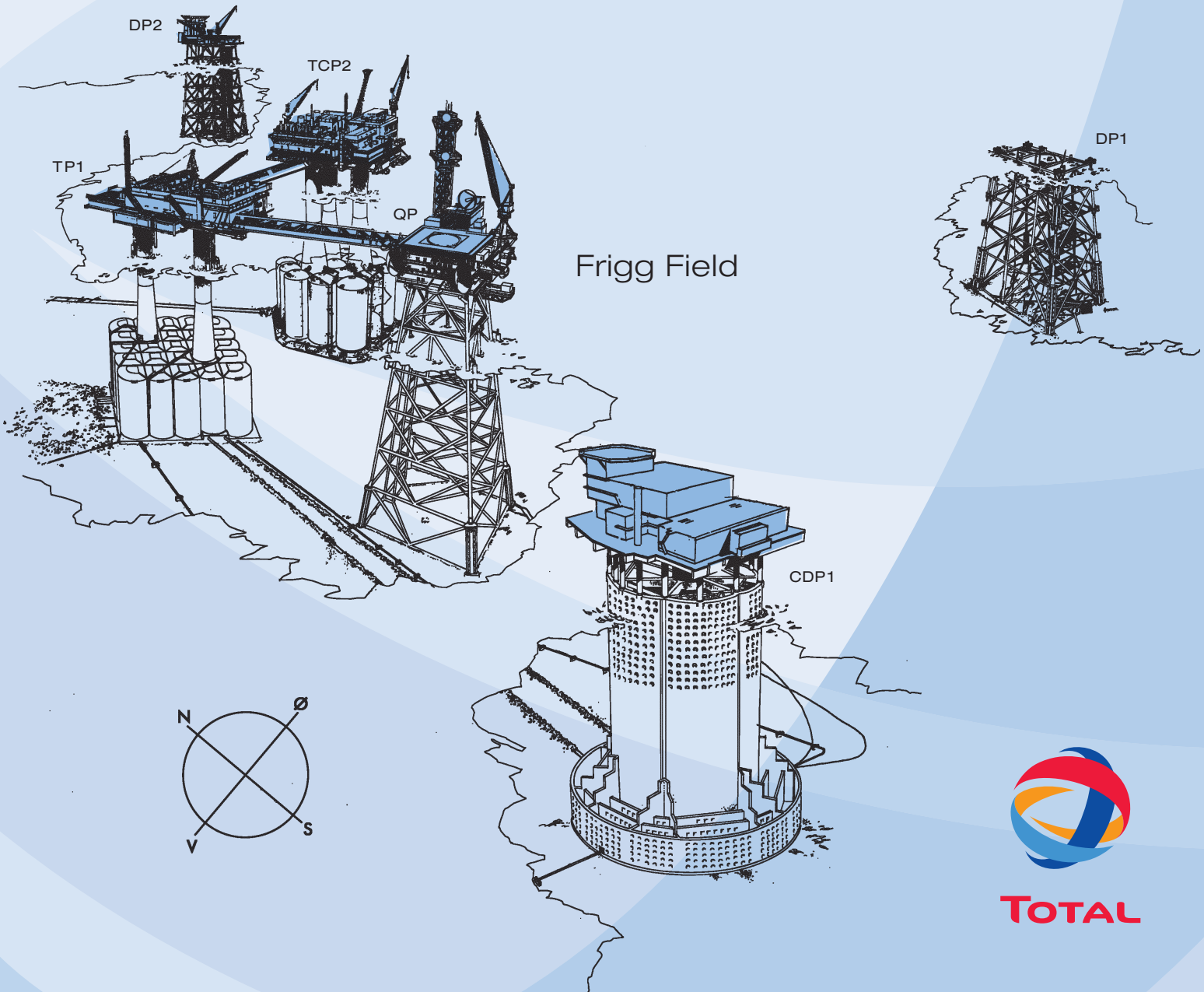
Frigg Field Cessation Plan

TOTAL E&P NORGE AS



TOTAL

TOTAL E&P NORGE AS

Frigg Field Cessation Plan

Stavanger, 9 May 2003

TOTAL NORWAY

TOTAL UK

HYDRO

STATOIL

TOTAL E&P NORGE AS, PO Box 168, 4001 Stavanger, Norway

Foreword

In accordance with the Norwegian Act of 29 November 1996 No. 72 relating to petroleum activities, this document is submitted by TOTAL E&P NORGE AS, on behalf of the Frigg Field Licensees, to the Norwegian Ministry of Petroleum and Energy and the Norwegian Ministry of Local Government and Labour as the Cessation Plan (Avslutningsplan) in respect to the following installations and associated infield subsea pipelines and cables:-

- **25/1 - Frigg - TCP2**
- **25/1 - Frigg - DP2**
- **25/1 - Frigg - DP1 Wreck**

Additionally, in accordance with the requirements of Part IV, Section 29 of the United Kingdom Petroleum Act 1998, this document is submitted by TOTAL E&P NORGE AS on behalf of the Frigg Field Licensees to the United Kingdom Department of Trade and Industry as the Cessation Plan (Decommissioning Programme) in respect to the following installations and associated infield subsea pipelines:-

- **10/1 - FRIGG - TP1**
- **10/1 - FRIGG - QP**
- **10/1 - FRIGG - CDP1**

Although not required for compliance with the provisions of the UK Petroleum Act 1998, details of the planned decommissioning of the subsea cables associated with these platforms are also included within this Decommissioning Programme.

This document, referred to hereafter as the Frigg Field Cessation Plan, is issued in both English and Norwegian.

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Approval of Frigg Field Licensees

The Frigg Field Licensees are:-

- TOTAL E&P NORGE AS (Operator)
- Norsk Hydro Produksjon a.s
- Statoil ASA
- Elf Exploration UK PLC
- TOTAL E&P UK PLC

The Frigg Field Licensees each confirm that they authorise TOTAL E&P NORGE AS, as operator of the Frigg Field, to submit an abandonment programme relating to the Frigg Field, as directed by the UK Secretary of State. They also each confirm that they support the proposals detailed in the Decommissioning Programme, dated 9 May 2003, (which in the case of the Frigg Field is known as the Frigg Field Cessation Plan) submitted by TOTAL E&P NORGE AS.

Letters from the Frigg Licensees confirming these matters are attached herewith.

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1 of 1

Norsk Hydro
E&D Norway

Our contact
Kjell Thorvald Sørensen

Our date
2003-05-14
Your date
2003-04-30

Your ref.
RDBF/003/0030/C

To
Offshore Decommissioning Unit
Department of Trade and Industry
4th Floor, Atholl House
86-88 Guild Street
Aberdeen AB11 6AR

SCOTLAND

Copy to

Dear Sir or Madam

FRIGG FIELD DECOMMISSIONING PROGRAMME
PETROLEUM ACT 1998

We acknowledge receipt of your letter dated 30 April 2003.

We, Norsk Hydro Produksjon a.s confirm that we authorise TOTAL E&P NORGE AS to submit on our behalf an abandonment programme relating to the Frigg Field facilities as directed by the Secretary of State on 30 April 2003.

We confirm that we support the proposals detailed in the Frigg Field Decommissioning Programme (by common consent known as the Frigg Field Cessation Plan) dated 9 May 2003, which is to be submitted by TOTAL E&P NORGE AS in so far as they relate to those facilities in respect of which we are required to submit an abandonment programme under section 29 of the Petroleum Act 1998.

Yours faithfully,
For Norsk Hydro ASA

Kjell Thorvald Sørensen
Frigg Field License Manager

Postal Address
N-0246 Oslo
Norway

Visiting Address
Kjørboveien 16
Sandvika
E-mail
Corporate@Hydro.com

Telephone
+47 22 53 81 00
Telex
72948 hydro n

Telefax
+47 22 53 27 25

Registration No.
NO 930 187 240 MVA
Head Office Address
Bygdøy allé 2
N-0240 OSLO

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Our date	Our reference	Your date	
2003-05-09		2003-04-30	1 of 1
		Your reference	
		RDBF/003/00030/C	

STATOIL

Statoil ASA

Offshore Decommissioning Unit
4th Floor
Atholl House
86-88 Guild Street
Aberdeen
AB11 6AR

Dear Sir/Madam

FRIGG FIELD DECOMMISSIONING PROGRAMME PETROLEUM ACT 1998

We acknowledge receipt of your letter dated 30 April 2003.

We, Statoil ASA confirm that we authorise TOTAL E&P NORGE AS to submit on our behalf an abandonment programme relating to the Frigg Field facilities as directed by the Secretary of State on 30 April 2003.

We confirm that we support the proposals detailed in the Frigg Field Decommissioning Programme (by common consent known as the Frigg Field Cessation Plan) dated 9 May 2003, which is to be submitted by TOTAL E&P NORGE AS in so far as they relate to those facilities in respect of which we are required to submit an abandonment programme under section 29 of the Petroleum Act 1998.

Yours faithfully

Jens Asbø
License Manager
Statoil ASA

Postal address | Office address | The Register of Business Enterprises | Telephone | Internet www.statoil.com
Telefax

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elf exploration uk plc

Elf Exploration UK PLC
Crawpeel Road, Altens Industrial Estate, Aberdeen AB12 3FG
Telephone: 01224 297000 Fax 01224 298999

NNS206/EH/am

15 May 2003

Offshore Decommissioning Unit
4th Floor
Atholl House
86-88 Guild Street
Aberdeen
AB11 6AR

Dear Sirs

FRIGG FIELD DECOMMISSIONING PROGRAMME
PETROLEUM ACT 1998

We acknowledge receipt of your letter dated 30 April 2003.

We, ELF EXPLORATION UK PLC, confirm that we authorise TOTAL E&P NORGE AS to submit on our behalf an abandonment programme relating to the Frigg Field facilities as directed by the Secretary of State on 30 April 2003.

We confirm that we support the proposals detailed in the Frigg Field Decommissioning Programme (by common consent known as the Frigg Field Cessation Plan) dated 9 May 2003, which is to be submitted by TOTAL E&P NORGE AS in so far as they relate to those facilities in respect of which we are required to submit an abandonment programme under section 29 of the Petroleum Act 1998.

Yours faithfully

pp Michel Contie
Managing Director
For and on behalf of ELF EXPLORATION UK PLC

Registered Office: 33 Cavendish Square, London W1G 0PW
Tel 44 (0) 20 7416 4200 Fax 44 (0) 20 7416 4499
Registered in England No 810743

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TOTAL E&P UK PLC

NNS206/EH/am

15 May 2003

Offshore Decommissioning Unit
4th Floor
Atholl House
86-88 Guild Street
Aberdeen
AB11 6AR

Dear Sirs

FRIGG FIELD DECOMMISSIONING PROGRAMME
PETROLEUM ACT 1998

We acknowledge receipt of your letter dated 30 April 2003.

We, TOTAL E&P UK PLC, confirm that we authorise TOTAL E&P NORGE AS to submit on our behalf an abandonment programme relating to the Frigg Field facilities as directed by the Secretary of State on 30 April 2003.

We confirm that we support the proposals detailed in the Frigg Field Decommissioning Programme (by common consent known as the Frigg Field Cessation Plan) dated 9 May 2003, which is to be submitted by TOTAL E&P NORGE AS in so far as they relate to those facilities in respect of which we are required to submit an abandonment programme under section 29 of the Petroleum Act 1998.

Yours faithfully

pp Michel Contie
Managing Director
For and on behalf of TOTAL E&P UK PLC

TOTAL
Crawpeel Road, Altens Industrial Estate, Aberdeen AB12 3FG - Tel 44 (0) 1224 297000 Fax 44 (0) 1224 298999
Registered Office: 33 Cavendish Square, London W1G 0PW - Tel 44 (0) 20 7416 4200 Fax 44 (0) 20 7416 4499
Registered in England No 811900

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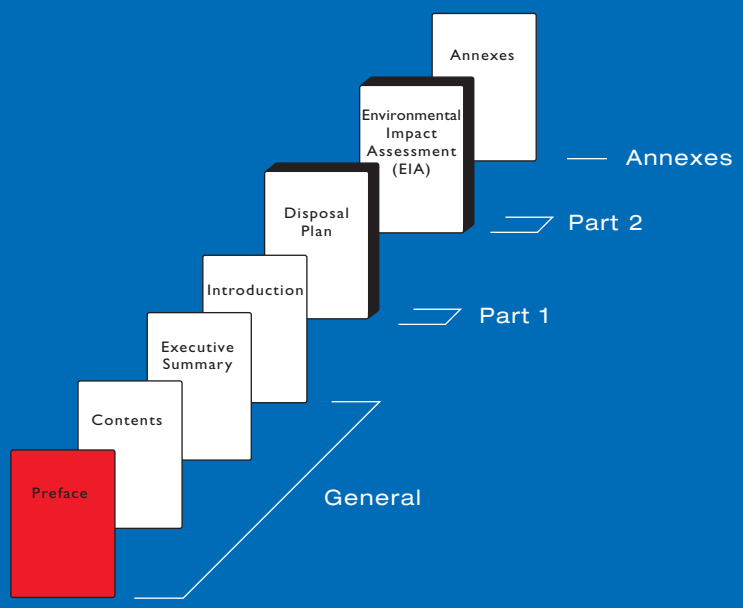

Frigg Field Cessation Plan

Preface

The Frigg Field has a long and successful record. Since the start of production in 1977, Frigg has gained a reputation as a safe and reliable producer of large quantities of gas for the UK. This has benefited Norway, the UK, the Licensees and the work force involved.

The Frigg Field straddles the boundary between the Norwegian and UK continental shelves, with facilities located in both the Norwegian and UK marine sectors. The recommended disposal arrangements for the Frigg Field Norwegian facilities will therefore be subject to approval by the Norwegian government, whilst the Frigg Field UK facilities will be subject to approval by the UK government. During the decommissioning phase however, the field will, as far as possible, be treated as one unit.

Planning for decommissioning is a lengthy and far-reaching process and thus, in 1998, we started to plan for the orderly decommissioning of the Frigg Field facilities. The level of care and attention to detail used in developing a new field will also be applied to these decommissioning activities. Our objective during decommissioning, as during operations, is to undertake the necessary work in a timely and effective manner whilst respecting the environment, protecting the health and safety of personnel, and ensuring a satisfactory working environment.

TOTAL E&P NORGE AS is experienced both in decommissioning installations at the end of their operational life and when possible, in finding new uses for them. The subsea facilities at North East Frigg were successfully removed in 1996/7 and reused onshore. The East Frigg and Lille-Frigg subsea production facilities were removed in 2001 and the Frøy Wellhead Platform in 2002.

The Frigg Field however represents a more complex challenge, not least because of the magnitude of the operation and the complex issues raised by the presence of the three concrete substructures. We have committed ourselves to working from a base-case of total removal of all the facilities, provided it is feasible, taking into account all factors – health and safety, environment, technical feasibility, cost and public acceptance. Reuse and recycling of all, or parts, of the facilities is a key objective in the plans we are presenting.

We will pay due respect to the legislation in force in Norway and in the UK, as well as conventions such as OSPAR and the International Maritime Organisation guidelines. We are committed to an open, honest and long-term dialogue with our stakeholders and we have listened and learned from the helpful comments we have received. We would like to thank all the parties involved during the preparation phase for their valuable contributions, which have been extremely beneficial in allowing us to make a better evaluation of the various disposal alternatives.

This Cessation Plan contains a thorough assessment of our recommended disposal arrangements for all the Frigg Field facilities. The plans for the Norwegian and UK facilities are being presented at the same time to the Norwegian and UK governments for approval.

Supported by the entire license group we, as Operator of the Frigg Field, are dedicated to continue the success story of Frigg throughout the Decommissioning Phase.

Pierre Offant
Managing Director,
TOTAL E&P NORGE AS

9 May 2003

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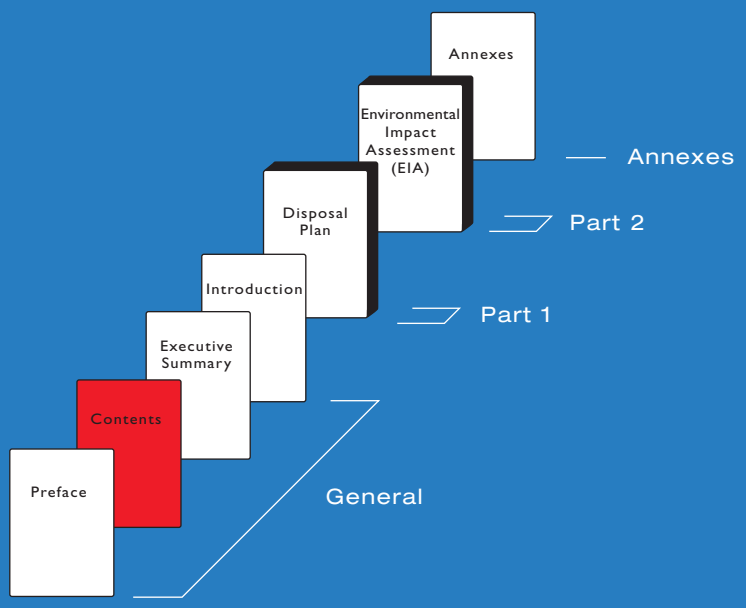
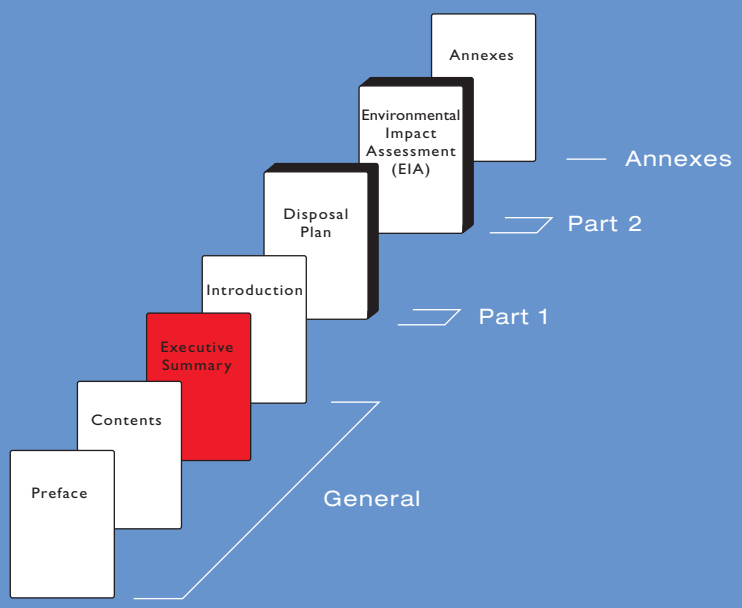


Frigg Field Cessation Plan

Frigg Field Cessation Plan – Contents



Frigg Field Cessation Plan

Executive Summary

1. General

The Frigg Field is a natural gas reservoir, with associated condensate, that extends across the median line between the Norwegian and UK sectors of the North Sea Continental Shelf. It is located in Norwegian Block 25/1 and UK Block 10/1.

Production from the Frigg Field started in September 1977 and is predicted to cease some time in 2004, depending upon reservoir performance.

The Frigg Field was developed in accordance with the provisions of the agreement between the governments of Norway and the United Kingdom known as the Frigg Treaty. Under the provisions of the Frigg Treaty signed in 1976., Elf Norge in Stavanger was defined as the operator of the Frigg Field while Total Oil Marine in Aberdeen was defined as the operator of both the UK and Norwegian gas export pipelines from Frigg to St. Fergus Gas Terminal in Scotland.

Following the merger of the TotalFina Group and the Elf Group in 2000 the TotalFinaElf Group was established, with the result that the Norwegian subsidiary operating the Frigg Field was named TotalFinaElf Exploration Norge AS. On 6 May 2003 the ultimate mother company of the Group TOTAL FINA ELF SA changed name to TOTAL SA. Hence the name of the Norwegian subsidiary was changed to TOTAL E&P NORGE AS.

Except where specifically noted in the text, the name “TOTAL NORGE” has been used in this document to mean both TOTAL E&P NORGE AS, or the predecessor companies in Norway that operated the Frigg Field.

The current Frigg Field Licensees are:

	Unitised License (%)
• TOTAL E&P NORGE AS (Operator)	28.664
• Norsk Hydro Produksjon a.s	19.992
• Statoil ASA	12.164
• Elf Exploration UK PLC *	26.120
• TOTAL E&P UK PLC	13.060

*) Under the management of TOTAL E&P UK PLC

The Frigg Treaty does not contain any specific provisions regarding the disposal of the platforms, seabed pipelines, cables or drill cuttings. The disposal of these facilities is therefore governed by the national legislation applicable to the location of each installation, pipeline or cable.

However, in the spirit of the Frigg Treaty it has been agreed that the Cessation Plan for the Frigg Field should encompass the complete field while respecting each nation’s legislative requirements. This is in line with the approach adopted for both the development of the field, and its operation since start of production. In addition, the decommissioning arrangements proposed have to comply with the requirements of the OSPAR Convention and the International Maritime Organisation guidelines.

2. Description of the Facilities to be Decommissioned

The Frigg Field facilities now consist of five fixed installations together with infield and export pipeline systems. In addition, the DP1 steel substructure, which was damaged during installation in October 1974, is still in the location where it sank.

The export pipelines from Frigg to St Fergus in Scotland (known as the Frigg Transportation System) will remain in operation, and approval for their disposal is not sought within this document. In addition, pipelines between the Frigg Field and other fields are not included within the provisions of the Frigg Field Production Licences and thus are not included within the scope of this Frigg Field Cessation Plan. Separate disposal plans have been, or will be, prepared for these pipelines at the appropriate time.

Three of the Frigg Field installations are located in the UK sector and three are in the Norwegian sector. The platforms were installed in the period 1974 to 1977.

The UK registered installations are:

- Treatment Platform 1 (TP1) registered as 10/1 - FRIGG - TP1
- Quarters Platform (QP) registered as 10/1 - FRIGG - QP
- Concrete Drilling Platform 1 (CDP1) registered as 10/1 - FRIGG - CDP1

The Norwegian registered installations are: -

- Treatment and Compression Platform 2 (TCP2) registered as 25/1 - FRIGG - TCP2
- Drilling Platform 2 (DP2) registered as 25/1 - FRIGG - DP2
- Drilling Platform 1 (DP1) registered as 25/1 - FRIGG - DP1

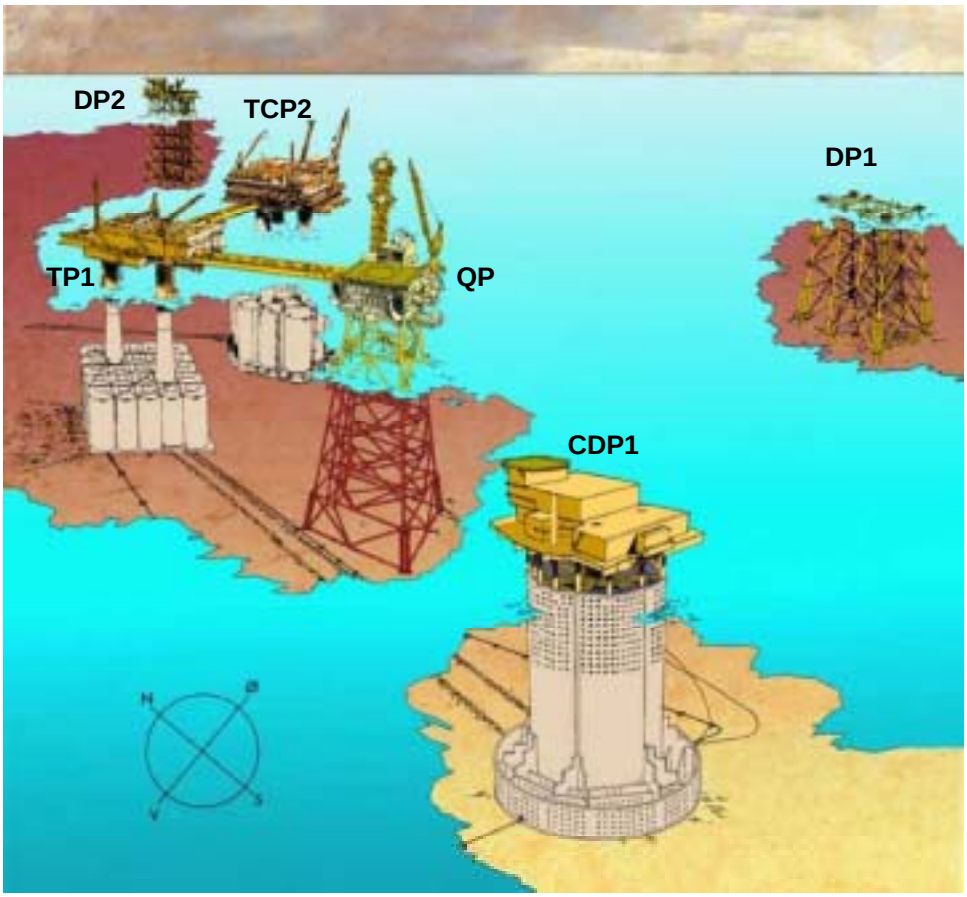


Figure E.1 Frigg Field Facilities

Three of the platforms, TCP2, CDP1 and TP1, have concrete “gravity base” type substructures. DP2 and QP have tubular steel “jacket type” substructures. DP1 is also a steel “jacket type” substructure. The topsides of all the platforms consist of steel decks, of various types, supporting a number of modules and pieces of equipment. **None of the concrete substructures have been used for the storage of crude oil**. With the exception of Module 35, on the Norwegian platform TCP2, there is no low specific activity scale on the Frigg Field facilities.

The infield pipelines and cables to be decommissioned are routed between: DP2 and TCP2, CDP1 and TP1/QP, and TP1 and the Flare Platform (The Flare Platform tower was removed in 1996 and the base in 2001).

There are small amounts of drill cuttings on the seabed around DP2, although the maximum thickness of this material is only 20cm. The drill cuttings from the wells on CDP1 are contained within the concrete walls of the substructure.

Three of the platforms, TP1, QP and TCP2, are permanently bridge linked and form what is known as the Frigg Central Complex. These facilities have been used to process and export the hydrocarbons from the Frigg reservoir to St. Fergus. Since the start of gas production from Frigg, the facilities on TCP2 have been modified and extended to allow treatment of hydrocarbons from North East Frigg, East Frigg, Lille-Frigg, Odin (operated by Esso) and Frøy satellite fields. Gas from these fields has been exported to St. Fergus in Scotland through the Frigg Norwegian pipeline of the Frigg Transportation System. Since 1995 the produced liquids from these fields have been transported to Sture in Norway via Frostpipe and the Oseberg Transportation System. Production from all the satellite fields tied into TCP2 has now ceased.

In addition, gas from the North Alwyn field has been routed, via TP1, into the Frigg UK Pipeline (PL 7) of the Frigg Transportation System to St Fergus. It is planned to make a direct subsea connection between the North Alwyn pipeline and the Frigg UK Pipeline (PL 7) in 2004.

Production from the main Frigg reservoir is most likely to be shut-in during 2004.

3. Overall Approach to Decommissioning

The OSPAR Commission meeting in Sintra in 1998 determined that there should be a “presumption for removal” of all redundant and decommissioned platforms in the North East Atlantic area, which includes the North Sea. Derogations may be sought for certain categories of facilities. Where derogation is not appropriate, this presumption led to the requirement that structures should be removed irrespective of any comparison of the environmental impact profile for removal with the environmental impact profiles of other alternatives. For each of the components to be decommissioned the following sequential process has therefore been followed to determine the recommended arrangements according to the “waste hierarchy” which values reuse above recycling and disposal onshore above disposal at sea.

- Evaluation of the possibility of reusing all or parts of the offshore facilities either in their current location or at another site
- Evaluation of the possibility of recycling all, or parts, of the offshore facilities
- Evaluation of the possibility of disposal onshore
- Evaluation of the possibility of disposal at sea

Studies and assessments have been conducted by many companies having specialist knowledge in the relevant field. The companies involved in the original design and construction of the platforms have been extensively used in this evaluation work. These companies have unique knowledge of the Frigg Field structures and have been responsible for considering how they might be removed, or disposed.

An extensive process of verification of the study findings has been conducted by leading independent experts from Norway, UK, Holland, Germany, Denmark, Switzerland and France. Seminars and workshops have been held to bring these experts together to the review the studies and ensure that both the input data, and the conclusions drawn from the work, were valid. References to both the studies and the verification reports are to be found at the end of each section of the Disposal Plan, and a full listing is provided in Section 20.

4. Evaluation Principles

The following aspects have been considered when evaluating the various disposal alternatives:-

- Technical Feasibility
- Risk to Personnel
- Environmental Impact (including impact on society)
- Cost

Technical Risk
Based upon the risk accepted during the production phase **the maximum acceptable probability of a major accident during the decommissioning operations (with the associated large financial loss) has been set as 1 x 10^{-3} (1 in 1000).**

This figure is in-line with the guidance contained in Part 1 of the "Rules for Planning and Execution of Marine Operations" published by Det Norske Veritas in January 1996. In these rules DNV state that it was not possible to set a definitive acceptable risk level for marine operations at that time, due to the scarcity of data. DNV further state that they will seek further data and that **"A probability of total loss equal to or better than 1/1000 per operation will then be aimed at."** These same rules indicate that during marine operations a probability of **structural failure** ten times less than this (that is 1 in 10,000) should be aimed at.

Risk to Personnel
The TOTAL NORGE criteria for acceptability of risk to personnel is that the risk of fatality for an individual shall not be greater than **1 x 10^{-3} per year** (1 in 1000) and **shall be as low as reasonably practicable.** This criterion is in accordance with generally accepted principles applied throughout industry and supported by the UK Health and Safety Executive.

For a "normal" offshore worker who spends approximately 3000 hours a year offshore, an average yearly risk of fatality of 1 in 1000 is equivalent to a Fatal Accident Rate of 33**.** This is **the highest risk that can be tolerated and a risk considerably less than this must be sought.** It should be noted that the average Fatal Accident Rate for personnel working on production platforms in the Norwegian sector of the North Sea, based upon experience in the last ten years, is currently 1.3.

Environmental Impact
The method used for assessing non-quantifiable environment impacts takes account of the effect itself and the sensitivity or value of the area in which the effect occurs. The method was developed by DNV and ASPLAN and further details are given in Section 3.3.1.of the Environmental Impact Assessment forming Part 2 of this Frigg Field Cessation Plan.

Costs
The costs presented are expressed in year 2002 money terms and represent a 50/50 estimate. The accuracy of the estimates is -24% /+31 % with an 80 % confidence interval. The exchange rate assumed is 13.08 NOK / £.

5. Possible Continued Use of the Frigg Facilities

A significant investment has been made in exploration in the Frigg area seeking hydrocarbon reservoirs that could be developed using the Frigg Field facilities. At present there are no other known reservoirs in the area that can be economically developed from Frigg.

Studies have also been undertaken which conclude that it is not economically attractive to use one or more of the Frigg Field platforms purely as an export centre to connect into the Frigg Field Transportation System pipelines. Technology today allows the direct subsea tie-in of pipelines to the Frigg export pipelines without the need for a platform. The use of the Frigg facilities as a processing centre is also found not to be viable.

A number of possible non oil and gas uses for the platforms have been evaluated including; artificial reefs; wind-generators; or emission free gas fired power plants. The feasibility of many of the options is technically uncertain and none of the arrangements are judged to be economically viable. The age of the installations is an important consideration when assessing their reuse potential.

No potential reuse application has been identified for the three Frigg Field steel substructures at another location. The three Frigg Field concrete substructures have some potential for reuse at another location, if it were possible to refloat and relocate them without undue technical risk or risk to personnel.

There may be possibilities for the reuse of some of the topside equipment although much of it is rather old. TOTAL NORGE will continue to actively pursue these possibilities.

6. Assessment of Disposal Alternatives

In the absence of any viable reuse potential for the Frigg Field facilities, evaluations and comparative assessments have been carried out to determine how the facilities can be decommissioned.

In accordance with Norwegian and UK regulations, and OSPAR Decision 98/3, full removal and onshore disposal has been the only disposal option considered for the **topsides** and **steel substructures.** For these elements an evaluation of feasible methods for removal and onshore disposal has been undertaken. The cost and risks associated with this work have also been estimated.

Full removal and onshore disposal has been the first option considered for the three **concrete substructures.** However, due to the complexity and uncertainties associated with the removal of these substructures, that were not specifically designed for such an operation, other disposal alternatives have also been considered, as provided for in OSPAR Decision 98/3.

In the case of the **concrete substructures**, the **infield pipelines/cables** and the **drill cuttings**, a comparative assessment of different disposal alternatives has therefore been undertaken.

Table E.1 below shows the various evaluations and comparative assessments undertaken for the Frigg Field facilities. For each of the alternatives, aspects such as technical feasibility, risk to personnel, cost and impact on the environment and society have been considered. The impact on the environment, and on society has been considered within the Environmental

Impact Assessment, which was undertaken by DNV and forms Part 2 of this Frigg Field Cessation Plan.

The purpose of the Environmental Impact Assessment is to :-

- Clarify the consequences of the relevant disposal alternatives for the Frigg Field facilities that may have a significant impact on the environment, natural resources and society.
- Present information about possible impacts in a manner that can form a basis for a decision on the disposal alternatives.
- Present proposals for mitigating any damage and nuisance caused by the chosen disposal alternatives.

Evaluation of Disposal Methods				
Steel Platform Topsides QP, DP2	**Alternative A** Removal and onshore disposal			
Steel Platform Substructures QP, DP2, DP1	**Alternative A** Removal and onshore disposal			
Concrete Platform Topsides TCP2, CDP1, TP1	**Alternative A** Removal and onshore disposal			
Comparative Assessment of Disposal Alternatives				
Concrete Platform Substructures TCP2, CDP1, TP1	**Alternative A** Refloat, tow to shore, demolish and dispose on-shore.	**Alternative B** Remove external and internal steelwork, refloat and dispose at a deep water location	**Alternative C** Remove internal and external steelwork and cut down sub-structure to provide a clear draft of 55m.	**Alternative D** Leave in place, removing as much external steelwork as reasonably practicable.
Infield Pipelines and Cables	**Alternative A** Remove, transport to shore and onshore disposal	**Alternative B** Leave in place but trenched	**Alternative C** Leave in place but bury ends	
Drill Cuttings DP2, CDP1	**Alternative A** Remove and onshore disposal	**Alternative B** Leave in place		

Table E.1 Evaluations and Comparative Assessments Conducted for Frigg Field Facilities

The wording used when describing the impact on the environment, is the same as established by DNV and ASPLAN when assessing non-quantifiable environmental impacts (see Table 6.1 in Section 6 of the Disposal Plan).

The results from the assessments together with the recommended disposal arrangements for the Frigg Field facilities in both the Norwegian and UK sectors are presented in the following sections.

7. Norwegian Registered Facilities

7.1 Drilling Platform DP2

DP2 Statistics

Topsides	
Weight	5479 tonnes
Dimensions	61m x 35m
Steel Substructure	
Weight	9797 tonnes incl.piles
Dimensions	62m x 44m x 106m high

Topsides and Steel Substructure

The studies undertaken indicate that conventional offshore methods of working may be used to remove the DP2 topsides and steel substructure. The removal of the steel substructure will however involve procedures equipment and operations that, at present, have not been widely used in the North Sea. It is anticipated that the work will be challenging and all the operations will need to be very carefully engineered and controlled. It is considered possible to undertake the majority of the underwater construction/demolition work using remotely operated work vehicles and thus it is believed that the work can be carried out without excessive risk to personnel. Divers may have to be used for specific tasks but strict procedures will be used together with appropriate risk reducing measures to ensure that risks are as low as reasonably practicable.

The impact on the environment of removing the topside and steel substructure of DP2 platform has been judged to be generally low. The impact on fisheries and the free passage of vessels is “moderate positive” and there is a “large positive” effect arising from the reuse of the steel. The aesthetic impact is judged to be “moderate negative” during the onshore cleaning and demolition of the structures. A “moderate negative” impact on the physical habitat offshore is predicted during the removal operations due to the disturbance of the seabed when cutting the steel piles. This arises due to the presence of a thin layer of drill cuttings on the seabed around and under the platform.

In accordance with national regulations and international conventions, the topside and steel substructure of DP2 platform will be removed and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The work will be undertaken using the most appropriate techniques and best environmental practice.

7.2 Drilling Platform DP1 Wreck

DP1 Statistics

Steel Substructure	
Weight	7300 tonnes
Dimensions	62m x 44m x 106m high

Steel Substructure

This steel substructure was severely damaged during installation in 1974. The structural integrity of the substructure gives some cause for concern but with adequate control it is considered that the work can be carried out without excessive risk to personnel.

The studies undertaken indicate that it is most probably technically feasible to remove the wreck of the DP1 steel substructure using conventional offshore methods of working. The work will however involve procedures and operations that, at present, have not been widely used in the North Sea. It is considered possible to undertake the majority of the underwater construction/demolition work using remotely operated work vehicles although

some tasks may require diver intervention. When diving is necessary, strict procedures will be used together with appropriate risk reducing measures to ensure that risks are as low as reasonably practicable. The condition of the structure gives some cause for concern, but with adequate control it is considered that the work can be carried out without excessive risk to personnel. An application for derogation under the provisions of OSPAR Decision 98/3 will not therefore be sought for the wreck of DP1 even though it is severely damaged.

The impact on the environment of removing the wreck of the DP1 steel substructure is judged to be generally low. The impact on fisheries and the free passage of vessels is “moderate positive” and there is a “large positive” effect arising from the reuse of the steel. The aesthetic impact is judged to be “moderate negative” during the onshore cleaning and demolition of the structures. The impact on the physical habitat offshore during the removal operations is considered to be “insignificant”.

In accordance with national regulations and international conventions the steel substructure of DP1 platform will be removed and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The work will be undertaken using the most appropriate techniques and best environmental practice.

7.3 Treatment and Compression Platform TCP2

TCP2 Statistics

Topsides	
Weight	22882 tonnes
Dimensions	85m x 65m
Concrete Substructure	
Weight	231179 tonnes incl.solid ballast
Dimensions	116m x 116m x 129m high

Topsides

It is considered to be technically feasible to remove the topsides of TCP2 and to bring them onshore for reuse or recycling. It is also judged that this work can be undertaken without posing unacceptable risks to the personnel involved. The work however will involve procedures and operations that, at present, are not widely used in the North Sea. The work will need to be very carefully engineered and controlled and the removal of the deck structure will be particularly challenging.

Concrete Substructure

Refloat and Onshore Disposal

There is a significant degree of uncertainty regarding the strength and integrity of the TCP2 concrete substructure in the vicinity of the so-called tri-cells. It must also be noted that the condition of the structure and the piping systems will have degraded in the 30-35 years between installation and decommissioning. Whilst this does not affect the safety of the platform during the present operational phase, it could be a critical factor during the removal operations. There are also a number of significant uncertainties associated with the method of freeing the substructure from the seabed including aspects relating to the soil properties, the slope of the seabed and the weight, buoyancy and suction under the structure, as it breaks free from the seabed. The need to use ballast pipework that was designed only for service during the installation phase also gives considerable concern.

The movement of the TCP2 substructure as it breaks free from the seabed is more or less impossible to predict with any degree of accuracy. There is

a possibility that the substructure could “skid” across the seabed in an uncontrollable manner after breaking loose and collide with TP1 which is only 35m away. There would be a similar risk for TP1 if it were removed first.

The consequences of a major accident during the refloat operations have been shown to be particularly severe, especially in respect to the safety of personnel and cost. In order to reduce the environmental impact of such a major accident, and limit the effect on users of the sea, it would be necessary to engage in a series of hazardous (or extremely hazardous) operations that would considerably increase the likelihood of fatalities.

During the anticipated activities involved in removal and onshore disposal operations, the probability of a fatality has been estimated as being in the order of 13% (1 chance in 8 of a fatality). The probability of fatalities would increase significantly if large amounts of offshore work were required as the result of a major accident during a removal operation. It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel.

The cost of removing the concrete substructure of TCP2, if possible, has been estimated to be approximately 2500 MNOK / £191m assuming that no major accidents occur and the operations go as planned. There is however a significant possibility that the cost could increase by a factor of 2 to 3 if a major accident occurred whilst the substructure was being refloated or towed to shore.

Based upon the judgement and input of leading independent experts, the probability of a major accident during the refloat and tow to shore arising from inherent uncertainties has been estimated to be in the order of 2% to 4%. This is twenty to forty times higher than 0.1%, which is the risk acceptance criterion for asset/financial loss during decommissioning, based upon the level of risk accepted during the Frigg Field production phase. The decommissioning risk acceptance criterion is in line with the guidance given in the DNV rules for marine operations. Additionally it is normal for additional problems to become apparent during the detailed engineering phase of a major project, and these would have the effect of increasing further the probability of accident and delay. It is also to be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

In view of the limited environmental benefit, and the severe safety and financial implications of a major accident, the inherent uncertainties surrounding the complete removal and onshore disposal of the TCP2 concrete substructure are considered unacceptable.

Refloat and Disposal in Deep Water
The refloat of the substructure for offshore disposal is similarly uncertain and, in addition, the dumping of structures in the deep ocean is generally considered to be undesirable by society. Consultation with the stakeholders indicated that if the substructure could be refloated, then it should be brought to shore for disposal, rather than dumped in the ocean. Alternative B, refloat and disposal in deep water, is therefore also rejected.

Cut Down to –55m
Cutting down the columns is felt to be theoretically feasible although the level of uncertainty surrounding the method of cutting makes this decommissioning alternative unattractive. Considerable effort and expenditure would be necessary before the feasibility of this option could be fully proven. Cutting the columns down to allow a clear 55m draft above the remaining substructure does however have the merit of allowing the free passage of vessels although remaining an obstruction to fishing activity.

Uncertainties associated with the process of cutting and removing the columns mean that there is a significant risk of delay. The external cofferdam and the cutting method itself both require the development and qualification of new technology and its deployment in difficult environments. Once the cutting work has been started the structural integrity of a column will be affected and after a relatively small section of a column has been cut it will not have

sufficient strength to resist a winter storm. In view of the unproven nature of much of the work significant delays could result in uncontrolled collapse of a column which would be unlikely to achieve a clear water draft of 55m.

The probability of collapse of a column has been estimated to be in the order of 2%, which is 20 times higher than acceptable. In such an event the remedial work necessary to achieve 55m would be both very hazardous and costly, involving substantially increased risk to personnel and a possible cost increase of more than 50%. Unknown factors related to the cutting methods also result in a 3% probability that the chosen cutting method would need to be re-engineered and re-qualified. This would result in a high level of cost uncertainty and a possible increase in the risk to personnel. Additionally, this method of decommissioning TCP2 is not considered desirable by either the Norwegian or UK fishing industries, due to the danger it represents to fishing activity.

Due to the uncertainties associated with the decommissioning operations, and the fact that this solution is also unattractive to some stakeholders, particularly the fishing industry, it is recommended that this alternative be rejected.

Leave In Place
Leaving the concrete substructure in place is therefore considered to be the best solution when considering health and working environment, safety, environmental aspects and cost.

The concrete substructure is not polluted with hydrocarbons or other chemicals or materials and thus there is judged to be an insignificant level of discharge to the marine environment. Tests on samples of concrete taken from the substructure and analytical studies support the view that long-term degradation of the concrete will have an insignificant impact on the local marine environment. By removing the external steelwork, the risk of sections of steelwork corroding and falling onto the seabed, where they could be a hazard for fishermen, is eliminated. Diesel fuel, hydraulic oil and methanol used for operational purposes in the columns, will be removed and the equipment and piping cleaned. It is important to note that cleaning of the TCP2 concrete substructure is not required, as it has **never been used for the storage of crude oil.**

Very little other environmental impact has been predicted if the substructure was left in place, apart from the obstruction caused to fishing vessels and other users of the sea. Quantitative assessments indicate that the probability of vessels colliding with the TCP2 concrete substructure is relatively low and appropriate risk reducing measures will be taken

It is recommended that the topsides of TCP2 platform should be removed and brought onshore for disposal, and that the concrete substructure should be suitably marked and left in place after removal of the external steelwork. As much as practicable of the equipment and materials brought onshore will be reused or recycled.

7.4 Pipelines and Cables

As the infield pipelines and cables are not buried, all the alternative disposal arrangements are considered to be technically feasible. Whilst the risk to personnel undertaking the work is higher if the pipelines and cables are retrieved and brought on shore for disposal, the increase in risk is relatively modest.

The environmental impacts of all the alternatives are quite small, however it is considered advantageous to provide a clean seabed around the concrete substructures. The risk of snagging fishing gear on the infield pipelines and cables (with the attendant risk of collision with the concrete substructures) would thereby be eliminated and the safety of fishermen improved. Moreover the cost increase to remove, rather than trench, the pipelines is relatively small.

It is recommended that all the Frigg Field infield pipelines and cables located in the Norwegian sector, together with their associated concrete blocks, concrete saddles and mattresses are retrieved and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The pipeline protective rock dumps will be spread out on the seabed and left in place.

7.5 DP2 Drill Cuttings

Approximately 7,000m^3 of drill cuttings were discharged from DP2. All the 24 wells were drilled using water-based mud apart from the re-drilling of two wells, where low toxicity oil based mud was used. A total of 120 m^3 of low toxicity oil based mud was brought ashore for treatment and disposal. The drill cuttings containing the remaining 116 m^3 of low toxicity oil based mud were cleaned on the platform and discharged onto the seabed. A survey in the summer of 2000 indicated that the drill cuttings are presently deposited in a thin layer on the seabed around the platform. The maximum thickness of the drill cuttings layer is 20cm. It is estimated that approximately 400 m^3 of drill cuttings are contained within an area of 80m x 120m around the platform. Outside this area the thickness of the drill cuttings layer is less than 4 cm.

Analysis of samples taken during the summer of 2000, show that most chemicals measured are within SFT Class I (slightly polluted coastal environment) except for a few chemicals characterised in Class II (moderately polluted). The SFT (Norwegian Pollution Control Authority) classification system is for use in fjords and coastal waters, and is here only used as a reference and not an absolute measure.

There are presently no proven methods to remove the thin layer of drill cuttings under and around DP2 without some negative effects due to the disturbance of the deposited materials. Removal of the drill cuttings will cause increased air emissions from the removal process and deposition onshore in dedicated landfill. The discharge impact is considered to be roughly the same for removal and leaving in place.

The risk to personnel is obviously higher if the drill cuttings are removed but it is envisaged that the work could be undertaken in a safe manner. Safety aspects are therefore not considered to be particularly significant in determining the disposal alternative to adopt.

Due to the very limited environmental impact of leaving the drill cuttings in place, it is recommended that the deposits under and around DP2 should be left in place and disturbed as little as possible during the removal of the DP2 steel substructure.

Since Second Draft of the Frigg Field Cessation Plan was issued, the final report from the UKOOA Drill Cuttings Initiative has been published. This states that in cases where the quantity and composition of the drill cuttings are similar to that found at DP2, the likely best environmental strategy is to leave the drill cuttings in place to degrade naturally. The recommendation for the DP2 drill cuttings thus accords with the results from the UKOOA initiative, which was also supported by OLF.

7.6 Debris Clearance

Debris on the seabed around the Norwegian installations will be removed after an initial survey. A post clean up survey will be undertaken and a trawling test carried out to ensure that no obstructions remain in the area that would impede fishing operations. The results from the surveys and trawl test will be submitted to the appropriate Norwegian authorities.

7.7 Costs

The estimated costs of the recommended disposal arrangements for the Frigg Field facilities located on the Norwegian continental shelf is 1852 MNOK (£141.6m). This figure does not include the cost of plugging and abandoning the wells on DP2 nor the cost of taking out of service the production facilities on DP2 and TCP2. The estimated cost of this additional work is 785 MNOK (£60.0m).

The total cost of the recommended disposal arrangements for all the Frigg Field facilities is estimated to be 3483 MNOK (£266.3m). The additional cost of plugging and abandoning the wells on DP2 and taking the topside equipment on TCP2, TP1, DP2 and QP out of service is estimated as 1050 MNOK (£80.3m). (For CDP1 the production system was taken out of service, and the wells plugged and abandoned, in 1990.)

The costs presented are expressed in year 2002 money terms and represent a 50/50 estimate. The exchange rate assumed is 13.08 NOK / £. The accuracy of the estimate is -24% /+31 % with an 80 % confidence interval. The actual cost may vary from the estimated value due to technical factors such as difficulties with cutting up DP1, or due to commercial factors such as market conditions.

Table E.2 below shows the cost for the recommended disposal alternatives for the facilities located in the Norwegian sector of the Frigg Field.

Steel Platforms Topsides (DP2)	Alternative A Removal and onshore disposal	250 MNOK (£19.1m)
Steel Platform Substructures (DP2, DP1)	Alternative A Removal and onshore disposal	777 MNOK (£59.4m)
Concrete Platform Topsides (TCP2)	Alternative A Removal and onshore disposal	647 MNOK (£49.5m)
Concrete Platform Substructures (TCP2)	Alternative D Leave in place, removing as much external steelwork as reasonably practicable.	77 MNOK (£5.9m)
Pipelines and Cables (between TCP2 and DP2)	Alternative A Retrieve, transport to shore and onshore disposal	65 MNOK (£4.9m)
Drill Cuttings (DP2)	Alternative B Leave the drill cuttings in place	0 NOK (£0.0)
Seabed Clean-up	Alternative A Removal of debris on seabed	36 MNOK (£2.7m)
Total		**1852 MNOK (£141.6m)**

Table E.2 Estimated Cost of Recommended Decommissioning of Frigg Field Norwegian Facilities

8. UK Registered Facilities

8.1 Living Quarters Platform QP

QP Statistics

Topsides	
Weight	3639 tonnes
Dimensions	35m x 30m
Steel Substructure	
Weight	4757 tonnes incl.piles
Dimensions	54m x 54m x 113m high

Topsides and Steel Substructure

The studies undertaken indicate that conventional offshore methods of working may be used to remove the QP topsides and steel substructure. The removal of the steel substructure will however involve procedures, equipment and operations that, at present, have not been widely used in the North Sea. It is anticipated that the work will be challenging and all the operations will need to be very carefully engineered and controlled. It is considered possible to undertake the majority of the underwater construction/demolition work using remotely operated work vehicles and thus it is believed that the work can be carried out without excessive risk to personnel. Divers may have to be used for specific tasks but strict procedures will be used together with appropriate risk reducing measures to ensure that risks are as low as reasonably practicable.

The impact on the environment of removing the topside and steel substructure of QP platform has been judged to be generally low. The impact on fisheries and the free passage of vessels is “moderately positive” and there is a “large positive” effect arising from the reuse of the steel. The aesthetic impact is judged to be “moderately negative” during the onshore cleaning and demolition of the structures and a “small/insignificant” effect on the physical habitat offshore is predicted during the removal operations. The energy use and the emissions during the removal and disposal activities are not considered to affect the feasibility of the planned operations.

In accordance with national regulations and international conventions, the topside and steel substructure of QP platform will be removed and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The work will be undertaken using the most appropriate techniques and best environmental practice.

8.2 Concrete Drilling Platform CDP1

CDP1 Statistics

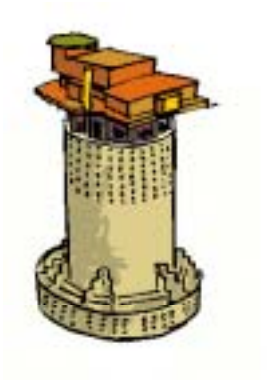
Topsides	
Weight	4840 tonnes
Dimensions	64m x 63m
Concrete Substructure	
Weight	418611 tonnes incl.solid ballast
Dimensions	101 x 101m x 107m high

Topsides

It is believed to be technically feasible to remove the topsides of CDP1 and to bring them onshore for reuse or recycling. It is also judged that this work can be undertaken without posing unacceptable risks to the personnel involved. The work however will involve procedures and operations that, at present, are not widely used in the North Sea. The work will need to be very carefully engineered and controlled.

Concrete Substructure

Refloat and Onshore Disposal



The main uncertainty relating to the possible refloat and onshore disposal of CDP1 is the water tightness of the substructure. There is a significant probability of leakage, either through the cofferdam (that has to be installed to seal the holes in the outer wall), or through ineffectively closed penetrations, broken pipes or cracks in the walls and base slab of the substructure. The holes in the base slab, which were cut to allow the wells to be drilled, are a particularly likely source of leakage. It is also uncertain that all the leakage experienced during the installation operations would be overcome by the use of the steel cofferdam around the upper section of the external walls.

The water tightness of the substructure cannot be verified until the cofferdam has been installed and the solid ballast removed. In that condition the substructure will be subject to larger wave forces and will have less stability. It would be extremely difficult at that stage to identify the source of the leakage, or to make repairs. There is a high probability of further cracking and leakage if the substructure could not be refloated in a single summer season and needed to remain in place throughout the winter period.

The possibility of leakage through the base slab after lift off from the seabed cannot be neglected, due to uncertainties surrounding the condition of the slab and the penetrations through it. Although small amounts of water might leak through these areas when the substructure is on the seabed, it is only when it lifts off that the full leak potential would be realised. In this situation pumps already installed on the substructure may be able to maintain adequate buoyancy, but if this was not possible the substructure would sink back to the seabed. It is likely that further damage would occur to the base slab and walls when the substructure impacted with the seabed, the severity of the damage being dependant upon the size of the leaks.

The condition of the structure has degraded since the platform was installed in 1975 and some further degradation may be expected before any removal operation was carried out. Whilst this does not affect the safety of the platform in its present condition, it is a critical factor during the removal operations

The consequences of a major accident during the refloat operations have been shown to be particularly severe, especially in respect to the safety of personnel and cost involved in the remedial operations. In addition, if due to leakage it proved impossible to refloat the substructure, then the only other removal alternative would be to cut up the concrete substructure into suitably sized sections which would then be transported to shore for

disposal. Such operations would involve considerable amounts of diving and would be unacceptably hazardous.

During the anticipated activities involved in removal and onshore disposal operations, the probability of a fatality has been estimated as being in the order of 46% (approximately 1 in 2). This is a very high risk. The average fatal accident rate for the removal and onshore disposal is estimated to be in the order of 22, which is considered not acceptable in the light of normal operating risk to personnel on oil and gas installations in the North Sea. The probability of fatalities would increase significantly if large amounts of offshore work were required as the result of major leakage or a major accident during a removal operation. It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel.

The cost of removing the concrete substructure of CDP1, if possible, has been estimated to be 4000 MNOK / £309m assuming that no major accidents occur and the operations go as planned. There is however a significant possibility that the cost could increase by a factor of 2 to 2½ if it was impossible to refloat the substructure or a major accident occurred whilst the substructure was being refloated or towed to shore.

Based upon the judgement and input of leading independent experts, the probability of being unable to refloat the substructure or a major accident occurring during the refloat and tow to shore has been estimated to be in the order of 30%. This risk is extremely high due to the inherent uncertainties in the condition of the structure, and the need for extensive offshore activities that have never been undertaken before. The risk of being unable to undertake the refloat operation is approximately 300 times higher than the 0.1% risk acceptance criterion for asset/financial loss during decommissioning, based upon the level of risk accepted during the Frigg Field production phase. The decommissioning risk acceptance criterion is in line with the guidance given in the DNV rules for marine operations. Additionally it is normal for additional problems to become apparent during the detailed engineering phase of a major project, and these would have the effect of increasing further the probability of accident and delay. It is also to be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

The inherent uncertainties surrounding the complete removal and onshore disposal of the CDP1 concrete substructure are considered unacceptable in the light of the limited environmental benefit and the severe safety and financial implications of being unable to refloat the substructure or of having a major accident during the work,

Refloat and Disposal in Deep Water
The refloat of the substructure for offshore disposal is similarly uncertain and, in addition, the dumping of structures in the deep ocean is considered to be generally undesirable by society. Consultation with the stakeholders indicated that, if the substructure could be refloated, then it should be brought to shore for disposal, rather than dumped in the ocean. Alternative B, refloat and disposal in deep water, is therefore also rejected.

Cut Down to –55m
Cutting down the walls and central core of the substructure is felt to be theoretically feasible, although many factors militate against such an approach. There is a high level of uncertainty surrounding the method of cutting up such an integrated structure as the strength and stability of each wall depends to a great extent on the adjacent walls. The feasibility of the concrete cutting method is also debatable and considerable effort and expenditure would be necessary before the method could be considered field proven. The amount of diving necessary also makes this alternative disposal method very questionable and the risk to personnel engaged in the work is considered to be unacceptably high. Due to the complexity of the CDP1 substructure and the amount of cutting required it is not considered feasible with today's technology to undertake the work using only remotely operated vehicles.

Cutting down the substructure to allow a clear 55m draft above the remaining substructure would allow the free passage of vessels. Uncertainties associated with the process of cutting and toppling the upper sections of wall result in a 20% chance that one or more walls might collapse in an uncontrolled manner. This is approximately 200 times greater than the acceptance criterion and is considered unacceptable. In the event of a major accident, the additional works to achieve the 55m draft would be extremely hazardous resulting in a significant increase in the risk to personnel. The total cost of the work would also be substantially increased. Additionally, this method of decommissioning CDP1 is not considered desirable by either the Norwegian or UK fishing industries, due to the danger it represents to fishing activity.

Due to the risk to personnel, the uncertainties associated with the decommissioning operations, and the fact that this solution is also unattractive to some stakeholders, particularly the fishing industry, it is recommended that this alternative be rejected.

Leave in Place
Leaving the concrete substructure in place is therefore considered to be the best solution when considering health and working environment, safety, environmental aspects and cost.

Apart from a small volume of drill cuttings in the solid ballast, the concrete substructure is not polluted by hydrocarbons or other chemicals or materials and thus there is judged to be insignificant level of discharge to the marine environment. There is no steelwork on the outside of the concrete substructure so there is no risk of corroded steel items falling onto the seabed where they could be a hazard to fishermen. It is important to note that cleaning of the CDP1 concrete substructure is not required, as it has **never been used for the storage of crude oil.**

Very little other environmental impact has been predicted if the substructure was left in place, apart from the obstruction caused to fishing vessels and other users of the sea. Quantitative assessments indicate that the probability of vessels colliding with the CDP1 concrete substructure is however relatively low and appropriate risk reducing measures will be taken.

It is recommended that the steel components of the topsides of CDP1 platform should be removed and brought onshore for disposal, and that the concrete substructure (including the concrete deck beams) should be suitably marked and left in place. As much as practicable of the equipment and materials removed from the platform will be reused or recycled.

8.3 Treatment Platform TP1

TP1 Statistics

Topsides	
Weight	7840 tonnes
Dimensions	90m x 44m
Concrete Substructure	
Weight	163179 tonnes incl. solid ballast
Dimensions	72m x 72m x 126m high

Topsides

It is believed to be technically feasible to remove the topsides of TP1 and to bring them onshore for reuse or recycling. It is also judged that this work can be undertaken without posing unacceptable risks to the personnel involved. The work however will involve procedures and operations that, at present, are not widely used in the North Sea. The work will need to be very carefully engineered and controlled.

Concrete Substructures

Refloat and Onshore Disposal

The main areas of concern relating to the possible refloat of the TP1 concrete substructure are the strength of the inner walls in the base, and the stability and strength of the structure during the separation and ascent from the seabed. It must also be noted that the condition of the structure and the piping systems will have degraded in the 30-35 years between installation and decommissioning. Whilst this does not affect the safety of the platform during the present operational phase, it could be a critical factor during the removal operations.

The ability of the inner walls to resist the loads due to different levels of water in the adjoining cells has been shown to be critical. This differential water pressure may arise as a result of; intended actions required to level the substructure as it is extracted from the seabed; or as a result of leakage through walls or penetrations; or as a result of the platform tilting as it breaks free form the seabed. Other factors that need to be considered are; the accuracy of water level monitoring equipment; and the dynamic behaviour of the water in the cells when the substructure is floating. Calculations indicate that as the platform rises in the water after breaking free from the seabed the maximum allowable difference in water level on the two sides of an internal wall is about 8m. There is a significant probability that it would not be possible to maintain this requirement during the refloat operation.

There are also a number of significant uncertainties associated with the method of freeing the substructure from the seabed, including aspects relating to the soil properties, the slope of the seabed and the weight, buoyancy and suction under the structure, as it breaks free from the seabed. The amount of grout that could fall off the underside of the substructure is impossible to determine. The need to use ballast pipework that was designed only for service during the installation phase also gives considerable concern. In unfavourable circumstances it is possible that the substructure could tilt by more than 17 degrees. The effect of this would be to increase the possibility of failure of the inner walls. The movement of the TP1 substructure as it breaks free from the seabed is more or less impossible to predict with any degree of accuracy. There is a possibility that the substructure could “skid” across the seabed in an uncontrollable manner after breaking loose and collide with TCP2, which is only 35m away. The risk of a collision would affect TCP2 if it were removed first.

The consequences of a major accident during the refloat operations have been shown to be particularly severe, especially in respect to the safety of personnel and cost. In order to reduce the environmental impact of such a major accident it would also be necessary to engage in a series of extremely hazardous operations that would considerably increase the likelihood of fatalities.

During the anticipated activities involved in removal and onshore disposal operations, the probability of a fatality has been estimated as being in the order of 15% (1 chance in 7 of a fatality). The probability of fatalities would increase significantly if large amounts of offshore work were required as the result of a major accident during a removal operation. It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel.

The cost of removing the concrete substructure of TP1, if possible, has been estimated to be approximately 1900 MNOK / £146m assuming that no major accidents occur and the operations go as planned. There is however a significant possibility that the cost could increase by a factor of 3 to 4 if a major accident occurred whilst the substructure was being refloated or towed to shore.

Based upon the judgement and input of leading independent experts, the probability of a major accident during the refloat and tow to shore arising from inherent uncertainties has been estimated to be in the order of 2% to 5%. This is between twenty and fifty times higher than the 0.1% risk acceptance criterion for asset/financial loss during decommissioning based upon the level of risk accepted during the Frigg Field production phase. The decommissioning risk acceptance criterion is in line with the guidance given in the DNV rules for marine operations. Additionally it is normal for additional problems to become apparent during the detailed engineering phase of a major project, and these would have the effect of increasing further the probability of accident and delay. It is also to be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

In view of the limited environmental benefit and the severe safety and financial implications of a major accident, the inherent uncertainties surrounding the complete removal and onshore disposal of the TP1 concrete substructure are considered unacceptable.

Refloat and Disposal in Deep Water
The refloat of the substructure for offshore disposal is similarly uncertain and, in addition, the dumping of structures in the deep ocean is generally considered to be undesirable by society. Consultation with the stakeholders indicated that if the substructure could be refloated, then it should be brought to shore for disposal, rather than dumped in the ocean. Alternative B, refloat and disposal in deep water, is therefore also rejected.

Cut Down to –55m
Cutting down the columns is felt to be theoretically feasible although the level of uncertainty surrounding the method of cutting makes this decommissioning alternative unattractive. Considerable effort and expenditure would be necessary before the feasibility of this option could be fully proven. Cutting the columns down to allow a clear 55m draft above the remaining substructure does however have the merit of allowing the free passage of vessels although remaining an obstruction to fishing activity.

Uncertainties associated with the process of cutting and removing the columns mean that there is a significant risk of delay. The cutting method requires the development and qualification of new technology and its deployment in a difficult environment. Once the cutting work has been started the structural integrity of a column will be affected and after a relatively small section of the column has been cut it will not have sufficient strength to resist a winter storm. In view of the unproven nature of much of the work significant delays could result in uncontrolled collapse of a column which would be unlikely to achieve a clear water draft of 55m.

The probability of collapse of a column has been estimated to be in the order of 4%. This is forty times higher than the 0.1% risk acceptance criterion for asset/financial loss during decommissioning based upon the level of risk accepted during the Frigg Field production phase. The decommissioning risk acceptance criterion is in line with the guidance given in the DNV rules for marine operations. In the event of a column collapse, the remedial work

necessary to achieve 55m would be particularly hazardous and result in a significant increase in the risk to personnel. It is also likely that the cost of the decommissioning work would increase by more than 80%. Unknown factors related to the cutting methods also result in a high level of cost uncertainty and possible increased risk to personnel. Additionally, this method of decommissioning TP1 is not considered desirable by either the Norwegian or UK fishing industries due to the danger it represents to fishing activity.

Due to the uncertainties associated with the decommissioning operations, and the fact that this solution is also unattractive to some stakeholders, particularly the fishing industry, it is recommended that this alternative be rejected.

Leave in Place
Leaving the concrete substructure in place is therefore considered to be the best solution when considering health and working environment, safety, environmental aspects and cost.

The concrete substructure is not polluted with hydrocarbons or other chemicals or materials and thus there is judged to be an insignificant level of discharge to the marine environment. Tests on samples of concrete taken from the substructure and analytical studies support the view that long-term degradation of the concrete will have an insignificant impact on the local marine environment. By removing the external steelwork the risk of sections of steelwork corroding and falling onto the seabed where they could be a hazard for fishermen, is eliminated. Diesel fuel, hydraulic oil and methanol used for operational purposes in the columns, will be removed and the equipment and piping cleaned. It is important to note that cleaning of the TP1 concrete substructure is not required, as it has **never been used for the storage of crude oil.**

Very little other environmental impact has been predicted if the substructure was left in place, apart from the obstruction caused to fishing vessels and other users of the sea. Quantitative assessments indicate that the probability of vessels colliding with the TP1 concrete substructure is however relatively low and appropriate risk reducing measures will be taken.

It is recommended that the topsides of TP1 platform should be removed and brought onshore for disposal, and that the concrete substructure should be suitably marked and left in place, after removal of the external steelwork. As much as practicable of the equipment and materials removed from the platform will be reused or recycled.

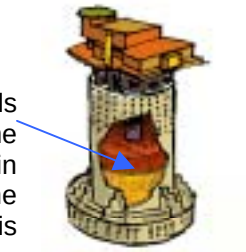
8.4 Pipelines and Cables

As the infield pipelines and cables are not buried, all the alternative disposal arrangements are considered to be technically feasible. Whilst the risk to personnel undertaking the work is higher if the pipelines and cables are retrieved and brought on shore for disposal, the increase in risk is relatively modest.

The environmental impacts of all the alternatives are quite small, however, it is considered advantageous to provide a clean seabed around the concrete installations. The risk of snagging fishing gear on the infield pipelines and cables (with the attendant risk of collision with the concrete substructures) would thereby be eliminated and the safety of fishermen improved. Moreover the cost increase to remove, rather than trench, the pipelines is relatively small.

It is therefore recommended that all the Frigg Field infield pipelines and cables in the UK sector, together with their associated concrete blocks, concrete saddles, and mattresses, are retrieved and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The pipeline protective rock dumps will be spread out on the seabed and left in place.

8.5 CDP1 Drill Cuttings



There are estimated to be 5,600m^3 of drill cuttings from the CDP1 wells contained within the outer wall of the concrete substructure of CDP1. All the wells on CDP1 were drilled using water based mud. It is recommended in Section 9 that CDP1 is left in place and thus the drill cuttings inside the substructure will not be disturbed. Leaving the drill cuttings in place is considered to have an insignificant effect on the environment around CDP1.

It is recommended that the drill cuttings inside CDP1 should be left in place within the concrete walls of the substructure.

8.6 Debris Clearance

Debris on the seabed around the UK installations will be removed after an initial survey. A post clean up survey will be undertaken and a trawling test carried out to ensure that no obstructions remain in the area that would impede fishing operations. The results from the surveys and trawl test will be submitted to the appropriate UK authorities.

8.7 Costs

The estimated costs of the recommended disposal arrangements for the Frigg Field facilities located on the UK continental shelf is £124.7m. (1631 MNOK). This figure does not include for plugging and abandonment of the wells on CDP1 (which was undertaken in 1990) nor the cost of taking out of service the production and accommodation facilities on TP1 and QP. The estimated cost of the future additional work is £20.3m (265 MNOK).

The total cost of the recommended disposal arrangements for all the Frigg Field facilities is estimated to be £266.3m (3483 MNOK). The additional cost of plugging and abandoning the wells on DP2 and taking the topside equipment on TCP2, TP1, DP2 and QP out of service is estimated as £80.3m (1050 MNOK).

The costs presented are expressed in year 2002 money terms and represent a 50/50 estimate. The exchange rate assumed is £1 / 13.08 NOK. The accuracy of the estimate is -24% /+31 % with an 80 % confidence interval. The actual cost may vary from the estimated value due to technical factors such as difficulties in removing the topsides or pipelines, or due to commercial factors such as market conditions.

The table below shows the cost for the recommended disposal alternatives for the facilities located in the UK sector of the Frigg Field:

Steel Platform Topsides (QP)	Alternative A Removal and onshore disposal	£21.1m (275 MNOK)
Steel Platform Substructures (QP)	Alternative A Removal and onshore disposal	£21.1m (276 MNOK)
Concrete Platform Topsides (CDP1, TP1)	Alternative A Removal and onshore disposal	£69.6m (910 MNOK)
Concrete Platform Substructures (CDP1, TP1)	Alternative D Leave in place, removing as much external steelwork as reasonably practicable.	£3.1m (41 MNOK)
Pipelines and Cables (between TP1 and CDP TP1 and FP Base)	Alternative A Retrieve, transport to shore and onshore disposal	£7.4m (97 MNOK)
Drill Cuttings (CDP1)	Alternative B Leave the drill cuttings in place	£0 (0 NOK)
Seabed Clean-up	Alternative A Removal of debris on seabed	£2.4m (32 MNOK)
Total		**£124.7 (1631 MNOK)**

Table E.3 Estimated Cost of Recommended Decommissioning the Frigg Field UK Facilities

The figures quoted in Table E.3 do not include for plugging and abandonment of the wells on CDP1 (which was undertaken in 1990) nor the cost of taking out of service the production and accommodation facilities on CDP1, TP1 and QP.

9. Common Aspects

9.1 Field-Wide Comparison of Recommended and Rejected Disposal Arrangements

The effects of the recommended disposal arrangements in terms of technical risk, risk to personnel, impact on the environment and cost have been compared with alternative disposal arrangements in the context of the whole Frigg Field.

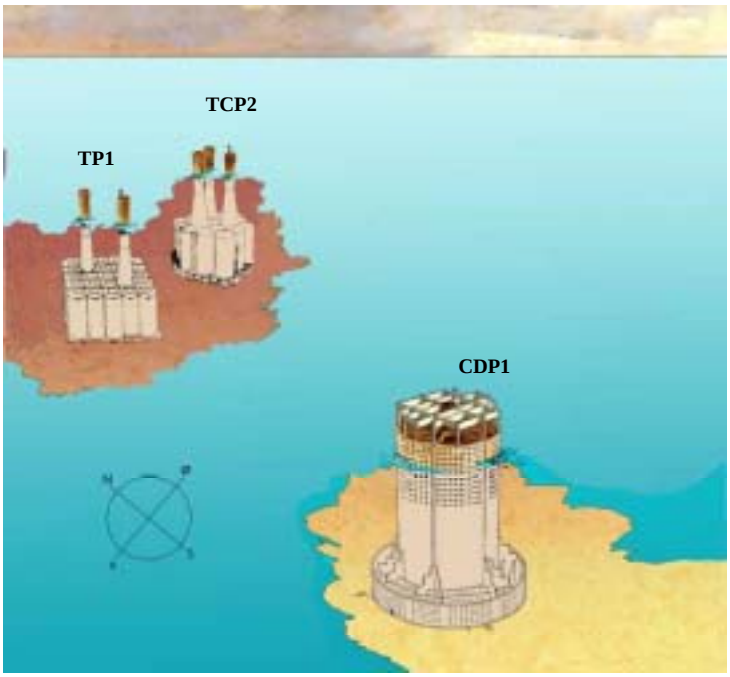


Figure E.2 Proposed Arrangement of Frigg Field Facilities after Decommissioning

Technical Risk

The operations involved in decommissioning the Frigg Field facilities, in line with the recommendations, use existing technology and are within the limits of current experience. The removal of the steel substructures will however involve procedures, equipment and operations that, at present, have not been widely used in the North Sea. Specific operations such as the cutting up and removal of the steel substructures (and particularly the damaged DP1 steel substructure) will however be particularly challenging and will require a high level of professionalism and attention to detail. The removal of the topsides from the five platforms (including the large TCP2 deck) will also involve complicated operations for which there is limited experience. It will therefore be essential that there is great attention to detail during the engineering phase and effective control during the offshore work phase. The main technical challenges are however relatively well known and understood, and although there will doubtless be many technical difficulties to be overcome, it is judged that the risk of being unable to complete the decommissioning work as planned is low.

As detailed in Section 9, there are large uncertainties associated with the condition of the concrete substructures, and their likely behaviour during an attempt to refloat them. The inherent uncertainties associated with CDP1 in particular mean that there is a 30% chance that it will be impossible to refloat the concrete substructure. Although the probability of major accidents during refloat attempts for TCP2 and TP1 are less (in the order of 2 to 5%), the possible consequences of such accidents, in terms of risk to personnel and large cost increases, are such as to make these risk unacceptable.

Consideration has been given to whether developing technology within the foreseeable future, might assist in removing the three concrete substructures. In view of the fact that the main areas of uncertainty relate to physical phenomena (necessary buoyancy, structural uncertainties, schedule and weather) and aspects that are unlikely ever to be determinable (e.g. the amount of grout that might fall off), it is felt that developing technology will not significantly affect the risks associated with attempting to refloat the Frigg concrete substructures.

The successful refloating of the Maureen steel gravity platform by Phillips Petroleum Company UK Ltd. in June 2001 prompted TOTAL NORGE to make a further review of the proposed methods for refloating the Frigg Field concrete substructures. Having carefully reviewed the refloat operation for the Maureen platform (which was specifically designed to be removed) significant differences were identified in the following aspects; platform size; soil and foundation conditions; structural strength; pipework / mechanical equipment; and risk. These differences are judged to be sufficiently major to prevent direct comparisons to be drawn between the successful refloat operations for the Maureen platform and the envisaged refloat operations for the Frigg Field concrete substructures.

Two concrete platforms in the Schwedeneck-See close to Kiel in the Baltic Sea have been successfully removed in 2002, operated by RWE-DEA. After review of the planned methods proposed for removal of these platforms it has been concluded that whilst the method may be satisfactory in the benign waters of the Baltic Sea, it would not be prudent to use such an arrangement in the much more hostile waters of the North Sea.

Risk to Personnel During Decommissioning
The table below provides a comparison of the predicted fatalities during the recommended decommissioning arrangements with the fatalities predicted for other disposal alternatives.

Decommissioning Alternatives	Predicted Number of Fatalities (Potential Loss of Life)	Probability of a Fatality
Recommended Decommissioning Arrangements • Remove all 5 topsides and 3 steel substructures and dispose onshore • Leave 3 concrete substructures in place after removing external steelwork • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	0.3	26% (1 in 4 chance)
Removal of Concrete Substructures • Remove all 5 topsides and 3 steel substructures and dispose onshore • Refloat 3 concrete substructures, tow to shore and dispose onshore • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	1.1	67% (2 in 3 chance)
Cut down Concrete Substructures • Remove all 5 topsides and 3 steel substructures and dispose onshore • Cut down the 3 concrete substructures to provide a clear draft of 55m for shipping • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	1.4	75% (3 in 4 chance)

Table E.4 Predicted Fatalities for Different Frigg Field Decommissioning Alternatives

The statistically predicted number of fatalities for the recommended decommissioning activities is 0.3. To gain an appreciation of the significance of this figure it may be assessed in relation to the number of fatalities associated with petroleum operations on the Norwegian Continental Shelf.

In the last 10 years (1990 - 2000) there have been six fatalities on Norwegian production installations. This means that the yearly fatality rate is 0.6. Thus it can be seen that the predicted fatalities for the **recommended decommissioning** arrangements is equal to **half** the number of fatalities on all Norwegian production installations in one year. The number of fatalities predicted if the concrete substructures **are removed** is approximately **twice** the number of fatalities on all Norwegian production installations in one year.

It can be seen that the probability of a fatality during the recommended decommissioning arrangements is 26% (approximately 1 in 4). If the concrete substructures were removed as well the probability of a fatality increases to 67% (approximately 2 in 3). This assumes that the removal operations can be carried out as planned. If a serious problem developed during the refloat, or during towing, it would be necessary to undertake remedial works to remove the substructure in a damaged condition. The predicted fatalities in that situation would be considerably higher.

Environmental Impact

Due to the many different activities involved, each having either positive or negative effects on the environment, it is not possible to effectively summarise the environmental impact of the entire recommended disposal programme for the Frigg Field facilities. A comparison of the environmental impacts of different decommissioning options for the **three concrete substructures taken together** has however been made and the main parameters are given in Table E.5.

	Alternative A (Base case) Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
Total Energy Impact(million GJ)	4.0	2.2	3.1	1.0
CO_2 Emissions (1000 tonnes)	265	108	168	14
Physical impact environment	Moderate negative	Moderate negative	Large/Moderate negative	Moderate negative
Aesthetic impact	Moderate negative	None/Insignificant	None/Insignificant	None/Insignificant
Material Management	Moderate positive	Non/Insignificant	Small positive	None/Insignificant .(Small positive)
Littering	None/Insignificant	None/Insignificant	Small negative	Small negative
Impacts on fisheries	Moderate positive	Moderate positive	Moderate negative	Moderate negative
Impact on free passage at sea	Moderate positive	Moderate positive	Moderate positive	Moderate negative

Table E.5 Summary of Environmental Impact of Alternative Disposal Arrangements for **All Three** Concrete Substructures (TCP2, CDP1 and TP1)

Costs
Table E.6 provides a comparison of the estimated cost for the recommended decommissioning arrangements with the estimated cost if the concrete platforms were removed or cut down.

Decommissioning Alternatives	Estimated Cost
Recommended Decommissioning Arrangements • Remove all 5 topsides and 3 steel substructures and dispose onshore • Leave 3 concrete substructures in place after removing external steelwork • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	3483 MNOK / £266.3m
Removal of Concrete Substructures • Remove all 5 topsides and 3 steel substructures and dispose onshore • Refloat 3 concrete substructures , tow to shore and dispose onshore • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	11273 MNOK / £861.8m
Cut down Concrete Substructures • Remove all 5 topsides and 3 steel substructures and dispose onshore • Cut down the 3 concrete substructures to provide a clear draft of 55m for shipping • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	10417 MNOK / £796.4m

Table E.6 Estimated Costs for Different Frigg Field Decommissioning Alternatives

The costs set out in the table are the best estimates (50/50), but may vary considerably due to technical problems and commercial uncertainties, particularly the market conditions at the time the work is scheduled. Although there are some technical uncertainties surrounding the recommended decommissioning arrangements, (principally the condition of the DP1 wreck), these are considerably less than the uncertainties associated with removing or cutting down the concrete substructures.

If as a result of inherent uncertainties, there was a major accident or incident during the removal of one of the concrete substructures then the quoted cost of decommissioning the Frigg Field facilities could increase by 60%.

9.2 Long Term Durability of Concrete Substructures

In view of the recommendation that the three Frigg Field concrete substructures should be left in place for natural decay, an assessment of their likely long-term durability has been made.

In the next 100 years, very little physical damage to the three Frigg Field concrete sub structures is predicted. After that time corrosion of the horizontal reinforcement in the splash zone is likely to give rise, initially to spalling of the concrete, and later to local damage, which may be expected in roughly 100 to 150 years. The overall integrity of the structures will however not be affected.

The columns of TCP2 and TP1, and the walls of CDP1, are predicted to remain in place for 500 to 800 years before collapsing. For TCP2 and TP1, local damage in the splash zone will reduce the protection to the vertical pre-stressing steel in the columns, which will eventually become corroded. In this event, the top section of the column may eventually be unable to sustain extreme wave loads and become more severly damaged. For CDP1 local damage to the structure will become more extensive over time. The above water deterioration of all three structures will however take place relatively slowly and the navigation aids may be expected to remain in place for several hundred years.

9.3 Schedule

The proposed schedule for undertaking the recommended disposal arrangements for the Frigg Field facilities is shown in Figure E.3 below.

The schedule assumes that there will be continuous offshore activity up until the end of the first quarter of 2007. After that, offshore works are assumed to take place mainly during the summer seasons. The amount of offshore work planned for any one year has been estimated on the basis of what can be reasonably undertaken during a summer season. Onshore disposal activities are assumed to be carried out continuously from 2007 onwards. The recommended programme of disposal activities will be completed by 31.12.2012 providing production from the field ceases in 2004.

The removal of the infield pipelines and cables has been scheduled during the last summer season when access to the area will allow the work to be conducted in a more efficient manner.

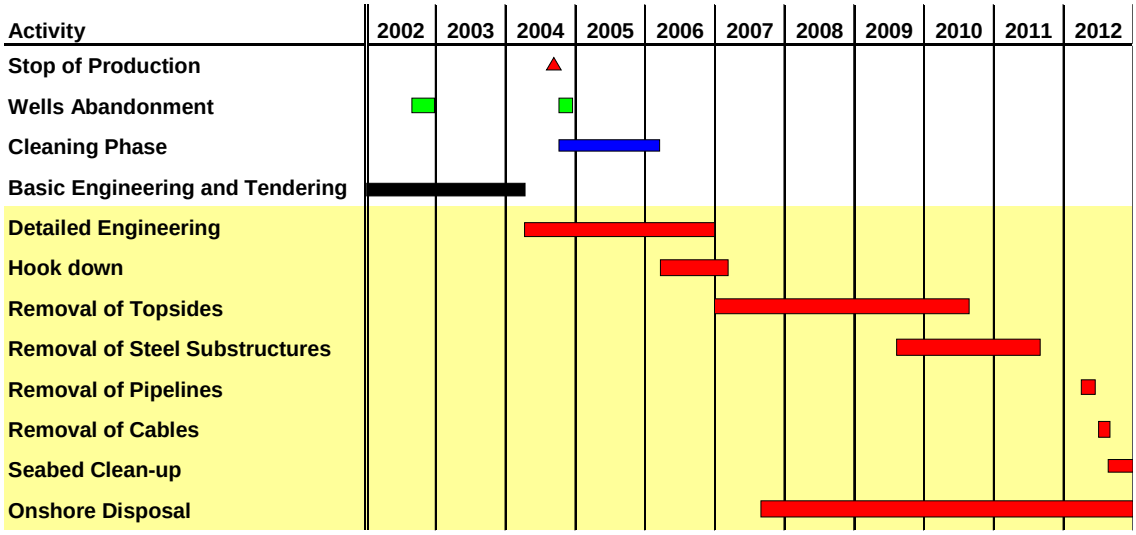


Figure E.3 Proposed Schedule of Decommissioning Activities

As a considerable time will have elapsed before the offshore disposal activities commence, it is possible that the proposed schedule may be modified in the light of changed circumstances.

If, as a result of better than expected reservoir performance, it becomes viable to produce gas from Frigg significantly beyond 2004, then the disposal schedule will be adjusted accordingly. Due to the level of activity in the North Sea it may also be advantageous to coordinate offshore activities with the planned work of other operators in the same time span.

The introduction of new technology may also have an affect on the schedule. It could be beneficial to postpone the disposal works if promising new removal concepts, offering cheaper, safer and more environmentally friendly disposal solutions, are in prospect.

In contracting for the removal and disposal activities, a degree of flexibility will be introduced in respect to the execution of the work. Past experience indicates that this is also cost efficient for the contractors performing the decommissioning work. Planning flexibility is also advantageous in relation to the onshore disposal work as it may encourage reuse alternatives.

9.4 Project Management

As operator of the Frigg Field, TOTAL NORGE will ensure that the commitment to safe and effective operation, that has been a mark of the development and production phases will continue throughout the cessation phase.

Controlling documents are in place in TOTAL NORGE defining the quality management principles, responsibilities and resources in the Company and setting out policies in respect to Health (including Working Environment), Safety, the Environment and Security**.** The methods by which these policies are implemented are defined in the management system documents.

It has been determined that a common approach will be adopted by TOTAL NORGE in respect to the cessation activities for the Frigg Field. Consequently, whenever possible, common documents will be prepared and submitted jointly to the relevant Norwegian and UK authorities.

Hazard identifications, risk analyses and risk reducing measure evaluations (including emergency preparedness), will form an integral part of the safety documentation submitted to the relevant national authorities prior to the execution of the approved disposal programme. For Norwegian registered installations this information will be contained in the Application for Consent prepared to cover the particular activities and submitted to the Norwegian Petroleum Directorate. For UK registered installations this information will be an integral part of the Abandonment Safety Case submitted to the UK Health and Safety Executive. Although there will be specific requirements necessary to comply with the separate national regulations the approach and general format of the information will be the same.

As a verification of the TOTAL NORGE's environmental management system, and to commit the company to continuous improvement and transparency, TOTAL NORGE has been certified according to NS-ES ISO 14001 and registered according to EMAS. TOTAL NORGE is the first company in Norway to be registered as an organisation according to the revised EMAS regulations.

Det Norske Veritas (DNV) was used as certifying body and accredited unit for the EMAS registration process.

It will be a condition of contract that Contractors undertaking the decommissioning of the Frigg Field facilities will, as a minimum, operate a independently verified Environmental Management System meeting the requirements of a recognised standard such as EMAS or ISO 14001.

9.5 Pre and Post Decommissioning Surveys

Environmental surveys involving seabed sampling have been undertaken in both the Norwegian and UK sectors of the Frigg Field four times since 1986. The marine environment in the area is thus well known. It is planned to undertake two further environmental surveys of the whole area (both Norwegian and UK sectors) after production from Frigg Field ceases in 2004.

At the end of the decommissioning work programme, a further environmental survey, including seabed sampling, will be undertaken to document the environmental conditions at the end of the removal and disposal operations. This survey will include sampling in the area of the drill cuttings around DP2, as well as in the general Frigg Field area.

A survey of the condition of the concrete substructures and the adjacent seabed will also be undertaken at the end of the decommissioning programme. The results from the environmental and condition surveys will be submitted to the appropriate Norwegian and UK authorities.

The need for further monitoring activities will then be determined based upon the findings of the surveys and discussions with the relevant parties. There is a possibility that leaving the concrete substructures in place will have a beneficial effect on fish stocks in the area, although it is not possible to be certain at this time. A project to monitor the level of local fish stocks after completion of the decommissioning activities may be of interest and receive general support.

9.6 Maintenance

The navigation aids installed on the concrete substructures will be designed to ensure a high level of reliability. They will incorporate back-up systems and parts of the navigational aids system will be changed at regular intervals. The navigational aids themselves, and their maintenance programme, will satisfy the requirements of both national regulations and the International Maritime Organisation in respect to both surface and sub-surface vessels

Regular surveillance will be carried out to check that the navigation aids are operational. It is envisaged that the navigation aids will be designed in such a way as to allow them to be changed from a helicopter, thus obviating the need to man the platform for this purpose. The responsibility for the maintenance of the navigation aids remains with the Frigg Field Licensees, unless otherwise agreed with the authorities.

Measures will be taken to ensure that the positions of concrete substructures that are left in place are correctly identified and marked on relevant charts. To assist fishermen, it is planned to introduce the position of the concrete structures into the UK “FishSAFE” programme.

The 500m safety zones around the three concrete substructures will remain in place during the approved decommissioning work, after which consideration will be given to removing it.

9.7 On-going Liability

The Frigg Field concrete substructures, which it is proposed are left in-place remain the property and responsibility of the Frigg Field Licensees. However, both the Norwegian and UK authorities recognise that the question of long-term residual liability should be discussed and agreed with the present owners in order that suitable arrangements are made.

It is therefore the intention of the Frigg Field Licensees to enter into a dialogue with the authorities in order to determine suitable arrangements regarding future liabilities in respect to these concrete substructures. These matters should be resolved well in advance of the expiry date of the Frigg Field production licences for the areas where the concrete substructures are located. The Norwegian production licence 024 expires in May 2015 while the UK production licence P.118 expires in June 2016.

9.8 Public Consultation

TOTAL NORGE began planning for the decommissioning of the Frigg Field in 1998. It was considered important to ensure that stakeholders became involved at the earliest possible stage and thus the process of public consultation began in April 1999. Efforts have been made to ensure that an open and transparent dialogue takes place with all interested stakeholders throughout the process of defining the Frigg Field Cessation Plan.

A similar process of public consultation is being carried out in both Norway and the UK, in accordance with the established principle of treating the Frigg Field as a single unit. In addition to the statutory consultations required by both Governments, efforts have been made by TOTAL NORGE to identify, and involve, a much wider range of stakeholders who have an interest in the decommissioning of the Frigg Field.

A copy of the First Draft of the Frigg Field Cessation Plan was sent to both the Norwegian and UK authorities for their review. In accordance with national practises, UK governmental organisations were invited to consider the First Draft of Frigg Field Cessation Plan, whilst in Norway comments are only sought on the Environmental Impact assessment contained in the Second Draft. An overview of the First Draft comments is contained in Annex C.

Based upon the comments received, the Second Draft of the Frigg Field Cessation Plan was prepared and distributed for a formal public consultation to the identified stakeholders (from 29 November 2001 to 28 February 2003). Those stakeholders who had just expressed the wish to be kept informed about the decommissioning process were notified that a copy of the document could be sent to them if requested, or it could be downloaded from the TOTAL NORGE web site.

In accordance with national practice, in Norway the Ministry of Petroleum and Energy issued the Frigg Field Cessation Plan to the stakeholders. In the UK, TOTAL NORGE, as operator of the Frigg Field, issued the document to the stakeholders, although responses from governmental organisations were coordinated by the UK Department of Trade and Industry. Details of the stakeholders participating in the formal consultation process on the Second Draft of the Frigg Field Cessation Plan, and details of the response received, are given in Annex D. A summary of the main issues raised by the stakeholders is provided in Section 16.2.4.

Figure E 4 below shows in diagrammatic form how the consultation process has been carried out simultaneously in both Norway and UK

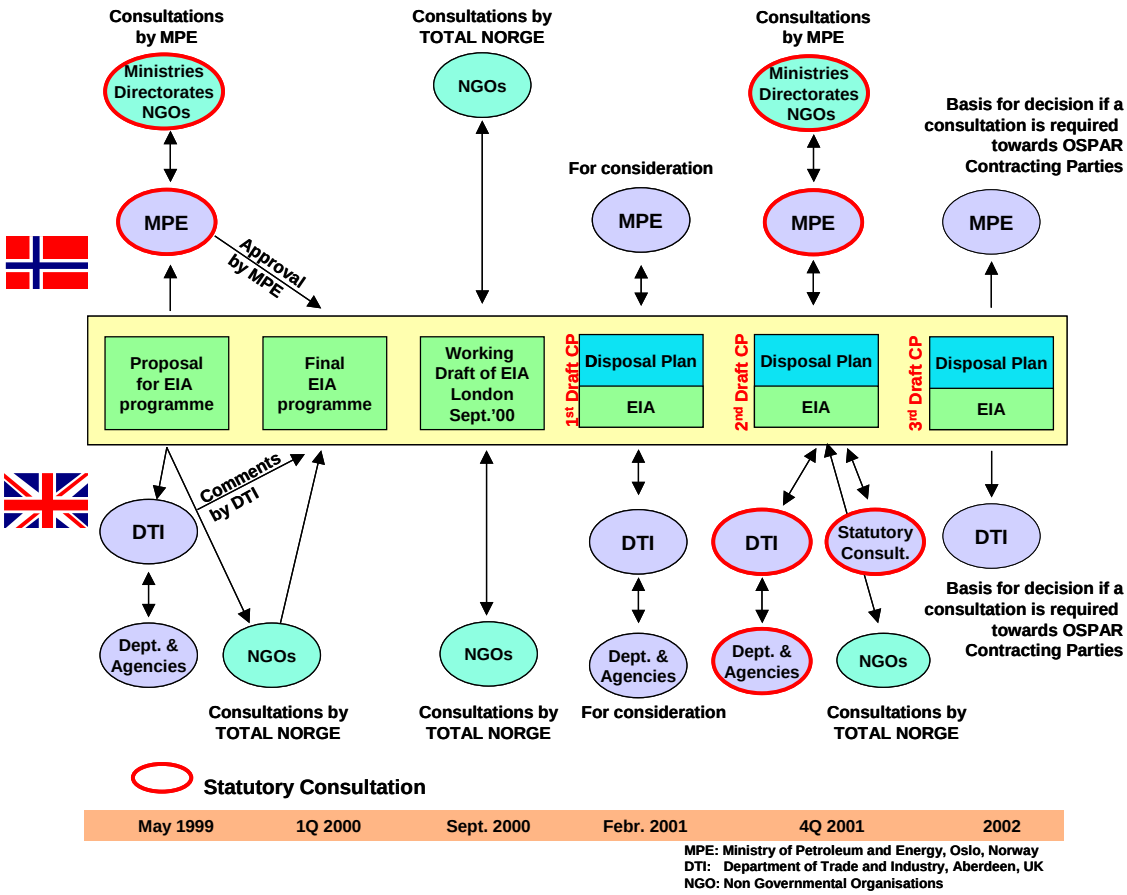


Figure E.4 Diagrammatic Representation of the Consultation Process

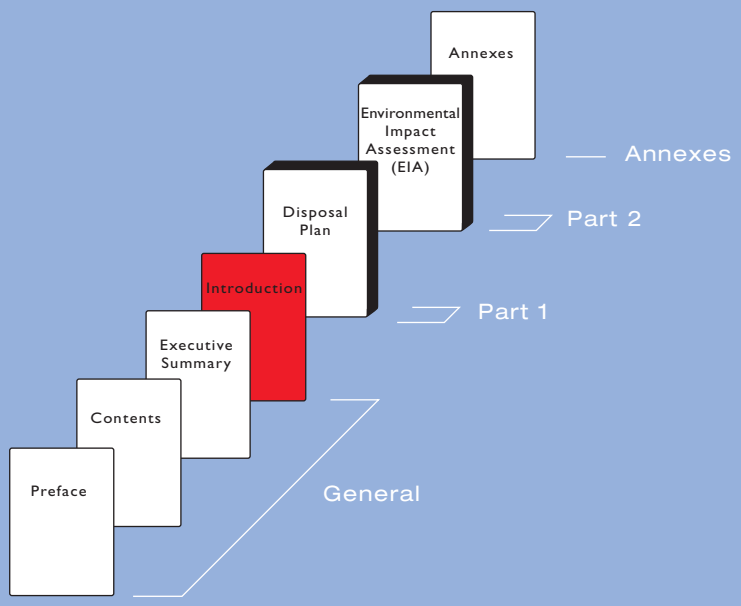
9.9 OSPAR Consultation

In view of the recommendation of the Frigg Field Licensees that the concrete substructures of TCP2, CDP1 and TP1 should be left in place, an assessment was prepared detailing the significant reasons why leaving the substructures in place is preferable to reuse or recycling or final disposal on land. This assessment was prepared strictly in accordance with the requirements set out in Annex 2 of OSPAR Decision 98/3.

The Norwegian Ministry of Petroleum and Energy and the UK Department of Trade and Industry notified the OSPAR Executive Secretary in mid September 2002 that they were each considering issuing a permit, under paragraph 3b of the OSPAR Decision 98/3, for the disposal of the Frigg Field concrete substructures under their jurisdiction, at their current locations in the Frigg Field. An assessment detailing the significant reasons why disposing of the concrete substructures at their current location was preferable to reuse or recycling or final disposal on land was attached to the letters from the Norwegian Ministry of Petroleum and Energy and the UK Department of Trade and Industry

The OSPAR Executive Secretary sent the assessment, together with the letters from the Norwegian Ministry of Petroleum and Energy and the UK Department of Trade and Industry, to all the OSPAR Contracting Parties on 20 September 2002.

By the end of the 16-week consultation period no objections had been received to either the Norwegian Ministry of Petroleum and Energy or the UK Department of Trade and Industry issuing a permit under paragraph 3b of OSPAR Decision 98/3 in respect to the Frigg Field concrete substructures. Comments were however received from Denmark, France, Germany and The Netherlands, and these are detailed in Section 16.3 and Annex E.



Frigg Field Cessation Plan

Introduction

The Frigg Field is a natural gas reservoir, with associated condensate, that extends across the median line between the Norwegian and UK sectors of the North Sea Continental Shelf. The treaty defining the median line, which was signed by the Norwegian and UK governments in 1965, also contained provisions for the development of hydrocarbon resources such as the Frigg Field.

Following the discovery of the Frigg Field in 1971, an agreement between the two governments was deemed necessary to regulate the exploitation of the Frigg Field reservoir and transmission of gas from the Frigg reservoir. Accordingly an agreement was prepared entitled ***"Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the Kingdom of Norway relating to the Exploitation of the Frigg Field Reservoir and the Transmission of Gas therefrom to the United Kingdom".*** This agreement, known as the Frigg Treaty, was dated 10th May 1976 and came into force later in that year.

The Norwegian section of the Frigg Field was developed under Production Licence PL. 024 which expires in 2015. The UK section was developed under Production Licence P.118 which expires in 2016.

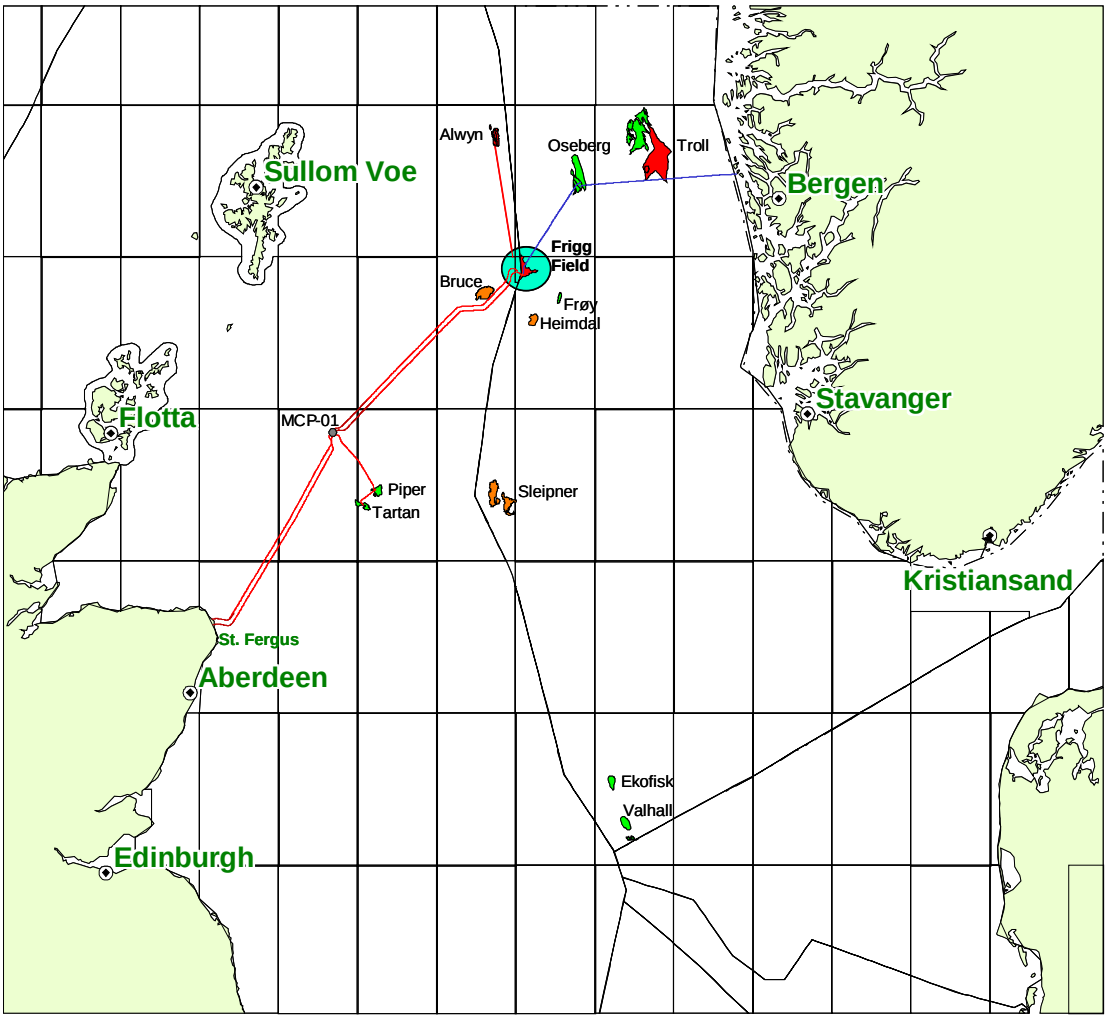


Figure I.1 Location of the Frigg Field and the Main Pipeline Connections

Under the provisions of the Frigg Treaty, Elf Norge in Stavanger was defined as the operator of the Frigg Field while Total Oil Marine in Aberdeen was defined as the operator of both the UK and Norwegian gas export pipelines from Frigg to St. Fergus Gas Terminal in Scotland.

The Frigg Field Licensees signed a Unitisation Agreement in July 1973 regulating development and operation of the field. It had been independently determined that 60.82% of the reserves were located in the Norwegian sector and 39.18% in the UK sector. Production from the Frigg Field started in September 1977 and is predicted to cease sometime in 2004, depending upon reservoir performance.

Following the merger of the TotalFina Group and the Elf Group in 2000 the TotalFinaElf Group was established, with the result that the Norwegian subsidiary operating the Frigg Field was named TotalFinaElf Exploration Norge AS. On 6 May 2003 the ultimate mother company of the Group TOTAL FINA ELF SA changed name to TOTAL SA. Hence the name of the Norwegian subsidiary was changed to TOTAL E&P NORGE AS.

Except where specifically noted in the text, the name “TOTAL NORGE” has been used in this document to mean both TOTAL E&P NORGE AS, or the predecessor companies in Norway that operated the Frigg Field. In accordance with common practice, the abbreviation UK has been used throughout this document to refer to the United Kingdom of Great Britain and Northern Ireland.

The current Frigg Field Licensees are:

	Unitised License (%)
TOTAL E&P NORGE AS (Operator)	28.664
Norsk Hydro Produksjon a.s	19.992
Statoil ASA	12.164
Elf Exploration UK PLC	26.120
TOTAL E&P UK PLC	13.060

*) Under the management of TOTAL E&P UK PLC

The heading “Unitised Licence” indicates the interest each Licensee has in the Frigg licences, which will also be the basis for the allocation of disposal costs.

The Frigg Treaty does not contain any specific provisions regarding the disposal of the platforms, seabed pipelines, cables or drill cuttings. The disposal of these facilities is therefore governed by the national legislation applicable to the location of each installation, pipeline or cable.

However, in the spirit of the Frigg Treaty it has been agreed that the Cessation Plan for the Frigg Field should encompass the complete field while respecting each nation’s legislative requirements. This is in line with the approach adopted for both the development of the field and its operation since start of production. In addition, the decommissioning arrangements proposed have to comply with the requirements of the OSPAR Convention and the International Maritime Organisation guidelines.

The Frigg Field facilities now consist of five fixed installations together with infield, inter-field and export pipeline systems. In addition, the DP1 steel substructure, which was damaged during installation in October 1974, is still in place in the field. The main section of the Flare Platform (FP), originally located in the field, has been removed under the provisions of the previously approved Flare Platform Abandonment Programme (Ref.I-1 and I-2). The base for the Flare Platform was removed in the summer of 2001 under the provisions of this previous abandonment programme. The disposal of the Flare Platform does not therefore form part of this Frigg Field Cessation Plan.

Three of the Frigg Field installations are located in UK Block 10/1 and two of the installations (together with the DP1 wreck) are in Norwegian Block 25/1. The platforms were installed in the period 1974 to 1977.

The UK registered installations are:

- Treatment Platform 1 (TP1) registered as 10/1 - FRIGG - TP1
- Quarters Platform (QP) registered as 10/1 - FRIGG - QP
- Concrete Drilling Platform 1 (CDP1) registered as 10/1 - FRIGG - CDP1
-

The Norwegian registered installations are: -

- Treatment and Compression Platform 2 (TCP2) registered as 25/1 - FRIGG - TCP2
- Drilling Platform 2 (DP2) registered as 25/1 - FRIGG - DP2
- Drilling Platform 1 (DP1) registered as 25/1 - FRIGG - DP1

Three of the platforms, TP1, QP and TCP2, are permanently bridge linked and form what is known as the Frigg Central Complex. The facilities on the Frigg Central Complex have been used to process and export hydrocarbons from the North East Frigg, East Frigg, Lille Frigg, Odin and Frøy satellite fields, as well as the main Frigg reservoir. In addition gas from the North Alwyn field has been routed via Frigg Central Complex into the export pipeline to St Fergus in Scotland.

Figure I.2 Frigg Field Installations (1999), indicating the border between Norwegian and UK Sectors of the North Sea

Production from all the satellite fields tied into Frigg Central Complex, and from Odin, has now ceased. Production from the main Frigg Field reservoir is most likely to cease during 2004. Also in 2004 it is planned to make a subsea connection between the Alwyn pipeline and the Frigg UK Pipeline (PL 7) thus allowing the continued export of Alwyn gas without it being routed via TP1.

Following consultation with the Norwegian Ministry of Petroleum and Energy (MPE) and the UK Department of Trade and Industry (DTI), the decision was taken to adopt a common approach to the disposal of the Norwegian and UK registered Frigg Field facilities.

In Norway the provisions relating to the cessation of petroleum activities are contained in the ***"Act of 29 November 1996 No. 72 relating to petroleum activities"*** *and the* ***"Regulations to Act relating to Petroleum activities laid down by Royal Decree 27 June 1997"*** made under the above Act.

The Norwegian Regulations of 27 June 1997 require that the licensees prepare a Cessation Plan (Avslutningsplan) which shall be submitted to the Ministry of Petroleum and Energy and the Ministry Local Government and Labour, with a copy to the Norwegian Petroleum Directorate. The Cessation Plan shall consist of two parts, one part dealing with the disposal of the facilities, and the other part dealing with the impact on the environment and society of such disposal activities. These two parts of the Cessation Plan are referred to in the regulations as the Disposal Plan (Disponeringsdel) and the Environmental Impact Assessment (Konsekvensutredning).

In the UK, the main provisions relating to the production of hydrocarbons are contained in the **Petroleum Act 1998**, Part IV of which deals with the decommissioning of offshore installations and pipelines.

Under the provisions of Section 29 of the UK Petroleum Act 1998 the Secretary of State may, by written notice, require the submission of a costed decommissioning programme detailing the measures proposed to be taken in connection with the decommissioning of an offshore installation or subsea pipeline.

Although there are some differences in the terminology and the detailed arrangements between the two national legislative frameworks, the general procedure and requirements are broadly similar. It has therefore been agreed that a common document, designated the **Frigg Field Cessation Plan,** may be used by TOTAL NORGE, on behalf of the licensees, to detail the arrangements proposed for decommissioning the Frigg Field facilities.

The Frigg Field Cessation Plan is organised in two parts :-

Part 1	Frigg Field Disposal Plan
Part 2	Frigg Field Environmental Impact Assessment Report

Therefore, in accordance with the Norwegian Act of 29 November 1996 No. 72 relating to petroleum activities, this document is submitted, by TOTAL E&P NORGE AS, on behalf of the Frigg Field Licensees, to the Norwegian Ministry of Petroleum and Energy and the Norwegian Ministry of Local Government and Labour as the Cessation Plan (Avslutningsplan) in respect to the following installations and associated infield subsea pipelines and cables:-

- **25/1 - Frigg - TCP2**
- **25/1 - Frigg - DP2**
- **25/1 - Frigg - DP1 Wreck**

Additionally, in accordance with the requirements of Part IV, section 29 of the United Kingdom Petroleum Act 1998, this document is submitted by TOTAL E&P NORGE AS, on behalf of the Frigg Field Licensees, to the United Kingdom Department of Trade and Industry as the Cessation Plan (Decommissioning Programme) in respect to the following installations and associated infield subsea pipelines and cables:-

- **10/1 - FRIGG - TP1**
- **10/1 - FRIGG - QP**
- **10/1 - FRIGG - CDP1**

Although not required for compliance with the provisions of the UK Petroleum Act 1998, details of the planned decommissioning of the subsea cables associated with these platforms are also included within this Decommissioning Programme.

This document, referred to hereafter as the Frigg Field Cessation Plan, is issued in both English and Norwegian.

In accordance with the requirements of Norwegian legislation, this Frigg Field Cessation Plan is being submitted two years before production from the Frigg reservoir is anticipated to cease. In line with the common approach to decommissioning adopted for the Frigg Field facilities, this cessation plan is submitted at this time to both Norwegian and UK authorities.

Further documentation relating to the implementation of the works outlined in this Cessation Plan will be submitted to the relevant authorities in accordance with the national legislation of Norway and the UK. This will include the appropriate Applications for Consent for the Norwegian registered installations and an Abandonment Safety Case for the United Kingdom registered installations. Other specific applications will be prepared and submitted as required.

The export pipelines from Frigg to St Fergus in Scotland (known as the Frigg Transportation System) will remain in operation, and approval for their disposal is not sought within this document. In addition, pipelines between Frigg Field and other fields are not included within the provisions of the Frigg Field Production Licences and thus are not included within the scope of this Frigg Field Cessation Plan. Separate disposal plans have been, or will be, prepared for these pipelines at the appropriate time.

Section References

I-1 “Frigg Field FP – Column Removal – Abandonment Program”, TFEE Norge Document, Ref 311E-MS/95/1533/SOV, Report No. 1533, Rev. 05G, dated 28.02.96.

I-2 “Revision to Frigg Field FP – Column Removal – Abandonment Program”, TFEE Norge Document, Ref DocsOpen No. 105727, dated November 2000.

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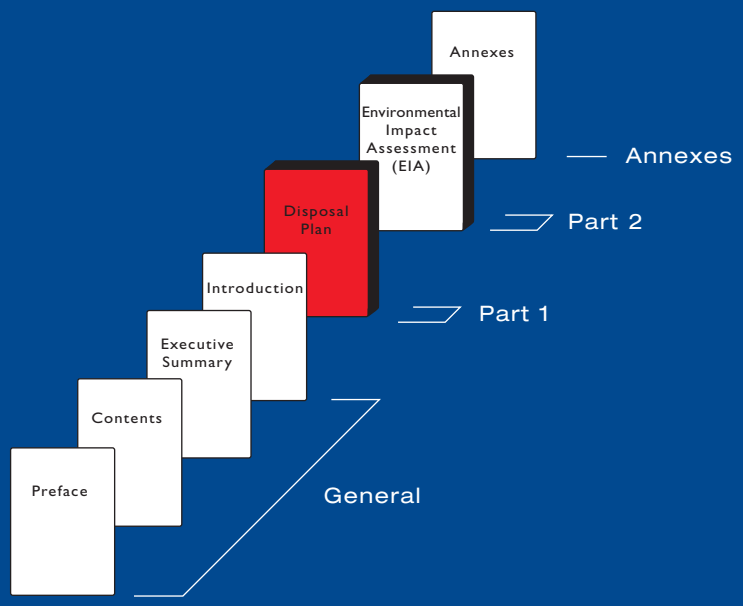

Frigg Field Cessation Plan

Disposal Plan Contents

1. Introduction to the Disposal Plan

The Frigg Field Cessation Plan has been arranged in two parts in order to comply, to the greatest extent possible, with both Norwegian and UK legislation, whilst still allowing a common document to be used for the whole Frigg Field.

The sections in the Frigg Field Disposal Plan, which forms Part 1 of the Frigg Field Cessation Plan, have been grouped in the following order :-

Sections 2 – 5 Background Information
This includes a description of the production history of Frigg Field, details of the facilities to be decommissioned and an inventory of materials.

Sections 6 – 13 Assessments and Recommendations
This includes assessment of possible disposal alternatives for the Frigg Field facilities and recommendations regarding the disposal arrangements for the platforms, the subsea pipelines and cables and the drill cuttings. A summary of the recommended proposals for the Frigg Field as a whole is included in Section 13 together with estimated costs. The overall impact of the decommissioning works in terms of risk to personnel is also presented together with details of the overall environmental impact of the proposed arrangements. A “field-wide” comparison of the recommended decommissioning arrangements with the other arrangements that were considered, but rejected, is also included in Section 13.

Sections 14 – 19 Details of Proposed Decommissioning Arrangements
These sections include information about the implementation of the proposed disposal activities including a description of the planned activities for the Norwegian and UK sections of the Frigg Field, the schedule, and the arrangements for managing the work in a safe and effective manner. A description of the ongoing public consultation activities being undertaken by TOTAL NORGE is also included. Details of the various surveys that will be undertaken before and after the decommissioning work are described and the question of long term liability addressed.

Section 20 Supporting Studies
This section provide details of all the supporting studies, investigations, tests and assessments that have been made in recent years to assist in determining the recommended disposal arrangements for the Frigg Field facilities. This list of supporting studies is provided to give an **overview** of the investigations that have been undertaken. **Specific documents,** which are particularly relevant to the text, are listed under the headings “Section References” at the end of each main section.

Environmental Impact Assessment
The Environmental Impact Assessment for the Frigg Field has been undertaken by Det Norske Veritas (DNV), and the findings are reported in their document entitled " **Frigg Field Cessation - Environmental Impact Assessment**", DNV Report No. 99-4030. Peer review of this report has been undertaken by the Netherlands Energy Research Foundation.

