Section 4. Items and Materials to be Decommissioned

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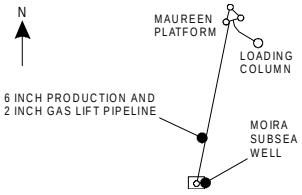
4.1 Introduction

This section provides a description of the Maureen Facilities, the facilities for which the Decommissioning Programme provides decommissioning solutions. It also provides a description of the materials on the seabed in the Maureen Area.

Figure 4-1 Photograph of the Maureen Platform and Loading Column

4.2 Description of the Maureen Facilities

4.2.1 The Maureen Platform



MAUREEN PLATFORM TECHNICAL DATA		
Water depth		95.6 m
Overall structure height (from seabed to top of flare)		239 m
Deck Area (one level)		6004 m^2 (79 m x 76 m)
Substructure weight (including ballast)		92,750 te
Topsides weight		19,000 te
Overall structure weight		111,750 te
Production capacity	Oil	80,000 bopd
	Gas	46 MMSCFD
Oil storage capacity		650,000 barrels
Usable oil storage capacity		600,000 barrels
Well slots		24
Wells drilled		12 oil producers
		8 water injection
		3 suspended
		1 spare
Docking piles*		2 off
Docking pile diameter		2.14 m (84")

*Docking Piles shown in Figure 4-3

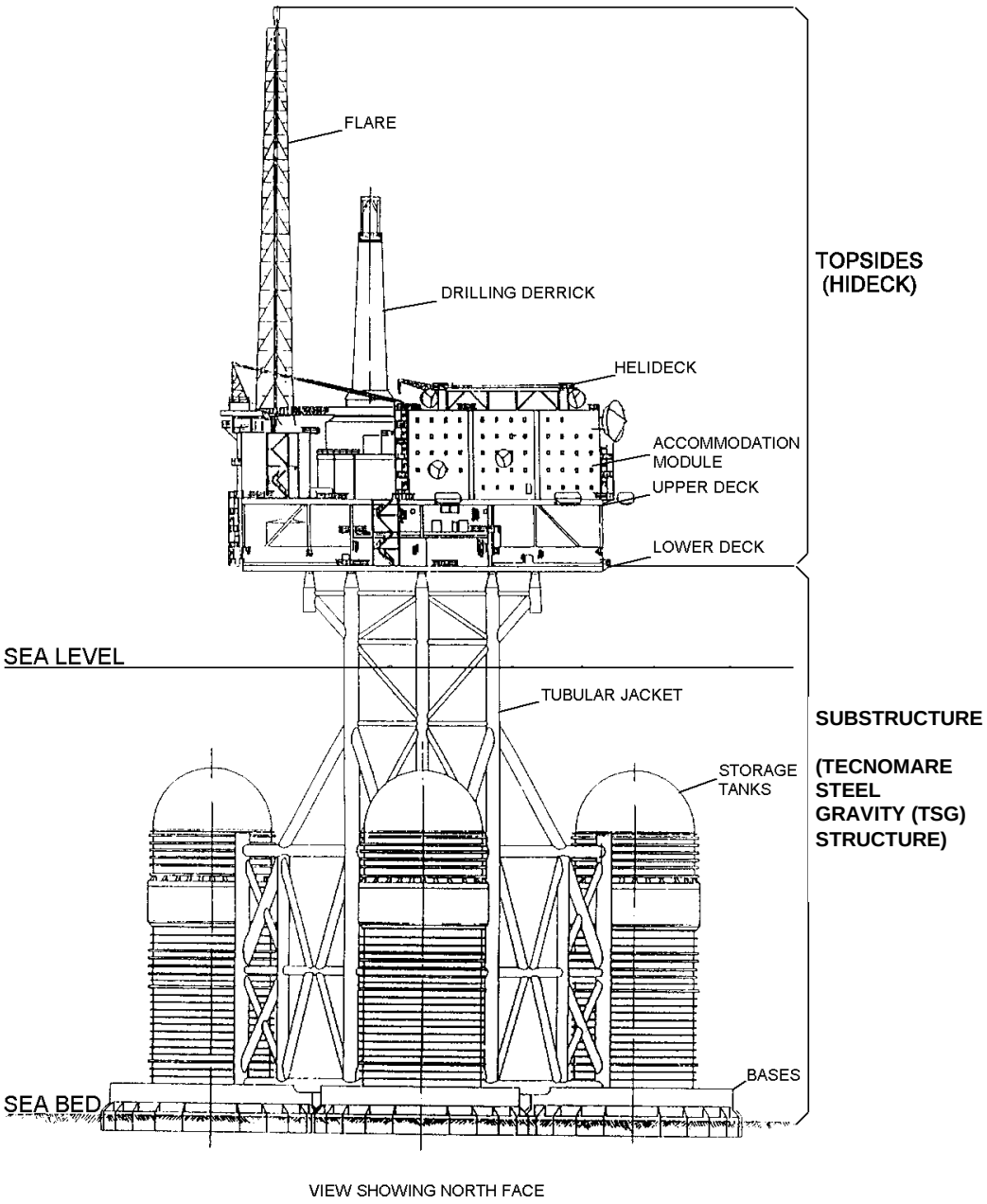
The Maureen Platform (see Figure 4-2) provided the production, drilling and accommodation facilities for the Maureen Field. It was installed in June 1983 by setting it on the seabed over a pre-installed drilling template. In addition, the Moira Field was developed via a single subsea well tied back to the Maureen Platform. Oil was exported to the Maureen Loading Column located 2.3 km from the Maureen Platform throughout field life. Associated gas was mostly re-injected into the reservoir to aid oil recovery (gas lift) and reduce flaring.

The Platform is a steel gravity based structure consisting of a triangular lattice frame (or jacket) with three submerged cylindrical storage tanks located at the corners of the lattice frame. The tanks were used for buoyancy and ballasting/deballasting during the marine operations preceding installation. During the production phase they were utilised as storage for the crude oil produced from the Maureen and Moira Fields. The base of each tank comprises sealed steel compartments containing solid ballast to anchor the structure to the seabed. Beneath each tank are 3.8 m deep metal skirts which penetrate the seabed (to a depth of about 3.4 m) to prevent lateral movement of the Platform.

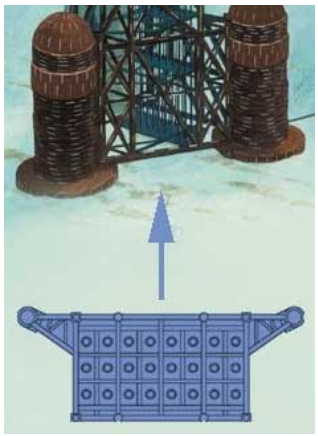
The integrated deck that is located on top of the substructure contains facilities for oil processing, gas compression, power generation, a drilling/workover rig and accommodation for 150 persons.

The Maureen Platform was designed and built to be able to float under tow to the field location and to be refloatable for decommissioning and reuse elsewhere at the end of the Maureen Field life. The facility has been well maintained throughout its operational service. Recent inspections and analysis have shown that it has the integrity and sufficient further life expectancy to justify redeployment on another hydrocarbon production project in a suitable water depth.

Figure 4-2 Maureen Platform



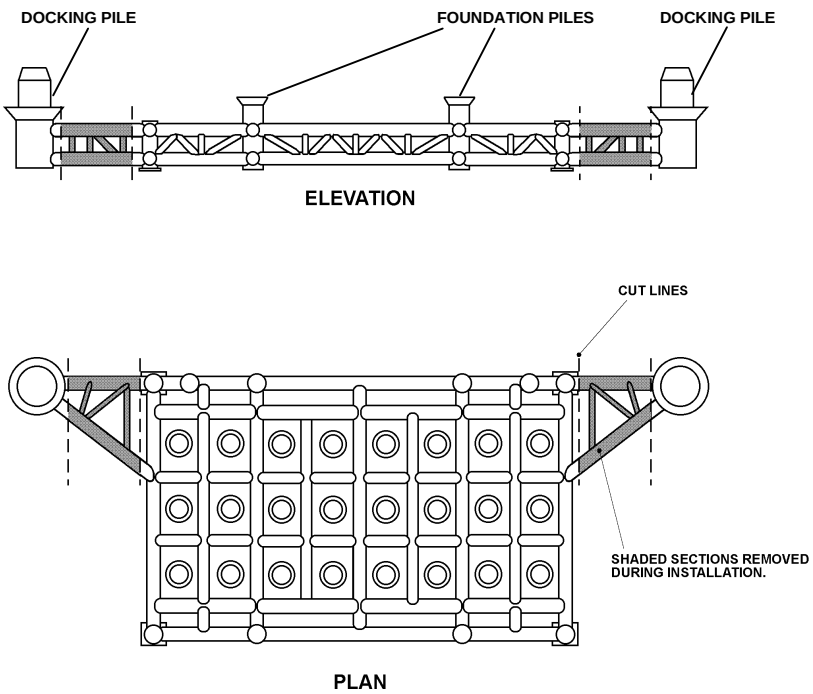
4.2.2 The Maureen Drilling Template



MAUREEN DRILLING TEMPLATE TECHNICAL DATA	
Overall dimensions	42 m x 18 m x 3.7 m
Weight in air	490 te
Number of well guides	24 off
Number of foundation piles	4 off
Diameter of foundation piles	1.067 m (42")

The Maureen Drilling Template (see Figure 4-3) was installed in 1979, prior to installation of the Maureen Platform, to enable pre-drilling of 20 wells. It is positioned directly under the south side of the Maureen Platform and is a tubular lattice structure which provided a total of 24 well slots for potential development. The Template is fixed to the seabed by four foundation piles. Docking piles attached to the Template by outriggers were used to accurately position the Platform during installation.

