabed under gravity, providing stability to the structure. Two static umbilicals emanated from the DUBS to the R-Block fields, one a control umbilical to the R-Block cross-over structure, and the other a control and hydraulic umbilical to the Renee manifold. A third dynamical umbilical connected the DUBS to the *AH001* FPF at the IVRR central location.

### Export pipelines

Once processed onboard the *AH001*, produced oil was returned to the RBM via a riser and exported to the Claymore A platform through a 14" steel pipeline (PL513). Processed gas was exported through an 8" steel pipeline (PL514) from *AH001*, via the RBM, to the Tartan A platform. They were trenched to a depth of around 1 m and measured approximately 40 km and 22 km respectively.

## 3.2 Operations undertaken

Production from the IVRR fields ceased in March 2009 and the *AH001* FPF, to which the fields were tied back, was removed in July 2009. The fields were initially suspended until the required partner agreements were reached and regulatory approvals granted. The Decommissioning Programmes gained formal approval in February 2013 and full field decommissioning operations commenced immediately thereafter.

### Comparative assessment

A comparative assessment was carried out for the decommissioning of subsea pipelines, flowlines and umbilicals, as required under the Petroleum Act 1998, in order to identity the operational approach for these activities. Factors such as complexity and technical risk, risks to personnel, environmental impacts, effects on other users of the sea and economics were considered for each available option. The options were then scored and ranked to identify the preferred decommissioning solution. It was concluded that all exposed pipelines, flowlines and umbilicals would be removed completely by reverse reeling for onshore disposal or recycling. Any pipeline, flowline or umbilical with buried sections would have the surface components removed and the cut ends buried, leaving the buried sections *in situ*. Any surface lines contaminated with Naturally Occurring Radioactive Material (NORM) were to be buried and also left *in situ.* However, due to improved onshore capacity for the treatment of NORM contaminated materials and lower than estimated levels of NORM contamination in the field flowlines, it was subsequently decided that these lines would be removed and transported to shore for treatment and recycling or disposal.

### Preparatory operations

The first preparatory step was completed in 2009 when the production equipment was flushed and cleaned and the *AH001* FPF released from the IVRR infrastructure (Phase 1). All flexible risers and the FPF mooring system were disconnected from the facility and laid on the seabed. The 14" oil and 8" gas export lines were disconnected at Claymore and Tartan respectively, and the spool sections were removed and recovered. The facility was then towed away, leaving the remaining IVRR infrastructure on the seabed and allowing for potential future redevelopment of the fields. A guard vessel was deployed to warn vessels of the presence of the subsea infrastructure and associated subsea equipment safety zones.

In preparation for the full decommissioning of the IVRR development, work was then completed in 2011 and early 2012 to remove certain items from the seabed (Phase 2). This work was planned and executed in agreement with DECC. The items removed during this phase of work were:

- Mid-water arches, including bend restrictors and gravity bases.
- Riser stabilising devices.
- Ten flexible risers, including the Riser Release Connector (RRC) sections, previously laid on the seabed.
- FPF mooring system.
- Drilling rig mooring system.
- Flexible jumpers between wells and production manifolds.

The removal of the risers and associated structures was carried out by a Construction Support Vessel (CSV), supported by a Remotely Operated Vehicle (ROV) equipped with shear cutters. As they had previously been laid on the seabed at the point of field suspension, the ten risers were cut and bundled on the seabed and then lifted to the vessel (Table 3.1). Due to the buoyancy of the mid-water arches, the arches and their gravity bases were lifted in unison using a crane and winch, before being broken up on the vessel. The concrete stability bases were also lifted directly to the CSV by crane.

**Table 3.1 Summary of removed IVRR infield flowlines**

| Start structure and location | End structure and location | Number | Flowline type |
|---|---|---|---|
| Riser Base Manifold (RBM) 58°11'35.3"N, 00°06'40.7"E | AH001 FPF 58°11'27.8"N, 00°06'46.9"E | PL513 | Oil export riser |
| | | PL514 | Gas export riser |
| | | PL515 | Production riser |
| | | PL516 | Production riser |
| | | PL517 | Production/test riser |
| | | PL518 | Gas lift riser |
| | | PL519 | Water injection riser |
| | | PL520 | Chemical injection riser |
| | | PL547 | Production riser |
| | | PL551 | Chemical injection riser |
| Ivanhoe Production Manifold (IVPM) 58°11'11.9"N, 00°05'19.8"E<br><br>Sections remain under mattresses (Section 3.4) | Riser Base Manifold (RBM) 58°11'35.3"N, 00°06'40.7"E | PL547 | 8" production flowline |
| | | PL548 | 5" production/test flowline |
| | | PL549 | 4" gas lift flowline |
| | | PL550 | 8" water injection flowline |
| | | PL551 | Chemical injection umbilical |
| Rob Roy Production Manifold (RRPM) 58°11'50.9"N, 00°08'08.1"E<br><br>Sections remain under mattresses (Section 3.4) | Riser Base Manifold (RBM) 58°11'35.3"N, 00°06'40.7"E | PL515 | 8" production flowline |
| | | PL516 | 8" production flowline |
| | | PL517 | 5" production/test flowline |
| | | PL518 | 4" gas lift flowline |
| | | PL519 | 8" water injection flowline |
| | | PL520 | Chemical injection umbilical |
| Ivanhoe wells - various locations (see Table 4.1) | Ivanhoe Production Manifold (IVPM) 58°11'11.9"N, 00°05'19.8"E | PL547 | Well 15/21a-59 (IH59) spare jumper |
| | | PL549 | Well 15/21a-59 (IH59) spare jumper |
| | | PL552 | Well 15/21a-27 (IB27) production jumper |
| | | PL553 | Well 15/21a-19 (ID19) production jumper |
| | | PL554 | Well 15/21a-32 (IE32) production jumper |
| | | PL555 | Well 15/21a-28 (IK28) production jumper |
| | | PL556 | Well 15/21a-27 (IB27) gas jumper |
| | | PL557 | Well 15/21a-19 (ID19) gas jumper |
| | | PL558 | Well 15/21a-32 (IE32) gas jumper |
| | | PL559 | Well 15/21a-28 (IK28) gas jumper |
| | | PL560 | Well 15/21a-30 (IG30) water injection |
| | | PL561 | Well 15/21a-29 (II29) water injection |
| | | PL562 | Well 15/21a-29 (II29) water injection |
| | | PL563 | Well 15/21a-27 (IB27) water injection |
| | | PL564 | Well 15/21a-19 (ID19) chemical jumper |
| | | PL565 | Well 15/21a-32 (IE32) chemical jumper |
| | | PL566 | Well 15/21a-28 (IK28) chemical jumper |
| | | PL567 | Well 15/21a-28 (IK28) chemical jumper |
| | | PL1769 | Well 15/21a-57 (IJ57) production jumper |
| | | PL1770 | Well 15/21a-31 (RE31) gas jumper |

**Table 3.1 Summary of removed IVRR infield flowlines (continued)**

| Start structure and location | End structure and location | Number | Flowline type |
|---|---|---|---|
| Rob Roy wells - various locations (see Table 4.1) | Rob Roy Production Manifold (RRPM) 58°11'50.9"N, 00°08'08.1"E | PL 521 | Well 15/21a-31 (RE31) production jumper |
| | | PL 522 | Well 15/21a-22 (RF22) production jumper |
| | | PL 523 | Well 15/21a-16 (RH16) production jumper |
| | | PL 525 | Well 15/21a-24 (RL24) production jumper |
| | | PL 526 | Well 15/21a-25 (RM25) production jumper |
| | | PL 527 | Well 15/21a-31 (RE31) gas jumper |
| | | PL 528 | Well 15/21a-22 (RF22) gas jumper |
| | | PL 529 | Well 15/21a-16 (RH16) gas jumper |
| | | PL 531 | Well 15/21a-24 (RL24) gas jumper |
| | | PL 532 | Well 15/21a-25 (RM25) gas jumper |
| | | PL 536 | Well 15/21a-26 (RI26) water injection |
| | | PL 537 | Well 15/21a-18 (RK18) water injection |
| | | PL 538 | Well 15/21a-18 (RK18) water injection |
| | | PL 539 | Well 15/21a-17 (RN17) water injection |
| | | PL 541 | Well 15/21a-31 (RE31) chemical jumper |
| | | PL 542 | Well 15/21a-22 (RF22) chemical jumper |
| | | PL 543 | Well 15/21a-16 (RH16) chemical jumper |
| | | PL 545 | Well 15/21a-24 (RL24) chemical jumper |
| | | PL 546 | Well 15/21a-25 (RM25) chemical jumper |
| | | PL 1881 | Well 15/21a-58 (RP58) production jumper |
| | | PL 1882 | Well 15/21a-58 (RP58) gas jumper |
| | | PL 1883 | Well 15/21a-58 (RP58) chemical jumper |
| Hamish wells - various locations (see Table 4.1) | Rob Roy Production Manifold (RRPM) 58°11'50.9"N, 00°08'08.1"E | PL 684 | Well 15/21a-40Z (HC40) production jumper |
| | | PL 685 | Well 15/21a-40Z (HC40) gas jumper |
| | | PL 687 | Well 15/21a-40Z (HC40) chemical jumper |

In order to recover the mooring chains, an area of sediment approximately 2 m in radius and 1 m in depth was excavated around the steel mooring piles, allowing access for cutting equipment. Using an ROV, each chain was then cut as close as possible to its respective pile, with the remaining chain lengths water jetted into the seabed to a depth of at least 0.6 m. The piles themselves were left in place as they were already submerged in the sediments, with the top of each pile at a depth of at least 10 m below the seabed. Once cut, the mooring chains were recovered using an anchor handling vessel, the *Far Sapphire*. The chains were picked up by a grapple and winched aboard the vessel for transport onshore and disposal by the nominated waste contractor. The drilling rig anchoring piles were addressed at the same time and in the same fashion as the FPF mooring system, bearing in mind one of these had already been removed in 1998. The drag embedment anchor and chain was removed later during full field decommissioning (see below). These operations were conducted under an Marine and Coastal Access Act (MCAA) licence (MCAA/060/2011).

The remaining preparatory work was facilitated through divers deployed from a Diving Support Vessel (DSV), carried out in June 2012. The divers disconnected all of the jumpers from the production manifolds and fitted blind flanges. The jumpers were then cut into smaller sections on the seabed, collected in debris baskets and lifted to the vessel (Table 3.1).

### Full field decommissioning

The field decommissioning programme involved the decommissioning and removal of all remaining subsea infrastructure which comprised pipelines, flowlines, umbilicals, manifolds and protective structures on the seabed over a number of phases. Well abandonment, including the removal of all wellheads, is dealt with separately in Section 4 below.

*Infield fixed structures*

Full field decommissioning commenced in 2013, with infrastructure recovery conducted through a series of DSV and CSV based campaigns. These operations were completed in 2015. The primary role of the DSV was to prepare components for lifting from the seabed and that of the CSV was to carry out those lifts. In September 2013 the three large manifold structures, the Ivanhoe and Rob Roy production manifolds and the RBM, were recovered by the Semi Submersible Crane Vessel (SSCV) *Hermod*. A specialist vessel was required due to the weight of these items. The piles which held these structures in place were cut at around 1.5 m below the seabed, exceeding the minimum depth requirement of 0.6 m. The depth at which cuts were made beneath the seabed was verified by measuring the cut piles stubs on the manifold after recovery. Along with the tripod piles, the CUBS unit was cut from its umbilicals, fitted with recovery rigging and lifted intact to the deck of the DSV. The remaining drag embedment anchor and chain were also recovered as part of these operations, using a grapple and winch.

*Pipelines, flowlines and umbilicals*

The infield flowlines were cut by divers from the DSV at the manifold ends and midline flanges. Additional cuts had to be made to certain flowlines where they were trapped under deteriorated concrete mattresses (Section 3.4). The cut flowlines were then fitted with recovery rigging and recovered to the vessel, where they were cut into smaller sections for transport. Table 3.1 details the flowline sections recovered from within the fields and their locations.

Similarly, the control umbilicals running between the CUBS and the production manifolds (CU2 and CU3) were recovered and then cut on the vessel. However, due to the shorter length of umbilical between the RBM and the CUBS, CU1 was cut at the seabed before being recovered to the vessel, leaving only the section trapped beneath the deteriorated concrete mattresses. Once cut and recovered, the flexible flowlines and umbilical sections were taken to shore for treatment at an appropriate facility prior to recycling or disposal in landfill.

The trenched oil and gas steel export pipelines were cut at the transition points by divers and the exposed cut ends were then buried to the full depth of the existing trench by water-jetting. This included removal of the mid-line tee sections (Section 3.4). The cut sections were fitted with recovery rigging and returned to the vessel, before being onshore for recycling.