Part 2 of this Frigg Field Cessation Plan, consists of the DNV report with minor editorial changes made to prevent undue repetition with the Frigg Field Disposal Plan, in Part 1. In addition the presentation style of the DNV report has been changed to ensure consistency throughout the Frigg Field Cessation Plan. Where aspects relating to environmental impact are considered in the Disposal Plan, a summary of the appropriate information is included in the Disposal Plan text, and a reference is provided to the detailed information in Part 2.

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2. Background Information

2.1 Discovery and Development

The Frigg Field was discovered in June 1971 by the drill rig Neptune P 81 drilling on Norwegian Block 25/1 for the Petronord Group (Elf, Total and Norsk Hydro). Shortly afterwards, in April 1972, gas was also encountered by the Total Oil Marine Group drilling in UK Block 10/1. In the spring of 1972 it became clear that Frigg was an extremely large gas reservoir straddling the dividing line between the Norwegian and UK sectors of the North Sea. The field was declared commercial on 28 April 1972.

In the summer of 1973 a contract was signed for the sale of gas from the UK section of the Frigg reservoir to British Gas Corporation. A contract for the sale of the Norwegian gas from Frigg, also to British Gas Corporation, was signed in July 1974. Both contracts involved the exclusive sale of gas from the Frigg reservoir to British Gas Corporation until 1 October 2000.

The development and operation of the Frigg Field was divided between Elf Norge, which was responsible for the field facilities, and Total Oil Marine, which was responsible for transportation of the gas and its treatment at St. Fergus Gas Terminal in Scotland.

Development of the Frigg Field took place between 1973 and 1977 based upon a two-phase programme in which the UK facilities were developed first, followed closely by the Norwegian facilities. The development plan included one drilling platform and one treatment platform in both the Norwegian and UK sections of the field, together with a living quarters platform and a flare tower, both located in the UK sector. The loss of the first platform, DP1, during installation, was a major setback for the project. The problem was however overcome by converting the concrete platform originally intended as the intermediate platform on the pipelines from Frigg to St Fergus Gas Terminal, for use as the UK drilling platform.

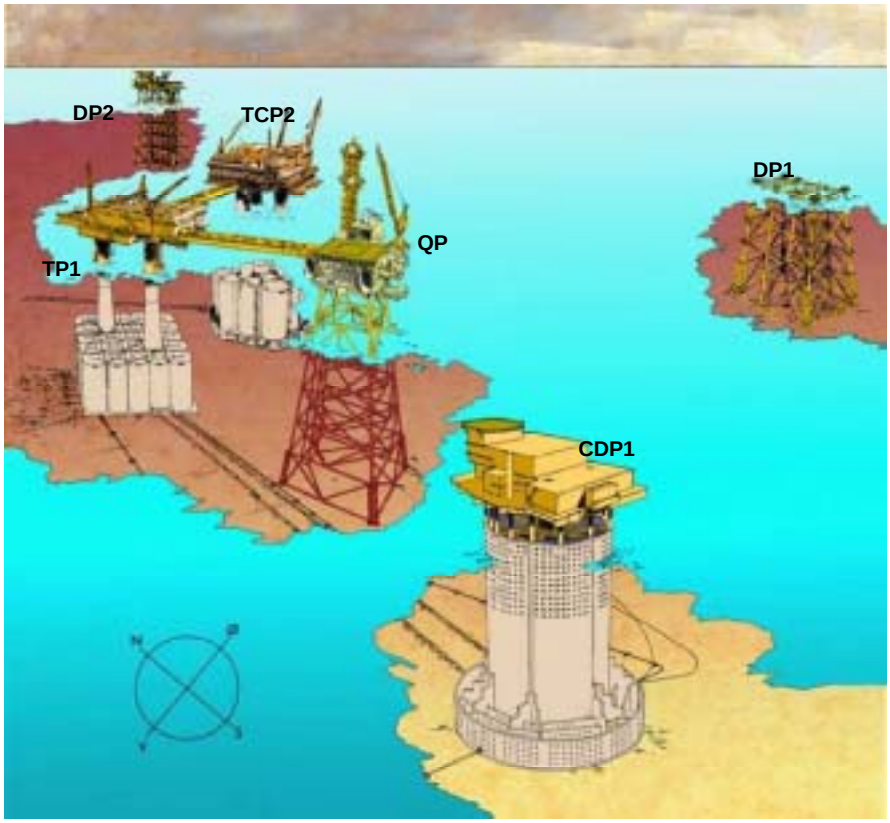

Figure 2.1 Frigg Field Facilities

The living quarters platform (QP) was installed in July 1975 followed by the converted concrete drilling platform (CDP1) in September of the same year. The drilling platform in the Norwegian sector (DP2) was then installed followed by the UK concrete treatment platform (TP1). Finally the treatment platform for the Norwegian sector (TCP2) was installed in June 1977.

The pipelines were laid over three summer seasons from 1974 to 1976.

First commercial gas flowed from the Frigg Field through the export pipeline to St Fergus on 13th September 1977.

Gas compression equipment was later installed on the concrete treatment platform in the Norwegian sector (TCP2) in order to allow a greater volume of gas to be exported through the two 32" diameter Frigg export pipelines. Additional processing equipment was also installed on the platform to receive and process gas and oil from various Frigg satellite fields, as described in the following section.

2.2 Satellites Fields and Tie-ins

A number of satellite reservoirs were discovered in the Norwegian Sector around Frigg at different times between 1973 and 1987. These were subsequently developed using either subsea-completed wells or, as in the case of the Frøy reservoir, by using a not-normally-manned wellhead platform. Oil and/or gas from the Frigg Field satellite fields, and from the Esso operated Odin platform (which was also connected to Frigg but has now been removed) were processed and metered on the Frigg Central Complex before the gas was exported to the UK via the Frigg Norwegian Pipeline and the oil to Norway via Frostpipe.

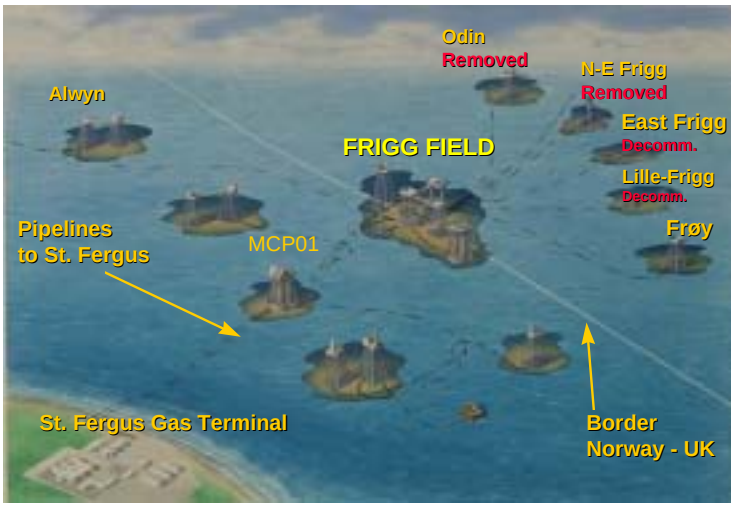

Figure 2.2 Frigg Field, Satellite Fields and Tie-ins

The North East Frigg gas reservoir was developed during the early 1980s using subsea-completed wells and a buoyant control tower anchored to the seabed. The field, which was the first subsea gas development in the North Sea, incorporated 6 wells and started production in 1983. North East Frigg ceased production in 1993 and was the first installation in the Norwegian sector of the North Sea to be decommissioned and removed in 1996/97.

The Odin gas field, which was developed by Esso Norge AS in Norwegian Block 30/10, was tied in to Frigg Central Complex at the same time as the North East Frigg development. Equipment to receive and process the gas from both North East Frigg and Odin was installed

on platform TCP2. Production from Odin ceased in 1994 and the platform has now been removed.

Production from the East Frigg reservoir started in 1988. The field, which was developed using five subsea-completed wells in two separate clusters, was the first diverless subsea development in the North Sea. Gas from the wells was gathered together in a collecting manifold and then exported to Frigg Central Complex through a 12” diameter subsea pipeline. Production from East Frigg was shut down in 1997 and the subsea production facilities were removed during the summer of 2001, for onshore disposal.

The Lille-Frigg reservoir was discovered in 1975. Development of the field, using three subsea-completed wells, was started in 1991 and the field came on-stream in 1994. It was the first high pressure - high temperature reservoir to be developed in North Sea. The design, construction and installation of the subsea production facilities and the treatment facilities on Frigg Central Complex was particularly challenging due to the high reservoir pressure and temperature. Production from the Lille Frigg subsea wells was shut down in 1999 and the subsea production facilities were removed during the summer of 2001 for onshore disposal.

The Frøy oil reservoir was discovered in 1987 and development started in 1992. The field was developed using a single not-normally-manned wellhead platform with ten wells. The platform is remotely controlled from the Frigg Central Complex. Production started from Frøy in the summer of 1995 and was stopped in March 2001.

In 1985, the Alwyn Field, located in UK Block 3/9 and at that time operated by Total Oil Marine, was connected to Frigg by a 24” diameter pipeline. After flow and pressure control on TP1, the gas from Alwyn was exported to St Fergus in Scotland via the Frigg UK Pipeline (PL7). Production from the Alwyn area is anticipated to continue for 15 or more years.

2.3 Operations

During the operational life of the Frigg Field the production availability has been close to 100%.

Many additions and alterations have been made to the production facilities to allow processing of the gas and oil from the satellite fields. Throughout this time strenuous efforts have been made to identify hazards and take steps to reduce or eliminate the risk to personnel. As a result of these efforts a high level of safety has been maintained throughout the operational life of the Frigg Field.

2.4 Prevailing Meteorological and Oceanographic Conditions

Details of the meteorology and oceanography of the Frigg Field area are detailed in Section 6 of the Environmental Impact Assessment forming Part 2 of this Frigg Field Cessation Plan. A summary of the conditions is provided below.

The climate in the area is mild and humid, with average winter temperatures in the order of 4-5° C and an average summer temperature in the order of 13 - 14° C. The prevailing wind directions are in the sector from south-southeast to north. This pattern is pronounced in the winter but is also in evidence in the summer.

Wind speeds during the summer months of June to August are on average 6.2m/s, while during the winter months of December to February the average wind speed is 9.9m/s. Wind speeds between 8.0m/s and 10.7m/s are characterised as a “fresh breeze”.

The most probable wave height when the wind is categorised as “fresh breeze” is 2.0m, whilst the most probable maximum wave height is 2.5m. During the summer season significant wave heights of more than 4m, occur for less than 5% of the time. (Significant wave height is a term used to define the sea state and is calculated as the average height of the largest waves.) During October the probability of significant wave heights above 4m is less than 25%. It may be noted that restrictions on lifting operations from a semi-submersible crane vessel normally come into force when the significant wave height reaches 4m.

The significant wave height during a **winter** storm that might occur once in 10 years is 12.1m and the maximum wave height is 24m. For an extreme storm that may occur once in 100 years, the significant wave height is 13.8m and the maximum wave height 29m.

During the **summer** period (June to August) the significant wave height for a 10 year storm is 8.1m and the maximum wave height is 16m. For a 100year summer storm the significant wave height is 9.5m and the maximum wave height is 19m.

The currents in the area vary considerably dependent upon the direction and speed of the prevailing winds.

Surface water temperatures vary between 6°C and 7.5^{o}C in winter increasing to between 11°C and 12°C in summer.

The water depth in the Frigg area is approximately 100 metres. The bottom sediments consist mainly of olive-grey coloured fine sand with small amounts of pelite (silt and clay), and medium sand. The content of organic matter in these sediments varies between 0.63% and 0.90%.

Based upon seabed monitoring activities in the area undertaken over a considerable time period, it is concluded that the environment in the Frigg area as a whole can be classified as relatively undisturbed. (See Section 6.2.1 of the Environmental Impact Assessment forming Part 2 of this Frigg Field Cessation Plan)

3. Frigg Field Reservoir

3.1 Introduction

The Frigg Field is a large hydrocarbon accumulation that was discovered in 1971. The field had an areal coverage of slightly above 100 km^2 at the initial gas-oil contact. The maximum gas column thickness was 160m, overlaying an oil ring with an average thickness of 8.6m. The reservoir initial gas-oil contact was at a level 1948m below mean sea level. Middle Eocene age marine shales create the seal. The gas is probably sourced from the late maturation of local middle and lower Jurassic shales.

Since the Frigg Field straddles the borderline between the Norwegian and UK sectors of the North Sea, an international expert was engaged to evaluate the volume of gas in place, and the split of the accumulation between the two countries. In 1976 the expert concluded that the original gas accumulation in the Frigg reservoir was 265 GSm^3, of which 60.82% was located on the Norwegian continental shelf and 39.18% on the UK continental shelf. The current estimate of the original gas in place is 247 GSm^3.

Commercial deliveries of gas from the Frigg Field started on 13th September 1977. During the years of plateau production, the annual gas production was 16.5 GSm^3 with an average peak daily flow of more than 60 MSm^3/d. The present daily production of gas from the Frigg Field varies around 3 - 4 MSm^3/d, illustrating that the depletion of the reservoir is now reaching the end.

3.2 Field Development

After drilling the discovery well 25/1-1 in 1971, eight appraisal wells were drilled and additional seismic data was acquired in the following years.

The development wells for the field were drilled from 1976 to 1979. In total 48 wells were used to deplete the Frigg reservoir. Twenty-four wells were drilled from both CDP1 platform and DP2 platform. Due to the very good flow properties of the reservoir rock/gas system, all production wells were located within an area of 5 km^2. Forty-seven of the wells drilled were used as active production wells, while one well (25/1-A22), was used as an observation well to monitor pressure and water contact evolution. This observation well was later used for injection of oily water.

The redevelopment of the Frigg Field in 1989/90 involved abandoning all the wells on CDP1, and drilling two deviated wells from DP2 (25/1-A17A and A4A). Well 25/1 A17A was drilled to drain a structurally high area to the north of the well cluster where simulations had demonstrated that there was a high potential for bad sweeping. Well 25/1 A4A was deviated to the south, to allow production of the remaining gas at the top of the geological structure below CDP1, after the wells on the platform were abandoned.

The production history of the Frigg Field is shown in the Figure 3.1. The swing in production during the plateau production period is due to seasonal gas demand from consumers in the UK.

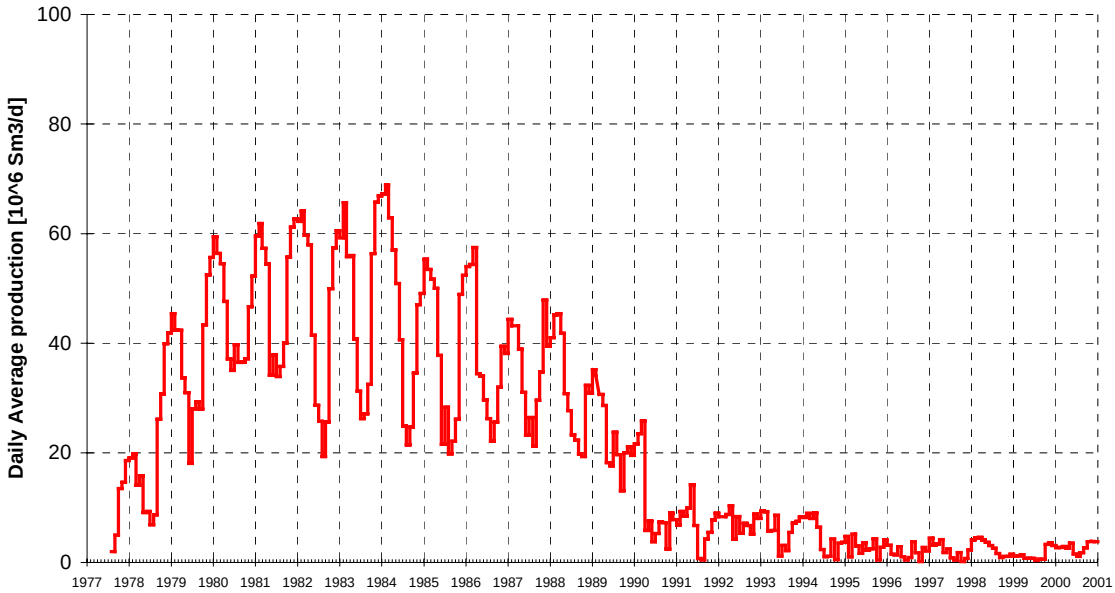

Figure 3.1 Frigg Field Production History

3.3 Optimisation of Production

The Frigg wells are able to produce gas at reasonable rates until only a few meters of screen is left above the water level. This good performance is due to a very small pressure drop from the formation into the well during gas flow; a situation achieved by the careful and successful well completion programme. As the field entered further into its decline phase, with CDP1 permanently abandoned and more wells on DP2 severely affected by water, it was decided to set bridge plugs inside some completion intervals. Plugs were set in three wells in 1993, one well in 1999, two wells in 2000 and one well in 2001 Shaly intervals are more frequent in the wells on DP2 than those in the CDP1 area and thus the plugs were set in shaly layers, where the swelling of the shale would assist in plugging back the liquid. This work has given a significant increase in the water-free gas production potential in all cases.

In September 1995 DP2 was transferred to "not-normally-manned" operation with the platform being controlled from QP platform. Thirteen wells remained operational on DP2, including 3 wells that had been previously plugged and were reopened.

A significant rise in the liquid level in the reservoir under DP2 occurred in 1993-94 during a high production period above the water-free-limit. The field production rate was then reduced significantly and since then liquid levels have been stable. The reduced production rate allows the distal areas of the field to be better drained, and thereby results in a high sweep efficiency.

3.4 Overall Recovery Performance

Data acquisition and interpretation activity on the Frigg Field has been going on continuously for over 30 years since the first seismic surveys were carried out in 1965. Some uncertainty regarding the recoverable reserves will however remain until the field ceases to produce. Nonetheless, the continuously improving knowledge gained has been crucial for the reservoir management of the field; especially in respect to the optimisation of the remaining production.

It appears likely that a recovery of 76.5 - 77% of the initial gas in place will be achieved for the Frigg reservoir (see reference at the end of this section). This is considered to be optimal in the case of strong aquifer drive. The following points are important in this respect:-

- The period of high rate production before 1990, allowed some depletion of the field despite the very strong aquifer. This is a classical reservoir engineering method of achieving a higher field recovery in practice than is possible by water flooding a piece of rock at constant pressure in a laboratory. In the case of Frigg, the actual recovery of 76% is considerably higher than the 70%, or so, measured on cores of rock from the Frigg reservoir.

- Careful production below the field critical rate during the tail-off after 1990, stabilised the macro cone that was growing under CDP-1 in the southwest part of the reservoir. A satisfactory recovery of the remote northern reserves was consequently achieved. In the last 10-year period during the tail-off of production, 17 GSm^3 have been produced increasing the recovery from 70% to 76% so far. This production tail was only economically possible due to the implementation of a drastic operating cost reduction program at the appropriate time, together with an optimum reservoir management and production strategy.

Present estimates from the reservoir simulation model indicate recoverable reserves ranging from 189.2 GSm^3 to 192.0 GSm^3. This gives a termination date for the field of 2002 to 2005 depending on field behaviour and economics. The most likely shut-in date is predicted to be some time in 2004 with total recoverable reserves of 190.1 GSm^3 of gas.

By the end of April 2002 the field had delivered 188.7 GSm^3 of gas after 24½ years of production. This represents 99% of the estimated recoverable reserves. The cumulative condensate production was approximately 750,000 tonnes. The remaining probable recoverable gas reserves in April 2002 were in the order of 1.4 GSm^3.

3.5 Future Production Strategy

A major milestone was reached on 1st October 2000 when the gas sales contract between the Frigg Field Licensees and British Gas plc was terminated. Frigg had then successfully delivered gas, with more or less 100% availability, for 23 years. The remaining recoverable gas in the Frigg Field is being sold on the UK market. The gas sales quantities will only be committed for a period of six months due to the uncertainties in the predictions during the tail-end production. This strategy for the nomination of gas quantities allows for adjustment of volumes in accordance with the semi-annual well logging campaigns.

Recovery of the remaining reserves is known to decrease if the production rate is above a critical rate. Field experience shows that when producing the field too hard, the cluster coning water table rises and severely affects the maximum field potential. This process is reversible to a certain extent due to the very good flow characteristics of the reservoir, but the process takes time if the field is produced at too high a rate over a longer period. A programme to ensure optimum production and recovery is therefore followed which involves monitoring closely the movement of the liquid level in the reservoir and testing wells at regular intervals.

Section References
A more comprehensive description of the reservoir is given in the following document:
"Frigg Field Status Report, Simulation Model Update 2001", TotalFinaElf Exploration Norge, dated 30.10.2001

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4. Facilities to be Decommissioned

This section provides a description of the Frigg Field facilities that are to be decommissioned after gas production ceases sometime during 2004.

The inter-field pipelines, the two gas export pipelines to St. Fergus, the liquids export pipeline to Oseberg (Frostpipe) and the gas import pipeline from Alwyn North are not described in this section as the decommissioning of these pipelines does not form part of this Frigg Field Cessation Plan. Separate documents will be, or have been, prepared in respect to the decommissioning of these pipelines.

The decommissioning of the Frigg Field Flare Platform was the subject of a previous submission and is therefore not part of this Frigg Field Cessation Plan.

4.1 Frigg Field Platforms

Figure 4.1 Frigg Field Installations (1999), indicating the border between Norwegian and UK Sectors of the North Sea

Sector	Platform	Current Status	Substructure
Norway	DP2	In operation as production platform.	8 leg steel substructure
	TCP2	In operation, oil and gas treatment, electricity generation.	Concrete substructure
	DP1	Unused damaged steel substructure.	8 leg steel substructure
UK	QP	In operation as living quarters and control centre for the Frigg Field.	4 leg steel substructure
	CDP1	Wells plugged and abandoned, platform partially decommissioned.	Concrete substructure
	TP1	In operation as riser platform connecting Alwyn pipeline to Frigg UK Pipeline (PL 7).	Concrete substructure

Table 4.1 Status of Frigg Field Installations

4.1.1 Norwegian Registered Installations

4.1.1.1 Drilling and Production Platform 2 - DP2

DP2 is a drilling and production platform supported by an 8-leg steel substructure. It was installed in 1976.

Twenty-four gas production wells were initially drilled from the platform. In 1989/90 two wells were re-drilled to optimise the remaining recoverable reserves in the reservoir. One well reached below CDP1 to drain remaining gas in that area after this platform was shut-in in 1989.

Gas is currently produced from 12 wells and an additional well is used to inject methanol-polluted water from the TCP2 treatment facilities.

All the equipment originally installed on the platform is still in place apart from the drilling derrick, which was removed in 1998.

The platform has been operated in not-normally-manned mode since 1995 being controlled from the central control room on Quarter Platform QP. The platform has a local control room and a small accommodation area with a few beds. The main living accommodation on the platform will be re-commissioned in 2002 in readiness for permanent re-manning of the platform during the plugging and abandonment operations for the DP2 wells.

DP2	Dry Weight (tonnes)	Overall Dimensions	Comments
Steel Substructure	Basic substructure 8,446 Piles 1,351 Grout 1,106 Conductors 3,204 Marine growth (estimate) 300	Height 106 m Plan size at elevation +8 m 48 x 25 m Plan size at elevation –100 m 62 x 44 m	
Topsides	Module Support Frame (MSF) 800 Modules 4,679 (The weight of the largest module is 944 tonnes)	Dimensions of topsides 61m x 35m (approx)	The topsides consist of the MSF, four main modules, six drilling packages, a helideck and two platform cranes.

Table 4.2 Key Platform Data for DP2

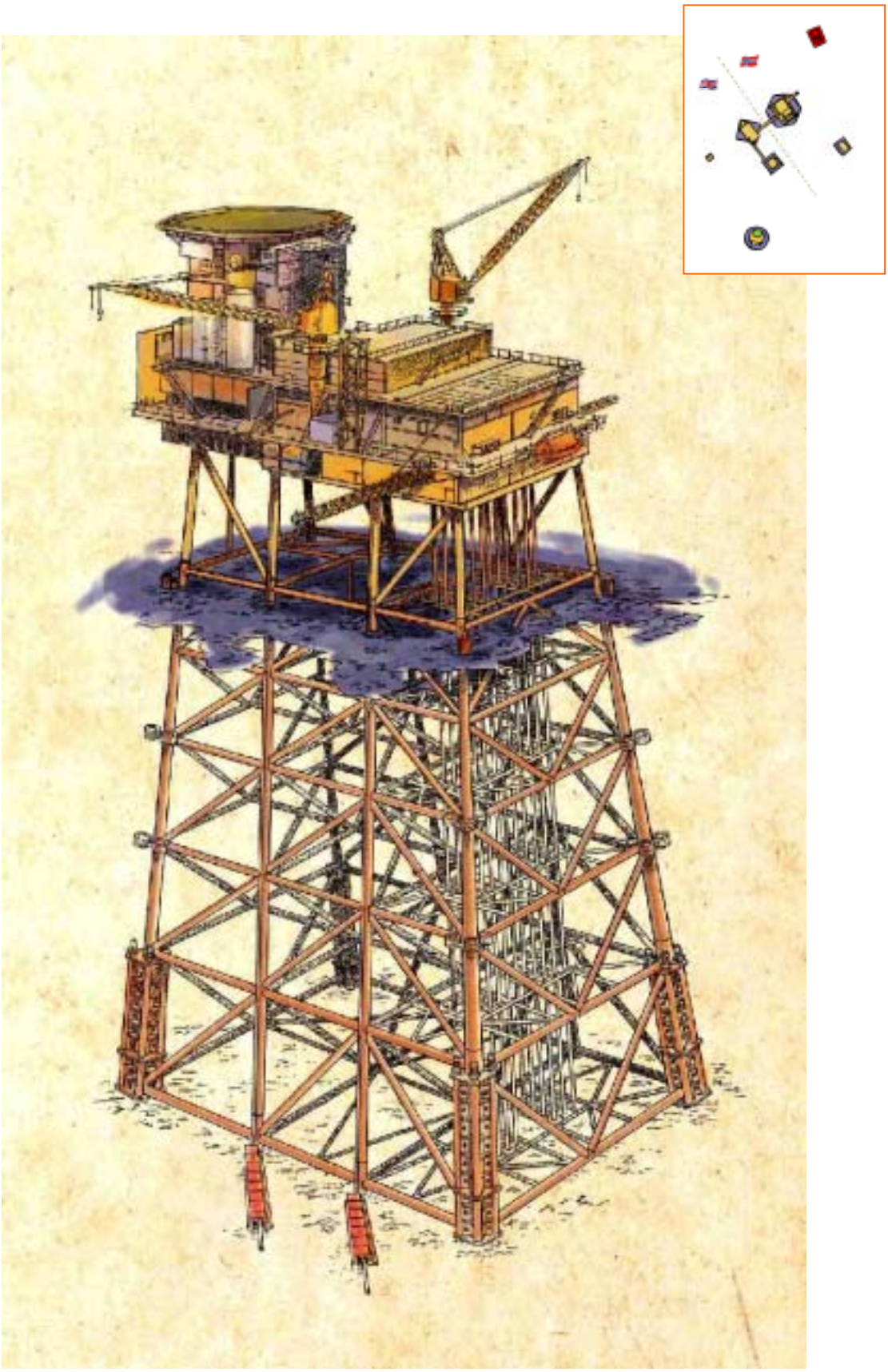

Figure 4.2 Drilling Platform 2 (DP2)

4.1.1.2 Treatment and Compression Platform 2 - TCP2

Gas from DP2 is processed on TCP2 before being exported to St Fergus via the 32" diameter Frigg Norwegian Pipeline.

The concrete substructure of TCP2 is a typical "Condeep" design with a base formed from 19 cylindrical cells. Three of the cells are extending upwards to form the columns supporting the 23,000 tonne topsides. The platform was installed in 1977. The cells in the base have **never been used for the storage of crude oil** and are filled with seawater.

The topsides consist of a steel deck structure composed of steel trusses, which support the modules and other topside equipment.

The platform has been modified many times during its operating life to allow processing of gas from other reservoirs in the Norwegian Sector of the North Sea. This has included Odin (operated by Esso), North East Frigg, East Frigg and Lille Frigg. Gas compression equipment was also installed in 1981 to increase the export capacity of the Frigg export pipelines although this equipment has now been taken out of service.

A new module was installed on the platform in 1995 to allow treatment of oil from the Frøy Wellhead Platform. This module also provided injection water for maintaining the pressure in the Frøy reservoir. The main electrical generation plant for the Frigg Field is also located on TCP2. The platform is connected to TP1 by a 90m long bridge. A new liquids export pipeline to Oseberg was installed in 1994.

Subsea pipelines and cables connecting with the platform are routed to deck level inside the concrete columns.

TCP2	Dry Weight (tonnes)	Overall Dimensions	Comments
Concrete Substructure	Concrete (incl. reinforcement and cast-in items) 159,173 Ballast in caisson 69,920 Grout under platform 18,254 Marine growth (estimate) 865 Steelwork inside columns 1,603 Steelwork outside the concrete substructure 483	Height 129 m Area of hexagonal foundation slab 9,340 m^2 Maximum width of substructure 116 m Height of caisson 40 m Number of cells 19 Diameter of cells 20 m	Volume of concrete is 60 000 m^3. Volume of grout under substructure is 13 725 m^3.
Topsides	Module Support Frame (MSF) 3,837 Pancakes and equipment inside the MSF 5,464 Modules 13,581 (The weight of the largest module is 3 099 tonnes)	Dimensions of topsides 85m x 65m (approx)	The topsides consist of the MSF and 18 modules, including Electrical Power Generation, Utilities, Treatment Facilities for Frøy, Lille-Frigg, North East Frigg, East Frigg and Odin
Bridge to TP1	Basic weight 564	Length 90 m	

Table 4.3 Key Platform Data for TCP2

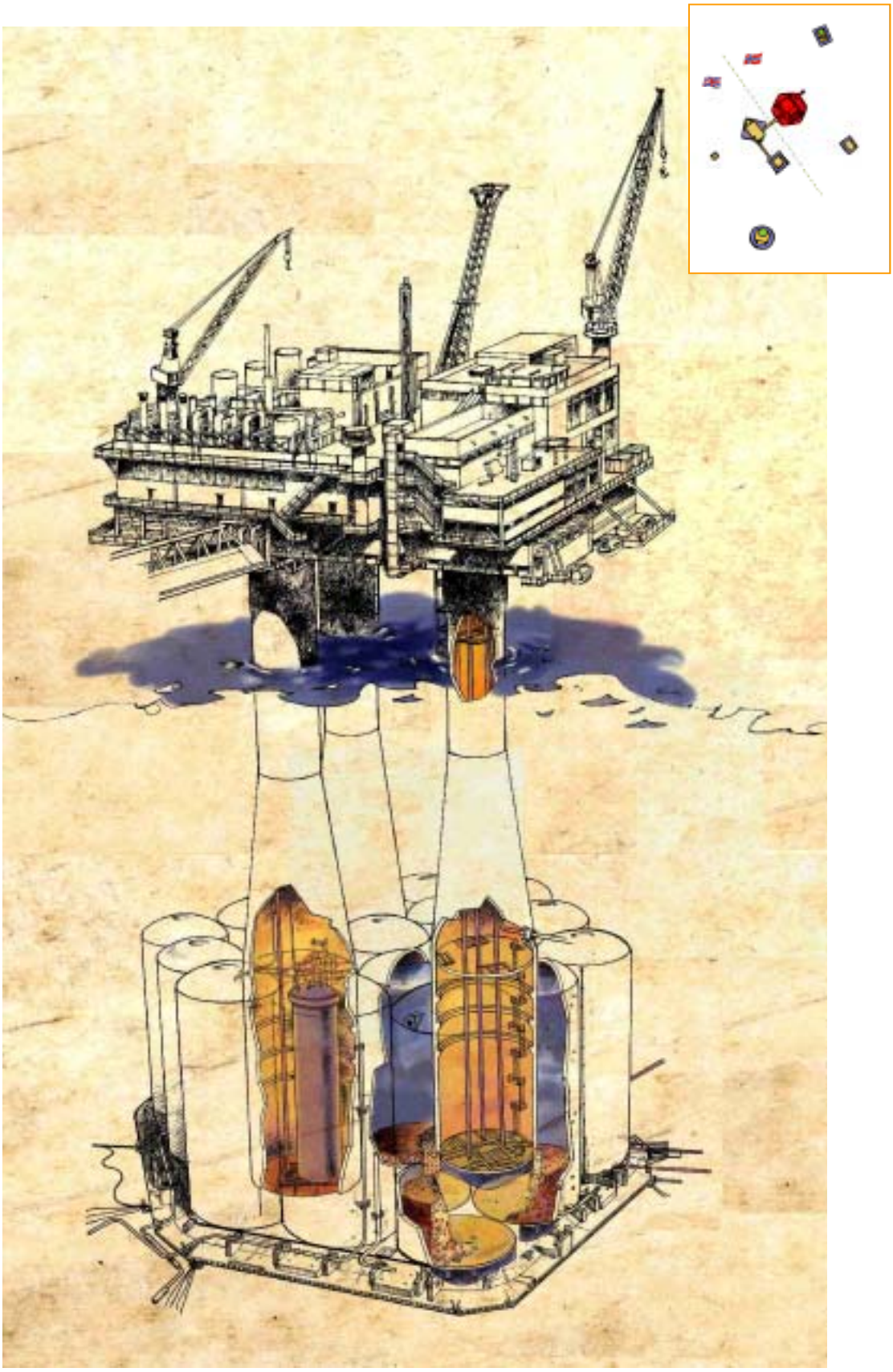

Figure 4.3 Treatment and Compression Platform 2 (TCP2)

4.1.1.3 Wreck of Drilling Platform 1 - DP1

DP1 is an 8-leg steel substructure that was intended to be the drilling and production platform for the UK sector of the Frigg Field. During installation activities, in autumn 1974, the substructure was seriously damaged and sank in the Norwegian sector approximately 800m east of the Frigg Central Complex. The cause of the sinking was the collapse of the ballast tanks providing buoyancy to the steel substructure during the installation process. The damage was so severe that it was not possible to repair and reuse the platform. Approval was obtained from the relevant authorities for the wreck of the steel substructure to be left in place until the Frigg Field facilities are decommissioned.

The section of the substructure above water level is equipped with navigation lights that are regularly maintained.

A number of the steel structural members have become detached and have either fallen to the seabed or are lodged within the main structure. The steel substructure is not piled to the seabed.

DP1	Dry Weight (tonnes)	Overall Dimensions	Comments
Steel Substructure	Basic substructure 7 300 Marine growth (estimate) 300	Height: 106.5 m Plan size at seabed 62 x 44 m	The basic weight of the structure includes fittings and buoyancy tanks

Table 4.4 Key Substructure Data for DP1

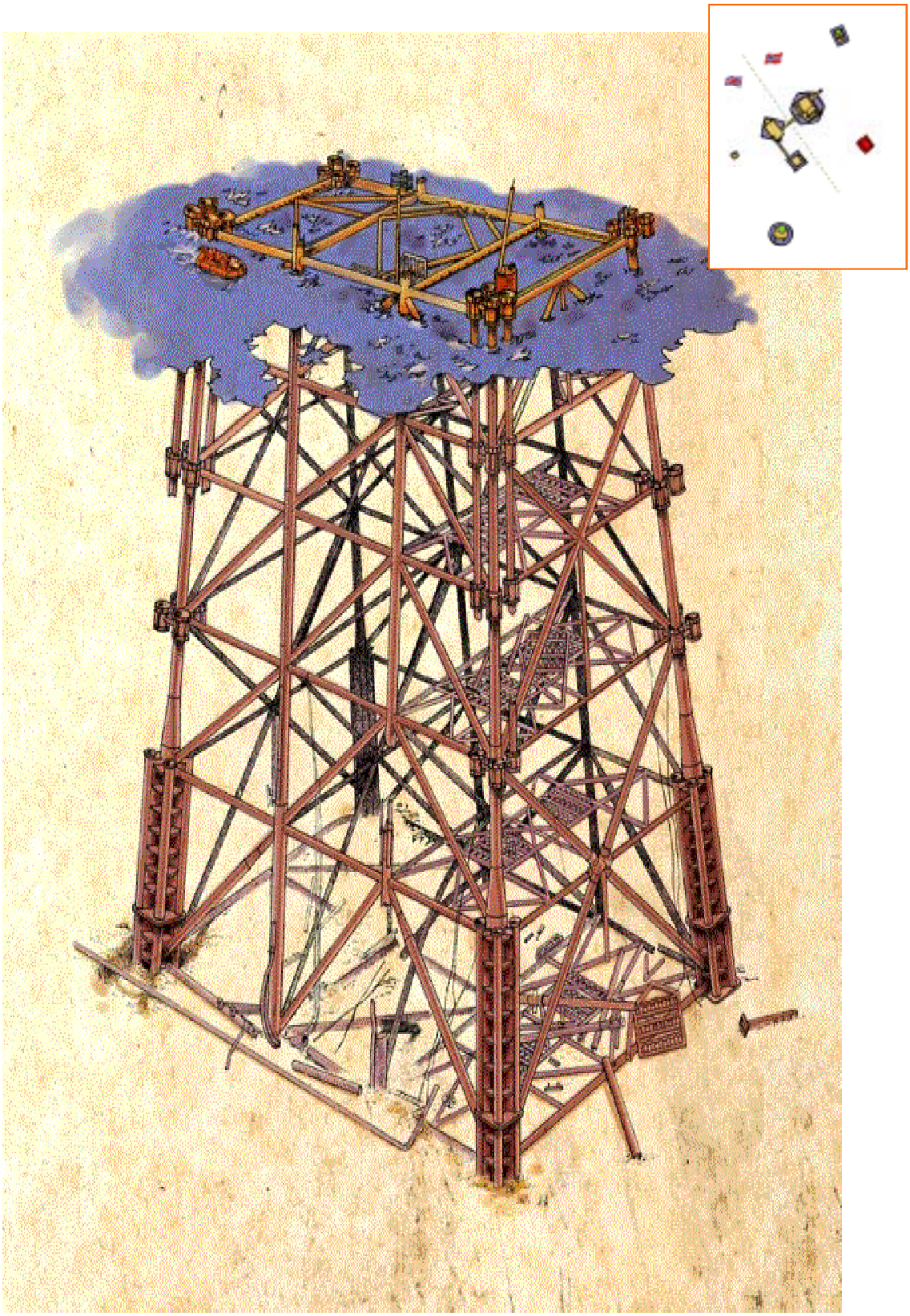

Figure 4.4 Wreck of Drilling Platform 1 (DP1)

4.1.2 UK Registered Installations

4.1.2.1 Quarters Platform - QP

Accommodation for the whole of the Frigg Field is provided on the Quarters Platform, QP. The platform, which was installed in 1975, consists of a 4-leg steel substructure which supports a steel deck frame and the topside modules. Accommodation facilities for 130 people are provided on 3 deck levels. Additional offices are also provided in the cellar deck.

The platform houses a telecommunications centre and the central control room for the entire Frigg Field.

The platform is equipped with a helideck that serves the three platforms in the Frigg Central Complex (QP, TP1, and TCP2). A helicopter hangar is located beside the helideck.

The platform is bridge-linked to TP1 from which a further bridge leads to TCP2.

QP	Dry Weight (tonnes)	Overall Dimensions	Comments
Steel Substructure	Basic substructure 4,210 Steel Piles 547 Grout 483 Marine growth (estimate) 250	Height: 113 m Plan size at elevation +6.1m 26.9 x 26.9 m Plan size at elevation –104 m 54.5 x 54.5 m.	
Topsides	Module Support Frame (MSF) 618 Modules 3,021 (The weight of the largest module is 1116 tonnes)	Dimensions of topsides 35m x 30m (approx)	The topsides consist of two connected accommodation modules, helideck/ heli-hangar / telecoms module, telecoms tower, offices and utilities rooms including batteries, fire pumps and emergency power generation.

Table 4.5 Key Platform Data for QP

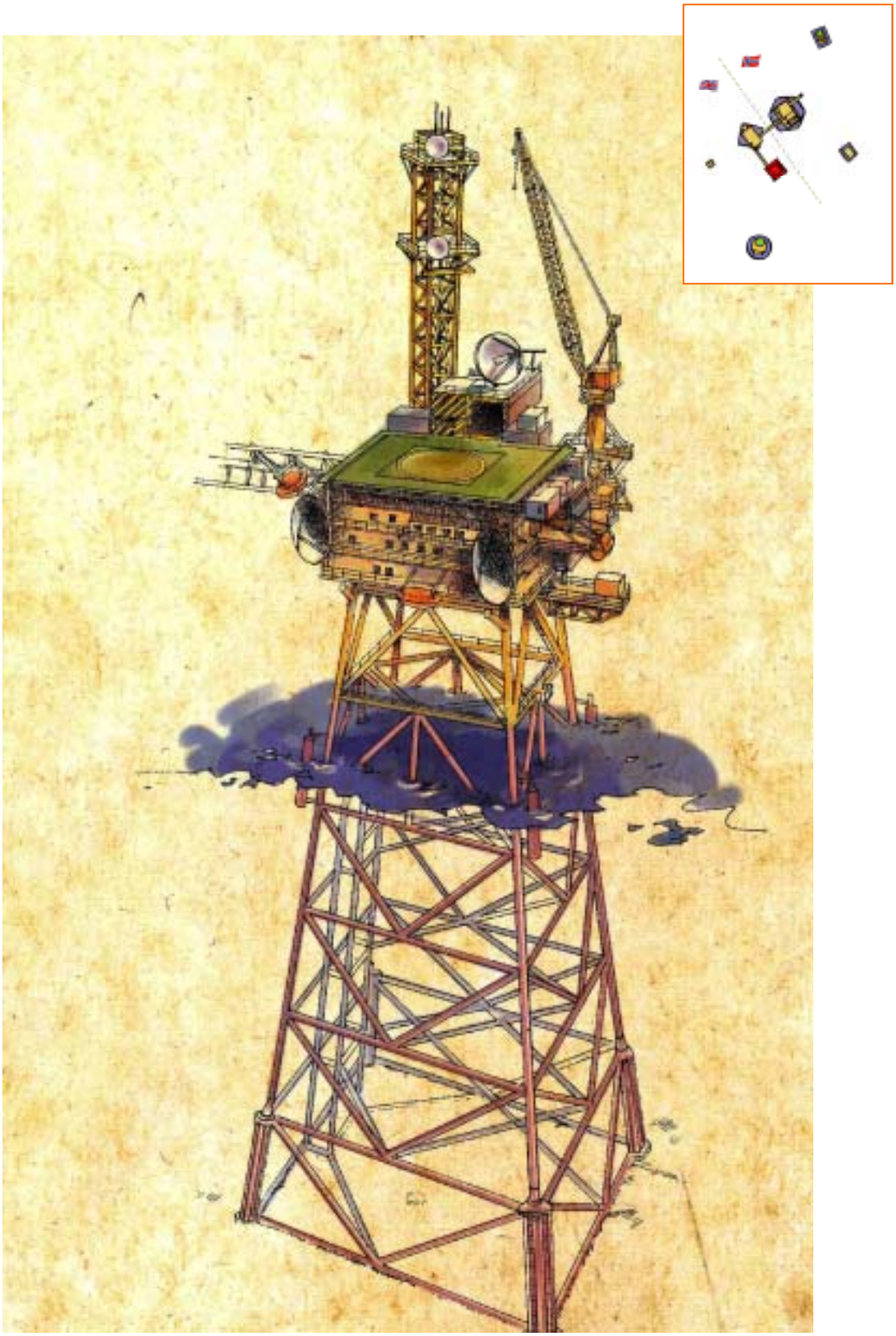

Figure 4.5 Quarters Platform (QP)

4.1.2.2 Concrete Drilling Platform 1 - CDP1

The concrete substructure of CDP1 was initially intended to be the booster station at the midpoint of the Frigg pipelines to St Fergus (Platform MCP01 in Figure 2.2). It was converted for use as the drilling platform for the UK sector of the Frigg Field after the loss of DP1.

The substructure, which was designed by CG Doris, consists of a series of concentric cylindrical concrete walls of different heights, connected together by the base slab and radial concrete walls. The main external wall extends from the base to about 8m above water level and the upper section of the wall is perforated to reduce the wave forces on the substructure. Inside the external wall a central concrete shaft runs from the base slab to deck level.

After the concrete substructure was installed in 1975 the space between the main external wall and the central core was filled with sand/gravel ballast to keep the platform stable on the seabed. When the wells were drilled on CDP1 the drill cuttings were deposited inside the main wall on top of the sand/gravel ballast. In 1981 more ballast was added on top of the drill cuttings to give the structure greater stability following the observation of large cracks in some of the radial walls after a period of severe weather.

The deck consists of a series of 4m deep concrete beams that are supported on the central concrete core and a series of concrete filled steel columns mounted on top of the main external wall. The topsides modules and equipment are supported on the deck beams.

In 1989/90 all the 24 wells were permanently plugged and abandoned and the well casings cut about 5m below the seabed. The drilling rig and cranes were dismantled and removed and the platform has been non-operational since 1990. The platform is now only visited for inspection of certain parts of the structure and for maintenance of the navigation aids. The helideck is maintained in operational condition to allow access to the platform.

The concrete substructure has never been used for the storage of crude oil.

CDP1	Dry Weight (tonnes)	Overall Dimensions	Comments
Concrete Sub-structure	Concrete 146,976 Sand, gravel and concrete ballast 268,703 Cellar deck modules incl. core cap, skid beams and steel panels 2,024 Marine growth (estimate) 1,900 Steelwork inside the external walls 854 Steelwork outside the external walls 54	Height: 107m Diameter of base slab 101m External wall diameter 62m Max. subsea width of substructure 101m Weight of the largest cellar-deck module 198tonnes	Volume of concrete is 56,263 m^3. The concrete-weight figure includes deck-beams, reinforcement steel, prestressed steel bars, deck support columns and other steel items integrated in the concrete structure.
Topside	Basic weight 4,840 Weight of the largest module is 1 252 tonnes	Dimensions of topsides 64m x 63m (approx)	The topsides consist of 18 modules incl. Living Quarters Electrical Power Generation, Well-heads, Production, Cement/Mud, Helideck etc

Table 4.6 Key Platform Data for CDP1

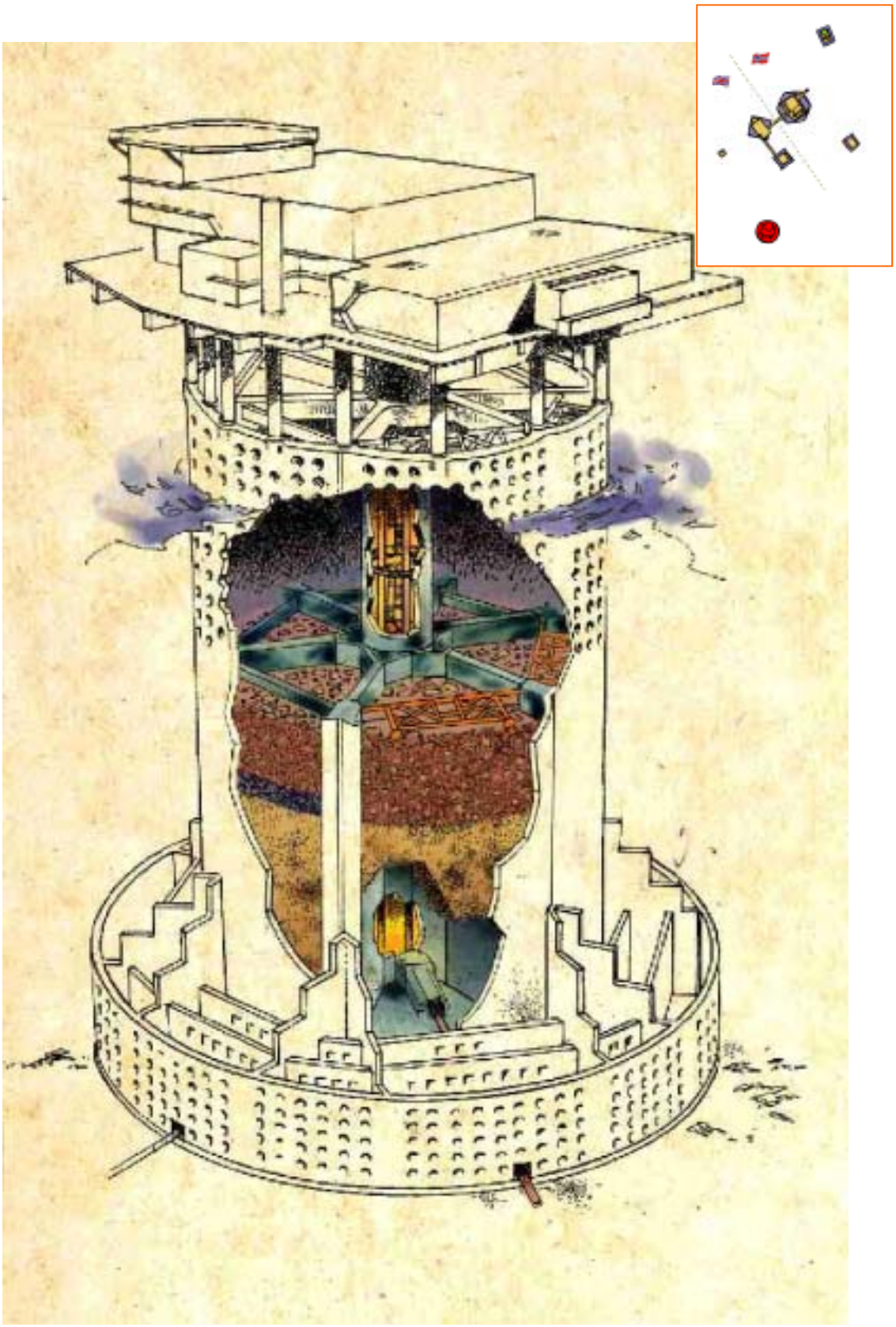

Figure 4.6 Concrete Drilling Platform 1 (CDP1)

4.2.1.3 Treatment Platform 1 - TP1

Gas from CDP1 was originally processed on TP1 before being exported to St Fergus via the Frigg UK Pipeline (PL 7). Since production from CDP1 ceased in 1989, TP1 has functioned as a riser platform connecting the Alwyn gas export pipeline to the Frigg UK Pipeline to St Fergus in Scotland.

The TP1 platform, which was designed by Sea-Tank, was installed in 1976. It consists of a square concrete base made up of 25 cells, two of which are extended to form the two concrete columns supporting the topsides. The cells in the base, and the columns, are normally water filled to enhance the stability of the platform. **None of the cells in the base have ever been used for the storage of crude oil.**

The topsides consist of a steel deck that supports the modules and other equipment.

The platform is bridge connected to both Quarter Platform QP and TCP2. There is a pipeline link across the bridge between TP1 and TCP2 to allow interconnection of the Frigg UK and Frigg Norwegian pipelines, if required.

Most pipelines and cables enter the platform though the bottom part of the structure into the two columns, where they rise up to the topside facilities. One pipeline penetrates directly into one of the concrete columns at top of the caisson level.

TP1	Dry Weight (tonnes)		Overall Dimensions		Comments
Concrete Substructure	Concrete	126,919	Height:	126 m	Volume of concrete 50,000 m^3. The concrete-weight figure includes reinforcement steel, pre-stressed cables and other steel items cast into the concrete.
	Concrete ballast	35,010	Dimensions of base	72 x 72 m	
	Grout	750	Height of base	49,0 m	
	Marine growth (estimate)	781			
	Steelwork inside the two columns	880			
	Steelwork outside the concrete substructure	370			
Topside	Modules	4681	Weight of the largest Module	1252 t	There are 8 equipment areas within the deck and 5 modules on the deck including gas processing and utilities.
	Steel deck	1903	Dimensions of Topside 90m x 44m (approx).		
	Structural steel elements & equipment in the deck	1256			
Bridge to QP	Basic weight	243	Length	89 m	

Table 4.7 Key Platform Data for TP1

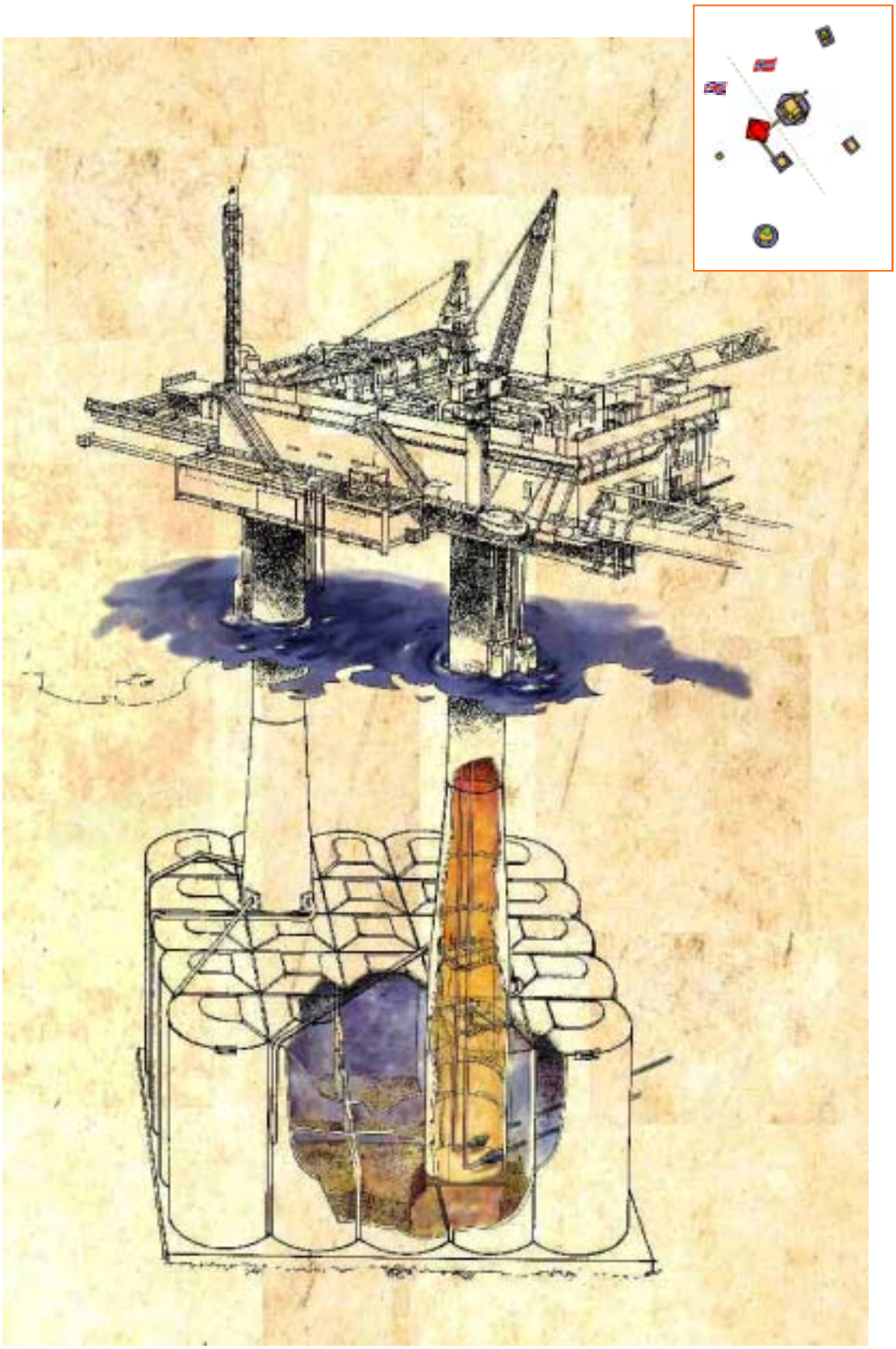

Figure 4.7 Treatment Platform 1 (TP1)

4.2 Frigg Field Infield Pipelines and Cables

The infield pipelines and cables, which are to be decommissioned as part of this Frigg Field Cessation Plan, are those wholly within the pink areas on Figure 4.8 below. That is, those between DP2 and TCP2, CDP1 and TP1/QP and from TP1 to the Flare Platform (now removed)

The inter-field pipelines and the Frigg export pipelines to St Fergus, shown in Figure 4.8, are **not** part of the facilities provided under the provisions of the Frigg Field production licences. Separate cessation plans have been, or will be, prepared and submitted for these pipelines at the appropriate time.

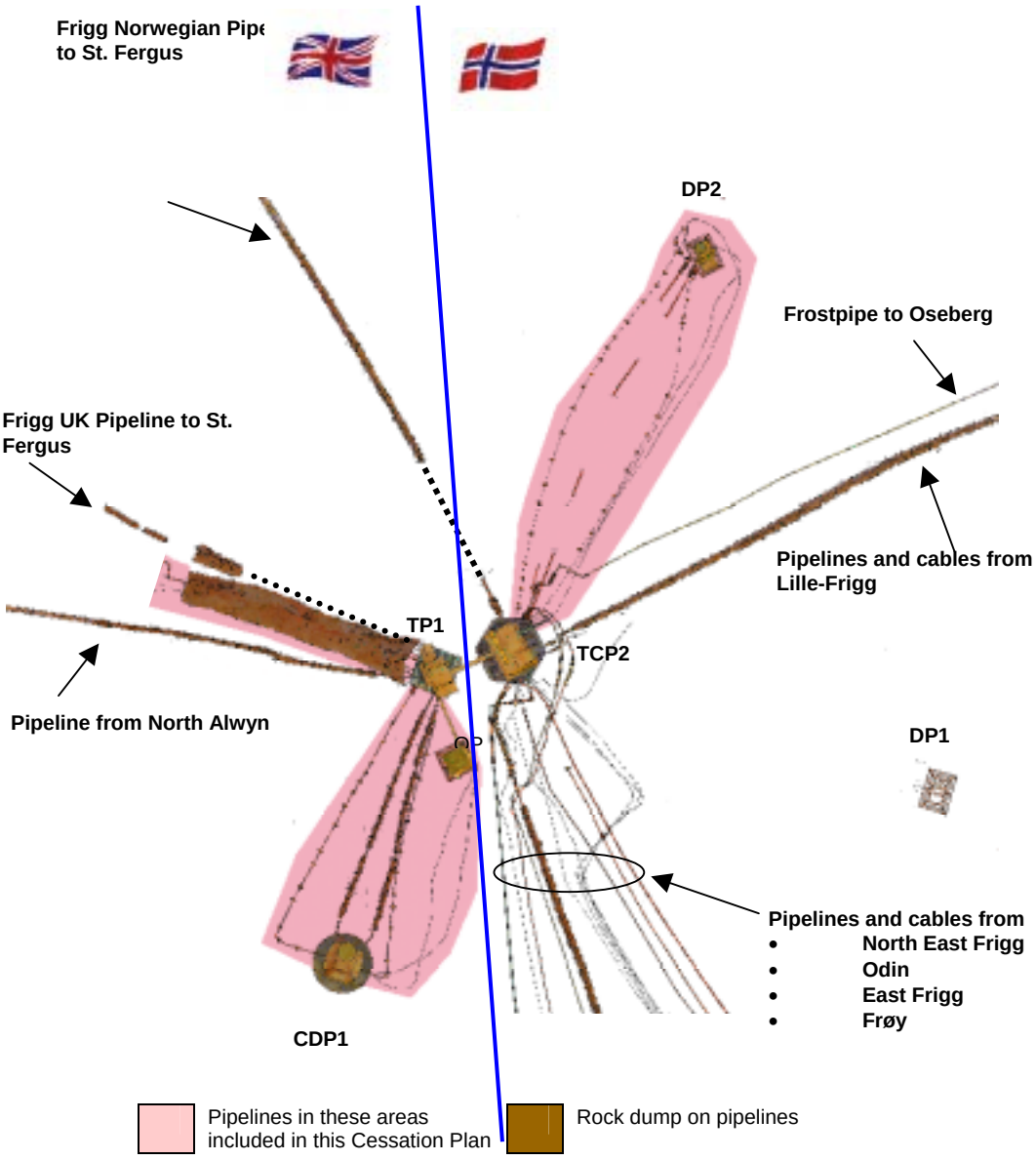

Figure 4.8 Subsea Pipelines and Cables in the Frigg Field

4.2.1 Pipelines and Cables in the Norwegian Sector

From DP2 to TCP2

These pipelines and cables are approximately 700 meters long:

Diameter and Type	Coverage on Seabed	Original Function	Present Function
2 x 26" Pipelines R2 and R3 (concrete coated)	12 concrete saddles, 2 grout bags and 1 mattress. Partly naturally covered by sand and clay particles.	Gas	One pipeline gas, the other shut in
4" Pipeline J1	3 gravel bags 23 mattresses	Condensate Export	Transport of methanol-polluted water to DP2
8" Pipeline J2	2 gravel bags 16 mattresses	Mud Kill Line	Cut close to DP2
3" Electrical Cable	1 mattress	Electrical Power	In use
1 5/8" Telecoms. Cable	None	Telecom	Cut at DP2

Table 4.8 Pipelines and cables between TCP2 to DP2

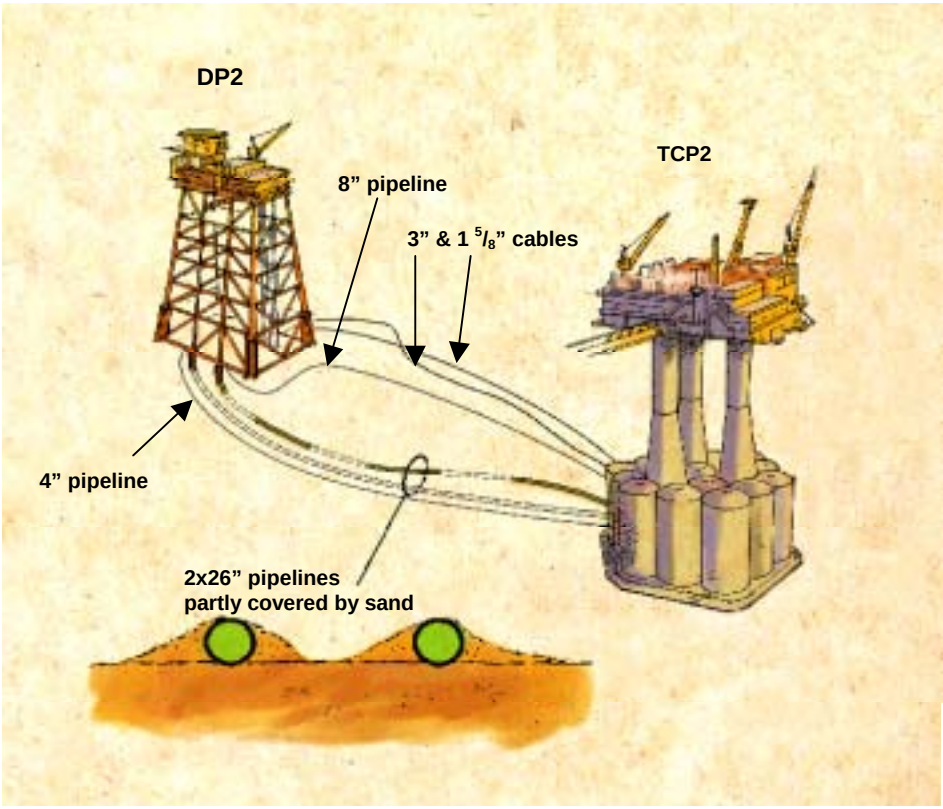

Figure 4.9 Pipelines and Cables between DP2 to TCP2

4.2.2 Pipelines and Cables in the UK Sector

From CDP1 to TP1/QP

These pipelines and cables are approximately 500 meters long.

Diameter and Type	Coverage on Seabed	Original Function	Present Function
2 x 26" Pipelines R5 and R6 (concrete coated) References PL 58 and PL 59	Rock dumped Approximate Covering Dimension Height: 1 m Width: 2.5 m Length: 400 m 16 Concrete Blocks 4 Grout bags	Gas	Air storage
4" Pipeline J5 Reference PL 60	2 Concrete saddles 12 mattresses	Condensate Export	Air storage
8" Pipeline J4 Reference PL 57	5 concrete saddles 16 mattresses	Mud Kill Line	Nitrogen storage
1 5/8" Telecoms Cable	None	Telecom	Passivated
3" Electrical Cable	None	Electrical	Passivated

Table 4.9 Pipelines between CDP1 to TP1, Cables from CDP1 to QP

From TP1 to FP Base (Now Removed)

These pipelines and cables are approximately 500 meters long.

Diameter and Type	Covering on Seabed	Original Function	Present Function
24" Pipeline R7 (concrete coated) Reference PL 61	All rock dumped Approximate Covering Dimension Height: 1m Width: 60m Length: 400m 9 concrete blocks and 2 grout bags on 24" pipeline 2 concrete saddles on 3" electrical cable.	Gas (flare)	All passivated
2" Pipeline Reference PL 62		Air	
2" Pipeline Reference PL 67		Pilot	
3" Electrical Cable		Electrical Power	
4" Telecoms. Cable		Telecom	

Table 4.10 Pipelines and Cables between TP1 to FP Base

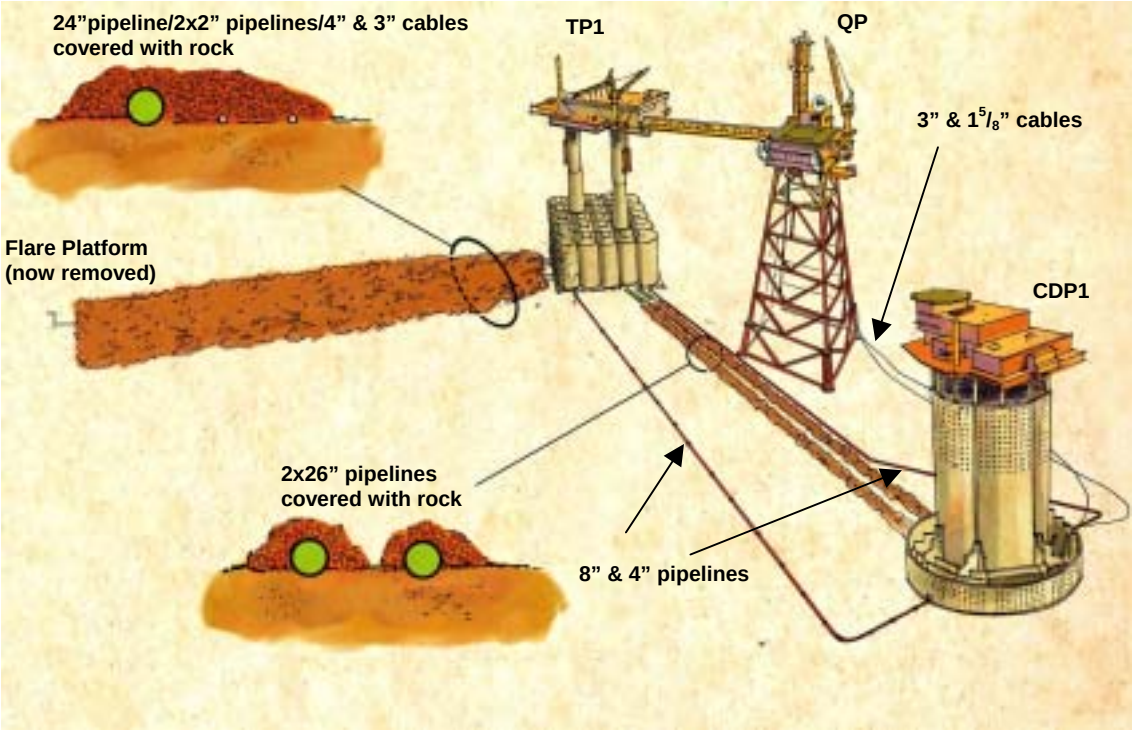

Figure 4.10 Pipelines and Cables between CDP1 and TP1, CDP1 and QP, TP1 and the Flare Platform (now removed)

4.3 Frigg Field Drill Cuttings

4.3.1 Drill Cuttings in the Norwegian Sector

Drilling Platform DP2

About 7,000m^3 of drill cuttings were discharged onto the seabed while drilling the 24 production wells on DP2, and later sidetracking two of the wells. A survey in the summer of 2000 (Ref. 4.1) indicated that the drill cuttings are presently deposited in a thin layer on the seabed around the platform. The maximum thickness of the drill cuttings layer is 20cm. It is estimated that approximately 400 m^3 of drill cuttings are contained within an area of 80m x 120m around the platform. Outside this area the thickness of the drill cuttings layer is less than 4 cm.

Water-based mud was used for drilling all the wells apart from side-tracking two of the wells in 1989/90, when 236m^3 of low toxicity oil based mud was used. A total of 120 m^3 of low toxicity oil based mud was brought ashore for treatment and disposal. The drill cuttings containing the remaining 116 m^3 of low toxicity oil based mud were cleaned on the platform so that they contained less than 10% oil, before being discharged onto the seabed.

Figure 4.11 Location of Drill Cuttings Around DP2

4.3.2 Drill Cuttings in the UK Sector

Drilling Platform CDP1

During the drilling of the 24 production wells on CDP1, 5600m^3 of drill cuttings were deposited inside the concrete substructure. All wells were drilled using water-based mud. The cuttings were deposited on top of the sand/gravel ballast and, after drilling was completed, an additional 21,000 m^3 of gravel was placed on top of the cuttings. This additional gravel ballast was added to improve the on-bottom stability of the platform.

In 1999 core samples were taken from the seabed around CDP1 to investigate whether there were any drill cuttings outside the platform (Ref. 4.2). The samples taken showed no traces of the typical characteristics of drill cutting material and it has therefore been concluded that all the drill cuttings are still retained within the concrete substructure.

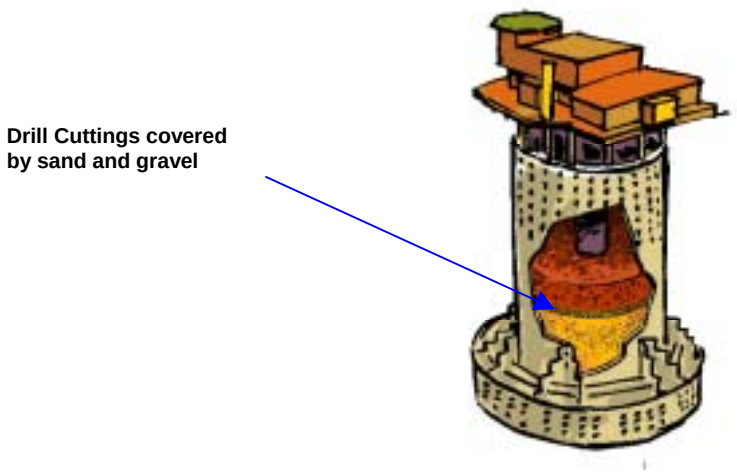

Figure 4.12 Drill Cuttings Contained within the CDP1 Concrete Substructure

Section References

4.1 "Environmental Investigation of Cutting Deposits in the Frigg Area", Rogalands Forskning Report Ref. RF 2000/219, Rev 1, dated 24.11.2000, DocsOpen 108057.

4.2 "Trace Metals and Hydrocarbons in the Cuttings Piles at Frøy and CDP1 Platforms", Rogalands Forskning Report Ref. RF 1999/773, Rev 1, dated 20.10.1999, DocsOpen 99677.

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5. Inventory of Materials

5.1 Platforms

Inventory inspections and analyses have been carried out for all the Frigg Field platforms, except for CDP1 (where access to the platform is very restricted due to safety considerations) and the wreck of DP1. The quantities of materials on CDP1, and in the wreck of DP1, have been estimated based on the platform data available onshore and comparable values from other Frigg Field platforms. The inventory of materials has been based upon surveys undertaken by independent organisations (Ref. 5.1.to 5.8).

Table 5.1 provides details of the composition of the Frigg Field platforms after removal of the process and utility fluids and cleaning of the equipment.

		Norwegian Platforms			UK Platforms		
Material	Unit	DP2	DP1	TCP2	QP	CDP1	TP1
Carbon steel	tonnes	18,151	7,010	39,438	7,946	16,888	15,442
Stainless steel	tonnes	17	0	206	90	18	13
Copper	tonnes	9	0	68.2	15	9	30
Copper/Nickel	tonnes	2.5	0	25.3	4	3	2.5
Titanium	tonnes	0	0	26	0	0	0
Aluminium	tonnes	290	290	0.2	56	0	1.2
Zinc	tonnes	2	0	85	0	2.8	10
Concrete in topsides	tonnes	1,158	0	0	559	0	0
Concrete substructure	tonnes	0	0	159,173	0	146,976	126,919
Ballast in Concrete substructures(1)	tonnes	0	0	69,920	0	268,703	35,010
Freon R22	Kg.	0	0	120	360	0	0
Fluorescent tubes	Number	960	0	3,600	1,200	1,000	1,180
Batteries		346 cells	16 batteries.	1800 banks	16 banks	21 banks	200 batteries
Halon (2)	Kg	860	0	4,450	463	0	400
Electric and electronic components	tonnes	212	0	988	151	223	393
Plastic	tonnes	11	0	86.2	16	11	40
Construction material	tonnes	31.5	0	146.9	95	34	6.5
Marine growth (3)	tonnes	300	300	865	250	1900	781
Olivine Ballast (4)	tonnes	0	0	69,920	0		0
Asbestos(5)	tonnes	7	0	10	19	8	6

Notes

(1) Sand, gravel or concrete ballast inside concrete substructures
(2) Dispensation obtained from relevant authorities for retaining this material
(3) Estimated figures
(4) Excluding concrete ballast
(5) From analysed and assumed hidden sources; e.g. in case of a fire door containing asbestos as fire isolation, the weight of the complete door is recorded.

Table 5.1 Frigg Field Platforms - Inventory of Materials

There is a possibility of LSA scale in the process equipment in Module M35 on the Norwegian platform TCP2. Apart from possibly in this module, no low specific activity (LSA) scale is likely to be found on the Frigg Field installations. During offshore decommissioning of the process equipment, checks will be made to ascertain whether LSA scale is present and to estimate the quantity. Module M35 will be removed together with the rest of the TCP2 topside and brought

to shore where suitable measures will be taken to dispose of it in accordance with appropriate procedures and regulations.

Special care will be taken during the recycling of painted steel components to prevent any hazard to health arising from the possible generation of isocyanates.

Currently checks for lead isotopes are made whenever process equipment is opened. To date no evidence of the presence of these materials has been found. Similar checks will be made during the decommissioning of the process equipment and the infield pipelines.

It is not known for certain whether the flooded members of the steel substructures contain biocide to prevent the activity of sulphate reducing bacteria. Biocide was however added to the water in one of the members of the QP substructure when it was repaired in the 1980s. Efforts will be made to take representative samples of the water in the steel substructures of DP2 and QP for testing to determine whether the water may be discharged to the marine environment or not. The results will be discussed with the appropriate UK and Norwegian authorities to ensure that discharges of any contaminated water accords with relevant regulations.

No release of contaminated water is anticipated during the removal of the topside facilities.

5.2 Infield Pipelines and Cables

The inventory of materials for the Frigg Field pipelines and cables that are to be decommissioned is outlined below.

5.2.1 Infield Pipelines and Cables in Norwegian Sector

Size	Original function	Present Status	Length (m)	Total Weight (tonne)	Steel Weight (tonne)	Coating Weight (tonne)	Concrete Weight (tonnes)
26”	Gas line (R3)	Gas	664	357	264	10	83
26”	Gas line (R2)	Passivated	630	338	250	10	78
8”	Mud line (J2)	Passivated	600	600	51.1	48	3
4”	Condensate	Methonolated-water injection	708	20	18	2	0
3”	Electrical cable	Electrical	760	10.5	Copper	Rubber	
15/8”	Telecom cable	Passivated	760	2.4	Copper	Rubber	

Table 5.2 Pipelines and Cables between DP2 and TCP2

5.2.2 Infield Pipelines and Cables in UK Sector

Size	Original function	Present Status	Length (m)	Total Weight (tonne)	Steel Weight (tonne)	Coating Weight (tonne)	Concrete Weight (tonnes)
26”	Gas line (R5) Ref. PL 58	Air	455	244	181	7	56
26”	Gas line (R6) Ref. PL 59	Air	464	249	184	7	58
8”	Mud line (J4) Ref. PL 57	Nitrogen	566	48	45	3	0
4”	Condensate Ref. PL 60	Air	505	13	12	1	0
3”	Electrical cable	Passivated	400	5.5	Copper	Rubber	
15/8”	Telecom cable	Passivated	400	0.8	Copper	Rubber	

Table 5.3 Pipelines and Cables between CDP1 and TP1/QP

Size	Original function	Present Status	Length (m)	Total Weight (tonne)	Steel Weight (tonne)	Coating Weight (tonne)	Concrete Weight (tonnes)
24”	Gas line (R7) Ref. PL 61	Passivated	460	218	159	6	53
2”	Pilot line Ref. PL 67	Passivated	460	4.5	3.9	0.6	0
2”	Air Ref. PL 62	Passivated	460	4.5	3.9	0.6	0
3”	Electrical cable	Passivated	460	6.7	Copper	Rubber	
4”	Telecom cable	Passivated	460	6	Copper	Rubber	

Table 5.4 Pipelines and Cables between Flare Base and TP1

5.3 Drill Cuttings

5.3.1 Drill Cuttings in Norwegian Sector - DP2

About 7,000m^3 of drill cuttings were discharged onto the seabed while drilling the 24 production wells on DP2, and later sidetracking two of the wells. It is estimated that approximately 400m^3 of drill cuttings are contained within an area of 80m x 120m around the platform. Outside this area the thickness of the drill cuttings layer is less than 4 cm (Ref.5.12).

The composition of these drill cuttings is shown in the Table 5.5, based upon the results of laboratory tests on samples taken during the summer of 2000 (Ref.5.11). Other investigations in the area are reported in References 5.9, 5.10 and 5.13.

The measured values for the drill cuttings at DP2 are shown in the table to the left, and details of the classification system for marine sediments produced by the Norwegian Pollution Control Authority (SFT) for use in fjords and coastal waters, is shown in the table on the right. This classification system should not be used as an absolute measure, but rather as a general indication. The SFT classification system consist of 5 classes as detailed below:-

Class I	slightly polluted
Class II	moderately polluted
Class III	markedly polluted
Class IV	severely polluted
Class V	extremely polluted

Measured Values		SFT Class Values for Comparison Purposes	
Chemical	mg/kg	SFT Class I mg/kg	SFT Class II mg/kg
Total hydrocarbon content	290	Not classified	Not classified
Chromium	18	< 70	70-300
Nickel	15	< 30	30-130
Copper	32	< 35	35-150
Zinc	330	< 150	150-700
Arsenic	7.8	< 20	20-80
Silver	0.09	< 0.3	0.3-1.3
Cadmium	0.5	< 0.25	0.25-1.0
Tin	5.6	< 150	150-700
Barium	500	Not classified	Not classified
Lead	72	< 30	30-120
Mercury	0.02	< 0.15	0.15-0.6
	µg/kg	µg/kg	µg/kg
Polycyclic Aromatic Hydrocarbons	240	< 300	300-2000
benzo(a)pyrene	15	< 10	10-50
Σ PCB_7	6 (2-14)	< 5	5-25

Table 5.5 Characterisation of Drill Cuttings at DP2

5.3.2 Drill Cuttings in the UK Sector - CDP1

The drill cuttings from the wells on CDP1 were all deposited inside the walls of the concrete substructure. The cuttings were deposited on top of the sand and gravel ballast and subsequently further solid ballast was placed on top of the drill cuttings in order to improve the stability of the platform. The total volume of the drill cuttings deposited inside the platform was approximately 5600m^3.

Taking samples of the cuttings inside the concrete wall was considered to be technically feasible. However, the operation was judged to be unacceptably hazardous as none of the safety and utility systems on CDP1 are operational. Visits to the platform are therefore minimized and strictly controlled. No sampling of the cuttings within the CDP1 concrete substructure has therefore been performed.

The CDP1 wells were drilled with water-based mud at approximately the same time as the wells on DP2. Based on the drilling and discharge records, there is good reason to believe that the characteristics of the drill cuttings deposited inside the concrete walls of CDP1 are comparable to the drill cuttings deposited on the seabed around DP2. (See Section 5.3.1)

Samples were however, taken from the seabed around CDP1 in the summer of 2000 and analysed (Ref. 5.11). None of the typical contaminants found in drill cuttings have been identified in these samples.

Section References

5.1 "Inventory Accounting QP", Kværner Oil and Gas Report, Ref. 005-TR-V-E-001, Rev A, Dated 10.02.2000 DocsOpen 108186.

5.2 "Inventory Accounting TP1", Kværner Oil and Gas Report, Ref. 005-TR-V-B-001, Rev A, Dated 17.02.2000 DocsOpen 108189.

5.3 "Inventory Accounting TCP2", Kværner Oil and Gas Report, Ref. 005-TR-V-C-001, Rev A, Dated 19.06.2000 DocsOpen 108190.

5.4 "Inventory Accounting Module M52/P48 – Lille Frigg Tie-in", Kværner Oil and Gas Report, Ref. 005-TR-V-G-001, Rev A, Dated 21.02.2000 DocsOpen 105411.

5.5 "Inventory Accounting Module M35 – Frøy Tie-in (TCP2)", Kværner Oil and Gas Report, Ref. 005-TR-V-F-001, Rev A, Dated 11.02.2000 DocsOpen 108191.

5.6 "Inventory Accounting Module M51 – East Tie-in (TCP2)", Kværner Oil and Gas Report, Ref. 005-TR-V-H-001, Rev A, Dated 15.02.2000 DocsOpen 108192.

5.7 "Inventory Accounting DP2", Kværner Oil and Gas Report, Ref. 005-TR-V-D-001, Rev A, Dated 28.02.2000 DocsOpen 108187.

5.8 "Asbestos Mapping on Frigg QP, TP1, TCP2 and DP2", DNV Report Ref. 2000-3396, Rev.1, dated 18.10.2000 DocsOpen 106058.

5.9 "Determination of Trace Metals and Hydrocarbons in Sediment Under the Frigg DP2 Platform", Rogalands Forskning Report, Ref. RF 1998/236, Rev. 1, dated 10.12.1998 DocsOpen 92093.

5.10 "Trace Metals and Hydrocarbons in the Cuttings Piles at Frøy and CDP1 Platforms", Rogalands Forskning Report Ref. RF 1999/773, Rev 1, dated 20.10.1999 DocsOpen 99677.

5.11 "Environmental Contamination at Frigg DP2 and CDP1", Rogalands Forskning Report, Ref. RF 2000/218, Rev 1, dated 23.11.2000 DocsOpen 108056.

5.12 "Environmental Investigation of Cutting Deposits in the Frigg Area", Rogalands Forskning Report Ref. RF 2000/219, Rev 1, dated 24.11.2000 DocsOpen 108057.

5.13 "Trace Metals and Organic Contaminations in Biota from the DP2 and QP installations at the Frigg area", Rogalands Forskning Report, Ref. RF 2000/259, Rev 1, dated 23.11.2000 DocsOpen 108058.

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6. Evaluation Process and Principles

6.1 General

The studies and assessments in this Frigg Field Cessation Plan have been undertaken to allow the best disposal arrangements for the Frigg Field facilities to be identified, and to demonstrate compliance with the relevant Norwegian and UK legislation.

It has been agreed with the authorities in both countries that a common approach shall be adopted for the decommissioning of the Frigg Field facilities located in both the Norwegian and UK sectors of the North Sea.

Both the Norwegian and UK governments are signatories to the **1992 Convention for the Protection of the Marine Environment of the North-East Atlantic**, known as the OSPAR Convention. As such, both governments have committed to take all possible steps to prevent and eliminate pollution from offshore sources. This commitment was reiterated in 1998 by the **Sintra Statement** of Ministers and the Member of the European Commission with the accompanying **OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations**.

In accordance with OSPAR Decision 98/3, "*the dumping or leaving wholly or partly in place, of disused offshore installations within the maritime area is prohibited*". If however it can be demonstrated that there are **significant reasons** why an alternative disposal method is preferable to reuse or recycling, or final disposal on land, then the relevant authority of a national government may issue a permit allowing part or all of the installation to be left in place. The granting of such a permit may only take place after the submission of an appropriate comparative assessment to the national authority and after a designated consultation process with the signatories to the OSPAR Convention.

The evaluations and comparative assessments detailed in this Frigg Field Disposal Plan are therefore undertaken in compliance with the Norwegian Act of 29 November 1996 No.72 relating to petroleum activities, the UK Petroleum Act 1998 and the OSPAR Decision 98/3.

6.2 The Evaluation Process

Evaluations or comparative assessments have been undertaken for all components of the Frigg Field facilities.

In accordance with Norwegian and UK regulations, and OSPAR Decision 98/3, full removal and onshore disposal has been the only disposal option considered for the **topsides** and **steel substructures.** For these elements an evaluation of feasible methods for removal and onshore disposal has been undertaken. The cost and risks associated with this work have also been estimated.

In the case of the **concrete substructures**, **infield pipelines/cables** and the **drill cuttings**, the evaluations have taken the form of comparative assessments of different disposal options. The various alternative arrangements considered in the comparative assessments are summarised in Table 6.1.

Evaluation of Disposal Methods				
Steel Platform Topsides QP, DP2	**Alternative A** Removal and onshore disposal			
Steel Platform Substructures QP, DP2, DP1	**Alternative A** Removal and onshore disposal			
Concrete Platform Topsides TCP2, CDP1, TP1	**Alternative A** Removal and onshore disposal			
Comparative Assessment of Disposal Alternatives				
Concrete Platform Substructures TCP2, CDP1, TP1	**Alternative A** Refloat, tow to shore, demolish and dispose on-shore.	**Alternative B** Remove external and internal steelwork, refloat and dispose at a deep water location	**Alternative C** Remove internal and external steelwork and cut down sub-structure to provide a clear draft of 55m.	**Alternative D** Leave in place, removing as much external steelwork as reasonably practicable.
Infield Pipelines and Cables	**Alternative A** Remove, transport to shore and onshore disposal	**Alternative B** Leave in place but trenched	**Alternative C** Leave in place but bury ends	
Drill Cuttings DP2, CDP1	**Alternative A** Remove and onshore disposal	**Alternative B** Leave in place		

Table 6.1 Evaluations and Comparative Assessments Conducted for the Frigg Field Facilities

During the summer of 2001 Vesterled pipeline from the Heimdal platform in the Norwegian sector was connected directly to the Frigg Norwegian Pipeline. A connection from this pipeline to the Frigg Field has been maintained to allow the continuing export of Frigg gas. After cessation of production from Frigg the pipeline between Frigg Field and the tie-in point will be disconnected. It is also planned to connect the Alwyn pipeline directly into the Frigg UK Pipeline (PL 7) in 2004. Both Frigg export pipelines will thus continue to operate after the Frigg Field platforms have been decommissioned. Accordingly the decommissioning of these pipelines is **not** included within the scope of this Frigg Field Cessation Plan. Similarly, pipelines and cables connecting with other fields are not covered by the Frigg Field production licences and accordingly, disposal arrangements for them are also not included in this document. Separate decommissioning plans for these pipelines have been, or will be, prepared and submitted to the relevant authorities.

The OSPAR Commission meeting in Sintra in 1998 determined that there should be a “presumption for removal” of all redundant and decommissioned platforms in the North East Atlantic area, which includes the North Sea. Derogations may be sought for certain categories of facilities. Where derogation is not appropriate, this presumption led to the requirement that structures should be removed irrespective of any comparison of the environmental impact profile for removal with the environmental impact profiles of other alternatives. For each of the components to be decommissioned the following sequential process has therefore been followed to determine the recommended arrangements according to the “waste hierarchy” which values reuse above recycling and disposal onshore above disposal at sea.

- Evaluation of the possibility of reusing all or parts of the offshore facilities either in their current location or at another site
- Evaluation of the possibility of recycling all, or parts, of the offshore facilities
- Evaluation of the possibility of disposal onshore
- Evaluation of the possibility of disposal at sea

6.3 Evaluation Principles

An assessment of the possible reuse potential of the Frigg Field facilities is contained in Section 7, where both oil and gas usage and non oil and gas usage is considered. In assessing the possible reuse potential of the facilities the technical feasibility has been assessed in the light of existing proven technology and the financial viability evaluated based upon current economics.

The general principle has been adopted that if reuse is not possible, either at the current location, or at another site, then as much of the equipment and materials as practicable will be recycled. This principle has been extensively applied throughout the Environmental Impact Assessment where the energy requirements and discharges during the recycling processes have been included.

In the event that it is impossible to reuse the Frigg Field facilities at their current location, the feasibility and environmental impact of removing them have been assessed. The general principle adopted in this situation has been that, if possible, all facilities shall be returned to shore where they may be reused, recycled or disposed off in the most effective manner.

In preparing this Frigg Field Cessation Plan, the principle has been adopted that facilities removed from Norwegian waters will be returned to Norway for reuse, recycling or disposal. Similarly it is assumed that facilities located in UK waters will be returned to the UK for reuse, recycling or disposal.

The removal and disposal work will however be undertaken by contractors who will be selected by international competitive tender, in accordance with the requirements of European Union directives. At this time it is therefore not possible to unequivocally state the final destination of the various elements removed from the field. No facilities will however be removed, transported, or disposed of without the necessary approvals being obtained from the relevant national and international regulatory authorities. Import duties will be paid as appropriate.

As previously described, full removal and onshore reuse, recycling or disposal of the Frigg Field facilities has been adopted as the solution considered first for all facilities. Where national regulations and international conventions allow (1992 OSPAR Convention and OSPAR Decision 98/3), alternative disposal methods have also been studied and assessed.

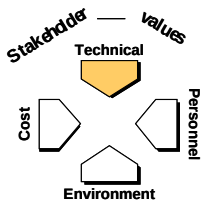
The objective of the evaluations and comparative assessments has been to identify the best disposal arrangements for the Frigg Field facilities that take due account of safety and working environment considerations, the environmental impact and commercial aspects, and are in accordance with national and international legislation and conventions.

A similar approach, in which consideration is given to the following aspects, has therefore been adopted for all the components of the Frigg Field facilities: -

- Technical Feasibility
- Risk to Personnel
- Environmental Impact (including impact on society)
- Cost

The recommended disposal alternative for each of the Frigg Field components has been based upon consideration of all the aspects listed above, in the light of the feedback received from the public consultation process. TOTAL NORGE has conducted an extensive programme of consultation with both statutory consultees and other interested parties in both Norway and the UK (see Section16 and Annexes A to D). The views and opinions expressed during various individual meetings, and at a workshop held in London in September 2000, have been particularly important in trying to balance conflicting or alternative factors. Particular attention has been given to the safety and environmental implications. In the case of the concrete substructures however, the uncertainties associated with the removal operations have resulted in technical feasibility being of particular importance.

Technical Feasibility

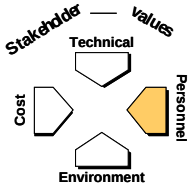


The technical feasibility of a disposal arrangement has been judged based upon knowledge of existing equipment and practices, although in some instances the possible extension of existing technology has been included, where this is reasonably foreseeable. In such situations the implication of being unable to develop and test the necessary technology prior to use, has been assessed. Leading independent experts in many different fields have been consulted to provide input to the studies and verify the conclusions. A major factor in assessing technical feasibility has been the level of uncertainty associated with the activities to be undertaken. This uncertainty particularly arises due to insufficient knowledge as to the exact structural condition of the installations and the behaviour of the structure under the load conditions arising during decommissioning activities. Again, specialist input has been obtained from independent experts in the relevant fields to allow verification of the results produced and the conclusions reached.

The technical feasibility of most operations has been assessed qualitatively based upon current technology and studies as well as the judgement of expert personnel. In the case of the concrete substructures, however, a quantitative analysis of the technical feasibility has been undertaken to allow more detailed consideration of the risks associated with the work. Independent experts from Norway, Germany and Switzerland, as well as TOTAL Group experts, have verified the quantitative assessment of technical feasibility.

Where quantitative analysis of the technical risks has been made, both the probability and the consequences of major accidents during the planned activities have been determined. The effect on personnel safety, the environment and project cost has been estimated, taking due account of both the original accident and any subsequent remedial work that would be required. The implication of these “worst case” scenarios has been an important factor in the decision making process.

Risk to Personnel



Both qualitative and quantitative assessments of the risks to personnel engaged in the removal and disposal operations have been carried out. Current practice has been a major factor in the qualitative assessments together with the expert judgement and experience of many of the personnel who were engaged in the initial design, fabrication and installation of the facilities. Practicable risk reducing measures, identified during the qualitative risk assessment, have been included into the planned activity arrangements.

Quantitative estimates of the risks to personnel have been made based upon the number of man-hours involved for the various tasks and the risk for each task, estimated from both offshore and onshore construction or demolition experience. This method is regarded as the best available at the present time but has a tendency to **underestimate the risk to personnel** due to the fact that hazards which are specific to the actual work are not fully included. The degree of underestimation of risk is not possible to quantify, but experts in this field judge that in some situations the actual risk may be up to double the risk estimated solely on the basis of generic historical data.

In common with risk analysis practice, the risk to personnel has been expressed in terms of the predicted number of fatalities during the work (often referred to as Potential Loss of Life or PLL). The predicted number of major injuries during the work (often referred to as Potential Major Injuries or PMI) have also been estimated. Both values are determined based upon the anticipated decommissioning work and historical accident statistics.

The physical significance of the parameters Potential Loss of Life and Potential Major Injuries is somewhat difficult to appreciate, particularly when expressing a fatality or injury level less than 1. Accordingly, the **probability** or "likelihood" of a fatality occurring during the work scope in question has also been calculated, and is expressed either in percentage terms, (such as a 13% chance of a fatality) or in terms of "odds" (such as a 1 in 7 chance of a fatality).

Potential Loss of Life (PLL) is the number of fatalities that are "likely" to occur whilst undertaking a defined amount of work.

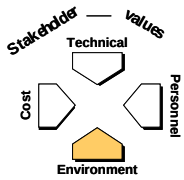
Similarly, Potential Major Injuries (PMI) is the number of major injuries that are "likely" to occur whilst undertaking a defined amount of work.

Where appropriate, the Fatal Accident Rate (FAR) for a particular activity or set of activities has been presented. Fatal Accident Rate is a statistical parameter that expresses the "likely" number of fatalities that would occur during 100 million man-hours of the activity (or activities) in question. Fatal Accident Rates are commonly used to express the risk associated with particular activities such as construction work, scaffolding, helicopter flying etc. Fatal Accident Rates are also widely used as a way of comparing the risk of different types of activity. Fatal Accident Rates are also sometimes used to express the "average " risk for an operation which includes many different activities, of differing durations, each having different numbers of participants. When used in this way FAR values only give a general indication of the "average" risk. This can be helpful in making relative comparisons between different options, but is not appropriate to use as an absolute decision making criterion.

Fatal Accident Rate (FAR) is the number of fatalities that are "likely" to occur whilst undertaking 100 million hours of a particular activity

Environmental Impact

The impact of the disposal operations on the environment and society has been estimated using generally accepted methods and principles. The Environmental Impact Assessment has been carried out by DNV. A slightly edited version of their report forms Part 2 of this Frigg Field Cessation Plan.



The purpose of the Environmental Impact Assessment is to :-

- Clarify the consequences of the relevant disposal alternatives for the Frigg Field facilities that may have a significant impact on the environment, natural resources and society.
- Present information about possible impacts in a manner that can form a basis for a decision on the disposal alternatives.
- Present proposals for mitigating any damage and nuisance caused by the chosen disposal alternatives.

The parameters studied in the environmental impact assessment fall generally into two main categories as listed below.

Environmental Impacts

- Energy
- Releases (emissions) to atmosphere
- Releases (discharges) to sea, water, or ground
- Physical impact on the environment
- Aesthetic impact including noise, smell and visual effects
- Waste/resources management
- Littering

Social / Community Impacts

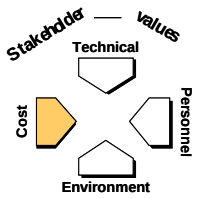
- Fisheries
- Free passage at sea
- Costs and national supply
- Employment effects
- Other social impacts

Some of these environmental impacts can be quantified, but where this has not been possible, qualitative assessments have been made based upon consideration of the scale of the effect and its value or sensitivity. Where qualitative judgements have been used, the impacts are presented using a series of categories ranging from “Very large positive” impact through “Insignificant/No” impact to “Very large negative” impact.

The overall environmental impact of a particular disposal alternative has been judged based upon the impact on the individual parameters listed above. The significance of both the overall and the individual impacts has been assessed from both the short term and long term perspective. The Environmental Impact Assessment has been peer reviewed by independent experts in The Netherlands.

Cost

The estimated cost of the various disposal alternatives considered has been based upon studies performed by several different consultants in both Norway and the UK, using appropriate current rates and norms. Independent consultants in the UK, Denmark and Norway have also been used to verify the estimated costs and experts within TOTAL in France have performed additional validation.



The costs presented for the different disposal alternatives are expressed in year 2002 money terms and represent a 50/50 estimate.

Overall Evaluation

The recommended disposal arrangements for the Frigg Field platforms, infield pipelines and cables, and drill cuttings have been arrived at following assessment of both short term and long term conditions. The recommendations are based upon judgements involving working environment, safety, environmental, technical and financial aspects, made on the basis of the best available information, and feedback from public consultation.

6.4 Risk Acceptance Principles

The general principles of risk management used within TOTAL, and industry as a whole, apply equally during decommissioning and disposal activities as during field development and production operations.

The following risk acceptance criteria have therefore been considered when assessing the various disposal alternatives (Ref. 6.1). For a definition of the various terms used see Section 6.3).

Personnel Risk

The risk of fatality for an individual shall not be greater than **1 x 10^{-3} per year** (1 in 1000) and **shall be as low as reasonably practicable.** This criterion is in accordance with generally accepted principles applied throughout industry and supported by the UK Health and Safety Executive (Ref.6.2). 1 in 1000 is the highest risk that can be tolerated and, in practice, a personnel risk level considerably lower than this is sought for all operations in accordance with the principle that risks should be as low as reasonably practical.

For a "normal" offshore worker who spends approximately 3000 hours a year offshore, an average yearly risk of fatality of 1 in 1000 is equivalent to a Fatal Accident Rate of 33**.** This is **the highest risk that can be tolerated and a risk considerably less than this must be sought.**

As a basis for assessing the acceptability of fatality risks during the decommissioning activities it may be noted that the average Fatal Accident Rate for personnel on Frigg Central Complex during 2000, **as predicted by quantitative risk analysis**, was approximately 4.

There have however been no fatalities on Frigg Field in the last 20 years, so the **actual fatal accident rate** for Frigg Field (as opposed to the predicted value) for this period is zero.

The average Fatal Accident Rate for personnel on production platforms in the Norwegian sector of the North Sea, based upon experience in the last ten years, is currently 1.3. This rate has changed very little over the last ten years. In 1990 the ten-year average fatal accident rate was 1.8.

Environmental Impact

The method used for assessing non-quantifiable environment impacts is described below based upon the method of categorisation shown in Figure 6.1. The method was developed by DNV and ASPLAN and further details are given in Section 3.3.1.of the Environmental Impact Assessment forming Part 2 of this Frigg Field Cessation Plan.

The assessment distinguishes the important impacts from those that are less important. This is done by considering the effect of an impact in the area in which it is occurring ("value" or "sensitivity"), combined with the scope of the effect, to arrive at the total impact. By using this method the same magnitude of effect may then give different impacts depending on the value or sensitivity of the impacted environmental component. Additionally, the same type of effect will give a different impact depending on the sensitivity of the recipient/environment. This is considered by DNV to be a sound basis for assessing and presenting the impacts.

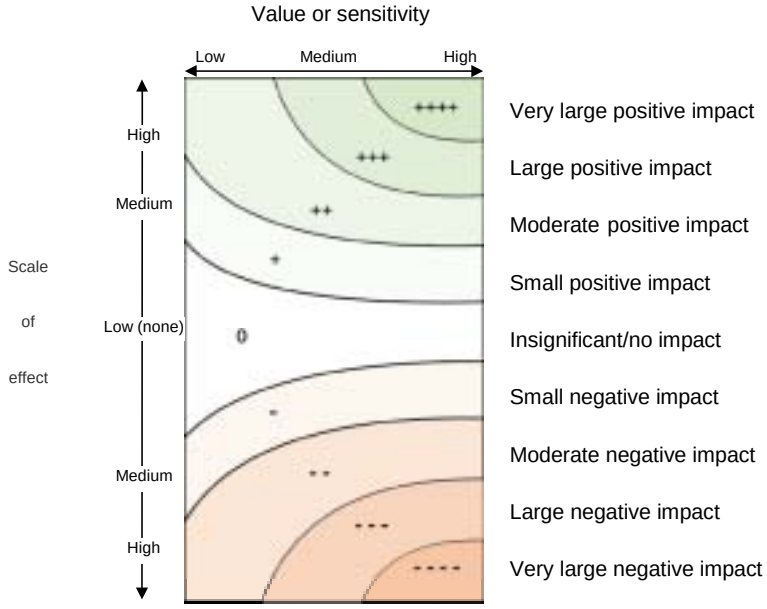


Figure 6.1 Methodology for Assessment of Non-Quantifiable Impacts.

When the terms defined in this figure are used in the text of this Frigg Field Cessation Plan, they are shown in inverted commas, as for example, “Moderate Negative” impact.

Technical Risk

The technical feasibility associated with an operation, or series of activities, may be expressed as the likelihood of being unable to complete the work as planned. There may be many reasons why it is impossible to complete the operation, including uncertainties in the original conditions, inappropriate or inadequate methods, or accidents due to failure of materials or equipment or due to human error. The risk of being unable to complete an operation or activity as planned is referred to as “**technical risk”**.

The consequences of being unable to complete an operation, or activity, as planned are normally expressed in terms of financial loss. The financial loss my result from delay, additional works, repairs and remedial works or replacement of facilities or equipment. For any operation there will normally be a number of possible consequences of differing seriousness, each with their own probability of occurrence. The acceptability of a technical risk is therefore based upon the acceptability of the estimated financial loss and other associated factors.

Criteria have been used within TOTAL for a number of years to limit the risk of financial loss arising from differing levels of damage to offshore platforms. These risk acceptance criteria have been adopted as the basis for determining the acceptability of technical risk during the decommissioning of the Frigg Field facilities.

Based upon these criteria, the maximum acceptable probability of a major accident during the decommissioning operations (with the associated large financial loss) has been set as 1 x 10^{-3} (1 in 1000).

This figure is in-line with the guidance contained in Part 1 of the “Rules for Planning and Execution of Marine Operations” published by Det Norske Veritas in January 1996 (Ref. 6.3). In these rules DNV state that it was not possible to set a definitive acceptable risk level for marine operations at that time, due to the scarcity of data. DNV further state that they will seek further data and that **“A probability of total loss equal to or better than 1/1000 per operation will then be aimed at.”** These same rules indicate that during marine operations a

probability of **structural** failure ten times less than this (that is 1 in 10,000) should be aimed at.

In the 1970s when the Frigg Field installations were constructed and installed quantitative risk analysis was not in general use and the necessary computational methods and tools were not available to allow a full quantitative assessment of the risks during the installation process. It is therefore not possible to directly compare the risks during the decommissioning phase with those experienced during installation.

If TOTAL NORGE were to install a new platform at the present time the probability of a major accident during the installation operations would need to be less than 1 in 1000, as indicated in the DNV Rules referenced above. In addition, the probability of structural failure during the installation operations would need to be less than 1 in 10,000 also as indicated in the DNV Rules. In actual fact, risk levels considerably lower than these values would be sought in accordance with the general risk acceptance principles defined in TOTAL standards.

Section References

6.1 “Principles for Risk Control and Acceptance Criteria”, TFEE Norge Report, Ref. 311SEQ/93/610, Revision 1, dated October 1997 DocsOpen 122880.

6.2 “The Tolerability of Risk from Nuclear Power Stations”, UK Health and Safety Executive Report, ISBN 0 11 886368 1, Dated 1988, Revised 1992.

6.3 “Rules for Planning and Execution of Marine Operations”, Det Norske Veritas, January 1996

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7. Assessment of Reuse Potential

7.1 Possible Oil and Gas Reuse in Place

7.1.1 Reuse as a Treatment Centre for Adjacent Fields

Since the early 1980s extensive efforts have been made to prolong the operational life of the Frigg Field facilities. These efforts have resulted in the development of the North East Frigg, East Frigg, Lille Frigg, and Frøy satellite fields in the Frigg area. The satellite fields have been developed using subsea production systems or, as in the case of Frøy, a not-normally-manned platform. Production from these satellite fields has been routed to Frigg Central Complex where it has been processed. The gas was then exported to the UK through the Frigg to St Fergus pipelines and, since 1994 the oil has been exported to Norway through Frostpipe. All of these satellite fields are no longer in production.

In addition, the Frigg Field facilities were used to process and export gas from Esso's Odin Field in the Norwegian Sector. Production from Odin started in 1984 and terminated in 1994.

In 1985 a 24" diameter pipeline was laid between the Alwyn Field in the UK sector and Frigg. Since then, gas from Alwyn has been received on TP1 and after metering and pressure/flow control has been exported to St. Fergus via the Frigg UK Pipeline (PL 7). Production from Alwyn is scheduled to continue for a number of years after the cessation of production from the Frigg reservoir. There is no requirement for any treatment of the Alwyn gas on Frigg and therefore it is planned to make a direct subsea connection between the Alwyn export pipeline and the Frigg UK Pipeline (see following section). The subsea tie-in will allow the export of gas from Alwyn to the UK without the need for pigging facilities, flow control or treatment on TP1.

A significant investment has been made in exploration in the Frigg area, seeking hydrocarbon reservoirs that could be developed using the Frigg Field facilities. At present there are no other known reservoirs in the area that can be economically developed from Frigg. In addition, the prospect for new developments in the area is limited. The operators of a number of discoveries in the Norwegian and UK sector of the North Sea have also been approached regarding the possible use of the Frigg Field facilities. None of these approaches has lead to the prospect of continued use for Frigg.

It is therefore concluded that the continued use of the Frigg Field facilities as a treatment centre is neither likely, nor economically viable.

7.1.2 Reuse as a Pipeline Export Centre

At present, Frigg is the starting point for three different export pipelines, namely the two 32" gas pipelines to St. Fergus in Scotland (known as the Frigg Transportation System), and the 16" Frostpipe oil pipeline to the Oseberg platform from where the oil is routed to the Sture terminal in Norway. Arrangements for the continued use of these pipelines, after cessation of production from the Frigg Field, have been extensively studied as part of field development studies.

It has been concluded from these studies that using the Frigg Field installations purely as an export centre connecting the different pipelines was not economically attractive. The technology to allow subsea connections of the pipelines is now well proven and thus an arrangement of pipelines which by-passes the Frigg Field installations has been selected. The future interconnection of the pipelines is shown in Figure 7.1.

The Vesterled pipeline from Heimdal was connected into the Frigg Norwegian Pipeline during Summer 2001 at a point approximately 50km west of the Frigg Field. The section of the Frigg Norwegian Pipeline between the tie-in point and the Frigg Field was at the same time connected into the Vesterled tie-in to allow the continuing export of gas from Frigg. Following

cessation of production from Frigg in 2004, the section of pipeline connecting with Frigg will be disconnected at the Vesterled tie-in point. During 2004 it is also planned to connect the Alwyn pipeline into the Frigg UK Pipeline (PL 7), at a point approximately 3 km west of the Frigg Field.

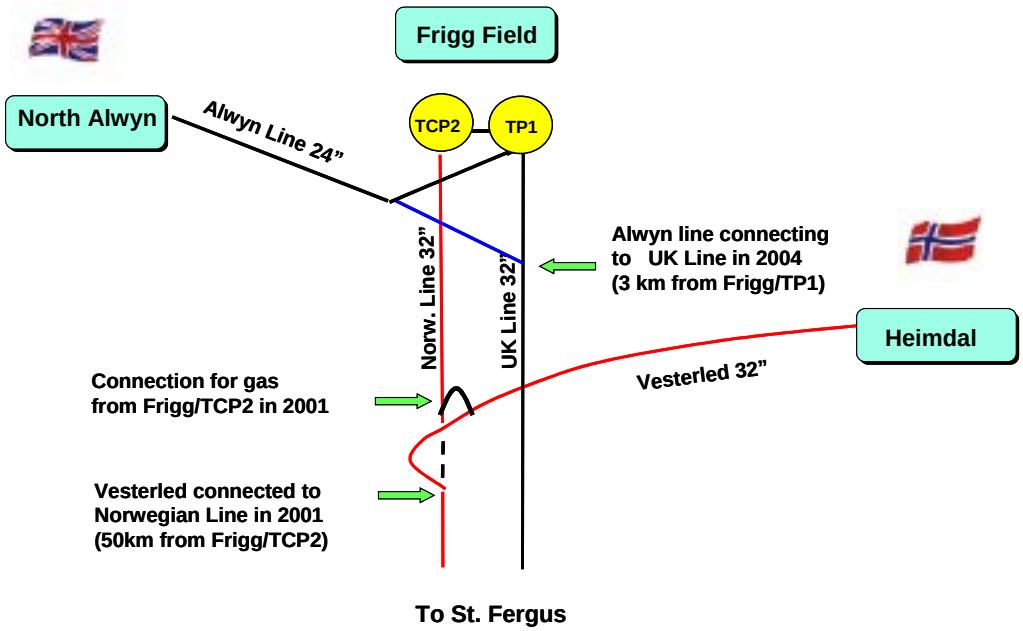

Figure 7.1 Arrangement for connecting the Alwyn and Vesterled Pipelines into the Frigg Transportation System by-passing the Frigg Installations

7.2 Possible Non Oil and Gas Reuse in Place

The following non oil and gas reuse alternatives have been specifically evaluated for the Frigg-Field installations:-

- Artificial Reefs
- Wind-generators
- Emission-Free Gas Fired Power Plants

The findings from these specific studies are summarised in the sub-sections 7.2.1, 7.2.2 and 7.2.3.

As a partner in the Ekofisk Field, TOTAL NORGE has been actively involved in reviewing, and considering the non oil and gas reuse studies commissioned by the operator of the Ekofisk Field. The studies are very extensive and contain a great deal of information. The results of these Ekofisk studies have been further reviewed to see if there are any reuse ideas that might be relevant to Frigg Field. The conclusions from this review are detailed in Section 7.2.4.

7.2.1 Artificial Reef

The following four alternative arrangements have been studied (Ref. 7.1) :-

- Star shaped reef for habitat/fish stock protection
- Clustered reef for habitat/fish stock protection
- A reef formed in a line for trawl fishing enhancement
- Substructures toppled in-situ for mainly economic reasons.

The studies show that none of the artificial-reef alternatives are likely to have a great enhancement effect on pelagic fishery, or a significant positive impact on the total marine environment.
The establishment of an artificial reef is only considered to be a favourable option if clearly positive effects can be shown. In view of the findings of the studies, it is concluded that the use of the installations as artificial reefs is not a desirable reuse alternative.

7.2.2 Wind-generators

The aim of the wind-generator study has been to investigate the possibility of utilising the redundant Frigg Field concrete substructures, CDP1, TP1 and TCP2 as foundations for offshore wind-generators (Ref. 7.2). The study has been based upon the export of the electrical power to the Heimdal Platform.

The study has shown that it is technically feasible to supply power from wind-generators located on the Frigg Field concrete substructures to Heimdal via subsea cables. This conclusion is also considered to be valid in respect to the supply of electricity to other platforms in the Frigg area.

The economic viability of offshore electricity generation based on wind-power systems depends upon its cost relative to electricity generation based on the combustion of hydrocarbons. The price of electricity generated by offshore wind power systems has been estimated to be considerably higher than the cost of electricity generated from hydrocarbons, even taking account of the tax levied on CO_2 emissions in the Norwegian Sector (Ref.7.3).

It is therefore judged that electricity generated by offshore wind-generators at Frigg would not be competitive in the energy market, even if the cost of production could be significantly reduced. The cost uncertainties associated with the conversion and maintenance of the aging Frigg installations and their logistical support, also mitigate strongly against their use as wind-generators

It should also be noted that any consumer of wind generated electrical power would need to install and maintain a back-up source of power for times when there is insufficient wind to meet the required power demand.

The export of wind-generated electricity from Frigg to shore is not economically viable due to the operating cost and the high cost of the transmission system to shore. (Frigg is 190 km from the Norwegian coast and 360 km from the Scottish coast.)

The reuse of the Frigg Field platforms as foundations for offshore wind-generators is therefore judged not to be viable at the present time.

7.2.3 Emission-Free Gas-Power Plant

The installation of an emission-free gas-fired power plant on the existing Frigg Field platforms has been studied based upon different gas supply scenarios (Ref. 7.4). It is assumed in the study that the electricity generated would be exported to other platforms in the area by subsea cable. The gas (CO_2/Nitrogen) from the power generation process would be exported, via pipelines, to fields in the area for use in reservoir pressure support and enhanced oil recovery.

The emission-free gas power plant scheme envisaged incorporates an oxygen/nitrogen separation plant located on one of the Frigg platforms with the main power generation plant located on an adjacent bridge-linked platform.