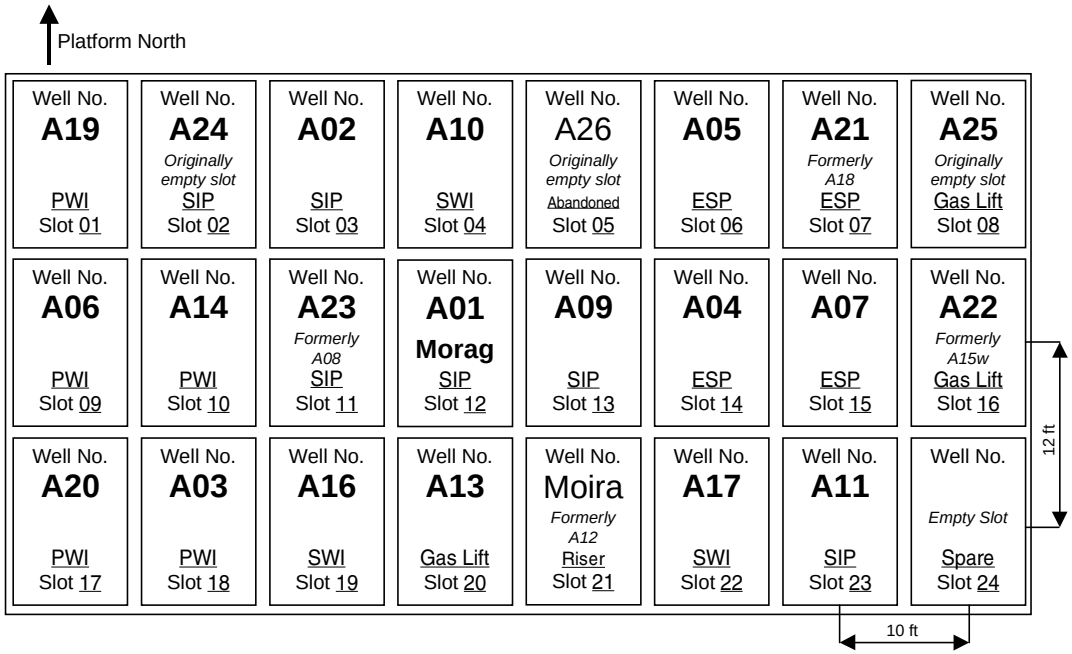
Figure 4-3 Drilling Template



4.2.2.1 Maureen Wells

Figure 4-4 shows the layout of the Maureen Wells at the Drilling Template. Further details on well histories are found in the Maureen Annual Field Reports (Phillips Petroleum Company United Kingdom Limited 1983 – 1997)[1] and the Maureen Cessation of Production (COP) report[2].

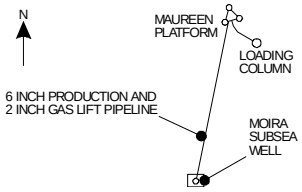
Figure 4-4 Maureen Final Well Layouts



Abbreviations:

ESP	Electrical Submersible Pump
PWI	Produced Water Injector
SIP	Shut In Producer
SWI	Sea Water Injector

4.2.3 The Maureen Loading Column



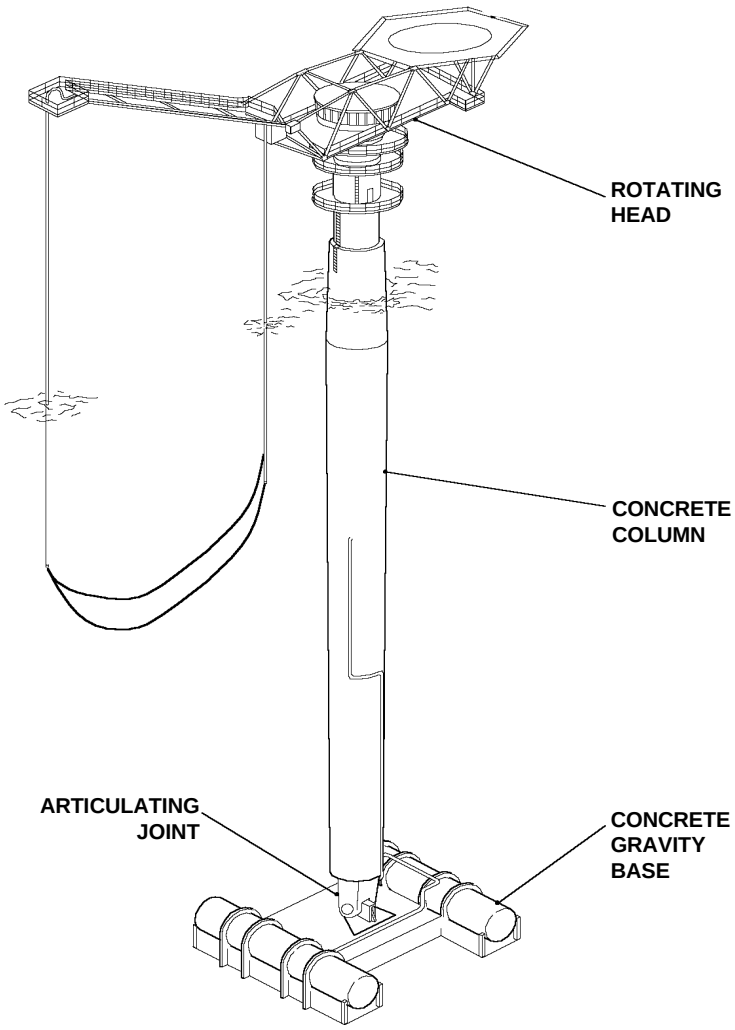
MAUREEN LOADING COLUMN TECHNICAL DATA		
Water depth	93 m	
Overall weight	8000 te	
Total height	131 m	
Loading rate	20,000 bbls/hour	
Concrete base	dimensions	36.6 m x 28 m x10.5 m
	dry weight	4,500 te
	on-bottom weight	2,700 te
Concrete column	height	89 m
	diameter	9 m, tapering to 6.5 m over the top 14 m
	wall thickness	350 mm

The Maureen Loading Column (see Figure 4-5) is a concrete gravity base structure within a pre-stressed concrete shaft. It functioned as the oil export facility for Maureen and Moira oil production, with the produced oil from the Maureen Platform being exported to tankers via the Maureen Loading Pipeline and onward through the Loading Column. The Loading Column has no crude oil storage facilities.

The Loading Column, located approximately 2.3 km southeast of the Maureen Platform, consists of four main parts:

- the concrete gravity base and foundation
- the articulating joint
- the concrete column
- the rotating steel offloading head.

Figure 4-5 Maureen Loading Column



Concrete Gravity Base and Foundation

The concrete gravity base anchors the column to the seabed. The base consists of two 9 m diameter, 28 m long buoyancy chambers supported 24 m apart on a grillage of concrete beams. The base is neutrally buoyant when the cylindrical chambers are empty. The base was fitted with rubber skirts around the perimeter in order to minimise scour.

Articulating Joint (Cardan Joint)

The column and gravity base are connected together with an articulating joint, consisting of two pairs of cast steel lugs and a cruciform bearing. One pair of lugs is attached to the base of the column. The other pair of lugs is attached to the gravity base structure. The two pairs of lugs are connected at right angles by the cruciform bearing which allow rotation about two horizontal axes. The cruciform bearing is made of cast steel and each of its four bearing trunnions is 800 mm in diameter.

The joint allows the column to rotate about each of the two horizontal axes. No rotation about the vertical axis is permitted. The cruciform is hollow and permits the passage of two 24" oil export lines; this arrangement is complemented by four in-line swivels mounted at the ends of each branch of the cruciform.

Concrete Column

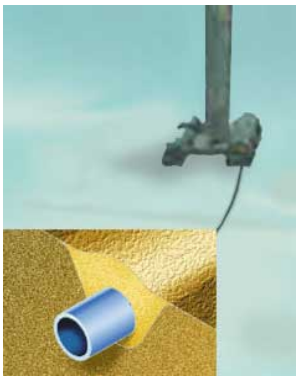
The concrete column is a cylindrical concrete construction with a fabricated steel extension at the top. The shaft is subdivided into water tight compartments to give adequate damage stability. A combination of concrete, haematite and water ballast is provided to reduce the vertical loading on the joint and provide a suitable restoring moment to keep the column upright. The base of the column is connected to the top section of the articulating joint. The column is constructed from reinforced concrete sections, which were joined by *in situ* casting and were then post tensioned together with 44 stressing tendons running the entire length of the column. The top steel section extends down into the tapered concrete section to satisfy compartment damage stability requirements and extends to support the rotating head bearing. The base of the column has a 1.6 m thick base slab to transmit loading into the articulating joint.

There are existing towing points on the column which are in good condition.

Rotating Head

The rotating head structure is a steel tubular lattice structure which carries the helicopter winch deck, the offloading boom, the tanker mooring hawser, the 16" offloading hose, the pipe swivel and ancillary items such as navigation aids and walkways. The structure is supported on a ring beam attached to the slewing bearing, which allows tanker loading to continue while the tanker swivels around the Loading Column.

4.2.4 The Maureen Oil Loading Pipeline

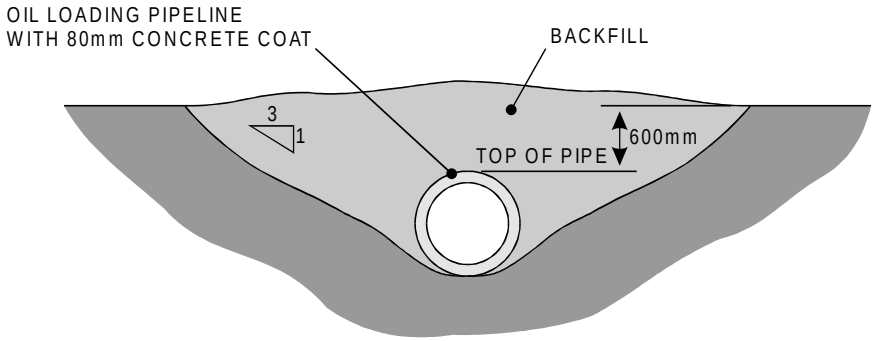


MAUREEN OIL LOADING PIPELINE TECHNICAL DATA	
Pipeline diameter	24" (610 mm)
Length of pipeline	2.3 km
Wall thickness	0.75" (19 mm)
Design flow capacity	20,000 bbls/hr
Design pressure	35.6 bar
Operating pressure	9.6 bar
Depth of burial	0.4 – 1.5 m (see below)

The Maureen Oil Loading Pipeline, fabricated from API 5L Grade 52 pipe, connects the Maureen Platform to the Maureen Loading Column approximately 2.3 km away.

The Loading Pipeline was laid in a trench which was allowed to naturally backfill as shown in Figure 4-6. On-bottom stability is ensured by a concrete weight coating 80 mm thick.

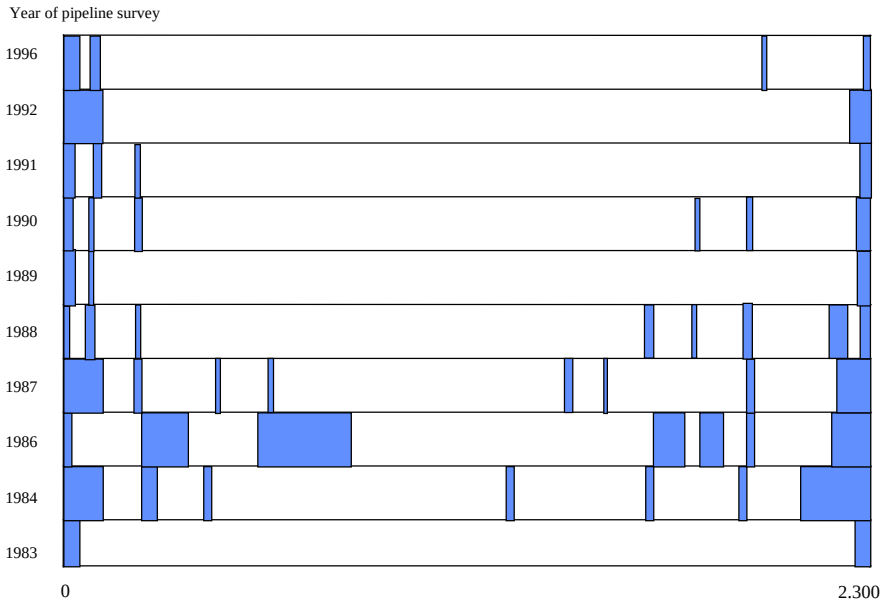
Figure 4-6 Loading Pipeline Trench as a Cross Section



Surveys of the Loading Pipeline were carried out in 1983, 1984, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1996 and 1997. The extent of exposure found in each of these years is shown in Figure 4-8 and Table 4-1. In 1986, gravel was placed over sections of the pipeline to counteract scouring that had exposed the crown of the pipeline in some places.

