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Borders & Southern Petroleum Plc.

ENVIRONMENTAL IMPACT STATEMENT

OFFSHORE FALKLAND ISLANDS EXPLORATION DRILLING

(Licence PL018)

Date: *February 2010*

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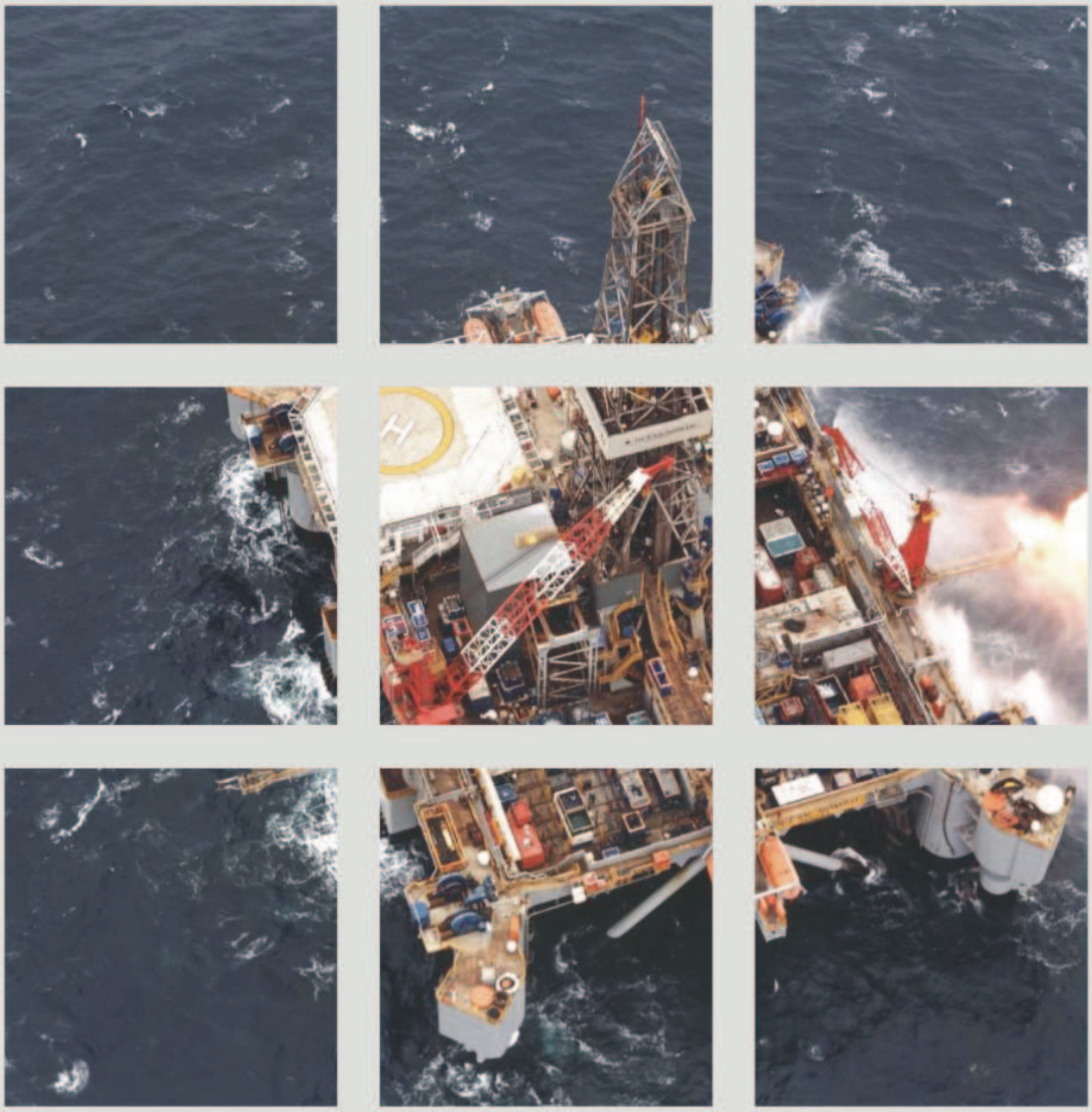

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(Licence PL018)

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February 2010

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Abbreviations

%	Percent
%Sat	Percentage Saturation
”	Inches
°	Degrees
°C	Degrees Celsius
µg.g-1	Micrograms per gram
3D	Three Dimensional
ACAP	Agreement on the Conservation of Albatross and Petrels
ADCP	Acoustic Doppler Current Profiler
ALARP	As Low As Reasonably Practicable
API	American Petroleum Industry
boe	Barrels of oil equivalent
BOP	Blow out Preventor
CBD	Convention on Biological Diversity
CCA	Clean Caribbean Coop
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CEFAS	Centre for Environment Fisheries and Aquaculture Science
CHARM	Chemical Hazard Assessment and Risk Management
CITES	Convention on the International Trade of Endangered Species
cm/s	Centimetres per second
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CO_2	Carbon Dioxide
CPI	Carbon Preference Index
DO	Dissolved Oxygen
DP	Dynamically Positioned
E	East
ED	Endocrine Disrupter
E&P	Exploration and Production
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMP’s	Emergency Management Plan
ERP	Emergency Response Plan
FC	Falklands Conservation
FCO	Foreign and Commonwealth Office
FICZ	Falklands Interim Conservation and Management Zone
FIDA	Falklands Island Designated Area
FIFD	Falkland Islands Fisheries Department
FIC	Falkland Islands Company Ltd

FIG	Falkland Islands Government
FIPASS	Falklands Interim Port and Storage System
FOC	Fractional Organic Compound
FOCZ	Falklands Outer Conservation and Management Zone
FOGL	Falklands Oil and Gas Limited
HSE MS	Health, Safety and Environmental Management Systems
HF	Hydrofluoric Acid
HMCS	Harmonised Mandatory Control Scheme
HOCNF	Harmonised Offshore Chemical Notification Format
HQ	Hazard Quotients
HSE	Health, Safety and Environment
IPIECA	International Petroleum Industry Environmental Conservation Association
IADC	International Association of Drilling Contractors
IBA	Important Bird Areas
ITOPF	The International Tanker Owners Pollution Federation
IUCN	International Union for the Conservation of Nature
JNCC	Joint Nature Conservation Committee
Kg	Kilogram
LAT	Lowest Astronomical Tide
LOI	Loss on Ignition
LTOBM	Low Toxicity Oil Based Mud
m	Metres
m2	Metres square
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973,
MIME	Managing Impacts on the Marine Environment
mm	Millimetres
MMO	Marine Mammal Observer
MoD	Ministry of Defence
MPC	Mount Pleasant Complex
ms-1	Metres per second
N	North
NASA	National Aeronautics and Space Administration
ng.g-1	Nanograms per gram
NNR	National Nature Reserves
NO_2	Nitrous Oxides
NO_X	Nitrogen Oxides
OCNS	Offshore Chemical Notification Scheme
OGP	Oil and Gas Producers
OSCP	Oil Pollution Emergency Plan
OSIS	Oil Spill Information System

OSPAR	Oslo / Paris Convention
OSR	Oil Spill Response
OSRL	Oil Spill Response Limited
OWA	Oil Water Separator
PAH	Polycyclic Aromatic Hydrocarbons
PEC	Predicted Environmental Concentration
PLONOR	Pose Little or No Risk to the environment
PNEC	Predicted No Effect Concentration
PON	Petroleum Operations Notices
ppg	Parts Per Gram
ppt	Parts Per Ton
PROTEUS	Pollution Risk Offshore Technical Evaluation System
PSA	Particle Size Analysis
PSD	Particle Size Distributions
Q1-4	Quarter 1-4
ROV	Remotely Operated Vehicle
RQ's	Risk Assessments
S	South
SBM	Synthetic Based Mud
SMRU	Sea Mammals Research Unit
SO_X	Sulphur Oxides
TD	Target Depth
THC	Total hydrocarbon concentrations
TOM	Total Organic Matter
TVD	Total Vertical Depth
UKOOA	United Kingdom Offshore Operators Association
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
W	West
WBM	Water Based Mud
WOAD	World Offshore Accident Databank

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Non Technical Summary

Borders and Southern Petroleum plc (Borders & Southern) is a UK based company engaged in the exploration for hydrocarbons with acreage in The Falkland Islands, a UK Overseas Territory located on the edge of the Patagonian Shelf in the South Atlantic Ocean.

Borders & Southern has been awarded Production Licences by the Falkland Islands Government for the exploration and production of oil and gas in Licences PL018, PL019, PL020, PL021 and PL022. The company holds 100% interest for five licences as a sole operator. The licence area lies approximately 150 kilometres south-east of the main Islands covering 19,598 sq km.

In 2010-2011 Borders & Southern is planning to undertake offshore drilling of two exploration wells (Stebbing and Darwin East) within the PL018 licence. The proposed wells lie to the south of the Falkland Islands at a distance of approximately 150 kilometres from the nearest landfall, in water depths ranging from 1,400 to 2,100 metres (Figure 1).

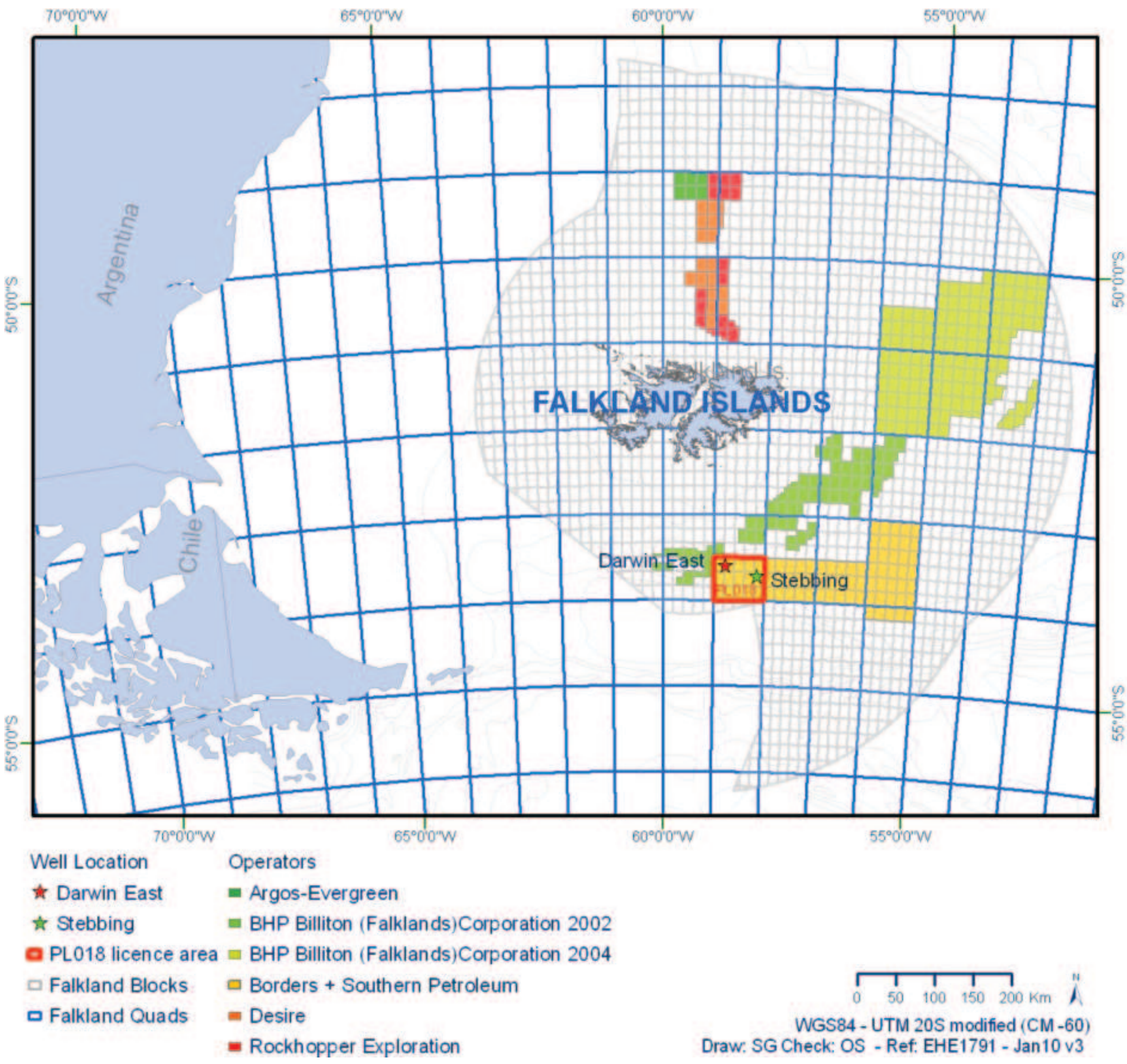

Figure 1 ***Borders & Sothern Licence Area and Proposed Well Locations.***

It is likely that the proposed exploration wells will be drilled using a drill ship or 5-6th generation DP semi-submersible rig. It is proposed that drilling will take place between Q4 2010 and Q2 2011, the programme will be finalised when a suitable rig has been secured.

Operations at the well sites are expected to last up to 75 days and water-based muds will be used to drill the wells. No well testing that involves flowing well fluids to the surface is planned. Following drilling and evaluation, the wells will be plugged and abandoned.

All chemicals to be used during the drilling have been selected to minimise the potential environmental impacts as much as possible. The vast majority (by volume) of planned chemicals have a Harmonised Offshore Chemical Notification Scheme category of 'E' (which are of low aquatic toxicity, readily biodegradable and non-bioaccumulative) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable.

This EIS provides an assessment of the potential environmental impacts associated with the proposed drilling, together with mitigation and management measures and a description of any residual impacts to the environment. The assessment utilises a study of the baseline environment, together with description of the proposed operations, in order to assess the risk of impacts occurring.

Existing Environment

The Patagonian Shelf, on which the Falkland Islands positioned, is of regional and global significance for marine resources. It comprises rich assemblages of seabirds, marine mammals, fish, squid and plankton populations.

A consortium of oil companies drilled six wells in the North Falkland Basin during 1998. As a result of this drilling programme a number of environmental studies were commissioned, focussing primarily on the North Falkland Basin. In comparison, the environment of the South Falkland Basin remains understudied. The proposed drilling campaigns by BHP Billiton and Borders & Southern have recently expanded the level of environmental knowledge within their respective Licence areas.

In order to obtain more detailed baseline information, Borders & Southern conducted environmental site surveys in 2008 / 2009 to aquire current data, water column profiles, sediment analysis, and to identify benthic habitats and geo hazards.

Water quality profiles revealed a consistent water mass throughout the region with a density related upper layer, caused by solar heating, in the surface 100m. Seabed salinity and temperatures were consistent at 34.7 practical salinity units and 2.3°C. The maximum and average current speeds observed near the sea surface were 1 knot and 0.34 knots, respectively, and predominant direction of the currents was north-easterly.

The results of benthic survey indicated that seabed within the regional survey area showed considerable variability in sediment distributions relative to location on the Burdwood Bank or within the South Falkland Basin. The sediments ranged from sandy silts in the northwest to silty gravely sands and occasional bedrock exposure.

The macrofaunal analysis revealed a community expected for the Magellan faunal area. Whilst similar to that of the Northern Boreal Region, the fauna is characterised by a low diversity in the echinoderms and a very high crustacean diversity. The overall faunal abundance and richness remained quite high and consistent throughout. A significant presence of epifaunal species was also recorded, and dominated by three major groups of cnidera, porifera, and bryozoa. No environmentally sensitive species or other habitats of conservational value were recorded during this regional survey.

The main fisheries resources are the squid species, *Illex argentinus* and *Loligo gahi*. The existing finfish fishery targets predominantly hake, hoki, red cod and blue whiting. The Falkland Islands' Government annual Fisheries Statistics volume 11 (1997–2006) show that the area in the vicinity of the proposed exploration wells has no fishing interests for the key commercial target species. There are some significant fisheries interests northward of the Licence area PL018, which may be impacted by vessel movements to and from the proposed drilling operations. It should be noted, that *Loligo gahi* and blue whiting fishing is most intense in the second half of the year between July and December.

Between February 1998 and January 2001 the Joint Nature Conservation Committee (JNCC) and Falklands Conservation (FC) conducted a 'Seabirds at Sea Survey' in the waters surrounding the Falkland Islands. Based on the results from this survey work (White et al., 2002), the following species of cetacean were recorded within the vicinity of the proposed drilling location: long-finned pilot whale, hourglass dolphin and Peale's dolphin. Additional marine mammal data has also been compiled based on the reports provided by Marine Mammal Observers (MMOs) during seismic acquisition (November 2007-February 2008) within the Borders & Southern Licence area. This data indicates the presence of a number of cetaceans, including long-finned pilot whale, hourglass dolphin, fin whale, sei whale, killer whale, peale's dolphin, sperm whale, and a few species of blue whale, minke whale and baleen whale. Given the migratory nature of cetaceans and the fact that effort during the JNCC/FC 'Seabirds at Sea Survey' was lower to the south and east of the Falkland Islands, the possibility that other species are present in the exploration area cannot be discounted.

Little is known of the at-sea distribution of Falkland Islands pinnipeds, and it is possible that South American sea lions, south American fur seals and southern elephant seals may be present within the vicinity of the proposed well locations during the drilling period in low numbers. It should be noted, however, that both proposed wells are located some distance from the know seal haul-out sites.

The Falkland Islands are an area of global importance for birdlife, particularly seabird species. The avifauna of the region is well studied and documented, and seabird distribution, breeding and foraging patterns have been studied extensively. Of the penguin species recorded in the Falkland Islands, only rockhopper penguins and magellanic penguins have been observed at significant distance from the Falkland Islands and may therefore be present during the proposed drilling period in the vicinity of the exploration wells. It is possible that a number of albatross species will be present in the vicinity of the proposed wells. Petrels and shearwaters known to be present in the Licence area include blue petrel, kerguelen petrel, atlantic petrel, prion species, sooty shearwater and diving petrel; although none of these species are considered to be present in significant numbers.

The proposed exploration wells are located away from the identified areas of highest seabird vulnerability. Highest vulnerability tends to be associated with the inshore waters around the Falklands Islands, largely due to the presence of resident species with a predominantly coastal distribution such as the endemic Falklands Steamer duck, imperial shag and gentoo penguin. The Patagonian Shelf waters to the north and west of the Falklands, which support high densities of black-browed albatrosses and royal albatrosses year-round are also associated with high vulnerability areas, but again these are remote from the proposed drilling locations. Seabird vulnerability in the vicinity of the proposed exploration wells is medium over October, November and January, with bird coverage decreasing between June to September (low vulnerability).

There are a number of protected National Nature Reserves (NNR) and internationally Important Bird Areas (IBAs) on the southern coast of Falkland Islands. The closest of these to the proposed exploration wells are Beauchêne Island, located approximately 80 kilometres to the east-north-east and Sea Lion Islands, located approximately 130 kilometres to the north-east from the Darwin East well. Both of the islands are designated NNRs and IBAs.

Impacts and Management Measures

The results of the impact assessment indicate that the majority of impacts from the proposed drilling operations will be negligible to moderate and mostly undetectable shortly after drilling is completed (Table 1).

The key environmental risks associated with the proposed drilling programme include drill cuttings disposal, waste disposal and use of resources (i.e. fuel and potable water). Oil spill modelling indicated that no oil beaching would occur in the unlikely even of a well blowout under typical weather conditions. However, crude oil released during blowout may have a major impact on the offshore seabirds (Table 1). Diesel spills will not impact the coastline and offshore wildlife is likely to be affected only in a close proximity to the spill. It can be concluded that the highest risk of pollution during the drilling programme is from large oil spills. These are highly unlikely events however, and can be effectively controlled through prevention, preparedness and response.

Table 1. Potential Hazards and Associated Impacts from the Proposed Drilling Operations

Hazard	Water & Air		Flora & Fauna							Socio-economic								Other		
	Water Quality	Air Quality	Plankton	Seabed Fauna	Fish Spawning	Offshore Sea Birds	Coastal Birds	Marine Mammals	Sensitive Coastal Sites	Fishing	Shipping	Military Activity	Pipelines, Wells & Cables	Drilling & Support Crews	Dredging	Archaeology	Tourism / Leisure	Land Use	Sediments	Resource Use
Physical Presence										5	5						5			4
Seabed Disturbance				4												5			4	
Noise & Vibration					4	4	5	4												
Atmospheric Emissions		4																		
Marine Discharges	5		5	4	5															
Solid Waste																		3		
Minor Loss of Containment	4		4		5	4		5		4	5						5			
Major Loss of Containment	3		3		3	2	3	4	3	3	3						3			

Key to Significance of Effect (see Table 4.1 for definitions)

1 Severe	2 Major	3 Moderate	4 Minor	5 Negligible	None

All operational risks will be controlled using safe drilling practices and effective planning. The potential impacts of the proposed drilling activity will be mitigated in a number of ways, including:

Maintaining a spirit of openness and ongoing consultation with the Falkland Islands Government (FIG), the public and key stakeholders;

Applying established UK standards to operations, particularly in offshore chemical use and emissions reporting;

Using water based drilling muds and low toxicity chemicals approved under the UK Offshore Chemical Notification Scheme.

Implementing a high level of environmental management offshore and applying environmental procedures for potentially impacting operations (chemical storage, bunkering, waste handling, maintenance programmes, seafloor surveys etc);

Establishing and implementing a project specific Oil Spill Contingency Plan and carrying out training of key personnel in spill response. Borders & Southern are members of Oil Spill Response which provide outside assistance in the case of a major spill. The Oil Spill Contingency Plan will be submitted to FIG for approval prior to commencement of the drilling operations.

Implementing a Waste Management Plan to minimise the quantity of waste going to landfill, prevent unsuitable disposal of waste, maximise the re-use of materials and establish procedures for the storage, treatment, transfer and disposal of waste materials. It is envisaged that normal waste will be disposed of on the Falkland Islands with hazardous waste likely to be exported to the UK, Chile or Uruguay. Specific waste handling/disposal routes and procedures will be detailed in the Waste Management Plan, to be submitted to FIG for approval prior to commencement of the proposed drilling operations.

Collecting and sharing environmental data wherever possible, for example in offshore sightings, seabed surveys and meteorological and oceanographic conditions.

Conclusions

In conclusion, despite the high sensitivity and international importance of the Falkland Islands' waters, there is clear dedication to carrying out these operations to a high environmental standard. Given the current operational commitments and proposed mitigation measures, it is considered that the proposed operations can be undertaken without significant impacts to the Falkland Islands' environment.

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1 Introduction

1.1 The Project

Borders and Southern Petroleum plc (Borders & Southern) holds a 100% equity interest and operatorship in five Exploration and Production Licences PL018, PL019, PL020, PL021 and PL022, which cover an area of 19,598 square kilometres (km^2) in the South Falklands Basin (Figure 1.1). The acreage is located approximately 150 km south-east of the Islands in water depths ranging from 200 to 3000 metres (m). The Production Licences, with an effective date of 1st November 2004, provide exclusive rights for surveying, drilling and production within the specified area.

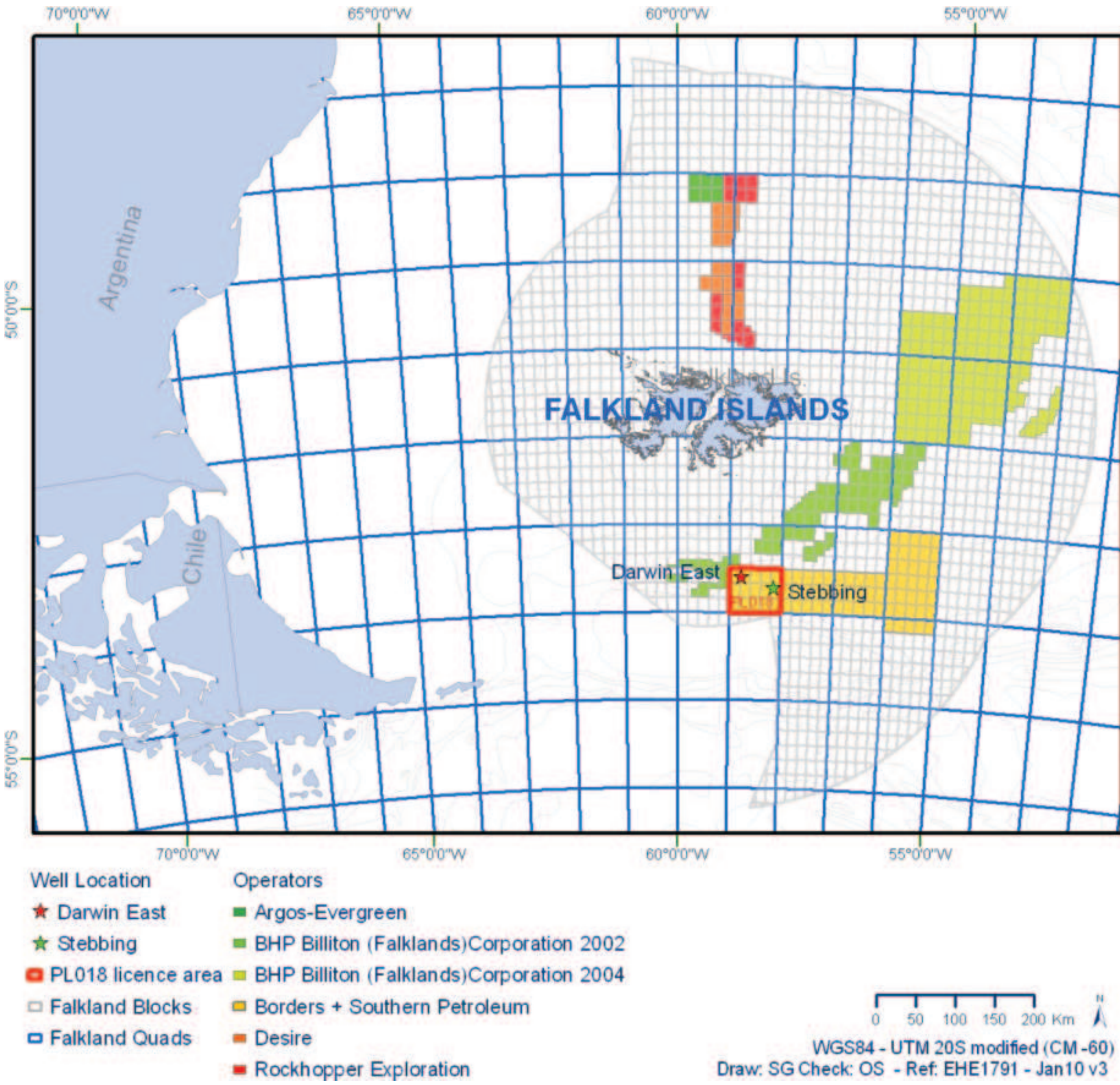

Figure 1.1 Borders &Sothern Licences and Proposed Well location

Six exploration wells were drilled within the North Falklands Basin during the 1998 drilling campaign together with a number of baseline studies and environmental surveys prior to and during the campaign. No wells have so far been drilled within the East or South Falkland Basin.

Borders & Sothern's objective is to explore the hydrocarbon potential of the South Falkland Basin, which contains numerous large simple structures (up to 150 sq km in area), including thrust cored anticlines and tilted fault blocks. The clear definition of these structures was achieved through the acquisition of 2,862 km of 2D seismic in 2005 and 1,492 sq km of 3D seismic data in 2008/2009.

The interpretation of the 3D seismic data significantly increased the understanding of the geology and prospectively of the area and provided confidence on the presence of reservoirs in the Tertiary, Upper Cretaceous and Lower Cretaceous, along with the presence of a working hydrocarbon system.

In 2010-2011 Borders & Southern plans to drill two exploration wells (Stebbing and Darwin East) within the PL018 license area. The proposed wells lie to the south of the Islands at the distance of 170 km (Stebbing) and 150 km (Darwin East) from the nearest landfall (Figure 1.1). The water depth at Stebbing well is 1479m and Darwin East well 2,010m.

The Darwin Prospect represents a large tilted fault block play of Lower Cretaceous age with a shallow marine sandstone target. The target interval is age equivalent to the successful Springhill units. In contrast the Stebbing well targets Tertiary and Upper Cretaceous deep water sandstone units that are structured within a large thrust cored anticline created when the foreland basin sediments were inverted during south to north compression.

The geology and stratigraphy in Borders & Southern's acreage is expected to be similar to the adjacent Magallanes and Malvinas sub-basins located to the west of the Falkland Islands, where working petroleum systems are proven. Exxon, YPF and Oxy drilled 17 wells in Argentine waters of the Malvinas Basin, of which five wells had encouraging shows of oil and gas in an under-charged Lower Cretaceous reservoir, and the Calamar x-1 well flowed about 3,200 barrels of 37° API oil per day from the Springhill sandstone.

It is likely that the proposed exploration wells will be drilled using a drill ship or $5^{th}/6^{th}$ generation DP semi-submersible rig. Start dates for the drilling of the wells will be determined when a suitable rig has been secured.

Operations at the well sites are expected to last up to 75 days (40 days for Darwin East and 35 days for Stebbing) and water-based muds (WBM) will be used to drill the wells.

Following drilling, the wells will be logged and evaluated. Following evaluation, the wells will be plugged and abandoned regardless of the results of the evaluation.

1.2 Scope

This document constitutes an Environmental Impact Statement (EIS) as specified under the Offshore Minerals Ordinance 1994 Part VI. It has been compiled by RPS Energy at the request of Borders & Southern. This EIS provides an assessment of the potential impacts from proposed exploratory drilling within the PL018 licence areas of the South Falklands Basin.

Undertaking an EIS ensures that potential environmental impacts associated with the proposed project, for both routine and non-routine operations, are correctly identified and assessed. In doing so, relevant preventative and management measures can be developed and implemented to mitigate adverse environmental impacts appropriately.

This document meets the requirements outlined in the Falkland Islands' legislation pertaining to offshore exploration and production activities – The Offshore Minerals Ordinance 1994; Amended 1997.

When a drill rig has been contracted and dates confirmed, an addendum to this EIS will be produced and submitted to the Falkland Islands' Government (FIG) for comment and approval, as per Borders & Southern's agreement with FIG. Impacts associated with the timing of the drilling will be included in this addendum along with proposed mitigation measures for seasonal impacts.

1.3 The Applicant

Borders & Southern Petroleum plc is a UK based company engaged in the exploration of hydrocarbons. Its current area of activity is in the Falkland Islands, located in the South Atlantic.

In May 2005 the Company was listed on the Alternative Investment Market (AIM) of the London Stock Exchange.

Borders & Southern currently hold five licences in the South Falklands Basin (Figure 1.1). Borders & Southern is the designated operator for the proposed drilling campaign and is therefore ultimately responsible for all operations. All operations will be undertaken by contractors under Border and Southern's management and oversight.

1.4 Consultations

Prior to submission of this EIS to the Falkland Islands' Government (FIG), Borders & Southern representatives met with a number of Falkland Islands' entities in 2007/2008. The key issues raised during this preliminary consultation process have been considered by Borders & Southern and addressed, where appropriate, in the EIS (refer to Table 1.1).

Public consultation will also be undertaken, as per legislative requirements, for 42 days after the submission of this EIS to FIG.

Stakeholders have been, and continue to be, consulted regularly throughout the proposed drilling programme.

Table 1.1. Summary of Borders & Southern Informal Consultation Responses

Organisation	Issues Raised	Comments to Issues Raised	ES Section Reference
Department of Mineral Resources	Borders & Southern to provide technical updates.	Technical details have been provided in this EIS, with further details to be presented in the Addendum and Basis of Design report.	Section 4
Civil Aviation and Stanley Airport	MoD is integral to all aviation issues. Charter flights to the Islands can be organised,	Details of crew transport to the Islands will be detailed in the Addendum and the MoD will be appraised of any aviation plans.	N/A
Environmental Planning Officer and Falklands Conservation	Seabirds are the main vulnerability due to the risk of spills.	This EIS has identified which seabirds are likely to be present in the region and within the licence blocks. Impacts to particular species will be included in the Addendum when the drilling schedule has been finalised.	Sections 5 and 6
Fisheries and Marine Resources	Notice to Mariners via Fisheries and Marine Resources, and minimal response capability for oil spills.	Notice to Mariners will be issued via the Fisheries and Marine Resources prior to commencing operations and an Oil Spill Contingency Plan (OSCP) will be prepared. The OSCP will be submitted with the Addendum for review and approval by FIG authorities.	Sections 6 and 7
Public Works	Waste – very limited capacity for storage, management and/or onshore processing. Some recycling available.	Borders & Southern notes the limited waste handling capacity on the Islands and will explore waste management options with a licensed waste contractor including shipping it to another destination. Waste management Plan will be submitted with the Addendum.	Sections 5 and 6
Emergency Response – FI Defence Force, Fire/Rescue Service, KEMH, Police Chief	National Emergency Response Plan	Borders & Southern's emergency response plan (ERP) and OSCP will compliment the Falkland Islands' National ER Plan. The ERP and OSCP will be submitted with the Addendum for the review and approval by FIG authorities.	Sections 6 and 7
British Military Base at Mount Pleasant	Understanding military operations and resources, and communicating with the military on proposed activities.	Borders & Southern will keep the military updated on its proposed activities.	Sections 5 and 6
Various service providers	Understanding service capabilities and logistics.	Borders & Southern has gained an early understanding of service capabilities on the Islands and will work with the drill rig provider and drilling contractor to ensure that comprehensive planning is undertaken so that no strains are placed on current capacities.	Sections 6 and 7

1.5 Structure of the Report

The report is presented in six main sections.

Section 1	Introduction - provides a background to the project.
Section 2	Legislative Framework – provides an overview of the Falklands' legislation relevant to this exploration drilling EIS.
Section 3	Alternatives to the Proposed Drilling Programme – provides justification of the planned drilling programme and why alternate methods were discarded.
Section 4	The Proposed Project – provides details of the proposed exploration wells including project overview and drilling operations.
Section 5	Description of the Environment – describes the background physical environmental characteristics, identifies the flora and fauna likely to be present within the area that can be potentially affected by drilling operations. Relevant sea users are also discussed.
Section 6	Environmental Hazards, Effects and Mitigation Measures – identifies the potential interactions of the proposed wells with the environment and details the control and mitigation measures to be implemented, to limit the impacts.
Section 7	Management Framework – provides an outline of Border and Southern's Health, Safety and Environment Management System.
Section 8	Conclusions.

In addition, the report includes a non-technical summary of the environmental assessment, which highlights its main conclusions, and provides a list of references used to obtain data and information to support the assessment. Further information is also included in the appendices.

1.6 Contact Address

Any questions, comments or requests for additional information regarding this EIS should be addressed to:

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2 Legislative Framework

This section summarises the international and national legal context for the proposed drilling activities. It is not intended to provide a complete analysis of the wider legal framework within the Falkland Islands, but only legislation relevant to the natural environment and local stakeholders. Legislation specific to health and safety, tax and finance are outside of the scope of this study.

The Falkland Islands are a United Kingdom Overseas Territory, where supreme authority is vested in HM The Queen and exercised by a Governor on her behalf, with the advice and assistance of the Executive and Legislative Councils, and in accordance with the Falkland Islands Constitution (*FCO, 2005*).

Falkland Islands' laws govern petroleum exploration and exploitation on the Falkland Islands Continental Shelf. The licensing system for offshore exploration and production activities is applicable to the Falkland Islands areas dedicated for offshore petroleum activities.

The Falkland Islands do not have any documents similar to the UK's white paper on 'Meeting the Energy Challenge', however, in the Government's Business Plan (The Islands Plan) a commitment has been made to produce a National Energy Strategy by 2011, which will place all on-going petroleum exploration in the Falklands' waters into context.

2.1 International Conventions and Agreements[1]

International conventions and agreements applicable to offshore petroleum activities in the Falkland Islands are summarised in Table 2.1.

Table 2.1. International Agreements of the Falkland Islands Applicable to this Proposed Drilling Programme

Known As	Full Title	Status	Summary
Aarhus Convention	1998 Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters	In 2004, the Executive Council decided to join this at a later date	Grants the public rights and imposes on Parties and public authorities obligations regarding access to information and public participation and access to justice.
ACAP	Agreement on the Conservation of Albatross and Petrels	Ratified* April 2004	Seeks to conserve albatrosses and petrels by co-ordination of international activity to mitigate known threats. ACAP has been developed under the umbrella of the CMS (see below).
Basel Convention	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal 1992	Under consideration	To reduce the trans-boundary movements and amounts of hazardous wastes and non-hazardous wastes to a minimum, and to manage and dispose of these wastes in an environmentally sound manner.
CBD	Convention on Biological Diversity 1992	Not yet ratified, applies through UK extension of overseas territories	Commitment to conserve biological diversity, to use biological resources sustainably and to share equitably the benefits arising from the use of genetic resources.
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources 1982	Ratified	Aims to protect the marine ecosystem south of 60°.
CITES or The Washington convention	Convention on International Trade in Endangered Species	Ratified* October 1976	Ensures that international trade in specimens of wild animals and plants does not threaten their survival.

[1] Adapted from the FIG 'The Principal Environmental Conventions and Agreements Relevant to the Falkland Islands and Foreign and Commonwealth Office (FCO)' online database.

Known As	Full Title	Status	Summary
CMS or The Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals	Ratified* 1985	Seeks to conserve terrestrial, marine and avian migratory species (those that regularly cross international boundaries, including international waters). Concluded under the aegis of the United Nations Environment Programme. All cetacean and Southern Hemisphere albatross species are listed in the CMS.
Environment Charter	Environment Charter	Signed 2001	Charter to protect the Falkland Islands' natural environment, with additional support from the British government through funding and expert advice.
Fisheries Agreement	Fisheries Agreement	1990, issued a joint statement	A joint statement between the British and Argentine governments to create the Falklands Outer Conservation Zone and the South Atlantic Fisheries Commission for the protection of fish stocks.
Hydrocarbons Agreement	UK/Argentine Joint Declaration on Hydrocarbons	1995, issued a joint statement	A joint statement between the British and Argentine governments for the cooperation of offshore activities in the south west Atlantic.
IUCN	International Union for the Conservation of Nature	*Not a legal agreement*	The IUCN assess the conservation status of animal and plant species and assign a threat level. Lists of threatened species status (IUCN red lists) are published for different countries. The list of species identified as under threat by IUCN is given in Appendices D and F.
Kyoto Protocol	Kyoto Protocol to the UN Framework Convention on Climate Change	By Extension March 2007	An amendment to the international treaty on climate change, assigning mandatory emission limitations for the reduction of greenhouse gas emissions to the signatory nations.
London Convention	1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.	Ratified* 1980. The 1996 Protocol does not yet extend to the Falkland Islands.	Aims to prevent pollution of the sea from dumping of waste and other matters liable to create hazards, harm living resources and marine life, damage amenities, or to interfere with other legitimate uses of the sea. The dumping of Annex I materials is prohibited, Annex II materials require a prior special permit and all other wastes require a prior general permit.
MARPOL 73/78	1973 Convention for the Prevention of Pollution from Ships, as modified by the Protocol of 1978	Most of the subsidiary agreements ratified.	Seeks to prevent pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage from ships.
Montreal Protocol	Montreal Protocol on Substances that Deplete the Ozone layer	Ratified* December 1988	Aims to protect the ozone layer by phasing out ozone depleting substances.
Ramsar Convention	1971 Convention on Wetlands of International Importance especially as Waterfowl Habitat	Ratified* in 1976	Aims to halt the world-wide loss of wetlands and promote the conservation of wetlands through wise use and management. Both Bertha's Beach and Sea Lion Island have been accepted by the Convention of Parties and listed as having Ramsar status (Section 5.3.12). Wetlands can include marine waters up to a depth of 6 m at low tide.
UNCLOS (or Law of the Sea)	The United Nations Convention on the Law of the Sea (1982)	Ratified* July 1997	Legislation of the world's oceans and seas governing all uses of the oceans and their resources.
UNFCCC	United Nations Framework Convention on Climate Change	By Extension March 2007	Aims to reduce greenhouse gas emissions to combat global warming.
World Heritage Convention	1972 Convention for the Protection of the World Cultural and National Heritage	Ratified* May 1984	Aims to identify, protect and preserve cultural and natural heritage worldwide. No natural and cultural sites of outstanding global value have been designated with the Falkland Islands.

* - Ratified by the UK and ratification extended to the Falkland Islands

As joint-signatories of Kyoto, the Falkland Islands are expected to reduce emissions in line with UK targets, but currently do not have any formal expectations or set targets to work towards. However, the Islands are reducing emissions and reliance on fossil fuels with the recent development of a wind farm, a heat recovery system linked into the diesel power station and through the provision of subsidies towards the cost of domestic wind turbines for the farming community.

The 1992 Convention on Biological Diversity (*UNCED, 1992*), ratified by the UK but not by the Falkland Islands, includes UK dependencies within the 'UK: Biodiversity Action Plan' (*HMSO, 1994*). In connection with the UK's goals to encourage implementation of the Convention, partnerships are formalised in Environmental Charters between the UK and various Overseas Territories.

The first Environmental Charter, stating mutual responsibilities of the UK and its Overseas Territories, was signed on 26 September 2001 by Councillor Mike Summers, representing Falkland Islands Government, and Baroness Valerie Amos, Minister of UK Overseas Territories.

2.2 National Legislation

This section details the regulatory framework applicable to this drilling project and the protection of the offshore environment around the Falkland Islands (Table 2.2).

The system of Petroleum Operations Notices (PON) are not legally binding but have been approved by the Mineral Resources Committee as best practice.

Table 2.2. Falkland Islands' Legislation relevant to Offshore Drilling and the Environment

Legislation	Key Requirements / Relevance to Proposed Operations
1) Relevance to Offshore Operations	
Environment Protection (Overseas Territories) (Amendment) Order 1997	Enables the provision of the London Dumping Convention to be implemented in the Falkland Islands' waters.
Merchant Shipping (Oil Pollution) Act 1971	Applied to the Falkland Islands by 1975 Order in Council (SI 1975/2167 as amended by SI 1976/2143 and SI 1981/218). This Act regulates responsibility for oil pollution from ships.
Offshore Minerals (Amendment) Ordinance 1997	Amends the Offshore Minerals Ordinance 1994 to make further provision in relation to the application of the Health and Safety at Work etc. Act 1974.
Offshore Minerals Ordinance 1994	The licensing framework for offshore exploration and production. Regulates offshore installations and pipelines, offshore health and safety, oil pollution, liability for environmental damage, and abandonment. Sets out the requirement for Environmental Impact Assessment and preparation of Environmental Impact statements. Production Licences (PL028 and PL015) are issued under this Ordinance.
Offshore Petroleum (Licensing) Regulations 1995	Provides the schedule, model clauses and format for application of exploration or production licences in Falkland Islands' waters, as well as conditions for record keeping, sampling and drilling.
Offshore Petroleum (Licensing) Regulations 2000	Updates the schedule, model clauses and format for application of exploration or production licences in Falkland Islands' waters, as well as conditions for record keeping, sampling and drilling.
Offshore Petroleum (licensing) Regulations 2000 – Invitation to apply for open door licences	Invites applications for production licences in respect of blocks specified within Schedules 1 and 2. Specifies exploration terms, conditions, financial terms and application criteria.
Offshore Petroleum (Licensing) (Amendments) Regulations 2004	Enables applications to be made under the Offshore Petroleum (Licensing) Regulations 2000 in respect of areas formerly licensed under the Offshore Petroleum (Licensing) Regulations 1995, but to prevent applications which were formerly licensed and being considered within two years of the expiration or sooner determination of that licence.
Petroleum Operations Notice No.1	Specifies the record and sample requirements for surveys and wells, including reporting requirements and sampling details.
Petroleum Operations Notice No.2	Specifies reporting procedures including monthly and daily reports, drilling reports and changes to the work programme.
Petroleum Operations Notice No.3	Provides guidance on the procedure to follow for notification prior

Legislation	Key Requirements / Relevance to Proposed Operations
	to carrying out a geophysical survey.
Petroleum Operations Notice No.4	Comprises the pro-forma and accompanying guidance notes to use for an application for consent to drill exploration, appraisal and development wells.
Petroleum Operations Notice No.5	Comprises the pro-forma and accompanying guidance notes to use for an application to abandon or temporarily abandon a well.
Petroleum Operations Notice No.6	Comprises the pro-forma and accompanying guidance notes to use for an application to complete and/or workover a well.
Petroleum Operations Notice No.7	Specifies the definition of a well and the system to be used for numbering a well.
Petroleum Operations Notice No.8	Specifies reporting requirements in the event of an oil spill, guidance on the use of dispersants and provides contact numbers and reporting forms to use in case of oil pollution.
Petroleum Survey Licences (Model Clauses) Regulations 1992	The regulatory framework governing offshore exploration activity, including; field observations, geological and geophysical investigations, the use of remote sensing techniques, and sea floor sampling.
2) Relevant to Environmental Protection	
Conservation of Wildlife and Nature Ordinance 1999	Replaces the Wild Animals and Birds Protection Ordinance of 1964. Protects wild birds, wild animals and wild plants, egg collection, prohibits the introduction of new species and designates conservation areas (National Nature Reserves). Fauna specified so far for protection are two species of trout and all species of butterflies. Protection of wild plants extends to 29 listed species, including those listed as threatened on the Falklands Red List (*Broughton, 2002*). National Nature Reserves can be designated to area of Crown land, marine area or privately owned land with the agreement of the owner. Marine areas may be designated in Falkland Islands territorial waters (12 nautical miles) or 3 nautical miles beyond, but no marine areas have been designated yet.
Control of Kelp Ordinance 1970	Makes provision for the licensing of seaweed harvesting and export
Endangered Species Ordinance 2003	Upholds the CITES, and controls the import and export of species listed in the CITES.
Marine Environment Protection Ordinance 1995	Implements the conditions of the London Dumping Convention 1972 and prohibits, other than under license, the deposition or incineration of materials in Falkland Islands' waters. Is a system of licensing and licence offences with strict liability for certain loss or damage in relation to polluting incidents. The Deposits in the Sea (Exemptions) Order 1995, as approved under the Marine Environment Protection Ordinance, specifies categories of material exempt from requiring a licence for deposition. Includes sewage or domestic waste discharge from a vessel or platform, drill cuttings or muds under specific circumstances and the incineration of hydrocarbons.
Marine Mammals Protection Ordinance 1992	Prohibits the killing or taking of marine mammals (or to use explosives within the FOCZ where this is likely to cause harm to any marine mammal) on land or in internal waters, territorial sea or fishery waters of the Falkland Islands. It is unlawful to import or export marine mammals without a licence.
National Parks Ordinance 1998	Establishes the system for designation of National Parks, based on natural beauty and recreation value. No marine areas are being considered under this ordinance.
Waste Management Framework	Apart from siting of disposal sites under the 1991 Planning Ordinance, there is no regulatory framework specifically for waste management and disposal.