Although the reuse of the Frigg Field platforms as an electrical power plant is considered to be technically feasible in principle, it has been concluded that such an option should not be pursued further, due to the following reasons:-

- There are a number of technical uncertainties surrounding the concept as it is still only at the pilot-scheme stage. The estimated capital cost of such a project therefore has to reflect this level of technical uncertainty.

- Although the cost figures are still somewhat uncertain it seems likely that there would not be a market for the electricity and gas at the price necessary to ensure commercial viability. This conclusion is valid even ignoring the cost of additional back-up power supplies that may be required by the electricity consumer. There will also be a significant financial risk associated with the continuing maintenance and logistical support of the aging structures.

- Although the concept is emission-free, large quantities of high-temperature cooling water would be discharged into the sea. There is no practical possibility of recovering and using this energy and thus the energy balance for such a scheme is not environmentally attractive.

7.2.4 Ekofisk Studies

As a partner in the Ekofisk Field, TOTAL NORGE has reviewed the studies that were carried out during the preparation of the Ekofisk 1 Environmental Impact Assessment, to assess whether the results are applicable to the Frigg Field. A significant number of potential reuse options were evaluated during the Ekofisk studies, but no economically viable in-situ reuse alternatives were identified.

Although there are significant differences between the Ekofisk installations and infrastructure and the Frigg Field, it has been has concluded that the findings of the Ekofisk studies are nevertheless applicable to the Frigg Field.

The options studied included:-
- Wave power
- Aquaculture
- Centre of communication and navigation
- Meteorology station
- Training centre for divers
- Launching base for research missiles
- Rescue and standby centre
- Marine research

The specific Frigg studies detailed in the preceding sections, together with the Ekofisk studies, are therefore considered to provide a thorough assessment of the possible non oil and gas reuse options for the Frigg Field facilities.

7.3 Reuse of the Frigg Field Facilities at Another Location

7.3.1 Reuse of Steel Substructures

The Frigg Field steel substructures will be nearly 30 years old when production from the Frigg reservoir ceases. The reuse potential for these substructures is rather limited and requires that they can be safely removed without damage. Efforts have however been made to identify possible reuses applications. These efforts will continue until the platforms are removed. It must also be remembered that the Frigg Field steel substructures were all installed by launching from a barge and were not designed to be lifted as a single unit. Extensive analytical, inspection and survey work would be needed before it was possible to say whether the steel substructures could be removed as a single unit for possible use elsewhere.

At present no suitable reuse potential for the QP, DP2 and DP1 steel substructures has been identified.

7.3.2 Reuse of Concrete Substructures

The technical feasibility of removing and relocating the concrete substructures is very questionable and has been carefully evaluated. There is a high level of uncertainty surrounding the necessary refloat operations, as detailed in Section 9.

However, a general assessment of the potential reuse opportunities has been carried out and possible scenarios established. One option, that could provide added value to society, is to use the concrete substructures as bridge foundations for fjord crossings. Such a use has the potential to provide cost savings on the bridge construction cost. The concrete substructures could also be incorporated into some form of quay foundation or be used as landfill for industrial purposes.

The feasibility of such schemes does however depend entirely upon the ability to safely re-float the substructures, which were not designed specifically for removal at a future date. The studies reported in detail in Section 9 indicate that for all the concrete substructures there is a unacceptable risk that a major accident or incident could occur during an attempted refloating operation that would prevent the operations being successful. There would also be risks associated with towing to a new location and installation which are not possible to quantify at present.

7.3.3 Reuse of Parts of the Frigg Field Topsides

In the absence of any reuse potential for the Frigg Field facilities as a whole, the possibility of using parts of the facilities has been considered. An evaluation has been made to assess whether it is viable to dismantle large parts of the facilities and reuse them at another location.

The original equipment on Frigg was constructed and installed in the mid 1970s. The possibility of being able to reuse the twenty five year old equipment is not considered to be very high.

The equipment installed in 1993 and 1995 for the development of the Lille-Frigg and Frøy fields is considered to have a higher reuse potential (Ref. 7.5). Strenuous attempts are therefore being made to reuse this equipment as part of a package including the Frøy Wellhead Platform and the Frigg flare boom. Specialists have been engaged to assist with this work and a series of pioneering initiatives have been taken to market this equipment worldwide, including advertising on the Internet and the distribution of 35,000 CD ROMs containing information about the facilities.

The reuse potential of all the Frigg Field equipment has been assessed in order that specific items may be specially preserved when they are taken out of service (Ref. 7.5).

7.4 Conclusion

None of the arrangements for the reuse of the Frigg Field facilities in their current location are judged to be economically viable at the present moment. There are also a number of technical uncertainties associated with many of the possible reuses. None of the Frigg Field Licensees see any further use for the Frigg Field facilities.

No potential reuse application has been identified for the three Frigg Field steel substructures at another location. In addition, the uncertainties inherent in trying to refloat the three Frigg Field concrete substructures (as described in Section 9) mean that it is not possible to reuse them at another location.

There are possibilities for the reuse of parts of the topside equipment, and TOTAL NORGE will continue to actively pursue these possibilities. It must however be remembered that the age of the equipment and structures, and the uncertainties associated with their ongoing maintenance and logistical support, reduce their reuse potential.

Section References

7.1 "Frigg Reef - Feasibility Study for an Artificial Reef on the Frigg Field", Report by Dames and More and Rogaland Research, Revision 0, dated 07.11.1999 DocsOpen 99662.

7.2 "Wind Power Study for the Frigg Field", Kjeller Vindteknikk Report, dated 30.06.2000 DocsOpen 105738.

7.3 "Cost Estimate – Wind Power at Frigg", TFEE Norge Report, dated 21.08.2000 Ref. DocsOpen 104902.

7.4 "Emission-Free Power Generation at Frigg", Aker Maritime Report, Ref. 58766-AE-A-001, dated 30.06.2000 DocsOpen 104348.

7.5 "The Reuse of Frøy Facilities and Equipment from Frigg", Valiant Report, Ref. VI-99-ER-0064, dated 19.11.1999 DocsOpen 99541.

8. Steel Platforms - Evaluation of Disposal Arrangements

8.1 Introduction

The possible reuse of the Frigg Field facilities in their existing location has been investigated, as detailed in Section 7. It has not been possible to identify any economically viable scheme for re-using the Frigg Field steel platforms at their existing locations. Further studies have therefore been carried out to consider their removal and disposal.

In accordance with Norwegian and UK regulations, and OSPAR Decision 98/3, full removal and onshore disposal of the topsides and steel substructures of QP and DP2 platforms and the wreck of DP1 has been the only option considered.

The studies detailed in this section describe the methods planned to be used to remove these platforms, evaluate the environment impact and estimate the risk to personnel and the cost of undertaking the work. **The evaluations are presented on a platform-by-platform basis, considering the relevant aspects for both the topsides and the steel substructure.**

The contents of Section 8.2 “Quarters Platform QP” and Section 8.3 “Drilling Platform DP2” are arranged as shown in Figure 8.1. As there are no topsides installed on the wreck of DP1, only the substructure assessment is included in Section 8.4 “Drilling Platform DP1”.

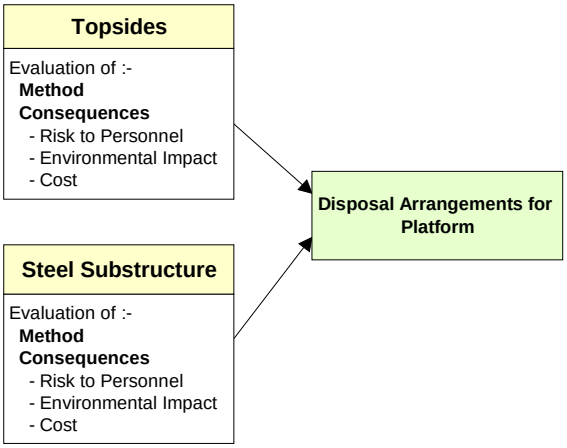

Figure 8.1 Evaluation of Disposal Arrangements for Platforms QP, DP2 and DP1

8.2 Quarters Platform - QP

8.2.1 QP Topsides

8.2.1.1 Method

Various methods of removing the topsides of platform QP and transporting them to shore have been evaluated and all the methods considered were found to be technically feasible (Ref. 8.1, 8.2 and 8.3). It is considered possible to remove the two living quarters modules and the deck as a single lift following the removal of a number of ancillary items such as the communications tower; heli-hanger; communications room; heli-fuel tanks; crane boom and rig office. Alternatively, the separate modules and the deck could be lifted individually from the platform. Lifting could be undertaken using a range of available crane barges and the topside sections transported to shore either on cargo barges or on the deck of the crane barge itself. The bridge between QP and TP1 would be removed prior to removing the QP topsides. Once onshore, as much of the equipment and materials as practicable would be reused or recycled.

No major problems affecting the feasibility of the removal and onshore disposal of QP topsides have been identified at this initial stage. It has therefore not been considered necessary to make a quantitative estimate of the technical risk associated with the disposal of the QP topsides. It is however anticipated that the work will be challenging and all the operations will need to be very carefully engineered and controlled.

8.2.1.2 Consequences

Risk to Personnel

The risk to personnel undertaking the removal and disposal of QP topsides has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref.8.4). The predicted number of fatalities and major injuries expressed in statistical terms are shown in Table 8.1 below. A definition of the terms used in this table is given in Section 6.3.

Predicted number of fatalities (Potential Loss of Life)	0.03 (0.0273) See note
Probability of a Fatality	3%
Predicted number of major injuries (Potential Major Injuries)	1.2
Probability of a Major Injury	70%

Note:- The PLL value shown has been rounded to the nearest percentage point. The actual calculated value is shown in parenthesis for comparison purposes.

Table 8.1 Estimated Risk to Personnel during Removal and Disposal of QP Topsides

Environmental Impact

The environmental impact of removing the topsides of QP may be found in Section 7 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. A summary of the findings is given in Table 8.2.

Parameter	Value
Energy Consumption (1000 GJ)	81
Total Energy Impact (1000 GJ)	81
CO_2 Emissions (1000 tonne)	7
Discharges to sea	None/insignificant
Physical impact on environment / habitat	None/insignificant
Aesthetic impact	Moderate negative
Material management	Large positive
Littering	None/insignificant
Impacts on fisheries	None/insignificant
Impacts on free passage at sea	None/insignificant

Table 8.2 Environmental Impact of Removal and Disposal of QP Topsides

Cost
The estimated cost of the removal, transportation and onshore disposal of Platform QP topsides has been estimated to be 275 MNOK / £21.1m.

8.2.2 QP Steel Substructure

8.2.2.1 Method

The QP steel substructure was installed by launching from a barge and was not designed to be lifted as a single unit. On the basis of studies undertaken to date (Ref. 8.1, 8.3) the planned method of removal for the steel substructure of QP would be to cut it into three large sections and a number of smaller pieces. The top section of the steel substructure would first be cut free and then lifted by a crane vessel onto a cargo barge. A number of small sections would then be cut out and lifted onto the cargo barge and the lower section of the main structure cut into two pieces. Lastly the steel piles supporting the substructure would be cut at a suitable depth below the seabed and the two lower sections of the steel substructure would then be lifted separately onto a cargo barge by the crane vessel. All the sections of the substructure would then be transported to the disposal yard where they would be cut up and the materials recycled.

The structural members and the steel piles would be cut using either diamond wire or abrasive water jetting techniques. Cutting of the substructure below sea level would be undertaken using remotely operated vehicles deployed and controlled from a work vessel.

Following the work, debris on the seabed would be removed as described in Section 12.

No major problems affecting the technical feasibility of the removal and onshore disposal of QP steel substructure have been identified at this initial stage. It has therefore not been considered necessary to make a quantitative estimate of the technical risk associated with the disposal of the QP steel substructure. The work will however involve complicated offshore operations for which there is only limited experience. It will therefore be essential that there is great attention to detail during the engineering phase and effective control during the offshore work phase.

8.2.2.2 Consequences

Risk to Personnel
The risk to personnel undertaking the removal and disposal of QP steel substructure has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 8.4). The predicted number of fatalities and major injuries expressed in statistical terms are shown in Table 8.3. A definition of the terms used in this table is given in Section 6.3.

Predicted number of fatalities (Potential Loss of Life)	0.01 (0.0129) See note
Probability of a Fatality	1%
Predicted number of major injuries (Potential Major Injuries)	0.8
Probability of a Major Injury	55%

Note:- The PLL value shown has been rounded to the nearest percentage point. The actual calculated value is shown in parenthesis for comparison purposes.

Table 8.3 Estimated Risk to Personnel during Removal and Disposal of QP Steel Substructure

Environmental Impact
The environmental impact of removing the steel substructure of QP may be found in Section 8 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. A summary of the findings is given in Table 8.4 below

Parameter	Value
Energy Consumption (1000 GJ)	140
Total Energy Impact (1000 GJ)	140
CO_2 Emissions (1000 tonne)	11
Discharges to sea	None/insignificant
Physical impact on environment / habitat	Insignificant/Small negative
Aesthetic impact	Moderate negative
Material management	Large positive
Littering	None/insignificant
Impacts on fisheries	Moderate positive
Impacts on free passage at sea	Moderate positive

Table 8.4 Environmental Impact of Removal and Disposal of QP Steel Substructure

Cost
The estimated cost of the removal, transportation and onshore disposal of Platform QP steel substructure has been estimated to be 276 MNOK / £21.1m.

8.2.3 Disposal Arrangements for Platform QP

The studies undertaken indicate that conventional offshore methods of working may be used to remove the QP topsides and steel substructure. The removal of the steel substructure will however involve procedures, equipment and operations that, at present, have not been widely used in the North Sea. It is considered possible to undertake the majority of the underwater construction/demolition work using remotely operated work vehicles and thus it is believed that the work can be carried out without excessive risk to personnel. Divers may have to be used for specific tasks but strict procedures will be used together with appropriate risk reducing measures to ensure that risks are as low as reasonably practicable.

The impact on the environment of removing the topside and steel substructure of QP platform has been judged to be generally low. The impact on fisheries and the free passage of vessels is “moderate positive” and there is a “large positive” effect arising from the reuse of the steel. The aesthetic impact is judged to be “moderate negative” during the onshore cleaning and demolition of the structures and a “small/insignificant” effect on the physical habitat offshore is predicted during the removal operations.

In accordance with national regulations and international conventions, the topside and steel substructure of QP platform will be removed and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The work will be undertaken using the most appropriate techniques and best environmental practice.

8.3 Drilling Platform - DP2

8.3.1 DP2 Topsides

8.3.1.1 Method

Alternative methods of removing the modules and deck that form the topside of platform DP2 have been investigated (Ref. 8.3, 8.5, 8.6). Based upon technical, schedule and cost considerations, it is considered that the most effective method would be to remove the topside elements using a procedure that is essentially the reverse of the installation sequence.

The modules, and deck, would therefore be lifted off the steel substructure using a crane vessel and placed on a cargo barge, or barges, for transportation to shore. Lifting could be undertaken using a range of available crane barges. Depending upon the crane vessel used for the lifting operations, it might be cost effective to transport the topside elements to shore on the deck of the crane barge itself.

Once onshore, as much of the equipment and materials as practicable will be reused or recycled.

No major problems affecting the feasibility of the offshore removal operations and onshore disposal of DP2 topsides have been identified at this initial stage. It has therefore not been considered necessary to make a quantitative estimate of the technical risk associated with the disposal of the DP2 topsides. It is however anticipated that the work will be challenging and all the operations will need to be very carefully engineered and controlled.

8.3.1.2 Consequences

Risk to Personnel

The risk to personnel undertaking the removal and disposal of DP2 topsides has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 8.4). The predicted numbers of fatalities and major injuries expressed in statistical terms are shown in Table 8.5 below. A definition of the terms used in this table is given in Section 6.3.

Predicted number of fatalities (Potential Loss of Life)	0.02 (0.0225) see note
Probability of a Fatality	2%
Predicted number of major injuries (Potential Major Injuries)	1.1
Probability of a Major Injury	67%

Note:- The PLL value shown has been rounded to the nearest percentage point. The actual calculated value is shown in parenthesis for comparison purposes.

Table 8.5 Estimated Risk to Personnel during Removal and Disposal of DP2 Topsides

Environmental Impact
The environmental impact of removing the topsides of DP2 may be found in Section 7 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. A summary of the findings is given in Table 8.6 below.

Parameter	Value
Energy Consumption (1000 GJ)	95
Total Energy Impact (1000 GJ)	95
CO_2 Emissions (1000 tonne)	8
Discharges to sea	None/insignificant
Physical impact to environment / habitat	None/insignificant
Aesthetic impact	Moderate negative
Material management	Large positive
Littering	None/insignificant
Impacts on fisheries	None/insignificant
Impacts on free passage at sea	None/insignificant

Table 8.6 Environmental Impact of Removal and Disposal of DP2 Topsides

Cost
The estimated cost of the removal, transportation and onshore disposal of Platform DP2 topsides has been estimated to be 250 MNOK / £19.1m.

8.3.2 DP2 Steel Substructure

8.3.2.1 Method

The DP2 steel substructure was installed by launching from a barge and was not designed to be lifted as a single unit. Various schemes for removing the DP2 steel substructure have been considered, most of which are judged to be technically feasible (Ref. 8.3, 8.6). The choice of method has therefore been determined to ensure a high level of safety at the minimum cost for the overall Frigg Field decommissioning project.

Before starting the removal work for the steel substructure the wells will be plugged and the well equipment removed down to a point at least 2m below the seabed.

At present it is planned to remove the 24 well conductors first and then to cut the steel substructure into three sections. The top section of the steel substructure would be lifted by a crane vessel and loaded onto a cargo barge. The two lower sections of the steel substructure would then be cut and lifted separately by the crane vessel after the steel piles have been cut at a suitable depth below the seabed. All three sections of the steel substructure would be transported to the disposal yard where they will be cut up and the materials recycled. The sections of steel pile above the cut line would be removed together with the steel substructure.

The structural members and the steel piles would be cut using either diamond wire or abrasive water jetting techniques. Cutting of the substructure below sea level would be undertaken using remotely operated vehicles deployed and controlled from a work vessel.

Debris on the seabed following the decommissioning work would be removed as described in Section 12.

No major problems affecting the feasibility of the offshore removal operations and onshore disposal of the DP2 steel substructure have been identified at this initial stage. It has therefore not been considered necessary to make a quantitative estimate of the technical risk associated with the disposal of the DP2 steel substructure. The work will however involve complicated offshore operations for which there is only limited experience. It will therefore be essential that there is great attention to detail during the engineering phase and effective control during the offshore work phase.

8.3.2.2 Consequences

Risk to Personnel

The risk to personnel undertaking the removal and disposal of DP2 steel substructure has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 8.4). The predicted numbers of fatalities and major injuries, expressed in statistical terms, are shown in Table 8.7 below. A definition of the terms used in this table is given in Section 6.3.

Predicted number of fatalities (Potential Loss of Life)	0.02 (0.0151) See note
Probability of a Fatality	2%
Predicted number of major injuries (Potential Major Injuries)	0.9
Probability of a Major Injury	59%

Note:- The PLL value shown has been rounded to the nearest percentage point. The actual calculated value is shown in parenthesis for comparison purposes.

Table 8.7 Estimated Risk to Personnel during Removal and Disposal of DP2 Steel Substructure

Environmental Impact

The environmental impact of removing the steel substructure of DP2 may be found in Section 8 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. A summary of the findings is given in Table 8.8.

Parameter	Value
Energy Consumption (1000 GJ)	260
Total Energy Impact (1000 GJ)	260
CO_2 Emissions (1000 tonne)	22
Discharges to sea	Moderate negative
Physical impact on environment / habitat	Insignificant /Small negative
Aesthetic impact	Moderate negative
Material management	Large positive
Littering	None/insignificant
Impacts on fisheries	Moderate positive
Impacts on free passage at sea	Moderate positive

Table 8.8 Environmental Impact of Removal and Disposal of DP2 Steel Substructure

Cost
The estimated cost of the removal, transportation and onshore disposal of Platform DP2 steel substructure has been estimated to be 446 MNOK / £34.1m.

8.3.3 Disposal Arrangements for Platform DP2

The studies undertaken indicate that conventional offshore methods of working may be used to remove the DP2 topsides and steel substructure. The removal of the steel substructure will however involve procedures, equipment and operations that, at present, have not been widely used in the North Sea. It is considered possible to undertake the majority of the underwater construction/demolition work using remotely operated work vehicles and thus it is believed that the work can be carried out without excessive risk to personnel. Divers may have to be used for specific tasks but strict procedures will be used together with appropriate risk reducing measures to ensure that risks are as low as reasonably practicable.

The impact on the environment of removing the topside and steel substructure of DP2 platform has been judged to be generally low. The impact on fisheries and the free passage of vessels is “moderate positive” and there is a “large positive” effect arising from the reuse of the steel. The aesthetic impact is judged to be “moderate negative” during the onshore cleaning and demolition of the structures. A “moderate negative” impact on the physical habitat offshore is predicted during the removal operations due to the disturbance of the seabed when cutting the steel piles. This arises due to the presence of a thin layer of drill cuttings on the seabed around and under the platform.

In accordance with national regulations and international conventions the topside and steel substructure of DP2 platform will be removed and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The work will be undertaken using the most appropriate techniques and best environmental practice.

8.4 Drilling Platform – DP1

8.4.1 Steel Substructure Wreck

8.4.1.1 Method

The steel substructure for platform DP1 was damaged during installation in 1974. The substructure is resting on the seabed but is not secured to the seabed by steel piles. The substructure is in a damaged condition due to the original installation accident and the subsequent effect of storms. No topsides were installed on the steel substructure.

OSPAR Decision 98/3 contains specific provisions that allow a derogation to be granted in the case of a structure that is damaged or has deteriorated. Notwithstanding these provisions, various engineering studies have been carried out in order to assess whether it is technically feasible to completely remove the DP1 steel substructure and thereby achieve a clean seabed in the area (Ref. 8.3, 8.7 to 8.10).

Many different removal schemes have been studied including re-floating, lifting as a single unit and removal in sections. Uncertainty regarding the exact condition of the structure suggests that the refloating alternative and the single lift alternative would be particularly difficult and hazardous. These methods of removal are therefore not considered to be advisable. Cutting the structure into a number of sections prior to removal is considered to be feasible and the most practical method of removal.

It is therefore planned to remove the DP1 steel substructure by cutting it into a number of sections that would each be lifted to the surface by a crane vessel. The removed sections of the steel substructure would then be transported to shore on cargo barges. Alternatively the steel sections might be lifted onto the deck of the crane barge for transport to shore. Before the main members are cut, various ancillary steel items such as the buoyancy tanks and “non-critical” structural members would be removed.

The structural members would be cut using either diamond wire or disc saw techniques or abrasive water jetting. Divers will only be used if absolutely necessary and then only after carrying out careful assessments to ensure that their safety is not compromised.

All the sections of the substructure that are brought onshore will be cut up and the materials recycled.

The condition of the substructure gives rise to a number of uncertainties which mean that the exact removal sequence may need modification as further information becomes available.

Matters of particular concern are; the condition of some members and nodes; the weight of the structure; and the method of removing the lower sections of the substructure that are partially buried in the seabed. The engineering phase will be particularly challenging in order to ensure that safe and effective operations are planned. It is also particularly important that extreme care is exercised during the removal process to minimise the risk to the personnel involved.

Debris on the seabed following the work would be removed as described in Section 12.

8.4.1.2 Consequences

Risk to Personnel

The risk to personnel undertaking the removal and disposal of DP1 steel substructure has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 8.4). The predicted numbers of fatalities and major injuries, expressed in statistical terms, are shown in Table 8.9 below. A definition of the terms used in this table is given in Section 6.3.

Predicted Number of Fatalities (Potential Loss of Life)	0.02 (0.0247) See note
Probability of a Fatality	2%
Predicted number of major injuries (Potential Major Injuries)	1.5
Probability of a Major Injury	78%

Note:- The PLL value shown has been rounded to the nearest percentage point. The actual calculated value is shown in parenthesis for comparison purposes.

Table 8.9 Estimated Risk to Personnel during Removal and Disposal of the Wreck of DP1 Steel Substructure

Environmental Impact

The environmental impact of removing the wreck of the steel substructure of DP1 may be found in Section 8 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. A summary of the findings is given in Table 8.10 below.

Parameter	Value
Energy Consumption (1000 GJ)	193
Total Energy Impact (1000 GJ)	193
CO_2 Emissions (1000 tonne)	16
Discharges to sea	None/insignificant
Physical impact on environment / habitat	Insignificant / Small negative
Aesthetic impact	Moderate negative
Material management	Large positive
Littering	None/insignificant
Impacts on fisheries	Moderate positive
Impacts on free passage at sea	Moderate positive

Table 8.10 Environmental Impact of Removal and Disposal of the Wreck of DP1 Steel Substructure

Cost

The estimated cost of the removal, transportation and onshore disposal of Platform DP1 steel substructure has been estimated to be 330 MNOK / £25.3m.

8.4.2 Disposal Arrangements for DP1 Substructure Wreck

The studies undertaken indicate that it is most probably technically feasible to remove the wreck of the DP1 steel substructure using conventional offshore methods of working. The work will however involve procedures, equipment and operations that, at present, have not been widely used in the North Sea. It is considered possible to undertake the majority of the underwater construction/demolition work using remotely operated work vehicles although some tasks may require diver intervention. When diving is necessary, strict procedures will be used together with appropriate risk reducing measures to ensure that risks are as low as reasonably practicable. The condition of the structure gives some cause for concern but with adequate control it is considered that the work can be carried out without excessive risk to personnel. An application for derogation under the provisions of OSPAR Decision 98/3 will therefore not be sought for the wreck of DP1, even though it is severely damaged.

The impact on the environment of removing the wreck of the DP1 steel substructure is judged to be generally low. The impact on fisheries and the free passage of vessels is “moderate positive” and there is a “large positive” effect arising from the reuse of the steel. The aesthetic impact is judged to be “moderate negative” during the onshore cleaning and demolition of the structures. The impact on the physical habitat offshore during the removal operations is considered to be “insignificant”.

In accordance with national regulations and international conventions the steel substructure of DP1 platform will be removed and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The work will be undertaken using the most appropriate techniques and best environmental practice.

Section References

8.1 “Removal and Disposal Study - QP Topside and Jacket”, Aker Offshore Partner Report, Ref. RE 175000-02-99, dated 07.09.1999 DocsOpen 98155.

8.2 “Preparatory work Necessary to Remove the Topsides from the Frigg Field Installations”, London Offshore Consultants Report, Ref. LOC-12800-TN-007A, Rev.0A, dated 23.03.2000 DocsOpen 103899.

8.3 “Frigg Cessation Study” Volume 1, Books 1 and 2, London Offshore Consultants Report, Ref. LOC-12800-RP-006, Rev.0C, dated 14.06.2000 DocsOpen 103922 & 103924.

8.4 “Frigg Field - Topsides, Jackets and Pipelines Disposal - Safety Evaluation”, Safetec Report, Ref. ST-8708-RA-2, Rev.04A, dated 24.11.2000 DocsOpen 107123.

8.5 “Lift Analysis of Frigg DP2 Module Support Frame for Removal of the Topside”, Kværner Oil and Gas Report, Ref.004-TR-J-D-002, Rev.00.01.19.00, dated 27.08.1999 DocsOpen 97342.

8.6 “Frigg DP2 Removal and Disposal”, HUB Report, Ref. OM0915-G-0005, dated 14.10.1999 DocsOpen 98259.

8.7 Feasibility Study for the Possible Removal of DP1”, London Offshore Consultants Report, Ref. 1023/LOCN/EAN/DP1/RE001, Rev. 01.01.19.00, dated 12.07.1993 DocsOpen 93931 & 93932.

8.8 “Frigg DP1 Re-Evaluation Study” London Offshore Consultants Report, Ref. 3924/R2/1/IJS7LOC, Rev.0B, dated 09.12.1997 DocsOpen 93934.

8.9 “Frigg DP1 Jacket Integrity Evaluation Recommendations for 1999 ROV Survey”, London Offshore Consultants Report, Rev.0A, dated 06.05.1999 DocsOpen 99663.

8.10 “Removal and Disposal of East Frigg, Lille Frigg, DP1 and Flare Base – Diving and ROV Services”, Stolt Comex Seaway Report, Ref. RE-624200-201, Rev.3, dated 01.09.1999 DocsOpen 98264.

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9. Concrete Platforms - Comparative Assessment of Disposal Alternatives

9.1 Introduction

The possible reuse of the Frigg Field facilities in their existing location has been investigated, as detailed in Section 7. It has not been possible to identify any method of reusing the Frigg Field concrete platforms for oil and gas, or non oil and gas activities that is technically feasible and economically viable.

In the absence of any feasible reuse for the facilities at their present location, studies have been carried out to consider their removal and disposal. **This section details the various evaluations and comparative assessments associated with the disposal of both the concrete substructures and their associated topside facilities.**

In accordance with Norwegian and UK regulations and OSPAR Decision 98/3, full removal and onshore disposal of the topsides and concrete substructures of all the three platforms has been the first option considered. For the topsides this is the **only** disposal option that has been actively considered, the evaluation being centred on how this may best be achieved.

The three concrete substructures, TCP2, CDP1, and TP1, are each different in design. Different procedures would therefore be required for their removal and disposal each of which present a different set of challenges and uncertainties. All of the substructures have currently been in-place for approximately 25 years and it is likely that some deterioration in their condition may have occurred. At the time these platforms were designed and constructed, consideration of the loading during a future removal operation was not included in the design process. In addition, the mechanical systems used in controlling and positioning the concrete substructures during installation were only designed for use during that phase, and were thus abandoned when the platforms were in place.

Due to these facts and the complexity and uncertainties associated with full removal and onshore disposal of the concrete substructures, other decommissioning alternatives have also been considered as specifically provided for in Clause 3 and Annex 2 of OSPAR Decision 98/3.

The main alternative disposal arrangements considered for each of the concrete substructures are summarised below:-

Concrete Platform Substructures TCP2, CDP1, TP1	**Alternative A** Refloat, tow to shore, demolish and dispose on-shore.	**Alternative B** Remove external and internal steelwork, refloat and dispose at a deep water location	**Alternative C** Remove internal and external steelwork and cut down sub-structure to provide a clear draft of 55m.	**Alternative D** Leave in place, removing as much external steelwork as reasonably practicable.

Note:-The requirement for the a clear water column of 55m above any parts of an installation left in place is taken from the International Maritime Organisation (IMO) document *"Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone"* adopted by the IMO Assembly in 1989.

The disposal alternatives for TCP2, CDP1 and TP1 are addressed in Sections 9.2, 9.3 and 9.4. The layout of each section is as shown diagrammatically in Figure 9.1.

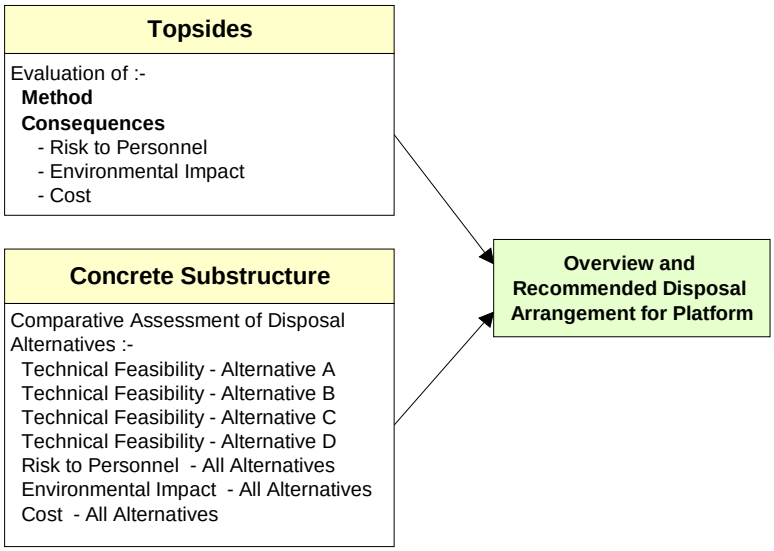


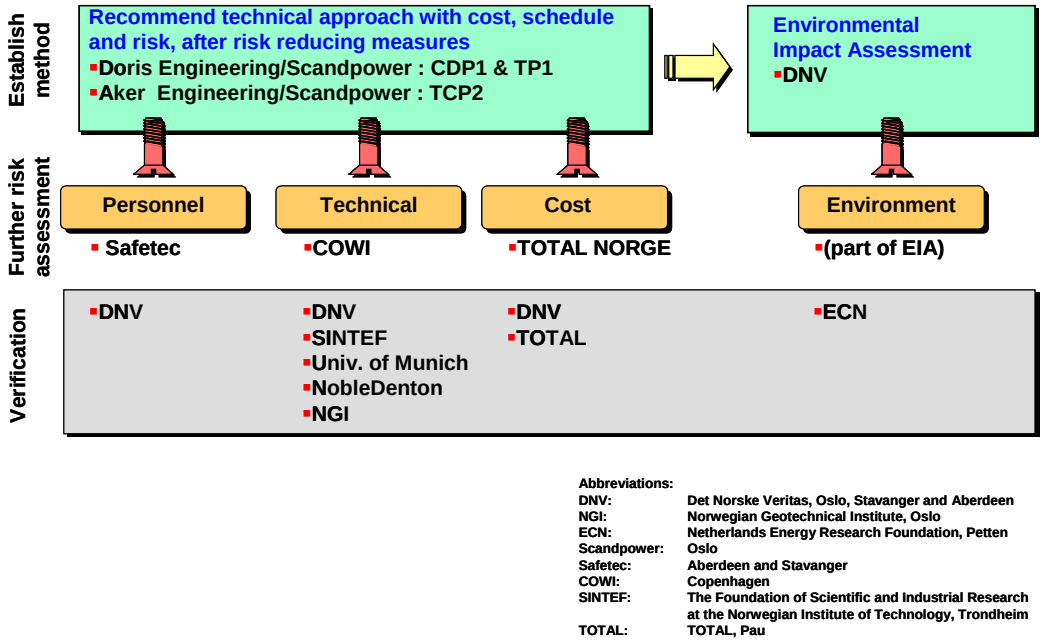
Figure 9.1 Evaluations and Comparative Assessment of Disposal Alternatives for TCP2, CDP1 and TP1

Alternative disposal arrangements have not been considered for the topsides as full removal and onshore disposal is considered to be technically feasible. Thus the evaluation of the topside disposal arrangements is limited to a description of the proposed method and an estimation of the consequences. When considering the disposal of the concrete substructures the technical feasibility of each alternative has been assessed as well as the risk to personnel, impact on the environment and the cost. The proposed method is included as part of the technical feasibility assessment.

TCP2 **CDP1** **TP1**

Considerable effort has been given to the assessment process. Input has been sought from the engineering companies who were responsible for the original design of the platforms; partner companies; independent consultants; academics from universities in a number of European countries; Det Norske Veritas and TOTAL experts.

Figure 9.2 gives an overview of the various studies and reviews that form part of the overall assessment for the concrete substructures. In addition a list of the studies that have been undertaken is to be found in Section 20 of this Disposal Plan.



Abbreviations:

DNV:	Det Norske Veritas, Oslo, Stavanger and Aberdeen
NGI:	Norwegian Geotechnical Institute, Oslo
ECN:	Netherlands Energy Research Foundation, Petten
Scandpower:	Oslo
Safetec:	Aberdeen and Stavanger
COWI:	Copenhagen
SINTEF:	The Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology, Trondheim
TOTAL:	TOTAL, Pau

Figure 9.2 Assessment Process for Refloat and Onshore Disposal Alternative (Alternative A)

Development of Method Statements

The companies involved in the original design and construction of the three platforms in the 1970s were; TCP2 - Norwegian Contractors (now Aker Engineering); CDP1 - Doris Engineering; and TP1 - Sea-Tank (now Doris Engineering).

These companies were engaged by TOTAL NORGE in 1999 to conduct the initial engineering and feasibility studies for the decommissioning of the platforms (Ref. 9.1, 9.2, 9.3). The main object of the studies was to assess the feasibility of refloating the substructures. Different methods were considered and a recommended method was proposed by the design companies based upon many engineering evaluations,. The recommended method was described in the form of a general procedure or “method statement”, which was then reviewed to identify risks to personnel engaged in the disposal activities. The method statement was then modified as necessary, to reduce or eliminate unacceptable risks. Scandpower, working together with Aker and Doris, undertook the qualitative safety assessments using “SAFOP” (Safe Operation) techniques.

Whilst developing the method statements, new or innovative activities or operations that were beyond current experience were identified. The feasibility of these activities was assessed and the need for programmes to develop the necessary technology was highlighted.

In parallel, the engineering contractors assessed the feasibility of other disposal options (Alternatives B, C and D as defined earlier in this section) and prepared method statements, which described the proposed method of undertaking the work.

After the method statements had been developed, further engineering studies were undertaken by Aker Engineering and Doris Engineering to investigate specific areas of uncertainty (Refs. 9.4 to 9.15).

The method statements and engineering studies were reviewed and validated by a group of independent experts including representatives from SINTEF, Norwegian Geotechnical Institute, Noble Denton, Munich University and Det Norske Veritas (Refs. 9.16 to 9.38).

Additional engineering studies were undertaken to investigate specific aspects (Refs. 9.41, 9.42, 9.46, 9.47, 9.48, 9.49 and 9.50).

Technical Risk Assessment
The Danish consulting engineers COWI, then conducted a technical risk assessment (Ref. 9.39) based upon the method statements developed by Aker Engineering and Doris Engineering. The aim of this technical risk assessment was to estimate, in quantitative terms, the risk of being unable to complete the removal and disposal work as planned. Experts from Norway, UK, Germany, Switzerland and France were used to provide specialist input to this technical risk analysis.

Inspection and Testing
Offshore inspections were carried out during 1999 and 2000 to determine the condition of certain key mechanical systems and structural elements. The results from this inspection and testing provided additional input and validation to the technical risk assessment.

Risk to Personnel
In addition to the qualitative safety assessments carried out during the development of the method statements, Safetec conducted a numerical assessment of the risk to personnel (Refs. 9.40 and 9.43). The probability of death or serious injury occurring during the removal and onshore disposal operations, was estimated based upon the planned activities and historical accident data for similar offshore and onshore activities. The safety of personnel involved in all the disposal alternatives was assessed.

Environmental Impact
The impact on the environment and society of the total removal option and other disposal alternatives were assessed by Det Norske Veritas, in Stavanger and Aberdeen, using well established principles and methods. Their report forms Part 2 of this Frigg Field Cessation Plan. The environmental impact assessment was peer reviewed by the Netherlands Energy Research Foundation.

Costs
The costs associated with each disposal alternative were estimated based upon the proposed disposal methods. Possible increases in the cost of the works were also estimated based upon the technical uncertainties associated with the disposal alternatives.

Public Consultation
Input from the stakeholder dialogue process conducted by TOTAL NORGE (see Section 16) has been particularly useful when assessing the sometimes-conflicting requirements of safety, environmental protection, cost and technical risk.

The studies and assessments detailed in this section have been structured to allow demonstration of compliance with the relevant legislation of Norway and the UK.

9.2 Treatment and Compression Platform 2 – TCP2

9.2.1 TCP2 Topsides – Evaluation of Removal Methods

9.2.1.1 Method

Various lifting and transportation arrangements for platform TCP2 topsides have been assessed. Based upon these studies it is presently planned to remove the modules and deck using a crane vessel working in a reverse installation sequence. The components of the topsides would then be transported to shore for disposal. The bridge between TCP2 and TP1 would also be removed and transported to shore in the same way.

If it was possible to refloat the concrete substructure and tow it to shore for onshore demolition (Concrete Substructure Alternative A), then only part of the topside would need to be removed offshore. The remaining modules and the deck would be removed after the substructure had been towed to an inshore location.

Prior to the start of removal operations further detailed inventory studies and hazard assessments would be carried out to ensure that there will be no adverse effects on the health and safety of personnel, or the environment, arising from these activities. Before disconnecting the various parts of the platform topside, all hazardous equipment and materials will be identified and either made safe or removed.

Although it is presently planned to remove the platform topsides using conventional reverse construction methods, further studies will be undertaken to assess the technical feasibility of the innovative topsides removal schemes being proposed by industry. The object of these studies will be to identify methods, which would allow the removal of the platform topsides in a safer and more cost effective manner.

Figure 9.3 Principle of Topsides Removal

9.2.1.2 Consequences

Risk to Personnel

The risk to personnel involved in the removal and disposal of TCP2 topsides has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 9.43). The predicted numbers of fatalities and major injuries expressed in statistical terms are shown in Table 9.1. A definition of the terms used in this table is given in Section 6.3.

Predicted number of fatalities (Potential Loss of Life)	0.05 (0.0529) See note
Probability of a Fatality	5%
Predicted number of major injuries (Potential Major Injuries)	2.8
Probability of a Major Injury	94%

Note:- The PLL value shown has been rounded to the nearest percentage point. The actual calculated value is shown in parenthesis for comparison purposes.

Table 9.1 Estimated Risk to Personnel during Removal and Onshore Disposal of TCP2 Topsides

Environmental Impact

The environmental impact of removing the topsides of TCP2 may be found in Section 7 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. A summary of the findings is given in Table 9.2 below.

Parameter	Value
Energy Consumption (1000 GJ)	300
Total Energy Impact (1000 GJ)	300
CO_2 Emissions (1000 tonne)	27
Discharges to sea	None/insignificant
Physical impact on environment / habitat	None/insignificant
Aesthetic impact	Moderate negative
Material management	Large positive
Littering	None/insignificant
Impacts on fisheries	None/insignificant
Impacts on free passage at sea	None/insignificant

Table 9.2 Environmental Impact of Removal and Onshore Disposal of the TCP2 Topsides

Costs

The cost of removal, transportation and onshore disposal of TCP2 topsides has been estimated as 647 MNOK / £49.5m.

9.2.2 TCP2 Concrete Substructure – Comparative Assessment of Disposal Alternatives

9.2.2.1 Technical Assessment of Alternative A - Refloat and Onshore Disposal

Proposed Method

To refloat the TCP2 concrete substructure it would be necessary to use a combination of buoyancy forces and water pressure beneath the base slab to free the substructure from the seabed.

Before the refloat operations were started, part of the topside would be removed to reduce the topside load.

Deballasting systems to allow water to be pumped out of the cells in the base and the column would then be installed. In order to avoid overstressing the concrete substructure during the refloat operation it would be necessary to introduce compressed air into the base cells as the water is pumped out. The compressed air system would therefore be installed next.

The system for injecting water under the base slab would also be installed, including the construction of injection points through the base slab. A layer of gravel would need to be placed around the substructure to help maintain the hydraulic pressure under the base slab.

The substructure would be partially deballasted by pumping water from the cells in the base. A positive load on the seabed due to the weight of the substructure would however be maintained. Water would then be injected under the base, thus creating a lifting force on the substructure. The hydraulic pressure under the base slab would be the primary force used for extracting the skirts and dowels from the seabed. As the platform rises the hydraulic pressure beneath the base will be lost due to outflow of the water to the surrounding sea. Final extraction of the skirts and dowels from the seabed would then be undertaken by further deballasting the concrete substructure, principally by pumping water out of the columns.

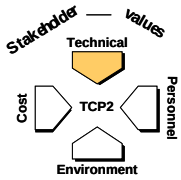
After the structure separates from the seabed, deballasting will continue until it reaches a suitable towing draft. During the refloat and towing operations the platform would be unmanned. Operation of the deballasting systems when the platform is unmanned would be by remote control, from an adjacent boat. It might however be necessary to re-man the platform for a period of time in the event of equipment malfunction.

Once the substructure has been refloated it would be towed to a sheltered inshore mooring. If the topsides have not been entirely removed offshore, the remaining topsides would be removed. The concrete substructure would then be moored close to the shore to allow demolition of the concrete substructure. The columns and the upper parts of the base cells would then be cut into sections and lifted away with a floating crane. Particular care would be necessary to preserve the structural integrity of the structure during demolition. The olivine rock ballast in the base cells would be dredged out and disposed onshore.

When the floating draft has been reduced sufficiently, the lower section of the substructure would be towed into a dry dock where it would be cut into sections.

All the sections of reinforced/prestressed concrete cut from the substructure would be crushed onshore to allow recovery of the steel and concrete. The steel would be sent to a steel works for re-smelting, whilst it is anticipated that the crushed concrete would be reused as some form of aggregate or disposed of as landfill.

Technical Feasibility



During the design of the TCP2 platform no consideration was given to the removal of the concrete substructure at a later date. Accordingly the ability of the structure to resist the loads during a refloat operation was not checked, and no specific features were incorporated into the design to facilitate removal.

In assessing the technical feasibility of refloating the TCP2 concrete substructure, a number of aspects have been identified that would be critical to the success of the operation. The most important aspects, which have the potential to cause the refloat operation to be aborted, are shown in Figure 9.4 and are explained further in the following text.

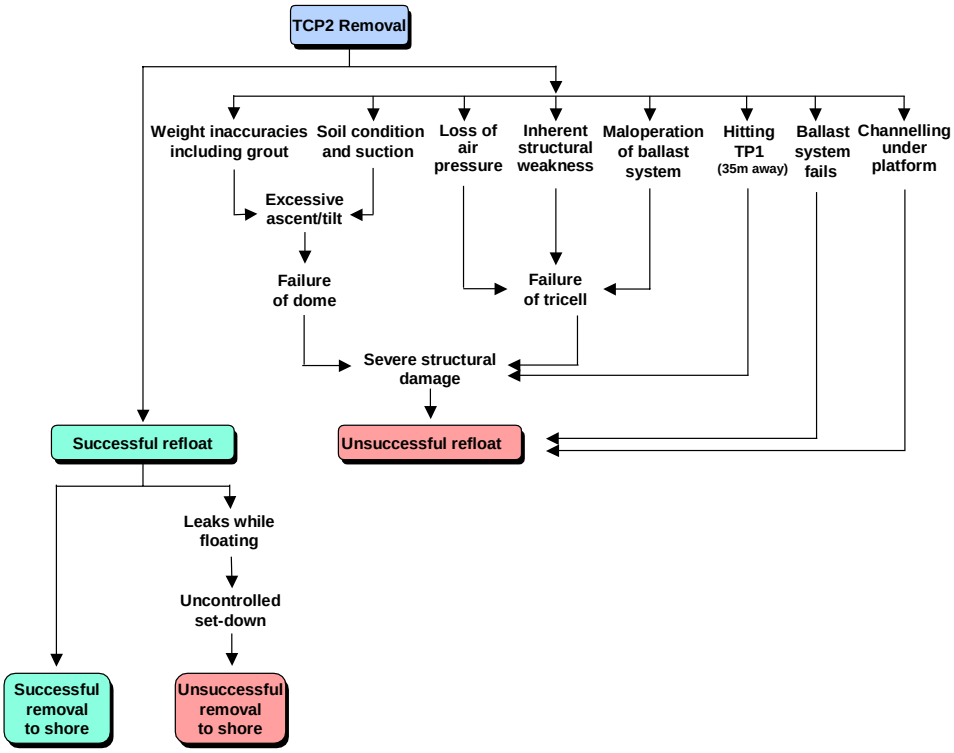


Figure 9.4 Areas of Uncertainty Affecting the Success of the Refloat and Towing of TCP2

Uncertainties During the Refloat Operations

- **Weight Inaccuracies Including Grout**
- **Soil Conditions and Suction**
- **Channelling Under Platform**

These are all aspects that have an effect on the success of the operations required to separate the concrete substructure from the seabed.

The substructure has a series of 1.7m deep “skirts” below the base slab that go into the soil to prevent horizontal movement of the platform when the platform is subject to large wave forces. In addition there are 3 dowels projecting from the bottom slab into the soil. These dowels were used to prevent the platform “skidding” across the seabed during the latter stages of installation.

The base slab is not a flat concrete slab but is formed from the domed ends to the cells in the base of the substructure. After installation the space between these domed cell ends and the soil was filled with cement grout to ensure an even bearing pressure on the seabed.

In order to successfully refloat the concrete substructure it would be necessary to pull the skirts and the dowels, attached to the bottom of the platform, out of the soil. The force necessary to extract the skirts and dowels from the soil is rather uncertain due to possible **variations in the soil strength**, the **weight of the substructure,** and any **suction** that might develop under the platform. The uncertainties associated with these aspects are all increased due to the time the platform has been in place.

Pulling the skirts and dowels out of the soil by buoyancy forces alone is not considered to be feasible due to the uncontrolled dynamic effects that could occur when the platform breaks free from the seabed. In such a situation the platform might rise well above its normal floating draft before stabilising. In addition, analysis has indicated that hydrodynamic effects during the ascent from the seabed could cause significant “tilt” of the substructure. These combined effects could result in **severe over-stressing of the domed roof** of the cells and, in worst-case situations, give rise to structural failure and loss of the substructure.

The possibility of an uncontrolled release from the seabed is increased due to **uncertainties in the weight of the structure** as it comes free. The main factors that make the weight less certain than at installation are; marine growth; deposits on the top of the cells and the amount of cement grout that might become detached from the base slab. These factors may adversely affect both the **tilt** and the **maximum ascent** of the substructure after breaking loose from the seabed.

The feasibility of the refloat operation is therefore dependent upon the successful use of adequate, and correctly controlled, hydraulic pressure beneath the base slab to initiate the extraction of the skirts and dowels from the soil.

Studies have indicated that in certain circumstances **channels** could form in the sand under the platform allowing the water to flow out too easily and thereby preventing the build up of the necessary pressure. This would limit the lifting force generated beneath the platform and would seriously jeopardise the feasibility of the refloat operation.

The placement of a surcharge of gravel on the seabed around the substructure will reduce the risk of channelling in the soil although it is not completely certain that this measure will ensure that the skirts and dowels can be extracted using hydraulic pressure under the base slab. Although extensive evaluation of the soil conditions at the Frigg Field has been undertaken it is known that the soil in the area is rather variable. There is likely to be a significant variation in the exact soil properties under and around the platform that may affect the efficiency of the hydraulic jacking operations.

Even if it is possible to start the extraction process using hydraulic pressure under the base slab, there is a possibility that the amount of extraction possible with this method may be limited. The reason for this is that as the platform is jacked up and the skirts begin to be pulled out of the seabed, it is inevitable that there will be an increased leakage through the soil. This will accordingly reduce the hydraulic pressures under the base slab and the effective upwards force.

If this should occur after limited extraction of the skirt, it would then be necessary to undertake the final extraction of the piles and dowels use buoyancy forces generated by deballasting the base cells and columns. The slope of the seabed and variations in the soil properties are both significant factors in determining how much of the skirts and dowels would be extracted before the pressure under the base slab was lost.

If it were impossible to extract the skirts and dowels a significant amount using hydraulic jacking, then a relatively high out-of-balance buoyancy force would be needed to pull them out of the seabed. There would then be a very significant risk that the substructure would rise to a level well above its normal floating draft, which would overstress or cause the failure of one or more cell roof domes. In that event, the buoyancy of the substructure would be lost and it would fall back onto the seabed, being severly damaged in the process.

The overload of the upper domes is due to the fact that the cells have to be filled with compressed air at high pressure to prevent damage to other parts of the substructure when it is emptied of water. This is explained further in the following sub-section.

- **Loss of Air Pressure**
- **Inherent Structural Weakness**
- **Mal-Operation of Ballast System**

The lower part of the substructure is composed of nineteen interconnected cylindrical cells with domed ends. The cylindrical cells are closed and the water level, and pressure, within them may be controlled. The triangular space formed where three cells join is often referred to as a “tri-cell”. This space is open to the sea at the upper end.

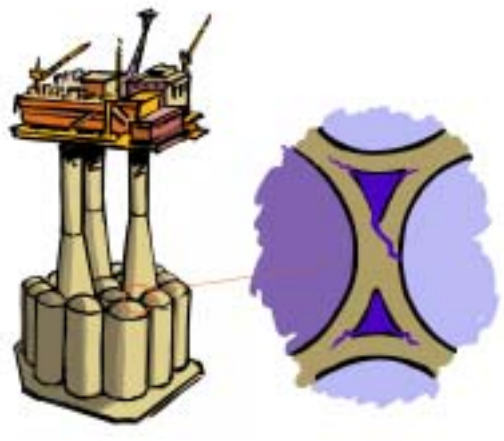


Figure 9.5 Location of Predicted Cracking in the “tri-cells”

A similar “Condeep” design of concrete substructure was lost during deep submersion testing in 1991, due to weaknesses in the design and construction of the tri-cells. As a result of these, the reinforcement was unable to resist the hydrostatic loads in the tri-cells and extensive cracking occurred which allowed the ingress of large amounts of water.

It is also known that problems occurred with the tri-cells of two other “Condeep” substructures during deep submersion testing and installation. Significant repairs to the concrete substructure were needed following severe cracking that occurred when the structures were subject to large hydrostatic pressures.

The TCP2 concrete substructure is similar, although not identical, in design to these other “Condeep” type structures. During de-ballasting operations large forces would be developed on the walls of the tri-cells which could cause severe cracking. The ambient water pressure penetrating into the crack would tend to open the crack further.

In order to limit the forces in the tri-cell walls it is proposed to pressurise the adjoining cells with compressed air. The **air pressure** that can be used in the cells has to be within certain limits. It has to be high enough to prevent overstressing of the structure around the tri-cells when the substructure is resting on the seabed, but not so high that it will cause over-stressing and possible collapse of the cell roof domes when the substructure is at its highest point of ascent after breaking loose from the seabed.

A further aspect that requires consideration when assessing the condition and strength of the tri-cell walls is that during the life of the structure the columns have been pumped dry a number of times for inspection of the risers. In addition, the substructure has had to withstand periods of adverse weather and emergency ballasting when severe weather was predicted during times when the columns were dry. It is believed that over-stressing of the reinforcing bars at particular locations in the vicinity of the tri-cells has occurred at these times and that

the concrete in these areas is **likely to already be cracked**. It is not considered possible to accurately inspect the inside of the tri-cell for cracks.

The integrity of the tri-cell structure during the planned refloat operations has been investigated using non-linear structural analysis to predict the degree of **cracking** in the area. The conclusion drawn from these studies is that cracks more than 1m deep are likely to occur during the deballasting and refloat operations. It is predicted that these cracks will occur at a number of locations in the substructure over a substantial section of wall. If these cracks do not propagate into the cells, then the water-tightness of the structure and its structural load bearing capacity would not be impaired.

Similar extensive cracking was, however, experienced on at least one other “Condeep” type substructure but in that case the cracks moved away from the centre of the wall and propagated into a cell. This allowed ingress of water to a cell. The leak was fortunately small enough to be controlled by the pumps installed on the platform. Structural analysis undertaken following this event was unable to predict why the cracks in the structure deviated from the centre of the wall.

The two-dimension structural analysis used to investigate the cracking in the TCP2 tri-cells is not considered adequate to correctly predict the propagation of the crack, as it does not account for three-dimensional or secondary effects. A three-dimensional structural analysis might provide better results, but such an analysis would also contain uncertainties, which would prevent the exact safety of the tri-cells from being established. The likely extent of the cracking in the tri-cells is therefore uncertain. It has however been established that quite extensive cracking is likely to occur and that there is a significant possibility that such cracks could propagate through the walls of a cell and thereby adversely affect the water-tightness and integrity of the structure.

If the **air pressure** in the cells is lost, or there is a mal-operation of the ballast system, then it is extremely probable that cracks will develop through the walls of the cells with subsequent flooding. This will either prevent the substructure being lifted off the seabed or would cause it to fall back onto the seabed after lift off.

Studies have been conducted to consider whether sealing off the tri-cells from the sea could reduce the probability of structural problems. Whilst this could reduce the probability of cracking in the tri-cell walls when the substructure is on the seabed, it would however increase the risks after the substructure breaks free from the seabed and rises in the water. If the tri-cells were closed to the sea, the stresses in the walls and domes of all the base cells would be significantly different from what they experienced during installation. Their capacity to resist these new stress distributions is uncertain. In practical terms, sealing the tri-cells would not be easy to achieve and would increase the risk to personnel due to the additional diving work required. For these reasons closing the tri-cells during the refloat operation has not been considered further.

- **Hitting TP1**

The movement of the TCP2 substructure as it breaks free from the seabed is more or less impossible to predict with any degree of accuracy. There is a possibility that the substructure could “skid” across the seabed in an uncontrollable manner after breaking loose. The possibility of this phenomenon was considered during installation, and steel dowels installed under the base to try and prevent this movement as the platform approached the seabed. Separating the substructure from the seabed is less controlled than installation and thus it is considered that the chance of uncontrolled horizontal movement would be greater.

In addition to the horizontal movement the substructure is likely to tilt as it breaks free from the seabed due to variation in the soil friction on the skirts, suction under the platform and the possibility of the grout falling off the bottom of the platform. Any initial tilt is likely to be increased by hydrodynamic forces, as the substructure starts moving.

The TCP2 and TP1 substructures are only 35m apart and accordingly there is a possibility of an impact after TCP2 lifts off the seabed.

- **Ballast System Fails**

The ballast system on TCP2 was only designed to be used during the original installation operations and was abandoned after the platform was in location. This system will need to be fully operational for the refloat operation with a high level of reliability. Failure of the system due to either leakage or blockage could give rise to uneven ballasting or flooding of cells. If this occurred during the refloat operation it would be extremely difficult to rectify the situation quickly as the substructure will be unmanned during the critical refloat operations.

Tests on the ballast pipework conducted in the summer of 2000 demonstrated that there were concerns about whether it would be fit to be used for refloating the concrete substructure in eight to ten years time.

Uncertainties During the Tow to Shore

- **Leaks While Floating**

When the substructure is floating there is a possibility that leaks could develop while the platform was being made ready for towing and during the tow to shore. During this period the platform will be unmanned and thus repairs would be difficult to make. Although the pressure on the ballasting system and walls penetrations would be less at towing draft, the pressure has to be sustained for a longer period. The longer-term performance of the ballast system is a particular concern due to uncertainty regarding the wall thickness of the pipework and the possibility of fractures in the pipe due to differential movements of the structure.

Probability of Failure During Refloat and Disposal

In view of the uncertainty associated with many aspects of the TCP2 concrete substructure removal operations, the probability and consequences of a major accident have been investigated. There are an infinite number of possible accidents and outcomes but in order to make a broad estimate of the likelihood and consequences of a major accidental event, four **representative** scenarios have been investigated: -

1. Accident before refloat	Damage to two cells due to dropped objects preventing the refloat operation starting
2. Accident during refloat	Failure of a critical system or structural member (walls, tri-cells, domes or base slab) during the refloat operation resulting in loss of buoyancy and impact with the seabed. The impact would result in severe damage to the walls and/or base slab.
3. Accident during tow	Failure of a critical system or a structural member during the tow to shore resulting in loss of buoyancy and impact with the seabed. The impact would result in severe damage to the walls and base slab. The substructure and topsides are likely to be totally submerged after impact with the seabed.
4. Accident during demolition	Failure of a critical system or structural member during the inshore demolition operation resulting in loss of buoyancy and impact with the seabed. The impact would result in disintegration of the remaining substructure.

For many of the worst case scenarios the risks inherent in the remedial works would be so high as to make them unacceptable and, in that case, remedial work would not be possible. However, when assessing the consequences of the worst case scenarios the risks involved have been estimated with no prior decision as to whether they are acceptable or not.

When assessing the implications of the accident scenario prior to the refloat operation, it has been assumed that in most cases it will be possible to repair the damage to the substructure. The damage occurring as a result of an accident during the refloat, tow and demolition phases would however be so severe that it would be impossible to refloat the substructure again. In order to maintain 55m clear draft for shipping (as required by the IMO Guidelines), it would then be necessary to cut up the concrete substructure into small sections which could be lifted to the surface and transported to shore for disposal.

These operations would be extremely hazardous due to the damaged condition of the substructure and the need for most of the cutting and lifting to be done underwater. In the case of accident scenarios 2 and 3 the work would also need to be undertaken at an exposed offshore location, which would significantly increase the risk. The risk of a fatality during the remedial operations has been estimated to be in the range of 16% to 60% and as such would not be acceptable.

The likely cost of such remedial work would be very high although the overall impact on the environment is generally small. The main negative impacts are the effect on the local marine environment (seabed and natural resources) and the emissions to atmosphere during the extensive remedial works. The environmental impact analysis did however identify a number of specific situations where the environmental impact would be much greater due to local conditions (e.g. when towing the substructure over an oil pipeline or in the area of particular fishing grounds or near inshore fish farms).

The likelihood of major accidents occurring during the removal and disposal operations has been estimated using probability theory based upon historical data (where appropriate) and input from a group of independent experts. The costs of the remedial activities required following a major accident have also been estimated in broad terms for all four accident scenarios, based on outline descriptions of the necessary works (Ref. 9.39). The probability and consequences of the various accident scenarios are given in Table 9.3.

	Description	Consequence	Probability	Estimated Cost (see note)
1	Accident before refloat	Damage to cells	0.1% - 0.2%	3200 MNOK £245m
2	Accident during refloat	Severe damage to walls (including tricells), domes and base of cells	1.3% - 2.5%	7100 MNOK £543m
3	Accident during tow	Severe damage to walls and base of cells	0.1% – 0.2%	8200 MNOK £627m
4	Accident during demolition	Disintegration of substructure	0.4% - 0.5%	4400 MNOK £336m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenarios the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

Table 9.3 Probability and Consequences of Major Accidents during TCP2 Refloat and Inshore Disposal Operations (Alternative A)

The overall probability of a major accident during the removal and disposal operations for the TCP2 concrete substructure is estimated to be in the order of 2% to 4% which is twenty to forty times greater than the acceptance criterion. Loss of structural integrity is a major contributor to the overall probability of a major accident as listed in the table above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.2.2.2 Technical Assessment of Alternative B - Refloat and Disposal in Deep Water

Proposed Method

The activities performed to refloat the substructure for disposal in deep water (Alternative B) are essentially the same as for onshore disposal (Alternative A). The main difference, apart from the final disposal method, is that the complete topside, and most of the steel items inside and outside the columns, would be removed before refloating the platform. The reason for this is that with Alternative A these items would be removed after the platform has been refloated and towed to shore.

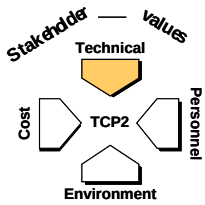
After the topsides have been removed offshore a new work platform would be installed on one of the columns to provide support for the temporary equipment needed for the refloat operation.

As for Alternative A, the platform would be unmanned during the refloat and towing operations. Operation of the de-ballasting systems when the platform is unmanned would be by remote control from an adjacent boat.

Following the refloat operation the substructure would be towed to the chosen deep-water disposal location. As much as practicable of the temporary ballasting and injection equipment installed on the column-top work platform would then be removed before the substructure was flooded. By taking water out of the cells and then submerging the substructure by pumping water into the columns it is considered possible to cause an “implosion” which would effectively demolish the concrete.

Technical Feasibility

The feasibility of Alternative B depends essentially on the possibility of being able to refloat the substructure. The concerns noted in Section 9.2.2.1 in respect to the onshore disposal option (Alternative A), also apply when disposing of the platform in the deep ocean.



Probability of Failure During Refloat and Disposal

The refloat operation for Alternative B is essentially the same as for Alternative A and the same uncertainties therefore apply. As a result, the accident scenarios considered for Alternative A are also valid for Alternative B, apart from Scenario 4 (Accident during demolition) which is obviously not relevant in the case of disposal in deep water.

The probability and consequences of the various accident scenarios have been estimated (Ref. 9.39) and are given in Table 9.4 below.

	Description	Consequence	Probability	Estimated Cost (see note)
1	Accident before refloat	Damage to cells	0.1% - 0.3%	1800 MNOK £138m
2	Accident during refloat	Severe damage to walls (including tri-cells), domes and base of cells	1.3% - 2.5%	5200 MNOK £398m
3	Accident during tow	Severe damage to walls and base of cells	0.01%	5700 MNOK £436m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenarios the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

Table 9.4 Probability and Consequences of Major Accidents during TCP2 Refloat and Towing Operations for Disposal in Deep Water (Alternative B)

The overall probability of a major accident during the removal and deep water disposal operations for the TCP2 concrete substructure is estimated to be in the order of 1.5% to 3% which is fifteen to thirty times greater than the acceptance criterion. Loss of structural integrity is a major contributor to the overall probability of a major accident as listed in the table above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.2.2.3 Technical Assessment of Alternative C - Partial Removal to Provide a Clear Draft of 55m over the Remaining Structure

Proposed Method

Alternative C involves cutting each of the columns just above the top of the cells that form the base of the substructure. The cut sections of column, which would each be 81m in length, would then be placed on the seabed adjacent to the base.

Whilst the topsides are in place, the piping, steelwork and electrical equipment in the columns would be removed and transported to shore for reuse or recycling. It would however be necessary to retain a means of access to the columns while they were being cut. In addition, the steel items attached to the outside of the concrete substructure would be removed and transported to shore. The topsides would then be removed as described in Section 9.2.1.

Several methods of cutting the concrete columns have been evaluated, including various combinations of drilling, diamond wire sawing and explosives. Diamond wire sawing from inside the column has been judged to be the best method. This method is different from that proposed for the columns of TP1 where saws or diamond wire cutting tools operated by divers outside the column was proposed as the best method. Both methods are considered feasible in principle but both would require considerable development work to achieve commercial applicability.

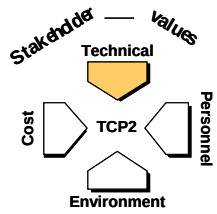
The amount of work that can be undertaken in the columns at any time is limited by health and safety considerations. If significant amounts of work were needed for the disposal activities, it would most likely be necessary to install additional access systems in the columns, which would in itself be a hazardous operation, with the possibility of fatality or serious injury. Even if this were done, operational safety limitations would control the way the work was conducted and result in low productivity rates.

In order to prevent the inflow of water during the cutting operation, a steel cofferdam would be installed around the outside of each column at the location of the cut. The steel cofferdam, which would be pre-fabricated onshore, would incorporate rubber-sealing elements to form a watertight seal with the concrete column.

Once cut, each column weighing approximately 5,600 tonnes in air, would be lifted as a single unit and placed on the seabed close to the base. The concrete ballast cylinder in Column 1 would be cut and removed in two sections before the columns were cut. Each section of the ballast cylinder weighing approximately 1240 tonnes in air would be placed on the seabed close to the base, as shown in Figure 9.6.

Figure 9. 6 TCP2 Concrete Substructure cut down to –55m.

Technical Feasibility



The method proposed is considered to be theoretically feasible although there are a number of critical operations that would need to be proven and specialist equipment that would need development and testing.

Cofferdam

The feasibility of being able to cut down the platform in the way suggested depends upon being able to seal-off the area of the cut from the sea using a cofferdam on the outside of the column. There are many uncertainties associated with the design, fabrication, testing and installation of such a cofferdam. Extensive design and thorough underwater testing would be vitally important and would need to be performed well in advance of offshore mobilisation. The cofferdam sealing mechanism is a critical element. A significant leak in the cofferdam during the cutting operation would seriously jeopardise the success of the planned operations and could cause multiple fatalities. Any movement of the column when in a partially cut condition is likely to adversely affect the performance of the cofferdam.

The work inside the columns would be particularly hazardous. Extremely rigorous arrangements for controlling personnel access and managing lifting operations would need to be developed and put into practice. The feasibility of undertaking some of the work, particularly the final cutting of the columns, by remote control from outside the column, would also need to be addressed, but this is not considered to be particularly easy to achieve.

Concrete Cutting Methods

Although based on proven technology, the diamond wire cutting equipment would need to be tested under realistic conditions well in advance, to prove that the equipment chosen is suitable for the task. In particular the effectiveness of diamond wire techniques for cutting the heavily reinforced and prestressed concrete column walls is difficult to gauge at the present time due to the lack of relevant experience. In order to allow the cutting wire to be correctly positioned, relatively large holes (at least 300mm in diameter) will need to be drilled using a diamond coring tool. Experience indicates that there is a very high possibility of the coring tool jamming whilst cutting the heavily reinforced concrete. In that situation considerable time and effort would be needed to free the tool and re-drill a hole in an adjacent location, which of course, needs to be within the section of wall covered on the outside by the cofferdam.

Extensive design work and thorough testing, in representative conditions, would be necessary before this method of cutting could be considered proven. Although the basic concept is relatively straight forward, the environment in which the cutting will be undertaken and the relative limited possibilities for remedial actions, in the event of a serious problem, make the cutting of the column walls particularly uncertain.

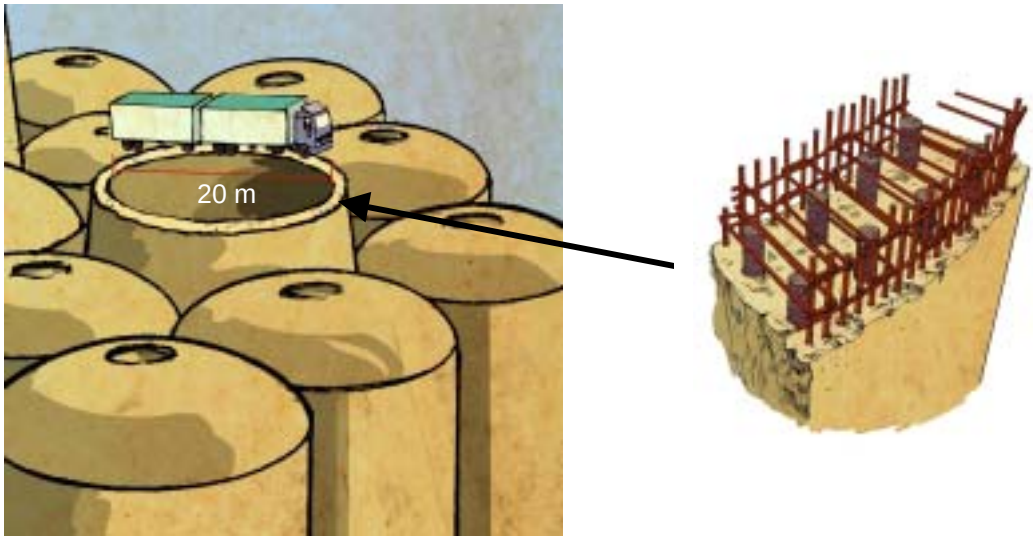


Figure 9.7 Dimensions of Column Wall to be cut and Details of Reinforcement

Stability of the Columns During Cutting
Preliminary calculations indicate that the columns when cut can resist the wave forces from a one-year summer storm as long as there is atmospheric pressure within the column. If more severe weather occurs after a significant proportion of the column has been cut then the stability of the column would be threatened. In addition, if the column was accidentally flooded after a significant proportion of the column had been cut, then the stability of the column would again be threatened in the event of severe weather. The strength of the column when partially cut is rather difficult to determine because in that condition it's fatigue strength is likely to be very low. It is possible that the fatigue life of the partially cut column would only be a matter of weeks or months and thus it could be vulnerable to fatigue failure in the event of a period of bad weather. If, due to difficulties, it was not possible to complete the cutting operation in the summer season, then it is highly likely that the column would have insufficient strength to resist winter storms and would collapse. Such uncontrolled collapse of the column would be unlikely to result in a clear shipping draft of 55m.

Jamming of the cutting wire, although less likely than jamming of the coring tool, is considered very probable during the cutting of the final sections of the wall. It is planned to undertake the final cuts by remote control but if the wire jams or the cutting machine mal-functions personnel would be required to re-enter the column to take remedial measures. The safety of such personnel would be of extreme concern given that the column would be likely to collapse or flood in the event of relatively severe weather.

Probability of Failure during Cutting Down Operations
Uncertainties surrounding the cutting and removal of the columns mean that these operations may not be successfully completed. In that event extensive remedial works would be required to rectify the situation and achieve a clear draft for shipping of 55m as required in the IMO Guidelines. The probability of this situation occurring and the consequences have been assessed based upon two representative scenarios as below:-

1. Unsuccessful cutting	Failure of the cutting systems, cofferdam or associated equipment requiring redevelopment and re-qualification of cutting system
2. Collapse or dropping of column	Collapse of the column or failure during lifting operations resulting in not achieving the required 55m of clear water above the remaining structure on the seabed.

The operations to rectify these unsatisfactory situations are likely to be extremely hazardous especially if the column was in an unstable condition that was sensitive to wave forces. In that

condition the risk of diving close to the column would be unacceptable and thus complex and expensive tools would need to be developed which could be deployed using underwater remotely operated vehicles. The likely cost of such remedial work would be very high. The overall impact on the environment would be generally small although the local marine environment would be affected by the remedial activities.

The likelihood that major problems would be encountered during the cutting and removal activities has been estimated, as for Alternatives A and B, using probability theory based upon appropriate historical data and input from a group of independent experts (Ref. 9.39). The costs of the actions necessary to rectify the unsatisfactory situations have also been estimated in broad terms, based upon outline descriptions of the necessary works. The probability and consequences of the various accident scenarios are given in Table 9.5.

	Description	Consequence	Probability	Estimated Cost (see note)
1	Unsuccessful cutting	Delay, increased cost and increased risk to personnel	In the order of 3%	2300 MNOK £176m
2	Collapse or dropping of column	Collapse with insufficient shipping draft, increased risk to personnel and increased cost	In the order of 2%	2600 MNOK £199m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenario the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

Table 9.5 Probability and Consequences of a Major Accident or Incident during the Cutting Down of TCP2 (Alternative C)

The overall probability of a major accident or incident during the cutting down of the TCP2 concrete substructure is estimated to be in the order of 5% which is fifty times greater than the acceptance criterion. This 5% overall probability of a major accident is based upon the assumption that many uncertainties and unknown factors will be eliminated by extensive inspection, testing and engineering work before conducting the work offshore. The probability of a major accident or incident predicted on the basis of the information available **at the present time** is in the order of 13%.

Loss of structural integrity is a significant (although not the only) contributor to the 2% possibility of collapse of a column, as considered in worst case scenario 2 above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.2.2.4 Technical Assessment of Alternative D - Leave In Place, Remove External Steelwork

Proposed Method

Alternative D involves leaving the concrete substructure in place after removing both the topsides and the steel items on the outside of the concrete substructure.

The modules and deck, forming the topsides, would be removed first, as described in Section 9.2.1. The steel items on the outside of the concrete substructure including the external risers, the external casings and their supporting steelwork would then be removed. The J tubes, flowlines and controls umbilicals would be cut at the seabed. Sections of pipe between the substructure and the seabed pipelines would be cut out and removed.

The majority of the subsea work necessary to remove the external steelwork is planned to be undertaken using remotely operated vehicles controlled from the surface. Some diving work would however be required.

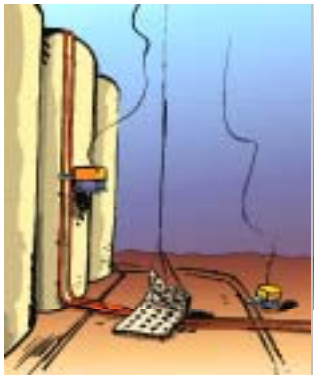


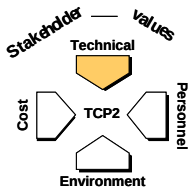
Figure 9.8 Principle of removing external steel work on TCP2 concrete substructure

Holes would be made in Column 1 (and the ballast cylinder inside it) so that the water level inside the column was the same as the external sea level.

The necessary navigation aids would then be installed on the substructure. Debris on the seabed around the substructure would be recovered as described in Section 12. These activities would be integrated with similar activities for the other platforms and would be planned and undertaken working closely with the various users of the sea.

Technical Feasibility

No aspects, which would significantly affect the technical feasibility of this alternative, have been identified. Alternative D is not considered to involve any unusual technical operations and thus the risk of not being able to complete the planned work tasks is considered to be very low.

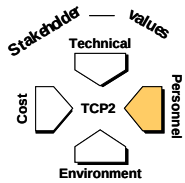


The main concern in respect to the Alternative D work is the safety of personnel engaged in cutting and lifting the external steelwork. As much as possible of this work would be undertaken using remotely operated vehicles.

9.2.2.5 Risks to Personnel – All Alternatives

During Decommissioning Operations

The risk to personnel engaged in the planned operations for the various disposal alternatives for TCP2 has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 9.40) The predicted number of fatalities and major injuries expressed in statistical terms are shown in Table 9.6 below. A definition of the terms used in this table is given in Section 6.3.



	Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
Predicted number of fatalities (Potential Loss of Life)	0.13	0.10	0.20	0.02
Probability of a Fatality	13%	10%	18%	2%
Predicted number of major injuries (Potential Major Injuries)	8.5	6.2	6.3	0.7
Probability of a Major Injury	More than 90%	More than 90%	More than 90%	50%

Table 9.6 Estimated Risk to Personnel during Disposal Alternatives for TCP2 Concrete Substructure

It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel. It can be seen from the table above that the probability of a fatality is approximately 7 times higher for Alternative A than for Alternative D. For Alternative A the inshore and onshore demolition work represents about two thirds of the total fatality probability. Based upon these predicted fatalities the **average** fatal accident rate (FAR value) for the complete removal and onshore disposal work is estimated to be in the order of 14. This is approximately 3 times the estimated average risk to workers on the Frigg Central Complex during 2000.

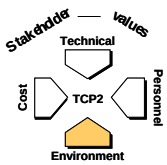
After Decommissioning
The effect on the safety of shipping of leaving TCP2 concrete substructure in place (Alternative D) has been assessed (Refs. 9.44, 9.45). Any concrete substructures left in place would be clearly marked with navigation aids that would be inspected at regular intervals.

The probability of fishing vessels colliding with the TCP2 concrete substructure, if left in place, has been estimated to be in the order of 1 in 100,000 per year based upon current fishing activity in the area. Because the concrete substructures are visible, the probability of fishing vessels snagging their gear on the substructure is considerably less than if the base were left on the seabed after the columns are cut down.

The probability of passing merchant ships colliding with the TCP2 concrete substructure, if left in place, has been estimated to be in the order of 1 in 20,000 per year based upon current shipping activity. The probability of a collision is predicted to reduce significantly in the years after decommissioning due to changes in shipping routes and the development of more sophisticated navigational equipment.

9.2.2.6 Environmental Impact – All Alternatives

The environmental impact of the four removal and disposal alternatives considered for the TCP2 concrete substructures may be found in Section 9 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. The environmental impacts of the four disposal alternatives considered are summarised in Table 9.7.



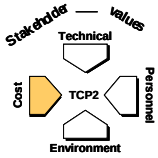
	Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
Energy Consump. (1000GJ)	738	530	644	53
Total Energy Impact (1000 GJ)	738	900	1010	460
CO_2 Emissions (1000 tonnes)	44	40	48	4.0
Discharges to sea	None/Insignificant	None/Insignificant	None/Insignificant	None/Insignificant
Physical impact on environment	Moderate negative	Moderate negative	Large/Moderate negative	Moderate negative
Aesthetic impact	Moderate negative	None/Insignificant	None/Insignificant	None/Insignificant
Material Management	Moderate positive	Non/Insignificant	Small positive	None/Insignificant (Small positive)
Littering	None/Insignificant	None/Insignificant	Small negative	Small negative
Impacts on fisheries	Moderate positive	Moderate positive	Moderate negative	Moderate negative
Free passage at sea	Moderate positive	Moderate positive	Moderate positive	Moderate negative

Table 9.7 Summary of Environmental Impact of Alternative Disposal Arrangements for the TCP2 Concrete Substructure

The environmental impact detailed in Table 9.7 assumes that the operations are carried out essentially as planned and that there is no need to undertaken extensive remedial works resulting from a major accident during the disposal operations. It is important to note that cleaning of the TCP2 concrete substructure is not required, as it has **never been used for the storage of crude oil.**

9.2.2.7 Costs – All Alternatives

The estimated costs of the four disposal alternatives for the concrete substructure of TCP2 are given in Table 9.8.



Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
2462 MNOK / £188.3m	1048 MNOK / £80.1m	1647 MNOK / £125.9m	77 MNOK / £5.9m (see note)

Note:- An additional figure of 7 MNOK / £0.5m is included in the cost estimate for the topside removal to cover the supply and installation of the new navigation aids.

Table 9.8 Estimated Cost of Alternative Disposal Arrangements for the Concrete Substructure of TCP2 (The cost of disposal of the topsides is not included)

9.2.3 TCP2 – Summary and Recommendations

9.2.3.1 Summary – TCP2 Topsides

The studies undertaken indicate that the TCP2 topsides may be removed using conventional offshore methods of working. The probability of a fatality during this work has been estimated as approximately 5% and the probability of a major injury as approximately 94%. These risk levels have been based upon experience data for offshore and onshore construction. All reasonably practicable risk reducing measures will therefore be taken to reduce this risk.

The impact on the environment of removing the topsides is generally low. The “small negative” or “moderate negative” impacts arising from the energy usage, emissions and aesthetic effects during the removal and onshore disposal, are balanced by the “large positive” impact in respect to materials management arising from the reuse and recycling of materials.

9.2.3.2 Summary – TCP2 Concrete Substructure

Refloat and Onshore Disposal

There is a significant degree of uncertainty regarding the strength and integrity of the TCP2 concrete substructure in the vicinity of the so-called tri-cells. This brings into question the advisability of attempting to refloat the platform, particularly in view of the fact that loss of air pressure in critical cells of the base would undoubtedly lead to loss of the platform. It must also be noted that the condition of the structure and the piping systems will have degraded in the 30-35 years between installation and decommissioning. Whilst this does not affect the safety of the platform during the present operational phase, it could be a critical factor during the removal operations.

There are also a number of significant uncertainties associated with the method of freeing the substructure from the seabed including aspects relating to the soil properties, the slope of the seabed and the weight, buoyancy and suction under the structure, as it breaks free from the seabed. The need to use ballast pipework that was designed only for service during the installation phase also gives considerable concern.

The movement of the TCP2 substructure as it breaks free from the seabed is more or less impossible to predict with any degree of accuracy. There is a possibility that the substructure could “skid” across the seabed in an uncontrollable manner after breaking loose and collide with TP1 which is only 35m away. The risk of a collision would affect TP1 if it were removed first.

The consequences of a major accident during the refloat operations have been shown to be particularly severe, especially in respect to the safety of personnel and cost. In order to reduce the environmental impact of such a major accident, and limit the effect on users of the sea, it would also be necessary to engage in a series of hazardous (or extremely hazardous) operations that would considerably increase the likelihood of fatalities.

During the anticipated activities involved in removal and onshore disposal operations, the probability of a fatality has been estimated as being in the order of 13% (that is a 1 in 8 chance of a fatality). The probability of fatalities would increase significantly if large amounts of offshore work were required as the result of a major accident during a removal operation. It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel.

The cost of removing the concrete substructure of TCP2, if possible, has been estimated to be approximately 2500 MNOK / £191m assuming that no major accidents occur and the operations go as planned. There is however a significant possibility that the cost could increase by a factor of 2 to 3 if a major accident occurred whilst the substructure was being refloated or towed to shore.

Based upon the judgement and input of leading independent experts, the probability of a major accident during the refloat and tow to shore arising from inherent uncertainties has been estimated to be in the order of 2% to 4%. This is twenty to forty times higher than 0.1%, which is the risk acceptance criterion for asset/financial loss during decommissioning based upon the level of risk accepted during the Frigg Field production phase. The decommissioning risk acceptance criterion is in line with the guidance given in the DNV rules for marine operations. Additionally it is normal for additional problems to become apparent during the detailed engineering phase of a major project, and these would have the effect of increasing further the probability of accident and delay. It is also to be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

In view of the limited environmental benefit, and the severe safety and financial implications of a major accident, the inherent uncertainties surrounding the complete removal and onshore disposal of the TCP2 concrete substructure are considered unacceptable.

Refloat and Disposal in Deep Water
The refloat of the substructure for offshore disposal is similarly uncertain and, in addition, the dumping of structures in the deep ocean is generally considered to be undesirable by society. Consultation with the stakeholders indicated that if the substructure could be refloated, then it should be brought to shore for disposal, rather than dumped in the ocean. Alternative B, refloat and disposal in deep water, is therefore also rejected.

Cut Down to –55m
Cutting down the columns is felt to be theoretically feasible although the level of uncertainty surrounding the method of cutting makes this decommissioning alternative unattractive. Considerable effort and expenditure would be necessary before the feasibility of this option could be fully proven. Cutting the columns down to allow a clear 55m draft above the remaining substructure does however have the merit of allowing the free passage of vessels although remaining an obstruction to fishing activity.

Uncertainties associated with the process of cutting and removing the columns mean that there is a significant risk of delay. The external cofferdam and the cutting method itself both require the development and qualification of new technology and its deployment in difficult environments. Once the cutting work has been started the structural integrity of a column will be affected and after a relatively small section of a column has been cut it will not have sufficient strength to resist a winter storm. In view of the unproven nature of much of the work significant delays could result in uncontrolled collapse of a column which would be unlikely to achieve a clear water draft of 55m.

The probability of collapse of a column has been estimated to be in the order of 2%, which is 20 times higher than acceptable. In such an event the remedial work necessary to achieve 55m would be both very hazardous and costly, involving substantially increased risk to personnel and a possible cost increase of more than 50%. Unknown factors related to the cutting methods also results a 3% probability that the chosen cutting method would need to be re-engineered and re-qualified. This would result in a high level of cost uncertainty and possible increased risk to personnel. Additionally, this method of decommissioning TCP2 is not considered desirable by either the Norwegian or UK fishing industries due to the danger it represents to fishing activity.

Due to the uncertainties associated with the decommissioning operations, and the fact that this solution is also unattractive to some stakeholders, particularly the fishing industry, it is recommended that this alternative be rejected.

Leave In Place
Leaving the concrete substructure in place is therefore considered to be the best solution when considering health and working environment, safety, environmental aspects and cost.

The concrete substructure is not polluted with hydrocarbons or other chemicals or materials and thus there is judged to be an insignificant level of discharge to the marine environment. Tests on samples of concrete taken from the substructure and analytical studies support the view that long-term degradation of the concrete will have an insignificant impact on the local marine environment (Ref. 9.46). By removing the external steelwork, the risk of sections of steelwork corroding and falling onto the seabed where they could be a hazard for fishermen, is eliminated. Diesel fuel, hydraulic oil and methanol used for operational purposes in the columns, will be removed and the equipment and piping cleaned. It is important to note that cleaning of the TCP2 concrete substructure is not required, as it has **never been used for the storage of crude oil.**

Very little other environmental impact has been predicted if the substructure was left in place, apart from the obstruction caused to fishing vessels and other users of the sea. Quantitative assessments indicate that the probability of vessels colliding with the TCP2 concrete substructure is however relatively low and appropriate risk reducing measures will be taken.

Comparison of Disposal Alternatives

The predicted consequences, in terms of safety, environmental impact and cost, of adopting the main disposal alternatives considered, are summarised in Figure 9.9. This table does not include the removal and offshore disposal alternative (Alternative B), as the implications are rather similar to the removal and onshore disposal alternative (Alternative A). In addition society's general aversion to offshore dumping makes this alternative unattractive.

	Remove and Dispose Onshore		Cut Down to –55m		Leave in Place	
	As Planned	Major Unplanned Event	As Planned	Major Unplanned Event	As Planned	Major Unplanned Event
Technical Feasibility Probability of a major unplanned event		Probability **2 to 4%** i.e. 20 to 40 times greater than acceptance criterion		Probability **5%** i.e.50 times greater than acceptance criterion		No potential for major unplanned event
CONSEQUENCES						
Safety Probability of a Fatality	13%	16% - 60%	18%	22-24%	2%	-
Impact on Environment Total Energy Impact (1000GJ)	738	1000 - 2100	1010	1600 - 2200	460	-
CO_2 Release (1000 tonnes)	44	80 - 160	48	115 - 160	4	-
Physical Impact on Environment	"Moderate Negative"	"Moderate Negative" plus "Small Negative"	"Moderate Negative"	"Moderate Negative"	"Moderate Negative"	-
Cost MNOK / £m	2462 £188m	3200-8200 £245-627m	1647 £126m	2300 – 2600 £176-199m	77 £5.9m	-

Figure 9.9 Predicted Consequences of Different Disposal Alternatives for the TCP2 Concrete Substructure

9.2.3.3 Recommended Disposal Arrangements for Platform TCP2

It is recommended that the topsides of TCP2 platform should be removed and brought onshore for disposal, and that the concrete substructure should be suitably marked and left in place after removal of the external steelwork. As much as practicable of the equipment and materials brought onshore will be reused or recycled.

Figure 9.10 Recommended Decommissioned Condition of the TCP2 Concrete Substructure after Removal of Topside and External Steelwork.

9.3 Concrete Drilling Platform 1 – CDP1

9.3.1 CDP1 Topsides – Evaluation of Removal Methods

9.3.1.1 Methods

The modules on CDP1 are supported on a series of concrete deck beams that are an integral part of the concrete substructure. The disposal of these concrete deck beams has therefore been considered in the assessment for the concrete substructure as detailed in Section 9.3.2. This section therefore, only deals with the removal of the topsides modules, steel deck beams and steel deck plating.

During the construction of CDP1, a gantry crane was used to install the modules on the concrete deck beams. Reinstallation of such a crane is not considered either practicable, or desirable, and thus it is planned to remove the modules, and the steel deck components, systematically using a crane vessel. The components will be transported to shore for disposal.

The platform has not been in operation since 1990, although it has been visited at regular intervals to check the safety and integrity of critical areas. Items that might be a hazard by falling onto personnel have been removed and access during the safety visits is restricted to designated areas. During the topsides removal operations it will however be necessary to have access to many other areas of the platform and particular attention will be needed to ensure the safety of personnel engaged in the work.

9.3.1.2 Consequences

Risk to Personnel

The risk to personnel undertaking the removal and disposal of CDP1 topsides has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 9.43) The predicted numbers of fatalities and major injuries expressed in statistical terms are shown in Table 9.9. A definition of the terms used in this table is given in Section 6.3.

Predicted number of fatalities (Potential Loss of Life))	0.04 (0.0427) See note
Probability of a Fatality	4%
Predicted number of major injuries (Potential Major Injuries)	2.1
Probability of a Major Injury	88%

Note:- The PLL value shown has been rounded to the nearest percentage point. The actual calculated value is shown in parenthesis for comparison purposes.

Table 9.9 Estimated Risk to Personnel during Removal and Onshore Disposal of CDP1 Topsides

Environmental Impact

The environmental impact of removing the topsides of CDP1 may be found in Section 7 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. A summary of the findings is given in Table 9.10.

Parameter	Value
Energy Consumption (1000 GJ)	130
Total Energy Impact (1000 GJ)	130
CO_2 Emissions (1000 tonne)	11
Discharges to sea	None/insignificant
Physical impact on environment / habitat	None/insignificant
Aesthetic impact	Moderate negative
Material management	Large positive
Littering	None/insignificant
Impacts on fisheries	None/insignificant
Impacts on free passage at sea	None/insignificant

Table 9.10 Environmental Impact of Removal and Onshore Disposal of the CDP1 Topsides

Costs
The cost of removal, transportation and onshore disposal of the CDP1 topsides has been estimated as 593 MNOK / £45.4m.

9.3.2 CDP1 Concrete Substructure – Comparative Assessment of Disposal Alternatives

9.3.2.1 Technical Assessment of Alternative A - Refloat and Onshore Disposal

Proposed Method
The topside modules and steel components would first be removed as described in Section 9.3.1. The pipelines would be disconnected and plugged and the utility risers, guide frames and diving rails removed. A water de-ballasting system, to be used in refloating the platform, would then be installed.

The solid ballast (sand and gravel) between the central shaft and the outer wall would then be removed using a suction dredging system working from the concrete deck beams. The top layer of sand and gravel ballast would be removed and deposited on the seabed a short distance away from the platform. There is a layer of drill cuttings in the ballast between the central shaft and the outer wall. When the top layer of solid ballast has been removed, the dredging system would be stopped, and the drill cuttings and any contaminated ballast would be removed using a crane with a grab system located on the deck beams. The drill cuttings and contaminated ballast would be transferred to a hopper barge for transportation to shore where they would be treated before onshore disposal.

The solid ballast below the drill cuttings would be removed using the air operated dredging system and also deposited on the seabed a short way away from the platform. Debris inside the foundation raft would be removed.

The wave-breaking holes in the outer wall would be sealed by installing a prefabricated steel cofferdam, made up of six separate sections, around the external face of the wall. The penetrations in the base slab would be plugged, and towing points on the substructure reinstated.

The substructure would then be de-ballasted by pumping out the water inside the outer wall. There are no “skirts” penetrating into the soil and no cement grout between the base slab and

the soil. Geotechnical studies indicate that only limited “suction” between the substructure and the soil would be likely to occur due to the absence of skirts and the permeability of the sand layer on which the platform is founded.

Following the “lift off” of the substructure from the seabed, it would continue to be de-ballasted until it reaches a draft suitable for towing. During the refloat and towing operations the platform would be unmanned. Operation of the de-ballasting systems when the platform is unmanned would be by remote control from an adjacent boat.

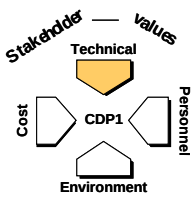
After the substructure reaches a suitable draft it would be towed to a sheltered inshore mooring.

The deck panels, deck extensions, skid beams, modules between the concrete deck beams and the steelwork in the central shaft would be removed first using a floating crane. The concrete deck beams and columns and a part of the central shaft would then be cut into pieces using diamond sawing techniques and removed also using the floating crane. Most of the steel cofferdam would then be removed and the outer concrete wall cut into pieces and lifted away. Demolition of the concrete shaft, outer walls and radial walls would continue until most of these walls have been removed. During this phase of the work the remaining solid ballast would be broken out and removed. A further cofferdam would then be installed around the wall on the edge of the foundation slab to provide buoyancy during the latter stages of demolition. The bottom section of the substructure would then be towed into a dry dock where it would be demolished.

All the sections of reinforced/prestressed concrete cut from the substructure would be crushed onshore to allow recovery of the steel and concrete. The steel would then be sent for re-smelting whilst it is anticipated that the crushed concrete would be reused or disposed of in landfill.

Debris on the seabed at the original platform location would be cleared using remotely operated vehicles or divers.

Technical Feasibility



During the design of the CDP1 concrete substructure no consideration was given to its removal at a later date. Accordingly the ability of the structure to resist the loads during a refloat operation was not checked and no specific features were incorporated into the design to facilitate removal. Additionally it must be remembered that the platform was originally designed as a booster platform on the Frigg to St Fergus pipelines. After the accident with the DP1 steel substructure in 1974 the platform was converted for use as a drilling platform, but by that time the design had been completed and the construction was well advanced. The substructure was completed in accordance with the original design.

In assessing the technical feasibility of refloating the CDP1 concrete substructure, a number of aspects have been identified that would be critical to the success of the operation. The most important aspects, which have the potential to cause the refloat operation to be aborted, are shown in Figure 9.11 and are explained further in the following text.

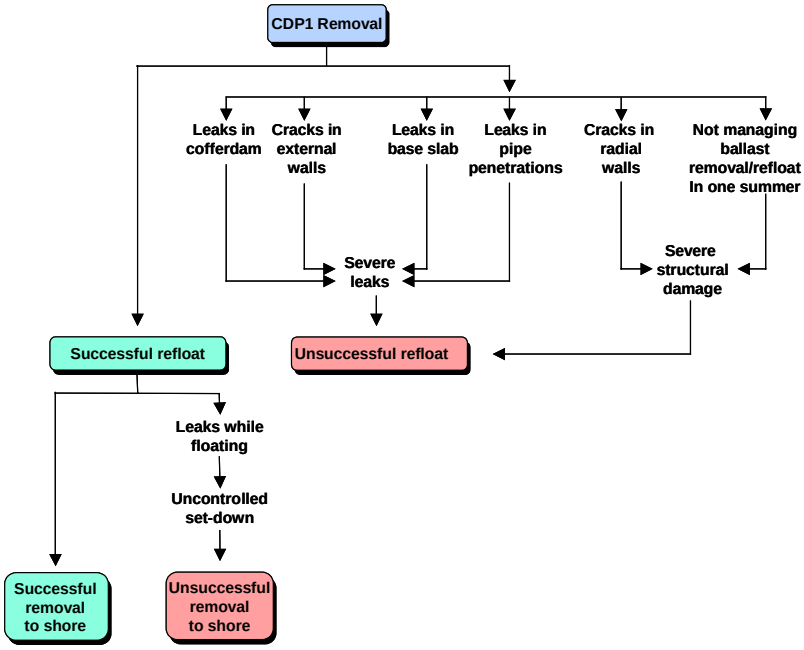


Figure 9.11 Areas of Uncertainty Affecting the Success of the Refloat and Towing of CDP1

Uncertainties During the Refloat Operations

- **Leaks in Cofferdam**
- **Cracks in External Walls**
- **Leaks in Base Slab**
- **Leaks in Pipe Penetrations**

The feasibility of refloating the CDP1 concrete substructure has been shown to be highly dependant on the water-tightness of the cofferdam, walls and base slab. The water-tightness of the substructure is the most critical aspect of the refloat operation. Additionally this aspect has a very high uncertainty factor associated with it.

During tow-out and installation of the platform in 1975, an in-flow of seawater of approximately 3,000 m^3/hour was measured. This large leakage was noted and documented at the time by the independent warranty surveyor, Noble Denton & Associates. The leakage is understood to have occurred at many locations in the vicinity of the wave-breaking holes in the outer wall. Leakage was recorded as occurring through construction joints between the pre-cast concrete units in the area and the in-situ concrete between the units. There is also record of **leaks through ineffectively plugged holes** for scaffolding or other temporary equipment. The use of a large external steel cofferdam during an attempted refloat operation would most probably reduce the leakage, but this is by no means certain.

If there are existing leaks below the bottom of the cofferdam these will not be evident until the cofferdam is installed and the water inside the outer wall pumped out. If serious leaks were discovered (principally by being unable to pump out the space inside the outer wall), it would be extremely difficult or perhaps impossible to locate or repair them.

As well as the known leakage there are a number of other places where significant leakage could occur during the water de-ballasting and refloat operation. The holes that were drilled through the base slab for the 24 wells are particular likely leak points. As the substructure was not initially intended to be a drilling platform, provision for the wells was not included in the design. The holes for the wells were therefore cut after the platform had been installed. This was done using the drilling facilities on the platform to drill through the reinforced and pre-

stressed concrete base slab. The wells were plugged and abandoned in 1990 but all the **holes in the base slab will still need to be sealed** before the platform can be refloated.

In addition to the holes for the wells, there are a number of other penetrations in the base slab principally for the instrumentation pipes used to monitor the bearing pressure under the platform. The condition of the pipework penetrating the base slab is unknown, as the system has not been used for many years. Two instrumentation pipes are reported to be broken and lost in the solid ballast. It is not possible at the moment to inspect these items as they are covered with solid ballast and lean mix concrete, the condition of which is unknown. It is unlikely that the lean mix concrete can be relied upon to prevent leakage from the instrumentation pipework. It would be necessary to **find and plug all the penetrations** in the base slab, including the conductor sleeves and instrument connections, before refloat operations could be started.

During the early life of the platform **severe cracking** occurred in the concrete structure due to wave loading on the platform. Additional solid ballast was added to the substructure to prevent further damage, but large cracks in the radial walls in the direction of the prevailing weather, had already formed. Throughout the operational life of the field the condition of the substructure has been monitored by bi-annual subsea inspection programmes to ensure the safety of the CDP1 platform at all times. It is however known that these cracks are as much as 11m long in some locations. These cracks are in the radial walls of the substructure and it is believed that there is only a low probability that they would propagate into the external walls of the substructure during the refloat and towing operations. Significant cracking in the outer wall of the substructure would however result in large leaks that could jeopardise the buoyancy of the concrete substructure whilst floating. Based upon the structural configuration of the walls expert opinion has judged that in its existing condition, such crack propagation, although possible, has a low probability. If however the substructure was left for a significant period of time in an un-ballasted condition with the cofferdam in-place, then the likelihood of cracks propagating into the external walls is much higher.

A further probable source of leakage is the **steel cofferdam** that would need to be installed around the outer wall to seal the 720 wave-breaking holes. This large steel structure, which would need to be approximately 250m in circumference, would have to be placed against the existing concrete walls of the substructure. It will be extremely difficult to ensure the water-tightness of the cofferdam. Extensive measures can be taken to prevent leakage, however the size of the cofferdam and the fact that it will need to be installed on an old concrete structure, in the open sea, means that there is a **very high probability of significant leakage occurring.**

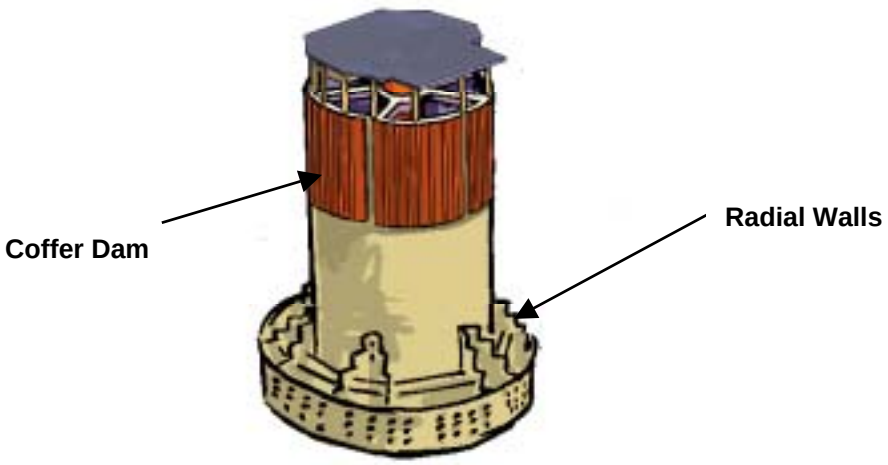


Figure 9.12 Location of the Steel Cofferdam Installed to Seal the Holes in the Outer Wall of CDP1

Due to the design of the substructure, it is not possible to test or demonstrate the water-tightness of the structure until the solid ballast has been removed, the cofferdam has been installed around the outer wall and the water inside the outer wall has been pumped out. In view of all these facts and, in the absence of information to the contrary, it must be assumed that there would be considerable leakage during any refloat operation.

With the cofferdam installed, and the solid ballast removed, the substructure would not be able to withstand a severe winter storm without significant damage, or movement on the seabed. Thus, if there was a delay of a number of months in the refloat operation caused by severe leakage, the platform would have to remain in position over the winter period and there would thus be a serious possibility of total loss of the substructure due to cracking in the walls and base slab.

- **Cracks in Radial Walls**
- **Not Managing Ballast Removal/Refloat In One Summer**

There is considerable uncertainty and concern regarding the structural integrity of the CDP1 substructure during the de-ballasting, “lift off” and ascent through the water. As noted above, the structure has been damaged during its life and large cracks in the radial walls are known to exist. It is not certain to what extent these would impair the strength of the substructure.

As also mentioned above, when the substructure was adopted as a drilling platform, 24 number holes 36” in diameter were cut through the base slab for the wells. The position of these holes was determined by the location of the wellheads and Christmas trees on the topsides. In cutting the holes for the wells in the base slab, it was therefore necessary to cut the reinforcement. The effect that this had on the ultimate strength of the base slab is also uncertain at the present time.

During a refloat operation the substructure would experience a totally new series of loads arising from the fact that the cofferdam is installed, and the platform is wholly or partially de-ballasted. In such a condition the platform could not withstand a 100-year winter storm.

A further uncertainty relating to the strength of the substructure concerns the possibility of the substructure sliding on the seabed. When the platform has been de-ballasted by the removal of approximately 200,000 tonnes of sand and gravel, there is a reduced factor of safety against the platform moving on the seabed in a severe storm. If, due to leakage, or other operational problems it was not possible to refloat the platform in the same summer season that it is de-ballasted, then there is a significant possibility that sliding of the platform could occur. If this should take place there is a distinct possibility of damage to the base slab, which, taken together with the known damage of the radial walls, could worsen the leakage problem and impair the integrity of the structure.

Difficulty in assessing the weight of items such as marine growth and the ballast remaining in the substructure could give rise to uncertainty in the final refloat weight of the substructure. This in turn could affect the stability and freeboard when floating. In addition, general uncertainty regarding the condition of the solid ballast (compaction, settlement, contamination, debris) could delay the removal of the solid ballast and could require the platform to remain in a lightly ballasted state over a winter period.

Probability of Failure During Refloat and Disposal

In view of the uncertainty associated with many aspects of the CDP1 concrete substructure removal operations, the probability and consequences of a major accident have been investigated. There are an infinite number of possible accidents and outcomes but in order to make a broad estimate of the likelihood and consequences of a major accidental event, four **representative** scenarios have been investigated :-

1. Accident before refloat	Damage to the external wall during marine operations.
2. Leakage preventing refloat or accident during refloat	Leakage preventing the removal of water from inside the external wall or failure of a critical system or structural member during the refloat operation. Failure during the refloat operation would result in loss of buoyancy and impact with the seabed. The impact would result in severe damage to the walls and/or base slab.
3. Accident during tow	Leakage, or failure of a critical system or structural member during the tow to shore resulting in loss of buoyancy and impact with the seabed. The impact would result in severe damage to the walls and base slab. The substructure including the deck is likely to be totally submerged after impact with the seabed.
4. Accident during demolition	Leakage, or failure of a critical system or structural member during the inshore demolition operation resulting in loss of buoyancy and impact with the seabed. The impact would result in disintegration of the remaining substructure.

For many of the worst case scenarios the risks inherent in the remedial works would be so high as to make them unacceptable and, in that case, remedial work would not be possible. However, when assessing the consequences of the worst case scenarios the risks involved have been estimated with no prior decision as to whether they are acceptable or not.

When assessing the implications of the accident scenario prior to the refloat operation, it has been assumed that in most cases it will be possible to repair the damage to the substructure. This does not however mean that the leaks, which are known to be present, can be repaired before the refloat operation is started. If it proved to be impossible to empty the structure of water due to leaks arising from accidental damage, cracking of the concrete or inadequately sealed holes then attempts would be made to identify the location of the leaks and then to repair them. It is questionable whether such repair operations would be successful even if it were possible to identify the location of the leak. If it was not possible to make the substructure watertight then the refloat operation would have to be aborted and consideration given to cutting the whole substructure into sections for transportation to shore. Such an operation would be extremely hazardous and very costly.

If significant leakage occurred whilst the substructure was floating, (that is, during the refloat, tow and demolition phases) then it is likely that the substructure would sink back onto the seabed. In this event, the damage to the base slab and lower walls would most probably be so severe that it would be impossible to refloat the substructure again. In order to remove the concrete substructure it would then be necessary to cut it into small sections which could be lifted to the surface and transported to shore for disposal.

These operations would be extremely hazardous due to the damaged condition of the substructure and the need for most of the cutting and lifting to be done underwater. In the case of accident scenarios 2 and 3, the work would also need to be undertaken at an exposed offshore location, which would significantly increase the risk. The likely cost of such remedial work would be very high, although the overall impact on the on the environment is generally small. The main negative impacts are; the effect on the local marine environment (seabed and natural resources); and the emissions to atmosphere during the extensive remedial works. The environmental impact analysis did however identify a number of specific situations where the environmental impact would be much greater due to local conditions (e.g. when towing the substructure over an oil pipeline or in the area of particular fishing grounds or near inshore fish farms.

The possibility of being unable to refloat the substructure due to leaks and the likelihood of major accidents during the planned removal and disposal operations has been estimated using probability theory based upon appropriate historical data and input from a group of independent experts (Ref.9.39). The costs of the remedial activities required following a major accident have also been estimated in broad terms for all four accident scenarios based on outline descriptions of the necessary works. The probability and consequences of the various accident scenarios are given in Table 9.11.

	Description	Consequence	Probability	Estimated Cost (see note)
1	Accident before refloat	Damage to external walls	4% - 5%	4700 MNOK £359m
2	Leakage preventing refloat or accident during refloat	Inability to deballast the substructure or severe damage to walls and base slab in an accident.	In the order of 25%	9300 MNOK £711m
3	Accident during tow	Severe damage to walls and base slab	0.2% - 0.3%	9800 MNOK £749m
4	Accident during demolition	Disintegration of substructure	0.5% - 1.0%	5200 MNOK £398m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenarios the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

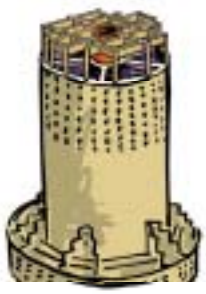
Table 9.11 Probability and Consequences of Being Unable to Refloat the Substructure or having a Major Accident during CDP1 Refloat and Inshore Disposal Operations (Alternative A)

The overall probability of being unable to refloat the substructure or having a major accident during the removal and disposal operations for the CDP1 concrete substructure is estimated to be in the order of 30% which is three hundred times greater than the acceptance criterion. Loss of structural integrity is a significant contributor to the overall probability of a major accident as listed in the table above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of structural failure during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.3.2.2 Technical Assessment of Alternative B - Refloat and Disposal in Deep Water

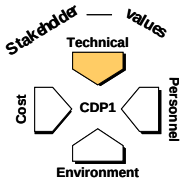
Proposed Method

The activities performed to refloat the substructure for disposal in deep water (Alternative B) are essentially the same as for the onshore disposal option (Alternative A). The main difference apart from the final disposal method is that additional steel items would be removed offshore. The steel deck panels, deck extensions, skid beams and modules between the concrete deck beams and the steelwork in the central shaft would therefore be removed before starting the refloat operations rather than at the inshore location, as would be the case for the onshore disposal alternative.



After the structure lifts off the bottom it would continue to be de-ballasted until it reaches a draft suitable for towing. It would then be towed to the deep-water disposal site and ballasted down to a draft of 75m. As for Alternative A, the platform would be unmanned during the refloat and towing operations. Operation of the deballasting systems when the platform is unmanned would be by remote control from an adjacent boat. The de-ballasting system mounted on the concrete deck, including generators, hydraulic power pack etc., would be retrieved before the substructure was sunk using explosive charges.

Technical Feasibility



The feasibility of Alternative B depends essentially on the possibility of being able to refloat the substructure. The concerns noted for Alternative A also apply to Alternative B (see Section 9.3.2.1).

Probability of Failure During Refloat and Disposal

The refloat operation for Alternative B is essentially the same as for Alternative A and the same uncertainties therefore apply. As a result, the accident scenarios considered for Alternative A are also valid for Alternative B, apart from scenario 4 (Accident during demolition) which is obviously not relevant in the case of disposal in deep water.

The probability and consequences of the various accident scenarios have been estimated (Ref. 9.39) and are given in Table 9.12.

	Description	Consequence	Probability	Estimated Cost (see note)
1	Accident before refloat	Damage to cells	4% - 5%	3600 MNOK £275m
2	Leakage preventing refloat or accident during refloat	Inability to deballast the substructure or severe damage to walls and base slab in an accident.	In the order of 25%	8700 MNOK £665m
3	Accident during tow	Severe damage to walls and base slab	0.2% - 0.3%	9200 MNOK £703m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenarios the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

Table 9.12 Probability and Consequences of Being Unable to Refloat the Substructure or having a Major Accident during CDP1 Refloat and Towing Operations for Disposal in Deep Water (Alternative B)

The overall probability of being unable to refloat the substructure or of having a major accident during the removal and deep water disposal operations for the CDP1 concrete substructure is estimated to be in the order of 29% which is two hundred and ninety times greater than the acceptance criterion. Loss of structural integrity is a significant contributor to the overall probability of a major accident as listed in the table above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.3.2.3 Technical Assessment of Alternative C - Partial Removal to Provide a Clear Draft of 55m over the Remaining Structure

Proposed Method

The modules, steel deck components, and the steelwork in the central shaft would be removed and the pipelines disconnected and plugged. The solid ballast between the central shaft and the outer wall would then be removed using an air operated dredging system working from the concrete deck beams. The ballast would be relocated into the open foundation cells around the outer wall. There is a layer of drill cuttings in the ballast between the central shaft and the outer wall. When the top layer of solid ballast has been removed the dredging system would be stopped and the drill cuttings removed using a grab system mounted on a crane located at deck level. The drill cuttings would be transferred to a hopper barge as they are recovered, for transportation to shore where they would be treated before onshore disposal.

Figure 9.13 CDP1 Concrete Substructure cut down to –55m.

The layer of ballast below the drill cuttings would be removed using the air operated dredging system and relocated outside the outer wall in the open foundation cells. Any steel items exposed when the ballast between the central shaft and the outer wall has been removed would be cut out of the structure and lifted away.

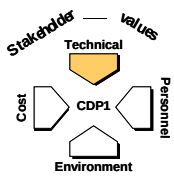
The concrete deck and the concrete filled steel columns on top of the outer wall would be cut into pieces, lifted, and placed on the seabed near the substructure.

The concrete substructure would then be partially demolished by isolating sections of the substructure and then toppling them outwards. Each section of wall would be separated from the rest of the substructure by cutting using either diamond saw or diamond wire cutting equipment, operated by divers. The last cuts for each section of wall and the toppling would be achieved using explosives. After the sections of the outer wall have been toppled, the radial walls and the central shaft would also be cut into sections and toppled using explosives.

The cuts would be made at locations that would ensure there was a minimum of 55metres of clear water above the substructure when all the sections had been toppled.