An independent study conducted in 1999 by Andrew Palmer and Associates,[3] based on the most recent survey data, reports that approximately 48% of the Loading Pipeline is buried to a depth greater than 600 mm and 40% is buried to a depth of between 400 and 600 mm. The remaining 12% is at present uncovered; the uncovered sections consist of exposed areas at each pipeline end and a smaller exposed area (approximately 20 m) near the Loading Column. The uncovered sections at each end of the pipeline will be removed, while the 20 m section will be covered by backfilling to at least seabed level in order to achieve adequate burial depth.

Figure 4-7 Exposed Lengths of Oil Loading Pipeline

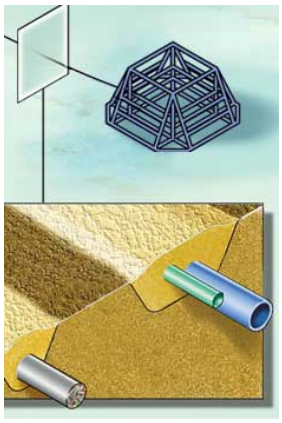


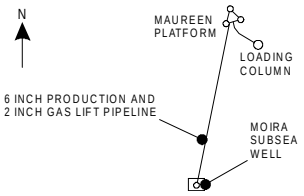
The Loading Pipeline has remained within its trench for its operational life. In addition it has shown a reduction in exposure as time has passed. The small amount of exposure experienced has not been sufficient to uncover the bottom of the pipe and cause any free spanning sections. There is no evidence to suggest that this trend will not continue. In any event the pipeline will be surveyed and monitored over time as agreed with the DTI prior to decommissioning.

Table 4-1 Oil Loading Pipeline Exposure over Time

Year	Number of Exposed Sections	Cumulative Total Exposed Length (m)	Percentage of Pipeline Exposed
1983	2	160	6.9%
1984	7	500	21.6%
1986	7	431	18.6%
1987	8	359	15.5%
1988	8	269	11.6%
1989	3	80	3.5%
1990	6	136	5.9%
1991	4	84	3.7%
1992	2	182	7.9%
1996	4	84	3.7%

4.2.5 Moira Subsea Facilities





MOIRA SUBSEA FACILITIES TECHNICAL DATA	
Water depth	96.6 m
Number of wells	1 off
Moira oil pipeline	6" diameter
Moira gas lift pipeline	2" diameter
Moira control umbilical	4" diameter
Length of pipelines	Approximately 10 km each
Wellhead Protection Structure	
dimensions:	18 m x 18 m x 8m
dry weight:	80 te

The Moira subsea development is located approximately 10 km south southwest of the Maureen Platform.

The Moira Subsea Facilities consist of a single subsea satellite well with its wellhead and Production Tree (the "Wellhead Facilities"), protected by a steel gravity protection structure (the "Wellhead Protection Structure" or "WPS"), as shown in Figure 4-8, as well as two small diameter pipelines and a control umbilical. Produced fluids from the Moira well were transported to the Maureen Platform via the 6" production pipeline. Well production was sustained by gas lift supplied from the Maureen Platform via the 2" gas lift pipeline. Hydraulic control of the wellhead was provided from the Maureen Platform via the control umbilical.

Figure 4-8 Moira Subsea Facilities – View in Elevation

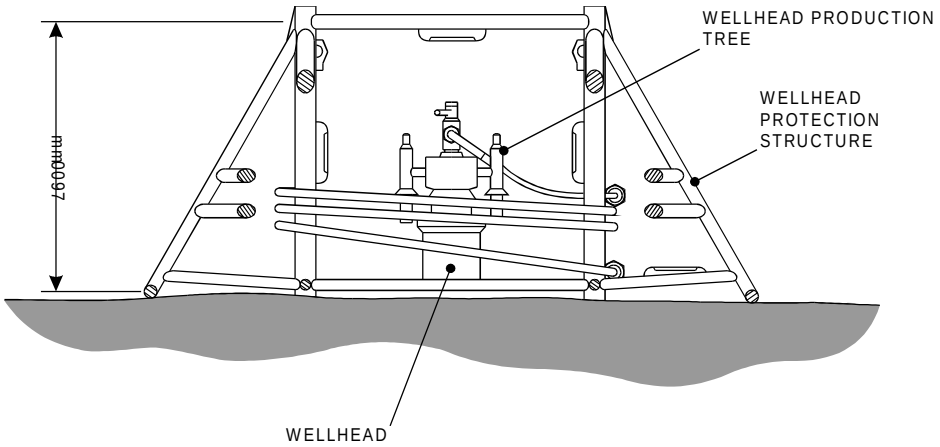
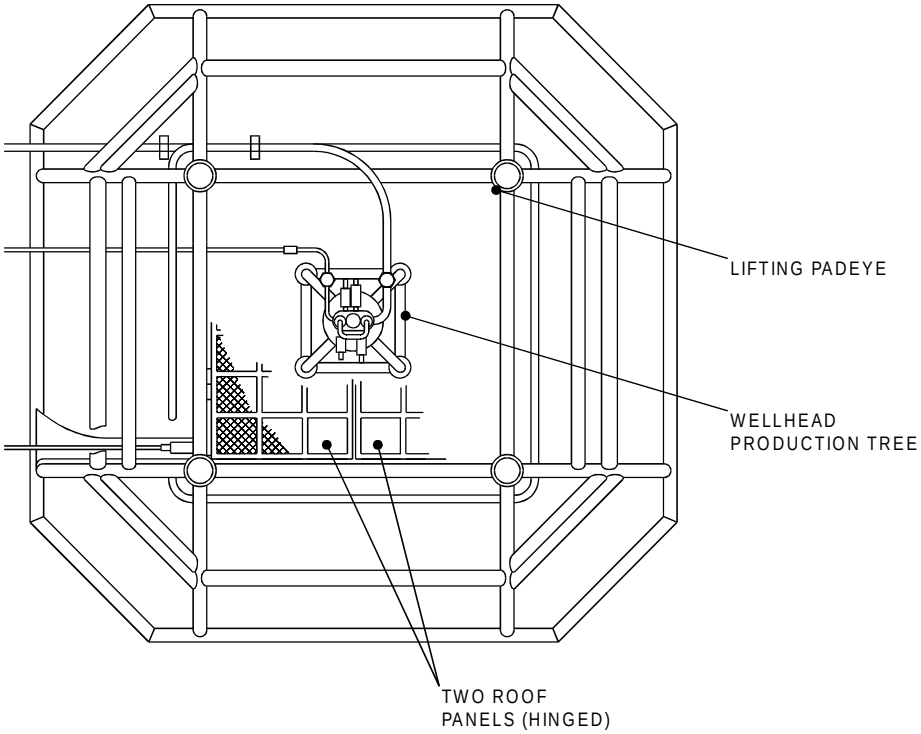


Figure 4-9 Moira Subsea Facilities – Plan View



Moira Wellhead and Wellhead Protection Structure

A conventional Vetco Gray Production Tree was installed on the Moira Wellhead. The wellhead, tree and control facilities were surrounded by the Wellhead Protection Structure, a lattice framework equipped with a hinged roof to permit access to the Production Tree. 300 mm deep skirts penetrate the seabed to prevent lateral movement.

Moira Subsea Well 16/29a-8z

The details of the Moira Subsea Well are as follows:

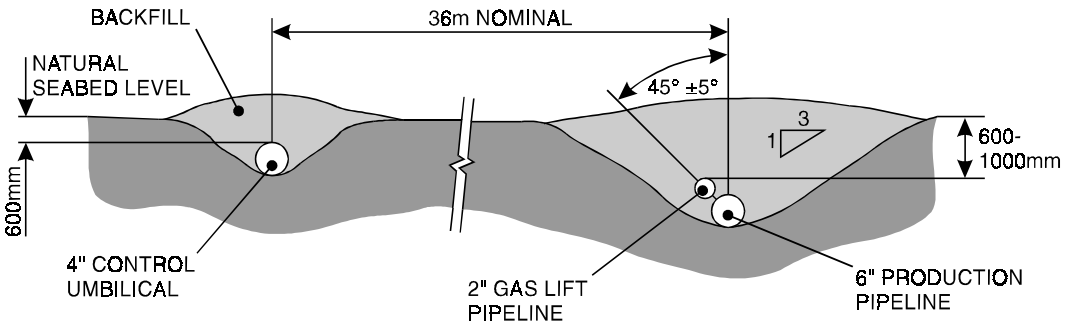
Well Type:	Oil Producer with gas lift.
Tree Type:	Vecto Gray 5000 psi subsea tree
Spud Date:	April 1988 (Discovery Well)
Completion Date:	August 1990
First Oil Date:	August 1990

The Moira Pipelines

The Moira subsea well was tied back to the Maureen Platform by two pipelines approximately 10 km in length.

The 2" gas-lift pipeline is strapped to the 6" oil production pipeline and both were laid in a pre-cut trench using a reel laying system. The pipelines were then buried using a plough trenching system. The trench was allowed to naturally backfill, as shown in Figure 4-10.

Figure 4-10 Moira Pipelines Cross Section



Both pipelines have external corrosion protection provided by a 0.5 mm fusion bonded epoxy coating and sacrificial anodes.

At the Maureen Platform, the Moira pipelines are connected to a riser bundle located in conductor guide frame slot A21. The Moira pipelines are supported on a pipe bridge between the guide frame and the seabed. Pipe loops at the base of the pipe bridge accommodate expansion caused by temperature and pressure.

At the Moira wellhead, expansion of the pipelines is accommodated by the use of flexible pipe sections.

The Moira pipelines have remained buried in a relatively stable condition for several years with the only exposed sections being at the pipeline ends. Surveys during the period 1991 to 1997 have indicated that less than 3% of the total pipeline length has been exposed and no areas have been found to be free spanning. Figure 4-17 shows graphically the results of the survey and Table 4-2 presents the extent of exposure and its variation over time.