2.2.1 Environmental Impact Assessment

The Offshore Minerals Ordinance 1994 PART VI 'Miscellaneous and General' provides the regulatory framework for requiring and undertaking an Environmental Impact Assessment (EIA) or EIS in the Falkland Islands. An EIA or EIS may be required if it is considered by the Governor that the environment might be substantially affected by the activity in question.

An EIA is an assessment commissioned by the Governor and carried out on his behalf. An EIS is a statement prepared by, or on behalf of, the applicant. The scope and content of an EIA and EIS are specified within Schedule 4 of the Offshore Minerals Ordinance 1994 and are essentially the same. An EIA commissioned by the Governor, however, does not have to go through a public review period, whereas an EIS submitted by an applicant will generally be required to go through a 42 day public consultation period. This process is summarised in Figure 2.1.

Schedule 4 of the Ordinance specifies that the following information may be required within an EIA or EIS:

- Description of the proposed development such as the location, and/or the design and size or scale of the development;
- Identification and assessment of the likely impacts of the development on the surrounding environment;
- Description of likely significant impacts, direct and indirect, on the surrounding environment; such as human beings, flora, fauna, seabed and subsoil, soil, water, atmosphere and air quality, climate, seascape or landscape, inter-action between any of the foregoing, material assets, and cultural heritage;
- Description of management measures to avoid, reduce or remedy significant impacts; and
- Non-technical summary of the information specified above.

Where public review is required, the EIS is published in the Falkland Islands Gazette for a period of 42 days following government submission. Opportunities for public discussion, dissemination of information, and feedback from stakeholders will be available. In addition, the document is also presented to the Executive Council.

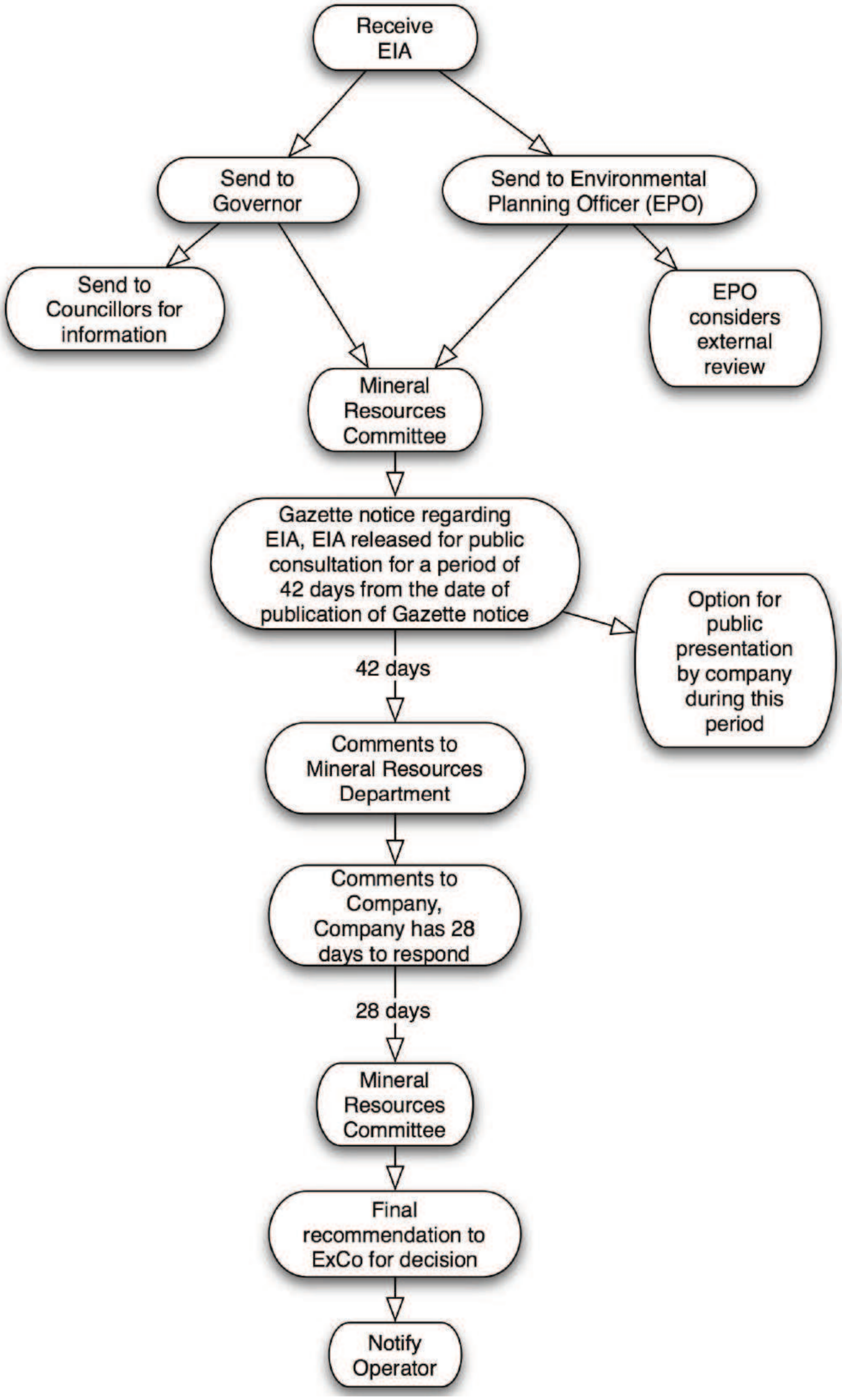

Figure 2.1. Falkland Islands EIA/EIS Process Flowchart

2.3 Petroleum Industry Standards and Guidelines

The following standards and guidelines, produced by the Exploration and Production (E&P) sector, are available either publicly (online) or just to members. Elements of the best practice guidelines will be utilised in developing the operations specific Environmental Management Plans for this project.

2.3.1 International Association of Oil and Gas Producers (OGP)

Guidelines for waste management – with special focus on areas with limited infrastructure. OGP 413. 2008

These guidelines provide advice on area-specific waste management planning, and handling and treatment methods for drilling and production waste streams, and are an update on the 1993 guidelines.

2.3.2 E&P Forum / United Nations Environment Programme (UNEP)

Joint Technical Publication; Environmental Management in Oil and Gas exploration and Production 1997

This publication provides an overview of environmental issues and technical and management approaches to achieve high environmental performance in oil and gas exploration and production.

2.3.3 International Association of Drilling Contractors (IADC)

Health, Safety and Environment Reference Guide 2004 contains all the necessary guidelines for establishing a sound safety program. Guidance topics include: Equipment Safety; Personal Protective Equipment; Fire Prevention, Fire Fighting and Fire Control; Confined Space Entry Guidelines; Cold Weather Safety; Offshore Safety; Hydrogen Sulfide; Protection of the Environment; Emergency Action Plans; Fall Protection;

2.3.4 Oil and Gas UK

Guidelines for Fisheries Liaison, Issue 5 (2008)

This document provides guidance on offshore seismic and survey work, and vessel operations supporting drilling campaigns.

For potential impacts on commercial fishing activities, liaison with fisheries is recommended. Guidelines state that due consideration should be given to: peak times of fishing activity, fish spawning and migration, and other factors relating to fish or fishing identified through the consultation process or environmental assessments of the area.

2.3.5 International Petroleum Industry Environmental Conservation Association (IPIECA)

The Oil and Gas Industry: Operating in Sensitive Environments (2003)

The case examples included in these guidelines aim to (a) demonstrate that minimal impact operations are achievable in a diverse range of environmental and social settings; (b) actively encourage exchange of company experiences and best practices; and (c) provide a basis for discussion with groups outside the industry with a view to promoting ongoing improvements in industry performance.

2.4 Borders & Southern Petroleum Health, Safety and Environmental Standards

Borders & Southern has its own set of Health, Safety and Environmental Standards that must be complied with at all stages of petroleum project related activities. The standards have been applied to this project and have heavily influenced the design and planned execution of the drilling programme. These standards are described in Section 7 and presented in Appendix I.

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3 Alternatives to the Proposed Drilling Programme

A necessary part of the impact assessment process is the consideration of alternatives to the proposed activity. Many complex factors control the situation of oil wells (geology, topography, communications, and engineering technology), meaning only a few viable alternatives can be considered environmentally. Two simple alternatives may be to drill or not drill at all.

Processed and interpreted seismic data are used to indicate areas where hydrocarbons may be trapped in oil or gas-filled geological structures. Without exploratory drilling, seismic data is unable to confirm whether oil and gas are present, the volume of the reservoir, whether the hydrocarbons can be commercially extracted, or even the actual rock types. Hence, exploratory drilling is a necessary step in the development of commercial hydrocarbons and is a requirement under the terms of the production licence awarded to Borders & Southern. Potential impacts from drilling activities and their management measures are discussed in subsequent chapters of this EIS.

Direct benefits to the region and country from the extraction of natural resources could be increased financial income and local business opportunities. Secondary or indirect benefits could be an increased standard of living, and better education, social services and amenities (for example, improved waste disposal). These benefits could also potentially raise awareness of environmental protection in the area.

The implications of not proceeding mean that the potential environmental and social impacts (positive and negative) from the drilling operations will not occur. The environment will not necessarily maintain its current baseline condition however, as impacts from fishing and vessel activity such as waste water discharge, sedimentation, fall-out of atmospheric pollutants, and ballast water discharge will still take place.

Should the drilling programme not proceed, the potential financial and social benefits of oil and gas production cannot be realised. Ultimately, no drilling would preclude development of offshore hydrocarbon resources with missed opportunities in business and economic investment.

Alternative drilling methods and types of drill unit exist and each have their own environmental impacts. The use of a dynamically positioned (DP) drill ship or semi-submersible drilling rig would minimise seafloor disturbance as anchoring would not be required (as in a traditional semi-submersible). Such a unit would however require continual positioning using thrusters and both fuel consumption and underwater noise would therefore be considerably higher than for an anchored unit. DP drill units are generally larger and more expensive than anchored units.

Directional drilling is also possible where the well cannot be positioned over the target reservoir, for example where the drilling target lies under an inaccessible or highly sensitive area. Directional drilling requires additional resources and time, is more complicated and more expensive than vertical drilling. It would only be considered where there is an exceptional reason why the well cannot be positioned over the target reservoir, which, taking full account of the baseline environmental and benthic data, is not considered to be the case in this instance.

Cuttings from the wells for this drilling campaign will be treated and disposed of to sea through the cuttings caisson (as water based muds will be used) in line with standard industry practice. Downhole injection of cuttings is not possible, as no suitable geological formation or old well exist to store the cuttings discharge.

In addition the use of water based muds, low toxicity chemicals and a solids control package on the rig will all mitigate the potential polluting impacts from cuttings disposal to sea.

Specifics of technology available onboard the rig cannot be considered at this time as the rig has not been contracted yet. However, all equipment on board the rig will have been certified and checked that it is functioning at optimum levels.

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4 Drilling Programme

4.1 Overview

Borders & Southern is currently planning to drill two exploration wells: Stebbing and Darwin East in PL018 licence area (refer to Figure 1.1). The proposed exploration wells are situated approximately 150 kilometres to the south of the Falkland Islands (FI) and within the boundaries of the FI Conservation Zone. The water depth at the Darwin East and Stebbing locations are 2,010 and 1,479 metres, respectively.

The Darwin East well targets an early Cretaceous tilted fault block 'Springhill' sandstone play and will be drilled vertically to the total depth (TD) of 4,850m TVD. The well will encounter Plio-Pliestocene (pelagic sediments and mudstone dominated debris flows), Paleogene-Neogene (predominantly claystone with rare limestone stringers and thin sandstones towards the base of the interval), Cretaceous (predominantly deltaic claystone and siltstones with thin limestone stringers increasing sandstones towards the base of the interval) (Figure 4.1).

The Stebbing well targets a large thrust cored anticline with over 2500m of closure. The well will be drilled vertically to the TD of 4,150m TVD, and will encounter Paleogene-Neogene (predominantly claystone, mudstone dominated debris flows and deep water distributary channel and fan sandstone complexes) and the Upper Cretaceous (claystone with inter-bedded sandstone) (Figure 4.2).

borders&southern petroleum plc

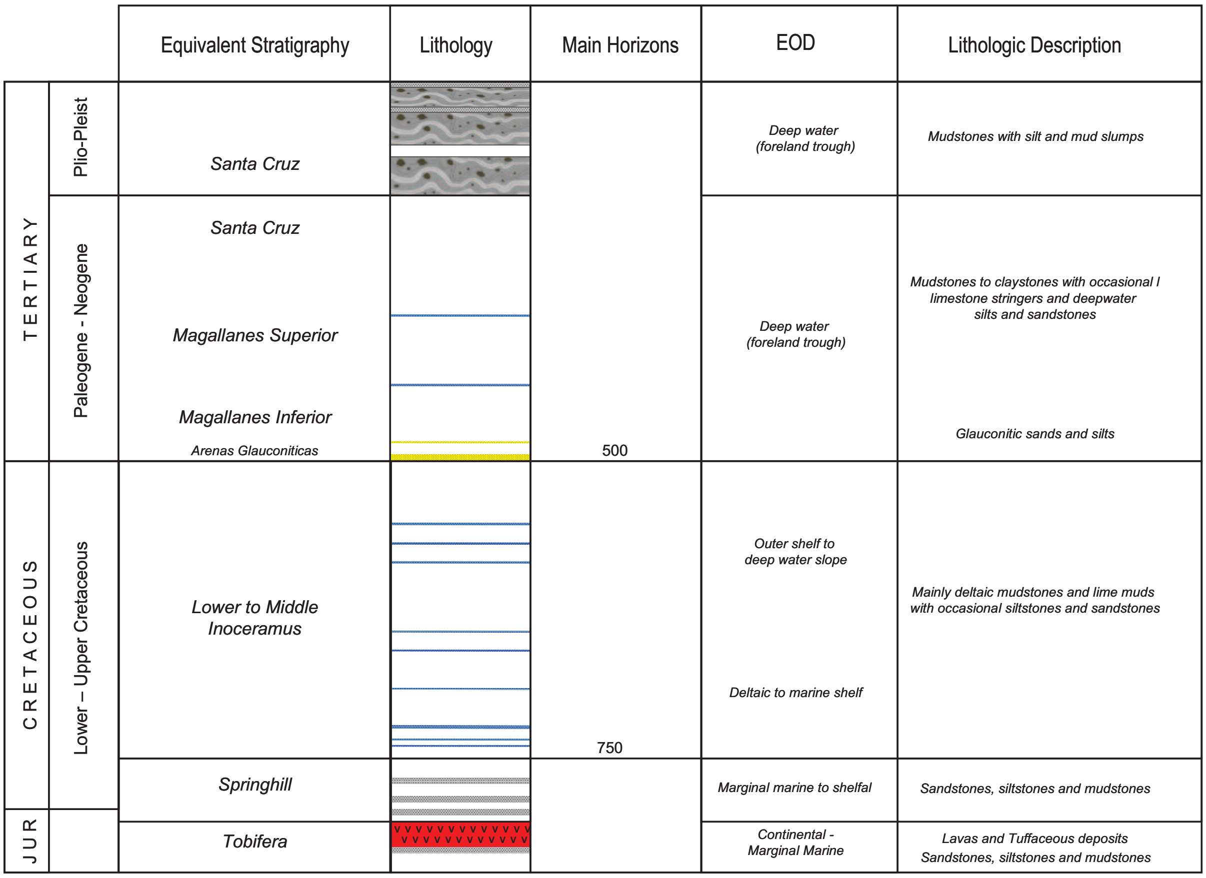


Figure 4.1 Darwin East Stratigraphic Column

borders&southern petroleum plc

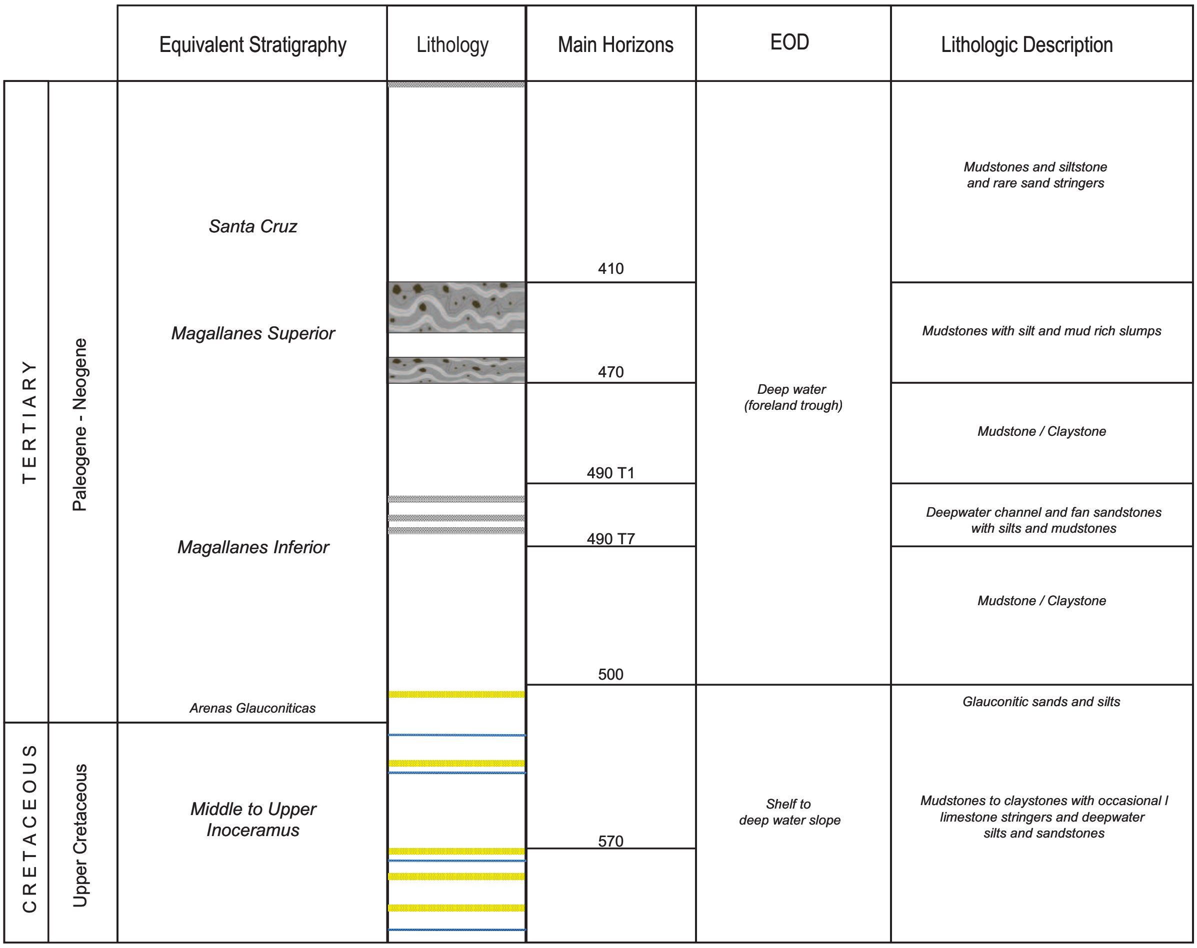


Figure 4.2 Stebbing Stratigraphic Column

It is anticipated that hydrocarbons, if discovered, would potentially comprise oil and gas with an API of 25° at Stebbing and API 32° at Darwin East wells.

Following drilling, the wells will be logged and evaluated. Regardless of the evaluation results, the wells will be plugged and abandoned in accordance with Oil & Gas UK guidelines. All obstructions will be removed from the seabed

4.2 Exploration Well Objective and Concept

The objective of this project is to explore hydrocarbon reservoirs in the Tertiary, Upper Cretaceous and Lower Cretaceous deposits of the South Falklands Basin through drilling and evaluation of two exploration wells (Darwin East and Stebbing).

4.3 Proposed Project Schedule

A provisional project schedule for the Borders & Southern drilling programme will be provided in an Addendum to this document when a drill rig and drilling contractor have been selected.

It is anticipated that the rig will be on location for a total of up to 75 days (40 days for Darwin and 35 days for Stebbing) . No well testing that involves flowing well fluids to the surface is planned. All evaluations will be undertaken by wireline.

4.4 Drilling Operations

4.4.1 Well Details

The key characteristics of the Darwin East and Stebbing wells are summarised in Table 4.1

Table 4.1. Proposed Drilling Programme Well Characteristics

Aspect	Proposed Well Locations in the Northern Falkland's Basin	
	Darwin East	Stebbing
Licence Area	PL018	PL018
Licence Block	61/17	61/25
Anticipated Drilling Location	053° 35' 43.7" S; 058° 45' 57" W	053° 42' 40.17" S, 058° 08' 17.9" W
Anticipated Drill Rig	Drill ship or 5-6th generation DP semi-submersible drill rig	
Support Location	Stanley	Stanley
Water Depth (m)	2,010	1,479
Primary Target (m) TDSS	4,610	2,470
Depth of Well (m) TDSS	4,850	4,150
Nearest Landfall	150 kilometres	170 kilometres
Anticipated Spud date	Q4 2010 – Q1 2011	Q1-Q3 2011
Estimated time to reach TD	40 days	35 days
Clean up and well testing	None Planned	None Planned
Hydrocarbons Anticipated	Oil and gas, Av. 32° API	Oil and gas, Av. 25° API
ITOPF Category	Group III	Group III
Anticipated Weight of Cuttings	1337 tonnes	1331.3 tonnes

4.4.2 The Drilling Rig

The proposed exploration wells will be drilled using either drill ship or a dynamically positioned (DP) 5-6th generation semi-submersible drilling rig. Further information on these types of rigs is provided in Appendix A.

4.4.3 Well Construction

Wells are drilled in sections, with the diameter of each section decreasing with increasing depth. During the drilling of the upper well section the drill string (also called drill pipe) and drill bit are typically left open to the seawater. However, before drilling lower sections of the well, a lining called casing is run and cemented in the well and riser pipe is used between the rig and the seabed with the drill string passing through the riser (from seabed back to rig) and the casing (below seabed).

Once the casing has been run therefore, the drilling fluid can be returned to the rig, in the space (or annulus) between the drill string and the casing / open hole and back up the riser to the rig. The lengths and diameters of each section of the well are determined prior to drilling and are dependent on the geological conditions through which the well is to be drilled. Once each section of the well is completed, the drill string is lifted and protective steel pipe or casing lowered into the well and cemented into place. The casing helps to maintain the stability of the hole and also helps reduce fluid losses from the well bore into surrounding rock formations.

Darwin East

The proposed Darwin East well will be drilled to a total vertical depth of 4,850 metres or approximately 2,840 metres below mud line (Table 4.2 and Figure 4.3).

Due to the limited offset data and the wildcat nature of the well a full-bore casing design has been assumed.

Pilot Hole

The well location is within the gas hydrate stability zone. No seismic reflector is observed in the area around the well location indicating the absence of free gas. However, the absence of seismic reflector does not preclude the presence of gas hydrates at this location.

For the purposes of time and cost estimation it has been assumed that a *12 ¼"* pilot hole would be drilled to the prognosed *20"* casing setting depth within 50m of the well surface location to confirm the absence of shallow gas and in situ hydrates, assess the potential for shallow water flows and to identify the optimum conductor and *20"* casing setting depths.

36" Conductor (Jetted)

The well design assumes that a 36" conductor with a mud mat will be jetted to 2,070m TVD (60 meters below the mud line) to provide a foundation for the subsequent casing strings.

26" Hole and 20" Casing

The 26" hole would be drilled from below the 36" conductor with seawater and benthonite sweeps to 2,450m TVD. The 20" casing would be run to 3m from bottom and cemented to surface. The planned setting depth is below the Plio-Pliestocene unconsolidated debris flow intervals. The predicted fracture and pore pressures at the 20" setting depth would provide sufficient kick tolerance to drill to the top of the primary target.

17 ½" Hole and 13 3/8" Casing

The 17 1/2" hole section would be drilled with a 9.0ppg inhibited mud system. The A 13 3/8" casing will be set at 4,500m, 110m above the primary target at 4,610m TVD to isolate any potential loss zones, unstable or reactive shales prior to drilling and logging the reservoir section. The 13 3/8" casing would be cemented back above the highest permeable formation in the 17 1/2" hole section using lead and tail slurries.

Note: If hole problems (losses, reactive shales, wellbore instability, shallow water flows) in the 17 1/2" hole section dictate that the 13 3/8" casing is set early, there is contingency to set a 9 3/8" casing above the reservoir and drill the reservoir in 8 ½" hole.

12 ¼" Hole and 8 1/2" Casing

The 12 ¼" hole will be drilled with 9.2ppg inhibited mud system to the TD 4.850m TVD and the logging program executed as required.

Table 4.2. Proposed Darwin East Well Profile

Hole Size		Casing Size	Section Length (metres)	Cuttings Volume, (cubic meters)	Cuttings Weight, (tonnes)	Proposed Mud Use
inches	**meters**	**Inches**	**meters**	**meters**	**tonnes**	
36	0.91	36	60	39.4	102.5	Seawater
26	0.66	20	380	130.2	338.5	Seawater + Bentonite
17 1/2	0.44	13 5/8	2050	318.2	827.2	WBM
12 ¼	0.31	8 1/2	350	26.6	69.2	WBM
Total			**2840**	**514.4**	**1337.3**	

Stebbing

The well will be drilled vertically in 1,479m of water. The primary target is 2,470m TVD and the well TD 4,150m TVD (Table 4.3 and Figure 4.4).

Due to the limited offset data and the wildcat nature of the well a full-bore casing design has been assumed.

Pilot Hole

Due to the proximity of the seismic reflector to the proposed wellpath a *12 ¼"* pilot hole would be drilled within 50m of the well surface location to:

- Confirm the absence of shallow gas
- Confirm the absence of in situ hydrates
- To assess the potential for shallow water flows

36" Conductor (Jetted)

The well design assumes that a 36" conductor with a mud mat will be jetted to 1,539m TVD (60 meters below the mud line) to provide a foundation for the subsequent casing strings.

26" Hole and 20" Casing

The 26" hole would be drilled from below the 36" conductor with seawater and bentonite sweeps to 2,350m TVD. The 20" casing would be run to 3m from bottom and cemented to surface. The planned setting depth is below the debris flow units in the Neogene-Paleogene at 1,934-2,256 m TDSS.

The predicted fracture and pore pressures will provide sufficient kick tolerance to drill to the top of the primary target.

17 ½" Hole and 13 $^{3}/_{8}$" Casing

The 17 $^{1}/_{2}$" hole section would be drilled with a 9.8ppg inhibited mud system to 3,200m TVD. The setting depth of the 20" casing and the estimated pore pressure and fracture pressure will provide sufficient kick tolerance at the 20" shoe to drill into the top of primary target (Horizon 490 at 2,470m TVD) if an oil column is assumed in the reservoir. If the gas is assumed it would be necessary to set a 13 $^{3}/_{8}$" casing close to the top of the reservoir to provide sufficient kick tolerance.

Note: If drilling of the primary target causes log quality problems it would be necessary to run 13 $^{3}/_{8}$" casing above the primary target or to drill the hole in 12 ¼" and open it up to 17 ½".

The 13 $^{3}/_{8}$" casing would be cemented back inside the shore using a lead and tail slurry.

12 ¼" Hole and 8 $^{1}/_{2}$" Casing

The well design assumes that 12 ¼" hole would be drilled below the 13 $^{3}/_{8}$", through the secondary targets, to the well TD with a 9.4ppg inhibited mud system. The secondary targets would then be logged as required.

The setting depth of the 13 $^{3}/_{8}$" casing (4,500m TVD) and the predicted pore pressures available for the secondary targets and predicted fracture pressure will provide sufficient kick tolerance at the 13 $^{3}/_{8}$" shoe to drill to TD (4,150 TVD).

If the sand intervals within the secondary target have varying pressures regimes, then it may become necessary to set casing and isolate the zones above prior to drilling ahead. A contingency 9 $^{5}/_{8}$" casing x 8 $^{1}/_{2}$" hole and 7" liner and 6" hole would be available in this case.

Table 4.3. Proposed Stebbing Well Profile

Hole Size		Casing Size	Section Length (metres)	Cuttings Volume, (cubic meters)	Cuttings Weight, (tonnes)	Proposed Mud Use
inches	meters	Inches	meters	meters	tonnes	
36	0.91	36	60	39.4	102.5	Seawater
26	0.66	20	761	260.7	677.8	Seawater + Bentonite
17 $^{1}/_{2}$	0.44	13 $^{5}/_{8}$	900	139.7	363.2	WBM
12 ¼	0.31	8 $^{1}/_{2}$	950	72.2	187.8	WBM
Total			**2671**	**512**	**1331.3**	

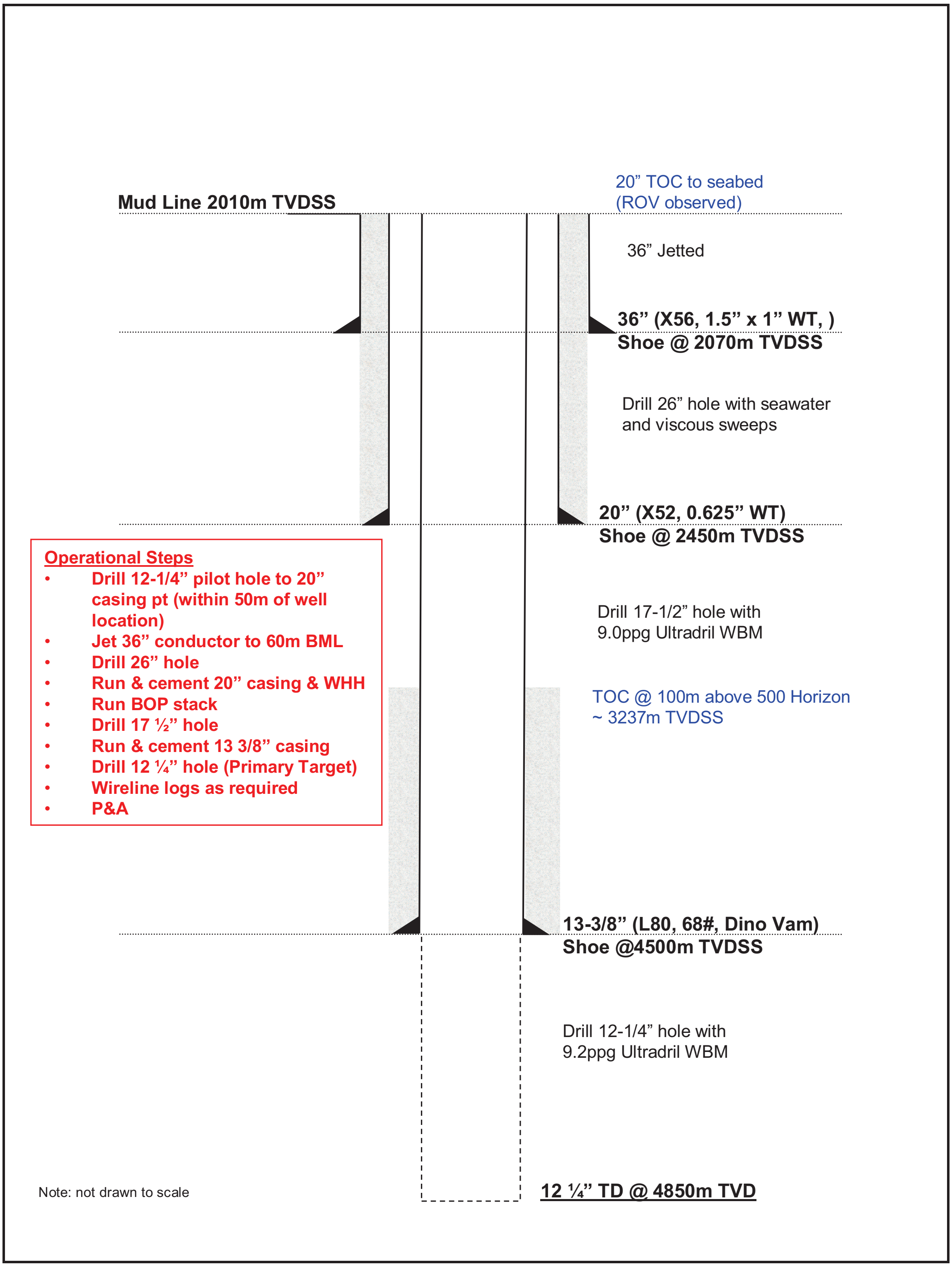


Figure 4.3 Proposed Darwin East Well Schematic

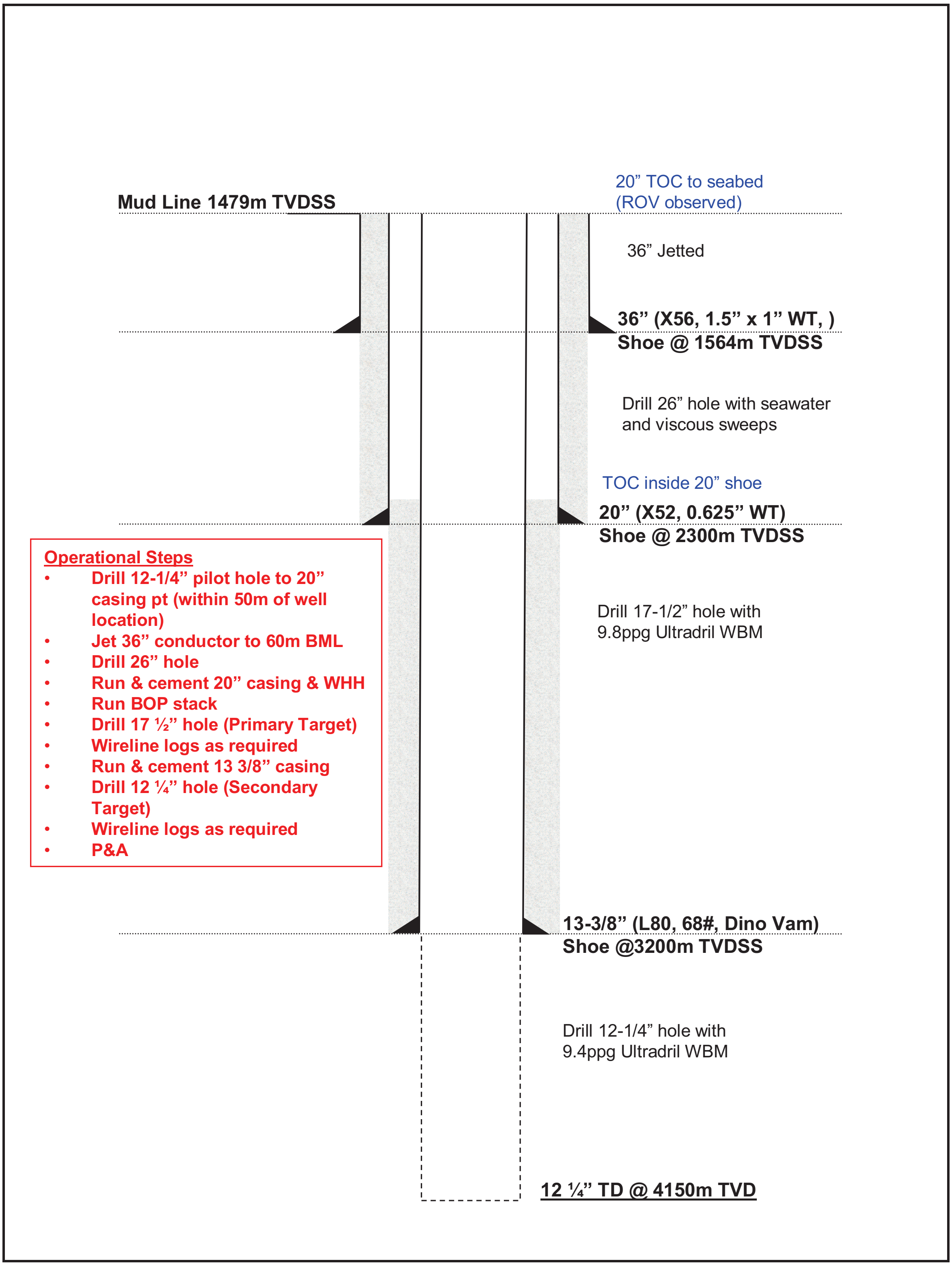


Figure 4.4 Proposed Stebbing Well Schematic

4.4.4 Disposal of Drill Cuttings

The two top hole sections will be jetted and drilled open to the seabed and the cuttings generated whilst doing so will be swept out of the hole using seawater. These will be deposited around the well bore. In two bottom sections the wells will be cased and drilled using a riser whilst circulating drilling mud to remove cuttings, to condition the well bore and provide weight down the hole.

Whilst drilling the wells, a riser will be set between the wellhead and the rig, with a blow-out preventor fitted on the seabed near the bottom of the riser. The mud and cuttings will be returned to the rig where they pass through the cleaning system (refer to Appendix A). This reduces the amount of drilling fluid retained on the cuttings to between 5 and 10 percent. The cuttings will be cleaned to the required specification and discharged to the sea. The cuttings are variously sized particles of rock cut from the strata as the drill bit progresses down the well bore and will be comprised of sedimentary rock.

Estimated amounts of cuttings that will be generated for the proposed Darwin East and Stebbing exploration wells are detailed in Tables 4.4 and 4.5.

Table 4.4. Estimate of Cuttings Generated for Proposed Darwin East Well

Hole Size (in)	Hole size diameter (m)	Length (m)	Volume (cu m)	Weight (tonnes)
36	0.91	60	39.4	102.5
26	0.66	380	130.2	338.5
17 1/2	0.44	2160	335.2	871.6
12 ¼	0.31	240	18.2	47.4
Total cuttings from Darwin East well			**514.4**	**1337.3**
Discharged at Seabed			169.6	440.9
Discharged at Surface			344.8	896.4
Returned to Shore			0	0

Note: Weight of cuttings calculated assuming density of 2.6 tonnes per cubic metre

Table 4.5. Estimate of Cuttings Generated for Proposed Stebbing Well

Hole Size (in)	Hole size diameter (m)	Length (m)	Volume (cu m)	Weight (tonnes)
36	0.91	60	39.41	102.46
26	0.66	761	260.70	677.83
17 1/2	0.44	900	139.68	363.17
12 ¼	0.31	950	72.25	187.84
Total cuttings from Stebbing well			**512**	**1331.3**
Discharged at Seabed			300.1	780.3
Discharged at Surface			211.9	551.0
Returned to Shore			0	0

Note: Weight of cuttings calculated assuming density of 2.6 tonnes per cubic metre

4.4.5 Drilling Mud and Casing Cement

A background to the use of drilling muds is given in Appendix A. Both wells will be drilled using water based mud (WBM). On the rig, the cleaned mud's composition will be monitored and its contents adjusted to ensure that its properties remains as specified and it will be recycled through the well. No low toxicity oil based mud (LTOBM) will be used for the proposed wells.

The drilling mud is specially formulated for each section of the well to suit the conditions in the strata being drilled. The selection is made according to the technical requirements for the mud and the environmental credentials of the chemical (refer to Section 4.4.8). The mud components which Borders & Southern currently propose to use for the two exploration wells are listed in Tables 4.6 and 4.7.

Once each section of the well has been drilled, the drill string is lifted and the casing is lowered into the hole and cemented into place (refer to Section 4.4.3). The cement is formulated specifically for each section of the well and contains small volumes of additives that are required to improve its performance (refer to Table 4.8). It is mixed into a slurry on the rig and is then pumped down the string and forced up the space between the well bore and the casing. To ensure that sufficient cement is in place and that a good seal is achieved, a certain amount of extra cement is pumped and some of this will be discharged to the seabed in the immediate vicinity of the wellhead, only in cases where cementing back to seafloor surface (e.g the upper most section of the well). Typically, the quantity discharged is less than 10 percent of the total volume used, however, in case of contingency, the quantity discharged could double.

Other contingency chemicals may be required if problems or emergencies are encountered during drilling or cementing operations.

4.4.6 Well Clean-up, Testing and Completion

Once drilling operations have been completed, Borders & Southern proposes to run electric logs to provide information on the potential type and quantities of hydrocarbons present in the target formations. Logging instruments will be attached to the bottom of a wireline and lowered to the bottom the well. They are then slowly brought back up, the devices reading different data as they pass each formation and recording it on graphs, which can be interpreted by the geologist, geophysicist and drilling engineer.

In the event that hydrocarbons are encountered in sufficient quantities, as determined by the electric wireline logs, attempts to recover reservoir fluid samples may be undertaken by wireline. No well testing is planned.

After evaluation, the wells will be plugged and abandoned. Plugging will be in accordance with UK Guidelines, however a notional description of the plugging procedure follows. The open hole will be cemented to seal off any hydrocarbon bearing formation. Further cement plugs will then be put inside the last casing string. Details of the exact plugging design will be provided in the Addendum and are dependent upon the formations encountered during drilling, and the evaluation of hydrocarbon potential at the site.

4.4.7 Rig Chemicals

Certain chemicals will be required for specific purposes on the drilling rig for example lubricant for the drill string threads and detergent to periodically wash rig equipment. These chemicals will be selected to minimise any environmental impact that they might otherwise have. The list of chemicals to be used onboard the rig will be presented in the Addendum report, when the rig has been contracted.

4.4.8 Selection of Chemicals to be used Offshore

Drilling offshore the Falkland Islands will follow the same model of chemical use as is required in the UK. Offshore chemical use in the UK is regulated through The Offshore Chemical Regulations 2002, which apply the provisions of the Decision by the Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention) for a Harmonised Mandatory Control System for the use and discharge of chemicals used in the offshore oil and gas industry. The Offshore Chemical Notification Scheme (OCNS) ranks chemical products according to Hazard Quotient (HQ), calculated using the CHARM (Chemical Hazard and Risk Management) model (refer to Appendix B for further information).

In the UK, the Centre for Environment, Fisheries & Aquaculture Science (CEFAS) maintains a list of chemicals under the OCNS that have been approved for use offshore for specific functions. Only chemicals on this list may be chosen for use when selecting the components of the drilling mud, cement, completion and general rig chemicals. Chemicals are therefore selected on their technical merits and are screened so that the collateral environmental effects are minimised as far as practical.