Technical Feasibility

The partial demolition of such a structure in the open sea has not been attempted before. It is considered that although such a process of demolition may theoretically be possible, many aspects would need to be resolved before the toppling operations could be regarded as practicable.



The following aspects limit the level of confidence that can be placed on the feasibility of Alternative C :-

Concrete Cutting Methods

A substantial programme of work would be needed to develop the equipment necessary for cutting the walls as this is considerably beyond anything that has been attempted to date. The thickness of the concrete walls and the large amount of pre-stressing and reinforcing steel in them would make them extremely difficult to cut. It is still far from certain that the subsea equipment necessary to effectively cut through the highly reinforced concrete walls could be developed.

The ability of explosives to effectively cut thick concrete walls with substantial amounts of pre-stressing and reinforcing steel is not well proven and involves many uncertainties. A considerable amount of development work, including full size trials, would be necessary before such a scheme could be confidently proposed. The firing of the explosion charges to topple the structure is a “point of no return” and may result in an unplanned situation from which it is impossible, or extremely difficult, to recover.

Structural Strength and Stability
The CDP1 concrete substructure is made up of a base slab and a series on interconnected walls. Each wall provides support and restraint to the neighbouring walls and slabs. The strength and stability of the individual parts of the substructure during the demolition process is therefore a major concern.

The integrity of the structure may also be impaired due to wave loading causing one or a number of partially cut sections of wall to topple in an unplanned manner. The structural integrity under wave loading would have to be addressed in detail for every step of the proposed dismantling sequence although the exact temporary condition of the structure might be unknown. It is also possible that a section of the outer wall could topple inwards rather than outwards due to the position of its centre of gravity.

If it proves impossible to complete all the toppling activities within one summer season the remaining part of the substructure will be subject to loads from winter storms. The uncertainties surrounding the cutting methods indicate that a delay over the winter period is quite possible. An unplanned collapse of all or part the substructure during a winter storm is likely to result in a pile of debris with less than 55m of clear water above it. It is also likely that the pile of debris would be unstable, thereby severly limiting the possible remedial measures.

Ineffective Toppling
The toppling of the different sections of the substructure is, by its very nature, a rather imprecise operation. Many sections of wall will need to be toppled. There is therefore a significant possibility that one or more of the sections may not fall in the intended position. If a section of wall becomes stuck or is left in an unstable condition it would be extremely dangerous to carry out the actions necessary to achieve the necessary 55m of clear water above the demolished substructure. The use of divers in this situation would be unacceptable to TOTAL NORGE.

Probability of Failure during Cutting Down Operations
Uncertainties surrounding the cutting and toppling of the various wall sections mean that these operations may not be successfully completed. There is a great deal of hazardous and technically uncertain work involved in cutting down the concrete substructure, due to the arrangement of interconnected walls. It is envisaged that at least 20 sections of wall would need to be cut and toppled if this disposal arrangement was adopted. There is therefore considerable potential for one or more sections of the substructure to fall in such a way that the clear draft for shipping of 55m, as required in the IMO Guidelines, was not achieved. In that event extensive remedial works would be required to achieve a satisfactory condition for the substructure.

The probability of this situation occurring and the consequences have been assessed based upon two representative scenarios as detailed below:-

1. Unsuccessful cutting	Failure of the cutting systems or associated equipment requiring redevelopment and re-qualification of cutting system.
2. Uncontrolled collapse of sections of wall	Collapse of walls during the cutting operations resulting in not achieving the required 55m of clear water above the remaining structure on the seabed.

The operations to clear a collapsed section of wall would likely be extremely hazardous especially if the wall were in an unstable condition. In that condition the risk of diving in the vicinity of the walls would be unacceptable and thus complex and expensive tools would need to be developed which could be deployed using underwater remotely operated vehicles. The likely cost of such remedial work would be very high. The overall impact on the environment would be generally small although the local marine environment would be affected by the remedial activities.

The likelihood that major problems would be encountered during the cutting and toppling activities has been estimated, as for Alternatives A and B, using probability theory based upon appropriate historical data and input from a group of independent experts (Ref. 9.39). The costs of the actions necessary to rectify the unsatisfactory situations have also been estimated in broad terms, based upon outline descriptions of the necessary works. The probability and consequences of the various accident scenarios are given in Table 9.13.

	Description	Consequence	Probability	Estimated Cost
1	Unsuccessful cutting	Delay, increased cost and increased risk to personnel	0.3% - 0.5%	5300 MNOK £405m
2	Uncontrolled collapse of a wall or walls	Collapse with insufficient shipping draft, increased risk to personnel and increased cost	In the order of 20%	5900 MNOK £451m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenario the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

Table 9.13 Probability and Consequences of a Major Accident or Incident during the Cutting Down of CDP1 (Alternative C)

The overall probability of a major accident or incident during the cutting down of the CDP1 concrete substructure is estimated to be in the order of 20% which is two hundred times greater than the acceptance criterion. Loss of structural integrity is the main contributor to the possibility of an uncontrolled collapse of a wall or walls, as considered in worst case scenario 2 above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of structural failure should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.3.2.4 Technical Assessment of Alternative D - Leave In Place

Proposed Method

Alternative D involves leaving the concrete substructure in place after removing the topside modules, the steel deck components, and the steel items on the outside of the concrete substructure.

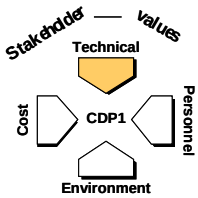
The topside modules would be removed first, as described in Section 9.3.1. Following this, the additional steel items in the deck would be removed including the deck panels, deck extensions, skid beams and the modules between the concrete deck beams.

There are no major steel items fixed to the outer walls of the concrete substructure which could corrode and fall onto the seabed. The main preparation work for the concrete substructure is therefore the plugging and disconnection of the subsea pipelines and cables prior to their removal (see Section 10).

After the removal of the topsides steel items, the necessary navigation aids would be installed on the substructure. As detailed in Section 12, debris on the seabed around the substructure would be recovered using remotely operated vehicles and divers. These activities will be planned and undertaken working closely with the various users of the sea, and the regulatory authorities.

Technical Feasibility

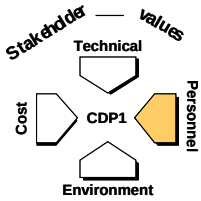
No significant technical problems associated with work have been identified. The work is not considered to involve any unusual technical risk and the risk of not being able to complete the planned work tasks is considered to be very low.



9.3.2.5 Risk to Personnel – All Alternatives

During Decommissioning Operations

The risk to personnel involved in the planned operations for the CDP1 disposal alternatives considered has been estimated based upon the anticipated work tasks and relevant historical accident rates. (Ref. 9.40) The predicted numbers of fatalities and major injuries expressed in statistical terms are shown in Table 9.14 below. A definition of the terms used in this table is given in Section 6.3.



	Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D removing as much external steelwork as reasonably practical
Predicted number of fatalities (Potential Loss of Life))	0.62	0.3	0.85	0.03
Probability of a Fatality	46%	26%	57%	3%
Predicted number of major injuries (Potential Major Injuries)	21.5	10.2	9.4	0.7
Probability of a Major Injury	More than 90%	More than 90%	More than 90%	50%

Table 9.14 Estimated Risk to Personnel during Disposal Alternatives for CDP1 Concrete Substructures

It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel. It can be seen from the table above that the probability of a fatality is approximately 20 times higher for Alternative A than for Alternative D. For Alternative A, diving operations contributes 43% of the total fatality probability, whilst offshore marine operations and the inshore/onshore demolition contribute 18% and 19% respectively. By far the largest contributor to the diving risk is surface diving in the area around the wave-breaking holes in the outer wall. From previous experience in the North Sea this is known to be particularly hazardous area, due to the strong currents and turbulence caused by the sea flowing through the holes.

Based upon the estimated fatalities, the **average** fatal accident rate (FAR value) for the complete removal and onshore disposal work is estimated to be in the order of 22. This is approximately 5 times the estimated average risk to workers on Frigg Central Complex while operational during 2000.

If the walls of the substructure were cut down to –55m (Alternative C) the predicted fatalities are 26 times higher than the leave in place option (Alternative D). Diving operations contribute 84% of the total fatality risk associated with Alternative C. The **average** fatal accident rate (FAR value) for the work involved in cutting down the walls of CDP1 is estimated to be in the order of 55. This is well above the maximum tolerable limit for operational personnel on Frigg Field and approximately 13 times the average risk to workers on Frigg Central Complex during 2000.

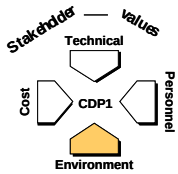
After Decommissioning
The effect on the safety of shipping of leaving CDP1 concrete substructure in place (Alternative D) has been addressed (Refs. 9.44, 9.45). Any concrete substructures left in place would be clearly marked with navigation aids that would be inspected at regular intervals.

The probability of fishing vessels colliding with the CDP1 concrete substructure, if left in place, has been estimated to be in the order of 1 in 40,000 per year based upon current fishing activity in the area. Because the concrete substructures are visible, the probability of fishing vessels snagging their gear on the substructure is considerably less than if the base were left on the seabed after the columns are cut down.

The probability of passing merchant ships colliding with the CDP1 concrete substructure, if left in place, has been estimated to be in the order of 1 in 10,000 per year based upon current shipping activity. The probability of a collision is predicted to reduce significantly in the years after decommissioning due to changes in shipping routes and the development of more sophisticated navigational equipment.

9.3.2.6 Environmental Impact – All Alternatives

The environmental impact of the four removal and disposal alternatives considered for the TCP2 concrete substructures may be found in Section 9 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. The environmental impacts of the four disposal alternatives considered are summarised in Table 9.15 below.

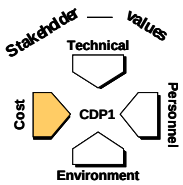


	Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
Energy Consump. (1000 GJ)	2180	660	1225	79
Total Energy Impact (1000 GJ)	2180	856	1460	310
CO2 Emissions (1000 tonnes)	150	50	90	6.3
Discharges to sea	None/Insignificant	None/Insignificant	None/Insignificant	None/Insignificant
Physical impact on environment	Moderate negative	Moderate negative	Large/Moderate negative	Moderate negative
Aesthetic impact	Moderate negative	None/Insignificant	None/Insignificant	None/Insignificant
Material Management	Moderate positive	Non/Insignificant	Small positive	None/Insignificant (Small positive)
Littering	None/Insignificant	None/Insignificant	Small negative	Small negative
Impacts on fisheries	Moderate positive	Moderate positive	Moderate negative	Moderate negative
Free passage at sea	Moderate positive	Moderate positive	Moderate positive	negative

Table 9.15 Summary of Environmental Impact of Alternative Disposal Arrangements for the CDP1 Concrete Substructure

The environmental impact detailed in Table 9.15 assumes that the operations are carried out essentially as planned and there is no need to undertaken extensive remedial works resulting from a major accident during the disposal operations. It is important to note that cleaning of the CDP1 concrete substructure is not required, as it has **never been used for the storage of crude oil.** The substructure does contain water based mud drill cuttings, but the impact of these on the environment has been assessed as being “None / Insignificant”.

9.3.2.7 Costs – All Alternatives



The estimated costs of the four disposal alternatives for the concrete substructure and concrete deck beams of CDP1 are given in Table 9.16 below.

Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
4048 MNOK / £309.5m	2989 MNOK / £228.5m	4440 MNOK / £339.5m	7 MNOK / £0.5m (see note)

Note:- As there is virtually no steelwork outside the external wall on CDP1, the figure quoted here is for the supply and installation of the new navigation aids. As with the other concrete platforms this cost has been included in the topside removal cost estimate.

Table 9.16 Estimated Cost of Alternative Disposal Arrangements for the Concrete Substructure of CDP1 (The cost of disposal of the topsides is not included)

9.3.3 CDP1 – Summary and Recommendations

9.3.3.1 Summary – CDP1 Topsides

The studies undertaken indicate that the steel topside components of CDP1 may be removed using conventional offshore methods of working. The probability of a fatality during this work has been estimated as approximately 4% and the probability of a major injury as approximately 88%. These risk levels have been based upon experience data for offshore and onshore construction. All reasonably practicable risk reducing measures will therefore be taken to reduce the risk.

The impact on the environment of removing the topsides is generally low. The “small negative” or “moderate negative” impacts arising from the energy usage, emissions and aesthetic effects during the removal and onshore disposal are balanced by the “large positive” impact in respect to materials management arising from the reuse and recycling of materials.

9.3.3.2 Summary – CDP1 Concrete Substructure

Refloat and Onshore Disposal

The main uncertainty relating to the possible refloat and onshore disposal of CDP1 is the water tightness of the structure. There is a significant probability of leakage, either through the cofferdam (that has to be installed to seal the holes in the outer wall), or through ineffectively closed penetrations, broken pipes or cracks in the walls and base slab of the substructure. The holes in the base slab, which were cut to allow the wells to be drilled, are a particularly likely source of leakage. It is also uncertain that the leakage experienced during the installation operations would be overcome by the use of the steel cofferdam around the upper section of the external walls.

The water tightness of the substructure cannot be verified until the cofferdam has been installed and the solid ballast removed. In that condition the substructure will be subject to larger wave forces and will have less stability. It would be extremely difficult at that stage to identify the source of the leakage, or to make repairs. There is a high probability of further

cracking and leakage if the substructure could not be refloated in a single summer season and needed to remain in place throughout the winter period.

The possibility of leakage through the base slab after lift off from the seabed cannot be neglected, due to uncertainties surrounding the condition of the slab and the penetrations through it. Although small amounts of water might leak through these areas when the substructure is on the seabed, it is only when it lifts off that the full leak potential would be realised. In this situation pumps already installed on the substructure may be able to maintain adequate buoyancy, but if this was not possible the substructure would sink back to the seabed. It is likely that further damage would occur to the base slab and walls when the substructure impacted with the seabed, the severity of the damage being dependant upon the size of the leaks.

The condition of the structure has degraded since the platform was installed in 1975 and some further degradation may be expected before any removal operation was carried out. Whilst this does not affect the safety of the platform in its present condition, it is a critical factor during the removal operations

The consequences of a major accident during the refloat operations have been shown to be particularly severe, especially in respect to the safety of personnel and cost. In addition, if due to leakage it proved impossible to refloat the substructure, then the only other removal alternative would be to cut up the concrete substructure into suitably sized sections which would then be transported to shore for disposal. Such operations would involve considerable amounts of diving and would be unacceptably hazardous.

During the anticipated activities involved in removal and onshore disposal operations, the probability of a fatality has been estimated as being in the order of 46% (approximately 1 in 2). This is a very high risk. The average fatal accident rate for the removal and onshore disposal is estimated to be in the order of 22 which is considered not acceptable in the light of normal operating risk to personnel on oil and gas installations in the North Sea. The probability of fatalities would increase significantly if large amounts of offshore work were required as the result of major leakage or a major accident during a removal operation. It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel.

The cost of removing the concrete substructure of CDP1, if possible, has been estimated to be approximately 4000 MNOK / £306m assuming that no major accidents occur and the operations go as planned. There is however a significant possibility that the cost could increase by a factor of 2 to 2½ if it was impossible to refloat the substructure or a major accident occurred whilst the substructure was being refloated or towed to shore.

Based upon the judgement and input of leading independent experts, the probability of being unable to refloat the substructure or a major accident occurring during the refloat and tow to shore has been estimated to be in the order of 30%. This risk is extremely high due to the inherent uncertainties in the condition of the structure, and the need for extensive offshore activities that have never been undertaken before. The risk of being unable to undertake the refloat operation is approximately 300 times higher than the 0.1% acceptance criterion for asset/financial loss during decommissioning, based upon the level of risk accepted during the Frigg Field production phase. The decommissioning risk acceptance criterion is in line with the guidance given in the DNV rules for marine operations. Additionally it is normal for additional problems to become apparent during the detailed engineering phase of a major project, and these would have the effect of increasing further the probability of accident and delay. It is also to be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

The inherent uncertainties surrounding the complete refloat and onshore disposal of the CDP1 concrete substructure are considered unacceptable in the light of the limited environmental benefit and the severe safety and financial implications of being unable to refloat the substructure or of having a major accident during the work,

Refloat and Disposal in Deep Water
The refloat of the substructure for offshore disposal is similarly uncertain and, in addition, the dumping of structures in the deep ocean is considered to be generally undesirable by society. Consultation with the stakeholders indicated that, if the substructure could be refloated, then it should be brought to shore for disposal, rather than dumped in the ocean. Alternative B, removal and disposal in deep water, is therefore also rejected.

Cut Down to –55m
Cutting down the walls and central core of the substructure is felt to be theoretically feasible, although many factors militate against such an approach. There is a high level of uncertainty surrounding the method of cutting up such an integrated structure in which the strength and stability of each wall depends to a great extent on the adjacent walls. The feasibility of the concrete cutting method is also debatable and considerable effort and expenditure would be necessary before the method could be considered field proven. The amount of diving necessary also makes this alternative disposal method very questionable and the risk to personnel engaged in the work is considered to be unacceptably high. Due to the complexity of the CDP1 substructure and the amount of cutting required it is not considered feasible with today's technology to undertake the work using only remotely operated vehicles.

Cutting down the substructure to allow a clear 55m draft above the remaining substructure would allow the free passage of vessels. Uncertainties associated with the process of cutting and toppling the upper sections of wall result in a 20% chance that one or more walls might collapse in an uncontrolled manner. This is approximately 200 times greater than the acceptance criterion and is considered unacceptable. In the event of a major accident, the additional works to achieve the 55m draft would be extremely hazardous resulting in a significant increase in the risk to personnel. The total cost of the work would also be substantially increased. Additionally, this method of decommissioning CDP1 is not considered desirable by either the Norwegian or UK fishing industries, due to the danger it represents to fishing activity.

Due to the risk to personnel, the uncertainties associated with the decommissioning operations, and the fact that this solution is also unattractive to some stakeholders, particularly the fishing industry, it is recommended that this alternative be rejected.

Leave in Place
Leaving the concrete substructure in place is therefore considered to be the best solution when considering health and working environment, safety, environmental aspects and cost.

Apart from a small volume of drill cuttings in the solid ballast, the concrete substructure is not polluted by hydrocarbons or other chemicals or materials and thus there is judged to be insignificant level of discharge to the marine environment. There is no steelwork on the outside of the concrete substructure so there is no risk of corroded steel items falling onto the seabed where they could be a hazard to fishermen. It is important to note that cleaning of the CDP1 concrete substructure is not required, as it has **never been used for the storage of crude oil.**

Very little other environmental impact has been predicted if the substructure was left in place, apart from the obstruction caused to fishing vessels and other users of the sea. Quantitative assessments indicate that the probability of vessels colliding with the CDP1 concrete substructure is however relatively low and appropriate risk reducing measures will be taken.

Comparison of Disposal Alternatives
The predicted consequences, in terms of safety, environmental impact and cost, of adopting the main disposal alternatives considered, are summarised in Figure 9.14. This table does not include the removal and offshore disposal alternative (Alternative B), as the implications are rather similar to the removal and onshore disposal alternative (Alternative A). In addition society's general aversion to offshore dumping makes this alternative unattractive.

	Remove and Dispose Onshore		Cut Down to –55m		Leave in Place	
	As Planned	Major Unplanned Event	As Planned	Major Unplanned Event	As Planned	Major Unplanned Event
Technical Feasibility Probability of a major unplanned event		Probability In the order of **30%** i.e. 300 times greater than acceptance criterion		Probability in the order of **20%** i.e. 200 times greater than acceptance criterion		No potential for major unplanned event
CONSEQUENCES						
Safety Probability of a Fatality	**46%**	**50-70%**	**57%**	**62-73%**	**3%**	**-**
Impact on Environment Total Energy Impact (1000GJ)	**2180**	**2300-3700**	**1460**	**2700-3900**	**310**	**-**
CO_2 Release (1000 tonnes)	**150**	**157-260**	**90**	**190-280**	**6**	**-**
Physical Impact on Environment	**"Moderate Negative"**	**"Moderate Negative" plus "Small Negative"**	**"Large / Moderate Negative"**	**"Large / Moderate Negative"**	**"Moderate Negative"**	**-**
Cost MNOK / £m	**4048 £309m**	**4700-9800 £359-749m**	**4440 £339m**	**5300-5900 £405-451m**	**7 £0.5m (see note)**	**-**

Note.- The cost of the supply and installation of the navigation aids is included within the topside removal cost estimate.

Figure 9.14 Predicted Consequences of Different Disposal Alternatives for the CDP1 Concrete Substructure

9.3.3.3 Recommended Disposal Arrangements for Platform CDP1

It is recommended that the steel components of the topsides of CDP1 platform should be removed and brought onshore for disposal, and that the concrete substructure (including the concrete deck beams) should be suitably marked and left in place. As much as practicable of the equipment and materials removed from the platform will be reused or recycled.

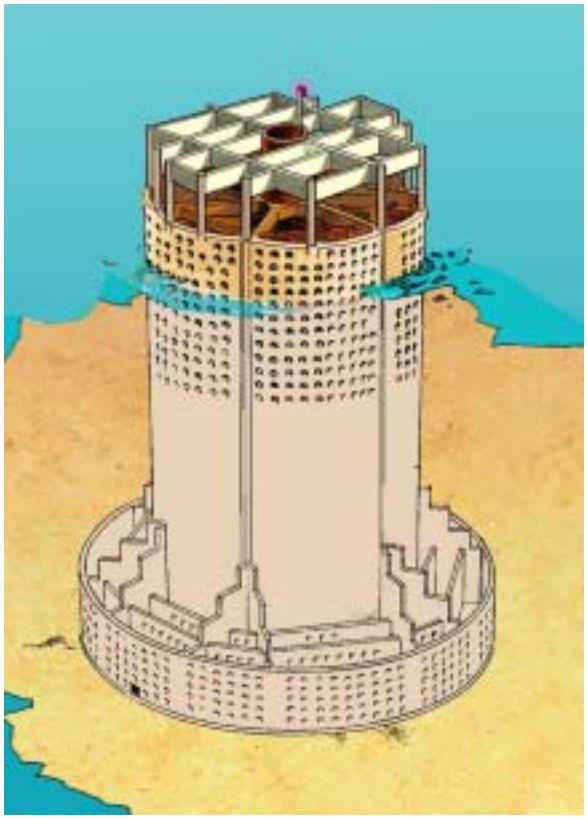


Figure 9.15 Recommended Decommissioned Condition of the CDP1 Concrete Substructure after Removal of Topside and External Steelwork

9.4 Treatment Platform 1 – TP1

9.4.1 TP1 Topsides – Evaluation of Removal Methods

9.4.1.1 Methods

A number of different sequences for the removal of platform TP1 topsides have been studied and found to be technically feasible. The following sequence of activities is presently planned, based upon the use of proven offshore construction methods.

The modules, deck and bridge between TP1 and QP would be removed using a crane vessel working in a reverse installation sequence. All the components would then be transported to shore. The steel transition pieces between the concrete columns and the deck would be removed with the deck. If it were possible to refloat the concrete substructure and tow to shore for onshore demolition (Concrete Substructure Alternative A), then only part of the topside would need to be removed offshore. The remaining modules and the deck would be removed after the substructure had been towed to an inshore location.

9.4.1.2 Consequences

Risk to Personnel

The risk to personnel undertaking the removal and disposal of TP1 topsides has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 9.43). The predicted numbers of fatalities and major injuries expressed in statistical terms are shown in Table 9.17 below. A definition of the terms used in this table is given in Section 6.3.

Predicted number of fatalities (Potential Loss of Life)	0.03 (0.0284) See note
Probability of a Fatality	3%
Predicted number of major injuries (Potential Major Injuries)	1.3
Probability of a Major Injury	73%

Note:- The PLL value shown has been rounded to the nearest percentage point. The actual calculated value is shown in parenthesis for comparison purposes.

Table 9.17 Estimated Risk to Personnel during Removal and Onshore Disposal of TP1 Topsides

Environmental Impact

The environmental impact of removing the topsides of TP1 may be found in Section 7 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. A summary of the findings is given in Table 9.18 below.

Parameter	Value
Energy Consumption (1000 GJ)	123
Total Energy Impact (1000 GJ)	123
CO_2 Emissions (1000 tonne)	10
Discharges to sea	None/insignificant
Physical impact on environment / habitat	None/insignificant
Aesthetic impact	Moderate negative
Material management	Large positive
Littering	None/insignificant
Impacts on fisheries	None/insignificant
Impacts on free passage at sea	None/insignificant

Table 9.18 Environmental Impact of Removal and Disposal of the TP1 Topsides

Costs
The cost of removal, transportation and onshore disposal TP1 topsides has been estimated as 316 MNOK / £24.2m.

9.4.2 TP1 Concrete Substructure – Comparative Assessment of Disposal Alternatives

9.4.2.1 Technical Assessment of Alternative A - Refloat and Onshore Disposal

Proposed Method
Before the refloat operations are started, part of the topside would be removed as described in Section 9.4.1.

All penetrations of risers and J-tubes through the walls of the substructure would need to be plugged and the towing points reinstated.

A new water de-ballasting system would then be installed to allow water to be pumped out of the columns and the cells in the base. This new system would make use of the existing ballasting pipes in the base section of the substructure. Tests undertaken in the autumn of 2000 indicated deterioration of the pipework resulting in several leaks. It is likely that additional deterioration of the pipework will occur in the years before attempting to refloat the substructure.

The platform would be refloated by pumping water out of the cells in the base until a net buoyancy force was achieved. The platform has 2m deep concrete skirts beneath the base slab to prevent horizontal movement of the platform. It is proposed to withdraw the skirts from the soil using buoyancy forces.

TP1 only has two columns and therefore it could be necessary to use different amounts of water in the base cells in order to level the substructure whilst the skirts are being extracted from the seabed and while it is floating.

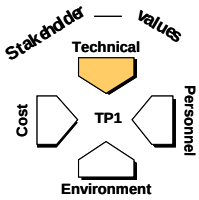
It is planned that the entire refloat and tow operation would be performed with the platform unmanned. Operations would be controlled from adjacent vessels.

Once the substructure has been refloated it would be de-ballasted to a suitable depth and then towed to a sheltered inshore mooring. The remaining sections of the topsides would then be removed. While the platform is floating near the shore, the columns and a major part of the substructure base would be demolished. Particular care would be necessary to preserve the structural integrity of the structure during demolition. The steelwork within the columns would be removed, as they are demolished. When the floating draft of the substructure has been reduced to approximately 10m, the lower section of the substructure would be towed into a dry dock where final demolition would take place.

After being cut out of the structure, the concrete and steel would be separated by crushing. The steel items and steel reinforcement would then be sent to a steel works for re-smelting. The concrete materials would be reused or disposed in an appropriate manner.

Technical Feasibility

During the design of the TP1 platform no consideration was given to the removal of the concrete substructure at a later date. Accordingly the ability of the structure to resist the loads during a refloat operation was not checked, and no specific features were incorporated into the design to facilitate removal.



In assessing the technical feasibility of refloating the TP1 concrete substructure, a number of aspects have been identified that would be critical to the success of the operation. The most important aspects, which have the potential to cause the refloat operation to be aborted, are shown in Figure 9.16 and are explained further in the following text.

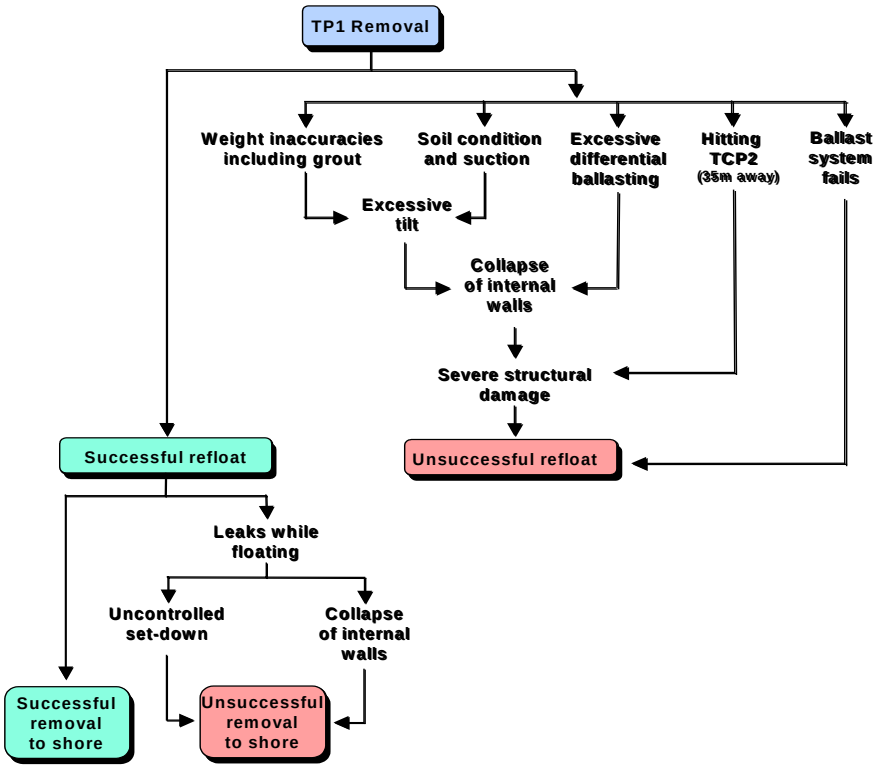


Figure 9.16 Areas of Uncertainty Affecting the Success of the Refloat and Towing of TP1

Uncertainties During the Refloat Operations

- **Weight Inaccuracies Including Grout**
- **Soil Conditions and Suction**

Uncertainty relating to the weight of the substructure during the refloat operation is a significant factor when considering the buoyancy force necessary to extract the skirts from the seabed. The main factors that make the weight less certain than at installation are; marine growth; deposits on the top of the cells and the amount of cement grout that might become detached from the base slab. These factors may adversely affect both the tilt and the maximum ascent of the substructure after breaking loose from the seabed, although for TP1, **tilt** is the critical aspect.

The break-loose resistance of the skirts is a particular uncertainty due to the fact that there is no existing experience of skirts in a similar condition. It is thus very difficult to estimate the lateral soil pressure on the skirts just before the skirt breaks loose and thereby estimate the amount of excess buoyancy that would be required. The opinion of various independent

experts has been sought by TOTAL NORGE in order to arrive at the best estimation of the maximum likely force that will be needed to extract the skirts from the seabed.

The maximum buoyancy force that can be applied to extract the skirts is limited by the effect on the substructure after breaking free from the seabed. If the buoyancy force was too high the platform would rise in an uncontrolled manner. Uncertainties in the weight of the substructure and in measuring the level of water in all the cells contribute towards the uncertainty in estimating the buoyancy force.

- **Excessive Differential Ballasting**

When the TP1 substructure was designed in the early 1970s the concrete design code used was less severe than present codes in respect to the hydraulic loads. Following the failure of a concrete substructure in August 1991 during a deep submersion test, the loads to be used in the design of concrete platforms were increased. Calculations indicate that the original code used for the design of TP1, results in the concrete substructure having a lower factor of safety against collapse than is normal today, although this was considered satisfactory at the time. The effect of this on the overall safety of any refloat operation is not directly obvious, but this factor has been considered in the technical risk analysis described later in this section. The consequences of structural failure are extremely high and thus a conservative approach needs to be adopted when considering the strength of all the structural members.

As TP1 only has two columns it could be necessary to have different levels of water in the base cells to keep the substructure level during refloat operations. Studies have shown that the internal walls have a **rather limited capacity to resist the loads arising from differential ballasting and tilt.** Leakage through the ballast system or the structure, incorrect operation of the ballast system or malfunction of the ballasting or monitoring systems have the potential to produce a differential pressure across an internal wall.

Figure 9.17 Tilt During Lift-off from the Seabed Causing Differential Water Pressure on some Inner Walls

The difference in water level across a wall would also be affected by the “tilt” of the platform after release from the seabed. This would be determined by the weight distribution of the substructure and dynamic effects that could occur when the substructure breaks free from the seabed and rises in the water. Variations in the original level of water in the cells, plus the negative effect arising from leakage between groups of cells will increase the differential pressure on particular walls. The capacity of the internal walls to resist differential water pressure varies with the depth. The walls have their least reserve of strength when the platform is at a depth of approximately 50 to 60 m. It is rather questionable whether the internal walls have sufficient reserves of strength to resist the forces due to the necessary differential ballasting and the possible tilt of the substructure as it rises through the water.

The adequacy of the structure to resist the loads during the refloat operation may also be affected by **constructional tolerances or initial defects.** The cells in the base slab are not possible to inspect and therefore conservative assumptions need to be adopted.

- **Hitting TCP2**

The movement of the TP1 substructure as it breaks free from the seabed is more or less impossible to predict with any degree of accuracy. There is a possibility that the substructure could “skid” across the seabed in an uncontrollable manner after breaking loose.

In addition to the horizontal movement the substructure is likely to tilt due to variation in the soil friction on the skirts, suction under the platform and the possibility of the grout falling off the bottom of the platform. Any initial tilt is likely to be increased by hydrodynamic forces, as the substructure starts moving.

The TP1 and TCP2 substructures are only 35m apart and accordingly there is a possibility of an impact after TP1 lifts off the seabed. If TCP2 were removed first, the risk of impact would affect the technical feasibility of removing TCP2 as noted in Section 9.2.2.1.

- **Ballast System Fails**

The reliability of the ballasting system and the integrity of the internal concrete walls is of prime importance for this disposal alternative because the substructure would need to remain floating for a considerable length of time whilst it is being demolished. The ballast system is approximately 25 years old at the present moment (2001) and would be over 30 years old at the time an attempt might be made to refloat the substructure.

Testing and inspections during the summer of 2000 have shown that the ballast pipework was impaired by some small leaks. It is not possible to deduce what the condition of the pipework may be like in a number of years time when the removal operations would be carried out. It is also not possible to predict the exact behaviour of the ballast piping under operational conditions due to the uncertainties arising from dynamic effects that could occur during the refloat operation. Testing also **identified leakage** between two groups of cells in the base. This leakage is relatively small at the moment and would not have a large effect on floating stability of the substructure. The leaks however are not accessible for repair. Due to the arrangement of the pipework there is particular concern that dynamic forces occurring during the refloat operation could rupture the pipework at a critical time. This situation is particularly critical in locations where there are short sections of exposed pipework inside the cells connecting sections of pipe encased in concrete.

Due to the fact that TP1 only has two columns the **substructure is relatively sensitive to the ballasting arrangements** in the base cells. Serious problems could arise if significant leakage was found to exist between two or three groups of cells when the refloat operation was about to be carried out. The same effect would arise if there were a malfunction of the ballasting system.

Failure of an inner wall due to differential water pressure could lead to progressive collapse of the base.

Uncertainties During the Tow to Shore

When the substructure is floating there is a possibility that leaks could develop while the platform was being made ready for towing and during the tow to shore. During this period the platform will be unmanned and thus repairs would be difficult to make. Although the pressure on the ballasting system and walls penetrations would be less at towing draft, the pressure has to be sustained for a longer period.

The platform will also be floating at an inshore location for a considerable period of time whilst the columns and base cells are demolished. During a significant percentage of this time serious leaks in the ballast system have the potential to cause the loss of the platform. The longer term performance of the ballast system is therefore of a particular concern.

Probability of Failure During Refloat and Disposal

In view of the uncertainty associated with some aspects of the TP1 concrete substructure removal operations, the probability and consequences of a major accident have been investigated. There are an infinite number of possible accidents and outcomes but in order to make a broad estimate of the likelihood and consequences of a major accidental event, four **representative** scenarios have been investigated :-

1. Accident before refloat	Damage to two cells due to dropped objects preventing the refloat operation starting.
2. Accident during refloat	Failure of a critical system or structural member during the refloat operation resulting progressive collapse of base, loss of buoyancy and impact with the seabed. The impact would result in severe damage to the walls and/or base slab.
3. Accident during tow	Failure of critical a system or a structural member during the tow to shore resulting in loss of buoyancy and impact with the seabed. Possible progressive collapse of base cells. The impact would result in severe damage to the walls and base slab. The substructure is likely to be totally submerged after impact with the seabed.
4. Accident during demolition	Failure of a critical system or structural member during the inshore demolition operation resulting in loss of buoyancy and impact with the seabed. The impact would result in disintegration of the remaining substructure.

For many of the worst case scenarios the risks inherent in the remedial works would be so high as to make them unacceptable and, in that case, remedial work would not be possible. However, when assessing the consequences of the worst case scenarios the risks involved have been estimated with no prior decision as to whether they are acceptable or not.

When assessing the implications of the accident scenario prior to the refloat operation, it has been assumed that in most cases it will be possible to repair the damage to the substructure. The damage occurring as a result of an accident during the refloat, tow and demolition phases would however be so severe that it would be impossible to refloat the substructure again. In order to maintain the 55m clear draft for shipping required by the IMO Guidelines, it would then be necessary to cut up the concrete substructure into small sections which could be lifted to the surface and transported to shore for disposal.

These operations would be extremely hazardous due to the damaged condition of the substructure and the need for most of the cutting and lifting to be done underwater. In the case of accident scenarios 2 and 3, the work would also need to be undertaken at an exposed offshore location, which would significantly increase the risk. The likely cost of such remedial work would be very high, although the overall impact on the on the environment is generally small. The main negative impacts are the effect on the local marine environment (seabed and natural resources) and the emissions to atmosphere during the extensive remedial works. The environmental impact analysis did however identify a number specific situations where the environmental impact would be much greater due to local conditions (e.g. when towing the substructure over an oil pipeline or in the area of particular fishing grounds or near inshore fish farms.

The likelihood of major accidents occurring during the removal and disposal operations has been estimated using probability theory based upon appropriate historical data and input from a group of independent experts (Ref. 9.39). The costs of the remedial activities required following a major accident have also been estimated in broad terms for all four accident

scenarios based on outline descriptions of the necessary works. The probability and consequences of the various accident scenarios are given in Table 9.19.

	Description	Consequence	Probability	Estimated Cost (see note)
1	Accident before refloat	Damage to cells	0.5% - 0.9%	2700 MNOK £206m
2	Accident during refloat	Severe damage to walls and base of cells	1.3% - 3.5%	6300 MNOK £482m
3	Accident during tow	Severe damage to walls and base of cells	Less than 0.01%	7000 MNOK £535m
4	Accident during demolition	Disintegration of substructure	0.3% - 0.4%	3800 MNOK £291m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenarios the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

Table 9.19 Probability and Consequences of a Major Accident during TP1 Refloat and Inshore Disposal Operations (Alternative A)

The overall probability of a major accident during the removal and disposal operations for the TP1 concrete substructure is estimated to be in the order of 2% to 5% which is twenty to fifty times greater than the acceptance criterion. Loss of structural integrity is a major contributor to the overall probability of a major accident as listed in the table above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.4.2.2 Technical Assessment of Alternative B - Refloat and Disposal in Deep Water

Proposed Method

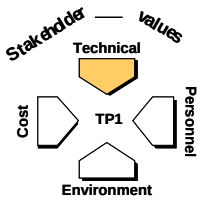
The activities performed to refloat the substructure for disposal in deep water (Alternative B) are essentially the same as for the onshore disposal option (Alternative A). The main difference, apart from the final disposal method is that the complete topside and most of the steel items inside and outside the columns would be removed before refloating the platform. The reason for this is that with Alternative A these items would be removed after the platform has been refloated and towed to shore.

After the topsides have been removed offshore a new work platform would be installed on one of the columns to provide support for the temporary equipment needed for the refloat operation.

As for Alternative A, the substructure would be unmanned during the refloat and towing operations. Operation of the de-ballasting systems when the substructure is unmanned would be by remote control from an adjacent boat.

Following the refloat operation the substructure would be towed to the chosen deep-water disposal location. As much of the temporary ballasting and injection systems as is practicable would then be removed before the substructure was flooded. By using a selected sequence of flooding it is would be possible to utilised the limited strength of the inner walls to cause a progressive collapse that would effectively demolish the concrete.

Technical Feasibility
The feasibility of Alternative B depends essentially on the possibility of being able to refloat the substructure. The concerns noted in Section 9.4.2.1, in respect to the onshore disposal option (Alternative A), also apply when disposing of the platform in the deep ocean.



Probability of Failure During Refloat and Disposal
The refloat operation for Alternative B is essentially the same as for Alternative A and the same uncertainties therefore apply. As a result, the accident scenarios considered for Alternative A are also valid for Alternative B, apart from Scenario 4 (Accident during demolition) which is obviously not relevant in the case of disposal in deep water.

The probability and consequences of the various accident scenarios have been estimated (Ref. 9.39) and are given in Table 9.20.

	Description	Consequence	Probability	Estimated Cost (see note)
1	Accident before refloat	Damage to cells	0.5% - 0.9%	1500 MNOK £115m
2	Accident during refloat	Severe damage to walls and base of cells	1.3% - 3.5%	5000 MNOK £382m
3	Accident during tow	Severe damage to walls and base of cells	Less than 0.01%	5400 MNOK £413m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenarios the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

Table 9.20 Probability and Consequences of a Major Accident during TP1 Refloat and Towing Operations for Disposal in Deep Water (Alternative B)

The overall probability of a major accident during the removal and deep water disposal operations for the TP1 concrete substructure is estimated to be in the order of 2% to 4.5% which is twenty to forty five times greater than the acceptance criterion. Loss of structural integrity is a major contributor to the overall probability of a major accident as listed in the table above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.4.2.3. Technical Assessment of Alternative C - Partial Removal to Provide a Clear Draft of 55m over the Remaining Structure

Proposed Method
Alternative C involves cutting the two columns just above the top of the cells that form the base of the substructure. The cut sections of the column, which would each be 76m in length, would be laid on the seabed adjacent to the base.

While the topside is in place the piping, steelwork and electrical equipment in the columns would be removed and transported to shore for reuse or recycling. The amount of work that can be undertaken in the columns at any time is limited by health and safety considerations. If significant amounts of work were needed for the disposal activities, it would most likely be necessary to install additional access systems in the columns, which would in itself be a hazardous operation, with the possibility of fatality or serious injury. Even if this were done, operational safety limitations would control the way the work was conducted and result in low productivity rates. In addition the steel items attached to the outside of the concrete

substructure would be removed and transported to shore. The topsides would then be removed as described in Section 9.4.1.

The concrete columns would then be cut. For the cutting operation it is proposed to use either diamond wire cutting tools or diamond tipped saws running on rails fixed to the outer surface of the concrete column. The cutting tools would be installed and operated by divers. During the cutting operations the columns would be filled with water. This method is different from that proposed for the columns of TCP2 where diamond wire cutting from the inside was the preferred method proposed. Both methods are considered feasible in principle but both would require considerable development work to achieve commercial applicability.

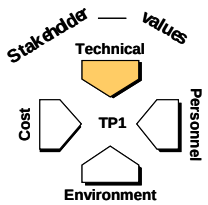
Figure 9.18 TP1 Concrete Substructure cut down to –55m.

After each column has been cut, it would be lifted using a crane vessel and laid down on the seabed adjacent to the base.

The use of explosives to cut the columns was considered but rejected principally because of the uncertainty surrounding the condition of the columns after toppling. It was considered possible that one or both of the columns could remain on top of the base and in that situation the clear draft of 55m of water above the remaining structure, as required in the IMO guidelines, would not be achieved. Due to the relatively large amounts of reinforcement and prestressing steel in the columns experts were unable to guarantee that complete cutting of the column could be achieved. As a result additional diving and ROV operations might be necessary to try and cut the remaining steel to allow a free sailing draft of 55m to be achieved. This would be extremely hazardous work with an unacceptable risk.

Technical Feasibility

The arrangements for cutting and lifting the columns are regarded as feasible in principle but, as suitable equipment does not currently exist to undertake this work, the practicability of the scheme is still questionable. A number of matters would require development before the feasibility of the scheme could be proven with a satisfactory level of confidence.



Concrete Cutting Method

Techniques already exist for cutting thick pre-stressed and reinforced concrete sections onshore. The equipment required for cutting the TP1 columns would be significantly larger than any cutting equipment previously used subsea. Such large-scale cutting operations have not been undertaken in an exposed offshore location. Thus, an extensive period of equipment development and testing would be needed before subsea diamond saw, or diamond wire cutting, at the scale necessary, could be confirmed as feasible.

The amount of diving associated with the work is another cause of concern and would need to be very carefully planned and executed to ensure that all possible safety measures were taken. The column cutting and lifting operation would be particularly weather sensitive and uncertainties associated with this would need further consideration.

Stability of the Columns During Cutting

The cutting of the concrete columns would be undertaken in two stages. The initial stage would involve cutting the major part of the structure but leaving a section of the column intact to provide stability. The final cutting would then be undertaken when the heavy lift vessel was on site to lift and place the cut section of column on the seabed. The ability of the column to resist environmental forces in the partially cut condition depends on the percentage of the column that is cut in the initial phase. If 70% of the column is cut then it has been estimated, based upon static strength conditions, that the column could resist a 10-year summer storm. The ultimate strength of the column when partially cut is however rather difficult to determine because in that condition it's fatigue strength is likely to be very low. It is possible that the fatigue life of the partially cut column would only be a matter of weeks or months and thus it could be vulnerable to fatigue failure in the event of a period of bad weather.

Jamming of the cutting tools (either wire or saw) is considered to be rather likely, especially when cutting the last sections of wall. Although it is envisaged that some form of wedges/jacks would be used to reduce the probability of jamming, practitioners in underwater cutting advise that jamming during the final cutting is highly likely. There would be a significant probability of collapse if the structure had to remain in a partially cut condition for a considerable period of time. In addition, if the columns could not be completely cut within one offshore work season due to weather delays, breakdowns or slow cutting rate, then it is very likely that the column would not have sufficient strength to resist a winter storm and would collapse.

Before the final cutting operation temporary steelwork could be installed on the outside of the column across the cut line to provide additional stability to the upper section of the column. Although this would improve the situation it is not considered practicable to provide sufficient temporary steelwork to ensure the stability of the column in all weather conditions.

Probability of Failure during Cutting Down Operations

Uncertainties surrounding the cutting and removal of the columns mean that these operations may not be successfully completed. In that event extensive remedial works would be required to rectify the situation and achieve a clear draft for shipping of 55m as required in the IMO Guidelines. The probability of this situation occurring and the consequences have been assessed based upon two representative scenarios as below:-

1. Unsuccessful cutting	Failure of the cutting systems and associated equipment requiring redevelopment and re-qualification of cutting system
2. Collapse or dropping of column	Collapse of the column or failure during lifting operations resulting in not achieving the required 55m of clear water above the remaining structure on the seabed.

The operations to rectify these unsatisfactory situations are likely to be extremely hazardous especially if the column was in an unstable condition that was sensitive to wave forces. In that condition the risk of diving close to the column would be unacceptable and thus complex and expensive tools would need to be developed which could be deployed using underwater remotely operated vehicles. The likely cost of such remedial work would be very high. The overall impact on the environment would be generally small although the local marine environment would be affected by the remedial activities.

The likelihood that major problems would be encountered during the cutting and removal activities has been estimated, as for Alternatives A and B, using probability theory based upon appropriate historical data and input from a group of independent experts (Ref. 9.39). The costs of the actions necessary to rectify the unsatisfactory situations have also been estimated in broad terms, based upon outline descriptions of the necessary works. The probability and consequences of the various accident scenarios are given in Table 9.21.

	Description	Consequence	Probability	Estimated Cost (see note)
1	Unsuccessful cutting	Delay, increased cost and increased risk to personnel.	0.1 – 0.3%	1500 MNOK £115m
2	Collapse or dropping of column	Collapse with insufficient shipping draft, increased risk to personnel, increased cost.	In the order of 4%	1800 MNOK £138m

Note:- For Scenario 1 the estimated cost includes the total planned cost of the work plus the additional repair cost. For the other scenario the estimated costs shown include the incurred cost up to the time of the accident plus the cost of remedial works following the accident.

Table 9.21 Probability and Consequences of a Major Accident or Incident during the Cutting Down of TP1 (Alternative C)

The overall probability of a major accident or incident during the cutting down of the TP1 concrete substructure is estimated to be in the order of 4% which is forty times greater than the acceptance criterion. Loss of structural integrity is a significant (although not the only) contributor to the 4% possibility of collapse of a column, as considered in worst case scenario 2 above. In this context it should be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

9.4.2.4 Technical Assessment of Alternative D - Leave In Place, Remove External Steelwork

Proposed Method
Alternative D involves leaving the concrete substructure in place after removing both the topsides and the steel items on the outside of the concrete substructure.

The deck and modules forming the topside would be removed first as described in Section 9.4.1. The steel items on the outside the columns would then be removed including the sections of pipeline immediately adjacent to the platform, the external risers, external piping and other miscellaneous steel work such as boat bumpers, ladders etc.

It is planned to remove the majority of the external steelwork using remotely operated vehicles controlled from the surface. Some diving work would however be required.

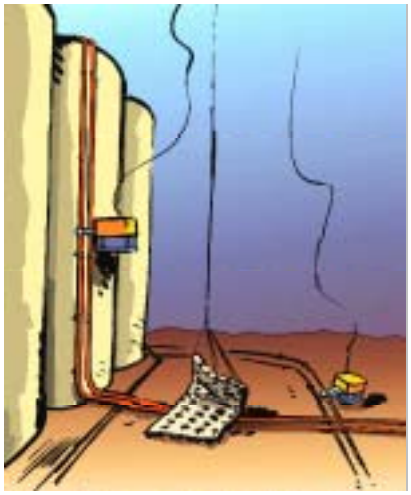
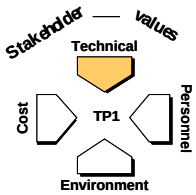


Figure 9.19 Removal of External Steelwork on TP1 Concrete Substructure

The necessary navigation aids would then be installed on the substructure. Debris on the seabed around the substructure would be recovered as detailed in Section 12. These activities will be planned and undertaken working closely with the various users of the sea and the relevant authorities.

Technical Feasibility

No aspects which would significantly affect the technical feasibility of this alternative, have been identified. Alternative D is not considered to involve any unusual technical operations and thus the risk of not being able to complete the planned work tasks is considered to be very low.

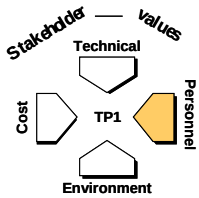


The main concern in respect to the Alternative D work is the safety of personnel engaged in cutting and lifting the external steelwork. As much as possible of this work would be undertaken using remotely operated vehicles but it is considered necessary to use divers for removing some items. Particular care would be needed to ensure that these operations are conducted in a safe manner.

9.4.2.5 Risk to Personnel – All Alternatives

During Decommissioning Operations

The risk to personnel involved in the four removal and disposal alternatives for the TP1 concrete substructure has been estimated based upon the anticipated work tasks and relevant historical accident rates (Ref. 9.40) The predicted numbers of fatalities and major injuries expressed in statistical terms are shown in Table 9.22. A definition of the terms used in this table is given in Section 6.3.



	Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
Predicted number of fatalities (Potential Loss of Life)	0.16	0.07	0.09	0.01
Probability of a Fatality	15%	7%	9%	1%
Predicted number of major injuries (Potential Major Injuries)	7.8	3.3	3.8	0.3
Probability of a Major Injury	More than 90%	More than 90%	More than 90%	26%

Table 9.22 Estimated Risk to Personnel during Disposal Alternatives for TP1 Concrete Substructures

It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel. It can be seen from the table above that the probability of a fatality is approximately 16 times higher for Alternative A than for Alternative D. For Alternative A, the inshore and onshore demolition operations contribute 50% of the total fatality probability, whilst offshore marine operations and the diving operations contribute 19% and 13% respectively.

Based upon these predicted fatalities, the **average** fatal accident rate (FAR value) for the complete removal and onshore disposal work is estimated to be in the order of 15. This is approximately three and a half times the estimated average risk to workers on the Frigg Central Complex during 2000.

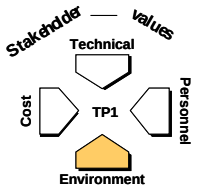
After Decommissioning
The effect on the safety of shipping of leaving TP1 concrete substructure in place (Alternative D) has been estimated (Ref. 9.44, 9.45). Any concrete substructures left in place would be clearly marked and the navigation aids would be inspected at regular intervals.

The probability of fishing vessels colliding with the TP1 concrete substructure, if left in place, has been estimated to be in the order of 1 in 130,000 per year based upon current fishing activity in the area. Because the concrete substructures are visible, the probability of fishing vessels snagging their gear on the substructure is considerably less than if the base were left on the seabed after the columns are cut down.

The probability of passing merchant ships colliding with the TP1 concrete substructure, if left in place, has been estimated to be in the order of 1 in 27,000 per year based upon current shipping activity. The probability of a collision is predicted to reduce significantly in the years after decommissioning due to changes in shipping routes and the development of more sophisticated navigational equipment.

9.4.2.6 Environmental Impact – All Alternatives

The environmental impact of the four removal and disposal alternatives considered for the TP1 concrete substructures may be found in Section 9 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. The environmental impacts of the four disposal alternatives considered are summarised in Table 9.23.



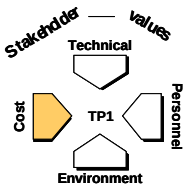
	Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
Energy Consump. (1000 GJ)	1115	244	404	46
Total Energy Impact(1000 GJ)	1115	420		246
CO_2 Emissions (1000 tonnes)	71	18	30	3.5
Discharges to sea	None/Insignificant	None/Insignificant	None/Insignificant	None/Insignificant
Physical impact on environment	Moderate negative	Moderate negative	Large/Moderate negative	Moderate negative
Aesthetic impact	negative	None/Insignificant	None/Insignificant	None/Insignificant
Material Management	Moderate positive	Non/Insignificant	Small positive	None/Insignificant .(Small positive)
Littering	None/Insignificant	None/Insignificant	Small negative	
Impacts on fisheries		Moderate positive	Moderate negative	negative
Free passage at sea		Moderate positive	Moderate positive	Moderate negative

Table 9.23 Summary of Environmental Impact of Alternative Disposal Arrangements for the TP1 Concrete Substructure

The environmental impact detailed in Table 9.23 assumes that the operations are carried out essentially as planned and there is no need to undertaken extensive remedial works resulting from a major accident during the disposal operations. It is important to note that cleaning of the TP1 concrete substructure is not required, as it has **never been used for the storage of crude oil.**

9.4.2.7 Costs – All Alternatives

The estimated costs of the four disposal alternatives for the concrete substructure of TP1 are given in Table 9.24.



Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
1908 MNOK / £145.9m	738 MNOK / £56.5m	965 MNOK / £73.8m	41 MNOK / £3.1m (see note)

Note:- An additional figure of 7 MNOK / £0.5m is included in the cost estimate for the topside removal to cover the supply and installation of the new navigation aids.

Table 9.24 Estimated Cost of Alternative Disposal Arrangements for the Concrete Substructure of TP1 (The cost of disposal of the topsides is not included)

9.4.3 TP1 – Summary and Recommendations

9.4.3.1 Summary – TP1 Topsides

The studies undertaken indicate that the TP1 topsides may be removed using conventional offshore methods of working. The probability of a fatality during this work has been estimated as approximately 3% and the probability of a major injury as approximately 73%. These risk levels have been based upon experience data for offshore and onshore construction. All reasonably practicable risk reducing measures will therefore be taken to reduce this risk.

The impact on the environment of removing the topsides is generally low. The “small negative” or “moderate negative” impacts arising from the energy usage, emissions and aesthetic effects during the removal and onshore disposal are balanced by the “large positive” impact in respect to materials management arising from the reuse and recycling of materials.

9.4.3.2 Summary – TP1 Concrete Substructure

Refloat and Onshore Disposal

The main areas of concern relating to the possible refloat of the TP1 concrete substructure are the strength of the inner walls in the base, and the stability and strength of the structure during the separation and ascent from the seabed. It must also be noted that the condition of the structure and the piping systems will have degraded in the 30-35 years between installation and decommissioning. Whilst this does not affect the safety of the platform during the present operational phase, it could be a critical factor during the removal operations.

The ability of the inner walls to resist the loads due to different levels of water in the adjoining cells has been shown to be critical. This differential water pressure may arise as a result of; intended actions required to level the substructure as it is extracted from the seabed; or as a result of leakage through walls or penetrations; or as a result of the platform tilting as it breaks free form the seabed. Other factors that need to be considered are; the accuracy of water level monitoring equipment; and the dynamic behaviour of the water in the cells when the substructure is floating. Calculations indicate that as the platform rises in the water after breaking free from the seabed the maximum allowable difference in water level on the two sides of an internal wall is about 8m. There is a significant probability that it would not be possible to maintain this requirement during the refloat operation.

There are also a number of significant uncertainties associated with the method of freeing the substructure from the seabed, including aspects relating to the soil properties, the slope of the seabed and the weight, buoyancy and suction under the structure, as it breaks free from the seabed. The amount of grout that could fall off the underside of the substructure is impossible to determine. The need to use ballast pipework that was designed only for service during the installation phase also gives considerable concern. In unfavourable circumstances it is possible that the substructure could tilt by more than 17 degrees. The effect of this would be to increase the possibility of failure of the inner walls. The movement of the TP1 substructure as it breaks free from the seabed is more or less impossible to predict with any degree of accuracy. There is a possibility that the substructure could “skid” across the seabed in an uncontrollable manner after breaking loose and collide with TCP2 which is only 35m away. The risk of a collision would affect TCP2 if it were removed first.

The consequences of a major accident during the refloat operations have been shown to be particularly severe, especially in respect to the safety of personnel and cost. In order to reduce the environmental impact of such a major accident, and limit the effect on users of the sea, it would also be necessary to engage in a series of extremely hazardous operations that would considerably increase the likelihood of fatalities.

During the anticipated activities involved in removal and onshore disposal operations, the probability of a fatality has been estimated as being in the order of 15% (1 chance in 7 of a fatality). The probability of fatalities would increase significantly if large amounts of offshore work were required as the result of a major accident during a removal operation. It should also be noted that the analytical method used to estimate the likely fatalities and major injuries tends to **underestimate,** rather than overestimate, the risk to personnel.

The cost of removing the concrete substructure of TP1, if possible, has been estimated to be approximately 1900 MNOK / £145m assuming that no major accidents occur and the operations go as planned. There is a significant possibility that the cost could increase by a factor of 3 to 4 if a major accident occurred whilst the substructure was being refloated or towed to shore.

Based upon the judgement and input of leading independent experts, the probability of a major accident during the refloat and tow to shore arising from inherent uncertainties has been estimated to be in the order of 2% to 5%. This is between twenty and fifty times higher than the 0.1% risk acceptance criterion for asset/financial loss during decommissioning, based upon the level of risk accepted during the Frigg Field production phase. The decommissioning risk acceptance criterion is in line with the guidance given in the DNV rules for marine operations. Additionally it is normal for additional problems to become apparent during the detailed engineering phase of a major project, and these would have the effect of increasing further the probability of accident and delay. It is also to be noted that some experts, including DNV, are of the opinion that the probability of **structural failure** during a refloat operation should be less than 0.01%, that is, ten times lower than the acceptance criterion adopted by TOTAL NORGE.

In view of the limited environmental benefit and the severe safety and financial implications of a major accident, the inherent uncertainties surrounding the complete removal and onshore disposal of the TP1 concrete substructure are considered unacceptable.

Refloat and Disposal in Deep Water
The refloat of the substructure for offshore disposal is similarly uncertain and, in addition, the dumping of structures in the deep ocean is generally considered to be undesirable by society. Consultation with the stakeholders indicated that if the substructure could be refloated, then it should be brought to shore for disposal, rather than dumped in the ocean. Alternative B, refloat and disposal in deep water, is therefore also rejected.

Cut Down to –55m
Cutting down the columns is felt to be theoretically feasible although the level of uncertainty surrounding the method of cutting makes this decommissioning alternative unattractive. Considerable effort and expenditure would be necessary before the feasibility of this option

could be fully proven. Cutting the columns down to allow a clear 55m draft above the remaining substructure does however have the merit of allowing the free passage of vessels although remaining an obstruction to fishing activity.

Uncertainties associated with the process of cutting and removing the columns mean that there is a significant risk of delay. The cutting method requires the development and qualification of new technology and its deployment in a difficult environment. Once the cutting work has been started the structural integrity of a column will be affected and after a relatively small section of the column has been cut it will not have sufficient strength to resist a winter storm. In view of the unproven nature of much of the work significant delays could result in uncontrolled collapse of a column which would be unlikely to achieve a clear water draft of 55m.

The probability of collapse of a column has been estimated to be in the order of 4%. This is forty times higher than the 0.1% risk acceptance criterion for asset/financial loss during decommissioning, based upon the level of risk accepted during the Frigg Field production phase. The decommissioning risk acceptance criterion is in line with the guidance given in the DNV rules for marine operations. In the event of a column collapse, the remedial work necessary to achieve 55m would be particularly hazardous and result in a significant increase in the risk to personnel. It is also likely that the cost of the decommissioning work would increase by more than 80%. Unknown factors related to the cutting methods also results in a high level of cost uncertainty and possible increased risk to personnel. Additionally, this method of decommissioning TP1 is not considered desirable by either the Norwegian or UK fishing industries due to the danger it represents to fishing activity.

Due to the uncertainties associated with the decommissioning operations, and the fact that this solution is also unattractive to some stakeholders, particularly the fishing industry, it is recommended that this alternative be rejected.

Leave in Place
Leaving the concrete substructure in place is therefore considered to be the best solution when considering health and working environment, safety, environmental aspects and cost.

The concrete substructure is not polluted with hydrocarbons or other chemicals or materials and thus there is judged to be an insignificant level of discharge to the marine environment. Tests on samples of concrete taken from the substructure and analytical studies support the view that long-term degradation of the concrete will have an insignificant impact on the local marine environment (Ref. 9.46). By removing the external steelwork the risk of sections of steelwork corroding and falling onto the seabed where they could be a hazard for fishermen, is eliminated. Diesel fuel, hydraulic oil and methanol used for operational purposes in the columns, will be removed and the equipment and piping cleaned. It is important to note that cleaning of the TP1 concrete substructure is not required, as it has **never been used for the storage of crude oil.**

Very little other environmental impact has been predicted if the substructure was left in place, apart from the obstruction caused to fishing vessels and other users of the sea. Quantitative assessments indicate that the probability of vessels colliding with the TP1 concrete substructure is however relatively low and appropriate risk reducing measures will be taken.

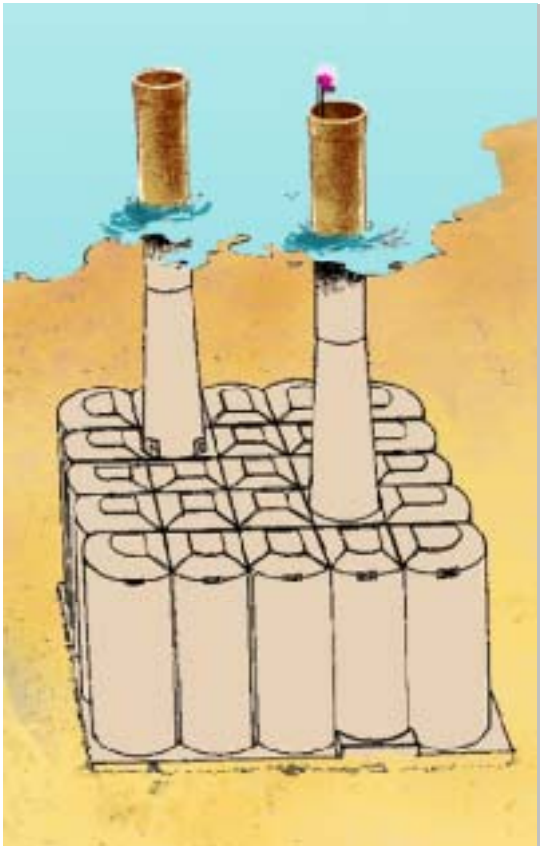
Comparison of Disposal Alternatives
The predicted consequences, in terms of safety, environmental impact and cost, of adopting the main disposal alternatives considered, are summarised in Figure 9.20. This table does not include the removal and offshore disposal alternative (Alternative B), as the implications are rather similar to the removal and onshore disposal alternative (Alternative A). In addition society's general aversion to offshore dumping makes this alternative unattractive.

	Remove and Dispose Onshore		Cut Down to –55m		Leave in Place	
	As Planned	Major Unplanned Event	As Planned	Major Unplanned Event	As Planned	Major Unplanned Event
Technical Feasibility Probability of a major unplanned event		Probability **2 to 5%** i.e. 20 to 50 times greater than acceptance criterion		Probability **4%** i.e. 40 times greater than acceptance criterion		No potential for major unplanned event
CONSEQUENCES						
Safety Probability of a Fatality	**16%**	**20-50%**	**9%**	**12-13%**	**1%**	**-**
Impact on Environment Total Energy Impact (1000GJ)	**1115**	**1200 - 2200**	**580**	**1000 - 1400**	**246**	**-**
CO_2 Release (1000 tonnes)	**71**	**80 - 150**	**30**	**71 - 90**	**4**	**-**
Physical Impact on Environment	**"Moderate Negative"**	**"Moderate Negative" plus "Small Negative"**	**"Moderate Negative"**	**"Moderate Negative"**	**"Moderate Negative"**	**-**
Cost MNOK / £m	**1908 £146m**	**2700 – 7000 £206-535m**	**965 £73.8m**	**1500 – 1800 £115-138m**	**41 £3.1m**	**-**

Figure 9.20 Predicted Consequences of Different Disposal Alternatives for the TP1 Concrete Substructure

9.4.3.3 Recommended Disposal Arrangements for Platform TP1

is recommended that the topsides of TP1 platform should be removed and brought be suitably marked and in place, after removal of the external steelwork. As much as practicable of the ed from the platform will be reused or recycled.



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10. Subsea Pipelines and Cables - Comparative Assessment of Disposal Alternatives

10.1 Introduction

The subsea pipelines and cables in the Frigg Field area fall into two categories:-

- Infield lines interconnecting platforms and facilities within the Frigg Field
- Inter-field export/import lines connecting TCP2 and TP1 with platforms and facilities in other fields (or with St Fergus in Scotland).

The inter-field export/import pipelines and cables are not included in the Frigg Field production licences and thus do not fall within the scope of this Frigg Field Cessation Plan. Approval has already been given by the Norwegian authorities for some of the pipelines to be left in place. This applies specifically to the interconnections with the Frøy, North East Frigg, East Frigg and Lille Frigg fields.

The two 32" diameter Frigg Transportation System pipelines to St Fergus will remain in operation after the decommissioning of the Frigg Field facilities. The decommissioning of these export pipelines to St Fergus and the inter-field pipelines has been, or will be, the subject of separate applications to the Norwegian or UK authorities at the appropriate time.

It may be noted that although the decommissioning of the inter-field lines does not fall within the scope of this Frigg Field Disposal Plan, it is the intention to remove them from TCP2 and TP1:-

- to a point where they are trenched, or
- to the boundary of the 500m zones around TCP2 and TP1

The decommissioning of the inter-field pipelines and cables will be carried out in accordance with a schedule to be agreed with the relevant national authorities.

The Frigg Field infield pipelines, which are described in detail in Section 4.2, are covered by the provisions of the relevant Frigg Field production licences and thus form part of this Frigg Field Cessation Plan.

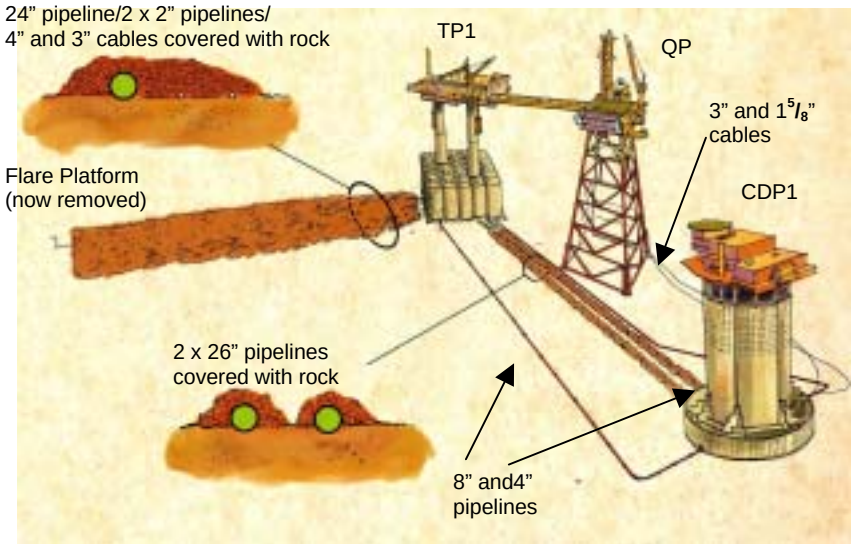

Figure 10.1 Pipelines and Cables Between CDP1 and TP1, CDP1 and QP and TP1 and the Flare Platform Base (now removed)

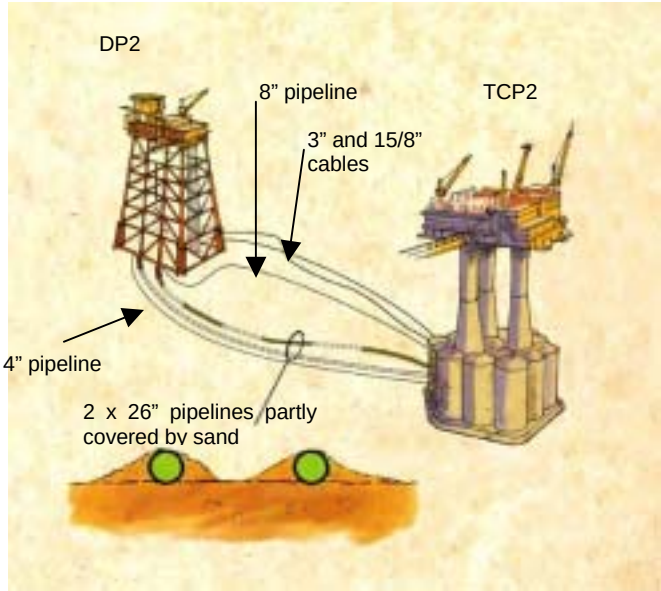

Figure 10.2 Pipelines and Cables between DP2 and TCP2

In Section 7 it is concluded that there is no possibility of reusing the Frigg Field platforms and thus studies have been undertaken to evaluate how the infield pipelines and cables may be decommissioned.

10.2 Disposal Alternatives for Infield Pipelines

The following disposal alternatives have been investigated (Ref. 10.1, 10.3) for the Frigg Field infield subsea pipelines and cables described in Section 4.2:-

Infield Pipelines and Cables	**Alternative A** Remove, transport to shore and onshore disposal	**Alternative B** Leave in place but trenched	**Alternative C** Leave in place but bury ends

10.2.1 Alternative A - Remove Pipelines and Cables, Transport to Shore and Onshore Disposal

Possible Methods

Using a Laybarge

Pipelines may be retrieved using a procedure that is the reverse of the laying method. The pipeline is winched onto the deck of the laybarge where it is cut into sections. The sections of pipe are then loaded onto transport vessels and brought to shore for reuse or recycling.

Using a Reel-ship

Steel pipelines of 16-inch diameter or less, without concrete cover, can be retrieved by winding the pipe onto a large reel, mounted on a reel-ship. The procedure used would essentially be the reverse of installation. Seabed cables can also be retrieved by winding onto a reel on a suitably equipped vessel.

Figure 10.3 Principle for Removing Smaller Pipelines and Cables

Removal by Cutting into Section
All types of pipeline can be retrieved by cutting into suitable lengths on the seabed and lifting the sections onto a transportation vessel. The pipeline can be cut either by divers or by remotely operated equipment. Seabed cables can also be retrieved in this way.

Removal by Towing
A longer length of pipeline may be retrieved by attaching buoyancy devices to lift it off the seabed, after which it may be towed to shore. The pipeline may then be winched onshore for cutting into suitable lengths for reuse or recycling. This is not considered to be a particularly appropriate method for removing seabed cables.

10.2.2 Alternative B - Leave Pipelines and Cables In Place but Trenched

Possible Trenching Methods

Jetting
This technique uses water jets to fluidise the soil under, and around, the pipe which will then sink into the seabed.

Ploughing
This technique involves using a plough to form a trench on the seabed into which the pipeline is placed. Ploughing is normally used for longer lengths of pipeline in areas away from platforms. Natural back filling of the trench will normally take place over time.

10.2.3 Alternative C - Leave Pipelines and Cables In Place but Bury Ends.

The ends of the pipelines may be trenched and buried using the same techniques described for Alternative B.

10.2.4 Comparative Assessment of Disposal Alternatives

Technical Feasibility

All the methods for retrieving and trenching pipelines and cables described above are regarded as technically feasible although some are less appropriate when considering the short length of the Frigg Field infield lines. Although the necessary equipment has been developed and is in service there is limited operational experience in retrieving pipelines and it may therefore be expected that the work would not be without technical challenges.

Risk to Personnel

The risk to personnel for each of the pipeline and cable disposal alternatives has been estimated using the same methodology as for the disposal of the topsides and substructures (Ref. 10.2). As in previous sections, the risks have been expressed in terms of the predicted number of fatalities (Potential Loss of Life) and predicted number of major injuries (Potential Major Injuries).

The results from these analyses are given in Table 10.1. A definition of the terms used in this table is given in Section 6.3.

	Alternative A Remove and onshore disposal	Alternative B Leave in place but trenched with natural backfilling	Alternative C Leave in place and bury ends
Predicted number of fatalities (Potential Loss of Life)	0.015	0.007	0.007
Probability of a Fatality	1.4%	Less than 1%	Less than 1%
Predicted number of major injuries (Potential Major Injuries)	0.3	0.2	0.1
Probability of a Major Injury	26%	18%	10%

Table 10.1 Estimated Risk to Personnel during Alternative Disposal Arrangements for Infield Pipelines and Cables

Environmental Impact

The environmental impact of the disposal alternatives considered for the infield pipelines and cables may be found in Section 10 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. The energy impact, emissions to air and other environmental impacts are summarised in Table 10.2 below.

	Alternative A Remove and onshore disposal	Alternative B Leave in place but trenched with natural backfilling	Alternative C Leave in place and bury ends
Energy Consumption (1000 GJ)	57	29	0 (see note)
Energy Balance (1000 GJ)	57	55	26
CO_2 Emissions (1000 tonne)	4	2	0 (see note)
Discharges to sea	None/insignificant	None/insignificant	Small negative
Physical impact on environment	None/insignificant	None/insignificant	None/insignificant
Aesthetic impact	None/insignificant	None/insignificant	None/insignificant
Material management	Small negative	None/insignificant	None/insignificant
Littering	None/insignificant	None/insignificant	Moderate negative
Impacts on fisheries	Small positive	Small positive	Small negative
Impacts on free passage at sea	None/insignificant	None/insignificant	None/insignificant

Note:- The work necessary to bury the end of the pipelines and cables has not been included.

Table 10.2 Environmental Impact of Disposal Alternatives for Infield Pipelines and Cables

Costs

The estimated cost of the alternative disposal arrangement for the infield pipelines and cables is given in Table 10.3 below.

Alternative A Remove and onshore disposal	Alternative B Leave in place but trenched with natural backfilling	Alternative C Leave in place and bury ends
161 MNOK / £12.3m	141 MNOK / £10.8m	40 MNOK / £3.0m

Table 10.3 Estimated Cost of Disposal Alternatives for Infield Pipelines and Cables

The costs for removing the pipelines (Alternative A) have been based upon cutting the pipelines into sections on the seabed, lifting them to the surface by crane and then transporting them to shore for recycling.

10.3 Summary and Recommendations

As the infield pipelines and cables are not buried, all of the alternative disposal arrangements are considered to be technically feasible. Whilst the risk to personnel undertaking the work is higher if the pipelines and cables are retrieved and brought on shore for disposal, the increase in risk is relatively modest.

The environmental impacts of all the alternatives are quite small, however, it is considered advantageous to provide a clean seabed around the concrete installations, which in Section 9 are recommended to be left in place. The risk of snagging fishing gear on the infield pipelines and cables (with the attendant risk of collision with the concrete substructures) would thereby be eliminated and the safety of fishermen improved. Moreover the cost increase to remove, rather than trench, the pipelines is relatively small.

It is therefore recommended that all the Frigg Field infield pipelines and cables as described in Sections 4, together with their associated protective concrete blocks, concrete saddles, and mattresses, are retrieved and brought onshore for disposal. As much of the equipment and materials as practicable will be reused or recycled. The pipeline protective rock dumps will be spread out on the seabed and left in place.

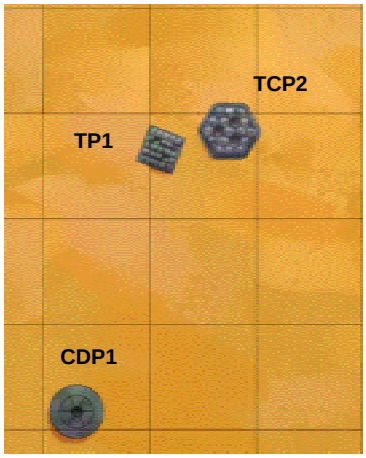

Figure 10.4 Seabed In Frigg Area after Completing Recommended Disposal Programme

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11. Drill Cuttings - Comparative Assessment of Disposal Alternatives

11.1 Introduction

Drill cuttings are present at the Frigg Field although in relatively small quantities. The cuttings originate from the wells drilled on DP2 and CDP1.

Platform DP2
Twenty-four wells were drilled on DP2, two of which have subsequently been re-drilled. The total volume of the drill cuttings from the wells is estimated to be approximately 7,000 m^3. A survey in the summer of 2000 indicated that the drill cuttings were deposited in a thin layer on the seabed around the platform. The maximum thickness of the drill cuttings layer is 20cm. It is estimated that approximately 400 m^3 of drill cuttings are contained within an area of 80m x 120m around the platform. Outside this area the thickness of the drill cuttings layer is less than 4 cm.

All drilling on DP2 was undertaken using water-based mud, except for the re-drilling of two of the wells, where 236 m^3 of low toxicity oil based mud (LTOBM) was used. A total of 120 m^3 of low toxicity oil based mud was brought ashore for treatment and disposal. The drill cuttings containing the remaining 116 m^3 of low toxicity oil based mud were cleaned on the platform before being discharged. The drill cuttings contained less than 10% oil when discharged. The water based mud cuttings, and the cleaned low toxicity oil mud cuttings, were both deposited on the seabed around DP2.

Platform CDP1
When the 24 wells on platform CDP1 were drilled, the drill cuttings were discharged inside the concrete substructure of the platform, on top of the sand ballast materials. All the wells were drilled using water based mud. Based upon the volume of the wells it is estimated that approximately 5,600m^3 of drill cuttings where deposited inside the substructure. After the wells had been drilled an additional 21,000 m^3 of gravel was placed on top of the drill cuttings as a means of improving the on-bottom stability of the platform. There is no evidence of any drill cuttings on the seabed around CDP1.

Other Frigg Platforms
None of the other Frigg Field platforms were used for drilling and therefore there are no drill cuttings around TCP2, TP1, QP or DP1.

11.2 Disposal Alternatives

For the drill cuttings on the seabed around DP2 two disposal alternatives have been considered: -

Drill Cuttings DP2,	**Alternative A** Remove and onshore disposal	**Alternative B** Leave in place

All the drill cuttings from CDP1 are contained within the concrete substructure and are covered with a layer of sand and gravel. In view of the recommendation in Section 9 that CDP1 should be left in place, it is proposed that the drill cuttings remain in place within the structure.

11.3 Studies and Tests

There are a number of joint industry projects and studies in progress at the moment funded by oil companies in Norway (OLF) and UK (UKOOA). The purpose of these studies is to increase knowledge and understanding of the effects of drill cuttings on the natural environment and to evaluate remediation methods.

The studies undertaken for the Frigg Field have therefore concentrated upon; identifying the composition of the cuttings; determining the thickness and extent of the layer of drill cuttings on the seabed; and assessing the present natural environment in the area (Refs. 11.1 to 11.5). Possible methods of remediation have also been evaluated. Of particular importance in this respect has been the assessment of the effect on the environment of the different disposal alternatives.

Core samples have been taken from the seabed around the drilling platforms DP2 and CDP1. This work has been undertaken to verify the extent, thickness and composition of the drill-cutting layer around DP2, and to verify that there are no drill cuttings on the seabed around CDP1.

The relationship between the drill cuttings and the local environment has been considered in the Environmental Impact Assessment, which forms Part 2 of this Frigg Field Cessation Plan. The findings are summarised later in this section.

A screening study to identify systems that are available for the removal of the drill cuttings around DP2 has been undertaken for TOTAL NORGE (Ref. 11.6). The capacity, previous experience in use, required support facilities and cost have all been considered for each of the systems. Similar evaluations also form part of the UKOOA studies.

11.4 Comparative Assessment of Disposal Alternatives

11.4.1 Drill Cuttings at DP2

11.4.1.1 Alternative A - Remove all Drill Cuttings on the Seabed and Transport to Shore for Treatment and Onshore Disposal.

Methods

A number of different methods have been proposed for the removal of drill cuttings. One method would be to use a grab arrangement operated either from the surface or from a remotely operated vehicle controlled from a surface vessel. Other systems involve the use of suction dredging with the suction head mounted, either on a self-propelled crawler tractor on the seabed, or on a remotely operated work vehicle. The feasibility of different methods of recovery of drill cuttings has been evaluated as part of the UKOOA joint industry project. The recovered material would be loaded into a hopper barge for transportation to shore and treatment.

Figure 11.1 Drill Cutting Deposits Around DP2

11.4.1.2 Alternative B - Leave the Drill Cuttings In Place.

Method

Leaving the drill cuttings undisturbed on the seabed will not involve any further activities. In order to remove the DP2 steel substructure it will however be necessary to cut the steel piles from the outside. During this operation there will be some disturbance of the drill cuttings near the legs of the steel substructure but efforts will be made to minimise the effect of these activities. The excavation around the piles may have a positive effect by covering the local area of drill cuttings by clean sand from the seabed.

11.4.1.3 Comparative Assessment

Technical Feasibility

As the drill cuttings form a thin layer over a relatively large area of the seabed, no practically proven methods for the effective removal of the cuttings has been identified at the present time. Present methods have the serious drawback of removing a great deal of the seabed, as well as the drill cuttings, which vastly increases the amount of material that needs to be treated onshore. Test results from the UKOOA studies indicate that large quantities of seawater would also be raised along with the solids.

Risk to Personnel

The risk to personnel during the removal activities for the DP2 drill cuttings has been estimated using the same methodology as for the disposal of the topsides. As in the previous sections, the risks have been expressed in terms of the predicted number of fatalities (Potential Loss of Life) and predicted number of major injuries (Potential Major Injuries).

The results from these analyses are given in Table 11.1. A definition of the terms used in this table is given in Section 6.3.

	Alternative A Removal and onshore disposal	Alternative B Leave in place
Predicted number of fatalities (Potential Loss of Life)	0.005	0%
Probability of a Fatality	Less than 1%	0%
Predicted number of major injuries (Potential Major Injuries)	0.3	0%
Probability of a Major Injury	26%	0%

Table 11.1 Estimated Risk to Personnel during Alternatives Disposal Arrangements for DP2 Drill Cuttings

Environmental Impact

The environmental impact of the disposal alternatives considered for DP2 drill cuttings may be found in Section 11 of the Environmental Impact Assessment in Part 2 of this Frigg Field Cessation Plan. The environmental impacts for the two disposal alternatives considered are summarised in Table 11.2.

	Alternative A Remove and onshore disposal	Alternative B Leave in place
Energy Consumption (1000 GJ)	65	0
Energy Balance (1000 GJ)	65	0
CO_2 Emissions (1000 tonne)	4.5	0
Discharges to sea	Small negative	Small negative
Physical impact on environment / habitat	None/insignificant	None/insignificant
Aesthetic impact	None/insignificant	None/insignificant
Material management	Small negative	None/insignificant
Littering	None/insignificant	None/insignificant
Impacts on fisheries	None/insignificant	None/insignificant
Impacts on free passage at sea	None/insignificant	None/insignificant

Table 11.2 Environmental Impact of Disposal Alternatives for Drill Cuttings

The energy balance and the emissions to air are regarded as small.

The layer of drill cuttings under and around DP2 has been found to have slightly elevated concentrations of cadmium, copper, lead and zinc. With the exception of the zinc, the metals are associated with the barite in the mud. They are tightly bound to the solids and have a very limited bioavailability to marine organisms. The zinc is believed to have originated from the platform anodes.

Elevated levels of Total Hydrocarbon Content (THC) and the harmful benzo(a)pyrene of the aromatic fraction Polycyclic Aromatic Hydrocarbons (PAH) were also measured. The THC concentrations found were, however, generally low compared with the results from other surveys of cuttings deposits in the North Sea. The levels of PAH showed a marked decrease with depth.

If the results of the offshore sampling are compared with the Norwegian SFT classification system for contaminated sediments in fjords and harbours, which has five categories, the samples fall into the **two least severe** of the categories, that is, SFT Class I (slightly polluted), and SFT Class II (moderately polluted). (See Section 5.3.1)

PCBs were detected just above SFT Class I although these are not believed to originate in the drill cuttings. Due to the low concentration it has not been possible to trace their origin. There was no indication that they are associated with the drilling waste. The EIA suggests that they may arise from paint, as indicated by recent studies in areas around construction yards.

Biota was found to be living in the contaminated area around DP2, which indicates that the effected bottom sediments have been re-colonised.

Discharges to sea during removal operations are mostly associated with the recovery process, but there is some leaching potential associated with the onshore disposal of the drill cuttings. Leaving the cuttings in place also has some potential for leaching of contaminants to the surrounding environment. As the drill cuttings have a low content of contaminants, the potential for damage will be limited. As such the impact of discharges is regarded as being “small negative” for both the disposal alternatives considered.

Removal of the drill cuttings from the seabed would leave a cleaner physical habitat for marine fauna but the positive impact is considered “insignificant”.

There is no particular impact on either fisheries or the free passage of users of the sea.

Cost
The estimated cost of removing the drill cuttings from the seabed around DP2, transporting them to shore and then treating and disposing of them, is estimated to be 120 MNOK / £9.2m.

11.4.1.4 Summary and Recommendations for Drill Cuttings at DP2

There are presently no proven methods to remove the thin layer of drill cuttings under and around DP2 without small negative effects due to the disturbance of the deposited materials. Removal of the drill cuttings will cause increased air emissions from the removal process and deposition onshore in dedicated landfill. The discharge impact is considered to be roughly the same for both disposal alternatives.

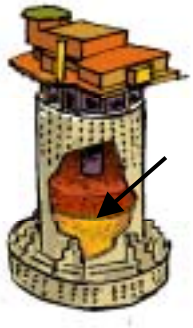
The risk to personnel is obviously more if the drill cuttings are removed but it is envisaged that the work could be undertaken in a safe manner. Safety aspects are therefore not considered to be particularly significant in determining the disposal alternative to adopt.

Due to the very limited environmental impact of leaving the drill cuttings in place, it is recommended that the deposits under and around DP2 should be left in place and disturbed as little as possible during the removal of the DP2 steel substructure.

Since the Second Draft of the Frigg Field Cessation Plan was issued, the final report from the UKOOA Drill Cuttings Initiative has been published. This states that in cases where the quantity and composition of the drill cuttings are similar to that found at DP2, the likely best environmental strategy is to leave the drill cuttings in place to degrade naturally. The recommendation for the DP2 drill cuttings thus accords with the results from the UKOOA initiative, which was also supported by OLF.

11.4.2 Drill Cuttings at CDP1

11.4.2.1 Assessment



The drill cuttings from the wells on CDP1 are all contained within the outer wall of the concrete substructure. It is recommended in Section 9 that CDP1 should be left in place and thus the drill cuttings inside the substructure will not be disturbed.

Seabed sampling outside the concrete substructure confirms that no drill cuttings have been discharged outside the substructure. Core samples taken immediately outside the wall of the substructure contained 20 mg/kg of hydrocarbons, that is, approximately twice the background level. The concentrations of metals and Polycyclic Aromatic Hydrocarbons (PAHs) were also somewhat higher than in the background sand, but were generally lower than found adjacent to DP2. No PCBs were detected outside CDP1 which supports the view that the low concentrations of PCBs found around DP2 may have originated from paint rather than drilling waste.

Leaving the drill cuttings in place is considered to have an insignificant effect on the environment around CDP1. Studies have been undertaken to evaluate the effect of the long-term release of the drill cuttings into the environment as the concrete structure degrades (see Ref. 11.7 and Section 11.3 of the Environmental Impact Assessment forming Part 2 of this Frigg Field Cessation Plan). Based upon the likely volume and contamination level of the CDP1 drill cuttings it has been estimated that the impact on the surrounding environment is expected to be “small negative” or “insignificant”.

The environmental impact is likely to be largest if the cuttings were released through a complete collapse of the concrete substructure. The effect would however be reduced due to the fact that the volume of sand and gravel contained in the structure is very much larger than the volume of drill cuttings.

Due to the very limited environmental impact of leaving the drill cuttings in place, it is recommended that the drill cuttings inside CDP1 should be left in place within the concrete walls of the substructure.

Section References

11.1 "Determination of Trace Metals and Hydrocarbons in Sediment Under the Frigg DP2 Platform", Rogalands Forskning Report, Ref. RF 1998/236, Rev. 1, dated 10.12.1998, DocsOpen 92093.

11.2 "Trace Metals and Hydrocarbons in the Cuttings Piles at Frøy and CDP1 Platforms", Rogalands Forskning Report Ref. RF 1999/773, Rev 1, dated 20.09.1999, DocsOpen 99677.

11.3 "Environmental Contamination at Frigg DP2 and CDP1 Platforms", Rogalands Forskning Report, Ref. RF 2000/218, Rev 1, dated 23.11.2000, DocsOpen 108056.

11.4 "Environmental Investigation of Cutting Deposits in the Frigg Area".

11.5 "Trace Metals and Organic Contaminations in Biota from the DP2 and QP installations at the Frigg area", Rogalands Forskning Report, Ref. RF 2000/259, Rev 1, dated 23.11.2000, DocsOpen 108088.

11.6 Aker Offshore Partner: Removal of Drill Cuttings at DP2-Cost Estimate dated 23.05.2000, Ref. DocsOpen Report No. 102633.

11.7 "Environmental Impacts of Cuttings and Mud Discharged into CDP1 Concrete Structure" Rogalands Forskning Report Ref. RF 2001/197, dated 27.08.2001.

11.8 "UKOOA Drill Cuttings Initiative Final Report" UKOOA, December 2001.

12. Debris Clearance

12.1 Introduction

The objective of the debris removal operation is to remove from the seabed, all debris forming a hazard to other users of the sea, within 500 meters of each of the Frigg Field platforms, including site of the Flare Platform, which has already been removed. After the clean-up activities have been completed the condition of the seabed will be verified by appropriate surveys and trawling tests.

The UK regulations relating to post-removal activities and seabed surveys are somewhat more prescriptive and extensive than the Norwegian regulations. It is judged that activities undertaken in order to ensure compliance with the UK regulations will also be adequate to ensure compliance with Norwegian regulations. In order to adopt a common approach to debris clearance in both national sectors of the Frigg Field, it is planned to undertake all seabed-debris clearance operations in accordance with the requirements set out in the UK regulations.

As shown in the project schedule in Section 15, debris cleaning and the subsequent post-clean-up surveys are planned to be the final activities in the decommissioning work.

12.2 Estimated Amount of Debris to be Recovered

An estimate of the likely amount of debris on the seabed around the Frigg Field platforms has been made as an aid to planning the debris removal operations and onshore disposal activities. The debris on the seabed is likely to have accumulated during the following phases of the field life:-

- Installation and construction activities
- Production operations over 25 years
- Removal and disposal activities

Based upon consideration of the activities undertaken during the field life it is estimated that the amount of debris on the seabed within 500-metres of the Frigg Field platforms is likely to be in the range of 100 - 1200 tonnes. This estimate includes debris originating from marine activity in the area including, supply vessels, support vessels and construction vessels.

It is anticipated that most of the debris under, or around, the platforms will have originated from the platform itself, whilst debris from marine craft will be scattered more widely within the 500-metre zone.

It is likely that sand movements, over time, covered a certain proportion of the smaller, heavier items.

12.3 Surveys and Debris Recovery

12.3.1 Pre-Debris Removal Survey

After the removal of the platform topsides, steel substructures and other items, as summarised in Section 14, a pre-debris removal survey will be carried out. The survey will identify the location of the debris within the 500-metre zone.

12.3.2 Debris Recovery

It is envisaged that a diving support vessel will be used for the debris clearance. The majority of the debris will be recovered using remotely operated vehicles, although diver assistance may be required in certain instances. If larger items are encountered it may be necessary to use divers to sling the load for recovery to the surface. Debris recovered from the seabed will be transported to shore for recycling or disposal.

12.3.3 Post Clean-Up Survey

At the end of the debris clearance operation, a post clean up survey will be undertaken by sonar sweep, to document that the seabed is clear. The results from the survey will be submitted to the appropriate Norwegian and UK authorities.

12.3.4 Trawling Test

Trawling tests are planned to be performed as part of the effort to open up the Frigg Field area for fishing activity. Such tests will verify that no obstructions remain in the area that would impede fishing operations. The test programme will be established in co-operation with the fishermen's federations in Norway and UK to ensure that representative equipment is used in the test. The results from the trawling test will be submitted to the appropriate Norwegian and UK authorities.

13. Recommended Disposal Arrangements and Costs

13.1 Summary of Recommended Frigg Field Disposal Arrangements

Based upon the assessments detailed in Sections 8, 9, 10 and 11, the following disposal arrangements for the Frigg Field facilities are recommended:-

Element	Recommended Disposal Arrangement
Steel platform topsides (DP2, QP)	Remove and dispose onshore
Steel platform substructures (DP2, QP, DP1)	Remove and dispose onshore
Concrete platform topsides (TCP2, CDP1, TP1)	Remove and dispose onshore
Concrete platform substructures (TCP2, CDP1, TP1)	Leave in place after removing as much of the external steelwork as is reasonably practicable
Infield pipelines and cables	Remove and dispose onshore
Drill cuttings (DP2, CDP1)	Leave in place

Table 13.1 Recommended Disposal Arrangements for the Frigg Field Facilities

Where onshore disposal of the facilities is recommended as much of the equipment and materials as practicable will be re-used or recycled.

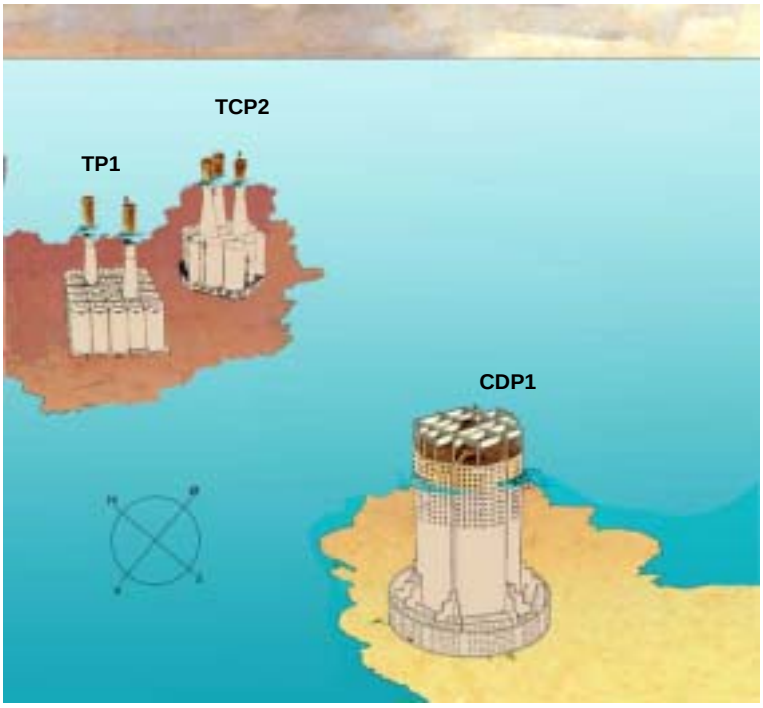


Figure 13.1 Proposed Arrangement of Frigg Field Facilities after Decommissioning

13.2 Summary for Frigg Field Disposal Costs

The estimated total cost of the recommended disposal arrangements for the Frigg Field is 3483 MNOK / £266.3m, as detailed in Table 13.2 below. The additional cost of plugging and abandoning the wells on DP2 and taking out of service the topside equipment on TCP2, DP2, TP1 and QP is estimated as 1050 MNOK / £80.3m. (For CDP1 the production system was taken out of service, and the wells plugged and abandoned, in 1990.)

Platform or Cost Element	Recommended Disposal Arrangement	Location	Total Cost
Platform QP	Remove topsides and steel substructure and dispose onshore	UK	551 MNOK / £42.1m
Platform TP1	Remove topsides and dispose onshore, leave concrete substructure in place	UK	358 MNOK / £27.3m
Platform CDP1	Remove topsides and dispose onshore, leave concrete substructure in place	UK	593 MNOK / £45.4m
Platform TCP2	Remove topsides and dispose onshore, leave concrete substructure in place	N	725 MNOK / £55.4m
Platform DP2	Remove topsides and steel substructure and dispose onshore	N	697 MNOK / £53.3m
DP1 Wreck	Remove and dispose onshore	N	330 MNOK / £25.3m
Pipelines and Cables	Remove and dispose onshore	N+UK	161 MNOK / £12.3m
Drill cuttings	Leave in place	N+UK	0
Seabed clean up	-	N+UK	68 MNOK / £5.2m
Total			**3483 MNOK / £266.3m**

Exchange rate: 13.08 NOK/£

Table 13.2 Estimated Cost of Recommended Decommissioning Activities for the Frigg Field

The cost estimate is based upon studies performed by several different contractors both in Norway and UK, using appropriate North Sea rates. Verification of the cost estimates has been undertaken by London Offshore Consultants, COWI and Det Norske Veritas. In addition, personnel within TOTAL have performed further validation of the cost figures.

The costs presented are expressed in year 2002 money terms and represent a 50/50 estimate. The accuracy of the estimates is -24% /+31 % with an 80 % confidence interval. The actual cost may vary from the estimated value due to technical factors such as difficulties with cutting up DP1, or due to commercial factors such as market conditions.

The split of costs for decommissioning the Norwegian and UK facilities is given in Section 14 (Tables 14.1 and 14.2).

Based upon an extensive cost-risk analysis it has been determined that the cost of decommissioning the Frigg Field facilities, which has only a 10% chance of being exceeded, is 4578 MNOK / £350.0m, plus the costs for well plugging and abandonment, and taking the topside equipment out of service.

13.3 Summary of Risk to Personnel During Disposal of Frigg Field Facilities

The predicted number of fatalities (Potential Loss of Life) arising from the recommended disposal arrangements has been estimated as 0.30. This equates to a 26% (1 in 4) probability of a fatality during the work. Based upon historical accident rates, approximately 14 major injuries could occur during the recommended disposal works. Risk reducing measures will however be implemented in order to ensure that the risks to personnel are as low as reasonably practicable.

Table 13.3 show the predicted number of fatalities (Potential Loss of Life) and the predicted major injuries (Potential Major Injuries) on a platform-by-platform basis.

Platform or Element	Predicted Number of Fatalities (Potential Loss of Life)	Predicted Number of Major Injuries (Potential Major Injuries)
Platform QP	0.040	2.0
Platform TP1	0.038	1.6
Platform CDP1	0.074	2.8
Platform TCP2	0.072	3.5
Platform DP2	0.038	2.0
DP1 Wreck	0.025	1.5
Pipelines and Cables	0.015	0.3
Drill cuttings	0	0
TOTALS	0.30 (Probability of a fatality 26%)	13.7

Table 13.3 Estimated Fatalities and Major Injuries during Recommended Decommissioning Activities for the Frigg Field

13.4 Summary of Environmental Impact of Frigg Field Disposal Arrangements

The total energy impact and the releases to atmosphere predicted to occur during the recommended disposal activities are detailed in Table 13.4 below.

	Impact
Energy Consumption (1000 GJ)	1,557
Total Energy Impact (1000 GJ)	2,395
CO_2 Emissions (1000 tonne)	130

Table 13.4 Total Energy Impact and Emissions to the Atmosphere for the Recommended Frigg Field Decommissioning Activities

The impact of leaving the TCP2, CDP1 and TP1 concrete substructures in place is shown in Table 13.5.

	Impact
Discharges to sea	None/Insignificant
Physical impact on environment / habitat	Moderate negative
Aesthetic impact	None/Insignificant
Material Management	None/Insignificant (Small positive)
Littering	Small negative
Impacts on fisheries	Moderate negative
Free passage at sea	Moderate negative

Table 13.5 Summary of Environmental Impacts from Leaving Concrete Substructures In Place

The impact of leaving the drill cuttings in place is shown in Table 13.6.

	Impact
Discharges to sea	Small negative
Physical impact on environment / habitat	None/insignificant
Aesthetic impact	None/Insignificant
Material Management	None/Insignificant
Littering	None/Insignificant
Impacts on fisheries	None/Insignificant

Table 13.6 Summary of Environmental Impacts from Leaving Drill Cuttings in Place

13.5 Long Term Durability of Concrete Substructures

In view of the recommendation that the three Frigg Field concrete substructures should be left in place for natural decay, an assessment of their likely long-term durability has been made (Ref. 13.1, 13.2).

In the next 100 years, very little physical damage to the three Frigg Field concrete sub structures is predicted. After that time corrosion of the horizontal reinforcement in the splash zone is likely to give rise, initially to spalling of the concrete, and later to local damage, which may be expected in roughly 100 to 150 years. The overall integrity of the structures will however not be affected.

The columns of TCP2 and TP1, and the walls of CDP1, are predicted to remain in place for 500 to 800 years before collapsing. For TCP2 and TP1, local damage in the splash zone will reduce the protection to the vertical pre-stressing steel in the columns, which will eventually become corroded. In this event, the top section of the column may eventually be unable to sustain extreme wave loads and become more severely damaged. For CDP1 local damage to the structure will become more extensive over time. The above-water deterioration of all three structures will however take place relatively slowly and the navigation aids may be expected to remain in place for several hundred years.

13.6 Field-Wide Comparison of the Recommended and Rejected Disposal Alternatives

When undertaking the necessary evaluations and comparative assessments each platform has been considered independently, as required by national legislation. However, the recommendations made for individual platforms, pipelines, cables and drill cuttings need to be considered from the perspective of the Frigg Field as a whole. This sub-section therefore compares the recommended disposal arrangements for the Frigg Field facilities with the alternative disposal arrangements that have been rejected.

13.6.1 Technical Risk

The operations involved in decommissioning the Frigg Field facilities, in line with the recommendations, use existing technology and are within the limits of current experience. The removal of the steel substructures will however involve procedures, equipment and operations that, at present, have not been widely used in the North Sea. Specific operations such as the cutting up and removal of the steel substructures (and particularly the damaged DP1 steel substructure) will however be particularly challenging and will require a high level of professionalism and attention to detail. The removal of the topsides from the five platforms (including the large TCP2 deck) will also involve complicated operations for which there is limited experience. It will therefore be essential that there is great attention to detail during the engineering phase and effective control during the offshore work phase. The main technical challenges are however relatively well known and understood, and although there will doubtless be many technical difficulties to be overcome, it is judged that the risk of being unable to complete the decommissioning work as planned is low.

As detailed in Section 9, there are large uncertainties associated both with the condition of the concrete substructures, and their likely behaviour during an attempt to refloat them. The inherent uncertainties associated with CDP1 in particular means that there is a 30% chance that it will be impossible to refloat the concrete substructure. Although the probability of major accidents during refloat attempts for TCP2 and TP1 are less (in the order of 2% to 5%), the possible consequences of such accidents, in terms of risk to personnel and large cost increases, are such as to make these risk unacceptable.

Consideration has been given to whether developing technology within the foreseeable future, might assist in removing the three concrete substructures. In view of the fact that the main areas of uncertainty relate to physical phenomena (necessary buoyancy, structural uncertainties, schedule and weather) and aspects that are unlikely ever to be determinable (e.g. the amount of grout that might fall off), it is felt that developing technology will not significantly affect the risks associated with attempting to refloat the Frigg concrete substructures.

13.6.2 Risk to Personnel

13.6.2.1 Risk to Personnel During Decommissioning Operations

A comparison of the fatalities statistically predicted during the recommended decommissioning arrangements with the fatalities predicted if the concrete platforms are removed or cut down is shown in Table 13.7.

Decommissioning Alternatives	Predicted Number of Fatalities (Potential Loss of Life)	Probability of a Fatality
Recommended Decommissioning Arrangements • Remove all 5 topsides and 3 steel substructures and dispose onshore • Leave 3 concrete substructures in place after removing external steelwork • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	0.3	26% (1 in 4 chance)
Removal of Concrete Substructures • Remove all 5 topsides and 3 steel substructures and dispose onshore • Refloat 3 concrete substructures, tow to shore and dispose onshore • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	1.1	67% (2 in 3 chance)
Cut down Concrete Substructures • Remove all 5 topsides and 3 steel substructures and dispose onshore • Cut down the 3 concrete substructures to provide a clear draft of 55m for shipping • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	1.4	75% (3 in 4 chance)

Table 13.7 Predicted Fatalities for Different Frigg Field Decommissioning Alternatives

The statistically predicted number of fatalities for the recommended decommissioning activities is 0.3. To gain an appreciation of the significance of this figure it may be assessed in relation to the number of fatalities associated with petroleum operations on the Norwegian Continental Shelf.

In the last 10 years (1990 – 2000) there have been six fatalities on Norwegian production installations. This means that the yearly fatality rate is 0.6. Thus it can be seen that the predicted fatalities for the **recommended decommissioning** arrangements is equal to **half** the number of fatalities on all Norwegian production installations in one year. The number of fatalities predicted if the concrete substructures **are removed** is approximately **twice** the number of fatalities on all Norwegian production installations in one year.

It can be seen that the probability of a fatality during the recommended decommissioning arrangements is 26% (approximately 1 in 4). If the concrete substructures were removed as well the probability of a fatality increases to 67% (approximately 2 in 3). This assumes that the removal operations can be carried out as planned. If a serious problem developed during the refloat, or during towing, it would be necessary to undertake remedial works to remove the substructure in a damaged condition. The predicted fatalities in that situation would be considerably higher.

13.6.2.2 Risk to Personnel After Decommissioning Operations

The overall effect on the safety of shipping of leaving the three concrete substructures TCP2, CDP1 and TP1 in place as recommended, is shown in Table 13.8 below.

Platform/s	Yearly Probability of Collision by Fishing Vessel	Yearly Probability of Collision by Passing Vessel
TCP2	1 in 100,000	1 in 20,000
CDP1	1 in 40,000	1 in 10,000
TP1	1 in 130,000	1 in 27,000
All Three Concrete Substructures	1 in 24,000	1 in 5,500

Table 13.8 Yearly Probabilities of Vessel Collisions with the Frigg Field Concrete Substructures If Left in Place

The figures given above are based upon current marine operations and are regarded as a best indication of the risk level after decommissioning of the Frigg Field. The introduction of more sophisticated navigational equipment such as ECDIS (Electronics Charts Display and Information System) and higher levels of training for mariners in accordance with international conventions (Ref. 13.3, 13.4) is predicted to reduce the probability of collision further. In addition TOTAL NORGE will take measures to ensure that the Frigg Field substructures remain marked on navigation charts and will circulate relevant information about the Frigg Field decommissioning project to mariners. Suitable navigation aids will be installed on the substructures and regularly maintained. Although it is rather difficult to quantitatively assess the effect of these measures, it has been conservatively estimated by specialists (Ref. 13.5) that the likelihood of collision could be reduced by as much as 50%.

13.6.3 Environmental Impact

Due to the many different activities involved, each having either positive or negative effects on the environment, it is not possible to effectively summarise the environmental impact of the entire recommended disposal programme for the Frigg Field facilities. A comparison of the environmental impacts of different decommissioning options for the **three concrete substructures taken together** has however been made and the main parameters are given in Table 13.9.

	Alternative A Refloat, tow to shore, demolish and dispose on-shore	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m	Alternative D Leave in place removing as much external steelwork as reasonably practical
Total Energy (million GJ)	4.0	2.2	3.1	1.0
CO_2 Emissions (1000 tonnes)	265	108	168	14
Physical impact environment	Moderate negative	Moderate negative	Large/Moderate negative	Moderate negative
Aesthetic impact	Moderate negative	None/Insignificant	None/Insignificant	None/Insignificant
Material Management	Moderate positive	Non/Insignificant	Small positive	None/Insignificant (Small positive)
Littering	None/Insignificant	None/Insignificant	Small negative	Small negative
Impacts on fisheries	Moderate positive	Moderate positive	Moderate negative	Moderate negative
Free passage at sea	Moderate positive	Moderate positive	Moderate positive	Moderate negative

Table 13.9 Summary of Environmental Impact of Alternative Disposal Arrangements for **All Three** Concrete Substructures (TCP2, CDP1 and TP1)

A full discussion of the significance of the impacts given in this table is to be found in Section 9 of the Environmental Impact Assessment forming Part 2 of this Frigg Field Cessation Plan.

13.6.4 Cost

Table 13.10 provides a comparison of the estimated cost for the recommended decommissioning arrangements with the estimated cost if the concrete platforms were removed or cut down.

Decommissioning Alternatives	Estimated Cost
Recommended Decommissioning Arrangements • Remove all 5 topsides and 3 steel substructures and dispose onshore • Leave 3 concrete substructures in place after removing external steelwork • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	3483 MNOK / £266.3m
Removal of Concrete Substructures • Remove all 5 topsides and 3 steel substructures and dispose onshore • Refloat 3 concrete substructures, tow to shore and dispose onshore • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	11273 MNOK / £861.8m
Cut down Concrete Substructures • Remove all 5 topsides and 3 steel substructures and dispose onshore • Cut down the 3 concrete substructures to provide a clear draft of 55m for shipping • Remove all infield pipelines and cables and dispose onshore • Leave drill cuttings in place	10417 MNOK / £796.4m

Table 13.10 Estimated Costs for Different Frigg Field Decommissioning Alternatives

The costs set out in the table are the best estimates (50/50) but may vary considerably due to technical problems and commercial uncertainties, particularly the market conditions at the time the work is scheduled. Although there are some technical uncertainties surrounding the recommended decommissioning arrangements, (principally the condition of the DP1 wreck), these are considerably less than the uncertainties associated with removing or cutting down the concrete substructures.

If, as a result of inherent uncertainties, there was a major accident or incident during the removal of one of the concrete substructures then the quoted cost of decommissioning the Frigg Field facilities could increase by 60%.

Section References

13.1 “Deterioration of Reinforced Concrete Platforms in the North Sea – The Frigg Field”, SINTEF Report, Ref. SFT 22 F01602, Latest Revision, DocsOpen 108671.

13.2 “Evaluation of Residual Lifetime for Oil Platforms in The North Sea Made of Reinforced Concrete - The Frigg Field”, Sintef Report, STF22F01601, January 2001, DocsOpen No. 108776.

13.3 The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (1978) as amended by STCW Convention 1995.

13.4 The International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code) (this code became mandatory in 1998 under the International Convention for the Safety of Life at Sea, SOLAS)

13.5 “Frigg Field Cessation Project – Assessment of Collision Risk from Passing Vessels”, Anatec Report, Ref. A1031-TFE-CR-00, Rev.00, dated October 2001, DocsOpen No. 125131

14. Project Execution

The decommissioning of the Frigg Field facilities will be undertaken as an integrated project involving both Norwegian and UK facilities. For convenience however, the activities falling under the jurisdiction of the two national regulatory regimes are described in the following sub-sections. In addition, the estimated costs for the planned decommissioning activities in both of the Norwegian and UK sections of the Frigg Field are presented.

The schedule for the integrated decommissioning programme of work for the Frigg Field facilities is given in Section 15.

The principle has been adopted that facilities removed from Norwegian waters will be returned to Norway for reuse, recycling or disposal. Similarly it is assumed that facilities located in UK waters will be returned to the UK for reuse, recycling or disposal.

The removal and disposal work will however be undertaken by contractors who will be selected by international competitive tender, in accordance with the requirements of European Union directives. At this time it is therefore not possible to unequivocally state the final destination of the various elements removed from the field. No facilities will however be removed, transported, or disposed of without the necessary approvals being obtained from the relevant national and international regulatory authorities. Import duties will be paid as appropriate.

14.1 Planned Decommissioning Activities for Norwegian Facilities

It is presently planned to remove the topsides of platforms TCP2, DP2 using conventional offshore construction techniques. They will then be transported to shore where as much as practicable of the materials and equipment will be reused or re-cycled.

The steel substructure of DP2 and the wreck of DP1 will be cut into sections and transported to shore where the materials will be recycled.

Alternative methods for the removal of the topsides and steel substructures may be used if they show significant advantages in terms of reduced risk to personnel or cost.

The steelwork on the outside of TCP2 including risers, clamps etc. will be removed and transported to shore where the materials will be recycled. Navigation aids, in accordance with both Norwegian and international regulations, will be installed on the TCP2 concrete substructure, which it is recommended to leave in place.

The infield pipelines and cables between TCP2 and DP2 will be retrieved and transported to shore where as much of the material as practicable will be reused or recycled.