Figure 4-11 Pipeline Surveys

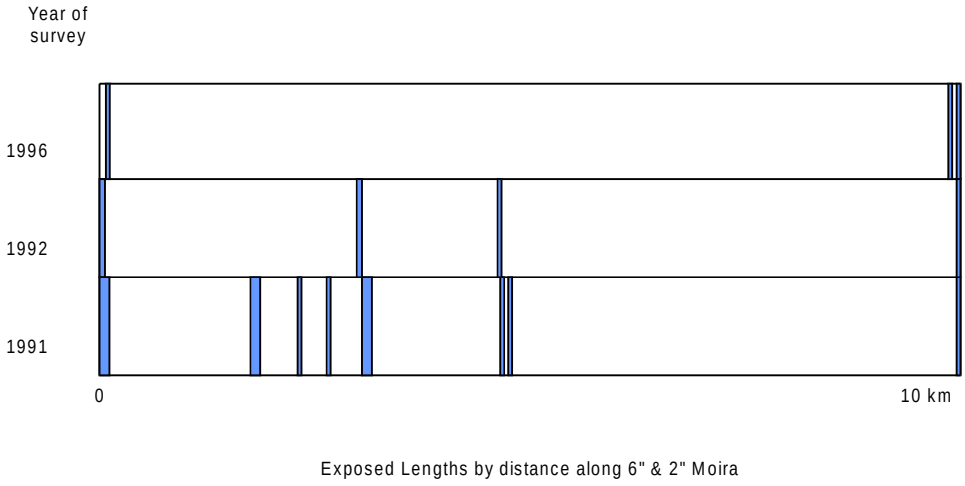


Table 4-2 Moira Pipelines Exposure over Time

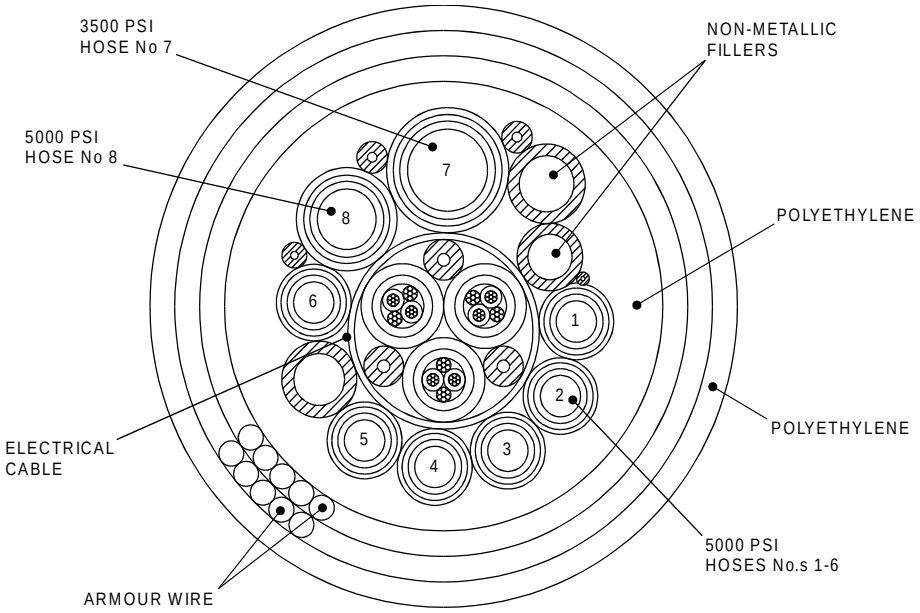
Year	Number of Exposed Lengths	Cumulative Total Exposed Lengths	Percentage of Pipeline Lengths Exposed
1991	8	294 m	2.9%
1992	6	91 m	0.9%
1996	3	99 m	1.0%

The Moira Control Umbilical

The 4" hydraulic control umbilical, shown in cross section Figure 4-12, runs in a trench parallel to the pipelines at a distance of approximately 36 m. The umbilical was buried using a plough trenching system and the trench allowed to naturally back-fill to provide a cover. The unburied lengths outside the trench at both ends were stabilised with concrete mattresses.

At the Maureen Platform end, the umbilical is guided up the same riser bundle as the pipelines to reach the termination frame on the Platform deck.

Figure 4-12 Umbilical Makeup as a Cross Section



The control umbilical carries hydraulic fluid and instrument cables for control and monitoring of the well.

4.3 Material on the Seabed

4.3.1 Seabed Surveys

A substantial body of data regarding the seabed in the Maureen area has been collected during surveys undertaken prior to any drilling taking place in 1979 and during subsequent surveys undertaken throughout the operational life of the field. The relevant references are listed in sub-section 4.5.

A series of new seabed surveys was recently conducted to establish the baseline seabed environment in advance of Maureen Platform decommissioning. In addition, surveys will be conducted both during and after the refloat and tow operations. Recent studies are described below and they supplement information gathered in previous surveys conducted throughout the operational life of the field.

Physical and Environmental Surveys

Maureen Refloat Study by Fugro[9] and The Assessment of the Sediment Contamination Beneath the Maureen Platform Cordah[10] together confirm the morphology of the cuttings layer, surrounding seabed and the platform-related infrastructure. Another survey of the platform area will be conducted after completion of decommissioning operations.

The Assessment of the Sediment Contamination beneath the Maureen Platform by Cordah[10] defines the quality, quantity, and position of deposits as they relate to the platform and adjacent area. Seabed samples taken from various locations around Maureen, Moira and the Maureen Loading Column were analysed for particle size distribution, total metals, total hydrocarbons and Polycyclic Aromatic Hydrocarbons (PAHs),

The Pre-Decommissioning Baseline Seabed Survey of the Maureen A Platform and Associated Infrastructure" by Cordah[11] involved additional seabed sampling to quantify concentrations and the extent of sediment entrained contaminants, with additional analysis of bottom living fish and shellfish. Commercial species (shellfish, flat and round fish) were collected by trawling in the surrounding vicinity to analyse for potential contaminants such as hydrocarbons. Additional pollutants such as Polychlorinated Biphenyl (PCB) congeners and Tributyl Tin (TBT) and its derivatives were also investigated. This report attempts to summarise and compare recent data with results from previous studies and identify overall trends.

Both the physical and environmental surveys can generally be compared with previous monitoring experience and data to describe the overall impact during the life of the field.

4.3.2 Drill Cuttings

Drill cuttings are small pieces of rock that are broken up by the drill bit as it penetrates the rock during the drilling of wells. The cuttings are carried back to the surface by special fluids, called "drilling muds", which are used to cool and lubricate the drill bit, transport the cuttings and contain the down hole pressure in the well. Drilling mud consists of a base fluid, such as water, oil or synthetic oil, plus other components, which are added to improve performance. Barite, for example, is added to increase density.

History of Maureen Drilling Activity and Drill Cuttings

Drilling the Maureen wells resulted in an accumulation of drill cuttings on the seabed in the vicinity of the Maureen Platform. Most of these cuttings were deposited between 1979 and early 1983 as a result of drilling twenty development wells through the Maureen Drilling Template, prior to installation of the Maureen Platform in mid 1983. A pile of cuttings approximately 5 m high was reported to have been present at the completion of the 20 pre-drilled wells.

In order to properly install the Maureen Platform in 1983, three 47 m diameter circles on the seafloor were cleared of debris to provide a flat surface for the tanks and platform legs to be placed securely on the seabed. Two of the three circular areas were located on either side of the 5 m pile (see map in Figure 4-13). The drill cuttings were disturbed by this activity, and additionally when conductors were threaded down through the cuttings pile and Template to access wellheads.

The drill cuttings accumulation then lay dormant from 1983 to 1988, a period during which there was no drilling activity and hence no new discharges of drill cuttings were made. Discharges resumed when three existing wells were re-drilled, generating additional cuttings in 1988, 1991 and 1992. This was followed by more discharge events when three new wells were drilled in 1996, 1997, and 1998. Cuttings have not been discharged at Maureen since early 1998.

It appears from the current size of the accumulation (1.3 m peak) that it has diminished through time partly owing to flattening and dispersion during installation of the Platform, and additionally owing to a natural weathering process (currents and storms).

The discharge history summarised in Table 4-3 provides an indication of the extent and composition of the Maureen drill cuttings accumulations.

Table 4-3 Discharges of Drill Muds and Cuttings from the Maureen Development Wells

Mud Type	Weight of Cuttings Discharged (te)	Weight of Mud Discharged (te)
Water based mud	16170	No data available
Low toxicity oil based mud	4074	2199
Synthetic mud	1571	447
Ester mud	160	96

The majority of Maureen drill cuttings were deposited prior to 1983 during drilling of the 20 "pre-drilled" wells before the Platform was installed. Around 75% of the muds used at Maureen were water based muds.

Amount and Physical Dimensions

Two studies by Fugro[9] and Cordah[10] report on the dimensions, quantity and composition of the drill cuttings under the Maureen Platform. The dimensions of the drill cuttings accumulation based on the Fugro data taken in 1998 are shown in Figure 4-13 below.

