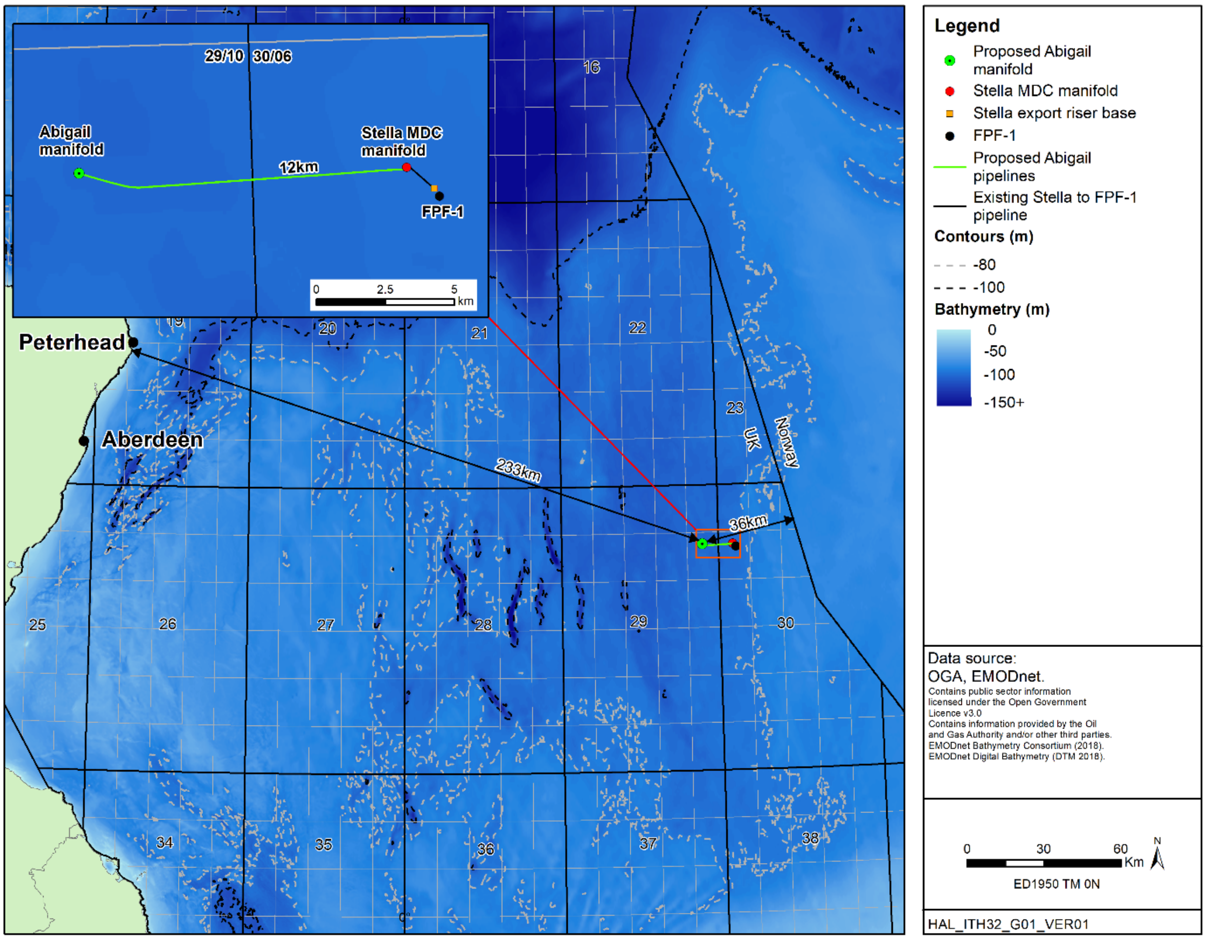
Ithaca Energy (UK) Limited

Abigail Field Development
Environmental Statement



Reference No: D/4263/2021

July 2021

Prepared by Ithaca Energy (UK) Limited

SUBMISSION INFORMATION SHEET

Section A: Administrative Information

A1 – Project Reference Number
Number: D/4263/2021

A2 – Applicant Contact Details
Company name: **Ithaca Energy (UK) Ltd**
Contact name: **Paul Shearer**
Contact title: **Environment Team Lead**

A3 – ES Contact Details (if different from above) – As above
Company name: **N/A**
Contact name: **N/A**
Contact title: **N/A**

A4 – ES Preparation
Please confirm the key expert staff involved in the preparation of the ES:

Company	Title	Relevant Qualification / Experience
Ithaca Energy (UK) Limited	Senior HSEQ Advisor	21 years experience in environmental role, 19 of which in oil and gas
Hartley Anderson Ltd	Principal Consultant	18 years experience in environmental role (marine energy including oil and gas)
	Principal Consultant	12 years experience in environmental role (marine energy including oil and gas)
	Senior Consultant	14 years experience in environmental role (marine energy including oil and gas)

A5– Licence Details
a) Please confirm licence(s) covering proposed activity or activities
Licence number(s): **P1665**

b) Please confirm licensees and current equity

Licence Number: P1665	
Licensee	**Percentage Equity**
Ithaca Energy (UK) Limited	80%
Ithaca Energy Developments UK Limited	20%

Section B: Project Information

B1– Nature of Project
a) Please specify the name of the project.
Name: **Abigail Field Development**

b) Please specify the name of the ES (if different from the project name)
Name: **N/A**

c) Please provide a brief description of the project

It is planned to develop the Abigail oil and gas field located in Block 29/10, in two phases, by means of up to two subsea production wells, linked by a new manifold and a pipeline to the existing FPF-1 installation in Block 30/06. Phase 1:

- Re-entering appraisal well (29/10b-8) and completing this as the first production well (P2-W), using a semi-submersible drilling rig
- Installation of a new (piled) manifold at the Abigail drill location and well tie-in spools and jumpers
- Installation of a new ~12km 6"/10" pipe-in-pipe export pipeline, gas lift pipeline and services umbilical, all trenched and buried in a single trench
- Use of associated protective material (mattresses, grout bags, rock) as required
- Installation of a new (gravity based) subsea isolation valve (SSIV) at the riser base location at the FPF-1

Abigail hydrocarbons will be commingled with Stella and Harrier hydrocarbons subsea at the Stella Main Drill Centre manifold at the FPF-1. Minor modifications will be required to the existing Stella and Harrier control system to facilitate the supply of power, control and chemical functionality to the Abigail manifold, this primarily achieved within the Stella MDC manifold, with some minor modifications to topsides (change out chemical injection pump and installation of SSIV panel). There are no modifications required to the production process to accommodate Abigail.

The earliest drilling is expected to commence is Q2 2022 (operational window for drilling Q2-3 2022), with the operational window for the subsea campaign also Q2-3 2022 with first oil Q3/4 2022. Estimated duration of offshore activities for Phase 1 is 120-130 days.

Phase 2:
Execution of the second phase will be dependant on field performance and will be feasible in the high production case. If progressed, this phase will comprise the drilling of a new production well (P1-E), using either a semi-submersible or jack-up rig and the tie-in of the well to the Abigail manifold using spools/jumpers, and associated protective material (mattresses and grout bags). The earliest activities would commence (drilling of the well) is Q3/4 2024. Estimated duration of offshore activities for Phase 2 is *ca*. 105 days.

B2– Project Location

a) Please indicate the offshore location(s) of the main project elements (for pipeline projects, please provide information for both the start and end locations).

Abigail Drill Centre and start location of pipeline
Quadrant number(s): **29**
Block number(s): **10**
Latitude: **56°47’30.64"N** Longitude **01°53’44.96"E**

Tie-in at FPF-1 (Stella Main Drill Centre manifold) and end location of pipeline
Quadrant number(s): **30**
Block number(s): **06**
Latitude: **56°47’28.21"N** Longitude **02°05’29.4"E**

Distance to nearest UK coastline (km): **233km**
Which coast: **Scotland**

Distance to nearest international median line (km): **36km**
Which line: **UK/ Norway**

B3– Previous Applications

If the project, or element of the project was the subject of a previous consent application supported by an ES, please provide details of the original project.

Name of project: **N/A**
Date of submission of ES: **N/A**
Identification number of ES: **N/A**

CONTENTS

GLOSSARY AND ABBREVIATIONS

Term	Explanation
Barg	A unit of gauge pressure
AIS	Automatic identification system used for vessel positioning
BEIS	Department for Business, Energy and Industrial Strategy, formerly the Department of Energy and Climate Change (DECC)
Biota	The collective term for fauna and flora at a particular location
BOP	Blowout preventer, specialised valve used to seal, control and monitor oil and gas wells to prevent the uncontrolled release of hydrocarbons
BOE	Barrel of oil equivalent, assumed to be 5.8 Mscf/BOE
Bscf	Billions of standard cubic feet of gas. The unit of measurement of large volumes of gas. Equivalent to 1,000,000,000 standard cubic feet.
Concrete mattress	A series of concrete blocks usually connected together by polypropylene ropes which resembles a rectangular mattress. These are used for the weighting and/or protection of seabed structures including pipelines
CATS	The Central Area Transmission system – transports gas from central North Sea to terminal at Teeside
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CSV	Construction support vessel
DECC	Department of Energy and Climate Change, now the Department for Business, Energy and Industrial Strategy (BEIS)
DEPCON	Deposit of materials on the seabed consent, part of the pipeline works authorisation (PWA) consenting process
DEPSAT	Deposit Subsidiary Application Template, a component linked to a Master Application Template (MAT, part of the BEIS Portal Environmental Tracking System (PETS) applications system.
DP	Dynamic Positioning: the use of thrusters and real time positional information to maintain the location of a vessel
DSV	Dive support vessel
E&P	Exploration and Production
EIA	Environmental Impact Assessment
EUNIS	European Nature Information System, a habitat classification system for habitat identification
EUOSD	European Union Offshore Safety Directive; Directive 2013/30/EU on safety of offshore oil and gas operations and amending Directive 2004/35/EC
FEAST	Feature Activity Sensitivity Tool; an online tool that uses a marine protected area habitat or species (feature) approach to provide a sensitivity assessment for Scotland's priority marine features.
FDP	Field Development Plan
GHG	Greenhouse gas

Term	Explanation
GWP	Global Warming Potential: an emissions metric used to indicate the contribution of a certain greenhouse gas to radiative forcing, accounting for the atmospheric lifetime of a given gas relative to carbon dioxide (the principal greenhouse gas)
HS&E	Health Safety and Environment
HSEQ	Health, Safety, Environment and Quality
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization
IWCF	International Well Control Forum
Jack-up rig	A mobile floating drilling rig typically with three long triangular truss legs which can be lowered to the seabed to provide stability once on location, used in water depths of less than 120m.
JNCC	Joint Nature Conservation Committee
km	kilometre: 1,000m, equivalent to 0.54 nautical miles
LTOBM	Low toxicity oil based mud
LWD	Logging while drilling
MARPOL	The International Convention for the Prevention of Pollution from Ships
MAT	Master Application Template, a central application in the BEIS PETS, linked to a particular activity type (e.g. drilling, pipeline installation, production), under which subsidiary applications (SATs) can be submitted to enable the activity to be carried out.
MBES	Multibeam echosounder
MCZ	Marine Conservation Zone: established under the Marine and Coastal Access Act 2009
MDBRT	Measure Depth Below Rotary Table
MDC	Main Drill Centre for the Stella Field
md	Millidarcy, the standard unit for permeability measurement
MEI	Major Environmental Incident
MMm^3	Million cubic metre
MoD	Ministry of Defence
MSFD	Marine Strategy Framework Directive
NCMPA	Nature Conservation Marine Protected Areas: established under the Marine (Scotland) act 2010
NDC	North Drill Centre, for the Stella Field
OBM	Oil based (drilling) mud
OEP	Operational Excellence Policy
OGA	Oil and Gas Authority
ONCS	Offshore Chemical Notification Scheme
OPEP	Oil Pollution Emergency Plan
OSCAR	Oil Spill Contingency and Response model

Term	Explanation
OSPAR	The Convention for the Protection of the Marine Environment of the North East Atlantic 1992
OSRL	Oil Spill Response Limited
PAH	Polycyclic Aromatic Hydrocarbons
PETS	Portal Environmental Tracking System
PEXA	Practice and Exercise Areas (for military use)
PiP	Pipe-in-Pipe
PLONOR	Pose Little Or No Risk
PMF	Priority Marine Feature
PWA	Pipeline Works Authorisation
ROV	Remotely Operated Vehicle: a small, unmanned submersible used for inspection and the carrying out of some activities such as valve manipulation
SAC	Special Area of Conservation: established under the Habitats Directive.
SEAL	Shearwater to Bacton pipeline
Semi-submersible drilling rig	A mobile floating drilling rig, typically used in deeper water (inaccessible to jack-ups) and harsher environments. Kept on station by either anchored mooring system or dynamic positioning.
SFF	Scottish Fishermen’s Federation
SL	Source Level
SOPEP	Shipboard Oil Pollution Emergency Plan
SOSI	Seabird Oil Sensitivity Index
SPA	Special Protection Area: established under the Birds Directive
SPL	Sound Pressure Level
SSIV	Sub-sea isolation valve
UKCS	United Kingdom Continental Shelf
VMS	Vessel Monitoring System
VSP	Vertical seismic profile
WBM	Water Based Mud

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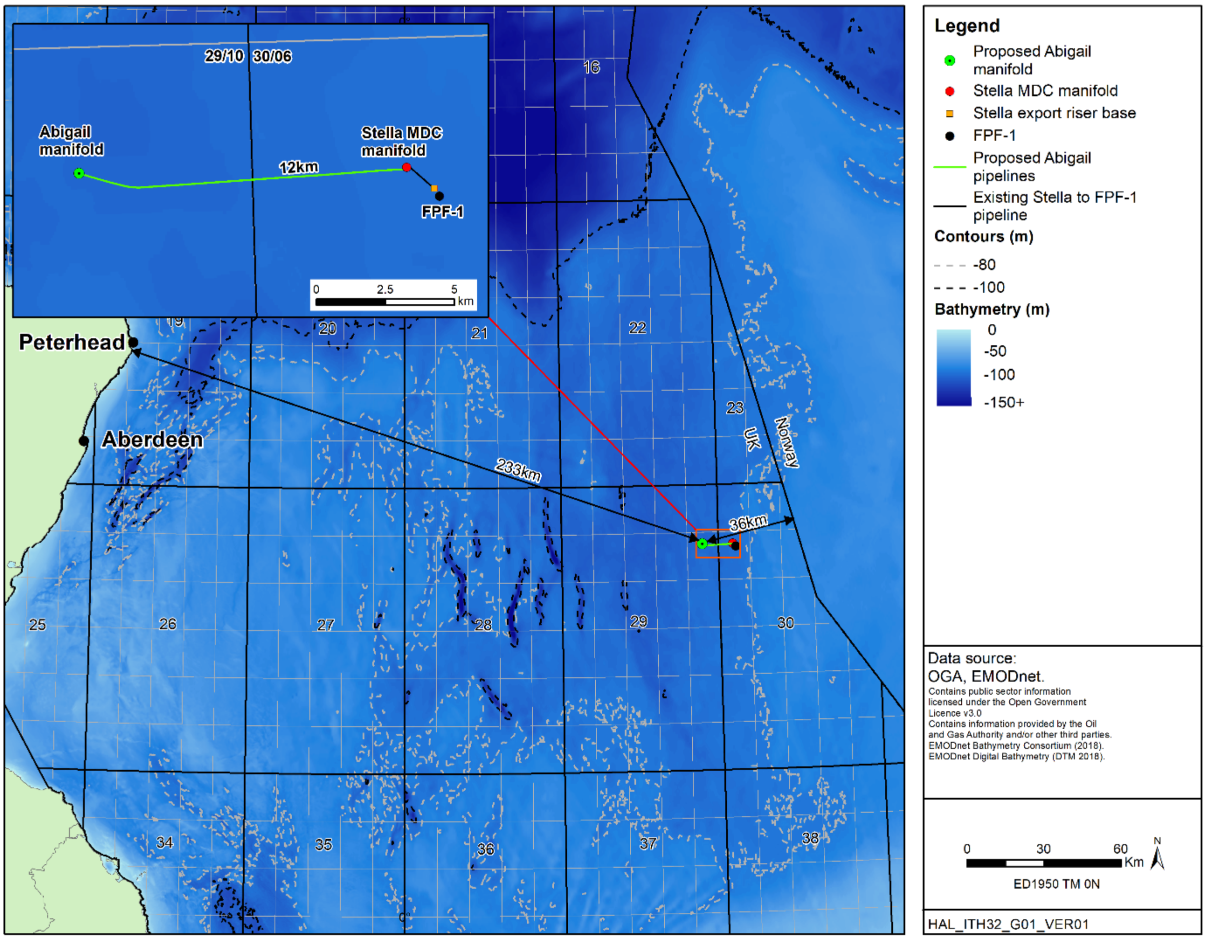
NON-TECHNICAL SUMMARY

This Environmental Statement (ES) presents the findings of the environmental impact assessment conducted by Ithaca Energy (UK) Limited (Ithaca Energy) for the development of the Abigail oil and gas field which lies in United Kingdom Continental Shelf (UKCS) Block 29/10. Block 29/10 is located in the central North Sea, approximately 233km east of Peterhead and 36km from the UK-Norway median line.

Location of the proposed Abigail development



The ES has been produced in accordance with *The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020* (the EIA Regulations); the submission of an ES to the Secretary of State for the Department for Business, Energy & Industrial Strategy (BEIS) is required for the extraction of oil and natural gas projects where the amount extracted exceeds 500 tonnes of oil per day or 500,000m^3 of gas per day. Estimated production from the Abigail Field exceeds these thresholds for both oil and gas and is therefore a project under Schedule 1 of the EIA Regulations. Ithaca Energy have therefore completed an assessment of the potential environmental impacts of the development and operation of the field, and have prepared this ES which also supports the Abigail Field Development Plan (FDP).

Proposed Activities

Proposed activities

Ithaca Energy propose to develop the Abigail field in two phases by means of up to two subsea production wells, linked by a new manifold and pipeline system to the existing Ithaca Energy owned and operated floating production facility, the FPF-1, which is located in UKCS Block 30/06.

The FPF-1 became operational in 2017 as a hub for the Greater Stella Area development and processes hydrocarbons from three existing fields, Stella (from the Stella north drill centre (NDC) and Stella main drill centre), Harrier (comingled at the Stella MDC) and Vorlich (Figure 3.1).

Phase 1 of Abigail will comprise the development of the western area of the field with the conversion of an existing appraisal well (29/10b-8) to a new production well (well P2-W), using a semi-submersible drilling rig. A new, *ca*. 12km pipeline system comprising a production pipeline, gas lift pipeline and service umbilical will be installed in a single trench and protected by mechanical backfill of sediment and protective material (rock, mattress and grout bags), where required. Other infrastructure installed during Phase 1 will be a new piled manifold at the Abigail drill centre and a new sub-sea isolation valve (SSIV) at the FPF-1. Hydrocarbons from the Abigail field will comingle with the Stella and Harrier hydrocarbons at the Stella MDC, and will be processed in the same process train on the FPF-1, before onward export using existing facilities.

No modifications will be required to the process system on the FPF-1 to accommodate Abigail, there will however, be minor modifications required e.g. to chemical control systems, primarily within the Stella MDC manifold.

Phase 2, will be contingent on field performance and only be feasible in the high production case. If executed, this phase will happen approximately 18 months after first oil. This phase will be the addition of a second, new production well, targeting the east of the field (P1-E), drilled using either a semi-submersible or jack-up drilling rig.

The current indicative schedule for Phase 1 activities has development activities commencing in Q2 2022, with work continuing through Q3 and first oil end of Q3/beginning of Q4. The schedule for the second phase of the development is not expected to commence for at least 18 months after production commences (*ca*. 2024), this phase being contingent on the first

Consideration of Alternatives and Options Selected

A number of development options were considered for the Abigail field including new standalone facilities, development by extended reach drilling, the joint development of other fields via daisy chain arrangements to a 3rd party host, and the subsea tie back to the existing FPF-1 facility.

The field is relatively small, with a short field life, and a standalone facility was uneconomic; extended reach drilling was not feasible, and the joint development to a 3rd party host discounted due to technical and economic feasibility.

A subsea tie-back to the FPF-1, which utilises existing production and export infrastructure, was therefore selected as being the most favourable, taking into account economic, technical, safety and environmental factors.

Well options screened included the drilling of a new well, however, the option to sidetrack from the existing well 29/10b-8, using smart completion technology was selected as this will produce both the Forties oil reservoir and Andrew formation, without the need to drill a new well, thereby reducing the overall environmental footprint from drilling activities. Drilling a new well for the first production well, was therefore discounted and conversion of an existing appraisal well selected. Given the water depths at the location, this well could be drilled using either a semi-submersible or jack up rig, however, Ithaca Energy have selected a semi-submersible to maximise rig use and synergise with other potential drilling projects in deeper water currently being reviewed.

Fewer options were available for the second well, with no existing well available for conversion to target the required areas. The second production well, if drilled, will be a new well. The option to use either type of drilling rig for this well remain feasible, and selection of the rig will be made at a future date. This will take into consideration rig availability and other potential projects (including third party projects), where rig use can be optimised.

A piled manifold was selected for Abigail, this being a proven design concept for manifolds in the Greater Stella Area. Given the soil conditions, the alternative would be a gravity based manifold, this requiring additional fabrication to accommodate the manifold pipework and control modules. This would result in an increase in weight and overall size of the manifold, potentially requiring an additional vessel campaign.

In addition to a production pipeline, Abigail also requires a gas lift line (gas lift is used to provide artificial lift to the reservoir), and a service umbilical, to provide chemicals and power etc. to the manifold. Although the overall footprint of the pipeline installation is initially large (a corridor of *ca.* 22m, this being the width of the trenching vehicles skis), this level of seabed disturbance is temporary and is considerably smaller than the alternative, which is to trench separately. Trenching separately would also necessitate the use of additional protective material. A ploughed system rather than a jetting system is preferred to make the trench, as a smooth trench is required to accommodate a pipeline, along with the other two lines, and enables the excavated material to be used as backfill, this not as available with a jetted system.

The Abigail pipeline route was selected based on a number of factors, including being the shortest route between its end points, the avoidance (if present, and as far as practicable), of sensitive habitats and features, (no habitats or species of conservation concern were identified), and to account for approaches both to the new drill centre and the receiving installation.

Summary of the environment of the area and potential issues

The main environmental features of the Abigail and wider area, along with the main sensitivities and potential issues, are summarized in the following table.

Aspect	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Operations window	Drilling of the first production well, pipeline and subsea installation activities are expected to take place over Q2 and Q3 2022. The second production well, the schedule for drilling of which is still to be determined, has been shown here as Q4 2024. First oil is scheduled for Q3/Q4 2022.											
2022 – Phase 1												
2024 – Phase 2												
	Key: Operational window of drilling activities shown in green, and for pipeline and subsea installation activities, including tie-in, shown in blue, and first oil shown in red											
Location	The Abigail Field lies within Block 29/10, in the central North Sea. The well site is approximately 233km from Peterhead on the Scottish east coast and approximately 36km from the UK-Norway median line. The Abigail development will tie into the Stella Main Drill Centre which ties into the FPF-1, these located in Block 30/06, approximately 12km from Abigail.											

<table>
<tr><th>Aspect</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>Water column, climate and hydrography</td><td colspan="12">Water depths are between 89-92m across the Abigail area. Wind direction varies, although dominant directions range from southeast to northwest through southwest. Residual near-surface currents are weak (0.5m/s) and predominately to the south and east, although the pattern of water movement may be strongly influenced by short-medium term weather conditions. Thermal stratification occurs in April/May; stratification breaks down with increasing frequency and severity of storms and cooling.

Potential issue:
• Contamination of water column associated with drilling discharges and operational phase and potential oil and chemical spills
• Air quality and climate change impacts associated with atmospheric emissions from drilling, subsea installation and operation</td></tr>
<tr><td>Seabed, sediments</td><td colspan="12">Flat and featureless seabed, predominately sandy sediments with areas of coarser material. The EUNIS habitat classification records the seabed sediments predominantly composed of circalittoral sand and mud. Site surveys also indicate ribbons of coarser material (primarily bivalve shells) which form ripples/waves and are ubiquitous across the Abigail and wider Stella area. Occasional boulder and cobbles present.

Potential issue:
• Seabed disturbance caused by drilling rig, installation of pipeline, use of protective material
• Contamination of sediments by drilling and other discharges</td></tr>
<tr><td rowspan="3">Plankton</td><td colspan="12">A phytoplankton bloom occurs in spring, followed by a smaller peak in autumn. Zooplankton abundance follows a similar seasonality to phytoplankton, although peak abundances are later. The zooplankton is dominated in terms of biomass and productivity by Calanoid copepods, which constitute a major food resource for the adults and/or larvae of many commercial fish species.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">***Key: Period of increased plankton abundance shown in darker blue***

Potential issue:
• Toxicity associated with drilling, subsea and operational discharges</td></tr>
<tr><td>Benthos</td><td colspan="12">Sensitivity similar throughout the year. No Annex I habitats observed, only species noted as a priority marine feature/on the OSPAR list of threatened and/or declining species was *Arctica islandica* in low numbers/no aggregations

Potential issue:
• Physical disturbance (including smothering) of benthic communities or species during drilling and subsea installation activities
• Toxicity associated with drilling, subsea and operational discharges</td></tr>
<tr><td rowspan="3">Commercial fish and shellfish</td><td colspan="12">The Abigail area is partly located in ICES rectangles 42F1 and 42F2 and overlaps reported spawning grounds of several commercially important fish species, reported in Coull *et al.* 1999 (mackerel, Norway pout and lemon sole) with low intensity spawning also identified by Ellis *et al.* 2012 for some species (cod, plaice and sandeel); plaice reported as spawning in ICES rectangle 42F2, nursery grounds in both. The area also supports known nursery grounds for blue whiting, herring, mackerel, whiting, sandeel, ling, hake, plaice and monkfish, haddock, Norway pout, spurdog and cod.</td></tr>
<tr><td>4</td><td>4</td><td>3</td><td>3</td><td>2</td><td>2</td><td>2</td><td>2</td><td>1</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td colspan="12">***Key: 1 = 1 species spawning, 2 = 2 species spawning etc, represents species from both Coull et al. (1999) and Ellis et al. (2012).***

Potential issue:
• Disturbance or disruption of spawning fish by underwater noise
• Toxicity associated with drilling, subsea and operational discharges
• Smothering associated with cuttings discharge and physical disturbance</td></tr>
</table>

<table>
<tr><th>Aspect</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>Birds</td><td colspan="12">The area may be considered to be of low importance for seabirds in the context of the North Sea as a whole. This is related to the distance from breeding colonies (Abigail is >230km from shore) and the availability of prey species. Birds present vary seasonally, and being far offshore, those present are likely to be (predominately) those transiting through the area during migration, and during post-breeding dispersion from colonies.

Seabird oil spill sensitivity is low in the Blocks for those months with data. Where no data coverage is available, JNCC guidance was used, where possible, to reduce the extent of coverage gaps (these are shown in red and highlighted yellow, below). Where these could not be reduced, these are shown with N and highlighted yellow.</td></tr>
<tr><td>Block 29/10</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>N</td><td>N</td><td>N</td></tr>
<tr><td>Block 30/06</td><td>5</td><td>5</td><td>5</td><td>N</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>N</td><td>N</td><td>N</td></tr>
<tr><td></td><td colspan="2">1=extremely high</td><td colspan="2">2=very high</td><td colspan="2">3=high</td><td colspan="2">4=moderate</td><td colspan="2">5=low</td><td colspan="2">N=no data</td></tr>
<tr><td></td><td colspan="12">Potential issue:
Risk from surface pollution including hydrocarbon spill during drilling activities or production
Noise from drilling activities</td></tr>
<tr><td>Marine mammals</td><td colspan="12">Harbour porpoise are frequently sighted throughout the central North Sea and are likely to be the most abundant species in the Abigail area. White-beaked dolphins, although generally less abundant, are also sighted in the area and throughout the year. Minke whales are widely distributed throughout the central and northern North Sea in summer; with a distinct peak in July and August. Densities of minke whale are likely to be low, with more sightings occurring further west, off the east coast of Scotland and northern England. Low numbers of Atlantic white-sided dolphins recorded. The area is distant from seal breeding colonies and haul-out sites; very low densities of both grey and harbour seal in the area.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="12">Key: Darker colours reflect months when marine mammals most frequently observed

Potential issue:
Disturbance of marine mammals by underwater noise</td></tr>
<tr><td>Conservation sites</td><td colspan="12">The region's coast has a variety of important habitats and species protected under international, national and local designations; however, the closest coastal site (the Buchan Ness to Collieston Coast Special Protection Area) is at least 230km from the Abigail location. The closest offshore Special Area of Conservation (SAC) is the Dogger Bank, approximately 157km to the south, the closest Marine Conservation Zone (MCZ) is the Fulmar MCZ, (designated for subtidal mixed sediment, subtidal sand, subtidal mud and Arctica islandica aggregation) approximately 20km to the south and the closest Nature Conservation Marine Protected Area (NCMPA) is the East of Gannet and Montrose Fields NCMPA (designated for deep sea muds and A. islandica aggregations) approximately 22km to the northwest.

Potential issue:
Physical disturbance or loss of Annex I habitat and associated communities and those on the OSPAR List of Threatened and/or Declining Species and Habitats
Contamination of Annex I habitat/threatened or declining habitats listed by OSPAR from drilling and other discharges
Disturbance of marine mammals from underwater noise</td></tr>
<tr><td>Other Users</td><td colspan="12">Fishing effort in the area is focused on Nephrops and demersal fish, but overall effort in the area is low. The area is within a wider mature oil and gas province, with considerable infrastructure in adjacent Blocks and the wider area. Shipping density is moderate. There are no Ministry of Defence exercise areas, dredging areas, or marine disposal sites in the vicinity and no telecommunication cables cross the development area. There are no designated protected wrecks in the area.

Potential issue:
Localised displacement/disruption of fishing activities and other offshore users
Physical disturbance of seabed and potential impact on fish communities
Collision risk</td></tr>
</table>

Oil and Gas Authority Period of Concern

Specific issues of relevance to the Blocks are listed in the 32nd Round compilation of other regulatory issues (OGA 2019b[1]), and are given below:

Seasonal concerns				4. Special Conditions
Block	1. Period of concern for seismic surveys	2. Period of concern for drilling	3. Spawning sites	
29/10b	May to August [MS]	-	-	-
30/6a	May to August [MS]	-	-	-

Notes: MS = Marine Scotland

Potential Sources of Effect

Through a systematic evaluation of the issues associated with the development and operation of the Abigail Field, and their interactions with the environment, a variety of potential sources of environmental effect were identified. The majority were of limited extent and duration, and deemed negligible, with these not assessed further No potential issues of concern were identified through the assessment process which could not be mitigated to meet regulatory requirements and company policy. A summary of the assessment is given below.

Physical Presence

The physical presence of the drilling rig and supporting vessels and those vessels used for the pipeline system and manifold subsea works, have been identified as potential sources of effect, primarily for fisheries and navigation. The Abigail Field is located within a mature oil and gas area, with shipping primarily servicing this industry. Fishing effort in the Abigail area is low throughout the year, with no clear seasonal pattern. A 500m safety exclusion zone centred on the Abigail well location will be in place for the duration of drilling, which other vessels will not be permitted to enter limiting any potential interaction. The anchors and related chains of the semi-submersible used to drill the first production well will extend beyond the 500m safety exclusion zone and the position of these anchors as laid, will be notified to fishermen and other users of the area.

A new subsea 500m safety exclusion zone will be applied for the Abigail Field, centred on the Abigail manifold. This zone will reduce the risk of fisheries interactions with the manifold through Abigail Field life.

A small number of vessels will be used to undertake the subsea elements of the first phase of the development; other users will not be excluded from this area, and Ithaca Energy will continue their engagement with the Scottish Fishermen's Federation with regard to vessel movement and duration in the field. The location of all aspects of the subsea infrastructure (wellhead, manifold and pipeline) will be publicised through Notices to Mariners, and marked on navigation and fisheries charts.

The same approach to notification for rig anchors/chains will be carried out if a semi-submersible is also used to drill the second production well. If a jack-up is used, the footprint of the rig should be within the rig 500m safety exclusion zone, part of which will also overlap the zone around the manifold. A single vessel will be used to tie-in this second well to the manifold, with work being localised to the well and manifold area.

Seabed Disturbance

Seabed disturbance will occur during both phases of the development. During Phase 1, physical disturbance of the seabed will principally result from the drilling rig (semi-submersible anchors/chain)

[1] OGA Other Regulatory Issues. Version at July 2019.

and the trenching and subsequent backfilling of the pipeline. The majority of protective material will also be deposited during this phase, the aim being to keep the quantity of material used to a minimum, whist ensuring the protection of the new and existing (i.e. at the crossing) infrastructure. The remaining seabed disturbance will result from the installation of the new Abigail manifold and the new sub-sea isolation valve (SSIV) at the FPF-1. The total, worst case, seabed disturbance from this phase, including contingency, was estimated at 335,033m^2 (0.3km^2).

During Phase 2, physical disturbance will result from the drilling rig, either a semi-submersible or jack-up, with greater seabed disturbance calculated for a semi-submersible, and a small subsea programme, tying in the second well, using spool pieces and jumpers, and a relatively small quantity of protective material. If executed, the seabed disturbance from the second phase of the development was estimated as 61,344m^2 (0.06km^2).

The majority of seabed species recorded from the European continental shelf are known, or believed to have, short lifespans (a few years or less) and relatively high reproductive rates, indicating the potential for rapid population recovery, typically between one to five years. Species which dominate infaunal assemblages at stations from surveys conducted in the Abigail and wider area are characterised by short lifespans and are likely to have high recovery rates. Epifauna is relatively sparse in comparison with infauna and most species are mobile. It would be expected that animals would be able to move away from, and then rapidly recolonise, recently disturbed sediment. It is considered probable that both the physical habitat consequences and benthic community effects of physical disturbance of the seabed will fully recover within a five to ten year period.

No seabed disturbance is expected during operation of the Abigail field once in production.

Discharges to Sea

During the development activities, the greatest discharge to sea is expected from the second phase of the development, if executed. The first production well drilled in Phase 1, will be a re-entry and completion of an existing well, with the well sections being drilled by a low toxicity oil based mud (LTOBM). Cuttings from sections drilled with LTOBM will be returned to the rig and skipped and shipped back to shore for processing. The existing top hole sections of the well will be reused, and so there will be no cuttings or water based mud discharges typically associated with these. Cementing and completion chemicals of low toxicity will be preferentially selected for use during the drilling programme. A relatively small suite of chemicals is also used for the installation and testing of the pipeline system, again, these will be minimised as far as practicable and those with the best environmental profile used where technically feasible to do so.

The second production well will be drilled using a combination of seawater and some low hazard chemicals (added to increase the viscosity to help sweep cuttings out of the wellbore) for the surface hole, and water based mud and low toxicity oil-based mud for the top and lower hole sections respectively. Material from the surface hole section of the well will be discharged directly to the seabed, and consist of sediments derived from the seabed and shallow geological formations. This material will form a small pile on the seabed, which will be re-mobilised over time by water currents and burrowing fauna activity. The predicted environmental effects are very localised and of short duration, involving smothering of benthic habitat and animals, with rapid faunal re-colonisation.

The Abigail hydrocarbons will be comingled with those from the Stella and Harrier fields subsea at the FPF-1 and received, and processed, through existing facilities on the FPF-1. No significant increase in operational chemical use and discharge are anticipated.

Operational discharges will primarily be from produced water. Water production from Abigail is estimated to result in a significant increase to that currently discharged from the FPF-1, associated with the Stella and Harrier fields. The current oil in water (OIW) permit limit is 20mg/l and over the last ca.

12-18 months, Ithaca Energy has undertaken work on the FPF-1 to achieve this. At time of process upset, and new fields coming online (e.g. Vorlich), an increase in OIW is experienced, before this reduces again and the system is in a steady state. An initial OIW elevation is expected when Abigail commences production and this will be continuously reviewed, the aim being to meet the discharge permit obligation as quickly as possible. Peak estimated water production from Abigail (501m^3/day, 182,865m^3/year), will result in an estimated peak annual discharge of 3.7 tonnes of oil based on an average oil in water concentration of 20mg/l. The effects of produced water discharges are relatively well understood, with the impacts of the discharge localised (most concentrated discharge <100m of the discharge point), with rapid dilution expected and the impacts beyond this predicted to be negligible.

Atmospheric Emissions

Emissions will be generated from fuel combustion on the rig and various vessels involved in the development activities for both phases of the development, if both are executed. As Phase 1 will include the main subsea installation programme, emissions from Phase 1 development activities are greater than those from Phase 2, estimated at 19,199 tCO_2eq and 14,979 tCO_2eq respectively. Combined, emissions from both phases amount to ~34,177 tCO_2eq.

For the operational phase, incremental fuel gas emissions will be associated with production from Abigail. The fuel gas increment associated with Abigail varies by production case and estimates have been made for the associated emissions for each of these and, on the basis of a high production case (P10), the incremental fuel gas use through field life is estimated to be 16,326t, equivalent to *ca.* 48,064tCO_2eq.

The Greater Stella Area Development, which will include the Abigail Field, has a minimum flaring approach, such that continuous flaring should not take place, with the exception of purge and waste streams, oily water degasser gas and other low pressure/atmospheric system vents. At present, this approach is not being met as the FPF-1 is experiencing flare ignition issues, such that continuous flaring daily average rate of 0.3MMscf/d (8.8t/d) is taking place to ensure the safety of the installation.

It is anticipated that the flare ignition package will be fixed in Q3 2020 after which continuous flaring will not be required, with a reduction equal to the 0.3MMscf/d presently used, and related CO_2 emissions. Following this work, any future gas flaring would be to account for factors such as process upsets and emergency shutdowns.

Abigail will not result in a greater number of flaring events on the FPF-1, nor will it result in a greater volume of gas being flared in any such event. Abigail gas will, therefore, only represent a proportion of the gas flared, but will not result in incremental flaring volumes or associated emissions.

To place the development of Abigail in the context of UK GHG emissions, Abigail (including operational emissions associated with the high production case and those from Phase 1 and Phase 2 infield activities) would represent an increment of 0.018% on those emitted from all UK sources in 2019, or 0.56% of those from installations on the UKCS 2018. The total emissions associated with the development and operation of Abigail have been considered against the targets set for each relevant carbon accounting period. Emissions associated with Abigail will take place within the end of the third carbon budget (2018-2022) and through the fourth carbon budget period (2023-2027). Emissions associated with Abigail are estimated to represent 0.0009% of the third carbon budget, including all Phase 1 activities and high case fuel gas emissions, and 0.0031% of the fourth carbon budget, including all Phase 2 activities and high case fuel gas emissions to the end of production.

Noise

The primary sources of noise from the Abigail development will be pilling noise during installation of the manifold, drilling noise (which is generally low frequency) and thrusters on vessels. Potential (and postulated) effects of anthropogenic noise on receptor organisms range from acute trauma to subtle behavioural and indirect ecological effects, complicating the assessment of significant effect.

It is generally considered that the most sensitive receptors of acoustic disturbance in the marine environment are marine mammals, due to their use of echolocation and vocal communication. Considering this evidence of likely effects on the most sensitive and abundant species to occur in the region, combined with the low anticipated density of all marine mammals in the Abigail area, the manifold piling may cause localised displacement (i.e. within a < 10km radius) of individuals for the day over which active piling will occur, and potentially a day thereafter, but will not result in significant disturbance to populations of any marine mammal species.

Reported responses of marine mammals to vessels include avoidance, changes in swimming speed, direction and surfacing patterns, and alteration of the intensity and frequency of calls and increases in stress-related hormones. Harbour porpoises, white-sided dolphins and minke whales have been shown to respond to survey vessels by moving away from them, while white-beaked dolphins have shown attraction. While some behavioural disturbance of harbour porpoise and other cetaceans may occur, the increase in underwater noise from vessel traffic associated with the proposed activities, relative to existing levels in the wider area, is expected to be small.

Considering the characteristics of all the relevant noise sources, the evidence for limited potential of short-term behavioural disturbance among the most sensitive receptors, the open nature of the habitat, the generally low densities of marine mammals likely to be present in the area and its apparent low importance relative to other areas within the North Sea, it is concluded that the proposed activities will not result in significant behavioural disturbance to relevant species.

Transboundary Effects

The UK has ratified the *Convention on Environmental Impact Assessment in a Transboundary Context* (Espoo Convention 1991) and thus an assessment is needed of the potential for the proposed activities to result in significant transboundary effects. Although the Abigail development is located relatively close to the UK/Norwegian median line (36km east), the development activities and production phase of the Abigail development have a limited likelihood of transboundary effects. Noise, atmospheric and aqueous emissions from the rig and support vessels are unlikely to be detectable or to significantly affect Norwegian national waters and air quality, nor are any operational discharges.

Cumulative Impacts

Incremental, cumulative and synergistic effects have been systematically reviewed. Minor incremental or cumulative risks (i.e. effects acting additively or in combination with those of other human activities) were identified in relation to discharges, physical presence and disturbance of the seabed, spills and emissions to atmosphere. None of these were considered to represent more than a small impact in a regional context. No significant synergistic effects – where the joint effect of two or more processes is greater than the sum of individual effects – are predicted.

Accidental Events and Major Environmental Incidents

Risk assessment of accidental events involves the identification of credible accident scenarios, evaluation of the probability of incidents, and assessment of their ecological and socio-economic consequences. Evaluating spill risk requires consideration of the probability of an incident occurring and the consequences of the impact. Historic data for the North Sea shows that the majority of accidental spills are of very small volumes; the probability of a large spill occurring is extremely low.

The 29/10b-8 appraisal well is currently suspended with 2 deep barriers and inhibited seawater above. There is a debris cap currently in place on the wellhead which is not pressure retaining. Well re-entry will involve the removal of the debris cap and latching the subsea BOP/riser package to the wellhead.

This is a standard operation, controlled by rig specific procedures that will be supported by a task specific risk assessment. The likelihood of this operation leading to a change in the barrier status, escalating to flow and release of hydrocarbons from the well is considered low. The BOP and Wellhead connection will be pressure tested after latching. With the BOP and riser in place, an additional 2 barriers are added to the system (monitored hydrostatic column of fluid and the BOP itself). Rig specific well control procedures will be in place for the monitoring of the fluid level and actions to take in the event of an influx, mitigating the potential for release of hydrocarbons to the environment

Of the accidental events identified, a well blowout of Abigail crude was identified as the worst case potential release of hydrocarbons. Spills can impact environmental and socio-economic sensitivities at distance from their source and risk assessment, therefore, requires the prediction of slick trajectory. For a given scenario, with defined spill volume and weather/metocean conditions, the behaviour of a slick can be modelled; the spill scenario assumes the failure of spill prevention equipment and no spill response for a period of time, and provides an indication of slick trajectory for spill response planning. Stochastic modelling of an Abigail well blowout (8,295.8 m^3/day on day 1, declining to 1,662.9 m^3/day at day 90) was undertaken seasonally (December-February, March-May, June-August and September to November) with the shortest time and related probability for oil to cross the median line or reach the coast calculated for the UK and adjacent states.

An Abigail well blowout is estimated to result in a maximum accumulation of oil onshore of 1,614m^3 after 100 days. It is estimated that oil would reach the nearest UK coastline (Grampian) in between 7 and 17 days, depending on season (March-May and December-February, respectively), with a shoreline oiling probability of 5-10% and 10-20% respectively. There is a high probability (90-100%) that surface oil would cross the UK/Norwegian median line in 15 (December-February and March-May) and 18 (June-August and September-November) hours and a similarly high probability (up to 100%, all seasons except September-November)) that oil would cross the UK/Danish median line, although the shortest time for this (45 hours, December-February) is longer. There is a high probability (up to 80%, June-August only), oil would also beach in Norway, within 12 days. The probability of surface oiling in the adjacent state of Sweden is the next highest (up to 70%, >20 days, June-August), with the probability for Norway and Sweden during the remaining seasons and the other adjacent states (Denmark, Germany, Netherlands), for all seasons, lower.

The potential impact from an Abigail well blowout was assessed for its potential to result in a Major Environmental Incident (MEI); an MEI can only occur as a consequence of a major accident. This assessment was done with reference to the key environmental receptors, including the protected sites of the UK and the bordering states; for protected species and natural habitats, the definition of a MEI describes this as *an incident which results in any damage that has significant adverse effects on reaching or maintain the favourable conservation status of such habitats or species*.

A number of protected sites where the probability of surface oil meeting or exceeding 0.3µm were identified, these were considered key sites where the impact of an uncontrolled release could potentially be significant. A number of these key protected sites are marine sites, and primarily designated for physical features and seabed habitats (e.g. reefs, pockmarks), and biological features primarily found on or around the seabed, including *Arctica islandica* aggregations and sandeels; where sites are fully submerged, it is unlikely that a spill from Abigail would result in damage to affect the conservation status of these, Abigail oil being light and expected to remain primarily on the sea surface and not penetrate deep into the water column.

The remaining sites include coastal sites and marine area Special Protection Area (SPAs) (e.g. extensions of existing, or marine areas around existing sites, to protect foraging grounds for seabirds) and Special Areas of Conservation (SAC), the qualifying habitats from this latter group not considered particularly sensitive to spills. Of those SPAs identified, in the unlikely event of a major crude oil spill from Abigail, weathered spilled oil could theoretically affect the qualifying features (e.g. breeding seabirds and wintering waterbirds) when present and when foraging within and outside the boundaries of the SPA. Fortunately, there is little experience of major oil spills in the vicinity of seabird colonies in the UK. And, where spills have occurred, e.g. the *Braer* (Shetland), long term effects on wildlife have proved to be less than feared with the most notable impact on breeding populations of resident seabirds closest to the spill.

Evaluating spill risk also requires consideration of the probability of an incident occurring. While it is evident from the Deepwater Horizon incident that well blowouts with environmentally significant consequences can and do happen, historically, spills of this magnitude, as a result of well blowouts, have not occurred on the UKCS or in the wider North Sea, and the probability remains remote

Ithaca have a well examination scheme operated by independent well examiners to ensure there is an independent check on well design, construction, maintenance and operation. These barriers (including well barriers) and preventative controls are in place to minimise the occurrence of an Abigail well blowout, including those at design stage, such as analysis of analogues wells, drill fluid design, and during operation through the deployment of a tested and maintained Blowout Preventor (BOP). Other measures to reduce the probability of an incident occurring include the identification and maintenance of safety and environmentally critical element (e.g. emergency shut down valves, isolation valves), and effective training and competency practices in place for staff.

Overall, while the spill modelling scenario for Abigail does demonstrate the potential for an MEI from a blow out of the Abigail well, for protected sites and species, this is a worst case scenario that assumes no intervention and response, and the probability of an incident occurring is remote due to preventative measures and response strategies in place.

Overall Conclusions

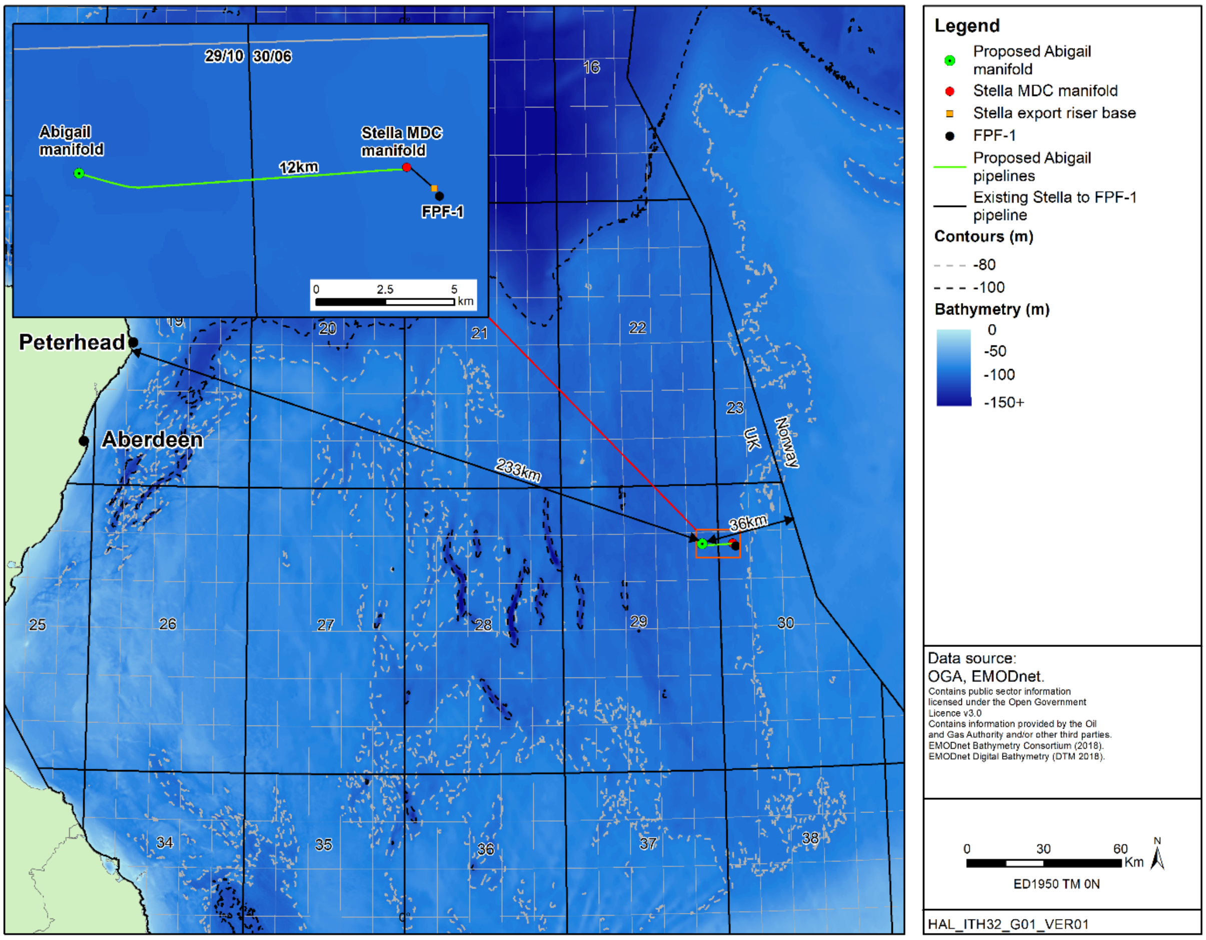
The overall conclusion of the Environmental Impact Assessment is that, with the implementation of the operational controls, risk reduction measures and commitments in Table 7.1 (Section 7), the development of the Abigail Field and the processing of hydrocarbons will not result in significant adverse effects on the environment or other users of the area.

No significant data gaps or limitations have been identified from the environmental assessment of the Abigail development activities and operation of the field.

1 INTRODUCTION AND BACKGROUND

This Environmental Statement (ES) presents the findings of the Environmental Impact Assessment (EIA) conducted by Ithaca Energy (UK) Limited (hereafter referred to as Ithaca Energy), for the phased development of the Abigail oil and gas condensate field. The field lies within United Kingdom Continental Shelf (UKCS) Block 29/10, approximately 233km south east of Peterhead and 36km from the UK-Norway median line. It is 13km to the west of the Ithaca Energy owned floating production facility, the FPF-1 (Block 30/06), which it is proposed the Abigail Field will be tied back to (Figure 1.1, see also Figure 4.10, Section 4.9). Production is expected to commence from Abigail in Q3/Q4 2022.

Figure 1.1 – Location of the proposed Abigail Development



The Abigail Field, comprising Forties and Andrew Formation sandstone, was discovered by Shell in 1995 with well 29/10-4 and its associated sidetracks but was not subsequently developed. In 2009, Ithaca Energy was awarded the licence (P1665) covering UKCS Block 29/10b and in 2012 successfully appraised the discovery with well 29/10b-8. Licence equity is Ithaca Energy (UK) Limited 80% and Ithaca Energy Developments UK Limited 20%.

With installation completed in 2017, the floating production facility the FPF-1 serves as the processing hub for the Stella and Harrier fields, production from which commenced in 2017 and 2018 respectively; Ithaca Energy has 100% equity in both fields. Export of oil from the FPF-1 is into the ConocoPhillips operated "Norpipe" system and gas is exported via the Kellas Midstream operated Central Area Transmission System (CATS) pipeline. The development of both fields and the installation of the FPF-1 was described and assessed in the Stella and Harrier Field Development, Block 30/06a Environmental Statement (DECC Project Ref: D/4125/2011) (Ithaca 2011). Petrofac Facilities Management Limited

(Petrofac) served as Duty Holder for the FPF-1 on behalf of Ithaca Energy up to 2018, at which time Ithaca Energy appointed them as Installation Operator. Petrofac remained Installation Operator until Q3 2020 when Ithaca Energy became Installation Operator.

Development of the Vorlich field, a joint venture between Ithaca Energy and BP (licence operator) and which also ties into the FPF-1, was completed in Q4 2020, with production commencing soon after.

1.1 The Environmental Statement and Environmental Assessment Process

1.1.1 Purpose

Environmental Impact Assessment (EIA) is an integral part of Ithaca Energy's operational excellence management system processes, which satisfies the company's environmental policy objectives with regard to the assessment of potential risks to the environment from its activities. This Environmental Statement (ES) documents the results of the EIA, highlighting environmental sensitivities, identifying potential hazards, assessing/predicting risks to the environment and identifying practical mitigation and monitoring measures to be carried forward into detailed design installation and operation of the field. The EIA has assessed the development of the Abigail Field through the consideration of the drilling of the wells, and the installation of the pipeline system and manifold; the Abigail Field will tie-into existing facilities and process train for which no process system modifications to the FPF-1 are required.

The ES has been produced in accordance with the *Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020* (the EIA Regulations), under which the submission of an ES to the Secretary of State for the Department for Business, Energy and Industrial Strategy (BEIS) is required for the development of a hydrocarbon reservoir, where the extraction of oil and gas exceeds 500 tonnes and 500,000m^3 day respectively (Schedule 1 project).

1.1.2 Environmental Assessment Process

The EIA process has been ongoing through the development of the project. The process undertaken considers the range of activities relevant to the development of the Abigail Field, and their potential impact on the receiving environment, focusing on those impacts that have been identified as potentially significant. This process is informed by project engineering studies, environmental surveys, and broader data and literature of relevance to the Abigail Field area (see Section 5). By incorporating environmental considerations into the development option selection process, project detailed design and operation, as far as practicably possible, this ensures best environmental practice is followed, in order to achieve a high standard of environmental protection.

For this ES, the interactions between the proposed activities and the environment (in its broad sense) were identified at the screening and scoping stages of the EIA process, and the potential for significant effects to arise were considered using defined severity criteria of relevance to those topics referred to in Schedule 6 of the *Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020*. Those interactions with the potential to result in significant environmental effects were then assessed in more detail (see Section 6), and mitigation measures identified, where appropriate.

The potential for cumulative effects to arise from interactions with other plans and projects as a result of the development of the Abigail Field, and the potential for transboundary effects, are also addressed.

The ES will be subject to the formal statutory public consultation process.

1.2 Consultation and Stakeholder Engagement

To aid the identification of potential environmental issues associated with the development of the field, Ithaca Energy engaged with a number of stakeholders during the planning stage. In particular, Ithaca Energy wanted to ensure:

- awareness of all relevant environmental information for the area
- identification of stakeholder issues and concerns to be considered in the environmental impact assessment process

Ithaca Energy presented a summary of the proposed development activities, the environment of the area and the perceived key issues, with consultees invited to discuss the proposals and raise any questions. Consultees were also given the opportunity to subsequently raise any further issues or concerns and provide details of new relevant information.

The consultees and responses are summarised below.

Consultee	Summary of comments	Section
BEIS – OPRED	Survey for proposed development area conducted 2010/2011, not a recent survey, but acknowledged recent surveys done (2017, 2018, 2019) in the wider area. Data from environmental scope as part of future pipeline route survey/site survey to be used to support term permit applications. No other comments at this stage.	4.1
JNCC	No comment at this stage	-
SFF	Noted the pipelines and umbilical to be trenched in single trench – positive. Fishing effort in general area had believed to have increased in 2019. Enquired as to expected application schedule for 500m safety exclusion zone around proposed manifold. No major concerns at this stage and no further comment made.	3.4 & 6.1

1.3 Scope

This ES includes a consideration of activities associated with all stages of the Abigail development, including drilling, installation, commissioning, operation and decommissioning. The development work will be completed in 2 phases:

Phase 1 – First production well, Abigail manifold, pipeline system and associated subsea infrastructure and protective material installation

- A semi-submersible rig will be used to re-enter the currently suspended appraisal well (29/10b-8) and complete this as a production well (designated as well P2-W) at the Abigail Drill Centre. The well will have a short flow test, be completed, then temporarily suspended, ready for subsea infrastructure installation. The earliest drilling activity is expected to commence is Q2 2022
- Subsea infrastructure will be installed. A new production pipeline, gas lift pipeline and services umbilical will be trenched and buried, in a single trench. A new Abigail production manifold will be installed at the well location and secured to the seabed with four piles. A new 500m safety exclusion zone will be centred on the new manifold. The subsea programme is expected to be completed by Q3 2022
- The pipelines and umbilical will tie-into the existing Stella production manifold at the Main Drill Centre (MDC), which is tied back to the FPF-1 installation; the Stella MDC has an established 500m exclusion zone – see Figure 4.11 Section 4.9 for this and existing exclusion zones in the area. A new subsea isolation valve (SSIV) will be installed at the FPF-1 riser base, located within the FPF-1 500m safety exclusion zone.

Phase 2 – Second production well and tie-in to Abigail manifold

Execution of Phase 2 is contingent on field production and is feasible in the high production case scenario. This phase has been included in this environmental risk assessment on this basis.

- Either a semi-submersible or jack-up rig will be used to drill a second production well (P1-E) at the Abigail drill centre and tied into the Abigail production manifold using tie-in spools and jumpers, with a small quantity of associated protective material.
- If progressed, the earliest commencement of activities for the second phase is Q3/4 2024, when the second production well would be drilled. Tie-in would be carried out as soon as practicable after drilling activities have been completed and production commencing soon after.

The Abigail development will comprise of up to two wells only, with no further wells planned.

2 ENVIRONMENTAL MANAGEMENT AND REGULATION

2.1 Ithaca Energy - Health, Safety and Environment

Ithaca Energy has an Operational Excellence Management System (OEMS) into which is integrated the Environmental Management System (EMS) certified to ISO 14001:2015 standard. The EMS was last verified in April 2021 and is designed to implement Ithaca Energy's environmental policy. This demonstrates a commitment by Ithaca Energy to comply with environmental legislation and Ithaca Energy's standards, processes and objectives for environmental management of their exploration, appraisal, development, production and decommissioning activities across the UKCS.

Ithaca Energy's policy for protecting people and the environment is the primary statement of Ithaca Energy's expectations for health, safety and environmental management, and provides a shared understanding throughout the Company of environmental performance expectations. Ithaca Energy's vision is reflected in the Operational Excellence Policy (Figure 2.1) which is endorsed by the Chief Executive Officer of Ithaca Energy on behalf of the Board of Directors. The policy acknowledges Ithaca Energy's responsibilities in relation to its business activities. This includes commitments to continual improvement, assessment and management of the risks and impacts associated with operations, including development activities, to meet legislative requirements and accepted best practice and a willingness to openly communicate these principles to company personnel and the general public.

2.2 Regulation

Ithaca Energy is committed to ensuring that activities carried out by the company and its contractors during the development programme are conducted within the criteria set by legislation, and that all operations will be carried out in compliance with required permits and consents. Under the current permit system, the BEIS Portal Environmental Tracking System (PETS), the range of permits and consents required to undertake the development of the Abigail Field include, but are not limited to, siting of the rig and vessels, installation of the pipeline system and the use and discharge of chemicals. Approvals for these are contingent on complying with the applicable legislation. This ES will support these applications in due course. At present, applicable legislation includes (but is not limited to):

- *The Merchant Shipping (Oil Pollution, Preparedness, Response and Co-operation Convention) Regulations 1998*
- *The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020*
- *The Greenhouse Gas Emissions Trading Scheme Regulations (2012)* (as amended)
- *The Greenhouse Gas Emissions Trading Scheme Order 2020*
- *Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001* (as amended)
- *The Conservation of Offshore Marine Habitats and Species Regulations 2017*
- *The Offshore Chemical Regulations 2002* (as amended)
- *The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005* (as amended)
- *The Energy Act 2008* (as amended), *Part 4 Consent to Locate*
- *Marine and Coastal Access Act 2009* (as amended)
- *The Offshore Combustion Installations (Pollution Prevention and Control) Regulations 2013*
- *The Merchant Shipping (Oil Pollution Preparedness, Response Co-operation Convention) Regulations 1998*

Legislation and compliance requirements may change over time and as part of their management system, Ithaca Energy has processes in place to monitor for new legislation relevant to their activities. Ithaca Energy will ensure that all relevant regulations are complied with for the development of the Abigail Field.

Figure 2.1 – Ithaca Energy Operational Excellence Policy

ITHACA ENERGY

Ithaca Energy (UK) Limited Operational Excellence Policy

Ithaca Energy (UK) Limited's Operational Excellence (OE) vision is to be recognised and admired by the industry and the communities in which we operate as a world-class performer in process safety, personal safety and health, environment, reliability and efficiency. Ithaca recognises the need to operate in a safe and responsible manner.

We will systematically manage OE with the aim of:

- **Identifying and reducing the risk of major accident hazards including environmental and process safety risks.**
- **Achieving an incident and injury free workplace.**
- **Promoting a healthy workplace and mitigating significant health risks.**
- **Operating incident free with industry leading asset integrity and reliability.**
- **Efficiently using natural resources and assets.**
- **Ensuring continual improvement in all aspects of our business.**

Through consistent application of OE, this policy and our Safety and Environmental Management Systems (SEMS), we aim to address the following:

Leadership

Our leaders are accountable for:

- Providing clear and consistent leadership in accordance with this policy and our tenets of operation.
- Ensuring clear roles, responsibilities and communications.
- Trusting and empowering their teams to apply a risk based approach to decision making in accordance with this policy.
- Creating a culture that is built on our values and behaviours, enabling safe, reliable and secure operations and environmental protection.
- Engaging with community and other stakeholders.
- Ensuring that we comply with all applicable policies, codes and regulations and that we constructively engage in consultation with regard to proposed legislation.

Organisation

Our organisation is fit-for-purpose and is designed to:

- Achieve results in accordance with Ithaca policies.
- Ensure suitable and sufficient control of Major Accident Hazards.
- Ensure that staff and contractors are competent of their roles through the application of the Ithaca Competence Assurance Process.
- Encourage structured and timely decision making.
- Ensure the management of safe work.

A Strong Safety Culture

Based on:

- Our tenets of operation.
- Compliance with the provisions of our safety cases and this policy.
- The identification and management of Major Accident Hazards.
- The involvement of, and consultation with, our staff and contractors.
- The reporting and investigation of incidents and near misses.
- The use of stop work authority.
- The recognition and reward of desired behaviours through the use of stop work authority, performance process and our recognition and award process.
- The implementation of corporate safety initiatives.

Risk Management

Our people, at all levels of the organisation will:

- Systematically assess, prioritise and manage risk.
- Regularly review and re-evaluate risks.
- Maintain the integrity of dedicated systems through fit-for-purpose design and operating practices.
- Ensure that there are multiple, independent barriers in place to prevent Major Accident Hazards including, but not limited to, unplanned releases of hydrocarbons.

Asset Integrity Management

Our facilities, reservoirs and wells are designed and maintained to be fit-for-purpose throughout their lifecycles. This includes

- Designing, constructing, modifying, operating and maintaining our facilities and wells to recognised safety and environmental protection standards, to avoid unplanned releases of hazardous substances and to prevent injury to people or harm to the environment.
- Minimising the potential for human error through the design and operation of our facilities.
- Maintaining the integrity of safety and environmental critical elements.
- Managing risks on a whole of life-cycle basis.
- Managing change in accordance with our management of change process.
- Compliance with all applicable codes, regulations and Ithaca standards.

Monitoring and Audit

Through a process of audit and workplace monitoring, we will examine our processes and operations to confirm:

- That we review and re-evaluate our goals and our organisational capability.
- That our plans and processes are being correctly implemented.
- That we continually improve the effectiveness of our management system including our verification and well examination schemes.
- The suitability and effective implementation of this policy.

Emergency Management

While prevention is the first priority, we are prepared for an emergency and have the tools to mitigate any incident quickly and effectively:

- We maintain a fit-for-purpose command and control system, based on defined scenarios and meet all UK legal requirements.
- We regularly test the effectiveness of the system through audits and exercises.
- We aim to prevent future incidents by identifying and eliminating their root causes.

This policy applies to all offices and facilities operated by Ithaca Energy (UK) Limited.

The Leadership Team shall champion the implementation of this policy across Ithaca and lead the monitoring and auditing of its ongoing effectiveness.

Every individual has a duty to ensure that they always comply with, and hold others accountable for compliance with this policy, and prevent harm to themselves and others, and to the environment. This policy is applicable without distinction between Ithaca employees and contractors working for the company.

This policy meets the requirements of the corporate major accident prevention policy pursuant to Regulation 7 of the Offshore Installations (Offshore Safety Directive) (Safety Case etc) Regulations 2015.