It is recommended that the drill cuttings on the seabed around DP2 be left in place and not disturbed, apart from where it is necessary to gain access to cut the steel piles supporting the platform.

Debris on the seabed around the platforms will be removed and the area left clear of any obstructions which could foul fishing gear.

The estimated cost of the decommissioning activities for the Norwegian registered installations and pipelines is set out in Table 14.1.

Platform or Cost Element	Cost
Platform TCP2	725 MNOK (£55.4m)
Platform DP2	697 MNOK (£53.3m)
DP1 Wreck	330 MNOK (£25.3m)
Pipelines and cables	64 MNOK (£4.9m)
Drill cuttings	0
Seabed clean up	36 MNOK (£2.7m)
Total Estimate	**1852 MNOK (£141.6m)**

Table 14.1 Estimated Cost of Decommissioning Activities for the Frigg Field Norwegian Facilities

The actual cost may vary from the estimated value due to technical factors such as difficulties with cutting up DP1, or due to commercial factors such as market conditions.

The figures in Table 14.1 do not include the cost of plugging and abandoning the wells on DP2 nor the cost of taking out of service the production facilities on DP2 and TCP2. The estimated cost of this additional work is 785 MNOK (£60.0m).

14.2 Planned Decommissioning Activities for UK Facilities

It is presently planned to remove the topsides of platforms QP, TP1 and CDP1 using conventional offshore construction techniques. They will then be transported to shore where as much as practicable of the materials and equipment will be reused or re-cycled.

The steel substructure of QP will be cut into sections and transported to shore where the materials will be recycled.

Alternative methods for the removal of the topsides and steel substructures may be used if they show significant advantages in terms of reduced risk to personnel or cost.

The steelwork on the outside of TP1 including risers, clamps etc. will be removed and transported to shore where the materials will be recycled. Navigation aids, in accordance with both United Kingdom and international regulations, will be installed on the TP1 and CDP1 concrete substructures, which it is recommended to leave in place.

The infield pipelines and cables between TP1 and CDP1, QP and CDP1 and between TP1 and the Flare Platform (now removed) will be retrieved and transported to shore where as much as practicable of the materials will be reused or re-cycled.

It is recommended that the drill cuttings inside the CDP1 concrete substructure be left in place along with the concrete substructure itself.

Debris on the seabed around the platforms will be removed and the area left clear of any obstructions which could foul fishing gear.

The estimated cost of the decommissioning activities for the UK registered installations and pipelines is set out in Table 14.2.

Platform or Cost Element	Cost
Platform QP	£42.1m (551 MNOK)
Platform TP1	£27.3m (358 MNOK)
Platform CDP1	£45.4m (593 MNOK)
Pipelines and Cables	£7.4m (97 MNOK)
Drill cuttings	£0m
Seabed clean up	£2.4m (32 MNOK)
Total	**£124.7m (1631 MNOK)**

Table 14.2 Estimated Cost of Decommissioning Activities for the Frigg Field UK Facilities

The actual cost may vary from the estimated value due to technical factors, or due to commercial factors such as market conditions.

The figures quoted in Table 14.2 do not include for plugging and abandonment of the wells on CDP1 (which was undertaken in 1990) nor the cost of taking out of service the production and accommodation facilities on TP1 and QP. The estimated cost of the future additional work is £20.3m (265 MNOK).

14.3 Common Activities

Prior to starting removal operations the materials inventory will be verified and hazard assessments carried out to ensure that there are no adverse effects on the health and safety of personnel, or the environment, arising from the planned activities. Hazardous equipment and materials would be identified, and either made safe or removed. Process equipment and pipelines will be cleaned by flushing, in accordance with the TOTAL NORGE specification which complies with national codes and standards.

Although it is presently planned to remove the platform topsides using conventional “reverse construction” methods, further studies will be undertaken to assess the technical feasibility of using one or more of the innovative topsides removal schemes being proposed by industry. The object of the studies will be to identify methods that would allow the removal of the platform topsides in a safer and more cost effective manner. Similar studies would be undertaken to investigate whether one of the innovative techniques for removing steel substructures could be used to reduce cost and improve safety.

All operations will be conducted in accordance with TOTAL NORGE management principles as described in more detail in Section 17.

14.4 Recent Industry Experience

The successful refloating of the Maureen steel gravity platform by Phillips Petroleum Company UK Ltd. in June 2001 prompted TOTAL NORGE to make a further review of the proposed methods for refloating the Frigg Field concrete substructures. As a major partner in the Maureen Field, (through Fina Exploration Ltd’s ownership of 28.96% of the Maureen facilities), TOTAL was involved in reviewing the decommissioning plans for the platform. Thus, TOTAL NORGE has been aware of the technical background to the Maureen refloat operation whilst preparing the Frigg Field Cessation Plan. The methods used for the Maureen platform are relevant in respect to all three Frigg Field platforms, but are particularly comparable with the methods considered for refloating the TCP2 concrete substructure. Meetings were therefore held with Phillips Petroleum Company UK Ltd. to discuss in detail the major technical aspects and to identify the similarities and differences between the structures, and their local environments.

Having carefully reviewed the refloat operation for the Maureen platform (which was specifically designed to be removed) it is concluded that there are many important differences between the Maureen steel gravity based platform and the Frigg Field concrete substructures (Ref 14.1). Significant differences were particularly identified in the following aspects; platform size; soil and foundation conditions; structural strength; pipework / mechanical equipment; and risk. These differences are judged to be sufficiently major to prevent direct comparisons to be drawn between the successful refloat operations for the Maureen platform and the envisaged refloat operations for the Frigg Field concrete substructures.

Two concrete platforms in the Schwedeneck-See close to Kiel in the Baltic Sea operated by RWE-DEA were successfully removed in 2002. Prior to the removal TOTAL NORGE have discussed the planned operations with the operator to identify any aspects that could be relevant to the decommissioning of the Frigg Field concrete substructures. The two Schwedeneck See platforms (which are of the tower and caisson type) are very much smaller than the Frigg substructures and stand in only 16m and 26m of water as compared with the 100m depth of water at Frigg. It was proposed to extract the Schwedeneck See platforms from the seabed using external steel buoyancy tanks attached by water pressure to the roof of the caisson. The use of similar devices for the Frigg Field concrete substructures has therefore been considered, but it has been concluded that whilst this arrangement may be satisfactory in the benign waters of the Baltic Sea, it would not be prudent to use such an arrangement in the much more hostile waters of the North Sea.

14.5 New Technology

Although it is presently planned to remove the topsides and steel substructures using conventional offshore lifting and transportation techniques, TOTAL NORGE is supporting development work to investigate whether the installations can be decommissioned in a safer and more cost effective manner.

In their 1998 Sintra Statement, the members of the OSPAR Commission agreed to promote *"Research and development by industry and relevant Contracting Parties on techniques for reusing and dismantling disused offshore installations and returning them to land for recycling or final disposal"*

As part of this initiative TOTAL NORGE has engaged in discussion with other operators to see how the development of new technologies for removal of offshore structures might be stimulated. The North Sea offshore industry is a mature industry, and several of the major fields are approaching the end of their production life.

As a result of these discussions, a Joint Industry Project Group (JIP Group) of operating companies was established to look further into the single lift concepts. TOTAL NORGE has taken a leading role in this group.

Several ideas and concepts are currently being marketed for the removal of topsides and steel substructures in a single lift. It was felt that the development of such concepts would increase the market capacity and provide competition.

As a first step, the JIP Group engaged Det Norske Veritas (DNV) to evaluate 12 single lift concepts in order to identify and evaluate the operational principles and their limitations.

The evaluation criteria, which were established by DNV in co-operation with the JIP Group and in discussion with the concept owners were; technical robustness; operational feasibility and safety and environmental aspects. It has generally been assumed that removal operations in the North Sea are to be qualified according to relevant international and national regulations, and project specific requirements set by the oil companies. In other words, the same requirements apply to removal operations as apply to similar operations in the North Sea.

The report from DNV has been received by the JIP Group, and has formed the basis for identifying further development work.

In the next phase, some of the single lift concepts were subject to further evaluation in studies financed jointly by the participating oil companies and the concept owner.

The following critical points received particular attention:-

- Station Keeping
- Platform Modifications
- Load Transfer
- Transportation
- Transfer Ashore

This phase of the Joint Industry Project is also now complete. It has provided the single lift concept owners with a good basis from which to further develop their concepts to a stage that would permit pre-qualification for tendering.

TOTAL NORGE is also supporting research and development programmes evaluating various underwater cutting methods and methods of back-loading lifted modules onto transportation barges.

TOTAL NORGE will continue to work actively to promote innovative and effective technology and to continually assess whether such techniques can be applied to the decommissioning of the Frigg Field facilities.

14.6 Mitigating Measures

A number of mitigating measures have been identified in Section 12 of the Environmental Impact Assessment, which forms Part 2 of this Frigg Field Cessation Plan. The suggested measures and the planned actions are detailed in Table 14.3.

Mitigating Measure Suggested by DNV	Planned Action
Clean-up of seabed debris to eliminate the risk of damage to fishing gear and reduce the potential for littering. This should be planned as a three stage process – identification, removal and verification	All these activities will be undertaken as described in Section 12 of this Disposal Plan.
Install navigation lights on the installations left in place to prevent the occurrence of dangerous situations with passing vessels	Navigation aids will be installed on the three concrete substructures that it is proposed to leave in place. These aids will be inspected at regular intervals to ensure high reliability.
Removal of external steelwork on the concrete substructures left in place, to limit the obstruction and risks to fisheries.	All steelwork on the outside of the concrete substructures which it is proposed to leave in place, will be removed as far as is reasonably practicable.
Cover cut ends of the steel substructure foundation piles to avoid damage to fishing gear.	Steel foundation piles will be cut sufficient distance below the seabed to ensure that they are not a hazard to fishing activity.
Select favourable time of year, favourable weather conditions and protect and scare fish away to limit impacts if using explosives to obtain the –55m clearance for the partial removal alternative for CDP1. Develop guidelines for observation for cetaceans to be incorporated in the execution plan..	Cutting down to a level 55m below the water surface is not the recommended disposal arrangement for CDP1 due to the high risk to personnel and the uncertainties associated with the cutting methods required.
Remove all pipelines within the safety zone, including export pipelines not being part of this EIA, to ensure access for fisheries without any possible obstacles on the seabed	All infield pipelines and cables will be removed and brought to shore for disposal. It is intended to remove, or bury, all export lines within 500m of the installations when they are no longer operational. (It should be noted that such export/import lines are not included within the scope of this Cessation Plan).
Comply with the implemented EMAS system to ensure that continuous improvement and openness are key parts of the planning and execution of all work associated with the decommissioning of the Frigg Field facilities.	The EMAS system will be used to achieve the defined objectives.
Steel items covered with polyurethane paint should be identified before the start of demolition. Cutting with thermal means will cause the release of isocyanates, which could cause serious harmful effects in humans.	For offshore work, TOTAL NORGE has in place procedures to prevent personnel being exposed to isocyanates when cutting polyurethane painted items. TOTAL NORGE will make the contractor who is responsible for the onshore demolition work, aware of the possible presence of polyurethane paint so that suitable protective measures may be taken.
Sound material and waste management with optimal reuse/recycling is considered very important, and a stretched target for reuse/recycle should be considered. A dedicated waste handling module capable of tracking all waste fractions has been developed to be included in the environmental accountancy system.	Comprehensive material and waste management procedures will be implemented.

Mitigating Measure Suggested by DNV	Planned Action
If required, contractual arrangements should be made with the onshore disposal contractor to ensure that possible negative aesthetics effects are mitigated.	Suitable clauses will be included in the contract with the onshore disposal contractor.
Assess whether the present rock dumps should be left in place or whether the material should be spread out on the seabed to reduce the impacts on fisheries.	It is proposed to leave the rock dumps in place but to make efforts to level them out.
Monitor the condition of the layers of drill cuttings if they are left in place after completion of the approved decommissioning programme.	The drill cuttings will be monitored as detailed in Section18.
Discuss liability issues with the authorities in respect to any facilities left in place.	TOTAL NORGE, on behalf of the Frigg Licensees, will discuss this matter with the relevant authorities with a view to reaching a conclusion before the termination of the Frigg Field production licenses.

Table 14.3 Mitigating Measures Proposed in the Environmental Impact Assessment and Planned Actions

Section References

14.1 "Technical Review of the Maureen Platform Refloat Operation and Comparison with the Envisaged Refloat Operations for the Frigg Field Concrete Substructures" TotalFinaElf Norge Report, dated 10.10.2001, DocsOpen 124567

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15. Schedule

15.1 Proposed Schedule for Undertaking the Recommended Disposal Activities

The time constraints applicable to the decommissioning of disused offshore installations are, in many respects, different from those applicable to offshore development projects. New development projects normally have a fixed time schedule, while a more flexible approach is possible in decommissioning work, enabling a more efficient use of resources. This is of assistance in optimising expenditure on costly offshore activities.

The age and general condition of the facilities are other important factors in determining the best time for the removal and disposal activities. The opportunities to reuse, or sell, parts or all of the installations are also factors that have an effect on a decommissioning project schedule.

The proposed schedule for undertaking the recommended decommissioning arrangements for the Frigg Field facilities is shown in Figure 15.1.

The schedule assumes that there will be continuous offshore activity up until the end of the first quarter of 2007. After that time, offshore works are assumed to take place mainly during the summer seasons. The amount of offshore work planned for any one year has been estimated on the basis of what can be reasonably undertaken during the summer season. Onshore disposal activities are assumed to be carried out continuously from 2007 onwards. The recommended programme of disposal activities will be completed by 31.12.2012 providing production from the field ceases in 2004.

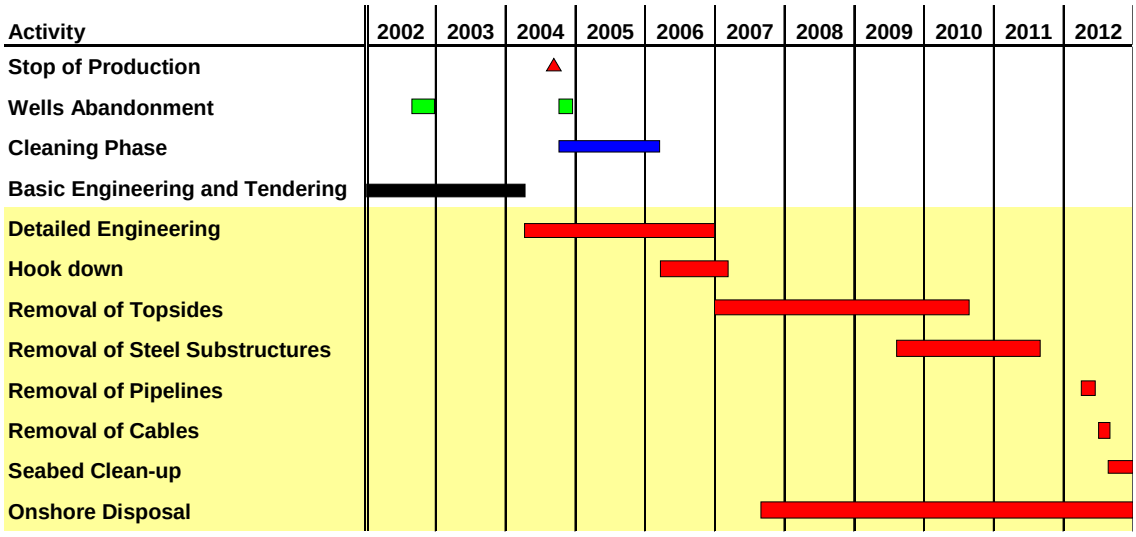

Figure 15.1 Proposed Schedule for Recommended Disposal Activities

15.2 Preparatory Activities

Before the Frigg Field facilities can be decommissioned a number of preparatory activities need to be undertaken one of which is the subsea connection of the Alwyn pipeline into the 32" diameter Frigg UK Pipeline (PL 7).

During the summer of 2004 it is planned to install a subsea connection between the 24" diameter Alwyn Field export pipeline and the 32" diameter Frigg UK Pipeline (PL 7) in the Frigg Transportation System. When this subsea connection is completed, gas from the Alwyn Field will bypass the Frigg Field facilities. Until this subsea connection has been established the gas export facilities on TCP2 will be maintained, in order to allow the export of Alwyn gas via the Frigg Norwegian Pipeline, if required.

During the summer of 2001 the Vesterled pipeline from Heimdal was connected into the 32" diameter Frigg Norwegian Pipeline in the Frigg Transportation System. The tie-in point is located about 50km west of the Frigg Field installations, in the UK sector of the North Sea. The end of the Frigg Norwegian Pipeline between the tie-in point and Frigg Field has be sealed and a crossover installed to connect Frigg Field with the Vesterled line (see Figure 7.1). This allows the export of Frigg gas to continue via the Frigg Norwegian Pipeline until production from the field ceases.

15.3 Factors Influencing the Proposed Schedule

As a considerable time will elapse before the offshore disposal activities commence, it is possible that the proposed schedule may be modified in the light of changed circumstances. Some of the factors, which may affect the proposed programme of work, are detailed below.

End of Production
It is presently predicted that production from the Frigg reservoir will cease in 2004. It is however very difficult to estimate when it is appropriate to cease production at the end of a long "tail-off" period from a once huge gas field. If, as a result of positive recovery experience, it becomes viable to produce beyond 2004, then the disposal schedule will be adjusted accordingly.

Co-ordination with other Projects
Other operators are known to be planning removal and development activities at approximately the same time as the scheduled Frigg Field disposal activities. Co-ordinating offshore activities will therefore be considered where the synergy effect would give obvious cost benefits.

New Technology
The introduction of new technology may also have an affect on the schedule. It could be beneficial to postpone the disposal works if promising new concepts, offering cheaper, safer and more environmentally friendly disposal solutions, are in prospect.

Contract Strategy
In contracting for the removal and disposal activities, a degree of flexibility will be introduced in respect to the execution of the work. Past experience indicates that this is also cost efficient for the contractors performing the decommissioning work. Planning flexibility is also advantageous in relation to the onshore disposal work, as it may encourage reuse alternatives.

Reuse Considerations
The recommended schedule for the Frigg Field disposal works has been prepared before the reuse potential of parts of the installations has been finalised. Hence, the schedule does not take the reuse opportunities fully into account. If opportunities for reuse arise, the schedule may be adjusted accordingly.

Removal of Infield Pipelines and Cables
The removal of the infield pipelines and cables has been scheduled during the last summer season when access to the area will allow the work to be conducted in a more efficient manner.

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16. Public Consultation

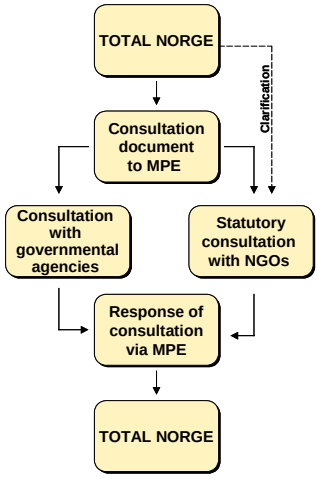
This section describes the public consultation process undertaken by TOTAL NORGE, on behalf of the Frigg Field Licensees. The feedback from the consultations has been used in developing the recommended disposal arrangements for the Frigg Field facilities.

A similar process of public consultation is being carried out in both Norway and the UK, in accordance with the established principle of treating the Frigg Field as a single unit. In addition to the statutory consultations required by both Governments, efforts have been made by TOTAL NORGE to identify, and involve, a much wider range of stakeholders who have an interest in the decommissioning of the Frigg Field.

16.1 Statutory Public Consultation

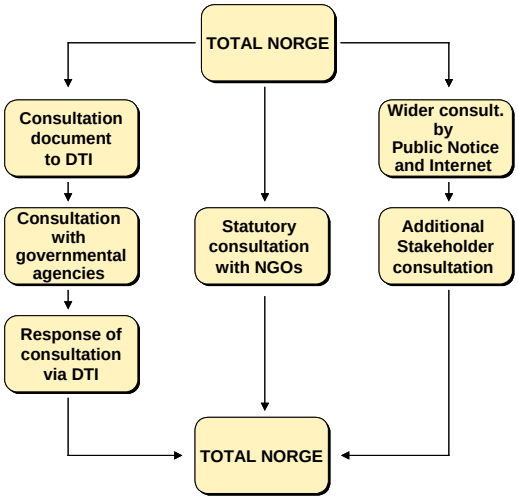
In Norway

The public consultation process in Norway is co-ordinated by the Ministry of Petroleum and Energy (MPE). It distributes consultation documents to other governmental bodies a well as to a number of Non-Governmental Organisations in Norway. The comments received by MPE are then forwarded to the operator.



In United Kingdom

The public consultation process in the UK is organised in a different manner to Norway. The UK Department of Trade and Industry (DTI) takes charge of the consultation process with different governmental bodies, whilst the organisation of consultation with the statutory stakeholders is the responsibility of the operator. In addition to consultation with the statutory stakeholders listed in the DTI Guidance Notes, it is also recommended that consultation takes place with other interested parties.



16.2 Frigg Field Public Consultation Process

16.2.1 Overview

Consultation with the public regarding the decommissioning of the Frigg Field is a long-term commitment for both the Frigg Field Licensees and the stakeholders. Norwegian regulations require that operators, on behalf of the Licensees, submit their recommended cessation plan to the regulators at least two years before the end of production. Cessation of production for the Frigg Field is expected to be in 2004. This means that the physical decommissioning of the Frigg Field facilities is not likely to begin until 2007 and is not planned to be concluded until 2012.

TOTAL NORGE began planning for the decommissioning of the Frigg Field in 1998. It was considered important to ensure that stakeholders became involved at the earliest possible stage and thus the process of public consultation began in April 1999.

The table below describes the main phases of stakeholder consultation that have already taken place.

Phase	Description
Phase 1	Research carried out to identify interested stakeholders in the UK and Norway. Advertisements placed in key UK and international publications inviting stakeholders to participate in the consultation process. A full list of the interested parties that were identified is in Annex D.
Phase 2	Consultation around the Environmental Impact Assessment (EIA) Proposal in both UK and Norway. Stakeholder comments were requested and these may be found in Annex A.
Phase 3	First round of face-to-face meetings held with stakeholders in UK and Norway.
Phase 4	Second round of face-to-face meetings with key stakeholder groups in UK and Norway.
Phase 5	Draft EIA document, previous stakeholder comments incorporated – (see Annex A) sent to stakeholders in UK and Norway and further comments requested.
Phase 6	Stakeholder workshop held in London on 5th September 2000 with UK and Norwegian stakeholders (see Annex B).
Phase 7	Stakeholder visit to Frigg Central Complex on 20 September 2001.
Phase 8	Statutory consultation around second draft of the Cessation Plan document – 29 November 2001 to 28 February 2002.

Table 16.1 Main Phases of the Stakeholder Dialogue Process

It is intended to continue the dialogue with stakeholders throughout the planning and implementation phases of the Frigg Field decommissioning process.

16.2.2 Stakeholder Dialogue and Statutory Consultation Process

Stakeholder Dialogue

Efforts have been made to ensure that an open and transparent dialogue takes place with all interested stakeholders during the development of the Frigg Field Cessation Plan.

To date the consultation with stakeholders has focused on a number of aspects, including:-

- ensuring that stakeholders view the consultation process as fair and open

- the technical uncertainties surrounding the decommissioning of the concrete substructures
- the presentation of the two documents which form this Frigg Field Cessation Plan viz. the Frigg Field Disposal Plan and the Frigg Field Environmental Impacts Assessment (EIA)
- other issues of concern

Dialogue and consultation with stakeholders is being carried out in a number of ways, as noted in the Table 16.2.

Method	Description
Web site	All documents of interest to stakeholders are posted on the Frigg Field Cessation web site which can be found at www.total.no/cessation
Advertisements	A series of public advertisements were placed in key UK and international publication to identify as wide a range of stakeholders as possible, and to raise awareness that plans for the decommissioning the Frigg Field were being prepared.
Newsletters	Regular newsletters are published and sent to stakeholders as well as posted on the web site.
Face to face meetings	Regular meetings are held with interested stakeholders to discuss issues of concern.
Offshore Visit	Some Norwegian and UK stakeholders have been taken offshore to the Frigg Field to provide a greater understanding of the decommissioning tasks.
Workshops	Interactive dialogue workshops have be held as required to bring all stakeholders together for discussion.
Letters, e-mails, telephone	On-going dialogue is conducted with all stakeholders as required. Feedback is welcomed at every stage.
Formal Consultation	A copy of the second draft of the Cessation Plan was sent to all stakeholders for their comments as part of the statutory consultation process; those who had indicated a wish to be informed received a letter notifying that the document could be reviewed at TOTAL NORGE web site.

Table 16.2 Methods of Communication with Stakeholders

Two video animations have been prepared by TOTAL NORGE illustrating the numerous uncertainties associated with attempting to refloat, or cut down the three concrete substructures. These videos have been used during discussions with stakeholders, who have expressed the opinion that they were very useful in gaining a better understanding of the problems involved. The video animations will continue to be used in the on-going consultation process.

Statutory Consultation Process

In preparation for the formal consultation period, a copy of the First Draft of the Frigg Field Cessation Plan was sent to both the Norwegian (MPE) and UK (DTI) authorities for their consideration. In accordance with national practises, UK governmental organisations were invited by DTI to consider the First Draft of Frigg Field Cessation Plan. The responses from the various UK governmental departments and agencies were collected and collated by the DTI. An overview of the comments received to the First Draft is included as Annex C. In Norway comments from governmental organisations are only sought on the Second Draft of the document where MPE asks for comments only on the Environmental Impact Assessment.

Based upon the comments received, the Second Draft of the Frigg Field Cessation Plan was prepared and distributed for a formal public consultation to the statutory stakeholders on 29 November 2001. A wider group of stakeholders were also sent a copy of the Cessation Plan and their comments sought. Those stakeholders who had just expressed the wish to be kept informed about the decommissioning process were notified that a copy of the document could be sent to them if requested, or available for viewing on the TOTAL NORGE web site. Stakeholders were given three months to review the Cessation Plan and were asked to respond by 28 February 2002.

In accordance with practice in Norway the MPE issued the Frigg Field Cessation Plan to the stakeholders asking for comments on the Environmental Impact Assessment while the Disposal Plan was to be considered for information in order to obtain a full view of the approach. In the UK, TOTAL NORGE, as operator of the Frigg Field, issued the document to the stakeholders, although supplementary responses from UK governmental organisations were coordinated by the DTI.

Details of the stakeholders participating in the formal consultation process on the Second Draft of the Frigg Field Cessation Plan, and details of the responses received, are given in Annex D. A summary of the main issues raised by the stakeholders is provided in Section 16.2.4.

16.2.3 Key Consultation Milestones to Date

Consultation with stakeholders began in May 1999 when interested parties were contacted by TOTAL NORGE and invited to participate in the Frigg Field decommissioning process. As well as on-going dialogue with stakeholders, TOTAL NORGE has sought specific input from key representative stakeholder groups in a number of areas.

Environmental Impact Assessment
The first input from stakeholders was sought regarding the Proposal for the Environmental Impact Assessment Programme (EIA). Comments from stakeholders were fed back into the EIA development process. An interim draft of the EIA Report was circulated to stakeholders for comment in August 2000, and the final draft is included as Part 2 of this Frigg Field Cessation Plan for statutory consultation.

The Challenges of Concrete Structures
One of the key issues surrounding the decommissioning of the Frigg Field facilities is the identification of the optimum management option for the three concrete substructures. These substructures present particular challenges and TOTAL NORGE shared the preliminary findings from their studies with stakeholders, to seek their views. Face-to-face meetings have been held since June 2000 with a number of the representative stakeholder groups.

Interactive Workshop
Following a year of on-going dialogue and consultation with stakeholders, TOTAL NORGE identified a need to bring stakeholders from both Norway and the UK together in a workshop to discuss views and concerns. An independent consultant was used to ensure an unbiased forum for discussion and an independent record of the day's activity. The transcript of the discussions can be viewed on the web site www.total.no/cessation.

The outcome of the workshop was very useful in finalising the Environmental Impact Assessment and in preparing the Frigg Field Cessation Plan.

Statutory Consultation on Cessation Plan document
The formal consultation on the recommendations made by the Frigg Field Licensees took place between 29 November 2001 and 28 February 2002. The consultation involved the statutory consultees as well as a much wider group of interested parties.

Figure 16.1 below shows in diagrammatic form how the consultation process has been and will be carried out simultaneously in both Norway and UK.

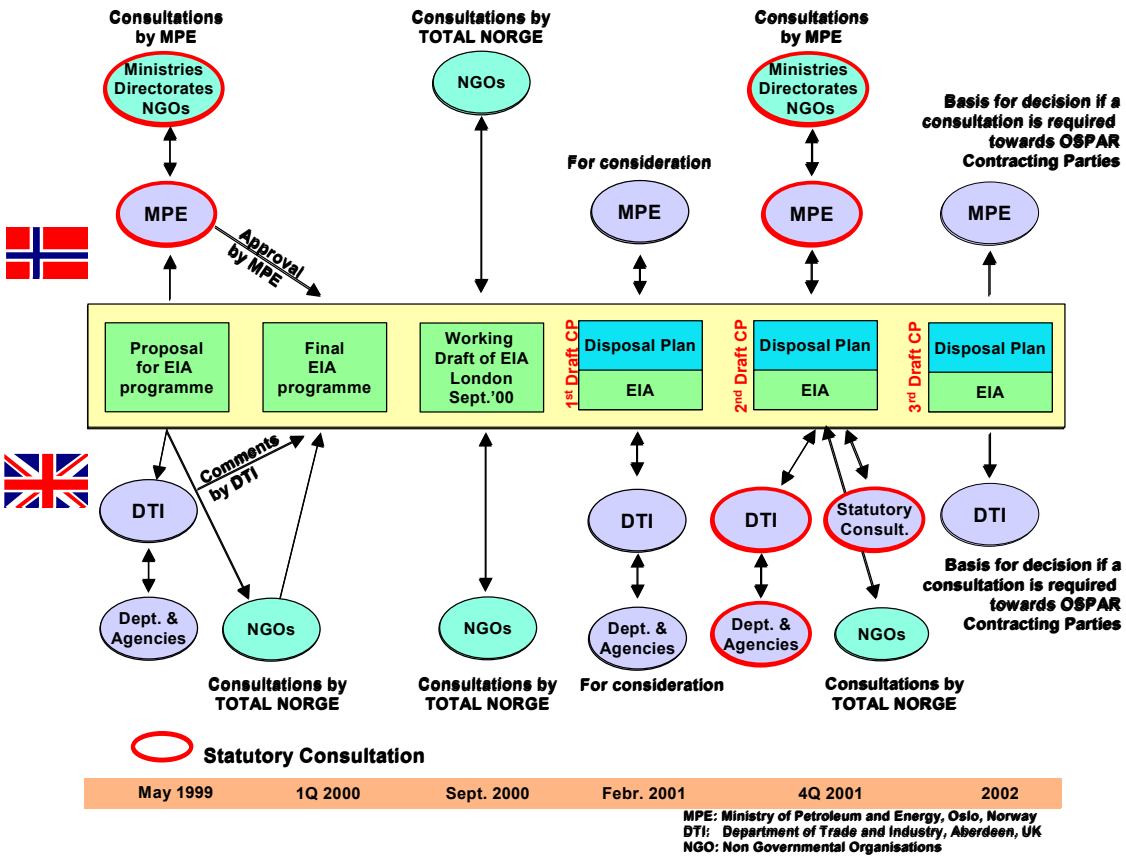


Figure 16.1 Decommissioning Consultation and Approval Process in Norway and UK

16.2.4 Stakeholder Responses to Formal Consultation on Second Draft of the Frigg Cessation Plan

Key Issues Raised by Stakeholders

Based upon an analysis of the comments received during the formal public consultation period, the following seven issues have been identified as being of most importance to stakeholders.

- three Fishermen's Federations have expressed the view that the three concrete substructures should be removed, while they recognise the difficulties this may represent
- the need for reliable navigation aids on the concrete substructures that are left in place
- the need for on-going monitoring of the substructures and the local marine environment
- concern that the reuse potential of the concrete structures has not been adequately evaluated.
- concern that advances in technology might make it possible to remove the concrete substructures at a later date.
- the management of the drill cuttings left in place
- the question of long-term liability and associated financial guarantees

These issues are addressed below.

Removal of the Concrete Substructures
The Licensees of the Frigg Field recognise the "presumption for removal" of all redundant and decommissioned platforms in the OSPAR Maritime Area.

The requirements of the 1992 OSPAR Convention and OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations have been fully complied with during the assessment of the disposal alternatives. The studies, which form the basis of this assessment, have been undertaken by independent specialists and have been the subject of peer review by experts from a number of European countries

Due to the significant reason set out in Section 9 in the Disposal Plan and the Environmental Impact Assessment in the Frigg Field Cessation Plan, it is considered preferable to leave the concrete substructures in place after that they have been suitably marked and navigations aids installed.

Navigation Aids
The safety of users of the sea is of critical importance and thus TOTAL NORGE will install appropriate navigation aids on the concrete substructures left in place in order to fully comply with national regulations and international conventions and to minimise risk to users of the sea. See also section 18 in the Disposal Plan.

Preliminary studies have been commissioned by TOTAL NORGE to investigate how navigation aids with the required high level of reliability may be provided. Such devices will need to incorporate adequate back-up systems to ensure that they remain operational for long periods of time. In addition, regular surveillance of the navigation aids will take place. The responsibility for maintaining the navigation aids would remain with the Frigg Field Licensees unless otherwise agreed by the authorities.

As operator of the field, TOTAL NORGE has already started a dialogue with the relevant Norwegian and UK marine authorities to ensure that the navigational aids themselves, and their maintenance programme, will satisfy the requirements of both national regulations and international conventions. Any new development in technology will be duly considered at the time such navigations aids are required to be in operation.

In addition, the concrete substructures will be marked on charts and it is also planned to incorporate these substructures into the FishSAFE programme which is a computerised system operated in UK waters to provide fishermen with a visual and audible warning of obstructions or hazards in the fishing grounds.

Monitoring
Environmental surveys of the Frigg Field have been carried out four times since 1986. A further two surveys are planned before cessation of production in 2004.

Once the decommissioning work has been completed a further survey will be carried out to document the environmental conditions. In addition, a survey of the condition of the concrete substructures and the adjacent seabed will also be carried out at that time. The requirements for further surveys will be determined in response to the results of the survey and in consultation with the authorities.

A visual examination of the above water sections of the concrete substructures will be made when the platforms are visited for inspection or maintenance of the navigation aids. Any observed deterioration of the substructures will be recorded and the implications, as related to the safety of users of the sea, will be assessed.

The plan for monitoring is further described in Section 18 in the Disposal Plan.

Reuse Applications
Extensive and detailed studies have been undertaken to evaluate the reuse potential of the Frigg Field facilities. Possible reuse in the oil and gas industry or in other applications has been carefully considered.

The reuse issue raised frequently by stakeholders was whether one or more of the concrete structures could be used as a bridge foundation in Norway. TOTAL NORGE agrees that such an application may be possible if it is feasible to successfully refloat a concrete substructure, and that a suitable location is identified satisfying both structural and geotechnical conditions. However, unlike more recently designed concrete structures, the Frigg concrete structures were not designed to be removed and the risks associated with such an operation have been shown to be many times higher than normally accepted for such marine operations.

The issue the reuse potential is covered in Chapter 7 of the Disposal Plan and Chapter 5 of the Environmental Impact Assessment (EIA).

New Technology
TOTAL NORGE has carefully considered the question raised by a number of stakeholders that it might be possible to remove the concrete substructures at a later date if suitable technology became available. It is difficult to see how the inherent uncertainty in many of the technical issues associated with refloating the substructures would be reduced by the development of new technology. Thus although advances in automation and robotics may allow some of the tasks to be done with less risk to humans, the technical risks associated with the refloat operation itself are unlikely to reduce significantly. This fact, taken together with other considerations, means that the present recommendations would remain unchanged.

Drill Cuttings
The main issues raised by stakeholders concerning the drill cuttings at the Frigg Field focused on the layer beneath the DP2 steel structure. This platform will be totally removed and there is a commitment to ensure that the cuttings are disturbed as little as possible during the removal operations.

At DP2 the amount of hydrocarbons in the cuttings has been estimated as only 150 kg. Moreover the area of seabed covered by the cuttings is small. These facts led DNV to recommend that the drill cuttings be left in place. (See EIA Section 1.5).

Since the Second Draft of the Frigg Field Cessation Plan was sent out for consultation, the final report from the UKOOA Drill Cuttings Initiative has been published (Ref. 16.1). The proposal to leave the layer of drill cuttings in place beneath DP2 is found to be in line with the drill cuttings initiative, which states that leaving the cuttings in place to degrade naturally is likely to the best environmental strategy when the potential environmental impact can be demonstrated to be insignificant.

Long Term Liability
Both Norwegian and UK regulations stipulate that residues left in place after decommissioning remain the responsibility of the field owners. Thus, the Frigg Field concrete substructures remain the property and responsibility of the parties to the programme, unless alternative arrangements are agreed with the authorities.

It is the intention of the Frigg Field Licensees to enter into a dialogue with the authorities in both countries in order to arrive at suitable arrangements regarding long-term future liabilities well in advance of the expiry date for the Frigg Field production licenses.

See also Section 19 in the Disposal Plan

16.3 OSPAR Consultation Process

OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations generally prohibits the leaving in place of offshore installations. However provisions, by way of derogation, are included for certain categories of installations (e.g. concrete substructures), provided there are significant reasons why leaving them in place is preferable to reuse or recycling or final disposal on land.

The reasons for seeking a derogation need to be set out in an assessment, as defined in Annex 2 to the OSPAR Decision 98/3 entitled "Framework for the Assessment of Proposals for the Disposal at Sea of Disused Offshore Installations".

In view of the recommendation by the Frigg Field Licensees that the concrete substructures of TCP2, CDP1 and TP1 should be left in place, an assessment in accordance with Annex 2 was prepared and submitted to the Norwegian and UK authorities. In line with the integrated approach to the decommissioning of the Frigg Field, a common assessment document was prepared, although each concrete substructure was considered separately (see Ref 16.2). This assessment document may be viewed on TOTAL NORGE's website www.total.no/cessation.

The Norwegian Ministry of Petroleum and Energy and the UK Department of Trade and Industry informed the OSPAR Executive Secretary in mid September 2002 that they were considering issuing a permit, under paragraph 3b of OSPAR Decision 98/3, for the disposal of the concrete substructures within their jurisdiction at their current locations in the Frigg Field.

The OSPAR Executive Secretary sent the assessment, together with letters from the Norwegian Ministry of Petroleum and Energy and the UK Department of Trade and Industry, to all the OSPAR Contracting Parties on 20 September 2002.

By the end of the 16-week consultation period no objections had been received to either the Norwegian Ministry of Petroleum and Energy or the UK Department of Trade and Industry issuing permits under paragraph 3b of OSPAR Decision 98/3 in respect to the Frigg Field concrete substructures. Some of the Contracting Parties raised a number of points for consideration, among which were the following:-

- The need to ensure that the concrete substructures are effectively marked with navigation aids and are suitably shown on charts.
- The need for the long-term liability for the substructures to be guaranteed, including the responsibility for maintaining the navigation aids in the coming decades.
- The need to take every possible effort, including the preparation of firm procedures, to empty any residual oil or hazardous chemicals from the substructures.
- The need to ensure that wellheads, if left in place, do not constitute a hazard to fishermen.
- The need to consider possible measures to ensure the safety of users of the sea when the concrete substructures start to disintegrate.

These matters have been addressed during the preparation of the Frigg Field Cessation Plan and, in accordance with OSPAR Decision 98/3, will be subject to the terms of the permits to be issued by the UK and Norwegian authorities.

Details of points raised by the Contracting Parties during the OSPAR consultation process may be found in Annex E, together with the comments of TOTAL NORGE.

Section References

16.1 "UKOOA Drill Cuttings Initiative" Final Report, December 2001

16.2 "Frigg Field Concrete Substructures – An Assessment of Proposals for the Disposal of the Concrete Substructures of Disused Frigg Field Installations TCP2, CDP1 and TP1", dated 06.August 2002.

17. Project Management and Verification

Effective management is as important during decommissioning activities as during field development and production. The same level of commitment is required from the operator and the licensees as throughout the life of the field. This principle has been clearly expressed by the regulatory authorities in both Norway and the UK.

As operator of the Frigg Field, TOTAL NORGE will ensure that the commitment to safe and effective operation, that has been a mark of the development and production phases will continue throughout the decommissioning phase.

The competence of personnel that has been built-up during the years of operation will be critical in ensuring the safe execution of the decommissioning activities.

Operated Assets within TOTAL NORGE is responsible for all operated asset activity in the Norwegian and the UK sections of the Frigg Field. Staff in the three departments of Operated Assets will all be involved in the decommissioning activities, as described below.

- The **Cessation Projects Department** is responsible for the execution of decommissioning, hook down and disposal activities.
- The **Drilling and Completion Department** is responsible for the plugging and abandonment of wells.
- The **Field Operations Department** is responsible for closing down production and for taking the equipment out of service.

The Cessation Projects Department also has a coordinating role and provides the project services functions on behalf of the three departments.

The Quality System in TOTAL NORGE is structured on three main levels:-

- Overall Company level
- Business Area level (Operated Assets level)
- Department level

At the Department level, decommissioning activities are described in the Cessation Projects Execution Plan, where interfaces and responsibilities are outlined.

The Operated Assets Quality manual defines the overall responsibilities within the business area and is connected to the Overall Company level through the document **"Management of Quality"**. This document outlines the standards and commitments of TOTAL NORGE.

The Overall Company level is complemented by the health, safety and environmental standards established for TOTAL NORGE.

Although decommissioning works are rather different from operational or development activities, existing specifications and procedures have been applied deliberately whenever possible and new documentation only prepared if strictly needed.

This approach has been based upon the fact that the existing specifications and procedures incorporate experience obtained over many years and are familiar to personnel. It is believed that this approach will ensure that the present high level of safety and performance within the company will be extended throughout the non-routine decommissioning activities.

During the Frigg Field decommissioning activities TOTAL NORGE will apply, whenever possible, the same health and working environment, safety and environmental standards as used during the Frigg Field operational phase.

The overall controlling document within TOTAL NORGE is **TOTAL NORGE Shared Principles.** This document details the **Vision, Objectives and Strategies** of the Company, provides **Ethical Guidelines** for the operation of the Company and defines arrangements for the **Management of Quality**. The Management of Quality document, within the TOTAL NORGE Shared Principles, gives an overall description of quality management principles, responsibilities and resources in the Company.

The policies of the company in respect to HSE matters are defined in four separate policy documents, that is; **Health Policy, Safety Policy, Environment Policy and Security Policy**. Working environment matters are covered in the Health Policy.

The methods by which these policies are implemented are defined in the documents; **Safety Management System** (SMS), **Environmental Management System** (EMS), **Working Environment Management System** (WEMS), and **Security Requirements.**

The document **Principles of Risk Control and Acceptance Criteria** defines the general principles to be adopted in the control of risk to personnel, the environment and company assets. A process of risk control and management is described which is in accordance with TOTAL practices and standards. Overall risk acceptance criteria are set out in the document and the process of establishing project specific risk acceptance standards defined.

These documents are applicable to all operations undertaken by TOTAL NORGE whether in the Norwegian or UK sectors of the Frigg Field.

The arrangement of these corporate documents within a hierarchical structure is shown in the figure below.

<table>
<tr><td colspan="4">TOTAL NORGE Shared Principles

Ethical guidelines</td></tr>
<tr><td>Health Policy</td><td>Safety Policy</td><td>Environment Policy</td><td>Security Policy</td></tr>
<tr><td>Working Environment Management System</td><td>Safety Management System</td><td>Management System</td><td>Security</td></tr>
<tr><td>Principles for Risk Control

Safety Case

Risk Analysis in TOTAL NORGE

Onshore Duty Manual</td><td colspan="2">Budget Delegation and Decision Making Process

Authority for Approval

Acquisition of Goods and Services</td><td>Interfaces and Entity Descriptions

Personnel Administration Manual

Information Security Manual</td></tr>
<tr><td colspan="4">Entity specific system documentation:
Quality Manuals
Procedures
Specifications
Guidelines</td></tr>
</table>

Figure 17.1 TOTAL NORGE Document Structure

It has been determined that a common approach will be adopted by TOTAL NORGE in respect to the decommissioning activities for the Frigg Field. Consequently, whenever possible, common documents will be prepared, and submitted jointly to the relevant Norwegian and UK authorities.

The general principle applied to all the decommissioning activities is that prior to any work being undertaken the hazards associated with the work shall be identified, the risks to personnel, the environment and assets evaluated, and measures put in place to reduce the risk to a level as low as reasonably practicable. Measures that reduce or eliminate the probability of accidental events occurring will be given preference over measures mitigating the effect of an accident. Adequate emergency preparedness arrangements will be in place at all times.

The methods and procedures used for the evaluation of risk shall be appropriate to the situation being considered. Quantitative risk evaluation may be used in situations where adequate input data is available and where the results can be effectively used in the decision making process. Qualitative risk evaluation, undertaken in a systematic manner, will be used as appropriate. Possible risk reducing measures will be identified during the various risk analyses. These will be assessed and those found to be reasonably practicable will be implemented to reduce the risk to personnel, the environment and assets. TOTAL NORGE will ensure that contractors working on the decommissioning activities undertake the necessary risk analysis and implement appropriate risk reducing measures.

The hazard identifications, risk analyses and risk reducing measure evaluations (including emergency preparedness) will form an integral part of the safety documentation submitted to the relevant national authorities. For Norwegian registered installations this information will be contained in the various Applications for Consent that will be prepared to cover the particular activities and submitted to the Norwegian Petroleum Directorate. For UK registered installations this information will be an integral part of the Abandonment Safety Case submitted to the UK Health and Safety Executive for acceptance. Although there will be specific requirements necessary to comply with the separate national regulations, the approach, and general format of the information, will be the same.

Procedures are in place within the company to ensure that only contractors having the necessary level of experience and competence are selected for relevant tasks. In addition TOTAL NORGE also undertakes audits and verifications of contractors systems and procedures to ensure that the highest standards of health and safety and environmental protection are complied with.

As a verification of the TOTAL NORGE's environmental management system, and to commit the company to continuous improvement and transparency, TOTAL NORGE has been certified according to NS-ES ISO 14001 and registered according to EMAS. TOTAL NORGE is the first company in Norway to be registered as an organisation according to the revised EMAS regulations.

Det Norske Veritas (DNV) was used as certifying body and accredited unit for the EMAS registration process.

It will be a condition of contract that Contractors undertaking the decommissioning of the Frigg Field facilities will, as a minimum, operate a independently verified Environmental Management System meeting the requirements of a recognised standard such as EMAS or ISO 14001.

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18. Pre and Post Decommissioning Monitoring and Maintenance

18.1 Pre and Post Decommissioning Surveys

Environmental surveys involving seabed sampling have been undertaken in both the Norwegian and UK sectors of the Frigg Field four times since 1986. The environment in the Frigg area is thus well known. It is planned to undertake two further environmental surveys of the whole area (both Norwegian and UK sectors) after production from Frigg Field ceases in 2004.

At the end of the decommissioning work programme, a further environmental survey, including seabed sampling, will be undertaken to document the environmental conditions at the end of the removal and disposal operations. This survey will include sampling in the area of the drill cuttings around DP2, as well as in the general Frigg Field area.

A survey of the condition of the concrete substructures and the adjacent seabed will also be undertaken at the end of the decommissioning programme.

The results from the environmental and condition surveys will be submitted to the appropriate Norwegian and UK authorities.

The need for further monitoring activities will then be determined based upon the findings of the surveys and discussions with the relevant parties. There is a possibility that leaving the concrete substructures in place will have a beneficial effect on fish stocks in the area, although it is not possible to be certain at this time. A project to monitor the level of local fish stocks after completion of the decommissioning activities may be of interest and receive general support.

18.2 Maintenance

The navigation aids installed on the concrete substructures will be designed and maintained to ensure a high level of reliability. They will incorporate back-up systems and parts of the navigational aids system will be changed at regular intervals. The navigational aids themselves, and their maintenance programme, will satisfy the requirements of both national regulations and the International Maritime Organisation in respect to both surface and sub-surface vessels.

Regular surveillance will be carried out to check that the navigation aids are operational. It is envisaged that the navigation aids will be designed in such a way as to allow them to be changed from a helicopter, thus obviating the need to man the platform for this purpose. The responsibility for the maintenance of the navigation aids remains with the Frigg Field Licensees, unless otherwise agreed with the authorities.

A visual check on the above-water condition of the concrete substructures will be undertaken and recorded when the navigation aids are being checked by helicopter. The implications of any observed deterioration of the substructures, in relation to the safety of users of the sea, will be assessed and any required action determined in consultation with the Norwegian and UK authorities.

Measures will be taken to ensure that the positions of concrete substructures that are left in place are correctly identified and marked on relevant charts. To assist fishermen, it is planned to introduce the position of the concrete structures into the UK “FishSAFE” programme.

The 500m safety zones around the three concrete substructures will remain in place during the approved decommissioning work, after which consideration will be given to removing it.

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19 On going Liability

The Frigg Field concrete substructures, which it is proposed to leave in-place, remain the property and responsibility of the Frigg Field Licensees. However, both the Norwegian and UK authorities recognise that the question of long-term residual liability should be discussed and agreed with the present owners in order that suitable arrangements are made.

It is therefore the intention of the Frigg Field Licensees to enter into a dialogue with the authorities in order to determine suitable arrangements regarding future liabilities in respect to these concrete substructures. These matters should be resolved well in advance of the expiry date of the Frigg Field production licences for the areas where the concrete substructures are located. The Norwegian production licence 024 expires in May 2015 while the UK production licence P.118 expires in June 2016.

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20 Studies Supporting the Disposal Plan

General Studies

- London Offshore Consultant: Frigg Cessation Study, Vol. 1 and 2 – Final Report & Technical Notes – CD ROM, dated 01.01.2000, DocsOpen 104335 (103922 & 103925)

Studies Related to Safety

- Safetec: "Frigg Field - Concrete Structures Disposal Options Safety Evaluation", Safetec Report, Ref. ST-8708-RA-1, Rev. 04, dated October 2000 DocsOpen 107122.
- Safetec: "Frigg Field - Topsides, Jackets and Pipelines Disposal - Safety Evaluation", Safetec Report, Ref. ST-8708-RA-2, Rev.04, dated 24.11.2000 DocsOpen 107123.
- Safetec: "Frigg Field Collision Frequency Prediction – Fishing Vessels", Safetec Document, Ref. 8708/Fish-TN.doc, dated 30.10.2000, DocsOpen No. 107121.
- Anatec "Frigg Field Cessation Project – Assessment of Collision Risk from Passing Vessels", Anatec Report, Ref. A1031-TFE-CR-00, Rev.00, dated October 2001, DocsOpen No. 125131

Studies Related to Topsides

- Aker Offshore Partner: "Removal and Disposal Study - QP Topside and Jacket", Aker Offshore Partner Report, Ref. RE 175000-02-99, dated 07.09.1999 DocsOpen 98155.
- Aker Offshore Partner: "Removal and Disposal Study – CDP1 Topside", dated 02.09.1999 DocsOpen 98153.
- London Offshore Consultants: "Preparatory work Necessary to Remove the Topsides from the Frigg Field Installations", London Offshore Consultants Report, Ref. LOC-12800-TN-007A, Rev.0A, dated 23.03.2000 DocsOpen 103899.
- London Offshore Consultants: "Frigg Cessation Study" Volume 1, Books 1 and 2, London Offshore Consultants Report, Ref. LOC-12800-RP-006, Rev.0C, dated 14.06.2000 DocsOpen 103922 & 103924.
- Safetec: "Frigg Field - Topsides, Jackets and Pipelines Disposal - Safety Evaluation", Safetec Report, Ref. ST-8708-RA-2, Rev.04A, dated 24.11.2000 DocsOpen 107123.
- Kværner Oil and Gas: "Lift Analysis of Frigg DP2 Module Support Frame for Removal of the Topside", Kværner Oil and Gas Report, Ref.004-TR-J-D-002, Rev.00.01.19.00, dated 27.08.1999 DocsOpen 97342.
- Kværner Oil and Gas: "TCP2 Topside Removal Study Offshore and Inshore Removal – Study Report dated 30.06.2000 DocsOpen 105157.
- HUB: "Frigg DP2 Removal and Disposal", HUB Report, Ref. OM0915-G-0005, dated 14.10.1999 DocsOpen 98259.
- HUB: "Frigg TP1 Removal and Disposal - Method Study and Associated Cost Estimates" dated 28.06.1999 DocsOpen 99323.
- HUB:"TP1 Topsides Removal by Barge Deballasting – Feasibility study" dated 09.09.1999 DocsOpen 98263.
- HUB: "Frigg TP1 Removal and Disposal - Volume 2– Cost Estimate", dated 09.09.1999 DocsOpen 98262.
- HUB: "Frigg TP1 Removal and Disposal - Volume 1– Method Statement", dated 09.09.1999 DocsOpen 98261.

Studies Related Steel Substructures

- London Offshore Consultants: "Feasibility Study for the Possible Removal of DP1", London Offshore Consultants Report, Ref. 1023/LOCN/EAN/DP1/RE001, Rev. 01.01.19.00, dated 12.07.1993 DocsOpen 93931 & 93932.

- London Offshore Consultants "Frigg DP1 Re-Evaluation Study" London Offshore Consultants Report, Ref. 3924/R2/1/IJS7LOC, Rev.0B, dated 09.12.1997 DocsOpen 93934.
- London Offshore Consultants "Frigg DP1 Jacket Integrity Evaluation Recommendations for 1999 ROV Survey", London Offshore Consultants Report, Rev.0A, dated 06.05.1999 DocsOpen 99663.
- Stolt Comex: "Removal and Disposal of East Frigg, Lille Frigg, DP1 and Flare Base – Diving and ROV Services", Stolt Comex Seaway Report, Ref. RE-624200-201, Rev.3, dated 01.09.1999 DocsOpen 98264.

Studies Related to Concrete Substructures

- Aker Engineering: "Disposal of Concrete Structure – GBS Disposal TCP2, Frigg", Aker Engineering Report, Ref. RE 58367 – 001, Rev. 2E, dated 16.12.1999 DocsOpen 101231.
- Aker Engineering: "TCP2 Disposal Study Phase II: Procedure for In-situ Inspection of Ballast System", Aker Engineering Report, Ref. RE 58367 – 003, Rev. 04, dated 01.09.2000 DocsOpen 109505.
- Aker Engineering: "TCP2 Disposal Study Phase II: Non-linear Analysis of Tricells walls, Analysis and Structural Consequences", Aker Engineering Report, Ref. RE 58367 – 004, Rev. 04, dated 01.09.2000 DocsOpen 109506.
- Aker Engineering: "TCP2 Disposal Study Phase II: Capacity Check Top of Domes", Aker Engineering Report, Ref. RE 58367 – 006, Rev. 02, dated 26.09.2000 DocsOpen 109509.
- Aker Engineering: "TCP2 Disposal Study Phase II: Feasibility of Hydraulic Jacking Method", Aker Engineering Report, Ref. RE 58367 – 007, Rev. 02, dated 21.09.2000 DocsOpen 109511.
- Aker Engineering: "TCP2 Disposal Study Phase II: Alternative Systems for Refloating", Aker Engineering Report, Ref. RE 58367 – 008, Rev. 02, dated 22.09.2000 DocsOpen 109512.
- Aker Engineering: "TCP2 Disposal Study Phase II: Evaluation of the Condition of the Cell Ballast System", Aker Engineering Report, Ref. RE 58367 – 011, Rev. 02, dated 15.01.2001 DocsOpen 109515.
- Aker Engineering: "TCP2 Disposal Study Phase II: Worst Case Scenario – Maximum Ascent During the Refloat, and Ship Impact Capacity", Aker Engineering Report, Ref. RE 58367 – 010, Rev. 003 dated 01.11.2000 DocsOpen 109469.

- Doris Engineering: "CDP1 Disposal Study", Doris Engineering Report, Ref. RE-FF-91-28-0001, Rev.1C, dated 01.12.2000 DocsOpen 96052.
- Doris Engineering: "TP1 Disposal Study – Disposal Options Final Report", Doris Engineering Report, Ref. RE-FF-95-28-0001, Rev.1C, dated 15.11.1999 DocsOpen 96053.
- Doris Engineering: "TP1 & CDP1 Disposal study – CDP1 Option 4 - On-bottom Stability During Removal Steps", Doris Engineering Report, Ref. 65-1570-CDP1-WT-D-004, Rev.02, dated 01.11.2000 DocsOpen 107000.
- Doris Engineering: "TP1 & CDP1 Disposal study – CDP1 Option 4 - Structural Assessment During the Removal Steps", Doris Engineering Report, Ref. 65-1570-CDP1-SC-D-0002, Rev.04, dated 01.11.2000 DocsOpen 106999.
- Doris Engineering: "TP1 & CDP1 Disposal study – TP1 Option 3 - Alternative Method using SSCV ", Doris Engineering Report, Ref. 65-1570-TP1-GL-E-0006, Rev.01, dated 01.11.2000 DocsOpen 107002.
- Doris Engineering: "TP1 & CDP1 Disposal study – TP1 Option 3 - Structural Assessment of Column Strength capacity after Partial Cutting", Doris Engineering Report, Ref. 65-1570-TP1-SC-D-0002, Rev.01, dated 01.11.2000 DocsOpen 107001.
- Doris Engineering: "TP1 & CDP1 Disposal study – TP1 Option 4 - Alternative Deballasting Systems for Refloat", Doris Engineering Report, Ref. 65-1570-TP1-PI-E-0002, Rev.02, dated 01.11.2000 DocsOpen 106944.
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- COWI: "Onshore Dismantling and Recycling of Offshore Structures-Verification Study of Cost and Environmental Parameters", dated 04.07.2000 DocsOpen 104104 &104105.

- DNV: "Asbestos Mapping on Frigg QP, TP1, TCP2 and DP2", DNV Report Ref. 2000-3396, Rev.1, dated 18.10.2000 DocsOpen 106058.

Comparative Studies Relating to the Decommissioning of Other Platforms

- TotalFinaElf Exploration Norge "Technical Review of the Maureen Platform Refloat Operation and Comparison with the Envisaged Refloat Operations for the Frigg Field Concrete Substructures" TotalFinaElf Norge Report, dated 10.10.2001, DocsOpen 124567.

Studies Relating to the Environmental Impact Assessment

- A full list of the studies supporting the Environmental Impact Assessment is to be found at the end of Part 2 of this Frigg Field Cessation Plan.

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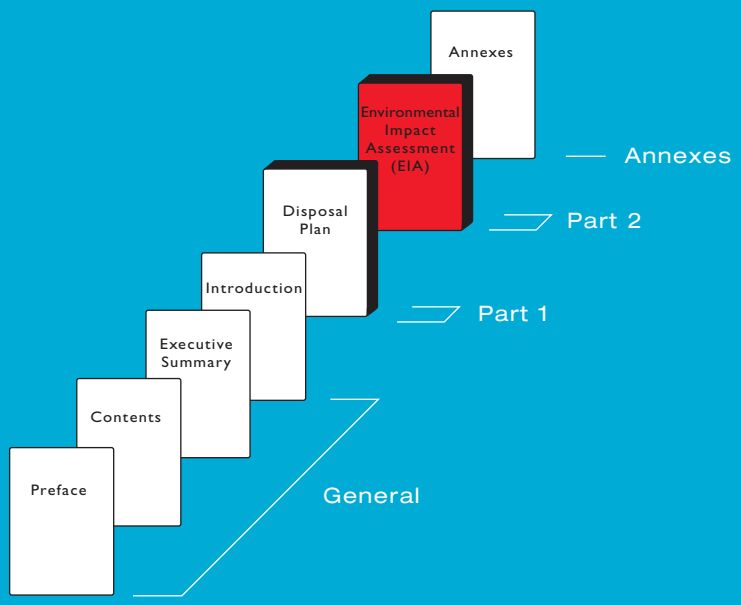

Frigg Field Cessation Plan

"The Environmental Impact Assessment for the Frigg Field has been undertaken by Det Norske Veritas (DNV), Stavanger and Aberdeen, and their findings are reported in their document entitled:

"Frigg Field Cessation –
Environmental Impact Assessment",

***DNV Report No. 99-4030*.**

The report forming Part 2 of this Frigg Field Cessation Plan, consists of the DNV report with minor editorial changes made to prevent undue repetition with the Frigg Field Disposal Plan in Part 1. In addition the presentation style of the DNV report has been changed to ensure consistency throughout the Cessation Plan."

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Environmental Impact Assessment Contents

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1. Summary

This part of the Frigg Field Cessation Plan represents the Environmental Impact Assessment (denoted EIA) of the disposal alternatives considered for the Frigg Field facilities, including 5 topsides, 3 steel substructures, 3 concrete substructures, 17 infield pipelines and cables, and about 400m^3 of drill cutting deposits on the seabed.

The EIA considers the Frigg Field as one unit, but since the field is located in both UK and Norwegian sector of the North Sea, it addresses the statutory requirements defined by Norwegian and UK legislation on equal terms. This has been done in agreement with both the UK and Norwegian authorities.

The scope of the assessment covers the processes associated with both disposal activities and final disposal. Shutting down the Frigg Field facilities (well abandonment, cleaning of process equipment and pipelines) is not explored since they come under the operational phase and as such is dealt with under different regulations.

The EIA covers issues relevant to environment, natural resources and society. The table below shows all relevant disposal alternatives for the Frigg Field facilities that are assessed in addition to reuse options. This overview also shows the Licensees recommended disposal alternatives (coloured in yellow).

Evaluation of Disposal Methods				
Steel Platform Topsides QP, DP2	**Alternative A** Removal and onshore disposal			
Steel Platform Substructures QP, DP2, DP1	**Alternative A** Removal and onshore disposal			
Concrete Platform Topsides TCP2, CDP1, TP1	**Alternative A** Removal and onshore disposal			
Comparative Assessment of Disposal Alternatives				
Concrete Platform Substructures TCP2, CDP1, TP1	**Alternative A** Refloat, tow to shore, demolish and dispose on-shore.	**Alternative B** Remove external and internal steelwork, refloat and dispose at a deep water location	**Alternative C** Remove internal and external steelwork and cut down sub-structure to provide a clear draft of 55m.	**Alternative D** Leave in place, removing as much external steelwork as reasonably practicable.
Infield Pipelines and Cables	**Alternative A** Remove, transport to shore and onshore disposal	**Alternative B** Leave in place but trenched	**Alternative C** Leave in place but bury ends	
Drill Cuttings DP2, CDP1	**Alternative A** Remove and onshore disposal	**Alternative B** Leave in place		

Table 1.1 Evaluations and Comparative Assessment Conducted for Frigg Field Facilities

The main findings of the Environmental Impact Assessment for the recommended disposal alternatives are presented as follows.

1.1 Steel and Concrete Platform Topsides

Topsides will be removed and taken to shore for dismantling in accordance with OSPAR Decision 98/3. The materials will to the extent possible be reused, recycled and certain parts be disposed of if no alternative is found feasible.

Impacts to environment are generally insignificant, though energy consumption and atmospheric emissions will occur. The total energy consumption of all operations is calculated to about 0.7 million GJ. The atmospheric emissions will be about 63,000 tonnes of CO_2.

The most positive environmental impact is the resource utilisation. It is estimated that about 97% of the materials will be recycled or reused.

The cost of removing the 5 topsides on the Frigg platforms is estimated to 2083 MNOK / £159m. The cost split between UK and Norway is 57% and 43%, assuming that UK facilities go to back to UK and Norwegian facilities go to Norway. The effect of the operations on employment will be about 2400 man-years (800 in UK, 1600 in Norway).

The topsides will be removed to onshore for reuse and recycling of the materials. The associated environmental impacts are generally “small negative”. However, the material recycling is assessed to have a "large positive" impact. The costs of the operations are considerable.

1.2 Steel Substructures

All 3 steel substructures will be removed from the field in accordance with OSPAR Decision 98/3. There are no severe environmental impacts associated with removal and demolition. Most impacts will be minor, of short duration and can be mitigated against to reduce eventual impacts further.

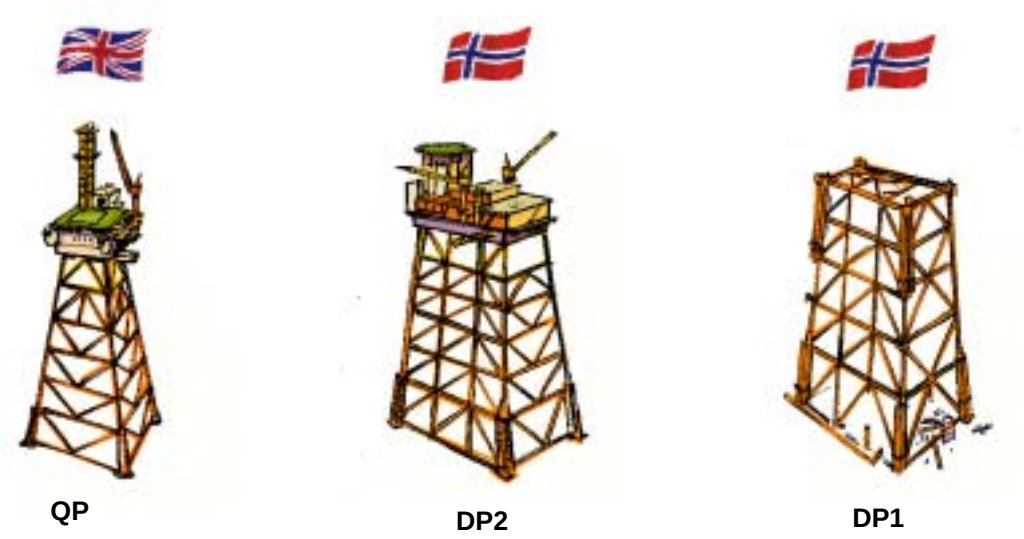

Figure 1.1 Steel Platforms on Frigg Field

Removing the steel substructures will represent a “moderate positive” impact on fisheries and free passage – based on an evaluation of importance of area and effect on the situation from this removal.

The cost of removing and demolishing the 3 steel substructures will be about 1050 MNOK / £80m. The cost split between UK and Norway is 26% and 74%. The associated effect on employment will be in the order of 700 man-years (70 in UK, 620 in Norway).

Removal of the steel substructures onshore for reuse and recycling of the materials is overall considered an environmentally sound solution. The associated environmental impacts are generally “small negative” to “moderate negative”. However, the material recycling and impacts on free passage and fisheries are representing “large positive” to “moderate positive” impacts.

1.3 Concrete Substructures

For the 3 concrete substructures, the impacts are more diverse and complex than for the steel substructures.

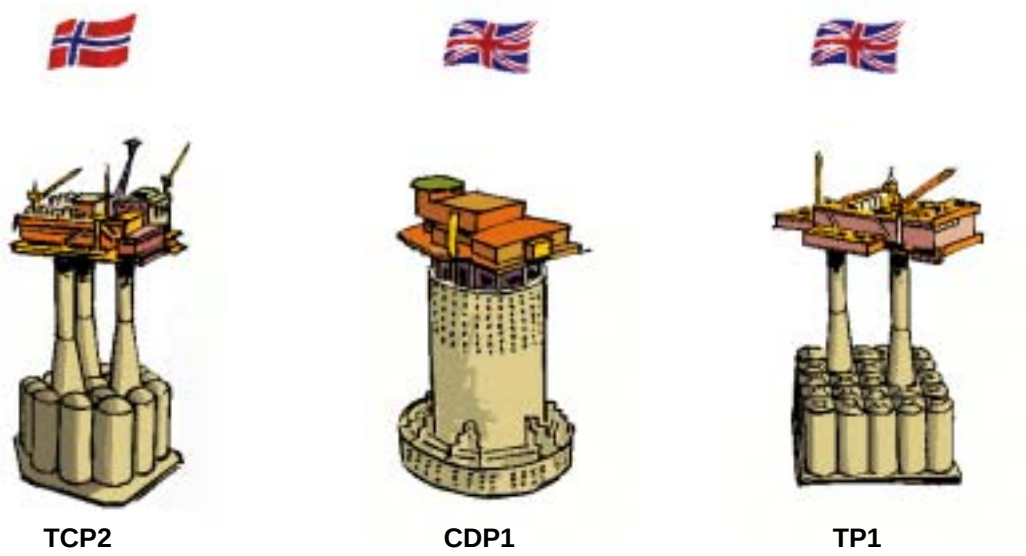

Figure 1.2 Concrete Platforms on Frigg Field

Table 1.2 presents the main results from the EIA.

	Alternative A Refloat, tow to shore, demolish and dispose on-shore.	Alternatives B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down sub-structure to provide a clear draft of 55m.	Alternative D Leave in place, removing as much external steel work as reasonably practicable
Energy Consumption (million GJ)	4.0	1.4	2.3	0.2
Total Energy Impact (million GJ)	4.0	2.2	3.1	1
CO2 emissions (1000 tonnes)	265	108	168	14
Discharges to sea	None/insignificant	None/insignificant	None/insignificant	None/insignificant
Phys./habitat effects	Moderate negative	Moderate negative	Large/Moderate negative*	Moderate negative
Aesthetic	Moderate negative	None/insignificant	None/insignificant	None/insignificant
Material management	Moderate positive	None/insignificant	Small positive	None/insignificant (Small positive)
Littering	None/insignificant	None/insignificant	Small negative	Small negative
Impacts on Fisheries	Moderate positive	Moderate positive	Moderate negative	Moderate negative
Impacts on free passage	Moderate positive	Moderate positive	Moderate positive	Moderate negative

Table 1.2 Summary of Environmental Impact of Alternative Disposal Arrangements for the three Concrete Substructures on Frigg Field (TCP2, CDP1 and TP1)

The recommended Alternative D – leaving the concrete substructures in place, has by far the best performance in terms of energy impact and CO_2 emissions. As part of Alternative D, external steel will be removed and recycled, giving only relatively modest emissions. Complete removal for onshore demolition (Alternative A) will give poor performance in terms of energy consumption (4.0 million GJ), large emissions of CO_2 (265,000 tonnes), physical and aesthetic impacts.

Alternatives B, C and D have no aesthetic impacts. Alternative A, however, has the potential to cause “moderate negative” aesthetic impacts.

On material utilisation, however, Alternative A has the best performance, due to the high level of material recycling and re-use. Performance is also positive for Alternative D (although to a lesser extent), since the external steel is removed for recycling.

With regard to the littering issue, Alternative D will have a “small negative” impact. However, although considered small, it will be a long-term impact.

With regard to fisheries and free passage, Alternatives A and B offer the best performance. Alternative C will further have good performance with regard to free passage, though not on fishing. Alternative D will have the least beneficial performance in terms of both fisheries and free passage, however the impacts are considered “moderate negative”, in real terms, meaning that the situation will be more or less similar to the present situation.

In terms of cost, Alternative A will be by far be the most expensive (8418 MNOK / £644m), followed by option C (7052 MNOK / £539m), and Alternative B (4775 MNOK / £365m). The recommended Alternative D will be comparatively inexpensive (118 MNOK / £9.1m). The cost split for Alternative D between UK and Norway is 65% and 45%.

The impact on employment generation will be about 15,900 man-years for Alternative A (7,900 in UK, 8,000 in Norway), about 3,700 for Alternative B, while Alternative C reaches 6,950 (1,850 in UK, 5,100 in Norway), and less than 100 for Alternative D.

Overall, leaving in place all three concrete substructures (Alternative D) will generally have less negative environmental impacts than the other three alternatives. It will not be the best alternative with respect to fisheries and free passage, but the impacts will be "moderate negative". In terms of cost, Alternative D is by far the least expensive.

1.4 Infield Pipelines and Cables

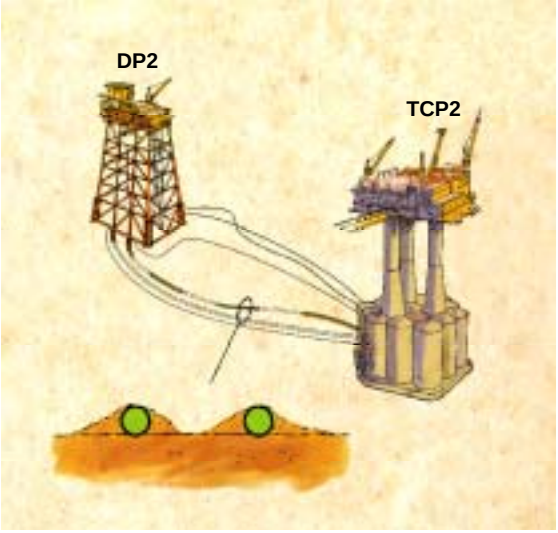

Figure 1.3 Infield Pipelines and Cables located in the Norwegian part of Frigg Field

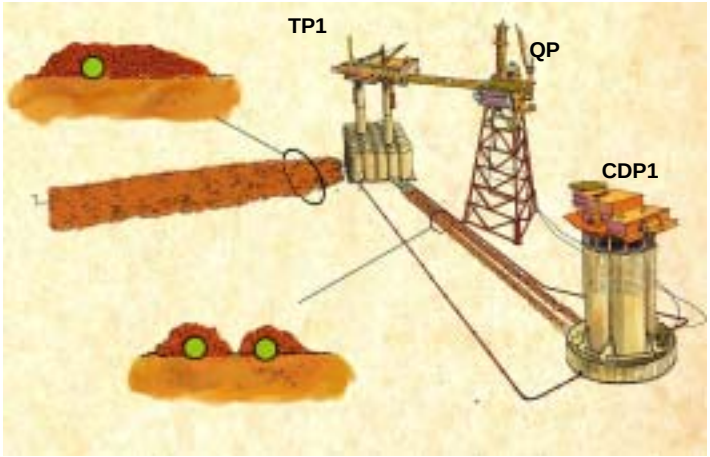

Figure 1.4 Infield Pipelines and Cables located in the UK part of Frigg Field

The three alternatives for the disposal of infield pipelines and cables generally only have limited potential for negative impacts on both the environment and society. Some of the impacts identified and assessed are summarised in Table 1.3.

	Alternative A Remove, transport to shore and onshore disposal	Alternative B Leave in place but trenched	Alternative C Leave in place but bury ends
Discharges to sea	None/insignificant	None/insignificant	Small negative
Material management	Small negative	None/insignificant	None/insignificant
Littering	None/insignificant	None/insignificant	Moderate negative
Impacts on Fisheries	Small positive	Small positive	Small negative

Table 1.3 Summary of Environmental Impact of Alternative Disposal Arrangements for Pipelines and Cables on Frigg Field.

The recommended alternative, to remove to shore and recycle/dispose of the Frigg Field pipelines and cables (Alternative A), is found to have the best performance. The only exception is that it will create some waste for disposal, as not all materials will be suitable for recycling. This is however only considered to have a “small negative” impact.

The greatest potential for negative environmental impacts is associated with the littering impact of Alternative C (Leave in place). This magnitude of these impacts is, however, uncertain. The littering impacts could be mitigated by means of trenching (burial) as proposed by Alternative B, but the cost of this alternative is close to that of complete removal.

The costs for the three Alternatives A, B and C are 161 MNOK / £12.3m, 141 MNOK / £10.8m, and 40 MNOK / £3.0m respectively. The cost split between UK and Norway for the recommended Alternative A is 60% and 40%. The effect on employment will be about 120 man-years (40 in UK, 80 in Norway).

The environmental impacts for the recommended disposal alternative with full removal of pipelines and cables are classified as “insignificant” or “small negative”. This alternative also eliminates the problems associated with long term littering.

1.5 Drill Cuttings

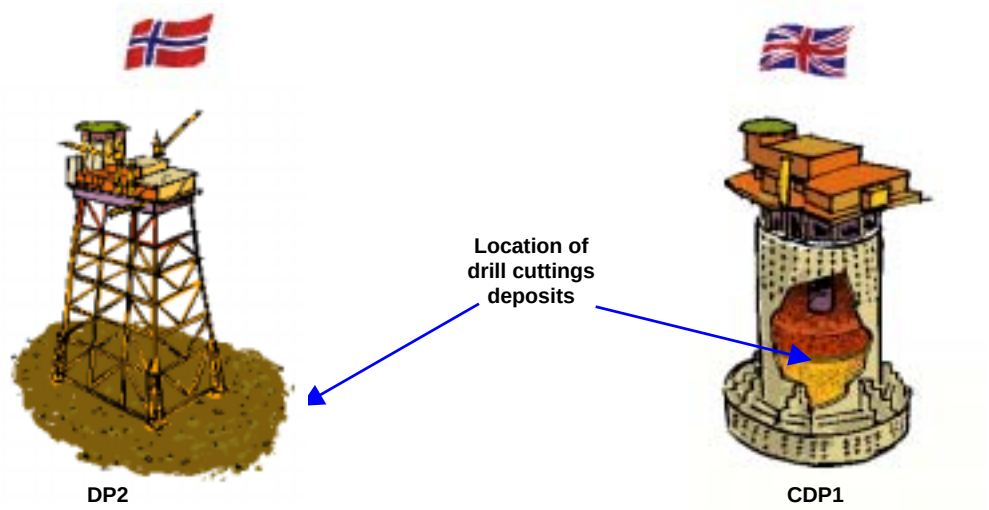

Figure 1.5 Location of Drill Cuttings deposits on Frigg Field (DP2 and CDP1)

Drill Cuttings deposits at DP2
The amount of drill cuttings at the Frigg Field is very small. It is estimated to be about 400m^3 at DP2 with a maximum thickness of 20cm contained within an area of 80m x 120m around the platform. The cuttings are also significantly less contaminated than other cuttings deposits in the North Sea. The reasons for this are that the wells are drilled mainly with water based mud, the cuttings have been very finely grained, and that the cuttings have been partially mixed with and covered by natural sedimentation. Only an amount of 150kg hydrocarbons is estimated to be present in the cuttings layer, i.e. less than 0.02% of the cuttings.

Some of the impacts identified and assessed for at DP2 are summarised in the Table1.4.

	Alternative A Remove and onshore	Alternative B Leave in place
Discharges	Small negative	Small negative
Material management	Small negative	None/insignificant

Table 1.4 Summary of Environmental Impact of Alternative Disposal Arrangements for Drill Cuttings deposits on Frigg Field DP2

Since the DP2 steel substructure will have to be removed, some of the cuttings layer may be further mixed with natural sediments during the removal operations. The environmental effects from removing/mixing the cuttings material at the field is considered small. In the long term, the seabed at the field will be left in a better condition than at present.

The cost of removal is high (about 120 MNOK / £9.2m), and there is no experience of lifting, dewatering and treating old cuttings. There will be some uncertainty related to the removal option both with regard to feasibility, duration (cost) and impacts on environment. The effect on employment will be in the order of 80-90 man-years.

Drill Cuttings Deposits inside CDP1
The drill cuttings (5,600m^3) were disposed inside the CDP1 concrete substructure, to form a layer between gravel ballast. These cuttings were produced when drilling with water based mud of similar type as for DP2. No traces of drilling residues have been found at the seabed outside the structure, proving that they are well contained inside.

The recommended disposal alternative is to leave the drill cuttings at DP2 and inside CDP1 in place (Alternative B). The environmental and social impacts are considered to be "small negative" or "insignificant", and it is favourable in terms of cost. In the further planning process this assessment will however be aware of ongoing research (e.g. extensive UKOOA JIP Programme and OLF studies) and consider new results as they become available.

(Note:- The report on the UKOOA JIP Programme has now been issued, see text in Section 11.4.1.4 of the Disposal Plan.)

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2 Introduction and Legislation

This part of the Frigg Field Cessation Plan represents the Environmental Impact Assessment (denoted EIA) of the disposal alternatives considered for the Frigg Field facilities, including 5 topsides, 3 steel substructures, 3 concrete substructures, 17 infield pipelines and cables, and 400m^3 of drill cuttings deposits on the seabed at one drilling and production platform.

The EIA evaluations consider the Frigg Field as one unit, but since the field is located in both UK and Norway, it addresses the statutory requirements defined by Norwegian and UK legislation, on equal terms. This has been done in agreement with both the UK and Norwegian authorities.

The scope of the assessment covers the processes associated with both disposal activities and final disposal. Decommissioning activities such as the plugging and abandoning of wells and the cleaning and purging of systems and tanks are not part of the assessment scope. The EIA cover issues relevant to the environment, natural resources and society. All relevant disposal alternatives for the Frigg Field facilities have been assessed and are presented in this EIA.

2.1 Description of the Frigg Field

The full description of the Frigg Field is described in Part 1 – Disposal Plan of this Cessation Plan under Section 4: “Facilities to be Decommissioned” and Section 5: “Inventory of Materials”.

Figure 2.1 Frigg Field Installations (1999), indicating the border between Norway and UK sectors of the North Sea

2.2 The Objectives

TOTAL NORGE has defined the following initial objectives for the process of field cessation for Frigg:

- The preferred disposal alternative shall be chosen based on an overall assessment of safety (human risk), technical risk, environment, social impact, and cost, and shall be in compliance with national and international regulations.
- The assessment process shall be transparent and made in an open dialogue with stakeholders.
- The selected disposal alternative should be conducted with the aim to obtain maximum reuse/recycling of redundant material and with a minimum of waste deposited at a landfill. Objectives for percentage recycling for different redundant material have been established. Stretched targets will be established and incentives for reaching such targets will be part of the requirements in a removal contract.

2.3 The EIA Planning in Brief

The planning process for Frigg Field cessation is a function of the expected remaining production life of the field and relevant UK and Norwegian legislative requirements.

The official planning process started with the Proposal for the EIA Programme being issued in May 1999 by the owners of the Frigg Field. This proposal for the EIA Programme is a regulatory requirement in Norway (cf. Section 2.4.1), and was sent as part of a public hearing by the Norwegian Ministry of Petroleum and Energy (MPE) to pre-defined stakeholders including other governmental bodies in Norway.

At the same time in UK the operator TOTAL NORGE sent the Proposal for the EIA Programme to statutory stakeholders listed in DTI Guidance Notes and to other interested parties. It was further made available in both Norwegian and English on the web and advertised in UK newspapers and magazines.

This first consultation process gave useful input to the operator in establishing the Programme for EIA. Annex A to this Cessation Plan gives a summary of the comments received from the Stakeholders to the proposed programme for the EIA.

The assessment phase followed the established Programme for the EIA. All relevant alternatives for the facilities that form part of the Cessation Plan have been assessed for compliance with the technical scope of the Programme (environmental) as well as UK and Norwegian regulations (safety, technical, cost, etc.). During the assessment process several consultation meetings have been conducted with the ambition to meet the objectives set.

Annex B to this Cessation Plan gives a summary of the comments received from the Stakeholders on a draft of the EIA presented in a stakeholder workshop in September 2000.

The outcome of this assessment phase resulted in the production of a **Cessation Plan consisting of a Disposal Plan and an EIA report**. The detailed planning process for the Cessation Plan, including the EIA and schedule for production, decommissioning and disposal, is fully described in the Disposal Plan of this Cessation Plan.

Section 16 in Part 1 “Disposal Plan” of this Cessation Plan describes in more detail the public consultation process in Norway and UK.

2.4 Regulations and Requirements

The Frigg Field reservoir is located in the Norwegian sector with 60.82% with the remaining part 39.18% in the UK sector. The relevant national decommissioning legislation that applies to each facility, is dependant on which sector the facility is located in (see below).

It is the Operator's intention to consider all the Frigg Field facilities together in the process of establishing a recommended disposal alternative. However, the EIA assumes that UK facilities are taken to the UK and that Norwegian facilities are taken to Norway. The tendering for the execution of the Frigg Field disposal will, however, follow international practice, which may result in the installations being taken to other locations than assumed in this EIA.

The EIA has been conducted in accordance with prevailing legislative regimes in both the UK and Norway. In addition international agreements on disposal and maritime safety (e.g. OSPAR and IMO) will also be prevailing during decommissioning of the Frigg Field, and these are given due consideration.

2.4.1 Norwegian Legislation

According to the Norwegian Petroleum Act, disposal decisions are to be made based on a broad-based evaluation in each individual case, with emphasis placed on technical, safety, environmental and economic aspects, as well as the consideration for other users of the sea. The Act envisages a socio-economic evaluation where the costs and safety risks associated with the various disposal alternatives are weighted against environmental, fisheries and other users' interests, and that alternative uses should be considered and may be acceptable.

The Regulations to the Petroleum Act specify that a Cessation Plan shall contain a Disposal Plan and an Environmental Impact Assessment report (EIA). The EIA must contain a description of the effects that each of the relevant disposal alternatives is expected to have on society and the environment. Furthermore to discuss mitigation measures that can be done to reduce discharges and emissions in connection with disposal and to remedy any damage or inconvenience.

The scope of the EIA is set by the Ministry based on the proposal for an EIA Programme submitted by the Licensees. The proposal shall give a short description of the relevant disposal solutions. On the basis of available information evaluate the expected impacts on the environment and society. The proposal shall also clarify the need for documentation. For the Frigg Field the Programme for the EIA was approved by the Norwegian Ministry of Petroleum and Energy 14 December 2000.

The Norwegian Parliament will make the final decisions concerning disposal of the Frigg Field facilities in accordance with the Norwegian Petroleum Act of 1996.

In addition to the Petroleum Act, other Norwegian legislation – such as the Pollution Control Act, the Harbours and Navigation Act and the Working Environment Act, with associated regulations – will be relevant for the Frigg Cessation Project. Application for consent, permits etc. will be made in accordance to these Acts.

2.4.2 United Kingdom Legislation

British law will have application to decisions on the disposal of the Frigg installations located in the UK sector.

The British legal framework regarding offshore cessation is presented in the DTI Guidance Note for Industry on Decommissioning of offshore Installations and Pipelines under the Petroleum Act 1998 [1]. The UK Petroleum Act requires a cessation (decommissioning) programme including an EIA before disposal can be executed.

Additionally, some other information is required where the following could be appropriate for the Frigg installations in UK sector:

- Confirmation that the requirements of the Coast Protection Act 1949 have been satisfied
- Acceptance of an Abandonment Safety Case under the Offshore Installations (Safety Case) Regulations 1992 (installations only)
- Fulfilment of notification requirements to HSE under regulation 22 of the Pipeline Safety Regulations 1996

The disposal of materials on land must comply with the relevant health, safety, pollution prevention and waste requirements, including in particular Part II of the Environmental Protection Act 1990. In certain circumstances authorisation under the Radioactive Substances Act 1993 may also be necessary.

Other important acts that have to be considered include, but are not limited to:

- Health and Safety at Work etc. Act 1974
- The Waste Management Licensing Regulations 1994
- Special Waste Regulations 1996
- Transfrontier Shipment of Waste Regulations 1994

A more comprehensive description of the UK regulative processes with regard to decommissioning is given on the UK DTI web site:
http://www.og.dti.gov.uk/upstream/decommissioning/index.htm

2.4.3 OSPAR Convention

In making decisions regarding disposal of the Frigg Field facilities, the Norwegian and UK authorities will also consider certain international conventions and guidelines, e.g. the 1992 OSPAR Convention and OSPAR Decision 98/3 taken pursuant thereto.

OSPAR Convention's Decision 98/3 states that dumping, and leaving wholly or partly in place, of disused offshore installations within the North East Atlantic (including the North Sea) is prohibited.

By way of derogation from the above requirement, if the national authority having jurisdiction of the offshore installation in question, are satisfied after carrying out an assessment in accordance with Annex 2 of OSPAR Decision 98/3 that there are significant reasons why an alternative disposal is preferable, the following permits may be issued:

- All or part of steel footings of steel substructures weighing more than 10 000 tons and placed in the maritime area before 9th February 1999, may be left in place
- A concrete installation or constituting a concrete anchor base, to be dumped or left wholly or partly in place
- Any other disused offshore installation to be dumped or left wholly in place, when exceptional and unforeseen circumstances resulting from structural damage or deterioration, or some other cause presenting equivalent difficulties, can be demonstrated

Any permit for a disused offshore installation to be dumped or permanently left wholly or partly in place, shall be subject to consultation within the OSPAR Convention which could last up to 32 weeks, before the national authority makes the final decision.

As part of this process OSPAR stipulates requirements on documentation that is required from the authorities to perform an assessment before a permit should be granted. These requirements are described in Annex 2 to the OSPAR decision 98/3.

2.4.4 IMO Guidelines

In 1989 the International Maritime Organisation (IMO) adopted Guidelines and Standards for the Removal of Offshore Installations ("the IMO Guidelines") for the purpose of promoting

safety of navigation. The IMO Guidelines are not formally binding and thus are advisory in nature. They are anyway followed by TOTAL NORGE in the planning process and will also be so during the execution of the work. The IMO Guidelines recommend a case-by-case evaluation to determine whether a redundant offshore installation should be left wholly or partly on the sea-bed, considering e.g. the effects on navigation, costs, risks, safety and technical feasibility.

According to the IMO Guidelines, if the coastal State determines that an installation shall be partly removed to below the sea surface and will not be re-used (e.g. as an artificial reef), then an unobstructed water column of at least 55 meters to the sea surface should be provided. None of the recommended disposal alternatives involve a partial removal where this requirement would be relevant.

The IMO Guidelines recommend that the coastal State ensures that installations that are not entirely removed be indicated on nautical charts and be properly marked with navigation aids. Any disused installation that projects above the sea surface should be adequately maintained. The purpose of the IMO's maintenance recommendation is to ensure preservation of the navigation aids and thereby promote maritime safety.

2.4.5 Company Systems, Procedures and Objectives

The superior Health, Safety and Environmental (HSE) requirements are laid down in TOTAL NORGE's management systems. They describe common values, principles and instructions and are valid for all employees.

The company document structure in TOTAL NORGE is shown in Table 2.1.

TOTAL NORGE Shared Principles Vision, Objectives and Strategies	Management of Quality		Ethical guidelines
Health Policy	Safety Policy	Environment Policy	Security Policy
Working Environment Management System	Safety Management System	Environment Management System	Security Requirements
Principles for Risk Control and Acceptance Criteria Safety Case Guidance for the Use of Risk Analysis in TOTAL NORGE Frigg Contingency Plan Onshore Duty Manual	Budget Delegation and Decision Making Process Authority for Approval Acquisition of Goods and Services Incoming and Outgoing Invoices	Organisation Chart Interfaces and Entity Descriptions Personnel Administration Manual Information Security Manual	
Entity specific system documentation: Quality Manuals Procedures Specifications Guidelines			

Table 2.1 TOTAL NORGE company document structure.

The highest level document is the TOTAL NORGE Shared Principles. It details the Vision, Objectives and Strategies of the Company.

The TOTAL NORGE Shared Principles are supported by four separate policy documents, that is; Health Policy, Safety Policy, Environment Policy and Security Policy. The methods by which these policies are implemented are defined in the documents; Safety Management

System (SMS), Environmental Management System (EMS), Working Environment Management System (WEMS), and Security Requirements.

At entity level, there is a raft of entity specific system documentation that includes quality manuals, procedures, specifications and guidelines.

As cessation activities has become a major activity for the company, the Environment Policy, Environmental Management System and procedures have been updated to reflect the changes in activity.

Being of special relevance, the procedures for “Handling of hazardous substances and management of waste”, “Operational discharges to air and sea” and “Evaluation, selection and procurement of chemicals” have been revised to detail requirements necessary to achieve TOTAL NORGE’s objectives.

Contractors will perform most of the work during a cessation project. Particular focus has therefore been towards contractual requirements concerning the care for the environment.

To manage the waste handling for cessation activities, the environmental accounting and management system (TEAMS), has been implemented. This system will, in addition to recording quantities, enable tracking of waste fractions to document fate of all reused, recycled and deposited material resulting from the cessation activities.

Objective setting and use of performance indicators are important tools to monitor conformance to TOTAL NORGE’s environmental policy.

Objectives are established on company levels and entity level.

Inclusion of environmental requirements in all contracts issued is an example of one objective related to cessation.

Detailed inventories have been made for each installation and specific objectives have been established as to the recycling rate for dedicated material fractions. These are detailed in this report. Reference is also made to Section 5 in Part 1 Disposal Plan in this report.

The overall company objective for waste handling is to minimise generation of waste and the amount disposed of at a landfill.

Other objectives are referred to elsewhere in the EIA.

As verification of TOTAL NORGE’s environmental management system, and to commit the company to continuous improvement and transparency also in the cessation process, TOTAL NORGE has been certified according to NS-ES ISO 14401 and registered according to EMAS. TOTAL NORGE is the first company in Norway to be registered as an organization according to the revised EMAS regulation.

Det Norske Veritas was used as the certifying body and accredited unit for the EMAS process.

3 The Environmental Impact Assessment Premises

3.1 Purpose

The Norwegian Petroleum Act, the DTI/UK Decommissioning Guidance Notes, and the OSPAR decision 98/3 describe disposal alternatives that should be addressed when planning for cessation. Relevant alternatives are discussed and presented in Section 5 in this EIA report.

It is important to underline that the Environmental Impact Assessment (EIA) should contain an objective assessment of all relevant disposal alternatives, not only the alternative being recommended by the Operator.

The purpose of an EIA is to clarify the effects of an activity, operation or end-point that may have significant consequences for the environment, natural resources, and society. The EIA shall ensure that all concerns are taken into account when the operations etc. are planned and when decisions are reached regarding whether, and under what conditions, the work may be carried out.

Furthermore, it is very important for the EIA to contain information about what can be done to reduce the emissions and discharges associated with the activities, and give proposals for how to mitigate any damage or nuisance.

Accordingly, the purposes of this EIA is to:

- Clarify the consequences of the relevant disposal alternatives for the Frigg Field facilities that may have a significant impact on the environment, natural resources and society.
- Present information about possible impacts in a manner that can form a basis for a decision on the disposal alternatives.
- Present proposals for mitigating any damage and nuisance caused by the chosen disposal alternatives.

3.2 Scope of Assessment and Issues Examined

This EIA examines the effects of activities and circumstances connected with decommissioning and removal of the respective installations, as well as the long-term effects of the removal alternatives on the environment, natural resources, and society, where knowledge about these factors exists. Circumstances relating to shutting down operations (well abandonment, purging and cleaning operations) on the installations are not explored since they come under the final stage of the production phase and as such are dealt with under different regulations.

The different disposal alternatives for the facilities on the Frigg Field are presented in Section 5 in this EIA report.

The technical issues that are discussed for each alternative were presented in “Proposal for EIA Programme for Frigg” [2]. The Proposal was circulated for external comments and comments have been received from many stakeholders.

The comments received in response to the Proposal for EIA Programme are presented in Annex A in this Cessation Plan, with comments on how the Operator plans to accommodate them.

The topics examined relate to operations and removal for all alternatives, and embrace both the short and the long-term effects. Typical activities are marine operations, demolition,

transport, and re-melting of scrap. The ”removal” aspect in the final analysis can cover anything from various forms of sea disposal, sale of parts and equipment, reuse, recycling or disposal on a waste facility.

Based on the Proposal for an EIA programme and the comments received from interested parties, the following issues are examined for each of the disposal alternatives:

Environmental impacts
- Energy
- Releases (emissions) to atmosphere
- Releases (discharges) to sea, water, or ground
- Physical impact to environment
- Aesthetic pollution: noise, smell, visual effects
- Waste/resources management
- Littering

Social/community impacts
- Fisheries
- Free passage at sea
- Costs and national supplies
- Employment effects
- Other social impacts

In cases where the documentation allows the releases or other effects to be quantified, this is done and discussed. In other cases qualitative assessments are made, together with discussions on the possible impacts and potential mitigating actions that could avert negative effects and promote positive benefits.

3.3 Methodology

3.3.1 Methodologies in General

The methodology presented is based on the principles set out in the Norwegian Oil Industry Association’s (OLF) Methodology Study for Decommissioning Environmental Impact Assessments [3]. The methodology has been further developed in the later Environmental Impact Assessment for cessation projects. The Frigg Field EIA therefore reflects this development in methodology. The methodology for the Frigg Field EIA is in full compliance with the contents for environmental impact assessment as specified in both UK and Norwegian regulations.

The methodology involves the quantification of those impacts on the environment, fisheries and society that are quantifiable, including, but not limited to, cost figures for estimated employment benefits in various industries, and the “national content” of the added jobs created.

Factors that cannot be quantified are described and subject to a technical evaluation of the type of effect, its scope, and its consequences.

Recently a slightly altered method of presentation and comparison of the Disposal Alternatives and their impacts has been introduced. This method is developed by Statens vegvesen (Norwegian Road Authority), and for decommissioning issues the method is further developed by DNV and Asplan. This process has sought to distinguish the important impacts from those that are less important. This was done by considering the effect of an impact in the area in which it is occurring (“value” or “sensitivity”), combined with the scope of the effect, to arrive at the total impact. The method is outlined in Figure 3.1. By using this method the same magnitude of effect may then give a different impact depending on the value or sensitivity of the impacted environmental component. Similarly, the same type of effect will give different impact depending on the sensitivity of the recipient/environment. This is considered a sound basis for assessing and presenting the impacts.

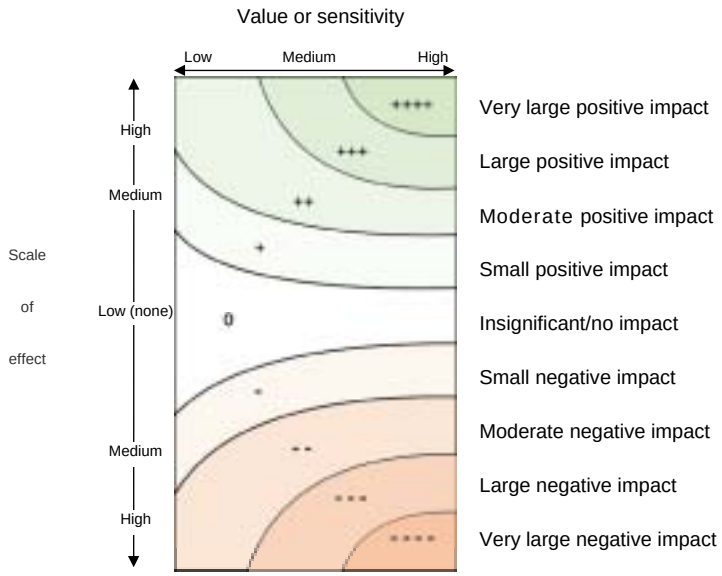

Figure 3.1 Methodology for assessment of non-quantifiable impacts.

Initially no attempt has been made to rank or weigh the factors against each other. However, this can be done in the form of an overall assessment for each component, normally done by the Operator in the process of determining the recommended solution.

In the text the assessment of the non-quantifiable impacts is marked with quotation marks, e.g. “small negative”.

3.3.2 Environmental Impact Assessment Methodologies

Energy

Energy issues are considered important factors in evaluation of the environmental impacts of decommissioning and disposal of redundant offshore installations. There are various ways of accounting for energy effects, and a wide range of input data may be relied upon. The method cited in this report is recommended as an international standard by the Institute of Petroleum in London [4], and was developed by Cordah and DNV. The method is based on a life cycle approach, and will as such put the different disposal alternatives into a broader perspective than if only considering the direct energy consumption.

Figure 3.2 indicates what is included in the scope of energy calculations. In general this includes all operations from preparatory work for e.g. removal, transport, onshore demolition, onshore transport, re-smelting of metals. Also for the replacement, calculations for the new production of metals are considered. This is based on generic data including mining, transportation and smelting. Steel is the most important material. Replacement of concrete is not included in the calculations, as this material will not be directly recycled as new raw materials (cement and sand). Possible reuse of such material is not included in the energy assessment, but will be part of the material management assessment.

In an assessment of the energy impacts of alternative disposal solutions, two factors predominate:

- Actual direct consumption of energy (fuel and electricity) for vessel operations and for melting down metals

- Theoretical energy consumption for virgin production of materials in amounts corresponding to those not being recycled (represents potential energy savings by recycling).

This report uses the following definition (developed by DNV for the Ekofisk I EIA, [5]):

"**Total Energy Impact**" (E_{TOT}) for an Alternative in a global perspective is represented by the formula:

$$E_{TOT} = E_{DIR} + E_{REC} + E_{REP}$$

where

E_{TOT} = the Total Energy Impact in a global perspective

E_{DIR} = the direct energy consumption for the solution (fuel, electricity)

E_{REC} = the energy consumed by recycling/melting down metal

E_{REP} = a theoretical quantity of energy equivalent to the amount of energy required to produce a quantity of material equivalent to the quantities of material disposed and not recycled/re-used (see Figure 3.2)

"Energy consumption" (E_{CONS}) is the sum of the direct energy used for disposal and for recycling. In evaluating energy consumption, the focus is on the actual energy consumption for implementing the disposal alternative, not on the global energy balance.

$$E_{CONS} = E_{DIR} + E_{REC}$$

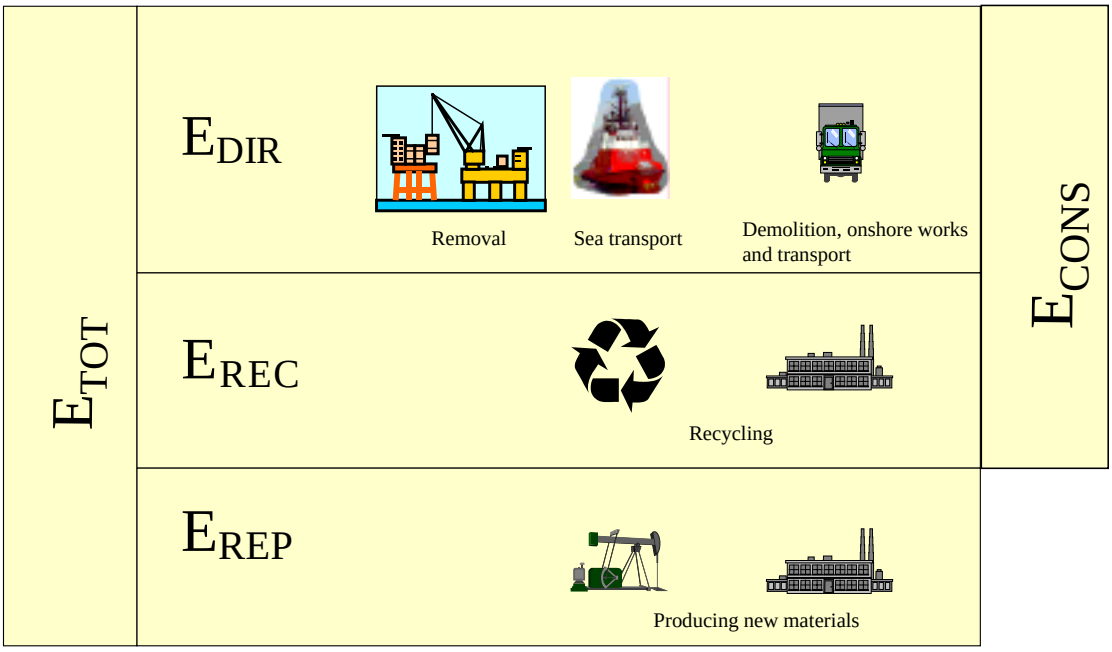

Figure 3.2 Illustration of the Elements in the Energy Calculations

The energy calculations in this report are made for the basic disposal alternatives. Calculations are based on data on duration, vessel type etc. from the technical background studies and data on fuel consumption etc. from the database provided in Institute of Petroleum's report [4]. Solutions possibly having some degree of reuse are therefore not included unless this reuse is defined and valid. Reuse will on a general basis be positive in respect of the energy calculations, provided the reuse is sensible with respect to the purpose

and the mass of materials being reused. Energy effects of reusing single items or equipment is considered minor compared to the total figures of the installations. Reuse of whole parts, such as topsides and/or substructures may on the other hand affect the total picture of the energy calculations.

The following "impact" key is developed specifically for this project and used in this report to categorise the energy impact and consumption of the different alternatives. See Table 3.1. It is important to note that this key is developed to evaluate significant differences, between alternatives and to rank the alternatives in relative terms. The "impact" is therefore not documented scientifically. The key also gives reference to energy consumption for a corresponding number of cars for one year to illustrate the magnitude of energy.

Reference unit	Impact Categories				
	None/ insignificant	Small negative	Moderate negative	Large negative	Very large negative
Energy (Million GJ)	<0.1	0.1-1	1-3	3-6	>6
Energy equivalent (Cars run in one year)	<2,500	2,500-25,000	25,000-75,000	75,000-150,000	>150,000

Table 3.1 Key for categorisation of energy impact.

Emissions to Atmosphere

Contrary to the energy assessments, the focus of atmospheric emissions is entirely on actual releases. They are quantified on the basis of the data given in Institute of Petroleum's standard [4]. The emission components CO_2, NO_X and SO_2 are assessed. The reason for not choosing a life cycle approach also for the emissions is that some of these emissions are not global but local or regional in their impact potential. Environmental impact could thus be very different from one area to another, even for the same emission.

CO_2 (Carbon dioxide) is the main contributor to the greenhouse effect. It is thus a global ecological problem and the exact location of the release is not relevant. Even if international regulations are still not agreed between countries to stabilise emissions of CO_2 (e.g. the Kyoto protocol is not yet in force), the Norwegian Authorities have decided to implement the intentions of the Kyoto protocol nationally (White Paper No. 54, 2000-2001 - Norwegian Climate Policy).

In the context of offshore field cessation $CO_{2,}$ is not a driving factor of the assessment, though different magnitudes of its emission will form part of the overall assessment of the alternatives. CO_2 emissions will mainly occur from vessel operation (exhaust) and re-smelting of metals.

For nitrogen oxides (NO_X) and sulphur dioxide (SO_2), the effects are more regional and local in nature. There is also significant geographical difference in tolerance to these emissions, related to nature of the soil and water, biota composition, and present and historical load of acid rain. Emissions of nitrogen oxides (NO and NO_2) react chemically with humidity in the air, transforming them mainly to nitric acid ($HNO_3 \rightarrow H^+ + NO_3^-$) that will fall as acidic precipitation (acid rain). NO_X forms part of the exhaust from combustion processes (e.g. ship engines and smelters for recycling metals). In the environment they are known to cause adverse effects on vegetation and fauna, and may contribute to respiratory complaints to humans. These effects arise because NO_X contributes to the generation of acid rain, the creation of ground-level ozone, over fertilisation and direct nitrogen precipitation. In offshore decommissioning and disposal the vessel operations are of particular relevance to NO_X. The majority of these operations will be offshore, and local effects are not relevant. The magnitude of NO_X emissions from such operations will also be small compared with other offshore operations and national emission statistics. NO_X emissions will however be part of the overall evaluation as there may be significant differences between alternatives, and their inclusion enables the evaluation to be based on a broad scope.

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

Due to the uncertainty regarding where the disposal work will take place, in particular relating to the location of the scrap furnace and remelting of steel, no assessment has been made of specific NO_X and SO_2 effects on a specific local environment. Only quantitative considerations of these emission components are therefore given. Even so, this offers an opportunity to look at relative differences between alternatives, independent of the location where the emission actually occurs.

Discharges to Sea, Water or Ground

Discharges into the sea, water or ground are normally assessed scientifically focusing on:

- Type and amount of discharge
- Time and duration
- Location of discharge
- Presence of susceptible natural resources, if any
- Effects on natural resources, their nature and how they can be mitigated.

With regard to field cessation of the Frigg Field discharges to water and ground recipient is of very little relevance. All systems will be cleaned prior to disposal for all alternatives. Any discharge of water containing chemicals and/or traces of oil will only be performed after having the proper discharge permit, and will also be in line with the project specific cleaning criteria. Discharges are therefore considered to be a very small contributor in the assessment process.

Where relevant, detailed assessments of these factors have been performed. These “discharges” will be mainly secondary pollution and increased turbidity following disturbance of sediments and discharge of solid ballast.

For onshore scrapping processes the yard will have a specific permission to perform such work, including controlled systems for collecting drainage etc. No discharges exceeding the permitted levels are thus anticipated.

Physical Impacts

This topic covers any potential impacts that are largely physical in nature. Examples are damage caused by underwater explosions to fish or the seabed, various operations that might have a physical impact on the seabed, reef-like effects, etc. “Reef effects” involve the structures forming a firm substrate for organisms to grow on, and which will in turn constitute part of the ecological system in the area.

These factors are considered in relation to type, scale and impact. For some generic disposal alternatives such physical or habitat changing type of effects can be an important factor in the assessment process.

Aesthetic Impacts

This topic covers issues largely related to health and the local environment (noise, dust, smells). Where relevant, assessments are also made of any “visual intrusion”. These matters are solely related to near shore and onshore activities, and then mainly to those alternatives involving work to be performed at an industrial yard (scrapping, maintenance etc.). Such operations are however not new to a yard, and will be covered in their concession. There may, however, in some circumstances be difference between building and demolishing

structures when it comes to these aesthetic factors. They could be considered important to local residents and recreation.

Material Management

The key issue for this topic is the sound utilisation of resources (redundant materials), with re-use and recycling as the most desirable alternatives. Therefore, this assessment makes a scientific evaluation of the materials in each installation to assess the potential for re-use and recycling, and to quantify volumes of substances that need to be disposed of as waste.

Sound waste management with optimal reuse/recycling is considered a very important factor in assessing disposal alternatives.

Littering

Littering in this EIA relates mainly to the sea, since waste taken to land will be handled in accordance to regulations with detailed waste handling procedures aimed to prevent littering.

To examine littering in an ecological perspective, this impact assessment report considers whether leaving a substructure in-place could have consequences in the form of littering and dispersal problems. The litter topic is considered to be among the most important environmental topics in a long-term view. In many respects there can be high degree of uncertainty related to the effects of littering in the long-term perspective; time of material deterioration, sedimentation processes, and other external processes. In cases where litter is deemed to potentially constitute a problem, this is therefore particularly emphasised.

Floating material will be collected and brought onshore for disposal, and floating material will not be a littering problem. The potential for littering is thus considerably reduced, and consists mainly of steel and concrete.

After final field disposal, the surrounding seabed will be cleaned for debris. Such litter could be components or parts of the installation, which have fallen off during previous activities, or tools, wires etc. from the decommissioning phase.

The littering aspect therefore mainly concerns alternatives involving final disposal offshore.

Debris clean up can be performed by dedicated survey vessel with the capability of running a side scan sonar array and a ROV, together with facilities to print out and interpret data obtained. The ROV should have a camera linked to a video recorder so as to visually document the debris that has been identified by the sonar [6].

Leaving materials in the sea after the exploitation period can also be perceived as part of the littering problem, and as such represents a more ethical issue. This aspect is not evaluated in this EIA.

3.3.3 Social Impact Assessment Methodologies

Fisheries

As part of an overall assessment of the effects on the fisheries of disposal of the Frigg Field installations, the importance of the area to the fishing industry has been evaluated. This is done in Section 6.3 and 6.4 in this EIA part of the Cessation Plan, where the fishery activities and catches in the Frigg area are reviewed and presented. Based on this evaluation the Frigg area is considered to be of “moderate importance” to fisheries – i.e. it is an area of medium value to North Sea fisheries. This establishes the basis for evaluating the impact on fisheries from operations and end point solutions for the Frigg disposal alternatives.

Marine operations and marine transport activities will occur in connection with most of the disposal alternatives. Marine operations related to disposal alternatives for the Frigg platforms will mostly take place within safety zones, and be of limited duration. As they will not affect fisheries, they will not be further assessed in this report. The marine operations for removal of infield pipelines and cables on the Frigg Field will also take place within the safety zones, and therefore no impacts on fisheries are expected during these activities either.

Transport operations in connection with the different disposal alternatives will entail limited increases in ship activity in some areas for short periods. Fishing vessels will have to exercise caution in this respect, but the transport operations are not expected to impede fishing.

According to OLFs method for impact assessments [3], the impacts on fisheries are assessed by calculating the obstructed area and comparing it with the statistics for catches in the vicinity[1]. This approach gives a theoretical value of the impact only – based on available statistics, and it is therefore also important to carry out a more specific evaluation of possible impacts, which has been done in this EIA.

The factors that have been identified as most crucial and therefore the subject of analysis are as follows:

- Area excluded for fisheries
- Direct hindrance to fishing (resulting in physically damaged harvest and gear)
- Effect of new reefs on fisheries

Free Passage at Sea

Offshore installations represent a risk to shipping. The magnitude of this risk will depend mainly on the extent of the shipping activities and the measures and systems used to identify the installation and avoid contact.

The maritime traffic is extensive throughout the most of the North Sea. The most important shipping lanes in the Frigg area are between Western Norway and Scotland, and pass east of the Frigg area (see Figure 3.3). The nearest lane passing the Frigg Field is the one between Bergen and Shetland, passing about 10 km to the north of the Frigg Field Centre. Lanes between Shetland/Orkney Islands and Western Norway pass to the south of Frigg. Additionally, fishing vessels will generally be present in the area as well (see Section 6.4 in the EIA).