Table 4.6. Planned Darwin East WBM Mud Components

Chemical Name	Function	Estimated Use (tonnes)	Estimated Discharge (tonnes)	HQ Band / OCNS group
36 inch section				
M-I BAR (All Grades)	Weighting chemical	17.2	17.2	E
M-I Gel	Viscosifier	6.6	6.6	E
Caustic Soda	Water based drilling fluid additive	0.5	0.5	E
Guar Gum	Viscosifier	0.75	0.75	E
Soda Ash	Water based drilling fluid additive	0.5	0.5	E
26 inch section				
M-I BAR (All Grades)	Weighting chemical	52.0	52.0	E
M-I Gel	Viscosifier	22.5	22.5	E
Caustic Soda	Water based drilling fluid additive	0.5	0.5	E
Guar Gum	Viscosifier	1.5	1.5	E
Soda Ash	Water based drilling fluid additive	0.5	0.5	E
17 ½ inch section				
POTASSIUM CHLORIDE	Water based drilling fluid additive	42.7	42.7	E
ULTRAHIB	Water based drilling fluid additive	46.9	46.9	SUB
ULTRACAP	Water based drilling fluid additive	6.5	6.5	GOLD
SAFE-CIDE	Biocide	0.85	0.85	GOLD
MAGNESIUM OXIDE	Acidity Control Chemical	1.1	1.1	E
FLO-TROL	Fluid Loss Control Chemical	8.5	8.5	E
POLYPAC – All Grades	Viscosifier	8.5	8.5	E
DUO-VIS	Viscosifier	5.2	5.2	GOLD
M-I BAR	Weighting chemical	75.0	75.0	E
DEFOAM NS	Defoamer (Drilling)	0.9	0.9	GOLD
ULTRAFREE NS	Drilling Lubricant	34.5	34.5	GOLD
MEG	Water based drilling fluid additive	43	43	E
12 ¼ inch section				
Sodium Chloride Brine	Water based drilling fluid additive	49.5	49.5	E
POTASSIUM CHLORIDE	Water based drilling fluid additive	14.1	14.1	E
ULTRAHIB	Water based drilling fluid additive	15.5	15.5	SUB
ULTRACAP	Water based drilling fluid additive	2.2	2.2	GOLD
SAFE-CIDE	Biocide	0.5	0.5	GOLD
MAGNESIUM OXIDE	Acidity Control Chemical	0.5	0.5	E
FLO-TROL	Fluid Loss Control Chemical	2.9	2.9	E
POLYPAC – All Grades	Viscosifier	2.9	2.9	E
DUO-VIS	Viscosifier	1.7	1.7	GOLD
M-I BAR	Weighting chemical	31.0	31.0	E
DEFOAM NS	Defoamer (Drilling)	0.5	0.5	GOLD
ULTRAFREE NS	Drilling Lubricant	11.5	11.5	GOLD
MEG	Water based drilling fluid additive	14	14	E

Table 4.7. Planned Stebbing WBM Components

Chemical Name	Function	Estimated Use (tonnes)	Estimated Discharge (tonnes)	HQ Band / OCNS group
36 inch section				
M-I BAR (All Grades)	Weighting chemical	17.5	17.5	E
M-I Gel	Viscosifier	6.5	6.5	E
Caustic Soda	Water based drilling fluid additive	0.5	0.5	E
Guar Gum	Viscosifier	0.5	0.5	E
Soda Ash	Water based drilling fluid additive	0.5	0.5	E
26 inch section				
M-I BAR (All Grades)	Weighting chemical	93.0	93.0	E
M-I Gel	Viscosifier	42.0	42.0	E
Caustic Soda	Water based drilling fluid additive	0.25	0.25	E
Guar Gum	Viscosifier	2.9	2.9	E
Soda Ash	Water based drilling fluid additive	0.25	0.25	E
17 ½ inch section				
POTASSIUM CHLORIDE	Water based drilling fluid additive	26.1	26.1	E
ULTRAHIB	Water based drilling fluid additive	28.8	28.8	SUB
ULTRACAP	Water based drilling fluid additive	4.0	4.0	GOLD
SAFE-CIDE	Biocide	0.55	0.55	GOLD
MAGNESIUM OXIDE	Acidity Control Chemical	0.65	0.65	E
FLO-TROL	Fluid Loss Control Chemical	5.25	5.25	E
POLYPAC – All Grades	Viscosifier	5.25	5.25	E
DUO-VIS	Viscosifier	3.2	3.2	GOLD
M-I BAR	Weighting chemical	165.0	165.0	E
DEFOAM NS	Defoamer (Drilling)	0.6	0.6	GOLD
ULTRAFREE NS	Drilling Lubricant	21.0	21.0	GOLD
MEG	Water based drilling fluid additive	26.1	26.1	E
12 ¼ inch section				
Sodium Chloride Brine	Water based drilling fluid additive	52.5	52.5	E
POTASSIUM CHLORIDE	Water based drilling fluid additive	15.5	15.5	E
ULTRAHIB	Water based drilling fluid additive	16.5	16.5	SUB
ULTRACAP	Water based drilling fluid additive	2.25	2.25	GOLD
SAFE-CIDE	Biocide	0.3	0.3	GOLD
MAGNESIUM OXIDE	Acidity Control Chemical	0.4	0.4	E
FLO-TROL	Fluid Loss Control Chemical	3	3	E
POLYPAC – All Grades	Viscosifier	3	3	E
DUO-VIS	Viscosifier	1.8	1.8	GOLD
M-I BAR	Weighting chemical	49.5	49.5	E
DEFOAM NS	Defoamer (Drilling)	0.3	0.3	GOLD
ULTRAFREE NS	Drilling Lubricant	12.0	12.0	GOLD
MEG	Water based drilling fluid additive	15.1	15.1	E

All of the planned chemicals, which Borders & Southern currently propose to use for the Darwin East and Stebbing exploration wells, appear on this Ranked Lists of Products approved under the OCNS. They all have an OCNS category of 'E' or have a Gold HQ band (i.e. are least toxic, refer to Appendix B) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable. Tables 4.6 to 4.7 present the current proposed chemical products for use during the drilling programme. The total weight of WBM chemicals used and discharged for Darwin East and Stebbing wells are 523 and 622.5 tonnes, respectively.

Table 4.8. Proposed Cement Chemicals and Ratings (for each well)

Chemical Name	Function	Estimated Use (tonnes)	Estimated Discharge (tonnes)	HQ Band / OCNS group
D095 Cement Additive	Cement or Cement Additive	0.58	0.06	E
LITEFILL Extender D124	Cement or Cement Additive	40.42	4.19	E
AccuSET D197	Cement or Cement Additive	6.10	1.59	Gold
Cement Class G D907	Cement or Cement Additive	426.41	66.13	E
D600G GASBLOK* Gas Migration Control Additive	Cement or Cement Additive	16.21	4.69	Gold (sub)
Environmentally Friendly Dispersant B165	Cement or Cement Additive	2.32	0.84	E
Liquid Accelerator D77	Cement or Cement Additive	4.36	1.70	E
Liquid Antifoam B143	Cement or Cement Additive	0.66	0.22	Gold
Silicate Additive D75	Cement or Cement Additive	5.91	1.20	E
UNIFLAC-L D168	Cement or Cement Additive	6.00	2.57	Gold
Viscosifier for MUDPUSH II spacer B174	Viscosifier	0.44	0.16	E
Tros Seadye	Well Stimulation Chemical	0.45	0.08	Gold
Low Temperature Retarder D081	Well Stimulation Chemical	0.64	0.04	E
Antifoam Agent D175	Antifoam (Hydrocarbons)	0.13	0.03	Gold (sub)
Antifoam Agent D206	Cement or Cement Additive	0.13	0.03	Gold (sub)
Iron Stabilizing Agent L001	Completion Additive	0.45	0.22	E
Surfactant D191	Other	0.45	0.15	Gold
Mutual Solvent U66	Cement or Cement Additive	0.41	0.14	Gold

4.5 Resource Use

4.5.1 Equipment and Chemicals

The remote drilling location will require sufficient materials and chemicals, equipment, spares and contingency supplies to be ordered in advance and shipped prior to rig mobilisation. These will be sourced in advance and most likely outside of the Falkland Islands.

4.5.2 Fuel

A typical drill ship or DP semi-submersible rig are likely to consume 30 tonnes of fuel a day during drilling operations, standby vessel (deployed daily) and support vessels (deployed 2-3times a week) are likely to consume 3 and 7 tonnes of fuel a day, respectively. The Darwin East and Stebbing drilling campaign will use an estimated 2,700 tonnes of fuel given that the rig will be on site for 75days. A detailed breakdown of fuel consumption is provided in Section 6. The fuel will be sourced from the Falkland Islands.

Helicopter trips for crew changes will occur 2-3 times a week (approximately 30 round trips) throughout the drilling programme, and are estimated to have a fuel consumption of 5 tonnes per 1,000 kilometre (round trip from Mt Pleasant Airport (southwest of Stanley) to Darwin East and

Stebbing is approximately 380 and 430 kilometres, respectively). Each flight is estimated to take approximately 2hrs. Total aviation fuel use is estimated at 120 tonnes for the entire drilling period.

4.5.3 Water

Water will be needed for operational and domestic use onboard the drill rig, and it is estimated that approximately 51 cubic meters (m^3) of drilling water per day and 0.22 m^3 of potable water per person per day is required for a typical drilling operation. The drilling campaign will require approximately 3,825 m^3 of drilling water. As the drill rig specifications are currently unknown, water consumption figures cannot be accurately calculated; however as a typical drill rig can carry up to 100 personnel onboard it is estimated that up to 1,650 m^3 of potable water may be required throughout the drilling programme: 880m^3 for the 40 day drilling campaign at Darwin East and 770m^3 for the 35 day drilling campaign at Stebbing. The same amount is assumed to be discharged.

Potable water will either be sourced from the ocean and treated in the desalination plant, if one is available onboard the rig, or will be obtained from the Falkland Islands, or a combination of both. Drilling water will be sourced from the ocean.

4.5.4 Waste Disposal

Waste will be disposed of on the Falkland Island with hazardous waste likely to be exported to the UK, Chile or Uruguay. Specific waste handling/disposal routes and procedures will be detailed in a Waste Management Plan, to be submitted for approval.

4.6 Support Operations

The drilling rig is likely to be supported by a stand-by vessel and a supply vessel. The stand-by vessel will at all times be within proximity of the drilling rig for safety purposes. It will be in close liaison with the drilling rig and will continuously monitor other vessel movement in the area. It will warn off vessels on a course that is likely to bring them into or near the safety exclusion zone around the rig, by using a prearranged series of signals of increasing intensity, to ensure that the vessel becomes aware of the obstacle and takes action to avoid it.

The supply vessel will provide the bulk logistics, transporting material required for the drilling and well construction to the rig from port and unwanted material and material generated by the drilling operations from the rig to the port.

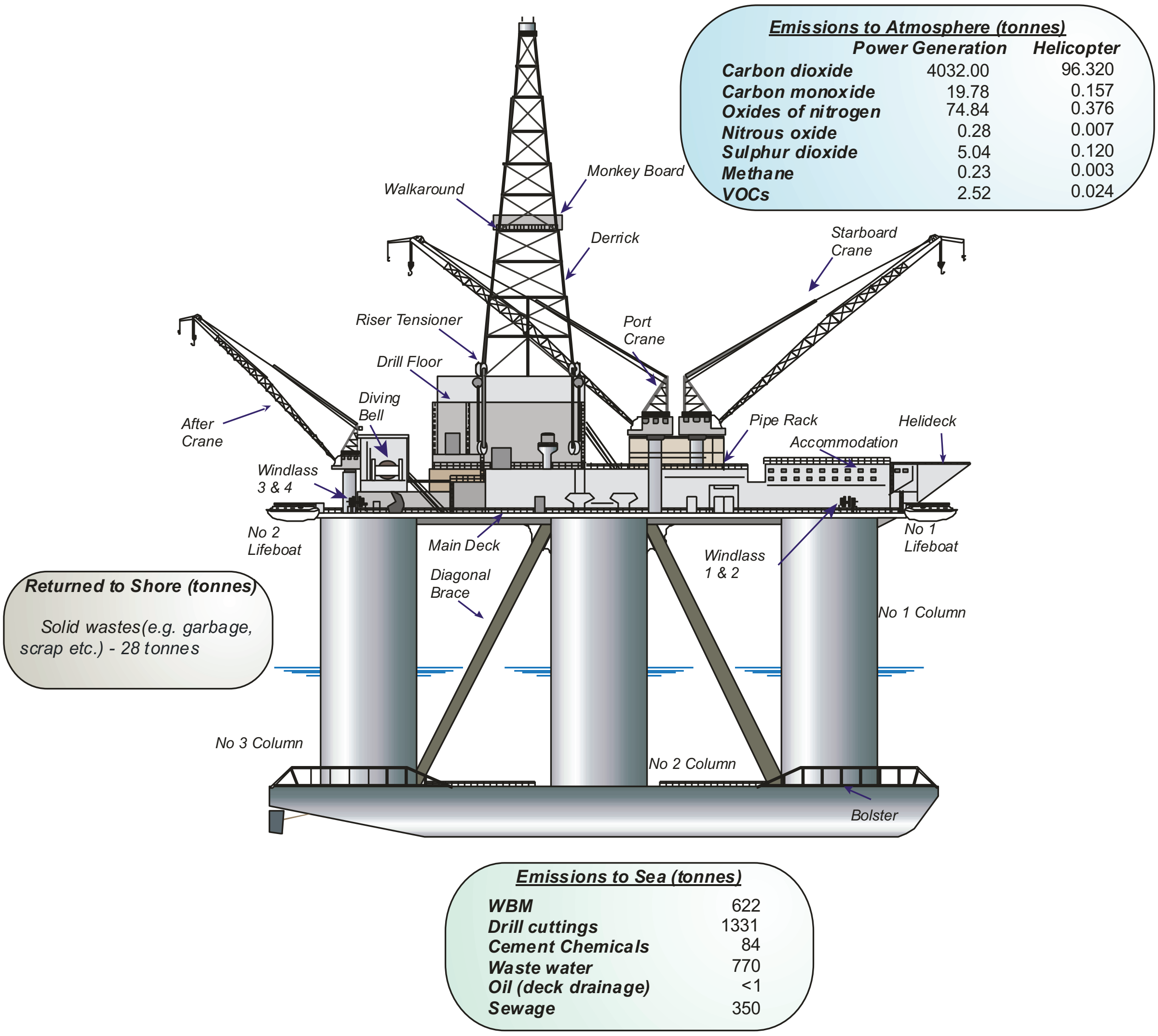
Rig crews will be transferred to and from the rig by helicopter. The helicopter base and number of scheduled flights that will be made to the rig per week will be determined when a rig and a drilling contractor have been contracted and be addressed in the Addendum. For the purpose of atmospheric emission calculations 2-3 flights a week have been assumed.

All the routes used by vessels and aircraft will be pre-planned to avoid creating unnecessary disturbance to sensitive elements along their routes refer to Section 6).

During routine crew changes, the crew will need to be temporarily accommodated on the Islands as they wait for their flights. It is noted that there is limited accommodation available on the Falkland Islands, and Borders & Southern will work with the drilling contractor and FIG, and possibly the MOD, to look at options such as setting up a camp or using accommodation in the military base. The impacts from increased demand will not be significant as the crew changes will not be in large numbers and as described above, a range of options exist.

4.7 Total Emissions Summary

Figures 4.5 and 4.6 provide a summary of estimated maximum emissions and discharges arising from routine operations associated with the drilling of two proposed wells (refer to Section 6 for further details). The calculations are based on 35 and 40 days of the rig deployment at Darwin East and Stebbing locations.



Emissions to Atmosphere (tonnes)

	Power Generation	Helicopter
Carbon dioxide	4032.00	96.320
Carbon monoxide	19.78	0.157
Oxides of nitrogen	74.84	0.376
Nitrous oxide	0.28	0.007
Sulphur dioxide	5.04	0.120
Methane	0.23	0.003
VOCs	2.52	0.024

Returned to Shore (tonnes)

Solid wastes(e.g. garbage, scrap etc.) - 28 tonnes

Emissions to Sea (tonnes)

WBM	622
Drill cuttings	1331
Cement Chemicals	84
Waste water	770
Oil (deck drainage)	<1
Sewage	350

Figure 4.5 Emissions Summary for Stebbing Well

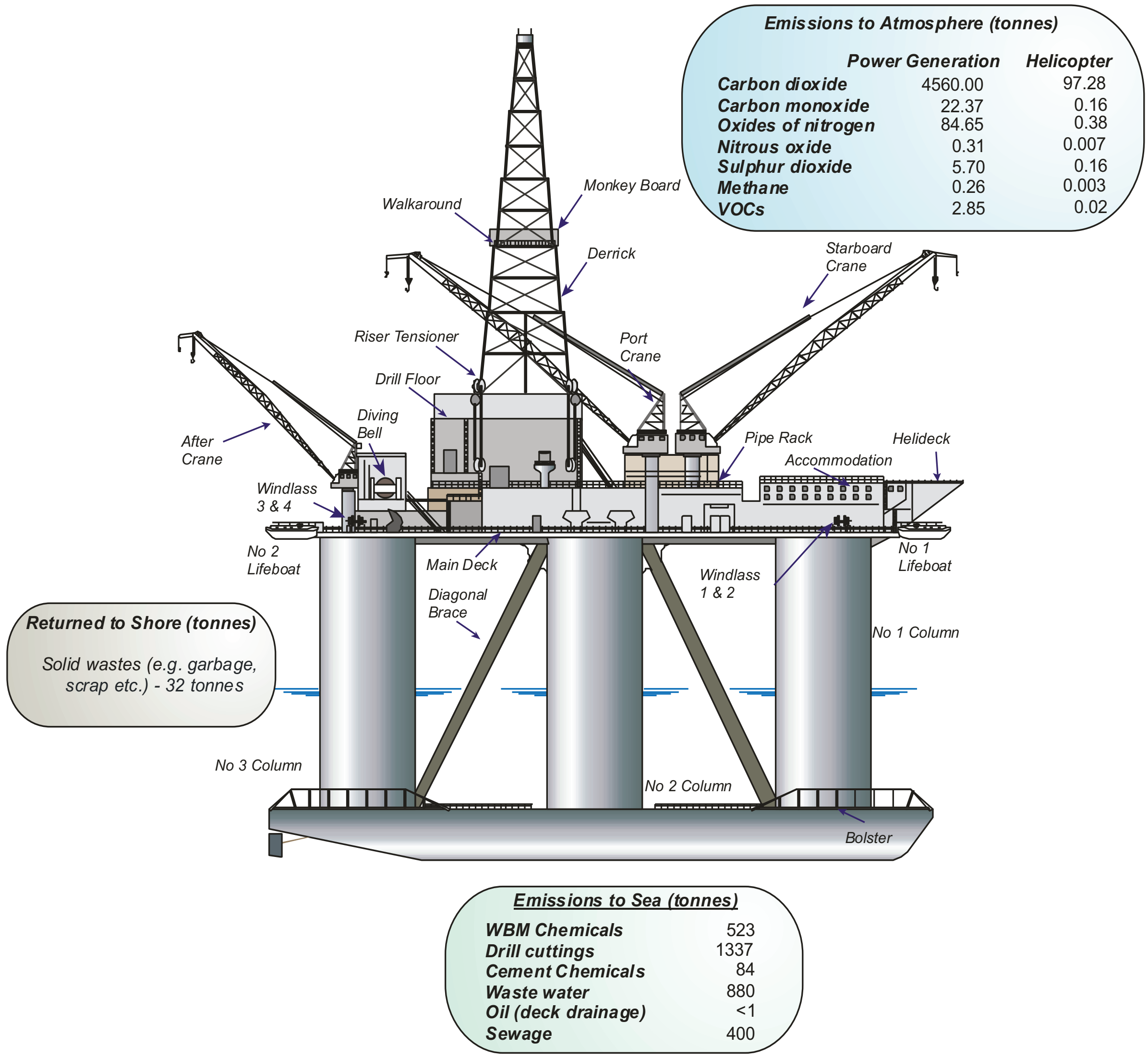


Figure 4.6 Emissions Summary for Darwin East Well

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5 Existing Environment

5.1 Introduction

This section describes the key physical, biological and socio-economic values of the marine environment within and adjacent to the proposed drilling locations. Where required, details of coastal, inter-tidal and terrestrial resources relevant to the proposed operations have also been included.

Data has primarily been sourced from:

- Desktop literature review – including publicly available material on websites and previous EIA's submitted for the region;
- Falkland Islands Environmental Baseline Surveys, 1997 and 2004;
- Benthic Survey, 2008;
- State of the Environment Report, 2008;
- Joint Nature Conservation Committee (JNCC) and Falklands Conservation publications;
- Consultation with relevant FIG authorities.

In addition, in order to gain more site specific information, Borders & Southern commissioned Benthic Solutions Limited to conduct an environmental survey in the prospective drilling areas. The survey methodology is summarised below and the full survey report is provided in Appendix C. In addition, metocean data was also collected during 3D seismic acquisition programme of Borders & Southern Licence area between Nov 2007 and January 2008.

Environmental Survey Methodology

The field environmental survey was undertaken by Benthic Solutions Limited in November 2008 from the Chilean supply vessel MV *Luma,* mobilised from Punta Arenas in the Magellan Straits. The field acquisition was based upon a benthic sampling campaign and water quality profiling over a regional area of the Burdwood Bank and the South Falkland Basin.

During the survey samples were collected from 23 stations (Figure 5.1) to include four prospective target areas, including Darwin East (station 13) and Stebbing (between stations 6 and 7) wells. As water depths were expected to range from between 1200 and 2100metres, benthic sampling was undertaken using a large 0.25m2 box corer sampler constructed of stainless steel, whilst a second large grab sampler was used in the event of limited penetration (such as compacted sands) or if insufficient surface material was recovered by the corer. Both devices were designed to completely enclose the sample on recovery and provide inspection/sub-sampling access to the samples surface without disturbing the integrity of the sediment layering. Recovered material was processed onboard over a 500µm aperture using a *Wilson Auto-siever*, or were sub-sampled for physico-chemical determination after the sample had been described and photographed.

For each of the 23 proposed sample locations, three separate sub-samples were acquired, two of these were analysed for sediment macrofauna and one for physico-chemical determination. All recovered samples were assessed under strict quality control criteria prior to acceptance and subsequent processing. On recovery, with the exception of sediment biology, all samples were immediately frozen and stored (< -18^{o}C) for later transportation (frozen) to the proposed laboratory, or for storage on demobilisation. This material was to remain frozen during transportation back to the analytical laboratories. The following physico-chemical analyses were undertaken:

- Full Particle size distribution (phi scale, includes the <63µm fraction);
- Total organic matter (by loss on ignition);
- Total organic carbon and carbonates;
- Total petroleum hydrocarbons (TPH) by GC-FID;
- Saturate hydrocarbons (nC10 – nC35) by GC-FID;

- Polycyclic aromatic hydrocarbons (2-6 ring & alkyl derivatives);
- Heavy & trace metals (double analysis following both aqua regia and HF digest by ICP or AAS for Ba, Cd, Cr, As, Cu, Ni, Zn, V, Pb, Al, Fe, Sr) and Hg (by cold vapour or ICPMS).
- Duplicate or triplicate Macrofaunal determination (over 500µm)

As nothing was known of the surface geology in the region and some concerns remained over the stability of the superficial substrates, particularly if carbonate oozes were encountered, an additional 3 metre gravity corer was taken to provide additional geotechnical samples at 6 locations.

Two or three replicate water quality profiles were also undertaken down to full depth within the geographical extremes of the survey area. Water profiles were collected using a continuous reading water quality profiler or CTD depth rated to 3000m. This was fitted with sensors to obtain and record measurements throughout the water column from sea surface down to the seabed.

5.1.1 Geography

The proposed exploration wells are situated in the South Atlantic Ocean approximately 150 kilometres to the south of the Falkland Islands (refer to Figure 1.1). The distance to the closest landfall (Beauchene Island (the national protected site)) is 80 km and 115 km from Darwin West and Stebbing, respectively.

The Falkland Islands are an archipelago of approximately 700 islands in the South Atlantic, the largest of which are East Falklands and West Falklands. Situated some 770 kilometres north-east of Cape Horn and 480 kilometres from the

The South Falkland Basin is located immediately nearest point on the South American mainland, the Falklands have a total land area of 12,173 km^2 and a permanent population of around 2,900 (*FCO, 2007*).

Regional Geology and Bathymetry south of the Falkland Islands and is bounded by the Malvinas Basin to the west, the Falkland Plateaux to the east and the Burdwood Bank to the south. The continental margin to the south of the Falkland Islands developed as a passive coastal margin bordering the developing Weddell sea during the late Jurassic and continued in this plate setting for much of the Cretaceous. During the late Cretaceous and early Tertiary plate movements that had initially created the Andean orogeny caused the subduction of the western Weddell oceanic plate, loading the continental plate to the south of the Falkland Islands. Loading created a foreland basin that was filled with sediments from both the emergent Falkland Islands and the developing thrust front. The northward movement of the Burdwood Bank initiated the inversion of the foreland basin creating a series of prograding north-vergent stack of blind and emergent thrusts seen along the southern margin of the South Falkland Basin (Figure 5.2).

The Falkland Islands themselves comprise of a series of Pre-Cambrian to Permo- Carboniferous aged rocks. Traversing south across the continental margin these 'basement' sequences can be seen to subcrop the seabed until onlapped by the late Jurassic and Cretaceous passive margin sequences (Figure 5.1). Downdip these extensional passive margin sequences are buried beneath a prograding wedge of Tertiary sediments that unfilled the developing foreland basin. Moving further south the tectonic front that marks the northern progress of the thrust sheets is expressed by a series of north-vergent stack of blind and emergent thrusts. The thrust front forms a series of elongate east-west oriented thrust tip anticlines. The magnitude of the uplift increases to the south stepping the seabed up from the foreland deep to eventually plateaux at the Burdwood Bank were the seabed shallows to just 200m. The water depths in the proposed drilling area vary between 1200 m and 2100 m (Figure 5.1).

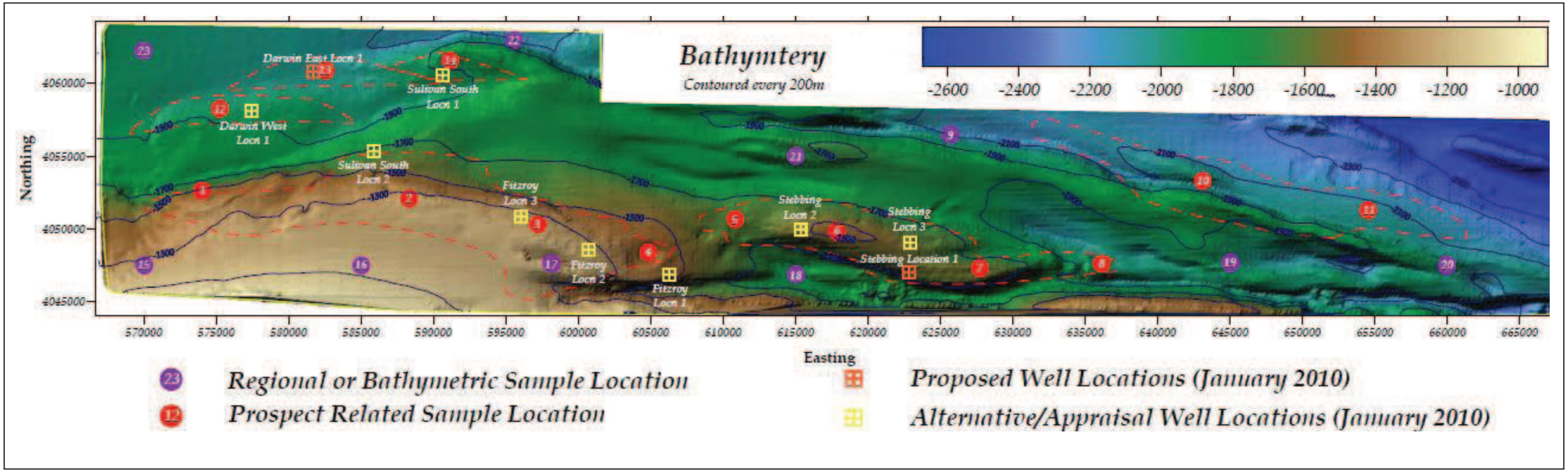


Figure 5.1 *Regional Bathymetry and Sampling Stations (Benthic Solutions, 2009)*

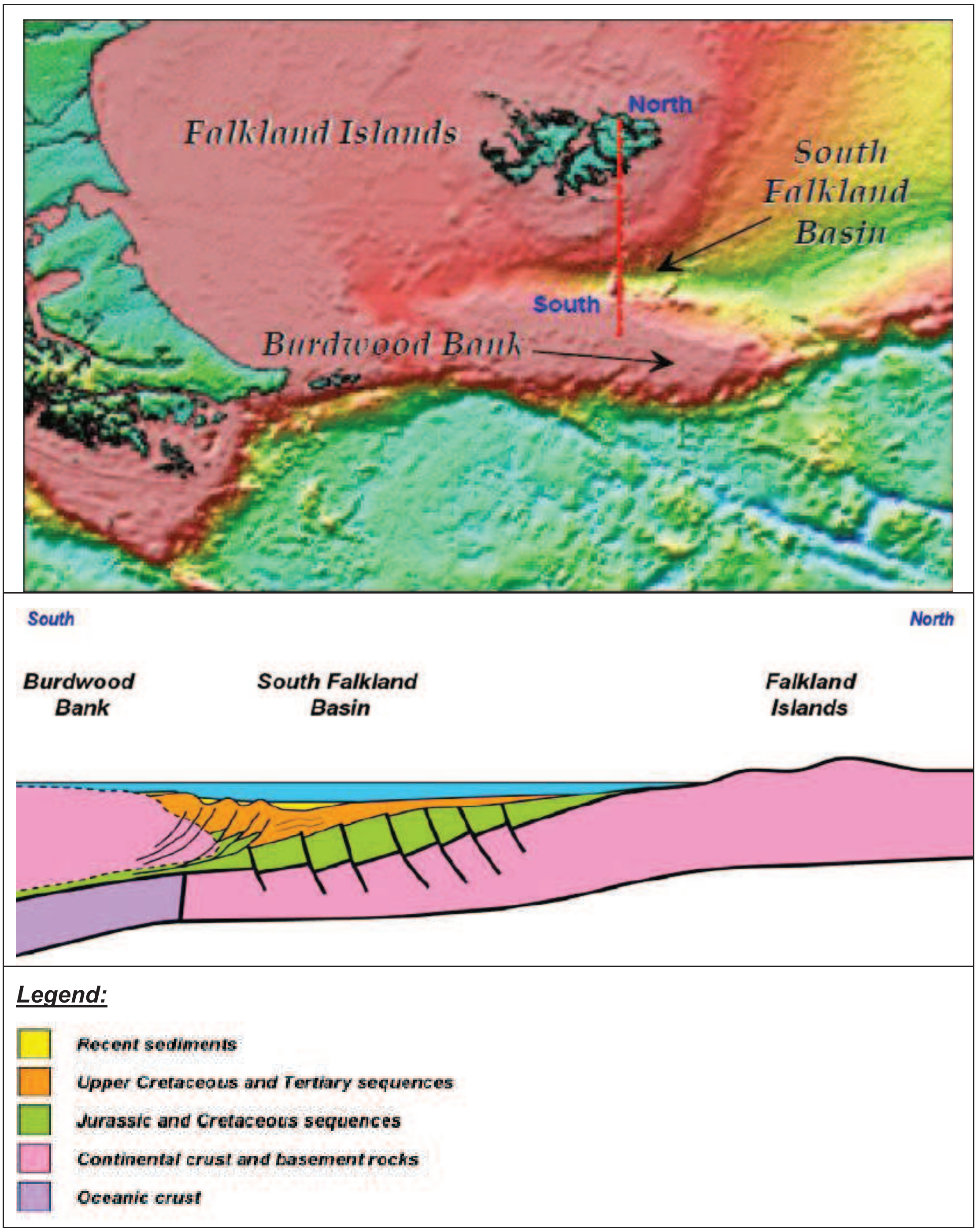


Figure 5.2 Regional Bathymetry and Geology of the South Falklands Basin (Benthic Solutions, 2009)

The inversion of the foreland basin in the south has led to the development of vast elongate thrust tip anticlines. The uplift led to subsequent erosion of sediments from the crest of the anticlines. The seabed in the south is therefore comprised of exposed older Tertiary sequences along the anticline crests and younger more recent eroded sediments in the troughs Further south across the Burdwood Bank it is anticipated that Cretaceous sequences subcrop the seabed. Moving northwards away from the thrusts the seabed represents the undeformed forland basin filled with the more recent sediment detritus. Seismic character of the sediments indicates that sediment infill is derived mostly from erosion of the hinterlands. Significant thrusting and uplift is thought to have ceased around 5 – 10 million years ago. The lack of sediment drape over the undulating seabed topography either indicates low pelagic productivity or sufficient water column movement to prevent pelagic sediment accumulation.

Borders and Southern acreage occupies the area between the northern boundary of the Burdwood Bank and the undeformed foreland basin. The proposed Stebbing well is located within the undulating seabed topography formed by thrust cored anticlines. Darwin East is located on relatively flat seabed areas above the undeformed foreland basin. These geological features can clearly be seen in a geographical representation of the regional bathymetry shown as an isometric view from the north (Figure 5.3).

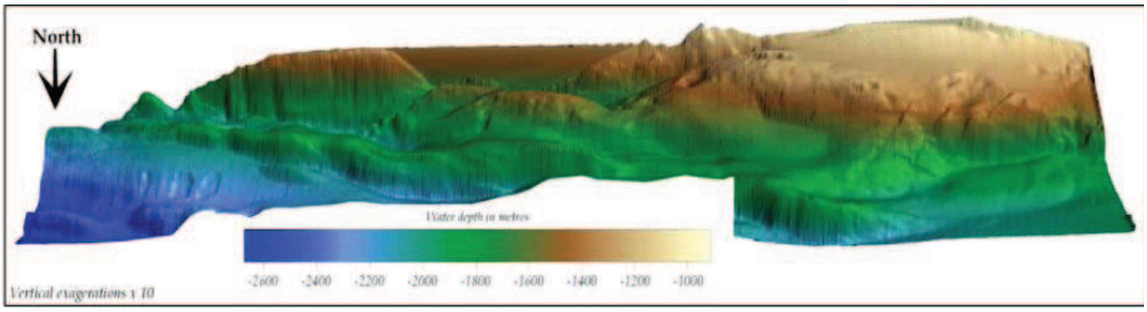


Figure 5.3 Isometric View of Bathymetry at Burdwood Bank Regional Survey Area (Benthic Solutions, 2009)

Currently, there have been no sampling operations carried out in this area, with all previous survey activities limited to the North Falkland Basin (*Gardline, 1998 a-f; BSL, 2008*). Neighbouring BHP Petroleum's blocks to the northwest of the Burdwood Bank area were recently surveyed using a combination of broad acoustic (swathe bathymetry), seabed sampling and some minor seabed video (acquired at two sites using ROV; *FSL 2009a-d*).

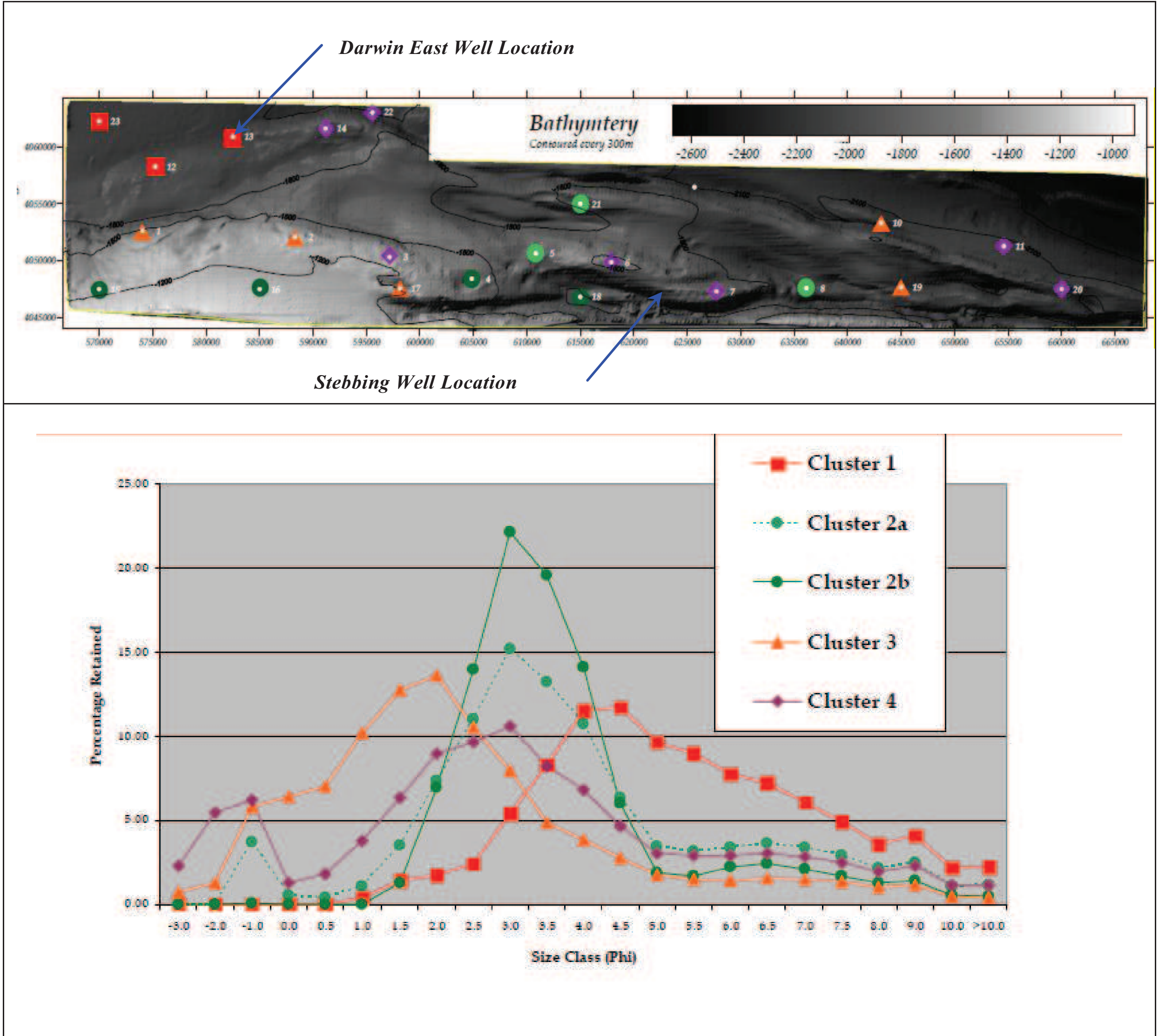
5.1.2 Seabed Sediments

The results of benthic survey indicated that seabed within the regional survey area showed considerable variability in sediment distributions relative to location on the Burdwood Bank or within the South Falkland Basin. The sediments ranged from sandy silts in the northwest to silty gravely sands and occasional bedrock exposure. Samples collected at Darwin East well location indicated the predominance of sandy silts, whereas at the Stebbing well slightly silty gravelly fine sands were predominant (Figure 5.4).

Granulometry

Further to assessing the proportion of sediment size extremes (i.e. gravels and fines), the full distribution of all samples were broken down into size classes at half phi intervals and compared to each other using a multivariate analysis to identify similarities between sediment types. Multivariate analyses were undertaken using the Plymouth Routines in Multivariate Ecological Research (PRIMER). Data for the percentage composition within each size class were clustered into a similarity matrix using a Bray Curtis similarity measure (*Benthic Solutions, 2009*). These data separate the sediments into 5 clusters, two of which can be considered to be sub-clusters of cluster 2. These are described further below and presented as size class distributions in Figure 5.4.

The most distinct particle size distribution (Cluster I) was exhibited at 3 of the 22 stations analysed, clustering at a 92% similarity. The mean distribution for all of these sites (presented as a red line/square in Figure 5.4) are classed as silty sands and exhibited a finely skewed distribution around fine sands and coarse silts, with some clays (12%) and minimal sediments above medium sands (3.5%). These stations (including Darwin East well location) all relate to a sedimentary regime typical of the low energy environment found within the western end of the South Falkland Basin.



Legend:

- PSA Cluster 1 (Sandy silts)
- PSA Cluster 2a (Slightly gravely silty sands)
- PSA Cluster 2b (Silty sands)
- PSA Cluster 3 (Slightly silty gravely coarse sands)
- PSA Cluster 4 (Slightly silty gravelly fine sands)

Figure 5.4 Distribution of Grouped Stations Based on Particle Size Distributions (separated at the 80% similarity level using Bray Curtis (Benthic Solutions, 2009)

Cluster 2 is separated into two further sub-clusters containing 3 and 4 stations respectively. Both sub-clusters show a similar normal distribution around fine sand, although the level of sorting in the silty sands of sub-cluster 2b (dark green line/ circle in Figure 5.3) is significantly higher than the slightly gravely silty sands of sub-cluster 2a (light green dotted line/circle). As a consequence the proportions of the outer size classes, such as coarse sands (> 500µm) and silts and clays (<63µm) decreases from 5.8 and 33% in Cluster 2a, to 0.1% and 21.8% for Cluster 2b, respectively. Cluster 2 is located through the central part of the area, with sub-cluster 2b stations positioned in the slightly shallower part of the bank where the sediments are better reworked by the prevailing currents.

Clusters III and IV, are represented by spatially more disparate sites within the area and reflect the variable levels of heterogeneity exhibited by the sediments throughout the survey area. Both are representative of slightly silty gravely sands. Cluster III, represented by 5 sites, showed very poorly sorted sediments peaking around medium sand (250µm), but with significant proportions of coarser sands and gravels (31.5%) and moderate silts and clays (20.9%). Cluster IV, represented by 7 sites (close to Stebbing well location), showed a similar shaped distribution to cluster III but centred on fine sand (125µm). As a result the proportion of sediments above coarser sands was markedly lower (14.8%), whilst silts and clays were marginally higher (28.4%). These clusters are respectively represented by an orange line/triangle, or purple line/diamond on Figure 5.4. Geographically, there appears to be no real pattern of distribution reflecting the variability of localised sediment conditions throughout the main part of the survey area.

The overall granulometric results of this survey showed a significant variability in the sediment habitats north of the Burdwood Bank. Whilst the presence of glacial deposits over the surface sediments would indicate a low depositional regime for much of the area since the end of the Pleistocene, the uneven coverage and grading of much of these coarser fractions would suggest that localised surface sediments may remain quite variable and subject to ongoing oceanographic influences. Sites located in the northwest of the surface area indicated a notably finer sedimentary habitat indicative of a lower energy regime in the western end of the South Falkland Basin. This is different for the field observations made at station 9 (in the eastern end of this basin), which indicated the presence of stiff clays at the surface with no overlying Holocene material. This would indicate an eroded surface and a more a significantly more rigorous boundary hydrodynamic. Station 17, located in area of slight bathymetric variability, indicating the presence of surface cropping bedrock.

The variability of these sediments at the Burdwood Bank is comparable to results from similar surveys carried out by BHP Petroleum along the length of the east Falkland continental margin (*FSL, 2009a-d*), but covering a much larger survey area.

Significant variations within the sediment granulometry have had a marked impact on the chemical but only partial impact on the biological components recorded within the sediments. As such, particle size parameters are the most dominant, statistically correlating with a significant number of other environmental factors including several metals and many organic components (in particular the PAHs and allkanes) often at the 99% confidence level (Pearsons' $P<0.01$). Many of these correlations will be an artefact of auto-correlation against key parameters, with the mean & median particle sizes, %fines, silts and clays and sorting coefficient being the most dominant.

Total Organic Matter, Organic Carbon and Carbonates

The level of total organic matter (TOM) was consistent ranging from 2.52 to 4.58% (mean 3.5%, SD 0.61). Spatially, the samples showed only a weak pattern of distribution relating to slightly higher concentrations in the northwest region. This would normally be associated with the increased proportion of sediment fines in this area (as indicative of greater sedimentation), although this parameter did not statistically correlate with this fraction in the granulometry. In fact, TOM only weakly correlated with the metals copper, iron and nickel, water depth and sediment sorting. This latter correlation is due to the fact that organic matter is predominantly related to the rate of sedimentation (detrital rain), with lower concentrations expected in the shallower sandier areas where surface sediments indicate some mobility and increased sediment sorting ($P<0.05$).

The overall level of TOM, however was low when compared to other studies in a similar depth and sediment type. Examples to the northeast are the sandy silts of Toroa at 6.0% (*FSL, 2009a*), or the mixed gravely sands at Loligo 5.3% (*FSL, 2009c*). Areas with lower TOM values were the shallower reworked sands recorded on the north Falkland Continental Shelf, at only 1.66% (*BSL, 200*8), or 1.3%, recorded at a similar continental margin, recorded in the northern hemisphere (by the Atlantic Frontier Environmental Network in the Northeast Atlantic).

In addition to total organic matter, the sediments were also analysed for total organic carbon and inorganic carbon (i.e. carbonates). The total mean values exhibited proportions of 0.31 and 2.06%, respectively. TOC represented around 9.1% of all organics present, a similar level to that recorded at other sites in the east Falkland Continental margin (5.1-8.1%; *FSL, 2009a & c*), but notably lower than that recorded on the north Falkland Continental Shelf (28.1%; *BSL, 2008*). Overall, this level remained relatively consistent, which statistically correlated to the proportion of sediments fines (silts, clays and mean size, $P<0.01$).

The proportion of carbonates were not recorded elsewhere in the east Falkland Continental margin, but averaged around 0.56% on the north Falklands Continental Shelf (*BSL, 2008*). As the current study is notably higher, these results would suggest a background influence from inorganic carbonate material, probably related to shell, and the tests of zooplankton and benthic organisms. The highest level of carbonates recorded at 3.73% was recorded at station 2, which indicated the reworked sediment (possible contourite) of biogenic material including broken shell, and sea urchin spines.

Overall, the presence of pelagic sediments from the deposition of planktonic materials (flocculants and detrital rain) is relatively low, with sediments indicative of granular reworked materils, predominantly sands and glacio-marine gravels. This is indicative of an erosional (or certainly non-depositional) hydrosdynamic regime across the survey area. This will prevent the natural formation of calcareous or silaceous oozes by the deposition of detrial skeletal material from the water column (foraminifera and coccolithophores, or diatoms respectively), commonly found in deep water sediments where the primary productivity of the overlying water mass is expected to be high.

Hydrocarbons

The total hydrocarbons (THC) concentrations of the sediments, measured by integration of all non-polarised components within the GC trace, showed moderate background concentrations at most sites sampled ranging from 6.4 to 24.1µg.g-1 (ppm). The mean for the whole survey area was 12.8µg.g-1 (SD 5). These levels are moderately high, and well above the range expected for uncontaminated similar sediments in the Northeast Atlantic (ca. 2.9µg.g-1; *AFEN 2000*). These can also be compared to sediments means from sites along the East Falkland Continental Margin (*FSL, 2009a & c*) and from the North Falkland Continental Shelf (*BSL, 2008*). In the former, the shallow sandy substrates indicated a mean background THC of 4.3µg.g-1, whilst the closer neighbouring sites of Toroa and Loligo, 75 to 380km northeast of the current site, indicated mean THC concentrations of 8.7 and 3.0µg.g-1, respectively (*FSL, 2009a & c*).

Within the survey area, the levels of total hydrocarbons indicated a pattern of distribution, where elevated levels were recorded to the west of the site, predominantly to the northwest. This pattern is partially due to a significant correlation with the sediment fines, which showed an association with the mean sediment size and clays, and in particular of silts (2-63µm, $P<0.001$). This is a common relationship as hydrocarbons are deposited into the sediments via a natural pelagic sedimentation process and will be found in higher concentrations where fines are allowed to settle to the seabed.

Detailed analysis of the data has clearly identified the presence of both biogenic and thermogenic hydrocarbon material.