Bill Dunnett, Chief Executive Officer
Ithaca Energy (UK) Limited

2.3 Marine Planning

The *Marine and Coastal Access Act 2009* (as amended) introduced a marine planning system which, along with legislation implemented by the devolved administrations (e.g. the *Marine (Scotland) Act 2010*), aims to provide a coherent approach to the management of the UK's marine areas. Policy objectives for activities taking place on the UKCS were originally set out in the UK Marine Policy Statement (MPS), and have been clarified at a regional scale through the various Marine Plans of the UK and devolved Governments, including those set out in Scotland's National Marine Plan (Scottish Government 2015); the Abigail development is located within the Scottish marine plan area and as such has been assessed against the relevant general and Oil&Gas marine planning policies (Table 2.1).

Table 2.1 – Scotland Marine Plan Polices and the proposed Abigail Development

Scotland Marine Plan Policies	Abigail assessment
General Policies[1]	
GEN1 - General planning - sustainable development	The Abigail development will be consistent with the polices of the Marine Plan
GEN2 - Economic benefit	The Abigail development will maintain existing employment (FPF-1 and associated personnel) and provide additional (short term, e.g. well, construction and pipeline installation) employment within Scotland plus the associated tax revenues to the economy
GEN4 - Co-existence	The Abigail development is to use existing infrastructure (FPF-1) and minimises, as far as practicable, new infrastructure footprints (only the Abigail manifold will have a new 500m safety exclusion zone, e.g. other users of the marine environment will not be excluded over the pipeline route area). Consultation with interested parties (i.e. Scottish Fisheries Federation) has been undertaken and will continue through the planning and project execution phases. The drilling and subsea activities will be of relatively short duration. Physical presence has been assessed in the EIA, which found no significant impact.
GEN5 - Climate change	Potential opportunities to reduce emissions during drilling programme through minimising flights, supply visits and fuel use, and the FPF-1 included in an asset wide programme being covered by an Ithaca Energy Emissions Strategic Working Group, looking at emissions reductions targets, small/large and sustainable improvements emissions key performance indicators (KPIs), development of white papers for each field, greenhouse gas management plan and strategy for Ithaca Energy assets, engagement with workforce.
GEN6- Historic environment	Previous site survey data has shown Abigail is not located near any designated protected wreck site.
GEN9 – Natural heritage	Previous site survey[3] data has shown Abigail is not located in or near any area with protected species or habitats. The potential for the presence of the OSPAR habitat Sea pen and burrowing megafuna communities and the potential for impact on priority marine features has been assessed.
GEN11- Marine litter	All vessel associated with Abigail will be equipped to meet MARPOL and related merchant shipping regulations for the prevention of pollution from ships.
GEN12 – Water quality	Chemical use and discharge associated with the phases of the development will be fully assessed as part of the environmental permit system (drilling, pipeline, operations). Where technically feasible to do so, chemicals with good environmental profiles will be selected for use, reducing the potential for deterioration of water quality. Processes and procedures are in place as part of the Ithaca Energy Management system for the prevention of spills to sea. Discharges have been assessed in the EIA, which identified no significant impact.

Scotland Marine Plan Policies	Abigail assessment
GEN13 - Noise	There is no VSP, check shots or other evaluation being undertaken with a noise source as part of the drilling programme, there will be pilling associated Abigail manifold installation and this has been assessed in the EIA, which found no significant impact. The only other noise source being the rig and vessels on location for relatively short periods, with these noise sources being of a non-pulsed/continuous nature.
GEN14 – Air quality	Emissions associated with the different development phases (vessel use for drilling and subsea programmes), flaring from well clean up and emissions as a result of Abigail operations have been assessed in the EIA, which concluded there will not be a significant impact on air quality.
GEN18 - Engagement	Ithaca Energy have engaged with interested stakeholders (e.g. SFF) as well as having early engagement with OPRED and statutory consultees (e.g. JNCC) for the development and will continue to liaise with stakeholders through the planning and execution phases. ES subject to formal period of public consultation.
GEN19 – Sound evidence	Environment baseline and assessment utilises site specific survey data[3], and survey date from the Greater Stella area for context, peer reviewed literature and experience and knowledge from analogous developments in the North Sea.
GEN20 – Adaptive management	Understanding of the environment within which Abigail is located comes from site specific survey data, survey data from the greater (Stella) area and available scientific literature. Ithaca Energy identify emerging information and incorporate this into planning and decision making.
GEN21 – Cumulative impacts	Cumulative impacts have been assessed within the EIA with no significant impacts identified.
Oil and Gas Policies	
O&G1 – Maximise and prolong O&G exploration and production – activity should be carried out using the principles of BAT and BEP	Development activities use BAT and BEP principles as far as practicable, e.g. in well design which aims to reduce waste generated and cement used, chemicals have been selected for better environmental profile, where technical requirements allow, no extended well test is being undertaken, the pipeline system contained within a single trench, rather than up to three separate trenches, rock use minimised as far as practicable, use of existing infrastructure (FPF-1), minimising new infrastructure footprint. Potential impacts associated with the Abigail were assessed within the EIA and no significant impacts identified.
O&G2 – Where re-use of O&G infrastructure is not practicable, decommissioning must take place in line with standard practice.	Potential for re-use of Abigail associated infrastructure, along with other decommissioning options, will be fully assessed at the time of field decommissioning, with decommissioning activities, including wells plug and abandonment, carried out in accordance with the regulatory process and industry guidance at that time.
O&G3 – Supporting marine and coastal infrastructure should utilise the minimum space needed for activity and take into account environmental and socio-economic constraints	Abigail will tie back to existing infrastructure (FPF-1) and utilise existing export facilities and use a single trench for the pipeline system minimising as far as practicable the space for the development and new infrastructure footprint.
O&G6 – Operators should have sufficient emergency response and contingency strategies in place that are compatible with the National Contingency Plan and the Offshore Safety Directive	Ithaca Energy have appropriately approved emergency response plans in place for the FPF-1 installation, compatible with the NCP and OSD and the rig selected for the drilling programme will have in place the required response plans.

Notes: [1]General policies and O&G policies not applicable to Abigail are not included here, [2]Reference to vessels for Abigail includes the rig. [3]A new site survey is being conducted at Abigail in June 2021

2.3.1 Block Specific Issues

Specific issues of relevance to the Blocks are listed in the 32nd Round compilation of other regulatory issues (OGA 2019b[2]), and are given below:

Seasonal concerns				4. Special Conditions
Block	**1. Period of concern for seismic surveys**	**2. Period of concern for drilling**	**3. Spawning sites**	
29/10b	May to August [MS]	-	-	-
30/6a	May to August [MS]	-	-	-

Notes: MS = Marine Scotland

No seismic surveys are to be conducted as part of the Abigail development activities.

[2] OGA Other Regulatory Issues. Version at July 2019.

3 PROJECT DESCRIPTION

3.1 Consideration and Selection of Development Options

The selection of options for the development of the Abigail Field was a staged and iterative process. High level development concepts were screened at an early stage of the project for technical and commercial feasibility together with associated safety and environmental considerations.

3.2 Do-nothing Scenario

The option of not developing the Abigail Field would have several implications for the environment, both direct and indirect, for example:

- Drilling discharges, noise, seabed disturbance and other sources of potential effects would not be made at the Abigail location
- Interaction with fisheries associated with the development (drill centre, pipeline installation) would be avoided
- Localised protection from trawling impacts, provided by proposed exclusion zone, would not occur
- For the operational term, other environmental effects and pressures on the area, e.g. ambient anthropogenic noise and oil spill risk associated with pipeline and wider vessel traffic, would be unaffected
- Security of domestic supply during the UK's transition to net zero by 2050, the alternative being potential import of fossil fuels by pipeline or shipping (which have associated, actual or potential environmental impacts)

This option was discounted on economic grounds and because an initial screening indicated that the development would be unlikely to pose significant risks to the environment which could not be effectively managed through design, operational controls and mitigation. Additionally, this scenario would not be consistent with the central obligation of the Oil and Gas Strategy (see 3.14 below).

3.3 Concept Options Screening

Of the concept development options identified, most were discounted during high-level screening, primarily on grounds of technical or economic feasibility. These included extended reach drilling, and new stand alone facilities.

Extended reach drilling from an existing surface facility was not feasible, as the nearest facility, the FPF-1 (*ca*. 12km), has no drilling facilities. New standalone surface facilities with the creation of a new export route (tanker or pipeline tie-in to an export line to shore), was also not taken forward as the modest reserves from Abigail preclude the significant capital investment that would be required for new standalone facilities. The use of a mobile production facility was considered not to be viable as it would have precluded recovery of the field reserves when production drops below the level required to meet the cost of operating such a facility. This option was discounted on commercial grounds and the environmental implications of the standalone option were not considered further. However, this option would have resulted in a greatly increased project footprint, use of resources and energy, compared to alternative subsea tie-back options.

The joint development of the Abigail and BP Capercaillie and Puffin fields via a well daisy chain arrangement to a 3rd party host was considered, but discounted, due to technical and economic feasibility. Any host options would be at significant distance away, and require process system modifications.

The development option selected was to develop the field as a subsea tie-back to existing facilities. This option was considered to be technically and economically viable, consistent with the scale of the field's reserves, and had the smallest environmental impact of the options considered.

3.4 Selected Development Options

The option taken forward was the development of the Abigail Field as a subsea tie-back to existing facilities. To manage uncertainty in the field, optimise field recovery and to make best use of the available capacity at the host installation, the option to develop the field in two phases was progressed, with Phase 1 developing the western area of the field via a single production well and the pipeline infrastructure, with Phase 2 being a potential second well targeting the east of the field. The first phase of the development will gather production data and improve estimates of connected volumes and this data will be used to determine if Phase 2 is justified. Environmental considerations were taken into account as part of the option selection process, to ensure best environmental practise is followed as far as practicably possible to do so.

Host Selection

The established floating production facility the FPF-1 was identified at an early stage as a potential host facility for the Abigail Field to be tied back to. The FPF-1 is located in the block adjacent to the Abigail Field, and would not require process system modifications, with only minor modifications required. The FPF-1 has established oil and gas export routes with the capacity to accommodate the Abigail production.

This option offers a number of environmental benefits such as maximising the use of existing process and export facilities, thereby minimising the use of natural resources for the construction of new surface facilities, and avoiding the physical impacts associated with the installation of new export facilities to shore or the spill risk of offshore tanker loading. Maximising the use of existing facilities can be considered best environmental practice in terms of host selection.

Well Strategy

The option selected for the first production well (designated well P2-W) is the re-entry and completion of an existing appraisal well (29/10b-8). The hole sections of this will be drilled with low toxicity oil based mud, with cuttings and mud returned to shore for processing and disposal, resulting in no discharge of this to the seabed. There will be no vertical seismic profiling (VSP), or extended well test as part of the drilling activities.

Well options screened included the drilling of a new well, however, the option to sidetrack from the existing well 29/10b-8, using smart completion technology was selected as this will produce both the Forties oil reservoir and Andrew formation (see Section 3.5), without the need to drill a new well, thereby reducing the overall environmental footprint from drilling activities Overall time on location should be reduced, minimising emissions from rig activities, and re-entering and completing an existing well should also use and discharge smaller quantities of chemicals compared with that required for a new well.

A semi-submersible rig is the selected rig option for drilling the first production well. This rig type was used to drill the original appraisal well 29/10b-8. Although the depths are such that both a semi-submersible or jack-up rig could be used, and the overall footprint from a jack-up rig in terms of seabed disturbance is less than that of a semi-submersible rig, Ithaca Energy have taken into consideration rig availability, synergies with other potential drilling projects in deeper water currently being reviewed, and in order to maximise rig use, have selected a semi-submersible rig to drill the first Abigail production well.

The layout at the Abigail drill centre has been developed to facilitate the installation of the majority of the subsea infrastructure whilst drilling is ongoing in order to minimise the overall development timescale. The layout also allows for the second production well to be drilled and tied-in whilst minimising any impact on the ongoing production from the first well.

Abigail Production Manifold

A piled manifold is the selected option for Abigail, this being a proven design concept for manifolds in the Greater Stella Area. Given the soil conditions, the alternative would be a gravity based manifold, this requiring additional fabrication to accommodate the manifold pipework and control modules. If gravity based, this would also have to be designed to be overtrawlable, in the event vessels accidentally entered the 500m safety exclusion zone. This would result in an increase in weight and overall size of the manifold; the increase in size/weight may necessitate an additional vessel campaign. A piled manifold does create additional noise impacts, however by following industry guidance (i.e. JNCC 2010), and operational controls, these can be mitigated for. By utilising a tried and tested design of manifold, and being piled, this minimises fabrication (and its associated use of resources and energy), minimises installation (time and footprint) as far as practicable, and ensures the manifold remains stationary.

Pipeline System, Route and Installation

The Abigail pipeline system will have several lines. Abigail requires gas lift[3] necessitating the inclusion of a gas lift pipeline, the other elements of the system being the production pipeline, to convey hydrocarbons from the production well to the FPF-1, and a service umbilical, to convey, for example, chemicals and power to the well and manifold.

The option for the pipelines and umbilical is to install all three lines in a single trench, mechanically backfilled with the trenched sediment and associated protective material used. Installation is to be carried out by reel-lay dynamic positioning (DP)-class vessel. This option results in a single trench being excavated and backfilled, thus reducing the size of any spoil heaps/berms bounding the trench. Backfilling the trench with the natural sediment also reduces the amount of protective material required; rock is not being used to cover the entire length of the pipeline system. Installation by reel-lay from a DP-vessel requires fewer vessel days offshore compared to s-lay or a bundle option, and does not use anchors. A smooth trench is required to accommodate a hot rigid production pipeline, with as much sediment backfill being left available to refill the trench and help mitigate upheaval bucking (thus also reducing the quantity of rockdump required). This is best achieved using a ploughed rather than a jetted system, and as the umbilical is also to be laid in the same trench, a ploughed system would also minimise backfill occurring before the umbilical is laid, which is not feasible with a jetted system. A ploughed trenching system was therefore selected.

Protective material in the form of concrete mattresses, biodegradable grout bags and rock is to be used, these being industry proven methods of protection for pipelines and associated infrastructure. The decommissioning of the protective material at the end of field life will be part of the decommissioning options assessed for the field, with the expectation being, if a requirement at the time, the mattresses and grout bags, which are not covered in rock, could be recovered.

The Abigail pipeline route was selected based on a number of factors, including being the shortest route between its end points, the avoidance (if present, and as far as practicable), of sensitive habitats and features, (no habitats or species of conservation concern were identified), and to account for approaches both to the new drill centre and the receiving installation.

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[3] Gas lift is an artificial lift method, whereby gas is injected into the production tubing to reduce the hydrostatic pressure of the fluid column

Phase 2

If Phase 2 is executed, the selected well option for the second production well (designated well P1-E) is a new well to target the gas cap in the east of the Forties reservoir. The option to re-enter and complete an existing well to target this reservoir was unavailable.

The planning for the second phase of the development is at an early stage, including the detailed design of the second well. The overall design and completion is expected to be similar to the first production well, albeit that re-use of an existing well will not be made. The current approach for the second well is for no VSP or extended well test to be carried out.

Rig selection for this well is still to be made, and either a jack-up or semi-submersible could be selected. Final selection will be based on a number of factors including rig availability and potential synergies with other Ithaca Energy projects and/or other Operator projects at that time. As it is unknown at this stage if a semi-submersible or jack-up will be used for the second well, both options have been included in this assessment.

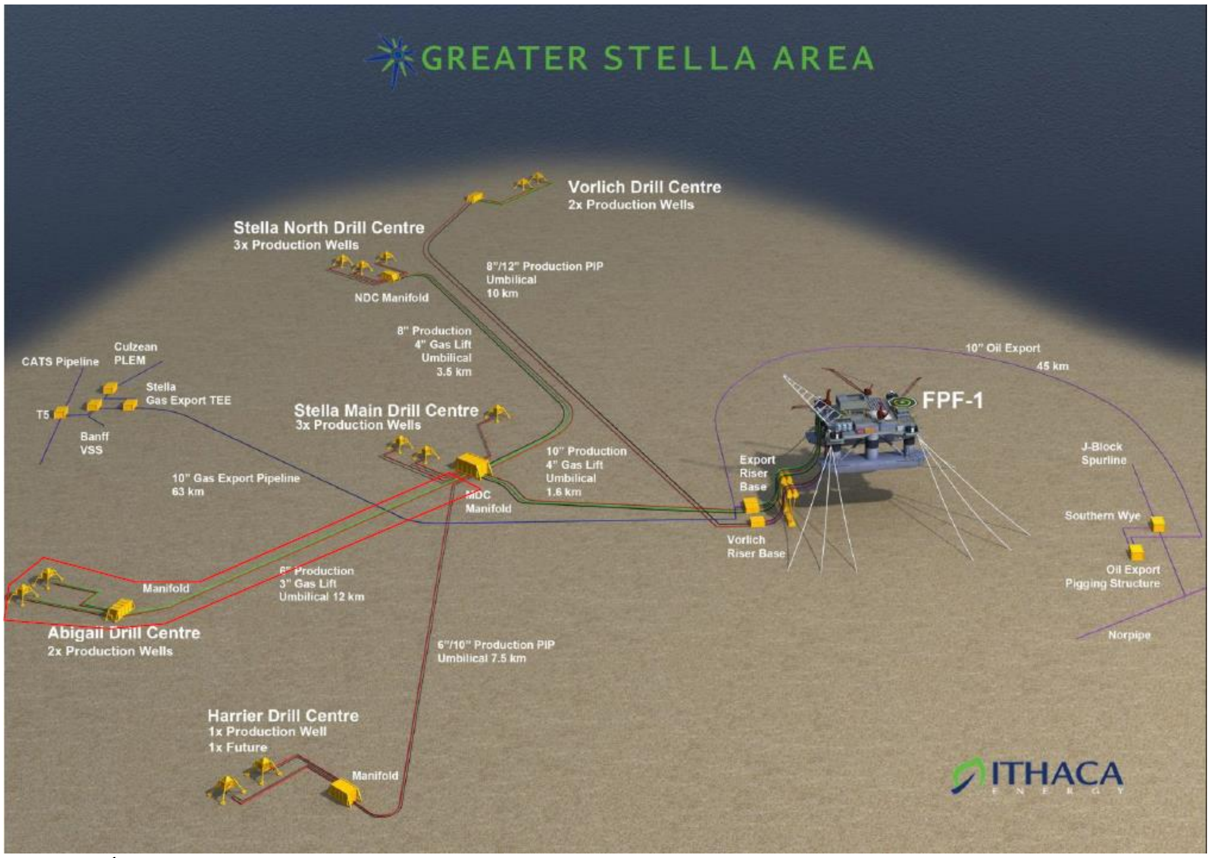
The subsea scope of work for the Phase 2 will comprise the tie-in of the second well to the Abigail manifold using spools and jumpers, and a small quantity of associated protective material, with no other subsea works being carried out.

Locations of the various development elements from the selected option for Phase 1 and 2 are shown below and the proposed development layout (showing the two wells) is shown in Figure 3.1 (red outline) (see also Appendix 1 for further detail); this also shows the development within the context of Ithaca Energy's wider Stella/Harrier field infrastructure and the Ithaca Energy/BP joint venture, Vorlich, tied-back to the FPF-1 in 2020.

New Elements	Location
Abigail drill centre (first production well)	56°47'30.64"N 01°53'44.96"E
Second production well[1]	56°47'35.27"N 01°53'48.50"E
Abigail manifold	56°47'32.32"N 01°53'50.93"E
SSIV	56°47'2.974"N 02°6'27.89"E
Abigail pipeline system	Start location: 56°47'32.32"N 01°53'50.93"E End location: 56°47'28.21"N 02°5'29.40"E
Existing Elements	**Location**
Stella MDC manifold	56°47'28.21"N 02°5'29.40"E
FPF-1 installation	56°46'43.11"N 02°6'37.92"E

Notes: [1]current location of second well, this is subject to change

Figure 3.1 – Abigail Field layout within the wider stella area[1]



Note:[1]Abigail well centre, manifold location and proposed pipeline system marked in red outline. The field layout shows the two wells at the Abigail drill centre, the second of these being Phase 2 of the development. The Greater Stella Area (GSA), describes the Stella and Harrier field, the FPF-1 and will include the Abigail Field.

3.4.1 Areas of Uncertainty

The first phase of the project is now well defined, with all preferred options selected.

There are some areas of the second phase of the project which are still to be defined; the final decision regarding rig type is yet to be made, with the second well being drilled by either a jack-up rig or semi-submersible rig. Any assumptions underpinning the assessment of these areas subject to uncertainty are identified throughout the ES.

Where definition is lacking, worst case estimates of emissions, seabed disturbance and other sources of interaction are used in the consideration of possible effects. It is not considered that the remaining flexibility in project definition results in significant uncertainty in assessment of environmental effects.

3.4.2 The Case for Development

The UK has been a net importer of gas and oil since 2004 and 2005 respectively and these are expected to remain an important part of the UK's energy mix for the foreseeable future. The development of the Abigail Field will contribute to security of energy supplies and maximise economic production of oil and gas from UK fields.

The Oil and Gas Authority's (OGA) Strategy, laid before parliament in December 2020, revises the OGA's Maximising Economic Recovery Strategy for the UK (the MER-UK Strategy), and takes account of the UK Government's Net Zero commitment[4], with alterations made to the central obligation, and supporting obligations.

Ithaca Energy seeks to play its role in the UK's net zero commitment by minimising greenhouse gas emissions during the life cycle of the Abigail field.

During the development phase of the field, and as part of Ithaca Energy's standard programme management and planning, fuel consumption will be reduced by minimising the use of vessels and sharing them where possible. The flaring of hydrocarbon gases during the well clean-up flows will be minimised, and equipment selected to safely and efficiently burn produced fluids.

In the production phase of the development, the field ties back to the FPF-1 vessel, where processing and support facilities are shared with several other producing assets. This minimises the incremental fuel gas demand caused by the development, and the FPF-1 facility is designed to have zero flare during routine production operations. The Abigail Development and its potential contribution to greenhouse gas emissions from flaring and power generation is considered in this assessment.

By utilising existing infrastructure in close proximity to the field and the use of smart well completion technology, the development of the field aligns with the OGA Strategy[5] central and supporting obligations; the central obligations being that, "*Relevant persons[6] must, in the exercise of their relevant activities, take the steps necessary to secure that the maximum value of economically recoverable petroleum is recovered from the strata beneath relevant UK waters and take appropriate steps to assist the Secretary of State in meeting the net zero target, including by reducing as far as reasonable in the circumstances greenhouse gas emissions from sources such as flaring and venting and power generation, and supporting carbon capture and storage projects*."

As an Operator in the UKCS, Ithaca Energy is working towards the Government's net zero target in a number of ways. Ithaca Energy has set up an Emissions Strategic Working Group, which is looking at small and large, and sustainable, improvements, and through which reduction targets (across its assets) are created, and emissions key performance indicators (KPIs) are set. Ithaca Energy are in the process of creating white papers for each field and a greenhouse gas management plan and strategy for all Ithaca Energy assets. In terms of environmental stewardship, Ithaca Energy also have an annual process that looks at environmental improvement, including emissions reductions, on all assets.

3.5 Abigail Field Reservoir and Production Profiles

The Abigail Field comprises two reservoirs, Upper Forties and the Andrew Sandstone Member. The Upper Forties Sandstone forms the primary reservoir in Abigail and comprises a west-east trending turbidite channel, with two structural culminations (Figure 3.2). Reservoir properties are favourable with typical porosity of 28% and permeability 200 md. The western side of the accumulation, penetrated by 29/10-4Z contains oil, whereas 29/10b-8 in the east encountered a rich gas condensate fluid. Pressure data suggests that both sides of the structure are in hydraulic communication. The Forties is estimated to contain 10.0 Million STB in the oil zone and 7.5 Bscf in the gas cap (mid case).

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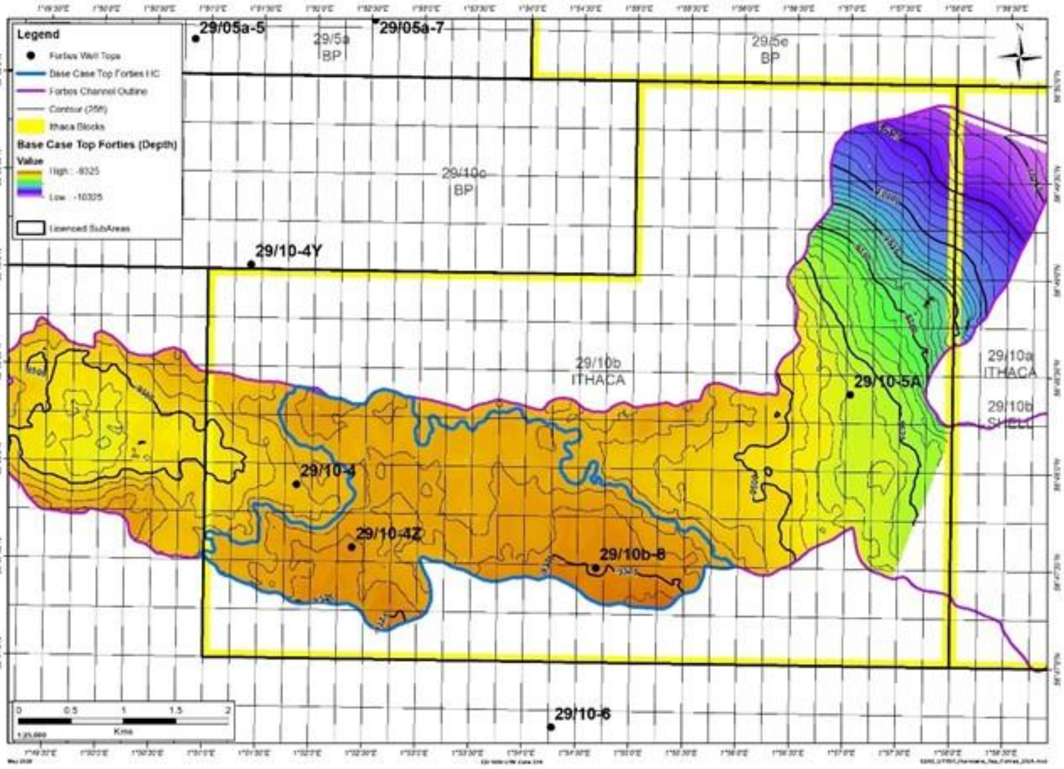
[4] As made legally binding under the *Climate Change Act 2008 (2050 Target Amendment) Order 2019.*

[5] The legislative authority for The OGA Strategy is the *Petroleum Act 1998* (as amended) Section 9A https://www.ogauthority.co.uk/media/7105/the-oga-strategy.pdf

[6] Defined under Section 9C of the *Petroleum Act 1998* (as amended), i.e. the holder of a petroleum licence; an operator under a petroleum licence; the owner of (a) a relevant offshore installation, or (b) upstream petroleum infrastructure.

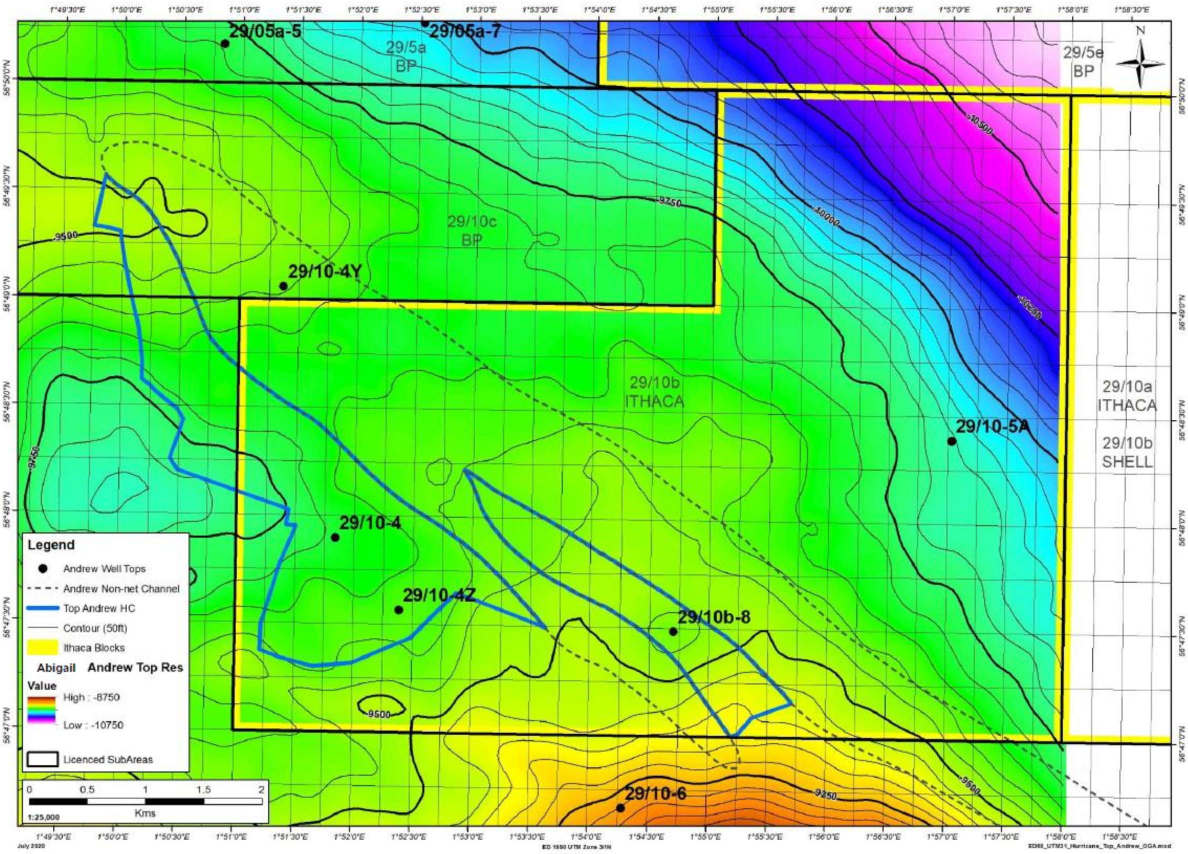
Figure 3.2 – Abigail Field outline, Forties reservoir



The secondary reservoir is the underlying Andrew Sandstone Member. This reservoir is typically 14ft (4m) thick, with average porosity 20% and permeability 1 - 30 md. The reservoir is 2100 psi over-pressured and contains gas condensate fluids. Wireline formation pressures show that this reservoir is compartmentalized. Gas condensate fluids were recovered from the wells tests performed in the field during the original drilling of the appraisal well and the total gas initially in place is estimated to be 22.9 Bscf (mid case)

Field life is estimated to be *ca*. eight years.

Figure 3.3 – Abigail Field outline, Andrew reservoir



A summary of the reservoir fluid properties in Abigail is given in Table 3.1.

Table 3.1 – Summary of Abigail hydrocarbon properties

Forties oil from 29/10-4Z wireline sample	Value
Residual oil gravity at stock tank conditions (ºAPI)	41.2
Bubble point at 254ºF [psia]	4196
Gas oil ration, Rs [scf/STB]	1199
Oil viscosity @ bubble point [cp]	0.226
Oil viscosity @ 4470 psia [cp]	0.232
Formation volume factor, Bo @bubble point [RB/STB]	1.703
Formation volume factor, Bo @4470 psia [RB/STB]	1.696
Forties Gas from 29/10b-8 wireline sample	**Value**
Residual oil gravity at stock tank conditions (ºAPI)	52.3
Dew point at 254ºF [psia]	4418
Condensate-gas oil ration, Rv [STB/MMscf]	166
Reservoir fluid molecular weight [lbmol/lbm]	31.8
Gas viscosity @4473 psia [cp]	0.041
Gas expansion factor, 1.Bg, at dew point [RB/STB]	208.2
Gas expansion factor, 1/Bg, at 4473 psia [RB/STB]	208.9
Andrew gas from 29/10b-8 recombined well test surface samples	**Value**
Residual oil gravity at stock tan conditions (ºAPI)	49.8
Dew point at 255ºF [psia]	5864.7
Condensate-gas oil ration, Rv [STB/MMscf]	88

Reservoir fluid molecular weight [lbmol/lbm]	23.5
Gas viscosity @ 6395 psia [cp]	0.026
Gas expansion factor, 1/Bg, at dew point [RB/STB]	256.0
Gas expansion factor, 1.Bg at 6395 psia [RB/STB]	266.1

Source: Ithaca (2021)

The field is expected to recover between 3.9 – 8.3 million barrel of oil equivalent (BOE) (gross), with the reference case forecast yielding 4.7 million BOE

3.5.1 Production Profiles

The base case development is a one producer, natural depletion, sub-sea development. This production well will be completed with a dual inflow control system that allows access to both the Forties and Andrew reservoir intervals in a single well bore. In the high production case reservoir scenario, the second well is required.

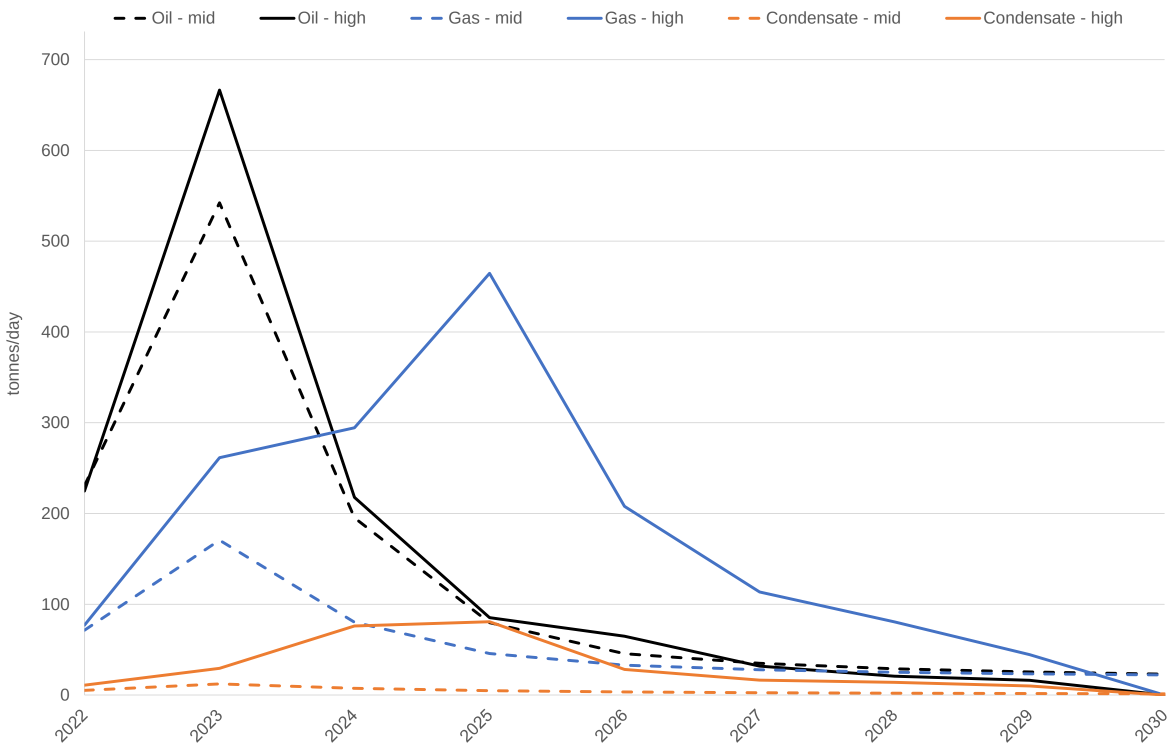
Production start-up for the first well is expected to be in Q3 2022. Estimated daily production profiles for oil, gas and condensate, are shown in Table 3.2 and Figure 3.4 for the mid (P50) and high (P10) cases. As the second well is contingent on production and is viable in the high case only, production from the second well (from Q4 2024) is only including in the High (P10) case below. The profiles for produced water are shown in Figure 3.5.

Table 3.2 – Production profile for Abigail development

Year	Oil		Gas		Condensate	
Mid Case (P50) – single production well						
	tonnes/d	m^3/d	tonnes/d	m^3/d	tonnes/d	m^3/d
2022	231	283	72	78,906	5	6
2023	543	665	171	188,314	11	15
2024	196	240	81	88,810	7	9
2025	81	99	46	50,956	5	6
2026	47	58	34	37,353	3	4
2027	36	44	29	31,764	3	3
2028	29	36	25	28,043	2	3
2029	26	32	24	26,430	2	2
2030	24	29	23	25,040	1	2
High Case (P10) – two production wells						
	tonnes/d	m^3/d	tonnes/d	m^3/d	tonnes/d	m^3/d
2022	226	276	77	85,105	10	13
2023	669	818	262	289,012	28	36
2024	223	273	302	332,665	73	96
2025	89	109	484	532,787	79	103
2026	67	82	215	236,909	27	36
2027	34	42	121	133,222	16	22
2028	22	27	85	94,097	14	18
2029	18	21	48	52,831	10	13
2030	0	0	0	0	0	0

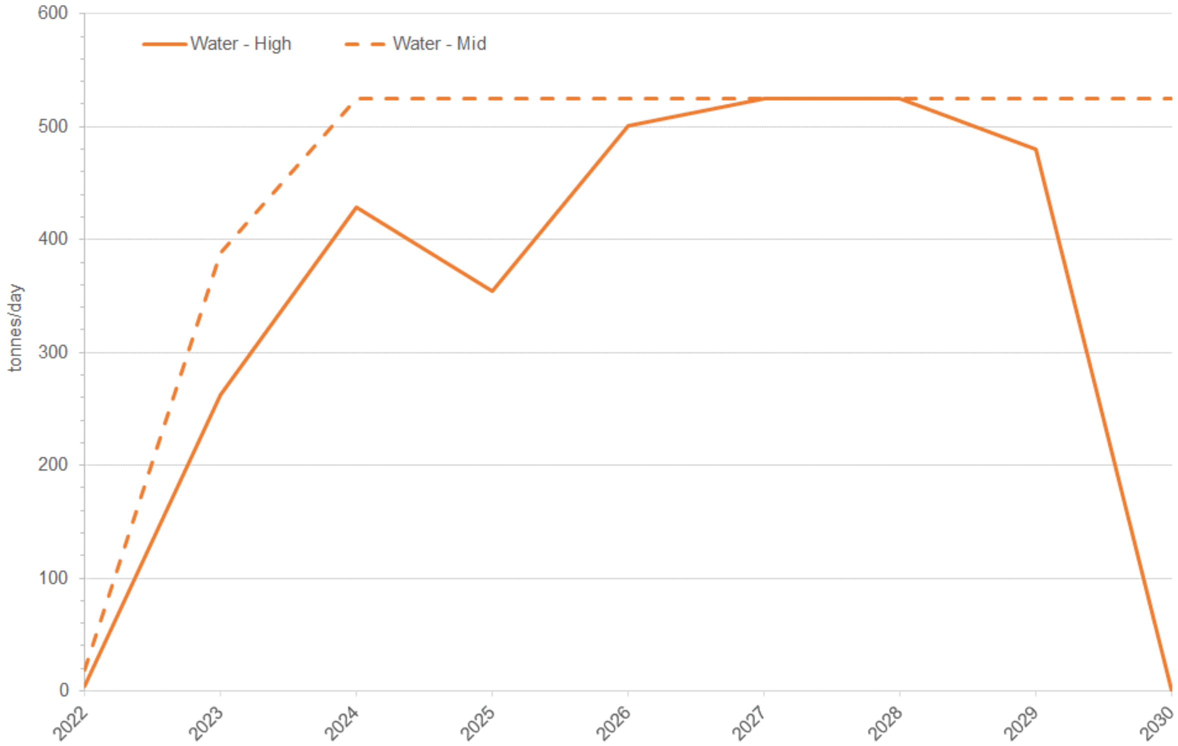
Notes: Numbers rounded to nearest whole number, oil and condensate tabulated here as separate figures, these are combined in the oil figures in the Abigail Field Development Plan. Conversions are follows:
Oil m^3 to tonnes: (m^3 x 817kg/m^3 (Abigail oil density) / 1000
Gas 000m^3 to tonnes: 000m^3 x 0.908kg/m^3 (Abigail gas density)
Condensate m^3 to tonnes: m^3 x 762.5kg/m^3 (Abigail condensate density) / 1000

Figure 3.4 – Daily Abigail mid (P50) and high (P10) production profiles



In the first full year of production (2023), the estimated volumes of produced water generated by the Abigail development are 370m^3/day (mid case) and 250m^3/day (high case); at peak water production, water volumes are expected to be 501m^3/day for both cases (Figure 3.5).

Figure 3.5 – Daily mid (P50) and high (P10) produced water profiles



3.6 Development Schedule

An indicative schedule of works for the development of the Abigail Field is shown in Table 3.5 below, although this is subject to change depending on, for example, rig and vessel availability. The earliest the drilling schedule could commence for the first production well (P2-W) is Q2 2022.

Table 3.5 – Summary schedule for the Abigail development, (Phase 1)

	2022											
	Q1			Q2			Q3			Q4		
	J	F	M	A	M	J	J	A	S	O	N	D
Drilling activities				■	■	■	■	■				
Subsea installation						■	■	■				
Tie in							■	■				
First Oil									■	■		

The scheduling of the second well (P1-E) will be dependent on the production performance of the P2-W well; it is estimated that two years of initial production from the first well will be required before a final decision is taken to drill the second well. Taking this into consideration, if drilled, the second well would be drilled around Q3/4 2024, with the subsea tie-in Q4 2024, with production commencing soon after.

3.7 Drilling and Completion Activities – Phase 1

3.7.1 Drilling Rig and Support

The first production well will target the Forties and Andrew reservoirs and will be a re-entry and completion of the appraisal well 29/10b-8[7], producing oil and gas. This well will be drilled using a semi-submersible rig and the selected rig will have in place all necessary permits and certification to allow it to operate in the UKCS and will meet MARPOL[8] standards required for emissions and discharges within Special Areas.

As the final rig is yet to be selected, a representative examples of a semi-submersible (the *Awilco WilHunter*, which was used to drill the original appraisal well), (Figure 3.8) has been included here.

This type of rig is effectively a deck supported on pontoons which contain ballast tanks, which floats at all times (i.e. is not directly in contact with the seabed). The height of the deck above the sea surface can be altered by pumping ballast (sea) water in or out of the pontoons. During drilling operations, the deck is lowered but still kept above wave height.

Figure 3.8 – Typical semi-submersible rig[9]

Rigs are towed to location by 2-3 anchor handler tug vessels and are maintained on station during drilling operations using anchors. Rig anchoring typically involves the deployment by anchor handler vessel, of eight or more 12 tonne seabed penetrating anchors.

The anchors are attached to the rig by cable and near the anchor by chain, of which a proportion lies on the seabed (the catenary contact). Hauling or paying out of cable can make minor adjustments to the rig position following anchor deployment.

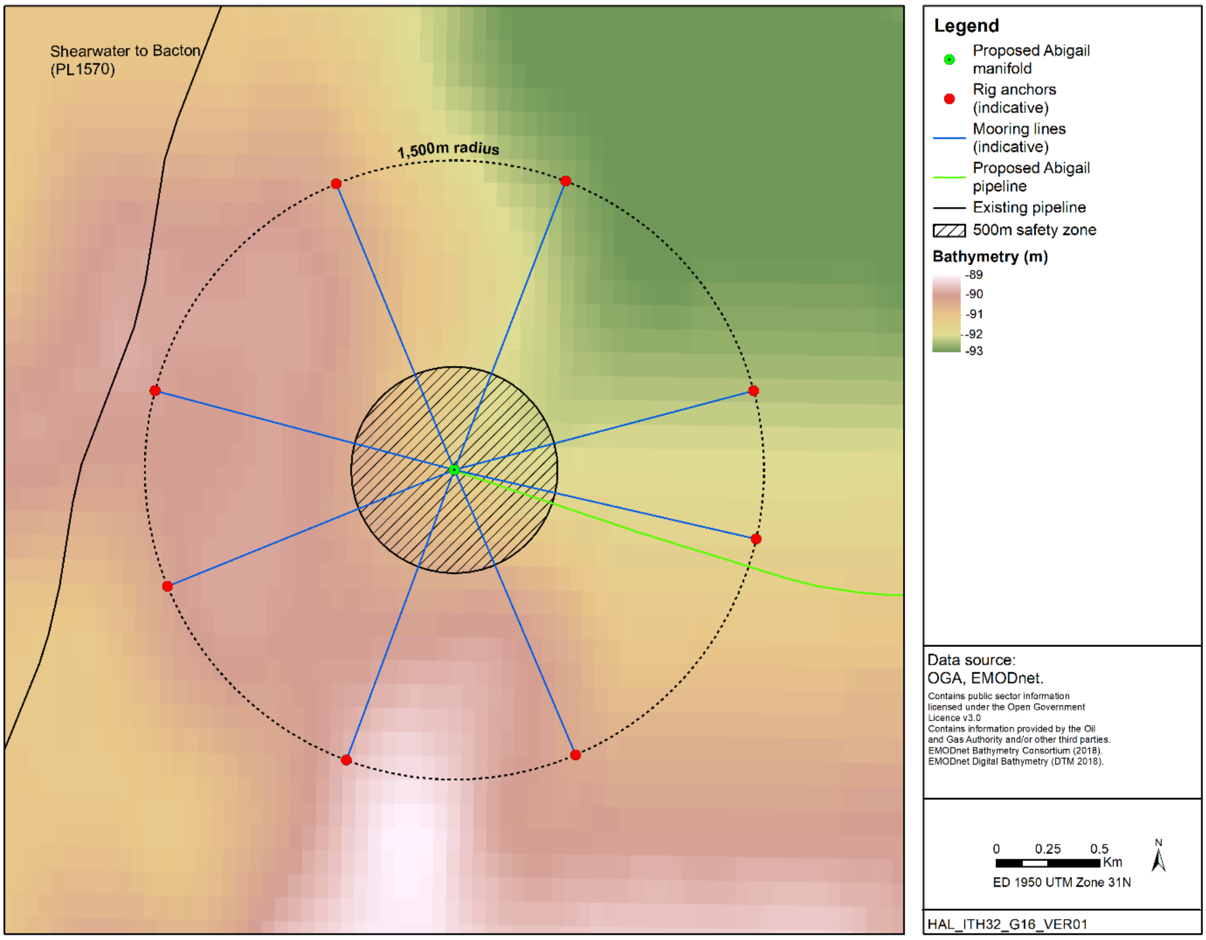
The precise arrangement of anchors around the rig will be defined by a mooring analysis which will be undertaken prior to bringing the rig into the field and taking account of water depth, tidal and other current, winds, seabed features, and existing infrastructure, including the Shearwater to Bacton pipeline (PL1570). An indicative anchor mooring pattern for an 8 anchor spread, centred on the Abigail well position is shown in Figure 3.9.

[7] As this is a development well, the success case is high. In the event an issue is encountered with the well or rig, the well would be temporarily suspended until a solution is developed. In the unlikely event of an unsuccessful geological/reservoir outcome, an assessment would be made for potential future use of the well slot, e.g. sidetrack to new target. If there is no potential future use, the well would be plugged and abandoned in accordance with OGUK guidelines and Ithaca Energy's internal procedures

[8] International Convention for the Prevention of Pollution from Ships

[9] https://awilcodrilling.com/wilhunter/

Figure 3.9 – Indicative mooring pattern for an 8 anchor spread



The relationship between water depth and lateral extent of the anchor pattern is not linear and typical radius of an anchor patterns for a semi-submersible drilling rig operating in a water depth of 100m (water depth at Abigail is between 89-92m) is 1300 – 1500m. Once on location and anchors have been set, a proportion of the anchor chain will lay on the seabed, with a degree of lateral movement depending on current strength. It is assumed that up to half the length of the chain could lay on the seabed (Drilling Superintendent, pers comms), (assuming a chain length of 1500m, this would equate to 750m laying on the seabed), and a lateral movement of 10m has been assumed for assessment.

The surface location of the Abigail well is *ca*. 1100m from the block boundary, and, based on potential anchor spread, the anchor(s) may extend into the adjacent block (as the final rig is not yet selected, the final anchor pattern is not yet known). If it is determined that the anchor(s) will extend into the neighbouring block, Ithaca Energy will commit to an agreement with the neighbouring Block Operator, regarding rig anchor placement. If it is also determined that the anchor(s) will extend over nearby infrastructure (i.e. Shearwater to Bacton pipeline), Ithaca Energy will liaise with the relevant Operator with regards to mooring analysis and any requirement for proximity agreements.

Once drilling activities are completed, the anchors are retrieved by anchor handler vessels by means of pennant wires which slide down the cable toward the anchor allowing a more or less vertical retrieval, facilitating anchor breakout from the seabed. The rig is then towed off station by the tugs.

During the drilling campaign, it is anticipated that rig supply trips will be required *ca*. 2-3 times a week, (3 used for the purpose of assessment) from a supply base in Peterhead or Aberdeen. For assessment purposes, it is has been assumed the supply base will be Aberdeen, being the greater distance at *ca*.

244km. An estimated 3 helicopter trips per week will make rig personnel transfers to and from Aberdeen. An indication of fuel consumption for the rig, support vessels and helicopter during the drilling campaign is given in Table 3.12 (Section 3.8) below, this also includes an estimate for the second production well.

Whilst in position, and in accordance with the *Petroleum Act*, a statutory 500m safety exclusion zone will be automatically established around the drilling rig. Unauthorised vessels including fishing vessels and commercial shipping are not permitted access to this area. A standby vessel will be on-station throughout the drilling operations.

Upon completion of the drilling programme, a post drilling debris survey will be conducted to confirm no debris remains on the seabed. Once the rig has moved off location, the 500m safety exclusion zone will no longer apply and Ithaca Energy will be applying for a new safety exclusion zone around the new production manifold and well. As the manifold is installed after the completion of drilling, as part of the subsea scope of work, there will be a period of time (*ca*. 30 days) between the rig moving off location and the manifold being installed; the Xmas tree will have an integral protection structure and the final location will be advised to mariners through the relevant channels. Ithaca Energy will ensure a timely application for the new safety exclusion zone, so that it will be in place at manifold installation.

The estimated schedule for commencement of drilling activities is Q2/3 2022 and is anticipated to last *ca*.83 days (including rig mobilisation and demobilisation and all contingencies). The relevant permits for drilling activities will be applied for through the BEIS Portal Environmental Tracking System (PETS).

Sewage and Waste Production

Mobile rigs have facilities for drilling, power generation, supporting utilities and accommodation. For cuttings cleaning and mud conditioning, a rig is normally equipped with high efficiency shale shakers together with centrifuges and the drilling area has a sealed drainage system. Spilled mud is returned to the mud tanks. During the drilling and completion programme, the rig will require bunkering. Bunkering will be conducted in favourable sea states and according to the rig operator’s procedures and so far as practicable, will be conducted during daylight hours.

Vessels will also transport various supplies to the rig and return wastes and surplus equipment to shore during the campaign. The wastes typically generated during a drilling campaign comprise:

- Galley and domestic waste
- General waste (paper, packaging, scrap metal)
- Special waste (empty chemical drums, oily rags, medical waste etc)

With the exception of food waste which will be comminuted (to less than 25mm) and discharged, domestic and rig waste will be shipped to shore for disposal. The rig will enforce a strict waste segregation policy and waste management operations are controlled via written procedures (including a garbage management plan). Segregated wastes will be stored in labelled compactor bags, dedicated skips or other containers. Low toxicity oil based mud (LTOBM) will be used to drill the well sections (see Section 3.5 below) and LTOBM contaminated drill cuttings will be stored in a bunded area in purpose designed lidded skips pending shipment to shore. The garbage record book will be maintained during the operation recording quantities of waste generated and their disposal routes in accordance with legislation. Spills on deck will be contained and cleaned-up and the rig will hold supplies of absorbent mats and granules for this purpose. Contaminated absorbents will be segregated for appropriate onshore disposal.

3.7.2 Well Design

The first of the production wells (Well P2-W) will be a re-entry of the 2012 appraisal well 29/10b-8, via the drilling of 12¼" and 8½" sidetrack sections.

The 29/10b-8 appraisal well was drilled in a series of steps, with the hole sizes and casing becoming progressively narrower. Water Based Mud (WBM) was used for the top hole sections and oil based muds for the lower hole section. Mud and cuttings from the lower hole section were contained on the rig and shipped to shore for treatment and disposal. Appraisal of the well was completed in September 2012 using the semi-submersible rig, *Awilco WilHunter*. The well was suspended with treated seawater, with corrosion inhibitor and biocide, above suspension plugs and with temporary abandonment caps installed.

An estimated drilling schedule for the first production well is shown in Table 3.6 and an indicative well design for the well is shown in Figure 3.10.

Table 3.6 – Estimated drilling schedule, Abigail Well P2-W

Item	Operation	Days
1	Rig mobilization, including positioning on location	5
2	Install BOP, plug and abandon existing well	7
3	Drill 12¼" sidetrack section	12
4	Run and cement 9⅝" casing	5
5	Drill 8½" hole	5
6	Logging operations	5
7	Run lower completion	7
8	Wellbore clean up and Xmas tree installation	10
9	Suspend well	4
10	Demobilise rig	2
11	Operational contingency (drilling contingency sidetrack)	16
12	Waiting on weather contingency	5
	Estimated Time (including all contingencies)	**83**

The sidetrack will be initiated from below the existing 13⅜" shoe at ±5,134ft Measured Depth Below Rotary Table (MDBRT). The pre-existing 9⅝" casing will be cut (at *ca.* 5,700ft) and recovered, prior to a cement plug being set. Prior to cutting the 9⅝" casing, a bridge plug will be set, trapping the volume of treated seawater below it. The treated seawater above the plug will be displaced out of the well and recovered to the rig surface. Here, it will be tested for hydrocarbon content, and if at or below 30mg/l, will be discharged to sea (this discharge will be assessed and applied for through the BEIS environmental permit system). If the discharge is not ≤30mg/l, this will be returned to shore for treatment and disposal.

A 12¼" hole section will then be drilled, to just above the reservoir at ±13,500ft MDBRT before setting the 9 5/8" casing string. An 8½" hole section will then be drilled to well total depth (TD) at ±15,253ft MDBRT; both hole sections will be drilled using a LTOBM system. This will then facilitate running and setting the open hole completion with dual flow control system over both reservoir sections.

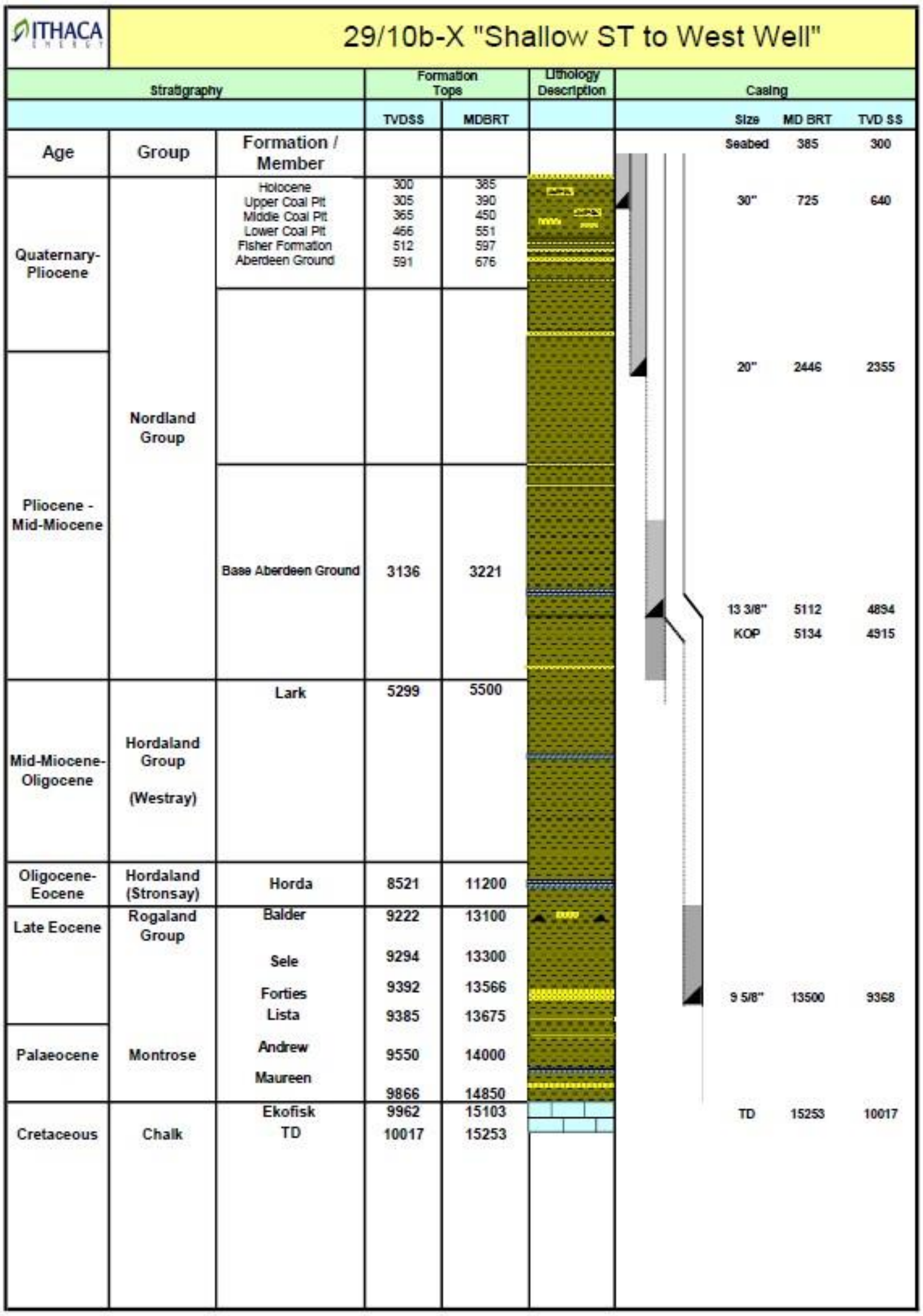
A contingency 7" liner system will be available, should any drilling problems be encountered. The wellbore will be cleaned up, and the fishing friendly Xmas tree installed, after which the well will be suspended (*ca* Q2 2022) until the subsea installation programme has been completed (*ca*. Q3 2022), at which point, the well will be tied into the Abigail manifold.

Mud System, Cuttings and Chemical Discharge

A range of drilling and cementing chemicals will be necessary to drill the wells. At the appropriate time, a chemical permit will be applied for covering the proposed use and discharge of chemicals, with approval required prior to commencement of drilling activities.

Drill muds are used to cool the drill bit, provide a hydrostatic head to control the well, stabilise the well bore and to circulate rock cuttings out of the hole. The LTOBM mud and cuttings from the P2-W well sections will be returned to the rig where mud will be recovered for re-use and the cuttings stored in purpose built lidded skips, pending shipment to shore for treatment at a licensed facility. It is anticipated that approximately 569 tonnes of LTOBM cuttings, (or approximately 114 skips) will be disposed of in this manner (assuming a skip capacity of *ca*. 5 tonnes) (see Table 3.7). A range of other chemicals are also included in the mud formulation to aid its performance.

Figure 3.10 – Anticipated well stratigraphy and proposed casing design (Well P2-W)



A contingency for additional 12¼" and 8½" sections has been included if a poorer than expected reservoir, missed geological target or other drilling problems are encountered in the well. An additional drill time of *ca*. 16 days would be required for each sidetrack. The length of section and quantity of mud and cuttings would be as per the original sidetracks drilled. As these would also be drilled using LTOBM, the mud and cuttings will be retained on board and shipped to shore for processing and disposal. The estimated amounts have also been included in Table 3.7 below. If both contingency sidetracks are also drilled, this would result in a total of 1,138 tonnes of LTOBM cuttings (or approximately 228 skips) shipped to shore for onshore disposal.

Table 3.7 – Well design and estimated cuttings – Abigail Well P2-W

Hole Section (")	Section Depth (m below seabed)	Length of Section (m)	Mud System	Mud chemicals discharged (tonnes)	Cuttings Discharge Point	Est. Weight of Cuttings (tonnes)
12¼	1,441-4,018	2,577	LTOBM	N/A	Skip & Ship to shore for disposal	519
8½	4,018-4,532	505	LTOBM	N/A	Skip & Ship to shore for disposal	50
Contingency sidetrack[1]						
12¼ sidetrack	1,441-4,018	2,577	LTOBM	N/A	Skip & Ship to shore for disposal	519
8½ sidetrack	4,018-4,532	505	LTOBM	N/A	Skip & Ship to shore for disposal	49
Total cuttings discharged to sea						**0**
Total cuttings skipped and shipped to shore						**569**
Total cuttings skipped and shipped to shore, including contingency sidetracks						**1,138**

Notes: [1.]For assessment purposes have assumed contingency sidetracks to be of same length as potential sidetracks, drilled with the same mud system and generating the same cuttings quantities. Numbers reflect a kick off at the 13⅜" shoe to the prognosed casing points/well total depth. Depths are metres below seabed Volume of cuttings per section in barrels, converted to m³ using 6.2898bbl per m³, volume of cuttings converted to tonnes assuming a cuttings SG of 2.65 for all

After each hole section is drilled, the bore is lined with steel casing which is cemented in place to maintain the integrity of the well. A measured amount of quick setting cement slurry is pumped into the casing and this is forced down to the bottom of the casing and then up the anulus (i.e. the space between the outside of the casing and the wall of the well). Once the cement has set, drilling re-commences; the cement remains between the casing and the rock. Logging will be carried out to measure the formation properties with data transmitted from tools integrated into the well assembly; logging while drilling (LWD) data can also be used as a guide for well placement, so that the wellbore remains within the target reservoir area.

A range of other chemicals will be used, including for the completion of the well and for clean up of the wellbore. These will be selected based both upon their technical specifications and their environmental performance. Chemicals which have been identified for substitution and/or containing any other warnings will be avoided where possible. A full inventory of chemicals, together with an assessment of their use and discharge, will be submitted through the applicable permit process.

3.7.3 Well Completion and Evaluation

Well Completion

Prior to running the completion, the casing is cleaned to remove any loose material and high viscosity pills are used to displace the fluids/inhibited brines which were used when it was drilled. The brines are initially collected in a tank to check for cleanliness/clean down to the required standard, before being discharged. An allowance to dispose of this waste stream will be included in the relevant permit along with an oil discharge permit, which will be obtained prior to any drilling activities commencing offshore. Any interface fluid from well clean up will be left to separate in the gauge tank, with hydrocarbon residues being flared or contained and the debris collected for onshore disposal. Fluids which cannot be cleaned to required standards will be retained onboard and returned to shore for treatment and disposal.

After the completion has been installed, a short duration well flow will be carried out (see below), with the well then isolated with Xmas tree and downhole valves shut in, ready for pipeline tie-in.

There will be no vertical seismic profiling (VSP), check shots or any other borehole seismic test conducted.

Well Clean Up / Test Flows

A well clean up/test flow will be conducted to ensure all waste and debris has been removed and to obtain reservoir information and fluid samples. Hydrocarbon flows associated with this will be flared.

The well will be flowed to temporary test facilities used on the rig and this equipment will be selected to promote efficient burning of hydrocarbons within the flare and prevent discharge of unburned hydrocarbons. The well test spread will contain equipment that will separate and meter the oil and gas produced from the well.

Discharges will be monitored at all times by dedicated personnel watching the flare and sea for any signs of hydrocarbon drop out and operations will cease (i.e. the well will be immediately shut in) if any visible oil is seen on the sea surface. The first flaring of hydrocarbons from the well will only be undertaken during daylight hours, so allowing the best visibility of identifying any potential issues. In addition, the standby vessel on site during the drilling programme will also be used to monitor the sea for any indication of a hydrocarbon sheen on the sea surface. Flaring will not recommence until any issue has been investigated and addressed.

Well 29/10b-8 was suspended with treated seawater above the suspension plugs, therefore the only potential for reservoir hydrocarbon residue at re-entry, would be that present in the treated seawater when this is displaced to surface. As the well test spread would not be on location at this stage of the drilling programme, any reservoir hydrocarbon encountered in the treated seawater would either be discharged, or returned to shore for disposal (as noted above), it would not be flared (see Section 3.5.1).

Ithaca Energy will ensure that well test objectives are reviewed and flows minimised consistent with achieving objectives. An estimated 1,071 tonnes of oil, 788 tonnes of gas and 266 tonnes of condensate will be flared over a period of *ca*. 54 hours for the well clean up/test flow for well P2-W. An extended well test will not be carried out.

3.8 Drilling and Completion Activities - Phase 2

If the second phase of the development is executed, the drilling of the second well (Well P1-E) will target the eastern high in the Forties gas cap, producing gas and condensate. This will be a new well (not a re-entry of an existing well) and be drilled by either a semi-submersible rig or a jack-up. As information on a semi-submersible has been included in section 3.7.1 above, information on a jack-up is included below.

3.8.1 Drilling Rig and Support

A jack-up is effectively a deck supported by 3 legs (Figure 3.6), each of which terminate in a spud can of *ca*.20m diameter and height of *ca*.12m, which can be lowered to the seabed when at a drilling location (Figure 3.7). This type of rig is typically used in shallower water, up to water depths of *ca*. 120m.