Figure 4-13 Thickness of Drill Cuttings at the Maureen Platform

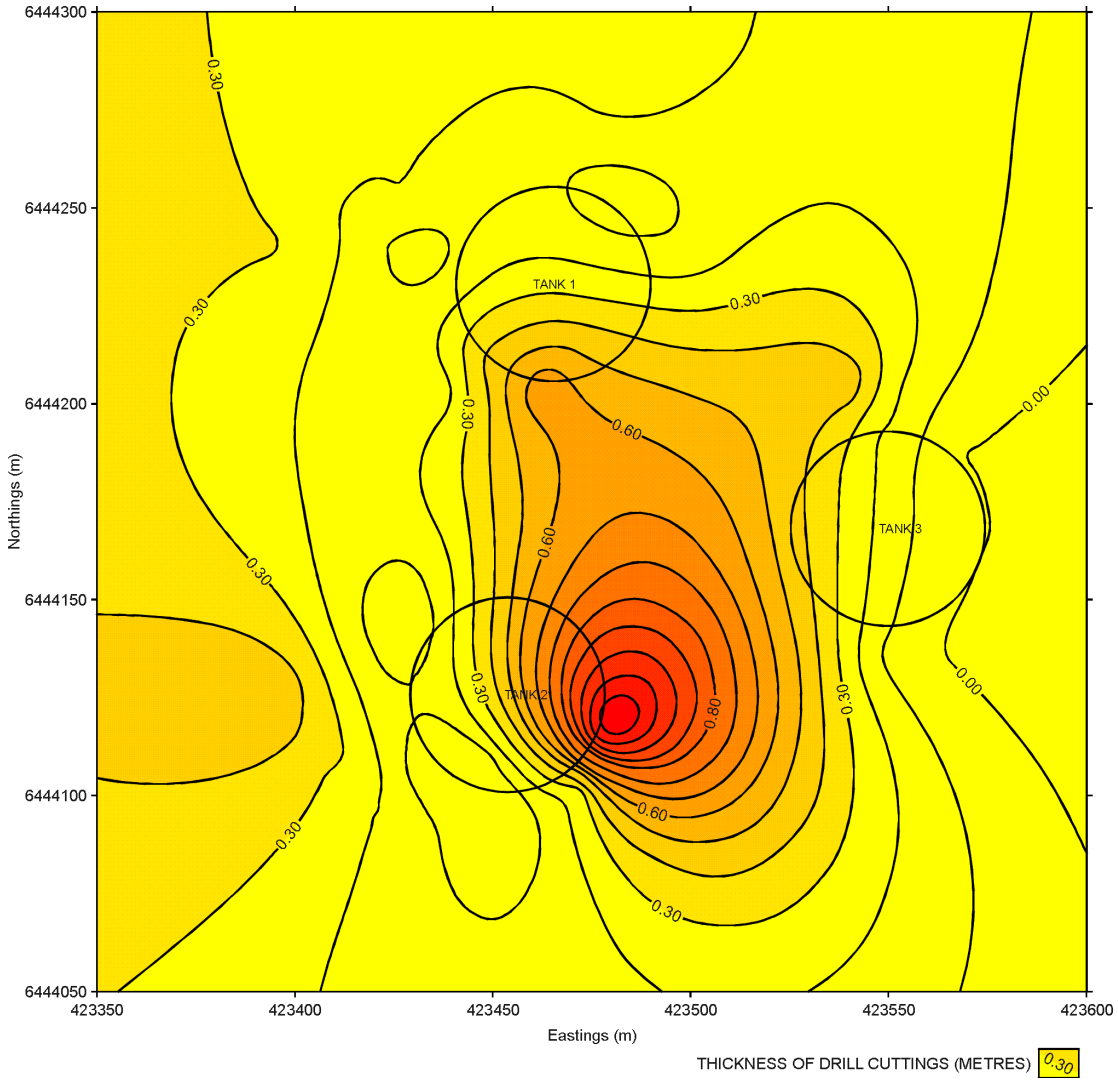


Figure 4-13 depicts the position and size of the cuttings layer on the seabed under the Platform (the "footprint"). The cuttings layer today is on average 60 cm high, with a single peak of approximately 1.3 m at the edge of the base of Tank 2.

According to the most recent studies, the quantity of cuttings remaining in the footprint of the Platform is estimated to be 6000 te. This is significantly less than the total volume produced during drilling operations throughout field life (estimated 21,000 te of cuttings discharged). Outside the footprint of the Platform there is evidence of a thin layer of drill cuttings to the west, which is generally less than 30 cm thick. From this it is evident that much of the original pile has been dispersed when preparations were being made to place the Platform on the seafloor and through subsequent dispersion (e.g. currents), leaving a relatively thin layer of cuttings which remains today.

Composition

The Maureen Owners have undertaken extensive surveys and sampling efforts to prepare for the decommissioning of the Maureen Facilities.

Information to consider in the overall evaluation of the cuttings accumulation consists of studies listed in section 4.4 (1983-1999). In addition, the Maureen Owners conducted baseline surveys in 1979 and 1981. These baseline studies, together with regular sampling events throughout the operational life of the Platform, provide a unique opportunity to evaluate the condition and quality of the drill cuttings and surroundings through time, and in some instances, where consistent method analyses allows, to compare existing conditions to previous or pre-drilling conditions. This is described below.

Assessment of Sediment in the Maureen Field

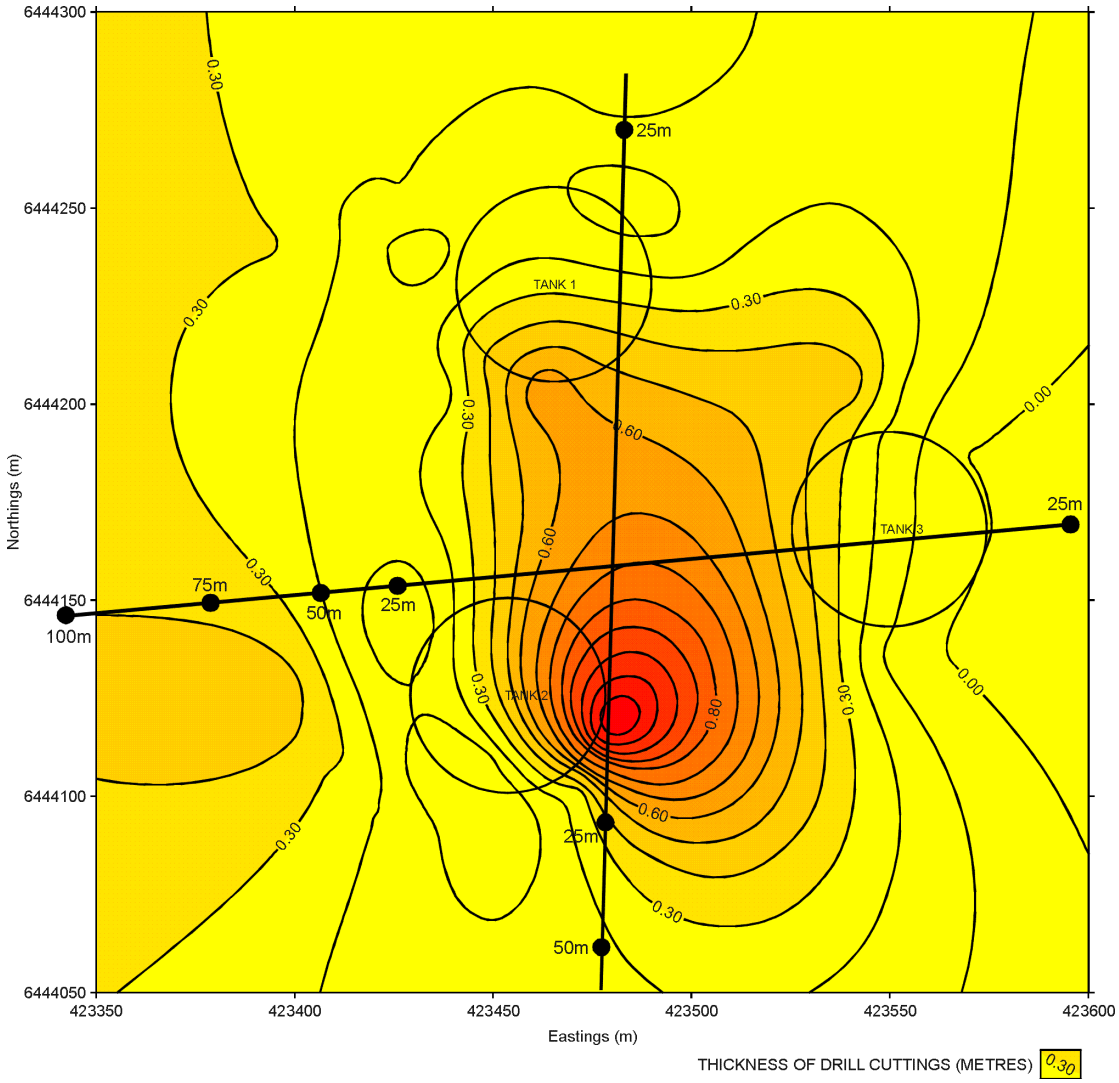
In preparation for the decommissioning of the Maureen Field, a characterisation and assessment of the drill cuttings layer and sediments surrounding the Maureen Platform, Moira Wellhead and the Maureen Loading Column, was undertaken by Cordah during the winter of 1998/9 (Cordah[10],). 154 seabed core samples were collected during December 1998 from 60 locations as follows:

- 13 beneath the skirts of the Maureen Platform tank bases
- 11 beneath and immediately adjacent to the Maureen Platform tank bases
- 22 on a transect centred on the Maureen Platform tank bases
- 8 on a transect centred on the Moira wellhead
- 6 on a transect centred on the Maureen Loading Column.

The core samples were sub-sampled for analysis of hydrocarbons and metals at various depths in the core.

As part of this 1998 survey, samples were taken on transects centred on the platform, out to a distance of 200 m. Additional data were then collected the following year in 1999, to supplement this 1998 survey, where sampling transects extended those used in 1998, with sample sites coinciding with those from historic surveys. Sampling transects showing sample points close to the platform are shown Figure 4-14.

Figure 4-14 Drill Cuttings Map Showing Sampling Transects and Locations



The 1999 Cordah survey report attempts to summarise and compare recent data with results from previous studies. Where possible, it provides a comparison of concentrations of hydrocarbons and metals over time. That comparison reveals a link between hydrocarbon/metals concentrations and drilling history, and indicates an overall decrease in concentrations through time and with distance away from the Platform.

Metals

A summary of the minimum and maximum concentrations of the main trace metals of interest identified at Maureen and reported by Cordah[10] (Oct.1999) are given in Table 4-4.

Table 4-4 1998/99 Concentrations of Trace Metals

	Arsenic	Barium	Cadmium	Mercury	Lead	Strontium	Vanadium	Zinc
Conc'n	As µg/g	Ba µg/g	Cd µg/g	Hg µg/g	Pb µg/g	Sr µg/g	V µg/g	Zn µg/g
Max [a]	21.7	85906	3	8.82	652	1399	185	10715
Max [b]	10.4	31779	2	5.67	391	806	159	2395
Location		25 m E	25 m E	50 m S	25 m E	25 m E	25 m S	50 m N
Min [c]	<1.0	2391	<1	1.63	53	152	20	73
Location		25m N	Most	200 m N	200 m N	100 m E	100 m E	100 m E
Typical background levels (NSTF) 1993	11	400-500	50	<25	21	-	-	39

Notes:

a. Maximum concentrations directly beneath the Maureen Platform

b. Maximum concentrations on transects centred on the Maureen Platform

c. Minimum concentrations on transects centred on the Maureen Platform

Barium is widely used as an additive in drilling fluids and its presence in sediments has been used as a marker of drill cuttings and fluids. The other metals identified most likely originated as impurities in the barium sulphate (barite) or from the natural rock. Most of the heavy metals from the muds are bound within the barite, and the possibility of leaching is considered to be low and bio-availability as negligible from the UKOOA drill cuttings JIP phase 1 research results.

The highest concentration of barium in 1998 was recorded in the surface sediment close to the Maureen Template (85906 µg/g). These concentrations reduced significantly further away from the platform.

Owing to different analytical methods it is difficult to directly compare recent barium concentrations with results from previous surveys. A refined analytical method, compared with the standard method used since 1996, was used for the extraction of barium in 1999. This method can extract more barium from the sample than earlier techniques, and so provides a more accurate estimate of the concentration. As a result of this, the concentrations determined in 1999 will be higher than if they had been measured using the same method as the previous years (Cordah[11]).

Keeping this in mind, Figure 4-15 and Figure 4-16 depict barium concentrations from 1979 to 1999, showing a general correlation with drilling history at the Maureen Platform, and illustrating the reduction in barium concentrations as distance from the Platform increases. On the SW/NE transect, the concentrations in 1999 were lower than in 1993 or 1988, and in the SW direction, they were also lower than in 1983. On the NW/SE transect, concentrations in 1999 were higher than in 1988, but lower than in 1983. Barium was not determined in 1993 at the sites on the NW/SE transect, but given the pattern on the NE/SW transect, it is expected that 1993 levels would be higher than in 1999. By 1999, concentrations similar to background levels (300-500 µg/g) were reached by 500-1000 m from the Platform on both transects (Cordah[10]).