Hydrocarbon data recovered from the current survey has been also compared to similar results acquired by BHP Billiton along the East Falkland Margin (refer to Appendix C). Regional concentrations of Total Hydrocarbons and Total Polycyclic Aromatic Hydrocarbons (PAHs) clearly show an increased concentration in the survey area, with marginal elevations at the Toroa survey. The regional distribution pattern could either results from a plume of material emanating from west of the South Falkland Basin, being carried along the prevailing Malvinas current, or more likely represent the regional distribution of a viable source interval with associated natural hydrocarbon seeps.

Heavy/Trace Metals

Of the metals analysed, the crustal or matrix metals aluminium and iron indicated significantly high and slightly variable concentrations with means of 40.8 and 58.0 mg.g-1, respectively. These levels reflect the naturally high level of these residual metals in the sediment of this region. This variability indicated a weak pattern of distribution, with elevated levels within the more granular sediment towards the east. Both Al and Fe indicating similar variability at other sites around the Falklands, the mean concentration for iron at Loligo was 110mg.g-1, for example (*FSL, 2009c*).

Barium remains the most abundant metal found in drilling related discharges due to its use as a weighting agent within the drilling mud program in the form of barite ($BaSO_4$). Consequently, it is often used as an indicator to the effects of drilling related discharges. For this baseline survey, natural barium levels remained relatively high and variable throughout the area ranging from 265µg.g-1 to 2,420µg.g-1 (mean 782µg.g-1), with no obvious pattern of distributions. This variability reflects the natural changes in concentrations relative to the natural sediment changes at these locations, the majority of which (89.2%) remaining soluble to a weaker acid digestion and available to the marine fauna. This high percentage is slightly unusual as Barium, a matrix bound metal, is generally found in an insoluble sulphate form, considered as non-toxic (*Gerrard et al, 1999*) and is rarely of toxicological concern. Overall results in the current survey are marginally higher than those recorded at the neighbouring sites at 236, 329 and 407µg.g-1, for the North Falkland Continental Shelf, Loligo and Toroa, respectively (*BSL, 2008 & FSL, 2009a & c*).

Strontium is a similar metal to barium as is also often associated with drilling related discharges. Here, natural levels were slightly less variable, and no pattern of distribution recorded, correlating only weakly with carbonates ($P<0.05$). Overall, total levels ranged from 102 to 479 µg.g-1 (mean 281µg.g-1), with around 80% soluble to the weaker extraction method.

The concentration of lead was also low, but slightly variable (mean 9µg.g-1 (SD 3.1). This was marginally higher than previously recorded at neighbouring sites (ranging from 5.8 to 6.7 µg.g-1), but exhibited a slightly weak pattern of distribution correlating with zinc and several of the hydrocarbon components (PAH, NPD and total hydrocarbons).

Other metals that showed correlations with different environmental parameters were copper and nickel, although these showed opposite distributions. Copper, which had a total mean of 14.6µg.g-1 (SD 2.9), showed a strong correlation with the finer sediments, sorting and TOM. Nickel, with a mean of 8.4µg.g-1 (SD 1.4), however, correlated with the proportion of gravels, mean size and TOM. In both cases, overall concentrations were generally low and within the range recorded at neighbouring sites around the Falklands.

All of the remaining metals analysed show generally low level concentrations expected for an uncontaminated offshore environment. Both mercury (Hg) and cadmium (Cd) remained at, or below detectable limits for the tests. Chromium (Cr) ranged from 32.1 to 61 µg.g-1 (mean 44.3µg.g-1) and within the range previously recorded in the Falklands 25.8 to 139µg.g-1 (*BSL, 2008*). The last remaining metal of vanadium (V) remained relatively consistent around a mean of 59.3 (SD 7.3), and was marginally higher than previously recorded in the north Falklands Continental Shelf 28.9 to 49µg.g-1.

When comparing the key elements with those of the OSPAR background reference concentrations (BRCs) values, the seven key metals cadmium, chromium, copper, mercury, nickel, lead and zinc all gave concentrations below OSPAR BRCs with the exception of cadmium which could not be determined to a low enough resolution.

5.1.3 Oceanography

Water Circulation and Tidal Currents

The Falklands lie to the north of the Antarctic Polar Front or Antarctic Convergence, where cool surface waters to the south meet warmer surface waters from the north. The Antarctic Polar Front (APF) is ecologically important (*Munro, 2004*) and occurs between 50°S and 60°S (*Laws, 1984*).

The Antarctic Circumpolar Current intensifies and deviates northwards as it flows around Cape Horn, and splits to either side of the Falkland Islands (Figure 5.5). The 'Patagonian' or 'West Falklands Current' flows north on the west side of the Falklands, whereas the stronger East Falklands current runs north, then swings west to re-converge with the 'West Falklands Current', continuing northwards in a 100 km wide band towards the warm south flowing Brazil Current (*Munro, 2004; Glorioso & Flather, 1995*).

Average diverging current speeds are less than 25 cm/s (0.5 knots) to the west and 25–50 cm/s (0.5–1 knots) to the east of the Falklands (*Hydrographer of the Navy, 1993*). Tidal cycles around the Falkland Islands are semi-diurnal (twice daily), with tides ranging from 0.3–3.5 m above local datum (*Brown & Root, 1997*).

The 1997 Proudman Oceanographic Laboratory current model for the Patagonian Shelf area showed the Falklands Current at depths below 200 metres flowing north, closely following the shape of the Continental Shelf slope. In the shallower water, closer to the Falklands, residual current flow is negligible and water movement is dominated by tidal flows.

From 5th November 2007 to the 31st January 2008, metocean data was collected during 3D seismic survey carried out by Borders & Southern in their prospective licence area. The summary of current speed and direction is presented in Figures 5.6-5.7. The maximum and average current speeds observed near the sea surface were 1 knot and the 0.34 knot, respectively, and predominant direction of the currents was north-easterly.

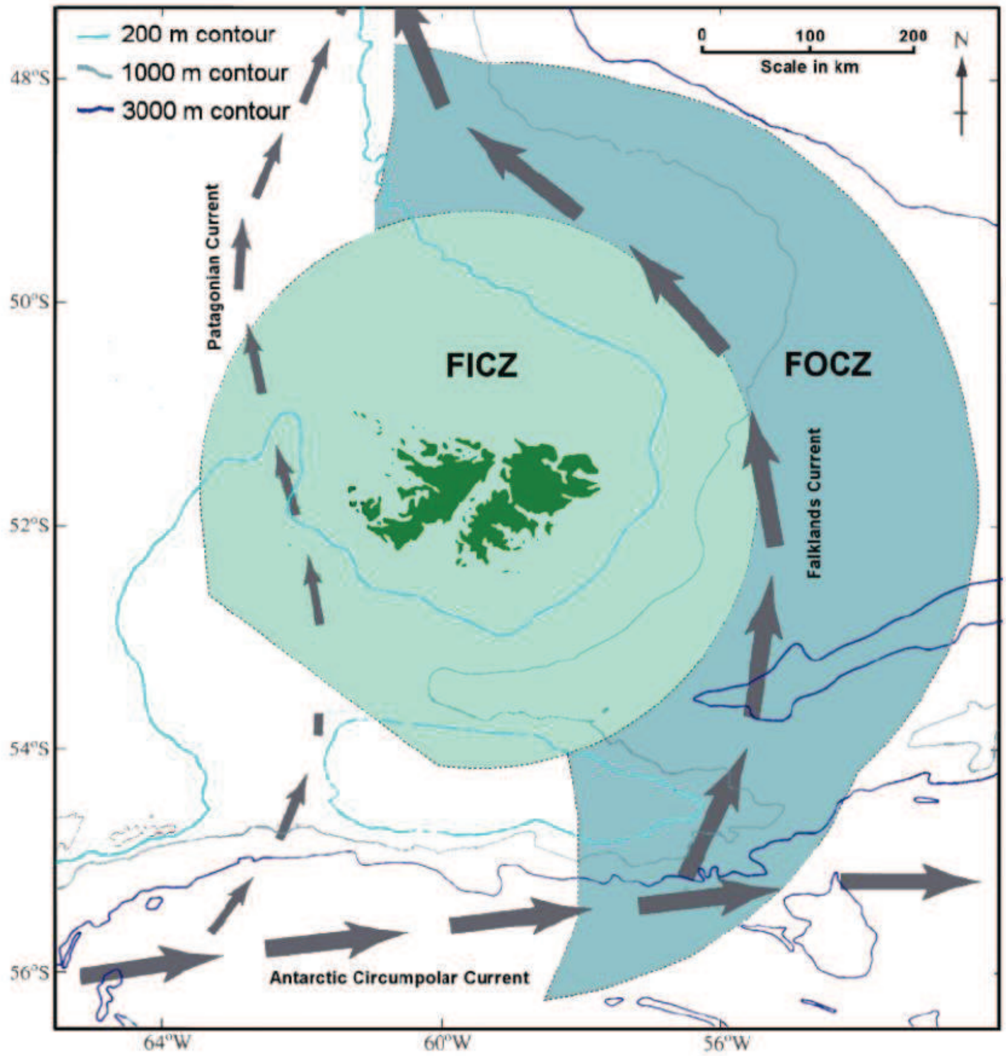


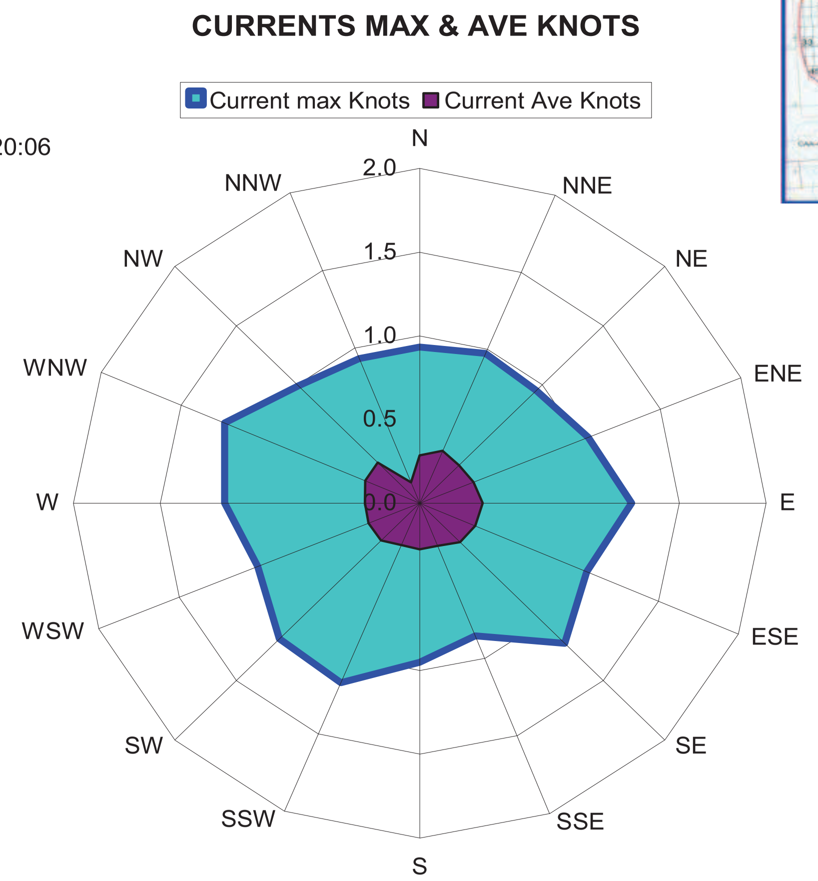
Figure 5.5 Falkland Islands' Conservation Zones (Inner and Outer) Plus Major Currents and Water Depths

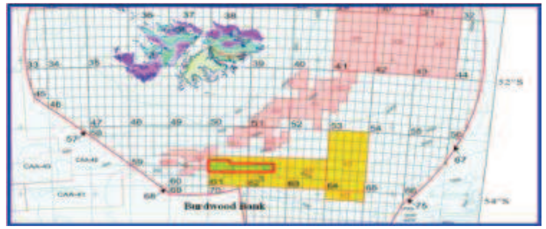
Waves

Winds can generate rough sea conditions with waves of variable direction and height.

Metrological frequency analysis data has been acquired from the UK Met Office for the area 48S to 54S and 62W to 53W. This data provides a breakdown of wave height and direction by month for the period 1978 to 2007. The figures have been averaged over this period to provide annual wave exceedance for the area encompassing the licence blocks (Figure 5.8). Maximum wave heights in the vicinity of the proposed drilling locations are in the region of 2 to 3 metres. The direction of wave approach was predominantly west to south-west.

The wave data recorded during the 3D seismic survey (Nov 2007 to Feb 2008) shows similar trend (Figure 5.8). A more energetic wave environment is be expected between June and September, corresponding to the Southern Hemisphere winter.

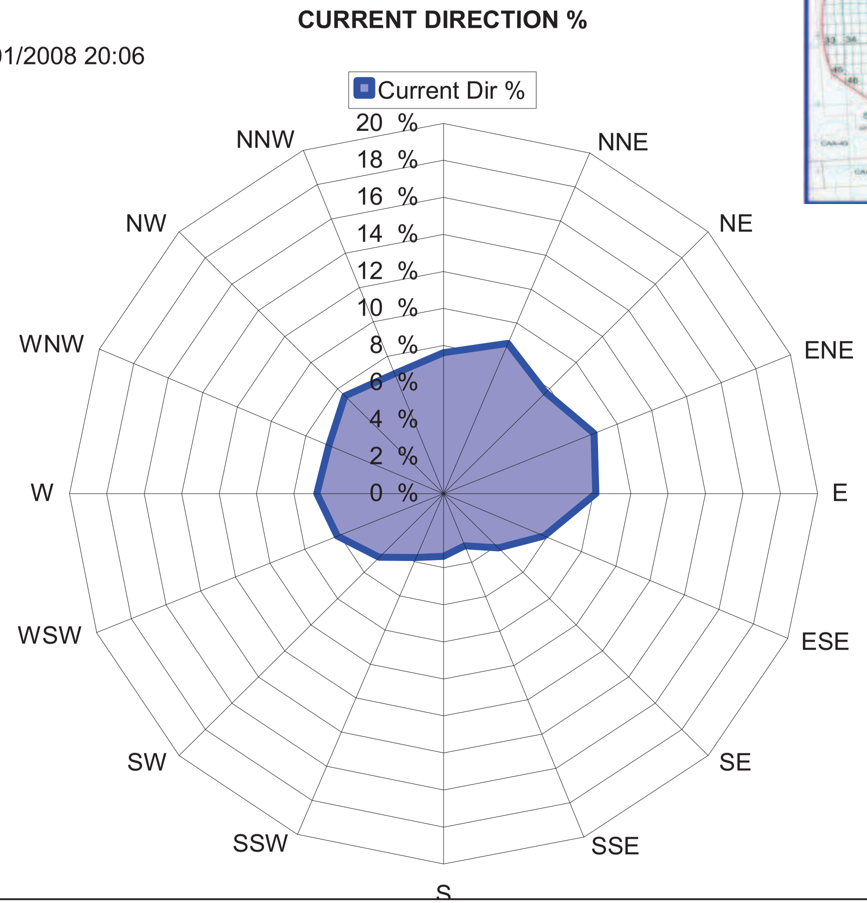


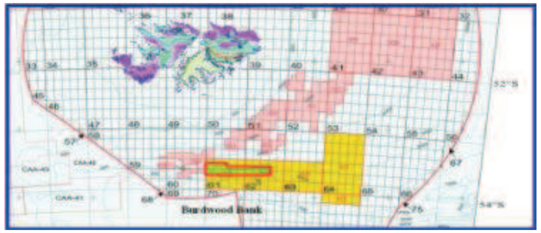


		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
Direction	**No Values**	3033	3512	3086	3459	3250	2334	1657	1215	1353	1497	1946	2445	2701	2659	2979	2783
Direction %	**% Values**	7.6	8.8	7.7	8.7	8.1	5.8	4.2	3.0	3.4	3.8	4.9	6.1	6.8	6.7	7.5	7.0
Dir Max Speed	**Max knots**	0.93	0.97	0.95	1.05	1.22	1.05	1.18	0.85	0.95	1.17	1.15	1.01	1.13	1.22	0.99	0.93
Dir Ave Speed	**Ave knots**	0.28	0.34	0.32	0.34	0.36	0.35	0.33	0.28	0.28	0.27	0.32	0.32	0.32	0.34	0.34	0.13

Figure 5.6 ***Current speed recorded within Borders & Southern Licence area during 3D seismic survey (Nov 2007to Jan 2008).***

05/11/2007 15:27 to 31/01/2008 20:06





		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
Direction	**No Values**	3033	3512	3086	3459	3250	2334	1657	1215	1353	1497	1946	2445	2701	2659	2979	2783
Direction %	**% Values**	7.6	8.8	7.7	8.7	8.1	5.8	4.2	3.0	3.4	3.8	4.9	6.1	6.8	6.7	7.5	7.0
Dir Max Speed	**Max knots**	0.93	0.97	0.95	1.05	1.22	1.05	1.18	0.85	0.95	1.17	1.15	1.01	1.13	1.22	0.99	0.93
Dir Ave Speed	**Ave knots**	0.28	0.34	0.32	0.34	0.36	0.35	0.33	0.28	0.28	0.27	0.32	0.32	0.32	0.34	0.34	0.13

Figure 5.7 Current direction recorded within Borders & Southern Licence area during 3D seismic survey (Nov 2007to Jan 2008)

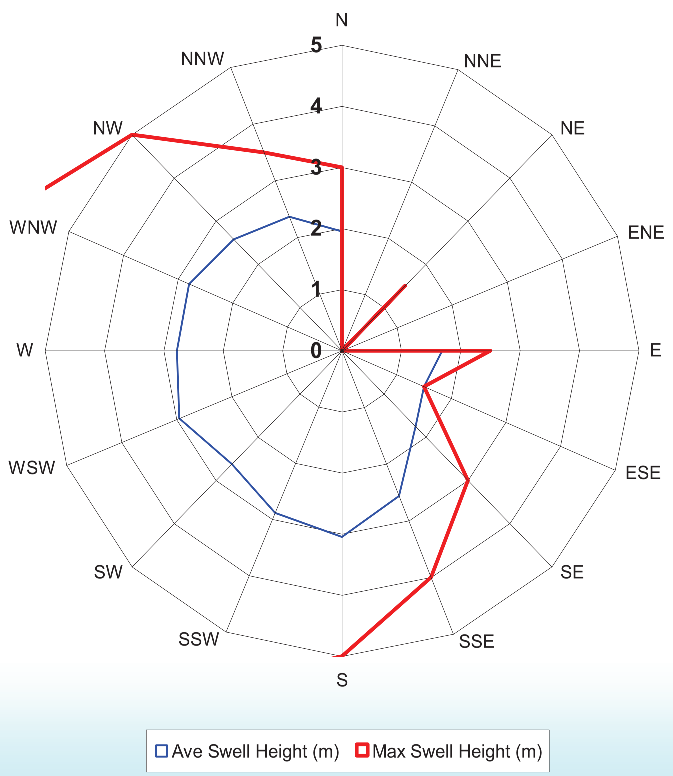


Figure 5.8 Wave height recorded within Borders & Southern Licence area during 3D seismic survey (Nov 2007-Feb2008).

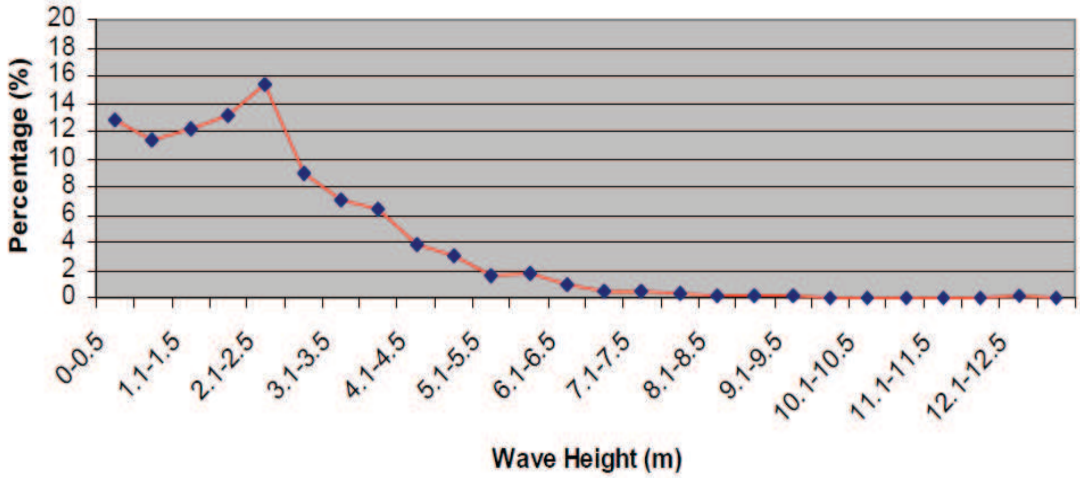


Figure 5.9 Annual Wave Exceedance, 48S to 54S and 62W to 53W (UK Met Office data from 1978 to 2007)

Water Column Characteristics

Water quality profiles were acquired during the environmental survey carried out by Benthic Solutions Limited on behalf of Borders & Southern (refer to section 5.1; *Benthic Solutions Limited, 2009*). The profiles were acquired at three locations (station 6 (near the proposed Stebbing well), station 13 (Darwin East well) and station 10; Figure 5.1). For each profile, data was acquired on both the decent and accent (down and upcast), with the variation in the two datasets indicative of the equilibration of the sensors. Raw data suggests that the system was deployed at a sufficient speed for the sensors to equilibrate to the change in ambient conditions.

Water column profiles are shown for the full depth of 2100 m (Figure 5.10) for all three profiles. All three profiles showed similar patterns even taking into account the shallower nature (by 600m) of the station 6, or the fact that stations 10 and 13 were at opposite ends of the survey area. Consequently, these results show that the physical characteristics of overlying water masses are homogeneous throughout the studied area.

The water profile results showed a consistent vertical structure within the water column with specific layering recorded at the following depths:

<u>Layer I Surface 20-40m:</u>

This is a typical density structure with solar heated water of between 6 and 7°C falling to 5.5°C. Surface salinity remained constant at around 34.1 practical salinity units (PSU: equivalent to parts per thousand). Surface Freshwater influences are minimal due to the lack of significant landmasses nearby and the consistent feed of residual current from the Southern Ocean, south and west of the survey area. As the survey was carried out in the spring period (November), the solar induced thermocline has yet to be fully developed. This is demonstrated by comparing results from the Loligo site taken 350km northeast, a month or so later, which showed a notably warmer surface layer.

<u>Layer II from 40m to around 100m</u>

This marks the base of the main surface thermocline and halocline. The temperature remains above 4.8°C, whilst the salinity indicated little or no change at around 34.1 to 34.15 psu. The base of this layer is marked by a rapid temperature change of approximately 1°C, and a slight rise in salinity to around 34.2 psu. A comparison with the Loliogo profiles taken slightly later into the summer, showed that the depth of this layer was also around 100m, but the layer itself merges directly into surface layer 1 as outlined above.

<u>Layer III from ~100m to the seabed</u>

The remainder of the water column indicates normal density structure with a slow entrainment of temperature from the warmer upper layers with that of the underlying water mass. Here the temperature and salinity changes by a constant rate decreasing from 4.6 to around 2.3°C and increasing from 34.2 to

34.7psu over the 1900m depth change. This water mass reflects the main flow of water from the Southern Ocean, flowing from the south and west, and is not expected to alter seasonally. This is partially supported by the profile from the Loligo project which indicated a similar temperature profile, although some fluctuations were recorded within this profile which are interpreted as an artefact of the sampling and the fact the profile was periodically halted to take water samples at selected depths. The Loligo salinity profile was also marginally higher throughout (0.4psu), although this may reflect a further artefact with a variation between the instruments used between the two studies.

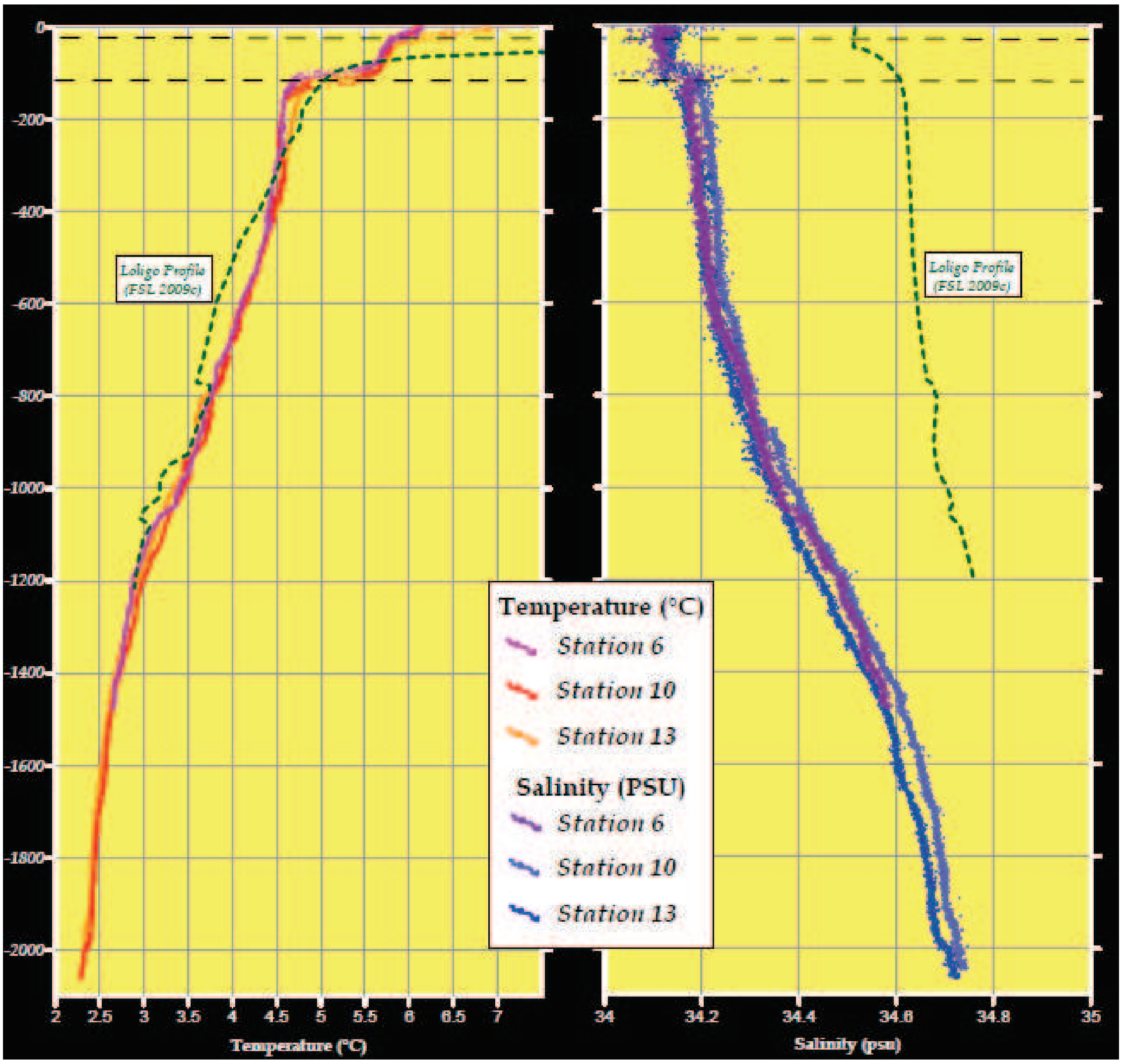


Figure 5.10 Water Column Profiles in the proposed drilling area as compared to Loligo site east of Falkland Islands (Benthic Solutions, 2009)

5.1.4 Meteorology

Meteorological data for offshore the Falkland Islands is sparse relative to other explored offshore areas, although the following available data has been reviewed:

- UK Meteorological Office data from vessel observations and weather station locations on the Islands;
- Baseline surveys, 1997 (Brown and Root) and 2004 (Falklands Conservation);
- Hydrographer of the Navy pilot information (1993);
- Published article in Aquatic Conservation Journal (Upton and Shaw, 2002);
- Site specific metocean data collected during 3D seismic survey by Borders & Southern.

The Falkland Islands have a cool temperate oceanic climate, dominated by westerly winds. As the Falklands lie to the north of the Antarctic Polar Front (APF) or Antarctic Convergence, where cool surface waters to the south meet warmer surface waters from the north, the climate is moderate preventing prolonged snow and ice cover (*Munro, 2004*). The region is exposed to an almost unbroken series of meteorological depressions and troughs that move across the area (*Hydrographer of the Navy, 1993*).

Temperature

The Falklands have a narrow terrestrial temperature range with mean annual maximum temperatures of approximately 10°C, mean annual minimum temperatures of approximately 3°C, and mean monthly ranges of between –5°C to 20°C (Figure 5.11). Temperatures over the open sea are less variable than on land.

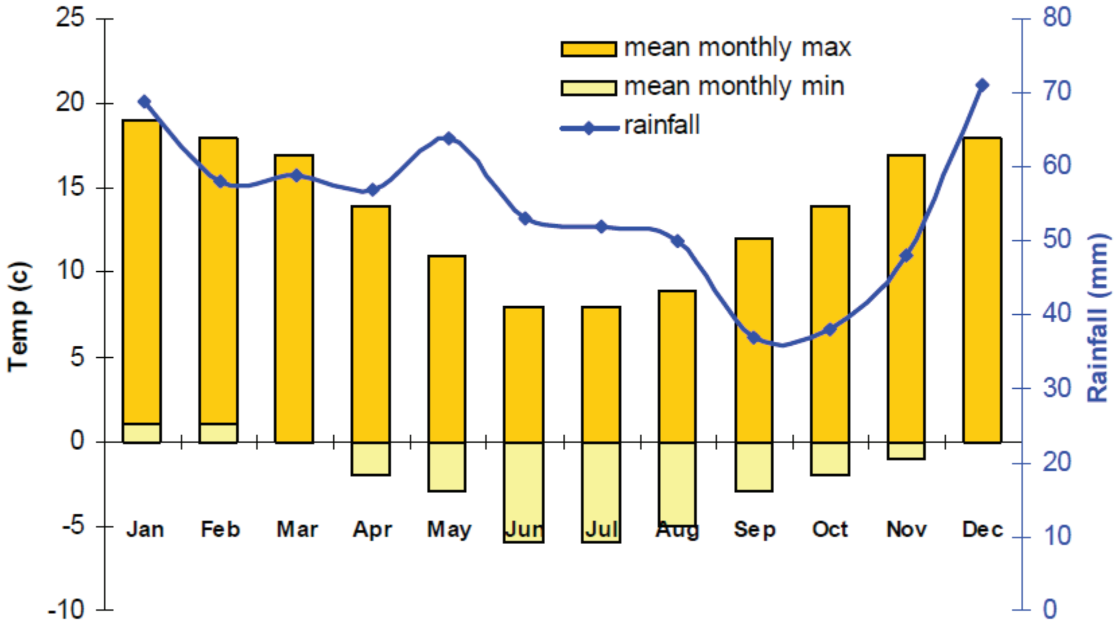


Figure 5.11 Climate averages for Stanley Harbour (UK Met Office data from 1978 to 2007)

Air temperature and atmospheric pressures recorded within the proposed drilling area during the 3D seismic survey (Nov-Feb) are presented in Figure 5.12. The average observed temperature was 7.5 ^{0}C (typical for summer season).

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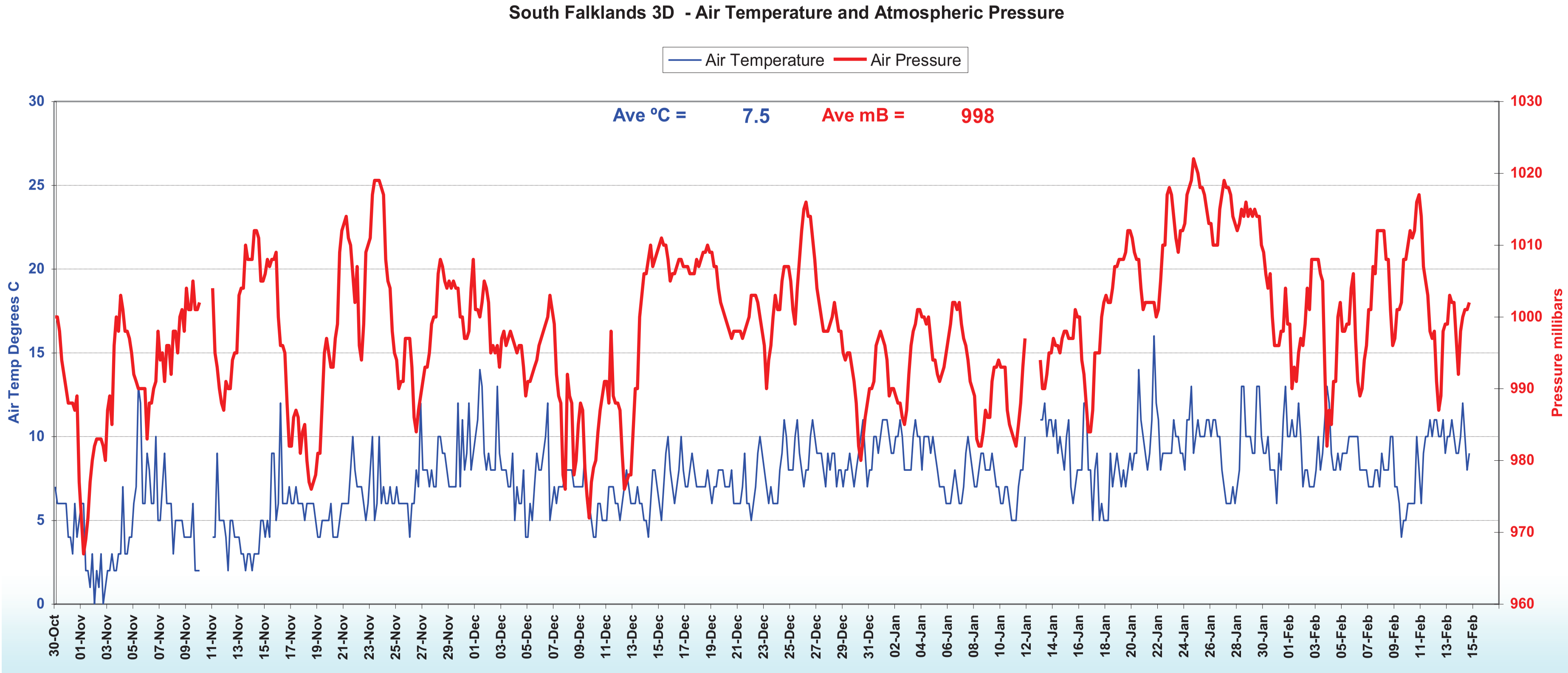


Figure 5.12 Air Temperature and atmospheric pressure recorded within Borders & Southern Licence area (Nov 2007to Feb 2008)

Precipitation

Figure 5.11 shows the average monthly rainfall for Stanley Harbour, the proposed supply base for offshore drilling operations. Average annual rainfall at Stanley is around 650 millimetres and average annual rainfall for the Falklands is low, but consistent. Due to their location in the lee of the South American continent the 'rain shadow' effect of the Andean cordillera is still prevalent (*Munro, 2004*).

The Falklands experience approximately 11 days of snow a year, most frequently in August. Weather conditions become more extreme further south, with the frequency of both violent storms and squalls increasing south of 50°S (*Hydrographer of the Navy, 1993*). There is no clear seasonal variation in atmospheric pressure with maximum pressures ranging between 1,003 and 1,035 millibars (*Upton and Shaw, 2002*).

Winds

Metrological frequency analysis data has been acquired from the UK Met Office for the area 48S to 54S and 62W to 53W. This data provides with wind speed and direction by month for the period 1978 to 2007. The figures have been averaged over this period to provide annual summaries of prevailing wind direction and annual for the area encompassing the licence blocks (Figure 5.13). It can be seen that winds predominantly range between 4 to 11 knots (Beaufort scale 4 to 5) or below. Strong gales and storms (Beaufort scale 7+) are rare in the area, but may occur in winter or from a westerly direction.

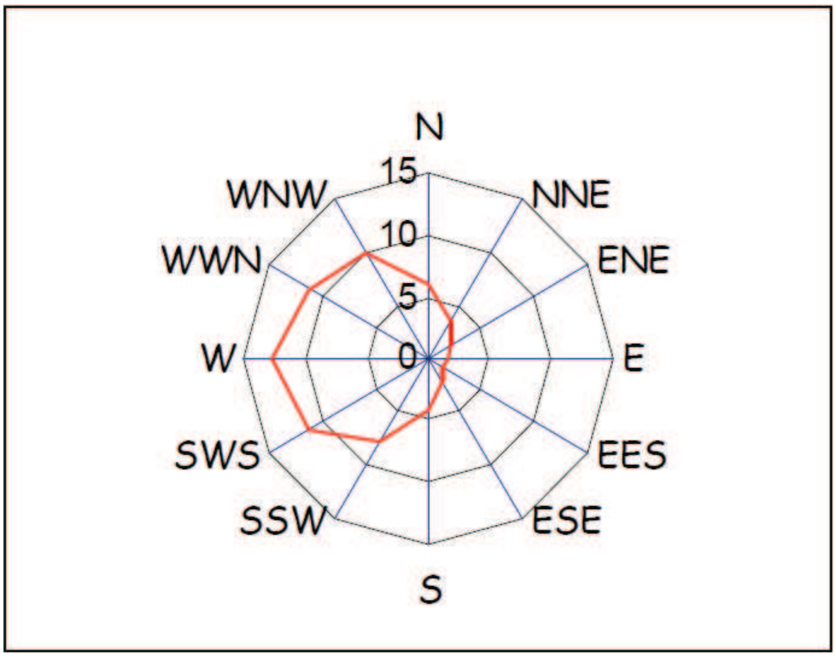


Figure 5.13 Annual Wind Speed (m/s) and Direction for the area 48S to 54S and 62W to 53W (UK Met Office data from 1978 to 2007)

Figure 5.14 provides the wind data for the months of Nov-Feb, which was recorded within the proposed drilling area during the 3D seismic survey.

Beaufort scale		Velocity	
Symbol	Name	Knots	m/sec
0	Calm	0-1	0 - 0,2
1	Light Air	1-3	0.3 - 1.5
2	Light Breeze	4-6	1.6 - 3.3
3	Gentle Breeze	7-10	3.4 - 5.4
4	Moderate Breeze	11-16	5.5 - 7.9
5	Fresh Breeze	17-21	8.0 - 10.7
6	Strong Breeze	22-27	10.8 - 13.8
7	Near Gale	28-33	13.9 - 17.1
8	Gale	34-40	17.2 - 20.7
9	Strong Gale	41-47	20.8 - 24.4
10	Storm	48-55	24.5 - 28.4
11	Violent Storm	56-63	28.5 - 32.6
12	Hurricane	64 ->	32.7 ->

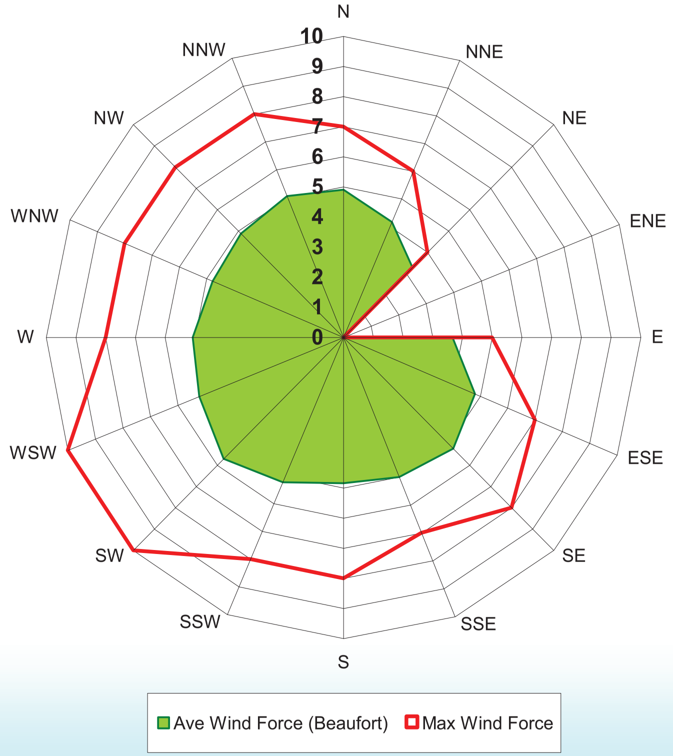


Figure 5.14 Wind force (Beaufort) and direction recorded within Borders & Southern Licence area (Nov 2007to Feb 2008)

5.1.5 Icebergs

A desktop assessment of icebergs in the Falklands (*Partington, 2006*) indicates that icebergs floating through the licence areas come from two sources – primary and secondary (Figure 5.15).

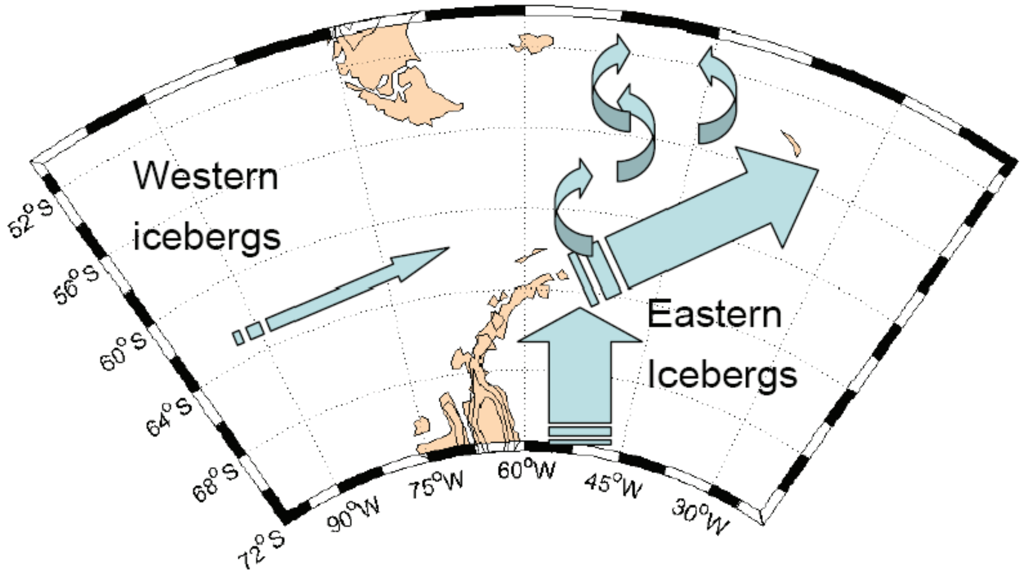


Figure 5.15 Sources and Movements of Icebergs in the Falklands Region

The primary source is known as the 'eastern' icebergs, which are transported along the western edge of the Weddell Sea and originate from east of the Antarctic Peninsula. All but one of the 70 large icebergs (>18.5 kilometres) north of 60°N and west of 40°W between 1992 and 2005 are classified as 'eastern' icebergs following an anti-clockwise route around the Antarctic. The majority of the icebergs (large and medium sized) following this route pass well to east of the Falkland Islands (outside of the licence areas). In late 2005, however, a stronger current from the south resulted in a greater quantity of icebergs entering the Falklands region.

The number of icebergs approaching the Falkland Islands is strongly influenced by the oceanographic conditions east of the Drake Passage, which in turn is likely to be influenced by the strength of the Antarctic Circumpolar Current and the positions of the oceanographic fronts converging in the Falklands region. The total number of icebergs being exported from Antarctica is believed to have less influence than the oceanographic conditions on the number of icebergs approaching the Falkland Islands (*Partington, 2006*).

The secondary source is the 'western' icebergs that are adverted north, away from the Antarctic coast predominantly in the Ross Sea and Bellingshausen Sea. The icebergs, drawn into the Antarctic Circumpolar Current, are transported through the Drake Passage to approach the Falklands from the south-west. In comparison, the secondary source is rare, with only one instance recorded in the large iceberg database out of 70. The Antarctic Circumpolar Current has rough weather conditions which are expected to lead to rapid disintegration of icebergs and modelling work by Gladstone et al. (2001) suggests that most icebergs disintegrate before reaching the Drake Passage.

The highest probability of icebergs is east of Falkland Islands and is nearer to the main export route for icebergs from the Antarctic. It is possible for icebergs to approach and enter the licence area areas from the south, but the risk reduces to the west. In the extreme west of the area, west of 59°W, the probability of icebergs is considered low. Because of the strong eddy activity in the Drake Passage, the presence of icebergs in any of the licence areas cannot be ruled out.

Little evidence exists for any seasonal behaviour in iceberg drifts or populations. There are fewer recordings of large iceberg calvings during winter (summer welt plays a role in calving), but as icebergs take months or even years to reach the Falklands region, any seasonal pattern in iceberg numbers no longer remains by the time they arrive.

There is no evidence that the 2002 peak in icebergs exiting the Weddell Sea was followed by an iceberg outbreak in the Falklands Islands shortly afterwards. It may be that the oceanographic conditions were not appropriate at the time to transport a significant number of these icebergs north into the Falklands, suggesting an oceanographic rather than source population control on the icebergs found in the lease areas.

5.2 Biological Environment

The Patagonian Shelf, on which the Falkland Islands sit, is of regional and global significance for marine resources (*Croxall & Wood, 2002*). It comprises rich assemblages of seabirds, marine mammals, fish, squid and plankton populations. The following sub-sections outline the existing biological resources known to occur around the Falklands and area to the south and east of the Islands.