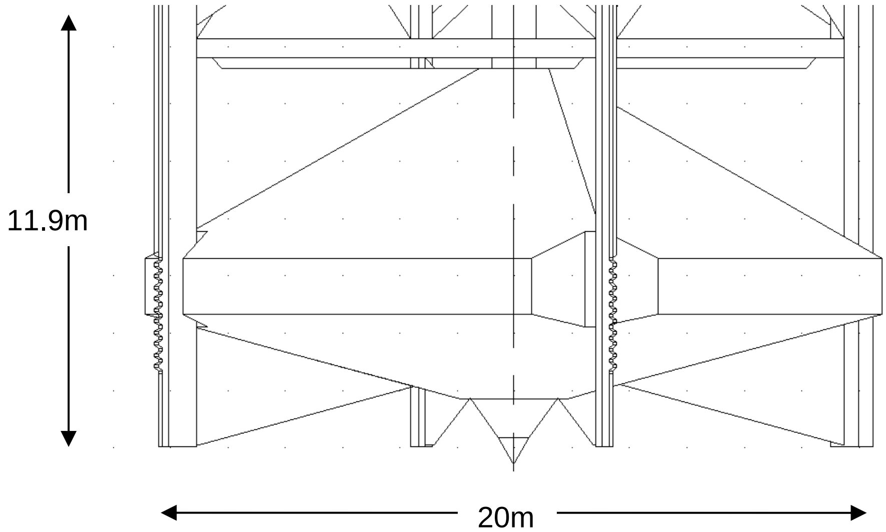
Figure 3.6 – Typical jack-up rig

The rig's hull and main deck are raised up, while the spud cans spread the load at the seabed and penetrate to a depth of *ca*. 4m.

The cantilever deck, which supports the drilling derrick and its associated equipment, is skidded out from the main deck. The main equipment and storage facilities, including fuel are contained in the main deck.

The main deck measures approximately 90m x 90m, and the air gap gives a rotary table elevation above mean sea level during drilling in the region of 45m. The drilling derrick, located above the drill floor, bears the weight of the "drill string", a series of sections of hollow pipe, at the bottom of which is the rotating drill bit.

Figure 3.7 – Schematic of spud can



Up to three anchor handler tug vessels will be used to tow the rig to the Abigail P1-E well location, with rig tow in and out routes unknown at present. The tugs move the rig to position, which may also be guided by the rig's anchors. Once in final position, and the rig's legs are in contact with the seabed, the rig jacks its hull up the legs until the deck reaches the desired elevation above wave height, and if used, the anchors are retrieved. Upon completion of drilling activities, the rig jacks down and is towed off location by the tug vessels.

Requirements for supply trips, crew changes, bunkering, sewage and waste for a jack-up, would be the same as those for the semi-submersible described above (Section 3.7.1) and not repeated here.

3.8.2 Well Design

Unlike well P2-W, well P1-E will include the drilling of the top hole sections. If drilled, the earliest the second production well will be drilled will be the latter part of 2024 and detailed well design for the second production well has not yet been undertaken. Therefore, for assessment purposes it has been assumed the well will be drilled in five sections, with decreasing hole diameter, with a contingency sidetrack. It has also been assumed that the well clean up programme will be similar to the first production well, and that no VSP or extended well test will be carried out.

An estimated breakdown of drilling operations is outlined in Table 3.8 with well design and estimated cuttings described in Table 3.9.

Table 3.8 – Estimated drilling schedule, Abigail Well P1-E

Item	Operation	Days
1	Mobilisation rig	5
2	Drill 36" hole, run and cement 30" conductor	3
3	Drill 26" hole, run and cement 20" casing, install BOP	7
4	Drill 17" hole, run and cement 13⅜" casing, install BOP	8
5	Drill 12¼" hole, run and cement 9⅝" casing	10
6	Drill 8½" hole and run lower completion	8
7	Install (fishing friendly) Xmas tree, complete well, including clean up	25
8	Demobilise rig	2
9	Operational contingency (drilling contingency sidetrack)	16
10	Waiting on weather contingency	5
	Estimated Time (including all contingencies)	**89**

For the second well, an estimated 1,040 tonnes of cuttings from the top hole sections (drilled with seawater sweeps and water based mud (WBM)) could be discharged to sea.

The lower hole sections, including contingency sidetracks, to be drilled with LTOBM, with cuttings from these section skipped to shore. Based on the skip size of 5 tonnes, this equates to 65 skips without the sidetracks, and 129 skips, with the sidetracks.

Table 3.9 – Well design and estimated cuttings – Abigail Well P1-E

Hole Section (")	Section Depth (m below seabed)	Length of Section (m)	Mud System	Mud chemicals discharged (tonnes)	Cuttings Discharge Point	Est. Weight of Cuttings (tonnes)
36	0-104	104	Seawater sweeps	207	Seabed	181
26	104-628	524	Seawater sweeps	969	Seabed	476
17½"	628-1,559	931	WBM	N/A	To sea from rig	383
12¼	1,559-3,022	1,463	LTOBM	N/A	N/A	295
8½	3,022-3,313	291	LTOBM	N/A	N/A	28
Contingency sidetrack[1]						

12¼ sidetrack	1,559-3,022	1,463	LTOBM	N/A	N/A	295
8½ sidetrack	3,022-3,313	291	LTOBM	N/A	N/A	28
Total cuttings discharged to sea						**1,040**
Total cuttings skipped and shipped to shore						**323**
Total cuttings skipped and shipped to shore (including contingency sidetracks)						**646**

Notes: [1] For assessment purposes have assumed contingency sidetracks to be of same length as potential sidetracks, drilled with the same mud system and generating the same cuttings quantities

As for the first well, a range of chemicals will be used in the drilling and completion of the second well and the associated environmental permits will be applied for.

A well clean up/test flow will be conducted to ensure all waste and debris has been removed and to obtain reservoir information and fluid samples, and testing will be conducted via temporary testing facilities on the rig. Metering of gas and monitoring of discharges from clean up/testing will be as described for the first production well and, Ithaca Energy will ensure that well test objectives are reviewed and flows minimised consistent with achieving objectives. An estimated 1,112 tonnes of gas and 679 tonnes of condensate would be flared over a period of *ca*. 54 hours for the well clean up/test flow for well P1-E.

The completion philosophy is driven by the need for maximum reliability and minimum intervention in the two development wells during the life of the field. The concept design is for the two production wells to access both the Forties and Andrew sands. The design will allow the Andrew reservoir to provide natural lift to aid in the production in the Forties reservoir, as its pressure declines and the water cut increases. An intelligent completion design has been adopted to ensure both the Andrew and Forties hydrocarbons can be produced simultaneously, individually and efficiently whilst maximising production and recoverable reserves. Gas lift will be installed in the upper completion as a contingency in the event the Andrew reservoir is unavailable to provide the pressure support to the Forties reservoir.

3.9 Pipeline System, Subsea Infrastructure and Protective Material

Phase 1

The subsea elements of the first phase of the Abigail development will consist of:

- 6"/10" Pipe in pipe (PiP) production pipeline
- 3" gas lift pipeline
- Services umbilical
- New production manifold with integrated protective structure
- Tie-in spools and control jumpers
- New SSIV at FPF-1 riser base

The technical details of the production pipeline, gas lift pipeline and services umbilical are described in Table 3.10. A number of factors were taken into consideration when identifying the Abigail pipeline route selection undertaken in 2010/2011, including the shortest possible distance between its end points, the avoidance (if present), and as far as practicable, of sensitive habitats and features (see Section 4, no habitats or species of conservation concern were identified), to account for future rig anchor pattern, the approach angle to crossings of existing pipelines, and the receiving platform, and potential future drilling locations. No technical concerns were raised over the proposed route and crossing location during route selection.

Table 3.10 – Abigail pipeline, gas lift line and umbilical technical summary

	Production Line	**Gas lift**	**Services umbilical**
Pipeline No.	PL number to be assigned	PL number to be assigned	PLU number to be assigned
Service	Oil	Gas	Services (chemicals, hydraulic fluid, power)
Type	6" / 10" Pipe in Pipe Rigid	3" Rigid	Thermoplastic
Nominal diameter	Inner - 6" (136.5mm ID / 168.3mm OD) Carrier – 10" (250.9mm ID / 273.1mm OD)	88.3mm OD 73.7mm ID	190mm
Length	12km	12km	12km
Wall thickness (mm)	12.7mm Carbon Steel plus 3.2mm liner (Inner) / 11.1mm (Carrier)	7.6mm, carbon steel	N/A
Design pressure (Barg)	421	421	LP Hoses 7500psi (517bar) HP Hoses 10000psi (690bar) Chemical hoses 7500psi (517bar)/1000psi (690bar)
Hydrostatic test pressure (bar)	486.3	631.5	N/A
Leak test pressure (Bar)	1.1 x Design Pressure	1.1 x Design Pressure	1.1 x Design Pressure
Impact resistance	3 x lines laid in same trench, this is backfilled with excavated materials, to target depth of 1.5m and minimum depth of 1m, along entire length except at crossing (see below). Rock and other protective material (e.g. mattresses) placed where required, e.g. trench transitions, crossings		
Start location	New Abigail manifold Block 29/10		
End location	Existing Stella MDC manifold Block 30/06 – this tied back to the FPF-1 installation (same Block)		
Main crossings	1 x 10" gas export to CATS (PL3078) Ithaca Energy Owner Crossing agreement not expected to be required. However, if this is not the case, Ithaca Energy will put the relevant agreement in place during the pipeline works authorisation (PWA) application process.		
Block crossings	The same Equity Group (Ithaca Energy) for the Abigail Field Development, have 100% equity in all relevant Blocks, therefore no Block Crossing agreements are expected. If these are required Ithaca Energy will put the relevant agreements in place during the PWA application process		

In addition to the pipelines and services umbilical, the new Abigail production manifold will be installed (Figure 3.11) along with short rigid spool pieces and control jumpers, these installed between the ends of the lines and the tie-in locations at the Abigail manifold and the Stella MDC manifold.

Figure 3.11 – Abigail Manifold

The manifold will commingle the production from the two wells and house control system/chemical injection distribution for the Abigail facilities. Gas Lift is only to be provided to the initial production well and as such is routed directly to the P2-W well only and is not routed through the manifold (see Figure 3.14a).

The manifold will be a near identical design to that used at Harrier and Stella and be a slab-sided, piled structure with integral protection frame, designed to be capable of withstanding trawlboard loads of up to 100 tonnes.

The total weight of the manifold is *ca*. 95 tonnes, with a length of *ca*.12m, width of *ca*.6m and height above seabed of *ca*.6m.

With the introduction of Abigail hydrocarbons and the resulting increase in inventory of the existing Stella production facilities, a subsea isolation valve (SSIV) will also be installed at the FPF-1 riser base; prior to commencement of production, this will be retrofitted at the riser base, within the FPF-1 500m safety exclusion zone, in order to minimise the risk of continued uncontrolled production to the FPF-1 topsides. The SSIV will not be designed to be fishing friendly, this being located within the FPF-1 installation 500m safety exclusion zone, in relatively close proximity to the installation, which has a dedicated standby vessel.

The SSIV valve is actuated hydraulically which is monitored and controlled by the FPF-1 master control room. The valves will be fail-safe closed and have remote indication of its status and can be tested periodically by means of partial closure. At present, the existing production dynamic riser at the FPF-1 connects directly to the static flexible flowline (connecting the FPF-1 to the Stella MDC) at the seabed interface. Typically of gravity-based design, the SSIV will be retrofitted at this seabed interface, which is located within the FPF-1 500m safety exclusion zone. The anticipated dimensions of the SSIV are 9.5m x 5m x 3.5m, with an anticipated weight of 85 tonnes.

3.9.1 Installation

A relatively small number of vessels, all using dynamic positioning (DP) systems, will be involved in the subsea campaign. Not all vessels will be on location at the same time and for the full duration of the installation campaign, with each vessel carrying out specific tasks before demobilisation. Estimated vessel time on location and fuel usage is shown in Table 3.12 (this has been used to estimate resulting atmospheric emissions associated with subsea construction activities).

A typical pipeline installation sequence for Phase 1 subsea activities is given below. The final sequence will depend upon the selected installation contractor's vessel spread and scheduling requirements:

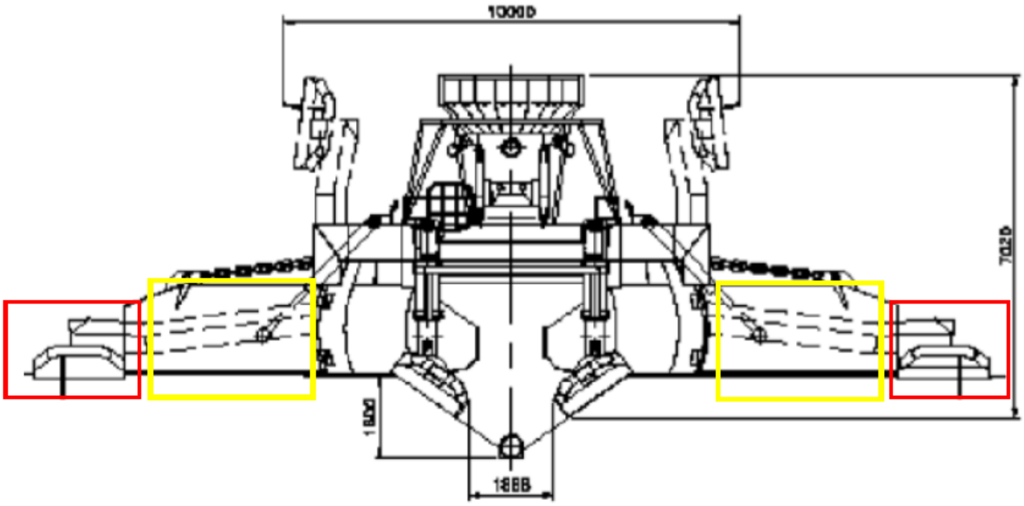
- Lay production pipeline and gas lift pipeline
- Trench lines
- Lay umbilical into trench

- Clean and strength test pipelines
- Install manifold
- Tie in pipelines and manifold with spools and jumpers at manifold and wellhead
- Leak test entire system(s)
- Backfill lines (and spot rock placement where required)
- Lay protective material (exception being that pre-laid at crossing locations where applicable)
- Pre-commission system

The production and gas lift pipelines and services umbilical will be installed using the reeled installation method. Pre- and post-lay surveys and general survey support will be carried out and a trenching vessel will utilise a towed backfill mechanical plough to trench the lines to a target depth of 1.5m (minimum depth of 1m); all three lines are to be laid in a single trench.

The width of the plough skids can extend to *ca*.22m, (see Figures 3.12 and area C on Figure 3.13 – these for illustrative purposes only) with the trench and spoil from the trench (area A on Figure 3.13), excavated within this wider area. There may be an area (area B on Figure 3.13) where there is no disturbance, but this is included in the overall corridor of disturbance for assessment purposes. The anticipated width of the trench, along with the area where excavated material is initially deposited, is estimated to be *ca*. 10m, this includes 6m for the trench and a buffer zone of 2m each side. For assessment purposes, the worst case of 22m has been used, to encompass the maximum width of the plough skis.

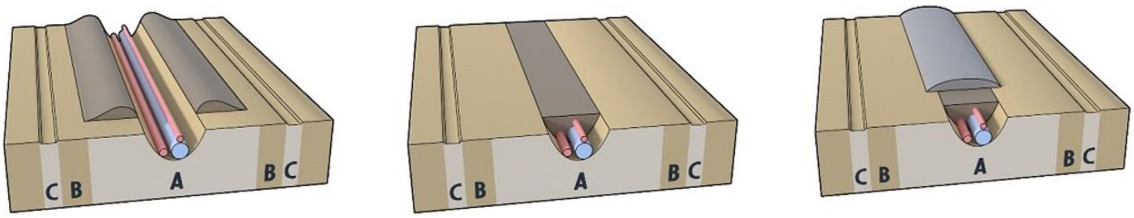
Figure 3.12 – Schematic of mechanical plough



Note: the extent of seabed disturbance has been assumed to be the width of the plough skis (area with red boundary), the area with yellow boundary sits above the seabed as the plough moves along, some of this area is where the trenched material will sit before being backfilled over the trench after the lines are installed (the material will not extend past the plough skis)

The trenching vessel will then bury the lines by backfilling the trenched material, minimising as far as practicable, associated spoil heaps/berms, thereby reducing the potential that fishing gear and catches could be damaged by excavated material. Figure 3.13 shows the initial trenching, with the excavated material running alongside the trench, this then backfilled to cover the pipelines. Where used for upheaval bucking (see Section 3.9.2 below), this is then laid atop, and extending just past the initial trenched area (Figure 3.13)

Figure 3.13 – Sequence of pipeline trenching, backfilling and rock cover



A post-lay survey will identify any potential spoil heaps/berm that could prove a snagging hazard. It should be noted that no significant spoil heaps/berms have been encountered during any of the previous pipeline installations (all of which are trenched and backfilled with natural sediment) in the Greater Stella Area where the same backfilling plough has been used as that proposed for Abigail

Should any spoil heaps/berms be encountered along the route of the Abigail pipeline system the following steps will be taken:

- Spoil heap/berm will be assessed for potential risk to fishing activities – the number and spread of any heap/berm that present a potential risk to fishing will be further assessed to determine requirement for and means of mitigation
- If mitigation is required, the next construction vessel on location as part of the subsea campaign, or a contracted fishing vessel with chain matting, will be utilised to effectively remove the spoil heap/berm
- FishSAFE and Kingfisher will be advised of potential risk and for this to be highlighted in their database

The Abigail manifold will be fixed by 4 piles (dimensions of 0.63m outside diameter x 22m length) driven into the seabed. These will be inserted into a guide cone/frame through the structure and it will self-penetrate part way. A hammer will be used to drive the pile the remainder of the way in or until refusal, at which point the pile will be cut. Expected penetration depth of the pile is approximately 16.5m. A hydraulic hydro hammer will be used with an estimated weight of *ca*. 35 tonnes. The duration of hammering would be approximately 2-3 hours on each pile over a total period of 1 day. A "soft start"[10] procedure will be implemented, as described in the JNCC protocol for the mitigation of potential impacts from piling activities (JNCC 2010).

A piled design for the Abigail manifold has been selected in line with the other manifolds structures in the Greater Stella Area, where it is a proven design concept. The only alternative, given the soil conditions, would be a gravity based design. However, a square-sided gravity based structure would not be able to resist the snagging load from fishing gear, if a vessel accidentally entered the 500m safety exclusion zone centred on the manifold. The manifold would therefore have to be overtrawlable, as this reduces the loads that have to be designed for. An overtrawlable design would have sloped sides; the pipework in the Abigail manifold is on different levels and contains control modules, which already adds to the weight of the structure. Therefore, an overtrawlable design, would significantly increase the size and weight of the structure, with the extra height required to accommodate the manifolds pipework. This would require additional fabrication (time and material) and to install this could also require the use of a separate crane vessel.

[10] The soft start procedure is where there is a gradual ramping up of piling power, incrementally over a set time period, until full operational power is achieved: https://data.jncc.gov.uk/data/31662b6a-19ed-4918-9fab-8fbcff752046/JNCC-CNCB-Piling-protocol-August2010-Web.pdf

The existing design of the Abigail manifold means there are no snagging points, but if caught, nets can be pulled clear by reversing the fishing vessel. The design of the manifold follows that of the Harrier and Stella manifold, and considers trawlgear coming at speed at the manifold, resulting in significantly greater design load than an overtrawlable structure. Therefore, the most practical wat to prevent the manifold from moving is to pile the structure.

The SSIV is to be installed at the base of the riser at the FPF-1 and connect to existing infrastructure. To do this, the flowline between the Stella MDC and the FPF-1 will require to be flushed to remove hydrocarbons, with fluid from the flushing operations routed to the oil export line on the FPF-1 and routed to shore. Prior to flushing operations, production from the Stella and Harrier fields will be shut-in and isolation valves in the MDC manifold closed to isolate the satellite manifolds (Harrier and Stella North Drill Centre). When the flushing operations are completed, the relevant valves will be closed in to isolate the flowline from other systems on the FPF-1 prior to the subsea flange being opened and the new infrastructure (SSIV) being installed to the system. When the subsea flange is opened, a small volume of the fluid (hydrocarbon and water) above the water line will be discharged to sea, with the majority of this being retained in the riser due to the vacuum effect. This discharge of hydrocarbon is estimated at around 0.1 litres (0.001m^3) and will be fully assessed as part of the environmental permits process for the installation of the development infrastructure.

Following installation, the production and gas lift pipelines, associated spools and jumpers will be pressure and leak tested before preparing the lines in readiness for production; the installation and testing programme will include the use and discharge of chemicals, these will be assessed and applied for as part of the pipeline permit applications, submitted through PETS.

Phase 2

If executed, the subsea elements of the second phase will only include new tie-in spools and jumpers to tie in the second well to the Abigail manifold, and a small quantity of associated protective material. This will involve a short, single vessel subsea campaign. Phase 2 will not require any trenching, backfilling or pilling to be carried out.

3.9.2 Protective Material

Protective material (e.g. mattresses, grout bags and rock) will be required for the Abigail subsea infrastructure. The final quantities and locations for the protective material will be determined at installation, but an estimated quantity, based on previous, similar, Stella and Harrier subsea campaigns has been included here (Table 3.11, see also Figures 3.14a and b, note this is for illustrative purposes only, with final position and quantities determined at installation).

The quantity of all protective material used will be minimised as far as possible while maintaining the technical function of the protection, including the immediate and future integrity of the infrastructure, as well as minimising any potential snagging hazards to fishermen and other users of the area. The quantities described in Table 3.11 are anticipated to be the upper limit, however, this cannot be finalised until the pipeline system is installed, and trenched and the profile of the pipeline is surveyed.

Table 3.11 – Expected protection required[1]

Phase	Grout bags (25kg each)	No. of mattresses (6mx3x0.15m)[2]	Rock (tonnes)
1	1,000 (400 at Stella MDC 600 at Abigail drill centre)	135 (Stella MDC = 42 Crossing = 3 Abigail drill centre = 90)	18,000 (Crossing and Stella MDC = 8,000, spot locations along pipeline length = 10,000)[3]
2[1]	500	25	-
Total	**1,500**	**160**	**18,000**

Notes: [1]The first phase will include the completion of a production well and the installation of the subsea infrastructure, the second phase will be the drilling and completion of a second production well, the protective material here represents an estimate of that required for the tie-in infrastructure (spools/jumpers) of the second well; no rock is expected to be required for the second well, with mattress and grout bags only being used. [2]Three mattresses used at the crossing will measure 6mx3mx0.3m. [3] The 10,000 tonnes spot locations includes rock at trench transitions.

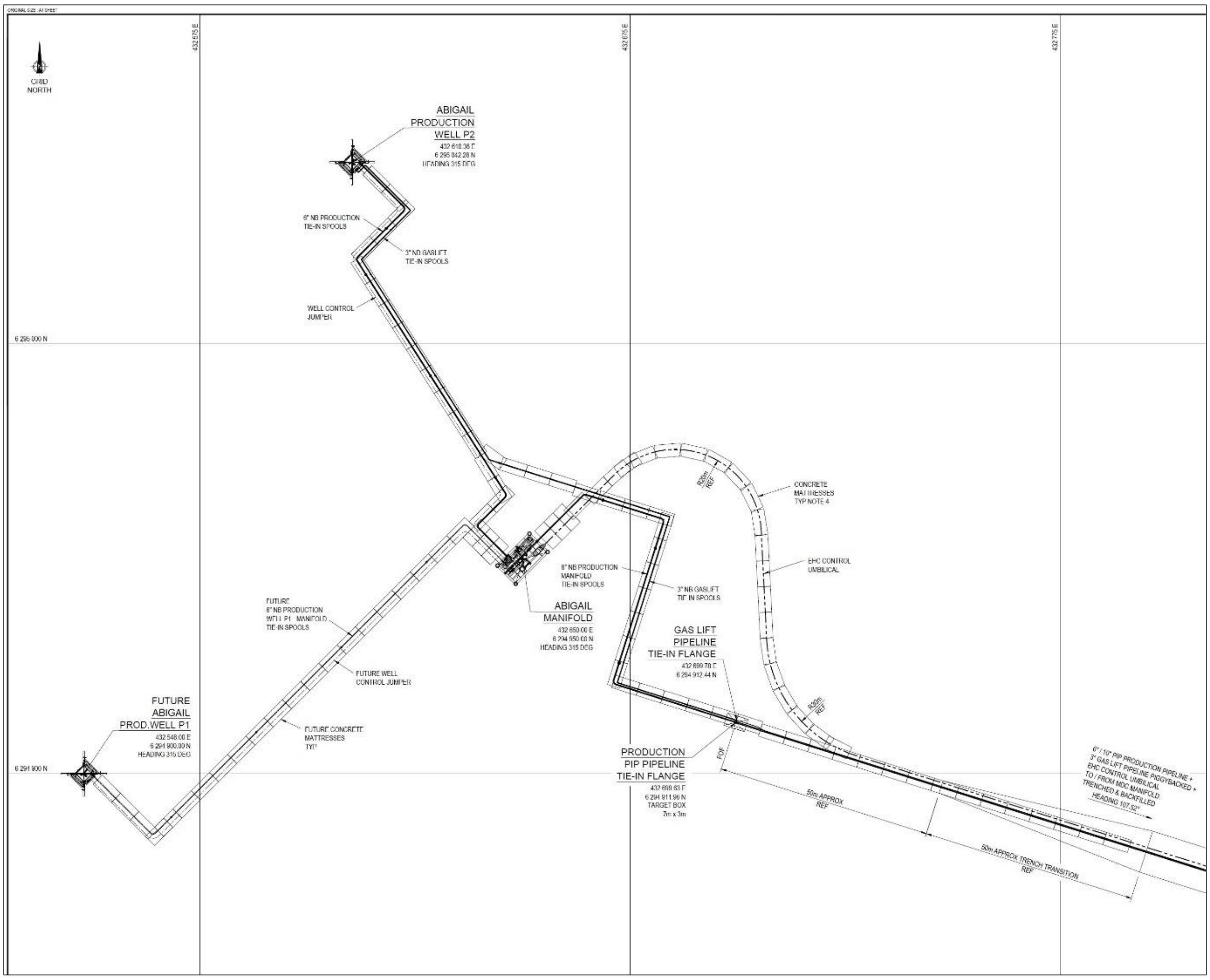
The Abigail pipeline system (production pipeline, gas lift pipeline and services umbilical, all in a single trench) will cross the 10" gas export pipeline from the FPF-1 to CATS (PL3078), owned and operated by Ithaca Energy. Prior to pipelay, concrete mattresses will be positioned at the crossing location in order to support the lines as they cross the existing pipeline, with rock then used to cover the newly overlain lines.

Concrete mattresses will also be used to protect the tie-in spools at the Abigail well location and at the tie-in to the Stella MDC. Grout bags will be used to support the spool pieces as well as filling any gaps between the concrete mattresses. Mattresses will measure 6m x 3m x 0.15m and be of a concrete, bevel edged design and the grout bags will be biodegradable and efforts will be made to keep mattress and grout bag numbers to a minimum.

An estimated 18,000 tonnes of rock will be used, primarily at the crossing location and trench transitions, although there may also be some requirement for spot rock cover at areas where the required level of backfilling has not been achieved, or to prevent upheaval buckling (included within the 18,000 tonnes estimate); it is anticipated that some form of upheaval buckling mitigation will be required along the pipeline and the only practical means of applying this is by fallpipe deployed rock.

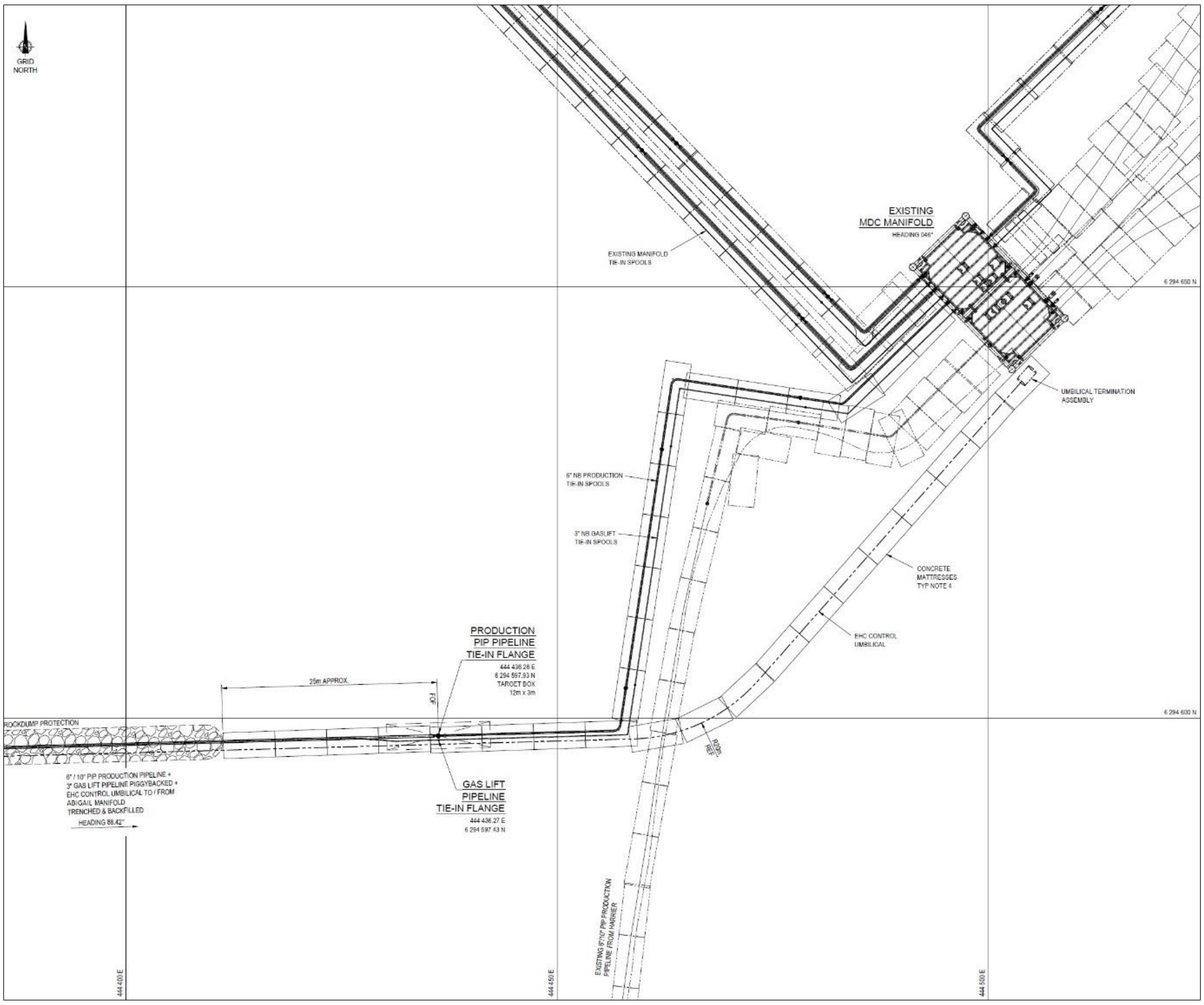
There is no rock use anticipated for the second phase, with protection provided by mattresses and grout bags (included in Table 3.11). If, during the planning of the drilling and tie-in of the second production well rock is required for the tie-in, this will be assessed and applied for under the term permit regime.

Figure 3.14a – Abigail Drill Centre/Manifold approach



Note: location of second well, if drilled, is provisional.

Figure 3.14b – Stella Main Drill Centre approach



The rock used will be graded (1-5" grade), quarried material and will be placed such that there will be a minimum depth of 0.6m over the pipelines and umbilical. Rock will be placed using a fallpipe vessel to provide a more accurate means of rock placement. The estimated total disturbance corridor width (22m) takes into consideration the width of the trench, the area where trenched material excavated is located prior to backfill, the area where rock is deposited (where used) and the potential width of the trenching vessel skis (see 3.9.1 and Figures 3.12 and 3.13 above).

A deposit consent (DEPCON) for the protective materials will be sought as part of the Pipeline Works Authorisation (PWA). The DEPCON lists individual line entries for rock, grout bags and mattresses; the corresponding environmental application, the DEP SAT, reflects the line entries as detailed in the submitted DEPCON and is supported by an environmental assessment of the finalised quantities and locations of the protective materials, taking into account any changes in these from that assessed here (the use of protective material, including rock, will be minimised as far as possible, consistent with pipeline protection and safety). These applications will be made and approval sought prior to any work commencing offshore.

On completion of pipeline installation, an "as laid" survey will be conducted, using a remotely operated vehicle (ROV) to accurately chart the subsea facilities and to identify any items of debris for recovery. This will also confirm that the pipeline system has been buried and any requirement for remedial rock placement.

3.10 Vessel Requirements

Along with the drilling rig, a variety of different vessels will be required for the development activities. While final vessel selection is still to be made, the types of vessels required are known and these are summarised in Table 3.12. Time on location and estimated fuel usages have been forecasted by Ithaca Energy's logistics team, based on tracking average consumption from previous, similar, drilling and subsea campaigns. Actual diesel consumption rates will be dependent upon which rig and vessels are chartered. In the absence of named vessels, the information in Table 3.12 forms the basis of estimating rig/vessel atmospheric emissions.

Table 3.12 – Approximate rig and vessel requirements for the Abigail Development

Activity	Approximate no. days on site	Fuel consumption rate tonnes/day	Fuel type	Total fuel consumption (tonnes)
Phase 1				
Well activities				
Anchor handler/tug (x 3)	1	16 (per vessel)	Diesel	48
Rig mobilisation and demobilisation[1]	7	10	Diesel	70
Rig (on site)	76	18	Diesel	1,368
Supply vessels[2]	37	9	Diesel	333
Standby vessel[3]	76	1	Diesel	76
Helicopter[4]	66 (hrs)	545 (kg/hr)	Helifuel	36
			Total for drilling campaign (diesel)	**1,895**
			Total for drilling campaign (helifuel)	**36**
Subsea infrastructure installation and tie-in				
Pipelay vessel	6	17	Diesel	102
Trenching vessel	8	20	Diesel	160
Utility vessel	14	19	Diesel	266
Rock placement vessel	4	20	Diesel	80
Construction vessel	11	20	Diesel	220
Dive support vessel	26	20	Diesel	520
Guard vessel[5]	30	2	Diesel	60
			Total for subsea campaign	**1,408**
			Phase 1 total Diesel Consumption (all activities (excluding helicopter), including contingency time for sidetrack, and waiting on weather for rig)	**3,303**
			Phase 1 total Helifuel consumption	**36**
Phase 2				
Well activities – Well activities				
Anchor handler/tug (x 3)	1	16 (per vessel)	Diesel	48
Rig mobilisation and demobilisation[1]	7	10	Diesel	70
Rig (on site)	82	18	Diesel	1,476
Supply vessels[2]	41	9	Diesel	369
Standby vessel[3]	82	1	Diesel	82
Helicopter[4]	72 (hrs)	545 (kg/hr)	Helifuel	39
			Total for drilling campaign (diesel)	**2,045**
			Total for drilling campaign (helifuel)	**39**

Activity	Approximate no. days on site	Fuel consumption rate tonnes/day	Fuel type	Total fuel consumption (tonnes)
Subsea well tie-in				
Single DSV[6]	15	20	Diesel	300
Total for subsea well tie-in				300
Phase 2 total Diesel Consumption (all activities (excluding helicopter), including contingency time for sidetrack, and waiting on weather for rig)				**2,345**
Phase 2 total Helifuel Consumption				**39**

Note: All figures rounded [1]Assuming 5 days for mobilisation, including positioning at location (jacking up for jack-up and running anchors for semi-submersible) and 2 days for demobilisation (including jacking down for jack-up and pulling anchors for semi-submersible). [2]The rig will require supply trips, assuming 3 per week for the duration of the drilling programme (Phase 1 ca. 11 weeks duration, Phase 2 ca, 12 weeks) and approx. 27hrs round trip for each sailing, including time at rig. [3.]A standby vessel will be on location for the duration of the programme in both phases. [4.]Average 3 helicopter round trips per week (Phase 1 ca. 11 weeks duration, Phase 2 ca, 12 weeks), average 2hr per flight. [5]It is estimated that a guard vessel will be required at the Abigail drill centre for the period between pipelines/umbilical being laid and then being tied in and protected – 4 week has been assumed for this. [6] It is estimated the tie-in of the second well will only require a single vessel campaign

A rig site survey, with an environmental scope, is being carried out in June 2021, with application for the survey consent applied for. The survey is a single (DP) vessel campaign of *ca*. 6 day duration. The survey programme includes sidescan sonar, sub-bottom profiling, visual (photographic) recording and grab sampling. A final pre-lay survey along the pipeline route will also be conducted, immediately prior to the pipeline system being installed. This will typically comprise ROV inspection and multibeam echo-sounder (MBES), conducted by the Utility Vessel included in Table 3.12. Applications for survey consents and/or notification, depending on the survey scope for this, will be applied for prior to survey work being conducted.

3.11 Pipeline and Subsea Operation, Inspection and Maintenance

Day to day operation of the pipeline will be from the FPF-1 installation, from where control commands and chemicals will be dispatched via the Stella MDC and the Abigail manifold to the Xmas tree. The FPF-1 will monitor infield pipeline inlet and outlet pressure and temperature sensors to detect any anomalous outputs which may indicate loss of integrity of the subsea system. In the event that this occurs, the pipeline can be shut-in and depressurised to limit any egress.

The existing pipeline integrity management strategy for the Stella and Harrier fields will be updated during detailed design to incorporate the addition of the Abigail pipeline system. In outline, the pipeline will be inspected at regular periods, by side-scan sonar, with any anomalies being visually inspected. Corrosion protection performance and ROV inspections will also be included within the inspection scopes, as required.

Operational pigging and intelligent pigging is not anticipated during the life of the field. Wax will be managed through the use of inhibitor injection and operational temperatures, whilst the use of a corrosion resistant alloy (chrome) material mitigate the requirement for intelligent pigging to be performed. In the unlikely event that this is required, then this can be achieved by removing a spool at the Stella MDC manifold end and connecting a pig launcher to the Abigail manifold and a receiver at the Stella MDC end.

3.12 Overview of FPF-1 Facilities and Operations

3.12.1 Stella Main Drill Centre Manifold

The Stella MDC comprises a central, piled manifold with five slots and facilities to accommodate up to 5 producing wells, a test header and a warming spool. The manifold, located 1.5km from the FPF-1, and connected via a 10" flexible flowline, distributes gas lift to all Stella MDC wells and to/from the Stella North Drill Centre (NDC), located approximately 3km to the north of the Stella MDC and production from Harrier, 7.5km to the south. The manifold also houses a subsea comingling system with associated valves for the control system/chemical distribution for the Stella MDC wells and each of the tie-backs; Abigail will tie-in with the same arrangement as these.

3.12.2 The FPF-1

The Stella field, discovered in 1979, comprises an Andrew sandstone reservoir, containing light oil and gas condensate and an Ekofisk reservoir containing a volatile oil, while the Harrier field discovered in 2003, comprises Ekofisk and Tor Chalk reservoirs, both containing gas condensate. The licence for Block 30/06a was initially awarded to Shell/Esso in Round 1 and Ithaca Energy acquired interests in the Block from Shell/Esso (in 2008) and Maersk (in October 2009). Ithaca Energy commenced development of the Greater Stella Area in 2011/2012 with the drilling of production wells and installation of subsea infrastructure, with first oil from the area in 2017. Ithaca Energy now holds a 100% interest in both the Stella and Harrier fields.

The FPF-1 is an eight column, twin hull vessel, initially built as a service vessel in 1976/77, and converted to a floating production unit in 1989, when her hull was modified to improve stability to increase deck loadings in order to accommodate production facilities and the mooring system was renewed (Figure 3.15). Since 1989, as the AH001, it was operated in the central North Sea for Hess processing and exporting hydrocarbons from various fields, until these ceased production in 2009, at which time it was acquired for use in the Stella/Harrier development and renamed the FPF-1. After extensive modifications to the hull and topsides, the FPF-1 was mobilised to the Stella area in late 2016.

Figure 3.15 – The FPF-1 facility

The FPF-1 is a spread moored facility, whereby wire ropes from each corner are connected to chains fixed to the seabed by piles and the FPF-1 is maintained on a set heading.

3.12.3 Processing Facilities and Export Overview

Abigail production fluids will be routed to the Stella high pressure (HP) separation facilities alongside Stella and Harrier fluids. Vorlich production fluids are processed through separate HP production facilities.

Separated oil from the HP separators is directed to the Low Pressure (LP) separator where gas is routed to the off-gas compression system. Gas from the HP and LP separation facilities combine with gas from the off-gas compressor and are routed to two export compression trains. The two compression trains each consist of three process stages; with the compression trains remaining separate for the 1st and 2nd stages. Gas enters the 1st stage and flows through the 1st compression stage, then is routed to the 2nd stage compressor suction drums and into the 2nd compression stage. Condensed liquids are routed back to either HP separator or to the NGL (Natural Gas Liquids) module for further processing. From the 2nd compression stage, the gas streams from each train combine and are routed to a TEG contactor, where it is dehydrated to meet the Central Area Transmission (CATS) pipeline specifications. Export quality gas then passes to the 3rd stage of compression before routed to the export riser. Gas is exported to the CATS pipeline via a 63km export pipeline tied in at the CATS T5 Tee.

The fuel gas off-take is located upstream of the 3rd stage gas compressor suction drum with the fuel gas conditioning system consisting of a knockout drum and superheater. The fuel gas network consists of a HP and low pressure (LP) header; the HP header is used to provide fuel gas to the turbines and export gas compressor turbines and the LP header is used as purge gas and stripping gas in the TEG reboiler.

After initial separation in the HP separator, oil from the LP separator flows to the booster pumps and main oil line (MOL) pumps prior to being exported via a 10"oil export line into the Norpipe. Export first ties into the Southern Wye of the J-block spurline before onward export via Norpipe.

Produced water from the LP and HP Separators is treated in the Produced Water Treatment System (hydrocyclones and a produced water degasser) to achieve an oil in treated water content of less than 20ppm. The produced water is then routed overboard via the produced water outfall caisson, located externally. Water is routed to approximately 9m below sea level.

The FPF-1 has dedicated HP and LP flare systems. The HP flare system handles all high-pressure releases, primarily process upset sources, and the LP flare system handles lower pressure releases, such as discharges from the LP separator and produced water degasser. During normal operation, the vented and relieved gases are reprocessed in the flare gas recovery package such that the FPF-1 is normally a non-flaring installation..

Under normal operations, power is supplied by three gas turbines driving the main power generators. These run predominantly on fuel gas and each turbine is fitted with a waste heat recovery unit for process heating. The FPF-1 also has two emergency diesel generators. During process start-up, when fuel gas is not available, the electrical load for the FPF-1 is below the recommended minimum load for running a single main gas turbine generator on diesel fuel. As a result, two diesel start-up generators facilitate the run up of electrical loads. This ensures fuel gas availability and main power generation at start-up. In normal operation, power generation is by fuel gas; diesel fuel is only required for start-up and emergency generators.

Other utilities include the seawater and heating medium systems. Seawater is primarily used to provide cooling for the process and utility systems via cooling medium pumps. The waste heat recovery unit on each power generator exhaust heats the heating medium, which is then circulated to users by the heating medium circulation pumps.

The maximum thermal input of combustion plant on the FPF-1 is in the region of 140MW(th) and the facility has an offshore combustion permit under the *Offshore Combustion Installations (Pollution Prevention and Control) Regulations 2013* to cover all of the qualifying combustion equipment.

3.13 FPF-1 Production and Abigail Operations

Minor modifications only will be required to the existing Stella and Harrier control system to facilitate the supply of power, control and chemical functionality to the Abigail manifold. This is primarily achieved within the Stella MDC manifold, with some minor modifications to topsides (change out chemical injection pump and installation of SSIV panel). There are no modifications required to the process system to accommodate Abigail.

3.13.1 Produced Water Discharges

Produced water from the Stella, Harrier and Vorlich fields is discharged from the FPF-1, and the oil in water (OIW) monthly permitted discharge limit is 20mg/l. In 2020, the total amount of produced water discharged was 88,303m^3 and based on average OIW figures throughout the year, this equated to 1,728kg (1.7tonnes) of oil discharged. Figure 3.16 and Table 3.13 below shows the monthly OIW performance during this period and up to March 2021.

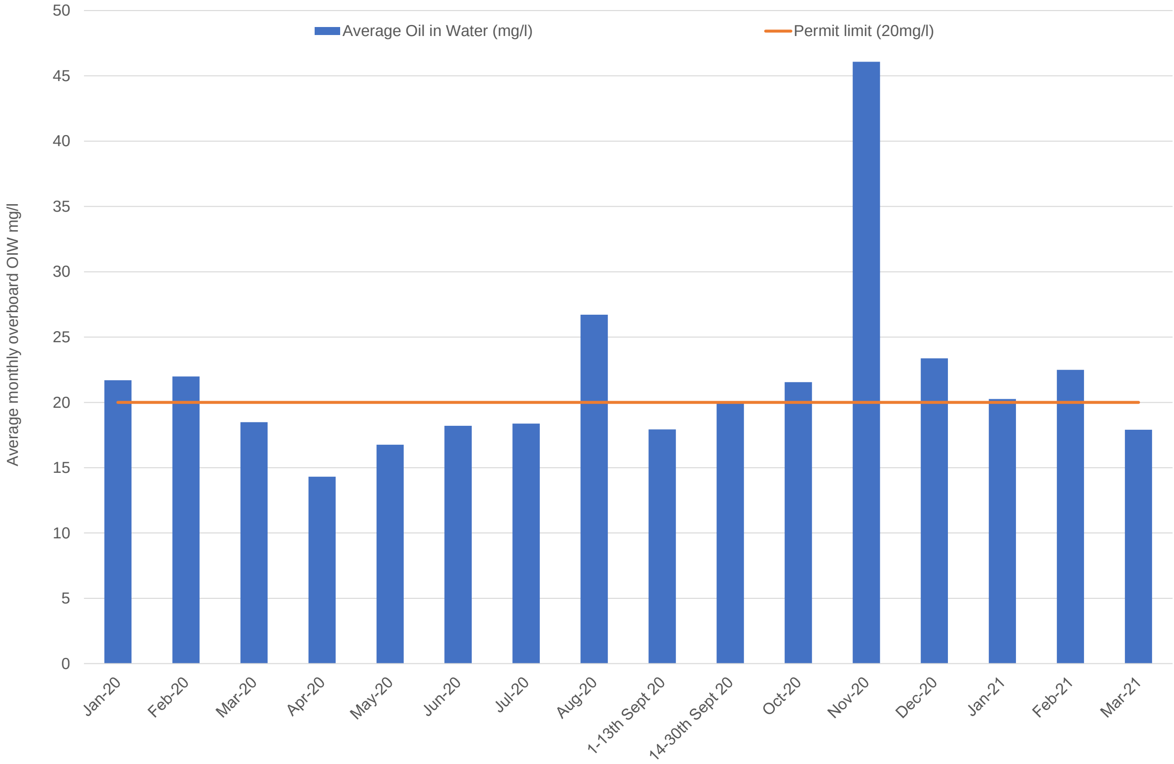
Table 3.13 – Produced water and oil in water discharge from the FPF-1

Time	Produced water discharged (m^3)	Average OIW (mg/l)	Estimated oil discharged (kg/month)
2020			
January	5,989	22	130
February	11,640	22	256
March	13,087	18	242
April	11,575	14	166
May	8,250	17	138
June	13,189	18	240
July	6,309	18	116
August	4,968	27	133
September	7,301	38	139
October	1,579	22	34
November[1]	1357	46	63
December	3059	23	71
2021			
January	1,212	20	25
February	2,777	23	62
March	3,385	18	61

Note: Numbers rounded to whole numbers. [1]Vorlich came online in November/December 2020. The average OIW for April and May 2020 was 17mg/l (17.33 April and 16.95 for May).

During 2020, the FPF-1 had a number of planned shut downs resulting in elevated average OIW (these due to for example colder temperatures at re-start of production). The commencement of production from Vorlich in November 2020 also resulted in an initial spike in OIW discharge, this then reduced back to below 20mg/l by March 2021.

Figure 3.16 – FPF-1 monthly OIW performance 2020-2021



Since production commenced at the FPF-1 in 2017, a number of modifications have been made to improve produced water and associated OIW discharges, including (but not limited to):

- Well optimisation – changes to well configuration, gas lift rates to optimise water rates/temperatures and minimise disruptions to topside plant
- Changes to increase temperature and aid phase separation
- Hydrocyclone optimisation
- Chemical optimisation – i.e. change out of wax inhibitor to stop interference with water quality and introduction of deoiler

Through a combination of the above and other changes, the FPF-1 effectively manages the OIW discharges overboard.

Increment from the Abigail Development

Abigail hydrocarbons are to be comingled subsea with the Stella and Harrier hydrocarbons, including the produced water from Abigail, and processed through the system described above (Section 3.10.3).

Predicted volumes of produced water for the Abigail field in 2022 when production commences, along with predicted volumes from the first full year of production (2023), are shown in Table 3.14 below[11]. These are shown in context with the produced water from Stella, Harrier and Vorlich.

[11] Produced water estimates are from the FPF-1 oil discharge permit as at May 2021

Table 3.14 – Annual produced water forecast with Abigail

Year	Stella Field (m^3)	Harrier Field (m^3)	Vorlich Field (m^3)	Abigail Field (m^3)[1]	FPF-1 total (m^3)
2021	8,588	14,333	24,836	0	47,757
2022	8,472	14,159	5,919	6,557	35,107
2023	8,298	13,927	1,683	135,091	158,999

Note: [1]Figures for Abigail produced water for 2022 and 2023 are derived from the production mid case.

Over the life of the Abigail field, peak water production is expected to be 501m^3/day (182,865m^3/year) for the both the mid (year 2024) and high (year 2027) production cases. The associated peak annual oil discharge, based on 20mg/l, is 3,700kg (3.7tonnes) of oil. These predicted volumes for Abigail, will be in addition to the produced water volumes from the Stella and Harrier fields.

At commencement of Abigail production, a temporary initial elevation in OIW (higher than the 20mg/l average) is expected, as seen for Vorlich (Figure 3.16 above). Assuming the initial elevation for Abigail to be similar to Vorlich (46mg/l), and based on a water discharge of 6,557m^3 (this being the Abigail water volume estimated to be discharged in 2022 (Table 3.14)), this would equate to an additional oil discharge of 302kg (0.3 tonnes) from the first few months of Abigail production.

3.13.2 Power Generation

Power generation on the FPF-1 is provided by three SGT300, Siemens gas turbines driving 6.6kV power generators, each with a rated output of 8.5MW. The fuel gas used in the turbines is derived from the native associated gas from the Stella, Harrier, Vorlich and in future, Abigail fields. During process start-up, fuel gas is not available to run the gas turbines, and while the units have dual fuel capability, the base load for the FPF-1 is below that recommended to run one of the turbines on diesel. Therefore, temporary diesel generators provide this base load; a review for the replacement of the temporary generators is still to be undertaken, with an aim being to replace these with a system which improves the process start up thus reducing emissions associated with this. The schedule for any potential replacement is still to be finalised, however, this is not directly connected to the development of the Abigail Field.

For context, the FPF-1 used 42,359 tonnes and 37,527 tonnes of gas as fuel gas in 2018 and 2019 respectively, relative to 768 tonnes and 795 tonnes of diesel. The existing FPF-1 power generation facilities outlined above will be used for the Abigail development. The likely increment to fuel gas use associated with the Abigail development is outlined below.

Increment from the Abigail Development

Fuel gas use on the FPF-1 is largely determined by the production volume, and the contribution of the Abigail development to power load and related fuel gas requirements on the FPF-1 is therefore dependent on the production case being considered. It has been estimated that there will be a minor increment to fuel gas use through field life ranging from a total of 10,352 tonnes (11.62 million m^3) for the low case, 11,767 tonnes (13.21 million m^3) for the mid case, and 16,326 tonnes (18.33 million m^3) for the high case. This is relative to a total fuel gas use associated with the Stella, Harrier and Vorlich fields across their entire field life of some 624,125 tonnes (700.73 million m^3). The estimated fuel gas use with and without Abigail is shown in Table 3.15.

Table 3.15: Estimated FPF-1 annual average fuel gas use without Abigail and with Abigail for the mid and high cases

Year	FPF-1 fuel gas use without Abigail		Fuel gas use with Abigail Mid case (P50)		Fuel gas use with Abigail High case (P10)	
	tonnes/d	m^3/d	tonnes/d	m^3/d	tonnes/d	m^3/d
2022	145	162,464	147	165,350	147	165,546
2023	135	151,811	141	157,784	143	159,998
2024	134	150,738	134	150,449	137	153,805
2025	134	150,582	134	150,704	134	150,992
2026	134	150,502	134	150,573	134	150,636
2027	92	103,299	116	130,732	123	138,628
2028	92	103,291	92	103,291	92	103,291
2029	92	103,291	92	103,291	92	103,291
2030	92	103,291	92	103,291	92	103,291

As already indicated, the FPF-1 uses gas turbines for its main power generation, and while diesel is used, the quantities are relatively minor and cannot be further offset by fuel gas (e.g. to reduce atmospheric emissions), as diesel is required mainly for process start-up and base load generation, at a time when fuel gas is not available.

3.13.3 Flare and vent

The Greater Stella Area Development, which will include the Abigail Field, has a minimum flaring approach, such that continuous flaring should not take place, with the exception of purge and waste streams, oily water degasser gas and other low pressure/atmospheric system vents. At present, this approach is not being met due to flare ignition issues, such that continuous flaring is taking place to ensure the safety of the installation. Current continuous flaring is taking place at a daily average rate of 0.3MMscf/d (8.8t/d). At a rate of 8.8t/d, associated emissions from the continuous flare are estimated to be approximately 25tCO_2/d. For context, emissions associated with gas flaring in 2018, 2019 and 2020 are estimated to be 10,052tCO_2 (27.5tCO_2/d), 24,569tCO_2 (67tCO_2/d), and 14,205tCO_2 (38.9tCO_2/d) respectively.

It is anticipated that the flare ignition package will be fixed in Q3 2020 after which continuous flaring will not be required, with a reduction equal to the 0.3MMscf/d presently used, and related CO_2 emissions. Following this work, any future gas flaring would be to account for factors such as process upsets and emergency shutdowns.

Abigail will not result in a greater number of flaring events on the FPF-1, nor will it result in a greater volume of gas being flared in any such event. Abigail gas will, therefore, only represent a proportion of the gas flared, but will not result in incremental flaring volumes or associated emissions. The estimated apportioning of Abigail gas to flaring under normal operations is shown in Table 3.16. Similarly, there will be no increment to venting from FPF-1 as a result of Abigail production.

Table 3.16 – Estimated Abigail gas contribution to FPF-1 flaring[1]

Year	Mid case (P50) Gas to flare		High case (P10) Gas to flare	
	tonnes/d	000m³/d	tonnes/d	000m³/d
2022	2.81	3.34	3	3.57
2023	1.94	2.31	2.85	3.40
2024	1.12	1.33	3.39	4.03
2025	0.81	0.97	6.33	7.54
2026	0.73	0.87	3.94	4.69
2027	0.81	0.96	2.98	3.55
2028	1.52	1.81	4.25	5.06
2029	2.09	2.49	3.55	4.23
2030	2.15	2.56	0.00	0.00

Notes: 1. This represent the contribution Abigail production will make to gas flared during process upsets etc, it does not represent additional gas flared as a result of Abigail. Figures for 2022 are based on the period of Abigail production from October to December inclusive.

Abigail fuel gas and flaring share will be allocated on a mass by component basis against the Stella/Harrier/Abigail separator readings and off platform meter readings using the existing allocation system.

3.13.4 Chemical Use and Discharge and increment from Abigail

The chemicals used on the FPF-1 are typical of those associated with an offshore processing installation and comprise antifoams, demulsifiers, scale and corrosion inhibitors, biocides and detergents/cleaning chemicals. In 2020, *ca*. 338 tonnes and 281 tonnes of chemical were used and discharged respectively from production operations on the FPF-1. The majority of these are either offshore chemical notification scheme (OCNS) E or Gold banded, chemicals with the lowest hazard.

Increment from Abigail

Abigail hydrocarbons are to be comingled subsea with the Stella and Harrier hydrocarbons at the Stella MDC and arrive topside through the same processing train, with no new chemicals required for Abigail processing; no compatibility issues with comingling the hydrocarbons from the different fields are expected, thus enabling the Stella/Harrier process train to be utilised. As Abigail production will also include an increase in produced water, there may be a requirement to increase the chemical use and discharge associated with this process.

At production start up and as Abigail production gets to a steady state, production chemical requirements will continue to be monitored, evaluated and optimised where technically feasible. At present, increases in a small suite of existing chemicals has been anticipated (Table 3.17) all of which are Gold banded, with no warning labels (low hazard chemicals).

Table 3.17 – Estimated increase in chemicals for Abigail[1]

Chemical type	Chemical notification category	Estimated annual use (discharge) tonnes
Subsea wax inhibitor	Gold	221 (2)
Scale inhibitor	Gold	13 (13)
Asphaltene inhibitor	Gold	34 (34)
Demulsifier	Gold	12 (12)
Deoiler	Gold	7 (7)

Chemical type	Chemical notification category	Estimated annual use (discharge) tonnes
Hydrogen scavenger	Gold	37 (37)
Corrosion inhibitor	Gold	24 (0)
Wax inhibitor	Gold	88 (0)

Notes: [1] This represents current identification and estimated quantities, this subject to change. All required changed to the existing FPF-1 chemical permit, will be assessed as part of the environmental permit (PETS) system.

Methanol is also expected to be required for field start up. The chemical management strategy on the FPF-1 is such, that, through ongoing dialogue with chemical suppliers and trialling of chemicals offshore, the aim remains to minimise the impact of chemicals on the environment, through the continued use of the lowest hazard chemicals, where technically feasible to do so.

3.14 Decommissioning

The arrangements for decommissioning of the Abigail Field facilities will be developed in accordance with the UK Government legislation and International agreements in force at the time. The design of the facilities have taken into consideration the current requirements for decommissioning; the production well(s) can be abandoned in accordance with the prevailing legislation and guidelines, and the Xmas tree(s) and wellhead(s) can be removed and conductors cut to 3m below the seabed surface. The current requirements are such that subsea infrastructure should be removed for re-use, recycling or final disposal on land; all structures above sea level, manifold, SSIV, riser base, spools and control jumpers can be removed, along with associated mattresses and grout bags (it should be noted that biodegradable grout bags are being used, the expectation being that only what remains of the grout bag can be recovered at time of decommissioning). The decommissioning of the Abigail pipeline system will be in accordance with the regulatory requirements at time of decommissioning; current requirement are for a comparative assessment to be carried out on pipeline decommissioning options.

In order to access the Stella MDC, the Abigail pipeline system requires to cross the 10" gas export to CATS (PL3078), with associated protective material used to protect both systems; installation of the Abigail proposed pipeline will be the fourth such crossing over PL3078. PL3078 is the pipeline from the FPF-1 to CATS and is owned and operated by Ithaca Energy. This is expected to remain operational for the life of the FPF-1 and, as such will not be decommissioned in advance of the Abigail facilities. This pipeline is trenched and backfilled at the location of the proposed crossing and, if at the time of cessation of production of the FPF-1 a comparative assessment of the decommissioning options for pipelines is still a requirement, this pipeline will be included in the assessment for the Greater Stella field area. The crossing to accommodate the Abigail pipeline system is not expected to impact the ability to decommission pipeline PL3078.

The overriding principles in the decommissioning philosophy will be the reuse of material as far as possible, generating the minimal environmental impact on the area and leaving a clean seabed.

Any material removed will be transported to shore and, in accordance with the waste hierarchy. Any option for decommissioning in situ, will be supported by demonstrating that recovery and recycle is not reasonably practical.

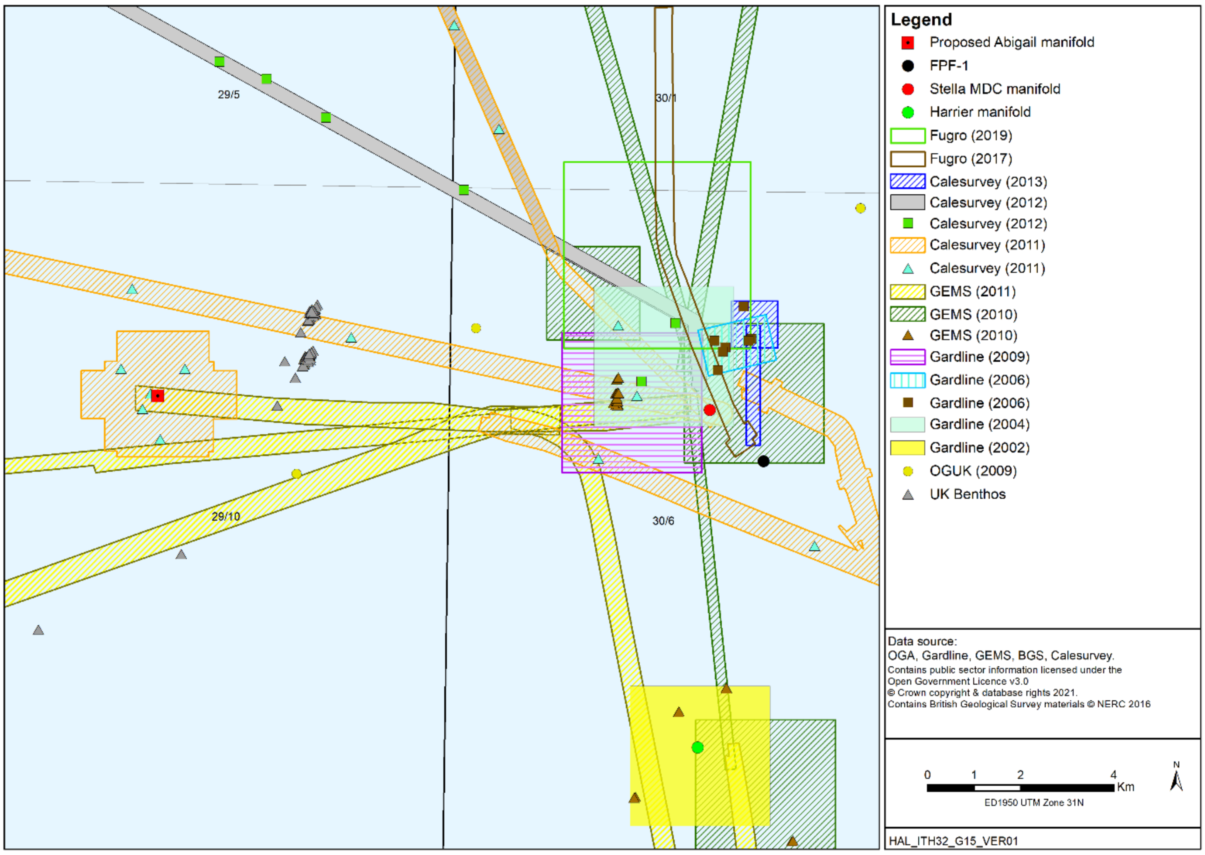
4 DESCRIPTION OF THE ENVIRONMENT

The proposed Abigail development lies in Block 29/10 in the central North Sea, some 233km from the nearest landfall at Peterhead on the northeast coast of Scotland and approximately 36km from the UK/Norway median line (see Section 1, Figure 1.1). The following section describes the Abigail area, the Greater Stella Area and the wider the central North Sea.

4.1 Seabed Topography and Seabed Sediments

A number of surveys have been undertaken in the region, including of the Abigail site and a series of pipeline routes, completed as part of the Greater Stella Area development (GSA) (Figure 4.1). The surveys conducted in the Abigail area focused on the potential drill and manifold locations and pipeline route. A similar approach was adopted for all surveys in the GSA, i.e. sample locations focused on identified drilling areas and pipeline routes. These surveys used a variety of methods including cone penetration test and vibrocores, grab sampling and drop cameras, and were carried out in order to identify any potential hazards for rigs, to help characterise the habitats present and to identify the presence of any sensitive habitats or species.