*Concrete mattresses*

Where safe to do so, the concrete mattresses covering unburied flowlines and flexible jumpers were recovered and brought ashore for recycling. Twelve polypropylene connected concrete mattresses protected structures in the Rob Roy field, ten protected spool pieces associated with Well 15/21a-58 and two were situated near the Rob Roy manifold. As they were of a newer plastic connective design these mattress were in a suitable state to be recovered lifted wholesale to the surface. These recovery operations also took place from the DSV, with mattresses recovered to the surface using a speed loader lifting sling.

The majority of concrete mattresses (over 90%) in the IVRR fields were of the older 'Armorflex' design. In this case, the individual concrete blocks were held together with metal wire. These mattresses were deployed to protect infield lines from the *AH001* moorings or any objects dropped from the facility, so were concentrated where the flowlines and control umbilicals entered the RBM. During pre-decommissioning lift trials, it was observed that the wire which held these mattresses together had deteriorated over time and was now unsafe for diver assisted recovery. Therefore, instead of the recovering these mattresses to surface, the affected areas were rock dumped, leaving the underlying sections of flowlines and the damaged mattresses in place. This, including the option considered, the methods used, the material left of the seabed, is described in Section 3.4.

*Remaining debris*

Once all flowlines and other seabed structures were removed, a final inspection survey was conducted in 2015 which identified any remaining items of debris on the seabed. Debris was removed from around the fields and along the export pipeline routes by divers during August 2015. Several over trawl surveys (Section 5.4) were also completed to ensure that the seabed was safe for future fishing activities. Once clearance was received and appropriate notifications made regarding the removal of safety zones and other navigational markings, the IVRR decommissioning operations were confirmed as complete.

## 3.3 Variations from decommissioning programme

The DECC guidance notes on decommissioning of offshore oil and gas installations and pipelines requests that close out reports highlight major variations from the approved programmes. Such variations encountered during field decommissioning are summarised below.

### Removal of Dynamic Umbilical Base Structure (DUBS)

Although located within the boundary of the IVRR fields, the DUBS unit provided control to the Endeavour R-Block field. Forming part of the Endeavour field decommissioning plans, the removal of the DUBS unit was initially included in a separate DP submitted by Endeavour, rather than the Hess IVRR DP. However, as Hess had procured the DUBS unit and installed it on behalf of Endeavour it was concluded that responsibility for its removal remained with Hess. Therefore, a letter was submitted to DECC, as the regulatory authority for decommissioning, providing written notice under section 34(1)(a) of the Petroleum Act 1998 that an alteration was required for the DP. The letter included written support from Endeavour for the alteration to the DP.

A MCAA (marine licence) application was then submitted to the DECC Environmental Management Team (EMT) and the DUBS subsequently removed under the associated approval letter (MCAA/284/2013). The DUBS unit was removed by crane from a DSV, the *Seven Osprey*, on 2 July 2013. The static umbilicals that ran to the R-Block fields were cut at the DUBS unit to allow its removal and left in place for future decommissioning by Endeavour. The dynamic umbilical which connected the DUBS unit to the FPF had previously been removed in 2010 along with the other risers.

### Rock dumping of mooring trenches

The final stage of the planned decommissioning activities was an overtrawl survey (see Section 5.4). The survey objective was to determine if the area was free of snagging hazards and could be declared safe for normal fishing operations to return. A typical North Sea fishing vessel was used to conduct sweeps across the IVRR fields, focusing on the safety zones which covered the former well clusters and manifolds, along with the corridors which protected infield flowlines and export pipelines.

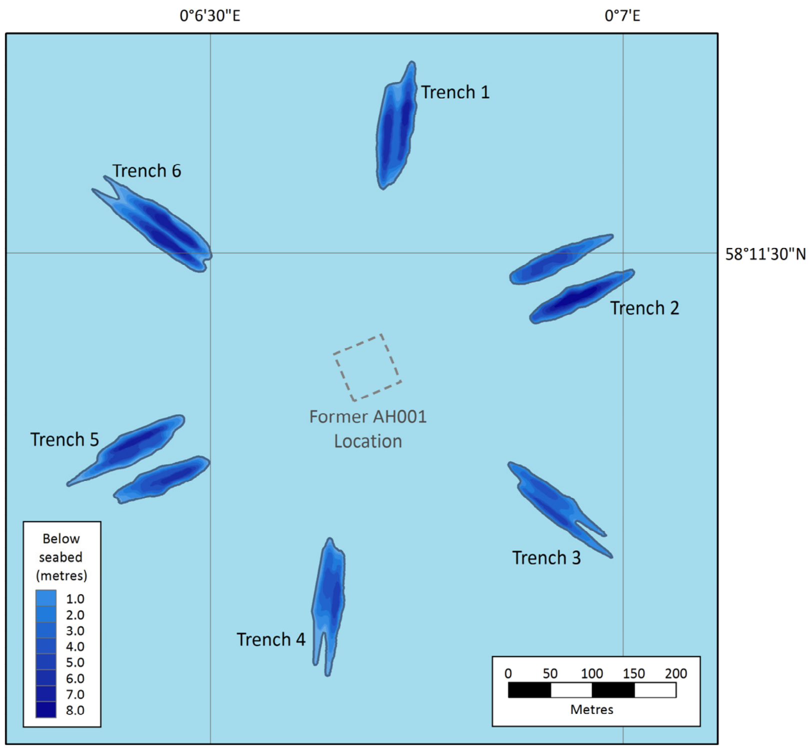
Sweeps were conducted using a chain trawl initially and then repeated with a trawl net to simulate fishing activity relevant to the IVRR area. Towards the end of the survey, the twin otter trawl used became repeatedly snagged on the seabed in the area around the previous *AH001* location. Referencing the snag locations against previously obtained seabed survey data identified that these snagging points corresponded with the seabed trenches created by the *AH001* mooring chains (Figure 3.2). It was noted that the vessel snagged when moving in specific directions, resulting in the vessel slowing down, having to slack off and hauling the net out of clay. A review of the survey report and photographs taken, as well as discussions with the vessel skipper, indicated that twin trawl net would fall into the trenches and, as the vessel continued forward, the net would then dig into the clay of the trench wall.

Snagging in the trench wall resulted in large quantities of mud collecting on the trawl doors and in the nets. The vessel skipper and the Scottish Fisheries Federation (SFF) confirmed that this posed a significant health and safety risk, with a vessel potentially having to haul weights in excess of the equipment capacity. Snagging also had the potential to damage fishing gear and foul catches. SFF also confirmed that the vessel used in the trials was larger and more powerful than many vessels working in the area and, if a smaller vessel became snagged in the same way and particularly if in poor weather conditions, there was potential for loss of the vessel.

Hess held a formal review meeting with SFF in September 2015 to discuss the snagging issue and concluded that, due to the issues described, the central IVRR 500 m safety zone remained a hazard to the return of normal safe fishing activity. Consultations to review the available options and to reduce the potential risks associated with the trenches took into consideration the length and depth of the man-made trenches and that seabed conditions would be prohibitive to natural recovery (back filling of sediments). It was agreed that the best way forward would be to fill in the trenches with sand or rock material.

A Fall Pipe Vessel (FPV) was mobilised immediately in order to fill the trenches to mean seabed level with crushed rock. The vessel used, the *Simon Stevin*, was equipped with a dynamic positioning system, geo-positioning equipment and a camera equipped fall pipe which reached directly to the seabed, allowing for the precise deposition of material in the areas required.

**Figure 3.2 Mooring scour trenches around the *AH001* location**




Previous geophysical survey work fields had established the particular location of the trenches, which formed a rough radial pattern around the previous FPF facility. However, prior to the commencement of rock dumping operations a Multi-Beam Echo Sounder (MBES) acoustic survey was conducted by the vessel to verify the locations. Dumping was conducted by the vessel to fill each trench to align it with the surrounding seabed topography, but without protruding beyond it. An ROV was additionally placed at the seabed in each dumping location to further confirm the accurate positioning of material during deposition. After the vessel had completed operations, a second acoustic survey was conducted to confirm that the operations were successful.

The rock used was sourced from a Norwegian quarry, consisting of freshly crushed pieces between 1 and 5 inches in diameter. The operations took place between 8 October and 6 November 2015, with a total of 241,291 tonnes of rock material ultimately deposited (Table 3.2).

**Table 3.2 Details of mooring trench rock dumping**

| Trench | Approximate orientation (Figure 3.2) | Location (ED50) (centre of trench) | Quantity of rock deposited (tonnes) | Area of seabed impacted ($m^2$) | Dimensions of impacted area (m) |
|---|---|---|---|---|---|
| 1 | North | 58°11'36.82"N, 00°06'49.43"E | 40,951 | 4,733 | 166 x 47 |
| 2 | Northeast | 58°11'31.20"N, 00°07'1.67"E | 47,251 | 5,058 | 135 x 55 |
| 3 | Southeast | 58°11'22.68"N, 00°07'0.69"E | 28,167 | 3,560 | 165 x 35 |
| 4 | South | 58°11'19.24"N, 00°06'44.43"E | 26,882 | 3,638 | 165 x 35 |
| 5 | Southwest | 58°11'24.22"N, 00°06'31.38"E | 52,304 | 5,996 | 160 x 65 |
| 6 | Northwest | 58°11'33.05"N, 00°06'32.83"E | 45,736 | 4,889 | 165 x 40 |

The described operations above were not included in the scope of work described in the approved IVRR DP. Due to the sudden nature of its development and the late stage of operations, a formal amendment was not made to the DP. Instead, informal consultation was held with the DECC decommissioning and environmental management teams to discuss the available options and way forward. These activities, specifically the deposition of crushed rock material and the associated seabed disturbance, necessitated the submission and approval of a marine licence application under the Marine and Coastal Access Act (MCAA) 2009. The application (ML/135/1/1) contained an assessment of potential impacts related to the proposed operations and the approval letter imposed conditions to be met during the work.

### Minor variations

*Removal of infield flowlines*

The planned removal of infield flowlines involved them being reversed reeled onto the support vessel and then cut into smaller sections onboard. However, due to them being trapped at one end under deteriorated concrete mattresses (Section 3.4), some sections of infield flowlines had to be cut into smaller sections at the seabed in order for them to be recovered to a CSV. This was not anticipated in the DP. Ultimately the operations were broadly similar with just some additional cuts made at the seabed rather than on the vessel and no additional techniques or equipment were required. This did not necessitate any additional permit applications beyond that submitted, and the approval received, for the general removal of infield flowlines (MCAA/289/2013).

## 3.4 Remaining features

The goal of the IVRR decommissioning operations was to remove or address all seabed infrastructure, pipelines, flowlines, wellheads and other items as far as possible, in order to return the seabed to a more natural state. However, some items of field infrastructure were buried beneath the seabed rather than recovered.

### Concrete mattresses and rock dumping

Concrete mattresses were deployed to protect the surface laid infield flowlines and control umbilicals from dropped objects from the FPF and from mooring movement. As such, they were located within the RBM 500 m exclusion zone, close to where each group of lines reached the RBM. As introduced above (Section 3.2), pre-decommissioning lift trials found that a large number of wire rope mattresses near the RBM had deteriorated and were unsafe for diver assisted recovery. Around 150 of the mattresses in the IVRR fields were found to be constructed using wire and plasticised rope to hold the individual blocks together, instead of more modern polypropylene material. These mattresses were constructed from individual concrete blocks each measuring approximately 35 x 30 x 25 cm. These blocks formed larger mattresses that measure 9.4 × 2.4 m (22.6 $m^2$), and weigh 4.5 to 5 tonnes each. A description and the location of these mattresses are given in Table 3.3.