5.2.1 Marine and Intertidal Vegetation

Seaweed is an important resource in the Falkland Islands for extraction and use in commercial products, such as fertiliser, and as an integral part of the health and biodiversity of the natural ecosystem. The giant and tree kelp are the most common macroalgae species in offshore zones of the Falkland Islands, extending from the 4 to 30 metres water depths.

Giant Kelp

Giant kelp (*Macrocystis pyrifera*), a species of marine brown algae, is one of the largest known ‘seaweeds’, able to grow to lengths of 60 metres with its upper fronds forming a dense canopy at the surface. *Macrocystis* provides food and habitat for a wide range of marine invertebrates and fishes.

Kelp species prefer depths of less than 40 metres, temperatures less than 20ºC and hard substrate, such as rocky bottoms, for attachment. The high nutrient rich waters of the Falklands are particularly conducive for kelp development. Studies suggest kelp fronds may grow at rates of 1–2 feet per day. Fronds of mature kelp plants start to deteriorate about six months after they are produced. Mature fronds continually develop, then die and break away in a process known as sloughing, giving way to new fronds.

Macrocystis pyrifera has a bipolar distribution, occurring both in the southern and northern hemispheres. Giant kelp is ubiquitous around the shores of the Falklands and is the most widespread and common marine algae found around the Falklands (*Munro, 2004*). Although it is typically found in inter-tidal areas it may also be found up to 1 kilometre from the shore. Little is known of the lifecycle of the species in the Falklands. It has been suggested that the Falkland Islands *Macrocystis* population is more stable than most other giant kelp beds at high latitudes, due to absence of winter storms.

Tree Kelp

Tree kelps (*Lessonia* sp.) are found in most open coastal areas. Three species of *Lessonia* have been distinguished: *L.flavicans, L.frutescens* and *L. nigrescens. L. flavicans* is the most common, although the distribution and status of individual species is reported to be unclear (*Strange, 1992*).

Few studies have been undertaken on these species in the Falklands. *Lessonia* plants are likely to be found entwined with the giant kelp canopy in depths of 3 to 20 metres, either in sub-tidal inshore or deep water offshore areas (*Searles, 1978*), where they form a fringing zone between the low water mark and the beginning of the offshore zone occupied by giant kelp. The tree kelp provides a valuable habitat for shorebirds, seabirds and other marine creatures as feeding grounds and spawning/nursery areas (*Munro, 2004*).

Given the range of water depths at the proposed drilling locations (approx. 550 to 1,490 metres), kelp species are only likely to be found as free-floating patches. Distribution of free-floating kelp patches in Falkland Islands waters was reported from the at-sea surveys carried out between February 1998 and January 2001 (*White et al., 2002*). These areas are important for the 22 seabird species recorded as associating with free-floating patches of kelp.

5.2.2 Plankton

Plankton are marine and freshwater organisms with limited swimming capability that drift with the prevailing currents. They represent an integral part of the marine ecosystem as they provide the basis of all food for higher levels of the marine food chain. Plankton is generally divided into broad functional groups – Phytoplankton (autotrophic) and Zooplankton (heterotrophic).

Due to a lack of knowledge on the distribution and ecology of plankton species in Falklands' waters, current information is based on the 'Discovery' research expeditions undertaken during the early part of the twentieth century between the Falkland Islands and South America, compiled from 1926–1986.

Phytoplankton

Phytoplankton is reliant on the availability of sunlight and nutrients for their photosynthetic processes. As such, it exists in the photic-zone of the ocean and in higher concentrations in summer at the polar and sub-polar regions. There may be as many as 5,000 species of marine phytoplankton with diatoms, cyanobacteria and dinoflagellates amongst the most prominent groups.

The results of the Discovery expedition, focusing on diatoms, can be found in the Discovery Report Vol. XVI (*Ingram Hendley, 1937*). At the nearest sampling station to the Falkland Islands, approximately 2 to 4 kilometres offshore, 10 species of diatom were recorded. South of 44ºS there were relatively few species and a marked increase in diatoms, in comparison to the dominance of dinoflagellates, ciliates and crustaceans further north. This confirms known trends that diatoms comprise a significant component of the plankton population in higher latitudes, compared to tropical waters (*Barnes & Hughes, 1988*).

NASA photographed a large phytoplankton bloom in December 2002 surrounding the Falkland Islands (Figure 5.16), including areas to the south and east of the islands. The image shows large chlorophyll concentrations, illustrating a phytoplankton rich region – partly due to the convergence of the Malvinas and Brazil ocean currents. The perennial winds buffering the Falklands from the east may generate waves which bring the nutrient rich waters to the surface. When sunlight penetrates, phytoplankton blooms may occur. Although large areas of the southern oceans are characterised by low productivity, inshore shelf waters where shelter, coupled with the nutrient up-welling, can increase numbers significantly.

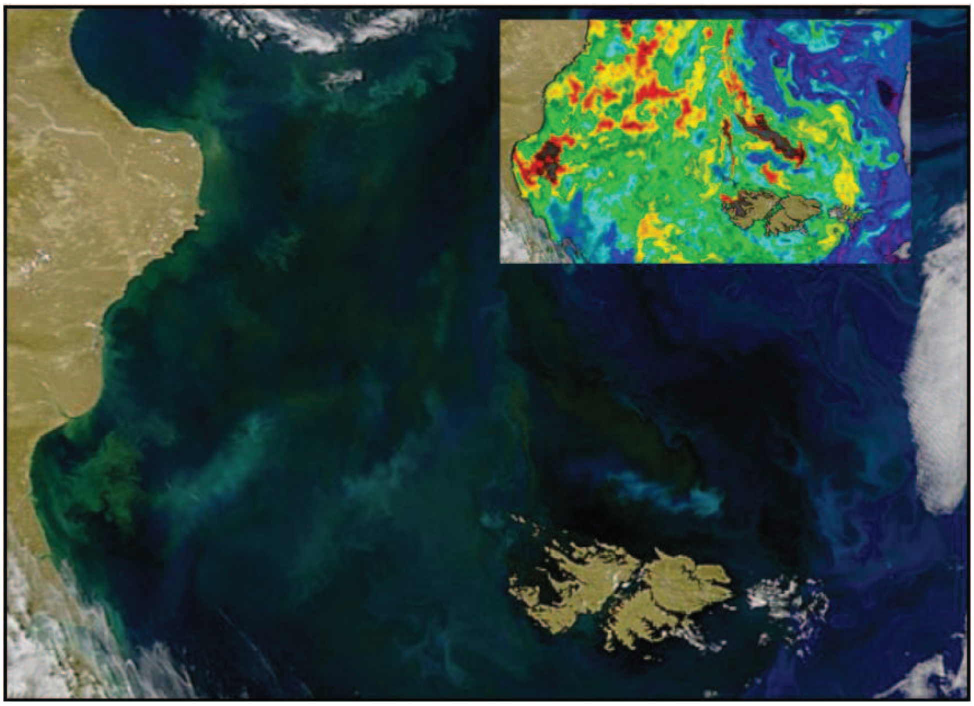


Figure 5.16 Phytoplankton Bloom (Areas of Light Blue / Green) near the Falkland Islands (NASA SeaWiFS, 2002)

Zooplankton

Zooplankton, the heterotrophic type of plankton represented by small floating or weakly swimming animals that drift with water currents and, with phytoplankton, make up the planktonic food supply on which almost all oceanic organisms ultimately depend. Included are many animals, from single-celled radiolarians to the eggs or larvae of herrings, crabs, and lobsters. Permanent zooplankton (holoplankton), such as protozoans and copepods, spend their lives as plankton. Temporary zooplankton (meroplankton), such as young starfish, clams, worms, and other bottom-dwelling animals, live and feed as plankton until they become adults.

The complex current patterns around the Falklands, with the rising bathymetry and the extensive shelf area, create stable areas to the north and to a lesser extent in the south-west, where high salinity and nutrient-rich waters enhance phytoplankton activity supporting high levels of zooplankton (*Agnew, 2002*).

As with phytoplankton, numbers appear to rise sharply leading into the summer months. Ciechomski and Sanchez (1983) noted that total zooplankton around the Falkland Islands does not peak until January / February when it is dense to the north of the Falklands, along the shelf break.

Important zooplankton species offshore Falklands include the swarming epipelagic 'krill' species such as *Munida gregaria* (Lobster krill), *Euphausia lucens*, *E. vallentini* and *Thysanoessa gregaria*. *T. gregaria* is most abundant in the southern part of the continental shelf, *E. lucens* is more common on the northern shelf area, whilst *E. vallentini* is most common in the cold Falklands Current (*Agnew, 2002*). Amphipods, particularly of genus *Themisto*, such as *T. gaudichaudi*, also occur in Falkland Islands waters. Krill, a key species in the food chain, is consumed by squid, fish, seals, baleen whales and seabirds (particularly the black-browed albatross and penguins) in the Falklands.

5.2.3 Benthic Fauna

The summary of results of the benthic survey carried out by Benthic Solutions Limited on behalf of Borders & Southern is presented below. The full survey report can be found in Appendix C.

Macrofauna

The benthic fauna of the Falkland Islands belongs to the Magellan faunal area (made up of the sea areas around the southern part of South America) and the northern Antarctic. Whilst this is generally comparable to the Northern Boreal Region, the fauna is characterised by a very high diversity in certain groups, such as crustacea, (with amphipods, in particular *Urothoe* sp, common over most sites, including the shallower sediments on the North Falklands Continental Shelf), or low diversity in the echinoderms. Univariate parameters indicated generally high and consistent levels across the regional survey area as all sites gave moderate to high species richness, diversity and evenness throughout. Statistically, univariate parameters indicated almost no correlations with either the granulometric or other environmental variables for the survey. This would generally suggest a consistent regional population where significant changes in sediment factors, in particular the proportion of fines and coarser deposits, make only subtle changes to the population. Multivariate analyses, equally confirmed a relatively diverse faunal population, but with relatively low levels of similarity between samples and stations. Separation of the stations into clustered groups of similarity was very limited and generally restricted to four poorly defined groups where similarity between stations also remained poor. With the exception of three sites, relating to the softer finer sediments in the northwest, none of these clusters indicated any geographical pattern of distribution.

The dominant macrofaunal population for the regions was based on that of a mobile surface dwelling polychaete, the Onuphid *Rhamphobranchium ehlersi*, Nematodes, and surface or shallow burrowing crustacean, such as a tenaid in the family Apseudidae, a couple of amphipods *Urothoe sp*, and Phoxocephaloidea sp.C (eyeless). Other common fauna present within the benthos were ostracods and a number of forams. Many of these groups (such as the Ostracods (mostly cypridoidea), forams and nematodes) are not usually included within the macrofaunal analysis normally due to their size (typically falling in the meiofaunal range). However, as very little is known about the sediments in this area and many of these species were clearly large enough (some as large as 5mm) to constitute an important role within benthic ecosystem, these additional groups have been included within the analysis for completeness.

Whilst polychaetes dominated the macrofaunal population overall, the most abundant annelid recorded during the survey was the onuphid *Rhamphobranchium ehlersi.* Unlike most polychaete species which live within the surface substrate, the omnivorous onuphids live within a sediment encrusted mucous tube which it physically drags across the surface of the seabed. Comparison with the macrofaunal population with the neighbouring sites in the eastern Falkland Continental Margin equally showed other onuphid species *Onuphis pseudoiridescens,* at Toroa 75km Northeast (*FSL, 2009a*) and *Kinbergonuphis oligobranchiata* at Loligo site 345km northeast (*FSL, 2009c*). To date, the former species has only been recorded from the south-west Atlantic (including in the vicinity of the Falkland islands) and from the south-east Pacific coast of Chile (*Rozbaczylo et al, 2006*). Onuphids were also recorded during ROV footage at the Toroa site.

R.ehlersi in the present study is a different genus to *Onuphis*, but in the same family. This genus is characterised by special long setae in the first three chaetigers (bristlebearing segment), with a different shape of hooks on the end. A general search of taxonomic records revealed at least six different onuphid species for the Magellan Province, with a further example *Nothria (Onophis) conchylega* which is in the same family and with a near cosmopolitan distribution, also recorded on the Burdwood Bank.

As with the univariate parameters, correlations between the environmental parameters and the multivariate trends groups indicated little or no significance, with only a very weak pattern relative to the proportion of gravels and/or medium sands within the sediments. Consequently, whilst there is significant variability recorded between sediment types throughout the survey area, this has had only a marginal impact on the faunal community which appears to be quite diverse throughout the whole survey area. Consequently, whilst environmental factors show very significant distributions relative to the granulometric properties of the sediments, the faunal population does not.

Overall, no environmentally sensitive species or habitats considered to be of conservational value were recorded within the macrofaunal analysis during the regional survey operations.

Epifauna

Many of the sites sampled indicated the presence of some coarser admixtures within the sediments relating to gravels ranging from granules through to large cobbles (25cm) sized fractions. Consequently, a number of sites indicated the presence of epifaunal species which have been identified qualitatively. Observations made during the sampling and the resulting particle size analysis undertaken on recovered material showed that 7 out of the 23 stations surveyed indicated gravels greater than 10% or the evidence of outcropping bedrock at the surface. Furthermore, most of the sites indicated a generally non-depositional environment, meaning that epifaunal species are able to become established on low lying harder substrates. Figure 5.17, shows a comparison of both epifaunal and infaunal species at each station along with the proportion of gravel content present for that station. For the most part, this shows a direct relationship of increased epifaunal with gravels, or low epifaunal species where gravels were absent.

Brief comments on the dominant epifauna recorded from three major groups, (Cnidera, Porifera, and Bryozoa), are outlined below:

<u>Cnideria</u>

Amongst the Cnidera, hydroidea were the least prominent and only represented by small colonies of widespread or cosmopolitan genera. However the Octocorals were well represented, with one stoloniferous species (*aff Sarcodictyon*) and four prominent Gorgonarians, *Melitodes sp, Pleurocoralloides sp, Callozostron carlottae* and *Stachyodes sp.* The fifth species was too fragmentary to identify. *Pleurocoralloides* is characterized by a strongly calcified central column, and is related to the precious coral of the Mediterranean. *Callozostron* was the most common species of this group and was characterized by scaly branches and spined calyces.

The madreporan coral *Lophelia* was recorded in a couple of samples, however live tissue was only found in one specimen in one sample. A couple of dead fragments were found in a couple of other samples near this station. Branched hard corals are of conservational interest as they are able to develop into extensive thickets creating large biogenic reefs which can be highly diverse, but extremely fragile. Madrepora are azooxanthellate coral species which do not rely on symbiotic algae to obtain nutrients, allowing growth to occur in dark and cold water environments well below the photic zone. However, as a result, they are very slow growing, developing by as little as 6mm a year. Consequently, larger reef structures which can be tens of metres high can take thousands of year to develop. This appears not to be the case for the current study as only a small example of this species and other hard corals were recorded, although the presence of this species does confirm the potential for more developed reefs to exist within the general survey area.

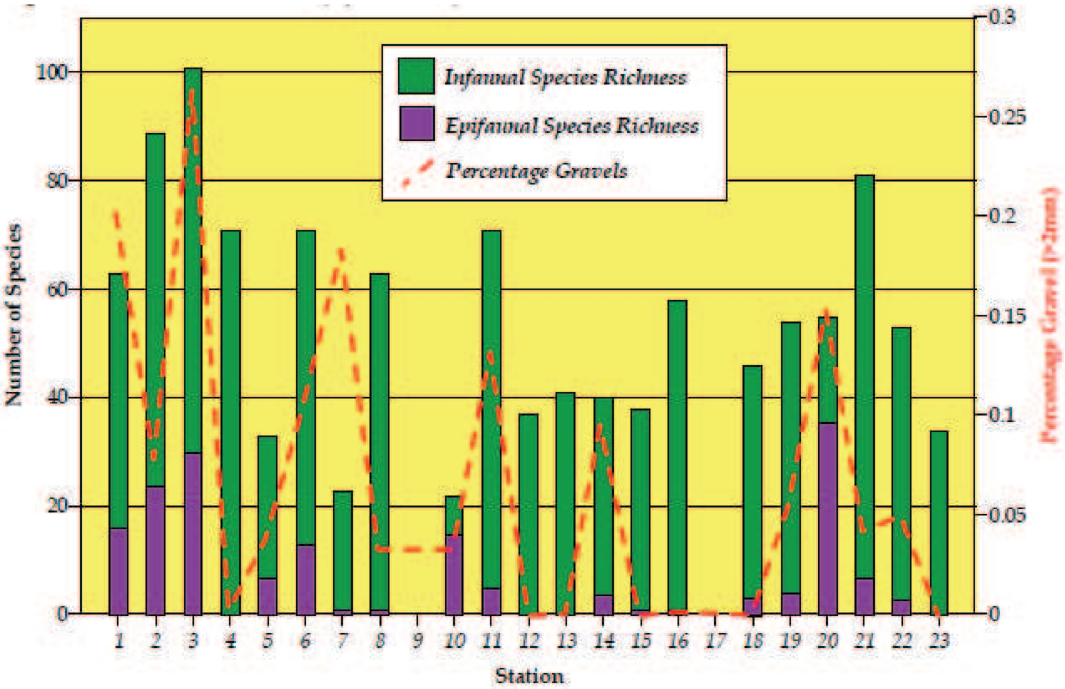


Figure 5.17 Epifaunal Species Richness vs Gravels

Although no extensive reefs were encountered, evidence from the Loligo area, located in a slightly shallower water depths (around 1350m) and a similar sediment type, taken by sampling and ROV operations showed sporadic, and at times, fairly extensive coverage from low level corals on some of the harder substrates (*FSL, 2009c*). Box core samples similarly showed fragments of *Lophelia pertusa*, although no live specimens were recovered. Existing ecological data for *L. pertusa* suggest that its range would not extend to the Falkland slope due to the low seabed temperature recorded (2.9°C). ICES (2002) state that *L. pertusa* prefers oceanic waters with a temperature of between 4°C and 12°C and a relatively high tidal flow (to facilitate filter feeding). Consequrntly, the coral identified from Loligo and in the present study may reflect an antarctic variant to this madreporan species or may simply extend the temperature range of the existing *L.pertusa* species, although stunting its development beyond minor isolated thickets due to temperature limitations.

<u>Porifera</u>

In addition to Cnideria, the phyla Porifera (sponges) were also well represented at a number of sites. Hexactinellidae were recorded only in fragmentary form, although the presence of numerous spicules in the sediments belonging to this class indicates that they are more common than indicated from the samples. This also applied to the Tetraxonida, where only one species was recorded with one specimen of *Tetilla*. Also of interest was the lithistid sponge *Gastropharella* sp. These sponges, a polyphyletic group, have a virtually solid skeleton of “Desmas” with a compliment of other spicules, in this case Tylota.

A common sponge genus throughout the deeper waters of the Atlantic is *Asbestopluma sp,* was well represented in the current study. These sponges are upright branching forms without the normal canal system and rely on a carnivorous mode of feeding. Their microscleres (anisochelae) catch small crustaceans which are then surrounded by tissue and digested.

The other genera recorded, generally related to the small encrusting patches on stones and were rarely massive, were also commonly represented in the sponge fauna of the Atlantic and elsewhere. Identification of these species was done on the base of internal characteristics of spicule shape and arrangement.

Bryozoa

Bryozoa were frequently recorded and found encrusting, as upright branches or flexible colonies. It is currently not practical to identify the Class Cyclostomata in detail as this group is awaiting revision and it also proved impossible to ascribe definite generic status to many of Cheilostomata with the keys available for this area. In this instance, affinities to existing Genera were used to define individual taxa. Where a definite species name is given this implies that the genus was represented with only one species or the species has otherwise defining characteristics. Some of these genera are also found in the northern hemisphere (e.g. *Escharoides, Fenestrulina, Escharina, Escharella, Rhynchozoon, Plesiothoa* and *Smittoidea).*

Only three species were ascribed to the Class Ctenostomata. Of interest was aff. *Metalcyonidium*, forming an upside down cone on a stalk devoid of zooids. This is reminiscent of *Metalcyonidium spp* found infrequently in the deep waters of the North Atlantic. With 38 taxa this group was well represented, frequent and diverse. Its composition aided by a lengthy larval lifespan which encourages dispersal. Amongst the other group's common colonies of the Pterobranchia *Rhabdopleura* were recorded with a typical black stolon and annulated tubes containing the zooids covering whole stones. Overall the fauna was very rich and diverse, typical of the depth regime.

Crustacea

In addition to the free-living infaunal species, the frequent occurrence of Cirripedia, the stalked Barnacle *Scalpellum* sp. and the acorn barnacle *Verruca sp*. was recorded, both being unusual for Deep Sea and Antarctic waters. These were clearly associated with stations where coarse gravels were present. Some copepoda appeared within samples which were neither epifaunal nor benthic but accidental pelagic specimens. These were related to the Euphausiacea (or Krill) and were probably caught by the sampler during the descent, or have been introduced to the samples thought he sea water processing phase of the operations.

5.2.4 Fish, Squid and Shellfish

Much of the information sourced for these sub-sections is based on work undertaken by the Falkland Islands Fisheries Department (FIFD) as commercial fishing is a significant part of the local economy. Additional information has been sourced from the 2008 State of the Environment Report (*Otley et al, 2008*).

In addition to the harvest of commercial fisheries, fish stocks are a major component of many seabirds and marine mammal diets, and any impacts on fish stocks are likely to affect these species. At least 80 species of fish have been recorded in Falkland Islands' waters ranging from small fish such as the rock cod to larger fish including tuna and sharks (*Strange, 1992*). Coggan et al, (2006) sampled twenty deep-water stations to the east and south of the Falkland Islands by commercial bottom trawl deployed in upper, middle and lower benthopelagic zones (depth range of approximately 500-1,000 metres). Forty-one species of teleost fish were recorded, 10 species of elasmobranch and one species of agnathan. Different assemblages of fish were found to characterize each depth zone (e.g. *Moridae* in deeper waters, *Bothidae* and *Rajidae* in shallower waters), with diversity being greatest in the mid-zone and biomass greatest in the upper and lower zones. Four species, namely the grenadiers *Macrourus carinutus* and *Coelorhynchus fasciatus*, the southern blue whiting *Micromesistius australis*, and the Patagonian toothfish *Dissostichus eleginoides*, accounted for 85 percent by weight of all fish caught.

Commercial fishing is described from a socio-economic perspective in Section 5.3.1.

The Falklands Interim Conservation and Management Zone (FICZ) was introduced in February 1987 to reduce uncontrolled fishing. Continuing conservation problems led to the declaration of the Falkland Islands Outer Conservation Zone (FOCZ) in December 1990, 200 nautical miles from coastal baselines.

The main fisheries resources are the squid species, *Illex argentinus* and *Loligo gahi*. The existing finfish fishery targets predominantly hake, hoki, red cod and blue whiting. Blue whiting provides the highest finfish catches with 80% of the catch targeted seasonally by large surimi trawlers. A specialised small ray fishery exists, and a small longline fishery operates targeting Patagonian toothfish.

Shellfish are not an important component of the commercial fishery although several species of crab are found around the Falkland Islands including the false king crab (*Paralomis granulosa*) and the larger southern king crab (*Lithodes antarcticus*). A small-scale scallop (*Zygochlamys patagonica*) fishery is also being developed (Munro, 2004) in the Falkland Islands Conservation Zone. Approximately 920 tonnes (green weight) of scallops was taken in 2003 and 2004, constituting the total allowable catch from the known scallop banks, situated mainly to the northeast of Stanley.

Some previous exploratory work, together with reports from other fisheries, has suggested that scallops might be more widely spread around the Falklands, although it remains to be seen whether there are significant concentrations elsewhere (The International Collective in Support of Fishworkers (ICSF); www.icsf.net.

5.2.5 Cephalopods

Cephalopods include species from the squid and octopus families. Squid provide economic benefits through commercial exploitation and are also a food source for a variety of marine vertebrate predators (*Munro, 2004*). Adult squid are active predators positioned near the top of the food chain, consuming fish, crustaceans and other cephalopods (*Hatfield, 1990*). Squid stock varies annually, influenced by success of the spawning season based on favourable environmental conditions. Octopi, found in kelp beds and crevices in rocks, are common prey for sea lions.

Distribution of cephalopods is dependent on temperature preference and influence of currents. Larval phases concentrate on the Patagonian shelf and shelf break area, and the adult phases utilise the currents for migration between feeding and spawning grounds (*Rodhouse et al., 1992*).

Cephalopod paralarvae and juveniles sampled in the south-west Atlantic Ocean found that the sub-Antarctic surface waters of the Falklands Current contain the richest assemblage of species including the sub-tropical/sub-Antarctic *Histioteuthis atlantica*, the sub-Antarctic *Batoteuthis skolops*, *H.eltaninae*, *H.macrohista* and the sub-Antarctic/Antarctic *Gonatus antarcticus*. In comparison, with the exception of some small *Gonatus antarcticus*, the polar frontal zone water of the Falklands Current was relatively poor in species (*Rodhouse et al., 1992*). Cephalopod species recorded on the Falkland Islands shelf included *Loligo gahi*, *Gonatus antarcticus*, Martialia *hyadesi*, *Moroteuthis knipovitchi*, *Batoteuthis skolops*, *Semirossia patagonica* and an Octopus sp. (*Rodhouse et al., 1992*).

An evaluation of the distribution of *Loligo gahi* paralarvae and *Gonatus antarcticus* found greatest concentrations around East Falklands (*Rodhouse et al., 1992*) and at the offshore stations sampled, particularly to the south of East Falklands, respectively. *Octopus* sp. was reported to be the most widely distributed.

Argentine Shortfin Squid *(Illex Argentinus)*

Illex argentinus, one of the most abundant cephalopods in the Southwest Atlantic, is distributed from approximately 30ºS to 54ºS over the Patagonian shelf, slope and around the Falkland Islands. *I.argentinus* is a demersal and schooling species.

Illex argentinus is caught in the FICZ between late February and June, at depths of 80–800 m (*FIFD, 2001; Rodhouse & Hatfield, 1990*). Fishing catch peaks between April and May with principal catch areas to the north and north-west of the Falklands, although they can vary annually.

The migration and dispersal of *Illex argentinus* is highly dependant upon the major oceanic currents and resultant water temperature, therefore abundance in the Falklands is highly variable. The species is predominantly a warmer water species and variations in current strength and flow, that modify sea temperatures and temperature gradients, can influence major changes in migration and aggregation of the species (*FIFD, 2001*).

Pantagonian Squid *(Loligo gahi)*

Loligo gahi is a demersal, schooling species found in shallower water around the coast to a depth of about 400 metres (*Boyle, 1983*). They have two main spawning periods; the spring (September-October) spawning group is larger than the autumn (March-April) group.

This fishing industry is focused to the south of East Falklands, mainly around Beauchene Island from February to June, later moving northwards to north-east of East Falklands around August–October. The trawling fleet targets *Loligo gahi* during its feeding phase, in depths of 120–250 metres, corresponding to the optimum commercial size

Squid eggs have been recorded in shallow marine areas (less than 30 metres depth) during dive surveys carried out in 1996 *(FIG, 1996*) and by the FIFD (*FIFD, 2000*). Eggs were found in inshore waters of all islands sampled, except the offshore islands to the south. In 1999 (*FIFD, 2000*) egg masses were encountered around the entire coast of East Falklands with the exception of the central part of Falklands Sound. All egg masses found were associated with and attached to kelp, although there was considerable local variation in egg mass density.

A third squid species, red squid (*Martialia hyadesi*) is not widely fished. It is larger in size than *Illex argentinus* or *Loligo gahi* and is thought to be abundant in the waters of the Antarctic Convergence Zone, near South Georgia. This species forms at least 90% of the squid intake of the grey-headed albatross population during the chick rearing period resulting in approximately 1400 tonnes of squid consumed each breeding season (*Brunetti & Ivanovic, 1992*).

5.2.6 Finfish

Some 11 species of finfish are caught in significant quantities. Southern blue whiting catch is found to the south-west and north-east of the Falklands. Hoki, rays, red cod and Patagonian toothfish are caught widely around the Falklands in the FICZ, except in the south-east. Within the FOCZ all are caught to the north of the Falklands. Patagonian toothfish and rays are also caught to the south-east within the FOCZ (*Munro, 2004*).

The distribution of migratory species such as hake may be affected by fluctuations in spawning success and external environmental affects. Many of the commercially caught demersal species are likely to spawn in deep water and have planktonic eggs and larvae. Immature stages of some species may occur inshore; however, there is little information on specific nursery areas.

Hake *(Merluccius sp.)*

Hake are widespread throughout the FICZ and two species are caught commercially; Patagonian hake (*Merluccius hubbsi*) and common hake (*Merluccius australis*), which are similar species and often counted together in catch statistics. The common hake is distributed mainly in the offshore waters to the north of the Falklands as opposed to the Patagonian hake, which is found to the south of the Falklands. Fishing effort concentrates in the far west of the FICZ where the highest abundance of hake are found, and also to the north (*Tingley et al., 1995*), and around Beauchene Island to the south (*Lisovenko et al., 1982; Tingley et al., 1995*). *Merluccius hubbsi* is thought to spawn in September and October, and *M.australis* in June and August. Hake are generally known to migrate diurnally, being found near the seabed during the day and migrating further up the water column to feed at night.

Southern Blue Whiting *(Micromesistius australis)*

Southern blue whiting are a food source for the Patagonian hake and consequently showing a similar distribution. Southern blue whiting migrate to the Falklands outer shelf and aggregate in dense schools to spawn. Specialised surimi vessels target feeding concentrations of southern blue whiting until the following March. Acoustic surveys of the southern blue whiting stock are conducted annually through a joint Argentine/Falklands project.

The Falklands sub-species are found at depths between 180 to 780 metres and appear to be most abundant at depths of 200 metres around the Falklands (*Inada and Nakamura, 1975*). Spawning occurs in August and September around the south of the Falklands and both eggs and larvae are pelagic. Pre-spawning fish congregate south of West Falklands during July (*Patterson, 1986*) and subsequent to spawning migrate into deeper water dispersing south and west where they are thinly distributed over the Patagonian Shelf.

Whiptail Hake / Hoki *(Macruronus magellanicus)*

Whiptail hake, or hoki, is the second most important commercial species in terms of annual catch. A pelagic and near-bottom fish, the species is present in Falklands' waters year round and is generally associated with warmer waters up to 200 metres deep in the north and west of the FICZ

(*Middleton et al., 2001*). Falklands' waters are primarily a feeding ground. The uniform distribution of *M.magellanicus* as a proportion of daily catch suggests that the species is taken as a part of a mixed finfish fishery rather than specifically targeted.

Cod *(Notothenia spp.)*

Antarctic cod are one of the most common fish in Antarctic and subantarctic waters, and 16 species have been recorded in Falklands' waters. Of these the predominant species are *Notothenia ramsayii* and yellow belly (*Notothenia macrocephala*); common in nearshore waters in summer, but migrating to deeper waters during the winter (*ERT, 1997*).

Fish and larval stages can be particularly vulnerable to the effects of hydrocarbon pollutants, such as PAHs (*Stagg and McIntosh, 1996*). Spawning of most species begins in autumn and progresses through winter, when the southern blue whiting and grenadier fish contribute to more than half of all eggs present in samples from around the Falkland Islands (*Ehrlich et al., 1999*). Sampling has shown that the greatest number of unidentified eggs (indicating early life stages) are found in the slope waters and deeper parts of the continental shelf (<400 metres). Fifty percent of all larvae collected during surveys over four years (1992-1995) were found in the 800-1000 metre depth range, shallower than the water depth at Darwin East and Stebbing wells.

The drilling period is likely to fall into the summer (Dec-Feb) and autumn (March-May) seasons. Autumn data show a very low density of eggs (64.63 eggs per $10m^2$) in samples collected throughout the Falkland waters and the Patagonian shelf. Peak levels are seen during the spring months (Sep – Nov) (3864.32 eggs per $10m^2$) outside of the proposed drilling period.

In summary, finfish species potentially found in the vicinity of the proposed exploration well include hake (*Merluccius sp.*), southern blue whiting (*Micromesistius australis*) and cod (*Notothenia spp.*). Spawning and nursery periods for these species are, however, not expected to coincide with the proposed drilling period for the well (Dec-to May).

5.2.7 Shellfish

Data on shellfish found in the shallow and offshore waters of the Falklands are scarce. Lobster krill is abundant in Falklands' waters. Crabs found in the shallow inshore waters of the Falklands include red crab (*Paralomis granulosa*) and, to a lesser extent, the king crab (*Lithodes antarcticus*). Trawling to the south of the Falklands has also shown there to be a probable significant population of sub-Antarctic stone crab (*Neolithodes* sp.).

Red Crab *(Paralomis granulosa)*

The red crab fishery utilises a small inshore vessel operating in Choiseul Sound. The operation is licensed by the Department of Fisheries with restrictions on minimum crab size. *Paralomis granulosa* is typically found in relatively shallow water of 10 to 40 metres depth and within sheltered inshore waters. The highest concentrations of *P.granulosa* are found around the south east of the Falklands. Juveniles and adults are found at the edges of kelp beds (*Hoggarth, 1993*).

Patagonian scallop *(Zygochlamys patagonica)*

A small commercial fishery exists for the Patagonian scallop in the northeast of the FICZ at depths of 130 and 142 metres. Stock assessment estimates a standing biomass in these beds of 18,000–27,000 MT (Metric Tonnes). Distribution is mainly along the north eastern, eastern and southern edge of the Falklands shelf. Distribution is thought to be determined by three main factors: the Falklands Current, bottom morphology and suitable depth. Scallops have not been found on areas of hard rocky bottom, nor in waters greater than 145 metres deep. In Falklands' waters no inshore scallop beds have yet been found (*Munro, 2004*).

5.2.8 Marine Mammals

Little is known about the populations, distribution and habits of marine mammals in the waters surrounding the Falkland Islands, particularly in the deeper waters to the south and east. There may be more than 20 species which occur in Falkland Islands' waters, but it is estimated that only 2 to 3 of these species would be resident to the area (Munro, 2004).

After the award of the initial round of hydrocarbon exploration licenses in 1996, six wells were subsequently drilled to the north. The threat to seabird and marine mammal populations was recognized, and in view of the lack of published data available the Joint Nature Conservation Committee (JNCC) and Falklands Conservation (FC) conducted a 'Seabirds at Sea Survey' between February 1998 and January 2001 (*White et al., 2002*). To date, the findings from these surveys are still the major body of work regarding the frequency and distribution of marine mammals, particularly cetaceans, in the region.

These at-sea surveys were carried out in every month between February 1998 and January 2001. Surveys were conducted throughout the south-west Atlantic – as far north as 35° S (*Black, 1999*), south to 65° S (*White and Gillon, 2000*), east to 28° W (*White and Gillon, 2000*) and west to 70° W (*Gillon et al., 2000*). The majority, over 82 percent, of survey effort was conducted within Falkland Islands waters. Analysis of the data within the White et al., 2002 report includes all survey effort within a rectangle defined by south-west co-ordinates 56° S 64° W and northeast co-ordinates 47° S 52° W.

In total, 91 survey cruises were conducted during the three years. In most cases single observers were on board, with the remainder being conducted with two observers. All mammals within a 300 metre transect to one side of a survey vessel with known position, speed and heading were counted (methods as per *Tasker et al., 1984; Webb and Durinck, 1992*).

A total of 20,907 km² of survey effort was conducted within the study area in the period under consideration. Monthly survey effort ranged from a low of 262.2 km² in November 2000 to a high of 1,546.7 km² in November 1998, with an average monthly survey effort of 676.5 km² (*White et al., 2002).*

The distribution of all the survey effort achieved from February 1998 to January 2001 is shown in Figure 5.18, below.

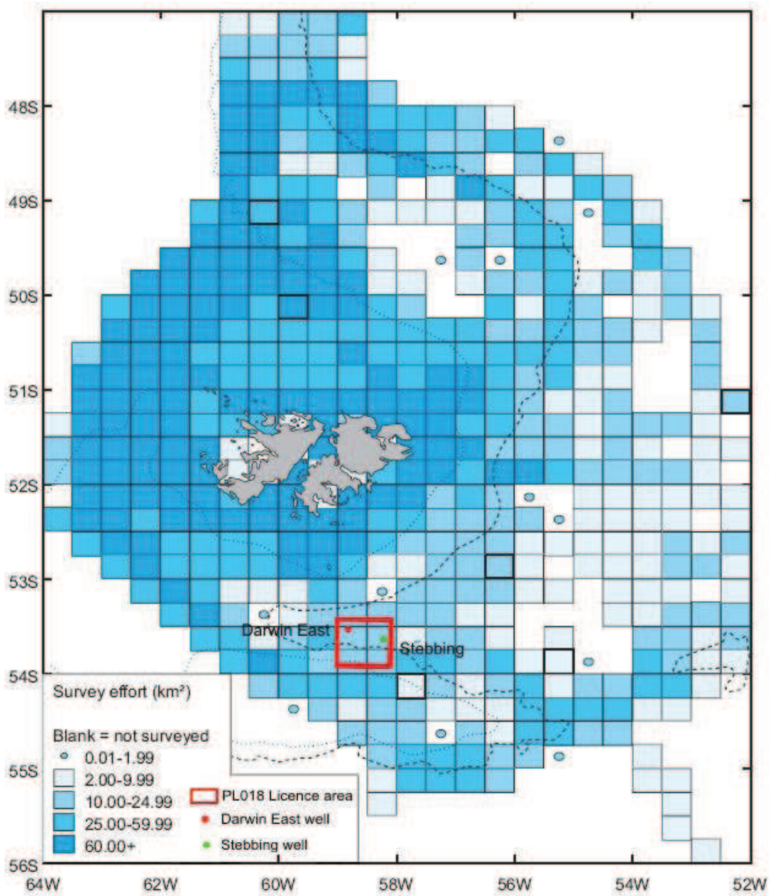


Figure 5.18 Total Survey Effort in All Months (White et al., 2002)

Highest levels of effort were concentrated over Patagonian Shelf waters, particularly waters around Stanley and in the west of the survey area. Although it can be seen from this that survey effort was lower in the vicinity of the proposed exploration wells, particularly compared to the north and west of the Falklands Islands, surveys were conducted within the area of the Borders & Southern license blocks. It is recognised, however, that a decrease in survey effort may decrease the number of species recorded. *White et al., 2002* noted that the rate of increase in sightings was greatest between zero and 20 km² of survey effort, although for levels of survey effort above 20 km² per month there was little increase in the number of species recorded.

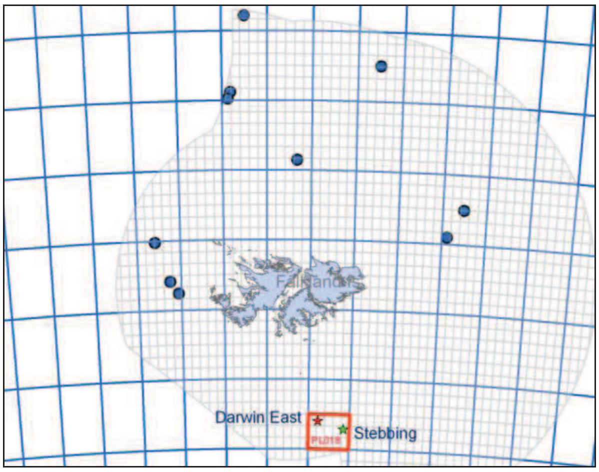
Cetaceans

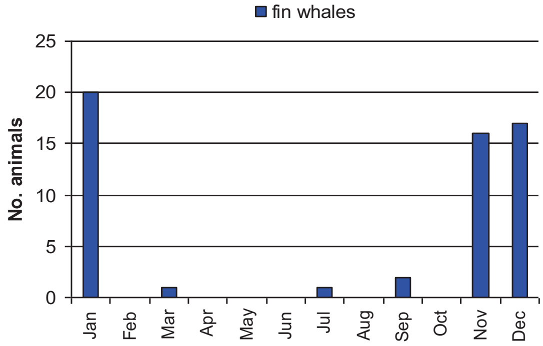
Prior to the JNCC survey (*White et al., 2002*), knowledge of the cetacean fauna of the Falkland Islands was based largely on coastal observations and records of stranded animals. Hamilton (1952) recorded a total of 16 species within Falkland Islands waters, while Strange (1992) recorded a total of 23 species. More recently, observations from FIG Air Service pilots and fisheries observers of the FIG Fisheries Department (FIGFD) give an indication of some of the species present in offshore areas, but interpretation of these casual observations is difficult (*White et al., 2002*).

The following results, unless stated otherwise, have been extracted from the Distribution of Seabirds and Marine Mammals in Falkland Islands' Waters report (*White et al., 2002*) and represent the findings of those surveys between 1998 and 2001.

Figures 5.19-5.20 depict the distribution, sightings and number of cetaceans recorded during all the surveys months.

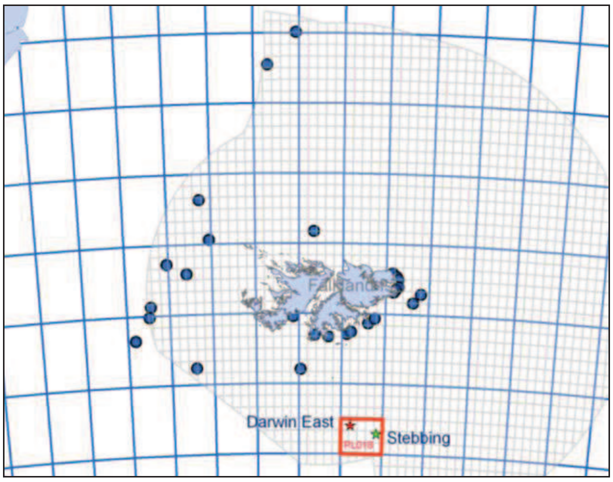
Fin Whale ***(Balaenoptera physalus)***

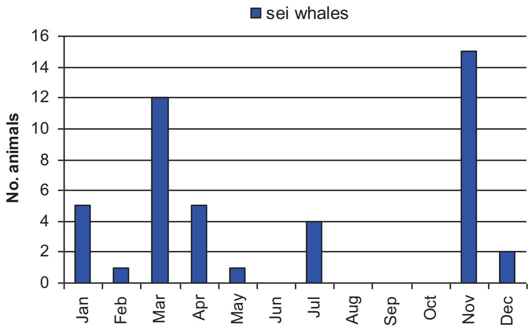




Majority of fin whales were recorded between November and January, with 57 recorded in total on 27 separate occasions over the survey area. Sightings were generally in water depths >200 m.

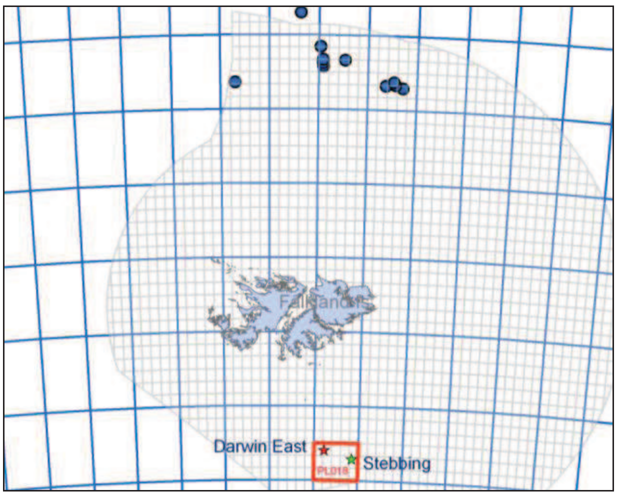
Sei Whale ***(Balaenoptera borealis)***

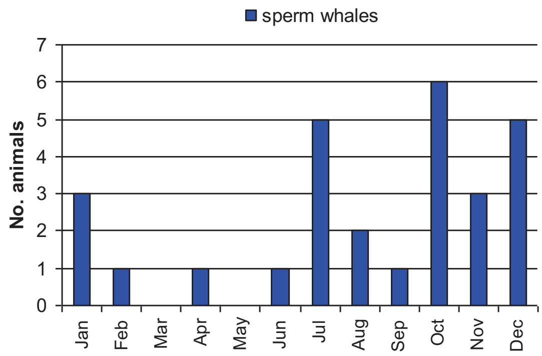




Most sei whale sightings were between November and April, with 45 individuals recorded on 31 occasions. Most records were from Patagonian Shelf waters, with others in relatively shallow waters.

Sperm Whale ***(Physeter macrocephalus)***

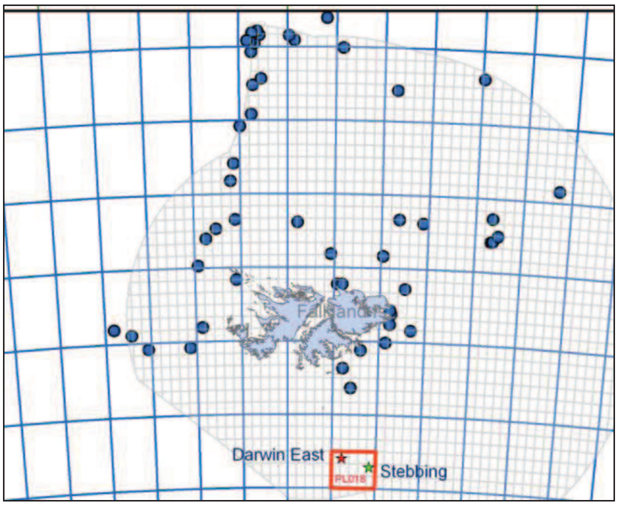


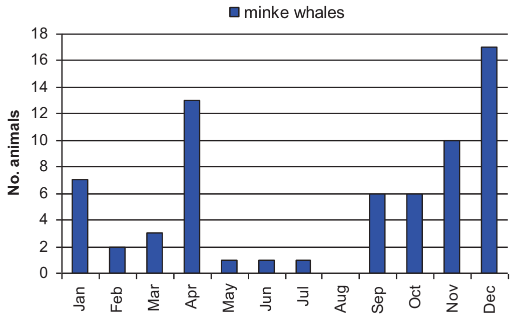


A total of 28 sperm whales were recorded on 21 occasions, mainly in July, October and December, but also throughout most months. All sperm whale sightings occurred in deeper waters (>200 m), with records clustered to primarily to the north of the Falkland Islands.