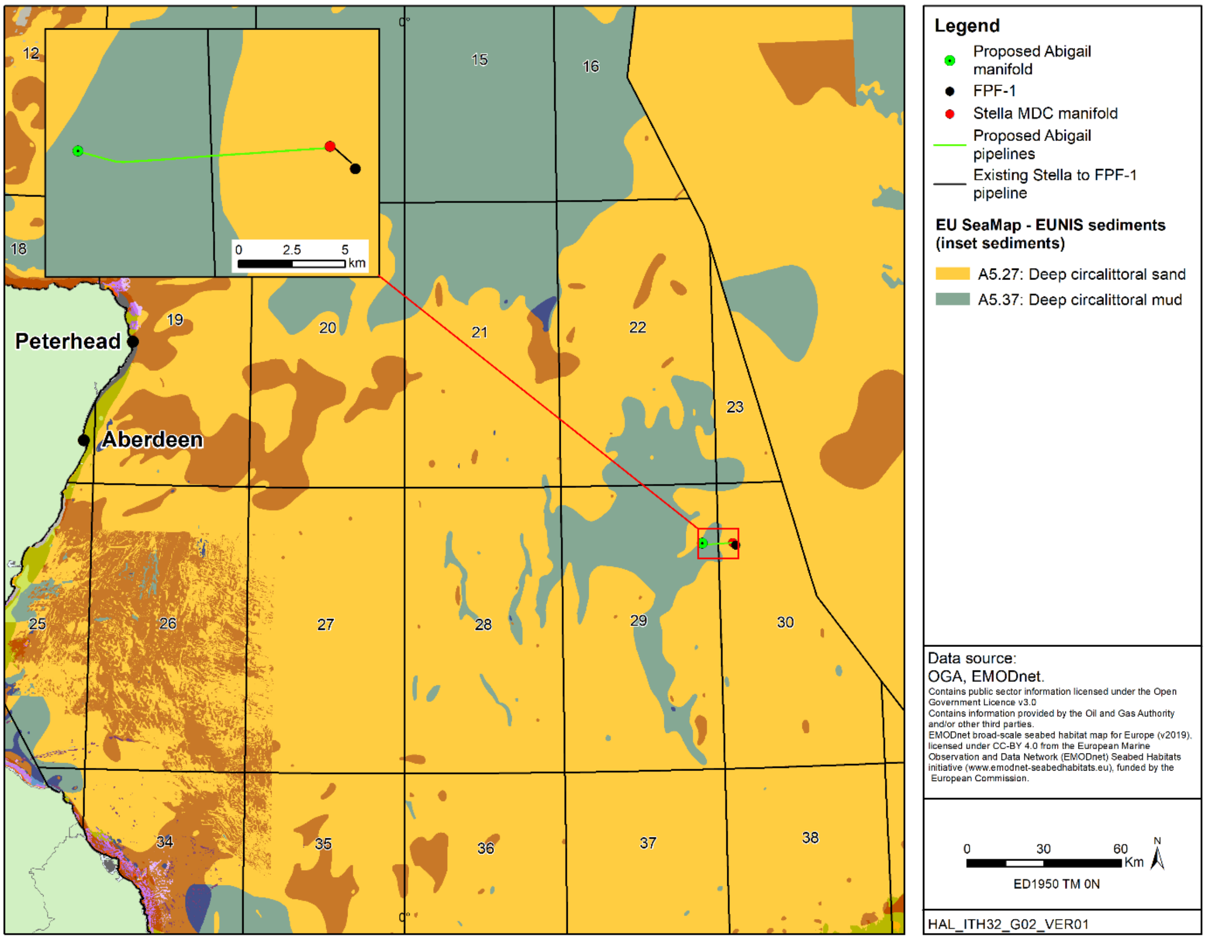
Figure 4.1 – Extent of seabed surveys undertaken in the GSA, including the proposed Abigail development



The Abigail sites survey and numerous pipeline route surveys of the Greater Stella Area (GEMS 2011, Calesurvey 2011, 2012a,b) along with published BGS and other data, combine to provide an understanding of the seabed and sediment characteristics of the Abigail and wider area and any potential features of concern or obstructions to the development plans. While it is acknowledged that the data from the Abigail area are now more than five years old, this data along with that collected during other surveys in the area, are considered to give a good representation of the area. The seabed sediments and fauna show long term persistence and are not expected to have changed significantly over the intervening period. An environmental survey to provide additional ground truthing at the proposed development area, is planned for the Summer 2021. Data from this will be used to support the term permit applications.

Seabed sediments in and adjacent to Abigail are sand to slightly gravelly sand (Gatliff *et al.* 1994), and are regionally described as shelf sublittoral sand and shelf sublittoral mud (MSFD broad habitat) or A5.27: Deep circalittoral sand and A5.37 Deep circalittoral mud (EUNIS classification) (EMODnet website[12]) (Figure 4.2). Based on the grain size analyses of sediment samples taken during seabed surveys of the Fulmar MCZ survey (approximately 20km to the south of Abigail), Lark (2015) assigned most of the area to the broadscale habitat A5.3 Subtidal mud which is in contrast to EUSeaMap predictions and the results of previous BGS and other surveys where most sediments would be classed as A5.2 Subtidal sand, with some areas of A5.3 Subtidal mud.

Figure 4.2 – Predicted seabed habitats

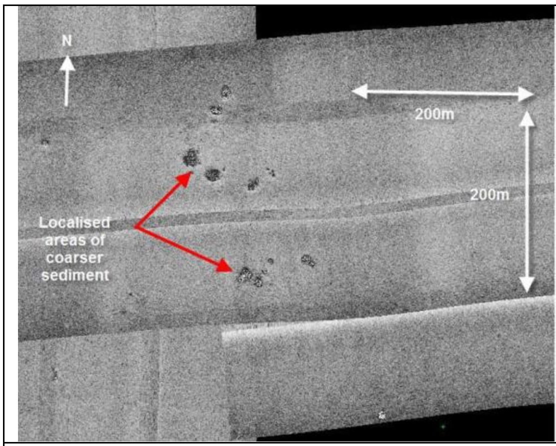
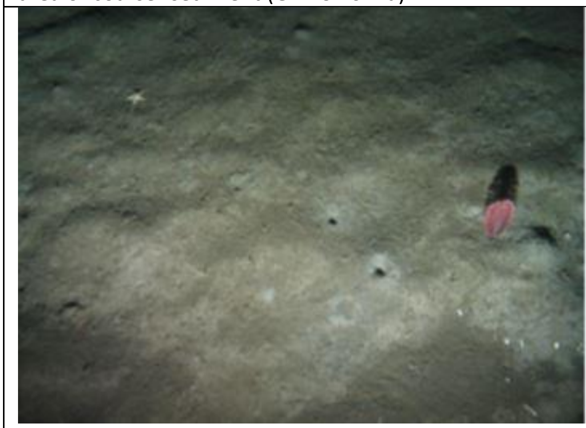


The seabed mapping undertaken at Abigail and the nearby Stella and Harrier areas have shown a relatively flat and featureless seabed, with gentle undulations; water depths at Abigail and along the pipeline route typically range from 89-92m (GEMS 2011b). The seabed sediments predominantly comprise silty sand, sandy silt and muddy sand with ribbons of coarser material (primarily bivalve shells, pebbles and cobbles) which form ripples/waves and are observed across the whole Abigail,

12 https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/ and https://www.emodnet-geology.eu/map-viewer/?p=seabed_substrate

Harrier, Stella (and Vorlich) area (GEMS 2010a,b, 2011a,b,c, Calesurvey 2012, Fugro 2017, 2019) (Figure 4.3). Surface sediments (depth 0-1.6m) at the Abigail drill centre were found to be loose to medium dense silty fine sand, overlying variable soils, the upper section comprising interbeds of fine clay to soft silty sand clay (depth 1.6m-19.9m) (Calesurvey 2011).

Figure 4.3 Typical seabed at Abigail showing evidence of bioturbation and patches of coarser sediment areas identified by side scan sonar

	
Sidescan sonar from pipeline route to Stella, with small area of coarser sediment (GEMS 2011a)	Slightly rippled sandy seabed pipeline route to Stella (GEMS 2011a)
	
Silty sand over finer, more consolidated material, significant bioturbation, (Calesurvey 2012)	Fine silty sand and bioturbation, at proposed well location (Calesurvey 2012)

Pockmarks are depressions or craters in the seabed, typically several tens of metres wide and a few metres deep, generally believed to be formed by the expulsion of fluid (gas or water) through the seabed sediment. Pockmarks have the potential to qualify as conservation (Natura 2000) sites for the Habitats Directive Annex I habitat, *Submarine structures made by leaking gases*. While pockmarks are present in some areas of the central North Sea none have been identified in any of the surveys carried out in the Abigail and wider Stella area (GEMS 2011, Calesurvey 2011, Fugro 2017).

4.1.1 Sediment Contamination

Shipping activity and oil exploration and production activities are the main anthropogenic sources of hydrocarbon contamination of water and sediments in the area (Ahmed *et al*. 2005, Russell *et al*. 2005). Analyses of samples taken during the various site surveys (e.g. Gardline 2006, GEMS 2010) and the Oil & Gas UK (OGUK) central North Sea regional survey in 2009, show contaminant concentrations (3.4-6.2µg/g) at background levels (<10 µg/g) in the region.

In March 2010, whilst drilling the Stella appraisal well, the *GSF Galaxy II* rig spilled 12.5 tonnes of whole low toxicity oil based mud (OBM) to the sea. Base oil comprised *ca*. 50% of the total weight spilled and was expected to sink rapidly to the seabed due to the density of the mud weighting agents; further information on sampling and analysis of the spill is described in the Stella and Harrier Environmental Statement (Ithaca 2011) A pattern of rapidly declining concentrations with distance from the spill location was evident (Hartley Anderson 2010, GEMS 2010a). The volume of oil lost in the Stella OBM spill was relatively small compared to previous permitted discharges associated with wells and recovery (ecological and degradable contaminants) was expected to take some 10 years.

The tophole sections of the Abigail appraisal well 29/10b-8 were drilled with seawater/WBM with cuttings discharged at the seabed. OBM was used in the lower hole sections and the resulting cuttings were returned to shore for processing. There are no OBM contaminated cuttings piles in the vicinity of the proposed Abigail wells.

4.2 Climate, Oceanography and Hydrography

Over the open central North Sea, wind direction varies considerably, dominant directions range from southeast to northwest through southwest. North to northwest winds dominate in spring and summer (UKHO 2013). Estimated annual mean wind speeds (at 100m above sea level) are approximately 8m/s, varying between 7.9m/s in summer and 12.1m/s in winter (BERR 2008).

The frequency of days experiencing gale force winds per month is approximately 15-20% in February, dropping to dropping to 2-4% in August (UKHO 2013). Sea fog is most frequent in summer, and most commonly associated with warm moist air blowing over a relatively cold sea with winds between southeast and southwest. Sea fog conditions account for approximately 3% of all days in the area in August, dropping to 1% in February (UKHO 2013)

The water mass in the area is described as ‘shelf water’; derived from Atlantic water, Scottish coastal water and central North Sea water (Turrell *et al*. 1992). Residual near-surface currents are weak (<0.5m/s) and predominantly to the south and east, although the pattern of water movement may be strongly influenced by short-medium term weather conditions.

Surface water temperatures range from 6.0-7.0°C in winter to 13-15°C in summer, while bottom temperatures show less variation at 6.0-7.0°C in winter and 6.5-7.0°C in summer (Berx & Hughes 2009). Thermal stratification of the water column develops in April/May, with a thermocline between warm surface waters and colder deeper waters at about 50m depth. Stratification breaks down in autumn due to increasing frequency and severity of storms and cooling. Annual mean surface and bottom salinities are 35‰ (Berx & Hughes 2009).

The predominant swell direction ranges from south to north through west (UKHO 2013). In spring/summer, swell direction is predominately northerly and north-westerly with more south-westerly swell in autumn/winter. Annual mean significant wave height is approximately 2.1m, ranging 1.5m in summer to 2.8m in winter (BERR 2008).

4.3 Plankton

The plankton community present in and around Abigail area is typical of the northern and central North Sea. The phytoplankton community is dominated by the dinoflagellate genus *Tripos* (*T. fusus*, *T. furca, T. lineatum*), with diatoms such as *Skeletonema costatum*, *Thalassiosira* spp. and *Chaetoceros* spp. also present (Johns & Reid 2001).

Zooplankton species richness is greater in the northern North Sea than in the southern North Sea and displays greater seasonal variability (Lindley & Batten 2002). This community is dominated by calanoid copepods (*Calanus finmarchicus* and C. *helgolandicus*), which constitute a major food resource for many commercial fish species (Brander 1992). Other zooplankton groups such as *Paracalanus* and *Pseudocalanus,* Euphausiids and *Acartia,* are also abundant (Johns & Reid 2001). Common jellyfish in the region include *Aurelia aurita*, *Cyanea capillata* and *Cyanea lamarckii* (Pikesley *et al.* 2014).

In recent decades, a plankton community has been observed as a northwards shift in the warmer-water *C. helgolandicus*, with a corresponding decline in the colder-water *C. finmarchicus* (Beaugrand 2003). The population of *C. finmarchicus* tends to peak in the cooler, spring months, and observations have indicated that the peak in abundance is arising earlier in the year, with the springtime *Calanus* community between 2009-2014 dominated by *C. finmarchicus* for the first time in almost two decades (Edwards *et al*. 2014, Edwards *et al*. 2016). However, total *Calanus* biomass has declined by 70% since the late 1950s (Edwards *et al*. 2016).

In the North Sea, a phytoplankton bloom occurs in spring followed by a smaller peak in the autumn. Diatoms are the first to bloom, then as nutrients essential for diatoms become depleted, other groups bloom such as flagellates, followed later by dinoflagellates. The progress of the spring bloom is dependent predominantly upon episodic turbulence following short periods of stratification, which allows the mixing of nutrients into the photic zone. Diatoms comprise a greater proportion of the phytoplankton community from November to May, when mixing in the water column is greatest (McQuatters-Gollop *et al*. 2007). Under certain conditions (e.g. rapid reproduction, reduced grazing pressure, favourable environmental factors), blooms can occur at other times of the year. Many of these blooms involve nuisance or noxious species and are described as Harmful Algal Blooms (HABs). Groups known to cause HABs and which occur in the central North Sea in 2014 include *Pseudo-nitzschia* spp and *Noctiluca* spp (Edwards *et al*. 2016).

4.4 Benthos

Benthic communities are traditionally considered as two groups: infauna and epifauna. The infauna live within the seabed sediment, and represent the most commonly surveyed and well-known benthic community. Epifauna live on the surface of the sediment, are generally larger than infauna, and may be sessile, such as sponges and hydroids; or mobile, such as echinoderms and crustaceans.

In regional-scale classifications of North Sea benthos, Künitzer *et al*. (1992) indicated that benthic infaunal communities in waters north of the 70m depth contour, were typified by finer sediments and the indicator species *Spiophanes kroyeri*, *Prionospio cirrifera* and *Myriochele* spp. (polychaetes). Similarly, Reiss *et al.* (2010) identified a northern and central North Sea infaunal assemblage in water depths of 96m (range 40-185m) characterised by *Myriochele* spp., *Amphiura filiformis* (echinoderm), *Spiophanes* spp. and *Paramphinome jeffreysii* (polychaete). Callaway *et al*. (2002) described the area as a region of transition in the epibenthic community with species typical of water >100m deep such as *Astropecten irregularis* (echinoderm), *Hyalinoecia tubicola* (polychaete), *Echinus* spp. (echinoderm), *Anapagurus laevis* and *Pagurus pubescens* (crustaceans), and the anemone *Hormathia digitata*, as well as species more characteristic of shallower water, including crabs *Hyas coarctatus* and *Pagurus bernhardus*, the whelks *Neptunea antiqua* and *Colus gracilis,* starfish *Asterias rubens* and the hydroid *Hydractinia echinata*. Reiss *et al*. (2010) reported a similar transition between epifaunal communities in the area.

Seabed surveys (as reported by Ithaca Energy 2011) of the nearby Stella and Harrier fields and pipeline corridors (adjacent Block 30/06 and including Block 29/10) indicated the top 3 species in terms of abundance were the polychaetes *P. jeffreysii, Notomastus latericeus* and *Eclysippe cf. vanelli*. The visible fauna is sparse, predominately hermit crab (*Pagurus bernhardus*), sea pens (V*irgularia* *mirabilis*) and lebensspuren related to crustacean burrows, vents and worm casts. Occasional large sea anemones (*Bolocera tuediae*) and soft corals (*Alcyonium* sp.) were observed, usually attached to large relict shells. *Arctica islandica*, a species for which the nearby Fulmar MCZ (see section 4.8) has been designated, has been long recorded in the area, see e.g. Petersen (1977) and Witbaard & Bergman (2003) who report relatively low densities in the wider vicinity compared to areas to the south and north. Sampling studies conducted by Hartley Anderson (2009) and Curtis *et al*. (2015) recorded the presence of low numbers of *A. islandica* in the wider region and *A. islandica* was present in three grab samples collected from nearby Block 30/1c for the Vorlich development pipeline route survey (Fugro 2017); this development also ties into the FPF-1.

Samples from Abigail site and pipeline route surveys (Calesurvey 2012, GEMS 2011a.b) were consistent with circalittoral silty sands and typical of wider parts of the central North Sea, with visible fauna being sparse but significant bioturbation and lebensspuren evident with large numbers of crustacean burrows, worm casts and spatangoid urchin furrows. Sessile fauna included the sea pens *Pennatula phosphorea* and *Virgularia mirabilis*, while mobile fauna included stone crab *Lithodes maja*, starfish *Astropecten irregularis* with juvenile flatfish also present (Calesurvey 2012).

Examples of epifauna typical of the Abigail area are shown in Figure 4.4, also see Appendix 2 which also provides the locations at which each photograph was taken. All images show a seabed of silty sand, with surface flocculant material, and evidence of bioturbation (Calesurvey 2012).

The presence of occasional seapens and evidence of bioturbation suggests the potential presence of the "sea pens and burrowing megafauna communities" habitat. The OSPAR (2010) definition of the habitat is "Plains of fine mud, at water depths ranging from 15–200 m or more, which are heavily bioturbated by burrowing megafauna; burrows and mounds may form a prominent feature of the sediment surface with conspicuous populations of sea-pens". Samples of the sediments at Abigail all contained over 70% sand sized particles (Calesurvey 2013). Seabed photos indicated that the density of seapens (*Virgularia mirabilis* and *Pennatula phosphorea*) was occasional[13] and that although there was evidence of some bioturbation by crustaceans (including rare observations of *Nephrops norvegicus* burrows), echinoids and polychaetes, the sediments were not heavily bioturbated (Calesurvey 2013). On the basis of this evidence it is considered that the sediments around Abigail do not constitute a "sea pens and burrowing megafauna communities" habitat as defined by OSPAR (2010) and expanded on by JNCC (2014) – see also Section 4.8).

Figure 4.4 – Seabed images from the Abigail and wider areas

Seabed image from pipeline route to Stella showing very slightly rippled sandy seabed, with starfish *Astropecten irregularis*

[13] The use of "occasional" used here accords with the definitions in the SACFOR scale


Seabed images from area (HU1 north east of well location) : showing juvenile flat fish and seapen *Pennatula phosphorea*


Area (HU3 south east of well location): showing seapen *Virgularia mirabilis*, starfish *Astropecten irregularis* and small hydroid colony


Area (HU4 (well location) and HU5 north west of well location): showing large *Nephrops* burrow and stone crab
Sources: Calesurvey 2012, GEMS 2010a,b, 2011a,b,c

4.5 Fish, Shellfish and Cephalopods

The demersal fish community of the North Sea was investigated by Callaway *et al*. (2002) and Reiss *et al*. (2010), including sampling at sites in relative proximity to the Abigail Field, while Heessen *et al*. (2015) present an atlas based on international survey results throughout the North Sea and other UK waters. The demersal fish community was dominated by dab (*Limanda limanda*), long rough dab (*Hippoglossoides platessoides*) and the hagfish (*Myxine glutinosa*) with Norway pout (*Trisopterus esmarkii*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), plaice (*Pleuronectes platessa*), grey gurnard (*Eutrigla gurnardus*) and lemon sole (*Microstomus kitt*) also present. Pelagic species include herring (*Clupea harengus*), mackerel (*Scomber scombrus*) and sprat

(*Sprattus sprattus*) (Heessen *et al*. 2015). Seabed photographs from the area show the presence of long rough dab, lemon sole and hagfish (Ithaca Energy 2011).

Ellis *et al*. (2004) recorded the distribution and relative abundance of dogfishes, skates and rays from groundfish surveys around the UK. They found 26 of the more than 50 species of elasmobranch fish known from British waters, of which a few species, including the spurdog and starry ray (*Amblyraja radiata*) were recorded from waters in the area.

Shellfish that may be found in the area include various crustaceans, the Norwegian lobster *Nephrops norvegicus*, the deep-water shrimp (*Pandalus borealis*) and a variety of cephalopod species. Cephalopods are short-lived, fast growing molluscs and are important elements in marine food webs. Among the most frequently recorded species in the central and northern North Sea are: the long-finned squids *Alloteuthis subulata* and *Loligo forbesii*, the short finned squids *Todarodes sagittatus* and *Onychoteuthis banksii*, various bobtail squids and the octopus *Eledone cirrhosa* (DECC 2016).

Block 29/10 is within ICES Rectangle 42F1 and Block 30/6 is within ICES Rectangle 42F2. These rectangles overlap or partially overlap spawning areas for a number of species (see Figures 4.5, 4.6a and b and Table 4.1). In addition Ellis *et al*. (2012) identified low intensity spawning activity for cod (*Gadus morhua*), whiting, plaice and sandeel (*Ammodytes* spp.) in the area. Blue whiting (*Micromesistius poutassou*), herring, mackerel, whiting, sandeel, ling (*Molva molva*), European hake (*Merluccius merluccius*), plaice and monkfish (*Lophius piscatorius*) all use the area, or nearby area as low intensity nursery grounds, with the exception of cod which uses it at high intensity; Coull *et al*. (1998) also identified Norway pout and haddock also using the area as nursery grounds. Fish spawning can vary temporally and spatially; spawning area is not rigidly fixed and fish may spawn earlier or later in the season.

Table 4.1 – Spawning periods for fish and shellfish in ICES Rectangle 42F1 and 42F2

Species	Spawning	Spawning period	Peak spawning	Nursery
Herring*	-	-	-	Low intensity[2]
Mackerel*	✓(High)[1]	May-August[1]	May-July[1]	Low intensity[2]
Blue whiting*	-	-	-	Low intensity[2]
Cod*	✓(Low)[2]	January-April[1]	February-March[1]	High intensity[2]
Haddock	-	-	-	✓
Whiting*	-	-	-	Low intensity[1,2]
Hake	-	-		Low intensity[2]
Norway pout*	✓(High)[1]	January-April[1]	February-March[1]	✓[1]
Ling*	-	-	-	Low intenity[2]
Plaice†	✓(Low)[2]	December-March[1]	January-February[1]	Low intensity[2]
Lemon sole	✓	April-September[1]	-	-
Monkfish*	-	-	-	Low intensity[2]
Sandeel*	✓(Low)[2]	November-February[1]	-	Low intensity[2]
Spurdog*	-	-	-	Low intensity[2]
Spotted ray	-	-	-	Low intensity[2]

*Notes: * Species considered Priority Marine Features in Scottish waters (SNH website)* † Spawning for plaice in ICES rectangle 42F2 only, nursery grounds in both 42F2 and 42F1
Source: [1]Coull et al. (1998), [2]Ellis et al. (2012)

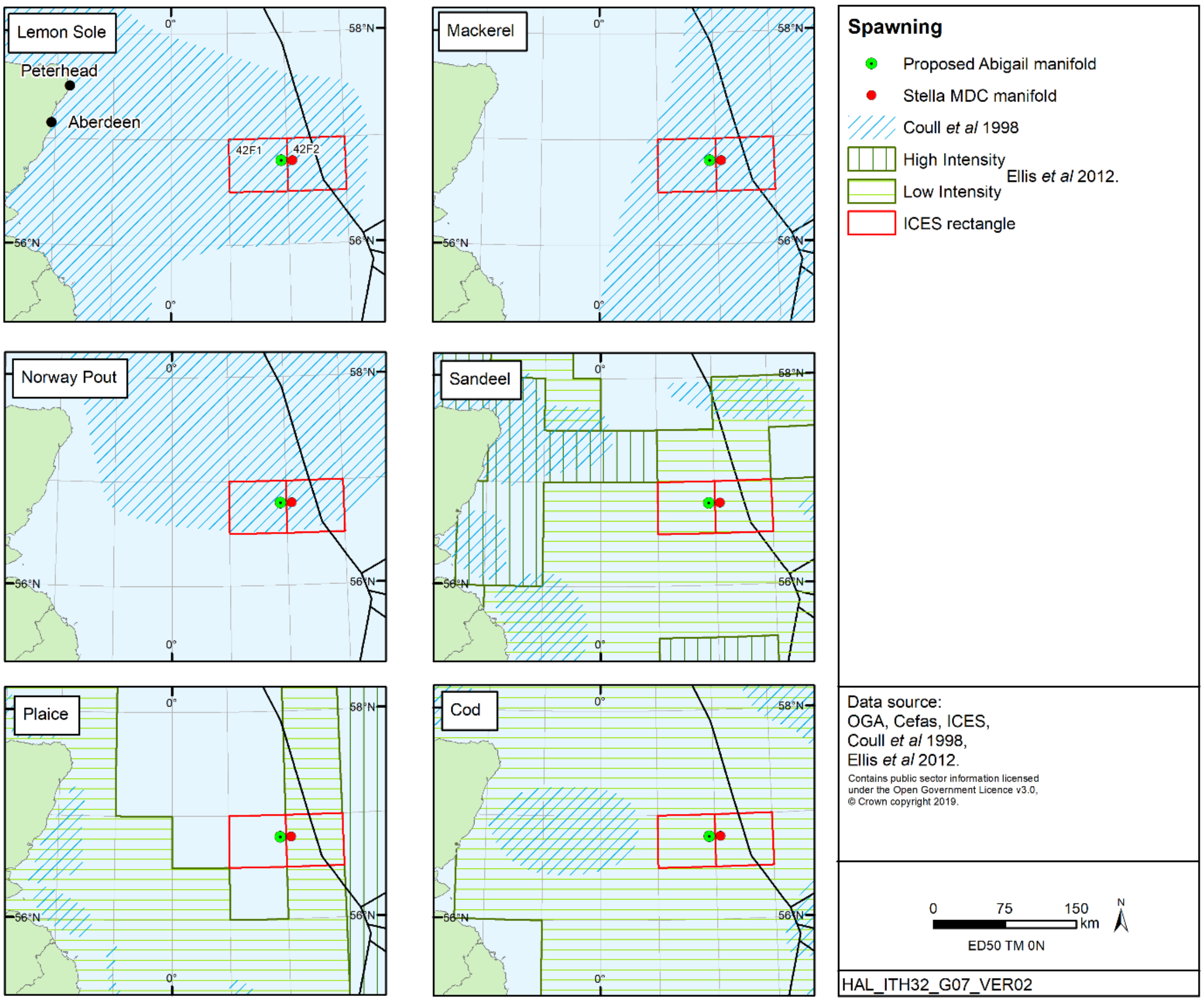
Ellis *et al.* (2012), identifies sandeels as spawning (at low intensity) in the Abigail and wider area; they indicate that low intensity spawning and nursery areas for this species may be present over the majority of the UKCS, and also note that there is no comprehensive data on demersal spawning grounds. Sandeels are a priority marine feature in Scottish waters and are also a protected feature of three Nature

Conservation Marine Protected Areas (NCMPA), the closest of these being Turbot Bank NCMPA 170km to the west of Abigail (see Figure 4.9). Of the five species found in Scottish waters the two most common are *Ammodytes marinus* and *Ammodytes tobianus*. The latter is present from the intertidal to depths of approximately 30m, and therefore is not expected to be present in the Abigail area (Mazik *et al*. 2015). The eggs of sandeels are demersal, and after hatching, the larvae is pelagic for around one to three months, before settling on the seabed. They have an active feeding period (April-September) with *A. marinus* taking a variety of prey including calanoid copepods and fish larvae (MacDonald *et al*. 2019) with larger sandeels also predating polychaete worms.

Of the other five species known to spawn in the area, three are also priority marine features in Scottish waters, mackerel, cod and Norway pout, all of which are pelagic spawners. Mackerel are widely distributed is Scottish waters (Tyler-Walters *et al*. 2016) and are fast growing. North Sea mackerel overwinter in deep water to the east and north of Shetland, before migrating south to spawn (DECC 2016). Eggs are shed in large batches (a 200g female may produce 211,000 eggs per batch) (von Damme & Thorsen 2014) and following spawning, North Sea mackerel will mix with immigrant western stock mackerel in the northern North Sea feeding grounds, (Jansen & Gialson 2013) before returning to over-wintering sites (DECC 2016).

Cod show a preference to spawn in waters with temperatures between 5-7ºC and high salinities, over coarse sand with a low tidal flow (González-Irusta & Wright 2015) and spawning is thought to be more widespread than suggested by Coull *et al*. 1998 (Ellis *et al*. 2012). Larval abundance peaks at fronts and juveniles remain pelagic until they reach a length of 5-7cm. Adult cod aggregate in loose shoals and generally remain within the continental shelf area (Hislop *et al*. 2015). Norway pout are generally found in waters of 80-200 m over sandy and muddy substrates, but also occur in waters of up to 450 m depth in the Norwegian Deep. The majority of the fish spawn for the first time when they are in their second year, but some may do so when they are one year old (Raitt & Mason,1968). During June and July, the pelagic 0-groups (fish within the first year of their lives), are thought to migrate vertically within the water column, spending most of the daylight hours close to the seabed, and moving in to midwater at night (Bailey, 1975).

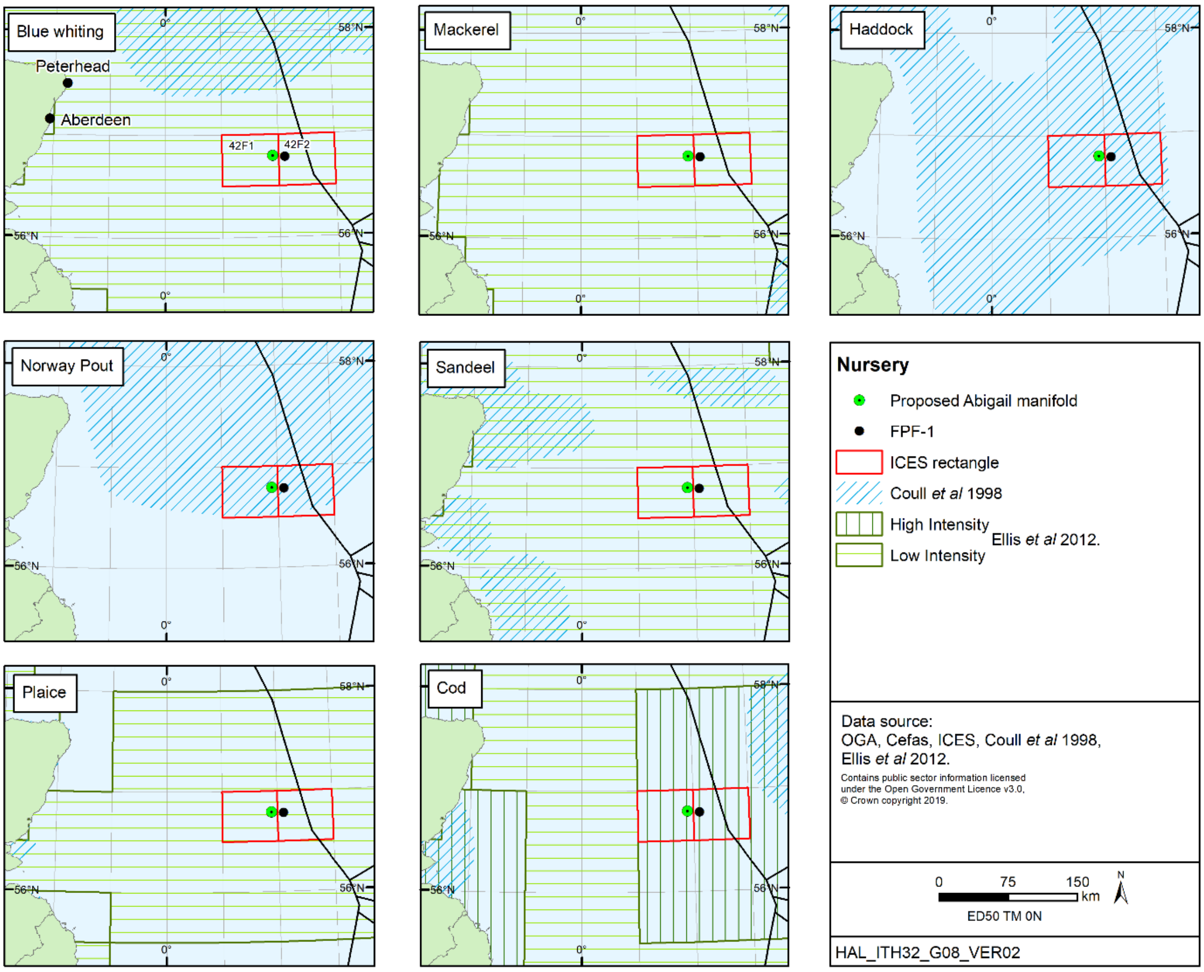
Figure 4.5 – Spawning areas around Abigail



Note: Areas identified in Coull et al (1999) and Ellis et al (2012), not overlapping the ICES rectangles of interest but present in the wider area included here for context.

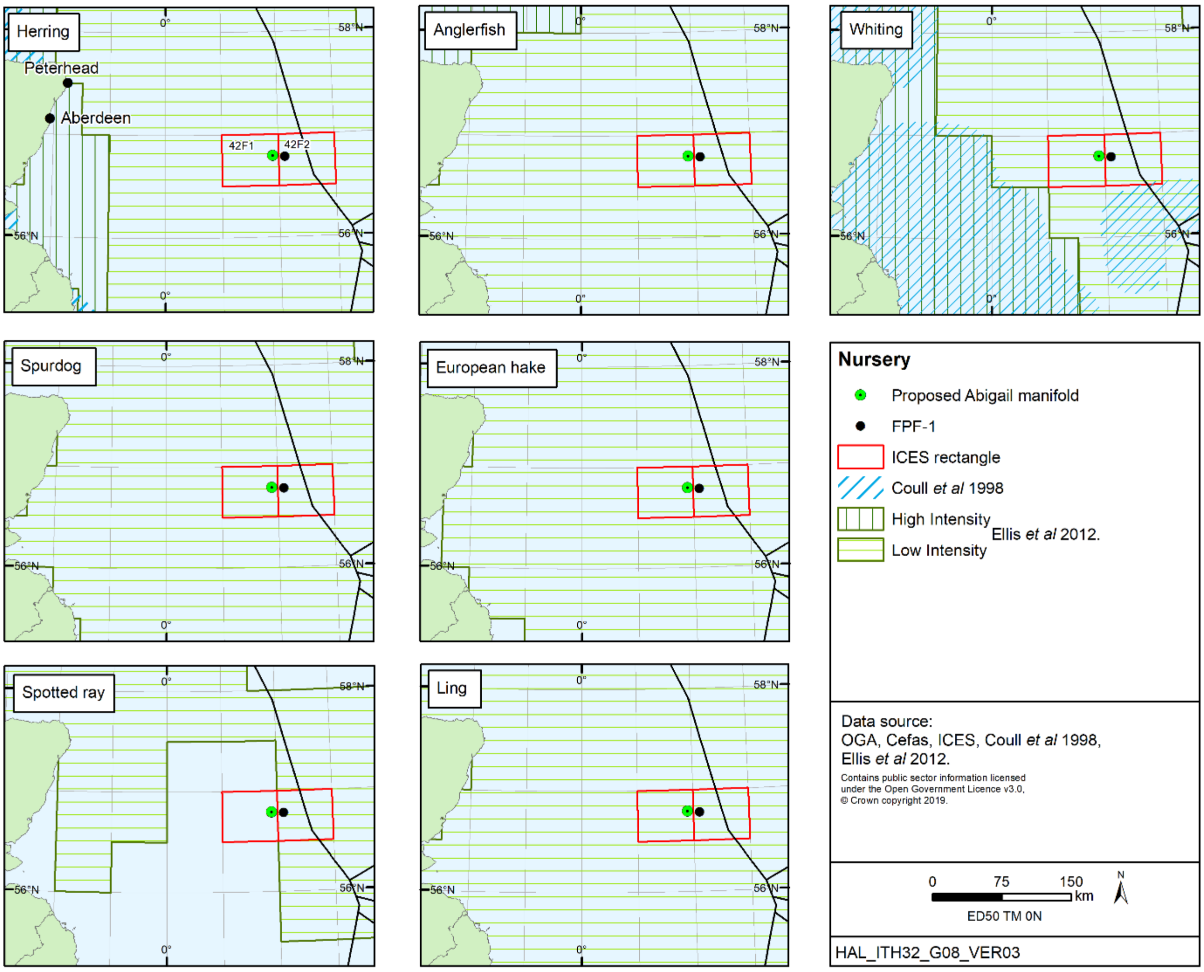
Aires *et al*. (2014), building on the nursery areas identified by Coull *et al*. (1998), identified areas of significant probability of large aggregations of 0-group fish in Scottish waters. No such major aggregations were identified in either 42F1 or 42F2, although haddock, whiting, hake and Norway pout juveniles and to a lesser extent cod and monkfish juveniles, may be present in the wider area (Figure 4.7). The area is not within any known elasmobranch spawning grounds, but is within a low intensity nursery ground for spurdog (*Squalus acanthias*) and spotted ray (*Raja montagui*) (Ellis *et al*. 2012).

Figure 4.6a – Nursery areas around Abigail



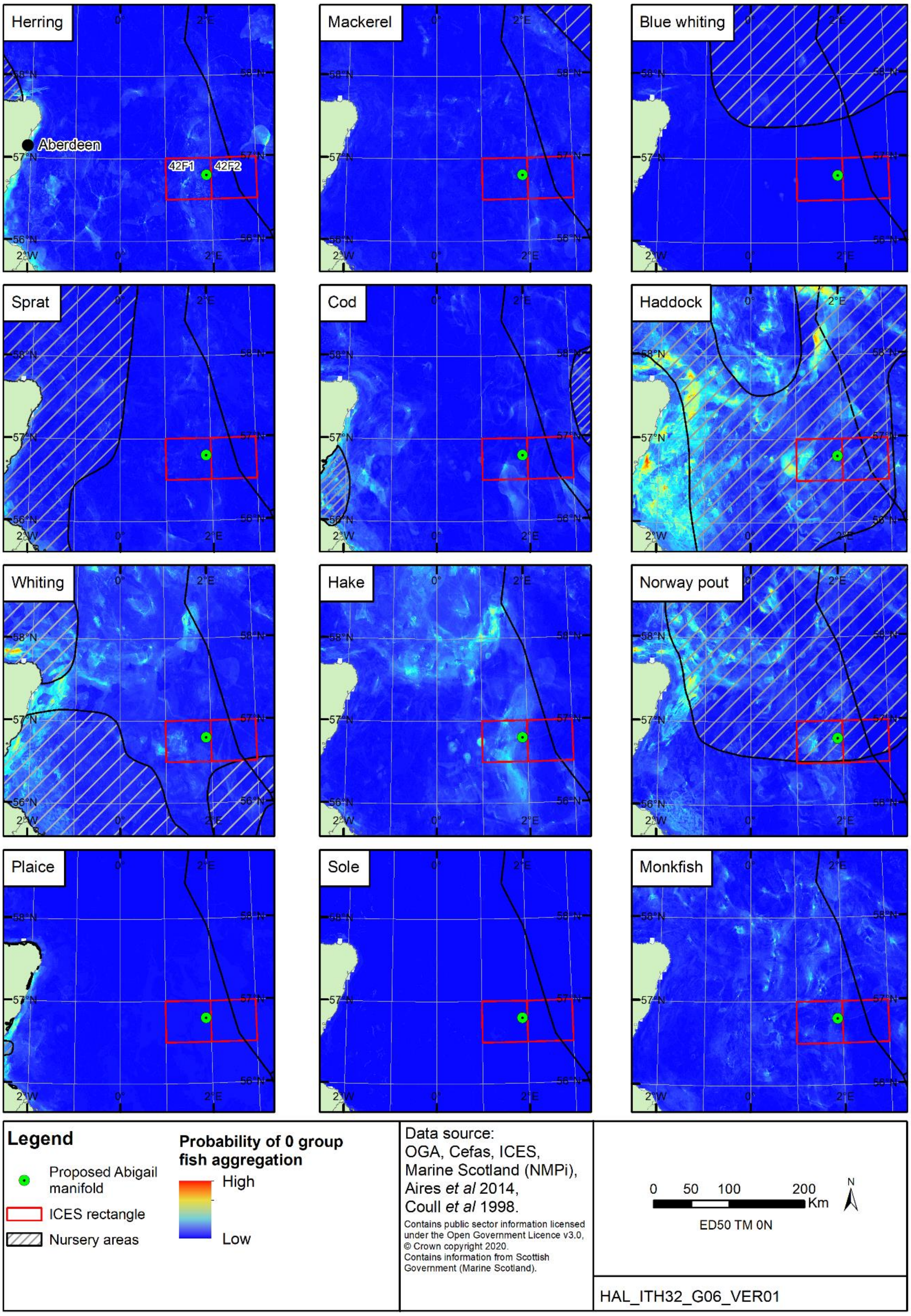
Note: Areas identified in Coull et al (1999), not overlapping the ICES rectangles of interest but present in the wider area included here for context.

Figure 4.6b – Nursery areas around Abigail



Note: Areas identified in Coull et al (1999) and Ellis et al (2012), not overlapping the ICES rectangles of interest but present in the wider area included here for context.

Figure 4.7 – Probability of 0-group fish aggregations



4.6 Birds

The offshore central North Sea may be considered to be of low importance for seabirds in the context of the North Sea as a whole. This is related to the distance from breeding colonies and the availability of prey species, including sandeels (Jensen *et al*. 2011). The species present in the area vary seasonally but may include northern fulmar (*Fulmarus glacialis*), black-legged kittiwake (*Rissa tridactyla*), common guillemot (*Uria aalge*), which are widespread and numerous for much of the year, with northern gannet (*Morus bassanus*), to a lesser extent and at lower densities. Atlantic puffin (*Fratercula arctica*) and razorbill (*Alca torda*) are present in large numbers in late summer (July-September). Herring gull (*Larus argentatus*) and great black-backed gull (*Larus marinus*) have a widespread distribution at sea, particularly in winter. Little auk (*Alle alle*) are present during autumn and winter, when migrating to more southern parts of the North Sea to overwinter.

Later in the year, large numbers of seabirds, particularly common guillemots and razorbills, disperse into the North Sea from breeding colonies, forming large rafts throughout the area. Many of these birds are flightless due to moulting of flight feathers. A summary of the seabird distribution in the area throughout the year is described in Table 4.2.

Table 4.2 – Bird distribution in the Abigail and wider area throughout the year

Month	Summary of distribution
January	Common guillemot and razorbill are abundant close to the coast of eastern Scotland, with herring and great black-backed gulls frequently seen off the eastern coast of Britain. Little auk are present off the east coast of Britain. Although commonest off Shetland, northern fulmars are present in most offshore areas of the northern and central North Sea, with spring migration in January in most years
February	Common guillemot and northern fulmar are widespread throughout the area. Blacklegged kittiwakes present, but are more abundant further north. Some adult northern gannets return to the North Sea in this month, with areas to the south off the north east coast of England most important at this time.
March	Common guillemot, razorbill, black-legged kittiwakes and northern gannets are returning to breeding colonies and although numerous throughout the area, they are beginning to concentrate in coastal waters rather than offshore waters. Highest densities of northern fulmar present off main breeding areas, but many also present in central North Sea. Herring and great black-backed gulls from Norway return north eastwards
April	Breeding season for some seabirds begins at the end of the month; most birds are concentrated around breeding colonies, although in April, female birds (e.g. common guillemots) may be feeding in more offshore areas than during the chick-feeding period. Atlantic puffins retain a more offshore distribution and may be present in the area, while black-legged kittiwake distribution remains similar to that in March.
May	Start of breeding season for most seabirds, therefore numbers offshore in the area will be generally low and probably limited to immature birds and non-breeders. Birds still forage at distances further from the colonies than during chick rearing.
June	Peak of breeding season. Majority of seabird sightings are in coastal areas. Offshore abundance of all species is generally low. Towards the end of June, large numbers of seabirds leave colonies and disperse out to sea.
July	The breeding season for some seabird species comes to an end in July and adult and juvenile birds start to leave colonies, out into the North Sea where they form moulting flocks, and some to move south to wintering grounds. The area of the Shetland Basin, over some of the banks of the central North Sea and off the Moray Firth and Aberdeenshire coasts support larger concentrations of birds than at any other time of the year. Birds widely dispersed so many areas of the North Sea hold vulnerable populations.
August	The highest number of auks occurs off east coast of Scotland and northern England. Atlantic puffins disperse rapidly from colonies. Young northern gannet start to leave and are flightless for a short period with areas close to colonies containing vulnerable concentrations. Black-legged kittiwakes leave colonies and move to similar areas as the larger auks. Northern fulmar are numerous and widespread throughout the area.

Month	Summary of distribution
September	Auks spread further out into the North Sea and the area is still important for common guillemot, razorbill and also black-legged kittiwake. Northern gannets disperse into the area and great skuas become widespread in the North Sea as they leave their breeding colonies and move south. Great black-backed gulls move across the North Sea from Norway and found off the east coast of England. Northern fulmars numerous and widespread across most of the northern and central North Sea. Peak autumn migration of northern gannet.
October	Southwards shift in common guillemot and razorbill populations, however the inshore band off Scotland and northern England still hold the largest numbers. Atlantic puffin found in offshore areas, with areas in central North Sea holding the most birds. Blacklegged kittiwake distribution moves south and large numbers found off the Moray Firth. Northern fulmar remain common.
November	The area remains relatively important for common guillemot and razorbill, although these are now widely dispersed across the North Sea. The east coast of Scotland holds relatively few birds compared to other times of the year, with the exception of the Firth of Forth and its approaches. Flocks of black-legged kittiwake are found around fishing fleets on the Fladen Ground and several winter visitors become more common; an obvious change is the arrival of gulls in offshore waters, with herring gulls from Norway moving south-west across the North Sea to areas including the Fladen Grounds.
December	Large numbers of common guillemot close to coasts with the most important area being the southern shore of the Moray Firth. Main area for Atlantic puffins is Outer Silver Pit, but also present in central North Sea, off the north-east and east coasts of England and Scotland. Northern gannets remain present in reduced numbers.

Source: Tasker & Pienkowski (1987), Skov et al. (1995), Tasker (1996), Furness (2015), Thaxter et al (2012), Woodward et al. (2019)

Vulnerability to Oil Pollution

The vulnerability of seabird species to oil pollution at sea is dependent on a number of factors and varies considerably throughout the year. The Offshore Vulnerability Index (OVI) (Williams *et al*. 1994) was updated by Webb *et al.* (2016) as part of a revised index, the Seabird Oil Sensitivity Index (SOSI).

The SOSI (Webb *et al*. 2016)[14] based on previous indices by Williams *et al*. (1994) and method refining by Certain *et al*. (2015) using seabird survey data collected from 1995-2015 from a variety of survey techniques (boat-based, visual aerial and digital video aerial). This survey data was combined with an individual seabird species sensitivity index value, these values being based on a number of factors considered to contribute towards a species sensitivity to oil pollution such as habitat flexibility (a species ability to locate to alternative feeding sites), adult survival rate and potential annual productivity. The SOSI is presented as a series of monthly UKCS block gridded maps, with each block containing a score on a scale of low to extremely high; these scores indicate where the highest seabird sensitivities might lie, if there were to be a pollution incident.

The seabird sensitivity in Blocks 29/10 and 30/06 and the wider area is low, with the exception of the surrounding Blocks 29/09 and 30/12, where sensitivity is medium for June and February respectively; it should be noted that data gaps are indicated for a high proportion of months (Table 4.3, Figure 4.8). Where this is the case, JNCC guidance describes a method to help reduce the extent of coverable gaps (JNCC 2017). For Abigail, the first of these steps, using data from adjacent months, has populated most of the remaining months (including May and March for Blocks 29/09 and 30/12) and these have been marked in red in Table 4.3; the months with coverage have values in black. Of those remaining after step 1 has been applied, none could be populated using step 2 (data from adjacent Blocks) and these have been denoted by N and highlighted yellow; three of these remain for Block 29/10 (October, November and December) and four remain for 30/06 (April, October, November and December)

[14] See JNCC: http://jncc.defra.gov.uk/page-7373.

Table 4.3 – Seabird oil sensitivity in and around the Abigail Development

Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
29/04	5	5	5	5	5	5	5	5	5	5	N	N
29/05	5	5	5	5	5	5	5	5	5	5	N	N
30/01	5	5	5	N	5	5	5	5	5	N	N	N
30/02	5	5	5	N	5	5	5	5	5	N	N	5
29/09	5	5	5	5	4	4	5	5	5	5	N	5
29/10	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**N**	**N**	**N**
30/06	**5**	**5**	**5**	**N**	**5**	**5**	**5**	**5**	**5**	**N**	**N**	**N**
30/07	5	5	5	N	5	5	5	5	5	N	N	5
29/14	5	5	5	5	5	5	5	5	5	5	N	5
29/15	5	5	5	5	5	5	5	5	5	N	N	N
30/11	5	5	5	5	5	5	5	5	5	N	N	N
30/12	5	4	5	5	5	5	5	5	5	N	N	5

Notes: Text in red is extrapolated based on JNCC (2017)

1 = Extremely high | 2 = Very high | 3 = High | 4 = Medium | 5 = Low | N = No coverage

Figure 4.8 – Monthly seabird oil sensitivity index scores

Note: Values presented in Webb et al. (2016) are the median, minimum and maximum of the smoothed SOSI scores in each oil licence block, the median value represents the central point of the smoothed values calculated for any given block and represent the most likely assessment of seabird sensitivity to oil pollution. Source: Webb et al. (2016)

4.7 Marine Mammals

The central North Sea has a moderate diversity and density of cetaceans, with a general trend of increasing diversity and abundance of cetaceans with increasing latitude (Reid *et al*. 2003). Harbour porpoise (*Phocoena phocoena*) are frequently sighted throughout the central North Sea area. While present throughout the year, peak numbers are generally recorded in summer months from June to October. White-beaked dolphins (*Lagenorhynchus albirostris*), although generally less abundant, are also sighted in the area and throughout the year, most frequently from July to October. Low numbers of Atlantic white-sided dolphins (*Lagenorhynchus acutus*) have been recorded in the area, with sightings in the northern and central North Sea most frequent from June to September. During summer months, minke whales (*Balaenoptera acutorostrata*) are widely distributed throughout the central and northern North Sea, particularly in the west (see Table 4.4).

Table 4.4 – Seasonal sightings of marine mammals in and around the Abigail Development area

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Atlantic white-sided dolphin						3	3	3	3			
Harbour porpoise						2	2	2	2	2		
Minke whale						3	3	3				
White-beaked dolphin							3	3	3	3		

Notes: Information on seasonal abundance of cetaceans is limited, so this table should be regarded as indicative of general trends.

1 = high density 2 = moderate density 3 = low density

Source: Reid et al. (2003)

A small, largely resident population of bottlenose dolphins (*Tursiops truncatus*) exists off the east coast of Scotland. They typically range in coastal waters from the Moray Firth to the Firth of Forth; sightings are most frequent within 15km of the coast in the inner Moray Firth (Thompson *et al*. 2011), although areas of persistent high use also occur along the southern coast of the Moray Firth, off the east coast between Aberdeen and Montrose and around the mouth of the Tay (Culloch & Robinson 2008, Cheney *et al*. 2013; Quick *et al*. 2014). Observations of bottlenose dolphins in offshore waters of the central and northern North Sea are rare (Reid *et al*. 2003, Thompson *et al*. 2011).

Hammond *et al*. (2017) provides the latest information on cetacean densities in the North Sea from the SCANS-III survey conducted in summer 2016; the Abigail area lies within survey stratum 'Q'. Estimated densities (animals per km^2) of surveyed species in this area were: 0.333 for harbour porpoise and 0.007 for minke whales. A small number of white-beaked dolphins were observed in the north of stratum 'Q' (some 100km north of Abigail), but in insufficient numbers to estimate abundance; waters to the north-west supported higher densities, with an average of 0.243 animals per km^2 across the adjacent stratum 'R' (Hammond *et al*. 2017). No bottlenose, common, Risso's, or white-sided dolphins were observed in stratum 'Q' during the surveys. These observed densities are relatively low for the species concerned, particularly compared to nearshore waters or, for the harbour porpoise, designated sites such as the Southern North Sea SAC.

Model-based assessments of the at-sea distribution of grey and harbour seals around the UK and Ireland have been derived from satellite tagging data and haul-out count data, including several dozen seals tagged at colonies on the east coast of Scotland and Orkney (Jones *et al*. 2015; Russell *et al*. 2017).

Results show that grey seals use offshore areas (up to 100km from the coast) connected to their haul-out sites by prominent corridors, while harbour seals primarily stay within 50km of the coastline (Jones *et al*. 2015). Models of marine usage highlight the importance of Scottish territorial waters to both species. Off the northeast coast of Scotland, higher densities of grey seals radiate out from colonies and haul-outs north of Aberdeen, the inner Moray Firth and Orkney; for harbour seals, the majority of animals in water of north east Scotland occur within the inner Moray firth and Orkney inshore waters. Models show both species to be present in low numbers in the Abigail area, with an estimated <1 harbour and grey seal per 5x5km grid cell (Russell *et al.* 2017).

The JNCC and SNH have developed a list of Priority Marine Features (PMFs) in Scotland to help focus future research, planning and conservation. The list, adopted in 2014, includes grey and harbour seals and most species of cetaceans occurring in UK waters, including all those species mentioned above which may be present in the Abigail area (Tyler-Walters *et al.* 2016).

4.8 Conservation Sites

The proposed development area is relatively distant (approximately 232km) from the closest coastal conservation sites (Figure 4.9 – these sites are also listed in Table 4.5 along with their distance from Abigail and their qualifying features). These include a number of sites (e.g. Special Protection Areas (SPAs), Ramsars) which are of importance for coastal seabird or waterbird populations, including the Ythan Estuary, Sands of Forvie and Meikle Loch, Loch of Strathbeg, Buchan Ness to Collieston Coast and Fowlsheugh. Special Areas of Conservation (SACs) along the north east coast feature a number of qualifying coastal habitats (e.g. Annex I embryonic shifting dunes, vegetated sea cliffs of the Atlantic and Baltic coasts) – for instance at Buchan Ness to Collieston and Sands of Forvie.

The closest offshore Natura 2000 site is the Dogger Bank SAC, *ca*.157km to the south. The site is designated for Annex I sandbanks which are slightly covered by sea water all the time.

Some species listed on Annex II have been observed in the area, including grey seal, harbour seal (albeit infrequently and in small numbers) and harbour porpoise. Six sites were submitted to the EU as SACs for supporting persistent high densities of harbour porpoise; the closest to the Abigail area is the Southern North Sea SAC, which lies >180km to the south. European species protected under Annex IV of the habitats directive include all cetaceans and Atlantic sturgeon, and in addition, a number of species listed on the OSPAR List of Threatened and/or Declining Species and Habitats (see below) may also occur in or around the area, (see below) including the sea pens *Virgularia mirabilis* and *Pennatula phosphorea*, bird species including lesser black-backed gull (*Larus fuscus*), as well as the harbour porpoise and a number of fish species including salmon (*Salmo salar*) and sharks including porbeagle (*Lamna nasus*).

The Scottish Government has designated 31 Nature Conservation Marine Protected Areas (NCMPAs) under the *Marine (Scotland) Act 2010* (as amended) and *Marine and Coastal Access Act 2009* (as amended). The closest NCMPA is the East of Gannet and Montrose Fields area, which is 22km to the northwest (Figure 4.9, see also Table 4.5). This area is identified as having protected features of offshore deep sea muds and *Arctica islandica*. The closest NCMPA which is designated for a marine mammal feature (minke whale), is the Southern Trench proposed NCMPA, which lies 212km to the north-west.

The *Marine and Coastal Access Act 2009* (as amended) enables the designation and protection of Marine Conservation Zones (MCZs) in English and Welsh waters. The closest offshore MCZ is Fulmar which lies 20km south and is designated for the presence of subtidal mixed sediment, subtidal sand, subtidal mud and *Arctica islandica* aggregations.

Figure 4.9 – Designated sites in and around the Abigail Development area

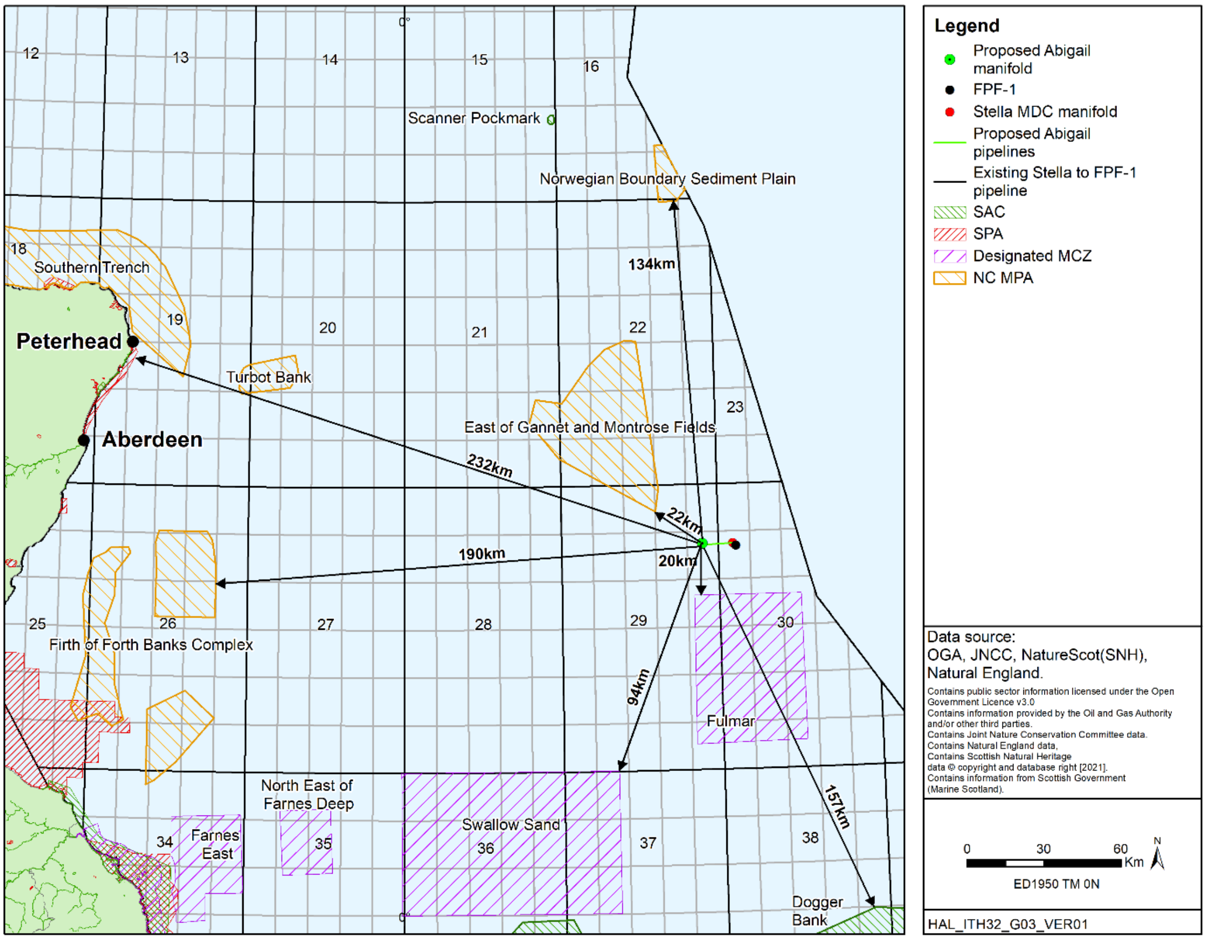


Table 4.5– Conservation sites in relation to the Abigail Development

Site	Feature Present[1]	Distance to Abigail (km)	Qualifying Feature
Special Protection Area (SPA) – all site in excess of 200km from Abigail			
Buchan Ness to Collieston Coast	B	232	**Qualifying feature:** Breeding seabird assemblage
Ythan Estuary, Sands of Forvie, and Meikle Loch	B, W	236	**Qualifying feature:** Common tern, little tern, pink-footed goose, wintering waterbird assemblage
Fowlsheugh	B	248	**Qualifying feature:** Common guillemot, black-legged kittiwake, breeding seabird assemblage
Outer Firth of Forth and St. Andrews Bay Complex	B, W, P	233	**Qualifying feature**: Red-throated diver, Slavonian grebe, little gull common tern, Arctic tern, common eider, European shag, northern gannet, wintering waterbird assemblage, breeding seabird assemblage non-breeding seabird assemblage.
Special Areas of Conservation (SAC) – all sites in excess of 150km from Abigail			
Buchan Ness to Collieston Coast	YR	235	**Qualifying feature:** Vegetated sea cliffs of the Atlantic and Baltic coasts, vegetated sea cliffs
Sands of Forvie	YR	240	**Qualifying feature:** Lime-deficient dune heathland with crowberry, shifting dunes, humid dune slacks, shifting dunes with marram
Dogger Bank	YR	157	**Qualifying feature:** Sandbanks which are slightly covered by seawater all the time

Site	Feature Present[1]	Distance to Abigail (km)	Qualifying Feature
Southern North Sea	YR	155	**Qualifying feature:** Harbour porpoise
Nature Conservation Marine Protected Areas (NCMPA)			
Southern Trench	YR, M	213	**Qualifying feature:** Proposed area for Burrowed mud, fronts, minke whale and shelf deeps, Quaternary of Scotland – sub-glacial tunnel valleys and moraines, submarine mass movement – slide scars
Firth of Forth Banks Complex	YR	190	**Qualifying feature:** *Arctica islandica* aggregations, offshore subtidal sands and gravels, shelf banks and mounds, moraines representative of Wee Bankie Key Geodiversity Area
Turbot Bank	YR	171	**Qualifying feature:** Sandeels
Norwegian-boundary Sediment Plain	YR	134	**Qualifying feature:** *Arctica islandica* aggregations
East of Gannet and Montrose Fields	YR	22	**Qualifying feature:** Offshore deep sea muds, *Arctica islandica* aggregations
Marine Conservation Zone (MCZ)			
North East of Farnes Deep	YR	178	**Qualifying feature:** Subtidal coarse sediment, subtidal sand, subtidal mixed sediments, subtidal mud, *Arctica islandica* aggregations
Farnes East	YR	209	**Qualifying feature:** Moderate energy circalittoral rock, subtidal coarse sediment, subtidal sand, subtidal mud, subtidal mixed sediments, sea-pen and burrowing megafauna communities, *Arctica islandica* aggregations
Swallow Sand	YR	94	**Qualifying feature:** Subtidal coarse sediment, Subtidal sand, North Sea glacial tunnel valley
Fulmar	YR	20	**Qualifying feature:** Subtidal sand, Subtidal mud, Subtidal mixed sediments, *Arctica islandica* aggregations.

Notes: [1]B=Breeding, W=Wintering, P=Passage, R=Resident, YR= Year round
Sources: JNCC website, Natural England website, NatureScot website

OSPAR Threatened and/or Declining Habitats

Several marine species occurring in the central and northern North Sea are of conservation concern. These are listed in a variety of international and national documents, including the OSPAR Initial List of Threatened and/or Declining Species and Habitats. This includes the habitat "Sea pens and burrowed megafauna communities" (SPBMC) defined (OSPAR 2010) as:

Plains of fine mud, at water depth ranging from 15-200m or more, which are heavily bioturbated by burrowing megafauna; burrows and mound may form a prominent feature of the sediment surface with conspicuous populations of sea pens, typically Virgularia mirabilis and Pennatula phosphorea. The burrowing crustaceans present may include Nephrops norvegicus, Calocaris macandreae or Callianassa subterranea. The burrowing activity of megafauna creates a complex habitat, providing deep oxygen penetration. This habitat occurs extensively in sheltered basins of fjords, sea lochs, voes and in deeper offshore waters such as the North Sea and Irish Sea basins.

The OSPAR definition has been interpreted (JNCC 2014) to mean that sea pens may or may not be present (e.g. may have been removed by anthropogenic activity), that any burrowed areas of mud would be deemed to be this habitat and, while the habitat predominately occurs in fine mud sediments, examples of the habitat have been identified in areas of sandy muds; regardless of the grain size composition of the sediment, where there is clear evidence of the relevant biological assemblages (burrowing megafauna), such habitats can be classified as "Sea-pen and burrowing megafauna communities". JNCC (2014) also states that the OSPAR agreement notes that the habitat is 'heavily bioturbated by burrowing megafauna with burrows and mounds typically forming a prominent feature of the sediment surface').

In the consideration of the presence or otherwise of the OSPAR habitat "Sea pens and burrowing megafauna communities" emphasis has been placed on the nature of the burrows and the scale of ejecta mounds since the burrowing megafauna is the essential defining characteristic of the habitat (rather than the seapens).

The surveys in and around the Abigail area have identified the presence of sea pens (*Pennatula phosphorea* and *Virgularia* sp.) and some burrows and mounds, including of *Nephrops* (at a rare frequency according to the SACFOR scale). However, since burrows with conspicuous mounds are not a prominent feature of the sediments it is concluded that the habitat is not consistent with the OSPAR habitat "Sea pens and burrowing megafauna communities".

4.9 Other Users of the Offshore Environment

Offshore Energy

Oil and Gas

Abigail is in a relatively mature oil and gas province (Figure 4.10), and lies close to a number of established oil and condensate fields including the Stella and Harrier fields, both of which tie into the Ithaca (Stella) FPF-1 installation.

The Vorlich field to the north is also served by the FPF-1. The FPF-1 has an existing 500m safety exclusion zone, as does the Stella main drill centre, Stella north drill centre, and the Harrier and Vorlich drill centres from which vessels are already excluded. There are also a number of previous wells drilled in the area (Figure 4.11). After the FPF-1, the closest surface infrastructure to Abigail is the Jasmine platform, *ca*. 20km away in Block 30/06.

The pipeline system of the proposed development will cross the Greater Stella 10" gas export pipeline (PL3078), while the nearest pipeline to Abigail is the Shearwater to Bacton (SEAL) pipeline, located *ca*.2km west of the Abigail well. Twelve wells have been drilled across Block 29/10, with 38 in Block 30/06, these including the wells associated with the Stella and Harrier developments.