The total number of merchant ships passing within the area of the map shown in Figure 3.3 will be in the order of about 500 per year (based on data from Collide; Safetec). According to a study performed by Technica [7] 150 merchant ships pass along the nearest lane, within 10 km from the Frigg centre, over the period of a year. The number and density of fishing vessels varies from season to season, and from year to year. In the Quantitative Risk Analysis (QRA) for the Frigg Central Complex [8] the density of fishing vessels is set to 1.8 within 10,000 km^2, which is equal to the map area in Figure 3.3. Approximately 10 % of these operate in transit on their way to or from harbour or shifting fishing grounds. Representatives from the fishery authorities in Norway indicate that the number of vessels in the area (fishing or in transit) will be in the order of 50-80 purse seiners in May-August, 50-60 in November/December, and less during winter/spring. Other vessels (UK, Danish, and Swedish) will normally be less than ten. Trawling will normally be limited in the area around Frigg [9]. Based on this information the Frigg area is regarded as being of less value for free passage at sea compared to other areas further south in the North Sea.

Disposal of the Frigg Field installations will imply increased maritime activity during the disposal work offshore. This will be restricted to a relatively short interval of time. Some

[1] The area occupied or restricted is calculated. This area is divided on a larger area of which fishery statistics exist (and as such an estimate of the value of catch may be given). This theoretically gives the “cost” of excluding that area for fisheries. There is, however, no established set of criteria saying when a value is “high” or “low”.

disposal alternatives will also result in a more extended or permanent hindrance to shipping. The risk of such will be calculated according to common risk analysis methodologies in a later stage of the decommission process of Frigg. At this stage the risk is evaluated qualitatively, based on among others information from QRA's for the Frigg Field performed for the field in operation.

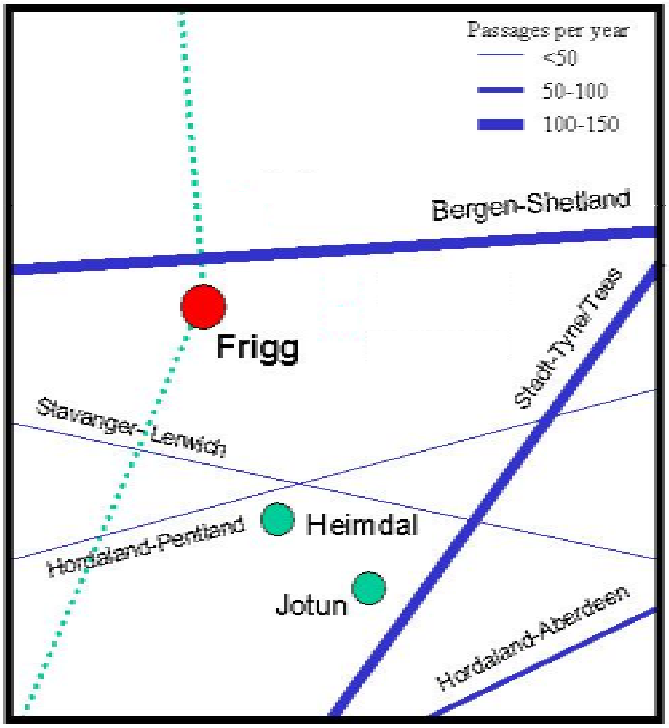

Figure 3.3 Shipping lanes in the Frigg area in the North Sea (based on "Collide" and [7]).

Cost and National Supplies

National supplies (goods and services) are estimated based on the cost estimates for the respective alternatives.

The Norwegian and UK content of goods and services connected with the Frigg disposal alternatives is based on general knowledge of petroleum related industries and information obtained from the field operator and the supplier industry.

The results and the employment estimates are subject to some uncertainties. The main sources of uncertainty are:

- Assumptions in cost estimates. e.g. the duration of the operations, the market situation and rates in the future.
- Developments in technology and removal methods.
- Assumptions for Norwegian and British supplies on Frigg Field. The supplies may be different from the assumed level and may also involve other industries.

The assessments of impacts on national supplies are based on a breakdown of costs into different components, representing different phases in the service and supply chain. Depending on type of activity and whether the different services can be given by national industry a national share of the work is established (see table 3.2). The uncertainty is quite large, but the results give an indication of the situation.

Components	UK	Norway
Project Management	0 – 10 %	60 – 90 %
Design and Engineering	0 – 20 %	60 – 80 %
Supply and Fabrication	20 – 40 %	10 – 50 %
Offshore Personnel and Spread	10 – 40 %	10 – 20 %
Onshore Personnel and Spread	25 – 75 %	25 – 100 %
Other Project Charges	10 – 30 %	70 – 100 %
Total	**10 – 45 %**	**30 – 45 %**

Table 3.2 Content broken down by component, given in %

Based on the cost breakdown into national share of work in different components, the impact on different industries may be assessed. Such industries include “maritime/marine operations”, yard industry, transport, goods, building/construction, and commercial services. This forms basis for calculation of employment figures.

Employment Effects

The Impact Assessment employed a model for assessing the employment effects of each alternative within different categories of trading and industry.

The assessment model is based on the estimated goods and provision of service broken down by industry and year, and calculates – from that basis – the total *production value* created in industry as a result of these deliveries, not only within the supplier firms, but also within their sub-contractors. The production value is then converted into employment calculated on a man-year basis, using the statistical production per man-year quoted for different industries [10]. The result of these modelling calculations is the estimated *direct employment effect* within vendor/supplier companies, and the estimated *indirect employment effects* within sub-vendors/subcontractors (vendors and subcontractors to the main vendors and contractors). The total is the project’s **production effects*.***

The term ”ripple effects” (direct and indirect effects) denotes the phenomenon whereby purchases of goods and services in one segment spreads impulses (increased purchases) in industry and society that in total enhance the value added. The basis is that supplies for the primary purchase instigate a chain of new supplies ”upstream” in industry. The **total employment effects** are the sum of the direct supplies, the indirect supplies, and delivered activities due to increased private consumption.

4 Description of the Frigg Field Facilities

4.1 Introduction

The impact assessment report for the Frigg Field includes five different types of facilities:

- Steel and concrete platform topsides
- Steel substructures
- Concrete substructures
- In-field pipelines and cables
- Drill cuttings

Topsides, steel substructures, concrete substructures, pipelines/cables and drill cuttings are treated individually in this report. In the following sections a brief description of all the Frigg Field facilities are given.

For a more comprehensive description, reference is made to Part 1 – Disposal Plan in this Cessation Plan Section 4: "Facilities to be Decommissioned" and Section 5: "Inventory of Materials".

The export- and inter-field pipelines, the satellite fields and the flare base are not included in the present Environmental Impact Assessment or the Cessation Plan.

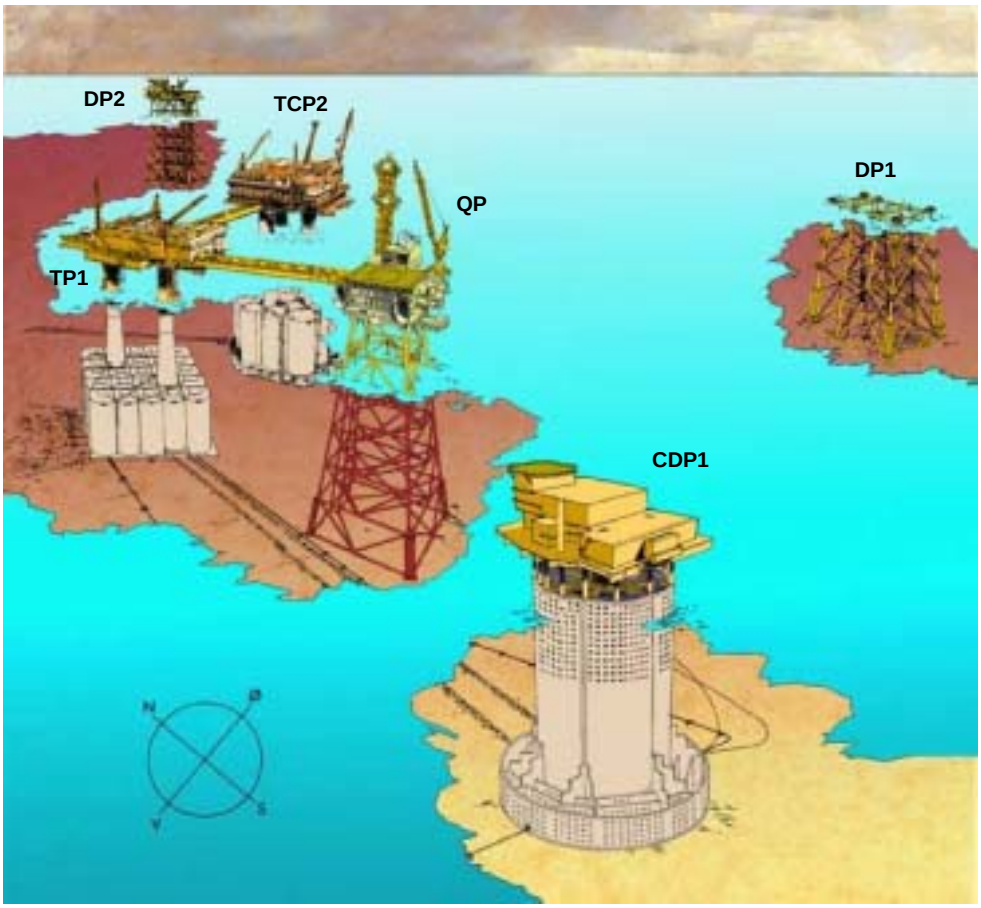

Figure 4.1 Platforms on the Frigg Field

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5 Description of Disposal Alternatives

5.1 Other Use of the Frigg Field Installations

5.1.1 Further Use in the Petroleum Industry

Extensive studies have previously been performed evaluating reuse of the Frigg installations in situ after the final shut-in of gas production; at present expected to take place sometime in 2004. In March 2001 the last satellite field in operation (Frøy) in the Norwegian Sector tied into Frigg was shut-in. At present there are no known recoverable hydrocarbon resources in the immediate vicinity of the Frigg Field that could utilise the Frigg installations.

Reference is made to Part 1 – Disposal Plan in this Cessation Plan, Section 7: ” Assessment of Reuse Potential”.

5.1.2 Other Use in Place

Several studies have also been conducted to investigate opportunities for using Frigg installations for non-petroleum related purposes.

The following non-oil and gas re-use alternatives have been specifically evaluated for the Frigg-Field installations:

- Artificial Reefs
- Windmills
- Emission Free Gas Fired Power Plants with CO_2 / Nitrogen Production for Enhanced Oil Recovery (EOR)

Reference is made to Part 1 – Disposal Plan in this Cessation Plan, Section 7: ”Assessment of Reuse Potential”.

5.1.3 Reuse of Concrete Substructures at another Location

The feasibility of the removal of the concrete substructures is a major concern that has been carefully evaluated.

However, a general assessment of the potential re-use opportunities has also been carried out and possible scenarios established. One option that could provide added value to society is to use the concrete substructures as bridge foundations for fjord crossings. Such a use has the potential to provide cost savings on the bridge construction cost. The concrete substructures could also be incorporated into some form of quay foundation or be used as landfill for industrial purposes.

The feasibility of such schemes does however depend entirely upon the ability to refloat the substructures that were not engineered for removal. Also the risk aspects will be important to evaluate for such options.

Although many of the in situ non-oil and gas re-use options studied are technically feasible it is concluded that with the present technology there is no economically viable reuse potential for the Frigg Field installations. In addition, the uncertainties associated with the refloat operations mitigate against the possible use of the concrete substructures at inshore or at-shore locations.

Reference is made to Part 1 – Disposal Plan in this Cessation Plan, Section 7: ” Assessment of Reuse Potential”.

5.1.4 Reuse of Modules or Equipment

Installations and equipment brought onshore will be marketed for re-use. If reuse is not possible, alternative methods for recycling will be investigated for the following components:

- Concrete
- Pipelines
- Cables
- Steel structures
- Equipment

Some of the equipment installed for Lille-Frigg and Frøy (at TCP2) are relatively new (installed in 1993 and 1995). This equipment will therefore be put on sale as whole packages. Generally, equipment assessed to have high reuse potential is being specially preserved.

5.2 Description of Non-Reuse Disposal Alternatives

Generally, the disposal alternatives evaluated for the Frigg Field installations include the following main alternatives:

- Complete Removal
- Partial Removal
- Leave in place

The disposal solutions of the various Frigg installations are not directly inter-dependent. All components have therefore been assessed individually in this report. However, some of the alternatives for the different Frigg Field installations will probably not be put into practice if they are not part of a combined disposal solution (e.g. artificial reefs).

Table 5.1 shows the disposal alternatives included in this assessment report, for the different components of the Frigg Field installations.

Details on methods and activities involved in the different disposal alternatives for each of the components are presented in Sections 7 to 11 in this EIA report.

Evaluation of Disposal Methods				
Steel Platform Topsides QP, DP2	**Alternative A** Removal and onshore disposal			
Steel Platform Substructures QP, DP2, DP1	**Alternative A** Removal and onshore disposal			
Concrete Platform Topsides TCP2, CDP1, TP1	**Alternative A*** Removal and onshore disposal			
Comparative Assessment of Disposal Alternatives				
Concrete Platform Substructures TCP2, CDP1, TP1	**Alternative A** Refloat, tow to shore, demolish and dispose on-shore	**Alternative B** Remove external and internal steelwork, refloat and dispose at a deep water location	**Alternative C** Remove internal and external steelwork and cut down sub-structure to provide a clear draft of 55m	**Alternative D**** Leave in place, removing as much external steelwork as reasonably practicable
Infield Pipelines and Cables	**Alternative A** Remove, transport to shore and onshore disposal	**Alternative B** Leave in place but trenched	**Alternative C** Leave in place but bury ends	
Drill Cuttings*** DP2, CDP1	**Alternative A** Remove and onshore disposal	**Alternative B** Leave in place		

* The first alternative is to remove all the topsides offshore. For the topsides on concrete platforms, linked to alternative A (Re-float of concrete substructures) there is however, an alternative method of removing the topsides partially offshore and partially inshore. This option is assessed in this EIA.

** Includes three different sub alternatives including various level of removal of internal and external steel items from the concrete installations.

*** For drill cuttings, a third alternative with the covering of cuttings in situ has been considered. Since the degree of contamination of the cuttings is relatively small, and since there is no distinct pile (i.e. the cuttings are spread in a wide area) this alternative was not considered viable.

Table 5.1 Components and actual Disposal Alternatives included in the Impact Assessment for

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6 Natural Resources and Environment - Current Situation

6.1 Meteorology and Oceanography

The climate in this area is mild and humid [17], with average winter temperatures in the order of 4-5^{0}C and average summer temperatures in the order of 13-14^{0}C.

The figure below shows the wind roses for the Frigg area (see Figure 6.1). The prevailing wind directions are in the sector from south/south-east to north. This is most pronounced in winter, but the pattern is also evident during summer [18].

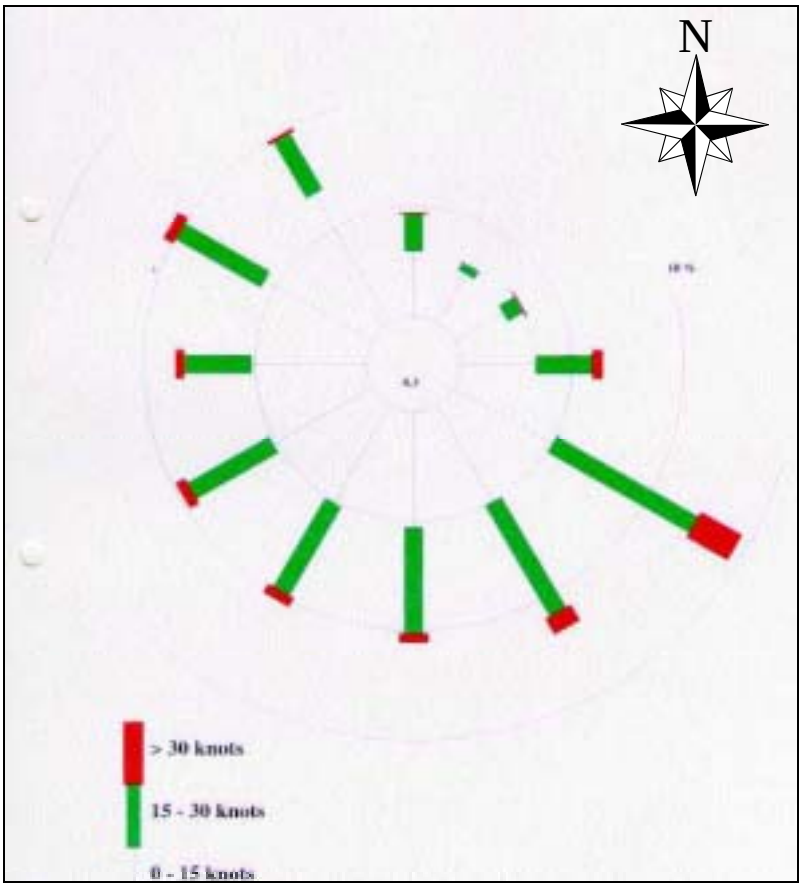

Figure 6.1 All year wind direction distribution (wind roses) in percent of total number of observations, 10 min. mean direction [18].

Wind speed during summer months (June-August) is on average 6.2 m/s, while during winter (December-February) the wind speed is on average about 9.9 m/s [19]. Spring and autumn wind speeds are in between these values. Wind speeds between 8.0 m/s and 10.7 m/s are characterised as a fresh breeze.

The most probable wave height in a fresh breeze is 2.0 m, while the most probable maximal wave height is 2.5 m [19]. Restrictions on lifting operations are assumed to come into force at wave heights around 4 m for a semi-submersible crane vessel (SSCV), although this is also dependent on other conditions (i.e. wave period, wave direction and type of operation). During summer season the probability for such significant wave height is less than 5%. For October the same probability will be less than 25% [18].

Currents from the Atlantic Ocean meet the Norwegian coastal current, i.e. water transported from the Baltic Ocean and the southern part of the North Sea. Current direction and speed varies considerably, depending on the direction and speed of prevailing winds [20].

Surface water temperature varies between 6^0C and 7.5^0C in winter, and increases to between 11^0C and 12^0C in summer. During the autumn the water masses become mixed, and there are no significant vertical difference in temperature and salinity. This situation will stay to early spring. In the summer, warming of the surface layers leads to stratification of the water masses and the formation of a thermocline. The thermocline is present at a depth of 25-50 m. Stratification is important in the passive transport of fish eggs and larvae [17].

6.2 Sea Bottom Conditions

6.2.1 Local Seabed

In Norway there is a mandatory system for environmental monitoring of petroleum activities. Such monitoring has been conducted at Frigg and the surrounding region on a regular basis and in accordance with the prevailing guidelines. Time series are therefore available with data on hydrocarbons, heavy metals (in sediment) and the benthic community. These data are used as a basis to assess the state of contamination at Frigg. In addition, specific surveys to monitor and map cuttings deposits and the associated degree of contamination have been performed.

Produced water from North East Frigg and Odin were reinjected from 1983 and from Frigg since 1986 into one well at DP2. Before that, the small amount of produced water from Frigg was discharged to sea. Since 1996 there has been some discharges of produced water from the Frøy production. The main source of contamination therefore is drilling waste (cuttings and associated mud). Specifically barite (a weight additive in the mud) is responsible for elevated metal concentrations. The cuttings sampled in the vicinity of the installation indicate that elevated concentrations of certain metals arising from the anodes were present.

The water depth in the Frigg area is about 100 meters. The bottom sediments in the Frigg area consist mainly of olive-grey coloured fine sand (83.7-92.5 per cent) with small amounts of pelite (silt and clay) and medium sand. The organic matter content of the sediments in the region varies between 0.63 and 0.90 per cent [21].

Production in the Frigg Field started in 1977, and drilling was performed in two campaigns in 1977/78 and in 1989. It was drilled mainly with water based mud, but oil based mud was used in the 12 ½“ section in the last campaign. The oil-based mud was taken to shore for treatment. Discharges of oil contaminated cuttings (subsequently cleaned to an oil content less than 10%) only represented a minor fraction of the overall discharge from the drilling operations (see Section 5 in the Disposal Plan for a more accurate description of the drilling discharges).

In the period from mid 1980’s to 1992 there was an increase in hydrocarbon content in the local sediments. Especially around DP2 elevated THC (Total Hydrocarbon Concentration) levels were found with values ranging from 10 mg/kg dry sediment to values below background level (7.0 mg/kg), see Figure 6.2. Only one of the stations had a THC content above 10 mg/kg [21]. The Environmental Monitoring Study from 1997 [21] does show a reduction or no change in the hydrocarbon content at the Frigg Field. Core samples show an almost uniform vertical distribution of THC down to a depth of 6 cm both in the reference sample as well as at a sampling station near TCP2. The Environmental Monitoring Study from 2000 [91] does show that the average THC concentrations in the sediments at Frigg have increased from 6.6 mg/kg dry sediment to 7.5 mg/kg since 1997. For an offshore petroleum field in this part of the North Sea such values are low. The THC levels in sediments from the stations respectively situated 200 m in the 350 ^{0} direction and 330 m in the 194 ^{0} direction relative to TCP2 are a little higher in 2000 than 1997. The same tendency is seen in

sediments from the station situated 200 m in the 350 ^{0} direction relative to DP2. At the other field stations the THC levels are comparable with those found in 1997. As the figure below illustrates, the only elevated concentrations of THC are found beyond and in the very near vicinity to the DP2 installation (associated with the thin cuttings layer).

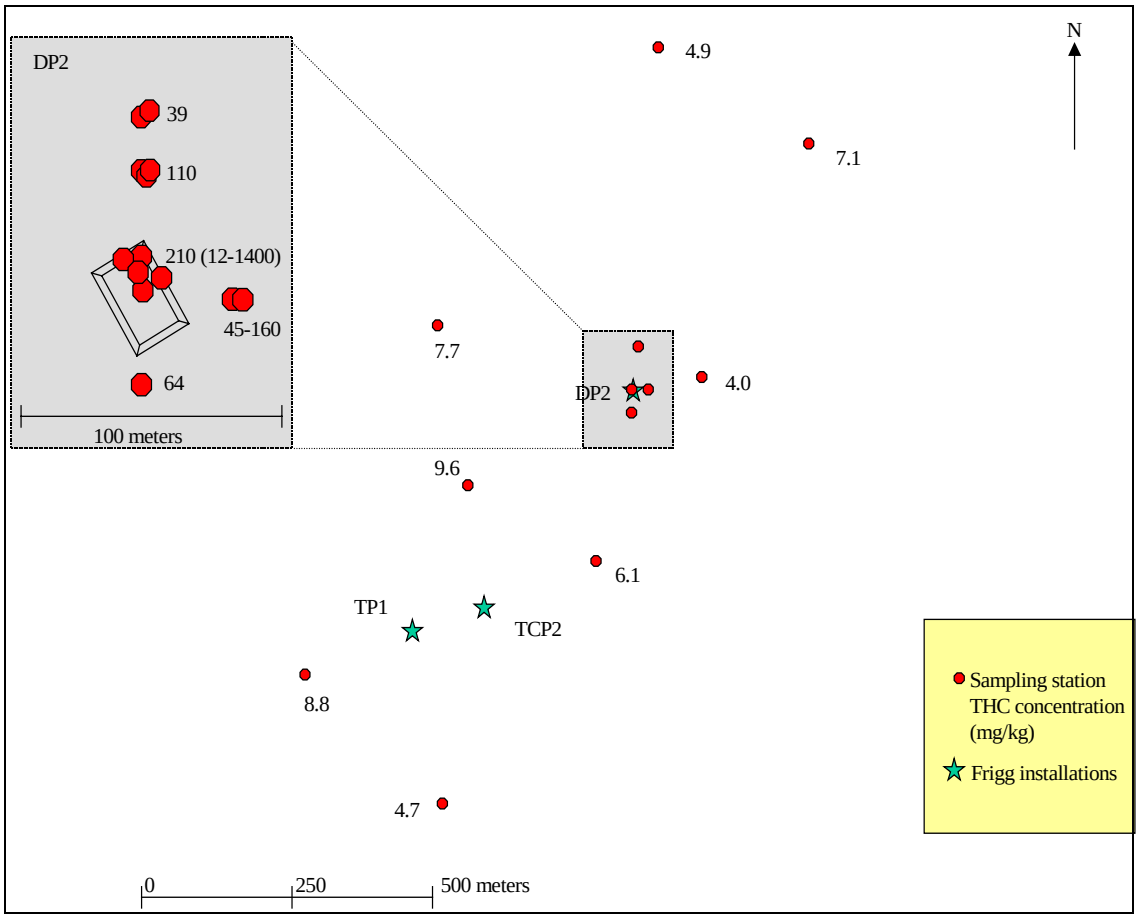

Figure 6.2 Sampling stations and THC concentrations (mg/kg) at the Frigg Field [11, 12]. Background level in the area is 7 mg/kg.

Metal concentrations are generally found comparable with Class II of the Norwegian sediment quality classification system for fjords and coastal waters [22], which normally means that no remedial action is necessary. The highest metal concentration of lead (Pb), zinc (Zn), copper (Cu) and cadmium (Cd) were found near the DP2 platform, where the highest hydrocarbon content was also found [21].

The 1997 study shows a reduction in the benthic fauna at the field stations compared to the 1992 survey. The number of individuals has decreased at most stations while the number of taxa has increased at some stations, and the diversity has generally increased. The 2000 study [91] does show that the faunal disturbance has increased in intensity since 1997. In the same period the concentrations of some heavy metals have increased at the same stations. ***The Frigg area as a whole can be classified as relatively undisturbed (i.e. Group A[2])*** [21]. This conclusion can be drawn based on the monitoring results.

[2] Relatively undisturbed communities, with low dominance (no species present in very high numbers) and a wide range of species from a variety of taxonomic groups, including molluscs, echinoderms and crustacea. Moderate species numbers and total abundance, high biomass.

The area in the very close vicinity to DP2 has a thin cuttings layer. This part is therefore described more detailed in the sub-section 6.2.2.

6.2.2 Drill Cutting Deposits

On the Frigg Field there are two drilling- and productions platforms, DP2 in the Norwegian sector and CDP1 in the UK sector. Drill cuttings are found underneath and around DP2. For CDP1 however drilling waste has been discharged inside the structure, and samples taken outside the installation confirm that there is no release of drilling waste to the marine environment.

Drill Cuttings Deposits at DP2

A study to estimate the quantity of cuttings, thickness layer and chemical content of the cutting deposits under the drilling production platform DP2 was carried out by Rogaland Research [11]. A new study was performed summer 2000 [12]. No distinct drill cuttings pile was observed under this platform either by visual inspection (divers) or by ROV. The core samples taken from the sediment show that the deposit from the drilling activities seems to be maximum of 20 cm thick at the centre, rapidly decreasing with increasing distance from the centre.

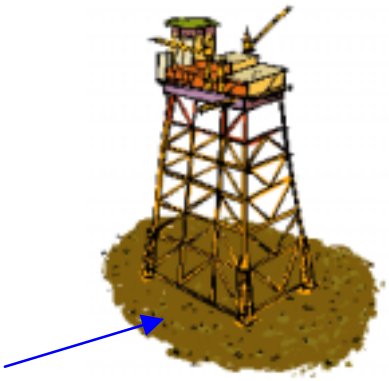

Figure 6.3 Drill cuttings deposits around DP2

The sediment contamination arises from the three basic sources [11]:
1. Drill cuttings
2. Drilling mud
3. Paint sources from construction and repair work on the platform and anodes

Frigg Field is a gas field, and thus any hydrocarbons found in the sediments are likely to originate from the drilling mud used – though only small amounts of oil based mud associated with cuttings have been discharged.

The RF [12] study has calculated the present cuttings layer under and around DP2 to be about 400m^3, i.e. about 4% of the total cuttings that have been discharged. It is quite a long time since any drilling waste was discharged from Frigg, and the samples also show that sand has naturally accumulated on top of the cuttings in most places (see Figure 6.4).

Analyses show that the sand content of the samples was 66-72%, while the fine pelite content was only 1.9-2.3%. For illustration, a picture of a core from the sampled cuttings is shown in Figure 6.5.

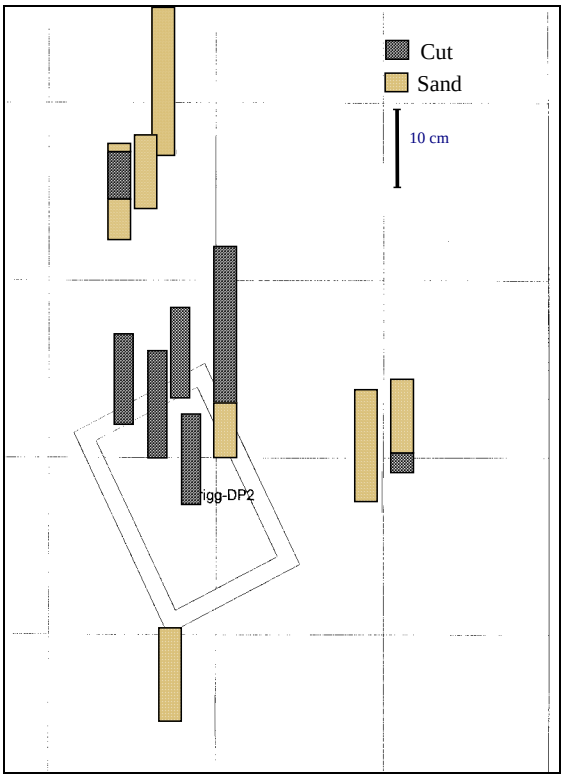

Figure 6.4 Cuttings layer around DP2 [12]. Bars indicate sampled layer, brownish layer being sand, dark/dotted area being cuttings.

The sampling performed in 2000 show that the cuttings have rather homogenous concentration of contaminants. The average concentrations of metals and hydrocarbons in the sediment under the DP2 platform are mainly low compared with the limits for SFT (Norwegian Pollution Control Authority) criteria on sediment quality in fjords and inshore water [22]. This comparison is shown in Table **6.1**. SFT's criteria have five classes, Class I representing slightly polluted sediments and Class V representing a very strongly polluted area. The amount of oil remaining in the thin cuttings layer at DP2 is estimated to only about 150 kg (in 400m^3 cuttings).

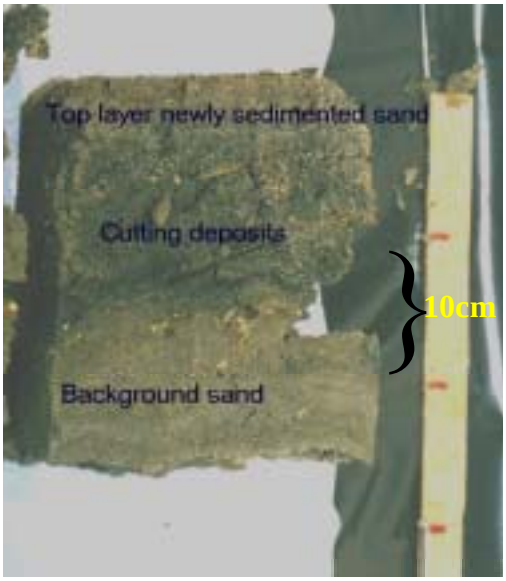

Figure 6.5 Picture of drill cuttings sample from Frigg.

The test results of samples taken in 2000 of the seabed around DP2 are shown in Table 6.1.

Element	DP2 [μg/g]	Reference station [μg/g]	SFT criteria* [μg/g]	
			Class I Slightly polluted*	Class II Moderately polluted*
Chromium (Cr)	18		<70	70-300
Nickel (Ni)	15		<30	30-130
Copper (Cu)	32	1.7	<35	35-150
Zinc (Zn)**	330	3.5	<150	150-700
Arsen (As)	7.8		<20	20-80
Silver (Ag)	0.09		<0.3	0.3-1.3
Cadmium (Cd)	0.5	0.017	<0.25	0.25-1
Tin (Sn)	5.6		<150	150-700
Barium (Ba)	500	52	-	-
Lead (Pb)	72	2.86	<30	30-120
Mercury (Hg)	0.020	0.006	<0.15	0.15-0.6
Hydrocarbons (THC)	290	8.3	Not classified	Not classified
	ng/g	ng/g	ng/g	ng/g
ΣPAH	240	NA	<300	300-2000
B(a)P	15	NA	<10	10-50
PCB	6 (2-14)	NA	<5	5-25

* Graduated classification in use by Norwegian Pollution Control Authority.

** The cause of the elevated zinc concentration is believed to be zinc anodes.

Table 6.1 Metal and hydrocarbon concentration in sediments under DP2 [12] compared with the reference station [21] and SFT criteria for sediment quality in fjords and coastal waters [22]. All data are dry weight.

By comparing these figures it can be shown that most of the samples from this investigation fall into SFT Class I (Slightly polluted), and some into SFT Class II (moderately polluted).

A comparison of the concentrations in the sediments under DP2 with the average background sediment composition seems to indicate that Zn, Cd and Pb have originated from offshore activity. The presence of cadmium and lead is assumed to be associated with the barite from drilling, whilst the presence of zinc is believed to have arisen from zinc anodes.

The source of barium (Ba) is barite in the drilling mud. Such barium is crystalline bound and has very low bio-availability. Drilling has occurred during several periods, and different batches of barite have been used. These batches were contaminated with different trace metal concentrations.

Elevated concentrations of THC were found, and also the harmful Benzo(a)pyrene (B(a)P of the aromatic fraction (PAH) was found in elevated concentrations – just into SFT class II. PAH was however measured to be decreasing markedly with depth [11]. The THC concentrations found are however generally low compared with results from other surveys of cuttings deposits in the North Sea. PCB was detected just above the SFT criteria for class I. There was no indication that this PCB is associated with the drilling waste [12], and the source may be paint as indicated through studies around construction yards in recent years.

The conclusion of the biological analyses performed [23] is that the DP2 location has only slightly disturbed fauna (Group B). The results found are comparable with that of the Frigg monitoring stations at distance 200 to 330 meters, indicating that the effect of the cuttings layer on the present fauna is small.

Drill Cuttings Deposits inside CDP1

The drill cuttings at CDP1 were disposed of inside the concrete structure, within the sand ballast area, and seabed sampling and analysis outside the structure indicate that no drill-cuttings have been discharged from the installation [12, 24].

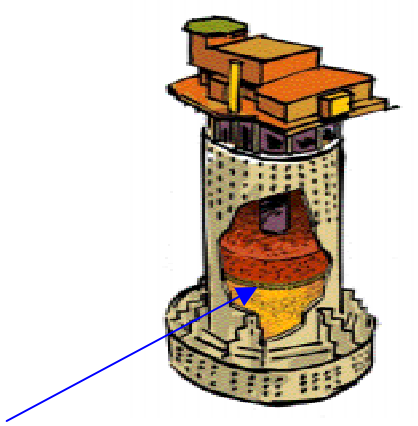

Figure 6.6 Drill cuttings inside CDP1

Core samples were taken immediately outside of the wall of the installation. The samples from CDP1 contained 20 mg/kg hydrocarbons, i.e. about twice the background level. The concentration of most metals and PAH was also somewhat higher than in the background sand, and generally less than found for DP2.

No PCB's were detected outside CDP1 [12].

6.3 Natural Resources

Natural resources in the Frigg area are well described in the Regional EIA for the North Sea [25]. This report therefore only contains a short summary description of those resources considered most relevant.

6.3.1 Fish

Fish species like mackerel, saithe, herring, cod, whiting and Norway pout are present in the central and North Sea, during different parts of the year, represented by different life stages [17].

The presence of eggs and larvae depends on the spawning area, spawning period, and the ocean currents. The north and central parts of the North Sea represent the most important spawning area for the North Sea mackerel. The spawning takes place during May-July, the eggs drift with the upper layer water currents, and hatch after 5-7 days.

There are important spawning areas for cod are along the East Coast of Scotland and central parts of the North Sea, i.e. south-west and south of Frigg. Spawning takes place during January-April, and eggs and larvae drift northwards with the currents. In spring and summer spawning products from cod may therefore be found in the northern parts of the North Sea, including the Frigg area.
The northern part of the North Sea is an important spawning area for saithe, Norway pout and haddock. Norway pout spawns near the sea bottom in the north and central parts of the North Sea during January-July. Larvae from Norway pout and haddock stay in the area during summer. Haddock larvae are distributed throughout most of the water column, while Norway pout larvae stay deeper, at 5-20 meters from the seabed.

Saithe spawns during January-April, along the shelf edge north and east of Frigg [17]. The pelagic eggs hatch after 6-15 days, and easterly currents transport eggs and larvae out of the area [17].

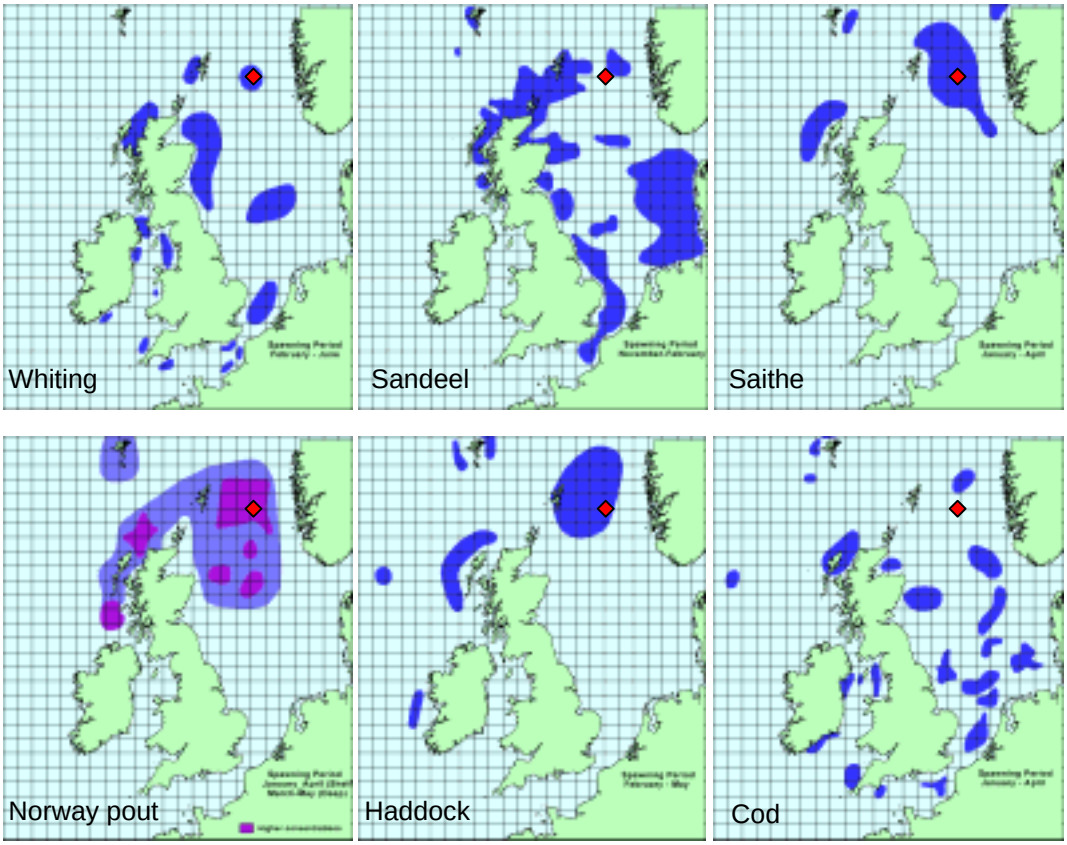

Figure 6.7 Spawning areas for selected fish species in the central and northern part of the North Sea [26]. Position for Frigg indicated by red mark.

Species/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cod			<	<								
Herring												
Haddock				<	<							
Saithe		<	<									
Mackerel						<						
Plaice												
Norway pout												

Table 6.2 Spawning periods for selected commercial fish species in the North Sea. The angle (<) indicate peak in spawning [60].

Herring and Sandeels may also occur in the ocean areas near Frigg. The herring spawns in areas west of Frigg, but eggs and larvae may drift through the area with currents directed into the central North Sea. Sandeel is widely distributed in this part of the North Sea and the drifting of their eggs and larvae also occurs in the Frigg area.

The different species are distributed vertically in the water column. During daytime mackerel, herring and the youngest age classes of haddock and whiting stay in the upper parts of the water columns (0 -50m). Cod, saithe, haddock, Norway pout and different flatfish stay near the seabed, at depths of between -100 and -200 m, while the blue whiting stay in even deeper water (-200 to -300m) [17].

Experiences from several experiments confirm that younger life stages of fish are more vulnerable to pollution than adult individuals [27, 28]. The younger stages are present in large numbers, and may be concentrated in restricted areas. The number of eggs/larvae reaching reproductive age will naturally affect population size. However, there are many different factors affecting the size of each age class [17] and the effect of local pollution/contamination or other forms of local disturbance on age classes and populations is therefore difficult to predict. It is however important to point out that the success of a single age class, may not necessarily be critical for the population development – but can be important to fisheries.

During disposal of offshore installations, potential use of explosives below sea level is regarded as the most critical activity for individual young and adult stages of fish. Only for one installation and one disposal alternative (cutting CDP1 down to –55m) is the use of explosives assumed necessary for the disposal of the Frigg Field facilities. However, the recommended disposal alternatives do not include plans to use explosives in water.

In addition, the extraction of sediments could have some effect on the spawning products of e.g. herring, although it is likely to be local and limited. [29,30].

6.3.2 Seabirds

Many species of seabirds are recorded in the Frigg area, including common guillemot, razorbill, puffin, little auk, kittiwake, blackheaded gull, great black backed gull, herring gull, great skuas, gannet, storm petrel and fulmar [85]. The density of different species varies throughout the year, as in other parts of the North Sea. As most seabirds are generally highly mobile and widely distributed, they are not expected to be affected by the disposal of the Frigg Field facilities. Sub-surface explosions offshore may however have an impact on diving birds like auks. Outside breeding season these birds gather offshore and can be found high numbers diving for fish, crustaceans and squid. The little auk is mainly diving for planktonic nourishment, and is present in the North Sea mainly in the winter season.

In the period late April through June distribution of most seabird species is heavily influenced by breeding activities. Breeding birds are largely concentrated in areas close to colonies although they may travel greater distances to feed [85]. Waters close to Shetland, Orkney, Northeast of Scotland, The Firth of Forth, The Farne Island and Flamborough Head are of major importance for the three offshore species of auk [86]. Guillemot and razorbill are therefore generally not seen at the Frigg Field from May to June [85]. Birds seen well away from the colonies are likely to be immature and/or non-breeders [86].

Late June and July the guillemot and razorbill chicks leave cliff ledges and swim together with the male parent out to sea. Guillemots tend to move rapidly south or east from the colonies, and are found in high numbers in the northern parts of the North Sea. JNCC [85] estimates the distribution of guillemots in July in the Frigg area to more than five birds/km^2. The razorbills do not disperse to the same extent as the guillemots, and the distribution is estimated to 0.01-0.99 birds/km^2 at the Frigg Field [85]. Towards the end of July fully grown birds start to moult and loose ability to fly. For these reasons both species are vulnerable to disturbance, and they tend to dive when they are disturbed.

In August-October the waters at the Frigg Field hold fewer guillemots than in July [85], and it seems like the birds move to the Fisher Bank and Skagerrak where larger concentrations occur [86]. The distribution increases from November to February, but ceases from March-April to July [85].

For the Frigg Field cessation work no use of explosives are planned. For the option of providing a safe sail-over (alternative C), however, the use of explosives will be necessary. For cutting of steel piles on fixed steel jacket structures the use of explosives will be a back-up method. As a mitigation measure it is in the case of such operations recommended to perform these in the period of year with least presence of diving birds, i.e. from April to mid July. As a second mitigation measure it will also be planned for observations of seabirds before the actual blasting takes place. This will be part of a guideline for use of explosives.

6.3.3 Marine Mammals

Marine mammals found at the Frigg area are basically many species of whales, and the abundance of particular species vary during the year due to their seasonal cycle which include feeding and breeding. The abundance also varies from year to year as food availability varies. Many species are observed migrating northwards (feeding) during summer and move southward during autumn and winter in a breeding migration to warmer waters.

Possible seals observed in the area (some seem to be resident at oil installations) will be individuals, most probably common seal (Phoca vitulina) and possibly grey seal (Halichoerus grypus). They are normally found in near shore/coastal waters, though some grey seal migrate over the North Sea.

Cetaceans that are regularly sighted within the northern North Sea include harbour porpoises (*Phocena phocena*), whitebeaked (*Lagenorhynchus albirostris*) and whitesided dolphins (*Lagenorhynchus acutus*) and pilot (*Globicephala melas*), killer (*Orcinus orca*) and mink whales (*Balenoptera acutorostrate*) [87]. The killer whale and pilot whale observed here as a part of their long distance migrations [87]. Killer whale might also be of a more stationary nature, but normally occurring closer to shore.

Bjørge and Øien [88] estimated the density of harbour porpoises between 56°N and 61°N to be about 61,000 with an average density of 0.83 individuals/sq. nautical mile. This survey did not cover fjords and coastal waters. The number of minke whales was estimated in the same area to 61,000 [90], and of Delphinadae sp. approximately 25,000 [89]. Other species reported in the area are bottlenose dolphins (*Tursiops truncatus*) and Sowerby's Beaked Whale (*Mesoplodon bidens*) [87]. Large whales like Sei whales (Balenoptera borealis), Fin whales (Balenoptera physalus), Humpback whales (Megaptera novaengliae) and sperm whales (Physeter macrocephalus) can also be observed in this area, but they are usually found in connection with the continental slope further north.

As for seabirds the one single activity that is considered likely to affect cetaceans is possible blasting. As mentioned such activity is not planned for, but could be a back-up method when removing steel substructures and for executing Alternative C (-55m) for the CDP1 concrete substructure. A possible blasting operation could have fatal consequences for possible cetaceans in the near area. Observation for cetaceans will therefore be mandatory if the means of explosives is to be used during these operations, and guidelines for this is recommended incorporated in the execution plan. Detailed calculations will be made to define a safe zone for any impact from the shock waves.

6.4 Fisheries Activity in the Frigg Area

6.4.1 Introduction

The North Sea is of international importance as a spawning-, growth- and feeding area for many different fish species. This is reflected in the high fishing activity in this area. Catches from the North Sea represent about 5 % of the total world catch from fisheries [31].

Fisheries in the North Sea can be split into three main groups [31]

- Trawling for bottom living species for direct consumption (mainly cod, haddock, whiting, and different species of flatfish)
- Industrial trawling (Norway pout, sandeel, blue whiting and sprat), and
- Fisheries with pelagic trawl and net gear which exploit species living in the water column (herring, horse mackerel and mackerel)

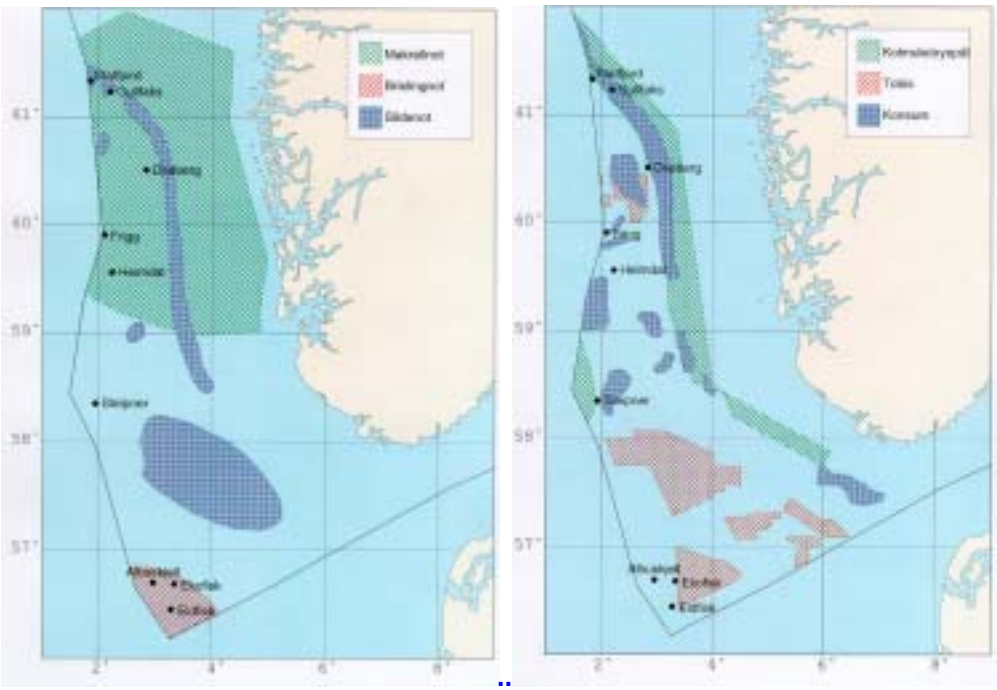

Figure 6.8 Areas for net fishery (left) and trawl fishery (right) in Norwegian sector (Maps from NFD).

The northern part of the North Sea is an important living area for adult stages of many common fish species, especially cod, saithe and herring. Because of high concentrations of commercially exploitable fish species in these areas, both trawl and net fisheries are present in the ocean areas around Frigg.

The border dividing the Norwegian and British (UK) offshore sectors passes through the Frigg area. Norwegian and UK fishing vessels expect the greatest fishing effort in this area.

Frigg is located in the south western part of Bergenbanken, which has traditionally been an important area to the consumption trawl fisheries, see Figure 6.8. However, the largest

industrial trawl areas for Norwegian fisheries are located outside the Frigg area, at Vikingbanken, 100 km north of Frigg, and along the Norwegian Trench, 80 km east of Frigg.

The Far Western parts of Bergenbanken are the British side of the sector border, and British fisheries are exploiting these areas. Other important fishing grounds in the British sector are located in areas further west and south of the Frigg Field.

Figure 6.9 shows the distribution of British fishing effort in different areas in the North Sea. The maps indicate that the Frigg Field area is of moderate importance to British demersal fisheries, but is located outside the most important areas for British pelagic fisheries.

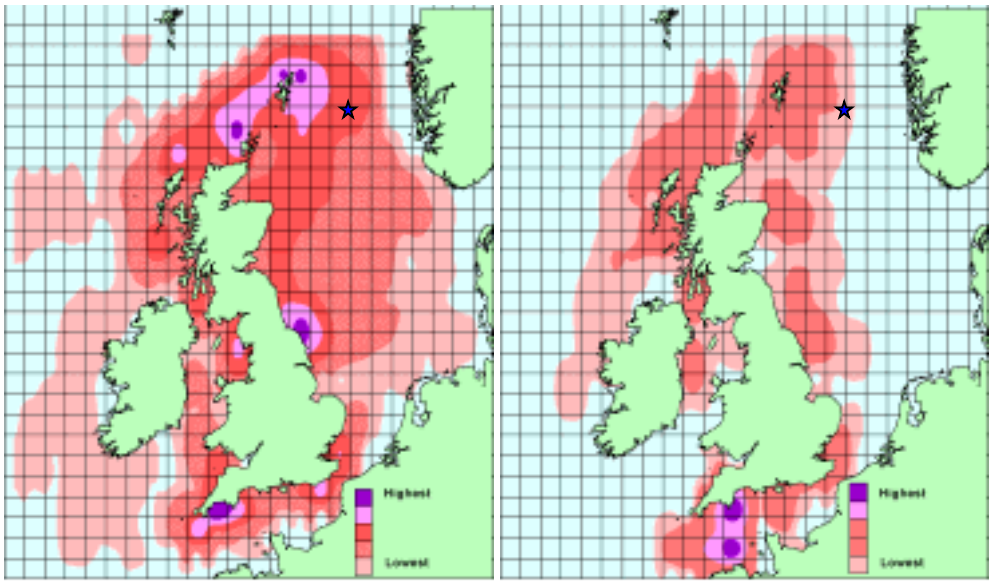

Figure 6.9 Distribution of fishing effort by British fisheries in the North Sea, split on fisheries for demersal species (left map) and pelagic species (right map). Frigg position indicated with blue star. Maps modified from UKOOA web pages [26].

6.4.2 Fishery Statistics

Fisheries statistics from the Norwegian Fisheries Directorate (NFD), Marine Laboratory in Scotland, and Ministry of Agriculture, Fish and Food (MAFF) in London have been obtained to allow the evaluation of the importance of the Frigg area and nearby fishing locations to the North Sea fisheries as a whole. However, in interpreting these data, it is necessary to keep in mind that the fisheries statistics are not complete, and contain biases. The limitations of the data are discussed in the technical appendix [72].

The fishery statistics refer to a division of the North Sea into statistical rectangles defined by the International Council for the Exploration of the Sea (ICES). Details on this reference system are given in the technical appendix [72]. The fishery statistics obtained from NFD, Marine Laboratory and MAFF are split on the Frigg area and nearby areas, as shown in Figure 6.10. Fishing effort, catch volumes, methods and general importance of the Frigg area and surrounding ocean areas to Norwegian and British fishery are presented in the following sections.

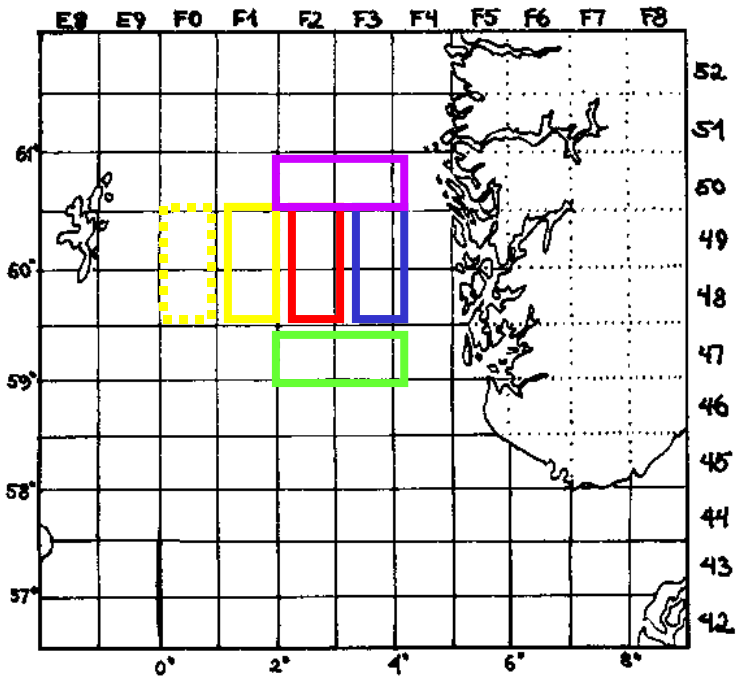

Figure 6.10 Distribution of fisheries locations which are basis for catch statistics from the Norwegian Fisheries Directorate and Marine Laboratory, Aberdeen. Frigg area (-), North-Northeast of Frigg (-), East of Frigg (-), South-Southeast of Frigg (-),West of Frigg (1)(-) and West of Frigg (2)(-) (location F048 and F049 only included in UK statistics).

6.4.3 Fishing Effort during the Year

Norwegian and British fishing vessels are present during the whole year in this part of the North Sea. However, the catch effort is in general lower in the first quartile than in other parts of the year. A more detailed presentation of fishing effort is given in reference [72].

6.4.4 Landing Volumes

The total landing volumes from Norwegian and British vessels (landings to Scotland and England) are presented here, giving an indication of the importance of the Frigg area and surrounding areas to the fishing industry.

Norwegian landings

Figure 6.11 shows that generally the volumes landed by Norwegian fishing vessels from the Frigg area (for definition of Frigg area; see Figure 6.10) are considerable, varying between 30,000 and 60,000 tonnes per year. In 1995 Norwegian fishermen landed a record of about 170,000 tonnes of fish from this area. It should be noted however that the statistics given in the figure only represents an indication of the activity, as there may be considerable changes in fishery effort during time depending on stock fluctuations and quota regimes. The Frigg area lies in the south western corner of an important trawl fishery area called Bergenbanken. The record landings this particular year was due to exceptionally high landing volumes from the industrial trawl fishery exploiting sandeel in this area.

The landings from surrounding ocean areas, north, east and south of Frigg, are in general of a comparable size as the normal landings from the Frigg area. The areas to the west of Frigg

(on the UK side the sector border) are of marginal importance to the Norwegian fishery according to the fishery statistics. A more detailed description, also including monthly variations is given in the Technical Appendix [72].

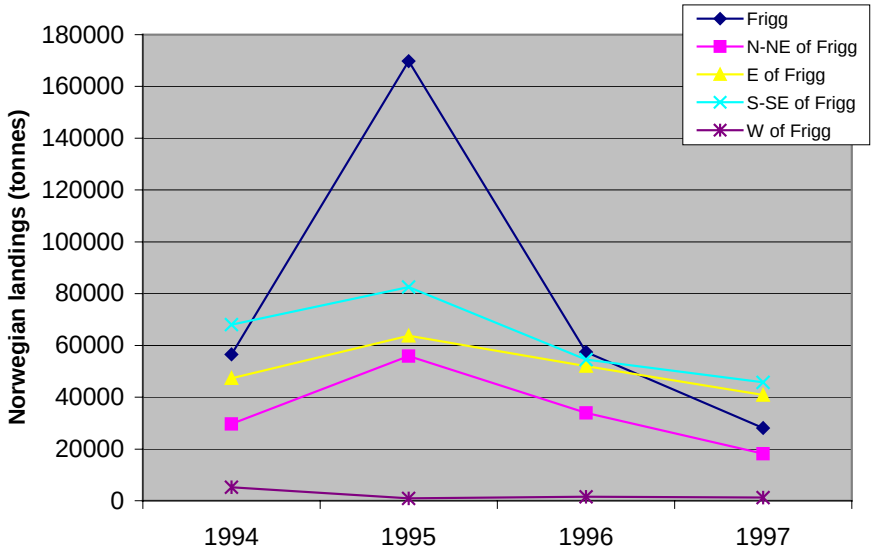

Figure 6.11 Annual Norwegian landings in the Frigg area and surrounding areas in the period 1994-1997. Areas defined as in Figure **6.10**. (Data from [32].)

Industrial trawl landings (mainly sandeels, blue whiting and Norway pout) dominate the Norwegian figures together with net fishery mainly exploiting herring and mackerel. The Norwegian consumption trawl fishery for high priced demersal fish is modest in the ocean areas around Frigg.

British landings

Although they are not of comparable size to Norwegian landings, British fishery statistics indicate that a considerable British effort with bottom gear is present at the UK side of the border. These are mostly Scottish fishing vessels landing in Scotland. Generally, only minor parts (<1 %) of the British catches from the Frigg ocean areas are landed in England or Wales.

The total UK landings from the Frigg area are between 5,000 and 7,000 tonnes per year as shown in Figure 6.12. Slightly larger landings are made from the neighbouring area to the west of Frigg. This is due to larger landings from consumption trawling, exploiting mainly *gadidae* (cod, haddock, saithe, and whiting), different flatfish (monk, lemon sole) and dogfish in these bank areas (Bergenbanken and westwards). Further west the landings are less, due to less trawl landings. These findings indicate that British trawling activity in this part of the North Sea is most intensive near the Sector border. British net fishing catches over the last few years, however, have been larger in the Frigg area than on the British side of the sector border.

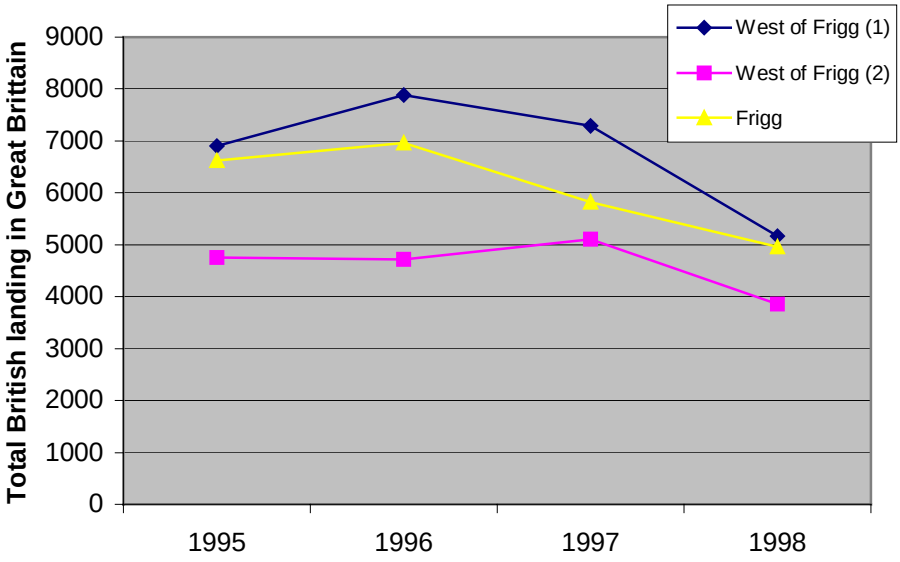

Figure 6.12 Annual landings (tonnes) in Scotland, England and Wales from vessels fishing in the Frigg area and two areas to the west of Frigg. (Areas refer to definition in Figure 6.10).

6.4.5 Relative Value of Frigg and Other Fishery Areas in the Northern North Sea

Compared to the rest of the North Sea the Frigg area is within an area of moderate importance to fisheries, bordering an area of even higher importance (See figure 6.13). The general picture of the fishery activity in the Frigg area is that there is a considerable Norwegian industrial bottom trawl fishery. Norwegian effort involving net gear is also significant. British fisheries are present in the area, exploiting demersal species (with net and trawl gear) for the consumption markets. However, this effort is limited to modest landings. Based on the low Norwegian and British consumption fish landings the Frigg area is considered to be of minor importance to the consumption fisheries. The fishery activity is most intensive during summer, autumn and winter.

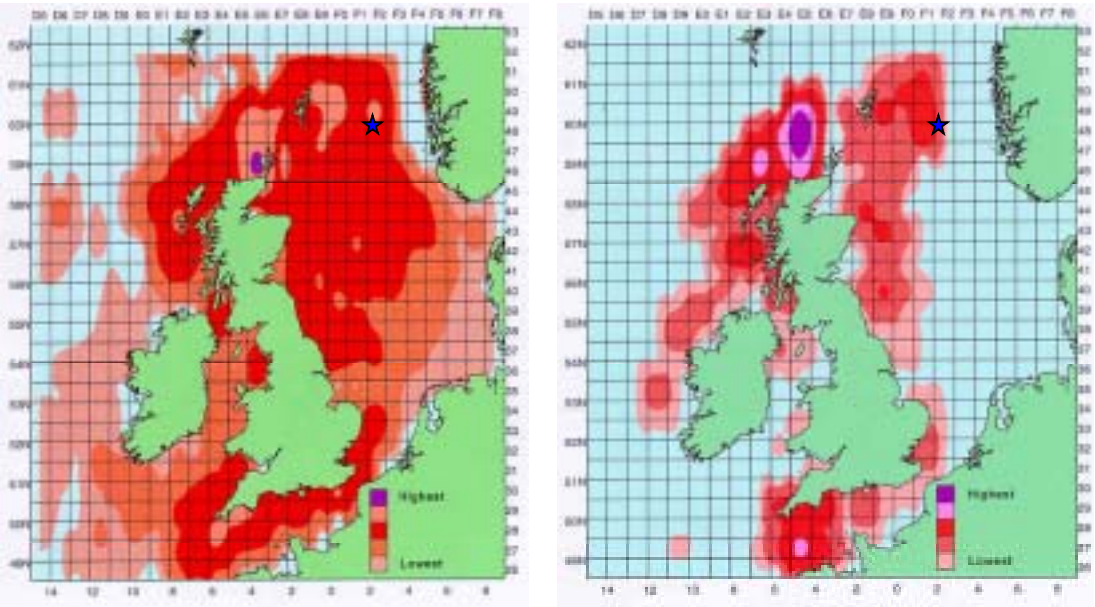

Figure 6.13 Relative value of different areas in the North Sea to demersal fisheries (left) and pelagic fisheries (right), 1996. Frigg position indicated with blue star. Maps modified from UKOOA web pages [26].

6.5 Emissions in the Frigg Area

For the Norwegian sector the "Frigg area" reflects the area from the Frigg Field south to Balder/Jotun in the statistics. In UK there is not published statistics for particular areas and statistics cited count the entire offshore activity, if not otherwise stated.

The figure below contains a prognosis for CO_2 emissions from this area (Norwegian part[3]). This shows that a normal annual emission will be in the order of 400-700,000 tonnes. For comparison the total prognosis from the Norwegian offshore industry in this period of time is 6-10 million tonnes. The emissions from the entire UK offshore industry in the period 1996-98 were 23-25 million tonnes [34].

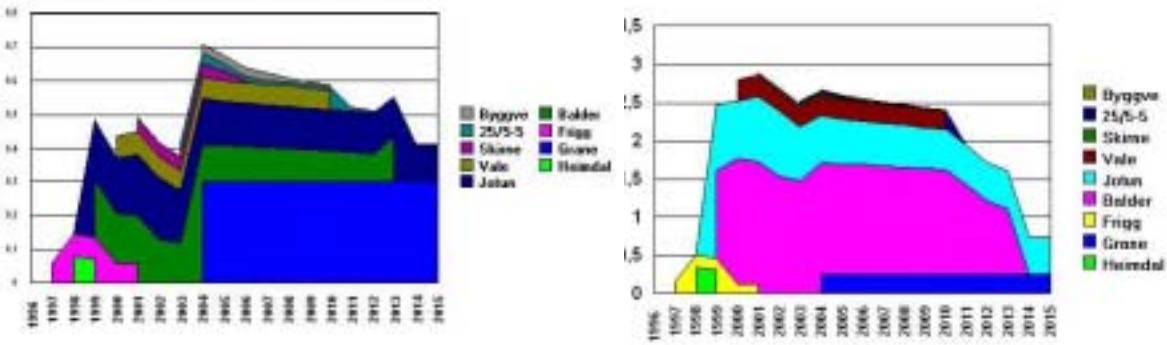

Figure 6.14 Prognosis for CO_2 (million tonnes per year) and NO_X (1000 tonnes per year) for the Frigg area [33].

NO_X emissions in the area are stipulated to about 2,500 tonnes per year. The corresponding value for the entire Norwegian offshore industry is 50-60,000 tonnes [33]. NO_X emissions from the UK offshore industry for the period 1996-1998 were 63-74,000 tonnes per year [34].

Annual SO_X emissions from UK offshore operations are in the order of 10,000-12,000 tonnes. Corresponding Norwegian emissions are 880 tonnes [35].

The emissions from the Frigg Field in 2000 are presented in the Table 6.3. The CO_2 emissions were about 82,000 tonnes, i.e. about 16 % of the total emissions in the area. NO_X emissions account for about 6 % and SO_X for about 0.1 %.

Source	CO_2	NO_X	SO_X
Flaring	5 555	26.7	0.0
Turbines, diesel fuel and gas	71 914	99.4	0.8
Diesel engines	121	2.6	0.1
Gas heaters	4 518	25.5	0.0
TOTAL	82 100	154.2	0.9

Table 6.3 Emissions from the Frigg Field in 2000 [92] (in tonnes).

[3] It should be noted that 25/5-5 has not been decided for development.

7 Impact Assessment for Disposal of Topsides

7.1 Description of Disposal Alternatives for Topsides

Steel Platform Topsides **Concrete Platform Topsides**	**Alternative A*** Removal and onshore disposal

* The base case alternative is to remove all the topsides offshore. For the topsides on concrete platforms, linked to Alternative A Re-float of concrete substructures, there is however an alternative method of removing the topsides partially offshore and partially inshore. This alternative is assessed in this EIA.

Table 7.1 The disposal alternative considered for Topsides on Steel and Concrete Platforms on the Frigg Field.

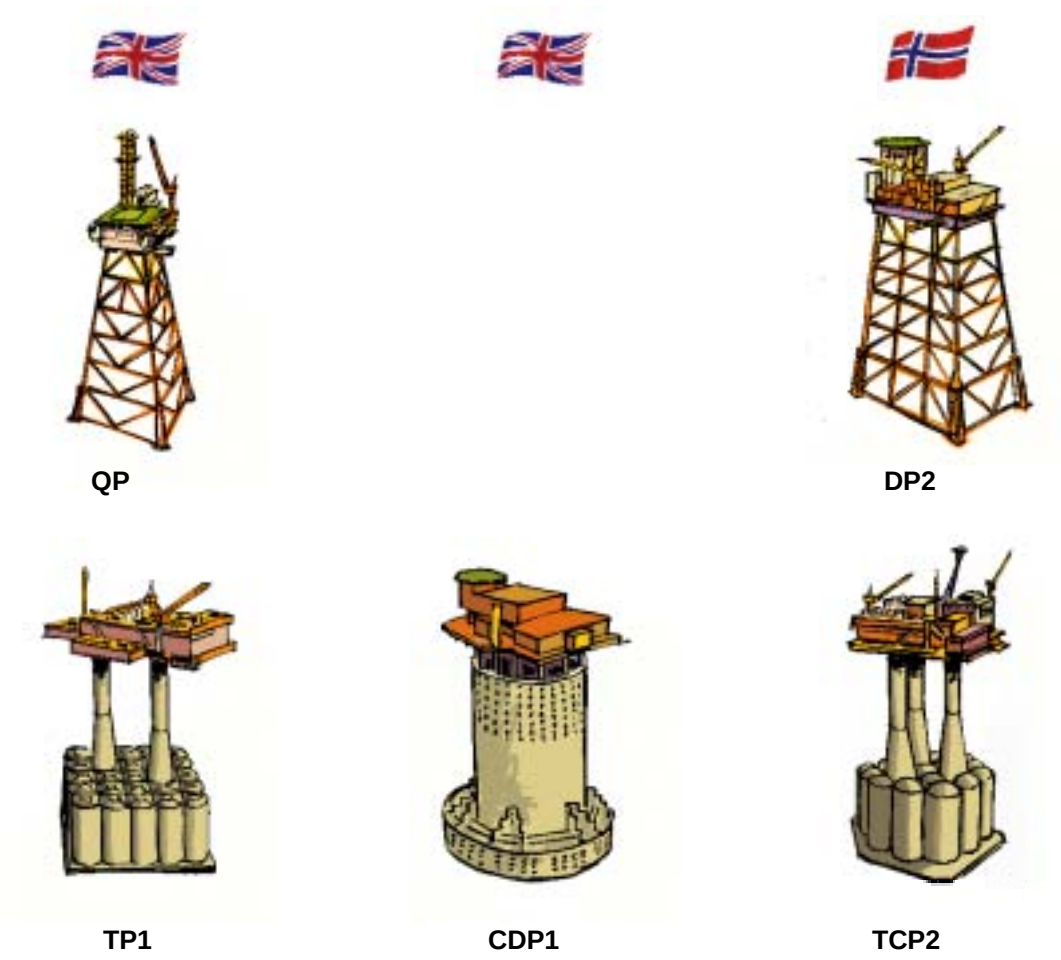

Figure 7.1 Topsides on Steel and Concrete Platforms on the Frigg Field.

Alternative A – Removal of topsides and onshore disposal

All topsides will be taken to shore for dismantling, recycling and potential reuse, all in accordance with OSPAR Decision 98/3.

Topsides resting on steel substructures can be removed offshore in several different ways; single lift of the whole topside or modules taken down in several smaller lifts. Both variations require extensive preparations offshore prior to lift and removal.

When lifted off the substructure, the topside or the individual modules will be placed on barges, alternatively directly on to the lifting vessel, and transported to shore. Upon arrival at quay the units will be lifted off the vessel and placed onshore for further handling. At the demolition site, breakdown into separate items suitable for recycle or disposal will be performed according to all relevant procedures and regulations. Parts suitable for reuse will be individually marked and preserved.

Typically, preparations for removal of the topsides could take from 3 to 7 months. As for the actual lift off, the operations on each of the platforms can normally be effected within a few days.

For offshore removal of topsides on concrete platforms the same methods as described for the topsides on steel substructures will apply.

Option – Partial offshore and onshore removal of concrete platforms Topsides before disposal

A second alternative is presented for the topsides on concrete platforms. This alternative includes partial removal of the topsides offshore and onshore, and is linked to optional re-float of substructures for inshore disposal. Topside removal is then co-ordinated with re-float, and removal of modules offshore is restricted to the minimum for performing re-float. The rest of the topside modules will then be removed inshore after the installation has been towed to an inshore dismantling site. The onshore work with dismantling and further disposal of the different components will be the same as for alternative A.

7.2 Environmental Impacts from Disposal of Topsides

In this section, one out of several possible removal methods is chosen in order to illustrate the scale of energy consumption and emissions. The numbers calculated are only indicative of the extent of the operations, and not definite figures.

7.2.1 Energy

Alternative A - Removal of topsides and onshore disposal

The energy impact for removing and onshore recycling of the topsides is found to represent a “small negative” impact, based on the impact key presented in section 3.3.2.

Table 7.2 below, shows the total energy impact, and its components, of removing the individual topsides for onshore disposal. The total energy demand of removing and recycling the topsides is about 730,000 GJ, corresponding to an average annual fuel (energy) consumption of 18,000 family cars.

As the whole topsides are recycled, E_{REP}, the energy for replacing the topsides is zero, and thereby the Energy Consumption (E_{CONS}) equals the Total Energy Impact (E_{TOT}).

Operation	Topsides on UK installations			Topsides on Norwegian installations		All topsides
	CDP1	TP1	QP	DP2	TCP2	
E_{DIR} Marine operations	70 000	45 000	47 000	42 000	62 000	266 000
E_{DIR} Dismantling	7 500	9 300	4 200	6 300	27 300	54 600
E_{REC} Recycle of metals	53 300	70 000	30 000	46 700	211 500	411 500
E_{CONS} **Energy Consumption**	**131 000**	**124 000**	**81 000**	**94 000**	**300 000**	**730 000**
E_{REP} Energy for replacing the materials	0	0	0	0	0	
E_{TOT} **Total Energy Impact Per topside**	**131 000**	**124 000**	**81 000**	**94 000**	**300 000**	**730 000**
E_{TOT} **Total Energy Impact Split on nation**	**336 000**			**394 000**		

For key of terms, see explanation of energy calculations. See Section 3.3.2.

Table 7.2 Total energy impact for removing and recycling topsides (in GJ).

Option – Partial offshore and onshore removal of topsides on concrete platforms before onshore disposal

Separate estimation of Energy Consumption and Total Energy Impacts for this alternative has not been performed. However, more removal operations performed inshore will result in less marine operations involving heavy lift vessels. This alternative therefore is considered to have lower energy demands compared to Alternative A for the removal of topsides on concrete platforms.

7.2.2 Emissions to Atmosphere

Alternative A - Removal of topsides and onshore disposal

Emissions to atmosphere from removing and onshore recycling the topsides are found to represent a “small negative” impact.

The general effects of the presented emissions to air are described in Section 6.5 in this EIA. Table 7.3 shows the different emissions to air from the removal and recycling of the topsides. The total emissions of CO_2 for removing and recycling the topsides are about 63,000 tons.

Due to relatively high creation of NO_X in the combustion of fuel in ship engines, the NO_X emissions are high compared with other operations (per fuel unit).

Compared with the emissions from the Frigg area in one year, removal of all topsides represents 9-16%, 16% and 24% for CO_2, NO_X and SO_X respectively (cf. statistical data in Section 6.5 in this EIA).

Operation	Topsides on UK installations			Topsides on Norwegian installations		All topsides
	CDP1	TP1	QP	DP2	TCP2	
CO_2 emissions						
Marine oper./ dismantle	5 100	3 300	3 400	3 100	4 600	
Recycle of metals	5 700	7 200	3 200	5 000	22 300	
Total per topside	**10 800**	**10 500**	**6 600**	**8 100**	**27 000**	**63 000**
Total split on nation	**27 900**			**35 000**		
NO_X emissions						
Marine oper./ dismantle	90	60	46	57	84	
Recycle of metals	9	12	5	8	37	
Total per topside	**100**	**70**	**50**	**65**	**120**	**405**
Total split on nation	**220**			**185**		
SO_2 emissions						
Marine oper./ dismantle	4.4	2.9	2.2	2.7	4.0	
Recycle of metals	24	36	14.3	21	100	
Total per topside	**30**	**40**	**16**	**24**	**104**	**214**
Total split on nation	**86**			**128**		

For key of terms, see explanation of emissions to atmosphere. See Section 3.3.2.

Table 7.3 Total emissions to air from removing and recycling topsides (in tonnes)

Option – Partial offshore and onshore removal of topsides on concrete platforms before onshore disposal

Separate estimation of energy demand and impacts for this alternative is not performed, and therefore no estimates of emissions are given. It is believed however that the involvement of heavy lifting vessels will be less probably giving some reduction in energy consumption and emissions from exhaust.

Even if some of the removal operations are moved closer to shore than for the offshore alternative, the impacts due to gaseous emissions are considered similar. This follows from the relatively modest emissions seen in relation to other input of such substances in the area. The duration of work will also be limited in such a context. Since no onshore dismantling site is specified at this stage, no further evaluation of impacts on the local and regional environment is possible.

7.2.3 Discharges to Sea, Water or Ground

Discharges from the process of removal and onshore recycling and disposal of the topsides are found to represent “insignificant” impacts on the environment.

Potential areas of concern, which have been identified and assessed, are:

- Discharges associated with cleaning of equipment, tanks, etc.
- Releases from onshore dismantling
- Leaching from disposed waste material on landfill sites

Both during the separation of topside modules and their removal or a complete lift of the topsides offshore, no discharges to the sea are expected.

Cleaning of systems will be performed prior to removal/disposal work starts. If any discharges are planned this will be subject to a discharge permit application. In the cleaning processes, the objective is to use minimum of chemicals, and base the work on steam or a “recycling cleaning” process.

As mentioned in Section 7.1 dismantling of topside modules will be performed at a demolition site according to relevant procedures and regulations. These yards are constructed with

proper drainage and collection systems to prevent discharge of any oils, chemicals etc. to surrounding environment. No discharges are thus expected from these operations.

The waste generation will be handled according to local and national waste regulations in the respective site. Deposited waste (e.g. isolation and building materials such as plastic, wood, gypsum) from this dismantling process is considered more or less inert, and potential seepage water from the landfill sites due to this waste is expected negligible. Some metals could in the long run be released and form part of the seepage water. Landfills are however required to have leachate water monitoring and control systems to avoid discharges of contaminated seepage water.

7.2.4 Physical Impacts to the Environment

The physical environmental impact in removing the topsides is considered as “insignificant”.

The only issue identified with relevance to possible physical effects is impact of anchors on the seabed during lifting (if not working on dynamic positioning).

7.2.5 Aesthetic Impacts

Alternative A - Removal of topsides and onshore disposal

Aesthetic impacts from the process of removal and onshore recycling and disposal of the topsides are found to be “moderate negative”.

Potential areas of concern, which have been identified and assessed, are:

- Visual impacts
- Noise

Due to the geographical location, the offshore part of the dismantling work is not viewed as a disturbing factor with regard to noise or any other aesthetic effect.

As the topside is transported to an onshore dismantling site, the visual effects could be perceived negative for the inhabited areas in the vicinity of the dismantling yard. There is no scientific documentation identified on this issue, however any effect will be temporary and is considered insignificant.

The negative aesthetic impacts from dismantling of the topsides are principally associated with noise. Materials being dismantled in a demolition site are expected to lead to some noise load to people in the local community. As an ordinary industrial activity, this will be included in existing permits and concessions. Nevertheless, results from different noise surveys taken at different Norwegian industrial sites engaged in similar activities, indicate that it is important to ensure a physical distance to the nearest neighbours [36].

As for other typical industrial noise, the potential for reducing the effects of dismantling the topside modules is considered to be significant. Efforts should therefore be made to reduce the noise connected to these operations.

The total aesthetic impact of removing and demolishing the topsides is expected to be “moderate negative”. Noise due to dismantling is the most important factor. TOTAL NORGE will make contractual arrangements with the demolition contractors to ensure that possible negative effects are mitigated.

Option – Partial offshore and onshore removal of topsides on concrete platforms before onshore disposal

This option involves more operations performed near shore compared to alternative A. Since the aesthetic impacts are mainly related to the onshore/near shore operations, the aesthetic impacts of this alternative will be slightly higher from the previous alternative. No quantification is made, but the operations associated with removal of more topside modules onshore, will last for a longer period, and possibly create more noise in an exposed area than the base case alternative.

7.2.6 Material Management

Since most materials from removal and onshore recycling and disposal of the topsides will be recycled the impacts are found to be “large positive”. The material assessment is based on detailed material inventories for every single installation [74].

Dismantling sites for the different topsides and substructures have not been chosen, hence the evaluation of waste/resource utilisation will concentrate on types and amounts of waste generated.

Types of waste considered are:

- Metals
- Concrete
- Wood
- Other building and construction material
- Insulation material
- Electrical and electronic waste
- Plastic products including flooring
- Paint
- Asbestos
- Anodes

Dismantling the topsides will generate considerable amounts of materials.

The different types of waste expected to be on the topsides are described Table 7.4.

As presented in the introduction, all systems will be purged and/or cleaned, and certified on cleanliness prior to offshore dismantling activities start. There will therefore not be hydrocarbon residues in utility systems, tanks etc. As part of this work halons, freons, fluorescent tubes and other items containing listed substances will also be removed for onshore treatment and disposal. As Frigg is a gas field no LSA (Low Specific Activity) scale material has been observed in the Frigg process systems. However, in module 35 on the Norwegian platform TCP2 treating oil and gas from Frøy, limited amount of LSA should be assumed.

The possibility for having lead isotopes in the gas stream was previously considered by TOTAL NORGE. It was considered unlikely and no further investigation was made.

TOTAL NORGE has established objectives with regard to recycling of materials [37]. These objectives for topside materials are presented in Table 7.4. “Expected recycling” reflects obtainable degree of recycling based on today’s technology.

Material	Amount (tonnes)	Recycling % - Expected
Carbon steel	45 134	95
Stainless steel	365	95
Copper	154	90
Aluminium	2.2	95
Titanium	34	95
Concrete	166.5	30
Plastics	269.2	20
Wood	0.4	80
Insulation	267.5	0
Glass		50
Furniture		40
Total	**46 393**	

Table 7.4 TOTAL NORGE objectives for recycling topsides materials.

Metals

The main materials on the topside are metals, notably steel, copper and some aluminium. In addition, nickel cadmium and zinc may also be present in minor amounts in alloys.

Material recovery of different kinds of metals have been an industrial topic for a long time, and sorting, handling and sale of these materials is well organised.

It is assumed that the main part of steel on the topside will be remelted (see Table 7.4). Any steel with coating, such as painted steel, may cause problems for the remelting plant. Emissions of toxic gasses, dust of heavy metals and contaminated slag during remelting are challenges met regularly by the industry. Emissions and waste-production are situations handled by concessions from local or national authorities.

Copper is mainly found in cables. In cables used offshore the content of metal is approx. 30-40%, and the rest 60 – 70 % is plastic material. Techniques for dividing metal from plastic materials have been established. The cables are cut and separated in a process using the specific gravity of the different kinds of metals and plastics. The metal (copper, aluminium and lead) is melted, while the plastic material will either be recycled, disposed on a landfill site or used as an energy source in combustion. 20% of the plastic is expected to be recycled [37]. There is a strict regulation of combustion processes, especially processes burning chlorinated plastics – which may create dioxins.

Aluminium is a part of the construction structure on the topsides, and will normally be recovered by the aluminium producers. 95% recycling of aluminium is expected [37].

Batteries are used for different purposes on the topside, for instance in all emergency lightning. Nickel and cadmium are parts of these batteries, and these metals will be remelted and recovered.

Some batteries also contain acid, and these will have to be treated as special waste when disposed of at approved receivers.

Concrete

On topsides, concrete is mainly used in the screed coats and is two-component concrete. The thickness of this concrete varies between 27 mm and 50 mm, depending on range of use of the floor. Areas with tiles often have a thinner layer of screed than areas covered by vinyl or carpet. Concrete from the topsides will most probably go to landfill as it may be contaminated with other materials. If clean, some parts may be reused as road fill or as raw material in new concrete. 30% of the concrete is expected to be recycled [37].

Other building and construction material

This material is mainly contained in panelled ceilings, doors and windows, and most often found in housing areas and analogous materials used in control rooms and compressor rooms. The walls contain painted steel plates isolated by mineral wool and an interior film of aluminium.

Reuse of this building and construction material is not considered likely. As these buildings and construction materials are made up of many different components, the recovery process may be a challenge to the contractor due to dismantling and sorting of the different materials.

Metal plates may be separated from the other materials and be recovered by remelting, but the main part of this material may not be reused and are disposed on landfill sites.

A coarse estimate on disposal of the different types of building and construction material, gives that 10 % will be recovered, 10 % will be used as energy source and 80 % will be disposed.

Insulation material

External walls in the housing areas and some of the walls in the modules contain insulation materials, mainly different kind of Rockwool-products. Some insulation may also be present on pipes and pressure vessels. Materials such as insulation and construction materials have a restricted reuse potential and will therefore normally be disposed of on a landfill.

Electrical and electronic waste

Accredited receivers of electrical and electronic waste have well established practices on shore, and these can receive the material from the installations. Computers, TV's and other electronic components will be removed prior to cold phase. Electrical waste as electrical equipment, instruments, cables and equipment for telecommunication, is a complex group and spread over most of the topside. Main part of the electronic material is cables, and these may be recovered as described under metals.

Electrical equipment contain heavy metals, and this will make the recycling process more complicated. The heavy metals will have to be removed prior to an automatic crushing of the electrical equipment.

Fluorescent tubes will have to be treated as special waste, and will have to be delivered for special treatment to accredited receivers.

A coarse estimate gives that 70 % of the electronic waste that is not directly reused, will be recovered. 20 % of the electronic waste will be used as an energy source and 10 % will be disposed on a landfill site.

Plastic products including flooring

Plastic is a mixture of many different components, and only minor amounts of this material may be reused. There exists a limited marked for reuse of this material, e.g. using plastic granules in the foundation on racetracks.

Clean fractions of plastic may be milled to granulates which may be combusted and used for energy recovery.

Plastics are today normally disposed of. However, as the energy content in this product is high, solutions to recover the energy in this type of waste are under development.

Of the total of both plastics and flooring, it is expected that 20 % will be recovered or used as an energy source. The rest will be disposed on a landfill site.

Paint

Different types of paint have been used on different parts of the topside, and the paint systems have developed through the years. This fact makes it difficult to get an overview of the contents of the residual paint, and possible heavy metals or other potential hazardous substances.

Paint will very seldom be removed prior to remelting and will follow the steel to the smelter (see above).

Paint and other kinds of coating may be removed by sandblasting prior to remelting, but this is an expensive process. In addition the used sand will have to be treated as special waste, due to its high content of minerals and various chemicals from the paint.

It is likely that a 50 microns layer of polyurethane paint has been used as topcoat in epoxy-paint systems on parts of all Frigg Field installations during the 1980's. Since then, it has not been used at the field. When steel items covered by polyurethane paint are heated by *e.g.* cutting it is known that such thermal process will cause the release of isocyanates.

Isocyanates could cause serious harmful effects to humans when breathed in (e.g. asthma, bronchitis, impaired lung function [38]). The situation should be monitored and proper health protection equipment should be used.

The demolition works both offshore and onshore should therefore be performed within the national rules and regulation for such activities. This type of paint is used in some areas only. Table 7.5 indicates where polyurethane paint is most likely to be found on Frigg-Field platforms.

UK installations			Norwegian installations	
QP	CDP1	TP1	TCP2	DP2
- Equipment - Over splash zone**	N/A*	- Equipment - Over splash zone** - Risers above water	- Equipment - Over splash zone** - Structure in columns below water - M50 module and equipment - Risers below water, above water and in tidal zone - J-tubes -	- Equipment - Over splash zone** - Tidal zone - Structure

* Information describing the usage of polyurethane paint on CDP1 is not available. It should still be assumed that such paint was used on the platform.
** Area between the level located 0.5m below the first horizontal wind bracing and top of the structure.

Table 7.5 Places where isocyanate containing paint might have been used.

PCBs might have been used in accumulators, capacitors, etc. A survey will be performed to check this issue. Any PCB identified will be collected and managed according to national regulations.

Asbestos

Material containing asbestos may have been used in the following areas on a topside:

- Fire walls – floor and roof
- Plates used for walls, floor and roof
- Interior insulation in gaskets, walls, roof and floor
- Insulation of pipes and vessels
- Piping systems and valve inserts/ weather stripping
- Weather stripping in fire doors
- Coating of pipelines on the seabed
- Brake bands and clutch plates

Asbestos is often combined with other building materials, and any removal of the asbestos from the building elements so as to recycle the latter would demand significant expenditure of resources, be difficult to achieve, and involve great risk to health.

Building materials, insulation materials and similar containing asbestos must be handled separately according to strict guidelines. When working on asbestos contaminated material special precautions must be taken and only certified personnel can undertake this work. Asbestos materials are classified as special waste and must be delivered to an accredited reception facility. Once delivered, materials containing asbestos are disposed of in landfills.

It is likely that the asbestos existing on the topside will have to be disposed of at licensed waste disposal sites in accordance to strict requirements. From analyses and assumed hidden sources it represent an the order of 20-30 tonnes (note that this represent the total weight, e.g. in case of a fire door containing asbestos as fire isolation, the weight of the complete door is recorded). Table 7.6 gives an overview of the amounts of the different kinds of materials/waste on the topsides on each platform.

Materials	UK installations			Norwegian installations	
	CDP1	TP1	QP	DP2	TCP2
Carbon steel	5 865	7 492	3189	5142	23 089
Stainless steel	21	13	90	17	148
Copper	11	30	15	9	68
Copper/Nickel	3	2.5	4,2	3	26
Copper from cables	NA	30	NA	NA	NA
Aluminium	NA	0	2,149	0	0
Zinc	NA	0	NA	0	0
Titanium	NA	NA	NA	NA	26
Concrete	614	0	76	53	25
Fire protection concrete	NA	2.8	NA	NA	NA
Paint	NA	0	0	0	14
Plastic	13	38	16	11	87
Halon	0	0.4	0.5	0.1	4.4
FM200	1		NA	0.9	NA
Floor covering	13		26	11	25
Batteries	0	9 banks + 1000 Ni Cd	16 batteries	356 cells	21 banks
Construction materials incl. floor covering	34	6.5	70	20.5	141
Electrical, and el-equipment	223	393	151	212	988
Fluorescent tubes	0	1 180	1 200 pc	960 pc	5 400 pc
Cooling medium, Freon 22	0	0	480 l	0	120 l
Asbestos	5 -10*	<0.1	18.6	6.4	<0.1
Total	**6 823**	**8 054**	**3 638**	**5 480**	**23 710**

*Assumption made based on data for topsides from same period of time, as CDP1 is not surveyed for asbestos.

Table 7.6 Topsides component weight breakdown (in tonnes).

Halon and freons will be collected, handled and delivered for destruction according to Norwegian and UK regulations.

Figure 7.2 gives an indication of the weight percentage distribution of waste management for the topsides.

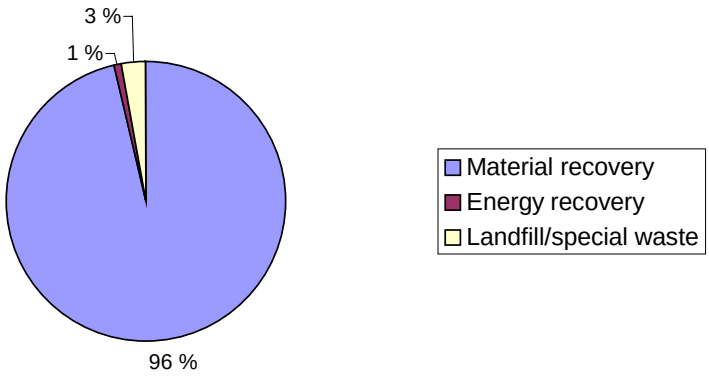

Figure 7.2 Material management for the topsides indicating maximum amount for recycling.

7.2.7 Littering

For topsides removal offshore there is no littering problem, and the field will be swept for debris when disposal work is completed. Onshore there will be waste handling systems and procedures in place to avoid any form of littering.

7.3 Social Impacts from Disposal of Topsides

7.3.1 Impacts on Fisheries

Impacts on fisheries from removal of the topsides are considered to be “insignificant”. No split between alternative A and the optional method is found necessary.

Both alternatives for removal of the topsides involve marine operations for a period of time in the Frigg area. The majority of this activity will be within the safety zones of the installation (field), and will not affect any fishing vessels.

7.3.2 Impacts on Free Passage

As long as the substructure still stands, and will be properly marked, the removal of the topsides has no/insignificant impact on the free passage. Today's presence of the platforms poses a risk of collision with passing ships.

The removal of the topsides implies an increased level of maritime operations in the Frigg area. The operations will mainly take place within the 500m exclusion zone around each of the installations. Duration of work will be in the order of one week per installation. The topsides will be transported to shore on barges or at the lifting vessel, and then moored at shore, lifted or pushed ashore.

Though the removal of the topsides implies an increased frequency of vessels going to and from the Frigg Field, the operation, including the duration of tow to shore, is not expected to have any practical impact on the free passage of the area.

A possible increased risk of collision with substructures with no topside is studied as part of the substructure assessments.

7.3.3 Costs and National Supplies (goods and services)

Only one solution for the topsides on Frigg has been studied: removal of the five topsides for demolishing, recycling and potential reuse. The total costs of offshore removal and onshore disposal of the topsides are estimated at about 2040 MNOK / £156m.

The plan includes offshore removal and onshore disposal of DP2 topside and TCP2 topside on the Norwegian side and CDP1 topside, TP1 topside and QP topside on the UK side. In this impact assessment it is assumed that the platforms on the Norwegian side will be taken to shore in Norway and the topsides on the UK side will be taken to the UK.

The Table 7.7 summarises the costs split per country.

Topsides	Installations in UK			Installations in Norway		All
	CDP1	TP1	QP	DP2	TCP2	
Cost	£45.4m	£24.2m	£21.1m	250 MNOK	647 MNOK	2083 MNOK / £159.3m
Cost split by nation	£90.6m			898 MNOK		

Table 7.7 Alternative A - Offshore removal and onshore disposal of topsides: Costs in 2002-value, exchange rate: 13.08 NOK/£.

If the concrete substructures are refloated and taken to shore, the topsides on the concrete substructures (CDP1, TP1 and TCP2) will be removed onshore. The total cost of removing the topsides will be about 1570 MNOK / £120m.

Based on expected Norwegian and British supply the national employment effects can be estimated.

The Norwegian content is estimated at 40% of the total supply. The UK content is estimated at 28%.

Figure 7.3 shows the Norwegian and UK content broken down into industries, which can potentially supply deliveries directly to the topsides project.

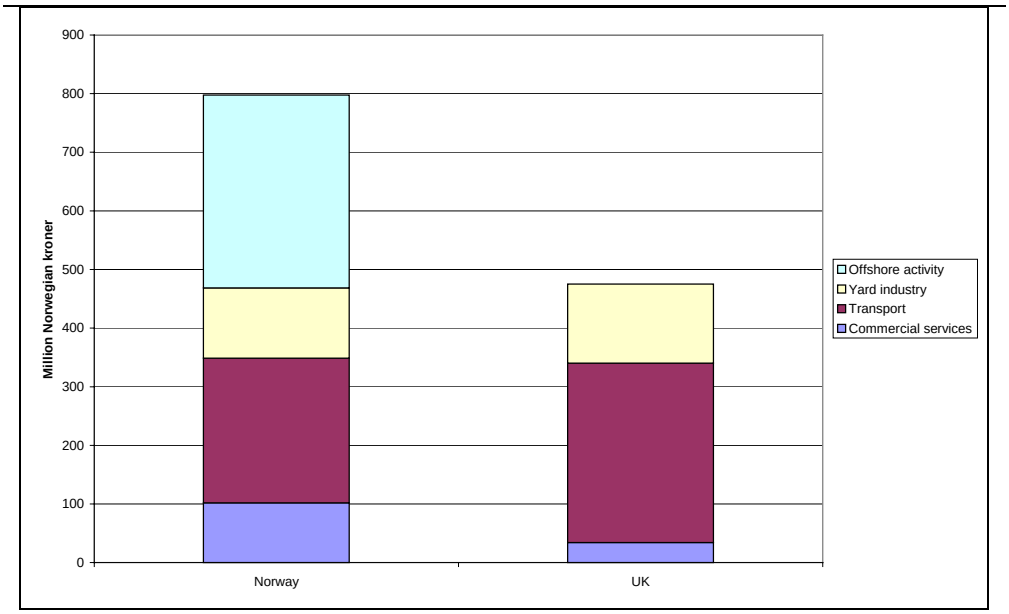

Figure 7.3 Frigg topsides. Norwegian and UK content (first level), broken down by industry (in MNOK)

The largest Norwegian and UK contracts are expected to be for the transport industry. Hire of a flotel, catering, helicopter transport, supply vessels, standby vessels, survey vessels, and towing operations are the main components of the contracts that will go to the transport industry. Offshore activity embraces TOTAL NORGE's project management and support. Yard industry in Norway and UK will carry out the work associated with preparing the topsides prior to lifting off, as well as the demolition and recycling work on shore. Commercial services include engineering design and consultancy.

Assuming a price of 400-600 NOK / £30 - £46 per tonne of recycled steel from the Frigg topsides, this will give an income in the range of 18-27 MNOK / £1.4m – £2.1m. Recycling the copper could result in an income of 1-2 MNOK / £76,000 - £153,000.

7.3.4 Employment Effects

Based on an industry breakdown of expected Norwegian and UK supplies the national employment effects have been estimated. The goods and services will be supplied directly and indirectly to give production effects at the national level in Norway and in UK.

Production effects in Norway are expected to total about 1,100 man-years from the offshore removal and onshore disposal of the topsides. Production effects in UK are expected totalling 550 man-years.

Figure 7.4 below shows the industry categories that may benefit from the production effects in Norway and in UK.

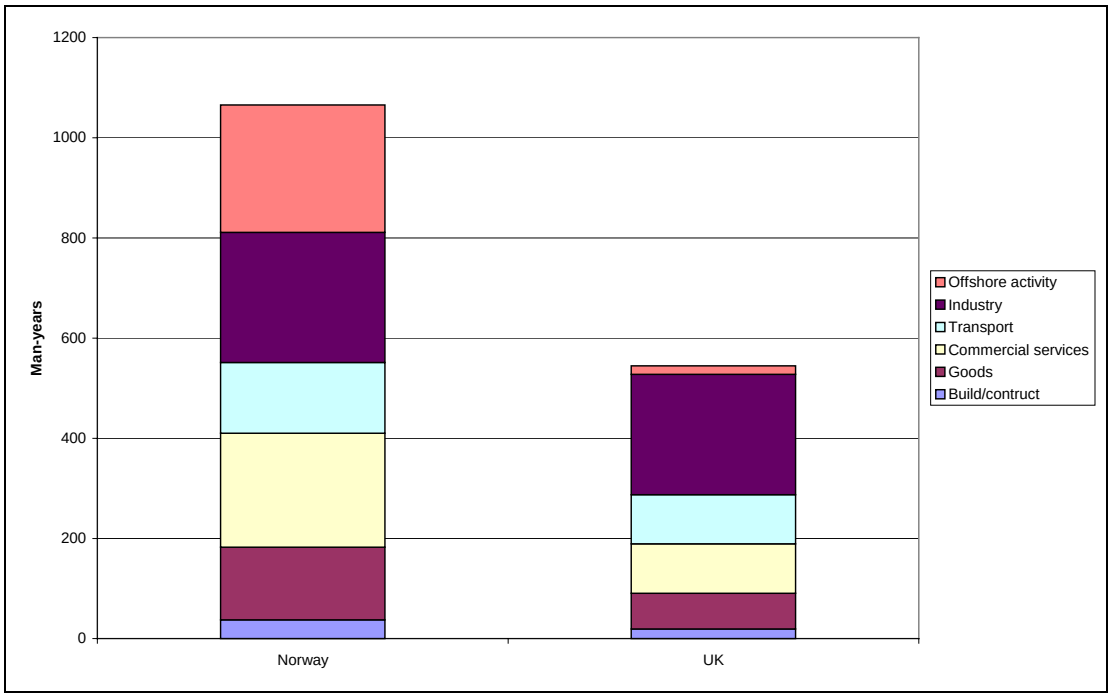

Figure 7.4 Frigg topsides – Norwegian and UK production effects broken down by industry (man-years).

In the above figure, commercial services include engineering and studies, and offshore activity includes operators project management and support.

A large part of the production effects is expected to come from yard industry. The work associated with preparing the topsides prior to lifting off, as well as the demolition and recycling work on shore can give production effects in the yard industry in Norway and in UK.

Consumer effects totalling about 50% of the production effects will also occur. The total employment effects in Norway are estimated to reach about 1,600 man-years and about 800 man-years in UK.

The employment effects will be spread over the years in which the removal, demolition and recycling phases will take place. The basic engineering is planned to start in 2002. The offshore removal of the topsides of the two steel platforms and three concrete platforms are planned to take place between 2007-2010. The onshore disposal will start when the facilities arrives onshore.

The schedule for undertaking the recommended activities are presented in Part 1 – Disposal Plan in this Cessation Plan, Section 15.

7.4 Summary - Topsides

For topsides there is only one disposal alternative, namely complete removal. There are however operational differences in methods that can be applied to reach this ultimate end point. The differences in environmental impacts for the options are considered minor, and only results for Alternative A are presented below.

	Alternative A Steel and concrete platform topsides Removal and onshore disposal
Energy Consumption (1000 GJ)	730
Total Energy Impact (1000 GJ)	730
CO_2 emissions (1000 tons)	63
Discharges to sea	None/ insignificant
Phys./habitat effects	None/ insignificant
Aesthetic	Moderate negative
Material management	Large positive
Littering	None/ insignificant
Impacts on Fisheries	None/ insignificant
Impacts on free passage	None/ insignificant

Table 7.8 Environmental Impact of Removal and Onshore Disposal of topsides from Steel and Concrete Platforms.

Alternative A is estimated to require energy consumption in the order of 730,000 GJ. No calculations are made for the inshore alternative for concrete structures.

The CO_2 emissions from the entire removal process are estimated to be above 60,000 tonnes, including the metal re-smelting. This corresponds to 0.25% of the annual offshore emissions from the UK in 1998 and 0.7% of Norwegian offshore emissions in 1999 [35].

Aesthetic impacts are considered moderate negative and are related to noise. Such issues are part of the yards' operating permission, and impacts should not be worse than corresponding effects from similar activities at the yard.

Since the majority of materials on the topsides will be reused or recycled the alternatives are performing well on the "waste/resource" issue. A large positive impact is quoted.

There are no identified significant negative effects on fisheries or free passage.
The impact on national supplies and employment for removal, demolition and recycling the topsides are summarised below.

	Norway	UK	Total
Costs	898 MNOK	£90.6m	2083 MNOK / £159m
National supplies	816 MNOK	£43.6m	1387 MNOK / £106m
Employment effects (man year)	1600	800	2400

Table 7.9 Summary of social impacts from removal of topsides of the Frigg Steel and Concrete Platforms.

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8 Impact Assessment for Disposal of Steel Substructures

8.1 Description of Disposal Arrangements for Steel Substructures

Steel Platform Substructures	**Alternative A** Removal and onshore disposal

Table 8.1 The disposal arrangement considered for the three Steel Substructures

The 3 steel substructures (QP, DP2 and DP1) will be taken to shore for demolishing and recycling, in accordance with the OSPAR Decision 98/3. With the exception of reuse alternatives no alternative disposal solution is assessed.

Figure 8.1 Steel Substructures on Frigg Field

Removing the substructures can be accomplished by cutting it in several pieces, either hoisting each individual part onto a barge or placing parts on the deck of the lifting vessel. The cutting can be done by the aid of a remotely controlled diamond-wire saw fixed to a ROV. The piles of the foundations will be cut 1-3 meters below the seabed in order to assure no debris sticks out above the seafloor.

It is planned to remove the wrecked DP1 steel substructure by cutting it into 5 parts, before lifting on to a barge and transportation to the disposal destination. Because this is a comprehensive operation, alternatives including explosives have also been taken into consideration.

Typically, preparation and removal of each of the steel substructure are estimated to be completed within one-two months. Upon arrival at the quay the steel substructure units will be lifted or pushed on to shore. At the demolition site, breakdown into items suitable for recycling will be performed according to relevant procedures and regulations. Marine growth will be removed prior to demolition, offshore or onshore. If removed onshore, the material will most probably be landfill.

8.2 Environmental Impacts from Disposal of Steel Substructures

8.2.1 Energy

Alternative A – Removal of steel substructures and onshore disposal

The energy impact for removing and onshore recycling of the steel substructures is found to represent a "small negative" impact, based on the impact key presented in section 3.3.2.

The alternative of onshore steel substructure disposal has an individual and total energy impact as shown in Table 8.2. The main component of the energy impact is the operation of vessels offshore, contributing with more than 50% of the total energy expenditure.

590,000 GJ correspond to the annual fuel consumption of about 15,000 family cars.

Operation	Steel substructures on UK installations	Steel Substructures on Norwegian installations		All Steel Substructures
	QP	DP1	DP2	
E_{DIR} Marine operations	91 000	119 000	123 000	333 000
E_{DIR} Dismantling	6 100	8 300	16 900	31 300
E_{REC} Recycle of metals	43 600	66 500	121 000	231 100
E_{CONS} Energy Consumption	**140 000**	**194 000**	**260 000**	**594 000**
E_{REP} Energy for replacing the materials		0	0	
E_{TOT} Total Energy Impact	**140 000**	**194 000**	**260 000**	**590 000**
E_{TOT} Total Energy Impact split on nation	**140 000**	**450 000**		

For key of terms, see explanation of energy calculations See Section 3.3.2.

Table 8.2 Total energy impact for the removal and onshore disposal of steel substructures (in GJ).

8.2.2 Emissions to Atmosphere

Alternative A – Removal of steel substructures for onshore disposal

Emissions to atmosphere from removing and onshore recycling the steel substructures are found to represent a "small negative" impact.

Emissions from the alternative of onshore recycling of the steel substructures are calculated and shown in Table 8.3. The total CO_2 emissions from the operations and final disposal are some 50,000 tonnes. The emissions from the marine operations are about 24,000 tonnes.

Compared with the emissions from the Frigg area in one year, removal of all topsides represents 7-13%, 20% and 14% for CO_2, NO_X and SO_X respectively (cf. statistical data in Section 6.5 in the EIA).

Operation	Steel Substructures on UK installations	Steel Substructures on Norwegian installations		All Steel Substructures
	QP	DP1	DP2	
CO_2 emissions				
Marine op./ dismantle	6 700	8 700	9 000	
Recycle of metals	4 600	6 900	12 800	
Total per substructure	**11 300**	**15 600**	**21 800**	
Total split on nation	**11 300**	**37 400**		**48 700**
NO_X emissions				
Marine op./ dismantle	124	160	167	
Recycle of metals	8	11	21	
Total per substructure	**132**	**170**	**190**	
Total split on nation	**132**	**360**		**492**
SO_2 emissions				
Marine op./ dismantle	6	8	8	
Recycle of metals	19	31	54	
Total per substructure	**25**	**39**	**62**	
Total split on nation	**25**	**101**		**126**

For key of terms, see explanation of emissions to atmosphere See Section 3.3.2.

Table 8.3 Total emissions to air for removal and onshore disposal of substructures (in tonnes)

8.2.3 Discharges to Sea, Water or Ground

Alternative A – Removal of steel substructures and onshore disposal

The environmental impacts from discharges and secondary effects during removal and onshore recycling are found to be insignificant with the exception of processes disturbing the cuttings layer beneath DP2. This disturbance could lead to “moderate negative” impacts if not properly mitigated.

Potential areas of concern, which have been identified and assessed, are:

- Marine growth
- Removal of sediments (spreading of hydrocarbons, metals and fine particles)
- Discharges from onshore dismantling

The majority of marine growth will be removed in a dry dock/industrial site onshore and the discharges to the sea due to this cleaning are limited. Estimated amount of marine growth on the steel substructures is 850 tons when still wet. Dried material for possible disposal is considered to be 10-30% of this.

Cutting of legs can be performed in different ways, and with different types of impacts potential for the environment. All piles are planned to be cut 1-3 metres below seabed level. If the legs and piles are to be cut from outside, removal of surrounding seabed sediments will be necessary. This can be done by use of a mud hose, and might cause considerable disturbance of sediments or drill cuttings deposits (DP2). Cutting of the legs from inside by a water jet will not cause such disturbance.

Parts of the bottom bracings of the steel substructures are partly buried in the seabed. Excavation around these bracings must be performed to a level that suits the external cutting tool. This final operation will cause a local re-suspension of sediments, which cause redistribution of particles and a temporarily deterioration of water quality (see illustration in Figure 8.2). For DP2 there is also the cuttings layer to consider. If this is still in place when the substructure is being removed, this may enhance release of contaminants to the surrounding water masses. The impact is considered “moderate negative”.

Onshore the dismantling of the substructure will most likely be performed in a dock or yard with containment systems. Any discharges will be collected and managed. No discharges are expected to sea, water ground/water table from the dismantling onshore.

Both steel and anode material will be recycled/reused.

During the dismantling, the marine growth has to be removed to avoid smell as it decomposes. The growth can be removed by high pressure water jetting, and the material may be deposited, possibly be composted and used as a fertiliser. Experiences from previous projects (e.g. Odin) indicate that it is simply land filled. Water jetting may release some underlying paint making the material unsuitable for common landfill. The material will thus be analysed for heavy metals prior to disposal.

8.2.4 Physical Impacts to the Environment

Alternative A – Removal of steel substructures and onshore disposal

The physical impacts from removing the steel substructures are found to be “insignificant to small negative”. The uncertainty is related to possible impacts associated with disturbance of the drill cuttings layer beneath DP2.

When the steel substructure is to be removed it will be cut in units and lifted out. The bottom piece of the substructure will be cut below the seafloor prior to lift-off.

The cutting operations will be performed using a remotely controlled diamond wire saw. The metal fragments from the cutting will spread in the water column before sinking to the seafloor. Mainly consisting of iron, these particles are expected to corrode and disintegrate within relatively short time, and hence this does not amount to any negative physical impacts.

The last cutting of the legs will occur 2-3 meters below the seafloor. If cut from outside this necessitates the removal of sediments around the legs in order to complete the cutting. The situation is illustrated in Figure 8.2. It is roughly estimated that as much as 2,000m^3 of sediment per substructure have to be removed to allow for the cutting of substructure foundations (piles).

It is likely in practice that the sediments will be resuspended around the legs, and create some turbidity. This turbidity is known to cover the breathing functions (gill and skin) and feeding functions of local organisms (e.g. [39, 40]). The effect is consider local and of little significance. The ditches created when relocating the sediments will most likely be back-filled as part of the operation. This digging operation will anyway result in the mixing of surface layer material with sediments from some meters down in the seabed.

After removal the seabed in the area within some tens of meters from the installation will be markedly changed with regard to sediment composition and quality. The sediments in the area are, however, considered quite homogenous and the effect on sediment composition will be minor. With regard to contamination in the top layer this mixing will generally dilute it, and as such improve the situation compared to the present.

The sediments at Frigg are only slightly contaminated. The exception is below DP2 where there are some residual cuttings and some elevated concentrations of especially hydrocarbons. Based on the above considerations, digging in these low contaminated sediments is evaluated to have “insignificant” to “small negative” physical impact.

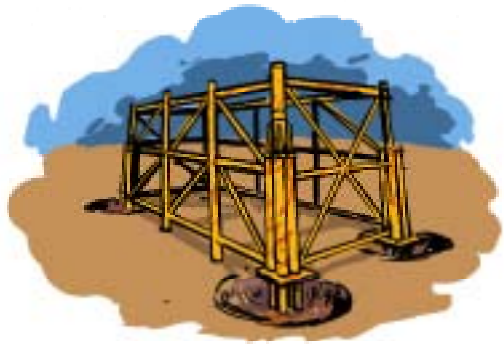

Figure 8.2 Illustration indicating pits around the legs of the steel substructure prior to cutting the steel piles.

8.2.5 Aesthetic Impacts

Alternative A – Removal of steel substructures and onshore disposal

Aesthetic impacts from the process of removal and onshore recycling and disposal of the steel substructures are found to be "moderate negative".

Potential areas of concern, which have been identified and assessed, are:

- Visual effects
- Smell
- Noise

As for dismantling the topsides, all of these factors will be regulated by local concessions and permissions. Construction and dismantling activities will be the normal operations at such yards, and the steel structures will thus not represent something new or unique to their normal business.

During dismantling onshore, storage, and final disposal of the steel substructures, visual effects may contribute to negatively perceived impacts for inhabited areas (if any) nearby the dismantling site. However, when performed in an already industrialised area the visual impacts from such an activity are considered insignificant.

Most of the marine growth will be removed onshore. Smell from the decomposition of marine growth may cause problems in inhabited areas in the vicinity of the dismantling yard. The marine growth can be removed by high pressure water jetting. The potential effect is dependent on the extent of marine growth, temperature and duration between being exposed to air, dried and being removed/disposed of. The potential effect of the smell depends on the local population pattern. If the area is highly populated or commonly used for recreation, the smell could have considerable effects for the local area.

The dismantling process will last for several months for each of the substructures. During this period, noise is expected to have the most significant potential for negative impact.