**Table 3.3 Details of remaining concrete mattresses and rock dumped over these**

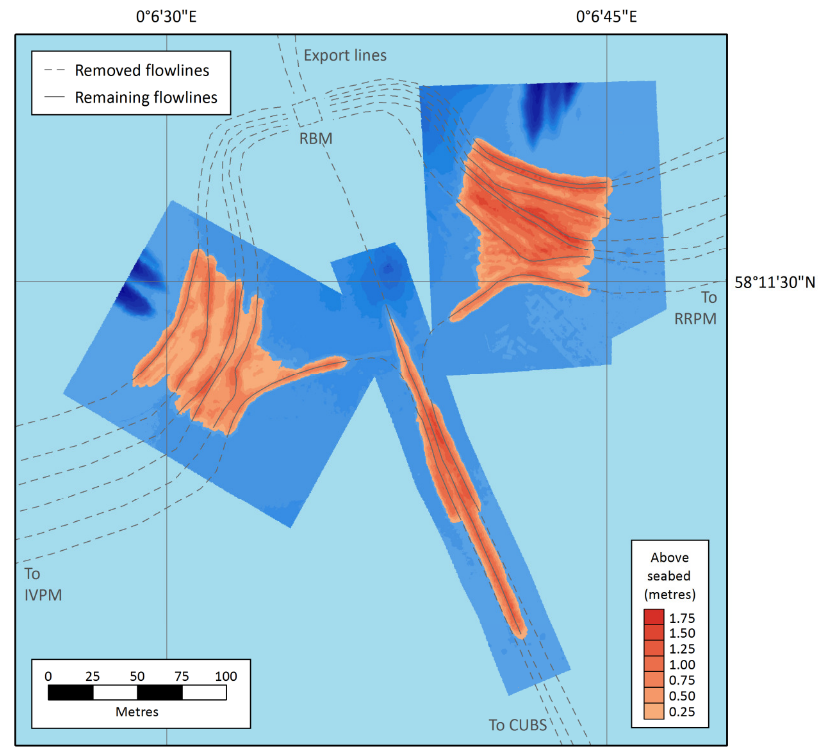
| Area of rock dump (Figure 3.3) | Description of area | Location (ED50) (centre of area) | Quantity of rock deposited (tonnes) | Area of seabed impacted ($m^2$) | Dimensions of impacted area (m) |
|---|---|---|---|---|---|
| Ivanhoe flowlines near RBM | Six lines composed of nine mattresses, approximately 75 m in length. Covers four flowlines and two umbilicals. | 58°11'30.93"N 00°06'37.90"E | 7,706 | 5,123 | 81 x 105 x 1.8 |
| CUBS to RBM umbilicals | Three lines covering three umbilicals. One 185 m line of 20 mattresses and two 50 m lines of 6 mattresses. | 58°11'29.13"N 00°06'45.54"E | 3,482 | 2,431 | 198 x 20 x 1.5 |
| Rob Roy flowlines near RBM | Seven lines of nine mattresses, 75 m in length. Covers five flowlines and two umbilicals, plus four third party lines. | 58°11'33.27"N 00°06'48.43"E | 8,897 | 5,099 | 82 x 100 x 1.9 |

Using a comparative assessment process, a range of options were considered to address the issue. The options included diver removal using lifting beam and baskets, crushing the mattresses *in situ* and using a high volume recovery grabbing tool. However, after evaluation of potential options and in consultation with the SFF, it was decided that the affected mattresses would be rock dumped instead of removed due to various safety and environmental issues. It was agreed that as they were trapped, the flowlines could be cut at the point they passed under the mattress and the remaining sections left in place (Table 3.3). Rock dumping was undertaken under an MCAA permit (marine licence) approval from DECC (MCAA/314/2013). Rock dumping operations were conducted from the *Simon Stevin*, a dynamically positioned FPV, in February 2014.

Rock dumping was conducted to achieve a minimum height of 0.6 m over the mattresses, forming a smoothly contoured mound ("berm") designed to ensure overtrawlability and appropriate depth coverage. A skirt or perimeter of rock material surrounding each line of mattress (approximately 2 m wide on either side of the line of mattresses) was deployed to allow for a smoothly contoured mound of rock material to be built up and leave an appropriate overtrawlable topography (1 in 3 berm gradient). The material was dumped over each line of mattresses, including any cut flowline or umbilical ends that protruded from beneath the mattresses. Infill rock dumping was conducted between adjacent berms that were less than 25 m apart. These areas were filled to a height of no less than 0.5 m below the top of the existing berms on either side. The rock material was delivered to the seabed via the fall pipe, which was equipped with an ROV at its outer end to allow for accurate positioning of the rock material during deposition. A total of 20,085 tonnes of rock material (1" to 3" crushed rock pieces) was dumped across the three areas (Table 3.3). The rock dumped areas covered a total of around 12,653 $m^2$ of seabed.

Full as found surveys were conducted on each line and the adjacent seabed before dumping and as left surveys of the rock dump were undertaken afterwards (Section 5.4). These surveys consisted of acoustic investigation with a MBES. The as found survey was undertaken ahead of rock dumping to establish the profile of the mattresses and inform the design of the rock dumping profile. Further multibeam work was then undertaken after the first pass of rock dumping and at the end of the operations to ensure the new seabed profile exceeded that designed ahead of time. Figure 3.3 illustrates the final rock dumped areas gathered from the multibeam survey work.

**Figure 3.3 Areas of rock dumped mattresses in the IVRR fields**




### Export pipelines

The export flowlines for the IVRR development were laid down in 1988. A 40 km 14" steel pipeline transported exported oil from the FPF via the IVRR RBM to the Claymore Alpha platform. Similarly, processed gas was exported through a 22 km long 8" steel pipeline to the Tartan Alpha platform.

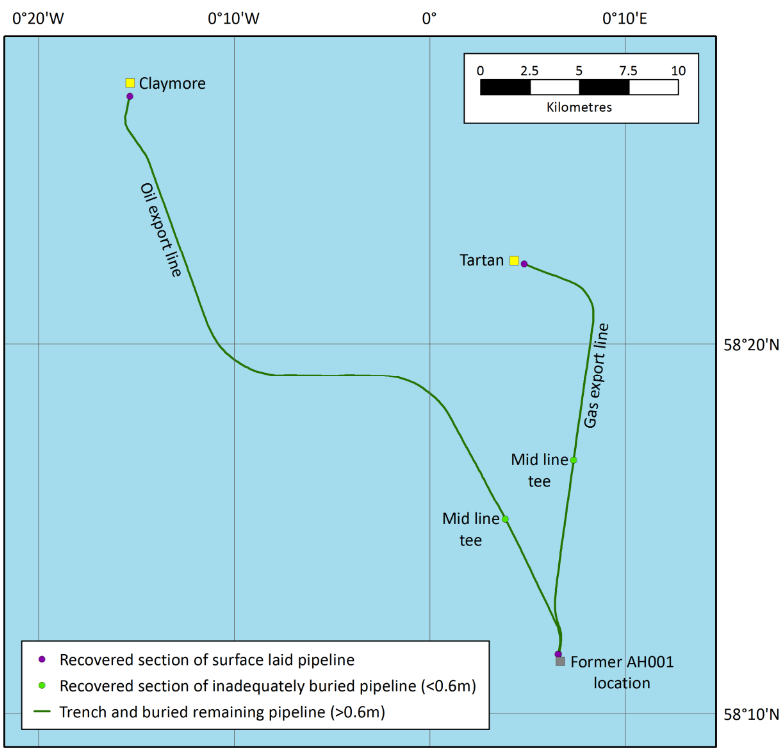
When first laid down for production operations, both export pipelines were trenched to a depth of around 1 m. The trenched pipelines were subsequently buried over time by natural sediment deposition. Inspection of the pipelines via Remotely Operated Towed Vehicle (ROTV) had verified that, within each trench, the majority of their length had become submerged by sediments measuring at least 0.6 m in depth. This meets the formal requirements for leaving pipelines *in situ* during decommissioning, so those lengths of export lines buried in this way were left in place in the seabed. Only the exposed sections lying on the seabed, or not verified as buried in at least 0.6 m of sediment, were recovered to the surface.

At the RBM end, approximately 50 m of the oil export line and the gas export line were laid on the seabed surface, so these lengths were both cut and recovered to the surface. Longer sections of exposed pipeline lay on the seabed at the Tartan and Claymore ends, so approximately 300 m of steel pipe was recovered from each. With the addition of grout bags for protection, it was not possible to verify the mid line tees as being buried to a minimum depth of 0.6 m. Therefore, to remove any future snagged hazard, the mid line tees and grout bags were also recovered. Due to its orientation, there was the potential that the Claymore mid line tee had not been fully flushed during earlier suspension operations, so the recovery of this section was carried out under an OPPC (oil discharge) permit (T01425.00), covering the discharge of the residual oil to sea. Table 3.4 and Figure 3.4 illustrate the remaining buried export lines and locations at which sections were cut and recovered. These sections were cut and removed using divers deployed from the SubSea 7 *Osprey* DSV, with on discharges observed during removal.

**Table 3.4 Remaining sections of buried export pipeline**

| | **Start location of remaining buried pipeline** (RBM end) | **Removed middle portion** (mid line tees) | **End location of remaining buried pipeline** (Claymore and Tartan ends) |
|---|---|---|---|
| **Oil export pipeline to Claymore (PL513)** | 58°11'40.2"N, 00°06'39.2"E | 58°15'19.0"N, 00°03'57.6"E | 58°26'40.9"N, 00°15'14.1"E |
| **Gas export pipeline to Tartan (PL514)** | 58°11'40.1"N, 00°06'41.1"E | 58°16'55.2"N, 00°07'27.2"E | 58°22'10.4"N, 00°04'55.8"E |

**Figure 3.4 IVRR export lines post decommissioning**




## Mooring and manifold piles

Mooring piles were required for the *AH001* FPF mooring system during production operations. Each of the twelve moorings used for this system was attached to a steel pile submerged into the seabed sediments, with the top of the pile at least 10 m below the seabed surface (Section 3.1). In addition to these mooring piles, two of the mooring piles and attached chains required for any mobile drilling rig visiting the Ivanhoe and Rob Roy wells were permanently piled into the seabed, requiring four additional mooring piles. One of these mooring piles was decommissioned when the flowline connecting the R-Block fields was put in place in 1998 as it obstructed the flowline route. At that time, the chain was cut beneath and seabed and the pile left in place (Section 3.1), and then replaced by an embedment anchor and chain.

As they were already buried at a depth (over 10 m), greater than the accepted minimum for decommissioning (0.6 m), all piles were left *in situ* rather than recovered (Figure 3.5). The moorings were cut and recovered, with the remaining short lengths of chain attached to the top of each pile jetted into the seabed to a depth of at least 0.6 m. Table 3.5 documents the locations of all remaining 16 piles. Figure 3.5 depicts the locations of both the FPF mooring piles and the four drilling rig mooring piles, along with the former positions of the now decommissioned moorings to illustrate the previous set up.

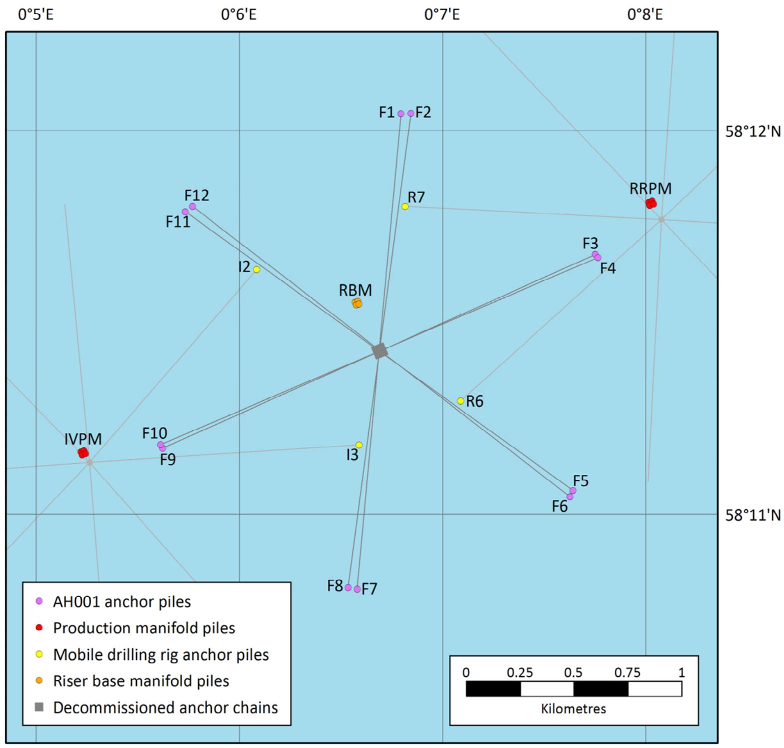
**Table 3.5 Details of remaining IVRR manifold and moorings piles**

| Remaining infrastructure | Location (ED50) | |
|---|---|---|
| | Longitude | Latitude |
| **Riser base manifold (RBM)** | | |
| Northwest corner pile | 58°11'51.0"N | 00°08'07.0"E |
| Northeast corner pile | 58°11'51.3"N | 00°08'08.1"E |
| Southeast corner pile | 58°11'50.8"N | 00°08'08.5"E |
| Southwest corner pile | 58°11'50.6"N | 00°08'07.4"E |
| **Ivanhoe production manifold (IVPM)** | | |
| Northwest corner pile | 58°11'12.1"N | 00°05'19.3"E |
| Northeast corner pile | 58°11'12.3"N | 00°05'20.2"E |
| Southeast corner pile | 58°11'11.8"N | 00°05'20.6"E |
| Southwest corner pile | 58°11'11.6"N | 00°05'19.7"E |
| **Rob Roy production manifold (RRPM)** | | |
| Northwest corner pile | 58°11'51.0"N | 00°08'07.0"E |
| Northeast corner pile | 58°11'51.3"N | 00°08'08.1"E |
| Southeast corner pile | 58°11'50.8"N | 00°08'08.5"E |
| Southwest corner pile | 58°11'50.6"N | 00°08'07.4"E |
| **AH001 FPF mooring pattern** | | |
| North mooring pile 1 (F1) | 58°12'05.0"N | 00°06'53.7"E |
| North mooring pile 2 (F2) | 58°12'05.0"N | 00°06'56.6"E |
| Northeast mooring pile 1 (F3) | 58°11'43.0"N | 00°07'51.1"E |
| Northeast mooring pile 2 (F4) | 58°11'42.5"N | 00°07'52.0"E |
| Southeast mooring pile 1 (F5) | 58°11'06.1"N | 00°07'44.5"E |
| Southeast mooring pile 2 (F6) | 58°11'05.1"N | 00°07'43.6"E |
| South mooring pile 1 (F7) | 58°10'50.7"N | 00°06'40.8"E |
| South mooring pile 2 (F8) | 58°10'50.9"N | 00°06'38.2"E |
| Southwest mooring pile 1 (F9) | 58°11'12.7"N | 00°05'43.3"E |
| Southwest mooring pile 2 (F10) | 58°11'13.2"N | 00°05'42.7"E |
| Northwest mooring pile 1 (F11) | 58°11'49.6"N | 00°05'50.1"E |
| Northwest mooring pile 2 (F12) | 58°11'50.4"N | 00°05'52.1"E |
| **Drilling rig mooring piles** | | |
| Ivanhoe northeast mooring pile (I2) | 58°11'40.6"N | 00°06'11.1"E |
| Ivanhoe east mooring pile (I3) | 58°11'13.2"N | 00°06'41.4"E |
| Rob Roy southwest mooring pile (R6) | 58°11'20.0"N | 00°07'11.3"E |
| Rob Roy west mooring pile (R7) | 58°11'50.5"N | 00°06'54.9"E |