Renewable Energy

There is no renewable energy associated infrastructure within the Abigail and wider area, with the closest lease area being >200km to the west (Hywind demonstration site). In 2020, the Sectoral Marine Plan for Offshore Wind Energy was published by the Scottish Government; this builds on the plans issued in 2011 and 2013 and which now includes opportunities for development within deeper waters (Scottish Government 2020). The plan aims to identify "sustainable plan options" (areas) for the future development of commercial-scale offshore wind energy. The closest plan options to Abigail are E1 and E2, these are some 96km and 102km from Abigail respectively (Figure 4.10)

Figure 4.10 – Oil and gas infrastructure and renewable energy

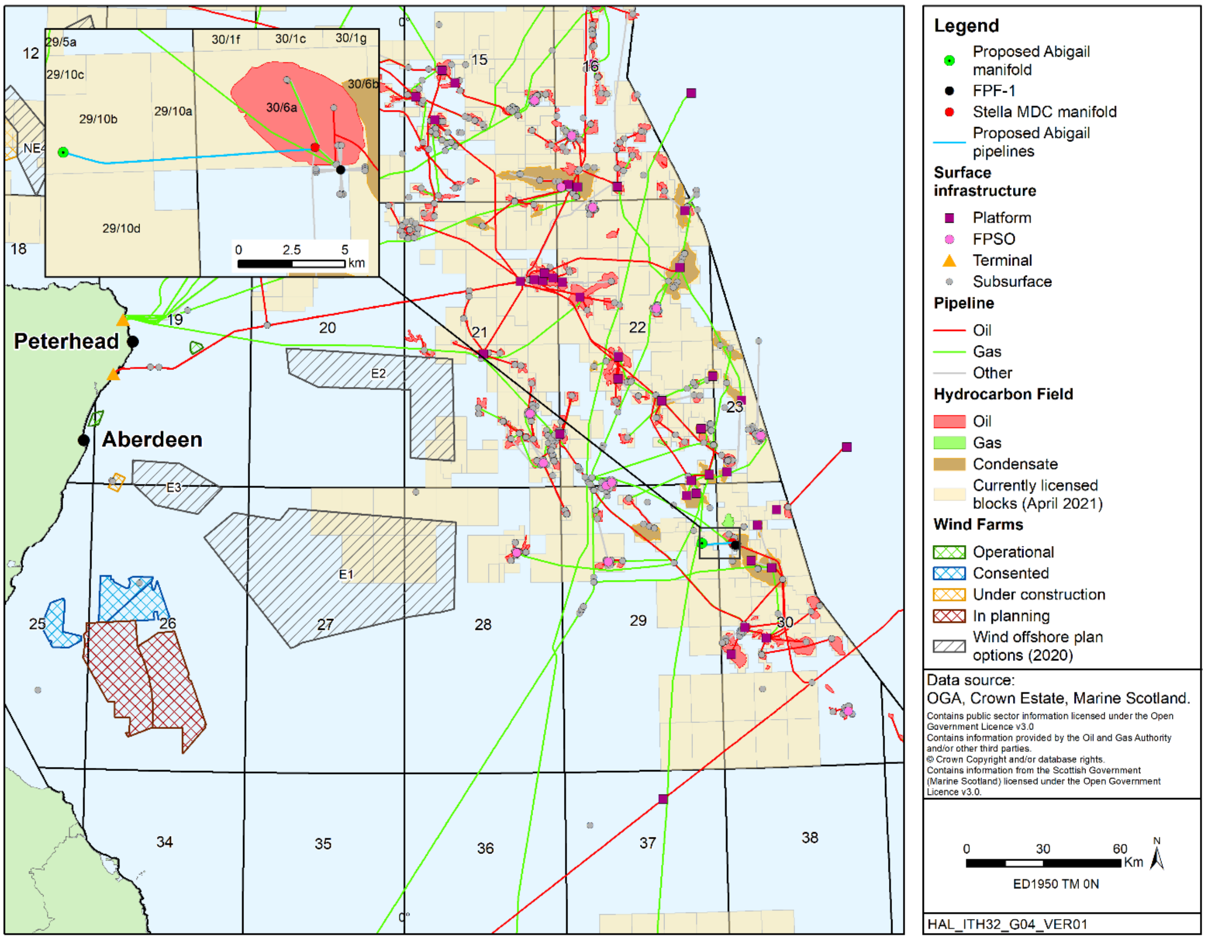
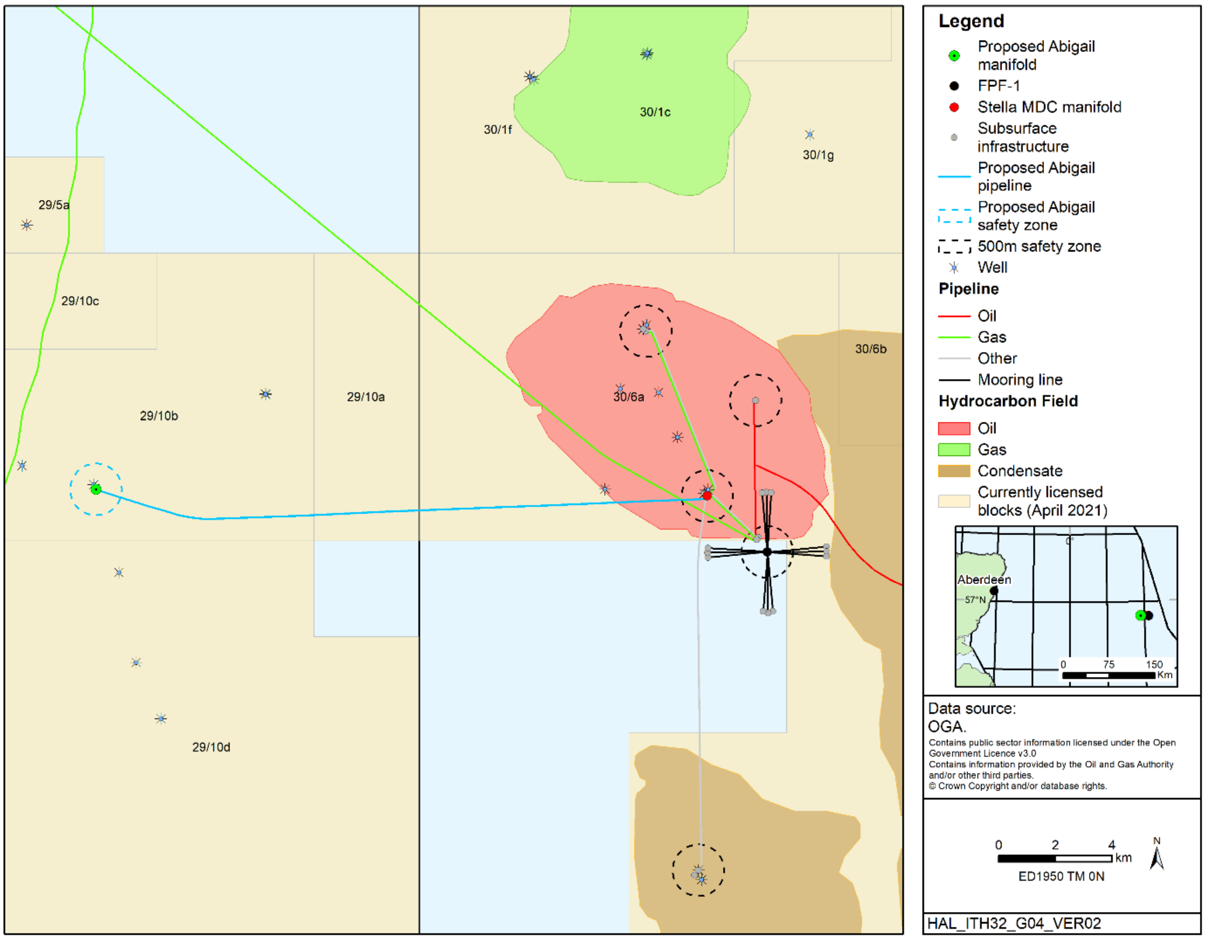


Figure 4.11 – Proposed Abigail development, proposed and existing exclusion zones



Fisheries

ICES rectangles are subareas of larger ICES sub-divisions and are used for fisheries data recording and management. The central and some of the northern North Sea lies in ICES sub-division IVb and Block 29/10 lies within ICES rectangle 42F1 and 30/06 within 42F2.

Table 4.4 lists the weight and first sale value of fish and shellfish landings into UK ports from these rectangles, over the period 2017-2019.

Table 4.4 – Landings (quantity and value)[1,2] by species type, 2017-2019

Species type	2017		2018		2019	
	Liveweight (tonnes)	Value (£)	Liveweight (tonnes)	Value (£)	Liveweight (tonnes)	Value (£)
ICES Rectangle 42F1						
Demersal	67	112,475	53	75,049	100	121,311
Pelagic	1	1,301	27	10,620	0	349
Shellfish	140	602,735	115	484,344	242	842,305
Total	**208**	**716,511**	**195**	**570,013**	**342**	**963,965**
UK Total[3]	**565,633**	**724,854,085**	**555,570**	**764,993,803**	**493,075**	**767,931,934**
% of UK total	**0.04**	**0.1**	**0.04**	**0.07**	**0.07**	**0.1**

Species type	2017		2018		2019	
	Liveweight (tonnes)	Value (£)	Liveweight (tonnes)	Value (£)	Liveweight (tonnes)	Value (£)
ICES Rectangle 42F2						
Demersal	12	18,785	D	D	19	32,600
Pelagic	0	75	D	D	0	0
Shellfish	1	3,249	D	D	0	449
Total	**13**	**22,109**	**-**	**-**	**19**	**33,049**
UK Total[3]	**565,633**	**724,854,085**	**555,570**	**764,993,803**	**493,075**	**767,931,934**
% of UK total	**0.002**	**0.003**	**-**	**-**	**0.004**	**0.004**
Total across both ICES rectangles						
ICES Total	**221**	**738,620**	**195**	**570,013**	**361**	**997,014**
UK Total[3]	**565,633**	**724,854,085**	**555,570**	**764,993,803**	**493,075**	**767,931,934**
% of UK Total	**0.04**	**0.1**	**0.04**	**0.07**	**0.07**	**0.1**

Note: [1]Landings by UK vessels into the UK and abroad and foreign vessels into the UK. [2]D = disclosive [3]Total from summing all landings and all values from all relevant rectangles in that year.
Source: Scottish Government website (Marine Scotland data), accessed May 2021

Over this period, reported landings for 42F1 were dominated by shellfish, followed by demersal fish species. Shellfish catches entirely comprised *Nephrops* and squid. Landings from 42F2 (2018 being disclosive) were dominated by demersal fish (plaice and lemon sole), then shellfish; opposite to that seen in rectangle 42F1.

Logbooks submitted by fishermen allow an examination of the gears operated and seasonal patterns in fishing effort (Table 4.5) Over the entire period effort was low for 42F2. There is minimal fishing activity in 42F1, and data for several months across the period is disclosive; an increase in activity, in the area, has been seen in 2019 (personal comments SFF), and this can be seen below, with an increase in the number of months with activity and an overall increase in total effort compared to that seen in 2018 and 2017.

Table 4.5 – Number of days fished per month (all gears) in ICES rectangles 42F1 and 42F2, 2017-2019

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ICES Rectangle 42F1													
2017	51	D	D	D	D	43	34	72	D	D	D	D	**222**
2018	98	11	D	D	D	D	D	42	D	D	D	31	**210**
2019	45	9	42	24	D	D	23	D	18	23	42	17	**251**
ICES Rectangle 42F2													
2017	D	0	0	0	D	D	0	D	0	0	0	0	**16**
2018	0	0	0	0	D	D	D	D	0	0	0	0	**-**
2019	0	D	0	0	D	D	D	0	0	0	D	0	**13**

Note: Monthly fishing effort by UK vessels >10m; 'days fished' includes time travelling within rectangles; green = 0-19 days fished, yellow = 20-39, orange = 40-59, red = ≥60, D = disclosive data.
Source: Scottish Government website (Marine Scotland data), accessed May 2021

Figures 4.11a and 4.11b illustrate the landings weight and value in 42F1 and 42F2 and surrounding ICES rectangles for 2015-2019 for each species type, with landings from 42F1 showing a degree of annual variability; negative values (42F2) indicate data that cannot be disclosed for reasons of confidentiality.

Figure 4.11a – Landings weight for 42F1 and surrounding rectangles, 2015-2019

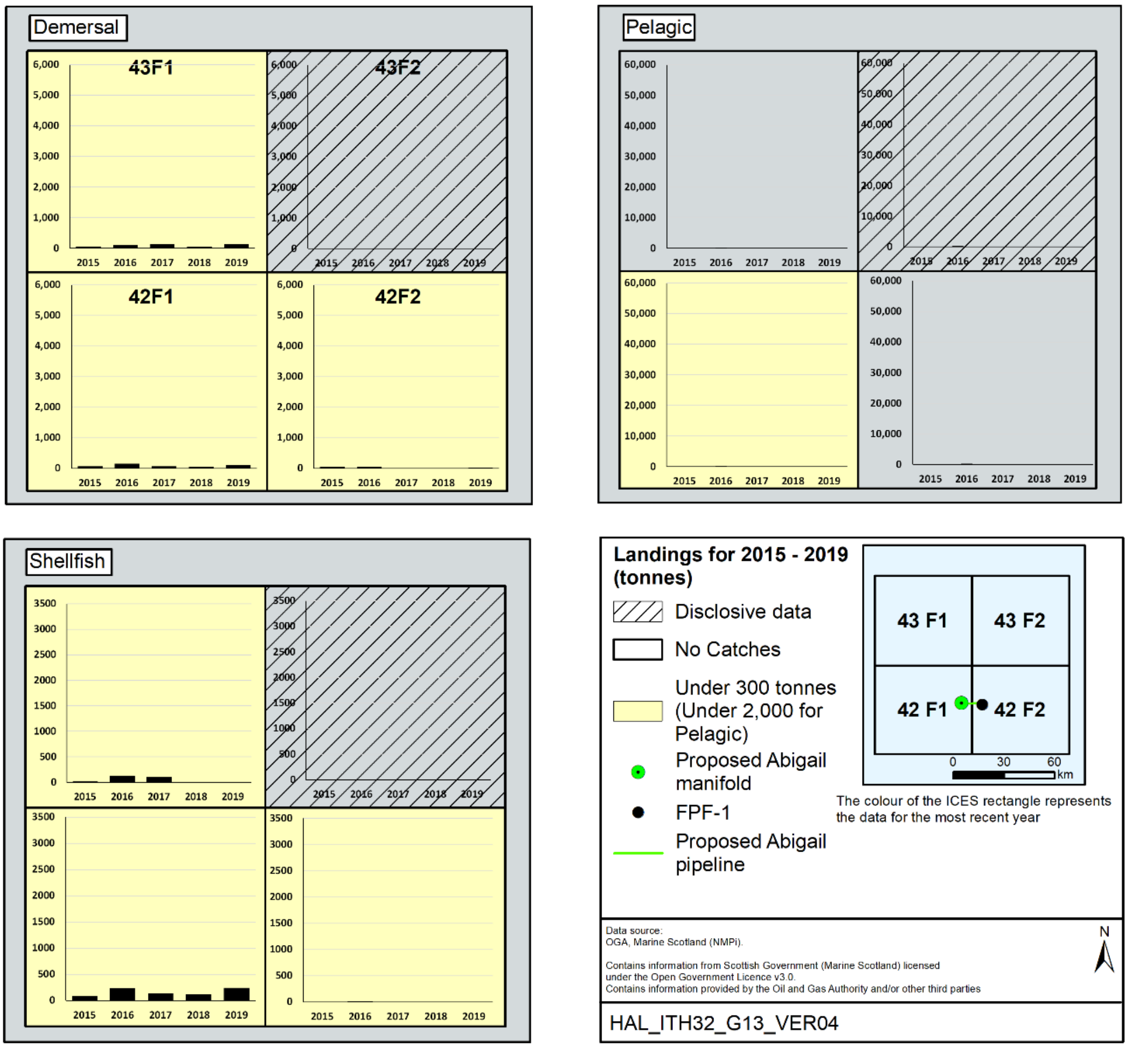
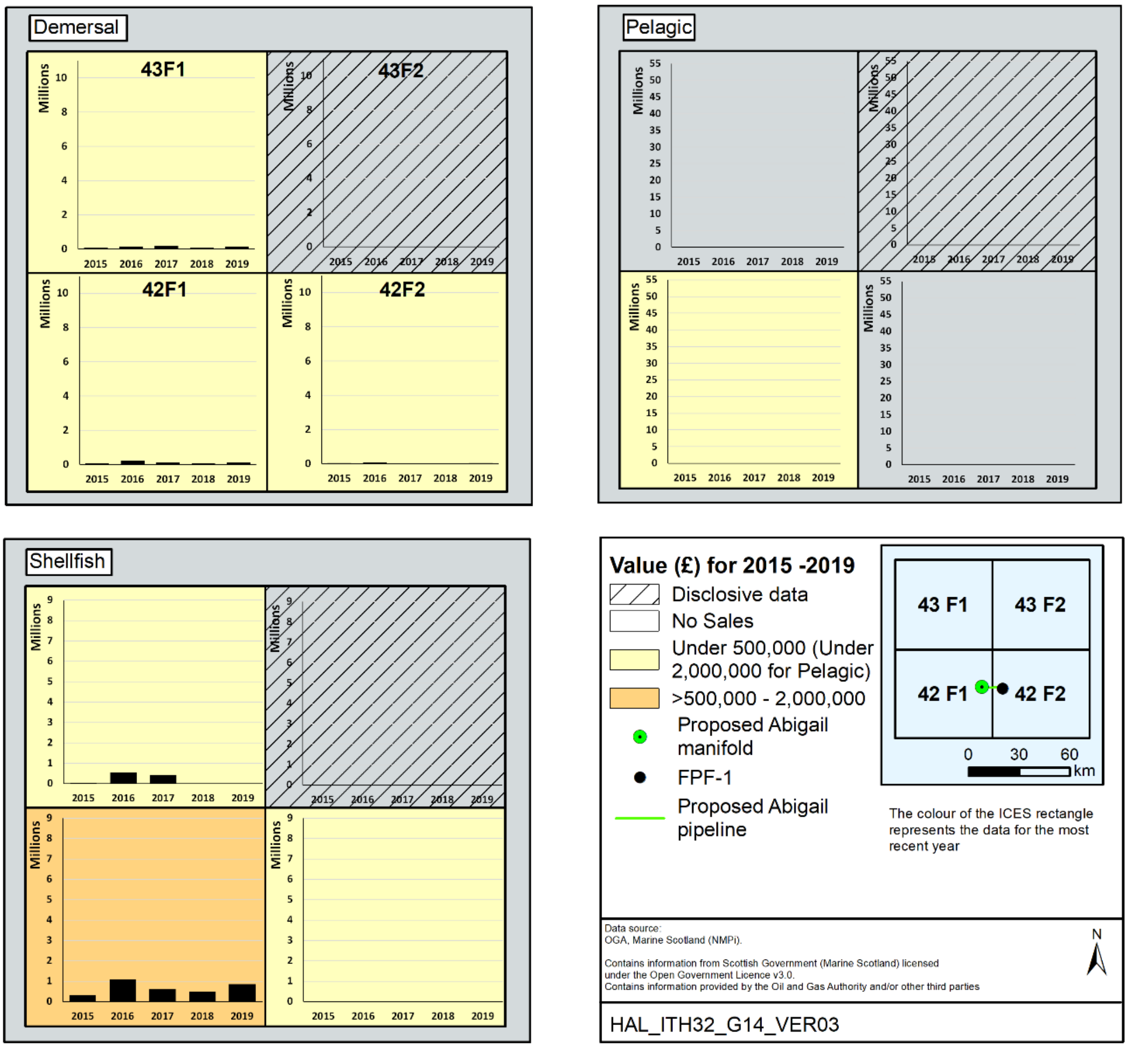
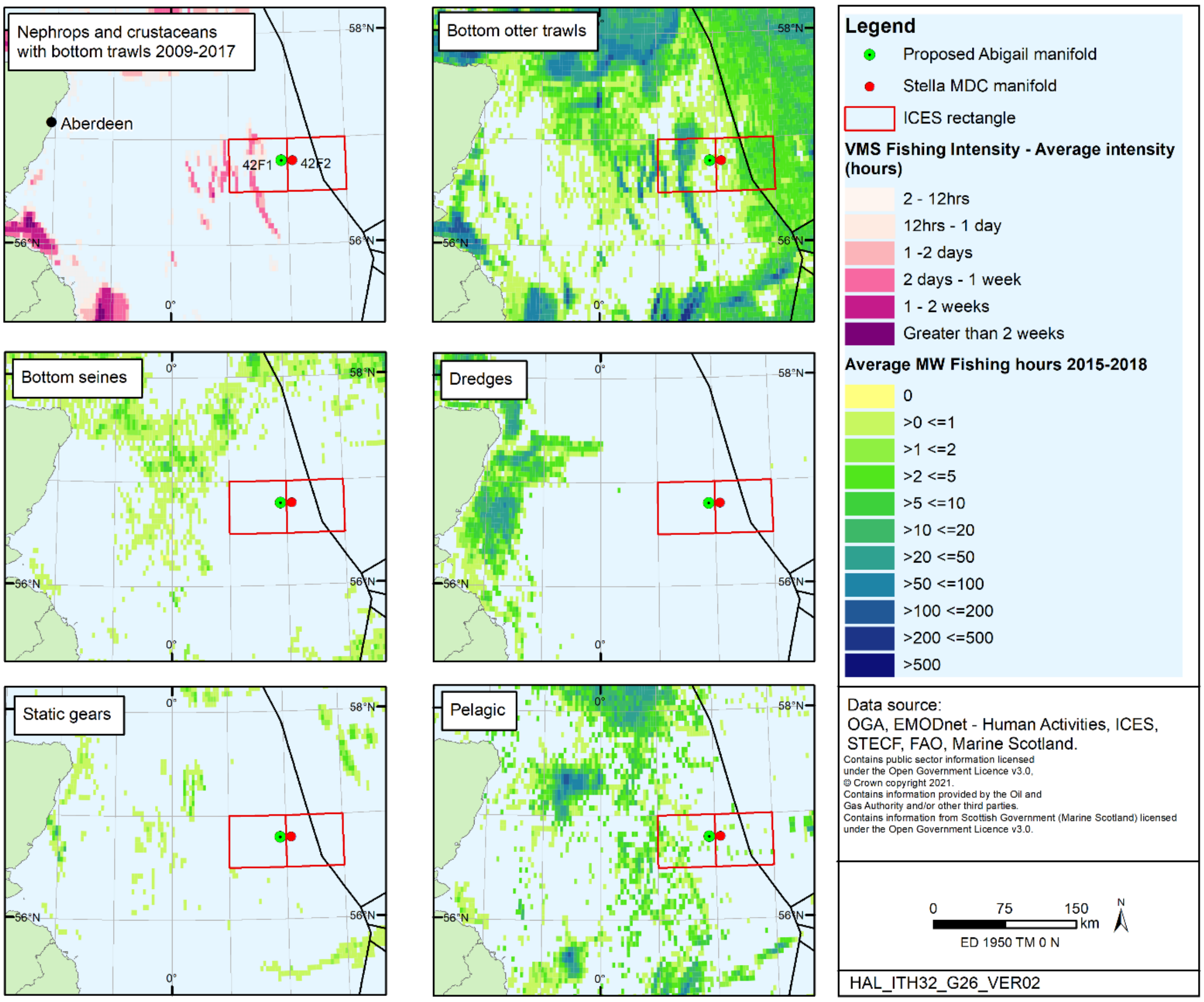


Figure 4.11b – Landings value for 42F1 and surrounding rectangles, 2015-2019



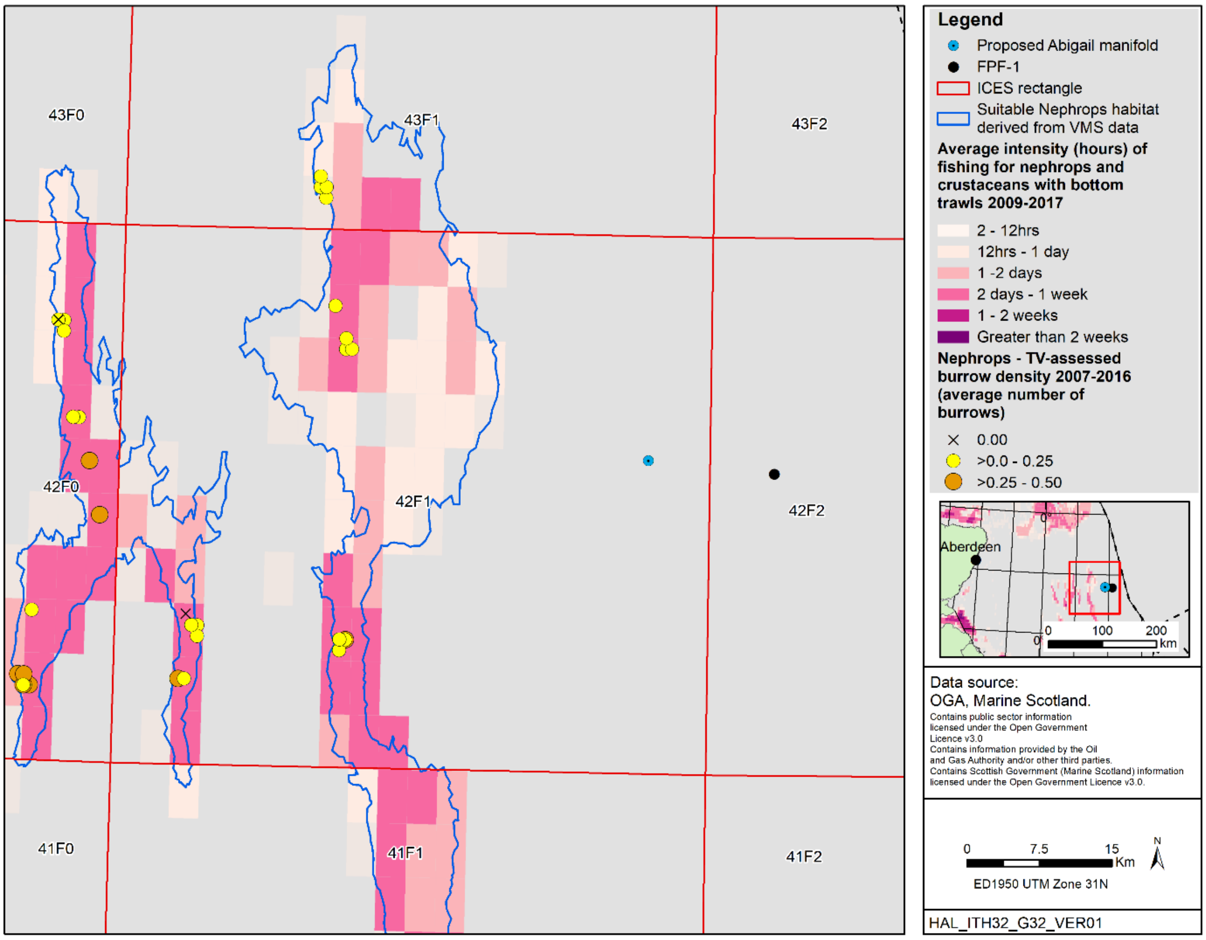
Vessel Monitoring System (VMS) data shows fishing activity in the area relative to the wider North Sea. The aggregated fishing effort covering the years 2009-2016 (and 2017 for *Nephrops*/crustacean) for the Abigail and wider Stella area is shown in Figure 4.12. The figure gives an indication of the broad patters of effort distribution. This shows the predominant fishing gear in the area is bottom trawl, these targeting *Nephrops*, this is shown in further detail in Figure 4.13. This shows that the Abigail and Stella areas experience a relatively low level of fishing effort, with high levels of effort concentrated over the deeper trenches to the west of the development. This may also account for the fisheries landings of *Nephrops* recorded in the ICES rectangle.

Figure 4.12 – Fishing intensity over the Abigail and wider area



Notes: Principally EMODnet information displayed here, with Nephrops and crustacean (2009-2017) from NMPI included. NMPI data shows same pattern of activity as above, just over a longer time frame.
Source – Marine Scotland (NMPI) website (http://marine.gov.scot/node/12832), EMODnet website https://www.emodnet-humanactivities.eu/view-data.php

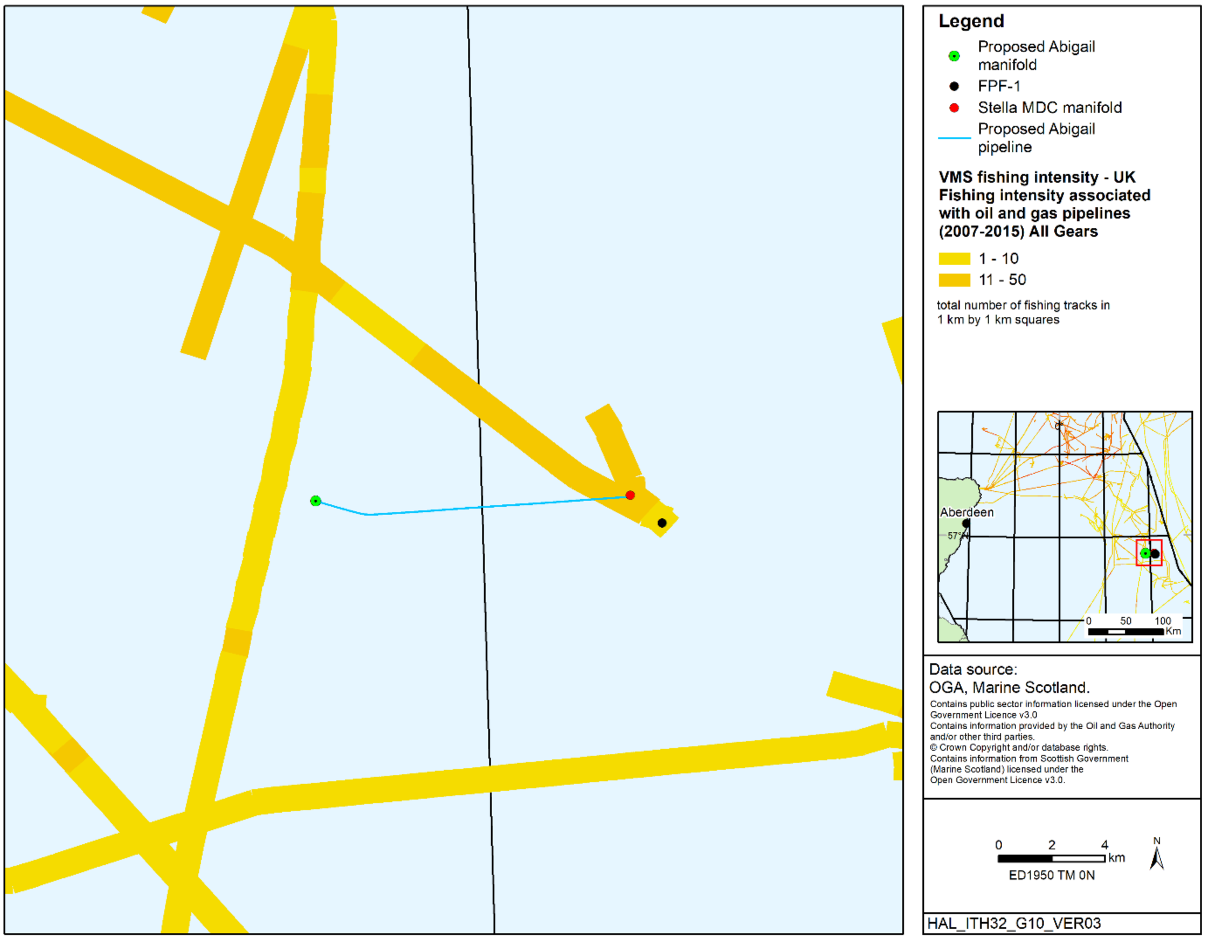
Figure 4.13 – Fishing intensity (*Nephrops*/crustacean) in and around Abigail area



Source: Marine Scotland (NMPI) website

Fishing vessels can also target large diameter pipelines, and VMS data has also been used to show effort along pipeline routes; tracks identified in the area of the proposed Abigail pipeline route, from nearby existing pipeline routes between 2007 and 2015, show these experience a relatively low level of fishing effort (Figure 4.13), although there are higher levels of effort to the north west and along pipeline systems further north (Scottish Government 2017, Marine Scotland (NMPI)).

Figure 4.13 – Fishing intensity (<15m) along pipeline and cable routes in and around the Abigail area, from data collected 2007-2015



Note: This map was created by calculating the number of fishing tracks in a 1km x 1km corridor along the length of each pipeline. It represents the activities of vessels <15m using four types of mobile demersal gears: otter trawls, pair trawls, beam trawls and dredges.

Shipping, Navigation, Military Activity and Submarine Cables

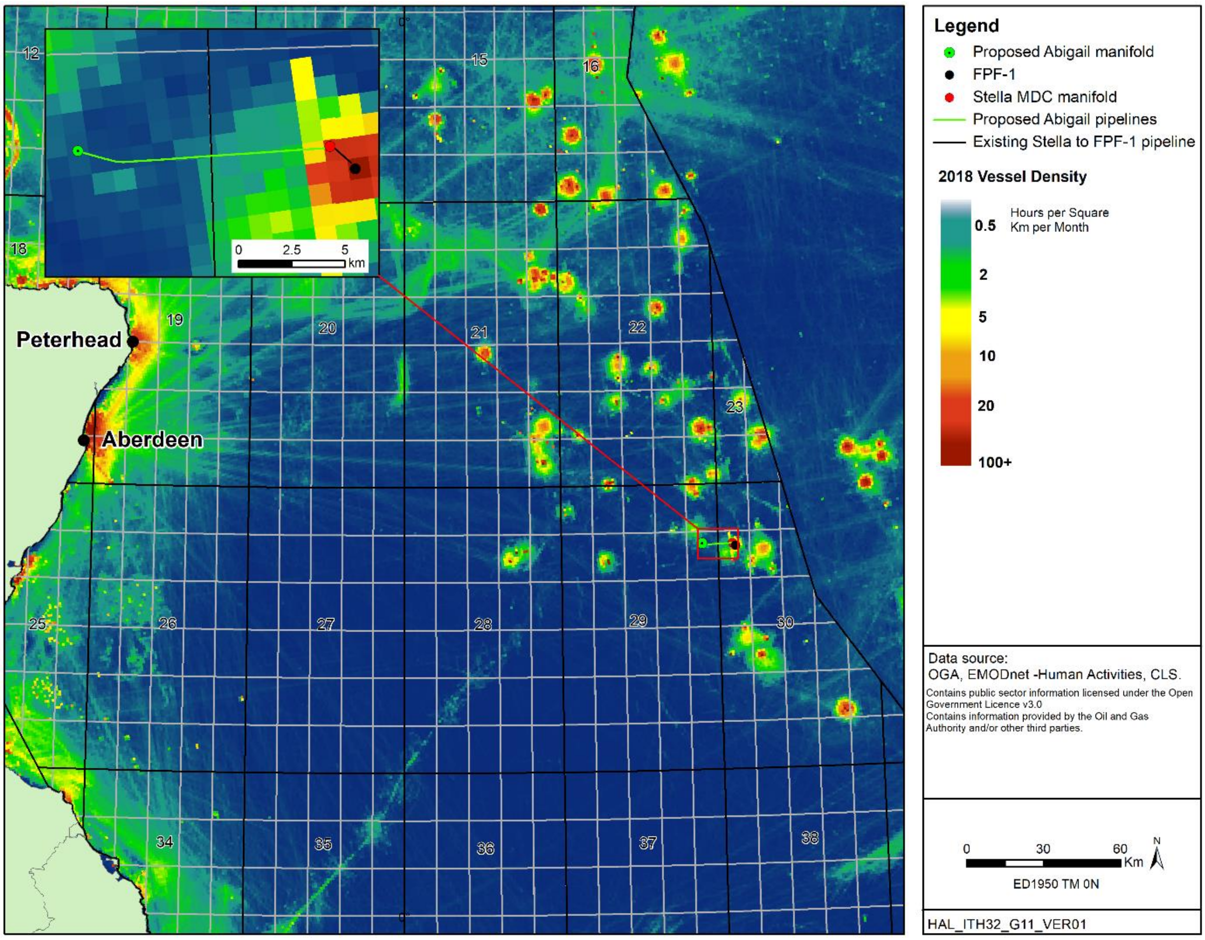
The shipping density information provided as part of the 29th Licensing Round (OGA website[15], see also Figure 4.14) indicates both Blocks 29/10 and 30/06 are categorised as having a moderate shipping density, most likely from traffic associated with servicing oil and gas installations. However, more recent (2018) AIS-based data also indicates a higher level of shipping activity associated with the FPF-1.

The vessel traffic survey report conducted for the Harrier well (located 14km) from the proposed Abigail well location) (Anatec 2017), found twenty seven shipping routes used by an estimated 1,600 vessels per year, passed within 10nm of the Harrier location, (which would encompass the Abigail area) corresponding to an average 4-5 vessels a day. Shipping traffic mainly consisted of offshore support vessels, making up nearly half (49%) of those recorded, followed by cargo ships (26%) and tankers (24%). The annual collision frequency was found to correspond to a collision return period of 792 years. Prior to siting the rig and vessel associated with the subsea campaign, a consent to locate will be applied for, and this will be supported by a vessel traffic survey specific to the Abigail area.

[15] OGA website, information on levels of shipping activity (29th Seaward Licensing Round).

Blocks 29/10 and 30/06 are not in close proximity to any IMO (International Maritime Organization) routeing measures.

Figure 4.14 – Annual average shipping density in 2018

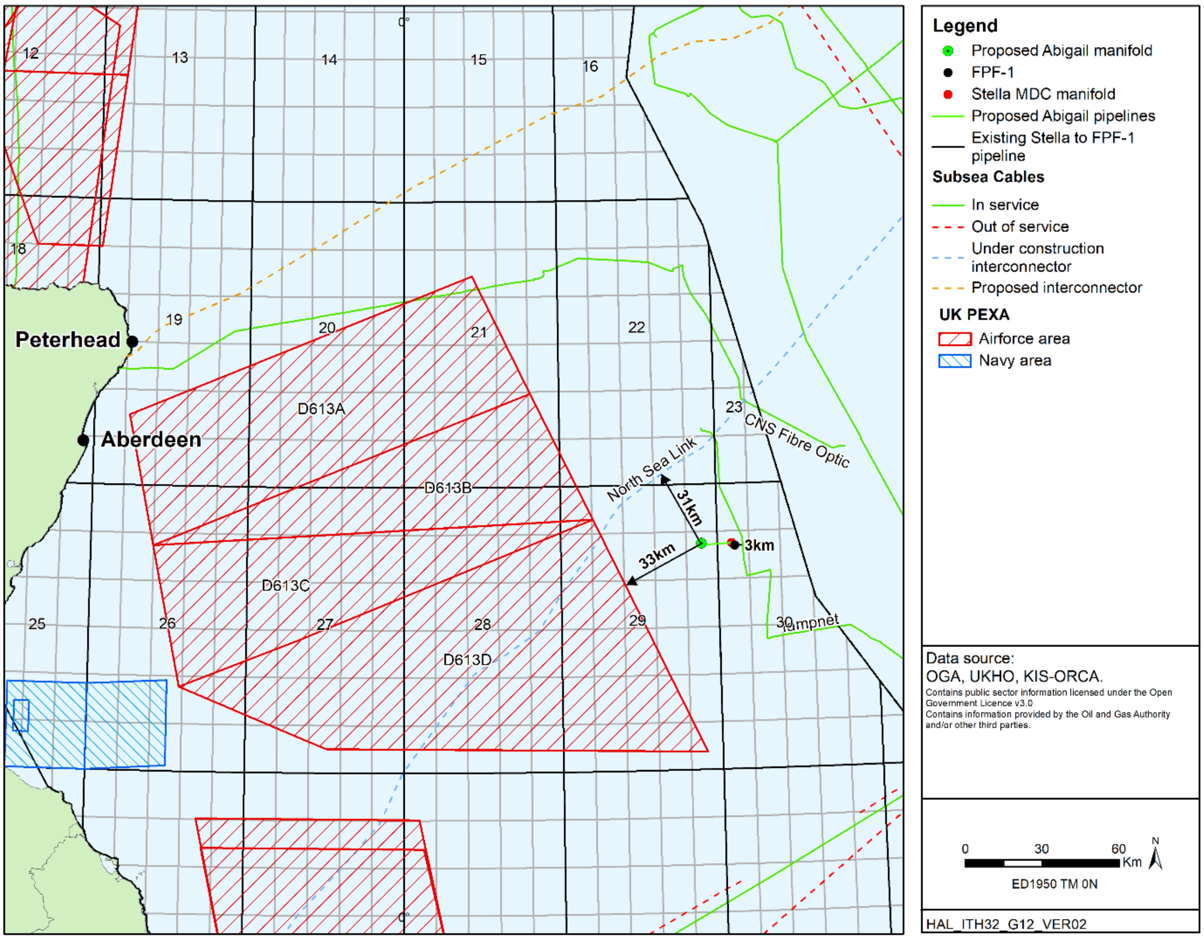


The proposed development is not within a military practice and exercise area (PEXA), nor are there any Ministry of Defence (MoD) related block restraints on 29/10 or 30/06. The nearest MoD practice and exercise area is approximately 33km to the west, which occupy a significant space off the east coast of Scotland. Demarcated as danger areas, these are used by the Royal Air Force for air combat training and high energy manoeuvres, although they do not impinge on the Abigail area (Figure 4.15).

No submarine telecommunications cables transect Blocks 29/10 or 30/06 or the immediate vicinity. The closest active cable to the Abigail development area is the TAMPNET Offshore (Norsea Coms) cable, located *ca*. 15km from the Abigail manifold and, at its closest point, *ca*. 3km from the FPF-1.

The North Sea Link (NSL) is a new electricity interconnector, passing *ca*. 31km to the north of the proposed Abigail manifold (Figure 4.15). Crossing the North Sea, it connects Kvilldal in Norway to Blyth in the UK (Northumberland), and this is expected to become operational in 2021.

Figure 4.15 – Military areas and subsea cables in the Abigail and wider North Sea area



Marine Archaeology and Wrecks

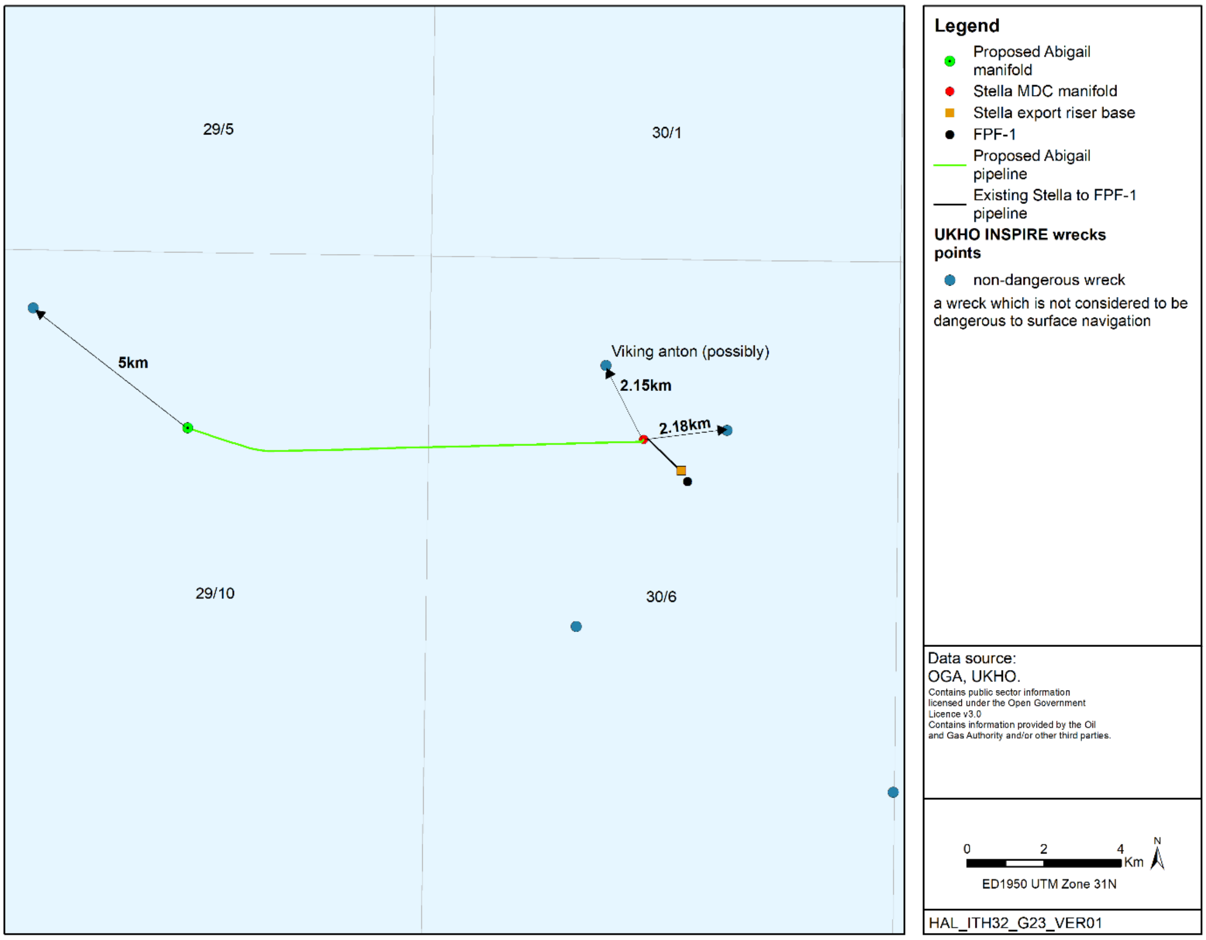
Flemming (2004a, b), Flemming *et al*. (2017) and Wessex Archaeology (2008) summarise the status of marine archaeology in the North Sea to date. These reports indicate that prehistoric submarine archaeological remains dating to *ca*. 12,000 years BP could occur with low probability anywhere between the northern mainland coast out to approximately 1°E. It is thought that prehistoric sites from the last 5-10,000 years (i.e. the late Palaeolithic up to the Neolithic) could have survived the last marine transgression (see Flemming 2004a, b).

In addition to finds that may be associated with the palaeolandscapes of the North Sea (see Gaffney *et al*. 2007, 2009), the importance of maritime trade routes and fishing grounds in the region and past military conflicts has lead to a large number of ship and aircraft wrecks (particularly in coastal areas). No archaeological sites or artefacts have been identified in the area to date. While many of the locations of these wrecks have been identified and listed by the UK Hydrographic Office, many more remain uncharted. No wrecks designated under the Protection of Military Remains Act 1986 lie close to the Abigail area.

A wreck search was conducted as part of the Stella and Harrier development assessment, with one potential wreck (the *Viking Anton* which sank in 1971) listed in the vicinity, approximately 2.2km north west of the Stella MDC (Figure 4.16). However, the last entry on the database for this wreck showed it as “reported unlikely to be a wreck but a manmade object about 10m in length and sitting hardly proud of the sediment surface”. This structure was not seen in the surveys undertaken by Ithaca Energy, that covered this area (Ithaca 2011, GEMS 2010a,b, Calesurvey 2011).

In a site survey undertaken for Ithaca Energy in 2010 in relation to the Stella area (GEMS 2010b), an unnamed wreck, measuring *ca*. 40m x 8m x 5m was identified in both bathymetry and side scan sonar data. The wreck is sitting upright in a water depth of 81m and remains unclassified, and lies *ca*. 2.2km east of Stella MDC where Abigail will tie in. There is a further unnamed wreck *ca*. 5km northwest of the proposed Abigail manifold, and one lying to the southwest of the FPF-1.

Figure 4.16 – Wrecks identified in the development area



Tourism and Recreation

The proposed Abigail development area and wider Stella area are located a significant distance from the coast and is not used for recreation with the possible exception of the occasional yacht on passage; there are no cruising routes passing close to the areas.

Population and Human Health

The World Health Organization definition of health is "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity." (http://www.who.int/about/mission/en/). A health outcome is a change in the health status of an individual, group or population which is attributable to a planned activity, and determinants of health are the range of personal, social, economic and environmental factors which determine the health status of individuals or populations. The Abigail development is distant from shore, nearest landfall being >233km away and the proposed activities are not visible or audible from land, and do not entail the use of hazardous or noxious materials (e.g. chemical use and discharge is subject to permit regulations, and all waste is subject to handling and disposal requirements).

5 IDENTIFICATION AND SCREENING OF POTENTIALLY SIGNIFICANT EFFECTS

5.1 Introduction

Activities associated with the development of the Abigail Field have the potential to affect the environment in a number of ways, including physical and other disturbance, emissions and discharges, waste generation and accidental events. This section describes the process used to identify and screen the relative significance of the potential environmental issues associated with the proposed development activities.

5.2 Method

Activities associated with the field development include all those from Phase 1: the drilling and completion of a production well (repurposing an existing appraisal well), the installation and commissioning of subsea infrastructure (including a new piled production manifold and new pipeline, gas lift pipeline and services umbilical), the tie-in to the Stella MDC, which is subsequently tied into the FPF-1,operations from Abigail production and those from Phase 2; the drilling and tying in of a second production well. These were considered together with their potential interactions with the environment and in the context of legislative and policy requirements. The activity/environmental interactions were identified using a range of sources, in particular:

- Regional and site specific environmental data
- Project specific and similar project engineering documents
- Typical jack-up and semi-submersible drilling rig specification (for well drill)
- Typical vessel specifications (e.g. for subsea infrastructure installation)
- FPF-1 host specific information
- Experience of analogous projects in the North Sea and elsewhere, including the Stella and Harrier developments
- Reviews and assessments of the environmental effects of offshore oil and gas operations
- Peer reviewed scientific papers on the effects of specific interactions and habitat processes
- Other publicly available “grey” literature
- Offshore Energy Strategic Environmental Assessment Environmental Reports and underpinning studies (e.g. DECC 2016)
- Conservation site designations, potential designations and related supporting site information
- Applicable legislation, guidance and policies
- Regulator and consultee engagement and feedback (see Section 1.2)

These were systematically screened against the defined consequence and likelihood criteria in Table 5.1. The results of this screening are given in Section 5.3.

5.2.1 Data Gaps and Limitations

Over the last ten years, Ithaca Energy have undertaken substantial seabed survey work in the Abigail and Greater Stella Area. These, together with other seabed surveys undertaken in the region, and peer reviewed scientific research of relevance to the North Sea, and the central North Sea in particular, provides a significant body of data from which to draw an understanding of the Abigail environment, and the wider context within which it sits. In addition to the site specific and Greater Stella Area surveys, Ithaca Energy have undertaken accidental hydrocarbon spill modelling to assess the potential impacts from a worst case accidental spill from the development and operational activities. Data gaps have also been addressed in the separate assessment sections within Section 6.

Table 5.1 – Criteria for the identification of potential environmental effects from the proposed Abigail development

Effect	Consequences
None Foreseen	No detectable effects
Positive	Activity may contribute to recovery of habitats Positive benefits to local, regional or national economy
Negligible	Change is within scope of existing variability but potentially detectable.
Moderate	Change in ecosystem leading to short term damage with likelihood for recovery within 2 years to an offshore area less than 100 hectares or less than 2 hectares of a benthic fish spawning ground Possible but unlikely effect on human health Possible transboundary effects Possible contribution to cumulative effects Issue of limited public concern May cause nuisance Possible short term minor loss to private users or public finance
Major	Change in ecosystem leading to medium term (2+ year) damage with recovery likely within 2 - 10 years to an offshore area 100 hectares or more or 2 hectares of a benthic fish spawning ground or coastal habitat, or to internationally or nationally protected populations, habitats or sites Transboundary effects expected Moderate contribution to cumulative effects Issue of public concern Possible effect on human health Possible medium term loss to private users or public finance
Severe	Change in ecosystem leading to long term (10+ year) damage with poor potential for recovery to an offshore area 100 hectares or more or 2 hectares of a benthic fish spawning ground or coastal habitat, or to internationally or nationally protected populations, habitats or sites Major transboundary effects expected Major contribution to cumulative effects Issue of acute public concern Likely effect on human health Long term, substantial loss to private users or public finance

Frequency with which Activity or Event Might Occur	Likelihood
Unlikely to occur	**Unlikely**
Once in the life of the rig or facility	**Low**
Once a year	**Medium**
Once a month or regular short term events	**High**
Continuous or regular planned activity	**Very High**

	Likelihood				
Consequences	Very High	High	Medium	Low	Unlikely
Severe					
Major					
Moderate					
Negligible					
Positive					
None foreseen					

	Issues requiring detailed consideration in the EA
	Positive or minor or negligible issues – not assessed further
	No effects expected – not assessed further

Notes:
1. The criteria to the left include consideration of issues of known public concern
2. In addition to screening on the basis of these criteria, issues/interactions raised during stakeholder consultation will be treated as requiring detailed consideration. These issues/interactions will be indicated in Table 5.2 by C (raised in stakeholder consultation).

Table 5.2 – Sources of potential effect, relevant environmental factors and related environmental receptors

Key	
■	**Potential for significance**
□	**Minor issue**

Activity/Source of Potential Impact	**Environmental Factor**														
		Land, soil, water, air, climate			**Biological, with particular attention to species and habitats protected under relevant legislation[1]**						**Material assets, other users, onshore**				
	Population and human health[2]	**Climate/air quality**	**Water Quality**	**Seabed and sediments**	**Benthic Fauna**	**Plankton**	**Fish and Shellfish**	**Marine Mammals**	**Birds**	**Conservation sites/species**	**Fisheries**	**Shipping**	**Other users[3]**	**Landfill/onshore resources**	**Transboundary issues**
Drilling and completion operations															
Drilling rig tow in/out		□						□			□	□	□		
Rig positioning, spud cans (jack-up) (Phase 2 only)[4]				■	■										
Rig positioning, anchors (semi-submersible) (Phase 1 and 2)				■	■										
Physical presence (including standby vessel, supply vessel)	□							□	□		■ C	□	□		
Discharge of cementing chemicals			■	■	■	□	■				□				
Discharge of drilling chemicals (excluding cementing chemicals)			□				■				□			□	
Drilling – disposal of LTOBM /cuttings														□	
Discharge of WBM / cuttings (Phase 2 only)			■	■	■	□	■				□				
Well and clean up discharges		■	□	□	□	□	□								

Potential for significance (■)
Minor issue (□)

	Environmental Factor														
		Land, soil, water, air, climate			Biological, with particular attention to species and habitats protected under relevant legislation[1]						Material assets, other users, onshore				
Activity/Source of Potential Impact	**Population and human health[2]**	**Climate/air quality**	**Water Quality**	**Seabed and sediments**	**Benthic Fauna**	**Plankton**	**Fish and Shellfish**	**Marine Mammals**	**Birds**	**Conservation sites/species**	**Fisheries**	**Shipping**	**Other users[3]**	**Landfill/onshore resources**	**Transboundary issues**
Power generation (including support vessels on DP)	□	■													
Fugitive emissions from fuel and chemical storage		□													
Machinery space, deck, sewage & other discharges			□	□	□	□									
Other solid and liquid wastes to shore	□	□												□	
Underwater noise							□	■	□						
Airborne noise	□								□						
Surface lighting									□			□	□		
Subsea infrastructure, installation and commissioning															
Physical disturbance of seabed			□	■	■	□	■				■				
Use of protective material	□			■	■						□				
Physical presence of vessels	□										□				

Potential for significance
Minor issue

Activity/Source of Potential Impact	Environmental Factor														
		Land, soil, water, air, climate			Biological, with particular attention to species and habitats protected under relevant legislation[1]						Material assets, other users, onshore				
	Population and human health[2]	Climate/air quality	Water Quality	Seabed and sediments	Benthic Fauna	Plankton	Fish and Shellfish	Marine Mammals	Birds	Conservation sites/species	Fisheries	Shipping	Other users[3]	Landfill/onshore resources	Transboundary issues
Underwater noise – trenching vessels and piling (Phase 1 only)[5]							Minor issue	Potential for significance	Minor issue						
Underwater noise - vessels							Minor issue	Potential for significance	Minor issue						
Pipeline installation chemical discharges			Minor issue	Minor issue	Minor issue	Minor issue									
Discharge of hydrocarbons (SSIV installation)			Minor issue	Minor issue	Minor issue	Minor issue									
Power generation - vessels	Minor issue	Potential for significance													
Physical presence of pipeline system and 500m safety exclusion zone											Minor issue				
Production operations															
Incremental power generation	Minor issue	Potential for significance													Minor issue
Abigail apportion to flaring/venting	Minor issue	Potential for significance													Minor issue
Abigail increment to produced water discharges	Minor issue		Potential for significance			Minor issue	Potential for significance								
Abigail increment to chemical discharge			Minor issue			Minor issue	Minor issue								

Potential for significance
Minor issue

Activity/Source of Potential Impact	Environmental Factor														
		Land, soil, water, air, climate			Biological, with particular attention to species and habitats protected under relevant legislation[1]						Material assets, other users, onshore				
	Population and human health[2]	Climate/air quality	Water Quality	Seabed and sediments	Benthic Fauna	Plankton	Fish and Shellfish	Marine Mammals	Birds	Conservation sites/species	Fisheries	Shipping	Other users[3]	Landfill/onshore resources	Transboundary issues
Accidental events															
Dropped objects	Minor issue			Minor issue	Minor issue						Minor issue	Minor issue	Minor issue		
Accidental spills of oil	Potential for significance		Potential for significance	Minor issue	Minor issue	Potential for significance	Potential for significance	Potential for significance	Potential for significance	Potential for significance	Potential for significance	Minor issue	Minor issue		Potential for significance
Accidental spill of diesel			Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue		Minor issue				Minor issue
Vessel collision	Minor issue		Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue		Minor issue	Minor issue	Minor issue		
Chemical spill			Minor issue			Minor issue	Minor issue	Minor issue	Minor issue		Minor issue				
Release of liquid hydrocarbon from re-entering well 29/10-8	Minor issue		Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue	Minor issue		Minor issue

Notes: [1]Relevant legislation includes: The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended); Marine (Scotland) Act 2010 and Marine and Coastal Access Act 2009. [2]This is largely considered in the context of other environmental factors e.g. effects on air quality, climate and other users. [3]includes offshore renewables, oil and gas, military activities, subsea cables, recreational etc [4] Rig selection for Phase 2 is still to be finalised, this could be either a jack-up or semi-submersible. A jack-up is included here for Phase 2 only. [5]Pilling of manifold will only take place under Phase 1, no piling is proposed for Phase 2

5.3 Consideration of Effects

5.3.1 Effects Considered Minor

A small number of potential sources of effect from Table 5.2 above have been considered minor and these have not been assessed further. These and the consideration of these are shown in Table 5.3 below.

Table 5 3 – Environmental effects considered minor

Potential source of effect	Summary consideration
Drilling and completion operations	
Drilling rig tow in/out	Drill rig movements will create temporary, short term and small scale increment to atmospheric emissions and physical presence whilst transiting the North Sea. Notification to mariners, operations are within an area of existing oil and gas associated shipping movements, small increment to existing traffic. Significant effects not predicted.
Disposal of LTOBM and cuttings	First production well is a re-entry and completion of an existing well, with only two sections anticipated to be drilled, both sections using LTOBM. LTOBM will also be used for the lower hole sections of the second well. Relatively small quantities of mud and cuttings returned to shore for processing and disposal from both wells, contributing to onshore activities and resource use. No discharge to sea from either well, significant effects not predicted.
Well completion and clean up discharges	Small quantity and variety of chemicals to be used and discharged, chemicals selected for best environmental performance where technically feasible to do so, risk assessment carried out and use and discharge approved prior to use offshore. Contribution to local water quality changes and associated interactions with water column and benthic biota. Short term, localised impact. Significant effects not predicted.
Fugitive emissions from fuel and chemical storage	Emissions include those from cement tanks, mudpits, diesel storage and cooling/refrigeration systems and have the potential to make minor contribution to air quality effects. Such emissions are minor in the context of those from combustion of fuel for power generation and in view of the location and prevailing meteorological conditions, these emissions are not considered to be a significant source of air pollutants. Significant effects not predicted.
Machinery space, deck, sewage and other discharges	Discharges will contribute to local water quality changes and associated interactions with water column biota. In view of location, current/wave action and dilution of discharges, significant effects are not predicted.
Other solid and liquid wastes to shore	Materials returned to shore contribute to well-regulated onshore activities such as materials processing and landfill. Significant effects are not predicted.
Airborne noise	Small increment to current levels, local, and short term. Significant effects are not predicted.
Surface lighting	Incremental surface lighting from rig and associated vessels will be temporary and will not significantly add to existing lighting levels in the area. Significant effects are not predicted.
Subsea infrastructure, installation and commissioning	
Pipeline installation chemical discharge	Chemicals to be used in the installation and testing of the Abigail pipeline system. Chemicals selected for best environmental performance where technically feasible to do so, and variety and quantities of chemicals used typically small. Risk assessment carried out and use/discharge approved prior to activities starting offshore. Contribution to local water quality changes and associated interactions with water column and biota. Short term, localised impact. Significant effects not predicted.
Discharge of hydrocarbon associated with SSIV installation	Small discharge of residual hydrocarbon expected at SSIV installation (small volume of riser contents, the majority of which will remain in riser system). System will be cleaned and flushed prior to disconnection of pipework and connection of SSIV, minimising the volume being discharged. Risk assessment carried out and approved prior to activities starting offshore. Contribution to local water quality

Potential source of effect	Summary consideration
	changes and associated interactions with water column and biota. Short term, localised impact. Significant effects not predicted
Production operations	
Operational emissions – transboundary effects	Incremental emissions associated with additional fuel gas use will make a minor contribution to global greenhouse gas loading. Air quality effects from atmospheric emissions are likely to be minor in a national and transboundary context due to the distance of the FPF-1 from the nearest coastline.
Incremental chemical discharge	No new chemicals expected to be required; Abigail hydrocarbons commingling with those from Stella and Harrier, process will use existing chemicals. Increment in use and discharge of existing chemicals expected to be small, will contribute to local water quality changes, and associated interactions with water column biota. Significant effects not predicted.

It should be noted, that, although some accidental events have been screened as minor (Table 5.2), all potential events have been included in the assessment section (6.8) below.

5.3.2 Potential for Natural Disasters

The vulnerability of the project to risks of natural disasters of relevance, e.g. earthquakes and tsunamis, has also been considered. The central North Sea shows relatively little seismicity and is not prone to significant natural disasters, therefore, the potential for effects to be generated by such events and the risk to the project from these, is extremely low.

5.3.3 Potential Effects to be Considered Further

A number of environmental interactions were identified with the potential to result in significant effects The major sources of potentially significant effect have been grouped against those activities identified as likely to, directly or indirectly, affect one or more relevant environmental factors (and interactions between these). These have been listed below (Table 5.4), and split out into those effects common to both phases and those specific to Phase 1 and Phase 2. These are described and assessed in detail in Section 6.

Table 5 4 – Environmental effects considered further in Section 6

Activity area	Issue	Potential Source of Effect	Section
Common to both phases of development			
Drilling, Subsea works, Operation	Physical presence	• Rig, supply and other vessels presence/movements – exclusion to other marine users • New 500m safety exclusion zone applied for around Abigail manifold	6.1
Drilling, Subsea works	Seabed disturbance	• Disturbance to seabed from cement discharges	6.2
Drilling, Subsea works, Operation	Discharges to sea	• Cementing and other chemical discharges during well drilling • Increment to existing FPF-1 produced water discharge	6.3
Drilling, Subsea works, Operation	Energy use and atmospheric emissions	• Atmospheric emissions from rig power generation, vessel operation	6.4

Activity area	Issue	Potential Source of Effect	Section
		• Incremental atmospheric emissions for operational power requirement (fuel gas use)	
Drilling, Subsea works	Underwater noise	• Underwater noise from rig associated with well and pipelay activities	6.5
Drilling Operations	Transboundary issues	• Hydrocarbon, diesel and other (e.g. chemical) spills	6.6
Drilling, Subsea works	Cumulative effects	• Possibility of interactions with other developments in the central North Sea or proposed activities/developments in the wider area (including renewables)	6.7
Phase 1 only			
Drilling, Subsea works	Seabed disturbance	• Disturbance of seabed from rig installation (semi-submersible anchors) • Ploughing for pipeline system installation, subsea infrastructure including manifold piles • Use of protective material (mattresses, grout bags and rock)	6.2
Drilling, Subsea works	Underwater noise	• Installation of manifold (piles), and pipelay activities (e.g. trenching/backfilling vessels)	6.5
Phase 2 only			
Drilling, Subsea works	Seabed disturbance	• Disturbance of seabed from rig installation (jack-up spud cans or semi-submersible anchors) • Use of protective material (mattresses, grout bags) • Disturbance to seabed from WMB/cuttings discharges	6.2
Drilling, Subsea works, Operation	Discharges to sea	• WMB/cuttings discharge	6.3

All sources of effect associated with accidental events are subject to further assessment in Section 6.

6 OVERVIEW OF POTENTIAL ENVIRONMENTAL IMPACTS

The following section presents a description and assessment of those potentially significant environmental effects identified in Section 5, from the offshore activities associated with the development and operation of the Abigail Field. Potential cumulative impacts and accidental events are also included.

6.1 Physical Presence During Development Activities

Potential Impacts on Other Users

The physical presence of the rig and supporting vessels during drilling and vessels during the subsea installation activities, has the potential to displace other users of the sea, including shipping and fishing. Potential effects on shipping and fishing activity are restricted to temporary spatial conflict, in areas outside of exclusion zones (both existing zones and new zones applied for in relation to this development), including when the rig and vessels are in transit.