Depending on the location of the dismantling site, the total scale of the negative aesthetic impacts will vary. If a location of low aesthetic value is used, and if noise-abatement measures are implemented, then the magnitude of the aesthetic impacts will be considerably reduced. Possible abatement measures could be to limit operations to normal daytime hours, to execute work in dry docks or other sheltered areas, etc.

8.2.6 Material Management

Alternative A – Removal of steel substructures and onshore disposal

Since most materials from removal and onshore recycling and disposal of the steel substructures will be recycled the impacts are found to be "large positive".

TOTAL NORGE has established some objectives with regard to recycling of materials [37]. These objectives for steel substructure materials are presented below.

Material	Amount(tonnes)	Recycling % - Expected
Carbon steel	25 434	100
Aluminium	344	98
Zinc	4	98
Concrete	2 039	80
Total	27 821	97

Table 8.4 TOTAL NORGE objectives for recycling steel substructure materials.

All of the steel will be remelted. The percentage recycling is based on the present knowledge as given by specialised companies in this reuse/recycle business. As the reuse/recycle methods is expected to evolve in the near future more ambitious targets for reuse/recycling could be established and specific objectives made for different material categories.

The substructures of various installations are protected from corrosion by aluminium or zinc based sacrificial anodes. All materials from the anodes are expected to be re-melted and recycled, i.e. a negligible amount of waste will be generated.

There are also some concrete plugs inside the substructure piles. This amounts to about 2,000 tonnes, the majority of which is expected to be reused as fill material.

The exact composition of the paint used on the steel substructures is not known. Sampling has been undertaken at Frigg (in biota) to analyse for possible PCB. No traces have been found in biota. Traces have been found in sediment, however, and these have been compared with known standards in order to track the source [75]. No clear answer was found, however paint from ships is indicated as a possible source.

Marine fouling could cause problems when the steel substructures are removed and dismantled onshore. The marine growth consists mainly of mussels and anemones, and some barnacles and algae. The greatest volume of growth will be in the upper 10-30 metres due mainly to the light and water temperature at this depth. Marine fouling can be removed mechanically from steel panels using a jet hose or similar. The harder calciferous deposits (barnacles, etc.) could also be scraped off. Due to dismantling the steel substructure onshore, the marine growth will be gathered after removal. The material may be deposited or possibly composted and used as a fertiliser[4]. On a landfill site the marine growth may be a part of the composting preparation. The potential for reuse depends on the quality of the material. Samples of marine growth from Frigg have been analysed for heavy metals [76]. Levels of chromium, copper, zinc, cadmium and lead have been found above the SFT environmental indicator class I [80] for both mussels and seaweed. Such contamination may form part of leachate from a landfill, and will also exclude the material for use as fertiliser [77, 78]. This also gives some indication about the potential exclusion of the material for use in compost.

[4] The feasibility for use as fertilizer will depend on the composition of the growth. Especially the fauna consist of proteins which are not suitable for composting processes [41].

Associated paint removed with the growth may also make it unsuitable for composting. Analysis will be made prior to any disposal.

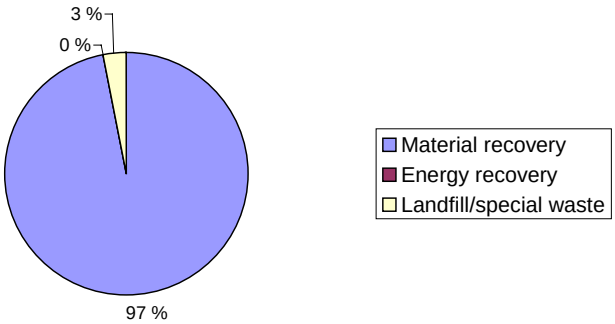

Figure 8.3 Material management for Steel Substructures (weight in %)

8.2.7 Littering

No littering impacts are foreseen from removing the steel substructures.

A clean-up operation of the field after disposal of the installations is mandatory, as described in the Part 1 - Disposal Plan in this Cessation Plan, Section 12.The surrounding seabed will be cleaned for any kind of litter employing sonar, ROV's and cranes. The litter could be components or parts of the installation that have fallen off in previous events, or tools, wires etc. from the decommissioning work.

8.3 Social Impacts from Disposal of Steel Substructures

8.3.1 Impacts on Fisheries

Alternative A – Removal of steel substructures and onshore disposal

The magnitude of positive impact on fisheries from removal of the steel substructures will to some degree depend on disposal of other field installations. The impact from removing the steel substructures is considered "moderate positive".

The area made available for fisheries by removing single installations will be limited if other installations at the Frigg Field are left in place. The corresponding effects on fisheries of removing single substructures are therefore regarded as limited.

This follows from the presumption that fishing vessels will avoid the area if other obstacles, like concrete substructures are present. The significance of removal of all steel substructures to the fisheries will therefore be dependent on the preferred alternatives for these structures.

If removal of the steel substructures is part of removing all the installations on Frigg, this will make an area of about 3 km^2 available for the fisheries in this area. If all hindrances on the seabed are removed from the field the consequences of Alternative A may be characterised as "moderate positive" to the fisheries in the Frigg area (i.e. medium effect and medium value area – cf. Section 3.3.1 in this EIA).

The use of the steel substructures as an artificial reef at Frigg was studied [42], however, no positive effects were foreseen.

8.3.2 Impacts on Free Passage

The impact on passing ships from removal of the steel substructures is considered “moderate positive”.

Today's presence of the platforms poses a risk of collision with passing ships.

The distance from the outlying installations (CDP1, DP1 and DP2) to the Frigg Central Complex is 400-700m and thereby the ship collision risk is assumed to be similar for these installations.

Removing the steel substructures includes extensive use of a lifting vessel, barges and tugs. The tasks will however be performed within the safety zone.

The substructures will be towed to shore on the deck of the lifting vessel or on large barges, with the aid of tugs. Each tow is estimated to last one day, and the impact on free passage is evaluated to be “insignificant”.

Removing the 3 steel substructures (DP1, DP2 and QP) eliminates obstacles in the shipping lane, and eases traffic for passing ships such as fishing vessels. Thereby the removal of the steel substructures is evaluated to have a positive impact on the free passage of the area. The value of this impact is difficult to estimate, but based on the traffic in the area and the small existing risk, the value is considered as “moderate positive”.

8.3.3 Costs and National Supplies (goods and services)

The total costs (for disposing the steel sub-structures) are estimated to about 1032 MNOK / £79m.

Table 8.5 gives the costs of the removal and onshore disposal of the three steel substructures, split by country.

Steel Substructures	In UK	In Norway		All Steel Substructures
	QP	DP1	DP2	
Cost	£21.1mm	330MNOK	447 MNOK	1053 MNOK/£80.5m
Cost split by nation	£21.1m	777 MNOK		

Table 8.5 Costs for removal, dismantling and onshore disposal of Frigg Steel Substructures, given in 2002-value, exchange rate 13.08 NOK/£.

Based on expected Norwegian and UK supply the national employment effects can be estimated.

The Norwegian content is estimated at 38% of the total supply. The UK content is estimated at 8%. The remaining 54% will then be supplied by industry from other nations.

The Figure 8.4 shows the Norwegian and UK content broken down into industries which can potentially supply deliveries directly to the substructure project.

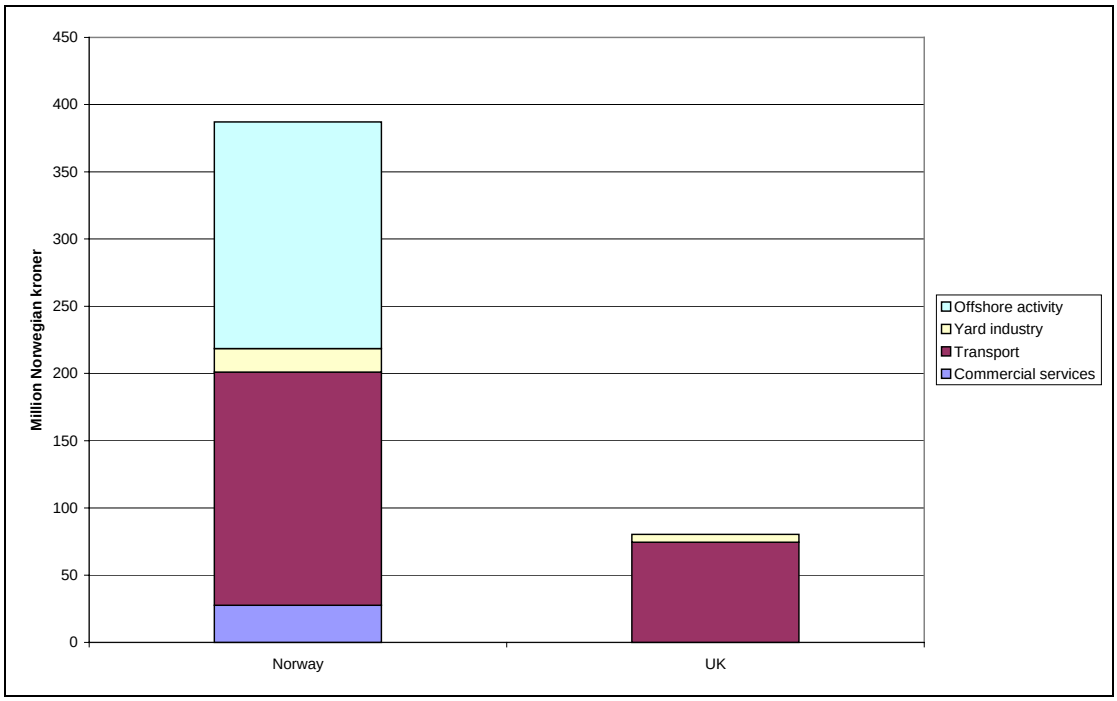

Figure 8.4 Frigg steel substructures. Norwegian and UK content (first level), broken down by industry (in MNOK)

The largest Norwegian and UK contracts are expected to be for the transport industry. Diving vessels (MSV/DSV), helicopter transport, supply vessels, standby vessels, survey vessels and towing operations are the main components of the contracts that will go to the transport industry.

Offshore industry embraces TOTAL NORGE's project management and support. A major part of this project management and support will be done from Norway.

Commercial services include engineering design and consultancy.

Assuming a price of 400-600 NOK / £30 - £46 per tonne of recycled steel from the Frigg sub-structures, this will give an income in the range of 10-15 MNOK / £0.8-£1.1m.

8.3.4 Employment Effects

Based on an industry breakdown of the expected Norwegian and British supplies the national employment effects have been estimated. The goods and services will be supplied directly and indirectly to give production effects at the national level in Norway and in UK.

Production effects in UK are expected to total about 50 man-years. The major part is expected to be in the yard industry and in the transport industry. The total employment effects included consumer effects are estimated to reach about 70 man-years.

Production effects in Norway are expected to total about 410 man-years. Consumer effects totalling about 50% of the production effects will also occur. The total employment effects are estimated to reach about 620 man-years.

Figure 8.5 shows the industry that may benefit from the production effects in UK and Norway.

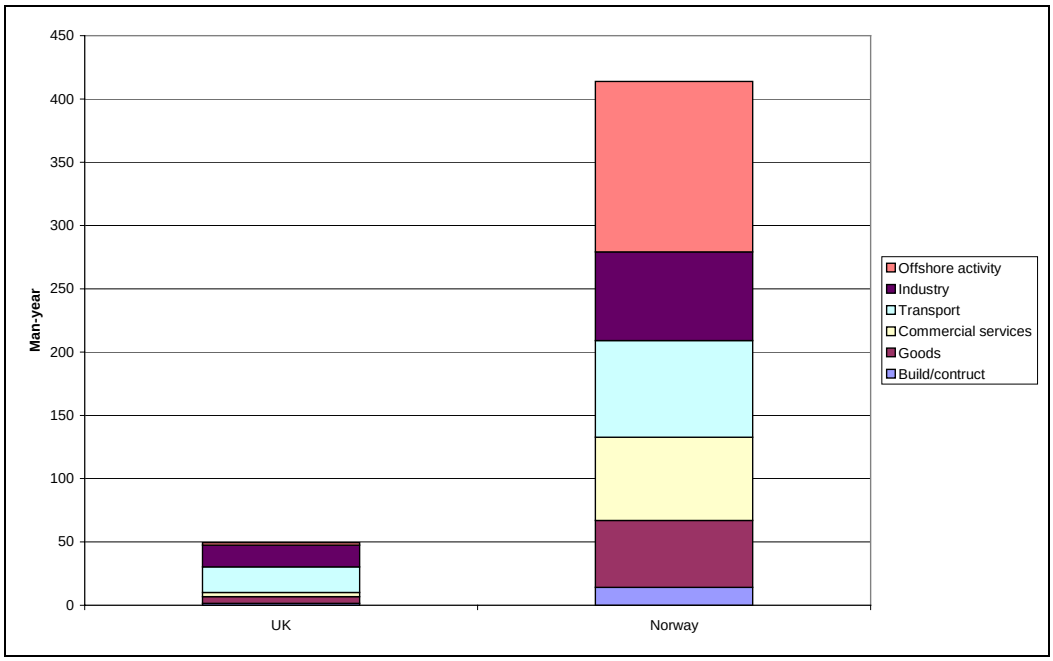

Figure 8.5 Frigg steel substructures. UK and Norwegian production effects broken down by industry (man-year).

The employment effects will be spread over the years during the removal, demolition and recycling will take place. The basic engineering is planned to start in 2002. The offshore removal and onshore disposal of the three steel substructures are planned to take place between 2008-2010. The onshore disposal will start when the facilities arrive onshore.

The schedule for undertaking the recommended activities is presented in Part 1- Disposal Plan in this Cessation Plan, Section 15.

8.4 Summary - Steel Substructures

In the matrix below the environmental impacts from removing, demolishing and recycling the steel substructures onshore are summarised.

	Alternative A Steel platform substructures Removal and onshore disposal
Energy Consumption (1000 GJ)	590
Total Energy Impact (1000 GJ)	590
CO_2 emissions (1000 tonnes)	48.7
Discharges to sea	Moderate negative or None/ insignificant*
Phys./habitat effects	Insignificant to small negative
Aesthetic	Moderate negative
Material management	Large positive
Littering	None/ insignificant
Impacts on Fisheries	Moderate positive
Impacts on free passage	Moderate positive

*Depends on presence of drill cuttings

Table 8.6 Environmental Impact of Removal and Onshore Disposal of the three Steel Substructures

Since the steel substructures will be entirely recycled the Total Energy Impact equals that of the Energy Consumption. It is estimated to require in the order of 590,000 GJ to remove the substructures from the field, take them to shore, cut them up and re-smelt the steel. This size of energy consumption corresponds to one month's electricity consumption of Stavanger or the fuel consumption of 15,000 family cars for one year.

Due to the cutting of the jacket piles, the slightly contaminated material below the DP2 installation may result in some negative environmental impacts (increased turbidity followed by re-sedimentation and smothering of benthic animals, leaching of trace contaminants to the seawater). These are considered to be "moderately negative", as they are of a temporarily duration. This effect is considered a physical effects issue.

Smell from degrading marine growth and noise from demolishing operations give potential for negative aesthetic impacts. They are considered "moderate negative", but could be partly mitigated and as such reduced. Rapid removal of the growth will reduce odour problems, while topographical conditions and physical improvements in the yard/dock could improve the noise situation.

As the metal will be re-smelted the alternative has a good performance with respect to waste/resource utilisation.

No littering effects are foreseen, as seabed debris removal will be carried out after the completed field disposal.

Impacts on fisheries and free passage should mainly be considered with due reference also to the other field installations. Looking isolated on the steel substructures the impacts will be quite negligible. In a more complete picture the impacts are found to be moderately positive, as they eliminate risk for the other users.

The impact on national supplies and employment for removal, demolition and recycling the steel sub-structures are summarised in Table 8.7.

Issues	In Norway	In UK	Total
Costs	777 MNOK	£21.1m	1053 MNOK / £80.5m
National supplies	393 MNOK	£7.8m	487 MNOK / £37.8m
Employment effects (man year)	620	70	690

Table 8.7 Summary of social impacts for Removal and Onshore Disposal of the three Steel Substructures.

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9 Impact Assessment for Disposal of Concrete Substructures

9.1 Description of Disposal Alternatives for Concrete Substructures

Concrete Platform Substructures TCP2, CDP1, TP1	**Alternative A** Refloat, tow to shore, demolish and dispose on-shore.	**Alternative B** Remove external and internal steelwork, refloat and dispose at a deep water location	**Alternative C** Remove internal and external steelwork and cut down sub-structure to provide a clear draft of 55m.	**Alternative D*** Leave in place, removing as much external steelwork as reasonably practicable.

*Includes three different sub alternatives related to more or less removal of internal and external steel items. It is considered most likely that any loose steel items outside the structure will be removed, and this is then forming the base case D option and reported in this EIA; see ref. [43].

Table 9.1 The main disposal alternatives considered for the three Concrete Substructures.

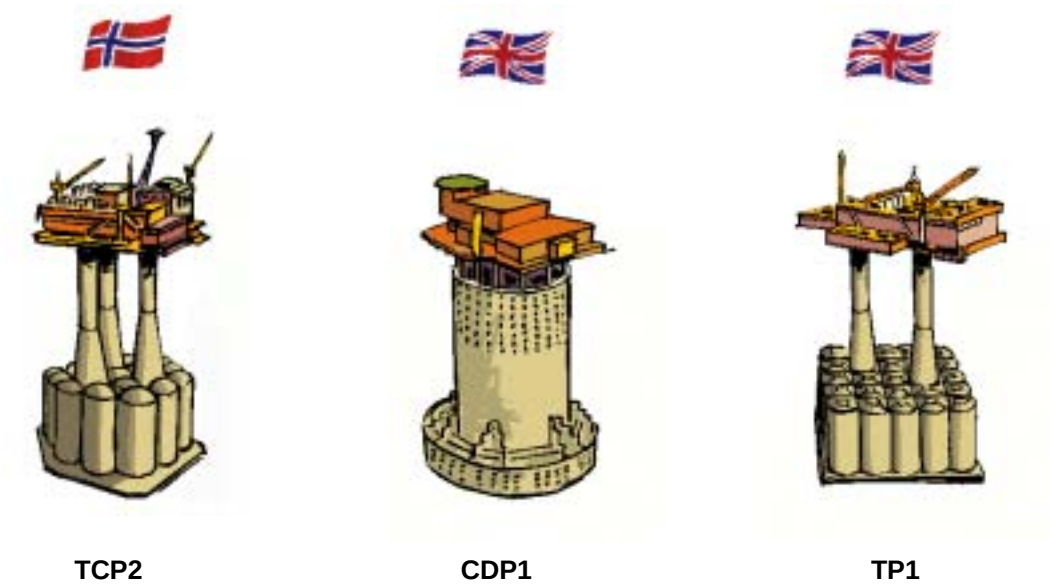


Figure 9.1 Concrete Substructures on Frigg Field

Alternative A – Refloat Concrete Substructures and Onshore Disposal

This alternative involves complete removal of the TCP2, CDP1 and TP1 installations for onshore disposal.

Preparatory work before re-float consists of removing steel items located inside and outside the concrete substructures, cleaning of marine growth on towing pennants, installation of ballasting/deballasting systems, and finally, if present, removing solid ballast or water.

The substructure preparatory offshore work will most probably be carried out over two years due to weather conditions.

The substructures will then be re-floated and towed by tugs to an inshore mooring for dismantling. When upper parts are removed the base parts of the GBS (Gravity Based Structure) will be entered into a dry dock for completion of the dismantling operation. Steel will be recycled, and some of the concrete may also be reused.

CDP1 concrete substructure
The solid ballast in CDP1 (268,700 tonnes) will be removed. The ballast may be disposed of on the seabed adjacent to the platform location, as an example possibly constituting an elevation of 1 meter in an area of 330 times 330 meters (assumed a total of 100,000 m^3). Drill cuttings, mud and adjacent contaminated solid ballast will most probably be recovered and sent onshore for disposal, but could also be disposed of in combination with the solid ballast.

TP1 concrete substructure
Some of the topside modules will be left on deck to ensure stability during re-float and save costs. The base structure will be prepared for re-float by removing ballast water, and installing necessary systems (ballasting/deballasting, power, monitoring and control systems).

TCP2 concrete substructure
Deballasting will be performed by removing about 125,000 m^3 of ballast water from the cells, and at the same time pressurise them with air compressors. Building an overpressure in the inner skirt compartments under the platform by the use of water will initiate the retraction and break loose operations.

A technical description on how a refloat of the three concrete substructures would take place is given in Part 1 – Disposal Plan in the Cessation Plan, as follows:

- TCP2 in Section 9.2.2.1
- CDP1 in Section 9.3.2.1
- TP1 in Section 9.4.2.1

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

Preparatory work before re-float in this alternative is similar in Alternative A, except that in addition to the steelwork located inside and outside, concrete substructures are also removed. In the final phase of this alternative, the installations will be towed and scuttled at the selected offshore location.

Because of its massive construction the CDPI concrete substructure is expected not to implode when lowered into the deep-sea location. The concrete substructures TCP2 and TP1 are believed to implode when it reaches about 150-200 m draught, leading to total disintegration of the structure, similar to what happened in the loss of the Sleipner A platform (in Gandsfjorden, Stavanger, 1991).

Two possible offshore disposal sites are presented as examples in the disposal studies [43], as shown on Figure 9.2. These deepwater offshore sites, AT010 (4,700 meters deep) and

UK/d (3,000 meters deep) are located in the Atlantic and have previously been used as disposal sites for other items. AT 010 is located to the southwest of UK, about 1000 nautical miles from the Frigg Field. UK/d is located west of Rockall (UK), about 850 nautical miles from the Frigg Field. The towing distance is assumed to be approximately 1000 nautical miles. Towing from the Frigg Field will take about 20 days.

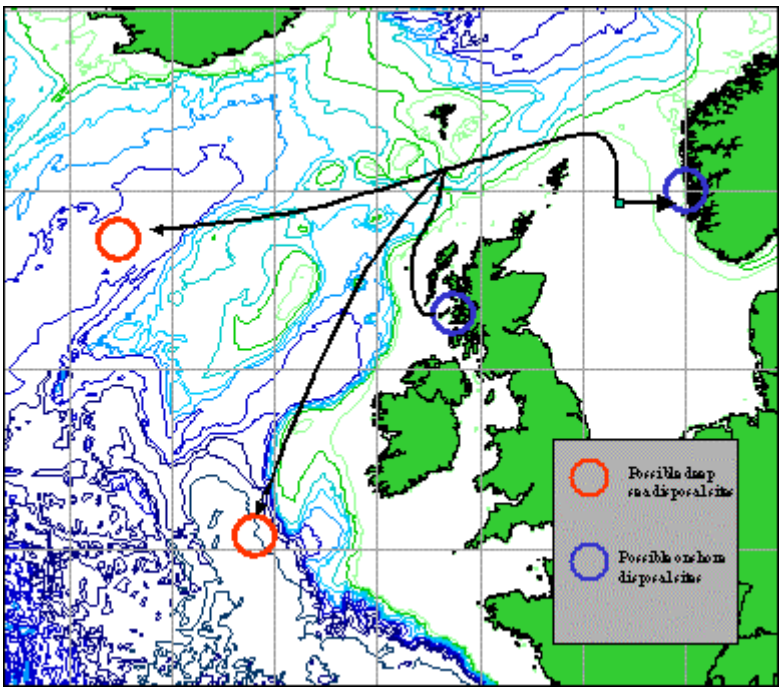


Figure 9.2 Optional deep-sea disposal sites in the UK waters (based on [43]), and indicative towing routes to shore.

Alternative C – Cut the Concrete Substructures down to –55m

The start point of this alternative implies that deck modules, steel deck panels and steel items on top of and in the gravity base structure have been removed.

The concrete gravity base structures will be cut to a depth of 55 meters below sea level. This alternative will result in a free sailing depth above the installation, which is in accordance with the IMO (International Maritime Organisation) guidelines.

Different cutting techniques have been proposed (mechanical and diamond wire techniques).

The disposal work will probably be split over two summer seasons. Removal of external equipment and cutting of columns are weather dependent operations. These operations are planned for the period between mid-April and the end of August. Removal of the topside must then be initiated in early March, which means that this alternative is more weather dependent than the other alternatives.

CDP1 concrete substructure
Solid ballast and drill cuttings down to –65 meters will be removed before cutting the structure (at –55m). The final cut of the inner column will have to be performed by means of explosives to obtain the –55m clearance.

The last cut of the inner column may have to be performed by means of explosives. This will need permission from the authorities. The cut sections will be relocated next to the parts left in place by a heavy lift vessel. This alternative for CDP1, after the final cuts, is illustrated in Figure 9.3.

Figure 9.3 CDP1 Concrete Substructure cut down to –55m.

TP1 and TCP2 concrete substructures
The extended columns will be cut at the level of the caisson roof as shown ion Figure 9.4. This will ensure a free water column of about 55m above the structure.

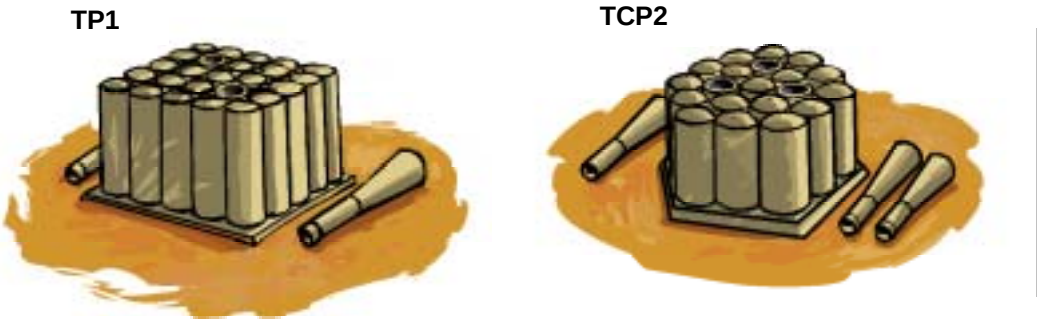


Figure 9.4 TP1 and TCP2 concrete substructures cut down to –55m.

Alternative D – Leave Concrete Substructures in Place

This alternative includes leaving the substructures after some preparatory work, which mainly consists of removing remaining steel decks, deck extensions, skid beams, and/or cellar deck modules.

The alternative includes different sub-alternatives involving partial or complete removal of steelwork inside and outside the structures before leaving them in situ. Removal of all external steelwork items is the base case for option D.

Piping and other steelwork inside and/or outside the columns will then be removed after consideration of safety aspects. Removal of steel from inside the columns and external casings will generally take place prior to topsides removal. Removal of external risers and other steelwork outside the structures, and piping between substructure cantilever and seabed interface point will be performed after topside removal.

The work including plugging and cutting seabed connections, removal of equipment inside and outside columns, flooding, and marking of the substructure is estimated to last for several months. Removal of steelwork equipment is weather sensitive, and will be performed only during the summer season. The disposal work may therefore last for two summer seasons.

In the final disposal phase of this alternative, navigation aids, e.g. marking lights and RACON (radio transmitter giving a distinct mark on radar screens) may be installed on the substructures. The marking system installation will be assisted by helicopter. An inspection and maintenance programme for the navigation aids will be necessary.

Impacts of Mission Failure

Refloating or partial removal of concrete structures have never been undertaken. Such alternatives have many technical risk elements that could fail, and as a worst case end by wreckage.

The potential environmental impacts of such mission failure during the removal of the concrete substructures of CDP1, TCP2 and TP1 have been evaluated separately [44].

“Mission failure” in the different main scenarios in this context implies:

1. Refloat and Onshore Disposal (Alternative A)
    - Accident before refloat
    - Accident during refloat
    - Accident during tow
    - Accident during demolition

2. Refloat and Deep Water Disposal (Alternative B)
    - Accident before refloat
    - Accident during refloat
    - Accident during tow

3. Cut Down to provide 55 m Clear Draft (Alternative C)
    - Unsuccessful cutting
    - Collapse or dropping of columns

The potential impacts are assessed by case studies, and have mainly been described qualitatively. Quantification of the consequences has been carried out when possible.

The following potential impacts have been evaluated:
- Impacts on environmental components (seabed, natural resources)
- Impacts on fisheries (ocean and coastal)
- Impacts on shipping (shipping lanes, port)
- Impacts on infrastructure (pipelines, cables)
- Impact on industries (fish farming)

Since mission failure logically is not part of the planned process, the summary of the impacts of such are not presented as part of the basic alternatives, but as a separate technical appendix [72].

9.2 Environmental Impacts from Disposal of Concrete Substructures

9.2.1 Energy

The Energy Consumption and Total Energy Impact for the concrete substructures vary from "insignificant" to "large negative".

Concrete cannot be recycled directly. Possible recycling is as a filling material for road construction or as an additive in the production of new concrete. The energy associated with these processes is relatively small compared to other material processing (steel). There is also quite large uncertainty what will happen with crushed concrete of the volumes in question. Therefore, in the energy calculations the concrete is not included in the recycle unit.

Alternative A – Remove Concrete Substructures and Onshore Disposal

As Alternative A leads to a complete recycling of all the steel from the substructure, its E_{REP} (energy for producing new materials) is set to zero. The Total Energy Impact then equals the Energy Consumption (see Section 3.3.2 for terms), and is calculated to about 4 million GJ. This represents about 7 months electricity consumption of Stavanger (app. 100,000 residents), or the annual fuel needed to run about 105,000 family size cars. See Table 9.2.

Operation Alternative A	Concrete Substructures on UK installations		Concrete Substructures on Norwegian installations	All Concrete Substructures
	CDP1	TP1	TCP2	
E_{DIR} Marine operations	1 900 000	850 000	381 000	3 131 000
E_{DIR} Dismantling	173 000	190 000	207 000	570 000
E_{REC} Recycle of metals	106 000	75 000	150 000	331 000
E_{CONS} Energy Consumption	**2 180 000**	**1 115 000**	**738 000**	**4 033 000**
E_{REP} Energy for replacing the materials	0	0	0	0
E_{TOT} Total Energy Impact	**2 180 000**	**1 115 000**	**738 000**	**4 033 000**
E_{TOT} Split per nation	**3 295 000**		**738 000**	

Table 9.2 Total Energy Impact for Alternatives A: Refloat, tow to shore, demolish and dispose onshore.

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

Total Energy Impact for Alternative B is calculated to 2.2 million GJ, i.e. 45% less than Alternative A. See Table 9.3.

Operation Alternative B	Concrete Substructures on UK installations		Concrete Substructures on Norwegian installations	All Concrete Substructures
	CDP1	TP1	TCP2	
E_{DIR} Marine operations	620 000	230 000	510 000	1 360 000
E_{DIR} Dismantling	4 500	1 500	2 200	8 200
E_{REC} Recycle of metals	35 000	12 000	17 600	64 600
E_{CONS} Energy Consumption	**660 000**	**244 000**	**529 800**	**1 433 800**
E_{REP} Energy for replacing the materials	196 000	177 000	370 000	743 000
E_{TOT} Total Energy Impact	**856 000**	**420 000**	**899 800**	**2 175 800**
E_{TOT} Split per nation	**1 276 000**		**899 800**	

Table 9.3 Total Energy Impact for Alternatives B: Remove external and internal steelwork, refloat and dispose at a deep-water location.

Alternative C – Cut the Concrete Substructures down to –55m

For Alternative C the high energy demand associated with marine operations is mainly due to probable use of a flotel during the operations at the field. Including the energy required to replace the metals in the abandoned substructures, Alternative C has a higher Total Energy Impact than Alternative B, but lower than Alternative A. See Table 9.4.

Operation Alternative C	Concrete Substructures on UK installations		Concrete Substructures on Norwegian installations	All Concrete Substructures
	CDP1	TP1	TCP2	
E_{DIR} Marine operations	1 200 000	390 000	624 000	2 214 000
E_{DIR} Dismantling	2 800	1 500	2 200	6 500
E_{REC} Recycle of metals	22 000	12 000	17 600	51 600
E_{CONS} Energy Consumption	**1 225 000**	**404 000**	**644 000**	**2 273 000**
E_{REP} Energy for replacing the materials	233 000	177 000	370 000	780 000
E_{TOT} Total Energy Impact	**1 460 000**	**580 000**	**1 010 000**	**3 050 000**
E_{TOT} Split per nation	**2 040 000**		**1 010 000**	

Table 9.4 Total Energy Impact for Alternatives C: Remove external and internal steelwork and cut down substructures to provide a clear draft of 55m.

Alternative D – Leave Concrete Substructures in place

In the Alternative D where the concrete substructures are left in place with external steel works removed to an extent reasonably practicable, the marine operations do not have the highest energy demand, as the E_{REP}, energy for replacing the materials is dominating. See Table 9.5.

Operation Alternative D	Concrete Substructures on UK installations		Concrete Substructures on Norwegian installations	All Concrete Substructures
	CDP1 (*1)	TP1 (*2)	TCP2 (*3)	
E_{DIR} Marine operations	54 000	43 000	49 000	145 000
E_{DIR} Dismantling	2 800	430	500	3 800
E_{REC} Recycle of metals	22 000	3 300	3 200	28 500
E_{CONS} Energy Consumption	**79 000**	**46 000**	**53 000**	**177 494**
E_{REP} Energy for replacing the materials	232 000	200 000	410 000	843 130
E_{TOT} Total Energy Impact	**310 000**	**250 000**	**460 000**	**1 020 000**
E_{TOT} **Split per nation**	**560 000**		**460 000**	

*1: Option is based upon: Vessels uses are set to 25% of the vessels calculated for removal of all steel
*2: Option is based upon: Vessels uses are set to 30% of the vessels calculated for removal of all steel.
*3: Option is based upon: Vessels uses are set to 20% of the vessels calculated for removal of all steel.

Table 9.5 Total Energy Impact for the disposal alternatives for Concrete Substructure. Alternatives D is leave in place with external steelworks removed.

9.2.2 Emissions to Atmosphere

Alternative A – Remove Concrete Substructures and Onshore Disposal

Emissions to atmosphere for this alternative is found to represent a “large negative” impact.

The total emissions to air from the removal of the three substructures are shown in Table 9.6.

If the installations are to be removed, this will be split over several seasons. A comparison of the emissions associated with such removal is made with other sources of emissions in the area. These are however annual emissions. Compared to the annual emissions from UK and Norwegian offshore operations (see Section 6.5 in this EIA) the contribution from the concrete substructure alternatives will be 38-66%, 170% and 39% for CO_2, NO_X and SO_X respectively.

Operation Alternative A	Concrete Substructures on UK installations		Concrete Substructures on Norwegian installations	All Concrete Substructures
	CDP1	TP1	TCP2	
CO_2 emissions				
Marine op./ dismantle*	140 000	62 700	28 000	
Recycle of metals	11 000	8 000	16 000	
Total per substructure	**150 000**	**71 000**	**44 000**	**265 000**
Split on nation	**221 000**		**44 000**	
NOX emissions				
Marine op./ dismantle*	2 500	1 170	520	
Recycle of metals	19	13	26	
Total per substructure	**2 500**	**1 200**	**550**	**4 250**
Split on nation	**3 700**		**550**	
SO_2 emissions				
Marine op./ dismantle*	120	55	25	
Recycle of metals	45	32	63	
Total per substructure	**165**	**90**	**90**	**345**
Split on nation	**255**		**90**	

For key of terms, see explanation of emissions to atmosphere See Section 3.3.2.

* Includes crushing of concrete.

Table 9.6 Total emissions to air for Alternative A: Refloat, tow to shore, demolish and dispose onshore for the three Concrete Substructures (in tonnes)

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

Emissions to atmosphere for this alternative are found to represent a “moderate negative” impact.

The total emissions to air from the removal of the three substructures are shown in Table 9.7. The CO_2 and NO_X emissions from alternative B are 55-60% less than alternative A, while SO_2 is 65% less. The level of marine operations is the main cause of this decrease in emissions.

Operation Alternative B	Concrete Substructures on UK installations		Concrete Substructures on Norwegian installations	All Concrete Substructures
	CDP1	TP1	TCP2	
CO_2 emissions				
Marine op./ dismantle	45 000	16 800	37 700	
Recycle of metals	3 700	1 300	1 900	
Total per substructure	**50 000**	**18 000**	**39 600**	**107,600**
Total split on nation	**68 000**		**39 600**	
NOX emissions				
Marine op./ dismantle	830	310	700	
Recycle of metals	6	2	3	
Total per substructure	**840**	**310**	**700**	**1 850**
Total split on nation	**1150**		**700**	
SO_2 emissions				
Marine op./ dismantle	40	15	33	
Recycle of metals	15	5	7	
Total per substructure	**55**	**20**	**40**	**115**
Total split on nation	**75**		**40**	

For key of terms, see explanation of emissions to atmosphere. See Section 3.3.2.

Table 9.7 Total emissions to air for Alternative B: Refloat and disposal in deep water for the three Concrete Substructures (in tonnes)

Alternative C – Cut the Concrete Substructures down to –55m

Emissions to atmosphere for this alternative is found to represent a "large negative" impact. The total emissions to air from the removal of the three substructures are shown in Table 9.8. The results show that the CO_2 emissions are about 35% less than Alternative A, and 55% more than Alternative B.

Operation Alternative C	Concrete Substructures on UK installations		Concrete Substructures on Norwegian installations	All Concrete Substructures
	CDP1	TP1	TCP2	
CO_2 emissions				
Marine op./ dismantle	85 000	28 600	45 800	
Recycle of metals	2 300	1 300	1 900	
Total per substructure	**90 000**	**30 000**	**47 700**	**168 000**
Total split on nation	**120 000**		**48 000**	
NOX emissions				
Marine op./ dismantle	1 500	530	849	
Recycle of metals	4	2	3	
Total per substructure	**1 500**	**530**	**852**	**2 850**
Total split on nation	**2 000**		**850**	
SO_2 emissions				
Marine op./ dismantle	75	25	40	
Recycle of metals	10	5	7	
Total per substructure	**85**	**30**	**47**	**162**
Total split on nation	**115**		**47**	

For key of terms, see explanation of emissions to atmosphere. See Section 3.3.2

Table 9.8 Total emissions to air for Alternative C: Cut the three Concrete Substructures down to –55m (in tonnes)

Alternative D – Leave Concrete Substructures in place

Emissions to atmosphere for this alternative are found to represent an "insignificant" impact.

The emissions from leaving the concrete substructures in place with external steel removed are calculated in Table 9.9. Due to the limited extent of large vessels involved in leaving the structures, this Alternative D has the lowest level of emissions.

Operation Alternative D	Concrete Substructures on UK installations		Concrete Substructures on Norwegian installations	All Concrete Substructures
	CDP1	TP1	TCP2	
CO_2 emissions				
Marine op./ dismantle	4 000	3 100	3.600	
Recycle of metals	2 300	355	336	
Total per substructure	**6 300**	**3 450**	**4 000**	**14 000**
Total split on nation	**10 000**		**4 000**	
NOX emissions				
Marine op./ dismantle	70	58	66	
Recycle of metals	4	0.6	0.6	
Total per substructure	**74**	**60**	**67**	**200**
Total split on nation	**134**		**67**	
SO_2 emissions				
Marine op./ dismantle	3.4	2.7	3.2	
Recycle of metals	10	1.4	1.3	
Total per substructure	**13.4**	**4**	**4.5**	**22**
Total split on nation	**17**		**4.5**	

For key of terms, see explanation of emissions to atmosphere See Section 3.3.2.

Table 9.9 Total emissions to air for Alternative D1: Leave the three Concrete Substructures in place and removing external steelwork (in tonnes).

9.2.3 Discharges to Sea, Water or Ground

Alternative A – Refloat Concrete Substructures and onshore disposal

Discharges from the process of removal and onshore recycling and disposal of the concrete substructures are found to represent "insignificant" impacts on the environment.

Potential areas of concern, which have been identified and assessed, are:

- Removal of marine growth
- Concrete slurry
- De-watering of the central shaft
- Removal of solid ballast
- Dismantling and disposal

Cutting operations to detach the structures will cause discharge of a slurry of fine particles of concrete and steel. The amount of concrete slurry produced during the cutting operations is assumed to be small. Since the slurry consists mainly of concrete and steel it is considered to be inert material, causing insignificant impacts on the local environment.

Solid ballast from the CDPI structure will most probably be disposed of on the seabed outside the lobate walls as part of the refloat operation. The majority of the ballast is inert material (stone, gravel and sand), with about 2,000 m^3 of old drill cuttings. The associated drilling fluid is used water based mud. It is found that this material preferably should be disposed of at the field together with and mixed with the solid ballast [43], but it could also be removed and treated/disposed of onshore.

As part of the remedial work, the central shaft of CDP1 will be de-watered. This discharge is not considered to contain environmentally harmful components (possibly some elevated iron concentrations from corrosion), and no impacts are foreseen.

At parts of the structure where inspections are required and equipment (such as towing pennants) are to be used, marine growth has to be removed prior to re-float. The fouling will be dispersed on the seabed around the installation. No environmental impacts are expected from this limited volume of organic material naturally occurring in this environment.

The onshore dismantling work could be performed in a dock with a concrete lined surface with on site pollution control monitoring and containment. This part of the dismantling is not expected to cause any discharges outside the permission limits.

The concrete material may be recovered or deposited on a landfill site. Most commonly the concrete will be used in material recovery and only minor parts of the concrete are expected deposited on a landfill site. Containing varying amounts of chlorides, alkalis and iron, disposal of concrete residues on landfill site may cause limited contaminated leachate. Due to the small part of the concrete expected be deposited in landfill, the environmental impact of the landfill is assumed to be negligible.

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

Discharges from the process of removal and offshore disposal of the concrete substructures are found to represent "insignificant" impacts on the environment.

Potential areas of concern, which have been identified and assessed, are:

- Marine growth
- Removal of solid ballast
- De-watering of the central shaft of CDPI
- Degradation of concrete
- Degradation of electrical and anode material

Removal of marine growth offshore is as in Alternative A regarded to have no impacts.

The substructures must be de-ballasted before re-float. This implies the same operations as in Alternative A, and hence the impacts will be similar. The same applies to the de-watering of CDPI central shaft.

After disposal the structures will slowly disintegrate. The process will be very slow and discharge of concrete components and corrosion products to surrounding areas will be very low. Concrete from the Frigg installations TP1 and TCP2 has been sampled and analysed. It is concluded that the quantity of leachable admixture is small, and that it is not expected to cause any long-term contamination problem [83]. No discharges with potential negative impacts are therefore expected from the disintegration of steel and concrete.

Decomposition of anodes etc. left on the structures will result in leaching of metals to the sea. The main components are copper, aluminium and zinc, with copper as the most important environmental concern. The impacts on the deep-water environment from the relatively small amounts involved are expected to be limited. For the TCP2 substructure there will be no discharges from anode material since anodes will be removed prior to disposal (No anodes on TP1 and CDP1).

The concrete substructures will be clean with regard to hydrocarbons when disposed of (they have never been used for storage of hydrocarbons).

Alternative C – Cut Concrete Substructures down to –55m

Discharges from the process of partially removal and disposal of the concrete substructures are found to represent “insignificant” impacts on the environment.

Potential areas of concern, which have been identified and assessed, are:

- Concrete slurry
- Degradation of concrete
- Degradation of electrical and anode material
- Drill cuttings (CDP1) and ballast

The partial removal of a concrete gravity base structure will cause discharge of concrete slurry due to the cutting of the substructure. Impacts will be more of physical character than from the chemical characteristics of the material.

As for alternative B the degradation of concrete must be considered. This is a slow process and the discharges connected to the decomposing process are evaluated to be “insignificant”.

Anode material will, as in alternative B, be a minor source of contamination to the surrounding environment.

The total extent of discharges to the sea during partial removal of the concrete substructures, is expected to be low, and the environmental impacts are evaluated to be “none or insignificant”.

Similar to alternative A and B, discharges as part of the removal of cuttings and ballast inside the lobate wall of the CDP1 substructure is only expected to give “insignificant” impacts on the environment.

Alternative D – Leave Concrete Substructures in place

Discharges from leaving the concrete substructures in place are found to represent “insignificant” impacts on the environment.

Potential areas of concern, which have been identified and assessed, are:

- Degradation of structural materials
- Degradation of electrical and anode material

Cuttings inside the CDP1 structure are evaluated in a separate study by Rogaland Research [84].

As for alternative C, leaching from the substructures when leaving them will be from decomposition of the concrete and electrical and anode material in the structures. However, the effects of this leaching are expected to be “insignificant”.

The discharges to sea or water due to leaving the substructures are expected to be limited. The environmental consequences are evaluated to be “none or insignificant”.

Three sub-alternatives involving varying degrees of removal of steel for dismantling and re-cycling onshore exist. In the case of removal of all steel, de-watering of the central shaft on CDP1 will be necessary prior to potential removal of all steel items. This operation is identical to de-watering described in alternative A. The effects of the discharges volume are expected to be “insignificant” and limited to a small area around the substructure.

The total environmental effects of discharges to the sea due to leaving the substructures and removing all steel items are expected to be limited. The environmental consequences are evaluated to be “insignificant”.

For the options assessed some steel items could be left together with the structure. The products from degradation of this steel are not considered to give any impact on the environment.

9.2.4 Physical Impacts to the Environment

Alternative A – Refloat Concrete Substructures and Onshore Disposal

The physical impacts from removing and onshore disposal of the concrete substructures are found to be “moderate negative”.

During the preparations for re-floating of the substructures, the sediments can be exposed to the same effects from anchors as narrated in Alternative A, removal of topsides. This will only give “insignificant” environmental impacts.

Operations to release the structures from the bases will disturb sediments and the water quality will deteriorate because of an increasing amount of particles in the water column. This effect has a very short duration and is considered overall as a small impact.

The sediments on the seafloor around the edge of the "raft-structure" of CDP1 will suffer from the dumping of the main bulk of ballast (200,000 tons) before re-floating. High turbidity during this operation will possibly constitute a threat to bottom dwelling organisms some distance away from the disposal site, though this effect is assumed to be small and of short duration. All benthic fauna in the discharge area will be covered. It is expected that new fauna could be re-established within a few years since the material will be clean. The CDP1 ballast material left on the seafloor will constitute an area with low nourishment for several years. As gravel constitutes an important part of the material (from 15cm stones to sand particles), this will form a contrast on the seafloor, where species of hard-bottom communities might establish. The area covered will be quite large with respect to such a complete change of sediment structure (e.g. a 1m thick layer equals to about 12 football pitches). The environmental impact is assessed to be “moderate negative” for habitat in the area.

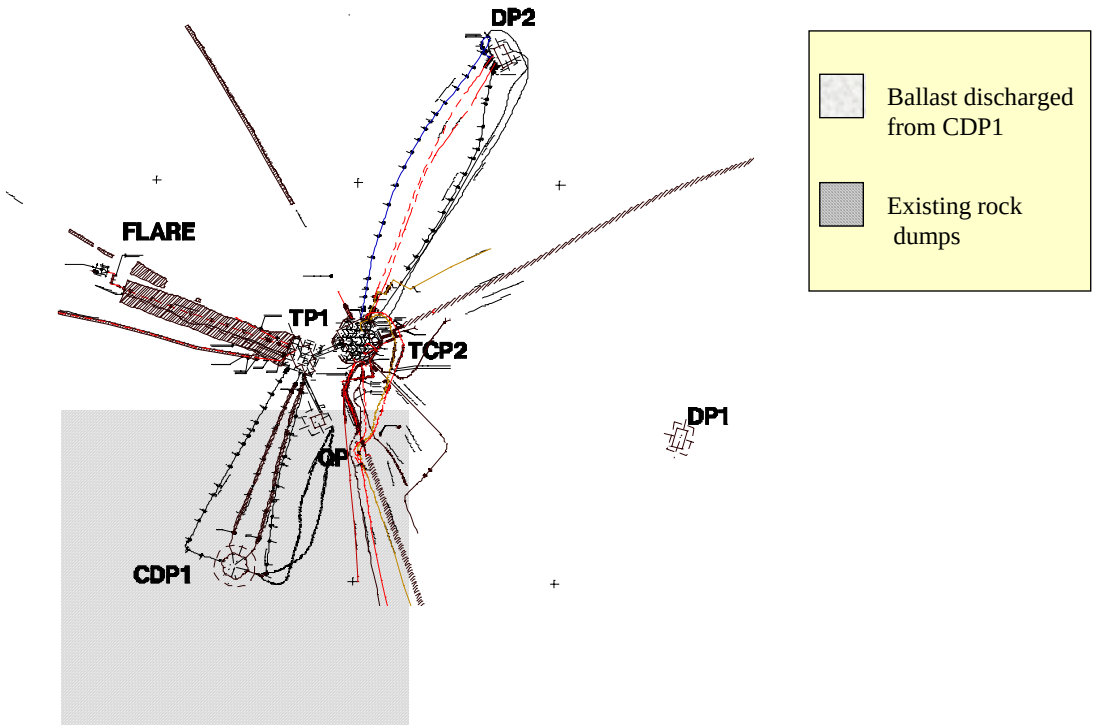


Figure 9.6 Present rock-dumps on pipelines/cables at Frigg, and indication of area (shaded) theoretically made if disposing solid ballast from CDP1.

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

The physical impacts of this alternative on the local environment at the Frigg Field are much the same as described for Alternative A, and reference is made to this section. The difference in total physical impacts between alternative A and B are related to possible impacts at the final deep sea disposal site. The overall physical impacts are found to be "moderate negative".

The following assessments are made for the deep-sea disposal location.

The characteristics of the TP1 and TCP2 substructures will most likely cause them to be crushed (implode) on their descent to the seafloor. Implosion of the structure will create shock waves in the water column (with impact on individual fish in the close vicinity). Because of the large depth, the amount of fish in the disposal area is expected to be low, hence the negative impact will be "insignificant". On the other hand, as a result of the implosion of the substructures the impacts when hitting the seafloor are expected to be less damaging than the CDP1.

The altered pressure from the impact of TP1 and TCP2 will create high turbidity in the disposal area. The deep sea seabed is dominated by fine sediments and silt. The expected high turbidity in the dumping area is assumed to smother or disturb organisms (disrupt breathing and/or feeding functions) a distance of several hundred meters away from the impact site (see e.g. [70]). This is anyway a temporary and local negative impact that is considered to be small.

The remnants of the substructure of TP1 and TCP2 will be spread over a larger area. This will constitute an altered seafloor that will attract the colonisation of species from hard-bottom communities. As the natural seafloor is soft-bottom, this change is considered negative, though of a "small negative" impact on the overall environment.

The CDP1 substructure is expected not to implode as it is lowered in the deep-sea area. The deep seabed is expected impacted by an intact structure, which on impact probably will partly or completely be crushed. The blow from the impact on the seafloor can create pressure waves similar to an explosion, but the effect of the pressure wave is expected to be small and local in nature. The expected turbidity in the dumping area is assumed to be similar as described above.

Mainly due to the extent of ballast material from CDP1 being dumped on the seafloor (similar to Alternative A), total physical impact from refloating this substructure and disposing in deep sea is found to be “moderate negative”. The total physical effect of disposing the TP1 and TCP2 in deep sea is found to be small negative.

Alternative C – Cut the Concrete Substructures down to –55m

The physical impacts from partial removal of the concrete substructures are found to be “moderate to large negative”. The uncertainty is related to whether explosives will have to be used for the final cuts at CDP1.

The alternative of partial removal of the substructure implies intensive work on and around the installation, which will have seabed impacts from anchors, similar to what is described under Alternative A, removal of topsides. Reference is made to this section for description of consequences.

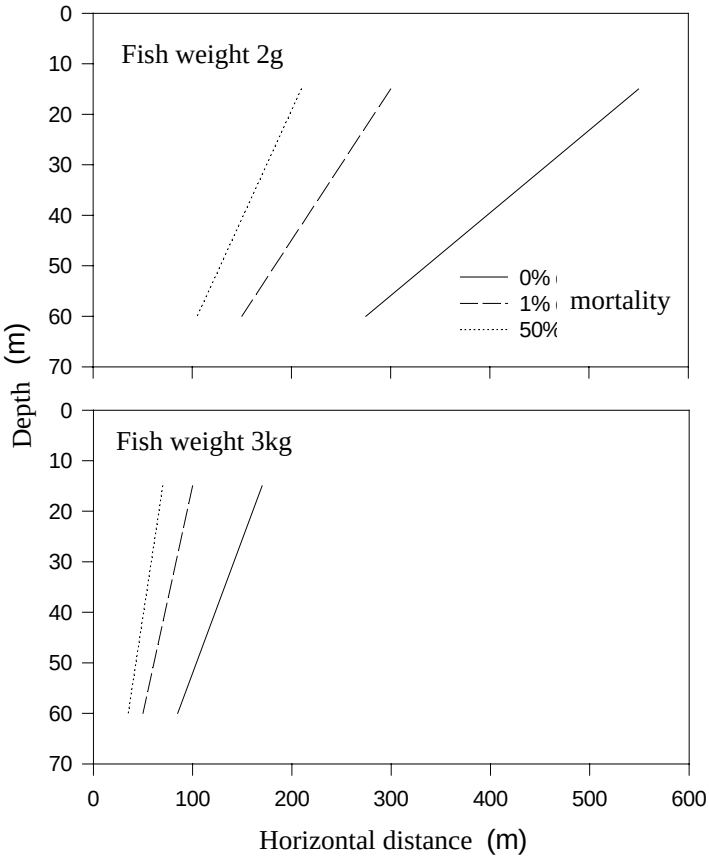


Figure 9.7 Mortality probability plot for 2g and 3kg fish with distance, and based on 80kg charges per meter at –60m water depth [48].

The effects of disposing the ballast from CDP1 on the seabed will be similar to that described under Alternative A, removing the substructure. More than 70% of the ballast will have to be removed from the structure as part of the work enabling partial removal.

Concrete slurry from cutting, and the turbidity from the relocation of the upper parts will cause deterioration of water quality, and final deposition on the seabed. Taking into consideration the short duration, and the localised nature of this effect, the impacts on the benthic community are expected to be “insignificant”.

The final cut of the inner column will have to be performed by means of explosive charges. Shock waves from explosives have a very damaging effect on fish, especially young life stages and in fish with a swimming bladder. Based on the amount of explosive and type of charge, the potential mortality picture for fish of different sizes and distance from the installation are

modelled based on [46] and [47]. See Figure 9.7.

As the result from the modelling show individual fish larvae will be killed within 300-600m distance, however with small probability. About 50% of such small individuals will be killed within100-200m depending on water depth. For larger fish (3kg) the lethal range is mainly within 50m. It should be noted however that surveys around offshore installations indicate that large fish (e.g. cod and saithe) are found in elevated concentrations within 50m [49].

Based on understanding of the fish behaviour and distribution it is likely to be more fish around/under a steel jacket structure than a concrete substructure. Generally, demersal fish (living at the sea bottom) like cod and saithe have higher tendency to aggregate around a structure than pelagic fish (living in the water column) as mackerel.

No surveys have been conducted at Frigg to estimate the present distribution of fish. Such surveys have been conducted at different fields (e.g. [49, 50, 51, 52, 53, 54]), but obviously it is impossible to foresee the presence of fish at a certain future point in time. Based on available results from such surveys it is however quite likely that a few to some tens of tonnes of demersal fish will be present within a 100m radius – of which one should assume a maximum 50% mortality from the blasting operation described. Compared with fish being caught by fishermen this amount is modest, however, such a consequence will in environmental terms be considered significant. The effect will be local and the situation will be recovered within a short time. Effects will only be on the individual level. There are, however, different means to mitigate such negative effects, and such should be planned for. These could be to use small charges before the blasting operation to scare fish off (e.g. ten repeated charges within half an hour). This is proven to have an effect up to some thousand meters, but since larvae have low mobility it will mainly be valid for larger fish [55]. Other means can be to perform the blasting operation when there is some wave action to prevent the deflected acoustic waves [56].

Temperature also affects the acoustic effects, higher temperatures in the top layer giving more effects in deeper layers. Depending on dominating presence of pelagic or demersal species one should therefore select a time of year with positive water temperature picture. The highest deflection is expected in August/September [48].

Finally, as larvae are most susceptible to blasting, and since mitigation measures mainly will not work on larvae, time of year should be selected when larvae are not present or only present in low concentrations. Fish larvae will mainly be present in the upper water level in this area in summer and early fall.

When finally disposed of, the structure on the seabed will represent reef-like solid substrata in a homogenous area of sand, and attract the settlement of hard-bottom species of organisms. As this constitutes a change in the natural environment the impact on the undisturbed seafloor is considered to be of a “moderate negative” nature, similar to a large shipwreck on the seafloor.

Partial removal is overall considered to give “large negative” impacts mainly due to the blasting operation. If being properly mitigated the effect should, however, be significantly reduced. The overall impact from the blasting and the longer term physical effect on the seabed is then considered to result in “moderate negative” impacts.

Alternative D – Leave Concrete Substructures in place

The effect of leaving the three concrete substructures in place, with or without removal of steelwork, is in itself practically maintenance of today's situation. The structures will degrade over several hundred years, and mainly constitute an obstacle with a hard-bottom effect for local organisms, as described under Alternative C.

The physical impact of leaving the substructure is found to be “none or insignificant” for the few next hundreds of years. When the installations are fully deteriorated they will form heaps of concrete fragments, reinforcement steel and solid ballast. The impact will be similar as for discharged ballast, i.e. moderately negative.

9.2.5 Aesthetic Impacts

Alternative A – Refloat Concrete Substructures and Onshore Disposal

The aesthetic impacts from removing and onshore disposal of the concrete substructures are found to be “moderate negative”.

Potential areas of concern, which have been identified and assessed, are:

- Visual effects
- Noise
- Smell
- Dust

The aesthetic impacts other than noise, of removing the concrete substructures for onshore disposal, are similar to corresponding impacts presented for Alternative A – Onshore disposal of the steel substructures (section 8.2.5).

Noise is evaluated to have the largest potential for negative aesthetic effects of dismantling the substructures. As part of previous cessation planning work [5] investigation of noise related to dismantling concrete structures was performed. It was concluded that the following sources of noise were most important:

- Chipping of concrete with a hydraulic chisel hammer
- Crushing of concrete in crushing mill
- Drilling/ blasting of concrete
- Constant noise from cranes and diesel engines

These are sources that would be of importance to the authorities in assigning permissions related to noise-load for the industrial site.

Blasting, drilling and crushing of concrete releases considerable amounts of dust. For one such crusher plant concentrations in the order of 4000mg/m^3 air some 30 meters from the plant have been measured [57]. As a reference the current Norwegian regulations for implementation of countermeasures are set to 300mg/m^3 air. Dust may be classified as two types – suspended dust and precipitating dust. Suspended dust is of most concern to human health. The dust problem can be reduced by spraying with water and reduce of the creation of dust. These are measures important to any licensee of such yards.

Both noise and dust are looked upon as irritants with potential for impacts on human health. Due to these reasons the negative aesthetic impacts of removing the concrete substructures for onshore disposal are considered to be of medium importance. The environmental consequences are evaluated to be “moderate negative”.

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

The potential negative aesthetic impacts (smell, noise) of disposing the concrete substructures in deep water will affect people working on this actual operation for a limited period of time. The impacts are considered “none/insignificant”.

Alternative C – Cut the Concrete Substructures down to –55m

The total aesthetic effect of cutting the concrete substructures down to –55m is evaluated to be none and the impact to be “none / insignificant”.

During the partial removal of the substructure, noise from cutting operations will only be relevant to those actually performing the removal operation (see Alternative B above), an issue which will be managed by procedures for conducting such work.

Alternative D – Leave Concrete Substructures in place

This alternative will have a visual element towards shipping, fisheries and other passing vessels. The concrete substructures will not change much visually except that the topside has been removed. The issue is considered trivial with no direct aesthetic impact.

9.2.6 Material Management

Dismantling sites for the different concrete substructures have not been chosen, and the evaluation of waste/resource utilisation will concentrate on types and amounts of waste generated. See also section 2.5.5 in this EIA for a description of the general waste management systems/procedures.

Alternative A – Refloat Concrete Substructures and Onshore Disposal

There is some uncertainty how much of the concrete material that realistically can be recycled. To the extent feasible the concrete material would as much as practically feasible be recycled, and the environmental impact is considered “moderate positive”.

Materials/types of waste considered are:

- Concrete
- Steel (reinforcement, pre-stressing cables)
- Cables and electrical equipment
- Marine growth
- Anodes

Removal of the substructures will cause considerable amounts of concrete, which have to be crushed and reused as aggregate, road fill etc, or be disposed of on a landfill site, if no reuse alternatives are found. The concrete and the reinforcing rods will probably be parted, and the majority of the iron will be recycled. As there is very little experience with recycling of large amount of solid concrete material, it is quite uncertain which recycling percentage that is realistic. TOTAL NORGE’s objective is to obtain as high a degree of recycling as possible, and specific objectives will be made for reuse and recycling of various materials and equipment. All reinforcement steel is considered suitable for recycling when separated from the concrete.

Separate steel components in the substructures will have to be separated from the substructure and delivered for smelting.

Marine growth will represent large amounts of organic waste (appr. 2650 tons), which will have to be handled shortly after transporting the substructure to shore to avoid smell problems. The sea disposal of large volumes of marine growth at the demolition yard would lead to a local concentration of organic waste in the water and seabed. Therefore this method is not recommended when demolishing the substructures. The marine growth will most probably be disposed of at a suitable waste disposal site or be used as fertiliser.

Cables and electrical equipment will be handled in a similar manner to that described for the topsides (Section 7.2.6 in this EIA).

The substructure (with the exception of TP1) is protected from corrosion by aluminium or zinc based sacrificial anodes. Reuse of these anodes is not feasible, and they will be melted down (90% recycling is expected [37]).

The total material distribution for this alternative is presented in the figure below. The majority will be recycled/reused (concrete, steel), solid ballast will be disposed of at sea or be reused, while some concrete, possibly drill cuttings and marine growth will be disposed of onshore.

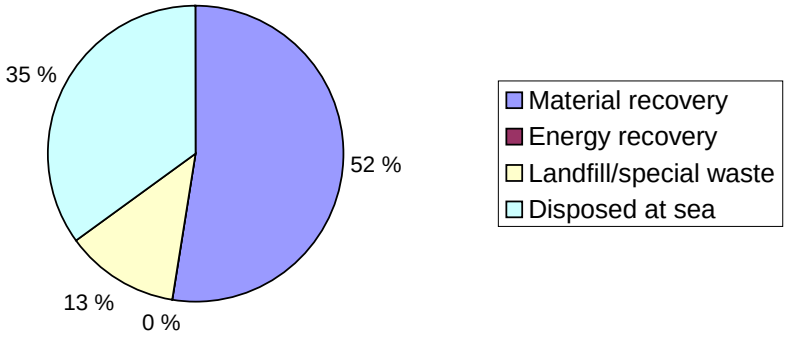


Figure 9.8 Material management for Alternative A full removal of the three Concrete Substructures (weight in %).

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

The impact on material management for offshore disposal of the concrete substructures is considered “insignificant”.

Some marine growth will have to be removed and discharged on site. These small amounts of natural biological material are not considered a waste problem.

No other waste is expected generated from this alternative.

The alternative means that a large amount of material with low recycling benefit (concrete) and some material with high recycling benefit (steel) will not be recycled.

Alternative C – Cut the Concrete Substructures Down to –55m

This alternative is similar to Alternative B with respect to generation of waste. The majority of internal and external steelwork will however be recycled, giving this alternative a “small positive” impact on the material management issue.

Alternative D – Leave Concrete Substructures in Place

Leaving the concrete substructures as they are will not generate any waste.

The different sub-alternatives involving removal of steel, are not expected to generate any waste. These alternatives involve recovery of steel that will be recycled onshore. This gives the alternative a “small positive” impact on the material management issue.

9.2.7 Littering

Both Alternative C (cut down to –55m) and Alternative D (leave in place) will result in some littering potential. Such effects may not show in the short term. However, in the long term it may be realistic as a result of deterioration of material and heavy influence from external forces (wave action, currents, etc.). Reinforcement and concrete fragments may be spread on the seabed in the vicinity of the installations. Fishing gears may further enhance the littering effect by spreading fragments over a larger area.

The magnitude of such littering potential is very uncertain, but as the materials considered are heavy and not easily spread the potential is considered rather small.

A clean-up operation of the field after final decision on disposal of the installations has been made, is mandatory, as described in the Part 1 - Disposal Plan of this Cessation Plan, Section 12.

9.3 Social Impacts from Disposal of Concrete Substructures

9.3.1 Impacts on Fisheries

Upon completion of the approved Cessation Plan for the Frigg Field facilities, the safety zone is likely to be cancelled. The disposal alternative decided will therefore theoretically not have any significant effect on the area open to fishing. In practice however this administrative zone is not considered the most important issue in evaluating the impacts on fisheries.

Alternative A – Refloat Concrete Substructures and Onshore Disposal

Removing of the concrete substructures is considered to result in “moderate positive” impacts on fisheries as it improves the access the Frigg Field.

If only one concrete installation is removed, this is not considered to give any particular improvement with regard to access for fisheries. The effect will be real when considering removal of all the installations in combination.

As described above, the elimination of the safety zone will make available an area of about 3 km^2 for fisheries. If all the installations are removed the area should be open to fisheries with no residual hindrance. The availability of the area could, however, be dependent on disposal of pipelines and other artificial material (gravel fillings, mattresses.). If all obstacles in the water column and on the seabed are removed from the field the impacts of this alternative are characterised as “moderate positive” to the fisheries in the Frigg area.

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

Removing of the concrete substructures for deep-sea disposal is considered to result in “moderate positive” impacts on fisheries.

In the Frigg area the impacts will be as presented for Alternative A.

On the deep-sea disposal site the substructure will be placed far deeper (> 2000 m) than current fishing vessels and gear will operate[5].

[5] Deep sea trawling is presently reported to take place down to 1500-1800 meters in other oceanic areas [58, 59]. Although it is possible that future trawling capacities extend beyond the current depth, it is not likely due to the relatively low densities of commercially interesting fish at these north-eastern Atlantic slopes.

No effects for fisheries in terms of obstacles are therefore expected at the deep-sea disposal site.

When being disposed of at sea the substructures will be clean, and the probability for contamination of fish is unlikely.

Alternative C – Cut the Concrete Substructures Down to –55m

Cutting down of three concrete substructures down to –55m is considered to result in "moderate negative" impacts on fisheries.

The lower parts of the concrete substructures (below –55m) will be left in place in this alternative, with the upper top sections disposed next to the base. To most fishing vessels this means that the area will still have to be avoided, because of risk of gear interfering with the remaining structures. The degree of avoidance may however be different to the different types of fishery. Smaller vessels fishing with net gear operating in the surface layers may not be completely hindered, while trawling vessels will be completely hindered by the remaining parts of the structure. Viewing fisheries in total, the situation for the dominating fisheries after such a disposal alternative is not expected to be significantly different from today, i.e. the area is within the safety zone of Frigg.

The concrete substructures have a design not suitable to function as an artificial reef if disposed according to this alternative. Irrespective of this, any possible artificial reef function has to be assessed on the basis of conclusions from the artificial reef study [42]. One of the conclusions from this study was that the pelagic fishery, which is dominant in this area, is unlikely to be significantly enhanced by any artificial reef at the Frigg Field. Based on this study and the limited knowledge on effects of artificial reefs in the North Sea in general, no significant positive consequences to fisheries are expected of this partial removal alternative.

This alternative represents a continued presence of the concrete substructures in the area until final disintegration (in the order of thousands of years). In this respect, this Alternative is similar to the alternative of Leaving the substructure (Alternatives D). The consequences for fisheries of such a long-term exclusion from the area are discussed in the following section on the Alternative D, and reference is made to this section for evaluation of the impacts to fisheries.

Generally, if Alternative C is chosen for single concrete substructures, it is considered to have minor impacts on the fisheries in this area. The overall impacts on fisheries from choosing this disposal alternative for single structures will however be strongly dependent on how other installations on the Frigg Field are disposed, as well as evaluation of the long term consequences.

If partial removal of single concrete substructures is a part of partial removal or leaving all the Frigg installations in situ, the consequence is characterised as "moderate negative", in terms of being a physical obstruction to the future fisheries activity in the area.

Alternative D – Leave Concrete Substructures in Place

Leaving the three concrete substructures in place is considered to result in "moderate negative" impacts on fisheries.

Today the exclusion zone in the Frigg area potentially affects especially trawling fisheries. The reason is that trawl vessels have to begin deflection manoeuvres very early to avoid moving into such an exclusion area, which implies that an area larger than the actual exclusion zone is unavailable. The practical exclusion area for net and trawl vessels due to a 500m safety zone surrounding an installation is illustrated in Figure 9.9.

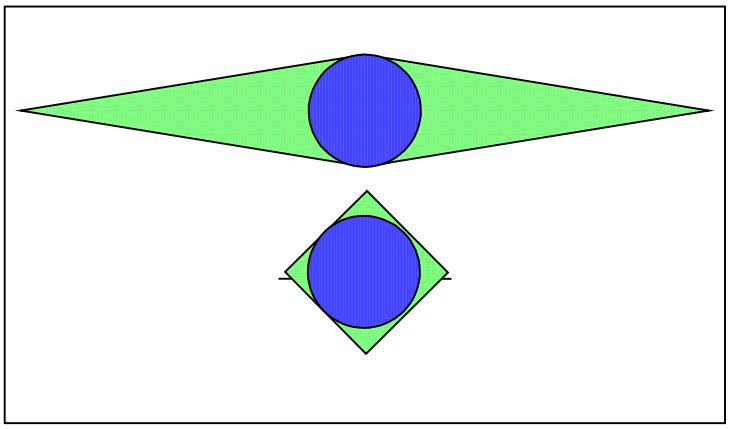


Figure 9.9 Principle sketch of safety zone (blue area) and actual exclusion area (green area) for trawl (upper) and net (lower) fisheries [60].

Leaving the substructures will, in the long-term perspective, imply a continued occupation of an area (though less than today's exclusion zone), excluding other interests in this area for an indefinite period into the future. The long-term consequences for the fisheries in the Frigg area are difficult to predict, because it is dependent on how the fisheries in this area will develop in the future. Based on fisheries statistics, the Frigg area is today regarded to be of medium importance to the fisheries in this part of the North Sea. This may change in the future, but no predictions are possible on this issue. However, assuming that in the future, the fishery will be present to a comparable extent as it is today, leaving the concrete substructures in place is regarded to have negative impacts on the fisheries.

When Alternative D for each of the substructures is evaluated separately, it is considered to have minor impacts on the fisheries in this area, due to the limited area of exclusion. The overall future impacts to fisheries of this disposal alternative for each structure will, however, be strongly dependent on how the other installations on the Frigg Field are disposed. If leaving a substructure is a part of leaving all the Frigg installations in place, the consequence may be characterised as "small negative" to "medium negative", in terms of being a physical obstruction to the future fishing activity in the area.

The sub-alternatives involving removal of external steel could be looked upon as positive to the fisheries, since potential obstacles to gear operating close to the installations are removed from the structures. This removal will however be very small compared to what is left behind, and the overall consequences for fisheries are considered similar.

9.3.2 Impacts on Free Passage

Alternative A – Refloat Concrete Substructures and Disposal Onshore

Removing of the concrete substructures is considered to result in "moderate positive" impacts on free passage.

The removal of the concrete substructures is a major operation, implying an extensive use of several vessels for a longer period of time in the area. Still, as for the removal of the topside, the main activity during the refloating of a concrete substructure will be within the 500m safety zone, and is thereby not expected to have any practical impact on the free passage of the area.

When the substructure is afloat it will be towed to shore. The tow operation includes the employment of six tugboats in a pattern around the floating structure. Duration of tow will be 1-2 weeks per installation depending on destination in Norway/UK. This tow will affect the free passage all through its duration.

The size of the tow (vessels and their configuration) and its duration of almost a week imply a "small negative" impact on the free passage in the area of its passage.

However, the complete removal of the substructures eliminates a hindrance in the sea, thereby inflicting a "moderate positive" impact on the free passage in the area.

Alternative B – Refloat Concrete Substructures and Disposal in Deep Water

Removing of the three concrete substructures is considered to result in "moderate positive" impacts on free passage.

As for Alternative A, the refloating option taking place mainly within the 500m exclusion zone is not expected to have any practical impact on the free passage in the area.

The tow of a concrete platform, practically of the same or slightly longer duration as for Alternative A, is evaluated as having the similar effect as for Alternative A, and thereby a low negative impact on the free passage.

Final disposal will be in deep water with no impacts to passage.

Alternative C – Cut the Concrete Substructures Down to –55m

Partial removal of the concrete substructures from the maritime zone is considered to result in "moderate positive" impacts on free passage.

Large heavy lift vessels, and several support vessels will carry through the cutting and lowering of the columns onto the seabed. The vessels are assumed to be active only within the exclusion zone, and thereby not in conflict with the free passage of the area. When the operation is completed there shall be a free passage of 55m water column (ref. IMO Guidelines). As this alternative does not imply any further marine activity, such as towing, the impact of the operation on the free passage in the area is considered to be low/negligible.

It is assumed that the raft structure and column members on the seafloor do not pose any substantial danger to passing submarines, as their presence will be marked on official maps.

The elimination of the concrete substructures as an obstruction to surface vessels is seen as a positive impact on the free passage in the area.

Alternative D – Leave Concrete Substructures in Place

Leaving the three concrete substructures in place is considered to result in "moderate negative" impacts on free passage.

The alternative, with or without removal of steel items before leaving the structure involves the operation of few vessels, all within the exclusion zone. Before being left, the substructures are to be sufficiently marked to prevent conflicts with passing ships. It is assumed that the substructures will be properly marked on any navigational charts.

In this alternative the free passage in the area will be restricted for several hundred years due to the presence of a substructure. Its mere presence will restrict larger vessels from passing the area nearby, and thereby exclude the full use of the area. Its presence will also to some extent pose a risk for collisions with ships. As the installation is left unmanned, there will be no human resources to warn any vessel on a collision course, as there is when it is in operation. RACON systems will, however, make the installations visible on radar.

Leaving the concrete substructures in place is evaluated to have a low to medium negative impact on the free passage in the area as the risk of ship/fishing vessel collision still stands.

9.3.3 Costs and National Supplies (goods and services)

Four disposal alternatives have been evaluated for the Frigg concrete substructures. The total costs for disposing the concrete substructures are estimated in 2002-value, exchange rate of 13.08 NOK/£.

Tables 9.10 to 9.13 give the costs of the disposal alternatives for the three concrete substructures, split by nations.

Alternative A	In UK		In Norway	All Concrete Substructures
	CDP1	TP1	TCP2	
Cost	£309m	£146m	2462 MNOK	8418 MNOK / £644m
Cost split by nation	£455m		2462 MNOK	

Table 9.10 Concrete substructures Alternative A - Refloat, tow to shore, demolish and dispose onshore.

Alternative B	In UK		In Norway	All Concrete Substructures
	CDP1	TP1	TCP2	
Cost	£229m	£56m	1048 MNOK	4775 MNOK / £365m
Cost split by nation	£285m		1048 MNOK	

Table 9.11 Concrete substructures Alternative B - Remove external and internal steelwork, re-float and dispose at a deep-water location.

Alternative C	In UK		In Norway	All Concrete Substructures
	CDP1	TP1	TCP2	
Cost	£339m	£74m	1647 MNOK	7049 MNOK / £539m
Cost split by nation	£413m		1647 MNOK	

Table 9.12 Concrete substructures Alternative C - Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m.

Alternative D	In UK		In Norway	All Concrete Substructures
	CDP1	TP1	TCP2	
Cost	0.5	£3.1m	77 MNOK	125 MNOK / £9.5m
Cost split by nation	£3.1m		77 MNOK	

Table 9.13 Concrete substructures Alternative D - Leave in place, removing as much external steelwork as reasonably practicable.

If the concrete substructures are left in place with removing as much internal and external steelwork as reasonably practicable the cost estimate will be about 1195 MNOK / £91m.

Based on expected Norwegian and UK supply the national employment effects can be estimated for the different disposal alternatives for the concrete substructures, as shown in Table 9.14.

Concrete Substructures	Alternative A Refloat, tow to shore, demolish and dispose on-shore.	Alternative B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down substructure to provide a clear draft of 55m.	Alternative D* Leave in place, removing as much external steelwork as reasonably practicable.
Norwegian content	35%	26%	36%	41%
UK content	40%	35%	29%	17%

Table 9.14 Frigg Field concrete substructures. Norwegian and UK content for the different disposal alternatives.

Figure 9.10 and 9.11 give the breakdown of Norwegian and UK supplies in connection with the disposal alternatives for the concrete substructures, by industry.

In Norway

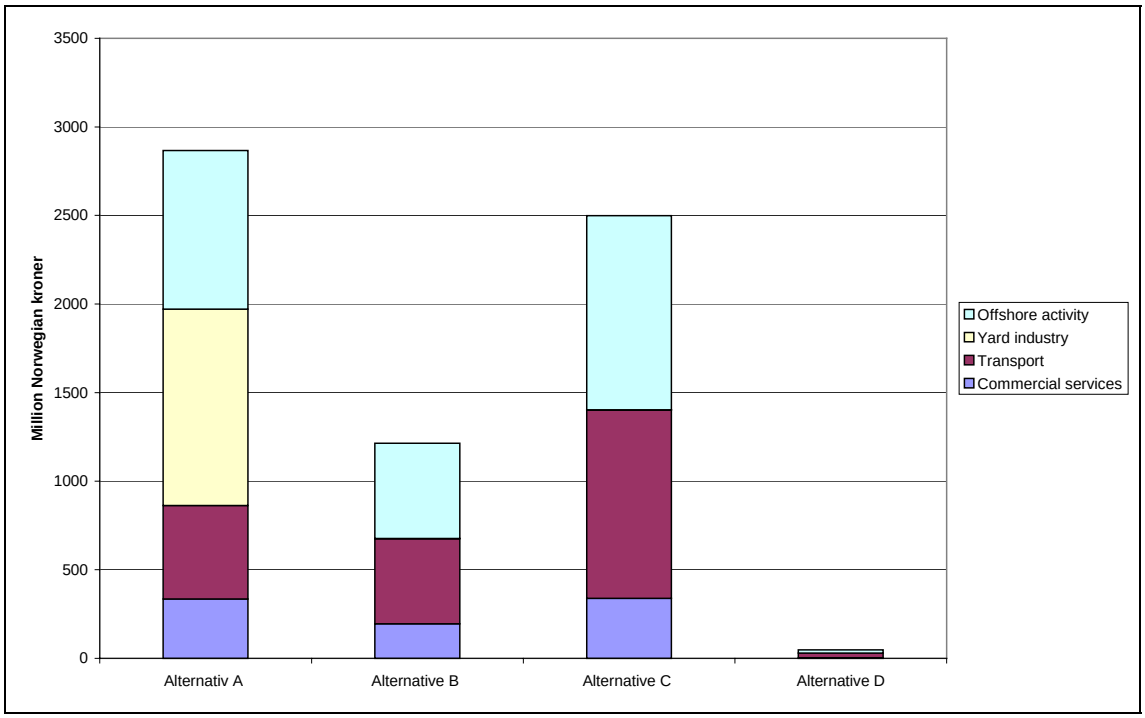


Figure 9.10 Frigg Field concrete substructures. Norwegian content (first level), broken down by industry for each alternative (in MNOK)

The largest Norwegian supplies are expected in the offshore activity and in the yard industry for alternative A with onshore disposal. Offshore activity includes TOTAL NORGE's project management and support. Contracts on onshore disposal are expected to be for the yard industry.

Diving vessels (MSV/DSV) helicopter transport, supply vessels, standby vessels and towing operations are the main components of the contracts that will go to the transport industry.

In UK

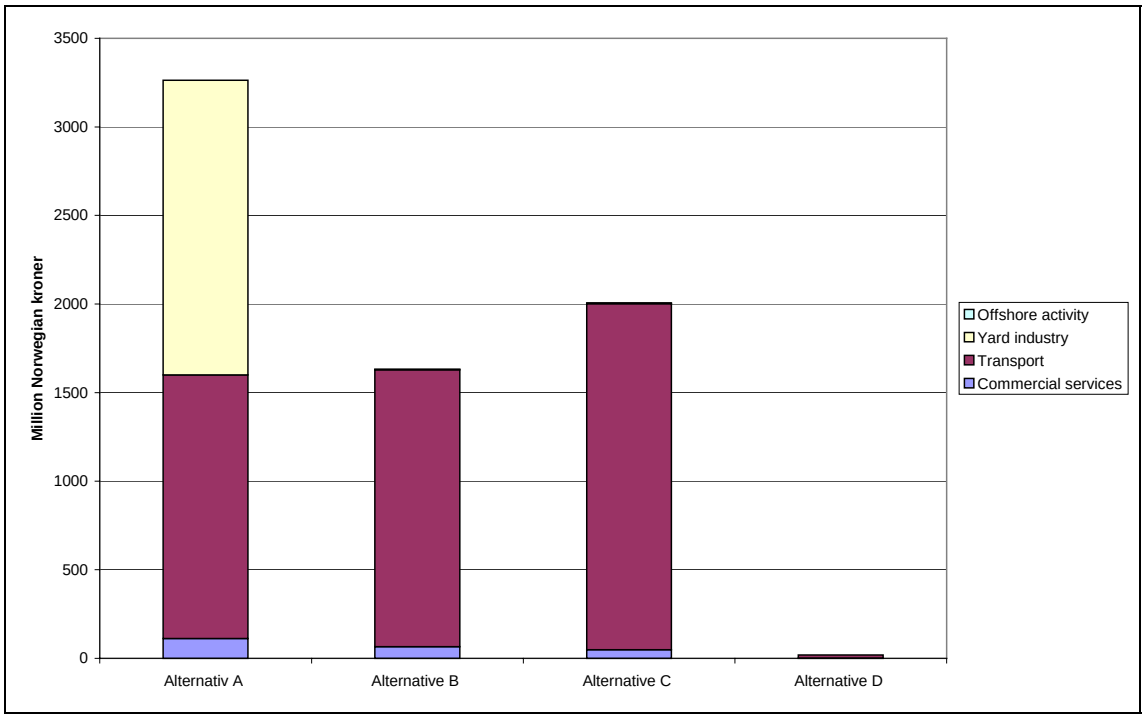


Figure 9.11 Frigg Field concrete substructures. UK content (first level), broken down by industry for each alternative (MNOK)

The largest contracts in UK are expected to be for the transport industry that includes offshore operations (vessels). Contracts on onshore disposal are expected to be for the yard industry.

Assuming a price of 400-600 NOK / £30 - £46 per tonne of recycled steel from the Frigg concrete substructures, will give the following approximately income:

- Alternative A 15 - 22 MNOK / £1.2m - £1.7m
- Alternative B 2.9 - 4.3 MNOK / £0.2m - £0.3m
- Alternative C 2.3 - 3.4 MNOK / £0.2m - £0.3m
- Alternative D 0.7 - 1.0 MNOK / £0.05m - £0.08m

Possible income from recycling concrete will have to be studied further. An assumed price on 30 NOK / £2.3 per tonne will give an income in the order of 12 MNOK / £0.9m

9.3.4 Employment Effects

Based on an industry breakdown of the expected Norwegian and UK supplies the national employment effects have been estimated. The goods and services will be supplied directly and indirectly to give production effects at the national level in Norway and in UK.

In UK

Production effects in UK are expected to be in total about 5,200 man-years from Alternative A, about 900 man-years from Alternative B, about 1,250 man-years from Alternative C, and about 10-15 man-years from Alternative D.

Consumer effects of about 50% of the production effects will come in addition. The total employment effects are estimated to reach about 7,900 man-years from Alternative A, about 1,400 man-years from Alternative B, about 1,850 man-years from Alternative C, and about 15-20 man-years from Alternative D.

In Norway
Production effects in Norway are expected totalling about 5,400 man-years from Alternative A, about 1,500 man-years from Alternative B, about 3,400 man-years from Alternative C, and about 50 man-years from Alternative D.

In addition to the production effects there will be consumer effects that will represent about 50% of the production effects. The total employment effects are estimated to reach about 8,000 man-years for Alternative A, about 2,300 man-years from Alternative B, about 5,100 man-years from Alternative C, and about 80 man-years from Alternative D.

The employment effects will be spread over the years during the removal, demolition and recycling will take place. If removal of the three concrete substructures should take place, the likely timing would be when all topsides and steel substructures have been removed from Frigg, but before removing the pipelines and cables. It is estimated that one need from 4 to 6 years until all three concrete substructures have been demolished onshore. Figure 9.12 shows the industries that may benefit from the production effects in UK and Norway.

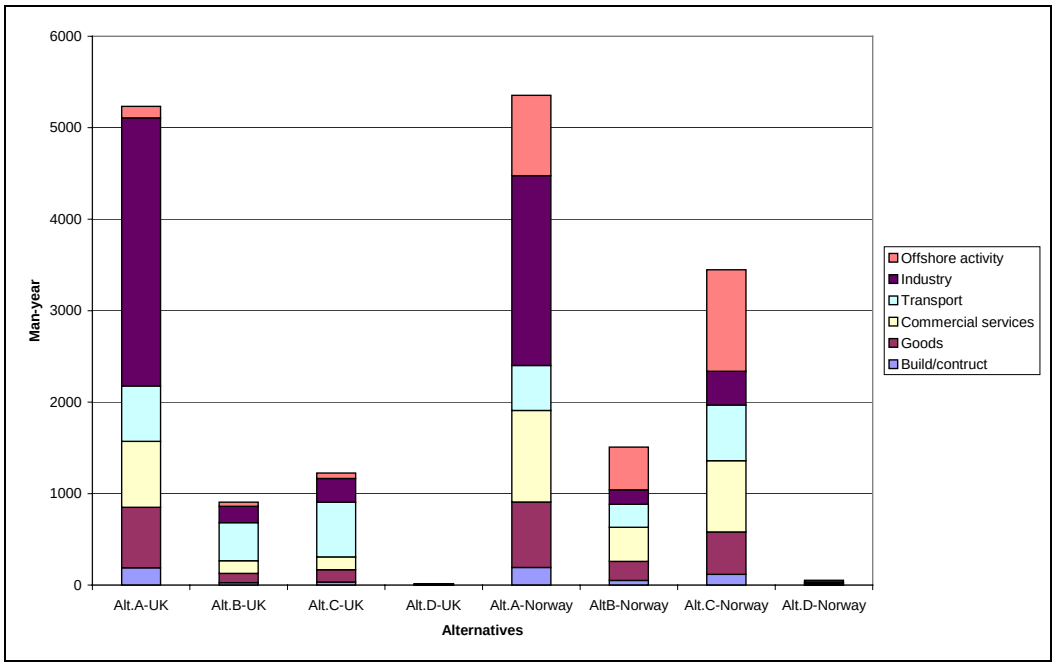


Figure 9.12 Norwegian and UK production effects broken down by industry for each disposal alternative for the Concrete Substructures. (man-years)

9.4 Summary – Concrete Substructures

The environmental and societal impacts associated with the different disposal alternatives for the concrete substructures are summarised in Table 9.15.

	Alternative A Refloat, tow to shore, demolish and dispose on-shore.	Alternatives B Remove external and internal steelwork, refloat and dispose at a deep water location	Alternative C Remove internal and external steelwork and cut down sub-structure to provide a clear draft of 55m.	Alternative D Leave in place, removing as much external steel work as reasonably practicable
Energy Consumption (million GJ)	4.0	1.4	2.3	0.2
Total Energy Impact (million GJ)	4.0	2.2	3.1	1
CO2 emissions (1000 tonnes)	265	108	168	14
Discharges to sea	None/insignificant	None/insignificant	None/insignificant	None/insignificant
Phys./habitat effects	Moderate negative	Moderate negative	Large/Moderate negative*	Moderate negative
Aesthetic	Moderate negative	None/insignificant	None/insignificant	None/insignificant
Material management	Moderate positive	None/insignificant	Small positive	None/insignificant (Small positive)
Littering	None/insignificant	None/insignificant	Small negative	Small negative
Impacts on Fisheries	Moderate positive	Moderate positive	Moderate negative	Moderate negative
Impacts on free passage	Moderate positive	Moderate positive	Moderate positive	Moderate negative

* Moderate if blasting operations are mitigated properly.

Table 9.15 Environmental Impact of disposal alternatives for the three Concrete Substructures.

The removal for complete demolition onshore has by large the highest energy consumption, more than twice that of removal for disposal in deep sea, and 45% more than the partial removal alternative. The leave in place alternative has quite modest energy consumption, but this will increase somewhat if some of the steelworks are to be removed. The energy consumption associated with alternative A is equal to the annual energy consumption of more than 105,000 family cars.

Considering the total energy impact, the picture changes slightly. All alternatives get closer to the onshore demolition (Alternative A). The increase for the deep water disposal (Alternative B) and partial removal alternative by cutting down to –55m (Alternative C), occur since non-removable steel materials in these alternatives are disposed of at sea. It could otherwise be recycled (in the method disposing steel that otherwise could be recycled is penalised by an energy amount equivalent to produce new steel). Compared with the leaving in place Alternative D, the difference from Alternative C will be the extensive marine operations to conduct the partial removal.

Emissions to air follow the same pattern as for energy consumption. Alternative A has the worst performance, while alternative D has a very modest level of emissions.

None of the alternatives will result in any direct discharges to sea.

Physical effects are foreseen in relation to the disposal of ballast materials at sea in quite large volumes, the direct physical effects following disposal of the substructures in deep waters (Alternative B) and leaving the structures in place. For the partial removal alternative the degree of ballast disposal will be about 40% less compared with the removal alternatives. However, the most significant physical impact for this Alternative C will be the short-term

impact from using explosives in performing the final cut. For the in situ disposal Alternative D, no physical impacts are foreseen in the short term, however in the long term they will be similar to the partial removal with regard to the physical presence of concrete and ballast.

Alternative A has the potential for aesthetic impacts mainly related to noise and dust spreading. Such impacts could partly be mitigated but there will still be some potential for negative impacts.

Alternative A has great potential for utilising the resources in the substructures. Steel materials will be remelted and concrete may be reused in road works or other types of reuse. There is, however, a challenge in utilising such amounts of material generated from one project, and there is no real demand for such material.

The alternatives having some element of disposal in situ will have a small potential for littering, especially in the long term. The environmental effect is not considered significant. In the long run when iron bars could be exposed and fractured from the rest of the installation, external forces (e.g. fishing gear) could enhance their spread in the near vicinity of the installations.

Alternatives, which involve removing the structures from the field, will have “moderate positive” impacts on fisheries. Correspondingly, leaving the installations partly or fully in place will give “moderate negative” impacts.

The situation has many similarities for free passage. As the traffic in the area is relatively high, the effect in reduced risk is considered even stronger. Thus the removal of the installations from the maritime zone is considered a moderate positive impact. Leaving the installations marked in place means continuing the situation of today. The impact is considered as a “small negative” to “moderate negative” impact.

The impact on national supplies and employment for disposal the concrete substructures are summarised in Table 9.16.

Issues	In Norway				In UK				Total			
Alternatives	A	B	C	D	A	B	C	D	A	B	C	D
Costs in MNOK Cost in £m	2462	1048	1647	77	 455	 285	 413	 3.1	8418 644	4775 365	7049 539	118 9.1
Supplies MNOK Supplies £m	2900	1200	2500	50	 248	 126	 153	 1.5	6150 470	2850 218	4500 344	70 5.4
Employment effects (man year)	8000	2300	5100	80	7900	1400	1850	20	15900	3700	6950	100

Table 9.16 Summary of social impacts each disposal alternative for the three concrete substructures.

10 Impact Assessment for Disposal of Infield Pipelines and Cables

10.1 Description of Disposal Alternatives for Infield Pipelines and Cables

Infield Pipelines and Cables	Alternative A Remove, transport to shore and onshore disposal	Alternative B Leave in place but trenched	Alternative C Leave in place but bury ends

Table 10.1 The main alternative disposal arrangements considered for Infield Pipelines and Cables

The infield pipelines and cables on Frigg Field are shown in Figure 10.2 and 10.3.

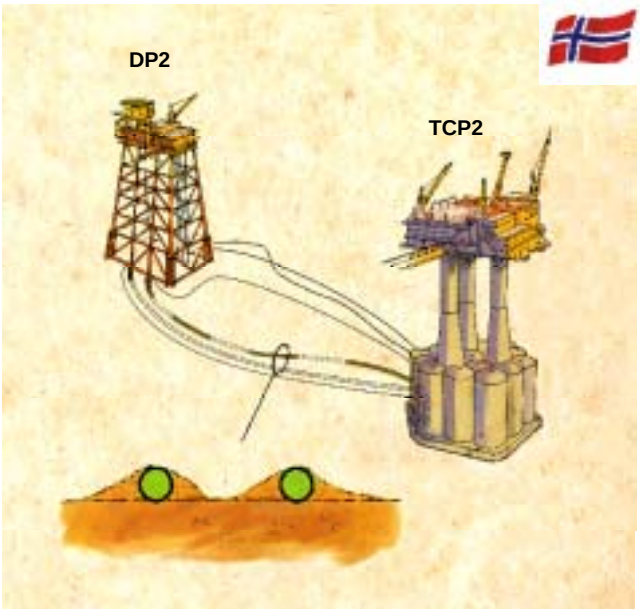


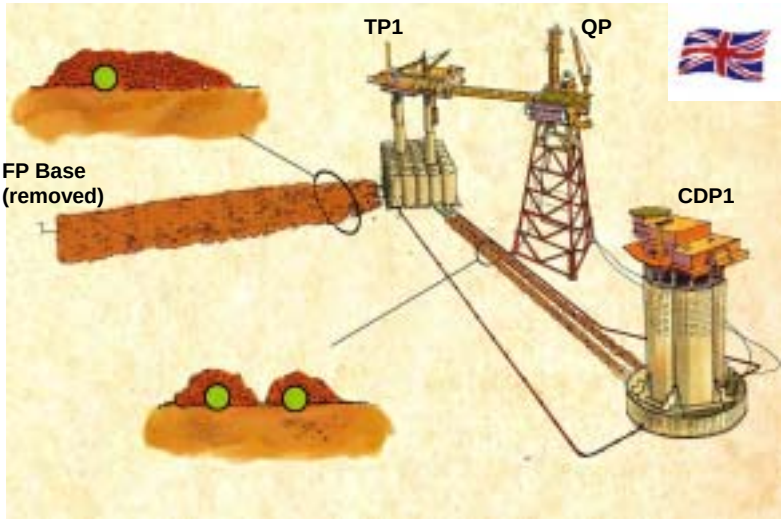
Figure 10.1:
Pipelines and Cables in the Norwegian sector of the Frigg Field*:*

Between TCP2 and DP2:
- 2x26” pipelines
- 8”pipeline
- 4” pipeline
- 3” cable
- 1 $^{5}/_{8}$” cable

Figure 10.2:
Pipelines and Cables in the UK sector of the Frigg Field:

Between TP1 and CDP1/QP:
- 2x26” pipelines
- 8” pipeline
- 4” pipeline
- 3” cable
- 1 $^{5}/_{8}$” cable

Between TP1 and FP Base:
- 24” pipeline
- 2x2” pipeline
- 4” cable
- 3” cable



For detailed description of the pipelines and cables, reference is made to Section 4. “Facilities to be Decommissioned” and Section 5: “ Inventory of Materials” in Part 1 “Disposal Plan”.

There are some operational limits relating to pipeline diameter and different recovery vessels. In the description below a split at 12 inch diameter is made. The reason for this split is that pipelines with a diameter of less than 12” may be spooled (i.e. removed with different technology than larger pipelines).

Pipelines more than 12” diameter
This classification includes 5 pipelines on the Frigg Field. Two pipelines both with a dimension of 26” go from CDP1 to TP1 on the UK sector. The two pipelines between the DP2 platform and the TCP2 platform on the Norwegian side, are also pipelines with a dimension of 26”. The pipelines at the UK side are rock-dumped, while the ones at the Norwegian side are partly naturally back-filled pipelines. Between the TP1 and the FP, there is a 24” rock-dumped pipeline.

All of the pipelines with a dimension over 12” are steel pipelines coated with various plastic products and a concrete layer is used to increase the pipeline weight. Both the thickness of the coating and thickness of the concrete layer vary dependent on the pipeline use.

Pipelines less than 12” diameter
This classification includes two 2” rock-dumped pipelines going from TP1 to FP, two 4” pipelines lying on top of the seabed from CDP1 and to TP1 on the UK side and from DP2 and to TCP2 on the Norwegian side. It also includes two 8” pipelines lying on the seabed between the TP1 and CDP1 on the UK side, and between TCP2 and DP2 on the Norwegian side.

The six pipelines with a dimension under 12” are all steel pipelines with a coating. There is no concrete cover on these pipelines.

Cables
Five cables are installed on the Frigg Field with dimensions ranging from 1 5/8” to 4”; three electrical power cables and three telecommunication cables. Four lie on top of the seabed while two are rock-dumped (see Section 4.2 in Part 1 – Disposal Plan).

Alternative A – Remove pipelines and cables and onshore disposal

This alternative involves removal of all the infield pipelines and cables from the Frigg Field. Complete removal of the pipelines involves preparatory work of inspecting the condition of the lines, cleaning and disconnecting the pipelines, and the removal of any rock fillings, concrete mattresses and other covers. Removal of the pipelines may be performed in several ways. Reversed S-lay, reversed J-lay, reversed reeling, towing and cutting/lifting are all methods evaluated in a separate removal cost estimate study for the Frigg pipelines and cables. All pipelines and cables will be taken onshore for reuse or recycling.

Alternative B – Leave in place pipelines and cables but trenched

The purpose of this alternative is to eliminate potential problems to fishery.

The preparatory work on the infield pipelines and cables in this alternative will be similar to Alternative A. After the preparatory work has been completed, the pipelines will be trenched to a sufficient depth using conventional vessels and methods. The cables and pipelines will then be naturally or mechanically back-filled (covered) left in place. All ends will be buried.

Alternative C – Leave pipelines and cables in place but bury ends

This alternative will leave the infield pipelines and cables in place, with a minimum of work. They are assumed to be flooded with seawater and plugged, before they are left at the field.

The pipelines and cables will be cut close to the platforms, and the ends lowered into the seabed and back-filled.
The pipelines and cables are partly rock-dumped or naturally self buried. Concrete mattresses and blocks, and grout bags will be removed also for this disposal alternative.

10.2 Environmental Impacts from Disposal of Infield Pipelines and Cables

10.2.1 Energy

The Total Energy Impact for all alternatives are found to represent a “none/insignificant” impact, based on the impact key presented in section 3.3.2.

Energy Consumption and Total Energy Impact for three disposal alternatives and for various size pipelines and cables are presented in the Table 10.2. Complete removal has a total energy impact in the order of 57,000 GJ, trenching about 55,000 GJ, and leave in place about 26,000 GJ.

The energy consumption (total energy demand) for leaving in place is zero, while for full removal it is equal to the total energy impact (57,000 GJ) and for the trenching alternative about 29,000 GJ.

Operation		Pipelines and cables in UK			Pipelines and cables in Norway		
		Alt. A Remove and onshore disposal	Alt. B Leave in place but trenched	Alt. C Leave in place bury ends	Alt. A Remove and onshore disposal	Alt. B Leave in place but trenched	Alt. C Leave in place bury ends
E_{DIR} Marine operations	>12”	5 100	2 700	-	4 000	3 000	-
	<12”	10 300	5 500	-	7 900	6 000	-
	Cable	10 300	5 500	-	7 900	6 000	-
E_{DIR} Dismantling	>12”	1 200	-	-	900	-	-
	<12”	270	-	-	200	-	-
	Cable	40	-	-	20	-	-
E_{REC} Recycle of metals	>12”	3 400	-	-	4 600	-	-
	<12”	590	-	-	330	-	-
	Cable	220	-	-	150	-	-
E_{CONS} Energy Consumption		**31 420**	**13 700**	**-**	**26 000**	**15 000**	**-**
E_{REP} Energy for replacing the materials	>12”	-	9 600	9 600	-	13 000	13 000
	<12”	-	1 600	1 600	-	900	900
	Cable	-	730	730	-	480	480
E_{TOT} Total Energy Impact		**31 420**	**25 630**	**11 930**	**26 000**	**29 380**	**14 380**
E_{TOT} Total Energy Impact split per nation		**69 980**			**69 760**		

For key of terms, see explanation of energy calculations. See Section 3.3.2.

Calculations of marine energy and emissions are split from total figures into 20% share to >12”, 40% share to <12” and 40% share to cables.

Table 10.2 Total Energy Impact for disposal of Infield Pipelines and Cables (in GJ)

10.2.2 Emissions to Atmosphere

Emissions to atmosphere for all alternatives are found to represent “none to insignificant” impacts.

Emissions to air associated with operations and recycling have been calculated and presented in Table 10.3. The leave in place alternative has no emissions to air. Complete removal has more operations and thus more emissions than trenching. The total CO_2 emissions for all alternatives are considered small.

Operation	Pipelines and cables in UK			Pipelines and cables in Norway		
	Alt. A Remove and onshore disposal	Alt. B Leave in place but trenched	Alt. C Leave in place bury ends	Alt. A Remove and onshore disposal	Alt. B Leave in place but trenched	Alt. C Leave in place bury ends
CO_2 emissions						
Marine op./ dismantle	1 900	1 000	-	1 450	1 100	-
Recycle of metals	440	-	-	540	-	-
Total	**2 340**	**1 000**	**-**	**1 990**	**1 100**	-
Total split on nation	**3 340**			**3 090**		
NO_X emissions						
Marine op./ dismantle	35	18	-	27	20	-
Recycle of metals	1	-	-	1	-	-
Total	**36**	**18**	**-**	**28**	**20**	-
Total split on nation	**54**			**48**		
SO_2 emissions						
Marine op./ dismantle	1.7	1	-	1.3	1.0	-
Recycle of metals	2.1	-	-	2.4	-	-
Total	**3.8**	**1.0**	**-**	**3.7**	**1.0**	-
Total split on nation	**4.8**			**4.8**		

For key of terms, see explanation of emissions to atmosphere See Section 3.3.2.

Table 10.3 Total emissions to air for the Infield pipeline and Cables disposal alternatives (in tonnes)

10.2.3 Discharges to Sea, Water or Ground

Alternative A – Remove pipelines and cable and onshore disposal

Removing of the infield pipelines and cables for onshore disposal is found to represent "insignificant" impacts.

Areas of concern, which have been identified and assessed:

- Cutting of pipelines offshore
- Dismantling onshore
- Recovering of iron onshore

Releases from removal of pipelines and cables are mainly connected to cutting of pipelines offshore, onshore operations from recovery of iron and production of new pipelines (see e.g. [61]). Disturbance of sediments during operations is considered of no impact since the sediments have low degree of contamination (See Section 6.2.1).

The cutting of the pipelines is not expected to take place at the anode locations, and the fine particle material released due to the cutting process will mainly contain metal from the pipelines, possibly some PAH and other components from the anticorrosive coating. Depending on function of the lines, they will be cleaned prior to cutting, and any release of hydrocarbons will be less than 40 mg/l (in accordance with regulatory requirement). Only limited releases to the sea are expected, and the impacts are considered "insignificant".

Onshore the pipelines will be cleaned for marine growth, if any, and cut to smaller sections for ease of handling. The marine growth is expected to be limited since both available area to marine growth and light conditions are expected to be limited.

Experience with removal and reuse of pipelines is limited. Metals in the pipelines and cables will most probably be recovered. If no realistic solutions for recovering and reuse are available for pipelines and cables, they will be recycled and some parts disposed in landfill.

Alternative B – Leave pipelines and cables in place but trenched

Leaving the infield pipelines and cables buried in place is found to represent an “insignificant” impact.

Areas of concern, which have been identified and assessed:

- Disturbed sediments
- Corrosion and degradation

Disturbance of sediments during operations is considered of limited impact, since the sediments have little contamination (See Section 6.2.1). There will however be some temporary increase in turbidity, but with sandy sediments as in the Frigg area this effect will be short. The impact is considered “insignificant”.

Release of metals and decomposition products of the insulating materials will be a consequence of the long-term corrosion/erosion process that the pipelines will be exposed to. Compared to Alternative C – Leaving pipelines and cables in place, the long term releases due to corrosion and decomposition will be smaller as buried pipelines are expected to be more slowly degraded than pipelines located on the seabed. Buried pipelines will generally be in less contact with oxygen and are going to be less exposed to damage to the coating (cf. [62]). The cover of stone and gravel will restrict the release of contaminants to the surrounding environment.

For the cables, which consists mainly of iron and plastic components and some copper, environmental effects are not foreseen in the short-term period. In the long term materials will deteriorate and metals will dissolve. Concentrations are, however, considered to be so low that any negative impacts on the environment are not considered likely.

Alternative C - Leave pipelines and cables in place but bury ends

Leaving the infield pipelines and cables in place is found to represent a “small negative” impact.

An area of concern, which have been identified and assessed, is:

- Erosion and releases of substances in the long term

Erosion, corrosion and decomposition of pipelines will mainly cause releases of metals to the surrounding environment. The anode material is expected to protect the pipelines for 50 – 70 years. Decomposition of the pipelines after the anode material has been degraded will depend on the condition of the concrete coating and protective coating.

When these coatings have been eroded, the release of metal is expected to last for a period of 400 years until the pipelines are totally degraded [62].

Since the gas pipelines will be cleaned prior to the decommissioning, the risk of releases of hydrocarbons or other substances from the pipelines is very limited.

For cables the situation will be as for Alternative B. The deterioration process is expected to be somewhat faster for the cables that are exposed.

10.2.4 Physical Impacts to the Environment

Alternative A – Remove pipelines and cables and onshore disposal

Removal of the infield pipelines and cables for onshore disposal is found to represent "insignificant" impacts.

Areas of concern, which have been identified and assessed:

- Damages due to anchoring
- Disturbance of sediments
- Changes in sea bottom substrata and seabed level

Neither pipelines nor cables are buried, but some parts are gravel dumped. Changes on seabed levelling/substrata distribution will only be limited, as a result of the retrieving operation.

As described previously, damage to the seabed from anchors etc. will have insignificant environmental impact.

The cutting process on the seabed will result in some disturbance of the sediments. This will be temporary and only minor effects are foreseen.

Removal of rock dumped pipelines will be of more importance and the cover material will eventually cover a wider area than today. The situation will however be very similar to present.

The total physical impact and impacts on habitat are considered minor. The environmental consequences are considered to be "insignificant".

Alternative B – Leave pipelines and cables in place but trenched

Leaving the infield pipelines and cables buried in place is found to represent "insignificant" impacts.

Following trenching the sediments will be actively or naturally back-filled. Since the sediments mainly consist of sand this process is assumed to take place within a relatively short time. Full recovery is assumed within 2-3 years.

As for Alternative A, only minor effects due to anchoring are expected in connection with trenching of the pipelines and cables.

The process of trenching and backfill of pipelines and cables will disturb the sediments located in the vicinity. Disturbance of sediment will only affect a limited area around the trenching operation location.

The total effect of trenching the pipelines and cables and leaving them is evaluated to be small and the environmental impacts are estimated to be "insignificant".

Alternative C - Leave pipelines and cables in place but bury ends

Leaving the infield pipelines and cables in place is found to represent "insignificant" impacts.

Changes on the seabed substrata will be as gravel/stone and pipeline mattresses left on the sea bottom. The physical consequences of such are considered as limited.

10.2.5 Aesthetic Impacts

Alternative A – Remove pipelines and cable and onshore disposal

The total aesthetic impacts of complete removal of infield pipelines and cables are evaluated to be insignificant.

Areas of concern, which have been identified and assessed:

- Smell - Marine growth
- Noise
- Dust
- Visual effects

Marine growth is not expected to be a problem for any of the pipeline alternatives as the amount is small.

Cutting of the pipelines onshore could generate some noise. Most pipelines can be cut by means of mechanical scissors, which will give far less noise than oxyacetylene torch cutting. Noise is thus not considered a very likely problem with regard to scrapping pipelines.

The concrete coating on some of the pipelines (25.4mm) will possibly have to be removed prior to cutting. This concrete is most often removed by chipping, and this process may cause generation of dust, cf. [63]. The magnitude will, however, be limited and mitigation measures are easy to enforce.

Compared to other offshore modules and equipment any negative visual effects of storing pipelines and cables are considered “insignificant”.

Alternative B – Leave pipelines and cables in place but trenched

Due to trenching and backfill of infield pipelines and cables, “no” problems of smell, noise or visual effects are expected.

Alternative C - Leave pipelines and cables in place but bury ends

Due to leaving the pipelines and cables in place with ends buried, “no” problems of smell, noise or visual effects are expected.

10.2.6 Material Management

Materials present that have been considered are:

- Steel
- Concrete
- Marine growth
- Coating
- Copper

None of the infield pipelines have been used for transport of oil. There is no LSA associated with the lines. The possibility for having lead isotopes in the gas stream was previously considered by TOTAL NORGE. It was considered unlikely and no further investigation was made.

Table 10.4 gives an overview of material in the pipelines on the Frigg Field. The information in the table is split on pipeline dimension and cables, and also indicates in which sector they are located. It is assumed that the cables have a composition of 10% plastics, 20% copper and 70% steel.

Dimension	Steel	Coat	Copper	Concrete	Total
UK pipelines >12”	380.8	14.4	0	119.5	514.7
UK pipelines <12”	65	5.5	0	0	70.5
UK cables	13.6	2.0	3.9	0	19.5
Total in UK	**459.4**	**21.9**	**3.9**	**119.5**	**604.7**
Norwegian pipelines >12”	514.3	19.5	0	160.8	694.6
Norwegian pipelines <12”	36.2	1.9	0	0	38.1
Norwegian cables	9.0	1.3	2.6	0	12.9
Total in Norway	**559.5**	**22.7**	**2.6**	**160.8**	**745.6**
Total on Frigg Field	**1018.9**	**44.6**	**6.5**	**280.3**	**1350.3**

Table 10.4 Inventory for Infield Pipelines and Cables on the Frigg Field (in tonnes)

Alternative A – Remove pipelines and cables and onshore disposal

Even though a large portion of the materials will be recycled, there will also be quite some materials to be disposed of. The impact of onshore disposal of the infield pipelines and cables is found to give a “small negative” impact.

The steel in pipelines may be remelted and recycled (see section 3.3.2 for a further description of steel recycling processes). Coating thinner than 0.5 mm may normally be remelted together with the pipelines. Contaminants such as concrete and some types of coating (e.g. asphalt) will have to be removed prior to remelting. Coating of plastic may to some extent go along with the pipelines for remelting, but this will have to be evaluated on a case-by-case basis [69].

The concrete coating on the pipelines is expected to be recovered and used as road fill or aggregate for new concrete. Half of the concrete material is expected to contain approx. 0.073 % chlorides, and it is impossible to separate this concrete from the concrete not containing chlorides. This salt content may reduce the reuse potential for the concrete.

The amount of marine growth is limited on the pipelines.

The cables have a complex design with several materials twisted together with very tight connected layers. Normally such cables are granulated and the materials separated; metals for remelting and insulation for combustion, disposal – and if properly separated to recycling.

Copper and duplex steel in the cables is considered valuable materials for recycling. As indicated above making these materials available for recycling is difficult and resource demanding. It is however believed to be economically viable to recycle these cables.

The total waste volume generated by retrieving and disposing pipelines and cables onshore is estimated to 20-25% of the total material (see figure below). The environmental impacts are estimated to be “small negative”.

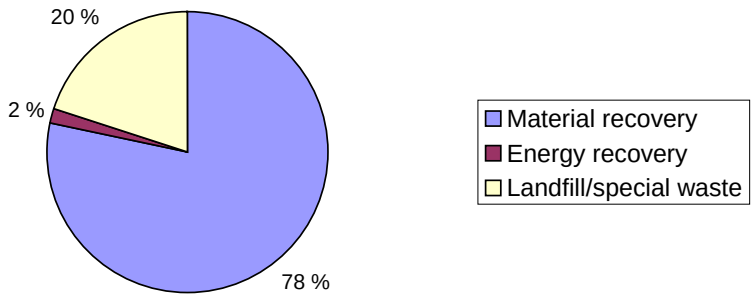


Figure 10.3 Material management for onshore scrapping of the Pipelines and Cables.

Alternative B – Leave pipelines and cables in place but trenched

No waste is expected generated from trenching and backfill of infield pipelines and cables.

Alternative C – Leave pipelines and cables in place but bury ends

No waste is expected generated from leaving the infield pipelines and cables in place with the ends buried.

10.2.7 Littering

Alternative A – Remove pipelines and cables and onshore disposal

The environmental impacts of littering from removing the infield pipelines is considered “none or insignificant”.

Due to the removal process of the pipelines and cables, parts of the concrete coating may loosen and fall off. These concrete parts may be spread by fishing gear over a wider area, and cause littering in the area locally to where the pipelines used to be. The amount of this littering is expected to be limited.

Alternative B – Leave pipelines and cables in place but trenched

No littering effects are expected due to trenching and back filling of infield pipelines and cables, and the environmental impacts of these processes are expected to be “none or insignificant”.

A trench will be made in the seabed next to the pipeline. The pipelines are then being pushed into the canal. No exposed parts of pipelines will be left uncovered.