Figure 4-15 Barium Concentrations on NW/SE Transects

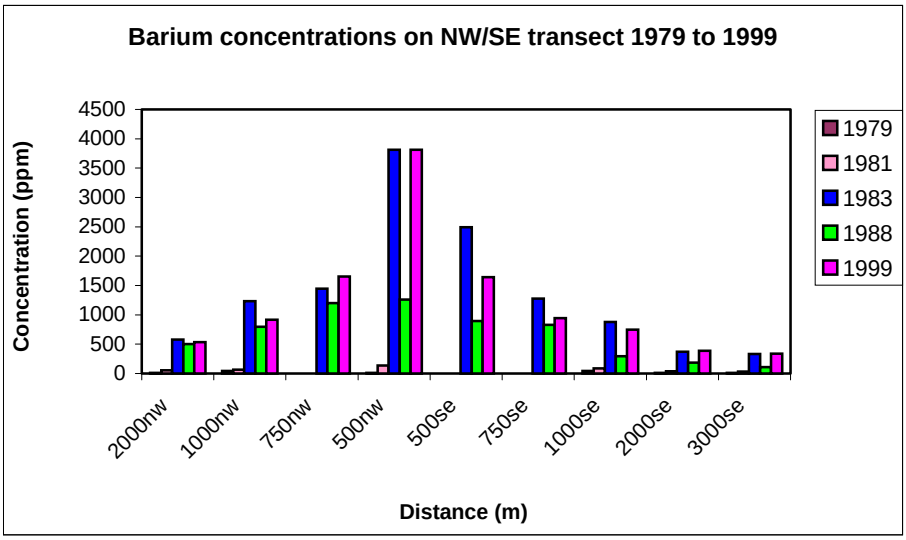
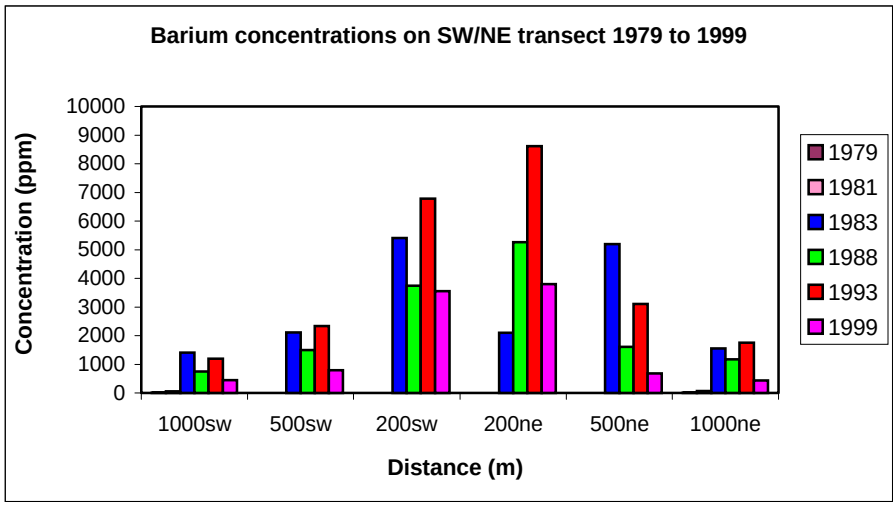


Figure 4-16 Barium Concentrations on SW/NE Transects



There was evidence of an increase in concentrations of barium at certain locations up to 200 m from the Platform, which may reflect the deposition of the cuttings that were redistributed from the area beneath the skirts at the time the Platform was installed. Lower concentrations were also detected in samples taken from beneath the skirts, which is consistent with the area being cleared of cuttings before the Platform was installed.

At Moira, the highest concentration of barium (22318 μg/g) was detected 50 m SSE of the wellhead. 200 m from the wellhead the concentrations had reduced significantly.

The barium concentration around the Loading Column was around 330μg/g at all sample locations which is within the range typical of the Loading Column background levels found in areas where no drilling activities occur.

The concentration of other metals in the surface sediments and shallow subsurface sections around the installations varied without any obvious pattern, although the highest concentrations in 1998 generally occurred immediately around and beneath the Maureen Platform. The concentrations of most metals found at Maureen are typical of those recorded around other installations in the North Sea, with the exception of zinc, which was found to be around 10-20 times higher in places. This can be explained by degradation (during the platform life) of the high number of sacrificial anodes attached to the structure.

Concentrations of arsenic and mercury were found to be low (traces detected were in nano-grams per gram) and varied little across all the locations sampled or through the depth of the sample cores taken. The concentrations of these elements are similar to those measured at other sites surveyed in the Central and North Sea.

Figure 4-17 and Figure 4-18 depict lead concentrations at the Maureen platform over time and with distance. On both the NE/SW and NW/SE transects, lead concentrations decreased as distance from the installation increased. On the NE/SW transect, the 1993 concentrations were higher than in 1988 or 1999. No sites were sampled on the NW/SE transect in 1993, but when the pattern on the other transect is considered, it is expected that the concentrations observed in 1999 would have been lower than in 1993. Concentrations typical of background (approximately 21 μg/g) were reached by 500-750 m from the installation (Cordah[11]).

Figure 4-17 Lead Concentrations on NW/SE Transect

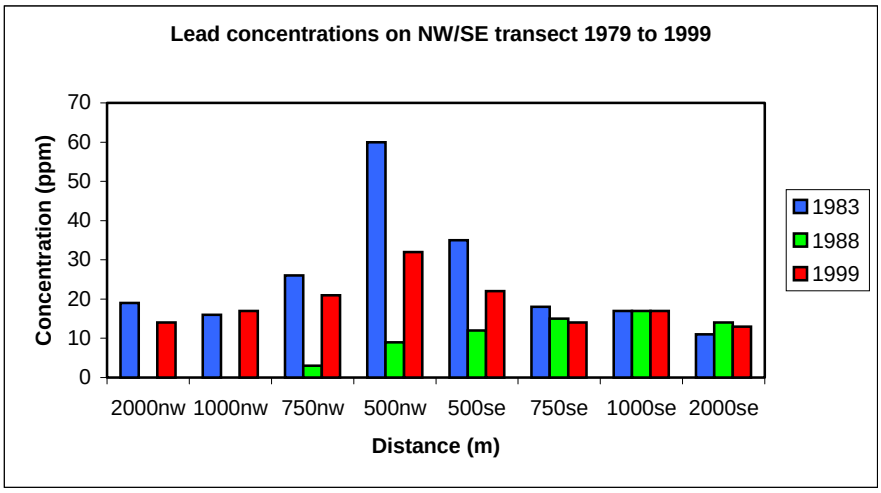
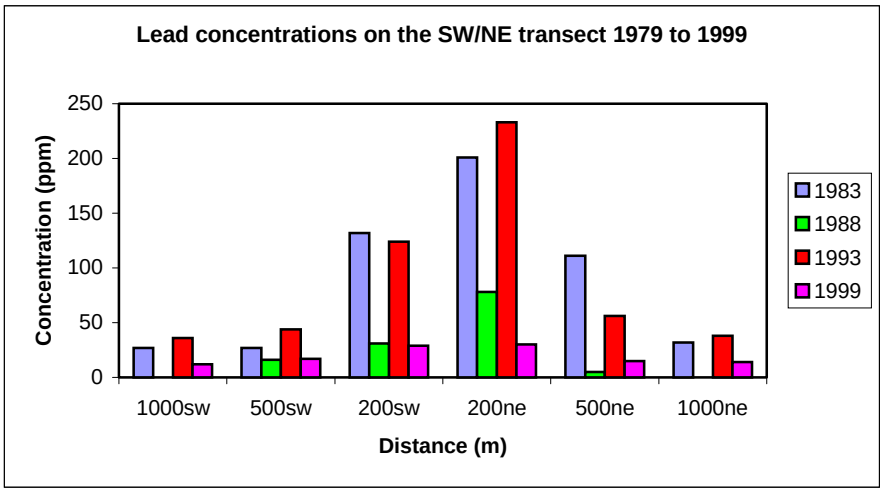


Figure 4-18 Lead Concentrations on SW/NE Transect



In conclusion, the metals analyses indicate that maximum metal concentrations are generally centred at the Maureen Platform with background levels being reached by 750-1000 m from the Platform. In most cases, the concentrations recorded during the 1993 survey were higher than in previous surveys. Importantly however, the concentrations determined in 1993 were almost exclusively higher than those recorded in 1999. In 1999, concentrations had often reduced to levels comparable to the pre-drilling surveys. This is evidence to suggest that contaminants have been removed, through winnowing or some other mechanism.

Hydrocarbons

Five distinct hydrocarbon compounds were characterised (Cordah[10]) in the sediments sampled around the Maureen Platform, the Moira Wellhead, and the Maureen Loading Column. These compounds reflect the drilling history at Maureen and Moira. The compounds are:

i. Low aromatic content, low toxicity drilling mud.

ii. Diesel-ranged oil based drilling mud, which is potentially a "first generation" low toxicity drilling mud, *e.g. Cleanspot.*