Figure 5.19 Cetacean Species Sightings (all months) (1998-2001) (White et al., 2002) and Cetacean Numbers Recorded per Month (JNCC, 2002)

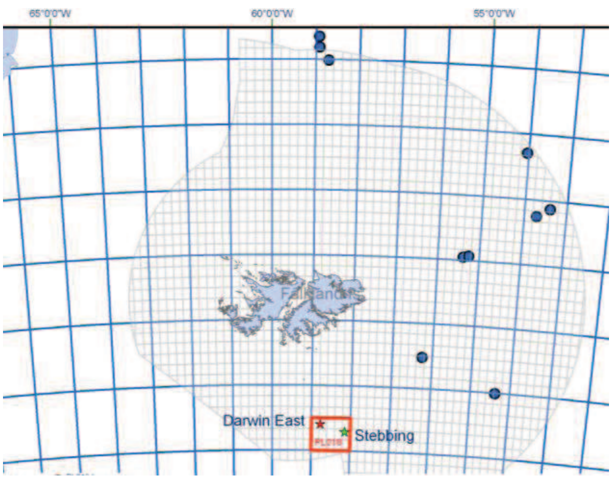
Minke Whale (*Balaenoptera acutorostrata*)

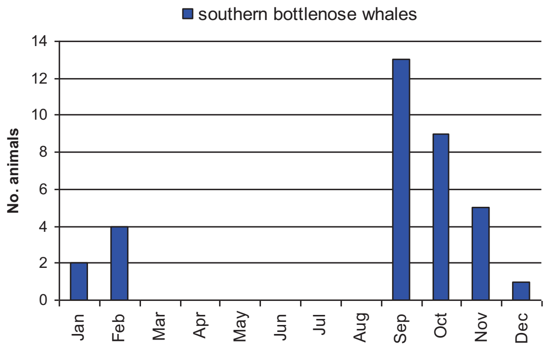




Minke whale sightings peaked in April and December, with a total of 68 whales recorded on 60 occasions. The majority of records were from Patagonian Shelf waters around East Falklands and in the north-west of the survey area.

Southern Bottlenose Whale (*Hyperoodon planifrons*)

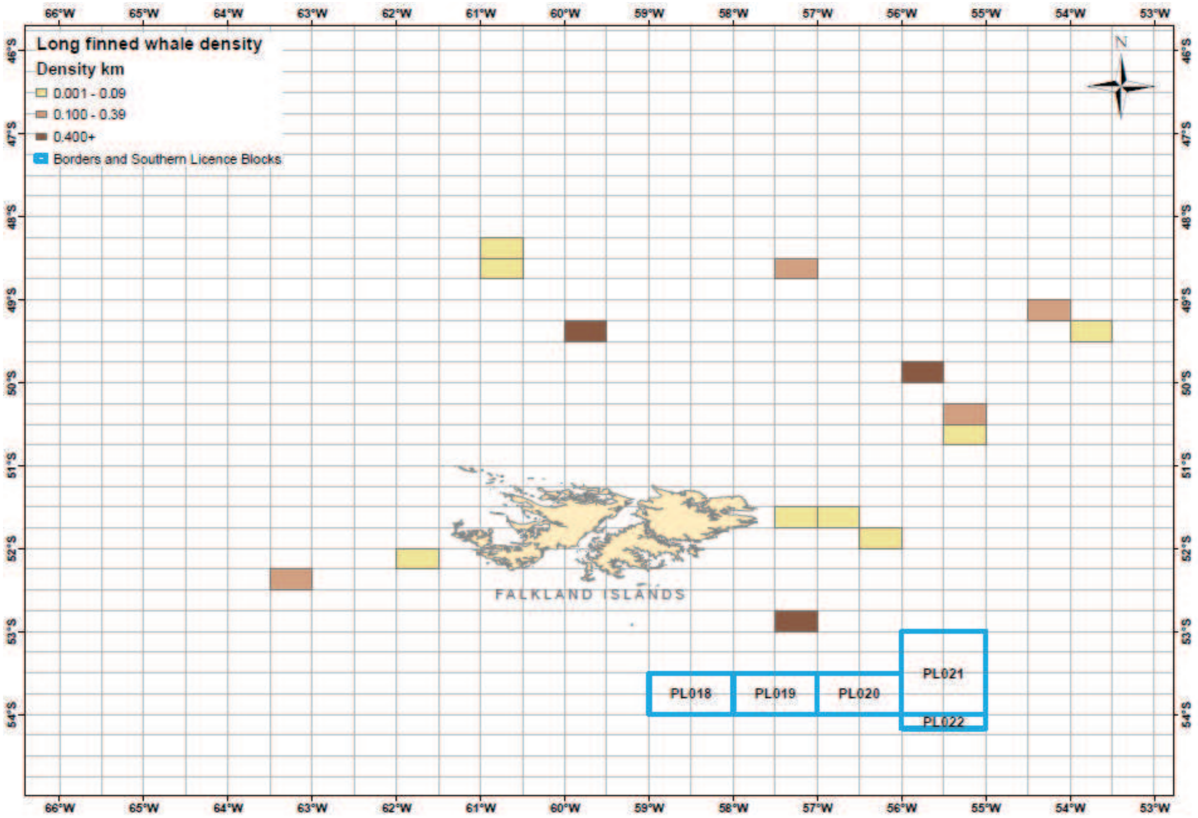


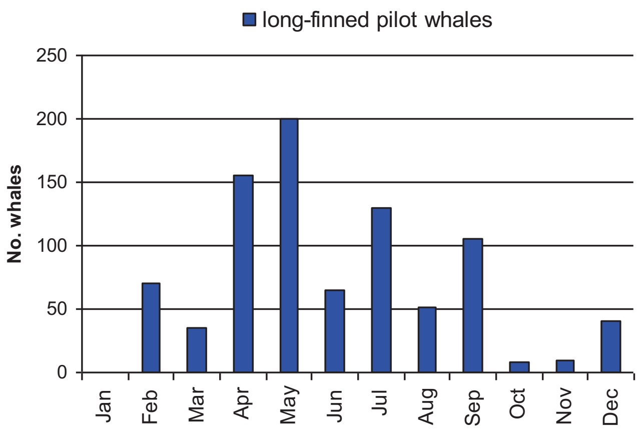


Southern bottlenose whales were recorded between September and February, with a total of 34 records on 18 occasions. All sightings were made in waters >1000 m, generally to the north, east and south.

Figure 5.19 Cetacean Species Sightings (all months) (1998-2001) (White et al., 2002) and Cetacean Numbers Recorded per Month (JNCC, 2002)

Long-finned pilot whale (*Globicephala melas*)

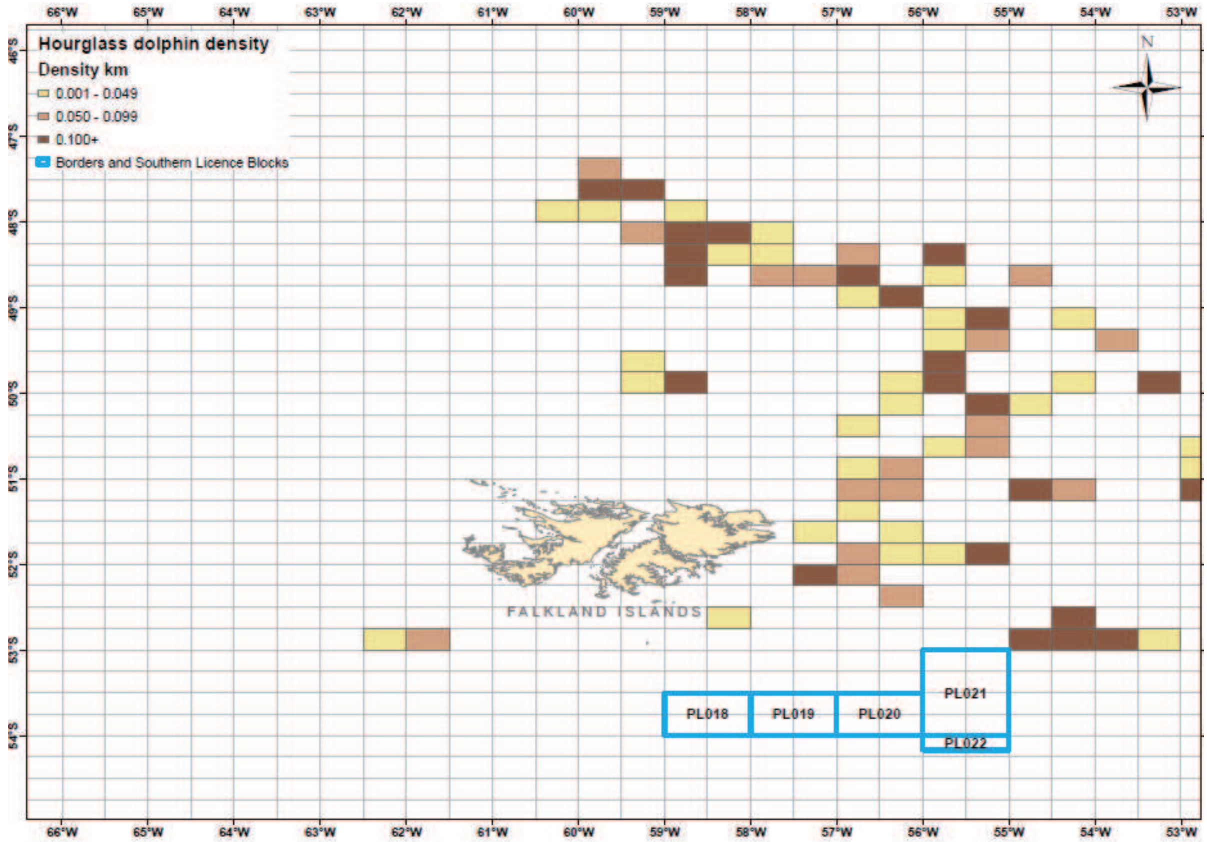


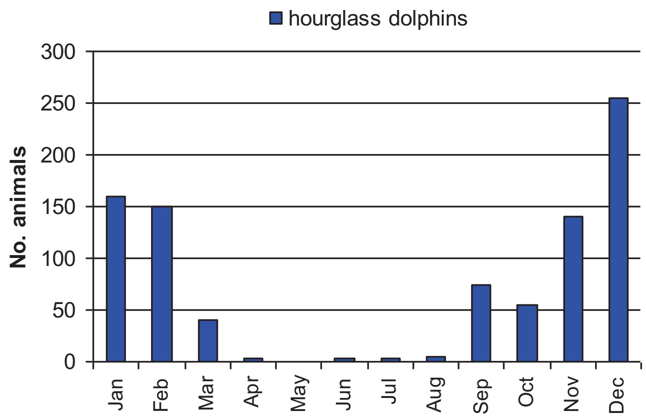


Large numbers of long-finned pilot whale were recorded (872 over 27 occasions), with group sizes of up to 200. Although these whales were recorded in all months except January, they were predominantly recorded between April and September in waters deeper than 200 m.

Figure 5.20 Cetacean Species Distribution (all months) (1998-2001) (White et al., 2002) and Cetacean Numbers Recorded per Month (JNCC, 2002)

Hourglass dolphin (*Lagenorhynchus cruciger*)

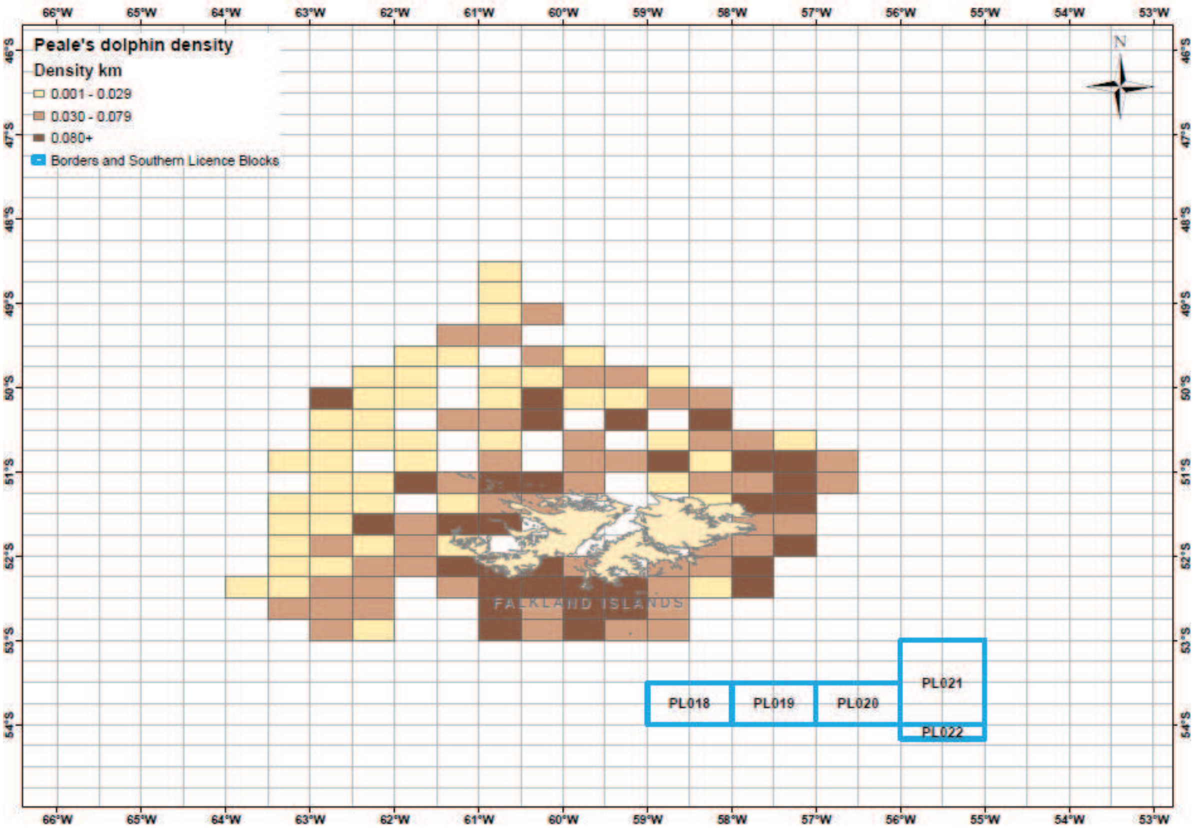


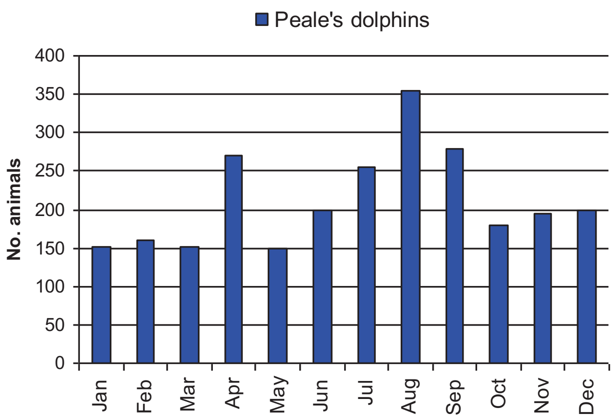


Hourglass dolphins were recorded in large numbers, with 866 Sightings over 177 occasions, mainly between September and March and in water depths of greater than 200 m.

Figure 5.20 (cont.) Cetacean Species Distribution (all months) (1998-2001) (White et al., 2002) and Cetacean Numbers Recorded per Month (JNCC, 2002)

Peale's dolphin (Lagenorhynchus australis)

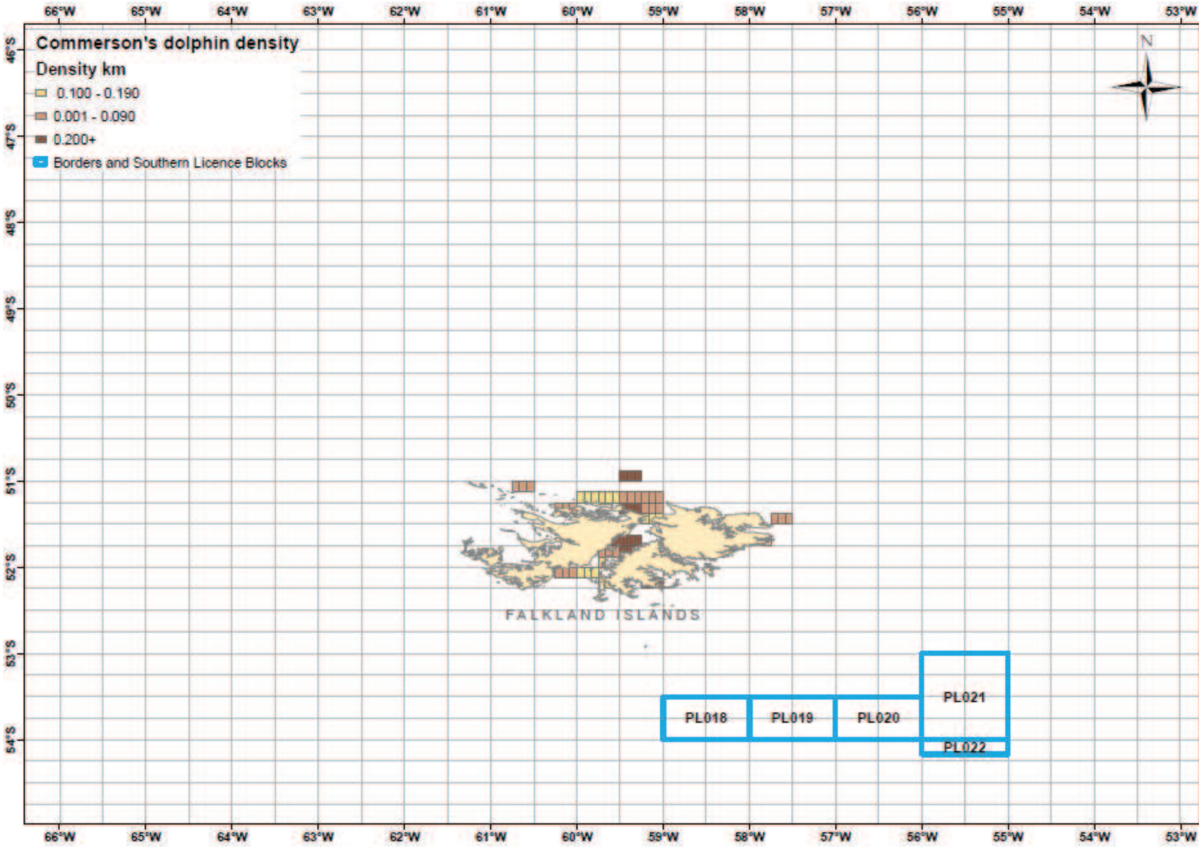


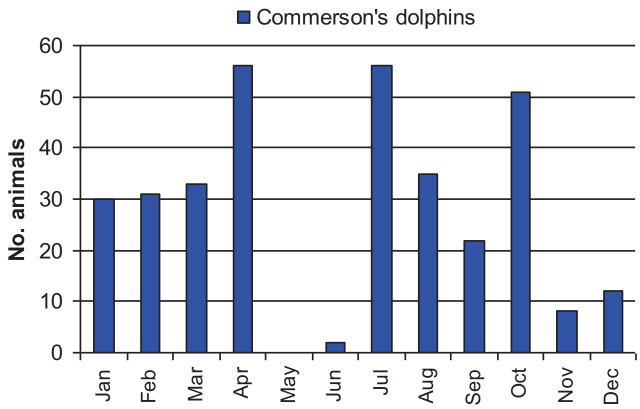


Peale's dolphins were the most numerous and frequently recorded cetacean with a total of 2617 animals recorded on 864 occasions. They were recorded in all months with a maximum of 358 animals in August. They were generally found in waters less than 200 m deep.

Figure 5.20 (cont.) Cetacean Species Distribution (all months) (1998-2001) (White et al., 2002) and Cetacean Numbers Recorded per Month (JNCC, 2002)

Commerson's dolphin (*Cephalorhynchus commersonii)*





A total of 336 Commerson's dolphin was recorded on 100 occasions, covering all months except May. Dip in records over May and June may be due to variation in the level of survey effort rather than seasonal variations. No observations were made over 25 km offshore.

Figure 5.20 (cont.) Cetacean Species Distribution (all months) (1998-2001) (White et al., 2002) and Cetacean Numbers Recorded per Month (JNCC, 2002)

Of note is that some inter-annual variation in the occurrence of cetaceans was recorded. There was a marked decrease in baleen whales, mainly fin, sei and minke whales, recorded in summer 2000/01 when compared with 1998/99 and 1999/2000. This can be explained in part by the reduction in survey effort in 2000/01, but this alone does not explain the size of the decrease. The distribution of survey effort is unlikely to be a factor, since species such as minke whales were recorded throughout the survey area while fin and sei whales were typically either deep water (fin) or shallow water (sei) species. It seems more likely that the occurrence of these species is linked to the local availability of food, which was perhaps relatively less in 2000/01 than in preceding years (*White et al., 2002*).

In addition to the sightings described above, several species of marine mammals were recorded on fewer than 10 occasions and are therefore described as rare in White et al. (2002). Descriptions of these sightings are provided in Table 5.1.

Table 5.1: Rare Species identified in the Falkland Islands waters (White et al., 2002)

Southern right whale (*Eubalaena australis*)	Two records, of two separate individuals, were recorded in 1998. A further record was made in June 2000 and two additional records of single animals in January 2001. Although the majority of sightings were to the north of the Falkland Islands, the low number sightings make geographic or seasonal modelling inaccurate.
Humpback whale (*Megaptera novaeangliae*)	Seven records were made over five occasions, all between October and March in Patagonian Shelf waters. Most records were made to the north-west of the Falkland Islands.
Unidentified beaked whale species (*Mesoplodon spp.)*	There were 15 animals sighted in seven occasions, none were specifically identified. All records were in waters deeper than 1,000 metres to the east of the Falkland Islands.
Killer whale (*Orcinus orca*)	A total of 18 animals were recorded in seven occasions, mainly in coastal and Patagonian Shelf waters. These sightings took place throughout the year in groups of between one and four animals. Longline fishing vessels have also reported interaction with killer whales in deep waters to the north and east, where they remove fish from the lines (*Munro, 2004*).
Southern right whale dolphin (*Lissodelphis peronii*)	Southern right whale dolphins were recorded on five occasions totaling 231 animals, all in deep waters to the east of the Falkland Islands.

Munro (2004) states that records of sightings in Falkland Islands waters of dusky dolphins (*Lagenorhynchus obscurus*), bottlenose dolphin (*Tursiops truncatus*) and spectacled porpoise (*Phococena dioptica*) have also been made. The lack of any sighting over the three year survey period, however, also indicates that these animals may be considered rare.

Based on the JNCC survey results (*White et al., 2002*), the following species of cetacean were recorded within the vicinity of the proposed drilling locations: long-finned pilot whale, hourglass dolphin and Peale's dolphin, although during the months of the proposed drilling period (April – June) only long-finned pilot whale and Peale's dolphin were recorded in significant numbers. Due to the migratory nature of cetaceans, and the lower survey effort to the south and east of the Falkland Islands the possibility of other species in the exploration area cannot be discounted. Species specifically recorded offshore the Falkland Islands during the proposed drilling period (April to June) include sei whale, sperm whale, minke whale and Commerson's dolphin.

Additional marine mammal data has also been compiled based on the reports provided by Marine Mammal Observers (MMOs) on seismic vessels during the seismic acquisition through the licence blocks PL018-PL022 (November 2007-February 2008). The following marine mammal species were recorded; Long-finned Pilot Whale (> 250 species), Hourglass dolphin (approx. 60 species), Fin whale (>40 species), Sei whale (approx. 4 species), Killer whale (approx. 7 species), Peale's dolphin (approx. 12 species) Sperm whale (approx. 8 species). Few species of Blue whale, Dwarf Minke whale and Baleen whale were also recorded,. Due to the migratory nature of cetaceans, it is possible that other cetacean species may move through the licence areas.

This data is comparable with the marine mammal records from the seismic surveys carried out in BHP Petroleum's licence areas (neighbouring Borders & Southern blocks) in June 2007 (Figures 5.21-5.22), where a Marine Mammal Observer was also stationed on board the seismic vessel.

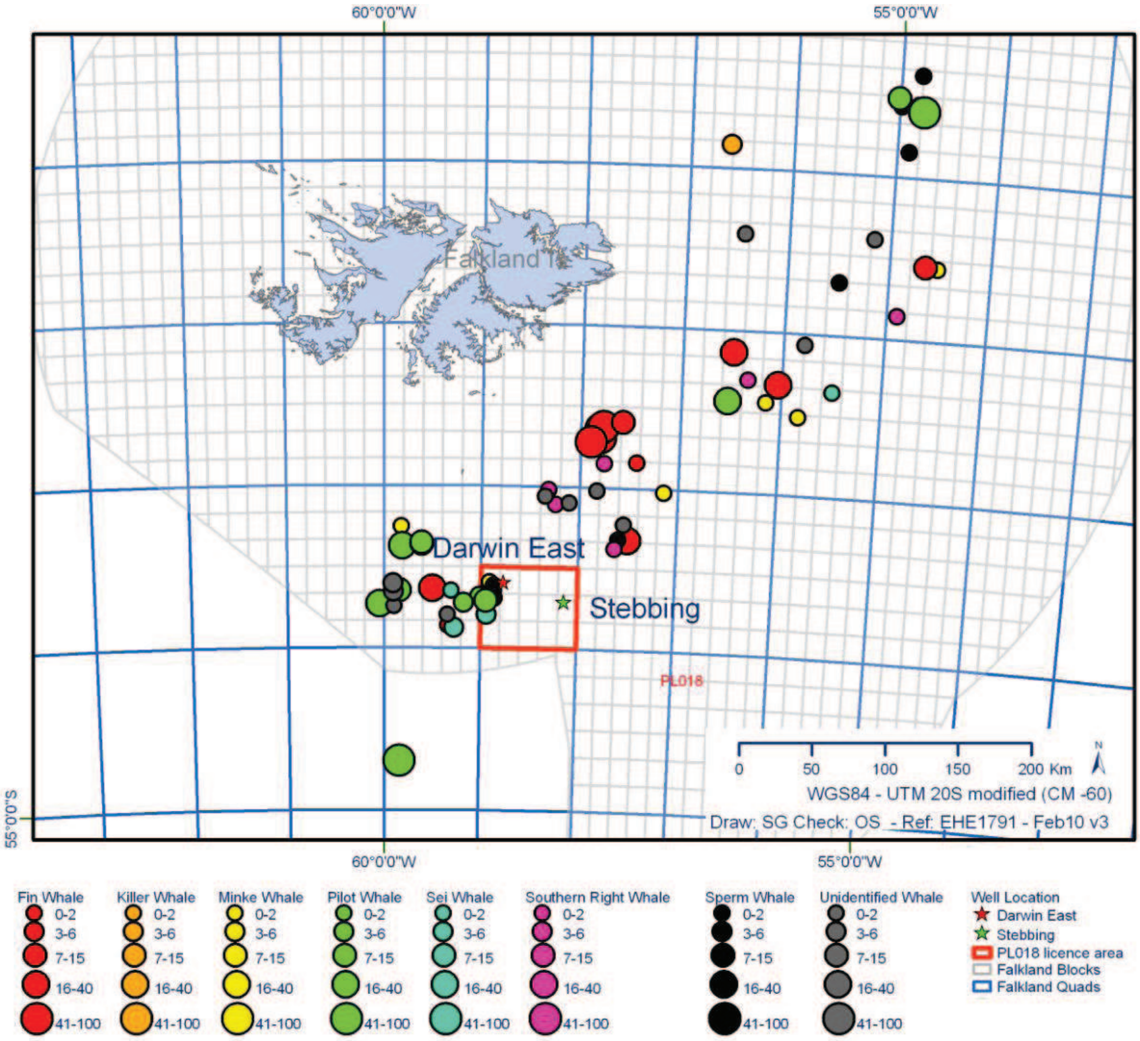


Figure 5.21 Numbers of Whales recorded by MMOs during the Seismic Surveys undertaken in BHP Petroleum's license areas (neighboring with Borders & Southern blocks) during June 2007.

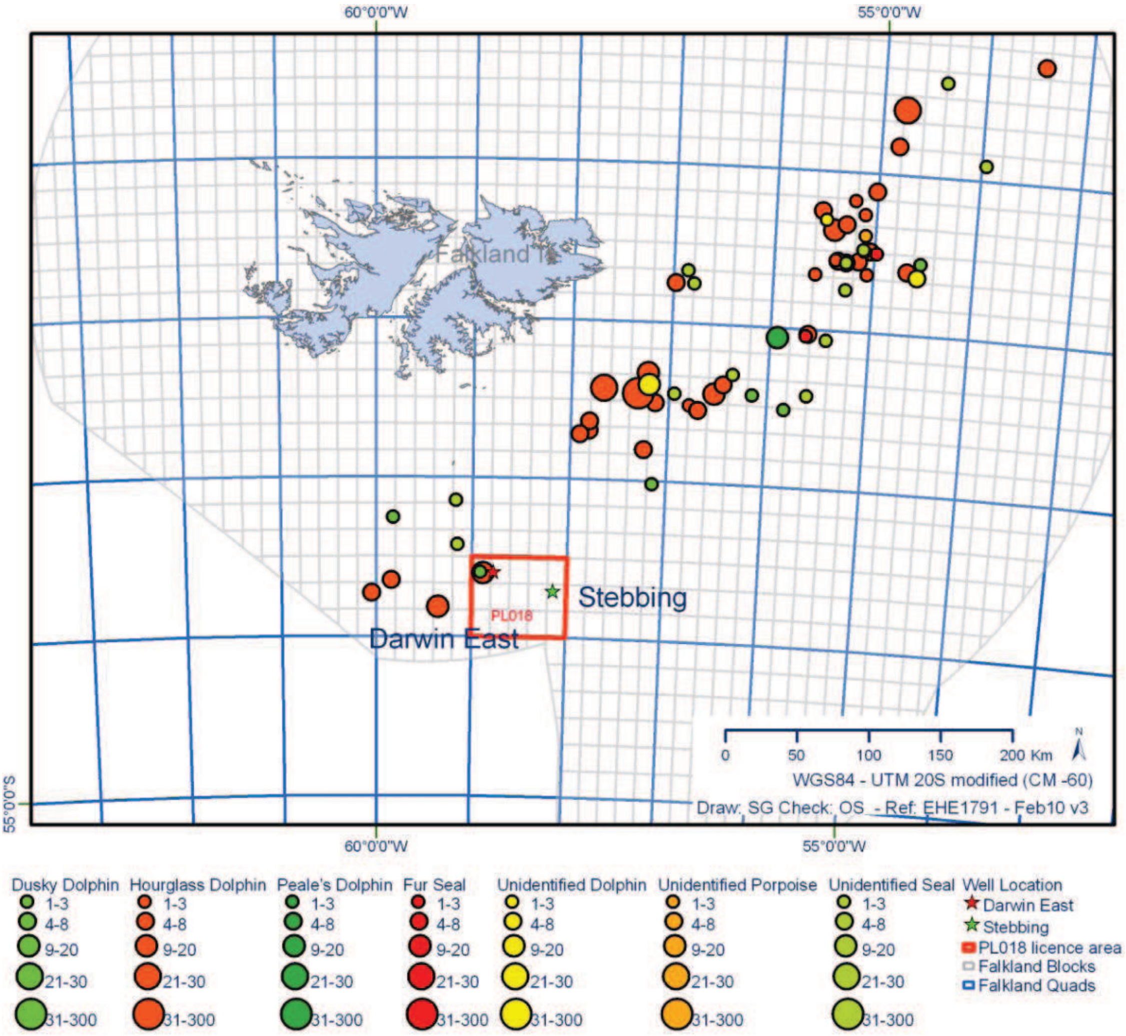


Figure 5.22 Numbers of Seals Dolphins and Porpoises recorded by MMOs during the Seismic Surveys undertaken in BHP Petroleum's license areas (neighboring with Borders & Southern license blocks) during June 2007

Pinnipeds

Three species of pinniped, South American sea lion, South American fur seal and southern elephant seal, breed in the Falkland Islands (*Strange, 1992*). A further two species, Antarctic and subantarctic fur seals, have been recorded breeding (D. Thompson pers. comm., in *White et al., 2002*) and a further species, leopard seal, is recorded annually as a non-breeding visitor to the islands.

Knowledge of the distribution and size of breeding pinniped populations indicates that the three species that regularly breed in the islands are currently at very low levels compared to historical populations (*Strange 1992; Thompson et al. 1995*). While these declines were probably linked with exploitation for skins and oil, which continued until the early 1960s, the populations have failed to recover since the cessation of hunting (*Strange 1992; Thompson et al. 1995*).

Little is known of the at-sea distribution of Falkland Islands pinnipeds. Prior to the start of a South American fur seal satellite tracking programme in 2000 (*Thompson and Moss 2001*), the only previous work was a satellite tracking study of South American sea lions (*Thompson et al. 1995*). In addition, satellite tracking of southern elephant seals from Patagonia (*Campagna et al. 1995*) and Antarctic fur seals from South Georgia (I. Boyd pers. comm. in *White et al., 2002*) have both tracked animals into Falkland Islands waters, but, in common with satellite tracking studies of seabirds, sample sizes are small.

South American Sea Lion (Otaria flavescens - formally Otaria byronia)

The southern sea lion (*Otario flavescens*) is widely distributed along the coast of South America. Within the Falkland Islands, sea lions breed in small colonies at around one hundred sites, mainly on remote sandy beaches with adjacent tussac grass.

Both males and females are an orange-colour with upturned snouts. The manes on males are lighter than females, but female fur on the head and neck is lighter than that of males. Size varies with males having an average length of 2.6 metres and an average weight of about 300 kg. Females are slightly smaller, having an average length of 1.8 to 2 metres and usually weighing approximately half the weight of the males, around 150 kg. Breeding begins in December when bulls establish territories, with the females arriving during late December and January to pup. This will, therefore, may coincide with the proposed drilling period for Darwin East well. Females mate shortly after pupping, but continue to rear the pups for up to 12 months or more (*Munro, 2004*)

The UK Sea Mammals Research Unit (SMRU) conducted the most complete census of southern sea lions on the Falkland Islands in 1995 and repeated it in 2003 to monitor population trends. The two censuses update partial surveys conducted between 1934 and 1937 by Hamilton and aerial surveys conducted by Strange in 1990 (*Strange, 1992*). Population estimates have varied with the JNCC at-sea surveys estimating a Falkland Islands resident population of 3,385. Thompson (2003) estimates a current Falkland Islands population of approximately 7,047 animals, with an estimated 2,744 pups born annually. The census trends concluded that while the overall population is increasing, it is still well below the peak populations recorded in the 1930's, due to heavy exploitation during the twentieth century.

During winter, non-breeding individuals appear to remain in the Falkland Islands, hauling out at breeding sites and at other localities (*Otley, 2008*).

The distribution of South American sea lions recorded during the JNCC Seabirds and Marine Mammals at Sea Survey between February 1998 and January 2001 (*White et al., 2002*) are illustrated in Figure 5.23. A total of 81 South American sea lions were recorded, on 77 occasions, with the majority recorded from coastal waters or Patagonian Shelf waters. Given the distribution pattern, it is possible that they might be present within the vicinity of the proposed drilling locations.

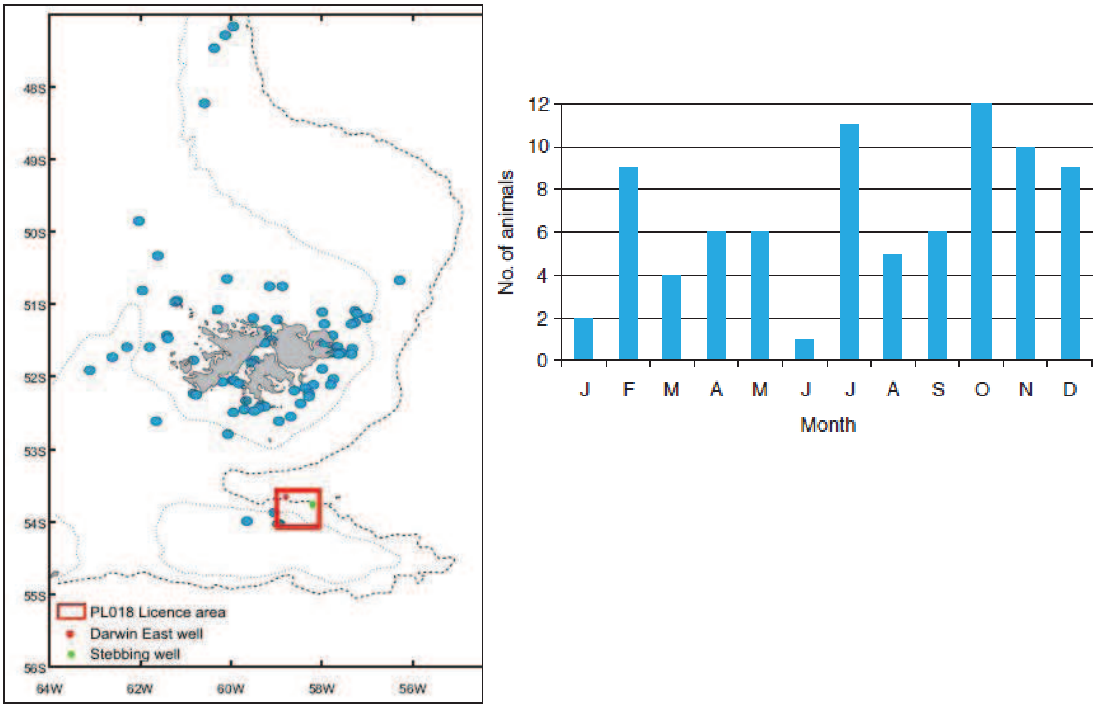


Figure 5.23 Distributions of South American Sea Lion Sightings (All Months) (White et al., 2002)

<u>*South American Fur Seal (Arctocephalus australis)*</u>

The South American fur seal is the smallest of the pinnipeds to breed in the Falkland Islands. It breeds at 15 known sites within the Falkland Islands, where it tends to concentrate in fairly large numbers on elevated rocky shores. Fur seals appear to prefer to inhabit rocky coastal strips above the reach of storms (*Laws, 1981*) and undercut cliff edges, with access to both offshore reefs or kelp beds and coastal tussac grass habitat (*Bonner, 1968*).

Males of the species have a dark grey coat of fur with the females and sub-adults having lighter grey or tan colouring on the chest and muzzle. On average, adult males measure up to 2 metres long and weigh 150–200 kg and females measure up to 1.5 metres long and weigh 30–60 kg. Mating commences in early November with the establishment of territories by the dominant bulls. Cubs are generally born around 6–8 weeks later in mid-December. This will, therefore, may coincide with the proposed drilling period.

It is estimated that the current Falkland Islands population stands at over 10,000 adults, however no dedicated population census has been conducted in recent years. It is probable that there may have been a steady increase this century following its near extermination by the fur trade during the last century (*Munro, 2004*).

In the Falkland Islands, the species is known to breed at about ten sites, including Jason Cays West, Elephant Jason Island, Seal Rocks, North Fur Island, North Island, New Island, Beaver Island, Bird Island, Volunteer Rocks and Eddystone Rock. Bird Island has two colonies, with 100 individuals in one (perhaps non-breeding males) and approximately 10,000 in another, a few hundred breed on Beaver Island and 150 animals breed on Volunteer Rocks (*Falklands Conservation, 2006*) and 2,000 adults and sub-adults on New Island (*New Island Conservation Trust, 2007*).

During the JNCC Seabirds and Marine Mammals at Sea Survey between February 1998 and January 2001 (*White et al., 2002*) a total of 937 fur seals was recorded, on 442 occasions. Fur seals were recorded in all months with a distinct midwinter peak in June and July and a further peak in November. The peak in June and July was largely a result of the locally high numbers of animals recorded in coastal and Patagonian Shelf waters. The November peak was a result of a marked increase in the number of records in deep waters to the north-east of the islands. Outside these months, fur seals were encountered in lower numbers throughout the survey area.

During winter, non-breeding individuals appear to remain in the Falkland Islands, hauling out at breeding sites and at other localities (*Strange, 1992*).

<u>*Southern Elephant Seal (Mirounga leonine)*</u>

The southern elephant seal is the largest of all the pinniped species. Found in most sub-Antarctic waters, the Falkland Islands hold only a very small percentage of the world population. Only one major breeding colony exists on Sea Lion Island and it is estimated to represent around 90% or more of the breeding population of the Falkland Islands.

The elephant seal gets its name from both its massive size and from the large proboscis which males have. Males are much bigger than the females with bulls weighing around 2000—3000 kg and 3 metres in length compared to about 600–800 kg for females. Southern elephant seals breed from August to November with the bulls arriving weeks before the females to claim territories. Pups are born 0–10 days after the females come to shore.

Falkland Islands' elephant seals were almost hunted to extinction by sealers in the past. A population peak of around 3,500 was recorded in the 1950's, but there are indications that the Falkland Islands population has declined over the last few years. Elephant seals feed on fish and squid and impacts to the food source and environmental changes are key factors in population decline.

Little is know about where elephant seals that breed in the Falkland Islands feed during the non-breeding season and pre-moult period. Most re-sights of female elephant seals that breed on Sea Lion Island are at South Shetland Islands and the Antarctic Peninsula (F. Galimberti and S. Simona, personal communication, in *Otley, 2008*). Only five elephant seals were sighted over two years of Falkland Islands at-sea survey effort (*White et al. 2002*).

During February and March 2007, approximately 10 female elephant seals hauled ashore on Livingston Island, South Shetlands were equipped with satellite transmitters (D. Costa, personal communication, in *Otley, 2008*). Although most of these animals head back to South Georgia to breed by September, one tracked female swam up to the Falkland Islands, arriving to Sea Lion Easterly, where it most likely bred.

This data suggests that elephant seals that breed at sites to the south of the Falkland Islands are most likely foraging to the south, including the Drake Passage and Antarctic waters. Thus conservation efforts in the Falkland Islands may ultimately play only a small part in achieving the international goal of securing long term survival of the Falkland Islands population (*Otley, 2008*).

The distribution of southern elephant seals recorded during the JNCC Seabirds and Marine Mammals at Sea Survey between February 1998 and January 2001 (*White et al., 2002*) are illustrated in Figure 5.24. A total of 13 southern elephant seals were recorded, with animals recorded in every season. All records north of 50°S occurred between January and May whereas all those south of 50°S were in June, August and November. None were observed within the vicinity of the proposed drilling locations.

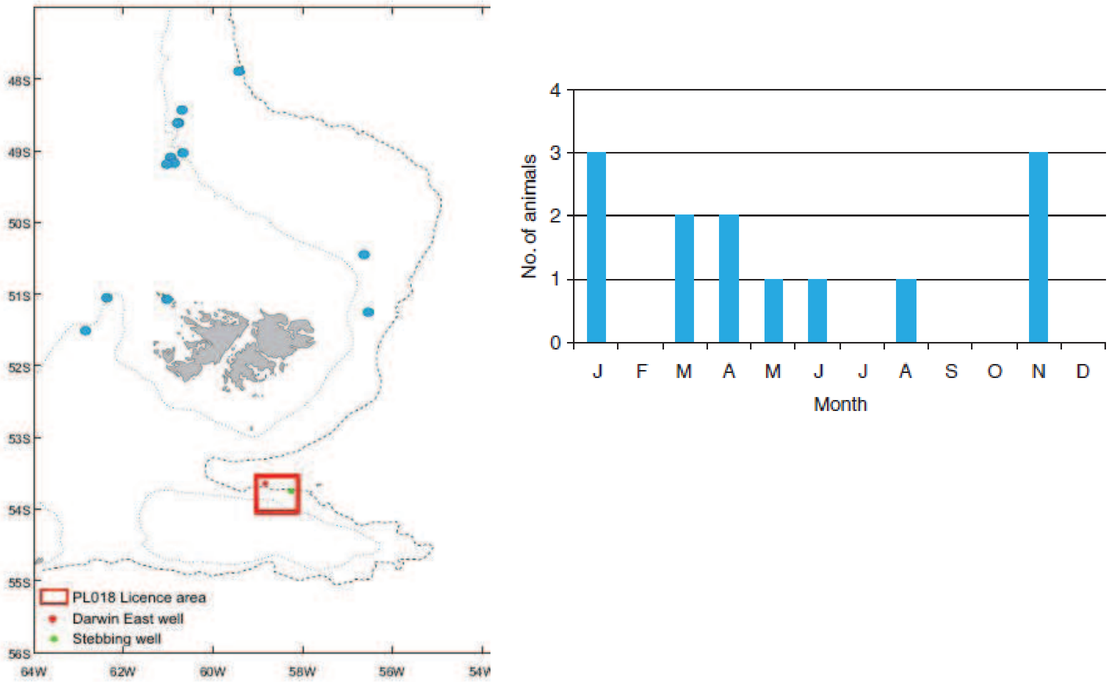


Figure 5.24 Distributions of Southern Elephant Seal Sightings (All Months) (White et al., 2002)

<u>Leopard Seal (Hydrurga leptonyx)</u>

The leopard seal is a winter visitor to the Falkland Islands, with only occasional sightings reported to Falklands Conservation. They are known to breed on sub-Antarctic pack ice and are highly unlikely to be impacted by normal offshore operations.