The IVRR production manifolds and the riser base manifold were also piled into the seabed to secure their position (Section 3.1). Each manifold was held in place by four steel corner piles, with each pile measuring approximately 30" in diameter. It was agreed that the manifolds would be cut from the piles at a depth of at least 0.6 m in order to meet decommissioning requirements; ultimately they were cut to a depth of around 1.5 m. The depth at which cuts were made beneath the seabed was verified by measuring the cut piles stubs on the manifold after recovery. Therefore, the manifold piles also remain at the former locations in the Ivanhoe and Rob Roy fields and at the central production facility location (Figure 3.5).

Although all these mooring (including the jetted in remaining pieces of mooring chain) and manifold piles remain in their respective locations (Table 3.5), as they are sufficiently buried to at least 0.6 m beneath the seabed in accordance with the decommissioning guidelines requirements, they will pose no obstruction to normal fishing activities returning in the future.

**Figure 3.5 Location of remaining submerged mooring and manifold piles**




## 4 Well abandonment operations

### 4.1 Pre-decommissioning status of wells

During the life of the Ivanhoe and Rob Roy fields a cluster of wells was present in each. Five production wells and three water injection wells were located at a depth of around 140 m in the Ivanhoe field (Table 4.1), connected to the IVPM and then tied back to the *AH001* FPF. An additional dry hole exploration well was also present (Well 15/21a-42), but this was abandoned at the time of drilling (Table 4.1).

Seven production and three water injection wells were present in the Rob Roy field, as well as the Hamish tie back (Well 15/21a- 58) (Table 4.1). Also present were an incomplete production well, Well 15/21a-23, and a dry hole appraisal well, Well 15/21a-42. These two wells were not part of the production operations and, prior to full field decommissioning commencing, already had permanent abandonment barriers set across them. Only the cutting of casings and wellhead removal was required to complete abandonment of these wells (Category 1 suspension).

Including the two Category 1 suspension wells, a total of 20 wells were present in the IVRR development. All of the IVRR wells utilised 5" x 3" conventional dual bore subsea trees for well control. The wells were predominantly of low to moderate inclinations, with total measured depths in the range of 2,500 to 3,300 m.

**Table 4.1 Summary of the IVRR production and water injection wells**

| DECC well number (and Hess ref) | Well type | Location (ED50) | Water depth (m) | Date drilled | Date abandoned |
|---|---|---|---|---|---|
| **Rob Roy and Hamish fields** (Block 15/21a) | | | | | |
| 15/21a-16 (RH16) | Producer | 58°11'49.59"N 00°08'09.83"E | 141 m | 4 July 1987 | 3 March 2015 |
| 15/21a-17 (RN17) | Water injector | 58°11'51.78"N 00°08'06.32"E | 140 m | 11 August 1987 | 5 October 2014 |
| 15/21a-18 (RK18) | Water injector | 58°11'49.70"N 00°08'07.84"E | 140 m | 17 August 1987 | 25 November 2014 |
| 15/21a-22 (RF22) | Producer | 58˚11'50.00"N 00˚08'09.33"E | 141 m | 17 January 1988 | 24 December 2014 |
| 15/21a-23 (RJ23) | Incomplete well (Cat 1 suspended*) | 58°11'49.21"N, 00°08'8.32"E | 140 m | 22 January 1988 | 25 November 2014 |
| 15/21a-24 (RL24) | Producer | 58°11'50.12"N 00°08'07.57"E | 140 m | 26 January 1988 | 13 July 2015 |
| 15/21a-25 (RM25) | Producer | 58°11'51.27"N 00°08'06.55"E | 141 m | 29 January 1988 | 22 January 2015 |
| 15/21a-26 (RI26) | Water injector | 58°11'49.35"N 00°08'09.23"E | 140 m | 27 February 1988 | 24 October 2014 |
| 15/21a-31 (RE31) | Producer | 58°11'51.60"N 00°08'08.32"E | 139 m | 8 April 1988 | 4 April 2015 |
| 15/21a-40Z (HC40; Hamish) | Producer | 58°11'52.56"N 00°08'07.54"E | 140 m | 25 February 1989 | 26 May 2015 |
| 15/21a-42 (RA42) | Dry hole appraisal (Cat 1 suspended*) | 58°11'52.24"N 00°08'05.72"E | 140 m | 26 May 1990 | 24 December 2014 |
| 15/21a-58 (RP58) | Producer | 58°11'51.92"N 00°08'04.64"E | 140 m | 20 July 2001 | 29 April 2015 |
| **Ivanhoe field (Block 15/21a)** | | | | | |
| 15/21a-19 (ID19) | Producer | 58˚11'12.87"N 00˚05'19.50"E | 138 m | 13 October 1987 | 15 August 2014 |
| 15/21a-27 (IB27) | Producer | 58°11'10.50"N, 00°05'13.20"E | 138 m | 31 March 1988 | 17 July 2014 |
| 15/21a-28 (IK28) | Producer | 58˚11'12.63"N 00˚05'18.27"E | 138 m | 6 September 1992 | 15 September 2014 |
| 15/21a-29 (II29) | Water injector | 58°11'13.15"N 00°05'18.82"E | 138 m | 5 April 1988 | 6 May 2014 |
| 15/21a-30 (IG30) | Water injector | 58°11'10.99"N 00°05'21.72"E | 138 m | 7 April 1988 | 18 April 2014 |
| 15/21a-32 (IE32) | Producer | 58°11'11.79"N 00°05'21.09"E | 141 m | 11 April 1988 | 22 March 2014 |
| 15/21a-33 (IF33) | Water injector | 58°11'11.36"N 00°05'21.31"E | 138 m | 13 April 1988 | 21 June 2014 |
| 15/21a-57 (IJ57) | Producer | 58°11'11.34"N 00°05'18.78"E | 138 m | 8 May 2000 | 29 may 2014 |
| 15/21a-59 (IH59) | Abandoned well (dry hole) | 58°11'10.213"N 00°05'20.024"E | 138 m | 27 May 2003 | 1 July 2003 |

** A category 1 suspension means that the well is fully abandoned, with the exception that the wellhead is still to be removed.*

## 4.2 Operations undertaken

### Overview

Following the cessation of production, all of the wells were shut in at the Xmas trees. Each of the trees were left in a suspended state, the tree flanges isolated with double block and bleed flanges. The wells were then isolated from the infield flowlines, with the production, water injection and gas lift jumpers which connected them to the production manifolds all disconnected and removed to surface (Section 3.2; Phase 2).

Once it was confirmed that the fields would not be redeveloped, planning for the well abandonment operations began. The ultimate goal of the well abandonments was to meet the regulatory requirements to isolate hydrocarbon formations and prevent any migration of oil to the environment. Each well had to be isolated by sufficiently verified barriers to ensure the prevention of leaks indefinitely. An additional key component was the complete removal of the well structures, with the intention of leaving the seabed free of any obstructions.

The wells were all plugged and abandoned in accordance with the Hess Global Drilling Design and Operations Standards and its Recommended Practice for the Abandonment of North Sea Subsea Wells, the latter being specifically compiled and approved for this decommissioning campaign. The activities for decommissioning of the IVRR wells were also performed in compliance with Oil and Gas UK Guidelines for the Abandonment and Suspension of Wells.

As described in the DP, the well abandonment operations were split over two general phases. As a precursor to the full abandonment operations, a Light Well Intervention Vessel (LWIV) re-entered and re-suspended each well. The Awilco operated *WilHunter* mobile drilling rig then completed full abandonment operations at each.

#### Well intervention

The presence of brittle bolts on a number of the suspended IVRR Xmas trees was identified prior to well operations commencing. Due to tensile limitations of these brittle trees, well abandonments could not be completed with a mobile drilling rig without first removing the trees. As such the operations were split into two phases.

The first phase of the abandonment operations was to use a light well intervention vessel. This programme of intervention operations commenced in 2010 and 2011 with the *Seawell* and *Well Enhancer* well intervention vessels, when an initial seven wells were plugged. The *Seawell* later returned in 2013 and 2014 to complete these operations at the remaining IVRR wells.

The intervention vessel re-entered and re-suspended the wells, via the placement of mechanical deep and shallow set plugs within the wells. This achieved the Hess internal requirement for two independently installed and tested barriers to be in place at all times, allowing for the safe removal of the trees in preparation for re-entry by a mobile drilling rig.

#### Full abandonment

*Overview*

All rig base aspects of the well abandonment operations were undertaken from the Awilco *WilHunter*, a semi-submersible drilling rig held on position using an 8-point anchor system. The operations commenced in February 2014, continuing until the end of June 2015.

Depending on the status of well intervention operations described above, when the rig arrived each well was either suspended with temporary deep and shallow set plugs in place, and with the tree still in place for added security, or suspended solely at the tree. Therefore, where the plugs were already set, the rig could immediately recover the tree and deploy the Blowout Preventer (BOP); but where the plugs were not set, the wells were re-entered and temporary plugs set first.

Once the BOP was deployed, the completions were recovered and the well logged to evaluate the annular sealing capability. Two appropriately positioned permanent cement barriers were set across the wellbores, with their type and location dependent on the logging results.

Environmental barriers were set further up to prevent any remaining chemicals leaking from the wells over time and finally each wellhead assembly was recovered to a minimum of 10 ft (3 m) below the seabed. The completion tubing strings, wellhead structures and trees were taken ashore for reuse, recycling or disposal as appropriate.

As introduced above, all of the IVRR wells were permanently abandoned in this fashion, in accordance with Hess' own standards and with due cognisance of the Oil and Gas UK guidelines for well abandonment.

*Well clean-up and logging*

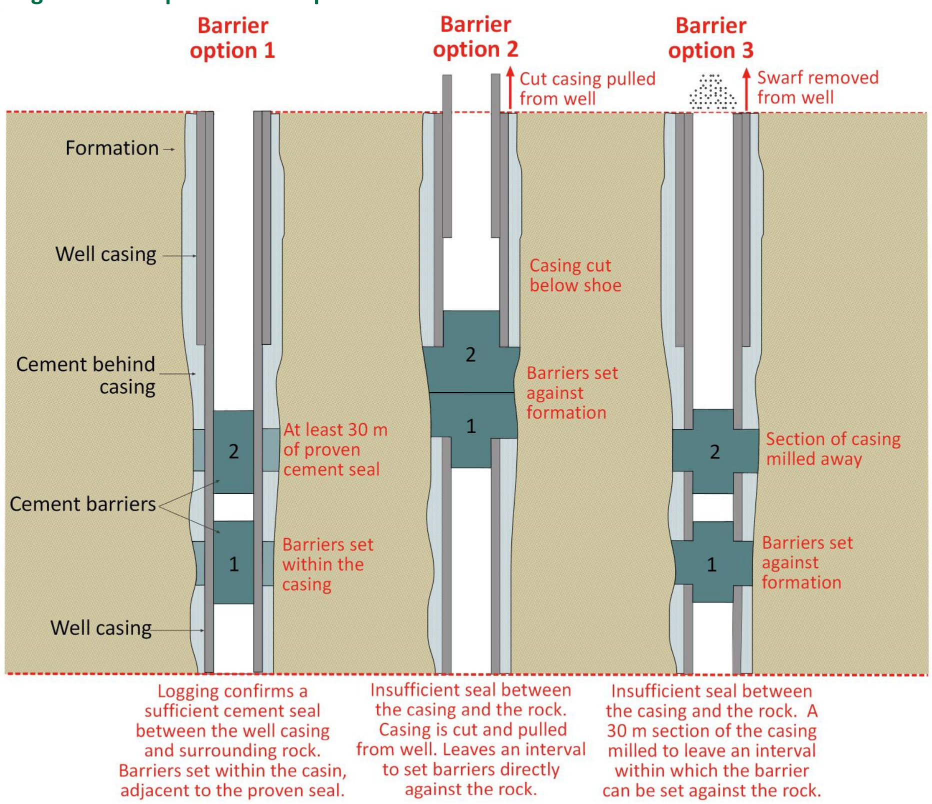
When setting a cement barrier across a wellbore, it is essential that the cement already in place between the well casing and the formation is intact to ensure a complete barrier. Therefore, when undertaking well abandonment operations, Hess does not consider inferred cement quality from historical drilling and cementing records to be sufficient. In order to meet Hess internal standards for well abandonment, the quality of cement seals must be directly verified at the time of well abandonment and remedial action taken if necessary. These standards were augmented upon review of the lessons learned from the Macondo incident.