iii. Paraffinic synthetic oil based mud, *e.g. XP07.*

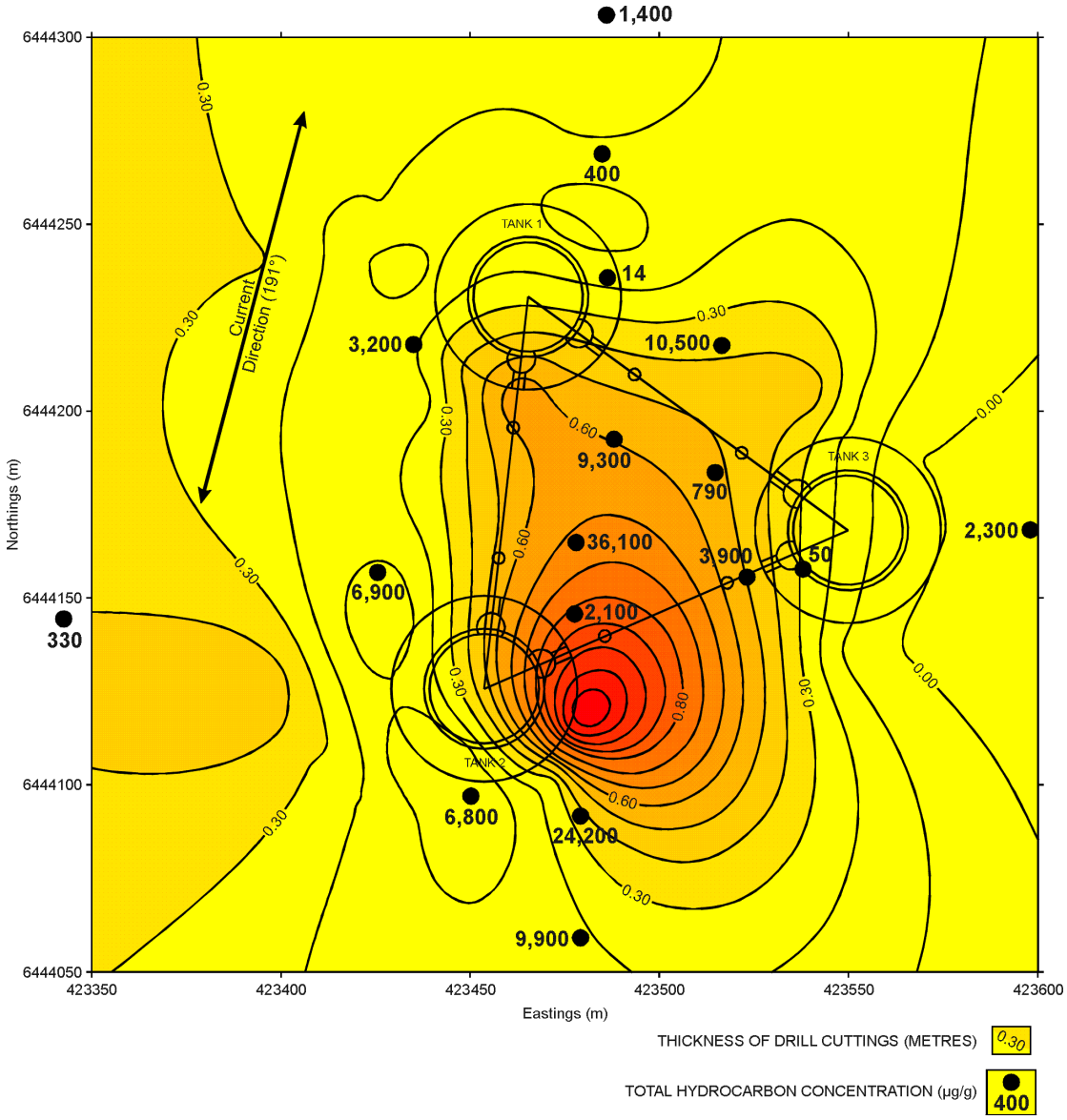
iv. Poly alpha olefin-based (PAO) synthetic oil based mud.

v. Paraffin wax (not detected in 1999 survey).

Compounds in categories i, ii and iii were detected in 1998 in surface sediments around the Maureen Platform, with total organic extract (TOE) concentrations ranging up to 36100 μg/g. The higher concentrations were generally to the south of the Platform, which is consistent with the prevailing current in the area. Concentrations decreased rapidly further away from the Platform.

Figure 4-19 shows total hydrocarbon concentrations on the seabed around the base of Maureen Platform, from the most recent survey (Cordah[11]).

Figure 4-19 Drill Cuttings Map Showing Hydrocarbons Concentrations



Different analytical techniques used in several of the hydrocarbon surveys, over the life of the Maureen Field, prevented an accurate comparison of total hydrocarbon concentrations through time at the Maureen Platform.

Concentrations of Total Organic Extracts (TOE) in the sediments around Moira ranged up to 9000 µg/g 50 m SSE of the wellhead with only 220-330 µg/g being measured 200 m from the wellhead.

The area around the Moira Wellhead was the only site where compounds in category iv were detected in addition to those in categories i & ii. This confirms that a PAO-based drilling mud had been used at this site.

Only low levels of aromatic hydrocarbons were detected around Maureen and only three sites had evidence of petrogenic input. Sites 200NW, 200SE and 500SE contained an aromatic UCM (unresolved complex mixture) that indicated aromatic compounds have been extensively weathered. Concentrations around the Moira wellhead were even lower.

No remnant of drilling mud was detected in any of the samples taken from around the Maureen Loading Column. However, a high concentration (5300 μg/g) of paraffin wax was detected 100 m NNE of the Maureen Loading Column in 1998 (absent in 1999). In addition, an enhanced level (up to 110 μg/g) of a high boiling point Unresolved Complex Mixture (UCM) in two samples around the Maureen Loading Column may represent the input of a crude oil, which has been extensively weathered and biodegraded.

A depth study of the aromatic hydrocarbons in one of the core samples at Maureen indicated that there has been extensive weathering and biodegradation throughout the depth of the core (greater than 50 cm) (Cordah[10]).

Concentrations of Naphthalene/Phenanthrene/Dibenzothiophene (NPD) increased with depth from 2100 ng/g at the surface to over 50000 ng/g in the 40-43 cm section.

The concentrations of NPDs in surface sediments along the transect NNW of the Maureen Platform increased out to 100 m and then decreased rapidly out to 200 meters.

These concentrations can all be considered low for sediments this close to a production platform. The naphthalene concentrations in the NNW transect were all below those considered sufficient to cause disturbance to the benthos (Cordah[11]).

As a result of differences in techniques used between studies for the quantification of total hydrocarbon fractions, it is not possible to compare the concentrations of this component over time. However, the aliphatic component from 1979, 1981, 1983, and 1999 did use consistent methods and these results are directly comparable. These results show a clear increase in aliphatic hydrocarbon concentrations in 1983 over the previous two surveys, which corresponds to the start of drilling using oil based muds. By 1999, aliphatic concentrations had decreased significantly at sites where elevated levels had been recorded in 1983 (Cordah[11]).

Consistent analytical methodologies also enabled a comparison to be made of NPD PAH results at two different locations (250 m, 1000 m) over time, and these results indicate hydrocarbon degradation is occurring at Maureen.

Two locations with elevated concentrations of NPD PAH were selected and graphed (Figure 4-20 and Figure 4-21) with results indicating hydrocarbon was elevated in 1983 and 1993 (roughly correlating with drilling activities) however, by 1999, concentrations significantly decrease. Concentrations of NPDs ranged from 40,650 μg/g at 250 m NE to 260 μg/g at 1000 m NE in 1983, but by 1999 the concentration had decreased to 210 μg/g at 250 m NE and 17 μg/g at 1000 m NE. The decrease in concentrations is most likely an indication of the biodegradation and recovery of the area.

In addition, Figure 4-22 depicts a decrease in concentrations of NPD PAH in sediment as distance away from the platform increases.

Figure 4-20 NPD PAH Concentration at 250 m NE

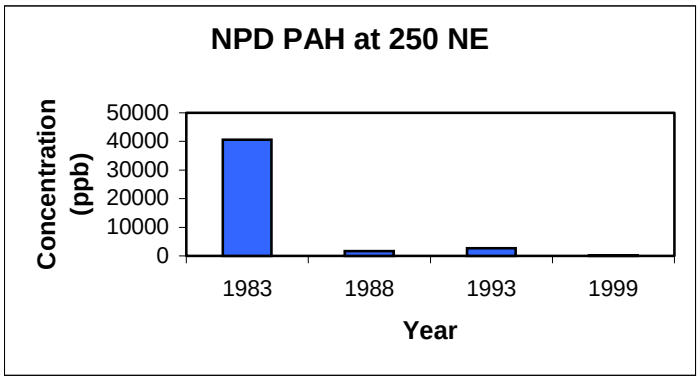


Figure 4-21 NPD PAH Concentrations at 1000 m NE

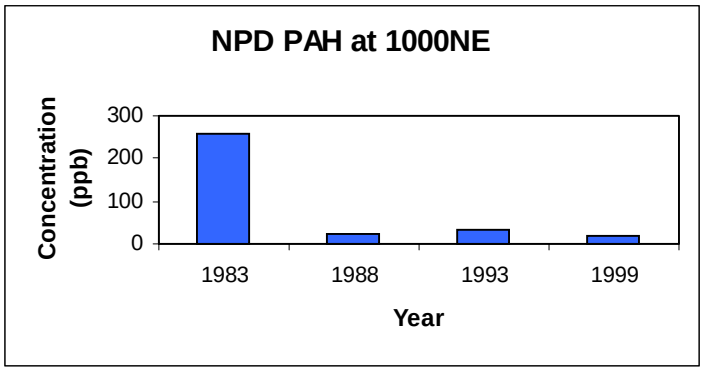
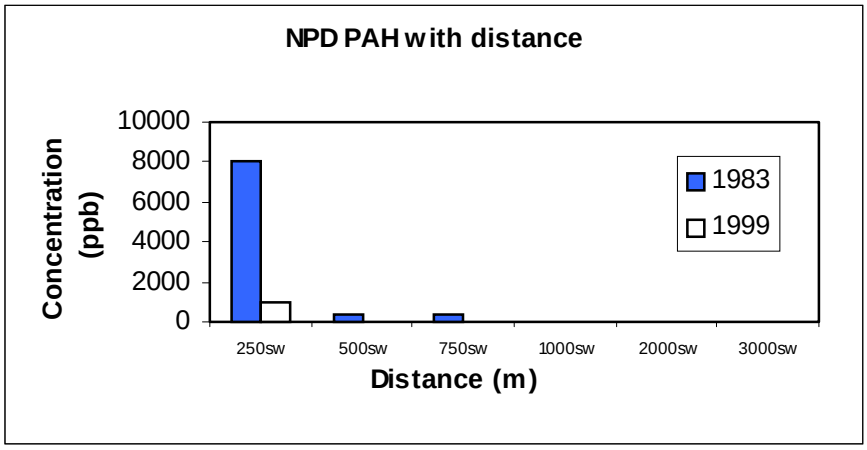


Figure 4-22 NPD PAH Concentrations with Distance



The maximum concentrations of total hydrocarbon fraction (THF) (2700 µg/g) in the 1999 survey was recorded at 200 m SE, which appears to be the direction of spread of the greatest THF levels. Again this is consistent with prevailing currents.

As expected, THF concentrations decreased rapidly as distance from the platform increased. Concentrations of THF appeared to be approaching background levels by 500 m from the platform in the South West - North East transect.

The 1999 sampling survey indicated several sites (1000 m, 2000 m) with a low level of petrogenic contamination (THF range 6.4 to 15 μg/g). At these sites the Gas Chromatography (GC) traces had a broad range, high boiling "hump", commonly known as the unresolved complex mixture (UCM), which often indicates biodegradation.

These distant sites probably represent North Sea background levels from long term low level input of general industrial and shipping activity (Cordah[11]). Total hydrocarbon background levels are 0.2 μg/g (NSTF[12]) Background. Total naphthalenes are 1-55 ng/g and total phenanthrenes are 1-50 ng/g. Background levels for the total NPD's are not as yet available.

Many sampling stations around Maureen had GC traces exhibiting UCM thought to be the biodegraded residue of diesel range oil based muds.

In addition, one sample in 1999 at the 500 m zone indicated the presence of a more volatile crude oil from a source other than Maureen. It is not known where this originated, however its presence is indicative of the difficulties encountered in determining the extent of impact a particular cuttings accumulation such as Maureen may have, considering it's limited size and the potential for other sources to exist.