Leopard seals have dark grey backs and light grey stomachs. They get their name from their spotted throats. Females are generally larger than the males. The males are usually about 2.8 meters long and weigh up to 320 kg, while females are around 3 to 3.5 metres in length and weigh up to 370–400 kg.

5.2.9 Seabirds

The Falkland Islands are an area of global importance for birdlife, particularly seabird species of international significance. The North Falklands Current upwells nutrient rich water from Antarctic waters and provides an area of high plankton activity, forming the basis of the marine ecosystem and supporting seabird activity in the region.

The avifauna of the region is well studied and documented, and seabird distribution, breeding and foraging patterns have been studied extensively. A number of publications outlining survey efforts by those such as Croxall et al. (1984), Woods (1988; 1997), Strange (1992) have recently been supplemented by ongoing seabird monitoring and survey programmes conducted by FC/JNCC such as the:

- Falkland Islands State of the Environment Report (*Otley et al., 2008*). This report documents the current knowledge of the Falkland Islands' environment.
- Origin, age, sex and breeding status of wandering albatrosses (*Diomedea exulans*), northern (*Macronectes halli*) and southern giant petrels (*Macronectes giganteus*) attending demersal longliners in Falkland Islands and Scotia Ridge waters, 2001 –2005 (*Otley et al., 2006*). The report summarises three years of survey work undertaken in Falkland Islands' waters between 2001 and 2005.
- Patterns of seabird attendance at Patagonian toothfish longliners in the oceanic waters of the Falkland Islands, 2001–2004 (*Otley, 2005*). The report summarises the surveys of seabirds attending Patagonian toothfish longliners during line setting and hauling activities in deepwater to the east of the Falkland Islands made between July 2001 and June 2004.
- The distribution of seabirds and marine mammals in Falkland Islands' waters (*White, 2002*). The report summarises three years of survey work undertaken in Falkland Islands' waters between February 1998 and January 2001.
- Vulnerable concentrations of seabirds *(White et al., 2001).* The report summarises two years of survey work in the form of a vulnerability atlas, with the aim of highlighting the locations of seabird concentrations that would be the most vulnerable to the effects of surface pollution.

These reports have been used extensively to provide a synopsis of seabird species numbers, locations and sensitivities, and the information presented below and in the following sections has been based on these sources.

Between 1998 and 2001 a total of 218 species were recorded along with some unconfirmed sightings and have been included within this list. There were 21 resident landbirds, 18 waterbirds, 22 breeding seabirds, 18 annual non-breeding migrants and at least 139 occasional visitors (*Woods et al., 2004*). Between 2001 and 2005 a total of 547 sightings of 291 banded wandering albatross *Diomedea exulans* and 21 sightings of 14 banded giant petrels *Macronectes* spp. were made (*Otley, 2005*).

There are five different species of breeding penguin in the Falkland Islands (rockhopper, Magellanic, gentoo, king and macaroni). The Falklands are the most important world site for the endangered rockhopper penguin and are also home to 80% of the world's breeding population of black-browed albatross. Several rare and threatened species of petrel nest on offshore islands.

A search of the BirdlLife International website for the IUCN Red List aves in the Falkland Islands, found 10 species as either 'Endangered' or 'Vulnerable', and a further seven as 'Near Threatened' species' (Appendix E).

Penguins

Nine penguin species have been recorded in the Falkland Islands with the following six species identified during the at-sea survey period (1998–2001) (Figure 5.25). Of these, only the Chinstrap penguin (p. *Antarctica*) is not considered to be a locally breeding species.

- King penguin (*Aptenodytes patagonicus*);
- Gentoo penguin (*Pygoscelis papua*);
- Rockhopper penguin (*Eudyptes chrysocome*);
- Macaroni penguin (*Eudyptes chrysolophus*);
- Magellanic penguin (*Speniscus magellanicus*);
- Chinstrap penguin (*P. antarctica*).

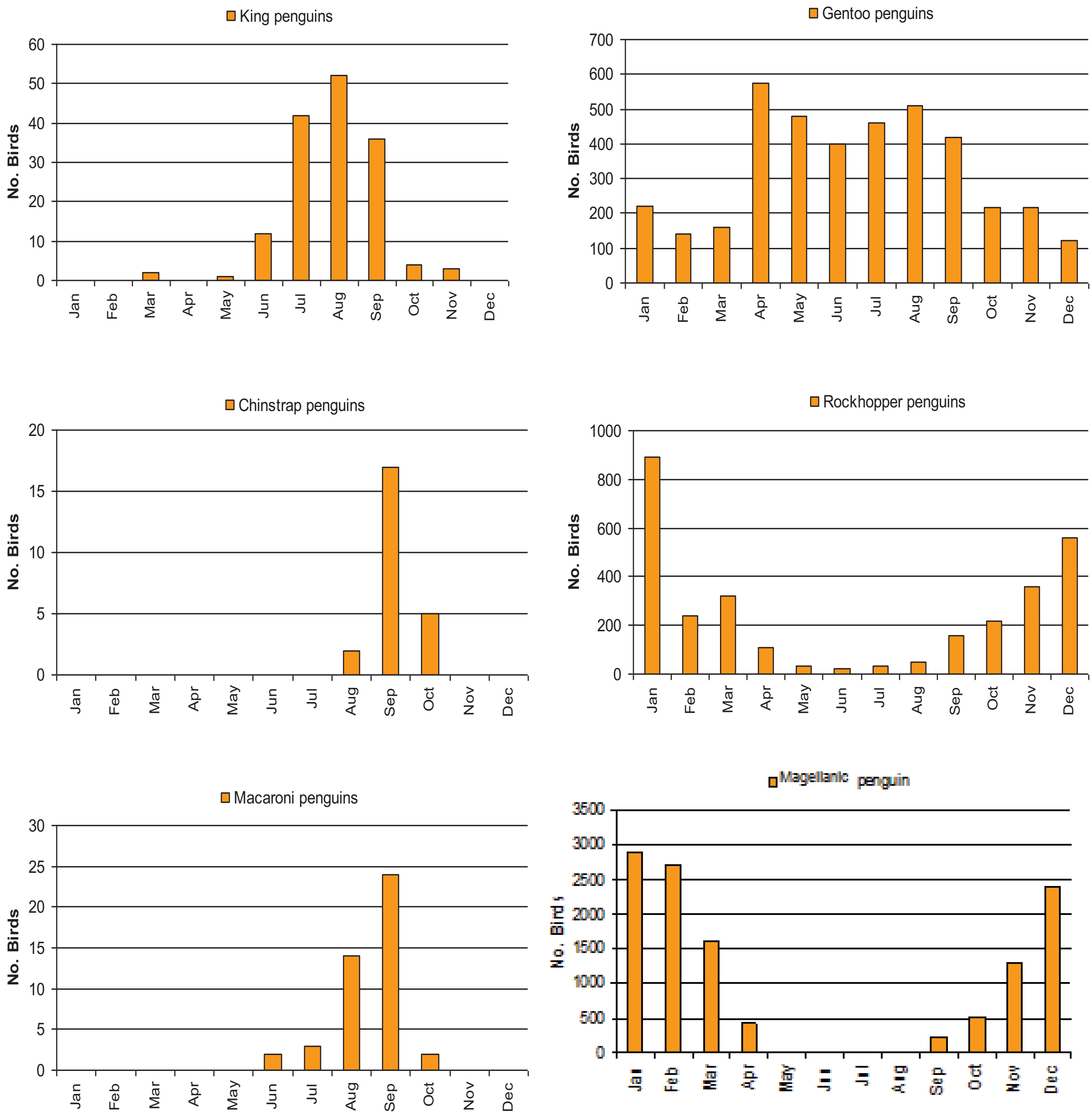


Figure 5.25 Penguin Numbers Recorded per Month (JNCC, 2002)

King Penguin (Aptenodytes patagonicus)

The Falkland Islands population of king penguin is almost entirely concentrated at Volunteer Point, although a few individuals can be found nesting amongst gentoo penguins at four to six locations within the Falklands (*Huin, 2007*). The 2005/2006 Penguin Consensus observed 260 chicks at Volunteer Beach (*Huin, 2007*). From the 1980s to 2001, the Volunteer Beach breeding population was estimated at between 344–516 breeding pairs increasing at additional 12–15 chicks per year. This increase has somewhat slowed over the past three years (*Huin, 2007*).

The Falkland Islands' population makes up only 0.04% of the world population and is considered to be of local rather than global importance (*Munro, 2004*), however since the population is mostly limited to one site its vulnerability increases, particularly to a polluting event.

By mid-winter birds begin to forage north of the Falklands, in an area used by many bird species as a winter feeding ground (Patagonian continental shelf and slope waters within the Antarctic

Polar Frontal Zone). In total 151 king penguins were recorded during the 1998–2001 at-sea surveys on 81 occasions, almost entirely between May and November.

The majority of king penguin records occur to the north of the Falkland Islands between June and September (Figure 5.25). Distribution maps also show scattered sightings to the south-east of the Falkland Islands, including within the licence area, primarily between June and September with a very small number of sightings between October and May.

Gentoo penguin (Pygoscelis papua)

The gentoo penguin is numerous and widely distributed throughout the Falkland Islands, although most are found around West Falklands and the outer islands. The population was estimated at 64,426 breeding pairs in 1995/1996, 113,000 in 2001/2002 and 65,857 in 2005/2006 and represents, of the 12 major breeding regions, the second largest gentoo population in the world after South Georgia (*Huin, 2007*). The reduction in gentoo numbers between 2000 and 2005 was due to paralytic shellfish poisoning resulting from a red algal bloom in 2002.

Tracking of foraging gentoo penguins show that the birds remain in predominantly inshore waters, preferring low coastal plains close to a sand or shingle beach and an open ocean free of kelp, although in winter foraging trips may be undertaken up to 300 km from the coast.

A total of 3,896 gentoo penguins were recorded during 1998 to 2001, covering all months but with an increase between April and September (Figure 5.25). They are only likely to be found outside coastal waters between April and November, with densities in offshore areas generally low.

There were no records of gentoo penguins within the licence area and the predominance in near-shore areas makes it unlikely this species would be encountered in the vicinity of the proposed drilling operations.

Rockhopper penguin (Eudyptes chrysocome)

The rockhopper penguin *Eudyptes chrysocome* has been split into the northern rockhopper penguin *E. moseleyi* and southern rockhopper penguin *E. chrysocome*. It is the southern rockhopper penguin that breeds in the Falkland Islands.

Rockhopper penguins are found in greatest numbers in the outer islands of West Falklands. There are around 52 breeding sites on the Falklands, with a population estimated at 211,000 breeding pairs in 2005/2006 (*Huin, 2007*). Three colonies of importance in the Falklands are on Beauchêne Island (31%), Steeple Jason (28%) and Grand Jason (5%). Forty-eight percent of the world's southern rockhopper population is found on islands in southern Chile, 29% on the Falklands and 24% in southern Argentina. The decline of the rockhopper population has lead to the IUCN classifying it as 'Threatened' (*BI, 2004*).

Annual surveys conducted at selected sites suggest that the rockhopper population has stabilised since the early 1990's, although there are still occasional periodic annual declines from which the populations do not fully recover. Tracking of rockhopper penguins has shown that they may enter the licence area on foraging trips.

Rockhopper penguins have been observed at significant distance from the Falkland Islands. Between December and March the majority of recorded sightings are from near-shore areas and to the west of the Falkland Islands, with very few scattered sightings within the vicinity of the proposed drilling operations. From September to November distribution is more widely spread across Falkland Islands' waters and scattered sightings are likely throughout Border & Southern's licence area. Between April and August there are fewer sightings and these are primarily to the north and west of the Falkland Islands, with only occasional records within the vicinity of the proposed drilling operations (refer to Figure 5.25).

Macaroni penguin (Eudyptes chrysolophus)

The macaroni penguin is the least common breeding penguin species in the Falklands, with 24 pairs recently recorded at 19 rockhopper penguin colonies, mostly on the eastern side of the Falkland Islands (*Huin, 2007*). Mixed pairs of rockhopper and macaroni penguins have been observed and suggests hybridisation may occur between the species (*White & Clausen, 2002*).

The macaroni penguin, however, is globally the most common species with millions of pairs present in the southern Atlantic and Indian Oceans (*Munro, 2004*). The occurrence of vagrant individuals in the Falklands is therefore of only local interest.

The distribution of macaroni penguin is mainly to the north of the Islands, although there is a possibility of occurrence within the vicinity of the proposed exploration wells.

Magellanic penguin (Speniscus magellanicus)

The Magellanic penguin is less colonial than the other penguin species on the Falkland Islands and an estimated 200,000 breeding pairs over 90 locations on the Islands are thought to comprise one third of the world's population (*Thompson, 1993*). As a significant proportion of the world population, the Falkland Islands are internationally important for the Magellanic penguins.

In excess of 12,000 Magellanic penguins were recorded during the 1998–2001 at-sea surveys, the majority between November and April. Few were recorded between May and August, with the highest densities recorded between December and February, primarily in inshore waters. Some locally high densities were recorded over Patagonian Shelf waters and continental shelf slope waters to the north of the Falklands.

Penguin tracking has shown that they may travel through Borders & Southern's licence area during long foraging trips into deeper waters, although majority of sightings were recorded to the north of the Falkland Islands and in near-shore waters. Distribution offshore peaks between November and April, with fewer records between September and October and hardly any between May and August (refer to Figure 5.25). Occurrence within the licence area is possible between November and April, but not in significant numbers.

Chinstrap penguin (P. antarctica)

Chinstrap penguins do not breed in the Falkland Islands, however a total of 24 individuals were recorded on 10 occasions (1998–2001). All records occurred between August and October to the south-east of the Falkland Islands. Occurrence in the vicinity of the proposed drilling activity is therefore possible over these months, but unlikely given the frequency of sightings.

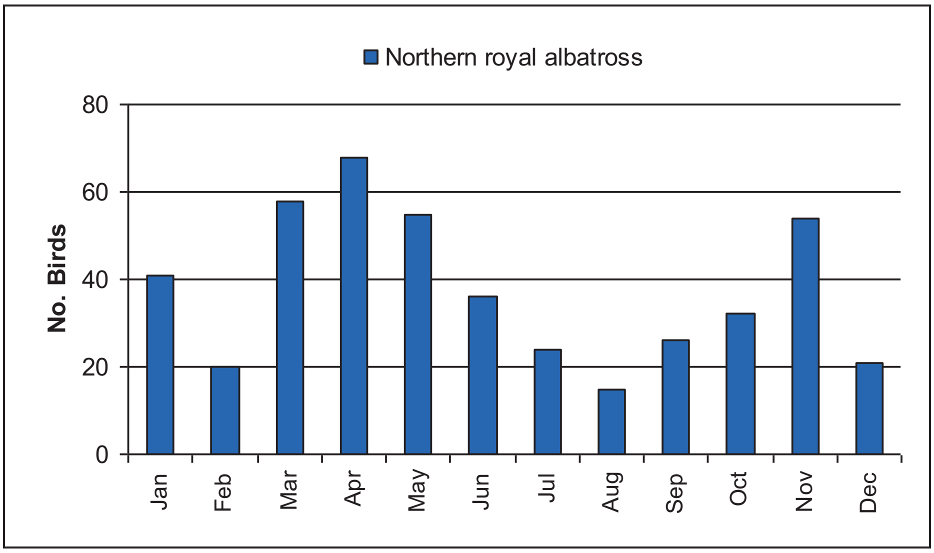
Albatrosses

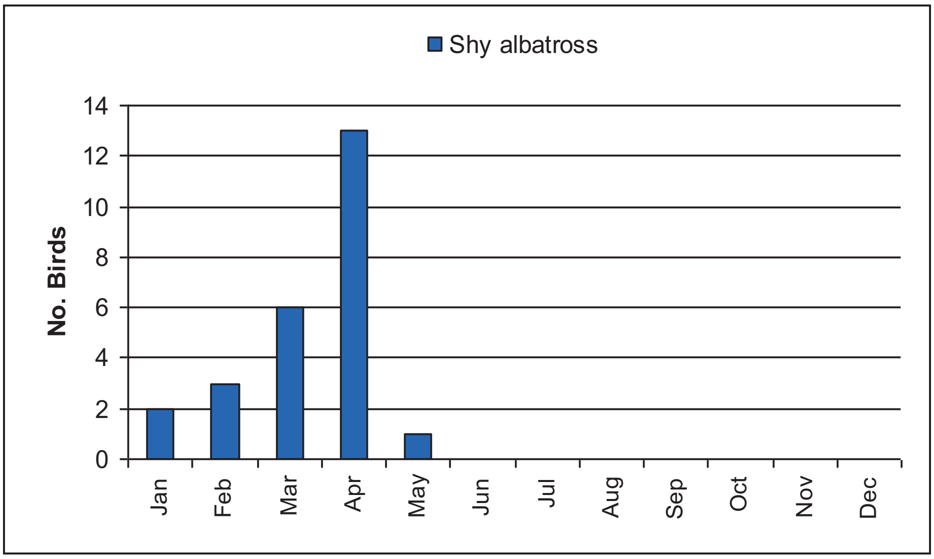
Albatross species are globally declining with populations in the Falkland Islands reported to have dropped by 28% in the last 20 years (*Woods, 1988*). Eleven species of albatross have been recorded in the Falkland Islands, although only the black-browed albatross is a resident breeding species.

Ten of the 11 species of albatross recorded in the Falkland Islands are afforded conservation status, and include:

- Black-browed albatross (*Thalassarche melanophris*) – Endangered
- Buller's albatross (*Thalassarche bulleri*) – Vulnerable
- Grey-headed albatross (*Thalassarche chrysostoma*) – Vulnerable
- Light-mantled sooty albatross (*Phoebetricia palpebrata*) – Near Threatened
- Northern royal albatross (*Diomedea sanfordi*) - Vulnerable
- Shy albatross (*Thalassarche cauta*) – Near Threatened
- Sooty albatross (*Phoebetria fusca*) – Endangered
- Southern royal albatross (*Diomedea epomophora*) - Endangered
- Wandering albatross (*Diomedea exulans*) - Vulnerable
- Yellow-nosed albatross *(Thalassarche chlororhynchos)* – Endangered

The numbers of individuals of each species observed during the at-sea survey period (1998–2001) per month are shown in Figure 5.26, and are described in detail below.





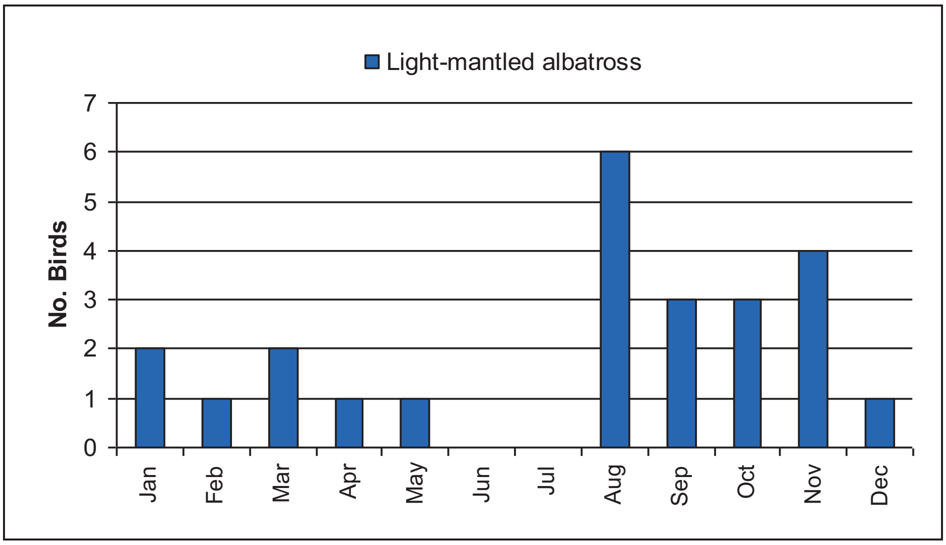
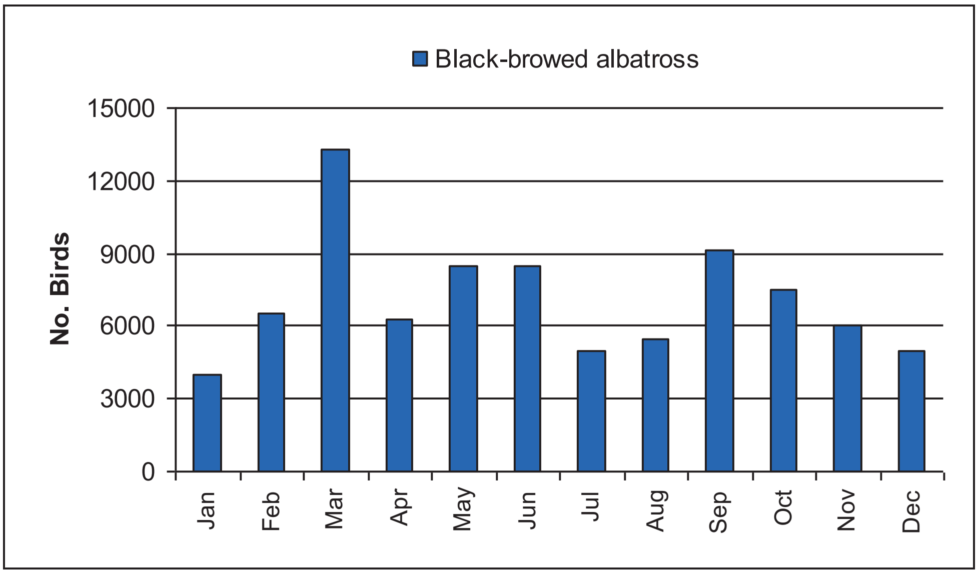


Figure 5.26 Albatross Numbers Recorded per Month (JNCC, 2002)



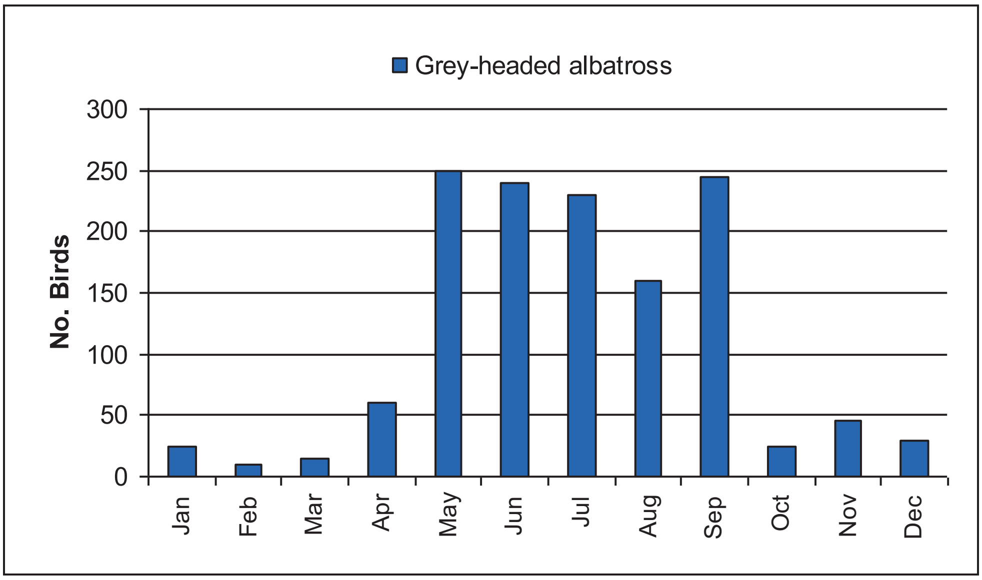


Figure 5.26. (cont.) ***Albatross Numbers Recorded per Month (JNCC, 2002)***

Black-browed albatross (Thalassarche melanophris)

The population in the Falkland Islands is genetically distinct from all other populations and is the only species that breeds on the Islands. The estimated 400,000 breeding pairs represents 70% of the world population, and makes the islands of critical importance for the conservation of this species. Black-browed albatross is now classified as 'Endangered' by Birdlife International and the IUCN Red List.

Black-browed albatross were recorded in all months (1998–2001), with a total of 84,614 birds recorded, reaching a peak in March. Between November and January the highest densities occurred in inshore waters to the west of the Falklands. Between February and June high densities occurred throughout Patagonian Shelf waters to the north-west of the Falklands and between July and October high densities shifted to the west and south-west of the Falklands (refer to Figure 5.26).

There is very low recorded distribution in the vicinity of the proposed drilling areas, although occasional sightings are likely, primarily between November and January but also at other times of the year.

Grey-headed albatross (Thalassarche chrysostoma)

Grey-headed albatross visit the Falkland Islands from breeding grounds in South Georgia and Diego Ramirez. The grey-headed albatross is classified as 'Vulnerable'.

A total of 1321 grey-headed albatross were recorded, covering all months (1998–2001) with a peak between May and September. Distribution varied throughout the year, with records over the licence area occurring throughout the year but primarily between July and September (refer to Figure 5.26). Greatest numbers of grey-headed albatross occur to the south and west of the Falkland Islands and occurrence within the licence areas is possible.

Light-mantled sooty albatross (Phoebetricia palpebrata)

The light-mantled albatross is also a non-breeding visitor from the South Georgia region where there are an estimated 5000–7000 breeding pairs.

In total 24 were recorded during the 1998–2001 at-sea survey, mainly between August and November and in waters deeper than 200 metres to the east of the Falklands. Occurrence within the vicinity of the proposed drilling activity is therefore not likely.

Northern (Diomedea sanfordi) and southern (Diomedea epomophora) royal albatross

The royal albatrosses are also visiting species, breeding in New Zealand and using South Pacific and Patagonian feeding grounds. The southern royal albatross is classified as 'Vulnerable' where as the Northern is 'Endangered'.

Of the 4,114 royal albatrosses recorded (1998–2001), 3252 were identified as southern and 447 as northern (with 415 not determined). Highest numbers of southern royal albatross were seen between March and June, particularly to the north-west of the Falklands. Highest numbers of northern royal albatross were seen between March and July (Figure 5.26).

Although occasional sightings of northern and southern royal albatross are probable within the vicinity of the proposed exploration wells to the south-east of the Falkland Islands, the predominance of sightings to the north-west indicates that occurrence within the licence areas is not significant.

Shy albatross (Thalassarche cauta)

Although the shy albatross is found in Patagonian waters, their dispersal from breeding grounds in Australia and New Zealand is not well known. The shy albatross is classified as 'Near Threatened'.

Few shy albatross have been recorded in the Falkland Islands previously. A total of 25 were recorded during the 1998–2001 at-sea survey, all between January and May. The majority of records were from the north and west of the Falklands. A single recorded sighting was made in the neighbouring operator's licence area and occasional sightings are possible between January and May, however this is unlikely and occurrence within the licence area is not considered significant.

Wandering albatross (Diomedea exulans)

The wandering albatross is a non-breeding visitor to the Falkland Islands, predominantly from breeding colonies in the South Georgia Islands around 1,300 kilometres to the east. The wandering albatross is classified as 'Vulnerable', as the population continues to decline with only 1,553 breeding pairs recorded in 2003–2004.

Wandering albatross were recorded by the at-sea surveys for all months, with a peak in November and highs between January and April (Figure 5.26). They were locally abundant in all deep waters surveyed and therefore could possibly occur within the licence area.

Petrels and Shearwater

Petrels and shearwaters form the largest group of oceanic birds, remaining at sea throughout their lives, except for a few months each year when they return to land to breed. The most common breeding species is the southern giant petrel (*Macronectes giganteus*) (*Otley et al., 2008*). As many as 26 species have previously been recorded in the Falkland Islands with nine species breeding on the Islands:

- Northern giant petrel (*Macronectes halli*)
- Southern giant petrel (*Macronectes giganteus*)
- Antarctic petrel (Thalassoica Antarctica)
- Cape petrel (Daption capense)
- Antarctic fulmar (Fulmarus glacialoides)
- Blue petrel (Halobaena caerulea)
- Kerguelen petrel (Pterodroma brevirostris)
- Soft-plumaged petrel (*Pterodroma mollis*)
- Atlantic petrel (Pterodroma incerta)
- Prion spp (Pachyptila spp)
- Grey petrel (Procellaria cinerea)
- White-chinned petrel (Procellaria aequinoctialis)
- Great shearwater (*Puffins gravis*)
- Sooty shearwater (*Puffins griseus*)
- Little shearwater (*Puffins assimilis*)
- Wilson's storm-petrel (*Oceanites oceanicus*)
- Grey backed storm-petrel (*Garrodia nereis*)
- Black-bellied storm-petrel (*Fregetta tropica*)
- White-bellied storm-petrel (*Fregetta grallaria*)
- White-bellied storm-petrel (*Fregetta grallaria*)
- Northern giant petrel (*Macronectes halli*)
- Southern giant petrel (*Macronectes giganteus*)

The Falkland Islands hold a significant percentage of the world population of the southern giant petrel and surveys have shown at-sea distribution to be concentrated mainly over Patagonian Shelf waters. Fishing related mortality is estimated to be around 100 birds per annum in these waters and world populations are declining. The species is classified as 'Vulnerable' (*BI, 2000*).

Giant petrels are divided between the northern and the southern, with only the southern giant petrel breeding regularly in the Falklands (population estimated at between 5,000 and 10,000 pairs (*Woods & Woods, 1997*)). In total 6,672 giant petrels were recorded in the at-sea survey (1998–2001), accounting for 3,535 southern and 751 northern giant petrel, with 2,386 recorded as unidentified giant petrel.

Southern giant petrels were recorded in all months during the at-sea survey, peaking in June and with highest densities between March and June over Patagonian Shelf waters to the west and south of the Falklands. The southern giant petrel breeds at 38 locations around the Falklands, in colony sizes ranging between one and 110,000 breeding pairs (*Reid & Huin, 2005*). Most colonies concentrate around the south of South Falklands and to the west of West Falklands. Nearly 20,000 breeding pairs were counted in 2004/2005, which account for 40% of the global population (*Reid & Huin, 2005*). Although sightings within the licence blocks are possible, distribution is concentrated away from this area and occurrence within the Borders & Southern acreage is not considered significant.

Northern giant petrels were recorded throughout the year. Between March and August densities were highest to the north and west of the Falklands. From September to February sightings were less concentrated and more widely scattered. Northern giant petrels were less likely to be recorded in coastal or inshore waters. Although scattered sightings have occurred over the licence area, the principal distribution of northern giant petrel is to the north-west of the Falkland Islands between March and August. Due to the low distribution over the licence blocks, occurrence is not considered significant.

A total of 56 Antarctic petrels were recorded, all between July and September in waters to the south-east of the Falklands. Antarctic petrels are winter visitors to the Falkland Islands. The distribution of Antarctic petrel sightings indicates that occurrence within the licence area is likely, although in low numbers and only during the austral winter when operations are less likely to be carried out.

Cape petrels were recorded every month, with a total of 15,199 records made over the survey. Highest numbers were recorded between May and September with very few records occurring between December and April. Distribution is primarily to the west of the Falkland Islands, although it becomes more widespread during October and November. There is a reasonable likelihood of occurrence within the licence area, although only in small numbers and the concentration to the west of the Islands indicates that this would not be of high significance.

A total of 18,061 Antarctic fulmars were recorded, all between April and December. Highest densities were recorded between April and June, dropping between July and October with only occasional sightings for the rest of the year. Only occasional records were made within the licence area and occurrence of this species is not considered significant.

Blue petrels, another non-breeding visitor to the Falkland Islands, were recorded in the period May to October. A total of 573 blue petrels were recorded, the majority in deep waters to the east and south-east of the Falklands. Occurrence within the licence area is considered likely, although only between May and November.

A total of 152 Kerguelen petrels were recorded, almost wholly between May and November and mainly in the deep waters to the north, east and south of the Falklands. Peak numbers were recorded in August. Distribution of Kerguelen petrel sightings was widespread and an occasional sighting within the licence area is likely, although the lack of any concentration of sightings makes this species less vulnerable to impacts.

Soft-plumaged petrels are non-breeding late summer visitors to the Falklands, with records occurring between November and April, peaking in January. In total, 861 soft-plumaged petrels were recorded, mainly in deep waters to the north-east of the Falkland Islands; hence occurrence within the licence area is considered unlikely.

A total of 252 Atlantic petrels were recorded, primarily between October and March but with records in all months. Most sightings were to the north-east and south-east of the Falklands in deep waters and occurrence of this species within the licence area is likely. The wide distribution of sightings decreases the potential impacts to this species from operations in any one area.

Due to the difficulty in identifying prions (small petrels) to species level at sea, most records from the survey were for 'prion species'. A total of 119,610 records make prions the most numerous seabirds encountered during the survey, with the highest numbers recorded between September and January. Highest densities were recorded to the west, north and south of the Falklands. Although occasional sightings within the licence area are likely, due to the concentration of prion sightings outside of this area occurrence is not considered to be significant.

The fairy prion was identifiable at sea and has been recorded separately. In total 228 fairy prions were recorded, in all months except February, with peaks in April, August and October. This species was recorded primarily in continental shelf slope and oceanic waters. Distribution of the fairy prion is widely scattered and sensitivity in the licence area is not considered to be significant.

Grey petrels were recorded mainly between December and March, with peak numbers in February. A total of 45 grey petrels were recorded, all in deep waters to the north and east of the Falklands. Although widely distributed, grey petrels are more likely to be sighted to the east and south-east of the Falkland Islands and occurrence in the licence area is therefore significant over the austral summer.

The white-chinned petrel breed on the Falkland Islands and survey work from summers of 2004/2005 and 2005/2006 indicate that this accounts for less than 1% of the global population. A total of 8,044 white-chinned petrel were recorded from the at-sea survey (1998–2001), encompassing all months but with the highest numbers between January and May. Most records were to the north and west of the Falklands. There were limited sightings to the east of the Islands and occurrence in the licence area is not considered to be significant.

Great shearwaters were recorded primarily between December and April during the at-sea survey, with almost none recorded between June and October. Total number of records was 6,468, mainly over shelf slope and oceanic waters to the north and east of the Falkland Islands. Although of importance at a local level, the population is not globally significant as an estimated five million breeding pairs are found on the Tristan da Cunha and Gough Island group. Distribution is widely scattered, primarily towards the north-east, and occurrence in the licence area is not considered to be significant.

Sooty shearwaters breed on the Falkland Islands, with a population estimated at 10,000 to 20,000 pairs (*Woods & Woods, 1997*). A total of 37,109 sooty shearwaters were recorded, mainly between September and March, peaking in October. Most records occurred throughout inshore waters of the

Falklands and shelf to the east and south. Although some sightings are likely in the licence area over the austral summer, distribution is mainly concentrated in shallower waters. The population is not considered to be globally significant as the world population is estimated to be in the millions.

A total of 24 little shearwaters were recorded, all between December and April with a peak in March. All records came from waters to the north and east of the Falklands. Probability of sightings within the licence areas is small and abundance in the licence blocks is not considered significant.

Of the six species of storm petrels previously recorded during the at-sea survey within Falkland Islands' waters, four species were recorded during at-sea surveys. Wilson's storm-petrel breeds on the Falklands with an estimated population in excess of 5,000 pairs (*Woods & Woods, 1997*). A total of 21,019 Wilson's storm-petrels were recorded, mainly between October and June. Most records were to the west and north-west of the Falklands, although high densities also occurred to the north-east between November and February. New colonies were recently found at Steeple Jason in 2004 and South Jason in 2006 (*Otley et al., 2008*). Offshore abundance is concentrated away from the licence area and not considered significant in this area.

The Falkland Islands support between 1000 and 5000 breeding pairs of grey-backed storm-petrels (*Woods & Woods, 1997*). A total of 2758 grey-backed storm-petrels were recorded, mainly between September and March. Records occurred on all sides of the Falklands, with high densities recorded to the north of the Falklands from November to March. A few recordings were made within the licence area to the south-east, however occurrence is not considered to be significant.

Black bellied and white bellied storm-petrels were both recorded, primarily between December and February and in the deep waters to the north-east of the Falklands, outside of the licence areas. There were 205 records of black bellied storm-petrels and 23 of white bellied storm-petrels. Numbers of both species peaked in January. Occasional sightings of black bellied storm-petrels are likely to the east and south of the Islands, although the number of sightings is not considered significant.

A total of 6078 diving petrels were recorded during the at-sea survey, incorporating both the Magellan (133 confirmed) and common (753 confirmed) diving-petrel. The remainder were not specifically identified, but have been combined with common diving-petrel numbers for the purposes of the report. Most diving petrels were recorded between September and February, with greatest densities to the west and south of the Falklands. Occasional sightings of the common diving petrel are possible in the licence area throughout all months of the year, particularly between March and August, although the number is not considered to be significant.

Shags

Three species of shags have been recorded in Falkland Islands' waters (*Woods, 1988*), of which only two are resident breeding species (rock shag (*Phalacrocorax magellanicus*) and imperial shag (*Phalacrocorax atriceps*) and the other (red-legged shag) is a vagrant (and was not recorded during the at-sea survey).

The population of rock shags is estimated at between 32,000 and 59,000 pairs (*Woods & Woods, 1997*). They are only found in the Falkland Islands and South America. A total of 796 rock shags were recorded during the at-sea survey, peaking in July and mainly within enclosed or partially enclosed waters. All rock shags were recorded within 27 kilometres of the coast, with evidence of birds remaining closest to the coast during summer. Occurrence of rock shags within the offshore licence area is therefore not considered to be significant.

The population of imperial shag in the Falkland Islands is estimated at 45,000 to 84,000 breeding pairs (*Woods & Woods, 1997*). A total of 39,264 imperial shags were recorded during surveys, peaking between June and September. The average sighting is within 12 kilometres of the shore during the summer, and 37 kilometres during June to October (*White et al., 2002*). Occurrence within the offshore licence area is therefore not considered to be significant.

Swans, Geese and Ducks

Twenty-one species of swans, geese and ducks have been recorded in the Falkland Islands including fourteen native and one introduced species breeding in the wild: black-necked swan, coscoroba swan, ashy-headed goose, ruddy-headed goose, upland goose, kelp goose, feral goose, crested duck, Falkland Islands flightless streamer duck, flying steamer duck, yellow-billed teal, Chiloe wigeon, yellow-billed pintail, silver teal and cinnamon teal (*Woods & Woods, 1997*). Most species are likely to be found in coastal areas, and are migratory.

Only one species of duck was recorded during the at-sea survey off the Falkland Islands; the Falklands Steamer duck (*Tachyeres brachydactyla*).

The Falklands Steamer duck is endemic to the Falklands with an estimated of between 9,000 and 16,000 pairs (*Woods & Woods, 1997*). A total of 699 Falklands Steamer ducks were recorded during the at-sea survey, however all records were made in coastal waters with peak numbers recorded in April, tailing off to nil in December. Occurrence within the offshore licence area is therefore not considered to be significant.

Skuas Stercorariidae

Five species of skua have been recorded in the waters of the Falkland Islands, of which one species breeds on the Falklands and four species were observed during the at-sea surveys:

- Falklands skua (*Catharacta Antarctica*);
- Arctic skua (*Stercorarius parasiticus*);
- Long-tailed skua (*Stercorarius longicaudus*);
- South polar skua (*Catharacta maccormicki*);
- Chilean skua (Catharacta chilensis).

The Falkland Islands support a population of between 5,000 and 9,000 pairs of Falklands skua, the majority of the world population of this subspecies. Of the 737 Catharacta skuas recorded during the at-sea survey, 573 were recorded as Falklands skuas, four as Chilean skuas and the remainder that could not be accurately identified were counted as Antarctic skuas for the purposes of the distribution atlas. Most records occurred between November and April in inshore waters. A few birds were sighted May to October offshore to the north of the Falkland Islands.

Arctic skuas are summer visitors to the Falkland Islands and only 35 were recorded over the at-sea survey period between January and April in inshore waters and deeper waters to the north of the Falklands.

Long-tailed skuas were recorded in the waters off the Falkland Islands between November and April. A total of 239 long-tailed skuas were recorded, mainly in deep waters to the north and north-east of the Falklands, outside of the licence areas.

Distribution of skuas is concentrated away from the licence area and occurrence of skuas in the offshore licence blocks to the south-east of the Falkland Islands is expected to be rare. Occurrence within the vicinity of the proposed drilling activity is therefore not considered to be significant.

Gulls Laridae

Seven species of gull have been recorded in the Falkland Islands, of which the following three species are known to breed in the Falklands (listed above) and were recorded during the at-sea surveys:

- Dolphin gull (*Larus scoresbii*);
- Kelp gull (*Larus dominicanus*);
- Brown-hooded gull (*Larus maculipennis*).

The Falkland Islands population of dolphin gulls is estimated at between 3,000 and 6,000 pairs (*Woods & Woods, 1997*). Accounting for 85% of the world population, the Falkland Islands' population is of global importance. A total of 114 dolphin gulls were recorded during the at-sea survey on 60 occasions for all months except March and peaking in July. Distribution was concentrated in coastal waters and no gulls were recorded more than 20 kilometres from the coast.

The Falkland Islands kelp gull population is estimated at between 24,000 and 44,000 pairs (*Woods & Woods, 1997*). A total of 2,288 were recorded during the at-sea survey, covering all months and peaking June to September. Records between November and April were primarily close to shore, whereas records from May to October were more widespread over Patagonian Shelf and continental shelf slope waters, although very rarely in deep waters.

The Falkland Islands brown-hooded gull population is estimated at between 1,400 and 2,600 pairs (*Woods & Woods, 1997*), compared to a global population of approximately 50,000 pairs. A total of 134 brown-hooded gulls were recorded during the at-sea survey over 69 occasions, covering all months with the highest recorded number in January. The majority of records were made within 10 km of the coast, with a recorded maximum of 53 kilometres from the coast.

The distribution of all gull species is concentrated on the coastal zone and near-shore area. Occurrence of gulls within the vicinity of the proposed drilling activity is therefore not considered to be significant.

Terns Sternidae

Three species of tern were recorded during the at-sea survey (listed below), although eight species have been previously recorded in Falkland Islands' waters (*Otley et al., 2008*) of which only one species is known to breed in the Falklands:

- South American tern (*Sterna hirundinacea*);
- Arctic tern (*Sterna paradisea*);
- Unidentified sterna tern (*Sterna spp*).

A total of 1894 South American terns were recorded during the at-sea survey for all months and peaking March to April. The South American tern is the only species known to breed in the Falkland Islands. Distribution was mainly in coastal waters.

Arctic terns are a summer visitor to the Falklands. A total of 21 Arctic terns was recorded during the at-sea survey, all between October and March. They were observed widely distributed throughout the at-sea survey area, mostly in offshore areas. A number of unidentified sterna terns were also recorded during the at-sea survey. Of the 160 unidentified terns recorded in offshore waters, the majority were between April and November. Distribution was widely scattered although very few sightings were made to the south-east of the Falkland Islands. No tern species have significant abundance or distribution within the licence area, although occasional sightings are possible.

Rare Seabirds

Less than ten sightings of the below listed seabird species were recorded during the at-sea surveys. Due to the low numbers observations, modelling of spatial or monthly distribution is not considered meaningful.

- Broad-billed prion (*Pachyptila vittata*)
- Ceyenne tern Sterna (*Sterna (sandvicensis) eurygnatha*).
- Chilean skua (*Catharacta chilensis*)
- Cory's shearwater (*Calonectris diomedea*)
- Great-winged petrel (*Pterodroma macroptera*)
- Grey phalarope (*Phalaropus fulicarius*)
- Manx shearwater (*Puffinus puffinus*)
- Sooty Albatross (*Phoebetria fusca*)
- Spectacled petrel (*Procellaria conspicillata*)
- White-headed petrel (*Pterodroma lessonii*)

5.2.10 Seabird Vulnerability

Seabirds are affected by a number of anthropogenic factors including, competition with commercial fisheries, mortality through longline fishing and contamination from various forms of pollution. Within Falkland Islands' waters, negative impacts on seabird productivity through competition for food with commercial fisheries have not yet been identified (*White, 2001*). Death from entanglement and snagging with longline hooks is considered to be of low risk due to a well managed fishery and a relatively low amount of longlining.

To date, reports of adverse effects to seabirds from surface pollution such as oil is low in the Falkland Islands. Hence, the increasing oil and gas exploration activities in the area are a potential threat to seabird populations.

The following information has been sourced from 'Vulnerable Concentrations of Seabirds in Falkland Islands Waters' (1998–2000), a report produced by the JNCC under contract to Falklands Conservation, with funding support from the FIG.

Seabird vulnerability was assessed with regard to species-specific aspects of their feeding, breeding and population ecology. Maps produced in the report can be used to identify areas supporting seabird concentrations at greatest risk to the threat of surface pollution. Methods used for development of the vulnerability atlas are complex and well documented (*White et al., 2001*) and are not expanded upon further here.

A summary of the seabird vulnerability survey results for each month of the year, focusing on the Borders & Southern licence area is given below with monthly vulnerability of seabird concentrations to surface pollution illustrated in Figure 5.27.

Seabird vulnerability in January is highest in coastal and Patagonian Shelf waters. Small petrels (prions, storm-petrels, diving-petrels and shearwaters) are the main species.

Vulnerability in the vicinity of the proposed exploration wells is low to medium over January and February with coverage decreasing between March and May before showing renewed patches of low to medium vulnerability from June through to the end of the year. There is a small patch of high vulnerability visible within the licence area in September, although overall the area to the south and east of the Falkland Islands is removed from areas of high sensitivity and are some of the least sensitive areas within the Falklands Conservation Zone.