In order to achieve this, the completion strings were removed and the well casings cleaned to remove any oil residues (Section 4.3). Cement logging was carried out using acoustic evaluation tools to determine the status of the cement seal between the well casings and the surrounding formation. The results of these logs were reviewed by Hess subject matter experts from Houston head office and verified by an independent third party. The results of these logging operations dictated the depth and type of permanent cement barriers set with the IVRR wells, as summarised below.

*Permanent cement barriers*

In all wells, two permanent cement barriers were required between the reservoir and the surface. Where satisfactory cement between the casing and formation was confirmed, at least a 30 m (100 ft) stretch of proven seal, an internal cement barrier was set. In these cases, the cement was used to fill the gap within the well casing, adjacent to the stretches of proven seal, and therefore form a contiguous barrier across the entire well (Figure 4.1).

**Figure 4.1 Options for the placement of cement barrier**




If the existing seal was not deemed to be sufficient, a section of the well casing was cut and removed or a section milled out to provide a 30 m open hole interval. This then allowed a continuous cement barrier to be set across the well and directly against the formation (Figure 4.1). In some cases, the removal and milling out of casings allowed old Oil Base Mud (OBM) trapped behind them to enter the well and mix with the Water Base Mud (WBM) system being used during the abandonment operations. This is discussed in more detail in Section 4.3.

In abandoning the IVRR wells, Hess used a magnesium resistant cement for all of the permanent barriers. This proven cement recipe provides long-term zonal isolation and protects against cement degrading. The High Magnesium Resistance (HMR) cement is a blend of blast furnace cement and fly ash, which reduces the cement permeability and prevents attack of alkaline brines found in the formation. Development work to optimise the cement barrier recipe was carried out following research into the Macondo incident and with reference to the recommendations made, with the specific objective of ensuring the long term integrity of the cement barriers and preventing leaks to sea. Unlike more conventional cements, the HMR blend is very resistant to long term corrosion, so it is anticipated that it will provide a robust solution to achieve permanent barriers for geological time.

*Environmental barrier*

An 'environmental' cement barrier was also set internally in each of the IVRR wells. This barrier was not designed as an abandonment barrier to seal off the reservoir, but instead to prevent the leaching of slops from within the well or behind the well casings once operations were complete and the rig has moved off site. Once the environmental barrier was in place and had been verified, the BOP was recovered. The well casings were then cut to approximately 3 m below the seabed, and the casing stubs and wellhead recovered. Once well abandonment operations were complete, an ROV debris survey was carried out to ensure that the area around the well was left free from obstructions (Section 5.1).

There were also two Category 1 suspended wells within the Rob Roy field (Wells 15/21a-42 and 15/21a-23). These wells were already effectively abandoned with two cement barriers in place, but there was still a requirement to cut the well casings approximately 3 m beneath the seabed, and then recover the casing stubs and wellhead. These operations were also undertaken during the Rob Roy well abandonment operations. By the end of operations all wells had been successfully abandoned and the seabed cleared of any well related structures.

*Chemical use*

Chemicals were required for the well re-entry, clean up and setting of abandonment barriers. The use and discharge of these chemicals was approved under an appropriate chemical permit, as initially described in the IVRR DP, and subsequently reported on via the Environmental Emissions Monitoring System (EEMS).

## 4.3 Variations from decommissioning programme

The aspects of decommissioning covered here were not described explicitly in the decommissioning programmes and therefore do not constitute variations from the programmes *per se*. However they did ultimately vary from the anticipated scope of well operations and involved increased discharges to the marine environment, which in some cases were above the normally accepted thresholds for such inputs. Therefore they have been described in more detail below.

**Reservoir oil discharges**

As part of well abandonment operations, and to facilitate the use of cement logging tools in particular (Section 4.2), the well casings were cleaned to remove any possible residual reservoir hydrocarbons. The wells were cleaned out using mechanical tools, including scrapers and brushes. Chemicals were also used to assist in the clean-up process, including surfactants to clean the well and viscosifiers to lift the residues to the surface. Clean brine was pumped into each well and circulated out again, continuing until visibly clean brine was returned. As a result, fluids used and returned to the rig during this phase were contaminated with the reservoir oil residues from the casings. These well abandonment operations also generated other oily fluids, such as oil contaminated cement spacer fluids used whilst setting the cement barriers. Various techniques were employed to reduce the volume of fluid becoming contaminated and that returned to the rig. However, those contaminated fluids which were returned to surface all required treatment to lower the oil content to a level where there would be no significant environmental impacts.

During the Hess well abandonment operations in the Fife, Fergus, Flora and Angus (FFFA) fields, oil contaminated fluids from the equivalent activities were treated using an MI Swaco EnviroUnit. However, due chiefly to the presence of viscosifiers and other intractable components in the returned fluids, the treatment process proved to be much more time consuming and inefficient than anticipated. Upon review, the holding tanks and chemical treatment which comprised part of the EnviroUnit process proved to be the most effective aspect of the oil treatment process. As water based fluids alone would not provide sufficient density or lifting capacity to facilitate operations, such as lifting dirt off the casings or metal swarf to the surface, viscosifiers were also required during the IVRR well abandonments. This time only the holding tank and chemical treatment aspects of the process were selected to deal with oil contaminated fluids, with fluids routed through this system to reduce the average oil in water concentration of fluids prior to discharged to sea.

The treatment to reduce the oil in water content at the FFFA wells to below 40 mg/l proved to be a very time consuming process, which extended the duration of operations, increasing emissions generated and produced large amounts of hazardous oil contaminated waste, such as oily slops and used filters, as well as oil contaminated chemicals. These had to be disposed of onshore incurring further issues such as atmospheric emissions, resource use and increased landfill use as part of waste treatment and disposal. The reduction in the oil content of the fluids discharged to sea achieved was not seen to justify the additional environmental impacts incurred elsewhere.

Based on the issues encountered at FFFA, it was not considered feasible to treat the returned fluids to meet a 40 mg/l concentration with existing technologies. Therefore an increased oil discharge concentration of 60 mg/l was requested for the IVRR wells. Due to the limited quantity of oil that would be released at each well, rapid dispersion of the oil through the water column and the lack of sensitive receptors, any environmental impacts from the discharges at this oil level were deemed to be insignificant and benefits of improving the oil concentration would not be sufficient to justify the associated environmental impacts. The requested oil concentration was approved and, under the appropriate oil discharge permits, 262 kg of oil was ultimately discharged during the Ivanhoe well abandonment operations (OTP/36), as well as 122 kg from the Rob Roy operations (OTP/178). Table 4.2 details the reservoir oil discharges made during the well abandonment campaign.

**Table 4.2 Reservoir oil discharges from IVRR wells**

| Well | Volume of waste stream discharged ($m^3$) | Max concentration of reservoir oil discharged (mg/l) | Quantity of reservoir oil discharged to sea (kg) |
|---|---|---|---|
| **Ivanhoe field** (Block 15/21a) | | | |
| 15/21a-19 (ID19) | 639 | 46 | 29.1 |
| 15/21a-27 (IB27) | 960 | 38 | 36.4 |
| 15/21a-28 (IK28) | 1,745 | 29 | 50.1 |
| 15/21a-29 (II29) | 518 | 22 | 11.4 |
| 15/21a-30 (IG30) | 438 | 30 | 13.1 |
| 15/21a-32 (IE32) | 1,086 | 43 | 46.7 |
| 15/21a-33 (IF33) | 1,165 | 37 | 42.7 |
| 15/21a-57 (IJ57) | 779 | 40 | 31.5 |
| **Rob Roy and Hamish fields** (Block 15/21a) | | | |
| 15/21a-16 (RH16) | 389 | 23 | 8.8 |
| 15/21a-17 (RN17) | 688 | 19 | 12.9 |
| 15/21a-18 (RK18) | 432 | 6 | 2.7 |
| 15/21a-22 (RF22) | 580 | 11 | 6.7 |
| 15/21a-24 (RL24) | 379 | 44 | 16.5 |
| 15/21a-25 (RM25) | 494 | 28 | 13.7 |
| 15/21a-26 (RI26) | 846 | 29 | 24.2 |
| 15/21a-31 (RE31) | 490 | 29 | 14.1 |
| 15/21a-40Z (HC40) | 371 | 37 | 13.8 |
| 15/21a-58 (RP58) | 280 | 30 | 8.5 |

### Old oil base muds

Where it was required that an interval be made in the well casings, to allow the setting of barrier directly against the formation (Section 4.2), consideration had to be given to the fluids behind the casing. OBM was used as the drilling fluid when originally drilling the majority of the IVRR wells and, when the well casings were set in place, some of this OBM would have been trapped behind them, as is normal practice during drilling operations. When opening up the space between the well casings and the formation through section milling or cutting of the casings, some of the old trapped OBM was able to enter the wellbore and mix with the WBM system used during the abandonment operations.

Once mixed with the WBM system, these old fluids were circulated back to the rig with the WBM, where they were captured and treated. Any separated base oil was stored in tote tanks and either pumped back down the well in between the cement plugs or returned to shore for treatment and disposal. Any solids were captured in tanks and returned onshore for disposal. The remaining base oil contaminated fluids were treated on the rig in order to reduce the oil content to below a maximum of 60 mg/l before being discharged to sea.

This aspect of the well abandonment operation and the associated treatment activities were not explicitly covered in the decommissioning programme. Details of the oil discharge were given in the respective master applications and approved under the chemical permits for the Ivanhoe (WIA/58 and CP/164) and Rob Roy (WIA/147 and CP/406) rig based well abandonments. The maximum permitted base oil discharge for each given well was 11.5 kg and this was not exceeded at any of the IVRR wells. A total of around 30 kg of base oil was discharged across seven affected Ivanhoe wells, with approximately 27 kg of base oil all discharged from the relevant Rob Roy well abandonments (Table 4.3).

**Table 4.3 Old OBM discharges from IVRR wells**

| **Well** | **Fluid used to drill the well** | **Volume of waste stream discharged** (m3) | **Max concentration of base oil discharged** (mg/l) | **Quantity of base oil discharged to sea** (kg) |
|---|---|---|---|---|
| **Ivanhoe field** (Block 15/21a) | | | | |
| 15/21a-19 (ID19) | WBM | 0 | 0 | 0 |
| 15/21a-27 (IB27) | OBM | 84 | 51 | 4.3 |
| 15/21a-28 (IK28) | OBM | 92 | 44 | 3.4 |
| 15/21a-29 (II29) | OBM | 126 | 56 | 6.9 |
| 15/21a-30 (IG30) | OBM | 60 | 57 | 3.4 |
| 15/21a-32 (IE32) | OBM | 125 | 56 | 4.2 |
| 15/21a-33 (IF33) | OBM | 167 | 56 | 8.1 |
| 15/21a-57 (IJ57) | WBM | 0 | 0 | 0 |
| **Rob Roy and Hamish fields** (Block 15/21a) | | | | |
| 15/21a-16 (RH16) | WBM | 0 | 0 | 0 |
| 15/21a-17 (RN17) | OBM | 60 | 24 | 1.4 |
| 15/21a-18 (RK18) | WBM | 0 | 0 | 0 |
| 15/21a-22 (RF22) | OBM | 32 | 27 | 0.5 |
| 15/21a-24 (RL24) | OBM | 74 | 42 | 3.1 |
| 15/21a-25 (RM25) | OBM | 30 | 1 | 0.6 |
| 15/21a-26 (RI26) | OBM | 177 | 56 | 9.1 |
| 15/21a-31 (RE31) | OBM | 160 | 49 | 6.7 |
| 15/21a-40Z (HC40) | OBM | 118 | 50 | 5.6 |
| 15/21a-58 (RP58) | WBM | 0 | 0 | 0 |

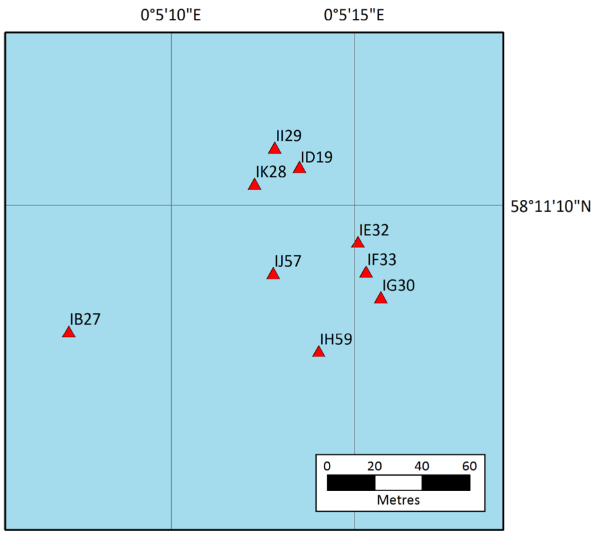
## 4.4 Remaining features

All IVRR wells were abandoned in accordance with Hess internal standards and the Oil and Gas UK guidelines for well abandonment (Section 4.2). Once cement barriers had been set and verified, each wellhead assembly was recovered to a minimum of 3m (10 ft) below the seabed. After each well abandonment was completed, as left ROV surveys were conducted from the Awilco *WilHunter* drilling rig, confirming there were no remaining items of debris on the surrounding seabed (Section 5.1). Therefore, nothing remains on the seabed at each former drill centre (Figure 4.2), as later confirmed by the final debris and overtrawl surveys (Section 5.4). Individual abandoned well locations are presented in Table 4.1 above.