Generally, in comparing concentrations of metals and hydrocarbon today with concentrations throughout the operational life of the platform, there is predominantly a decrease in concentration through time and with distance away from the platform. The decrease in concentrations appears to be a clear indication of the combined weathering/erosion effect, biodegradation of hydrocarbon, and overall recovery of the area.

TBT and PCB - 1999 Survey

Samples were analysed for Tributyl tin (TBT) and Polychlorinated biphenyls (PCB) to assist in evaluating quality of sediments in the area. These are the first sample results for these components and therefore comparisons to previous Maureen studies are not possible.

TBT- Tributyl Tin

TBT compounds have been used as ship hull anti-fouling compounds for many years, and while no longer used, this compound can still often be detected in sediments. Only low concentrations were recorded around Maureen, and only at the four 200 m sites. TBT derivatives were recorded at two of the Loading Column sites and none at the Moira sites. The source of these compounds is likely to have been the hulls of supply and standby vessels (Cordah[11]).

PCB- Polychlorinated Biphenyls

Overall, PCB concentrations around Maureen were low, mostly less than 100 ng/kg. The three highest total PCB concentrations were at 250 m NW, SE and NE (3562 ng/kg, 3304 ng/kg, and 1696 ng/kg respectively). Beyond these sites, concentrations significantly decreased as distance from the Platform (and likewise the Moira wellhead) increased. PCB concentrations around the Loading Column were uniform and less than 100 ng/kg.

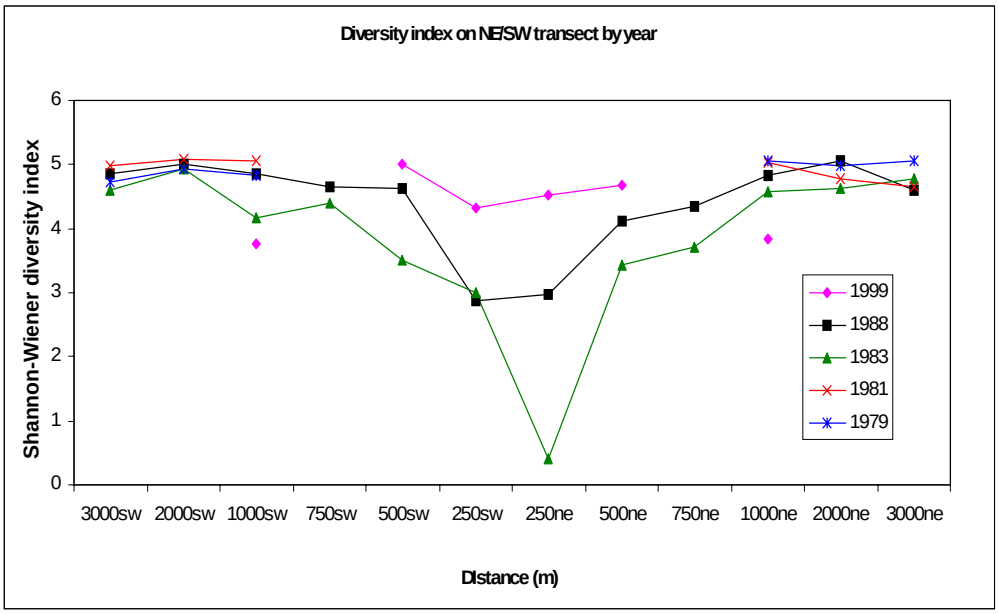
Macrobenthos

Analysis of the macrobenthic infaunal (living within the sediment) community structure provides detailed information on the long term ecological effects of the platform operations. The typical response of infaunal organisms at the community level is a reduction in species richness and diversity, sometimes with an increase in the densities of individuals of the low number of species recorded.

The study (Cordah[11]) showed clear evidence of a localised disturbed faunal community centred on the Maureen Platform. Background, or undisturbed, community structures were reached within the limits of the survey area.

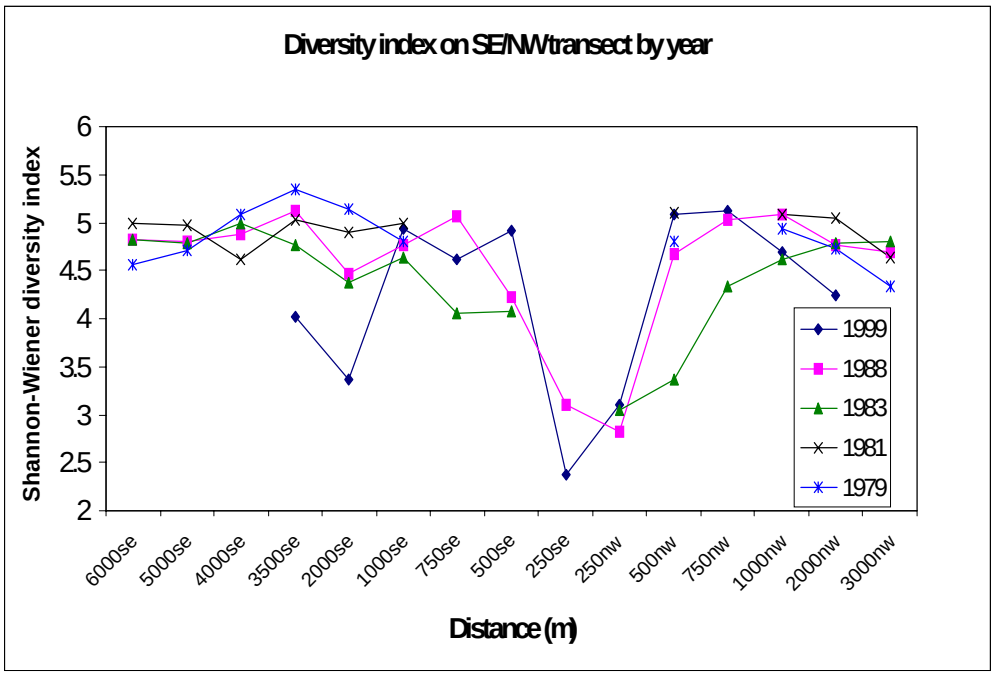
On the SW transect (NE/SW) there was clear evidence of disturbance (reduced diversity and high densities of low number of taxa) at the 250 and 500 m sites in 1983, and to a lesser degree in 1988. By 1999 however, these components had values representative of pre-development dates. This indicates a high degree of recovery (Cordah[11]) and is graphically depicted below in Figure 4-23. General scientific opinion considers that if the Shannon-Wiener Index is greater than 4 it is representative of undisturbed areas in the northern and central North Sea.

Figure 4-23 Diversity Index on NE/SW Transect



The SE/NW transect (see Figure 4-24) follows the direction of the seabed current, and consequently the areal extent of disturbance effects is generally expected to be greatest. At 250NW the community was clearly impacted between 1983 and 1999 with no evidence of recovery. However, at 500 NW, which was impacted in 1983, there has been a gradual recovery with the condition in 1999 being typical of the pre-development dates (Cordah[11]). At 1000 NW to 3000 NW, there has been no evidence of disturbance and no change in faunal community condition.

Figure 4-24 Diversity Index on SE/NW Transect



The two faunal diversity plots reflect the temporal changes (1979 to 1999) across the platform location. These axes, being perpendicular to each other, illustrate the relatively greater extent of disturbance on the SE/NW transect and probably reflect the main axis of seabed current.

Overall, the faunal disturbance picture is one of dynamic change centred on the Platform, with clear patterns of disturbance and then recovery (Cordah[11]).

Fish and Shellfish

In addition to the results described above, the DTI requested that as part of the 1999 survey, fish were to be caught and subjected to sensory assessment and quantification of hydrocarbon loading.

Lemon sole from 500 m from the installation were compared against others from 6 km distant. The conclusion was that there was no evidence of taint in the lemon sole (Cordah[11]).

There was evidence of low concentrations of petrogenic hydrocarbons in fish (in the form of UCM which, as earlier mentioned, was most likely a result of North Sea background levels from long term, low level input of general industrial and shipping activity (Cordah[11]). The concentrations were low when compared with other studies of fish from the North Sea. There was also evidence of the presence of low levels of the diesel range OBM in two whelk (*Buccinum*) samples.

There was no significant increase in PAH loading in 500m samples of Sole and *Nephrops* compared with those collected 6 km away.

4.3.3 Debris

Debris around the Maureen Platform is minimal with the items observed typically being scaffolding boards and poles or small sections of under deck walkway displaced during storms. However, standard operating procedures allowed these items to have routinely been recovered throughout field life during the underwater inspection and maintenance programmes.

Any such items remaining on the seabed following refloat will be cleared during the site clearance activities.

4.4 Decommissioning Studies

Studies to determine seabed quality in the area of Maureen have been undertaken by the Oil Pollution Research Unit [4,5,6], Aberdeen University Marine Studies Ltd[7], Gardline Surveys[8], Fugro Ltd[9] and Cordah[10,11,12].

4.5 Notes and References

The notes below provide additional reference information relevant to this section. A Glossary of terms and abbreviations is also included in Appendix A and a complete list of supporting study reports is contained within Section 17.

1 Maureen Annual Field Reports may be viewed at the offices of Phillips Petroleum Company United Kingdom Limited: Phillips Quadrant, 35 Guildford Road, Woking, Surrey, GU22 7QT.

2 Cessation of Production (COP) consent was granted by the DTI on 7th October 1999.

3 Decommissioning Philosophy Review. A report for Phillips Petroleum Company United Kingdom by Andrew Palmer and Associates 1999.

4 Biological Survey of the Maureen Oilfield - August 1979, Oil Pollution Research Unit. Orielton, Pembroke, Wales

5 Biological Survey of the Maureen Oilfield - August 1981, Oil Pollution Research Unit. Orielton, Pembroke, Wales

6 Biological Survey of the Maureen Oilfield - August 1983, FSC/ORPU/15/84, Oil Pollution Research Unit. Orielton, Pembroke, Wales

7 Environmental Survey of the Sediments around the Maureen Oilfield - October 1988, BE-88-58, Aberdeen University Marine Studies Limited

8 Environmental Survey of the Sediments around the Maureen Oilfield - August 1993, 3988, Gardline Surveys, Great Yarmouth

9 Maureen Refloating Study, February 1999, Report 73573-1, Fugro Limited

10 Assessment of the Sediment Contamination Beneath the Phillips Maureen Platform: The Implications for Decommissioning, 0572-33-493, Feb 2000, Cordah Environmental Management Consultants, Aberdeen

11 Assessment of the Environmental Impacts of the Operations to Refloat the Maureen A Platform, 0572-33-492, October 1998, Cordah Environmental Management Consultants, Aberdeen

12 Pre-Decommissioning Baseline Seabed Survey of the Maureen Alpha Platform and Associated Infrastructure, Cordah Report 0572-33-506 (Draft) March 2000, Cordah Environmental Management Consultants, Aberdeen

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