A semi-submersible rig will be used for drilling the first Abigail well and a temporary 500m safety exclusion zone will be in place over approximately 83 days (including rig mobilisation and demobilisation). The rig anchors can extend out to a radius of 1.5km, the majority of which will be outside the 500m safety exclusion zone. A mooring analysis will be undertaken and agreements will be arranged and put in place with other block operators and infrastructure owners, if the rig anchors are going to extend into neighbouring blocks and/or over existing infrastructure. Rig move and final rig anchor locations will be notified to mariners, and these will only be in place for a relatively short duration; notification is also given when the rig moves off of location.

If the second well is drilled, either a semi-submersible or jack-up rig will be used. In either case, a 500m safety exclusion zone around the rig will apply. Although the 500m zone for the rig placement will partly overlap with the 500m zone for the manifold, there will be an additional area from which vessels will be excluded, while the rig for the second well is on location. This additional area will be temporary (89 days), after which the 500m zone associated with the rig will be removed.

Although the semi-submersible rig anchors can extend out to a radius of 1.5km, potential impacts on wrecks within the vicinity are not expected, the closest of these to the drill centre being 5km to the north west (Section 4.9, Figure 4.16).

Activity outside the exclusion zone, i.e. along the pipeline route, will represent a short-term increment in vessel presence over that which the area normally receives. The potential longer term source of effect to other users (in particular, fisheries) is the physical presence of the pipeline system and the protective material used, i.e. at the crossing location.

Fishing effort in the Abigail area is relatively low and most activity is by demersal gear. Bottom trawling close to subsea facilities carries the risk of fishing gear snagging with potential loss of gear, or in extremely remote circumstances, the vessel. Snagging occurs when the trawl gear becomes “stuck” under the pipeline and this is most likely to occur where freespans have developed between the seabed and the pipeline, creating potential snags for trawl otter boards (of wood and/or steel and up to 1.5 tonnes each) used to hold open a demersal trawl net. The pipeline will be buried along its length, and as this area of the North Sea is not subject to vigorous currents, and has low sediment mobility, the pipelines are expected to remain buried and freespans are not expected to develop. Snagging on the pipeline is considered unlikely unless substantial scour occurs along the pipeline (not expected) or there are obstacles along the pipeline route, which would be detected during the post installation (as-laid) survey and subsequent planned regular inspections.

The final position of the subsea facilities will be marked on the appropriate navigation charts and notified via the Kingfisher bulletin.

Potential Impacts on Sensitive Species

Birds

The physical presence of the rig and vessels may potentially cause displacement and/or other behavioural responses in birds. Seabird distribution and abundance in the central North Sea varies throughout the year, but the area as a whole is of low importance, due to the distance from shore, and availability of prey; the offshore area in general, containing peak numbers of birds following the breeding season and through winter (see Section 4.6), with birds present likely to be on transit through the area. From the mean and mean maximum foraging distances for seabird species during the breeding season, (as described in Woodward *et al.* 2019), the Abigail area is considered too far offshore (>230km) for the majority of these to forage during this period, although non-breeding adults may be present. Of those species that could be present, such as northern fulmar, northern gannet, lesser black-backed gull, these show no or slight disturbance to ship traffic (Furness *et al*. 2012, see also Fliessbach *et al*. 2019).

Species typically susceptible to vessel disturbance such as seaduck (e.g. common scoter), are not likely to be present in the area; this species forages shellfish from the seabed, and has maximum dive depths of *ca*.20m (Furness *et al*. 2012).

The potential effects of light on birds has been raised in connection with offshore oil and gas over a number of years (e.g. Wiese *et al*. 2001). As part of navigation and worker safety, and in accordance with international requirements, rigs and associated vessels are lit at night and the lights will be visible at distance (some 10-12 nm in good visibility). Although development activities may occur during periods of bird migration, significant effects from the rig and associated vessel lights are considered to be unlikely; the lights used are primarily non-flashing so the behavioural effects noted by Bruderer *et al*. (1999) in response to a strong searchlight being switched on and off are unlikely.

Marine mammals

In addition to potential disturbance to birds, the physical presence of the rig and vessels may influence the distribution and movements of sensitive species of marine mammals. As hearing specialists, any displacement of marine mammals is most likely associated with acoustic disturbance and this is further discussed in Section 6.5 below. There may also be responses from marine mammals to the general physical presence of infrastructure and vessels, along with the risk of collisions from vessels in transit.

While the Abigail area is known to be frequented by several marine mammal species, their distribution is expected to be wide, and at relatively low abundance (see Section 4.7). Development activities will result in a small increase in vessel traffic within the immediate Abigail and wider area. However, the physical presence of vessels, including slow-moving vessels for pipeline installation, are anticipated to cause no more than temporary and localised low-level behavioural responses similar to those from normal operations, such that significant effects are not predicted.

Operational Controls, Mitigation and Data Gaps

As part of the Ithaca Energy contractor selection process, all contractors providing equipment, materials or services for field operations are subject to evaluation prior to contract award, and must demonstrate the necessary capacity, experience and technical capability to undertake the work safely and in an environmentally sound manner. Ithaca Energy has in place an Operational Excellence Policy (OEP) which commits to (amongst others): ensuring HS&E performance is prominent in the selection of contractors and assess and manage operations through all stages to minimise risk of harm to people, the environment and facilities.

To support consent to locate applications for the drilling rig and other vessels (where required), a vessel traffic survey will be carried out and if necessary, a collision risk assessment.

Vessel movements and the "as laid" positions of the semi-submersible (Phase 1) and jack-up spud cans or semi-submersible anchors (Phase 2), will be notified to fishermen and others through the normal routes, including publication in Notice to Mariners and in Kingfisher bulletins detailing positionings, activities and timings; the as laid position of the pipeline system will also be charted through normal routes. In addition, there will be full navigation lighting on the rig and associated vessels – all vessels used will meet applicable national and international standards (e.g. in terms of signals and lighting).

No specific additional mitigation was considered necessary beyond application of established operational controls.

No significant data gaps have been identified. The expected duration on location of the rig and vessels is based on experience of drilling similar wells and installing similar pipeline systems/infrastructure in this area and the wider North Sea, and contingencies have been accounted for such that actual vessel timings will not exceed those considered. There is a good understanding of the fishing effort in the area and the presence of mobile species potentially impacted by the physical presence of the vessels associated with the development. A vessel traffic survey is also to be undertaken prior to siting the rig, providing the most current information regarding other traffic in the area and to support environmental permitting.

Conclusion

During development activities, potential interactions with other users of the area, specifically fishing and navigation will be of short duration. Upon completion of Phase 1 drilling and subsea activities, there will be a new 500m safety exclusion zone centred on the Abigail manifold, from which vessels will be excluded for the duration of field life (*ca*. 8 years).

Vessels will not be excluded from the pipeline area. The potential for significant effects on fisheries from installation of the pipeline system, following normal operational controls described above, are considered low as the system is trenched and buried.

With the exception of seismic activity (see Section 2.3.1), of which none is planned as part of the Abigail development, there are no particular periods of concern on Block 29/10 for drilling, therefore, no sensitive periods to avoid.

Activity outside the exclusion zone, i.e. along the pipeline route, will represent a short-term increment in vessel presence over that which the area normally receives and it is not considered that this will result in a significant effect on other sea users.

6.2 Effects of Seabed Disturbance

Physical disturbance to the seabed will be associated with a number of development activities, primarily:

Phase 1

- Semi-submersible anchors and anchor chains
- Discharge of cementing chemicals
- Pipeline trenching and backfilling
- Installation of new Abigail manifold and SSIV

- Use of protective material (mattresses, grout bags, rock)

Phase 2

- Semi-submersible anchors and anchor chains or Jack-up rig spud cans
- Discharge of cementing chemicals
- Discharge of WBM/cuttings
- Installation of tie-in spools and jumpers
- Use of protective material (mattresses and grout bags)

Rig Anchoring (semi-submersible) and Spud Cans (jack-up) and Drilling Discharges

It has been assumed that the mooring system of a semi-submersible rig will comprise an 8 anchor system, and the *Awilco WilHunter* has been used a representative example, this being the semi-submersible used to drill the original appraisal well 29/10b-8 (see Section 3.4.1). Each anchor will produce a linear scar on installation in the order of 50m length, with additional disturbance generated by surface scrape as a result of catenary contact of the anchor chain with the seabed. The area affected by the deployment of the semi-submersible rig at the Abigail drill centre has been based on the length and width of the anchors (6m x 6m) and an assumption that one half of the total chain length (1,500m) would be on the seabed (*ca*. 750m), with a total lateral movement of 10m (Table 6.1 and Table 6.2).

The removal of anchors has the potential to form mounds on the seabed, and these more typically form where the underlying sediment is clay. While surface sediments (depth 0-1.6m) at the Abigail drill centre is loose to medium dense silty fine sand, this overlies variable soils, the upper section comprising interbeds of fine clay to soft silty sand clay (depth 1.6m-19.9m) (Calesurvey 2011). The anchors therefore have the potential to form mounds upon recovery. The as laid anchor locations will be included in Notices to Mariners and the potential hazard posed to other sea users from anchor pull out pits or displaced sediments will be assessed as part of the rig debris clearance survey post drilling.

Other vessels involved in development activities will be kept on station using dynamic positioning (DP) and seabed disturbance will be minimal.

If a jack-up rig is selected for drilling the second well in Phase 2, the spud cans of the rig will form seabed depressions as a result of sinking into the seabed during the process of jacking up the rig deck. Such jack-ups have spud can jetting systems with both bottom and top jets to facilitate spud can release from seabed sediments, this will result in the displacement of sediments in these localised areas. The assumed area of disturbance is similar to that of the spud can contact area. Disturbance has been based on spud can diameter (20m) and number of cans (3) (Table 6.2).

Pipeline System and Seabed Infrastructure Installation and Associated Protective Material

The pipeline system will be laid from a DP reel lay vessel, thereby mitigating against potential anchoring disturbance with all three lines being laid in a single trench (Section 3.7). Post-lay trenching with a target trench depth of 1.5m (minimum 1m) and a worst case width of 22m (the maximum width of a trenching plough skis – see Section 3.7.1) will cause sediment displacement and re-suspension of sediments along the entire length (12km) of the pipeline, with smothering of sessile fauna. Displacement, suspension and smothering of fauna will also occur as material excavated from the trench is backfilled to cover the laid lines, creating a seabed profile similar to that before pipelay. The use of excavated material as backfill will reduce the potential for damage to fishing gear.

The placement of protective material, including rock, will also result in physical trauma and smothering of fauna, displacement and re-suspension of sediments and habitat modification, by the introduction of new hard (rock) substrate. However, surveys from the area have identified existing naturally occurring areas of coarser material, typically shell fragments, with cobbles and boulders also present.

The majority of subsea activities will be carried out during Phase 1 and the estimated disturbance from each phase is described below.

Estimated Seabed Disturbance from Phase 1 Development Activities

Drawn from the information available and based on a number of assumptions (see above), an area of seabed affected by the first phase of development activities has been estimated (Table 6.1).

Table 6.1 – Estimated seabed disturbance from Abigail Phase 1 activities

Item	Activity	Estimated seabed disturbance m^2 (km^2)
Drilling Activities with Semi-submersible rig		
1	Anchors[1]	288 (0.0003)
2	Anchor chains[2]	60,000 (0.06)
	TOTAL m^2 (km^2) of seabed disturbed from drilling activities	**60,288 (0.06)**
Subsea Activities		
3	Pipeline system installation[3]	264,000 (0.26)
4	Tie-in spool pieces and jumpers[4,]	480 (0.0005)
5	Abigail manifold installation[5]	112 (0.0001)
6	SSIV Installation[6]	80 (0.0001)
7	Protective material mattresses at Stella MDC and Abigail manifold (not expected to be covered by rock)[7]	5,280 (0.005)
8	Protective material mattresses at crossing (to be covered by rock)[8, 11]	120 (0.0001)
9	Grout bags (assumed not to be covered by mattresses or rock)[9]	113 (0.0001)
10	Protective material rock – at crossing and Stella MDC locations only[10]	4,680 (0.005)
	TOTAL m^2 (km^2) of seabed disturbed from subsea activities	**274,745 (0.3)**
	Total m^2 (km^2) of seabed disturbance from Phase 1 development activities[11]	**335,033 (0.3)**

Notes: Shaded row not included in final total – see note 11 below
[1]based on 8 x Stevpns Mk6 (12 tonnes) anchors measuring 6m x 6m,
[2]Based on 8 x 750m length of chain on seabed with a total lateral movement of 10m,
[3]Based on length of 12,000m (12km) and assumed overall, worst case width of disturbance corridor of 22m, to account for plough maximum width.
[4]Based on a spool and jumper length of 120m each and estimated width of disturbance corridor on seabed of 2m (this will be protected by mattresses, accounted for in table)
[5]Based on manifold structure 12m x 6m, plus an additional 2m area of impact (so 14m x 8m) for diver intervention the seabed disturbance calculated from the overall size and buffer of the manifold, includes the disturbance from the piles.
[6] Based on the size of the SSIV structure 8m x 6m, plus an additional 2m area of impact (10m x 8m) for diver intervention
[7]Based on 132 mattresses (42 at Stella MDC and 90 at Abigail drill centre) (size of mats: 8 (includes 2m for diver disturbance) x 5m (includes 2m for diver disturbance)) these are assumed not to be covered by rock (these will also cover the spool piece and jumpers)
[8]Based on 3 mattresses at crossing location (these will be covered in rock),
[9]Based on dimensions of bags being 0.45m x 0.25m, assumed here not to be covered in mattresses or rock
[10]Rock at crossing location (cover assumed to measure length of 180m width of 6m and length 180m), and rock at trench transition at Stella MDC, (cover assumed to measure width of 6m and length of 600m), as this rock is being placed at areas where pipeline system not trenched (crossing) or transitioning (crossing and Stella MDC) it has been assumed for assessment purposes not to fall within the disturbance corridor of 22m, calculated under #1 –

the spot rock locations will only be known at installation and these are expected to fall within the 22m disturbance corridor and have not been included here.
[11] It should also be noted that disturbance calculated under number 8 will all occur within the pipeline installation corridor of disturbance and does not represent additional disturbance and has therefore not been included in the total expected disturbance from Phase 1 of the Abigail development.

The area of seabed disturbance from Phase 1 activities is approximately 335,033m^2 (0.3km^2) the majority of which is from disturbance caused by the semi-submersible rig during drilling activity and the disturbance from pipeline installation, both of which have been assessed on a worst case basis. However, it should be noted that the majority of this disturbance, e.g. scrape from anchor chain, is considered temporary, including the pipeline trench, as once backfilled, a clear seabed will be left, with relatively rapid recolonisation by benthic communities (see below). The only areas of permanent disturbance being those areas with rock, mattress and grout bag placement.

In addition to the seabed disturbance described above, there will be small, localised disturbance associated with the cement returns during drilling activities. These annulus returns will be at the surface hole location and expected to be relatively small in nature, the vast majority of cement remaining downhole to cement the casing in place. These are further discussed in Section 6.3 below.

Estimated Seabed Disturbance from Phase 2 Development Activities

Execution of Phase 2 will be dependent on field performance. As planning for this phase is still at an early stage, the rig selection is still to be finalised and either a semi-submersible or jack-up could be used. Estimated seabed disturbance for both rig types have therefore been included here (Table 6.2).

The subsea programme for the second phase, will only comprise of the installation of new spool pieces/jumpers to connect the new well to the Abigail manifold and associated protective material (mattresses and grout bags only). A preliminary layout has been developed for the second phase which requires to be finalised but what is presented in Table 6.2 is expected to be a worst case.

Table 6.2 – Estimated seabed disturbance from Abigail Phase 2 activities

Item	Activity	Estimated seabed disturbance m^2 (km^2)
Drilling activities – Semi-submersible rig		
1	Disturbance as described from Table 6.1	60,288 (0.06)
TOTAL m^2 (km^2) of seabed disturbed from drilling activities (semi-submersible)		**60,288 (0.06)**
Drilling activities – Jack-up rig		
2	Jack-up spud cans	942 (0.0009)
	TOTAL m^2 (km^2) of seabed disturbed from drilling activities	**942 (0.0009)**
Subsea activities		
4	Installation of spool pieces and jumpers[2, 4]	480 (0.0004)
5	Protective material (mattresses and grout bags)[3]	1,056 (0.001)
	TOTAL m^2 (km^2) of seabed disturbed from subsea activities[4]	**1,056 (0.001)**
Total m^2 (km^2) of seabed disturbance from Phase 2 development activities (semi-sub)		**61,344 (0.06)**
Total m^2 (km^2) of seabed disturbance from Phase 2 development activities (jack-up)		**1,998 (0.002)**

Notes: [1]based on 3 x 20m diameter spud cans,
[2]Based on a spool and jumper length of 120m each and estimated width of disturbance corridor on seabed of 2m (this will be protected by mattresses, accounted for in table)
[3]Based on 25 mattresses measuring 6m x 3m with a buffer of 2m (so 8m x 5m for assessment) and 500 grout bags measuring 0.45 x 0.25
[4] The spool pieces and jumpers will be covered by mattresses, these have not been included in total seabed disturbance as they are not additional disturbance to that of the mattresses

The total area of seabed disturbance from Phase 2 activities if a semi-submersible is used, is approximately 61,344m^2 (0.06km^2) the majority of which is from disturbance caused by the rig anchors; this disturbance would likely overlap areas previously disturbed by anchors laid during Phase 1. If a jack-up rig is used, based on three spud cans with diameter of 20m each, and assuming rock is not required for stabilisation, the seabed disturbance would amount to 1,999m^2 (0.002km^2). This disturbance is considered temporary. With the exception of the tie-in spools/jumpers to connect the second production well to the Abigail manifold, and associated protective material (mattresses and grout bags – no rock is proposed for the second phase) no other subsea work is associated with the second phase of the development.

As for the first production well, there will be localised seabed disturbance associated with the discharge of annular returns of cement at the well surface. The returns are expected to be small in quantity. The second well would be a new well, with the top hole sections drilled with a water based mud system. Seabed disturbance will also result from the discharges of mud and cuttings from these top hole sections. These are further assessed in Section 6.3 below.

6.2.1 Potential Impacts

Seabed and Benthic Fauna

Physical effects of seabed disturbance may include mortality to benthic fauna as a result of physical trauma, smothering by re-suspended sediment, and habitat modification due to changed physico-chemical characteristics, including from the introduction and removal of hard substrates.

The response of benthic macrofauna to physical disturbance has been well characterised, with increases in abundance of small opportunistic fauna and decreases in larger more specialised fauna (e.g. Eagle & Rees 1973, Newell *et al*. 1998, van Dalfsen *et al*. 2000, Dernie *et al.* 2003). The duration of effects on benthic community structure are related to individual species' biology and to successional development of community structure. The majority of seabed species recorded from the central North Sea are known or believed to have short lifespans (a few years or less) and relatively high reproductive rates, indicating the potential for rapid population recovery, typically between 1 to 5 years (Jennings & Kaiser 1998), such that any effect will be temporary.

The infauna of the Abigail area is characterised by a range of small, short lived species, which have a widespread distribution and are characteristic of silty, fine sands, while seabed imagery and grab samples from the Abigail and wider area, showed the larger visible fauna to be relatively sparse. Mortality of pennatulid seapens (*Virgularia mirabilis* and *Pennatula phosphorea*), both recorded from surveys in the area (Section 4.4), may be high following physical disturbance, but crustaceans are probably able to restore burrow entrances following limited physical disturbance of the sediment surface (a few cm). *P. phosphorea* spawns annually and its fecundity is high (Edwards & Moore 2008), information on the reproduction of *V. mirabilis* is sparse but based on its wide distribution and abundance is considered likely to be similarly fecund. Gates & Jones (2012) suggest that re-establishment of pennatulids is likely to take in excess of five years due to their slow growth rate (based on the Arctic species *Halipteris willemoesi*).

Relevant information on the recovery of benthic habitats to smothering mainly comes from studies of dredge disposal areas (see Newell *et al*. 1998). Recovery following disposal occurs through a mixture of vertical migration of buried fauna, together with sideways migration into the area from the edges, and settlement of new larvae from the plankton. Defaunated sediments will be rapidly recolonised, likely by a combination of opportunistic species and the species more typical of the Abigail area (Eagle & Rees, 1973). Harvey *et al*. (1998) suggest that it may take more than two years for a community to return to a closer resemblance of its original state (although if long lived species were present this could be much longer). In contrast to habitats in energetic shallow waters, a stable sand and gravel habitat in deeper water is believed to take years to recover (see Newell *et al*. 1998, Foden *et al*. 2009).

The seabed disturbance from anchor scars/mounds (and spud can depressions if a jack-up is used to drill the second well) and other development activities, such as pipeline trenching, are temporary and habitat recovery will depend primarily on re-mobilisation of sediments by current shear (as reviewed by Newell *et al*. 1998, Foden *et al.* 2009). A combination of sediment type (silty sand, sandy silt and muddy sand with ribbons of coarser material), and weak to moderate near bottom water currents together with oscillatory currents during storm events, would cause periodic mobilisation of surface sediments which will infill for example, the anchor scars or spud can depressions over time. Any sediment resuspension into the water column during activities would be expected to be short-lived and with rapid resettlement.

Burrows of *Nephrops norvegicus* are visible in some seabed photos from the Abigail development area although these are classed as rare on the SACFOR scale. This accords with the apparent absence of fishing effort for *Nephrops* and crustaceans in the Abigail area (Figures 4.12 and 4.13). Consequently although there is the possibility of injury or mortality to individual *Nephrops* from rig anchoring, pipelay and other sources of seabed disturbance, given the likely density of the species it is concluded that any such effects at a local or regional scale would be negligible.

In areas of sand/gravel sediments, the introduction of hard substrate (deposits of protective material including rock), might facilitate biological colonisation, including by non-indigenous species, by allowing species with short lived larvae to spread to areas, using these “stepping stones” where previously they were effectively excluded. A concern of introducing hard substrate to a seabed area where currently there is none, is this could result in changing the seabed from one type to another, adversely affecting species with habitat preferences. For example, although not characteristic of any particular known habitat, *Arctica islandica* is known to occur in a range of sediments (i.e. coarse clean sand to muddy sand) and a change in habitat type may result in the habitat being unsuitable, with *A. islandica* considered to have a high sensitivity to physical change to another seabed habitat type (Scottish Government website – FEAST).

Survey data (e.g. GEMS 2010a,b, Calesurvey 2011, Fugro 2017) indicates the existing presence of harder substrate (coarser sediment, identified as shell fragments, and cobbles and boulders) in the Abigail and wider (e.g. Stella and Vorlich) areas and the material introduced as a result of the development activities is not expected to effect a physical change to another seabed type. No species of conservation concern including aggregations of *A. islandica* have also been identified from any of these surveys. It can be expected that all introduced hard substrates (i.e. wellhead infrastructure, manifold, SSIV and protection materials) will be colonised by epifaunal assemblages of various densities and compositions.

Fish

Sandeels have low intensity spawning in the proposed Abigail development area, (November – February) and these are a species feature of existing and proposed protected areas. Sandeels are known to prefer depths of 30 to 70m, although they can occur between depths of 15 and 120m (Holland *et al*. 2005). For example. Jensen *et al*. (2003) found sandeels between 6 and 65mm to depths of 80m. The water depths at Abigail and along the proposed pipeline route range from 89-92m. Studies have also shown sandeels require well flushed, tidally active areas (Pinto *et al*. 1984, Wright *et al*. 2000, cited in Holland *et al*. 2005), with areas where most *A. marinus* occur in sediments have current flows of >0.6ms^{-1} (Wright *et al* 2000). The currents in the Abigail area are relatively weak at around 0.24ms^{-1}.

Sandeels have a habitat preference of sediments composed of fine sand and coarse, medium and fine silt, (with the proportion of these in the overall sediment composition of importance, e.g. Holland *et al.*

2005) and any form of disturbance that disrupts the physical structure of the sediment can result in an indirect threat to sandeel populations (Mazik *et al*. 2015).

Sandeels prefer sediments with a silt and clay content of less than 10% (Wright *et al*. 2000, Jensen *et al*. 2003). Holland *et al*. (2005) found the occupancy and density of sandeels in sediments containing more than 4% silt was extremely low. From surveys, undertaken by Ithaca Energy across the Greater Stella Area, including the proposed development location, the sediment samples which were fines (silt and clay) ranged from 8.9% (at 2 sample locations out of 25) to 39.5% (Calesurvey 2013). The fines from the survey undertaken at Vorlich by BP, just to the north, ranged from 12.4% to 18.5% (Fugro 2017). As the sediment has a high silt content, an absence of sandwaves/banks, and given the water depths and currents the habitat at Abigail is not likely to support abundant sandeels.

Of the range of activities associated with the development, *sub-surface abrasion/penetration*, which could cause local mortality and *physical change to other seabed type*, which sandeels are sensitive to as they have specific sediment requirements which affect presence and density (Wright *et al*. 2000), have been identified as being "high" pressures for this feature from the Feature Activity Sensitivity Tool (FEAST) (Scottish Government 2013). The latter of these is included as protective material is being laid, which introduces new habitat, (hard substrate) at localised areas. However, numerous surveys in the region have identified pre-existing hard substrate in the form of cobbles, boulders and shell fragments and significant habitat modification from the protective material is therefore unlikely.

Operational Controls, Mitigation and Data Gaps

Ithaca Energy’s contractor selection process takes into consideration a prospective contractors ability (including resources and experience) to undertake work in an environmentally sound manner (see Section 2.1), with interfaces detailing responsibilities development, including environmental responsibilities, and regular HS&E meetings, as required.

Project planning includes minimising, as far as practicable, rig/vessel movements, including the use and movement of anchored vessels and the installation of the production pipeline, gas lift pipeline and services umbilical within a single trench, with backfill of excavated material. The use of protective material, including rock, quantities, are to be minimised as far as practicably possible and placed as accurately as possible from vessels; a condition of the permit is to deposit material at and within coordinates applied for.
No specific additional mitigation was considered necessary beyond application of established operational controls.

No significant data gaps have been identified. The dimensions of the infrastructure being installed and protective material (mattresses and grout bags) are known and this has been used to estimate the scale of seabed disturbance from development activities. Assumptions have been applied in some cases (e.g. length of anchor chain on the seabed, lateral movement, and number of mattresses used), however, these are based on the potential worst case disturbance, with final disturbance expected to be less than this. There is a good understanding of habitats and fauna present, from site and surrounding seabed surveys and peer reviewed scientific data, and potential impacts of these from similar development activities. A site survey is planned for the Summer of 2021, data from which will supplement existing understanding of the Abigail environment.

Conclusion

For Phase 1 activities, seabed disturbances will occur; anchor and catenary scars will be formed from the semi-submersible rig, and installation of the pipeline system and associated protective material will result in physical disturbance of the seabed. If Phase 2 is progressed, the overall level of seabed disturbance will be smaller, reflecting a smaller programme of activity, and particularly if a jack-up rig is used.

With the exception of the introduction of new hard substrate (i.e. rock), these disturbances are expected to be temporary in nature, and not expected to persist or result in changes in sediment characteristics, significant compaction or faunal effects. The duration of effects on the benthic community will be temporary.

Multiple seabed surveys in the Abigail and wider area have reported no indication of Annex I or other sensitive habitats or species present, including the presence of *Arctica islandica* aggregations (Calesurvey 2012, GEMS 2010a,b, Ithaca 2011), with only individuals observed (e.g. Fugro 2017). In all cases, the scale of changes to the seabed and its fauna are such that effects on higher trophic levels (e.g. fish and marine mammals), and any related effect on species of commercial interest are not predicted.

Although the Abigail area coincides with low intensity sandeel spawning (Ellis *et al*. 2012), which is noted to be present over wide areas across the UKCS, site-specific survey data suggests that the habitat present does not fall within that preferred by sandeels.

In additional, the current schedule is to complete subsea installation and tie-in by September (Table 3.5, Section 3.3), prior to the start of the spawning period. Taking these factors into consideration, and that surveys in the Abigail and wider area did not identify the presence of sandeels, it is therefore considered likely that if sandeels are present it is only in low numbers.

6.3 Effects of Discharges to Sea

Drilling Discharges

The only potentially significant discharges identified for the development were from drilling. The range and quantities of those used in the pipeline system installation are typically smaller, the majority of these being components (e.g. corrosion inhibitor, biocides) in the potable or sea-water flushes and dyes for hydrostatic pressure testing and are not considered further here (see Table 5.3 above).

Discharges to sea from these activities will be as a result of:

- Chemical discharge from drilling activities (including cementing chemicals and well clean up) (Phase 1 and 2)
- Water-based mud (WBM) and cuttings (Phase 2 only)

The range of chemicals for drilling activities will be typical of those widely used in the oil and gas industry throughout the UKCS.

The UK is a contracting party to the 1992 OSPAR Convention under which it has a requirement to, amongst other things, register and assess chemicals used and discharged by the oil and gas industry. In the UK this is done under the Offshore Chemical Notification Scheme (ONCS) administered by BEIS, using scientific and environmental advice from CEFAS (the Centre for Environmental, Fisheries, and Aquaculture Science). Information required for the OCNS includes a ranking for each chemical, either their HQ (Hazard Quotient) value (categories being Gold, Silver, White, Blue, Orange, Purple) or OCNS Group (A, B, C, D and E), which gives an indication of whether they would have a significant environmental effect; HQ Gold and OCNS E representing the least potential hazard (see CEFAS website). Using expert judgement and after assessment, the OSPAR Commission also regularly publish a list of PLONOR substances, which are considered to Pose Little or No Risk to the environment, and as such the use and discharges of which do not require strong regulation.

Small discharges of cementing chemicals is likely both as direct annular returns at seabed and at surface following displacement of cement from the hole. The amount of cement slurry pumped is based on the experience and offset well information in the North Sea. It is important to have the top of cement back to the seabed level to provide the necessary structure support for the whole well, providing the well integrity and zonal isolation required. The slurry returns to the seabed will most likely be dispersed by the seawater due to the current at seabed level and as such has not been assessed here as a separate area of seabed disturbance. Upon completion of drilling activities, the seabed is surveyed assessed as part of the rig debris clearance survey post drilling.

The second production well, if drilled, is expected to utilise a water based mud system for the top hole sections. The mud and cuttings from these sections will be discharged to sea. Surface hole cuttings are displaced directly from the well bore (rather than via the drill rig) and accumulate immediately around the wellhead, typically forming a low mound of material around the wellhead. Hartley (1996, Figure 1) reported a mound up to 1m high and extending to 5m around UKCS well 29/12-2 in 88m water depth. Such surface hole cuttings accumulations are predicted to disperse naturally over time.

The sections for the first production well will be drilled using a low toxicity oil based mud (LTOBM), as will the lower hole sections of the second well during Phase 2. The mud and cuttings from these sections will not be discharged to sea, but will instead be retained on the rig for skip and ship to shore for processing (see Section 3.72 and 3.8.2). Therefore, only the estimated WBM and cuttings from the top hole (36", 26" and 17½") sections of the proposed second well have been included here.

WBM will be used and discharged on cuttings and as excess mud expelled from the wellbore for the top hole sections. Although well design is still to be finalised, the design will aim to minimise hole sizes as far as technically possible, and thus the volume of cuttings generated.

WBM cuttings are typically discharged at, or relatively close to the sea surface during closed drilling (i.e. when steel casing in the well bore and a riser to the rig are in place), whereas surface hole cuttings are normally discharged at seabed during open-hole drilling. Surface hole cuttings are derived from shallow geological formations and a proportion will be similar to surficial sediments in composition and characteristics. The WBM constituents are typically comprised of the least harmful chemicals with the majority expected to be on the PLONOR list.

There may also be a discharge of interface fluids, after recovery of the LTOBM cuttings and clean up fluids when inhibited seawater is circulated through the well to ensure removal of all LTOBM. This discharge contains substitute hydrocarbons, components of the LTOBM system. The discharge from this is typically small, a few 100 cubic metres in most cases, and only discharged if cleaned up to at least 30mg/l or below. For example, a discharge of 300m^3 of interface fluid, at 30mg/l, would equate to a discharge of 9kg of substitute hydrocarbons, which would be expected to rapidly disperse upon discharge.

Operational Discharges

Discharges to sea from operations will principally be as a result of:

- Produced water discharge

The principal discharge of potential concern from operations is produced water. It is anticipated that no new chemicals will be required for the Abigail Field production and as the Abigail hydrocarbons are comingled subsea with those from Stella and Harrier and processed on the existing production stream, any increase in existing chemical use and discharge on the FPF-1 will be minor.

Produced water is derived from formation water in the reservoir and has a complex composition, including dispersed oil, metals and organic compounds including dissolved hydrocarbons, organic acids and phenols. Produced water composition varies between specific installations, and generally differs considerably between oil and gas reservoirs. The development of the Abigail Field will result in a considerable increase in the discharge of produced water compared to that currently discharged from the FPF-1. Peak produced water from Abigail is estimated at 501m^3/day (182,865m^3/year), with an associated annual oil discharge of 3.7 tonnes, based on 20mg/l; in 2020, the produced water discharged from the FPF-1 amounted to 88,303m^3 (with an associated oil discharge of 1.7 tonnes of oil) – see Section 3.11. At commissioning, Abigail production is expected to result in an initial spike in oil in water discharge, as the process moves into a steady state of production and, based on the average OIW discharge at commissioning of the Vorlich field, and the expected produced water discharge from Abigail in 2022, this has been estimated to be *ca*. 302kg (0.3 tonnes) of oil (see Section 3.11).

In 2018, the produced water discharged to sea in the UKCS as a result of oil and gas production was 139 million m^3 and around 2,180 tonnes of dispersed oil was discharged to sea with produced water (OGUK 2019). The produced water discharge had increased in 2019 by 0.32% to 143 million m^3, while the associated oil discharged had increased by 5% to 2,296 tonnes, as the average OIW concentration being discharged had increased from 16.1mg/l in 2018 to 16.9mg/l in 2019 (OGUK 2020).

Estimated peak produced water from Abigail (501m^2/day in 2024, mid case and 2027 high case) equates to 0.1% of the UKCS produced water total in 2019 and 0.2% of the oil discharged.

Potential Impacts

Chemical and Cuttings Discharges

A range of chemicals will be used and discharged during the drilling and completion of the well(s), those with the best environmental profile selected where technically feasible to do so. The fish species known to spawn in the area, some of which are priority marine species in Scottish waters, are pelagic spawners, with the exception of sandeels, although the larvae of these are pelagic for around one to three months. The eggs and larvae of these commercially important species may therefore be present in the water column, and these may be affected if they interact with chemical discharges.

If executed, WBM cuttings will be discharged as part of Phase 2 activities only. Dispersion of these is influenced by various factors, including particle size distribution and density, vertical and horizontal turbulence, current flows and water depth. The WBM cuttings discharged at sea surface will separate into larger particles and flocculated solids, representing about 90% of the mass of the solids (Neff 2005), which will settle to the seabed over a considerable distance, dependant on hydrographic conditions and cuttings particle characteristics. Once deposited on the seabed they may be further mixed into surficial sediment through bioturbation (the activity of burrowing fauna). Remaining fine-grained unflocculated clay-sized particles and a portion of the soluble components of the mud will remain in suspension in the water column and disperse rapidly in the receiving waters. In deeper water, the range of cuttings particle size results in a significant variation in settling velocity, and a consequent gradient in the size distribution of settled cuttings, with coarser material close to the discharge location and finer material very widely dispersed away from the location, generally at undetectable loading (DECC 2016, JNCC PAD 2018).

Effects of WBM and cuttings discharges on the bottom environment are related to the total mass of the drilling solids discharged and the relative energy of the water column and benthic boundary layer at the discharge site. In low hydrodynamic energy environments such as the central North Sea, redistribution of cuttings accumulations will be slow, and the topographic pile will probably persist over decades (unless disturbed by future activity at the well, decommissioning or other anthropogenic disturbance). Where several wells are drilled from one location and/or where the depositional footprint of several drilling locations overlap, the deposition of cuttings will be cumulative; the first of the Abigail production wells is a re-entry of the existing appraisal well 29/10b-8, and the lower hole sections will be drilled with an LTOBM with no mud/cuttings discharged, therefore no further cuttings will be deposited at the well location from this drilling activity. The second well, if drilled, has potential for cumulative impact as the depositional footprint of WBM/cuttings (finer particles) from this well may slightly overlap those from the appraisal well when it was drilled in 2012; this second well is approximately 155m from the location of the first well.

As part of the assessment of the Greater Stella Area development (Ithaca 2011), cuttings discharge was modelled as a plug discharge of 6,062 tonnes, corresponding to discharges of 507 tonnes for the 26" section and 359 tonnes for the 17½" section, from each of seven wells. The discharge was apportioned between the three drilling centres in the relative proportions: Stella MDC 57.1% (4 wells), Stella NDC 14.3% (1 well) and Harrier 28.6% (2 wells); cuttings discharge from the second Abigail well is estimated as 1,051 tonnes, corresponding to discharges of 178 tonnes for the 36" section, 467 tonnes for the 26" and 406 for the 17½" (see Section 3.6). Cuttings settling velocities for 13 categories in the range 1.4-200 µm (median particle size 10µm) were obtained from the BenOss Stoke's law module, (see Cromey 1998), using an empirical particle size distribution for water-based mud cuttings from "hard" rock. Model output was parameterised as solids deposition (grams) per unit area (m^2). The predicted cuttings footprint had a total area (estimated by contouring at 400m grid resolution for the area >10 g/m^2) of 119,426,868m^2. The individual settlement footprints from the three release points interacted; however a large proportion of the material predicted to deposit within the model area was located within distances of 5,000m NNE and SSW of the well locations, which was consistent with residual current velocity (0.007m/s) and median settling velocity ($\approx 10^{-4}$m/s). Predicted peak settling rates were equivalent to 97.6 g/m^2, equivalent (for material with a specific density of 2.1 g/ml) to a deposited thickness of ≈0.047mm. These values are comparable to natural erosion/deposition rates recorded in the North Sea (20-200g/m^2/year) (OSPAR 2000) and were considered unlikely to have significant ecological effects through smothering or physical disturbance. The estimated cuttings from the proposed second Abigail well are considerably less than that modelled from the Greater Stella Area assessment.

Pre-and post drilling ROV surveys of an exploration well drilled West of Shetland, in *ca*. 600m water were compared (Jones *et al*. 2006, 2012) and documents physical smothering effect within 100m of the well and fine sediment was visible on the seafloor (outside the area of smothering), up to at least 250m from the well; finer particles may be dispersed over greater distances than coarser particles although exposure to WBM cuttings in suspension will in most cases be short-term (Bakke *et al*. 2013). After 3 years, there was significant removal of cuttings particularly in the areas with relatively low initial deposition (Jones *et al*. 2012). The area impacted by complete cuttings cover had reduced from 90m to 40m from the drilling location, and faunal density within 100m of the well had increased considerably and was no longer significantly different from conditions further away (DECC 2016).

In contrast to historic oil based mud discharges, effects on seabed fauna of the discharge of WBM cuttings and excess and spend mud, are usually subtle or undetectable, although the presence of drilling material at the seabed is often detectable chemically close to the drilling location (<500m); considerable data has been gathered from the North Sea and other production areas, indicating that localised physical effects (including smothering) are the dominant mechanism of ecological disturbance where water-based mud and cuttings are discharged (e.g. Cranmer 1988, Neff *et al*. 1989, Hyland *et al*. 1994, Daan & Mulder 1996, Currie & Isaacs 2005, OSPAR 2009a, Bakke *et al*. 2013). The use of ROV has allowed the detection of small scale changes in benthic fauna in the immediate vicinity of a wellbore, for example Hughes *et al*. (2010) found declines of the density of sea urchin *Gracilechinus acutus* within 50m of a well in the Norwegian sector of the North Sea; such effects are considered temporary and negligible.

Field experiments examining effects of WBM cuttings on benthos found only minor differences in faunal composition between the control and those treated with cuttings after 6 months (Trannum *et al*. 2011). This corresponds with the results of UK and international field studies from a wide range of water depths, and hydrographic and ecological conditions where complete recovery was recorded within 1-2 years after WBM cuttings deposition (Cranmer 1988, Hartley Anderson 2005, Daan & Mulder 1996, Currie & Isaac 2005). Bakke *et al*. (2013) reflect a similar conclusion but note the possibility that WBM discharges may cause subtle changes to benthic community structure on a wider geographical scale and that such effects would be extremely difficult to distinguish from natural benthic community changes.

Chemically inert, suspended barite has been shown under laboratory conditions to potentially have a detrimental effect on suspension feeding bivalves. Standard grade barite, the most commonly used weighting agent in WBMs, was found to alter the filtration rates of four bivalve species (*Modiolus modiolus, Dosinia exoleta, Venerupis senegalensis* and *Chlamys varia*) and to damage the gill structure when exposed to 0.5mm, 1.0mm and 2.0mm daily depth equivalent doses (Strachan 2010, Strachan & Kingston 2012). All three barite treatments altered the filtration rates leading to 100% mortality. The horse mussel (*M. modiolus*) was the most tolerant to standard barite with the scallop (*C. varia*) the least tolerant. Fine barite, at a 2mm daily depth equivalent, also altered the filtration rates of all species, but only affected the mortality of *V. senegalensis*, with 60% survival at 28 days.

The bulk of WBM constituents (by weight and volume) are on the OSPAR list of substances used and discharged offshore which are considered to Pose Little or No Risk to the Environment (PLONOR). Barite and bentonite are the materials typically used in the greatest quantities in WBMs and are of negligible toxicity. Field studies undertaken by Strachan (2010) showed that the presence of standard grade barite was not acutely toxic to seabed fauna but did alter benthic community structure. When the suspended barite levels used in laboratory studies are translated to field conditions (i.e. distances from the point of discharge) it is clear that any effects will be very local to a particular installation (in the case of oil and gas facilities, well within 500m).

Produced Water

The toxic effects of produced water are influenced by bulk dispersion and dilution processes following discharge and by bioaccumulation and biomagnification of individual contaminants. Chemical composition and effects of produced water discharges have been reviewed previously (e.g. Middleditch 1981, 1984, Davies *et al*. 1987, Ray and Engelhardt 1992, E&P Forum 1994, Reed and Johnsen 1996, OLF 1998). Chemical composition is strongly field-dependent, with generally no correlation between the oil-in-water content (which is used as the standard for environmental regulation) and the aromatic content. Studies of acute and chronic toxicity of produced water in Norway (OLF 1998) concluded that Polycyclic Aromatic Hydrocarbons (PAH) and alkylated phenols were the major contributors, with immune toxic, carcinogenic and teratogenic effects in the former, and oestrogenic effects in the latter case; other components of produced water include metals and residual process chemicals and these are considered likely to have significant effects (OLF 1998).

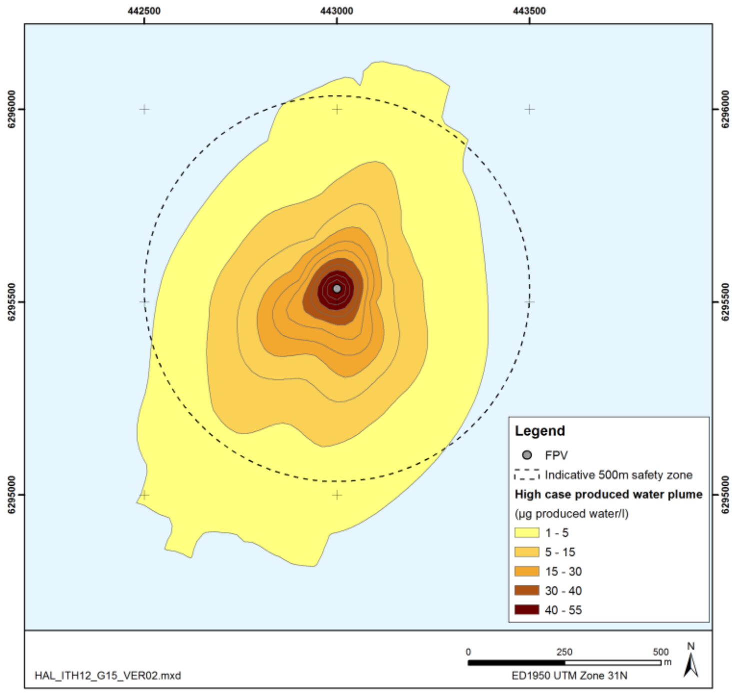
Bakke *et al*. (2013) reviewed research on the biological effects of offshore produced water discharges, with focus on the Norwegian waters. Produced water discharges are a continuous source of contaminants to continental shelf ecosystems, and alkylphenols and PAHs were found to accumulate in cod and mussels caged near the discharge points, but these compounds are rapidly metabolized in cod. Such compounds may affect reproductive functions, and various chemical, biochemical and genetic biomarkers but Bakke *et al*. (2013) concluded that the risk of widespread impact from such operational discharges is low.

Dispersion modelling of produced water discharges was undertaken as part of the Stella and Harrier environmental assessment, over a representative spring tidal period, using the generic mass conservation, dynamic compartment modelling framework for aquatic systems *Water Quality Analysis Simulation Program* (WASP, Ambrose *et al*. 1993) (Ithaca 2011). WASP provides a structure for modelling in one, two or three dimensions and incorporates time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange.

WASP incorporates two kinetic sub-models to simulate two of the major classes of water quality problems: conventional pollution (involving dissolved oxygen, biochemical oxygen demand, nutrients and eutrophication) and toxic pollution (involving organic chemicals, metals, and sediment); the latter was used in FPF-1 case. Bulk dispersion of produced water from the source under consideration was modelled as a simple toxicant, with continuous discharge of a neutrally buoyant effluent at rates derived from forecast production data at the time.

One of the representative PW discharge rates modelled was 4,122 bwpd; the peak produced water volumes generated by Abigail, is estimated to be 3,150 bwpd (501m^3). This model utilised extrapolated current data from charted tidal diamond "E" (57º 10.0'N 002º 22.0'E), for a nominal 4 day period, with charted neap and spring velocities and directions from the tidal diamond scaled at 1h intervals in relation to predicted tidal heights for Aberdeen over the modelled period (Figure 6.1, see also Ithaca 2011). The segment network consisted of two layers, each of 20x6 100m square segments. The surface layer was defined as 20m thick, and the bed layer as 70m. Volume was estimated as the product of these. Flow time series were defined for surface and bed layers and the output concentration data from WASP were contoured for bed and surface layers using SURFER v8.0. A mass balance for the model was carried out using the volume function in SURFER; confirming that total PW mass at the end of each model run was >98% of mass released (Ithaca 2011).

Figure 6.1 – Plume contours for produced water discharge from the FPF-1



Notes: Plume contours for 4,122 bwpd produced water forecast rate

Predicted plume dispersion of the discharge indicated dispersion of around 200 million (i.e. to 5µg of produced water/l) within 500m of the platform. In general, the 1µg of produced water/l contour lies within 500m for the median case discharge. Peak concentrations in the bed layer are around 20% those in the surface layer, as a result of limited vertical mixing.

A small number of dispersion modelling studies of produced water plumes from offshore installations have been published (e.g. Washburn *et al.* 1999 (produced water outfall in 12m water Santa Barbara Channel, California), Burns *et al*. 1999 (produced water from Harriet A platform, northwest shelf of Australia), Riddle *et al*. 2001 (distribution of dispersed oil, East Shetland Basin, North Sea), Berry & Wells 2004 (dispersion in nearfield (0-150m) depths on Sable Island Bank, Scotian Shelf, Canada). As part of a long-term programme of studies undertaken by SFT[16] in Norway, mussels and semi-permeable membrane devices (SPMDs) were deployed in the Ekofisk and Tampen Regions and analyzed for more than 50 polycyclic aromatic hydrocarbons (Durell *et al*. 2006). PAH concentrations in ambient seawater were estimated based on the mussels and SPMD concentrations, and compared to model predictions using the DREAM model (Reed *et al*. 2001). Surface water total PAH concentrations ranged from 25 to 350 ng/l within 1km of the platform discharges and reached background levels of 4–8 ng/l within 5–10 km of the discharge; a 100,000-fold dilution of the PAH in the discharge.

Overall, the consensus of both predictive modelling and observational studies (using dye and contaminated tracers) is that dilution in the range of several thousand to several hundred thousand will be achieved over a down-plume distance of the order of 1000m; the achieved dilution being largely dependent on water depth and degree of vertical mixing. The assessment of produced water dispersion from the Stella and Harrier development predicted dispersion exceeding this range, largely as a result of the relatively low discharge rate and of initial mixing into a relatively large surface model segment with subsequent mixing throughout the full water column. The validity of the prediction is dependent on density of the discharge plume and density stratification of the water column; however, most produced waters are both high salinity and high temperature (relative to ambient) and assumptions of neutral buoyancy is therefore considered reasonable (Ithaca 2011).

Studies of "whole effluent" toxicity of produced water have generally concluded that No Effect Concentrations are in the range 500-10,000 ppm of produced water. For example, in two of three experiments, additions of fresh produced formation water to seawater had little or no effect on 14C uptake by phytoplankton up to concentrations of 1% (10,000 ppm v/v). In contrast dilutions of 500 ppm (v/v) (<1/2000) resulted in clear inhibition of bacterial thymidine uptake in three out of four experiments (Burns *et al*. 1999). Although spanning several orders of magnitude, these concentration levels were predicted to be limited to the immediate vicinity (<100m, the segment resolution of the WASP model) of the Stella/Harrier fields discharge; and the total area affected to be small (< model resolution of $0.01km^2$). At a wider scale, produced water discharges are distributed at a broadly comparable density (i.e. discharges of comparable rate, at comparable spatial separation) over developed reservoir basins in the central and northern North Sea (although large areas of the North Sea are without production discharges), and an overall affected spatial proportion of around 1% is probably a reasonable estimate. This conclusion would support the assumption that dispersion of any individual plume is by sea water with no significant contamination from other sources (i.e. that there is no cumulative effect of multiple discharges). A further consideration in assessment of the overall effects of produced water discharges is the assumption, (used for the Stella/Harrier discharge), of conservative behaviour of the toxic components of the discharge. In reality, volatilisation and biodegradation of many organic components will be significant within the modelled timeframe (96h) and toxicity effects would be expected to be correspondingly reduced.

Operational Controls, Mitigations and Data Gaps

Chemicals for the drilling activities will be selected with potential environmental impacts in mind, with those with the best environmental profile selected, where technically feasible to do so. For other drilling and subsea campaigns undertaken by Ithaca Energy in the area, these have primarily been E, PLONOR or Gold, with the same approach to chemical selection and management to be taken for Abigail activities.

All relevant chemicals will be subject to a chemical assessment, as part of the chemical permitting process, prior to any activities being undertaken offshore. Where sufficient justification cannot be provided for the use and discharge of a chemical, these will be identified for replacement.

[16] The Statens ForurensningsTilsyn – the Norwegian pollution control authority

Chemicals, such as demulsifiers, are used in the produced water process stream on the FPF-1, which aids in the removal of entrained oil, "cleaning" the produced water. No new additional chemicals are expected to be required for Abigail. The use and discharge of the existing chemical suite may be required, given the increased quantities of produced water. As for drilling and subsea activities, operational chemical use and discharge is assessed and applied for through the permitting process. There is an ongoing chemical management approach for the FPF-1 which includes the trialling of new chemicals to improve the overall quality of produced water discharges.

There is limited scope for additional mitigation measures to reduce the quantity of produced water discharged from Abigail; re-injection facilities are not available. Production chemistry will be assessed, to identify any potential impact on water quality, with any additional application topsides to aid in oil/water separation and water treatment evaluated, the aim being to meet the discharge permit obligation as quickly as possible.

No significant data gaps have been identified. Although final chemical selection for the drilling campaign(s) is not known, there is a good understanding of the type of chemicals used, with preference for those with a better environmental profile, where technically feasible to do so. There is a good understanding of the behaviour of WBM and cuttings (relevant to Phase 2 only) upon discharge and the effects on the fauna known to be present in the Abigail area. Previous modelling studies of produced water discharges predicted from the FPF-1, and other UK and international studies of produced water discharges, provide a good understanding of the behaviour of these discharges and their effects on water quality and the surrounding fauna.

There is continued monitoring and review of production chemistry on the FPF-1 and this will continue at the start of Abigail production and during operation of the field.

Conclusion

The discharge of chemicals from the drilling and subsea activities will be kept to a minimum and be assessed prior to work being undertaken offshore. Chemicals of low toxicity and bioaccumulation potential, and without substitution or other warnings, will be preferentially selected for use where technically feasible to do so. Chemicals discharged to the water column have the potential to interact with fish species with known spawning and nursery ground in the area. However, in the context of the wider availability of the spawning/nursery areas of these species, any effect on population levels is likely to be negligible. Given the mobility of juveniles, and their use of the wider nursery areas, they are expected to be able to move away before any lethal levels are experienced. Chemicals are typical of those used in the UKCS and their discharge is not expected to have a significant effect on the marine environment.

The effect of WBM cuttings are expected to cause some smothering near the vicinity of the discharge, but these are expected to be localised and of short duration and the effects on benthic fauna typically subtle or undetectable (e.g. OSPAR 2009, Daan & Mulder 1996). WBM drilling discharges would only be made from the second production well if drilled. The species present in the Abigail area, are considered relatively resilient to the effects of sediment disturbance and to rapidly recolonise disturbed or displaced sediments. Beyond the zone of physical smothering immediately around the wellhead, significant ecological effects of surface hole cuttings are not predicted.

Abigail production will result in a significant increase in produced water volumes from the FPF-1, particularly at peak water. The effects of produced water discharges are relatively well understood, with the impacts of the discharge localised (most concentrated discharge <100m of the discharge point), with rapid dilution expected and the impacts beyond this predicted to be negligible.

6.4 Effects of Atmospheric Emissions

Atmospheric emissions were identified in Section 5 as being a potential source of effect from the development activities. Sources of emissions include:

- Drilling power generation and helicopter traffic
- Combustion emissions from vessels
- The increment to the FPF1 production and resulting power generation emissions and flaring

Emissions of relevant gas species and their associated Global Warming Potential (GWP) have been estimated for these activities, using standard Environmental and Emissions Monitoring System (EEMS) conversion factors (DECC 2008) to estimate the relative quantity of each gas species from combustion for offshore works, and the most recent GWP metrics (Myhre *et al*. 2013 Table 6.2). The result is a value in tonnes of CO_2 equivalent (CO_2 eq.) based on the radiative forcing effect of each GHG species relative to CO_2 and the atmospheric residence time of each gas. The GWP factor therefore changes depending on the "time horizon" considered (see IPCC 2001, 2007, Myhre *et al*. 2013, and Shine 2009 for a synthesis and critical review). For the purposes of this assessment, a 100 year time-horizon has been used, in line with its adoption by the United Nations Framework Convention on Climate Change (Myhre *et al*. 2013), and nationally for the calculation of carbon dioxide equivalent emissions (Shine 2009).

Table 6.3 – Emissions Factors

Gas	CO_2	N_2O	CH_4	NOx	SO_2	CO	NMVOCs
Diesel (engine)	3.22	0.00022	0.00018	0.0594	0.004	0.0157	0.002
Aviation fuel (helicopter)	3.15	0.00012	0.00035	0.012	0.0009	0.00953	0.00306
Diesel (turbines)	3.2	0.00022	0.0000328	0.0135	0.004	0.00092	0.000295
Gas (turbines)	2.86	0.00022	0.00092	0.0061	0.0000128	0.003	0.000036
Gas flaring (associated gas)	2.8	0.000081	0.01	0.0012	0.0000128	0.0067	0.01
GWP at 100 years	1	265	28	-	-	-	-

Notes: [1]sulphur content of marine diesel fuel assumed to be 0.1% based on requirements for Emissions Control Areas: IMO website.
Source: IPCC (1996), DECC (2008), Myhre et al. (2013), AEA-Ricardo (2015)

Emissions Associated with Phase 1 and 2 Development Activities

The emissions calculations (Table 6.4 a and b) are based on the emission factors described in Table 6.3 above and on a range of assumptions relating to rig/vessel type and timings (Table 3.12, Section 3.8).

Table 6.4a – Estimated emissions drilling activities

Gas	Helicopter traffic	Standby vessel	Supply vessel	Rig mob and demob	Anchor handling	Rig on location	Well cleanup	Total Mass	Total ($tCO_2eq.$)
Phase 1									
CO2	113	243	1,066	224	154	4,378	6,359	12,536	12,536
N2O	0.004	0.02	0.07	0.02	0.01	0.30	0.17	0.59	157
CH4	0.01	0.01	0.06	0.01	0.01	0.25	67.90	68.25	1,911
NOX	0.43	4.51	19.78	4.16	2.85	81.26	5.75	118.74	

Gas	Helicopter traffic	Standby vessel	Supply vessel	Rig mob and demob	Anchor handling	Rig on location	Well cleanup	Total Mass	Total ($tCO_2eq.$)
SO_2	0.03	0.30	1.33	0.28	0.19	5.47	0.03	7.64	
CO	0.34	1.19	5.23	1.10	0.75	21.48	28.64	58.73	
VOC	0.11	0.25	0.67	0.14	0.10	2.74	36.39	40.38	
								Total from Phase 1	14,604
Phase 2									
CO_2	124	262	1,181	224	154	4,723	5,286	11,954	11,954
N_2O	0.005	0.02	0.08	0.02	0.01	0.32	0.15	0.60	158.89
CH_4	0.01	0.01	0.07	0.01	0.01	0.27	67.01	67.39	1,887
NO_X	0.47	4.87	21.92	4.16	2.85	87.67	3.85	125.79	
SO_2	0.04	0.33	1.48	0.28	0.19	5.90	0.02	8.24	
CO	0.37	1.29	5.79	1.10	0.75	23.17	19.67	52.15	
VOC	0.12	0.16	0.74	0.14	0.10	2.95	22.54	26.75	
								Total from Phase 2	14,000
								Total from Phases 1 and 2	28,603

Table 6.4b – Estimated emissions from subsea activities

Gas	Phase 1							Phase 2	Total	Total ($tCO_2eq.$)
	Pipelay vessel	Trenching vessel	Utility vessel	Rock placement vessel	Construction vessel	Dive support vessel	Guard vessel	Second well tie-in		
CO_2	326	512	851	256	704	1,664	192	960	5,466	5,466
N_2O	0.02	0.04	0.06	0.02	0.05	0.11	0.01	0.07	0.4	99.6
CH_4	0.02	0.03	0.05	0.01	0.04	0.09	0.01	0.05	0.3	8.6
NO_X	6.06	9.50	15.80	4.75	13.07	30.89	3.56	17.82	101.5	
SO_2	0.41	0.64	1.06	0.32	0.88	2.08	0.24	1.20	6.8	
CO	1.60	2.51	4.18	1.26	3.45	8.16	0.94	4.71	26.8	
VOC	0.20	0.32	0.53	0.16	0.44	1.04	0.12	0.60	3.4	
									Total	**5,574**

The programme of activities from Phase 1 including the drilling of the first production well, related cleanup, and the installation of the new pipeline system and associated subsea infrastructure is estimated to result in emissions of ~19,199 $tCO_2eq.$; the second phase including the drilling of a new production well and short duration subsea campaign is estimated to result in emissions of ~14,979 $tCO_2eq.$ Combined, emissions from both phases amount to ~34,177 tCO_2eq

Emissions Associated with Production

Incremental fuel gas emissions will be associated with production from Abigail (Section 3.11.2). The fuel gas increment associated with Abigail varies by production case and estimates have been made for the associated emissions for each of these (Table 6.5). On the basis of a high production case (P10), the incremental fuel gas use through field life is estimated to be 16,326t, equivalent to *ca*. 48,064$tCO_2eq.$

To provide a current context, CO_2 emissions from operations at the FPF1 in 2018 were 136,301 tonnes, with power generation (gas turbines, using fuel gas) the main source accounting for 87% of this total. When compared with the estimated cumulative emissions associated with the Stella, Harrier and Vorlich fields across the producing interval for each of the Abigail production cases, Abigail represents an estimated 1.7%, 1.9% and 2.6% increment in emissions for the Low, Mid and High cases respectively. The estimated increment to fuel gas emissions can be seen in the context of fuel gas use in the absence of Abigail (i.e. incorporating only the Stella, Harrier and Vorlich Fields), in Figure 6.2.

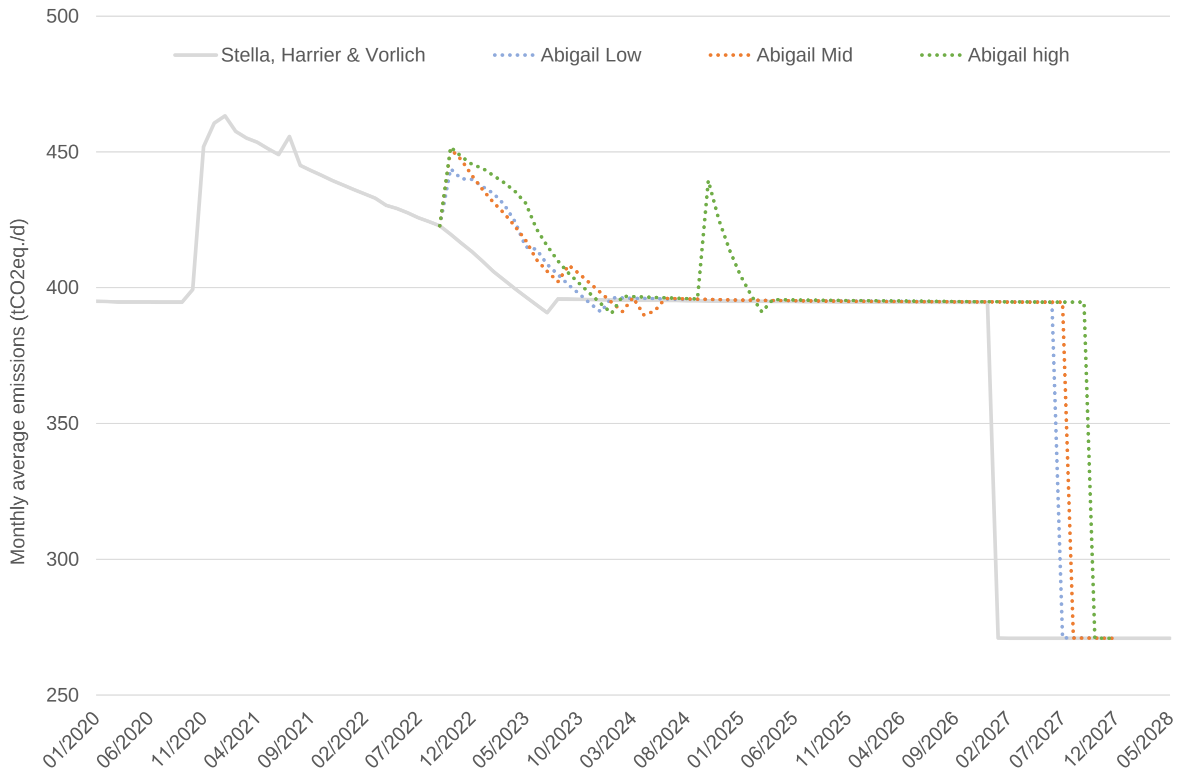
Table 6.5: Total emissions associated with each Abigail production case (tonnes)

Gas	Low	Mid	High
CO_2	29,607	33,653	46,691
N_2O	604	686	952
CH_4	267	303	421
NOx	63.15	71.78	99.59
SO_2	0.13	0.15	0.21
CO	31.06	35.30	48.98
VOCs	0.37	0.42	0.59
CO2eq.	30,477	34,642	48,064

Note: Emissions and GWP metrics used to estimate the above values are those presented in Table 6.2

As noted in Section 3.13.3, flaring is restricted to compressor trips, plant trips, emergency shutdowns, weather outages etc. The addition of Abigail will not result in an increase in the number of such events, nor will it change the mass of any such flaring event. Any flaring associated with Abigail is, therefore, a proportion of the gas attributable to the field that is combusted during a flaring event, but this will not represent any increment to the emissions of flaring on FPF-1. Similarly, there will be no increment to the current levels of venting on FPF-1, and therefore, no incremental emissions from venting.

Figure 6.2: Incremental emissions associated with Abigail in the context of those from Stella, Harrier and Vorlich

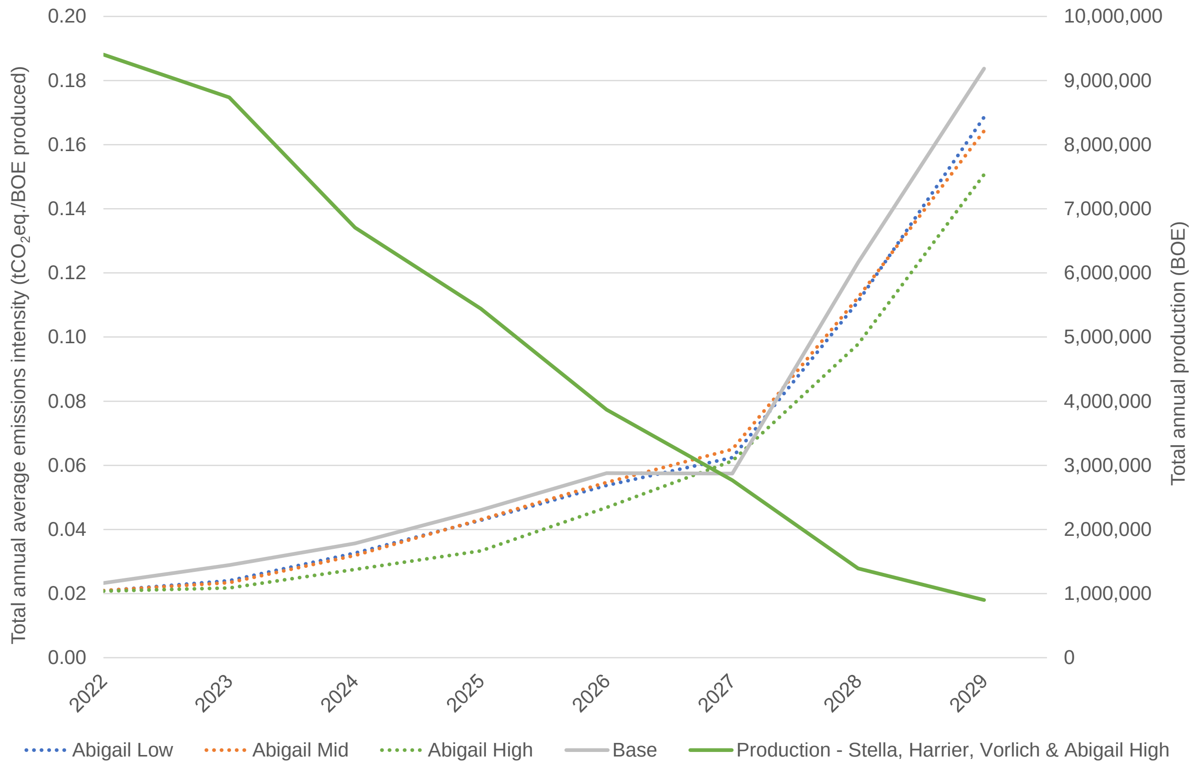


Notes: Negative numbers in 2024 is caused by a small dip in the power demand being deferred (ca.18 months), by bringing on Abigail production.