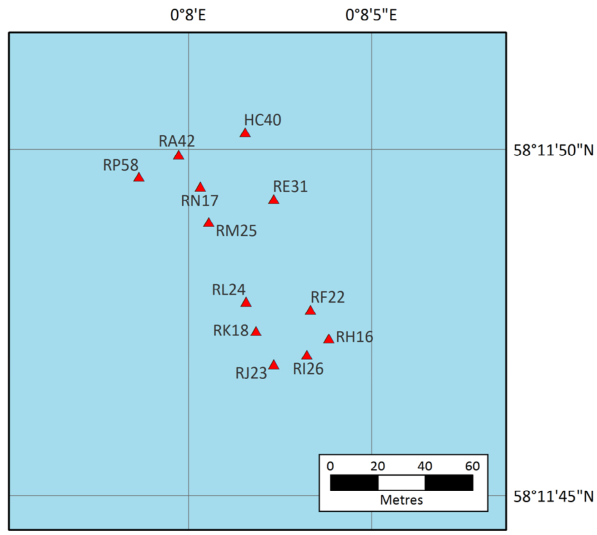
Once each wellhead and associated casings were removed, a 30" diameter hole remains in the seabed which will be naturally filled by sediment deposition over time, leaving a shallow depression. The positions of the now fully abandoned Ivanhoe and Rob Roy well clusters are illustrated in Figures 4.2a and 4.2b respectively.

**Figure 4.2 Location of the abandoned IVRR wells**

a) Abandoned Ivanhoe wells




b) Abandoned Rob Roy wells




## 5 Verification of completion

Over the course of the IVRR field decommissioning operations, various seabed surveys have been undertaken to support and inform the decommissioning activities as they were carried out and to provide information on seabed conditions, status of remaining infrastructure, the location of any debris, and potential environmental impacts. This work has also helped to formally verify the completion of the IVRR decommissioning operations. Regular inspections of the status of infrastructure have also been undertaken during the decommissioning period, as well as during the production life cycle. The following sections provide a basic summary of the surveys undertaken and their findings.

### 5.1 Inspection surveys

Inspection and verification surveys have been conducted in the IVRR fields on an annual basis, since the removal of the *AH001* FPF in 2009 and up until a final post-decommissioning inspection survey in July 2015. These surveys used sidescan sonar and video cameras attached to a ROTV in order to assess the status of the remaining field infrastructure. Depending on the stage of decommissioning, inspections covered export lines, infield flowlines, risers, spools, umbilicals, manifolds, mid-water arches and tree assemblies. Where potential issues were identified within the sonar data, these were further investigated visually. Flowlines and seabed structures including manifolds and wellheads were investigated as appropriate for any damage (including impact damage from debris and snagging), corrosion and marine growth, anode depletion, signs of scour or sediment deposition and leakage of hydrocarbons or other fluids.

Wall thickness measurements were taken at all predefined locations on manifold pipework and at any additional places where external signs gave cause for concern. The underside of piping and particularly bends, which are most prone to internal corrosion, were carefully inspected. Additional reading positions were marked and incorporated into subsequent inspections. Divers were also used to manually inspect bolt tightness at every flange and on supports, clamps and guides. These positions were closely scrutinised for leaks, including less accessible areas such as the rear and underside. Signs of either scour or deposition around the base of the protective structures were reported and assessed.

The only exception to this schedule and methodology was in 2014, when no formal inspection programme was undertaken. During the well abandonments undertaken in 2014, the *WilHunter* drilling rig instead undertook detailed "as left" inspections at each well location upon the completion of the related abandonment process (described below). All locations were then investigated in 2015 during the final inspection survey.

### Flowline inspections

As mentioned above, the IVRR subsea infrastructure including flowlines has been the subject of annual inspection surveys using ROTVs equipped with sidescan sonar and video equipment, as well as part of *ad hoc* surveillance such as in relation to rock dumping using a MBES. Infield flowline and export pipeline routes were investigated to identify:

- The status of burial and exposure.
- Any change in position of the flowline (usually evident from a series of small, parallel embedment trenches).
- Any spanning of a flowline.
- Any damage to flowlines.
- Any large debris on or in the vicinity of a flowline.
- Position of any stabilisation mattresses, or similar features, to determine if these had been displaced or not.

The surveillance conducted was used to confirm the position of the flowlines and related degrees of embedment, spanning, buckling and erosion of trench walls. Inspection also helped identify damage such as abrasion, scarring and marine growth, as well as the degree of cathodic protection and the depth of cover in the case of buried flowlines. Wall thickness measurements of flowlines would also be undertaken if indicated as necessary through the prior inspection work. Depending on the review of data gathered, diver inspection would follow the sidescan sonar surveillance.

The last survey was conducted along flow and pipeline corridors, as well as within 500 m safety zones, immediately after removal of final items in July 2015. Data gathered on the burial depth for all remaining lines was reviewed and compared with earlier data where possible; the average burial depth was seen to be well in excess of the minimum 0.6 m criteria and in excess of 1 m in most cases. This includes the trenched export pipelines which have been confirmed as being buried by sediment back filled to a minimum depth of 0.6 m (Section 3.4). Inspection surveys carried out during or after decommissioning have observed that there has been no perceptible change in the status of these export lines over the period since their burial. MBES work carried out over the rock dumped sections of remaining infield flowline section also indicated no significant change in the profile of dumped material (Section 5.2), even after recent overtrawling with chain mats and trawling gear.

### Well inspections

While left in a suspended state, inspections of the suspended Xmas trees were conducted as part of the annual schedule of inspections described above, looking particularly for any leakage of hydrocarbons or other fluids.

As each well abandonment operation was completed, a detailed as left survey was conducted from the Awilco *Wilhunter* drilling rig, using its work class ROV. The ROV was used to inspect the former well location as well as the area around the wells, initially using acoustic survey techniques, followed by visual verification of any items identified. Used to identify any debris in the area, each ROV survey covered a 100 m radius around the well. As the wells within the Ivanhoe and Rob Roy clusters were in close proximity to each other (Figure 4.2), some areas of seabed were covered multiple times during the as left ROV inspections. On each occasion, the visual feed from the ROV was observed during the inspection itself and then reviewed onshore prior to approval and sign off. Any debris identified was documented for recovery during the final debris removal operations, which was carried out at the end of field decommissioning operations in August 2015.

In addition to these individual as left ROV surveys, the 500 m safety zones and therefore the well locations were covered again during the final inspection ROTV survey carried out in July 2015. Again, any identified debris was noted for collection during the debris recovery operation. This survey was also used to look for an evidence of issues with the abandoned wells.

## 5.2 Surveys of seabed conditions and debris

### Inspection of seabed conditions

*Rig site survey*

A rig site survey was carried out in early 2013, prior to well abandonment operations. Centered on the RBM, this extended survey covered a total area of 5 x 8 km and encompassed both the Ivanhoe and the Rob Roy fields.

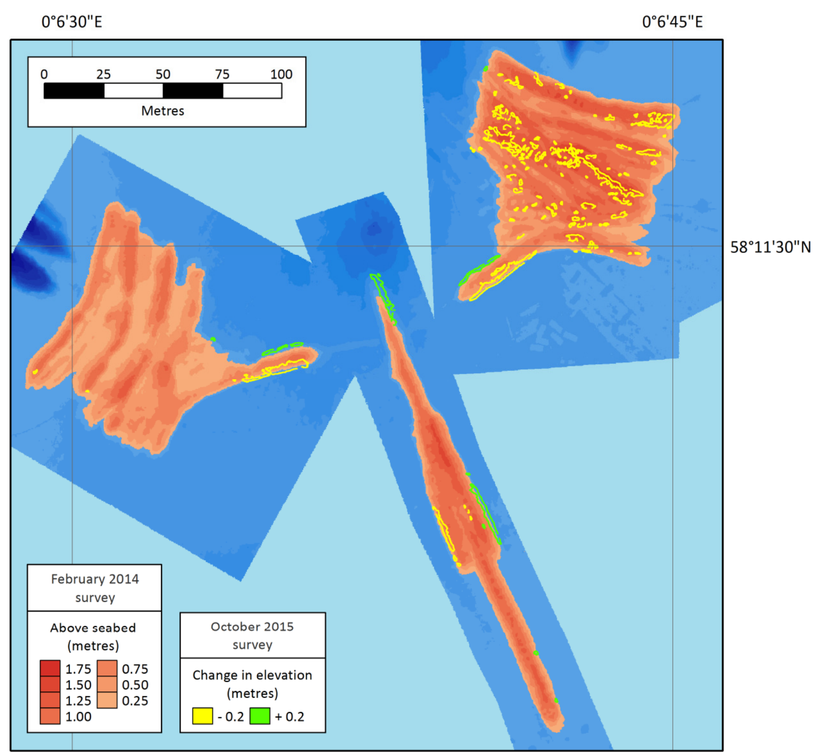
Geophysical analogue survey techniques were used to investigate seabed conditions and any possible hazards prior to anchoring the mobile drilling rig over the Ivanhoe and Rob Roy well clusters for the abandonment operations. Geophysical surveillance was also conducted over a 200 m wide corridor along the export flowline routes to Claymore and Tartan, PL513 and PL514, respectively.

The survey found the soft clay seabed to be generally flat, but with numerous depressions forming chain like features across the area. In addition to these naturally occurring features, remaining radial anchor patterns were observed around the Ivanhoe and Rob Roy well clusters, as well as particularly pronounced scour marks where the *AH001* FPF was previously moored (see Section 3.3). Trawling scars were also observed across the area. The former infrastructure and pipeline positions were also detected and correlated with the known positions. Sidescan sonar contacts were investigated by the ROV, encountering boulders, seabed depressions, anchor scars, protective mattresses and items of debris.

*Inspection of the mattress rock dump*

As discussed in Section 3.4, rock was dumped over the damaged concrete mattresses which could not be removed for safety and environmental reasons. In early 2014, a seabed profile inspection of the deteriorated mattresses was carried out prior to the rock dumping operations and repeated immediately after completion (Figure 3.3). This consisted of a MBES acoustic investigation to ensure an adequate depth coverage over the mattresses and to verify that an appropriate seabed profile had been established to facilitate overtrawling (Section 3.4). Whilst undertaking the further rock dumping activities in late 2015 (Section 3.3), the opportunity was taken to carry out an further acoustic survey of the rock dumped over the damaged mattresses, to determine if there had been any changes in coverage over time. The data gathered indicated that there had been no changes beyond a very minor reduction in the rock profile in some areas (Figure 5.1). The lack of change suggests that these rock berms are very stable, especially considering these areas had recently undergone comprehensive over trawling by a typical North Sea fishing vessel. Based on this stability and the general low energy current regime, it is felt that it would be unnecessary to conduct further verification surveys over the rock dumped pipelines and mattresses in future.