An important issue with regard to leaving pipelines/cables in place is erosion/sedimentation, specifically the local seabed stability conditions. This will influence on whether the lines will stay buried/covered or if they will become exposed during time. The area is generally considered “geologically stable”. However, when it comes to a more detailed level, local conditions may influence on the seabed conditions. Experience from the field during 25 years indicates that there will be some, but minor, variations during time. It is also experienced that the prevailing current direction is N-S, meaning that lines in the E-W direction are more susceptible to become exposed.

Back filling of pipelines and cables implies sand/sediment filled over the left pipelines and cables to make sure that no parts are left exposed.

Alternative C – Leave pipelines and cables in place but bury ends

Leaving the infield pipelines and cables in place is considered to represent a “moderate negative” impact with respect to littering.

Exposed ends of the pipelines will be buried or covered. As stated above, the seabed in the Frigg Field is generally considered to be stable and no ground movement is expected that could bend or break the pipelines. They will however stay mainly exposed on the seabed. During time they will deteriorate, and fractures may spread if affected by external physical forces (trawls, anchors etc). As the magnitude of pipelines present is modest the littering potential is considered “moderate negative” (All together about 4400 meters with cables and pipelines will be left exposed on the seabed within an area of about 1.5km^2).

Some uncertainty exists with regard to predicting the exact erosion/sedimentation processes locally on the field tin the future. Evaluations made for other pipelines indicate the remaining lifetime to be from hundreds to several thousand years [62,81].

If the pipelines/cables are to be left in place the situation with regard to their status (degree of burial etc.) should be monitored. The frequency and magnitude of such monitoring should be discussed with relevant authorities, also discussing future liability issues.

10.3 Social Impacts from Disposal of Infield Pipelines and Cables

10.3.1 Impacts on Fisheries

Alternative A – Remove pipelines and cables and onshore disposal

Dependent on disposal of other components on the Frigg Field, removal of infield pipelines and cables is considered to have a “small positive impact” on fisheries.

Impacts of removing pipelines and cables will be somewhat dependent on whether or not the other components of the Frigg Field installations are removed. Additionally, inter-field pipelines may still be present in the area after Frigg cessation.

Some of the pipelines are rock dumped. Rock dumped pipelines are identified as a problem to trawling vessels, as rocks may enter the trawl and cause damage on gear and catch. Removal of the pipeline itself may not have any significant effect, as the rock fillings will not be removed. Hence leaving the rock fillings will outweigh the positive effects of removing pipelines. Concrete mattresses covering parts of the pipelines will be removed with the pipelines, representing a “small positive” benefit.

Removal of uncovered pipelines and cables will be positive from a fisheries point of view, as hindrances are removed from the seabed.

Alternative B – Leave pipelines and cables in place but trenched

Dependent on disposal of other components on the Frigg Field, trenching and back-filling of infield pipelines and cables are considered to have an overall effect on fisheries similar to Alternative A; i.e. “small positive” effect.

Trenching and backfilling of all infield pipelines and cables will leave the seabed in this location free from hindrances to trawling and other fisheries using bottom gear. Effects on fisheries from this alternative will, as for the other pipeline alternatives, be affected by disposal of the other components as well as the presence of inter-field pipelines.

Based on the possibility that the Frigg area may be opened to fishery in the future, trenching and back filling of the in-field pipelines at Frigg is considered positive for the fisheries.

Disposal of rock fillings and mattresses covering some of the pipelines today is important for the overall effect of pipeline disposal. If these structures are left on the seabed next to trenched pipelines, they will be obstacles representing a risk of entanglement and damage to bottom gear. This may outweigh the positive effects of trenching the pipelines.

Alternative C - Leave pipelines and cables in place but bury ends

Leaving the infield pipelines and cables with the ends buried is considered to represent a “small negative” impact for the fisheries.

Impacts of leaving pipelines and cables will be dependent on whether or not the other components of the Frigg Field installations are removed. Additionally, inter-field pipelines will still be present in the area after Frigg abandonment.

If installations are removed, and pipelines and cables are left in place, the impacts on fishery of this Alternative could have some significance. Leaving them in place mean that obstacles still will be present in the area for a long time into the future, representing a small negative impact potential.

If the Frigg area is opened for fishery in the future, the presence of rock dumped pipelines may mean that fishing vessels will still have to avoid the area.

No effects on fisheries are expected from leaving pipelines that are trenched and naturally back-filled. Other pipelines are not covered, but lie exposed on the seabed. These will slowly start to disintegrate as they are not maintained. An uncovered fractured pipeline may entangle and cause damage on fishing gear, and be a safety risk for fishing vessels. The impact is however considered “small negative”.

10.3.2 Impacts on Free Passage

The pipelines are considered not to have any impact on the free passage of the area (except for fisheries, Section 10.3.1), regardless of being removed or not.

The operations of removing, trenching the pipelines and cables or covering pipeline ends will involve support vessels and pipeline (reeling) vessels. This activity will, for a short period of time (a few weeks), lead to an increased frequency of vessels in the area. This is not found to have any practical effect on free passage in the area.

10.3.3 Costs and National Supplies (goods and services)

Three disposal alternatives have been explored for the Frigg Field in-field pipelines and cables. The total costs for disposing the pipelines and cables are shown in the Table 10.5:

The plan includes disposal of pipelines and cables on the UK side (60%) and on the Norwegian side (40%).

The tables below give the costs of the disposal alternatives for the pipelines and cables.

Pipelines and cables	Alternative A Remove, transport to shore and onshore disposal	Alternative B Leave in place but trenched	Alternative C Leave in place but bury ends
UK	97 MNOK / £7.4m	85 MNOK / £6.5m	24 MNOK / £1.8m
Norway	64 MNOK / £4.9m	57 MNOK / £4.3m	16 MNOK / £1.2m
Total	161 MNOK / £12.3m	142 MNOK / £10.8m	40 MNOK / £3.0m

Table 10.5 Costs for the different disposal alternatives for Disposal of infield Pipelines and Cables.

Based on expected Norwegian and UK supply the national employment effects can be estimated.

The table below gives the estimated Norwegian and the UK national service contribution.

Pipelines and cables	Alternative A Remove, transport to shore and onshore disposal	Alternative B Leave in place but trenched	Alternative C Leave in place but bury ends
Norwegian content	35%	40%	46%
UK content	30%	35%	29%

Table 10.6 Norwegian and UK content for different disposal alternatives for Pipelines and Cables

Figures 10.4 and 10.5 give the breakdown by industry for the Norwegian and UK supplies in connection with the disposal alternatives for the pipelines and cables.

Norwegian Content

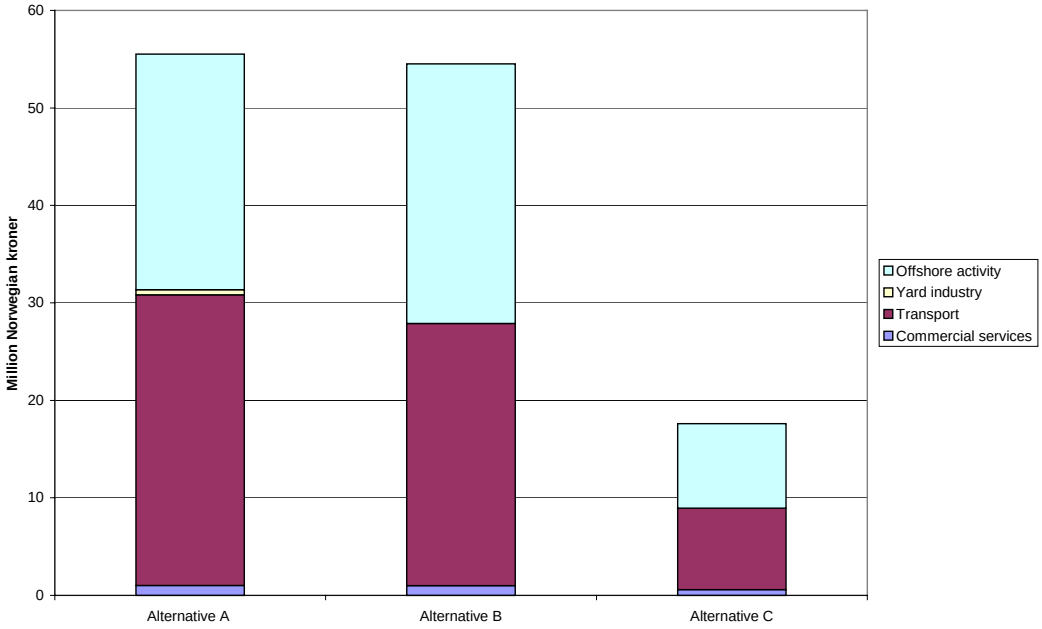


Figure 10.4 Frigg Field Pipelines and Cables: Norwegian content (first level), broken down by industry for each alternative (MNOK).

The largest Norwegian supplies are expected in the offshore activity and transport industry. Offshore activity includes TOTAL NORGE's project management and support. Transport is connected to the removal or trenching of the pipelines.

UK Content

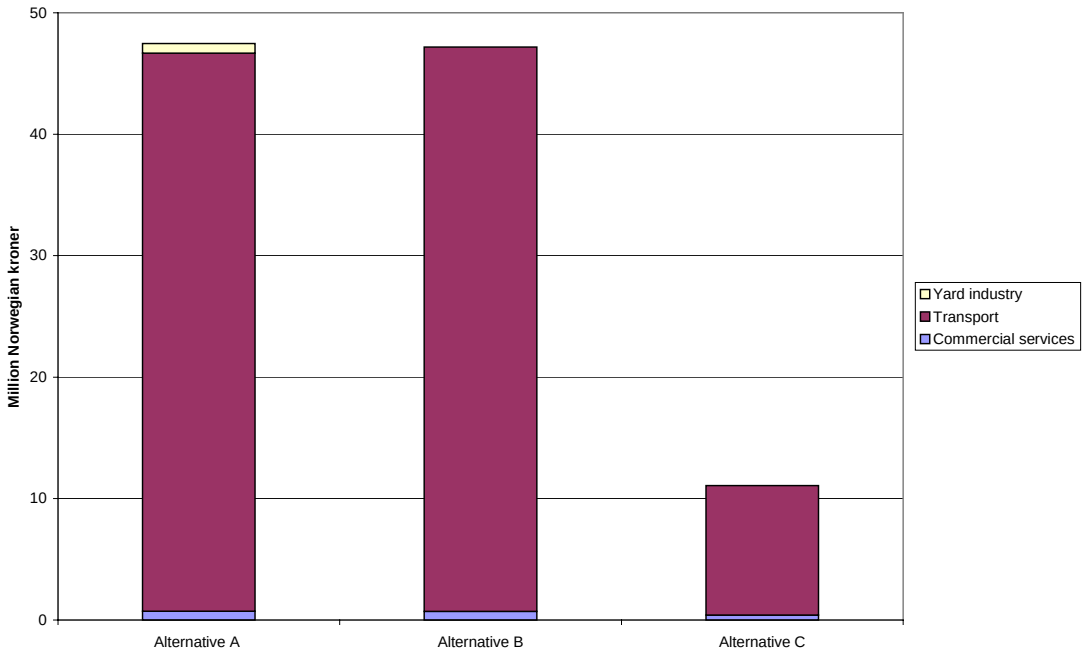


Figure 10.5 Frigg Field Pipelines and Cables: UK content (first level), broken down by industry The largest UK supplies are expected in the transport industry, which is connected to the removal or trenching of pipelines.

Assuming a price of 400-600 NOK / £30 - £46 per tonne of recycled steel from the pipelines and cables, this will give an income in the range of 0.2-0.3 million NOK / £15,300 - £23,000.

10.3.4 Employment Effects

The breakdown by industry of the national goods and services input forms the basis for the following employment estimates. The delivery of goods and services by each nation would have direct and indirect production effects at the national level.

Figure 10.6 shows the industries that may benefit from the production effects in UK and in Norway.

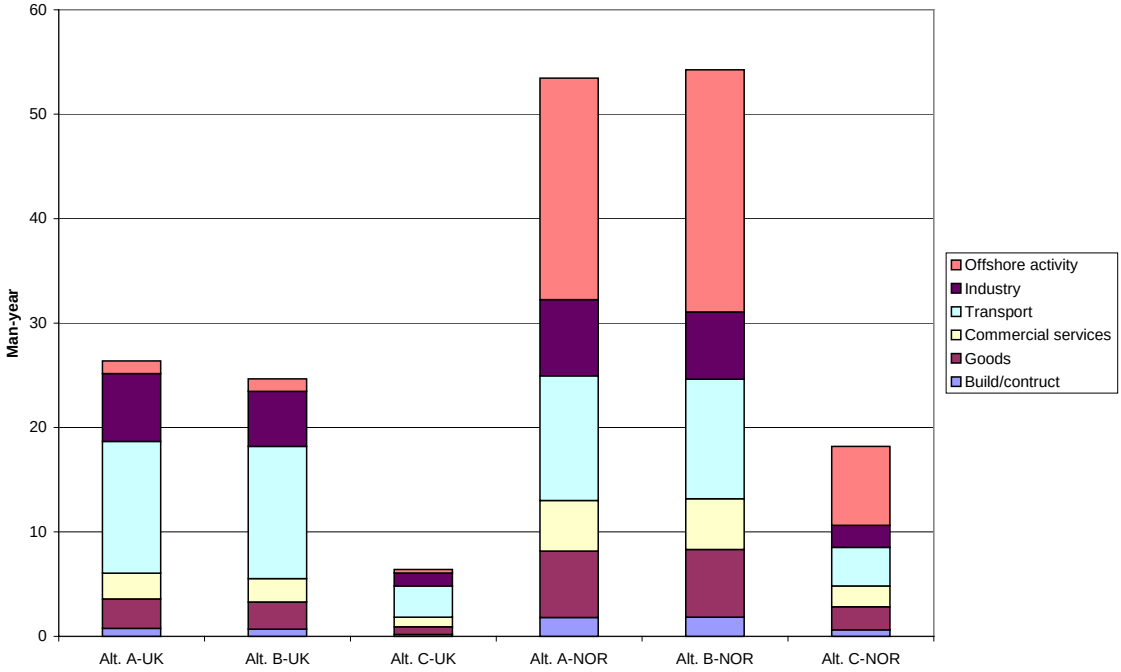


Figure 10.6 Pipelines and cables – UK and Norwegian production effects broken down by Industry (man-year)

In UK
Production effects in UK are expected to total about 25 man-years from alternative A, about 25 man-years from alternative B, and about 5-7 man-years from alternative C.

Consumer effects representing about 50% of the production effects will also occur. The total UK employment effects are estimated to reach about 40 man-years from Alternative A, about 35 man-years from Alternative B, and about 10 man-years from Alternative C.

In Norway
Production effects in Norway are expected to total about 55 man-years from Alternative A, about 55 man-years from Alternative B, and about 20 man-years from Alternative C.

Consumer effects representing about 50% of the production effects will also occur. The total employment effects are estimated to reach about 80 man-years from Alternative A, about 80 man-years from Alternative B and about 25 man-years from Alternative C

The employment effects will be spread over the years during which the removal, demolition and recycling will take place. The basic engineering is planned to start up in 2002. The offshore removal operations are planned for 2012.

10.4 Summary – Infield Pipelines and Cables

Environmental and societal impacts associated with the different disposal alternatives for pipelines and cables are summarised in Table 10.7.

	Alternative A Remove, transport to shore and onshore disposal	Alternative B Leave in place but trenched	Alternative C Leave in place but bury ends
Energy Consumption (1000 GJ)	57	29	0
Total Energy Impact (1000 GJ)	57	55	26
CO_2 emissions (1000 tonne)	4	2	0
Discharges to sea	None/insignificant	None/insignificant	Small negative
Phys./habitat effects	None/insignificant	None/insignificant	None/insignificant
Aesthetic	None/insignificant	None/insignificant	None/insignificant
Material management	Small negative	None/insignificant	None/insignificant
Littering	None/insignificant	None/insignificant	Moderate negative
Impacts on Fisheries	Small positive	Small positive	Small negative
Impacts on free passage	None/insignificant	None/insignificant	None/insignificant

Table 10.7 Environmental Impact of the different disposal alternatives for the in-field Pipelines and Cables.

Energy consumption associated with the pipelines alternatives is quite modest compared with the other entities. However, there is significant difference between the pipeline alternatives. Atmospheric emissions are low for all alternatives.

Only “insignificant” to “small negative” impacts are identified associated with trenching (reduced water quality, turbidity) and leaving in place (long term disintegration and leaching of metals). Similarly, only insignificant physical impacts are identified for all alternatives, they represent different impacts but the scale of impact is considered more or less equal.

Removal and scrapping of the pipelines and cables would produce some materials for recycling but would also leave some materials for disposal. The effects are thus both positive and negative, but the negative effect is considered most pronounced.

Leaving the pipelines and cables in place will, in the long term, represent a littering potential. The destiny for the field installations may influence the significance of this impact, and if installations are left in place, the impact of litter will be less. If all field installations are removed, the area will be open to fisheries. Trawl gear may enhance spreading of cables and pipe fragments and as such increases the littering effect.

Removing or trenching the pipelines and cables will leave the seabed open and levelled for trawling. This is considered to be a “small positive” impact. Leaving the pipelines and cables in place could conversely present a risk scenario whereby pipe fractures damage fishing gear, or for the largest pipelines, represent a risk for vessel and personnel. As the probability for such an incident is very low the impact is considered “small negative”.
The impact on national supplies and employment for disposal the pipelines and cables are summarised Table 10.8.

	In Norway			In UK			Total		
Alternatives	A	B	C	A	B	C	A	B	C
Costs in MNOK Cost in £m	64	57	16	 7.4	 6.5	 1.8	161 12.3	142 10.8	40 3.0
Supplies in MNOK Supplies in £m	55	55	18	 3.4	 3.4	 0.8	112 8.6	104 8.0	30 2.3
Employment effects (man year)	80	80	25	40	35	10	120	115	35

Table 10.8 Summary of social impacts each disposal alternative for the Infield Pipelines and Cables located in the Norwegian and UK part of Frigg Field.

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11 Impact Assessment for Disposal of Drill Cuttings

11.1 Description of Disposal Alternatives for Drill Cuttings

Drill Cuttings DP2, CDP1	**Alternative A** Remove and onshore disposal	**Alternative B** Leave in place

Table 11.1 The main disposal alternatives considered for Drill Cuttings at DP2 and inside CDP1

The drill cuttings are only discharged externally from Norwegian platform DP2. Section 11.2 makes a comparative assessment on the impact in removing or leaving the drill cuttings in place.

The drill cuttings from CDP1 drilling activity were disposed of inside the platform and are assessed in Section 11.3.

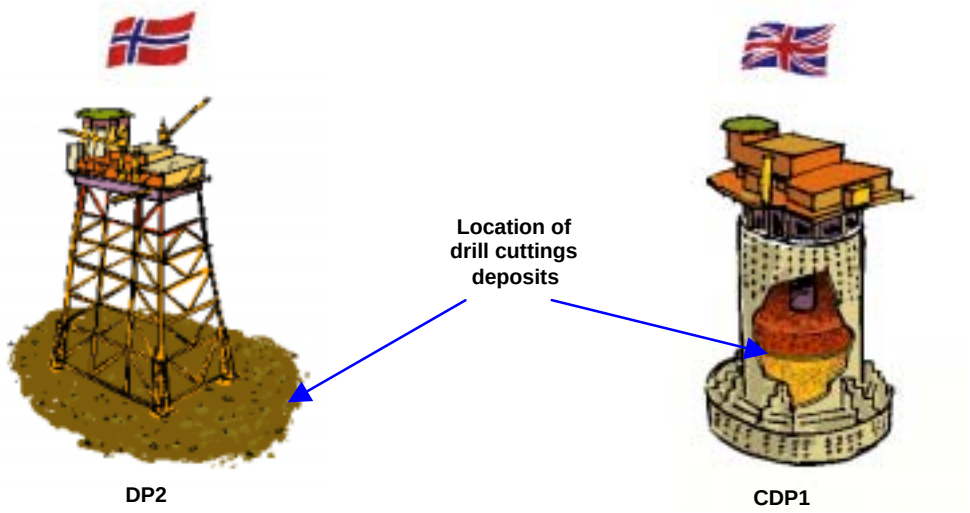

Figure 11.1 Location of Drill Cuttings deposits at DP2 and inside CDP1.

The amount of cuttings deposits at Frigg is quite modest in comparison with many other fields (see section 6.2.2 about amount and degree of contamination). No distinct cuttings pile has been found at the field, with the deposits having a maximum height of 20cm, decreasing outwards. Thorough sampling has been performed, both in terms of distribution and content, in accordance with the OLF guidelines [93]. The total volume is estimated to about 400m^3, covering an area of 80×120m.

An alternative with covering of the cuttings has been evaluated, however not found feasible for the Frigg field.

The information available is considered sufficient to assess impacts. In the further planning process this assessment will however be aware of ongoing research (e.g. extensive UKOOA Programme and OLF studies) and consider new results as they become available.

Alternative A – Remove drill cuttings and onshore disposal

If removed, removing the drill cuttings should be performed prior to removal of the steel substructure structure (DP2). The reason is that removal of the steel substructure will disturb the cuttings and possibly result in release of contaminants, with a potential for negative environmental effects.

Drill cuttings on the seabed may be retrieved by different methods such as mechanical dredging or suction pumping, but only one of the methods evaluated was found acceptable for removing the drill cuttings under and around the DP2 platform [64]. This was due to the complexity of removing a thin layer of cuttings from below the installation, between steel members, and with difficult access.

This method includes the use of a subsea crawler operated from a vessel. The cuttings will be removed by pumping the material from the seabed into storage tanks on a barge for transportation to an onshore disposal plant. As the drill cuttings are spread on the seabed, recovering drill cuttings will also bring sea water and natural sediments. This will increase the volumes removed considerably. Water could be separated at the vessel, but may represent a problem if re-discharged, mainly due to hydrocarbon content. Sand retrieved from the sea bottom along with the cuttings will also have to be treated [64].

Even if this method is considered technically viable, one has to underline the fact that such operations have never been conducted before, and there will thus be large uncertainty concerning the details of the operation.

Onshore treatment is assumed to be at one of the existing Norwegian onshore processing plants. There has never been any test of processing aged and recovered cuttings material. The evaluations are therefore based on data from processing “fresh” cuttings (i.e. recently drilled cuttings).

Alternative B - Leave drill cuttings in place

This alternative involves leaving the drill cuttings in place, after disposal of the DP2 steel substructure. Complications may arise when the substructure is to be completely removed. In this case the piles have to be cut below the seabed level, involving excavation of the seabed around each pile. This will cause disturbance of the drill cuttings layer.

11.2 Environmental Impacts from Disposal of Drill Cuttings at DP2

11.2.1 Energy

The Energy Consumption and Total Energy Impact for both alternative for the drill cuttings at DP2 is found to be “none” and “insignificant” respectively, as total values. It is however obvious that the removal option require much more energy than the leave in place option, though within the same “energy category”, cf. Table 3.1.

The operations of removing drill cuttings have a high-energy demand, calculated at about 61,000GJ (Table 11.2). Large amount of vessel mobilisation and use for removing a small amount of cuttings gives very high energy consumption per unit removed. In such recovery operations, 5-10 times as much water as solid material will be lifted. The majority of this water will have to be separated from the material prior to onshore processing, possibly using thermal treatment techniques. There are many uncertainties regarding the energy consumption of this process, but an estimate of 0.4 GJ per tonne has been made. Finally, some energy is required to handle, transport and process the material onshore. For fresh cuttings this is normally in the range of 1-3 GJ per tonne in Norway [68]. In total, the entire Energy Consumption for lifting,

dewatering, processing and disposal of about 400 m^3 cuttings is found to be about 64,000 GJ or about 80-90 GJ per tonne.

With such a low oil content as the Frigg cuttings (amounts to about 150 kg), the benefit from using the energy generated from recovered oil (in the thermal process) will be negligible compared to the energy required to make it available (equal to an oil amount of nearly 1500 tonnes).

Operation	Remove and onshore disposal
E_{DIR} Marine operations	61 000
E_{DIR} dewatering	1 500
E_{DIR} Onshore processing	1 200
E_{CONS} Energy Consumption	**63 700**

For key of terms, see explanation of energy calculations. See Section 3.3.2.

Table 11.2 Energy Consumption for removal of drill cuttings at DP2 - Alternative A (in GJ).

11.2.2 Emissions to Atmosphere

Alternative A – Remove drill cuttings and onshore disposal

The impacts from emissions to the atmosphere are considered “insignificant”.

Emissions associated with recovery, dewatering and processing drill cuttings from the seabed are presented below. The CO_2 emissions are estimated to be about 6,500 kg per tonne cuttings lifted. For comparison the normal rate of CO_2 emitted per tonne fresh cuttings transported and processed will be in the order of 80-100 kg.

Operation	Remove and onshore disposal
CO_2 emissions	
Marine operation	4 529
Dewatering	111
Onshore processing	60
Total	**4 700**
NO_X emissions	
Marine operation	83.5
Dewatering	2.1
Onshore processing	0.004
Total	**85**
SO_2 emissions	
Marine operation	4.0
Dewatering	0.1
Onshore processing	0.002
Total	**4.1**

For key of terms, see explanation of emissions to atmosphere. See section 3.3.2..

Table 11.3 Total emissions to atmosphere for removal and onshore disposal of drill cuttings at DP2 - Alternative A (in tonnes)

11.2.3 Discharges to Sea, Water or Ground

Alternative A – Remove drill cuttings and onshore disposal

Impacts from discharges associated with removing and disposal onshore of drill cuttings at DP2 are found to be “small negative”.

This alternative removes contaminated material from the seabed, and should intuitively be positive when considering discharges to sea.

However, the removal operation itself will lead to disturbance of the drill cuttings deposits. This operation could therefore generate leaching to sea, with negative impacts that might outweigh the positive on-site impacts from removal.

Areas of concern associated with a removal operation, which have been identified and assessed are:

- Recovery from sea-bottom
- De-watering, discharges from vessel or onshore processing
- Landfilling capacity
- Discharges from final disposal of recovered material

Removal Offshore at DP2

The main concern associated with removal of the drill cuttings, is the disturbance and spreading of contaminants during the actual removing process. Fractions of this contamination may spread to surrounding water masses.

The layer beneath DP2 steel substructure has slightly elevated concentrations of cadmium, copper, lead and zinc. Most of the metals are associated with the barite from the mud (except zinc that is believed to originate from anodes). They are crystalline bound and have a very limited bio-availability to marine organisms. The concentration of THC and B(a)P found in the pile was also elevated (see Section 6.2.2)

The amount of water entrained with the drill cuttings will be a problem when brought for treatment onshore. The drill cuttings that are recovered, could be loaded in tanks, or as bulk, and transported to shore.

Even if the amount of drill cuttings which will be removed from under and around the DP2 steel substructure is limited, by using suction dredging equipment 4-5 times as much water as drill cuttings will normally be lifted (ref. [65]) which may then be discharged. The environmental consequences of letting this water out offshore, after proper treatment, are evaluated to be small. Since the cuttings layer is very thin lifting of the cuttings material will also result in lifting of overlying and underlying clean sand. How much this will amount to has not been calculated. It is however, believed to be at least twice the amount of cuttings. This will mix with the cuttings and result in much more material for transport and treatment.

The total extent of discharges to sea from removing the drill cuttings beneath the DP2 steel substructure has been estimated to be small. The environmental impacts are evaluated to be “small negative”.

Onshore Disposal

The oil concentration in the DP2 cuttings is already far below (0.2 kg/tonne) the concentration that normally is achieved by the existing thermal cuttings processing plants. This should normally be below 0.5% (5kg/tonne) – which is the Norwegian limit for disposal in landfill. Being mixed with clean sand during lifting and transportation the amount will be even less. It is therefore questionable whether thermal treatment of the DP2 cuttings is meaningful at all.

Traces of heavy hydrocarbon fractions and heavy metals may still be associated with the solid residue. After disposal the metals may, over time, leach into the landfill drainage and collection system. It should however be noted that there has been some concern expressed with regard

to the possible content of heavy metals in disposed treated cuttings, but no documentation has been found directly linking elevated metal concentrations in nearby fjords/lakes to leakage from disposed cuttings material. Rather than speculating on possible leaching it is found more appropriate to list the estimated amount of metals that will have to be disposed of with the cuttings (Table 11.4). This will then be the same amount as is present in the cuttings layer for the "leave in place" alternative.

Trace metal	Amount (kg)
Chrome (Cr)	13
Nickel (Ni)	11
Copper (Cu)	24
Zinc (Zn)	244
Cadmium (Cd)	0.4
Lead (Pb)	53
Mercury (Hg)	0.015

Table 11.4 Trace metals in the DP2 drill cuttings [12], based on 400m^3 cuttings (in kg).

It is not recommended to process the cuttings with the aim to extract the associated heavy metals. The concentrations are far below what is normally considered practicable and beneficial to process.

Alternative B - Leave drill cuttings in place

Impacts from discharges associated with leaving the drill cuttings at DP2 in place are found to be "small negative".

Areas of concern, which have been identified and assessed:

- Leakage of heavy metals
- Leakage of hydrocarbons
- Removal of the steel substructure

If the drill cutting deposits are left in place, a gradual leakage of hydrocarbons and metals to the surrounding water masses and sediments is anticipated. Such secondary contamination could increase by physical disturbance. Studies performed indicate that lighter hydrocarbons in the cuttings layer may migrate to the surface [66]. The amount of leakage of organic components and metals from the drill cutting pile is estimated to be small and decreasing over time (total oil content estimated to be 150kg). During work conducted by UKOOA in 1999 [71] it was generally found that the most sensitive individuals of the more prone species were affected by THC concentrations at 10-50 mg/kg. Generally it was found that such leakage represented low environmental risk.

Release of a majority of very fine particles being widely spread is assumed the main reason since only about 4% of the discharged cuttings still are present around the installation.

Whether metals leak gradually to the surrounding water masses or penetrate further into the pile, is not known at present time. If the metals leak to the surrounding water masses, this will be as a gradual release of contaminants or spreading with the solid material. Bio-availability may only be possible if sediments get into oxygenated environments (pore water or seawater near bottom). These metals are believed to rapidly disassociate and associate with particles and as such will only be exposed to biota for a short time. Organic components will then decompose shortly after release and the metals will be spread or deposited. The amount of metals associated with the DP2 cuttings is also limited (see table above), and the cuttings are also covered by natural sedimentation.

Layers of cuttings deposits tend to rapidly become anoxic as a result of the microbial degradation processes occurring. Lack of oxygen tends to further retard the process of

hydrocarbon biodegradation. In the DP2 cuttings layer aerobic processes are found to be dominating [12], thus enhancing biodegradation.

When the DP2 steel substructure is removed, the drill cutting will be exposed to possible additional physical disturbance (waves, currents, trawlers etc.).

As described in Alternative A, the layer of drill cuttings under and around the DP2 platform is slightly contaminated with cadmium, copper, lead and zinc. Due to limited amounts of drill cuttings, and low level of contamination the impact from leakage to the surroundings and contamination is considered “small negative”.

The impact from leaving the cuttings layer as is in place is thus considered “small negative” with regard to leaching. In this context it should also be taken into consideration that the cuttings will be partly buried when the DP2 structure is being removed (see Figure 8.2), and be further mixed and buried as a consequence of the removal operation.

Some leaching of contaminants to the sea is expected from the process of removing the steel substructure when the drill cuttings pile is in place. A major part of the drill cuttings and under laying sediments will have to be dug out to allow for cutting of the substructure piles (a few metres below the mud line). These sediments (and cuttings) will then be mixed and temporarily piled in the vicinity prior to being moved back into the pit around the cut pile after the removal of the substructure.

A majority of the cuttings will then be mixed with normal sediments. The sediment quality in the area will then in the long term be better than today. The main concern is the release of contaminants during the removal of sediments/drill cuttings to enable the cutting of the steel piles, and then the levelling of the seabed after the substructure is removed. This will be an operation with duration of days to weeks, so any effect will be temporary.

According to prevailing guidelines from Norwegian authorities [67] the seabed at an offshore field should be monitored also after final production shut down. TOTAL NORGE will include cuttings deposits as part of the regular monitoring. This will be carried out in accordance with the OLF guidelines for cuttings deposits monitoring [79].

11.2.4 Physical Impacts to the Environment

Alternative A – Remove drill cuttings and onshore disposal

Physical impacts associated with removing and disposal of drill cuttings at DP2 are found to be “insignificant”.

Areas of concern, which have been identified and assessed:

- Disturbance of contaminated masses
- Changing the local habitat

As described for discharges to sea, water or ground, removing the drill cuttings will cause re-suspension of particles and locally, time limited spreading of contaminants. The environmental consequences are evaluated to be “small negative” due to the small amount of drill cuttings under and around the DP2 platform.

As a result of the re-suspension, a layer of fine particles will cover the sea bottom in the very near vicinity of DP2 and will change the sea bed composition. This change is expected to cover a limited area.

The physical impact of habitat due to removal of the drill cuttings for onshore treatment is evaluated to be “insignificant”. At the same time, leaving behind relatively cleaner sediment could be considered a small positive effect. Since the benthic community is only slightly

disturbed at present, and it is also believed that it will improve over time, this effect is considered “insignificant” in the long term.

Alternative B - Leave drill cuttings in place

No physical impacts are expected with leaving the drill cuttings at DP2 in place as they are.

However, the situation may be different. As described under steel substructures (section 8.2.4 in the EIA), the disposal of the substructure will influence significantly the cuttings deposits below. In addition disturbance may be expected from freeing of bottom braces, mud mats and pipelines/cables prior to lifting out the DP2 jacket. This effect has however more to do with the steel substructure disposal than the drill cuttings, and is consequently described in section 8 in this EIA.

11.2.5 Aesthetic Impacts

Alternative A – Remove drill cuttings and onshore disposal

Aesthetic impacts associated with removing and disposal of drill cuttings at DP2 are found to be “insignificant”.

Issues identified and assessed are:

- Smell
- Dust
- Noise

The retrieved drill cuttings will be transported to shore most probably in bulk. It may temporarily be stored in tanks or containers in the quay area.

Treatment of drill cuttings by the thermal distillation processes is performed in closed systems and no disturbing smell is generated.

The dry residue, which is one of the processing products, is a very fine particular material and may cause dust problems. This material will be similar to “normal” residue also from fresh cuttings after processing. The usual procedure is to sprinkle the dry residue as soon as it has left the processing machine or pack it in big-bags directly after processing. For the operating processing plants processing fresh cuttings these problems are mitigated and no problems due to dust are reported presently [68].

Noise as well as smell or dust, are not expected to cause problems in the vicinity of the processing site. The processing equipment will cause some noise in the processing hall, but this disturbance will shortly be reduced to a minimum as one move from the processing hall. The element on the processing sites causing the most noise is the wheeled loaders transporting untreated and treated drill cuttings [68].

The aesthetic impacts of removing the drill cuttings for onshore treatment are evaluated to be “none/insignificant”.

Alternative B – Leave drill cuttings in place

No visual effects, smell or noise will be relevant due to leaving the drill cuttings in place at DP2. The environmental consequences are evaluated to be “none or insignificant”.

11.2.6 Material Management

Alternative A – Remove drill cuttings and onshore disposal

Removal and onshore disposal of the cuttings at DP2 is considered to result in "small negative" impacts.

Areas of concern, which have been identified and assessed:

- Dry residue
- Water
- Oil
- Salt
- Landfill space

There will not be any onshore processing capacity limitations from the Frigg cuttings in Norway (DP2).

The products of the processing onshore of the drill cuttings are dry residue, water and oil.

The water should be tested to be clean enough to be let out to the nearest sea outfall, in accordance with the plants operating permission. Depending on the technology used to treat the drill cuttings, oil may or may not be reused in the internal process (energy). The amount of oil that will be recovered is very low.

The dry residue generated by processing the drill cuttings will contain heavy metals, possibly PAH and other components dependent on the drilling mud used originally. The amounts of the different components in the dry residue are dependent on technology used. The heavy metals found in thermally treated drill cuttings may be e.g. chrome, cadmium, lead, copper and mercury (see Table 11.4).

To deposit the dry residue of the treated drill cuttings, the content of oil must not exceed 0.5 % by weight. The amount of oil in the DP2 cuttings, even at the field, is far less than this.

The amounts of dry residue generated due to removal of the drill cuttings beneath the DP2 steel substructure, will be limited and the environmental impacts of this process are considered "small negative".

Alternative B – Leave drill cuttings in place

No waste will result from leaving the drill cuttings in place at DP2.

11.2.7 Littering

Alternative A – Remove drill cuttings and onshore disposal

Removing the drill cuttings at DP2 for onshore disposal is not expected to cause any littering effects to the Frigg Field.

Alternative B – Leave drill cuttings in place

The littering impacts of leaving the drill cuttings at DP2 are evaluated to be "none or insignificant".

The amounts of drill cuttings beneath and around the DP2 steel substructure are limited both geographically and in volume. It is not assumed to form any kind of littering problems, and the material is considered be contained in the local area.

11.3 Environmental Impacts from Disposal of Drill Cuttings inside CDP1

The environmental impacts of disposing the CDP1 cuttings at sea together with the solid ballast are considered to be" insignificant".

The solid ballast in the CDP1 concrete substructure contains about 5600 m^3 of old drill cuttings. The associated drilling fluid used is water based mud. It has been evaluated whether this material preferably should be taken to shore for treatment and/or disposal, or if it should be disposed of at the field together with and mixed with the solid ballast. From drilling operations such material normally is permitted discharged to sea without any particular measures. Impacts documented from discharges of such mud are mainly smothering effect on the seabed, ref. is made to DP2 where similar type of mud is discharges.

Discharged together with the solid ballast, the spreading of water based mud is considered to be even less than from normal drilling operations, and the material will be mixed and deposited on the seabed. The impact from this as a discharge is considered "small negative" to "insignificant". Such a discharge will however need permission from the relevant UK authorities.

To take the material to shore will also imply some technical difficulties separating it from the rest of the solid ballast. It is assumed that twice the volume will have to be removed. It is uncertain which type of treatment process that should be used for the material if brought onshore. It is considered more likely that it will simply have to be de-watered and disposed of. Type of disposal will depend on the characteristics of the material. It is therefore considered the best environmental option that the cuttings materials are being disposed of at the field together with the solid ballast.

Within the likely volume and contaminated level of drill cuttings within CDP1, the impacts from releasing this to the surroundings are expected to be "small negative" or "insignificant" [84].

The impacts are likely to be largest if the cuttings are released through a complete structural collapse. However, the ballast sand and gravel represents a larger volume compared to the fractions of cuttings.

The environmental impacts of leaving the drill cuttings inside CDP1 are considered to be "insignificant", as the solid ballast will cover the benthic community in that local area, independently of the cuttings.

11.4 Social Impacts from Disposal of Drill Cuttings at DP2

11.4.1 Impacts on Fisheries

Alternative A – Remove drill cuttings and onshore disposal

Removal of drill cuttings at DP2 is considered to represent "insignificant" impacts on fisheries.

If the DP2 steel substructure is removed, the area may be opened for fisheries in the future. Bottom gear and catch may then come in contact with contaminated sediments and drill cuttings on the seabed. Removal of the drill cuttings from the DP2 location results in elimination of this risk, and is therefore positive for the fisheries in this area. This effect must, however, be seen in relation to how field installations will be disposed of.
In summary, since the extent of contamination by drill cuttings in the Frigg area is quite modest, removal of drill cuttings is not considered to have any pronounced effects on fisheries.

Alternative B – Leave drill cuttings in place

Leaving the drill cuttings in place is considered to represent “insignificant” impacts on fisheries.

If the DP2 steel substructure is removed the area may be opened for fisheries. As previously described the cuttings will also be mixed with sediments when cutting the piles, and the drill cuttings finally left in place will not be significantly contaminated.

Since the extent of contamination by drill cuttings in the Frigg area is quite small, the possibility for contamination or damage on catch and gear is considered negligible. In summary, leaving drill cuttings in place is therefore not considered to have any pronounced effects on fisheries.

11.4.2 Impacts on Free Passage

Drill cuttings are situated on the seafloor, not affecting passing vessels in any way. The presence or non-presence of the drill cuttings will not affect the free passage in the area.

The operation of removing the drill cuttings can probably be performed with only few vessels involved. Considering the duration and extent of the operations, the impact on free passage is found to be “none” or “insignificant”.

11.4.3 Costs and National Supplies (goods and services)

The cost and national supplies for the two disposal alternatives for the drill cuttings are shown in Table 11.5. Note that removal of the drill cuttings within CDP1 when the concrete substructure is left in place is not evaluated.

	Alternative A Remove and onshore disposal	Alternative B Leave in place
DP2	120 MNOK / £9.2m	0

Table 11.5 Costs for disposal alternatives for Drill Cuttings at DP2.

Based on expected Norwegian supply the national employment effects have been estimated. The Norwegian content is expected to be at about 35%.

11.4.4 Employment Effects

The breakdown by industry of the national goods and services input forms the basis for the following employment estimates. The national deliveries would have direct and indirect production effects at the national level. It is expected that a production effect of about 55 man-year (would occur in connection with removal and inshore disposal of the drill cuttings. (See Figure 11.2). The production effects will mainly occur in offshore activities. In addition there would also be consumer effects estimated at 30 man-year. The total employment effect in Norway is expected at about 80-90 man-year.

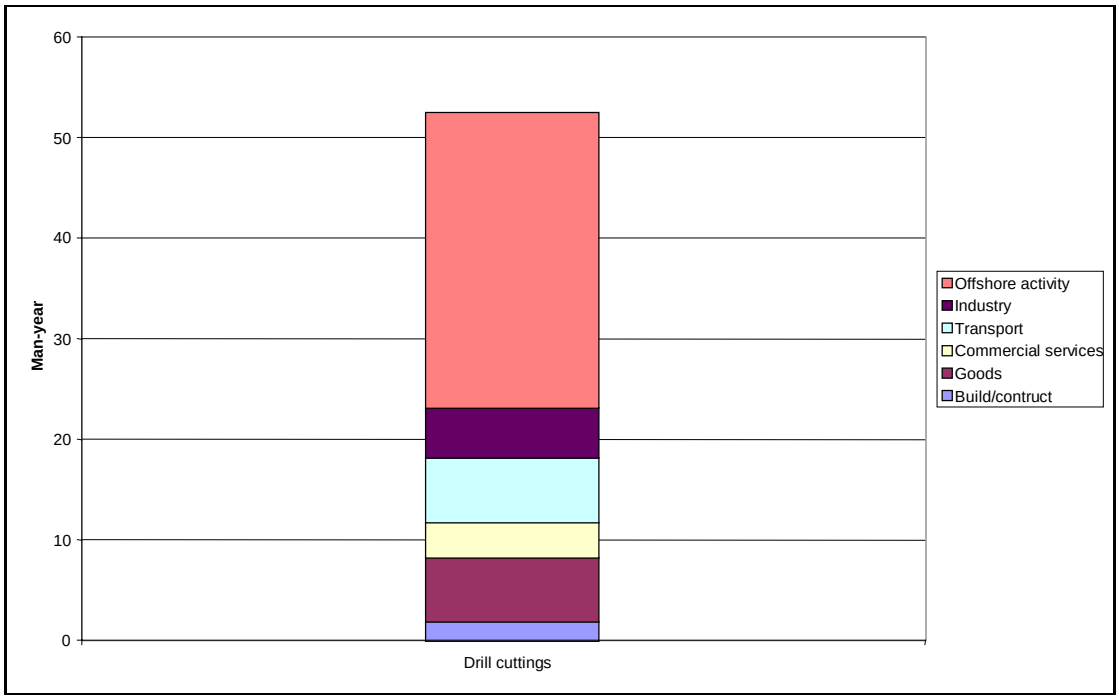

Figure 11.2 Drill cuttings at DP2: Production effects in Norway for removal and onshore disposal (man-years).

11.5 Summary - Drill Cuttings

Drill cuttings at DP2

The environmental impacts for the two disposal alternatives for the drill cuttings layer at DP2 are summarised below.

	Alternative A Remove and onshore disposal	Alternative B Leave in place
E_{CONS} Energy Consumption (1000 GJ)	64	0
E_{TOT} Total Energy Impact (1000 GJ)	64	0
CO_2 emissions(1000 tonnes)	4.7	0
Discharges	Small negative	Small negative
Physical	None/insignificant	None/insignificant
Aesthetics	None/insignificant	None/insignificant
Material management	Small negative	None/insignificant
Littering	None/insignificant	None/insignificant
Impacts on fisheries	None/insignificant	None/insignificant

Table 11.6 Environmental Impact of the different disposal alternatives for the Drill Cuttings at DP2.

Recovery, de-watering, transport and processing cuttings result in some energy consumption. Since the amount of cuttings is small and processing technology has low levels of emissions, the emissions to air will be very small.

Discharges to sea from removal are mainly associated with the recovery process, but there is also some leaching potential associated with solids being disposed of onshore. Leaving the cuttings in place also have some potential for leaching of contaminants to surrounding environments. As the cuttings have a low content of contaminants the potential will be limited. Since the cuttings will be affected by the disposal of the substructure there is a higher potential for releases of contaminants during this operation. This effect should however be considered as part of the DP2 steel substructure disposal impacts.

Removing the contaminated material from the field will leave a cleaner physical habitat for marine fauna. This could be argued a positive impact, but its magnitude is considered "insignificant".

Taking the recovered material onshore for disposal will require some landfill space, which is considered a "small negative" impact.

There are no particular impacts on either fisheries or free passage from either of these alternatives.

The impact on national supplies and employment for removal and disposal of drill cuttings	Norway
Costs	120 MNOK / £9.2m
National supplies	41 MNOK / £3.1m
Employment effects (man year)	80-90

Table 11.7 Summary of social impacts if removal of Drill Cuttings at DP2.

Drill cuttings inside CDP1

The environmental effects are considered to be "insignificant", as the solid ballast inside CDP1 will cover the benthic community in that local area, independently of the cuttings.

12 Mitigating Measures and Monitoring

It is one of the main objectives of an EIA to suggest mitigation measures to reduce negative impacts and to enhance positive impacts. Many mitigation measures have already been incorporated to the solutions at the feasibility stage, based on knowledge of impacts and previous experience of different measures.

Some additional mitigation measures, suggestions for monitoring and other remedial actions are also discussed as part of the assessment of impacts for the different alternatives. The planned actions in response to the suggested mitigating and monitoring measures are given in Section 14.6 in Part1 – Disposal Plan in this Frigg Field Cessation Plan.

The most important measures are listed below (not by order of priority):

- Clean-up of seabed debris to eliminate the risk of damage to fishing gear, and to reduce the potential for littering. This should be planned as a three-stage process – identification, removal and verification.
- Install navigation lights on the installations left in place to prevent the occurrence of dangerous situations with passing vessels.
- Removal of external steelworks on the concrete substructures left in place to limit the obstruction and risks to fisheries.
- Cover cut ends of the steel substructure foundation piles to avoid damage to fishing gear.
- Select favourable time of year, favourable weather conditions and protect and scare fish away to limit impacts if using explosives to obtain the –55m clearance for the partial removal alternative for CDP1. Develop guidelines for observation for cetaceans to be incorporated in the execution plan.
- Remove all pipelines within the safety zone, including export pipelines not being part of this EIA, to ensure access for fisheries without any possible obstacles on the seabed.
- Comply with the implemented EMAS system to ensure that continuous improvements and openness are key parts of the planning and execution of all work associated with the decommissioning of the Frigg Field facilities.
- Steel items covered by polyurethane paint should be identified before the start of demolition. Cutting with thermal means will cause release of isocyanates, which could cause serious harmful effects to humans.
- Sound material and waste management with optimal reuse/recycling is considered very important, and a stretched target for reuse/recycle should be considered. A dedicated waste-handling module capable of tracking all waste fractions has been developed to be included in the environmental accountancy system.
- If required, contractual arrangements should be made with the onshore disposal contractor to ensure that possible aesthetic effects are mitigated.
- Assess whether present rock dumps should be left in place or whether the material should be spread out on the seabed to reduce the impacts on fisheries.
- Monitor the condition of the layers of drill cuttings if they are left in place after completion of the approved decommissioning programme.
- Discuss liability issues with authorities in respect to any facilities left in place.

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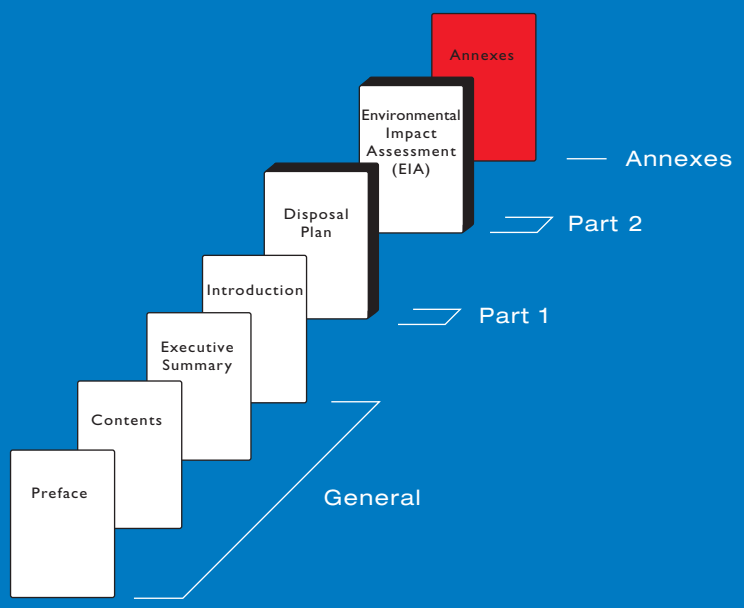

Frigg Field Cessation Plan

Annexes

Annex A Stakeholder Comments on the Proposed Environmental Impact Assessment Programme.

Annex B Stakeholders Comments from Decommissioning Workshop September 2000 (Notes on how the comments have influenced the Environmental Impact Assessment Report are included).

Annex C Comments on First Draft of the Frigg Field Cessation Plan from UK Governmental Organisations

Annex D Stakeholders' Comments on Second Draft of the Frigg Field Cessation Plan

Annex E Comments from Contracting Parties during OSPAR Consultation Process

Annex F Abbreviations and Glossary

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Annex A

Stakeholder Comments on the Proposed Environmental Impact Assessment Programme

Introduction

The Proposal for the Environmental Impact Assessment Programme (EIA) for Frigg Field Cessation Plan was submitted under separate letters dated 11th June 1999 to the Norwegian Ministry of Petroleum and Energy (MPE) in Oslo and Department of Trade and Industry (DTI) in Aberdeen. The Proposal was then subjected to a simultaneous public consultation in Norway and UK. The written comments received have been summarised and are reported in this annex.

As part of the consultation process, the proposal for the EIA programme was made available on an Internet web site from July 1999.

Public Consultation in Norway

In Norway the public consultation was co-ordinated by MPE. The proposed EIA was submitted to governmental and non-governmental organisations (NGOs) in a letter dated 23rd June 1999 with a deadline for comments of 15th October 1999.

In addition to the formal correspondence, meetings have been held with some of the leading NGOs at which the proposed programme for the EIA was presented.

Public Consultation in UK

In the UK the public consultation with the non-governmental organisations (NGOs) about the proposed EIA programme was co-ordinated by TOTAL NORGE, as the Frigg Field operator. The consultation with governmental bodies was managed by the DTI.

The proposed EIA programme was sent to 25 stakeholders including the statutory list defined by DTI in a letter dated 14th June 1999. The deadline for comments was 31st August 1999, later extended to the end October 1999.

In addition advertisements were published in seven selected UK newspapers/magazines which appeared during the first weeks of July 1999. Thirty-nine representatives of the media were informed by letter of the public consultation process being started by TOTAL NORGE relating to the decommissioning of the Frigg Field facilities.

As a result of the advertisement and media coverage, additional stakeholders expressed a wish to be involved in the Frigg Field public consultation process.

In the UK meetings were held with some of the leading NGOs at which the proposed EIA programme was presented.

Response to the Public Consultation of Proposed EIA

In Norway 8 of the 11 stakeholders on MPE's mailing list submitted written comments to the proposed programme for the EIA

In the UK, 25 stakeholders were approached, of whom four submitted written comments.

This Appendix presents the comments received and discusses their relevance in relation to the original proposal for the EIA programme. The way these comments have been incorporated into the EIA process has also been noted.

Comments not specifically relevant for the EIA have not been addressed here, but have been taken into account in the Disposal Part of the Cessation Plan.

Written comments were received from the following parties :-

1. Wilkinson Environmental Consulting, Halesworth, Suffolk, UK

2. Joint Nature Conservation Committee, Aberdeen, UK

3. Marine Conservation Society, Ross-on-Wye, UK

4. National Federation of Fishermen's Organisations (NFFO), Grimsby, UK

5. Norwegian Ministry of the Environment, including:-
   Norwegian Pollution Control Authority (SFT)

6. Norwegian Ministry of Fisheries, including:-
   Institute of Marine Research (Havforskningsinstituttet), Bergen
   Directorate of Fisheries (Fiskeridirektoratet), Bergen
   Coastal Directorate (Kystdirektoratet), Oslo

7. Norwegian Ministry of Local Government and Regional Development, including:-
   Norwegian Petroleum Directorate, Stavanger

8. Norwegian Ministry of Defence, including:-
   Civil Engineering Dept. (Forsvarets bygningstjeneste), Oslo

9. Norwegian Fishermen's Federation (Norges Fiskarlag), Trondheim

The comments are presented on a chapter-by-chapter basis, grouped into categories covering, technical, environmental and social issues. The organisation or person making the comment is identified by a number in brackets, corresponding to the list above.

General Comments

Chapter 1 “Introduction” and Chapter 2 “Description of the Frigg Field Facilities”

Comment	Given by:
The project should await the results of the Norwegian governmental pipeline research project.	[5]
Evaluation	Action
The Norwegian research results will be taken into account in the EIA.	To be included.

Comment	Given by:
Norway has ratified the OSPAR decision 98/3 generally prohibiting dumping or leaving behind installations.	[5]
Evaluation	Action
The scope of the EIA follows the OSPAR intentions.	Comment Noted

Comment	Given by:
The assessment should define locations for temporary anchoring and assess impacts from such anchoring on other users of these areas.	[6]
Evaluation	Action
Destinations of the installations will not be known at the time of assessment. Such evaluations will thus for the purpose of the EIA be based on general knowledge and assumptions. However, in the detailed planning of the operations such considerations will be made, and the involved parties will be consulted and the necessary permits will be obtained.	Comment taken into Account

Comment	Given by:
The EIA should contain an overview of regulations and permits related to each of the disposal alternatives.	[6]
Evaluation	Action
Some permits will depend on methodologies within an option and some permits will depend on destination (country). As far as practicable an overview as requested will be made, and will anyway describe the most applicable regulations.	Comment taken into Account

Chapter 3 “Disposal Options”

The comments received mainly comprise views on the merits or demerits of different options with some comments regarding the associated consequences. No suggestions were received requesting the assessment of additional disposal options.

Since the public consultation however a new option has now been considered involving leaving the concrete substructures in place and removing as much of the external steelwork as practicable whilst leaving the internal steelwork in place.

Comment	Given by:
Recycling should be the basic disposal option as recycling metals reduces environmental emissions compared with new production.	[5]
Evaluation	Action
Removal of steel structures for reuse or recycling is one of the options to be evaluated. In the EIA, all alternatives are assessed to make a complete decision basis and to keep opportunities open.	Already included in scope

Comment	Given by:
The topsides of all installations must be returned to shore.	[4]
Evaluation	Action
With the exception of possible reuse opportunities, removal of topsides is the only option being assessed.	Already included in scope

Comment	Given by:
All structures less than 10,000 tonnes must be totally removed. Piles to be cut below the seabed level to avoid interference.	[4]
Evaluation	Action
With the exception of possible reuse /other use opportunities, removal is the only option following OSPAR 98/3. Piles are normally cut at least 1m below seabed.	Already included in scope

Comment	Given by:
The aim should be maximum removal of concrete substructures. Options are disposal at deep water site, or leaving parts in place after demonstrating that the area around is clear of hazards or debris, providing any remaining parts projecting above surface are adequately maintained, fitted with a RACON or similar, and ensuring that liability for meeting any claims for damages are clear.	[4]
Evaluation	Action
The options mentioned will be assessed.	Comment taken into account.

Comment	Given by:
If a fishing reef is to be created the location should be identified through a widespread consultation within the industry.	[4]
Evaluation	Action
A specific study is initiated to look into the artificial reef concept at the Frigg location.	Comment taken into account

Comment	Given by:
Unburied pipelines should be removed. Rock dumping on decommissioned pipelines is not acceptable.	[4]
Evaluation	Action
Several alternatives will be evaluated, including those mentioned here. Various measures to reduce risks if left in place will be evaluated. The effects will be evaluated.	Already included in scope

Comment	Given by:
Partial removal to 55m is not good enough. This also leaves a long term liability which will have to be sorted.	[1]
Evaluation	Action
Partial removal is one option among several which will be assessed.	Comment taken into account

Comment	Given by:
The presumption to remove all steel structure of 10,000 tonnes or below is illogical as environmental impacts of leaving them are small anyway.	[1]
Evaluation	Action
The general rule for disposal follows from OSPAR and is not for interpretation by the Operator.	Not applicable

Chapter 4 "Estimated Consequences of Disposal"

Technical Issues

Comment	Given by:
Long-term impacts should be included in the assessment together with the immediate impacts. Also details for long term management and monitoring should be given.	[3]
Evaluation	Action
It is the intention of the EIA to assess both immediate and long term impacts. Biological effects as well as potential littering effects due to structural disintegration will be included. Section (12) of the EIA document is dedicated to mitigation and monitoring. This should give more details of long-term management plans for the relevant options. Long-term costs will be included in this presentation.	Already included in scope

Comment	Given by:
Legislative consequences should be assessed.	[3]
Evaluation	Action
Both in the UK and Norway the EIA regulations are generally well defined. How the long term management of any facilities disposed at sea will affect regulation will be discussed with relevant authorities.	Long term liability and regulation associated with leaving structures at sea will be discussed with relevant authorities

Environmental Issues

Most of the comments received asked for confirmation that the issues of concern will be included in the assessment. Some were already planned to be included but had not been sufficiently described in the proposal for EIA programme. Other issues, as suggested, have been taken into account, as indicated below.

Comment	Given by:
Risk for acute pollution and contingency/preventive measures should be evaluated. This should particularly focus on stored chemicals, structures with drill cuttings, process modules, pipes and service lines.	[5]
Evaluation	Action
Decommissioning activities such as the cleaning of tanks and equipment is part of the production phase as per legislation, and permits will be obtained from the relevant authorities where required. Pollution contingency systems will then be put in place. The scope of this EIA, in accordance with the legislation, starts when systems are made "cold". For some issues (e.g. drill cuttings and safety systems) there will, however, be some grey areas with regard to acute pollution risk. Such issues will be included in the EIA when found to be appropriate.	Comment will be implemented in accordance with relevant legislation.

Comment	Given by:
Plans for follow up of environmental issues during decommissioning/disposal and after the field cessation is completed should be presented.	[5]
Evaluation	Action
TFFE Norge aim to be registered in EMAS (Eco-Management and Audit Scheme) regulation. Procedures and documentation for ensuring sound environmental performance during all stages of the operation; from field to final disposal will be prepared and implemented. These requirements will be valid for removal contractors, waste contractors etc.	Comment taken into account

Comment	Given by:
Description of natural resources etc. should be based on the original EIA for development and production and regional EIA's.	[5]
Evaluation	Action
The Frigg Field was developed in the mid 1970s. If environmental considerations were taken into account at the time they were not formalised an EIA. Available data will be used where possible.	Comment taken into account

Comment	Given by:
All possible steps should be taken to prevent contamination of benthic sediments or water with material from drill cuttings piles. A pre and post decommissioning seabed survey should be conducted to establish the levels.	[2]
Evaluation	Action
A programme for such a survey will be presented in the Cessation Plan.	Already included in scope

Comment	Given by:
Harmful residues in pipelines must be tackled appropriately.	[2]
Evaluation	Action
The EIA will contain an inventory of materials in the pipelines. If pipelines are left in place they will be pigged and flushed. Environmental impacts of all pipelines options will be assessed.	Already included in scope

Comment	Given by:
Cuttings piles and environmental issues related to different solutions should be assessed.	[6]
Evaluation	Action
As described in section 5.2, a study has been conducted to quantify and analyse the cutting accumulations present. Different disposal options and associated impacts will be assessed in the EIA. The recent research results from the UKOOA and OLF R&D programmes will be a basis for this.	Already included in scope

Issues of Relevance to Society, Trade and Industry

Comment	Given by:
Arrangement including trawl sweep covering as a minimum the 500 m zone should be carried out after field cessation to verify the absence of debris.	[4]
Evaluation	Action
Debris removal will be planned for. Different measures for verifying the success of this will be evaluated.	None

Comment	Given by:
The area must not be a hazard to fishing vessels following completion of the cessation.	[2]
Evaluation	Action
Debris will be removed as part of the offshore work	Included in scope

Comment	Given by:
Pipelines could be a problem with regard to snagging of trawl doors.	[11]
Evaluation	Action
The risk for snagging will be evaluated for the relevant pipelines for the leave-in-place option.	Included in scope

Comment	Given by:
Cost estimates for all options including post decommissioning activities and follow-ups should be given.	[3]
Evaluation	Action
The Frigg Cessation plan will consist of two parts; the Disposal Plan and the EIA. The EIA will focus on environmental and socio-economical issues while the Disposal Plan will cover technical, economical and safety issues. Cost estimate for each disposal alternative (including long-term costs) will be worked out as part of the Disposal plan. The EIA will, however, analyse employment effects and national production effects.	Only employment effects are to be considered in the EIA

Comment	Given by:
Based on safety and conditions of relevance to military activities leaving in place is not appreciated and should be avoided.	[8]
Evaluation	Action
The leave-in-place option is included in the assessment as it is a realistic option. If such an option is selected measures will be enforced to limit negative consequences for other users of the sea.	The issue will be assessed in the EIA

Chapter 5 “Proposed Studies”

No comments have been received with regard to the studies proposed nor any proposal for additional studies.

Chapter 6 "Methodology for the EIA"

Comment	Given by:
The EIA should make reference to the EIA made for development and production in the seventies. Comparisons will indicate how environmental prognoses have hit the real emission figures. A total environmental emission account should also be presented. Together with data from Regional EIA this will give the best basis for assessment of the cessation activities.	[5]
Evaluation	Action
When Frigg was developed in the mid 1970s there was no defined method for impact assessment for such developments. Prognoses for emissions are made based on the technology and production prognoses of that time. During the last 25 years large changes have taken place both with regard to technology and production at Frigg. A total emission account will be useful for statistics but will have very little use for the cessation process.	None

Comment	Given by:
A thorough evaluation of environmental cost-benefit should be performed including worst-case scenarios when pricing the consequences. Prices should reflect international not national conditions.	[5]
Evaluation	Action
Such an evaluation approach was suggested in the mid 1990s, but has since been discarded.	None

Comment	Given by:
Bio-physical environment description should include disposal sites.	[3]
Evaluation	Action
The EIA will be based on feasibility studies, since the exact location of demolition or disposal will not be known. This will be agreed with the removal contractors after the authorities have made a decision for a disposal option. Issues of concern will be highlighted and assessed in general terms in the EIA, and thus forming essential input to the decision-making process but also for choosing the best location. The basis is that "waste" from the Norwegian side will be brought ashore in Norway, and waste from the UK side to the UK. With regard to "leave-in-place", environmental monitoring has been conducted at the Frigg field for many years, including chemical, biological and physical parameters. For the disposal site(s) more general evaluations will have to be made in the EIA (due to the reason mentioned above). However, when it comes to the final disposal option selected, such surveys will be conducted as judged necessary.	Comment will be taken into account

Chapter 7 "Tentative Project Plan"

Comment	Given by:
Details of the decommissioning time scale for all proposed options should be included.	[3]
Evaluation	Action
A schedule for the recommended disposal alternatives will be presented in the EIA.	Comment will be taken into account

Annex B

Stakeholders' Comments from Decommissioning Workshop September 2000

Comment	Discussion and Implementation in EIA
Towing issues need to consider risk of technical disaster – how to measure this risk?	The technical risk of the refloating and towing operations are being studied. The impacts of mission failure are being reviewed by DNV in 2000. The conclusion of this work is summarised in the Cessation Plan.
LSA – naturally occurring radioactive material – is it an issue for Frigg gas or any oil treatment?	LSA is generally not relevant for Frigg. The only module where it might be relevant is the Frøy processing module placed on TCP2 in the Norwegian sector of Frigg. This module will be checked for LSA and the possible contaminated material will be managed according to national regulations. The issue of radioactive lead isotopes has been studied previously. New samples will be made to document the situation.
Split up the energy costs on non-quantifiable method use	A key for quantification of energy is included in the methodology section.
Mitigation effects	Mitigation measures to reduce negative impacts and enhance positive impacts will be recommended in the EIA report. Such measures will be further assessed during the pre-engineering phase and following work.
Leaving in place the concrete substructures, does this also include topsides?	No. All topsides will be removed and are to be assessed independently of the disposal of the concrete substructures.
Safety of workforce and fishermen	Safety is an important factor for the overall recommendation of a disposal option. Safety of both internal and external personnel is of equal importance. The majority of safety evaluations are documented in the Cessation Plan. The EIA will focus is on some key issues to present comparable issues in relative terms.
Use standard phrase for "littering" similar to Ekofisk.	In this EIA, the pollution effects related to debris/littering are being assessed.
Drill cuttings. Evaluate effects from Frigg together with all drill cuttings in the North Sea.	It is the intention of a field specific EIA to assess impacts associated with this particular. EIAs are often useful to correlate total impacts spanning other fields. However, as the cuttings at Frigg have a relatively low degree of contamination (they were produced mainly when drilling with water based mud) the amount is small. No comparable data for the overall North Sea exist, and thus it is planned to assess the Frigg drill cuttings alone. However, correlations with the total situation will be made as far as possible.
The Energy and CO_2 emissions should be put into a larger perspective, including construction and operating phase of the field.	Frigg is an old field, and no data exists for the construction and early production phases. Such comparison is therefore not possible.
Will there be any debris on bottom?	Debris within the Frigg Field will be removed after completing the approved disposal programme.
UKOOA R&D on drill cuttings also considers other options such as covering .	The maximum thickness of the layer of drill cuttings at Frigg is 20cm. When the DP2 jacket is removed it will be necessary to dig into the seabed at each leg. This will cause the cuttings with the natural seabed sediments to mingle resulting in some covering.
Is the situation of transfer of waste e.g. from UK to Norway considered?	As a basis for this EIA, it is stated that UK installations will be taken to UK and Norwegian installations to Norway. When it comes to the execution of the work, the location of demolition cannot be certain. Trans-frontier shipment, if required, will be performed in accordance with national and international regulatory requirements.
Include information on energy	Details about this are presented in Technical Appendix to the

Comment	Discussion and Implementation in EIA
savings on recycling vs. producing new materials.	EIA [72].
Very little information on ecosystem effects, and biology/natural resources.	Ecosystem effects are assessed when found to be appropriate. Based on experience it is, however, found that such effects are minor for most disposal options. Information about the biology of the North Sea is well documented and is therefore not repeated in the EIA. (See the following references in the EIA [17] North Sea Quality Status Report [25] Regional EIA for the North Sea)
Energy life cycle data i.e. for making new materials vs. reuse should be included.	This is part of the energy assessment. All data are included in [72]. (See reference list in the EIA report) For concrete the situation is different in comparison with steel. Concrete cannot be recycled, however, it can be reused in different forms. Comparison with new production is therefore less appropriate.
What are the impacts of mission failure?	Such assessments are included in [72]. (See reference list in the EIA report)
What about re-injection of drill cuttings?	There are no appropriate wells at the Frigg Field for re-injecting the drill cuttings. The volume of cuttings at Frigg is small and, with present technology, it would be difficult to retrieve them all for re-injection without removing substantial amounts of the seabed as well.

Annex C

Comments from UK Governmental Organisations on First Draft of the Frigg Field Cessation Plan

In accordance with UK practice, the First Draft of the Frigg Field Cessation Plan which was issued to the UK Department of Trade and Industry for review, was also circulated by DTI to other Government Departments and Agencies. The following entities were given the opportunity to review the document and send comments to DTI who collated the responses and passed them to TOTAL NORGE.

1. Department of Trade and Industry (DTI), Aberdeen

2. The Crown Estate, Edinburgh

3. Department of Environment, Food and Rural Affairs, London
   Marine and Waterways Division, Marine Environment Branch II

4. Department of Environment, Food and Rural Affairs, London
   Marine and Waterways Division, Marine Pollution Branch II

5. Department of Transport, Local Government and the Regions, London
   Ports Division

6. Foreign and Commonwealth Office, London

7. H M Customs and Excise, Aberdeen

8. Health and Safety Executive, London
   Offshore Division

9. Inland Revenue, London
   International (Energy Group)

10. Inland Revenue, Aberdeen
    Oil Taxation Office

11. Joint Nature Conservation Committee, Aberdeen

12. Scottish Environment Protection Agency, Stirling

13. Scottish Executive Environment and Rural Affairs Department,
    Marine Environment and Wildlife Branch, Edinburgh

14. Scottish Executive Environment and Rural Affairs Department,
    Environment Protection Unit, Edinburgh

14 Scottish Executive Environment and Rural Affairs Department, Fisheries Research Services – Marine Laboratory, Aberdeen

15 The UK Hydrographic Office, Somerset

The following table summarises the comments received from DTI under cover of letters dated 17 May 2001 and 16 July 2001, and provides details of the actions taken by TOTAL NORGE.

Subject	Summary of Comments	TOTAL NORGE's Response
Statutory Consultees	The current list of statutory consultees who should receive a full copy of the Second Draft of the Frigg Field Cessation Plan, is provided.	Annex D of the Frigg Field Cessation Plan has been duly modified and copies of the Second Draft were sent to all the statutory consultees.
Navigation	Further details of the navigation aids, which will be used to mark the remaining concrete structures, should be provided.	Details of the exact flashing pattern for the navigation aids is acknowledged and noted. Confirmation is provided in the Third Draft that discussions have started with the relevant national authorities and that the navigation aids provided will comply with nation regulations and international conventions.
	Confirmation should be provided that back-up navigation lights will be installed in case the main lights fails.	The text in subsequent drafts has made it clear that adequate back-up systems will be provided.
	How will the navigation aids be maintained when the structures start to deteriorate?	The intention will be to install a navigation aid system that will be possible to install and maintain by helicopter.
	It should be clarified that TOTAL NORGE is responsible for the ongoing maintenance of the navigation aids unless otherwise agreed with the authorities.	Text, reiterating this point, has been duly added to the Second Draft and subsequent drafts.
On-going Liability	To avoid confusion about TOTAL NORGE's ongoing liability for the concrete substructures left in place, the words "in principle " should be removed from the text in the Executive Summary and the Disposal Plan.	The wording in the Second Draft, and subsequent drafts, has been modified accordingly.
Strategic Destruction	Has consideration been given to the possibility of taking action to enhance the decay of the concrete substructures left in place?	Studies were commissioned by TOTAL NORGE to assess possible methods for accelerating the decay of concrete. The studies identified a considerable uncertainty about the effect of such methods. In addition it is considered beneficial for the structures to remain intact and well marked.
Safety Zones	After completion of the decommissioning there will no longer be any safety zones around the platforms.	Following an updated advice from DTI, the question of removing the safety zone will now be considered when the approved decommissioning work is completed.
Imports	It should be noted that items of equipment currently located in the Norwegian sector will be subject to full import duty on entering the UK.	Suitable text has been included in the Second Draft and subsequent drafts clarifying this matter.
Notification of Marine Activities	Adequate notification of offshore activities needs to be provided to the UK Hydrographic Office and the Radio Navigations Warnings (RNW)	Comment is duly acknowledged and noted.
	Notification should be given to the Hydrographic Office in the event of any deterioration of the concrete substructures that may result in falling debris.	Comment is duly acknowledged and noted.

Subject	Summary of Comments	TOTAL NORGE's Response
	Is it the intention of TOTAL NORGE to survey the structures whilst conducting maintenance of the navigation aids?	A visual examination of the above water section of the concrete substructures will be undertaken when maintaining the navigation aids. Suitable text explaining this has been included in the Second Draft and subsequent drafts.
Seabirds and Mammals	There is limited detail regarding seabirds and the possible impacts from the decommissioning work. The effect of the possible use of explosives is of concern.	Additional information on the possible impacts on seabirds and mammals has been added to the programme. The proposed disposal arrangements for the Frigg Field facilities do not include the use of explosives. Explosives would only have been considered if attempts were made to cut down the concrete substructures, but this is not the proposed solution.
	The Joint Nature Conservation Committee would like to meet TOTAL NORGE to discuss these issues.	TOTAL NORGE met with The Joint Nature Conservation Committee following receipt of the comment. It is believed that their concerns were allayed when it was understood that it was not planned to use explosives.
Drill Cuttings	In view of the current concerns regarding drill cuttings it would be helpful if the long-term implications of leaving the drill cuttings in place within CDP1 were addressed.	TOTAL NORGE commissioned a study to review the effects of possible release of drill cuttings in the long term. The study undertaken by Rogaland Research indicates that the environmental impact would be "small negative" or "insignificant". A summary of the results and a reference to the study has been included in the Second Draft and subsequent drafts.
Waste Identification and Disposal	Clarification should be provided that the LSA scale waste originating from Module 35 on TCP2 will be disposed of in Norway. Once the module has been checked further detail of the amount of LSA scale would be helpful. It would also be helpful if it could be stated near the front of the document that, with the exception of Module 35 on TCP2, there is no LSA scale on Frigg.	The comments are acknowledged. Suitable text has been included in the Second Draft and subsequent drafts.
	Further clarification should be provided about the possibility of lead isotopes.	Text has been added to clarify that checks for lead isotopes will be made whenever process equipment is opened.
	Further clarification is required on the discharge of contaminated water.	Text has been added explaining that no release of contaminated water is anticipated during the removal of the topside facilities. Text has also been included detailing the measures that will be taken to check the composition of water in flooded members of the steel substructure.
Safety Case	TOTAL NORGE will need to comply with all relevant regulations and to ensure that risks to personnel are as low as reasonably practicable. The measures to control risk will need to be described in the Safety Case. It would be helpful to HSE to receive an early submission of Safety Cases.	The comments are acknowledged and noted. A preliminary meeting has been held with HSE and an on-going dialogue process started to ensure that all requirements are complied with.

Subject	Summary of Comments	TOTAL NORGE's Response
Schedule	There should be a definite undertaking to complete the work by a set date under the proviso that cessation of production takes place in 2002/3.	The text has been modified to make this point clear. In the Third Draft the schedule dates have been modified to reflect the fact that cessation of production is now anticipated in 2004 rather than 2003.
	Is there any scope for removing the pipelines earlier in the decommissioning programme?	A note has been added into the text to explain that the pipeline removal is scheduled during the last summer season to allow it to be undertaken in the most efficient way.
General	It should be a condition of contract that contractors undertaking the work should have, as a minimum, an independent verified Environmental Management System meeting the requirements of a recognised standard such as EMAS or ISO 14001	TOTAL NORGE agrees with this comment and have included the appropriate text in Section 17.
	Methods which can be implemented to improve the habitats associated with the structures left in place should be considered and so improve the bio-diversity and associated ecosystems	A study shows that a concrete substructure is likely to have little effect as an artificial reef due to its large flat surfaces. CDP1 may have some merit due to holes in external walls. The text has been amended stating that a monitoring of the local fish stock may generate interest.
	It should be noted that the decommissioning of cables is not included within the provisions of the Petroleum Act 1998.	A suitable note has been added to the text to explain that details of the cables are provided for the sake of completeness.
	The Act does not place any special emphasis on the Operator for submission of the decommissioning programme. All Section 29 notice holders are equally responsible.	The comment is acknowledged and noted. The text in the Second Draft and subsequent drafts has been modified.
	Please confirm whether Norsk Hydro Produksjon has changed name to Norsk Hydro asa.	The Frigg Field Licensee is Norsk Hydro Produksjon. The text has been modified accordingly.
	Amend text relating to CDP1 to make reference to the drill cutting inside the substructure	Text suitably amended.
	Pipeline numbers to be included in relevant tables	Pipeline numbers have been added to the tables and included where appropriate in the text.
	Mattresses and rock dumps associated with the pipelines should be listed	Text and tables modified accordingly.
	The results from trawling tests should be submitted to DTI.	The text has been suitably modified to note that the results of trawling tests will be submitted to the appropriate authorities.
	Further details about the cleaning of the installations and pipelines should be included.	Suitable text has been added.
	It should be noted that a summary of the comments from the statutory consultees, and how these are to be addressed, is to be included in subsequent drafts of the Frigg field Cessation Plan.	A note was added in the Second Draft noting this fact. A summary of the responses from consultees is included in Section 16 in the Third Draft and fuller details are provided in Annex D.

Subject	Summary of Comments	TOTAL NORGE's Response
	It should be noted that the Guidance Notes for Industry on the decommissioning of offshore installations and pipelines have now been published and are no longer in draft format.	Comment acknowledged and noted. The text has been suitably modified.
	The weight make-up of DP2 should be reviewed to clarify the weight of, conductors, piles, grout etc.	A clearer definition of the weight has been provided for DP2.
	The costs resulting from a major accident or incident during any attempted cutting down operations for TCP2 should be reviewed to ensure consistency with the other substructures.	The costs have been reviewed and checked. The way of expressing the cost increase has also been simplified to assist comprehension.

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Annex D

Stakeholders' Comments on the Second Draft of the Frigg Field Cessation Plan

Contents

1. Introduction

This Annex contains a summary of the responses received from stakeholders during the formal consultation period for the Second Draft of the Frigg Field Cessation Plan. This started on 29 November 2001 and finished on 28 February 2002.

The formal consultation process in the UK included the statutory consultations required under Section 29(3) of the Petroleum Act 1998. In Norway the formal consultation process followed previously established principals with regard to the stakeholders who were consulted and the fact that comments were sought relating solely to the Environmental Impact Assessment. The entire Frigg Field Cessation Plan was however freely available to all stakeholders.

Sixty-one entities were either issued with a copy of the Second Draft of the Frigg Field Cessation Plan, or notified that a copy could be provided if requested. Hard copies of the document were made available for review at public libraries in London and Aberdeen and notices advertising this fact were placed in the UK national press. The document was also available on the Internet. TOTAL NORGE received a total of 20 written responses from stakeholders.

The comments summarised in this Annex D originate solely from the formal consultation process described above. It is, however, important to note that a wide-ranging consultation process with stakeholders has been on going since June 1999. The views and concerns expressed by stakeholders over the last two years has been an important input when preparing the Frigg Field Cessation Plan. Many of the comments received during this consultation period are set out in Annexes A, B and C.

Many responses to the Second Draft of the Frigg Field Cessation Plan contained particular statements of fact whilst others posed questions. In summarising the responses every effort has been made to accurately reflect the views of stakeholders, whilst at the same time allowing an overview of the comments to be obtained. The full text of all the stakeholder responses is contained in the TOTAL NORGE document entitled “Public Consultation of Second Draft of Frigg Field Cessation Plan”. The following tables summarising the stakeholder comments, also include brief responses by TOTAL NORGE to the points raised.

2. Stakeholders Involved in Formal Consultation Process

2.1 Consultation in Norway

The following Norwegian entities received a copy of the Second Draft of the Frigg Field Cessation Plan dated November 2001 from the Norwegian Ministry of Petroleum and Energy (MPE).

Norwegian Governmental Organisations

1. Ministry of Labour and Government Administration (Arbeids- og administrasjonsdepartementet)

2. Ministry of Finance (Finansdepartementet)

3. Ministry of Fisheries (Fiskeridepartementet)

4. The Directorate of Fisheries (Fiskeridirektoratet)

5. Institute of Marine Research (Havforskningsinstituttet)

6. The National Coastal Administration (Kystverket)

7. Ministry of Environment (Miljøverndepartementet)

8. The Directorate for Cultural Heritage (Riksantikvaren)

9. The Pollution Control Authority (Statens forurensningstilsyn)

10. Ministry of Foreign Affairs (Utenriksdepartementet)

11. Public roads Administration (Statens Vegvesen)

Norwegian Local Authorities

12. Governor of Hordaland County (Fylkesmannen i Hordaland, Bergen)

13. Hordaland County Council (Hordaland Fylkeskommune, Bergen)

14. Governor of Rogaland County (Fylkesmannen i Rogaland, Stavanger)

15. Rogaland County Council (Rogaland Fylkeskommune, Stavanger)

Norwegian Non Governmental Organisations

16. Norwegian Fishermen's Federation (Norges Fiskarlag, Trondheim)

17. Norwegian Society for the Conservation of Nature (Norges Naturvernforbund, Oslo)

18. Nature and Youth (Natur og Ungdom, Oslo)

19. Bellona Foundation (Mijøstiftelsen Bellona, Oslo)

20. Norges Miljøvernforbund, Bergen (Green Warriors)

21. Greenpeace Norway (Greenpeace Norge, Oslo)

Norwegian Private Individuals

22. Mr. J.O. Strand, Stavanger

2.2 Consultation in UK

The following UK entities received a copy of the Second Draft of the Frigg Field Cessation Plan dated November 2001. Copies of the document were issued to the UK Departments and Agencies via the Department of Trade and Industry, who also gathered and collated their responses. The document was issued directly by TOTAL NORGE to the Statutory Consultees and the Non-Statutory Consultees listed.

UK Governmental Organisations

1. Department of Trade and Industry (DTI), Aberdeen

DTI distributed and collated the response on the Second Draft from the UK Departments and Agencies (in the same way as described in Annex C).

UK Statutory Consultees

2. National Federation of Fishermen's Organisation, Grimsby

3. Northern Ireland Fishermen's Federation, Newry, County Down

4. Scottish Fishermen's Federation, Aberdeen

5. UK Cable Protection Committee

UK Non-Statutory Consultees

6. Advisory Committee on Protection of Sea, London

7. BT Worldwide, London

8. Environment Agency-Radioactive Substances Regulation Section, Bristol

9. Friends of the Earth UK Ltd, London

10. Greenpeace UK, London

11. Institute of Petroleum, London

12. International Association of Oil and Gas Producers, London

13. Joint links Oil & Gas Environmental Consortium, Aberystwyth

14. KIMO-Local Authorities International Environmental Organisation, Lerwick

15. Marine Conservation Society, Ross-on-Wye

16. Orkney Fishermen's Association, Kirkwall

17. Royal Society for the Protection of Birds, Sandy

18. Scottish Natural Heritage, Edinburgh

19. The British Institute of International and Comparative Law, London

20. The Scottish Association for Marine Science, Oban

21. United Kingdom Offshore Operators Association (UKOOA), London

22. University of Hull University Scarborough Campus, Scarborough

Other UK Consultees

The following consultees in the UK had indicated previously that they wished to be kept informed about the progress of the Frigg Field decommissioning process. Accordingly TOTAL NORGE notified them by letter that the Second Draft of the Frigg Field Cessation Plan was available for review and comment and that the formal consultation period would last from 29 November 2001 to 28 February 2002. They were also informed that the document was available on the Internet and could be viewed on the TOTAL NORGE website www.total.no/cessation

23. Mr. Anthony L. Rice, Farnham

24. Mr. Clive Harber, Portmead

25. Mr. Mike Jones, Taunton Somerset

26. Mr. Neil Preston, Trowbridge

27. Mr. Simon Brogan, Stronsay

28. Department of Oceanography, Southampton

29. Lloyds register of Shipping, Aberdeen

30. Robert Gordon University, Aberdeen

31. SustainAbility, London

32. The Marine Information Association, London

33. UK Centre for Economics & Environmental Development, Cambridge

34. Western Isles Fishermen's Association / Federation of Highlands and Islands Fishermen, Stornoway

35. World Wide Fund for Nature UK, Godalming

2.3 Consultation in Denmark

The following entity received a copy of the Second Draft of the Frigg Field Cessation Plan dated November 2001 from TOTAL NORGE:

1. Danish Fishermen's Federation (Danmarks Fiskeforening, Copenhagen)

2.4 Consultation in Germany

The following entity received a copy of the Second Draft of the Frigg Field Cessation Plan dated November 2001 from TOTAL NORGE:

1. World Wide Fund for Nature, Bremen

3. Stakeholder Responses

Written responses to the Second Draft of the Frigg Field Cessation Plan were received from the following stakeholders.

Norway

1. Ministry of Fisheries (Fiskeridepartementet)

2. The Directorate of Fisheries (Fiskeridirektoratet)

3. Institute of Marine Research (Havforskningsinstituttet)

4. The National Coastal Administration (Kystverket)

5. Ministry of Environment (Miljøverndepartementet)

6. The Directorate for Cultural Heritage (Riksantikvaren)

7. The Pollution Control Authority (Statens forurensningstilsyn)

8. Ministry of Finance (Finansdepartementet)

9. Ministry of Foreign Affairs (Utenriksdepartementet)

10. Ministry of Labour and Government Administration (Arbeids- og administrasjonsdepartementet)

11. Public Roads Administration (Statens Vegvesen)

12. Hordaland County Council (Hordaland Fylkeskommune)

13. Norwegian Fishermen's Federation (Norges Fiskarlag)

14. Norwegian Society for the Conservation of Nature (Norges Naturvernforbund)

15. Ole Johan Strand (Private individual)

UK

16. Department of Trade and Industry (see Note 1 below)

17. Scottish Fishermen's Federation

18. National Federation of Fishermen's Organisations

19. KIMO- Local Authorities International Environmental Organisation (see Note 2 below)

Notes:

1) Comments from the UK Departments and Agencies (see Annex C) were collated and submitted by the UK Department of Trade and Industry.

2) As the KIMO secretariat is located in Lerwick, Shetland, it is shown under the UK list of stakeholders. They represent over a hundred local authorities in 9 countries mainly having a coastline to the North Sea.

It should also be noted that, in accordance with the UK practise, the UK Governmental Entities were invited to review and comment on the First Draft of Frigg Field Cessation Plan. An overview of these comments is included as Annex C. The comments received were taken into consideration when preparing the Second Draft of the Frigg Field Cessation Plan.

The written responses from stakeholders, received during the formal consultation period for the Second Draft of the Frigg Field Cessation Plan, are summarised in the following tables.

NORWAY – Governmental Organisations

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
1.	**The Royal Ministry of Fisheries**	28 February '02 – Letter	• The Ministry praises the operator for a good and comprehensive EIA. • The Ministry supports the study's recommendations for remedial measures and monitoring.	• Comments acknowledged.
2.	**The Directorate of Fisheries – Office for Fishery Research and Advice**	4 February '02 - Letter	• Fishery activities in the Frigg area appear to be satisfactorily described in Chapter 6 of the EIA. • The Directorate of Fisheries will recommend that the disposal alternatives recommended in the assessment be chosen. • The importance of implementing the proposed remedial and monitoring measures as described is emphasised. • The Directorate of Fisheries would like to have an observer on board when the area is cleared and over-trawled.	• Comments acknowledged • TOTAL NORGE will ensure that the Directorate of Fisheries is given the opportunity to have an observer onboard during the trawling tests when the decommissioning work is completed.
3.	**Institute of Marine Research – Department of Marine Environment**	17 February '02 - Letter	• The plan illustrates the various problems in a comprehensive and prudent manner and we will therefore support the implementation of the recommended [disposal] alternatives. • After 30 years in place, the Frigg installations have become part of the ecosystem. • Leaving the three concrete structures in place will not harm the fishery resource or other marine fauna. • Partial removal can cause disturbance to the marine environment and would entail extensive energy use which would generally have a negative impact on the environment. • Total removal to land would also be energy intensive and thus polluting. • The Institute supports leaving the layer of drill cuttings under DP2 in place, untouched to the greatest extent possible. • Quantities of polluting metals and hydrocarbons are limited, and what is left of the cuttings has been mixed with and covered by sediments and does not appear to pose any danger to the ecosystem • The Institute recommends a physical and biological survey of the environment during and after decommissioning activities.	• Comments acknowledged • TOTAL NORGE will perform environmental surveys in the Frigg area both before and at the completion of the decommissioning work in accordance with the coordinating environmental surveys in the region (Region II).
4.	**Norwegian National Coastal Administration**	16 January '02 – letter	• The impact assessment largely falls outside the jurisdiction of this organisation. • Should temporary mooring be required for those structures being towed to shore, permission must be secured pursuant to the Harbours and Territorial Waters Act (section 6).	• Comments noted. When undertaking the decommissioning work, TOTAL NORGE will take measures to ensure that relevant authorisations and permissions are obtained.

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
5.	**The Royal Ministry of the Environment**	6 March '02 – letter	• The Ministry of the Environment endorses the comments made by the Norwegian Pollution Control Authority (SFT) and the Directorate for Cultural Heritage.	• Comment acknowledged
6.	**Directorate for Cultural Heritage**	22 February '02 – letter	• The EIA programme was not sent to the Directorate for Cultural Heritage in June 1999 and the topic 'Cultural monuments and cultural milieus' are not covered in the EIA – this is seen as a serious omission and the Directorate for Cultural Heritage proposes remedial measures and follow-up studies. • The experiences gained from the construction and installation of TCP2 has made an important contribution to this type of platform construction in Norway. • The Condeep concept represents a breakthrough for the use of concrete in large structures. Securing physical preservation and possible reuse of this type of structure is a preservation task of national importance. • Due to the Frigg Field's significance in the oil industry in Norway, TCP2 in particular should be subject to a documentation project. • An agreement should be entered into between the MPE and the Norwegian Petroleum Museum for such a documentation project, possibly linked with a UK institution. • The project should also address the consequences for possible under water monuments at the Frigg Field which are not installations related to the oil industry – i.e. shipwrecks or Stone Age artefacts.	• The comments and proposals are duly noted. TOTAL NORGE will contact the Directorate for Cultural Heritage and other relevant parties to consider how the suggested actions may be implemented. • TOTAL NORGE have already contacted the UK Department of Trade and Industry who have committed to relay the information to the appropriate UK institution.
7.	**The Norwegian Pollution Control Authority (SFT)**	15 February '02 – letter	• The SFT has no comments to make on the report's conclusions on the disposal of the steel structures and the cables and pipelines. • The leaving in place of the concrete structures could constitute an undesirable risk to shipping traffic in the area – the SFT would like to have seen an evaluation of potential reuse of the entire concrete substructure (i.e. bridge foundations or similar projects). • The SFT would view the concrete substructures left in place as littering of the marine area. • With reference to the UKOOA studies on drill cuttings, the SFT cannot see that there is any significant environmental risk associated with leaving the cuttings around DP2 in place. • In view of the pioneering nature of the decommissioning of the Frigg Field, SFT would like to see a report prepared at the end of the project to ensure transfer of information for future projects. • SFT expects to receive applications for discharges where relevant.	• The comments provided are duly acknowledged. • The reuse of the concrete substructures as bridge foundations, or similar structures, is an interesting possibility and one that TOTAL NORGE considered seriously. The feasibility of reusing the substructures in this way does however depend upon being able to practically and safely remove the substructures from their present locations. The Disposal Plan demonstrates that there are serious risks associated with such activities and therefore detailed evaluation of reuse in another location was not undertaken. • SFT's comments regarding experience

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
				feedback are noted and considered to be relevant. TOTAL NORGE will produce the relevant documentation at the end of the decommissioning project. • SFT's comment regarding applications for discharge permits is acknowledged and noted.
8.	**The Royal Ministry of Finance**	26 February '02	• The Royal Ministry of Finance has no comments concerning the impact assessment.	• Response duly noted.
9	**The Royal Ministry of Foreign Affairs**	06 March '02	• The Royal Ministry of Foreign Affairs has no comments.	• Response duly noted.
10.	**The Royal Ministry of Labour and Government Administration**	22 March '02	• Before any disposal work can start, consent for the work shall be received from NPD.	• TOTAL NORGE will ensure that all the necessary permissions and consents are obtained prior to starting the relevant sections of work.
11.	**Norwegian Public Roads Administration**	25 February '02 – letter	• It is appropriate to mention that large concrete substructures possibly can be reused in connection with a bridge construction. • If the challenges of moving the concrete structures can be solved from a technical and safety point of view, sufficient pressure should be asserted on the relevant companies to have the reuse as bridge foundations properly assessed. • The Norwegian Public Roads Administration is prepared to contribute to the assessment work concerning the reuse of concrete substructures as bridge foundations providing that the problems relating to refloat, transport etc are satisfactorily solved.	• The comments of The Norwegian Public Roads Administration are acknowledged, particularly their interest in participating to evaluate schemes for reusing the concrete substructures as bridge foundations. • The reuse of the Frigg Field concrete substructure in this way could be an interesting alternative were it not for the fact that studies indicate that the risk during refloating operations would be unacceptably high.
12.	**Hordaland County Municipality**	26 February '02 – letter	• The impact assessment in the Frigg Field Cessation Plan is satisfactorily performed. • There are no significant comments concerning the selected removal plan. • The County Executive assumes that the plans will be adjusted along the way in the event of new knowledge regarding environmental impacts.	• The comments of Hordaland County Municipality are duly acknowledged.

NORWAY – Fishermen's Organisations

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
13.	**Norwegian Fishermen's Federation**	01 March '02 – telefax	• The dialogue process the operator has followed has been very beneficial in clarifying possible disposal solutions. • The view of the Norwegian Fishermen's Federation is that all installations should be removed leaving a clear seabed. • TOTAL NORGE recommends that the concrete substructures be left in place since the structures may not withstand the removal forces. This is based on today's technology and the Norwegian Fishermen's Federation, as a basis has to accept this. • It is requested, however, that no final decision is made regarding the concrete substructures since future technology may develop solutions that may allow removal. • If the Authorities should approve the recommendations made by the Operator, the decision should contain requirements for future safe marking for other users of the sea and the long term liability should also be addressed	• The comments of the Norwegian Fishermen's Federation are acknowledged. • TOTAL NORGE has started a dialogue with the relevant Norwegian and UK authorities to ensure that the substructures left in place are satisfactorily marked in accordance with national legislation and international conventions. • The types of inherent uncertainties associated with refloating the substructures are such that it is difficult to see how advances in technology would significantly reduce the risks during a refloat operation.

NORWAY – Non-Governmental Organisations

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
14.	**Norwegian Society for the Conservation of Nature**	27 February '02 – letter	• The drill cuttings under DP2 should insofar as it is practical / technically / financially feasible, be collected for disposal on land even though they have been 'degreased'. • The three concrete structures should be left in place at present, pending possible reuse opportunities in the future either in Norway or the UK • Norwegian Society for the Conservation of Nature encourages the Norwegian authorities to establish, possibly with the UK, a state owned company, which can look for reuse applications for concrete platforms in the North Sea with the objective of removing them, rather than leaving them in place forever. • The significant cost savings of leaving the structures in place should not benefit the owners of the substructures, but should be released to fund other environmental tasks remain unresolved in connection with the environmental burdens placed on the North Sea.	• The comments of Norwegian Society for the Conservation of Nature are acknowledged. • In relation to the comments regarding drill cuttings, it should be noted that recently published research, undertaken by UKOOA and supported by OLF, recommends that the best environmental strategy for the disposal of drill cuttings similar to those beneath DP2 is to leave them in-place undisturbed.
15.	**Ole Johan Strand – Private individual**	28 February '02 – letter	• The Cessation Plan is complex and well ordered. • With regard to CDP1 removal, the matter is so complex that it would be difficult to voice an opinion. • It would seem that the complexities of CDP1 are used as 'standards' for the basis of a derogation for all three platforms. • The cost and risks studies performed on TP1 and TCP2 should be reviewed by an independent group. • The lifetime span evaluation study of the concrete structures is not presented in the report. • There appears to be a difference in the conclusions from the study carried out on Statoil concrete structures and those carried out by the Frigg Field Licensees. • Costs are a key factor and these can be very high as illustrated in the Plan particularly with regard to refloating TP1 and TCP2. • The issue of 'synergy of operations' is not covered in the Cessation Plan as regards technological development of removal methods and employment. • The possibility of repair to the concrete structures has not been documented sufficiently.	• All the comments put forward by Mr. Strand have been carefully reviewed. • It must be stressed that each of the Frigg Field platforms has been considered individually. The disposal solution proposed for each platform has been the result of extensive study and investigation <u>for that installation</u>. The studies have been subject to extensive peer review by experts in the particular field. Section 20 of the Disposal Plan contains a comprehensive list of studies carried out by the Frigg Field Licensees. All three concrete substructures have received a similar amount of study and results for a particular substructure have not been applied generally to the field. • It is also important to understand that the designers of the concrete substructures have been closely involved in the decommissioning assessments and were responsible for

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
			• For Ekofisk there was good reason for not attempting to move the structure as there are operative platforms in the vicinity – this will not be the case at Frigg. • Even if there were a collision or tilting during a refloat operation at Frigg – there would be no personnel in the vicinity, so why shouldn't it be attempted? • The risk of material loss in the event of refloat problems should not be an acceptance criterion. • The use of the structures for bridge foundations could save costs in building bridges.	developing "best method" statements for all of the substructures. • None of the three concrete substructures were designed for removal. • Concerning reuse as a bridge foundation, reference is made to the comments received from the Norwegian Public Roads Administration (ref.no. 11) and TOTAL NORGE's response. • Most of the questions raised are addressed in the various technical studies and evaluations listed in Section 20 of the Frigg Field Disposal Plan.

UK – Governmental Organisations

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
16.	**Department of Trade & Industry** (including collated comments from other UK Departments and Agencies)	28 February '02 – letter	• How the split of the decommissioning cost between Norway and UK is finally agreed should be reflected within the programme. • The cost of CDP1 in Table 9.13 in the EIA and as listed in page 170 in the Disposal Plan should be the same. • The results of the UKOOA Drill Cutting Initiative are now available this should be reflected in next revision of the Frigg Field Cessation Plan. • You are unclear about whether the flooded members of the steel substructures contain biocide. It is important that any discharges are in accordance with regulations – amendment to text suggested. • Navigation aids will be critical for any remains left in place and you must demonstrate that you have taken all reasonable steps to protect other users of the sea – please include the studies in the document. • The Duty Officer Radio Navigations Warning should be notified as soon as you begin operations. • The programme should describe an appropriate monitoring regime for the concrete substructures. • It would be prudent to check for lead isotopes during the pipeline decommissioning operations. • There are some reference errors in the EIA. • Onshore legislation is not exclusive to disposal of materials but may apply to the handling and recovery operations (ref. page 270).	• All comments noted and accepted • Subsequent drafts of the Frigg Field Cessation Plan will be modified accordingly. • The cost split between Norway and UK will be added to the Final Draft if agreed upon at that time.

UK – Fishermen's Organisations

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
17.	**Scottish Fishermen's Federation (SFF)**	25 February '02 - letter	• The SFF would formally like to place on record its sincere appreciation for the fair and open manner in which the TOTAL NORGE team have conducted the Frigg dialogue process. • The SFF warmly welcomes the proposal to bring all steel structures to shore. • The SFF's least favoured option is to cut the concrete substructures down to -55 metre and we would object vociferously to such a disposal solution. • Leaving the concrete structures in situ is unacceptable to the SFF members, certainly, without further safeguards for our fishermen. • Long term liability issues of leaving these structures in place have not yet been satisfactorily addressed by either TOTAL NORGE or the UK/Norwegian authorities, and SFF expect these to be satisfactorily resolved before approval. • The recent Maureen decommissioning and the plans for Hutton should provide a greater sense of optimism for successful removal than those laid out in the document. • Drill cuttings are not as crucial an issue in the context of Frigg – there are however drill cuttings present and these do need to be addressed – the SFF would be delighted to work with all involved in achieving a structured strategy for the Drill Cuttings issue. • The SFF supports the proposal for removing all the pipelines and cables and all associated materials. • Discharges should be kept to a minimum and be carried out in strict accordance with legislative requirements. • The SFF is pleased to note the commitment to remove all debris post decommissioning operations. • The SFF is pleased to note the Trawl Verification Sweep that is proposed post decommissioning operations. However, trawl should include pipeline corridors as well as platform area. • The SFF believe that removal operations should be carried out in a consecutive fashion so that fishermen are not exposed to unacceptable risks during the operations.	• SFF's comments have been reviewed and the points raised have been carefully considered. Concerns relating to the issue of leaving the concrete structures in place have been noted. However, the comparative assessment shows leaving in situ is the most appropriate disposal solution. • The long-term liability issues are acknowledged as being of great importance to the fishing industry in particular. The parties to the Frigg programme will remain responsible for the substructures in accordance to prevailing legislation in Norway and UK, unless agreed otherwise with the authorities. TOTAL NORGE are in discussion with both the Norwegian and UK authorities about this issue. • The two structures referenced are radically different from the three Frigg Field concrete substructures. The Maureen platform is a steel structure whilst the Hutton platform is floating. The main problems associated with the refloat of the Frigg concrete substructures did not arise in the cases of Maureen and Hutton. • TOTAL NORGE acknowledge SFF's offer to work together with them and other relevant parties to develop a realistic strategy for the drill cuttings. • SFF's comments regarding the safety of fishermen during the decommissioning operations are noted. TOTAL NORGE will inform relevant bodies about the marine activities being undertaken. • The trawl test will not include any pipeline

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
			• The SFF supports the proposal for pre and post decommissioning benchmark environmental surveys. • The SFF has no specific comments on the EIA document. • The SFF found that the Cessation Plan to be user friendly, well structured and a comprehensive document.	corridors as all infield pipelines and cables will be removed.
18.	**National Federation of Fishermen's Organisations (NFFO)**	28 February '02 – letter	• The NFFO fully supports the proposal for the removal of all of the steel structures. • The NFFO accepts the proposal to leave the drill cuttings under DP2 as long as they are disturbed as little as possible and that there are no adverse effects for fishermen. • It is recognised that the removal of concrete substructures presents some real challenges. However, the NFFO feels that some attempt must be made to remove the structures as they are the first ones in the UK sector to be considered in a field decommissioning plan. • It is felt that the cheapest option has been put forward while transferring the long-term risks to other maritime sectors and creating unacceptable permanent displacement for fishermen. • The NFFO supports removal of infield pipelines and cables. • The evidence presented failed to persuade the NFFO members to lend support to a leave in situ policy for the concrete structures. • The NFFO retains concerns in respect of residual liability surrounding the remnants of decommissioned field.	• The views of NFFO relating to the decommissioning of the concrete substructures have been carefully reviewed and the points considered. However, the comparative assessment shows leaving in situ is the most appropriate disposal solution. • Concerning residual liability, reference is made to the response given to SFF in No. 17.

UK – Local Authorities with North Sea Coastlines

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
19.	**KIMO (Local Authorities International Environmental Organisation)**	01 March '02 - letter	• KIMO express their appreciation at being invited to participate in the Frigg field stakeholder dialogue. • KIMO welcomes the commitment to remove all topsides and complete removal of steel structures. • KIMO believes that all structures should be removed, however, accepts that there maybe safety and technical reasons as to why this may not be possible and are pleased to see that the operators recommendations	• The views expressed by KIMO are acknowledged and KIMO are thanked for their input to the consultation process. • Concerning residual liability, reference is made to the response given to SFF in No. 17.

No	Organisation	Date and Communications means	Summary of comments	TOTAL NORGE's Response
			have been independently verified. • KIMO is of the opinion that the substantial cost saving of leaving the concrete structures in situ should be placed in a trust so as to fund technology for removal at a later date. If a derogation is given, it should contain a condition that these issues are reviewed within a reasonable period. • KIMO is also of the opinion that public funds should not be used to undertake long-term liabilities for maintenance. Any future financial burdens should remain with the field owners. • The owners should undertake to provide a financial guarantee to fully cover long-term liability issues. • Should the concrete structures remain in situ, existing exclusion zones should remain in place indefinitely and policed.	• The safety zones around the installations will remain in place throughout the decommissioning process after which time consideration will be given to their removal in consultation with the appropriate authorities. • Concerning new technology, reference is made to the comments received from the Norwegian Fishermen's Federation (ref.no. 13) and TOTAL NORGE's response.

Annex E

Comments from Contracting Parties during OSPAR Consultation Process

On 20 September 2002 the OSPAR Executive Secretary circulated to all the OSPAR Contracting Parties letters from the Norwegian Ministry of Petroleum and Energy and the UK Department of Trade and Industry saying that they were considering issuing a permit, under paragraph 3b of OSPAR Decision 98/3, for the disposal of the concrete substructures within their jurisdiction, at their current locations in the Frigg Field.

At the same time an assessment, prepared in accordance with the requirements of Annex 2 of OSPAR Decision 98/3, was also sent to the OSPAR Contracting Parties. The assessment entitled "Frigg Field Concrete Substructures – An Assessment of Proposals for the Disposal of the Concrete Substructures of Disused Frigg Field Installations TCP2, CDP1 and TP1", dated 06 August 2002 may be viewed on the TOTAL NORGE website at www.total.no/cessation.

By the end of the 16-week consultation period no objections had been received to either the Norwegian Ministry of Petroleum and Energy or the UK Department of Trade and Industry issuing a permit under paragraph 3b of OSPAR Decision 98/3 in respect to the Frigg Field concrete substructures.

A number of comments were however received from the OSPAR Contracting Parties and these are detailed in the table below together with TOTAL NORGE's comments.

Comment of Contracting Party	Comments by TOTAL NORGE
The concrete substructures need to be effectively marked with navigation aids to warn other users of the sea and be suitably shown on charts.	The navigation aids installed on the concrete substructures will be designed and maintained to ensure a high level of reliability. They will incorporate back-up systems and parts of the navigational aids system will be changed at regular intervals. The navigational aids themselves, and their maintenance programme, will satisfy the requirements of both national regulations and the International Maritime Organisation. TOTAL NORGE has made contact with the responsible authorities in both Norway and UK and a dialogue has been started to ensure that the navigation aids will comply fully with relevant national requirements. In addition measures will be taken to ensure that the Frigg Field substructures remain marked on navigation charts and relevant information about the Frigg Field decommissioning project will be circulated to mariners.
The long-term liability for the substructures needs to be guaranteed, including the responsibility for maintaining the navigation aids in the coming decades.	The Frigg Field concrete substructures, which it is proposed to leave in-place, remain the property and responsibility of the Frigg Field Licensees, unless other arrangements are agreed with the Governments of Norway (TCP2 concrete substructure) and UK (CDP1 and TP1 concrete substructures). This includes the maintenance of the navigation aids.

Comment of Contracting Party	Comments by TOTAL NORGE
Every possible effort needs to be taken, including the preparation of firm procedures, to ensure that any residual oil or hazardous chemicals are emptied from the substructures.	TOTAL NORGE will take necessary actions to ensure that the substructures left in place do not contain any residual oil or hazardous chemicals. All tanks and pipes containing diesel oil, hydraulic oil and methanol, used for operational purposes within the columns will be drained and cleaned in accordance with accepted practice and procedures. None of the concrete substructures has ever been used for the storage of crude oil and thus cleaning operations to remove hydrocarbon deposits within the cells or columns are not required.
Wellheads, if left in place, should not constitute a hazard to fishermen.	None of the wells drilled at the Frigg Field had wellheads on the seabed. (Seabed wellheads were used for some of the satellite fields connected to Frigg, but these have now all been removed, together with the well casings.) All the wells drilled from CDP1 were located within the external concrete wall of the substructure and passed through the base slab. The wells are therefore located under the concrete substructure. The wells were plugged and abandoned in 1989/90 and all the well casings cut and removed down to a point at least 2m below the seabed. The wells drilled from Frigg Platform DP2, which will be completely removed and brought to shore for disposal, will be plugged and abandoned before the platform is removed. The steel well casings will be removed to a point at least 2m below the seabed. These measures will eliminate the risk of fishermen "hooking" any parts of a well with their fishing gear and will thus allow safe fishing operations in the area.
The safety of users of the sea needs to be ensured when the concrete substructures start to disintegrate.	TOTAL NORGE has commissioned studies to evaluate the effect of natural decay and the long-term durability of the concrete substructures (see Ref. 13.1, 13.2 in the Disposal Plan). In the next 100 years, very little physical damage to the three Frigg Field concrete sub structures is predicted. After that time corrosion of the horizontal reinforcement in the splash zone is likely to give rise, initially to spalling of the concrete, and later to local damage, which may be expected in roughly 100 to 150 years. The overall integrity of the structures will however not be affected. The columns of TCP2 and TP1, and the walls of CDP1, are predicted to remain in place for 500 to 800 years before disintegrating. For TCP2 and TP1, local damage in the splash zone will reduce the protection to the vertical pre-stressing steel in the columns, which will eventually become corroded. In this event, the top section of the column may eventually be unable to sustain extreme wave loads and become more severely damaged. For CDP1 local damage to the structure will become more extensive over time. The above-water deterioration of all three structures will

Comment of Contracting Party	Comments by TOTAL NORGE
	however take place relatively slowly and the navigation aids on the substructures may be expected to remain in place for several hundred years. After that time suitable measures, such as buoys, will be provided to ensure the safety of users of the sea.

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Annex F

Abbreviations and Glossary

Ag	Silver
As	Arsenic
Ba	Barium
B(a)P	Benzo-a-pyrene
CDP1	Frigg Field Concrete Drilling Platform 1
Cd	Cadmium
CO_2	Carbon dioxide
Cr	Chromium
Cu	Copper
DNV	Det Norske Veritas
dowel	A vertical steel member projecting downwards from the base of a gravity platform, used to restrict horizontal movement of the substructure during installation
DP	Dynamic Positioning
DP1	Frigg Field Drilling Platform 1 (Wreck)
DP2	Frigg Field Drilling Platform 2
DSV	Diving Support Vessel
DTI	UK Department of Trade and Industry
E_{tot}	Total Energy Impact
E_{cons}	Energy Consumption
EIA	Environmental Impact Assessment
EMAS	Eco-Management and Audit Scheme
EMS	Environment Management System
EOR	Enhanced Oil Recovery
FAR	Fatal Accident Rate (fatalities per 100million manhours of exposure)
FCC	Frigg Field Complex (the three bridge linked platforms TCP2, TP1 and QP)
flowline	A pipeline between a well and the processing facilities
FP	Flare Platform
GJ	Giga Joules (1000 million joules)
GSm^3	Giga cubic meters of gas at standard conditions (1000 million m^3)
guide frame	A steel frame fixed to the platform substructure which provides support to the steel well casing between the seabed and the topsides.
Hg	Mercury
HSE	UK Health and Safety Executive
Hydrostatic	Used as in “hydrostatic pressure” to indicate the pressure at a particular depth in the sea ignoring any effects of currents or waves
ICES	International Council for the Exploration of the Seas
IMO	International Maritime Organisation
IMO Guidelines	International Maritime Organisation document “Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone” adopted by the IMO Assembly in 1989 (Resolution A.672(16)
IP	UK Institute of Petroleum
J-tube	A J shaped steel tube fixed to a platform which provides a conduit for small diameter pipelines from the seabed to the topsides
JIP	Joint Industry Project
kg	Kilogram
km	Kilometre
kWh	Kilo watt hour
l	litre
lean mix	Used in the context of “lean mix concrete” to describe concrete made using smaller than usual amounts of cement and thus having a relatively low strength
LSA	Low Specific Activity

m	metre
m^3	cubic metre
manifold	Process equipment for joining a number of pipes into one pipe
MAFF	UK Ministry of Fisheries and Food
mg	milligram
MNOK	Million Norwegian Kroner
MPE	Norwegian Ministry of Petroleum and Energy
MSF	Module Support Frame
MSV	Multi Service Vessel
NFD	Norwegian Fishing Directorate
NGO	Non-Governmental Organisation
Ni	Nickel
NOK	Norwegian Kroner
NO_x	Nitric Oxides
NPD	Norwegian Petroleum Directorate
NSTF	North Sea Task Force
OLF	Norwegian Offshore Operators Association (Oljeindustriens Landsforening)
olivine	A type of rock used as ballast in the TCP2 concrete substructure
OSPAR	The Convention for the Protection of the Marine Environment of the North East Atlantic 1992.
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PCB	Poly Chlorinated bi-phenyls
PLL	Potential Loss of Life (predicted number of fatalities)
PMI	Potential Major Injuries (predicted number of major injuries)
QP	Frigg Field Quarters Platform
QRA	Quantitative Risk Assessment
RF	Rogaland Research
RKU	Regional Environmental Impact Assessment for the North Sea
riser	The part of a subsea pipeline running from the seabed up to the topside
ROV	Remotely Operated Vehicle
SFT	Norwegian Pollution Control Authority
SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology
SMS	Safety Management System
Sn	Tin
SO_2	Sulphur Dioxide
SSCV	Semi Submersible Crane Vessel
TCP2	Frigg Field Compression and Treatment Platform 2
TEAMS	The Environmental Accounting and Management System
TFEE Norge	TotalFinaElf Exploration Norge AS
TOTAL NORGE	TOTAL E&P NORGE AS or the predecessor companies in Norway that operated the Frigg Field.
THC	Total Hydrocarbon Concentration
TP1	Frigg Field Treatment Platform 1
UK	The United Kingdom of Great Britain and Northern Ireland
UKOOA	United Kingdom Offshore Operators Association
WEMS	Working Environment Management System
Zn	Zinc
“	inch