The estimated emissions intensity of production from the FPF-1 ($tCO_2eq.$ per barrel of oil equivalent, BOE) is shown in Figure 6.3 below. For the purposes of this calculation, BOE includes both the oil and gas hydrocarbons produced. The chart includes estimates without Abigail (production from Stella, Harrier and Vorlich) and with Abigail for each production case (low, mid and high). The emissions intensity has been calculated based on fuel gas use and, for the base case excluding Abigail only, the projected flare and vent volumes. These volumes are based on the intended maximum consent level and so are likely to be greater than the actual emissions generated. The estimates do not include start up diesel use, and any third party emissions from, for example, supply vessels used to support operations or emissions related to the installation of the facilities used to produce and export the hydrocarbons. To place the emissions intensity in context, the carbon dioxide intensity of UKCS production (excluding other GHGs such as CH_4 and N_2O) in 2018 was $0.02tCO_2$/BOE (OGUK 2019).

The additional production from Abigail results in a lower emissions intensity due to a higher level of production relative to the incremental fuel gas use for each case, however there is a peak in fuel gas use attributable to Abigail in 2027 which when combined with declining production rates lead to a higher intensity figure in this year. The generally higher intensity through field life reflects a proportionately higher power demand and related emissions from FPF-1 relative to the rate of production decline.

Figure 6.3: Forecast emissions intensity for the FPF-1 with and without Abigail, in the context of total production levels



Notes: Base = FPF-1 without Abigail, Abigail Low = FPF-1 including Abigail Low Production Case, Abigail Mid = FPF-1 including Abigail Mid Production Case and Abigail High = FPF-1 including Abigail High Production Case.

Abigail Development Emissions in Context

In 2019[17], UK emissions of the basket of seven greenhouse gases covered by the Kyoto Protocol are estimated to be 454.8 million tonnes (Mt) CO_2 eq; CO_2 being the most dominant of these, accounting for *ca.*81% of the emissions (365.1 Mt). The total emissions were 2.8% lower than the 2018 figure of 468.1 million tonnes CO_2 eq., and net CO_2 emissions were 3.9% lower than the 2018 figure (365.7 Mt); primarily related to a decrease in the use of coal in electricity generation (BEIS 2021). Approximately 14.63 $MtCO_2$ was attributable to installations in the UKCS in 2018 (OGUK 2019).

To place the development of Abigail in the context of UK GHG emissions, Abigail (including operational emissions associated with the high production case and those from Phase 1 and Phase 2 infield activities) would represent an increment of 0.018% on those emitted from all UK sources in 2019, or 0.56% of those from installations on the UKCS 2018 (OGUK 2019). The total emissions associated with the development and operation of Abigail have been considered against the targets set for each relevant carbon accounting period. Emissions associated with Abigail will take place within the end of the third carbon budget (2018-2022) and through the fourth carbon budget period (2023-2027). Emissions associated with Abigail are estimated to represent 0.0009% of the third carbon budget, including all Phase 1 activities and high case fuel gas emissions, and 0.0031% of the fourth carbon budget, including all Phase 2 activities and high case fuel gas emissions to the end of production.

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[17] It is noted that BEIS (2021) includes provisional figures of GHG emissions for 2020. Due to the anomalous nature of that year (a decrease of total GHGs by 8.9%) due to the impacts of the COVID-19 pandemic, 2019 figures have been used for the purposes of comparison.

Potential Impacts

The consideration of effects from the emissions of greenhouse gases (GHGs) has been limited to the Abigail development activities and operation of the Abigail Field; those activities which are the subject of this EIA. As hydrocarbons are traded commodities, their end use (the carbon intensity of which would be highly variable) is outside the scope of this assessment. Ithaca Energy are cognisant of the UK Government's commitment to achieving net zero GHG emissions by 2050 which has also been legislated for under *The Climate Change Act 2008 (2050 Target Amendment) Order 2019*, but also that the UK Government has indicated that oil and gas production will be required for some years to come in order to support such a transition.

Ithaca Energy are also obligated under the OGA Strategy to maximise the economic recovery of hydrocarbons and, in the future, by the proposed changes to this strategy *to take appropriate steps to assist the Secretary of State in meeting the Net Zero Target, including by reducing, as far as reasonable in the circumstances greenhouse gas emissions from sources such as flaring and venting, and power generation.* While the updated strategy is yet to be formally published, in keeping with its proposals as "relevant persons", Ithaca Energy will continue to maximise gas from fields tying into the FPF1 as fuel gas, (e.g. Stella and Harrier) including that from Abigail, avoiding the operational use of diesel in power generation for which carbon emissions would be greater for the equivalent energy production (e.g. related to the production, shipping and greater CO_2 emissions associated with diesel). Note that diesel is used in the start-up generators – see Section 3.11.2). Ithaca Energy will continue to minimise flaring (noting the minimal quantities estimated above associated with Abigail production, and that, under operations there is a minimum flaring approach at the FPF1, see section 3.11.2). Ithaca Energy are also cognisant of the emissions generated from power generation using fuel gas or diesel and of the offshore emerging energy integration concepts[18], the aim of which is to transition to renewable sources for power and reduce upstream emissions consistent with the UK's net zero commitment. While some of these concepts are more advanced than others, in terms of proven technology, e.g. offshore wind turbines or shore-connected cables for platform electrification, none of the concepts so far identified could be implemented during the field life of Abigail (*ca*. 8 years) to reduce emissions directly resulting from development activities (principally emissions from vessel and rig power generation) and operation of Abigail. It is unfeasible to install a power cable from the FPF1 to land (a distance of approximately 233km) and there are no nearby operational renewable energy sources (the closest renewable sites being the Hywind demonstrator site >200km to the west) to evaluate the potential for use as energy hubs.

Anthropogenically enhanced levels of GHGs (principally CO_2) have been linked to global climate change (IPCC 2013) and incremental emissions of CO_2 and other GHGs during development activities will contribute to wider anthropogenic atmospheric carbon loading.

Predicted effects include *inter alia* an increase in global temperate (Kirtman *et al*. 2013, Collins *et al*. 2013), rising sea-levels (Lowe *et al*. 2009, Church *et al.* 2013, Horsburgh *et al.* 2020), changes in ocean circulation (Collins *et al*. 2013) and potentially more frequent extreme weather events (Wolf *et al.* 2020), and other effects including ocean acidification generated by enhanced atmospheric acid gas loading, deposition and exchange (see Humphreys *et al*. 2020). These effects, most recently summarised in the Intergovernmental Panel on Climate Change (IPCC) 5th assessment report (IPCC 2013, also see Dolan 2015), are the rationale underpinning global carbon dioxide reduction measures such as the Paris Accord and the UK Government commitment to achieving net zero GHG emissions om 1990 levels, by 2050.

In addition to effects associated with atmospheric greenhouse gases, emissions also have the potential to have negative effects on air quality. Poor air quality can result in effects on human health, the wider environment and infrastructure. Reduction in local air quality through inputs of contaminants such as

[18] https://www.ogauthority.co.uk/news-publications/publications/2020/ukcs-energy-integration-final-report/

oxides of nitrogen (NO_X), volatile organic compounds (VOCs) and particulates (e.g. PM_{10}, $PM_{2.5}$), may contribute to the formation of local tropospheric ozone and photochemical smog, which in turn can result in human health effects (see WHO 2013, EPA 2017).

Present climate change projections (see Lowe *et al.* 2009, Palmer *et al.* 2018, Pörtner *et al*. 2019) are unlikely to significantly alter prevailing conditions during the time horizon of the development activities or operational life of the field. The principal GHG of concern is CO_2 as it constitutes both the largest component of global combustion emissions (generally *ca*.80% of total GHG emissions) and has a long atmospheric residence time such that emissions made today continue to contribute to radiative forcing for some time[19].

Operational Controls, Mitigation and Data Gaps

As part of their standard programme management and planning, Ithaca Energy look to minimise vessel time in the field as far as practicable and will make use of vessel synergies where possible. Ithaca Energy's contractor selection process enables Ithaca Energy to select contractors with, for example, modern and fuel efficient vessels, and rigs where available, while satisfying the other selection criteria; offshore activities are due to commence in 2022 and with the advancements in technology, energy storage systems and other hybrid technologies may be available on rigs whereby fuel use is reduced resulting in a reduction in emissions. Emissions are also reduced by following relevant industry best practices and minimising fuel consumption where possible.

Ithaca Energy will examine potential options to reduce work programme GHG emissions including avoidance, where possible, of flowing well tests. For well tests, fluid flow will be minimised consistent with information gathering, and recovery of fluids will be considered. Where this is not practicable well test equipment will be selected to promote efficient burning of any hydrocarbons. Ithaca Energy will also coordinate activities to ensure efficient use of vessels. As part of their contract selection process, Ithaca Energy will also review the audit history of well supplies and services contractors, drilling rig and vessels.

It is considered that there is limited scope for additional mitigation measures to reduce the residual effect on atmospheric GHG loading, or any local effects on air quality. However, these effects are naturally mitigated through the area being far offshore (*ca*.233km), the predominant air flow in the region and relatively short duration of development activities.

Emissions have been estimated based on rig and vessel fuel consumption rates from previous similar drilling and subsea campaigns, and estimated activity durations, incorporating contingencies. These have been considered together with estimates of operational emissions based on the high (P10) production case. Taken together, these represent a likely worst case source of emissions from Phase 1 and 2 installation activities and all subsequent operation. It is considered that sufficient information is available to place these emissions in the context of wider emissions from the UK and UKCS, and in providing an indication of their contribution to carbon budgets.

Conclusion

Abigail development activities will lead to emissions of gases which contribute both to localised and short-term increases in atmospheric pollutants, and to global atmospheric GHG concentrations. In the context of wider UK emissions these effects are considered to be negligible.

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[19] Figures vary widely from between 5-200 years (Houghton et al. 2001) to *ca*.1,000 years (Archer 2005); Ciais, et al. (2013) indicate that, based on emissions projections, 15-40% of CO2 emitted until 2100 will remain in the atmosphere longer than 1,000 years.

Blocks 29/10 and 30/06 are some distance from coastal environments (>230km) which play a role in climate change adaptation and mitigation, for example saltmarshes, seagrass beds and kelp forests which act as long-term carbon sinks and have a role in natural carbon sequestration (e.g. see Burrows *et al*. 2014) though sediments will contain carbon indirectly sequestered (Smeaton & Turrel 2020).

Therefore, overall effects are considered to be negligible.

Ithaca Energy are cognisant of their duty under the OGA strategy, to assist the Secretary of State in achieving the Net Zero Target. While it is acknowledged that the development of Abigail will result in emissions that contribute to global atmospheric GHG concentrations, Ithaca Energy are reducing, as far as reasonable in the circumstances, GHG emissions from activities associated with the development of the field.

6.5 Effects of Noise from Development Activities

Effects of Noise

Underwater Noise Sources and Propagation

No vertical seismic profiling (VSP) is within the scope of planned activities; therefore, the only source of high intensity impulsive noise relates to the driving of pin piles to secure the manifold. All other noise sources will be of a non-impulsive nature, the characteristics of which result in a far lower potential to cause injury to marine fauna. Non-impulsive sound occurs when the acoustic energy is spread over a significant time (several seconds to hours); it may contain broadband noise and/or tonal (narrowband) noise at specific frequencies and its amplitude may vary. Mechanisms for non-impulsive noise generation from offshore activities include propeller cavitation and rotating machinery from vessels, rigs and ROVs, and the use of underwater cutting tools.

The key noise sources associated with the proposed activities include:

- positioning and jacking down/up of the rig or running anchors (as applicable), including associated vessels;
- operation of the rig, including drilling, power generation and other machinery involved in rig operations such as such as hydraulic systems and compressors;
- pile-driving of the manifold;
- cutting excess piles following piling of the manifold;
- pipeline installation, including rock placement;
- standby and supply vessel operations; and,
- helicopter movements.

Pile-driving of Manifold

The manifold will be secured in position using four piles, each anticipated to be 0.63m in diameter, 22m long, and each take up to 2-3 hours to pile to the target penetration depth using a maximum hammer energy of 90kJ. Installation of all four piles will be completed in a single day. Key factors influencing the sound levels produced by pile driving are the diameter of the pile and the hammer energy used to drive the pile. There is also evidence that the surface area of pile in the water column also influences sound levels (e.g. Graham *et al*. 2019), such that sound levels reduce as less pile remains in the water column. Sound levels from driving of comparable piles include measured source levels of 193 and 201 dB re 1 µPa @1m during the driving of 0.51m and 0.91m diameter steel piles, respectively, reported by Nedwell *et al*. (2006).

MacGillivray (2018) reported underwater noise measurements during the piling of 0.66m diameter conductor piles (hollow steel construction) at a platform in 365m water depth. Broadband sound pressure levels recorded at 10m from source were between 180-190dB re 1µPa (SEL = 173-176dB re 1µPa·s), reducing to 149-155dB re 1µPa (SEL = 143-147dB re 1µPa·s) at 400m from source. Peak frequency was around 200Hz, dropping off rapidly above 1kHz; hammer energies ranged from 31-59kJ per strike. Jiang *et al.* (2015) also reported noise levels from conductor piling operations (diameter not specified), at a jack-up rig in the central North Sea in 48m water depth, and found $L_{p,pk}$ not to exceed 156dB re 1 µPa at 750m (the closest measurement to source). Peak frequency was around 200Hz, dropping off rapidly above 1kHz; hammering was undertaken at a stable power level of 85kJ.

Based on the aforementioned empirical measurements, this assessment assumes **a precautionary source level from the manifold piling operations of $L_{p,pk}$ 200dB re 1µPa @1m, with peak energy between 200-400Hz and the majority of energy at < 1kHz**. Sound levels will reduce rapidly with distance from source, likely reaching $L_{p,pk}$ 150-160dB re 1µPa around 500m from the source. For comparison, it is noted that underwater noise generated by driving large diameter (4-8m) monopile foundations for offshore wind turbines requires hammer energies of up to 3,000kJ and generates source levels of a considerably higher amplitude (typical $L_{p,pk}$ of 240-250 dB re 1 µPa @1m).

Should it be necessary to cut any excess pile, this will be done using a subsea cold cutting tool (Clyde tool, or similar) deployed from the DSV. This is widely used mechanical tool which utilises a hydraulic or pneumatically-driven cutting element within a circular housing for cutting and bevelling pipes. Direct measurements of noise levels generated by cutting and other non-impulsive underwater tools are limited, but where available they have been reported to generate sound of an amplitude that does not exceed those from average vessels. For example, measurements of an ROV-operated diamond wire cutting tool on a platform conductor at 80m water depth found noise levels to be not easily discernible above background levels between 100-800m from the source, with associated increases of around 4dB and up to 15dB re 1 µPa^2 per 1/3 octave band for some frequencies, mostly above 10kHz (Pangerc *et al*. 2016). As part of a review of diver noise exposure, Anthony *et al.* (2009) present estimates of source levels of 148-180 dB re 1µPa@1m for several non-impulsive underwater tools

Drilling and Rig Operations

Well re-entry, drilling (sidetracks) and completion will be undertaken from a semi-submersible rig for Phase 1 and either a jack-up or semi-submersible rig for Phase 2. The rig will be towed to the location by two to three assisting tugs. Once on-site, a jack-up rig will jack up, while a semi-sub will be anchored by anchor-handling vessel(s), assisted by DP thrusters. At the end of operations, the rig will either jack down or have anchors retrieved, before being towed off location by tugs. The rig is anticipated to be on-site for up to 76 days (excluding mob/de-mob), within which up to 17 days is allocated to active drilling.

Underwater noise associated with a jack-up rig is of a very similar dominant frequency range as that from large merchant vessels, albeit of lower average intensity. Measurements alongside a three-legged jack-up rig drilling in shallow water on the Dogger Bank showed that sound levels were in the order of $L_{p,rms}$ 120dB re 1µPa broadband with most energy between 2-1,200Hz; sound levels dropped off rapidly above 8kHz and were in the region of 15-20dB quieter during operations other than drilling (Todd & White 2012). It was noted that, at lower frequencies, the rig was considerably quieter than its associated support vessels (Todd & White 2012). Similarly, measurements of underwater noise during drilling from a jack-up rig in the Cook Inlet (Alaska) in *ca*.25m deep water reported sound levels for third octave bands from 10-1,400Hz to rarely exceed $L_{p,rms}$ 120dB re 1µPa across the measuring range of 185m to 3.7km from the rig centre (Marine Acoustics Inc. 2011). Consequently, underwater noise emissions from the rig during drilling operations are likely to represent small inputs to the local soundscape, and are unlikely to exceed contributions from nearby vessels in passage.

Slightly higher source levels are likely from semi-submersible rigs due to greater rig surface area contact with the water column. If position is maintained by DP, noise from thrusters may dominate the lower frequency band (Wyatt 2008). Martin *et al*. (2019) present several months of acoustic recordings taken at 2km and 20km from a semi-submersible rig operating in continuous DP mode while undertaking a drilling campaign in over 2,000m deep water in Canadian waters. At the 2km location, rig operations accounted for most of the variations in soundscape, whereas sound levels at the 20km location were primarily correlated with wind speed and wave height. Based on measurements at 2km distance, a mean broadband radiated sound pressure level (akin to a source level) of $L_{p,rms}$ 181.5dB re 1µPa was estimated for the rig, reducing to *ca*.130dB re 1µPa at 1km distance. The actual maximum received sound pressure levels at 2km distance were *ca*.120dB re 1µPa. Peak energy was around 200Hz, with a pronounced tone at 190Hz from the DP thrusters. The broadband sound pressure level was *ca*.8dB higher at 2km than 20km from the rig.

Vessel Noise, including Pipelay and Rock Placement Operations

In addition to the use of tugs to mobilise/de-mobilise and position the rig, supply and statutory standby vessels will support the rig while on-site. Supply vessels will undertake three round trips per week, and a single standby vessel will be on-station throughout the well operations in case of emergency necessitating evacuation, or in case of person-overboard situations. At this stage in planning, the details of vessels to be used are subject to change; for the purpose of this noise assessment, all are assumed to be of 50-100m in length.

Noise levels during trenching/pipelaying and rock placement will likely be dominated by the vessel noise associated with installation (Nedwell & Edwards 2004, Genesis 2011). In generic terms, support and supply vessels (50-100m) are expected to have source levels in the range 165-180dB re 1µPa@1m range and with most energy in lower frequencies of a few hundred Hz; vessels of >100m length, as is likely the case for the pipelay vessels, are generally in the range of 180-190 dB 1µPa@1m, and also dominated by low frequencies (OSPAR 2009). Veirs *et al*. (2016) estimated sound characteristics for a wider variety of ships (from pleasure craft to container ships) in transit across the Haro Strait (west coast of North America). Median received levels of ship noise within the study area were measured to be most elevated above ambient noise at the lower frequencies (20-30dB from 100-1,000Hz), and to a lesser extent also at higher frequencies (5-13dB from 1-40kHz).

In addition to noise generated by vessels in transit, cavitational noise is important when vessels are operating under high load conditions (high thrust) and when DP systems are in use (Spence *et al*. 2007, Abrahamsen 2012). For example, the use of thrusters for DP has been reported to result in increased sound generation of *ca*.10dB compared to the same vessel in transit: measurements at 600m range to an offshore supply vessel of 79m length recorded broadband $L_{p,rms}$ (18-3,000Hz) of 148.0dB re 1µPa when in DP mode, compared to 135.5dB re 1µPa when in transit at a speed of 10 knots (Rutenko & Ushchipovskii 2015).

The overall source levels resulting from pipelaying operations on the UKCS are not typically measured; however, near-field sound levels associated with pipe lay for the Clair project were predicted to be a maximum of 177dB re 1µPa (Lawson *et al.* 2001). A pipeline installation which includes trenching and backfilling activities, is likely to be comparable to dredging activities, particularly cutter trailing dredgers and trailing suction hopper dredgers, where source levels typically range from 168 to 186dB re 1 µPa and most energy within a few hundred Hz (Genesis 2011).

Acoustic modelling in support of oil & gas operations have shown that across a variety of vessels, activities and localities, exposure to $L_{p,rms}$ >180dB re 1 µPa is highly unlikely; levels >160dB re 1 µPa are encountered only within the immediate vicinity of the activity (<50m), while levels >120dB re 1 µPa are encountered up to a few kilometres (Neptune LNG 2016, Fairweather 2016, Owl Ridge Natural Resource Consultants 2016).

Helicopter Operations

Helicopters will be used to transfer personnel to and from the rig, with approximately three helicopter flights per week. Measurements of an air-sea rescue helicopter over the Shannon estuary (Berrow *et al*. 2002) indicated that due to the large impedance mismatch when sound travels from air to water, the penetration of airborne sound energy from the rotor blades was largely reflected from the surface of the water with only a small fraction of the sound energy coupled into the water. The limited number of helicopter flights will occur within established routes.

Potential Impacts

Anthropogenic noise in the marine environment is widely recognised as a potentially significant concern, especially in relation to marine mammals. Potential (and postulated) effects of anthropogenic noise on receptor organisms range from acute trauma to subtle behavioural and indirect ecological effects, complicating the assessment of significant effect. The sources, measurement, propagation, ecological effects and potential mitigation of underwater noise have been extensively reviewed and assessed (e.g. Richardson *et al*. 1995, McCauley *et al*. 2000, MMS 2004, Southall *et al*. 2007), while the Offshore Energy SEAs (DECC 2009, 2011, 2016) provided a detailed strategic assessment of the effects of underwater noise associated with offshore energy activities at a regional scale for the UK marine environment.

Marine Mammals

Marine mammals, for which sound is fundamental across a wide range of critical natural functions, show high sensitivity to underwater sound. Generally, the severity of effects tends to increase with increasing exposure to noise with both sound intensity and duration of exposure being important. A distinction can be drawn between effects associated with physical (including auditory) injury and effects associated with behavioural disturbance. With respect to injury, risk from an activity can be assessed using threshold criteria of sound levels (Southall *et al*. 2007, 2019). In addition, auditory capabilities are frequency-dependent and vary between species. Table 6.5 provides details of the relevant marine mammals listed by functional hearing group, their relevant auditory bandwidth and proposed injury criteria, defined as the sound level at which a permanent threshold shift (PTS; permanent hearing damage) and temporary threshold shift (TTS) is estimated to occur (Southall *et al*. 2019). Thresholds have been suggested for both impulsive (e.g. seismic airgun pulses, pile-driving, explosions) and non-impulsive (e.g. vessel noise, drilling) sounds, due to the characteristics of impulsive sounds (e.g. steep rise time) having a greater potential for injury than non-impulsive sounds.

It is noted that two metrics are provided for proposed injury threshold criteria (Table 6.6). Broadband SPL, annotated as $L_{p,\mathrm{pk}}$, is a more straightforward calculation best suited to single pulses and for all sounds which include intense peak pressure components. The second metric, sound exposure level (L_E) refers to the total sound energy received over time relative to a reference value in water of $1\mu Pa^2 \cdot s$; this allows sounds of different durations to be compared in terms of total energy and is better suited to assessing cumulative exposure. The L_E thresholds presented in Table 6.6 correspond to a cumulative exposure over a 24h period with a frequency weighting to compensate quantitatively for the differential frequency response between functional hearing groups.

Table 6.6 – Marine mammal auditory injury criteria to impulsive and non-impulsive sounds by functional hearing group

Functional hearing group (species relevant to the Abigail area)	**Estimated hearing range (region of greatest sensitivity) [frequency of peak sensitivity]**	**Proposed injury (PTS onset) threshold criteria**		**Proposed TTS onset threshold criteria**	
		Impulsive sounds ***Lp,pk*** (dB re re 1 µPa)	**Non-impulsive sounds** $L_{E,24h}$ (dB re 1 µPa²·s)	**Impulsive sounds** ***Lp,pk*** (dB re re 1 µPa)	**Non-impulsive sounds** $L_{E,24h}$ (dB re 1 µPa²·s)
Low-frequency cetaceans Minke whale (*Balaenoptera acutorostrata*)	7Hz to 35kHz (200Hz to 19kHz) [5.6kHz]	219	199	213	179
High-frequency cetaceans White-beaked dolphin (*Lagenorhynchus albirostris*) Atlantic white-sided dolphin (*L. acutus*)	150 Hz to 160 kHz (8.8 kHz to 110 kHz) [58 kHz]	230	198	224	178
Very High-frequency cetaceans Harbour porpoise (*Phocoena phocoena)*	275 Hz to 160 kHz (12 kHz to 140 kHz) [105 kHz]	202	173	196	153
Phocid seals in water Grey seal (*Halichoerus grypus*) Harbour seal (*Phoca vitulina*)	50 Hz to 86 kHz (1.9 kHz to 30 kHz) [13 kHz]	218	201	212	181

Notes: $L_{p,pk}$ *= unweighted peak sound pressure level (SPL);* $L_{E,24h}$ *= cumulative sound exposure level over 24 hours, weighted according to functional hearing group.*
Source: Southall et al. (2019)

Of the species likely to occur in the Abigail area, the harbour porpoise (very high-frequency hearing group) has the lowest threshold criteria for the onset of PTS from both impulsive and non-impulsive sounds, at $L_{p,pk}$ 202dB re 1µPa and $L_{E,24h}$ 173dB re 1µPa²·s; thresholds for all other functional hearing groups are $L_{p,pk}$ ≥218dB re 1µPa and $L_{E,24h}$ ≥198dB re 1µPa²·s. Harbour porpoise also has the lowest threshold criteria for the onset of TTS (153 dB re 1µPa²·s).

Assuming a precautionary $L_{p,pk}$ 200dB re 1µPa @1m source level, no frequency-dependent absorption (negligible at dominant frequencies and relevant distances), and a 15logR propagation loss, estimated received levels from manifold piling will drop to *ca*.170dB within 100m of the piling location and *ca*.160dB within the 500m mitigation zone; therefore, it is concluded that the risk of hearing damage to any species of cetacean from the proposed piling activities is negligible and standard mitigation practises (JNCC 2010) will be effective. Source levels from sources of non-impulsive noise including cutting of manifold piles, rig operations and vessel movements (including those associated with pipelaying and rock placement) may achieve source sound pressure levels of *ca*.180dB re 1µPa; however, received levels within the general vicinity of operations (i.e. hundreds of metres to a few kilometres) are likely to be of the order of 120-160dB re 1µPa. Consequently, it can be concluded that the proposed activities will not result in auditory injury to any species of marine mammal.

Underwater noise from manifold piling and rig and vessel operations associated with the proposed Abigail activities could potentially cause behavioural disturbance of marine mammals present in the area. It has proved difficult to establish broadly applicable threshold criteria for disturbance of marine mammals based on exposure alone. This is due, in part, to the challenges encountered in studies of wide-ranging species with complex behaviour, but also because many behavioural responses are context-specific.

Harbour porpoise are considered to be among the most sensitive cetaceans to acoustic disturbance, and are known to exhibit behavioural responses to high amplitude impulsive noise such as seismic surveys and impact pile-driving; this generally takes the form of a temporary reduction in acoustic detections within a variable distance of the noise source, interpreted as temporary displacement. For example, Thompson *et al*. (2013) observed a reduction in harbour porpoise density within 5-10km of a 2D seismic survey in the Moray Firth, with animals returning within 19 hours. At 5-10km from the source, received peak-to-peak SPLs were estimated to be between 165 and 172dB re 1 µPa, while the source levels were estimated to be 242-253dB re 1 µPa at 1m. More recently, Sarnocińska *et al*. (2020) reported changes in acoustic detections of harbour porpoise in response to a large 3D seismic survey in Danish waters. A dose-response effect was observed, with the lowest activity closest to the source vessel, and activity increasing up to a range of 8-12km, beyond which baseline acoustic activity was attained. No long-term and large-scale displacements of porpoises were observed throughout the *ca*.3 month survey.

A review of monitoring results at seven offshore wind farms in the German North Sea (Brandt *et al*. 2018) reported declines in harbour porpoise detections to a maximum of 17km from pile-driving activity, but noted declines of around 50% within 10-15km. Declines within the vicinity (up to 2km) of piling occurred several hours before piling began, likely due to disturbance from pre-piling vessel movements and other activity, with porpoise detections returning to baseline within 1-2 days after the cessation of piling (Brandt *et al*. 2018). Also of relevance are the findings of Graham *et al*. (2019) on harbour porpoise behavioural responses to pile-driving during construction of the Beatrice offshore wind farm in the Moray Firth. Each turbine base was secured using four 2.2m diameter steel piles, installed with a typical hammer energy of 600-700kJ. An array of acoustic loggers revealed porpoise to be present within the windfarm construction site throughout the construction period; there was a ≥50% probability of a behavioural response (significantly reduced detections) at a distance of 7.4km from piling at the start of construction, reducing to 4.0km midway through construction, and 1.3km at the final piling event. It is noted that Acoustic Deterrent Devices were used prior to almost all piling events examined and may have increased response levels.

In considering such examples, it must be noted that the proposed manifold piling will result in noise levels which are of considerably lower amplitude and shorter duration than both seismic survey and pile-driving of offshore wind foundations. The scale of pin-pile installation for the Beatrice wind farm (Graham *et al*. 2019) is mechanically closer to that of manifold piling than monopile foundations, but is still more than three times the pile diameter, and of greater hammer energy, than the proposed manifold piling. Consequently, the spatial scale of behavioural response (i.e. displacement) is expected to be less.

Considering this evidence of likely effects on the most sensitive and abundant species to occur in the region, combined with the low anticipated density of all marine mammals in the Abigail area, the manifold piling may cause localised displacement (i.e. within a < 10km radius) of individuals for the day over which active piling will occur, and potentially a day thereafter, but will not result in significant disturbance to populations of any marine mammal species.

Reported responses of marine mammals to vessels include avoidance, changes in swimming speed, direction and surfacing patterns, and alteration of the intensity and frequency of calls and increases in stress-related hormones (review in Erbe *et al.* 2019). Harbour porpoises, white-sided dolphins and minke whales have been shown to respond to survey vessels by moving away from them, while white-beaked dolphins have shown attraction (Palka & Hammond 2001).

While some behavioural disturbance of harbour porpoise and other cetaceans may occur, the increase in underwater noise from vessel traffic associated with the proposed activities, relative to existing levels in the wider area, is expected to be small. In UK waters, a modelling study indicated a negative relationship between the number of ships and the presence and abundance of harbour porpoises within relevant management units when shipping intensity exceeded a suggested threshold of approximately 50 ships per day (within any of the model's 5km grid cells) in the Celtic Sea/Irish Sea and 80 ships per day in the North Sea (Heinänen & Skov 2015). An analysis of 2017 AIS data[20] suggests that the majority of 1km^2 grid cells across Block 29/10 experience <0.5 vessel hours *per month*; vessel occurrence is also low (< 2 vessel hours per month) across much of the adjacent Block 30/06, although moderate levels of activity (>5 vessel hours per month) occurs to within a few km of the FPF-1, along with other installations and active developments (e.g. Harrier field in 2017).

It is noted that the Abigail area does not overlap and is not close to any designated or proposed marine protected areas for marine mammals, and is not an area identified as of particular importance to marine mammals. The density of grey and harbour seals in the area is expected to be very low.

Considering the characteristics of the relevant noise sources, the evidence for limited potential of short-term behavioural disturbance, the open nature of the habitat, the generally low densities of marine mammals likely to be present in the area and its apparent low importance relative to other areas within the North Sea (for example: the southern North Sea for harbour porpoise; waters further west for white-beaked dolphin), it is concluded that the proposed activities will not result in significant behavioural disturbance to any species of marine mammal.

Fish and Fisheries

Many species of fish are highly sensitive to sound and vibration and broadly applicable sound exposure criteria have been published (Popper *et al*. 2014); all levels considered to have the potential to cause injury are >207 dB re 1 µPa (peak) and, therefore, the potential for injury to fish from the proposed activities is limited to within a few metres of the manifold piling location. There is no evidence of mortality or potential mortal injury to fish from ship noise (Popper *et al*. 2014). While it is recognised that impulsive noise, vessel and other continuous noise may influence several aspects of fish behaviour, including inducing avoidance and altering swimming speed, direction and schooling behaviour, (e.g. De Robertis & Handegard 2013, Popper *et al*. 2014), any such effects will be localised and short-term.

Given the source level characteristics and the context of similar contributions to the ambient anthropogenic noise spectrum of the area over several decades (i.e. the oil and gas associated installations, vessels and rigs movements in and around the Abigail and central North Sea area), no injury or significant behavioural disturbance to fish populations is anticipated.

Diving Birds

Evidence for underwater noise impacts on diving seabirds is very limited. While exposure to very high amplitude low frequency underwater noise (i.e. with tens of metres of underwater explosions) has been shown to cause acute trauma to diving seabirds (Danil & St Leger 2011), no activities which could generate such high intensity impulsive noise will occur during the proposed Abigail activities.

Hearing sensitivity for species measured so far peaks between 1 and 3kHz, with a steep roll-off after 4kHz (Crowell *et al*. 2015). The observed region of greatest hearing sensitivity suggests limited overlap

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[20] EMODnet - Human Activities & CLS. Data access: https://www.emodnet-humanactivities.eu/view-data.php. Further information: https://www.emodnet-humanactivities.eu/documents/Vessel%20density%20maps_method_v1.5.pdf

with peak energy from piling, rig and vessel operations. As such, and given the short-term duration of vessel presence, in the context of many decades of shipping and fishing activity in the region, and the relatively low importance of the Abigail area to diving seabirds, significant disturbance to diving seabirds is assessed as highly unlikely.

Operational Controls, Mitigation and Data Gaps

Pile-driving of the manifold will be undertaken in accordance with the published protocol for minimising the risk of injury to marine mammals from piling noise (JNCC 2010), including soft start procedures by gradually increasing hammer energy, this protocol to be followed at all times during the piling operation.

Normal project planning will mean that activities are scheduled to occur consecutively, rather than simultaneously, thereby reducing multiple vessels being on location (other than support vessels) working simultaneously.

No specific additional mitigation was considered necessary beyond application of established operational controls and following industry guidelines where applicable.

No significant data gaps have been identified, in terms of marine mammal responses to noise sources associated with the Abigail development.

Conclusion

Piling of the manifold represents the only source of high-amplitude impulsive underwater noise from the proposed Abigail activities. The potential for injury to the most sensitive species occurring in the area, the harbour porpoise, from exposure to manifold piling noise is extremely low, and will be appropriately mitigated by following standard protocols (JNCC 2010). All other sources of underwater noise are non-impulsive and will be dominated by that from vessel and rig operations.

Considering the characteristics of all the relevant noise sources, the evidence for limited potential of short-term behavioural disturbance among the most sensitive receptors (harbour porpoise), the open nature of the habitat, the generally low densities of marine mammals, diving birds and fishing activity likely to be present in the area and its apparent low importance relative to other areas within the North Sea, it is concluded that the proposed activities will not result in significant behavioural disturbance to relevant species.

6.6 Transboundary Impacts

The UK has ratified the Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo Convention) and thus an assessment is required of the potential for the proposed development activities to result in significant transboundary effects.

The routine drilling and subsea activities associated with the development of the field are considered to offer a remote risk of transboundary effects (36km to UK/Norway median line). In the event of an oil spill crossing the median line, the terms of the NORBRIT agreement would be implemented, which establishes procedures to be followed in joint Norwegian/UK counter-pollution operations at sea. The Agreement is primarily orientated towards spills resulting from major incidents at offshore installations and damage to submarine pipelines.

The physical presence of the rig and other vessels, noise, discharges and atmospheric emissions from the development activities and operations, are unlikely to significantly affect Norwegian waters and air quality, as are the physical presence of the rig and other vessels.

6.7 Cumulative Impacts

Current guidance (BEIS 2021) to The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020, requires the assessment to consider, where relevant to do so, *the impacts of other existing, consented or planned activities in the development area, and determine whether there are likely to be any significant in-combination or cumulative impacts.* As such, consideration has been given to the cumulative effects arising from development activities in the context of all other activities taking place in the area.

Ithaca Energy have also looked to DTI 2003, which defined three categories of "additive" effects in the context of Strategic Environmental Assessment:

Incremental effects are considered within the assessment process as effects from licensing exploration and production (E&P) activities, which have the potential to act additively with those from other oil and gas activity, including:

- Forecast activity in newly licensed areas
- New exploration and production activities in existing licensed areas
- Existing production activities
- Forecast decommissioning activities
- Legacy effects of previous E&P activities, post-decommissioning (e.g. unrecovered debris)

Cumulative effects are considered in a broader context, to be potential effects of development activities which act additively or in combination with those of other human activities (past, present and future); given the existing uses of the sea in and around Abigail and the activities, the cumulative effects have the potential to arise with other activities, notably:

- Fishing
- Shipping and navigation
- Other Oil and gas and other industrial related activity (e.g. exploration, appraisal, development, marine aggregate extraction)
- Oil and gas decommissioning activities

Synergistic effects – synergy occurs where the joint effect of two or more processes is greater than the sum of individual effects – in this context, synergistic effects may result from physiological interactions (for example, through inhibition of immune response systems) or through the interaction of different physiological and ecological processes (for example through a combination of contaminant toxicity and habitat disturbance).

Effects from development activities or accidents associated with them, which are considered to have potential to act in an incremental, cumulative or synergistic manner are summarised below.

Physical presence	**Incremental**: the presence of the drilling rig, associated vessels and vessels for the subsea installation will be of a temporary nature, and signify a small and transient incremental increase in surface infrastructure (rig) and vessels in the area. The temporary 500m safety exclusion zone around the rig during drilling activities covers an area of 0.8km^2, as does the permanent zone that will be applied for centred on the new Abigail manifold. This area is not regarded as commercially significant in terms of loss of access for fishing; the area records low overall fishing effort. The physical presence of the pipeline system will not result in loss of fishing area (pipeline system trenched and backfilled), with a single crossing. **Cumulative**: No other significant access bans or restrictions to navigation exist in the area; there are existing 500m exclusion zones around the FPF-1, and its associated tie-back fields. Duration of the drilling/subsea activities is such that cumulative effect with shipping of the wider North Sea oil is not considered significant.

	Synergistic: none
Physical disturbance	**Incremental**: There will be minor incremental disturbance to the seabed as a result of the Abigail development, from positioning the rig, subsequent drilling and pipeline/subsea infrastructure installation. Total area affected is small. The other subsea tie-back development in the near vicinity is the Vorlich development, however, the spatial extent of disturbance from Abigail is limited and widely separated from this project, with no footprint overlap. There are other field developments in the wider area, such as Jackdaw, *ca.* 32km to the north east, this includes drilling, subsea activities and the installation of new surface infrastructure. However, although there is slight temporal overlap with activities, there is no spatial overlap, as this development is some distance from Abigail. **Cumulative**: fishing effort is low in comparison to other areas, with demersal the main gear type, and probably represents the principal source of seabed disturbance in this and the wider area. **Synergistic**: none
Discharges (drilling, subsea, operational)	**Incremental**: Discharges associated with drilling and subsea activities will be incremental to that resulting from previous exploration, appraisal and development wells and pipeline installations in the area. The vast majority of chemicals are expected to be E, PLONOR or Gold, with the lowest hazard potential. Discharges of chemicals associated with Abigail operations, while expected to increase, are not expected to be significant, with no change in chemical type; the majority of existing chemicals used and discharged on the FPF-1 are E or Gold. Operational discharge of produced water from Abigail will be a considerable increase to that currently discharged from the FPF-1. **Cumulative**: Discharges from drilling and subsea of short duration and expected quantities. Operationally, no other significant local sources of discharge and no cumulative interaction with remote contaminates of concern (e.g. PAHs etc); zone of greatest impact of PW discharges within 100m of FPF-1. **Synergistic**: none
Emissions	**Incremental**: Emissions associated with power generation on drilling rig, support and subsea construction vessels will represent an increment to North Sea oil and gas emissions, though in the context of annual UKCS emissions, represent a very small increment. Very high available dispersion. **Cumulative**: Greenhouse gas emissions will be cumulative in a global context. **Synergistic**: none
Noise	**Incremental**: Piling for subsea infrastructure, rig and vessel noise will be the primary source of underwater noise during development activities, and will be incremental to other similar activities in the Abigail and adjacent areas. However, the increment will be small and short-term, and is not considered to have significant synchronous effects (i.e. additive to other acoustic disturbance at the time) or significant temporal effects (i.e. additive to previous and subsequent disturbance by seismic and other activities). **Cumulative**: Other sources of anthropogenic noise include shipping – the cumulative increment from the development of Abigail will be minor in the context of existing noise levels from shipping transiting the area. Noise sources associated with Abigail will be spatially and temporally minimal. **Synergistic**: In addition to those noise sources identified above, high contaminant burdens and their effects on reproductive success are a concern for many species of marine mammal in the north-east Atlantic (e.g. Murphy *et al*. 2015, Jepson *et al*. 2016), while other stressors may include changes in oceanographic conditions, prey availability, predator distribution and outbreaks of pathogens. No synergistic effects between noise and other stressors have been conclusively demonstrated to date, with the identification of interactions between multiple stressors being notoriously difficult to study, particularly among marine mammals (The National Academies of Sciences 2017). Nonetheless, given the limited potential for the effects of noise associated with Abigail, the low potential for incremental or cumulative effects identified above, alongside many decades of human activity in the wider area, synergistic effects arising from the development of Abigail are considered to be highly unlikely.

Accidental events	**Incremental**: The combined probability of ecologically significant oil spills from drilling and production activity in the Abigail and surrounding area is extremely low, this area being a mix of oil, and gas condensate fields and being some distance offshore **Cumulative**: The adjacent coasts (the closest coastal conservation site is *ca*. 232km away) are exposed to risks associated with oil/product tanker and other vessel traffic through the region and adjacent ports (Peterhead/Aberdeen/Dundee). The contribution to overall risk of the proposed Abigail development drilling, subsea installation and production operations is small. **Synergistic**: none

6.8 Accidental Events and Major Environmental Incident

As part of the EIA process, and in fulfilment of the EIA Directive, there is a requirement to describe and assess the likely significant effects on the environment as a result of accidents; the current BEIS guidance describes the requirement to assess *the impact of the major accident scenario that would result in the worst-case potential release of hydrocarbons* (BEIS 2020b).

The publication of Directive 2013/30/EU on safety of offshore oil and gas operations (EUOSD) and *The Offshore Installations (Offshore Safety Directive) (Safety Case etc) Regulations 2015* (SCR 2015) that transpose the requirements of the Directive into UK law also aims to increase the protection of the marine environment against pollution, and requires major accident hazards, which may result in a major accident, to be identified in relevant offshore safety directive (OSD) submission[21], and an assessment made of the potential for these to result in a Major Environmental Incident (MEI) and the environmental consequence of these (BEIS 2020).

The SCR (2015) regulations define a Major Accident as:

a) *an event involving a fire, explosion, loss of well control, or the release of a dangerous substance causing, or with a significant potential to cause death, or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;*
b) *an event involving major damage to the structure of the installation or plant affixed to it or any loss in the stability of the installation causing, or with a significant potential to cause death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;*
c) *the failure of life support system for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations[22];*
d) *any other event arising from a work activity involving death or serious personal injury to five or more persons on the installation or engaged in an activity on or in connection with it or*
e) *any major environmental incident resulting from any event referred to in paragraph a, b or d*

To be classed as a MEI, the incident must have as a precursor, a safety related major accident which relates to petroleum activities carried out offshore (see e above). In its definition of MEI, the EUOSD describes this as an incident which *results, or is likely to result, in a significant adverse effects on the*

[21] Relevant OSD submissions include installation Safety Cases and Well Notifications

[22] Inclusion here as part of the SCR2015 Regulations, this is not included in the definition of major accident in Directive 2013/30/EU

environment in accordance with Directive 2004/35/EC[23]. Within the Directive, there are different types of damage covered (BEIS 2017):

i. *damage to protected species and natural habitats which is any damage that has significant adverse effects on reaching or maintaining the favourable conservation status of such habitats or species. The significance of such effects is to be assessed with reference to the baseline conditions, taking account of the criteria set out in Annex I (of the Directive)*[24]
ii. *water damage which is any damage that significantly adversely affects the ecological, chemical and/or quantitative status and/or ecological potential as defined in Directive 2000/60/EC or the environmental status of the marine waters concerned as defined in Directive 2008/56/EC*
iii. *land damage, which is any land contamination that creates a significant risk of human health being adversely affected as a result of the direct or indirect introduction in, on or under land, of substances, preparations, organisms or micro-organisms*

Here, "protected species and natural habitats" means species, habitats of species and natural habitats listed in Articles and Annexes of Directive 2009/147/EC (Bird Directive) and Directive 92/43/EEC (Habitats Directive); assessment for MEI therefore applies to all species or habitats listed in these Directives. "Damage" is defined as a measurable adverse change in natural resource or measurable impairment of a natural resource service which may occur directly or indirectly and must be severe enough to have a significant adverse effect on reaching or maintaining favourable conservation status (as derived from the Habitats Directive).

Taking account of the above requirements, the following sections addresses accidental events and the potential for MEI in the context of the Abigail development activities.

[23] Directive 2004/35/CE on the environmental liability with regard to the prevention and remedying of environmental damage.

[24] The significance of any damage that has adverse effects on reaching or maintaining the favourable conservation status of habitats or species has to be assessed by reference to the conservation status at the time of the damage and should be determined by means of measurable data as listed in Annex 1 of Directive 2004/35/EC

6.8.1 Accidental Events Assessment

Evaluation

Risk assessment of accidental events involves the identification of credible accident scenarios, evaluation of the probability of incidents and assessment of their ecological and socio-economic consequences. Given the nature of activities being undertaken for the proposed development, a variety of unplanned incidents have been considered by the Environmental Assessment (Table 5.1, Section 5). In all cases, a risk-based approach is used, which considers probability and consequence. The following potential sources of accidental events have been identified:

- Dropped object
- Accidental spill of oil
- Accidental spill of diesel
- Vessel collision
- Chemical spill

During development activities (drilling and subsea) and operations, there is the potential for dropped objects to sea. Ithaca Energy are committed to the industry standard procedure for dropped objects and where it is considered any dropped object could pose a significant risk (to the environment or other sea users), action will be taken to recover such objects. Dropped objects will have a localised effect, with only a remote probability of any interaction with existing infrastructure, and not expected to result in a significant release of hydrocarbons.

Initiating events which may result in a spill include mechanical failures, corrosion, collision, hose failures, fire and explosion. The risk of vessel collision is considered low; the area has low overall fishing effort, and moderate shipping levels, mainly servicing the oil and gas industry (see Section 4.9) with operational measures for vessels (and rig) undertaking activities including lighting, marking and Notices to Mariners.

A diesel spill from this or a spill from fuel transfer (bunkering), credible scenarios for spillage, is not considered to be a significant threat to the marine environment due to its characteristics and subsequent behaviour upon release. Diesel has very high levels of light ends, evaporating quickly on release. Evaporation can be enhanced by higher wind speeds, warmer water and air temperatures. The low asphaltene contents prevents emulsification, reducing its persistence in the marine environment (see below); a diesel spill will also be limited to the inventory held onboard (rig and vessels).

The rig (drilling) and vessels (subsea campaign) will carry a range of drilling, cementing and other chemicals required to drill and complete the wells and install and test the pipeline system. The accidental discharge of these chemicals is unlikely to represent a significant effect given that chemicals with the best environmental profile, for example PLONOR (Pose Little or No Risk) chemicals, and those without substitution warnings and other labels will be preferentially selected as far as practicably possible and quantities will be restricted to those inventories on board.

Other sources of hydrocarbon associated with the development include diesel fuel, helicopter fuel, lube and hydraulic fluids. These hydrocarbons, as with drilling and other chemicals, are limited in quantity to the inventory contained on the vessels, rig, in use, or being transferred; this also includes those hydrocarbons transferred through the pipeline system during the operational phase, the extent of hydrocarbons present is the pipeline inventory. An instantaneous release of 186m^3 (pipeline volume) from the pipeline was modelled. Oil from this scenario had a 5-10% probability of crossing the median line, with the shortest time being 12 hours (March-May). There is only a 1-5% probability for shoreline oiling (Grampian, Norway, Denmark), the shortest time being 12 days (Grampian, March-May and

Norway, September-November); the maximum accumulation onshore[25] after 20 days is estimated to be $0.18m^3$ (*ca*. 0.1 tonnes).

Control measures are in place for all identified risks, and most spillages are likely to be small-scale and contained by drainage systems on the rig and vessels. Dropped objects, accidental spill of diesel, vessel collision and chemical spill have therefore been determined minor issues (Table 5.2, Section 5), with an overall negligible effect and as such have not been considered further here.

The potential risk from a liquid hydrocarbon release from the re-entry of well 29/10-8 has also been considered. The 29/10b-8 appraisal well is currently suspended with 2 deep barriers and inhibited seawater above. There is a debris cap currently in place on the wellhead which is not pressure retaining. Well re-entry will involve the removal of the debris cap and latching the subsea BOP/riser package to the wellhead. This is a standard operation, controlled by rig specific procedures that will be supported by a task specific risk assessment. The likelihood of this operation leading to a change in the barrier status, escalating to flow and release of hydrocarbons from the well is considered low. The BOP and Wellhead connection will be pressure tested after latching. With the BOP and riser in place, an additional 2 barriers are added to the system (monitored hydrostatic column of fluid and the BOP itself). Rig specific well control procedures will be in place for the monitoring of the fluid level and actions to take in the event of an influx, mitigating the potential for release of hydrocarbons to the environment

The accidental event that has the potential to result in a significant environmental impact from the Abigail development is an accidental uncontrolled spill of oil – this being from a well blow out. Evaluating spill risk requires consideration of the probability/likelihood of an incident occurring and the consequences of the impact. The following discussions therefore considers:

- Possible mechanisms of blowouts
- Historic frequency of relevant incidents
- Environmental consequences of relevant historic events
- Consideration of the environmental fate of spilled oil and quantitative modelling of spill
- Environmental sensitivities of potentially affected habitats, species and human activities
- Mitigation and oil spill response

Blowout Mechanisms and Likelihood

Well control incidents (i.e. "blowouts" involving uncontrolled flow of fluids from a wellbore or wellhead) have been too infrequent on the UKCS for a meaningful analysis of frequency based on UK data. A review of blowout frequencies cited in UKCS Environmental Statements as part of the OESEA2 gave occurrence values in the range 1/1,000-10,000 well-years. Analysis of the SINTEF Offshore Blowout Database which is based on blowout data from the US Gulf of Mexico, UKCS and Norwegian waters for period 1980 to 2014, provided blowout frequencies (per drilled well) for North Sea standard operations, for exploration drilling of normal oil ($1.3x10^{-4}$) and gas wells ($1.6x10^{-4}$), as well as deep high pressure high temperature oil ($8.0x10^{-4}$) and gas ($9.8x10^{-4}$) wells (IOGP 2019). Accident statistics for offshore units on the UKCS estimated an annual average frequency of blowouts for mobile drilling units of $6.6x10^{-3}$ per unit year for the period between 2000 and 2007 (based on analysis of a total of 455 unit years, OGUK 2009).

Possible release locations of reservoir fluids from a blowout may be subsurface (with possible escape to seabed outside the well conductor), subsea through loss of containment at the riser, or from the rig (e.g. at the drill floor). Blowout rates and duration may vary significantly according to the reservoir

[25] This is the maximum accumulated onshore across all beaching locations from one of the 100+ simulations.

and the formation conditions and to the intervention. Under most conditions, initial flow rates reduce quickly due to natural bridging (reduction in permeability of the rock formations and well bore).

Fate and Behaviour of Spilled Oil

The main processes which cause spilled oil to weather at sea are generally recognised as: spreading, evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation and biodegradation. The rates of individual processes are inter-dependent, and influenced by hydrocarbon characteristics, temperature and turbulence. Spreading is the process of lateral transport of the oil due to the driving force of winds and currents, and is the primary driving mechanism for oil spills; oil typically moves at 3% of the wind speed and 100% of the current speed.

Abigail Oil Spill Modelling

Spills can impact environmental and socio-economic sensitivities at distance from their source, and risk assessment, therefore, requires the prediction of slick trajectory. For a given scenario, with defined spill volume and weather/metocean conditions, the behaviour of a slick can be modelled. A spill of oil representative of a blowout of Abigail crude was modelled stochastically using the Oil Spill Contingency and Response (OSCAR) model v11.0.1.

For Phase 1, drilling activities are expected to be carried out during Q2-3 2022 (April-August) and, if executed, drilling activities for Phase 2 are expected during Q3-4 2024 (July-December). Modelling was undertaken seasonally (December-February, March-May, June-August and September to November) for a well blowout scenario, with the shortest time and related probability for oil to cross the median line or reach the coast calculated for the UK and adjacent states. Metocean and release parameters used in the model are summarised in Table 6.7 and the results are summarised in Tables 6.8 and 6.9 and Figures 6.3 -6.5.

Table 6.7 – Metocean and modelled parameters used for oil spill modelling

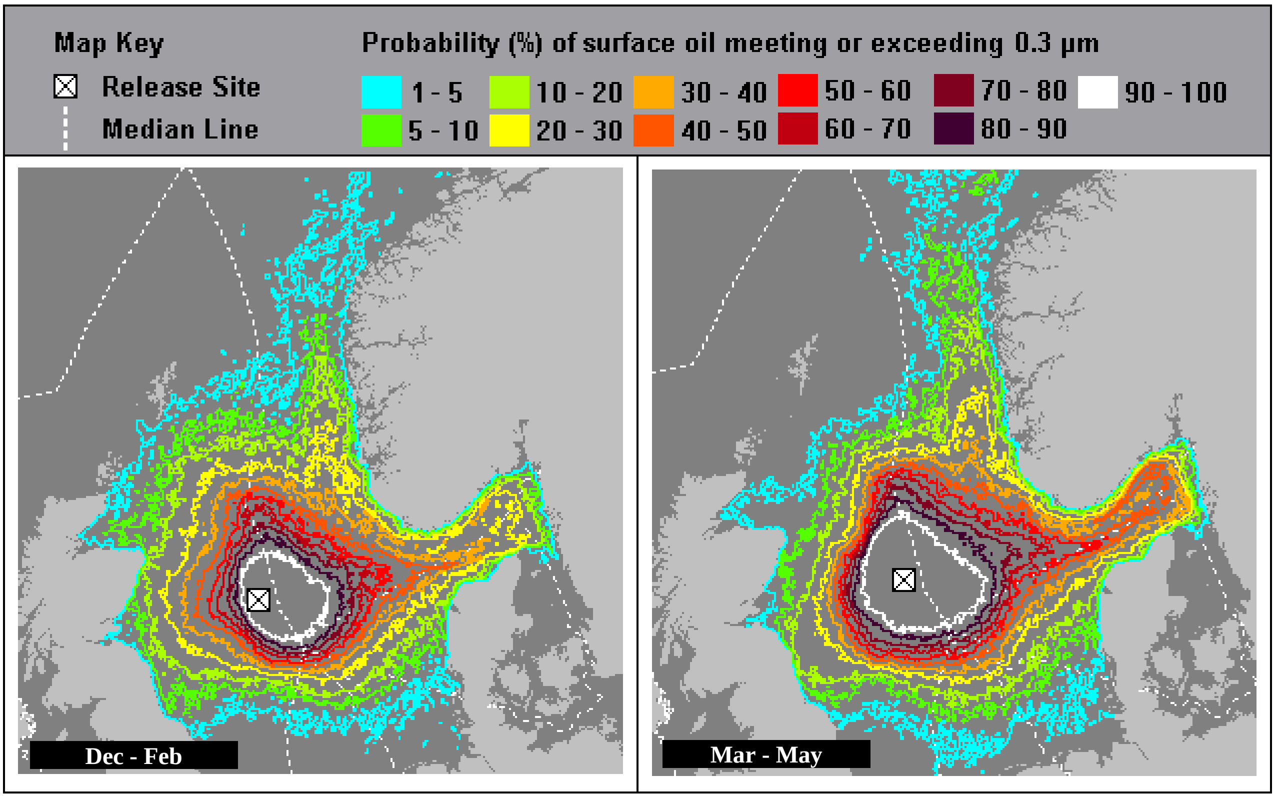
Metocean Parameters			
Air temperature	Variable	Sea temperature	Variable
Wind data (years covered)	2008 - 2014	Wind data reference	European Centre for Medium-Range Weather Forecasts (ECMWF)
Current data(years covered)	2008 - 2014	Current data reference	Hybrid Coordinate Ocean Model (HYCOM)
Modelled Release Parameters			
Release rate/quantity	8,295.8 m^3/day on day 1, declining to 1,662.9 m^3/day by day 90[1]		
Total simulation time	100 days		
Release period	Multi year statistic (seasonal)		
Number of simulations	25 per year		
Total number of simulations	Total number of simulations per season in excess of 100		
Diameter of release pipe	8 inches		
Density of released gas	0.908 kg/m^3		

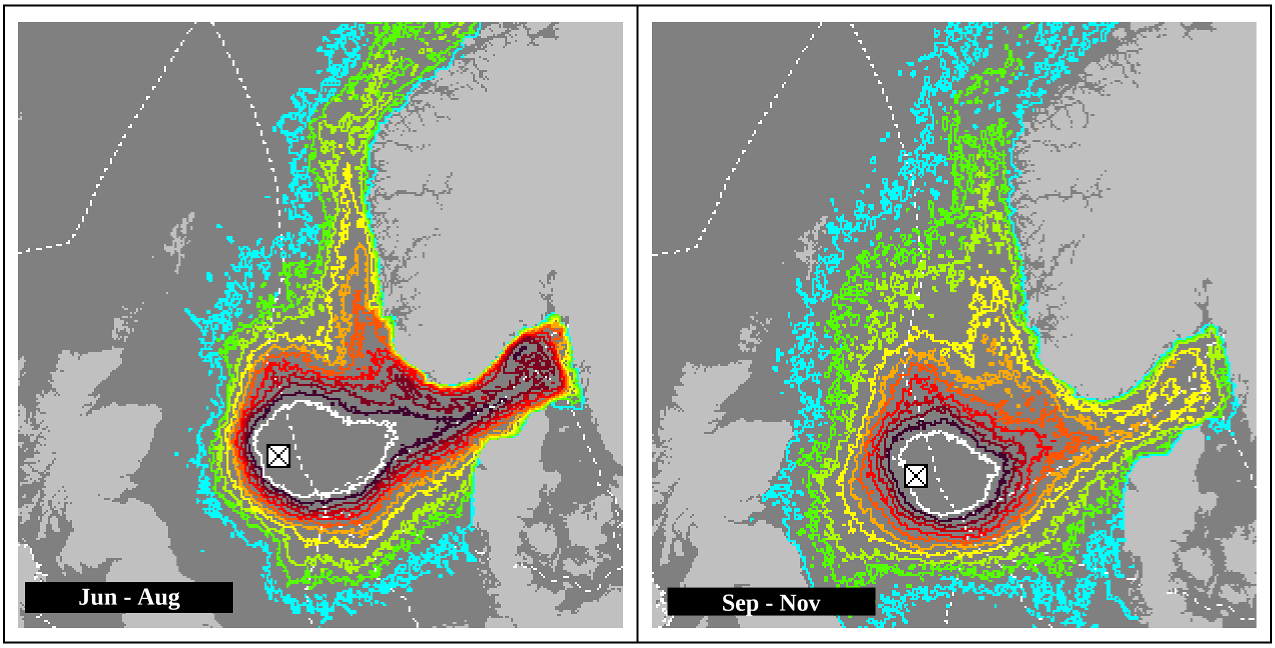
Notes: 1. Release duration assumed to be arrested after 90 days, as indicated by estimated worst-case relief well drill timings

Table 6.8 – Probability (≥1%) and shortest time of surface oil crossing Median line

Member states	Dec-Feb	Mar-May	Jun-Aug	Sept-Nov
Norwegian Waters	90-100%	90-100%	90-100%	90-100%
	15 hours	15 hours	18 hours	18 hours
Danish Waters	90-100%	90-100%	90-100%	80-90%
	45 hours	5 days	3 days	3 days
Swedish Waters	20-30%	40-50%	70-80%	30-40%
	13 days	15 days	17 days	14 days
German Waters	70-80%	80-90%	80-90%	60-70%
	5 days	6 days	7 days	5 days
Dutch Waters	60-70%	70-80%	50-60%	40-50%
	7 days	6 days	6 days	6 days

Figure 6.3 – Probability (≥1%) of surface oil (≥0.3µm) crossing Median Line





The modelling scenario indicates the oil from an unconstrained release, without emergency response, has the potential to beach on the UK coastline (Scotland and England) and the coastline of a number of other countries which border the North Sea (Norway, Denmark, Sweden, Germany and the Netherlands), with Grampian, Tayside to Fife (Scotland) and the North East (England) in the UK (10-20% each) and Norway (70-80%) having the highest probability for oil beaching (Table 6.9).

Grampian in the UK has the shortest estimated time for oil reaching the shoreline, at 7 days, with the probability of this being 5-10% (Mar-May), with the highest probability (10-20%) of beaching (Grampian and Tayside and Fife) during Dec-Feb. The worst case beaching accumulation (total across all beaching locations) is estimated at 1,614m^3 (Dec-Feb).