**Figure 5.1 Change in the profile of rock dumped over the mattress**

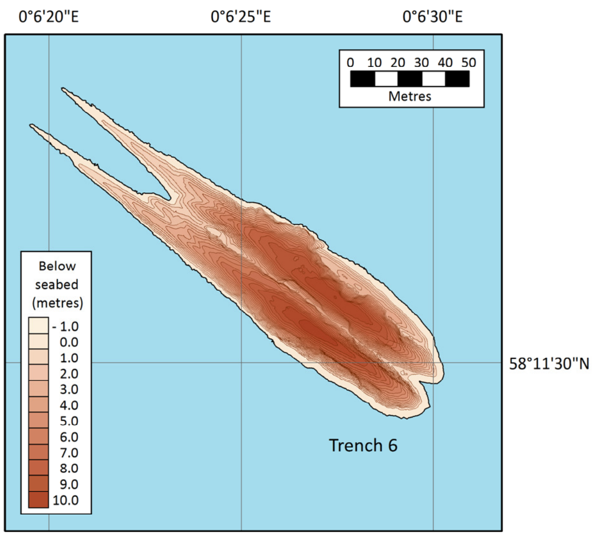


*Inspection of the trench rock dump*

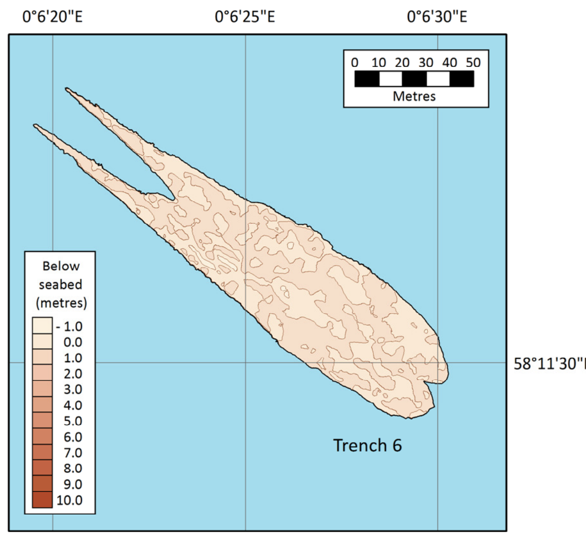
As one of the final steps in decommissioning, an overtrawl survey was conducted to determine if the seabed was safe for normal fishing activities to resume in the area (Section 5.4). During this survey, the chain mats and fishing trawls used became snagged on the trenches scoured out by the constant movement of the FPF moorings, indicating that these trenches presented a significant safety risk to fishing vessels. To alleviate risks and allow normal fishing activities to resume, the trenches were filled with crushed rock, as described in Section 3.3. The profiles of the trenches were known from the previous rig site survey (see above), facilitating detailed planning of operations. However, prior to filling these trenches with crushed rock, an acoustic survey was undertaken to further verify the location and dimensions of the trenches (Figure 5.2a). With each trench filled to align it with the surrounding seabed topography but not protrude beyond it, a second acoustic survey was then conducted to confirm that this objective had been completed successfully (Figure 5.2b). This was followed by a further overtrawl survey with no further snagging issues verified (Section 5.6).

**Figure 5.2 Example mooring scour trench before and after rock dumping**

a) Trench profile prior to rock dumping




b) Trench profile post rock dumping




*Final inspection survey*

As mentioned above (Section 5.1), a final inspection survey was undertaken in 2015 using sidescan sonar and video systems attached to an ROTV. This survey also observed a relatively uniform seabed with numerous depressions. As well as numerous trawl scars across the area surveyed, the same radial mooring patterns were also detected within the acoustic data gathered. These scars were subsequently verified visually by the ROTV.

**Debris surveys and clearance**

*Identification of debris*

As well as investigating anchoring conditions for the mobile drilling rig operations, the rig site survey carried out in 2013 used sidescan sonar to look for possible debris items. Several debris items, including handrails, wooden beams and fishing nets, were detected during the survey and subsequently verified by ROV. This was used to inform the later debris removal operations. The annual inspections of the seabed described above, as well as the as ROV debris surveys performed around each well post abandonment, were also used to document debris for later recovery during decommissioning.

The final post decommissioning ROTV inspection survey, completed in July 2015, was further used to provide information on any remaining debris in the fields. The sidescan sonar detected multiple contacts that were each investigated by ROV. In many cases, these were confirmed to be boulders, seabed depressions, anchor scars or known areas of protective rock dump material. However, additional debris items were also identified and logged from removal.

*Debris recovery*

During August 2015, divers were deployed to remove the identified items of debris from the IVRR fields as well as along the export pipelines. Where necessary, the divers recovered the debris using baskets or rigging for direct recovery to the deck of the vessel. Removal of debris was conducted under a marine licence approval (ML/100). Once this work was successfully completed, the final overtrawl trials were undertaken (Section 5.4).

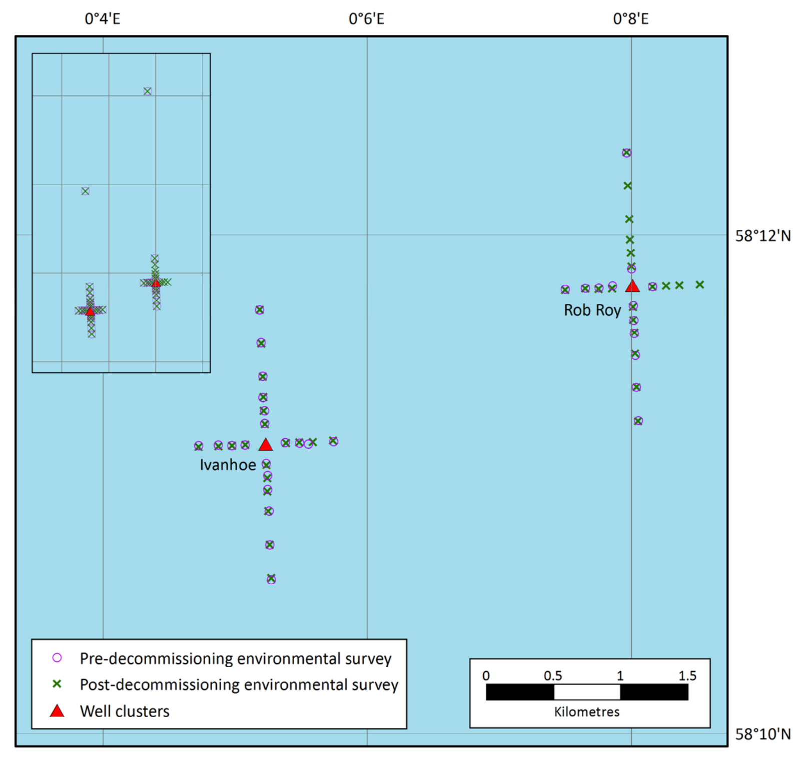
Various forms of surveillance have now confirmed that all debris and seabed surface items have been removed, with the minimum burial depth criteria of 0.6 m for the remaining infrastructure exceeded in many cases. This is further supported by the clearance certificate provided after the final overtrawl survey, described in detail in Section 5.4.

## 5.3 Environmental surveys

### Background

Prior to the removal of all relevant flowlines, wells and seabed infrastructure from the IVRR fields, a pre-decommissioning environmental baseline survey was undertaken on behalf of Hess. The survey took place in two legs over August and October 2010 respectively. It was designed to establish the existing physical, chemical and biological characteristics of the IVRR fields prior to the decommissioning operations commencing. As part of this seabed samples were acquired from sample stations arranged in an approximate cruciform pattern around each field's wellhead centre (Figure 5.3). Consultation with DECC, Marine Scotland, the Joint Nature Conservation Committee (JNCC) and SFF was conducted to inform the development of the survey scope and ensure it would address their particular information requirements.

**Figure 5.3 Environmental survey sampling locations**




The same sample locations were revisited in 2015 in order to identify the current status of the seabed after decommissioning and compare that to the pre-decommissioning baseline. This would give an indication of potential extent and significance of any changes incurred by the operations themselves.

Prior to this support work for the decommissioning, the most recent environmental surveys in the IVRR area were carried out in 1989 to 1990. This was broadly the same time period as the drilling activity carried out to develop the fields (1987 to 1990). Respective surveys were also conducted surrounding individual exploration well locations in the two fields in 1987. These earlier surveys focussed on chemical characteristics of the seabed with no samples acquired for macrofaunal analysis.

**Changes in environmental characteristics**

*Hydrocarbon contamination*

The earliest data available on hydrocarbon contamination for the IVRR fields is from 1987. Elevated oil concentrations were found in seabed sediments in the IVRR fields even at this early juncture, most likely due to the previous exploration drilling conducted (starting in 1975). The total hydrocarbon concentration was not calculated for the 1987 survey samples, UV analysis gave a mean value of 93 mg/kg at Ivanhoe and 59 mg/kg at Rob Roy.

A large increase in the levels of oil contamination in sediments in the IVRR fields was then observed between the surveys in 1987 and 1990; with a mean Total Hydrocarbon (THC) concentration by UV analysis of 625 mg/kg recorded for Ivanhoe and 159 mg/kg at Rob Roy. This is mostly likely due to the considerable amount of development drilling using oil base drilling fluids conducted in that short period. In the 2015 surveys, evidence of a kerosene-like drilling fluid was encountered, most likely deposited with drill cuttings as part of these earlier activities. This is seen as the peak level of anthropogenic contamination in the fields.

Natural degradation of oil in the seabed would be expected over time due to physical and biological weathering. The 2010 pre-decommissioning survey observed that in the intervening period between drilling and field suspension, the THC in the IVRR fields had decreased dramatically to 44.4 mg/kg at Ivanhoe. Between 2010 and 2015, average THC levels had declined significantly again to 23.8 mg/kg. At Rob Roy the average total oil concentration has shown a lower decline, from 87 mg/kg in 2010 to 71.5 mg/kg in 2015. However, average THC levels at Ivanhoe are now more than an order of magnitude lower than the 1990 levels, and values from Rob Roy have declined by over 50%.

Poly-Aromatic Hydrocarbon (PAH) levels at Ivanhoe and Rob Roy have decreased from averages of 47 and 39 mg/kg in 1990 to 30 and 28 mg/kg in 2015 respectively. The levels recorded at both fields in 2010 and 2015 were largely the same, indicating no new input of contaminants during the decommissioning operations. PAHs present were also predominantly pyrogenic in origin (arising from the deposition of burnt material from freshwater and atmospheric inputs) rather than from oil based substances.

Based on collected survey data, the existing level of oil contamination in the IVRR fields is higher than background criteria for the North Sea as well as the identified threshold for ecological effects in invertebrates (both of which are approximately 10 mg/kg). This is unsurprising given the developed nature of the site. However, this series of results suggests that natural breakdown of oil contamination has significantly lowered pollution in the IVRR fields and the act of removing the wells and infield infrastructure has not resulted in any significant re-distribution or concentration of oil contamination.

*Heavy metals*

Heavy metal analysis can provide further information assessing the dispersion of discharged materials and extent of impacts on the seabed around the decommissioning activities. All of the heavy metals analysed at Rob Roy and some of those at Ivanhoe had increased slightly in the concentrations recorded between 1990 and 2010. These observations may be due to an improved accuracy of analytical methods and instrumentation rather than an increase in metal contamination over time. Other metals recorded at Ivanhoe, such as cadmium, mercury and lead all showed an overall decrease in concentration. Regardless, all values encountered at the IVRR fields in 2010 were below the OSPAR accepted “effects range” (ER) concentrations. Ecological impacts are rarely observed in animals when heavy metal concentrations fall below these levels.

Post decommissioning, the average levels of a number of metals were found to be higher than in 2010, although lead and mercury levels had decreased at Rob Roy. This may have been due to the disturbance of sediments and re-distribution of adsorbed metals. Changes in the geographic pattern of barium concentrations around the drill centres at Ivanhoe and Rob Roy also indicated that there may have been a redistribution of the associated sediments during decommissioning. However, the levels encountered were all still below the agreed background concentrations and effects range levels indicating that there should not be any related ecological effects.

*Biological data*

There are no biological data available for the IVRR fields prior to the 2010 pre-decommissioning survey. This survey observed that the invertebrate communities present were consistent across the fields and dominated by infaunal species, particularly the polychaete worm *Paramphinome jeffreysii* and the bivalve mollusc *Parvicardium minimum* which are characteristic of the wider area.

When compared to the 2010 values, the average number of taxa and individuals were found to be significantly higher across the fields in 2015. Communities typical of the wider North Sea area were also encountered in IVRR in 2015. The increase in both abundance of individuals and number of taxa, as well as the consistency with communities in the wider region, suggests that the invertebrate communities in the area have been unaffected by decommissioning and are currently in a largely natural state.

**Cuttings piles**

OSPAR recommendation 2005/6 on the management of cuttings piles required all operators to assess the environmental characteristics of cuttings piles associated with their assets (Stage 1) and determine whether they needed an immediate Best Available Technique and Best Environmental Practice (BAT/BEP) assessment of potential methods for their remediation (Stage 2) in order to prevent further impacts. Hess carried out this first stage assessment based on theoretical relationships between drilling activity and size of piles established through previous joint industry research and existing environmental survey data. It was determined that the nature of drilling and contamination status in the IVRR fields was such that any cuttings piles present would not exceed the key environmental thresholds provided in the OSPAR recommendation. As such no immediate work to manage them was required during production operations.