Table 6.9 – Shoreline oiling: shortest time (days) to beach and probability (%) for shoreline oiling

Shoreline	Dec-Feb	Mar-May	Jun-Aug	Sept-Nov
United Kingdom				
Shetland	1-5%	-	-	1-5%
	>20 days	-	-	>20days
Orkney	1-5%	-	-	-
	>20 days	-	-	-
Highlands	1-5%	1-5%	-	-
	>20 days	12 days	-	-
Grampian	10-20%	5-10%	-	1-5%
	17 days	7 days	-	15 days
Tayside & Fife	10-20%	1-5%	-	1-5%
	17 days	15 days	-	18 days
Lothian & Borders	5-10%	5-10%	-	1-5%
	>20 days	>20 days	-	15 days

Shoreline	Dec-Feb	Mar-May	Jun-Aug	Sept-Nov
England				
North East	5-10%	10-20%	-	1-5%
	14 days	14 days	-	11 days
Yorkshire and The Humber	1-5%	1-5%	-	5-10%
	>20 days	>20 days	-	>20 days
East Midlands	-	-	-	1-5%
	-	-	-	>20 days
Coastal States				
Norway	30–40%	30-40%	70-80%	50-60%
	11 days	9 days	12 days	10 days
Sweden	20-30%	10-20%	60-70%	30-40%
	15 days	17 days	>20 days	16 days
Denmark	50-60%	20-30%	40-50%	30-40%
	11 days	15 days	18 days	12 days
Germany	5-10%	1-5%	1-5%	1-5%
	>20 days	>20 days	>20 days	>20 days
Netherlands	1-5%	1-5%	-	-
	>20 days	>20 days	-	-
Maximum accumulations onshore across all beaching locations				
After 100 days[1, 2]	**1,614m³**	1,446m³	1,591m³	1,020m³

Notes: [1]This is the maximum mass accumulated onshore across all beaching locations from one of the 100+ simulations. [2]Figures in bold, period over which drilling is expected to be carried out

Figure 6.4 – Probability (≥10%) of surface oiling meeting or exceeding 0.3µm

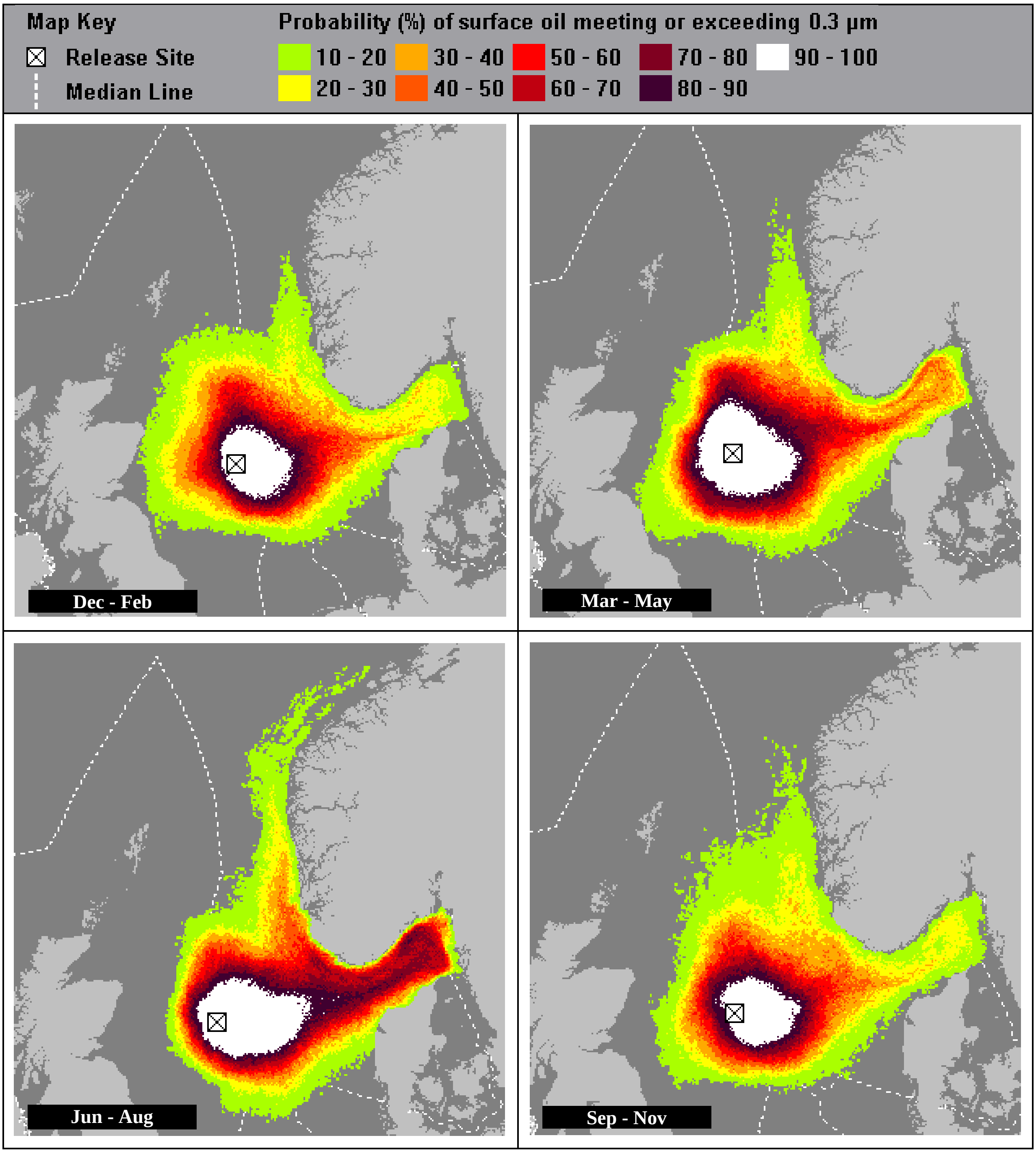
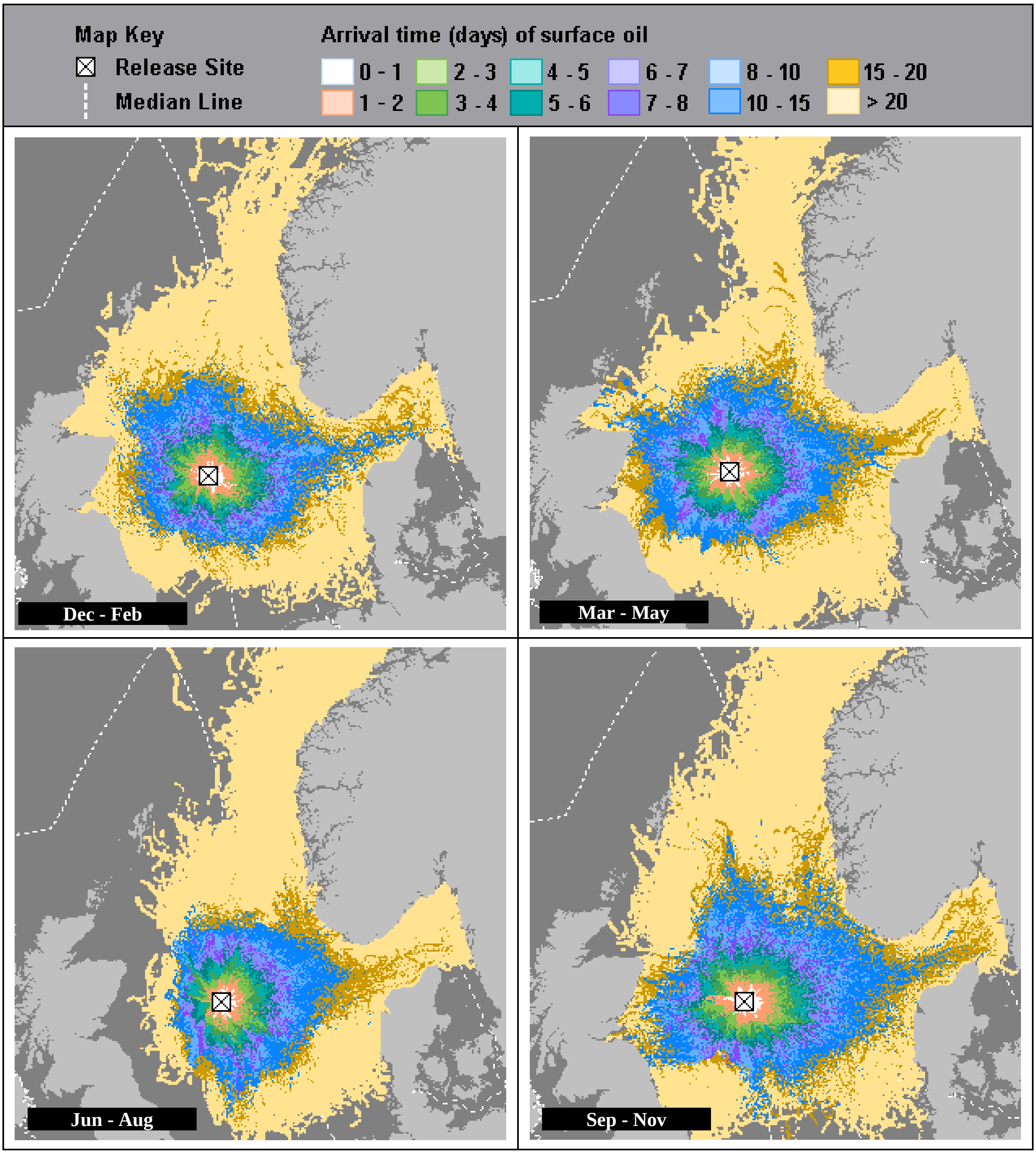


Figure 6.5 – Arrival time of surface oil



6.8.2 Spill Risk and Major Environmental Incident Assessment

The loss of diesel inventory and inventories of chemicals are expected to rapidly disperse to levels where their impact would not be considered significant. Therefore, the impact from these accident hazards would not constitute an MEI, in terms of the above, and have not been considered further.

The remaining uncontrolled release of a liquid hydrocarbon related to a major accident from Abigail is a well blowout during drilling of the production well (based on a loss of 8,295.8m^3/day, declining to 1,662.9m^3/day at day 90).

Environmental and Socio-economic Sensitivities and Potential Impact

The impact from the well blowout has been identified as a MEI, due to the potential environmental impacts on protected sites and species (if the release were to occur in the absence of mitigation and response). An uncontrolled spill of Abigail oil is not expected to result in water or land damage as described above, and are not considered further, with the focus of this assessment therefore the potential damage to protected species and natural habitats.

The impact that may be caused by a spill is dependent on the location of the spill, spill size, the hydrocarbon properties, the prevailing weather and metocean conditions at the time of the spill, the sensitivities of environmental receptors that could be impacted by the spill, and the success of the spill response process.

Coastal sensitivities to oil spills are well-recognised[26], and despite the controls and mitigation measures in place, the possibility of a crude oil spill resulting in oiling of the coast (assuming a worst-case scenario) cannot be ruled out, though the probability of such a spill occurring and affecting the coast is considered extremely remote.

Special Protection Areas (SPA) are classified for rare and vulnerable birds, listed in Annex I of the Birds Directive (2009/147/EC), and for regularly occurring migratory species, and Special Areas for Conservation (SAC) are classified for habitats and species most in need of conservation at a European level, as listed in Annex I and Annex II of the Habitats Directive (92/43/EEC) respectively.

The UK offshore and coastal sites potentially affected by oiling as a result of an uncontrolled release (well blowout) from the proposed activities are shown in Figure 6.6a-b (for all four seasons). Sites have been selected for inclusion/exclusion with respect to whether there was the potential for an interaction with the marine features for which they are designated, and an oil spill.

[26] Special Protection Areas (SPA) are classified for rare and vulnerable birds, listed in Annex I of the Birds Directive (2009/147/EC), and for regularly occurring migratory species, and Special Areas for Conservation (SAC) are classified under Directive 92/43/EEC for habitats and species most in need of conservation at a European level. The other principal offshore designated areas established for the protection of species and habitats are Nature Conservation Marine Protected Areas (NCMPA) and Marine Conservation Zones (MCZ).

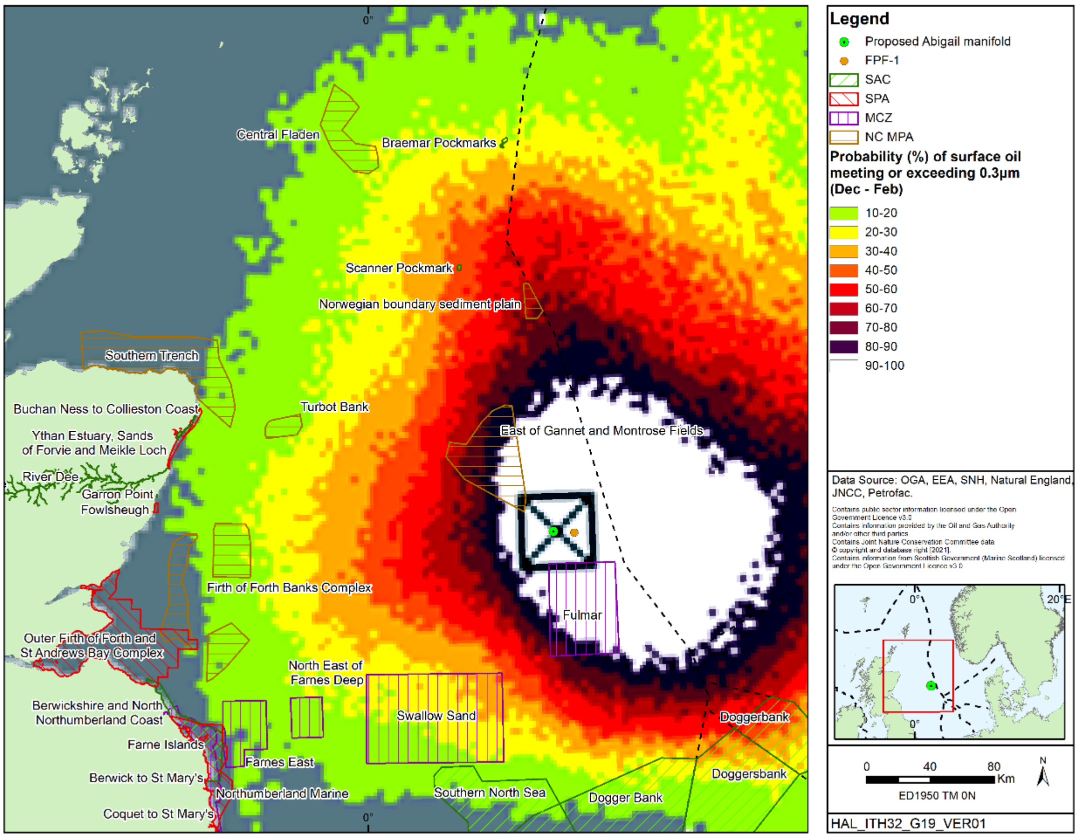
Sites relevant to UK coasts and waters are listed in Table 6.11 below and, as the fundamental principle in an MEI assessment is determining whether the damage is severe enough to have a significant adverse effect on reaching or maintaining favourable conservation status, the conservation status, derived from the Habitats Directive, is shown in Table 6.10; conservation status is "favourable" when all of these are achieved, taking into consideration Annex I of Directive 2004/35/EC[27] (BEIS 2017).

Table 6.10 – Conservation status, as derived from the Habitats Directive

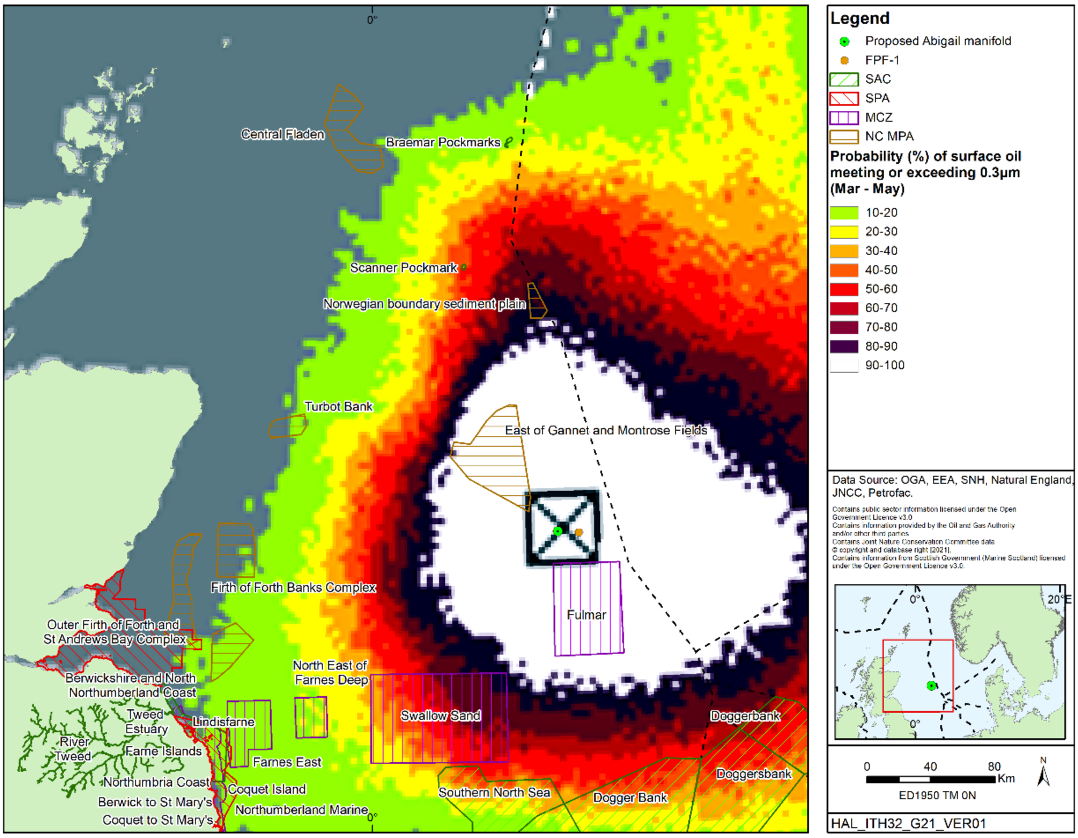
Species	Population dynamics data indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitat Its natural range is neither being reduced nor is likely to be reduced for the foreseeable future There is and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis
Habitats	Its natural range and the areas it covers within that range are stable or increasing The specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future The conservation status of its typical species are favourable

Source: BEIS (2017)

Figure 6.6a – Protected areas potentially impacted by uncontrolled release of hydrocarbons from Abigail – Phase 1[1]

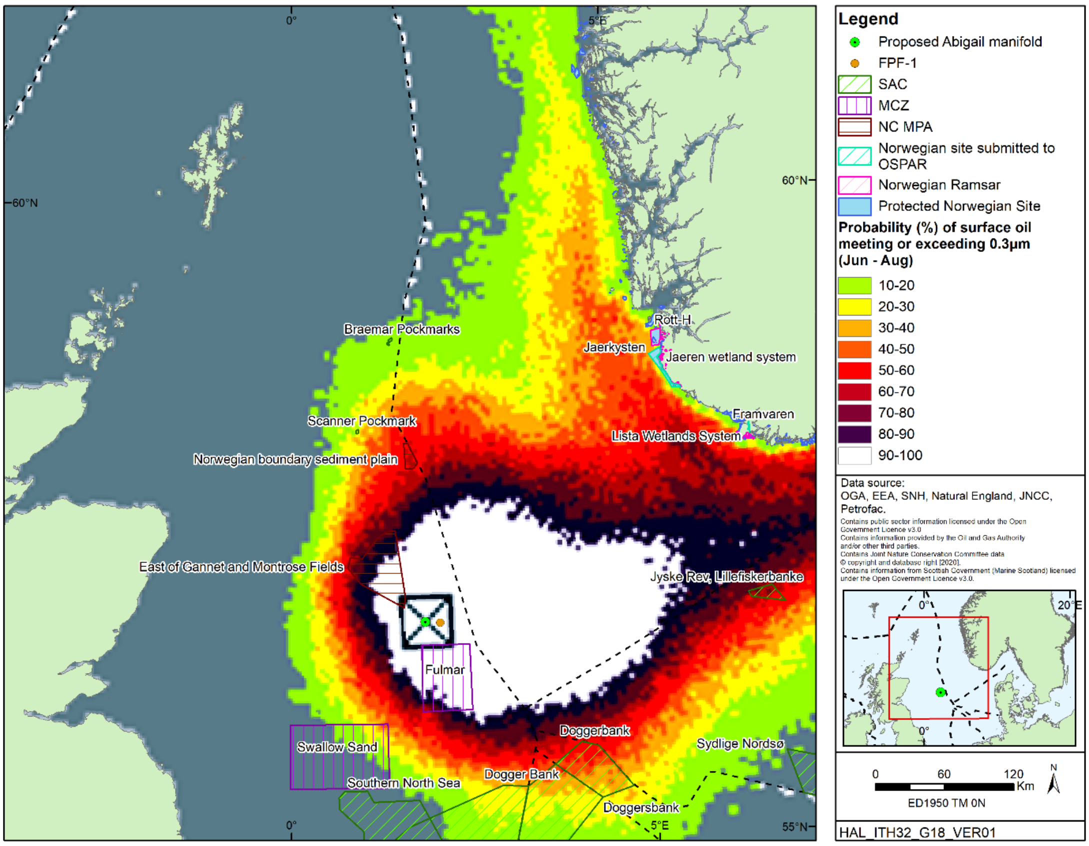


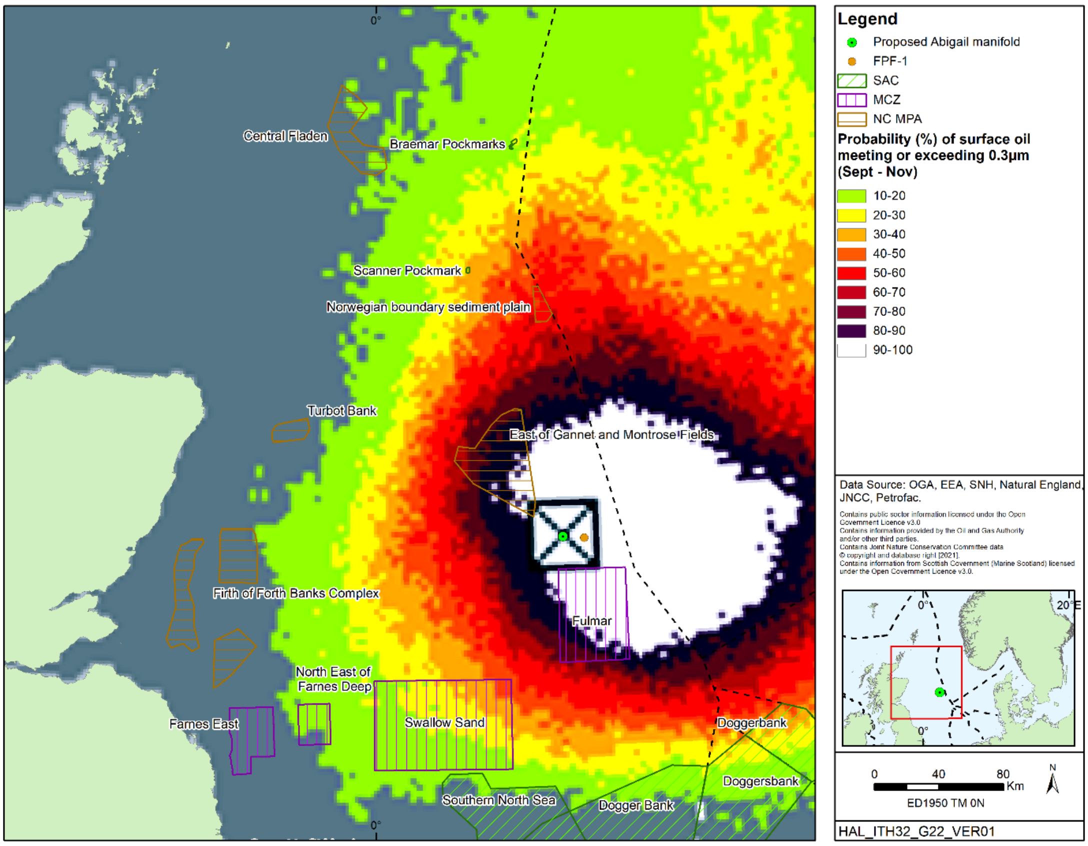
[27] The significance of any damage that has adverse effects on reaching or maintaining the favourable conservation status of habitats or species has to be assessed by reference to the conservation status at the time of the damage and should be determined by means of measurable data as listed in Annex 1 of Directive 2004/35/EC



Notes: [1]*If drilling in Phase 2 extends into late Q4, then it could extend into December, shown here.*

Figure 6.6b – Protected areas potentially impacted by uncontrolled release of hydrocarbons from Abigail - Phase 2[1]





Notes: [1]If drilling in Phase 1 extends into late Q2, then it could extend into June, shown here.

For non-UK sites, the time period Jun-Aug is shown in Figure 6.6c, this being the time frame with the greatest potential impact, (highest probability and highest number of sites) (drilling activity is currently estimated Q2-Q3 (April-August) for Phase 1 and Q3-Q4 (July-December) for Phase 2); the modelling outputs for the other three seasons show a lower potential impact (lower probability and lower number of sites) and have not been included here.

Figure 6.6c – Protected areas potentially impacted by uncontrolled release of hydrocarbons from Abigail (continued)

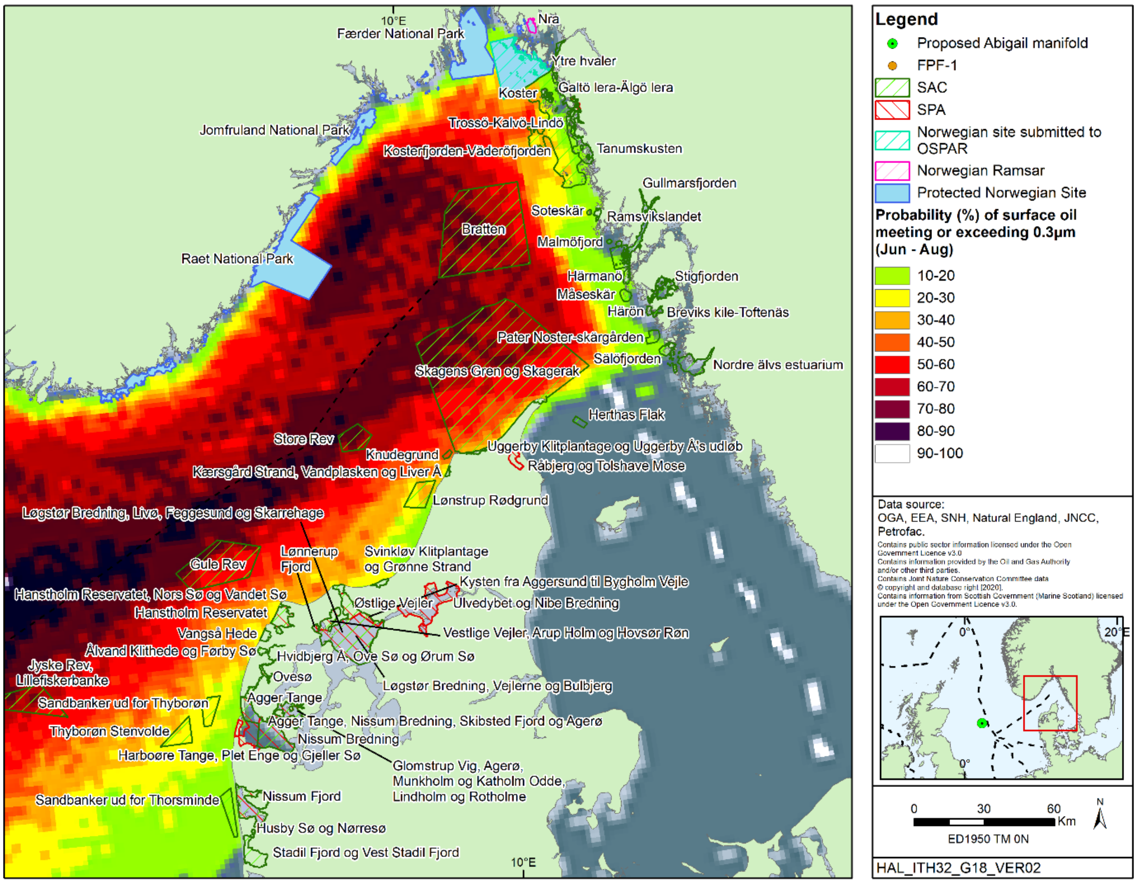


Table 6.11 – UK protected sites and species potentially impacted by uncontrolled release of hydrocarbons[1]

Site	Feature Present[2]	Spill modelling season[3]	Distance to Abigail (km)	Qualifying Feature	Consideration
Special Protection Area (SPA)					
Buchan Ness to Collieston Coast	B	Dec-Feb	232	**Qualifying feature:** Breeding seabird assemblage	Low probability (1-5%) of oil beaching and for the Dec-Feb season only (shortest time being >20 days). Conservation status of qualifying features unlikely to be significantly affected by weathered spilled oil because of time of year of presence (breeding birds not yet returned to colonies, breeding season not yet started, majority of breeding birds not yet present).
Ythan Estuary, Sands of Forvie, and Meikle Loch	B, W	Dec-Feb	236	**Qualifying feature:** Common tern, little tern, pink-footed goose, wintering waterbird assemblage	Season for potential beaching is Dec-Feb, a vulnerable time for the site, supporting wintering water bird assemblages, although probability is low to medium (10-20% and shortest time to beach is 17 days). Conservation status of qualifying features unlikely to be significantly affected by weathered spilled oil because of time of year of drilling activity and species present at site (majority of wintering birds will have departed site).
Fowlsheugh	B	Dec-Feb	248	**Qualifying feature:** common guillemot, black-legged kittiwake, breeding seabird assemblage	Low to medium probability of beaching (10-20%) during Dec-Feb season only (time to beach 17 days). Conservation status of qualifying features unlikely to be significantly affected by weathered spilled oil because of time of year of presence (breeding season will not have started and majority of birds will not yet have returned to breeding colonies).
Outer Firth of Forth and St. Andrews Bay Complex	B, W, P	Dec-Feb Mar-May	233	**Qualifying feature:** Proposed (pSPA) area stretching from Arbroath to St. Abb's Head, encompassing the Firth of Forth, the outer Firth of Tay and St Andrews Bay, supports important populations of 21 species of marine birds. Includes breeding common tern, Arctic tern, European shag, northern gannet, over-wintering red-throated diver, little gull, Slavonian grebe, common eider, and seabird and waterbird assemblages.	Area provides a rich foraging habitat for both breeding and non-breeding bird species. Spill modelling indicates a low to medium probability (10-20%, shortest time is 17 days) of shoreline oiling in this region for Dec-Feb and low probability (1-5%, 15 days) for Mar-May. In the unlikely event of a major spill, weathered spilled oil is not expected to affect conservation status of qualifying species due to time of year of presence in abundance; breeding species will not yet have started the breeding season and wintering birds have left during period when drilling activities most likely.
Farne Islands	B	Mar-May	251	**Qualifying feature:** Arctic tern, Common tern, Sandwich tern, common guillemot, breeding seabird assemblage	Low to medium probability (10-20%) of oil beaching and for the Mar-May season only (shortest time being 14 days). Conservation status of qualifying features unlikely to be

Site	Feature Present[2]	Spill modelling season[3]	Distance to Abigail (km)	Qualifying Feature	Consideration
					significantly affected by weathered spilled oil because of time of year of presence (early in the breeding season majority of birds only just returning to colonies).
Lindisfarne	B, W, P	Mar-May	259	**Qualifying feature:** little tern, roseate tern, bar-tailed godwit, golden plover, whooper swan, ringed plover, grey plover, greylag goose, light-bellied brent goose, sanderling, wigeon, dunlin, ringed plover, long-tailed duck, red-breasted merganser, eider, shelduck	Low to medium probability (10-20%) of oil beaching and for the Mar-May season only (shortest time being 14 days). In the unlikely event of a major spill, weathered spilled oil is not expected to affect conservation status of qualifying species due to time of year of presence in abundance; majority of breeding species will not have returned to their colonies to start their breeding season and wintering birds will have departed their wintering grounds (counts of wintering birds typically conducted Sept-March).
Northumberland Marine	B	Dec-Feb Mar-May	240	**Qualifying feature:** Arctic tern, common tern, common guillemot, little tern Atlantic puffin, roseate tern, sandwich tern, breeding seabird assemblage	Low probability (5-10%, shortest time is 14 days) of oil beaching for Dec-Feb and low to medium probability (10-20%, 14 days) for the Mar-May season. Conservation status of qualifying features unlikely to be significantly affected by weathered spilled oil because of time of year of presence majority of breeding species will not have returned yet to colonies to start their breeding season.
Northumbria Coast	B, M	Mar-May	258	**Qualifying feature:** Arctic tern, little tern, purple sandpiper, turnstone	Low to medium probability (10-20%) of oil beaching and for the Mar-May season only (shortest time being 14 days). Conservation status of qualifying features unlikely to be significantly affected by weathered spilled oil because of time of year of presence majority of breeding species will not have returned yet to colonies to start their breeding season.
Coquet Island	B	Mar-May	268	**Qualifying feature:** Arctic tern, common tern, roseate tern, Sandwich tern, breeding seabird assemblage	Low to medium probability (10-20%) of oil beaching and for the Mar-May season only (shortest time being 14 days). Conservation status of qualifying features unlikely to be significantly affected by weathered spilled oil because of time of year of presence majority of breeding species will not have returned yet to colonies to start their breeding season.
Special Areas of Conservation (SAC)					
Berwickshire and North Northumberland Coast	YR	Dec-Feb Mar-May	243	**Qualifying feature:** Mudflats and sandflats not covered by seawater at low tide, Large shallow inlets and bays, Reefs, Submerged or partially submerged sea caves, Grey seal.	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological feature. The sensitivity assessment for grey seals for hydrocarbon contamination pressure is “n/a” indicating an assessment has not been undertaken for this pressure; taking the

Site	Feature Present[2]	Spill modelling season[3]	Distance to Abigail (km)	Qualifying Feature	Consideration
					precautionary approach, it is therefore assumed to be sensitive. Grey seals spend significantly more time ashore during the moulting period (February-April and particularly pupping season (September-December); neonatal pups are most susceptible to oil effects. Spill modelling indicates potential beaching during these periods Dec-Feb (5-10% probability, shortest time is 14 days) – this being the latter part of pupping season and Mar-May (10-20%, 14 days).
North Northumberland Dunes	YR	Mar-May	259	**Qualifying feature:** Embryonic shifting dunes, Shifting dunes along the shoreline with *Ammophila arenaria*, Fixed coastal dunes with herbaceous vegetation, Dunes with *Salix repens* ssp. *argentea*, Humid dune slack, Petalwort *Petalophyllum ralfsii*	Low to medium probability (10-20%) of oil beaching and for the Mar-May season only (shortest time being 14 days). Weathered spilled oil not expected to affect the primary feature; dunes.
Scanner Pockmark	YR	All	174	**Qualifying feature:** Submarine structures made by leaking gas	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological feature, as oil is not expected to penetrate far enough into the water column to cause significant effect.
Braemar Pockmark	YR	All	242	**Qualifying feature:** Submarine structures made by leaking gases	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological feature, as oil is not expected to penetrate far enough into the water column to cause significant effect.
Dogger Bank	YR	All	157	**Qualifying feature:** Sandbanks which are slightly covered by seawater all the time	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological feature, as oil is not expected to penetrate far enough into the water column to cause significant effect.
Southern North Sea	YR	All	155	**Qualifying feature:** Harbour porpoise	The highest probability across seasons is 5-10%, with the shortest time being >20 days. Weathered spilled oil as predicted from modelling, not expected to affect the conservation status of the mobile feature.
Nature Conservation Marine Protected Areas (NCMPA)					
Southern Trench	YR, M	Dec-Feb	213	**Qualifying feature:** Proposed area for Burrowed mud, fronts, minke whale and shelf deeps, Quaternary of Scotland – sub-glacial tunnel valleys and moraines, submarine mass movement – slide scars	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological or habitat features; burrowed mud is sensitive to oil from spills, however oil would have to penetrate deep into the water column to affect the feature. Therefore, significant impact not expected.

Site	Feature Present[2]	Spill modelling season[3]	Distance to Abigail (km)	Qualifying Feature	Consideration
Firth of Forth Banks Complex	YR	Dec-Feb Mar-May Sep-Nov	190	**Qualifying feature:** *Arctica islandica* aggregations, offshore subtidal sands and gravels, shelf banks and mounds, moraines representative of Wee Bankie Key Geodiversity Area	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological or biological features, *Arctica islandica* is classed as sensitive for hydrocarbon pressure however, this is precautionary as a sensitivity assessment cannot be completed to give a final score. Oil would have to penetrate deep into the water column to affect the features, therefore, significant impact is not expected.
Turbot Bank	YR	Dec-Feb Mar-May	171	**Qualifying feature:** Sandeels	Sandeels are a burrowing fish, found in areas with sandy, low silt sediments and tend to remain buried between Sept-Feb, other than for spawning (eggs are demersal, and larvae drift in the plankton for up to a few months before settling in May/June). Sandeels form large schools in the water column during spring and summer. Weathered spilled oil would have to penetrate deep into the water column to affect sandeels in burrows. Although given a sensitive score to hydrocarbon pressure, in general sandeels are thought to be fairly tolerant of the pressure benchmark. Therefore, significant impact on the conservation status of the qualifying species is not expected.
Central Fladen	YR	Dec-Feb Mar - May Sept-Nov	252	**Qualifying feature:** Burrowed mud (seapens and burrowing megafauna and tall seapen components), Sub-glacial tunnel valley representative of the Fladen Deeps	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological or habitat features; burrowed mud is sensitive to oil from spills, and seapen has been labelled sensitive as precautionary, although no assessment to assign a sensitivity score. However, oil would have to penetrate deep into the water column to affect these features. Therefore, significant impact not expected
Norwegian-boundary Sediment Plain	YR	All	134	**Qualifying feature:** *Arctica islandica* aggregations	Qualifying feature is classed as sensitive to hydrocarbon pressure, however, this is precautionary as a sensitivity assessment cannot be completed to give a final score. Weathered spilled oil as predicted from modelling, is not expected to affect this conservation status of the feature as oil is not expected to penetrate far enough into the water column to cause significant effect.

Site	Feature Present[2]	Spill modelling season[3]	Distance to Abigail (km)	Qualifying Feature	Consideration
East of Gannet and Montrose Fields	YR	All	22	**Qualifying feature:** Offshore deep sea muds, *Arctica islandica* aggregations	Both qualifying features are classed as sensitive to hydrocarbon pressure, however, this is precautionary. Weathered spilled oil as predicted from modelling, is not expected affect the conservation status of either feature as oil is not expected to penetrate far enough into the water column to cause significant effect.
Marine Conservation Zone (MCZ)					
North East of Farnes Deep	YR	Dec-Feb Mar-May Sept-Nov	178	**Qualifying feature:** Subtidal coarse sediment, subtidal sand, subtidal mixed sediments, subtidal mud, *Arctica islandica* aggregations	*Arctica islandica*, is classed as sensitive to hydrocarbon pressure, however, this is precautionary as a sensitivity assessment cannot be completed to give a final score. Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological or biological features as oil is not expected to penetrate far enough into the water column to cause significant effect
Farnes East	YR	Dec-Feb Mar-May Sept-Nov	209	**Qualifying feature:** Moderate energy circalittoral rock, subtidal coarse sediment, subtidal sand, subtidal mud, subtidal mixed sediments, sea-pen and burrowing megafauna communities, *Arctica islandica* aggregations	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological and biological features as oil is not expected to penetrate far enough into the water column to cause significant effect.
Swallow Sand	YR	All	95	**Qualifying feature:** Subtidal coarse sediment, Subtidal sand, North Sea glacial tunnel valley	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological feature, as oil is not expected to penetrate far enough into the water column to cause significant effect.
Fulmar	YR	All	20	**Qualifying feature:** Subtidal sand, Subtidal mud, Subtidal mixed sediments, *Arctica islandica* aggregations.	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological and biological features, as oil is not expected to penetrate far enough into the water column to cause significant effect.

Site	Feature Present[2]	Spill modelling season[3]	Distance to Abigail (km)	Qualifying Feature	Consideration
Berwick to St Mary's	YR	Dec-Feb Mar-May	246	**Qualifying feature:** Common eider	Common eider are highly vulnerable to oil spills due to spending a lot of time on the sea surface. In the unlikely event of a major oil spill, weathered oil could theoretically affect the qualifying feature, although the impact is not expected to be significant so as to affect the conservation status of this species; there is only a low (5-10%) probability of oil reaching the North East England coast during Dec-Feb and low to medium (10-20%) probability during Mar-May, (shortest time for beaching in both cases being 14 days).
Coquet to St Mary's	YR	Mar-May	262	**Qualifying feature:** High energy infralittoral and intertidal rock, intertidal coarse and mixed sediments, intertidal mud, sand and muddy sand, boulder communities, low energy intertidal rock, moderate energy circalittoral, infralittoral and intertidal rock, peat and clay exposures, subtidal coarse and mixed sediments, subtidal mud and sand	Weathered spilled oil as predicted from modelling, not expected to affect conservation status of geological and biological features, as oil is not expected to penetrate far enough into the water column to cause significant effect.

Notes: [1]Uk sites with a probability of surface oil meeting or exceeding 0.3µm [2]B=Breeding, W=Wintering, M = Migratory, P=Passage, R=Resident, YR= Year round [3]Spill modelling season denotes which season from the modelling output, which has a probability of oil beaching at that location. Operational window of Phase 1 drilling (April-Aug) coincides with the modelling periods Mar-May and Jun-Sept and operational window of Phase 2 drilling activities is June-August and September-November (Q4 does include Dec) (Phase 2 being contingent on production performance from Phase 1). "All" denotes all seasons applicable.
Sources: JNCC website, Natural England website, NatureScot website, Scottish Government – FEAST website, MarLIN website, Wright et al 1997, Ross et al 2017

Any weathered oil as a result of a well blowout from Abigail, is not expected to have, or likely to have, a significant effect on certain habitat features of those sites identified, for example sandbanks covered by seawater all of the time, submarine structures made by leaking gases, or reefs (e.g. features of Dogger Bank, Scanner pockmark); and geological features of NCMPAs (e.g. those of the Firth of Forth Banks Complex, Central Fladen), as these features are not generally considered sensitive to oil spills.

Any spilled oil would be expected to float on the sea surface (SG of Abigail being lower than that of seawater), some low viscosity oils (Abigail has a viscosity of 37.8) may disperse naturally within the top few metres of the water column. Concentrations of oil in the upper levels of the water column may be sustained close to the release point, in the event the release of oil is continuous. However, spilled oil, with the Abigail SG, is not expected to penetrate the lower depths of the water column, and as such the impact on species in these lower levels, or on the seabed, is expected to be low (ITOPF 2014).

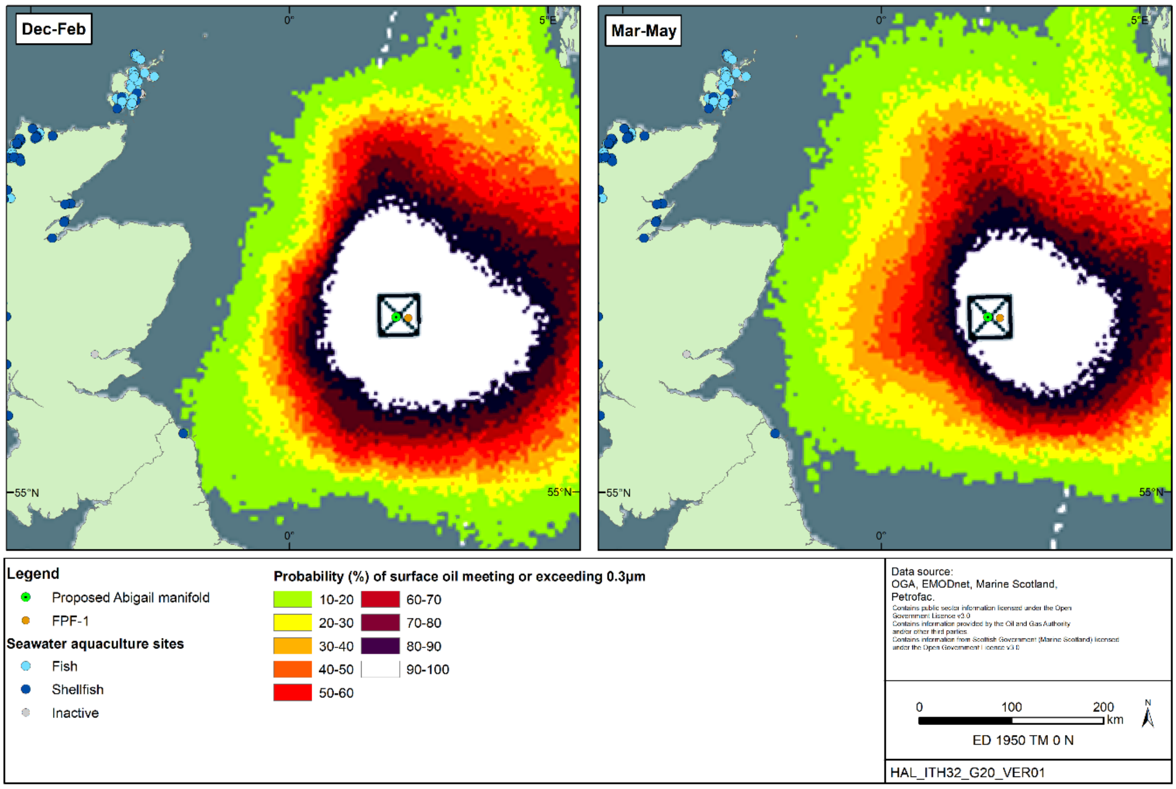
The sensitivity of planktonic and pelagic communities (e.g. fish and cephalopods) is believed to be lower, both in terms of exposure pathways and the higher recovery potential associated with reproductive capacity. In the unlikely event of oil reaching the seabed, there is potential for localised smothering of habitats used by fish, either as spawning, feeding or nursery grounds, and other benthic fauna.

Benthic habitats and species may be sensitive to deposition/sedimentation of oil. Effects on sediment communities are typically associated with deoxygenation and organic enrichment. Benthic species (primarily *Arctica islandica* and burrowing megafauna communities) are a qualifying feature for some of the protected sites in the wider area, including the NCMPAs; Firth of Forth Banks Complex, Central Fladen and the Norwegian Boundary Sediment Plain, and the Fulmar MCZ.

In addition to direct toxicity of oil and dispersants, oil and certain chemicals have the potential to introduce taint (defined as the ability of a substance to impart a foreign flavour or odour to the flesh of fish and shellfish, following prolonged and regular discharges of tainting substances). Perceived or actual contamination of target species with hydrocarbons may result in economic damage to the fishing industry and associated industries. Following a spill or other incident, in some circumstances exclusion orders may be issued preventing marketing of seafood from areas considered to be contaminated, resulting in economic impacts on both the fishing and processing industries. Loss of public confidence in seafood quality from an affected area may also impact on sales revenues. The landings from Scottish vessels include fish from the Abigail and wider Stella area; over the period 2017-2019, monthly fishing effort was variable, although is low or disclosive most of the year, with fisheries mainly targeting demersal species from ICES rectangles associated with the Abigail area (42F1 and 42F2) – see Section 4.9.

There are a small number of shellfish/fish aquaculture sites (some of which are inactive) along the eastern coast of the UK; the majority of aquaculture sites are located on the west coast of Scotland. Of the east coast sites, the site with the highest potential for a spill to reach it, is at Lindisfarne, where oysters are farmed on intertidal trestles (Figure 6.7); modelling indicates oil is not expected to beach at this location.

Figure 6.7 – Aquaculture sites and uncontrolled spill trajectory



A number of sites in adjacent states (e.g. Nissum Fjord SAC, Kærsgård Strand, Vandplasken og Liver Å SAC, Løgstør Bredning, Vejlerne og Bulbjerg SAC), are designated for migratory and diadromous fish which have the potential for an interaction with any spill, however, fish are at greatest risk from contamination by oil spills when the water depth is very shallow.

Seabirds and marine mammals are generally considered the most vulnerable components of the ecosystem to oil spills in offshore and coastal environments, because of their close association with the sea surface.

Mechanisms of impact on seabird populations include oiling of plumage and loss of insulating properties, and ingestion of oil during preening causing liver and kidney damage (Furness & Monaghan 1987). Indirect effects associated with bioaccumulation of contaminants from prey, and reduced prey availability, are also possible. The impact of the Macondo (Deepwater Horizon) well blowout on birds offshore is difficult to quantify due to the low resolution of antecedent seabird surveys and the paucity of observed carcasses during the oil spill response, potentially due to the rapid decomposition rates of bird carcasses in the relatively warm seas, opportunistic scavenging (e.g. by tiger sharks), and due to in situ burning of surface oil slick (Haney *et al*. 2014a).

Modelling (Haney *et al*. 2014a, b) estimated mortality of 200,000 in coastal and open waters immediately after the blowout, when considered across the range of species known to be affected by the spill, would represent <10% of their breeding population. When considering those birds exposed in coastal and estuarine environments, Haney *et al.* (2014b) estimated that bird mortality was approximately 700,000. Within coastal waters, mortality was estimated to have mainly affected four species: northern gannet *Morus bassanus* (8%), brown pelican *Pelecanus occidentalis* (12%), royal tern *Thalasseus maximus* (13%) and laughing gull *Leucophaeus atricilla* (32%). Both studies suggested future work is required to understand the demographic consequences to the Gulf's coastal birds from this large marine spill. Sackmann and Becker (2015) criticised the study by Haney et al, who suggested there was an overestimation of bird deaths, from the underestimation of carcass transport probability to shoreline, this subsequently refuted by Haney *et al.* (2015) (Beyer *et al*. 2016).

The vulnerability of seabirds to surface oiling is related to individual species' behavioural patterns, distribution and ecological characteristics, such as potential rate of population recovery. There are a number of SPAs along the north east coast of the UK, such as the Buchan Ness to Collieston Coast, and Northumberland Marine and Coquet Island, and some in adjacent states including Denmark (Harboøre Tange, Plet Enge og Gjeller Sø SPA) which have breeding seabird features. There is the potential for these mobile qualifying species of relevant sites to interact with waters where surface oil has the potential to meet or exceed 0.3µm in thickness. There is, therefore, the potential that if a major spill from Abigail were to occur, weathered oil could theoretically affect these mobile species; seabird sensitivity in Blocks 29/10 and 30/06 and neighbouring Blocks is low, for those months with data, with the exception of a small number adjacent blocks scored as medium (see Table 4.3, Section 4.6); for seven months of the year no data are available.

Fortunately, there is little experience of major oil spills in the vicinity of seabird colonies in the UK. In January 1993 the *Braer* ran aground at Garth's Ness in Shetland and began leaking Norwegian Gulfaks crude oil, spilling a total 85,000 tonnes of oil. 207 birds were received at the cleaning centre set up to deal with oiled birds, of these 23 were successfully rehabilitated, while an estimated 31 out of 34 seals were successfully rehabilitated. There was difficulty in determining the number of birds that died as a result of the oil as some would never have been found and stormy weather at the time of the spill caused a high mortality of storm victims that became oiled after death. 1,538 dead birds were found on the beaches including European shag (857), black guillemot (203), black-legged kittiwake (133), and long-tailed duck (96), as well as great northern diver (13), common eider (70) and great black-backed gull (45). There was a clear excess of females over males found. The main groups of breeding seabirds affected by the spill were locally resident species, as summer visitors were not in Shetland waters at the time of the spill. In general the 1993 breeding season was successful for most species that may have been affected by the oil spill, with the exception of shag and black guillemot (SOTEAG 1993, DTI 2003). The stormy weather during the *Braer* spill resulted in the rapid dispersion of the oil in the water column. Long term effects on wildlife have proved to be less than first feared with the most notable impact on breeding populations of resident seabirds closest to the spill (SOTEAG 1993).

Generally, marine mammals (which rely on blubber for insulation) are less vulnerable than seabirds to fouling by oil, but they are at risk from hydrocarbons and other chemicals that may evaporate from the surface of an oil slick at sea within the first few days. As for seabirds, indirect effects associated with bioaccumulation of contaminants from prey, and reduced prey availability, are also possible. In contrast to seabirds there is relatively little evidence of direct mortality associated with oil spills (Geraci & St. Aubin 1990, Hammond *et al*. 2003), although the aggregated distribution of some species (especially dolphins) may expose large numbers of individuals to localised oiling.

In their study analysing muscle tissue samples for total PAHs (which are found in oil), from 26 UK-stranded harbour porpoise, Law & Whinnett (1992) found levels were relatively low, with only one death considered to be the result of cancer. In the unlikely event of mortality from a spill, population recovery rates are likely to be lower than for most bird species.

Grey seals (e.g. Berwickshire and North Northumberland Coast SAC) and harbour seals (e.g. Skagens Gren og Skagerak SAC) come ashore regularly throughout the year between foraging trips and additionally spend significantly more time ashore during the moulting period (February-April in grey seals and August-September in harbour seals) and particularly the pupping season (October-December in grey seals and June-July in harbour seals). Animals most at risk from oil coming ashore on seal haulout sites and breeding colonies are neonatal pups, which rely on their prenatal fur and metabolic activity to achieve thermal balance during their first few weeks of life, and are therefore more susceptible than adults to external oil contamination. Animals exposed to oil over a period of time developed pathological conditions including brain lesions. Additional pup mortality was reported in areas of heavy oil contamination compared to un-oiled areas.

The modelling scenario indicates the oil from an unconstrained release, without emergency response, has the potential to beach on the UK coastlines and also that of a number of other countries which border the North Sea (see Table 6.8 above). The extent to which beached oil can have an impact will depend on a number of factors, including the oil characteristics, (Abigail oil is a light crude), the volume of oil beaching, the levels of energy to which the shoreline is exposed, as well as the sensitivities present and their tolerance/recovery rates. High energy rocky shores, exposed to the scouring effects of wave action and tidal currents, which elicits the natural break up of oil, with any beached oil on rock surface exposed to weathering, are generally more resilient to the effects of an oil spill. More sheltered, low energy areas, not exposed to the same rigorous wave and tidal regimes, are less resilient and more sensitive to spill.

6.8.3 Prevention, Mitigation, Response and Data Gaps

Spills from production facilities, drilling rigs and support vessels, are largely preventable through provision of appropriate equipment (e.g. the primary and secondary well control features of the chosen rig), maintenance, procedures and training. Awareness of environmental sensitivities and practical measures to reduce risks will be integral to the contractual and management arrangements for the Abigail well and specific measures which will be implemented for the well are described below.

Preventative Measures

Ithaca Energy have a well examination scheme operated by independent well examiners to ensure there is an independent check on well design, construction, maintenance and operation. These barriers (including well barriers) and preventative controls are in place to minimise the occurrence of an Abigail well blowout, including those at design stage, such as analysis of analogues wells, drill fluid design, and during operation through the deployment of a tested and maintained Blowout Preventor (BOP).

Safety and environmentally critical elements (SECEs) are identified and are part of a maintenance programme and these include, for example, emergency shut down vales, non-return valves, and isolation valves, all of which are in place to control design failure. Systems are also in place to mitigate against over pressurisation of equipment, such as pressure alarms, and velocity checks. Safety and Environmental Management systems (SEMS) are in place, along with documented interfaces between contracted parties and Ithaca Energy have well established practices and procedures in place to also ensure effective training and competence; all Ithaca Energy drilling/completions and production supervisors must complete well control training and pass written and practical examinations approved by the International Well Control Forum (IWCF) every two years.

For the drilling of the well, Ithaca Energy will develop a Communication and Interface Plan (CIP) which will include the actions and notifications, and the roles and responsibilities of the offshore personnel in the event of an oil spill incident; Ithaca Energy have an existing onshore OPEP and the FPF-1 has an existing offshore (installation) OPEP, into both of which Abigail will be incorporated, with the updated OPEPs approved prior to production start up from the Field. Any rig to be used will have its own Non Production Installation OPEP.

Smaller spills of for e.g. diesel can also occur through bunkering and supply operations, storage of fuel/chemicals and rig operations. These are prevented and controlled through measures including adequate storage and maintenance of hoses, with couplings subject to inspection, critical valves being locked and controlled by permits to work, storage in bunded areas, presence of drip trays and provision of deck spill containment and clean up kits on the rig.

Measures to Stem the Well Flow

Well procedures and equipment are in place to control the well, including killing the well and the deployment of a BOP. Well kill typically involves the pumping of a higher density mud into the wellbore, while the BOP is, typically, a large specialised valve, when closed stops the flow of hydrocarbons in the event of an emergency. Another measure is a capping device, this designed to seal off the well and regain control in the event of a blowout.

If primary and secondary well control is lost and oil flows uncontrollably from the well to the environment (blowout), then a relief well may be required to stop the flow and bring the well back under control.

Ithaca Energy estimate that approximately 90 days would be required to both source a suitable replacement rig, and to drill a relief well and regain well control (including time to rent in a surface wellhead system, use a combination of conductor from stock/purchase and gather any other equipment requirements, through the existing call-off contracts Ithaca Energy have with suppliers).

Oil Spill Response Measures

Ithaca Energy follows the international and UK best practice regarding oil spill response, and adheres to the three tiered approach defined in the UK National Contingency Plan.

Ithaca Energy is a member of Oil Spill Response Limited (OSRL) and the Oil Pollution Operator's Liability Association (OPOL) and Ithaca Energy has contracts in place with OSRL for Tier 2 and Tier 3 response resources. During the drilling of the Abigail well, the a dedicated standby vessel will be on location, this will be equipment with dispersant and spraying equipment.

Ithaca Energy will be the well operator during the drilling and subsequent operational phase.

Data Gaps

No significant data gaps were identified.

Conclusion

The risks of significant environmental or socio-economic impacts resulting from an accidental spill from the Abigail wells are extremely low, given the low historical frequency of significant incidents associated with well drilling, completion and production, the technical operational and management measures in place to prevent spills, the spill response strategies to effectively respond to a spill.

Diesel and chemicals are not present in any volume that, if spilled, would result in a significant environmental impact, or indeed a major environmental incident. A diesel spill is not considered to be a significant threat to the marine environment, due to the characteristics of diesel and subsequent behaviour upon release. Diesel has very high levels of light ends, evaporating quickly on release. Evaporation is more rapid in higher wind speeds, warmer water and air temperatures. The low asphaltene contents prevents emulsification, reducing its persistence in the marine environment.

While the modelling scenario indicates there is a probability of beaching in some areas along the UK coast, the corresponding probability that this surface oil will reach, or exceed 0.3µm can be much lower; and, while it is difficult to determine the quantity of oil that will give rise to damage to a protected site or species to significantly affect it from reaching or maintaining its conservation status, it can be assumed the greater the volume of oil beaching, the greater the potential for a significant environmental impact.

For protected sites where their primary features are geological (e.g. reefs), habitats (e.g. burrowed mud) and/or species living in/on seabed sediment (e.g. *Arctica islandica*), the spill modelling and subsequent considerations does not demonstrate the potential for an MEI, as described in the EUOSD and SCR (2015), with any spilled oil not expected to penetrate the water column and cause significant damage.

While the well blowout spill modelling scenario for Abigail does demonstrate the potential for an MEI as described in the EUOSD and SCR (2015) for mobile species which are the qualifying features of coastal and offshore sites (e.g. common eider, grey seals) this is a worst case scenario that assumes no intervention and response. The probability of oil reaching the UK coast is low or low to medium across seasons, the highest probability of beaching being 10-20% with the shortest time being 7 days and, the probability of a well blowout incident occurring is remote due to preventative measures and response strategies in place.

Evaluating spill risk also requires consideration of the probability of an incident occurring. While it is evident from the Deepwater Horizon incident that well blowouts with environmentally significant consequences can and do happen, historically, spills of this magnitude, as a result of well blowouts, have not occurred on the UKCS or in the wider North Sea, and the probability remains remote.

Overall, while the spill modelling scenario for Abigail does demonstrate the potential for an MEI as described in the EUOSD and SCR (2015) for protected sites and species, this is a worst case scenario that assumes no intervention and response, and the probability of an incident occurring is remote.

7 ISSUE MANAGEMENT AND OVERALL CONCLUSION

7.1 Introduction

Through a systematic evaluation of the Abigail development activities and their interactions with the environment, a variety of potential sources of effect were identified; the majority of these were of limited extent and duration and deemed minor (Section 5.2, Table 5.2). Those activities which were identified as being of potentially greater concern were assessed further in Section 6.

Predicted environmental effects from the development activities are comparable with those from other subsea tie-back development activities on the UKCS and during the assessment process, no potential issues of concern were identified that could not be addressed by operational controls.

The risks of spills have been assessed in detail and preventative measures and procedures put in place to minimise the likelihood of their occurrence and possible environmental damage.

7.2 Environmental Management Commitments

The development activities will be conducted in accordance with Ithaca Energy's OEP and integrated environmental management system (Section 2.1).

A number of contractors will be involved in the detailed planning and execution of the development activities and Ithaca Energy has established contractor selection and management procedures which include evaluation of health, safety and environmental aspects and environmental management and compliance.

Table 7.1 below presents a summary of environmental management commitments identified through the assessment process and actions for the development activities, matched with their responsible team; the table below does not include legal requirements, e.g. obtaining and complying with approved permits and consents, including the pipeline works authorisation (PWA) and those required under PETS, and the required oil spill response documents (i.e. OPEPs). These are to be taken forward into detailed design and planning, and through the project execution phase into operations. These commitments are over and above those required by relevant legislation.

Table 7 1 – Summary of Ithaca Energy Commitments and Actions for the development of the Abigail Field

Item	Issue	Actions	Responsibility
Overall Project			
1	Environmental objectives	• Ensure indicators and targets consistent with company policy and the project environmental goals are established for each of the main development activities (drilling, subsea installation, commissioning and operations) • Monitor and review performance against indicators and targets, ensuring remedial action is instigated where necessary	Projects/HSE Departments
2	Contractor management – offshore operations	• Ensure contractor management assurance processes in place and include environmental aspects for all contracted elements of the offshore activities. • Ensure all relevant licences/consents in place for rig/vessels	Projects/HSE Departments

Item	Issue	Actions	Responsibility
3	Communication	• Continued communication with BEIS and consultees (SFF, JNCC) throughout project planning, detailed design and execution	Project Department
4	Compliance assurance	• Ensure a process is in place to manage the applications for and monitoring of compliance with the requirements of environmental permits and consents.	HSE Department
5	Review	• Ensure a post project review is carried out to assess the accuracy of environmental assessment predictions in the context of actual impacts. • Assess the extent to which commitments made in the EIA have been implemented.	HSE Department
Drilling Activities			
6	Contractor management	• Audit of drilling rig/vessels/well suppliers and service contractors (as required) • Monitor environmental performance during well decommissioning operations	Projects/HSE Departments
7	Bunkering	• Bunkering to be conducted in favourable sea states, according to the rig operator's procedures and during daylight hours so far as practicable	Drilling/HSE Departments
8	Waste procedures	• Waste management and procedures to be raised at pre-operations meeting • Raise expectations of waste recycling • Monitoring of waste management practices and ensure appropriate documentation and record keeping	Drilling/HSE Departments
9	Chemicals	• Selection (as far as technically possible), use and discharge, managed through chemical management procedures	HSE Department
10	Non-routine and accidental events	• Audits, risk assessments and mitigation assurance. • Interface documents • Spill prevention expectations and bunkering to be raised at pre-operations meetings	Projects/Drilling/HSE Departments
Subsea activities			
11	Pipelines design and route	• Ensure trenching design and procedures in place to minimise undue seabed disturbance	Subsea/HSE Departments
12	Contractor management	• Audit of subsea service contractors, pipelay and other vessels as required • Establish interface documents for contractors • Monitor environmental performance during operations	Subsea/HSE Departments
13	Vessels – emissions and discharges	• Coordination of vessel activities to ensure efficient use of vessels (e.g. minimum number of vessels, time on location)	Subsea Department
14	Installation	• Follow JNCC guidance (piling) • Rock placement requirements to be minimised, consistent with pipeline protection and safety	Subsea/HSE Departments
15	Non-routine and accidental events	• Audits, risk assessments e.g. HIRA/HAZOP • Interface documents • Spill prevention expectations raised at pre-operation meetings • Ensure vessels have SOPEPs	Subsea/HSE Departments
16	Completion of pipelay activities	• Ensure as-laids are provided, and any remediation if carried out (if required), in consultation with fishermen's organisation	Subsea Department

Item	Issue	Actions	Responsibility
Operations			
17	Contractor management	• Interface documents • Monitor environmental performance during operations	Projects/HSE Departments/Asset Team
18	Discharges (produced water/chemical)	• Monitor and review environmental performance against permit limits and targets • Monitor chemical management system	Asset Team/HSE Department
19	Atmospheric emissions	• Maintain the Greater Stella Area minimum flaring philosophy (no continuous, operational flare)	Asset Team/HSE Department

7.3 Overall Conclusion

The overall conclusion of the Environmental Impact Assessment is that, with the implementation of the operational controls, risk reduction measures and commitments in Table 7.1, the development of the Abigail Field and the processing of hydrocarbons will not result in significant adverse effects on the environment or other users of the area.

No significant data gaps or limitations have been identified from the environmental assessment of the Abigail development activities and operation of the field.

8 REFERENCES

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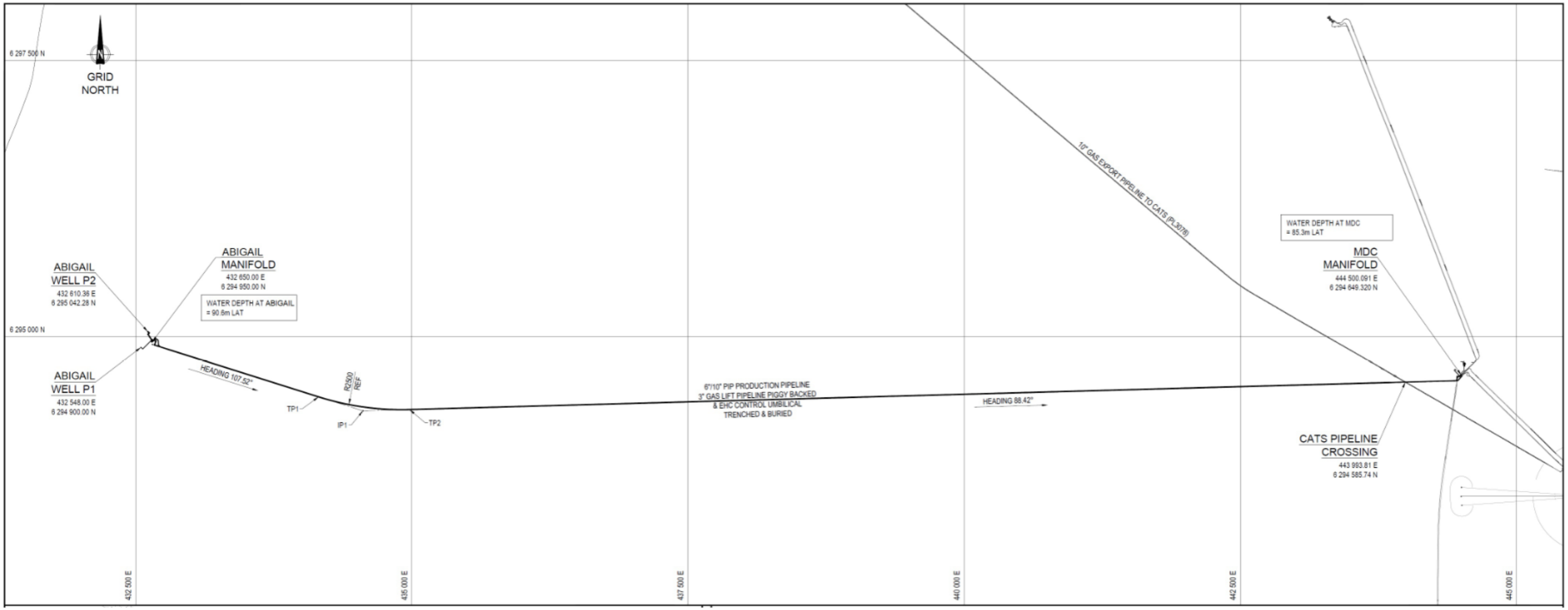
APPENDIX 1 FIELD LAYOUT



Note: location of second well, if drilled, is provisional

APPENDIX 2 – ABIGAIL SURVEY LOCATIONS