However, cuttings piles may be disturbed during decommissioning resulting in the release and dispersal of contaminants. Therefore, as part of decommissioning guidelines DECC require that, where the Stage 1 OSPAR assessment was based on extrapolation of existing data, the results should be verified with new surveys of the piles in question. These surveys can then be used in relation to the management of cuttings piles and the associated planning of decommissioning to reduce environmental impacts.

The pre-decommissioning survey would have been an appropriate point to conduct a specific investigation of the IVRR cuttings piles and verify their characteristics. However, it was known that a relatively small amount of drilling had been concentrated in any one drill centre in these fields and there had not been a fixed installation for cuttings to accumulate around. Bathymetric surveys of the IVRR fields also recorded very little change in the seabed topography around each drill centre. The depth varied by around only 1 m, suggesting no distinct accumulations of discharged material around the respective drilling locations. As such it was felt that notable cuttings piles would not be present in the fields and additional investigation prior to decommissioning would be unnecessary.

Discussions were held with DECC to establish pre-decommissioning survey requirements, including possible cuttings piles investigation, along with wider consultation with expert bodies and stakeholders (Marine Scotland, JNCC and SFF). Based on this communication and the survey data provided, it was agreed that a specific investigation of drill cuttings was not required for the IVRR fields. Therefore, a traditional baseline survey approach was deemed sufficient for the purposes of monitoring any impacts related to decommissioning.

**Conclusion**

The review of data gathered suggests that there has been little significant contaminant redistribution or other disturbance caused by the decommissioning operations. Overall, the environmental data gathered for the IVRR fields in 2015 indicated that the local seabed sediments are largely at background levels for this region of the North Sea. It should also be noted that the act of spreading seabed substrates during decommissioning, such as during overtrawl surveys (Section 5.4), should encourage increased aeration of the previously deposited material facilitating further degradation by natural processes. With no further site specific anthropogenic inputs expected, at least not associated with Hess activities, it is felt that further monitoring surveys are not required. Natural degradation of contaminants should help restore the area to pre-developed conditions on a relatively short timescale.

## 5.4 Overtrawl surveys

Upon completion of field decommissioning operations, including the identification and recovery of any final debris items (Section 5.2), DECC require that an overtrawl survey be undertaken to determine if the fields have been successfully cleared of all debris that could interfere with fishing, that no anchor mounds remain, and that all pipeline ends have been sufficiently protected. This survey was primarily used to ensure the area is retuned to a more natural state and that there are no obstructions or snagging risks for future fishing activities.

Completed in August and September 2015, an overtrawl survey was carried out by SFF Services Ltd (ML/123). The vessel conducted sweeps across the IVRR fields, focusing on the extent of the four 500 m safety zones which covered the former well clusters, the FPF and the RBM. Running between these 500 m safety zones, the survey also covered the 200 m safety corridors which protected infield flowlines. The actual trawl tracks as displayed on the vessel plotter, both the targeted trawling and the required line turns, are shown in Figure 5.4a. As well as the infield flowlines which connected the fields and the RBM, the survey covered the 200 m safety corridors which formerly protected the two export pipelines which ran up to the Claymore and Tartan platforms. Based on actual track lines provided by the fishing vessel, Figure 5.4c illustrates the spatial extent of the overtrawl surveys.

The trawling vessel used was typical of those active in this region of the northern North Sea, and therefore able to provide an indication of whether the area would be safe for normal fishing activity. Sweeps were initially conducted using a chain trawl, which was used to break down any obstacles, assessing the results and repeating the process until all required areas had been cleared. The vessel then conducted additional passes of the seabed, following broadly the same sweep pattern as adopted for the chain mat, but using a single trawl net and then a twin trawl net to simulate fishing activity relevant to the IVRR area.

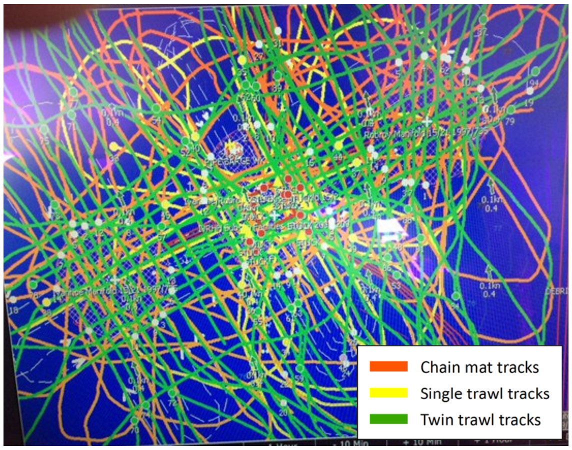
During the overtrawl survey, the twin trawl became snagged on several occasions. Investigations found that the vessel gear was snagging on trenches in the seabed, scoured out by the constant movement of the moorings that previously help the *AH001* FPF in place, as discussed in Section 3.3. The snagging incidents which occurred during the survey indicated that these trenches presented the potential for future damage to fishing gear and furthermore pose a significant safety risk to normal fishing vessel activities.

Hess held a formal review meeting with SFF in September 2015 to discuss the survey findings. It was confirmed that that the majority of areas covered by the survey, including the production manifold locations and flowline routes, had been successfully cleared of any items, allowing normal fishing to be resumed safely. It also showed that the rock dumping conducted over deteriorated mattresses had formed a safe, over-trawlable seabed. However, due to the snagging issues described above, the central IVRR 500 m safety zone remained a hazard to the return of normal safe fishing activity. It was concluded that the trenches should be filled in immediately to alleviate safety risks and allow normal fishing activities to resume safely in the area (Section 3.3). The trenches were then filled in with crushed rock, using a FPV under the conditions of an approved marine licence. Once the trenches were filled in satisfactorily, it was necessary to return with the chain mat and trawl net to check for further snagging hazards.

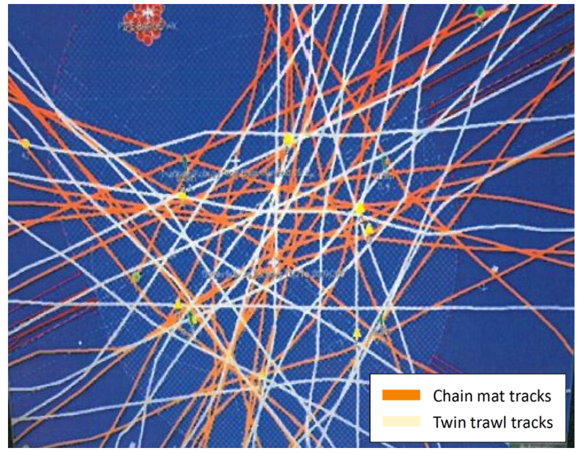
This second phase of the overtrawl survey took place in November 2015, once rock dumping operations were complete. Concentrating on the RBM 500 m safety zone (Figure 5.4b), the fishing vessel returned to the area and conducted sweeps with the chain mat and the twin trawl net to check for any further snagging hazards. The survey was completed satisfactorily with no further hazards encountered. A trawl clearance certificate (Appendix A) was provided by SFF Services Ltd, confirming that the survey had been completed and that all relevant areas have been successfully cleared, allowing normal fishing to resume safely.

**Figure 5.4 Actual trawl tracks carried out during the overtrawl survey**

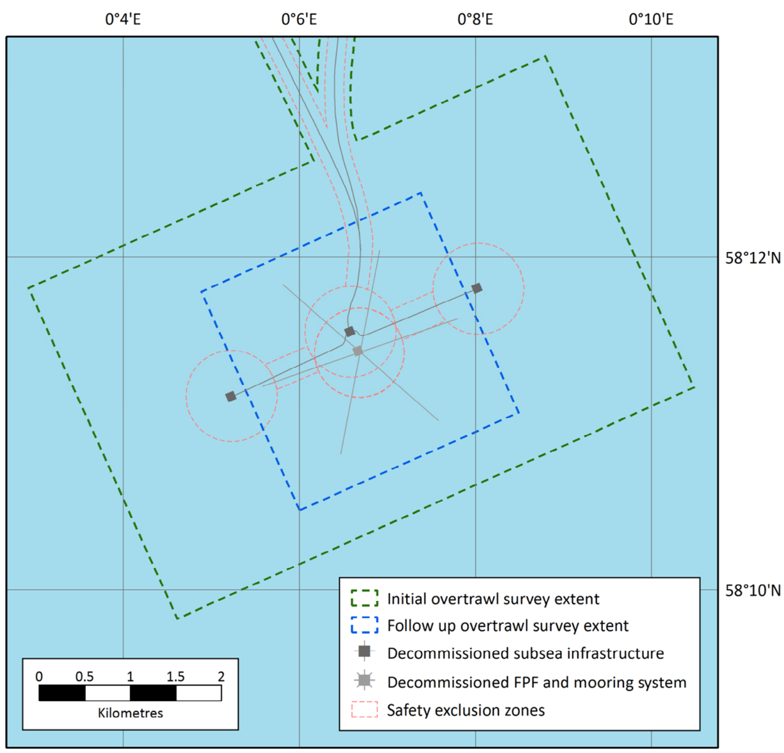
a) Trawl tracks during the initial overtrawl survey




b) Trawl tracks during the follow up overtrawl survey




c) Basic spatial extent to the overtrawl surveys




## 6 Comparison of costs for decommissioning

A comparison of gross estimated and actual costs for the completion of the IVRR decommissioning is provided in Table 6.1. This is based on the abandonment of a total of 20 wells, along with the decommissioning and full removal of seabed infrastructure as per the approved IVRR Field Decommissioning Programmes. This includes recycling of 95% of suitable materials. Costs cover project management, execution of works, onshore treatment of materials and field surveys.

**Table 6.1 Cost summary for IVRR decommissioning**

| Phase | Scope of cost coverage | Estimated cost | Actual cost |
|---|---|---|---|
| Phase 1 | Cessation of production and field suspension, including flushing of seabed infrastructure. Tow away of the FPF, including disconnection of flexible risers and laying on seabed. | £15.0M | £15.0M |
| Phase 2 | Pre-decommissioning environmental baseline survey. Recovery of FPF mooring system, the flexible riser system and associated items. Isolation of wells and recovery of jumpers. Waste management | £70.5M | £70.4M |
| Phase 3 | Well abandonment. Removal of remaining flowlines, manifolds and other infrastructure. Rock dumping of mattresses and trenches. Surveys, overtrawling and other verification activities. Waste. | £352.7M | £343.9M |

# 7 Conclusions

Following completion of the IVRR decommissioning operations, Hess has reviewed all activities to ensure that the scope has been fully executed in accordance with the approved DP, that risks to other sea users have been removed or reduced as far as possible and all regulatory requirements have been met. Where any variations to the DP have arisen, these have been documented in this close out report.

As a result of monitoring and review of recorded data, Hess believes that all residual risks to other sea users have effectively been removed on a long term basis and that a programme of future field infrastructure surveys would not provide any useful information in this regard. Based on the stability of the remaining structures and the general low energy current regime, Hess feels it unnecessary to conduct further inspection and verification work in future.

Analysis of environmental survey data also suggests that the local environment is returning to a state typical of the wider North Sea region. With no further site specific anthropogenic inputs, it is felt that that natural degradation of contaminants should help restore the area to pre-developed conditions on a relatively short timescale. Accordingly, Hess proposes that no additional site and environmental surveys or inspection of remaining features in the IVRR area are necessary.

Approval for the final status of the seabed in the former development area has been acquired from SFF, in the form of the trawl clearance certificate (Appendix A). Hess, on behalf of the Joint Venture partnership, now seeks DECC Offshore Decommissioning Unit formal approval to enable full project close-out. This close out report is provided in order to help inform the related decision making process.

## Appendix A Trawl clearance certificate

SFF SERVICES LIMITED

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09th November 2015

**HESS SERVICES UK LIMITED: IVANHOE/ROB ROY FIELD**
**POST DECOMMISSIONING CLEARANCE / VERIFICATION TRAWL SWEEPS**

This is to certify that the MV "Jacqueline Anne" FR 243 has carried out a full post decommissioning sea bed / trawl verification sweep of the four 500 metre safety zones, rock filled anchor mounds, connecting pipelines and all rock berm locations.

We believe, to the best of our knowledge and using best endeavours and practice available, the 500 metre safety zones protecting the Ivanhoe and Rob Roy Manifolds, PL 513 and PL514 including all inter-connecting pipelines also all rock berm areas covering the concrete mattresses have been successfully cleared of all equipment / infrastructure to allow normal fishing to be resumed safely.

Signed for on behalf of the Owners of the MV "Jacqueline Anne" FR 243

.........................................................
Adam Tait (Skipper)

Signed for on behalf of SFF Services Limited

.........................................................
John Watt (Director of Marine Operations)

Doc. No. 5, Rev 5.4, April 2015

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