Based on the findings of this survey and the conclusions presented in the publication (*White et al, 2001*), the Austral summer months of December through to February have the highest overall vulnerability for the seabird species in the waters surrounding the Falklands. July and the winter months are the period of lowest overall vulnerability. Highest vulnerability coincides with the breeding season for most seabird species on the Falklands.

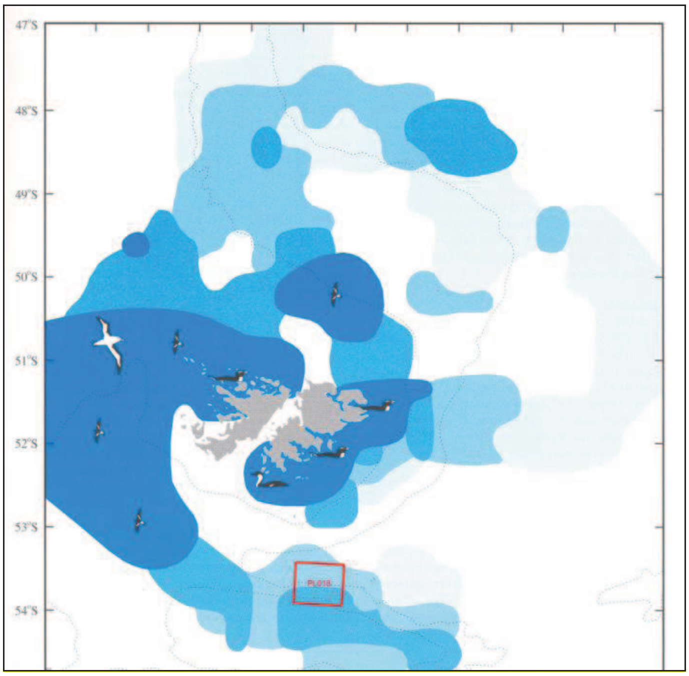
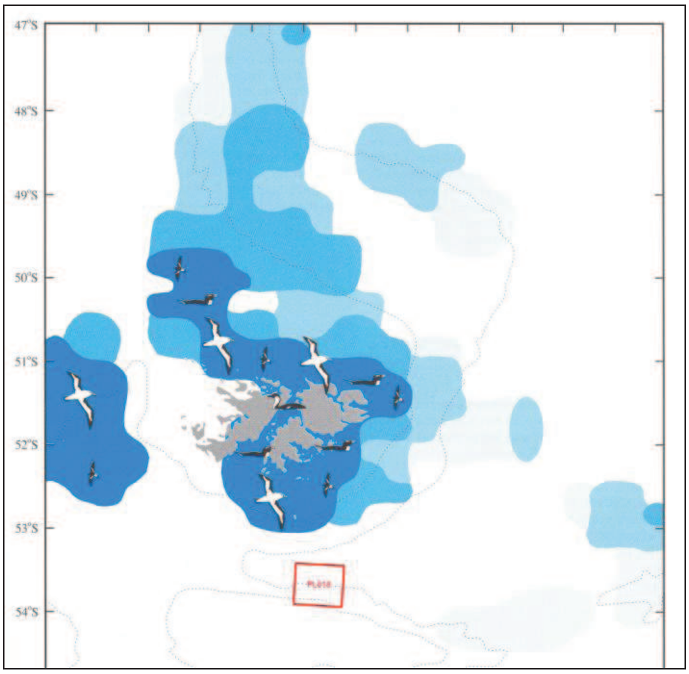
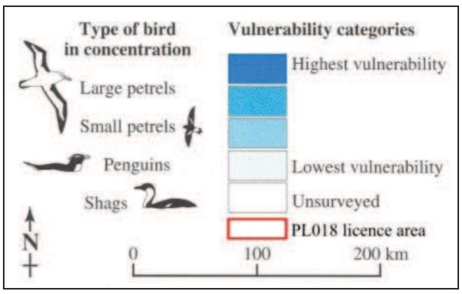
Concentrations of seabirds in coastal waters are more vulnerable to the effects of surface pollution than in all other areas. Although this summary concentrates on the proposed operational locations, the Falkland Islands' coastline has been included on the adapted maps of seabird vulnerability (Figure 5.27) to account for the potential spread of oil spills towards the coastline, particularly smaller spills from near-shore activities or during bunkering operations in port.

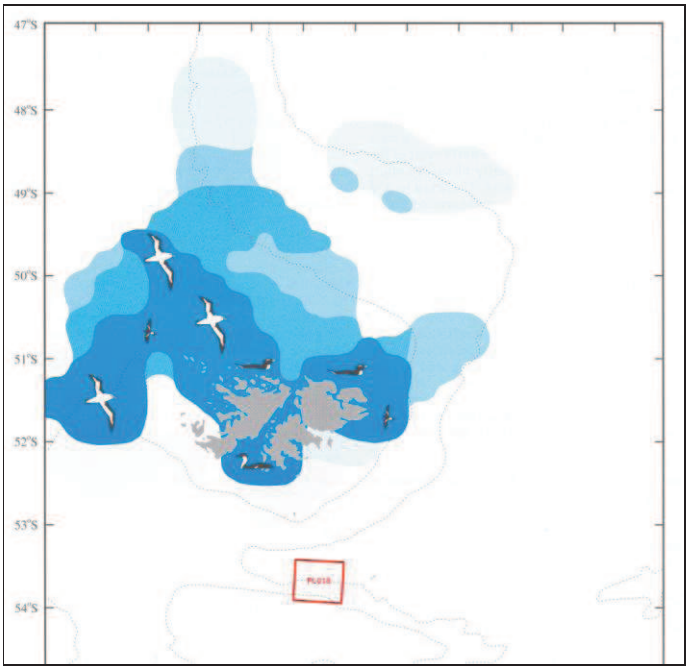
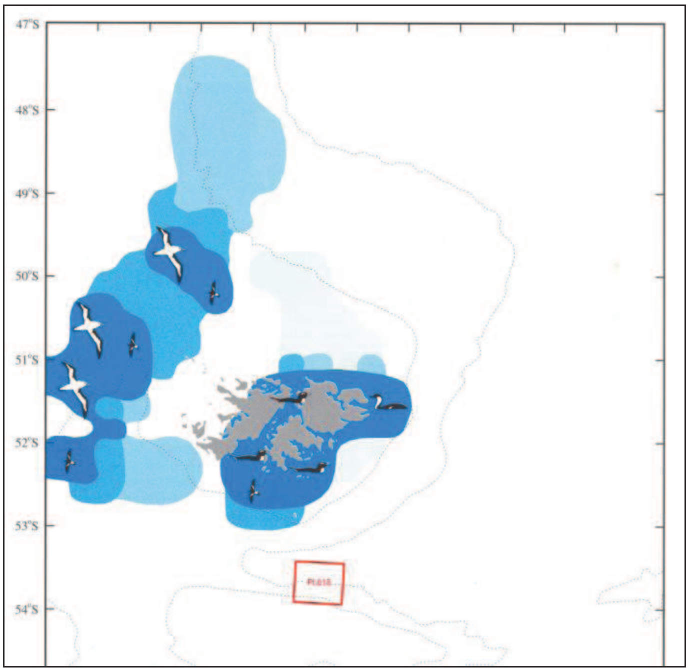
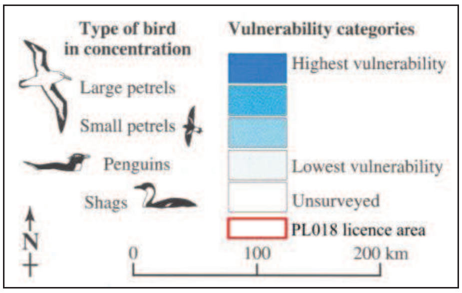
The vulnerability atlases show inshore waters to be particularly important for all months of the year, largely due to the presence of resident species with a predominantly coastal distribution such as the endemic Falklands Steamer duck, imperial shag and gentoo penguin.

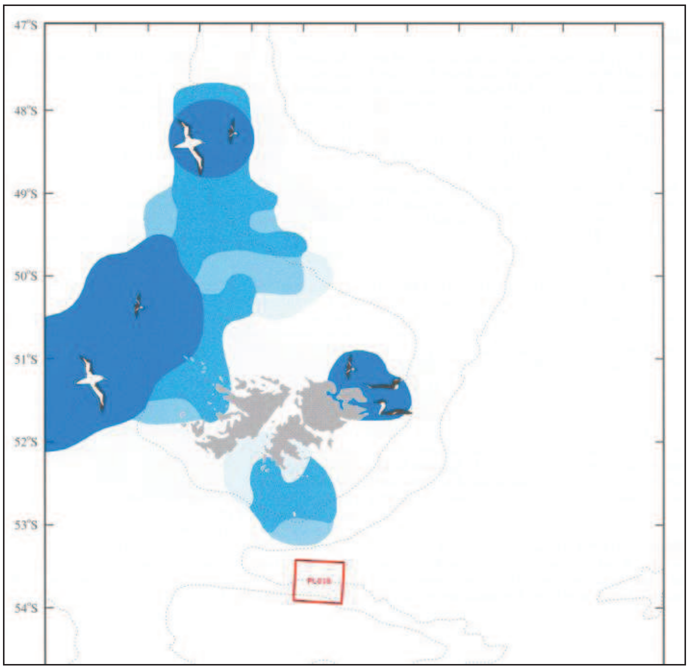
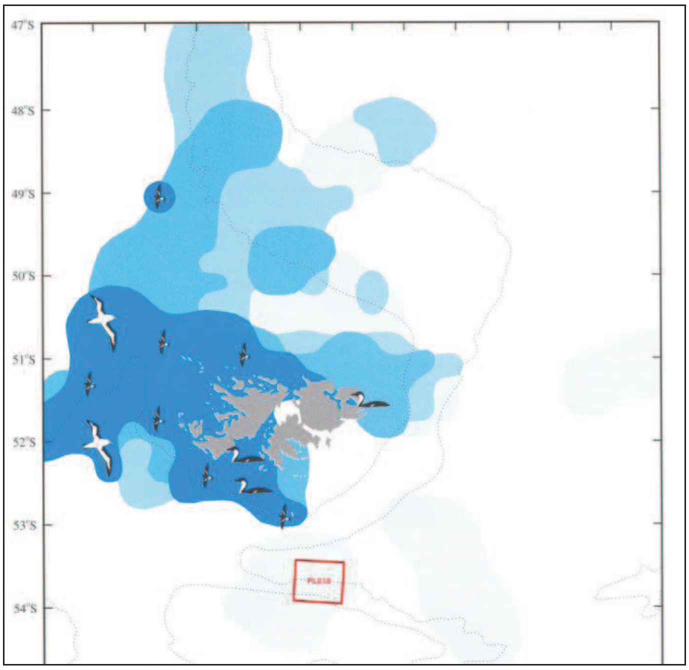
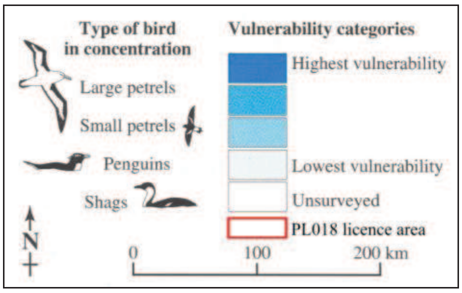
Other areas of importance to seabirds are the Patagonian Shelf waters to the north and west of the Falklands, which support high densities of black-browed albatrosses and royal albatrosses year-round. Low densities of seabirds encountered in deep waters areas generally result in low to moderate vulnerability for all months (*White et al., 2002*).

Oiled seabirds were recorded for all three survey years, peaking between March and October, and coinciding with the period of highest shipping activity. Many seabirds migrate through the Patagonian Shelf waters, so surface pollution in other areas may also have an impact on Falkland Islands populations. An estimated 40,000 penguins die from oil pollution on the coast of Argentina each year due to chronic oil pollution such as the discharge of oily waste from ballast tanks.

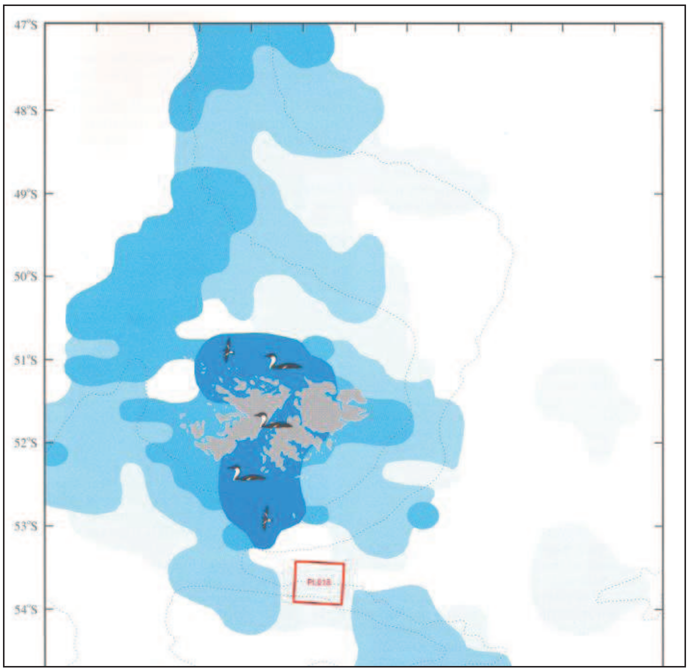
In White et al. (2002) hydrocarbon exploration is only one of the threats facing seabird populations at sea and awareness of problems for the albatross and petrel populations from interactions with fisheries in the Southern Oceans is growing.

January	
February	
	

March	 47°S 48°S 49°S 50°S 51°S 52°S 53°S 54°S PL018
April	 47°S 48°S 49°S 50°S 51°S 52°S 53°S 54°S PL018
	 Type of bird in concentration Large petrels Small petrels Penguins Shags Vulnerability categories Highest vulnerability Lowest vulnerability Unsurveyed PL018 licence area N 0 100 200 km

May	47°S 48°S 49°S 50°S 51°S 52°S 53°S 54°S PL018
June	47°S 48°S 49°S 50°S 51°S 52°S 53°S 54°S PL018
	Type of bird in concentration Large petrels Small petrels Penguins Shags Vulnerability categories Highest vulnerability Lowest vulnerability Unsurveyed PL018 licence area N 0 100 200 km

July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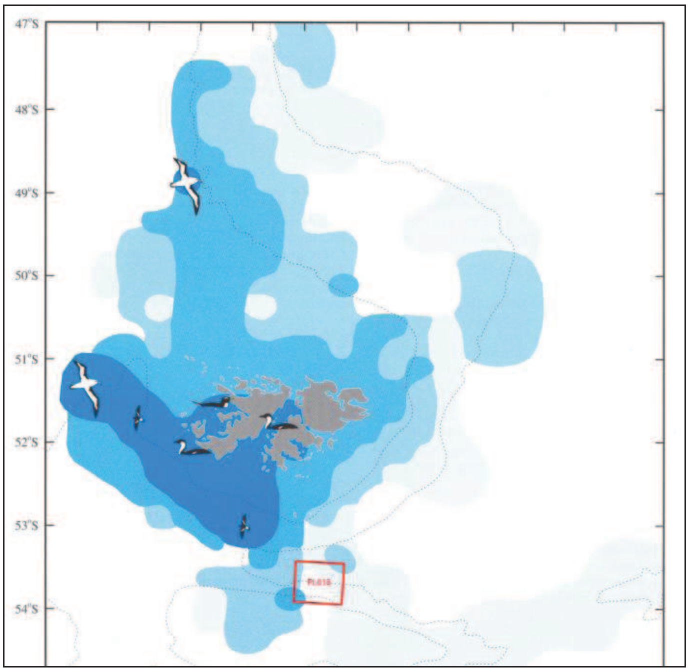
August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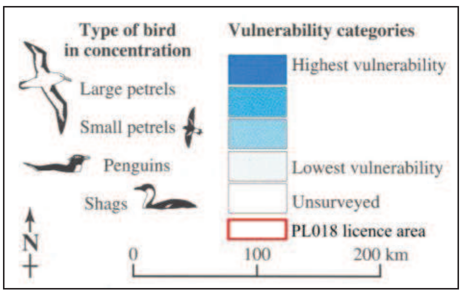
Type of bird in concentration
Large petrels
Small petrels
Penguins
Shags
Vulnerability categories
Highest vulnerability
Lowest vulnerability
Unsurveyed
PL018 licence area
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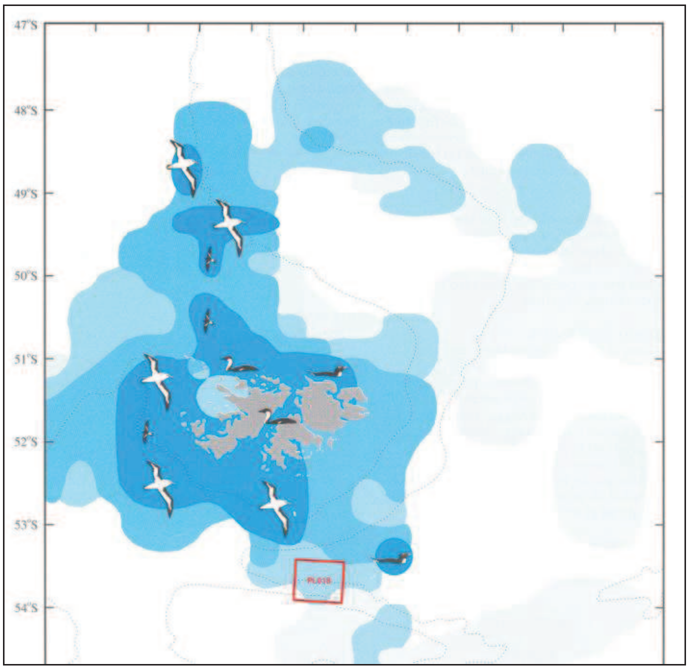
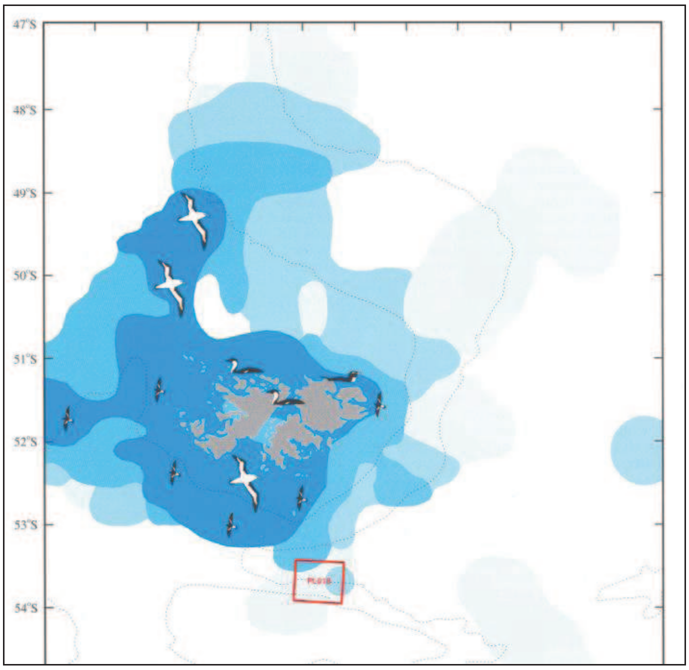
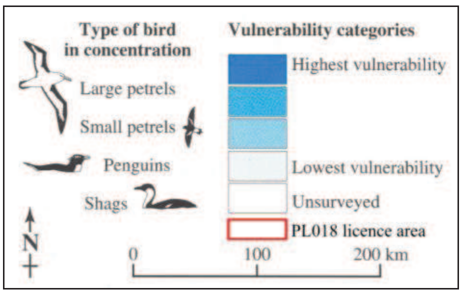
200 km

September

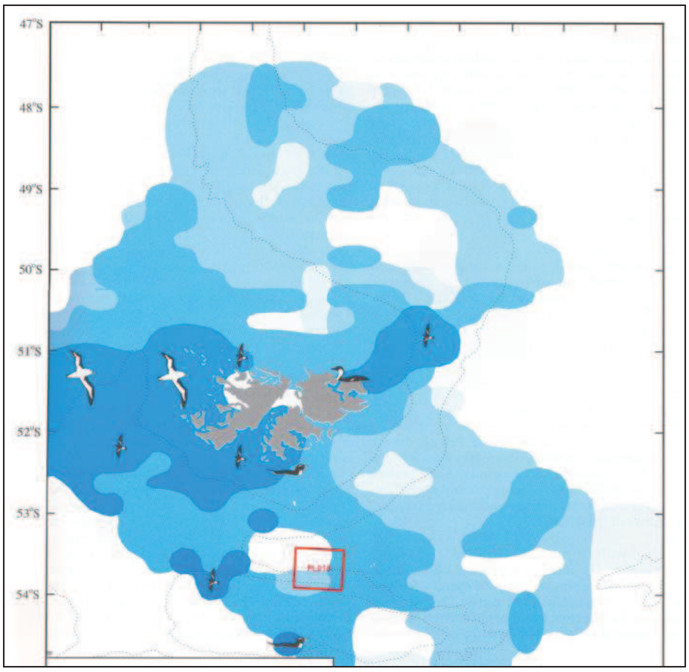


October

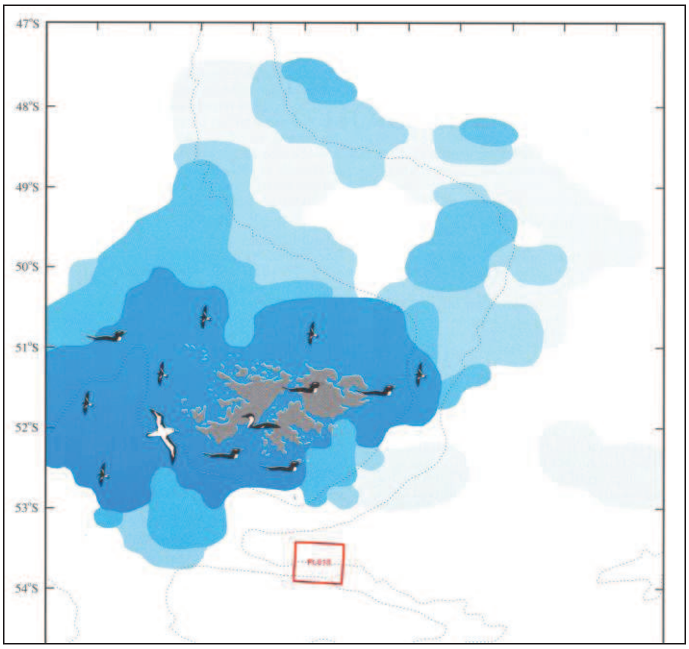




November



December



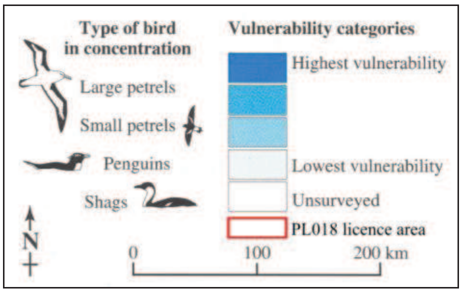


Figure 5.27 Monthly Vulnerability of Seabird Concentrations to Surface Pollution (1998-2000)

5.2.11 Threatened Species

The IUCN Red List is a comprehensive listing of all species within the Falklands marine environment which are characterised as 'endangered', 'threatened' or 'vulnerable' to 'extinction'.

A search of the Red List found 43 species recorded as threatened, and 31 classified as 'Least Concern. Most pinnipeds are of the latter category. There were seven species (two cetaceans and five birds) listed as endangered – the highest level of conservation status.

Overall the Red List results included:

- 17 species of cetaceans;
- 2 species of fish;
- 24 species of birds.

The list of species identified as under threat by IUCN is given in Appendix F and Appendix E.

5.2.12 Protected Habitats and Areas

The following three types of formally protected areas are located in the Falkland Islands:

- National Nature Reserves (NNR) (designated under the Conservation of Wildlife & Nature Ordinance (1999));
- National Parks (designated under the National Parks Ordinance); and
- Ramsar sites.

These protected areas are illustrated in Figure 5.28. Although FIG can designate marine reserves, to-date no marine NNR has been created in the Falkland Islands.

Existing Nature Reserves were designated under the Nature Reserves Ordinance 1964 and Sanctuaries designated under the Wild Animals and Birds Protection Ordinance 1964 are now designated as NNR and Nature Reserves respectively (Table 5.2).

Table 5.2. National Protected Areas in Falkland Islands

Date		Order	Designated Area
Nature Reserve Orders (now National Nature Reserves)	1964	Nature Reserves (Kidney & Cochon Islands) Order 1964 (1/64)	Cochon Island 51° 36'S 57° 47'W Kidney Island 51° 38'S 57° 45'W
	1966	Nature Reserves (Flat Jason Island) Order 1966 (2/66)	Flat Jason 51° 06'S 60° 53'W
	1969	Nature Reserves (Bird Island) Order 1969 (4/69)	Bird Island 52° 10'S 60° 54'W
	1973	Nature Reserves (Crown Jason Islands) Order 1973 (10/73)	Elephant Jason 51° 09'S 60° 51'W South Jason 51° 12'S 60° 53'W North Fur Is. 51° 08'S 60° 44'W South Fur Is. 51° 15'S 60° 51'W Jason East Cay 51° 00'S 61° 18'W Jason West Cay 50° 58'S 61° 25'W The Fridays 51° 03'S 60° 58'W White Rock 51° 17'S 60° 53'W Seal Rocks 51° 07'S 60° 48'W
	1978	Nature Reserves (Sea Dog & Arch Islands) Order 1978 (2/78)	Sea Dog Island 52 00'S 61 06'W Arch Islands 52 13'S 60 27'W (Inc. Arch Island East, Natural Arch, Clump Island, Tussac Island, Pyramid Rock, Last Rock & Albemarle Rock)
Sanctuary Orders	1964	Wild Animals & Birds Protection (Sanctuaries)(The Twins) Order 1964 (2/64)	The Twins, 51° 15'S 60° 38'W Adjacent to Carcass Island, West Falklands

Date		Order	Designated Area
	1964	Wild Animals & Birds Protection (Sanctuaries) (Low Island) Order 1964 (3/64)	Low Island, 51º 19'S 60º 27'W Adjacent to Carcass Island, West Falklands
	1964	Wild Animals & Birds Protection (Sanctuaries) (Beauchene Island) Order 1964 (4/64)	Beauchene Island, 52º 54'S 59º 11'W
	1966	Wild Animals and Birds Protection (Sanctuaries) (Middle Island) Order 1966 (4/66)	Middle Island, 51º 38'S 60º 20'W King George Bay, West Falklands
	1968	Wild Animals and Birds Protection (Volunteer & Cow Bay Sanctuary) Order 1968 (11/68)	Volunteer Point and Inside Volunteer, Cow Bay area of Carysford Camp. 51º 29'S 57º 50'W
	1968	Wild Animals and Birds Protection (Cape Dolphin Sanctuary) Order 1968 (12/68)	Extreme end of Cape Dolphin. 51º 15'S 58º 51'W
	1970	Wild Animals & Birds Protection (Bleaker Island Sanctuary) Order 1970 (3/70)	Bleaker Island north of Long Gulch. 52º 18'S 58º 51'W
	1973	Wild Animals & Birds Protection (Stanley Common and Cape Pembroke Peninsula Sanctuary) Order 1973 (1/73)	Stanley Common & Cape Pembroke. 51º 43'S 57º 49'W
	1993	New island South Sanctuary Order 1993 (14/93)	New Island South 51º 43'S 61º 18'W
	1996	Moss Side Sanctuary Order 1996 (26/96)	Pond and sand-grass flats behind Elephant Beach (Top Sandgrass Camp & Sorrel Pond Camp). 51º 23'S 58º 49'W
	1998	Narrows Sanctuary Order 1998 (53/98)	Narrows Farm, West Falklands. 51º 41'S 60º 19'W
	1998	East Bay Sanctuary Order 1998 (54/98)	East Bay Farm, West Falklands 51º 48'S 60º 13'W
	N/A	Wild Animals and Birds Protection (East Bay, Lake Sulivan and River Doyle)	Proposed
	N/A	Wild Animals and Birds Protection (Pebble Island East)	Proposed
	N/A	Wild Animals and Birds Protection (Port Harriet Point and Seal Point)	Seal Point 57°50'W 51°44'S
National Parks	N/A	Hill Cove Mountains	Proposed
Ramsar Sites	1999	Bertha's Beach	51°55'S 058°25'W
	1999	Sea Lion Island	52°25'S 059°05'W
	N/A	Lake Sulivan, River Doyle and East Bay	Proposed
	N/A	Pebble Island East	Proposed

Important Bird Areas (IBAs) have been defined and are an initiative of Birdlife International, a global partnership of conservation organisations. IBA identification is based on a standard set of criteria applied consistently worldwide, with Falklands Conservation responsible for the cataloguing and description of IBA's within the Falklands. IBAs are not part of any international agreement or convention, and were created to address the increasing global threat to birds from habitat loss and fragmentation.

Currently, 22 sites of international conservation importance for birds (IBA) have been identified in the Falkland Islands (Table 5.3). These are illustrated on Figure 5.29. The closest of these to the proposed exploration wells are Beauchêne Island, located approximately 80 kilometres to the east-north-east and Sea Lion Islands, located approximately 130 kilometres to the north-east from Darwin East.

Table 5.3. Internationally Important Bird Areas(IBAs) in Falkland Islands

• Beauchêne Island	• Beaver Island Group
• Bertha's Beach (East Falklands)	• Bird Island
• Bleaker Island Group	• Bull Point (East Falklands)
• Elephant Cays Group	• Hope Harbour (West Falklands)
• Hummock Island Group	• Jason Islands Group
• Keppel Island	• Kidney Island Group
• Lively Island Group	• New Island Group
• Passage Islands Group	• Pebble Island Group
• Saunders Island	• Sea Lion Island Group
• Seal Bay (East Falklands)	• Speedwell Island Group
• Volunteer Point (East Falklands)	• West Point Island Group

Beauchene Island

Forming the southernmost land in the Falklands archipelago, Beauchene Island is located approximately 54 kilometres south of the mainland.

More than 30 bird species have been recorded on the Island, the majority being migratory seabirds that are present in very large numbers during the breeding season. The site is significant for the second largest populations in the world of black-browed albatrosses and Rockhopper penguins. Beauchene Island is also important for Wilson's storm-petrels, grey-backed storm-petrels and common diving petrels. It is the only confirmed breeding site for fairy prions in the Falkland Islands. Southern giant petrels and Magellanic penguins are present, but populations are too small to qualify. The total congregation of seabirds far exceeds 10,000 breeding pairs, making this site classifiable under the A4iii criterion (A4iii criterion is modelled on criterion 5 of the Ramsar Convention for identifying wetlands of international importance) (*BirdLife International, 2009a*).

Sea Lion Island

Sea Lion Island is 8 kilometres from east to west and 2 kilometres at its widest point. The island is a slightly inclined plateau with steep cliffs of about 30 metres at the south-western point and long sandy bays to the east. Habitat inland is largely open heath and grassland. There are permanent ponds and boggy ground, which are attractive to a variety of waterbirds (*BirdLife International, 2009b*).

Between 1983 and 1993, 53 bird species were recorded on Sea Lion Island during fieldwork for the Breeding Birds Survey. Of these, 43 were breeding or probably breeding, including eight of the nine resident songbirds and five species of penguins. The macaroni penguin occasionally breeds among the Rockhoppers but not in sufficient numbers to warrant site qualification. The predator-free status Sea Lion Island makes it important for small passerines and burrowing petrels. It is noticeable that Tussacbirds and Cobb's Wrens are very numerous, particularly on the beaches of the islands. Endemic sub-species present include the White-tufted/ Rolland's Grebe, Black-crowned Night-heron, Upland Goose, Short-eared Owl, Dark-faced Ground-tyrant, Falkland Pipit, Falkland Grass Wren and the Falkland Thrush (*BirdLife International, 2009b*).

Sea Lion Island is an important wildlife tourism destination within the Falklands archipelago, with an estimated 2,000 visitors per year.

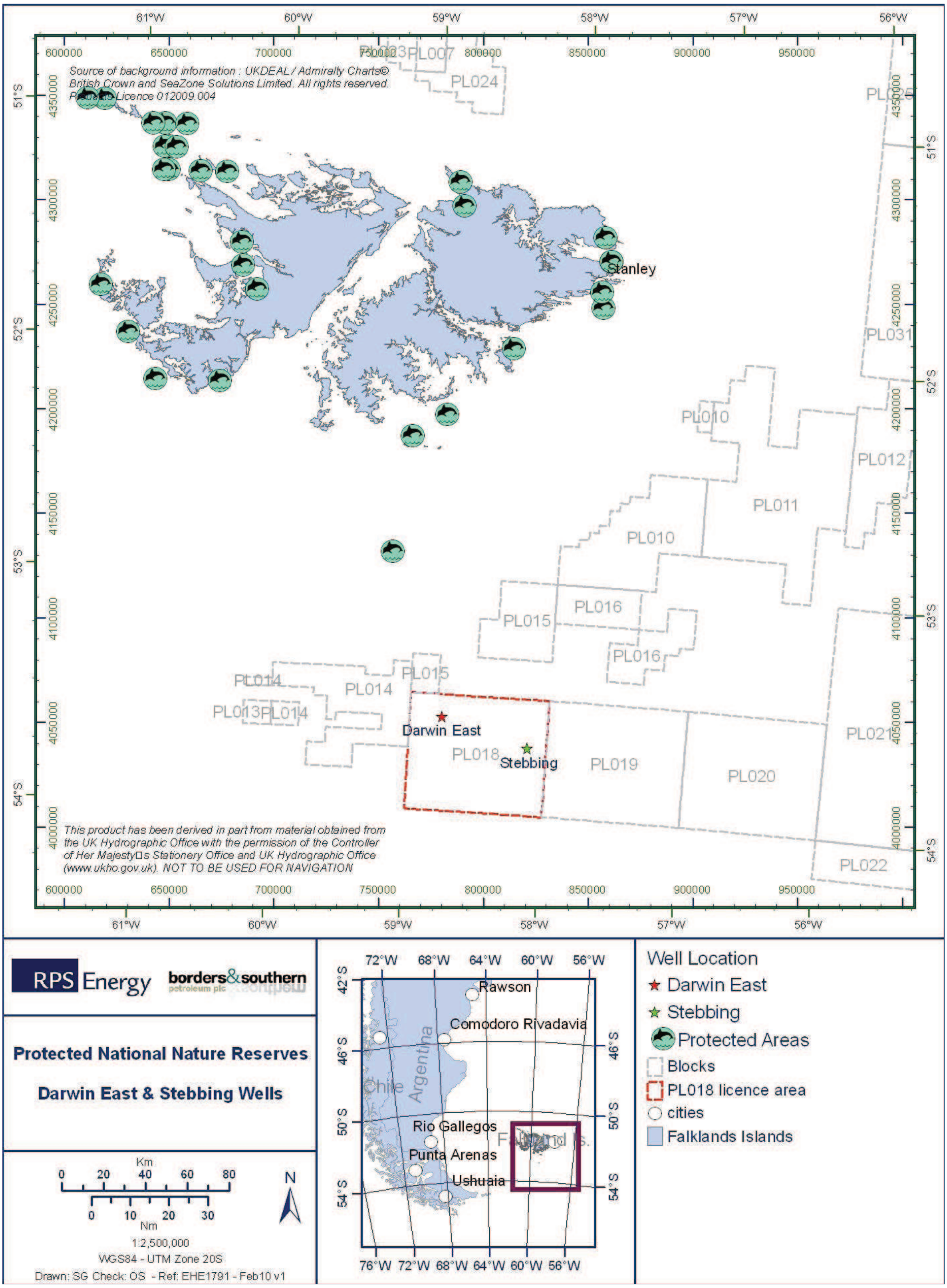


Figure 5.28 Protected areas around the coastline of the Falkland Islands (World Database on Protected Areas, 2009)

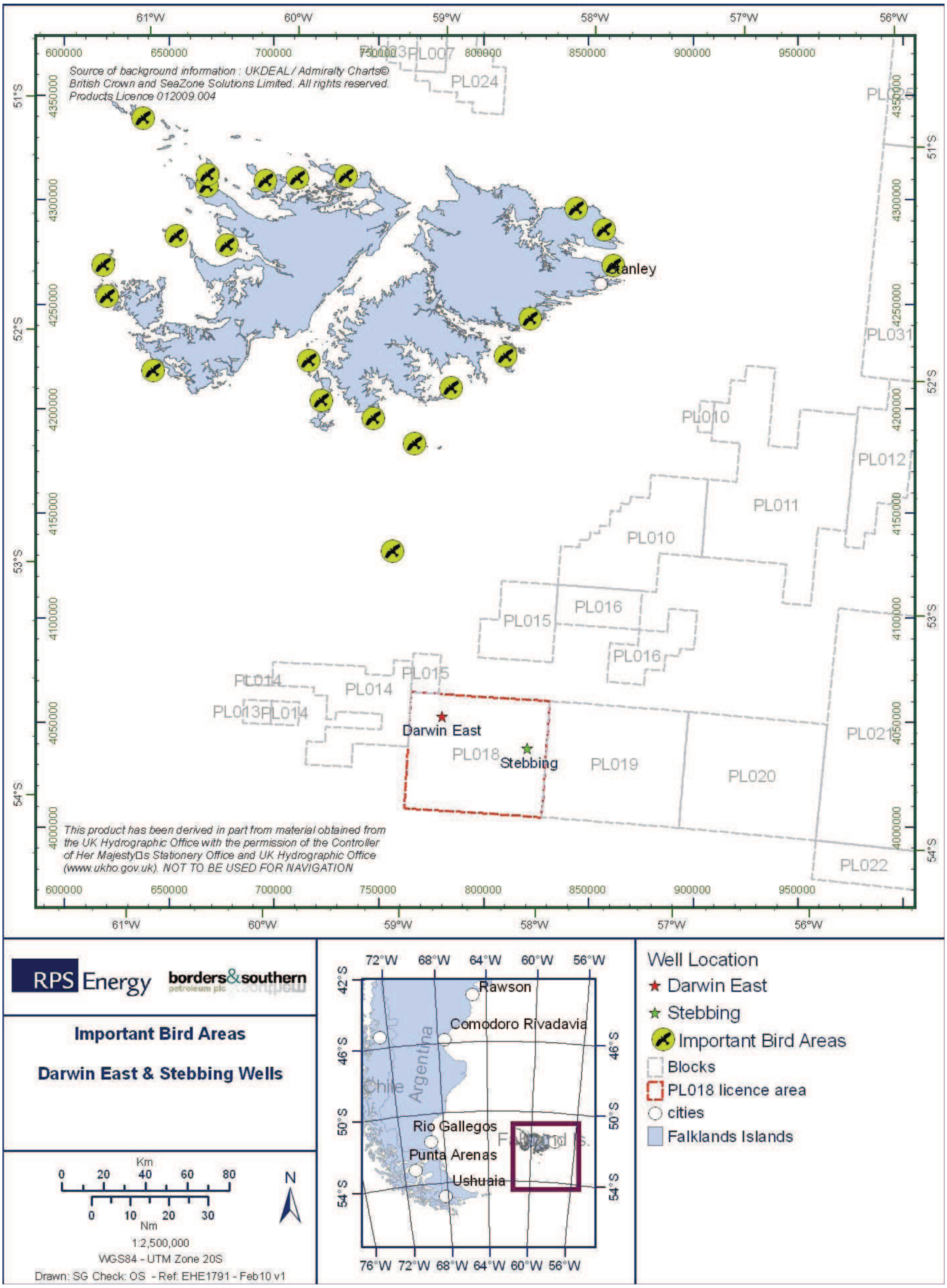


Figure 5.29 International Bird Areas (Birdlife International, 2009)

5.3 Social and Economic Environment

The information for the following sub-sections is based on the last census undertaken in 2006, sourced from the Foreign and Commonwealth Office (FCO). The population of the Falklands was recorded as 2955[1] with the majority living in the capital, Stanley. An additional 2,478 military personnel are located at the Mount Pleasant Complex (MPC). Christianity is the major religion on the Falklands.

5.3.1 Economy

The general economic characteristics of the Falkland Islands are summarised below:

Gross Domestic Product:	£70 million (2001)
Gross Domestic Product per Head:	£24,030 (2001)
Annual Growth:	2% (estimated)
Inflation:	3.5% (estimated)
Major Industries:	Fisheries, tourism and agriculture
Major Trading Partners:	United Kingdom, Spain and Chile
Exchange Rate:	UK£1 = FI£1

The economy of the Falklands has traditionally been restricted due to its small population and isolation from external markets. Since 1982 the economy has grown rapidly, initially as a result of UK aid but more recently from the development of fisheries. The Falklands have received no aid from Britain since 1992 and are now self-sufficient in all areas except defence (*FCO, 2007*).

The three largest industries are agriculture, tourism and commercial fisheries, which are discussed in the below sections. Statistics for 2005/2006 indicate that £16.1 million revenue was bought in by the Fisheries industry, followed by £14.6 million from retail sales.

A workforce of approximately 2,492 exists in the Falklands, with the FIG the largest employer, employing around 500 people. The fisheries, tourism, infrastructure development and retail industries are quickly growing and employing more people.

Agriculture

Agriculture remains a large industry on the Falklands, and the FIG funded modern abattoir meets EU standards and hopes to capitalise on the Falklands' certification as an organic country (*FCO, 2007*).

Tourism

The tourism industry is growing rapidly, with large numbers of passengers arriving in Stanley each year from cruise ships. The main attractions are the Falklands' unique environment and wildlife.

Passenger numbers in recent years on cruises to the Falklands have increased significantly, and are predicted to continue to increase. In the 2006/2007 tourist season 51,000 cruise ship passengers visited the Falkland Islands, rising to 62,000 in the 2008/09 season. The Falkland Islands Tourism Board aims to increase the number of cruise-ship day visitors and longer-staying tourists in a manner that is sustainable.

The Islands' main tourist lodges are located at Port Howard, Darwin, Pebble Island, Sea Lion Island and Weddell Island. Self-catering accommodation can be found at a selection of holiday cottages on island farms, and several locations in East and West Falklands. In Stanley, there is only one hotel (the Malvina House) and a choice of guest house and bed & breakfast accommodation.

Cruise ships from various points of origin travel to the Falkland Islands, although the movement of vessels through the waters to the south and east of the islands is likely to be limited. The recent growth in cruise ship movements increases the significance of this aspect and emphasis the need

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[1] This figure includes persons present in the Falkland Islands in connection with the military garrison, but exclude all military personnel and their families (*Consensus 2006*)

for early notification, ongoing communication and the use of standby vessels to support drilling operations.

Fisheries and Aquaculture

Commercial fisheries are the largest source of income for the Falkland Islands. All fishing within 200 nautical miles of the Falklands is subject to licensing by the FIG. The fisheries generate over £21 million per annum in licence fees, roughly half the government revenue. Since 1990 Britain and Argentina have worked together to conserve fish stocks under the auspices of a UK/Argentine South Atlantic Fisheries Commission (*FCO, 2005*). Approximately £6 million of fisheries income is spent each year on catch and conservation monitoring, research and administration.

Target species for the commercial fisheries operating in the Falkland Islands are:

- Argentine shortfin squid (*Illex argentinus*)
- Patagonian squid (*Loligo gahi*)
- Southern blue whiting (*Micromesistius australis australis*)
- Hoki (*Macruronus magellanicus*)
- Patagonian toothfish (*Dissostichus eleginoides*)
- Patagonian hake (*Merluccius australis*)
- Common hake (*Merluccius hubsii*)
- Red cod (*Salilota australis*)
- Skates & rays *(Rajidae)*

The key catches are the squid species: *Illex argentinus* and *Loligo gahi*, followed by the southern blue whiting. Approximately 2.4 MT of Illex, 1.2 MT of Loligo, and 20,500 tonnes of southern blue whiting were caught in 2006.

Research shows that the commercial squid species are short-lived and fast growing, living for about a year and spawning once within that time (*Rodhouse, 1988*). Typically, species with this sort of lifecycle are susceptible to changes in environmental conditions. This can create a high level of variability in stocks on a year-to-year basis.

Illex had been in decline since 2002, but resurged in 2006 after oceanographic conditions returned to normal following years of warm anomalies. Seasonal jigging fishery for the Illex takes place between February and June and is concentrated over the Patagonian Shelf to the north and west of the Falklands. The trawl fishery for *Loligo* squid operates between February and May and between August and November off the east coast of the Falklands.

The FIG annual Fisheries Statistics volume 11 (1997–2006) indicate that the offshore licence areas are not within any large catch (by volume) locations for the key species (Figure 5.30 to Figure 5.35). No key target species are caught in the licence areas.

In 2006, 194 fishing licences were issued predominantly for the squid and finfish species. Previous licence allocations varied from 372 in 1989 to 205 in 2005. The majority in 2006 were issued to fleets from the Falkland Islands, Spain and Korea.

To protect against poachers, the waters are patrolled by FIG aircraft and a fishery protection vessel.

Aquaculture in the Falkland Islands is relatively new with salmon fish-farming trialled in the early 1990s. Although commercial growth rates could be achieved, no external market for Falkland Islands grown salmon was found. *Mytilus edulis chilensis*, native blue mussel, is farmed in the Falklands over an area covering 22 ha and approximately 20 tonnes of mussels are on ropes at any one time (*Otley et al., 2008*). Pacific oysters (*Crassostrea gigas*) are farmed over approximately 200 ha at Darwin in the Falkland Islands for the local market (*Otley et al., 2008*).

The mussel and oyster farming is currently small-scale, although the aquaculture industry has been identified as a potential economic diversification sector (*Otley et al., 2008*).

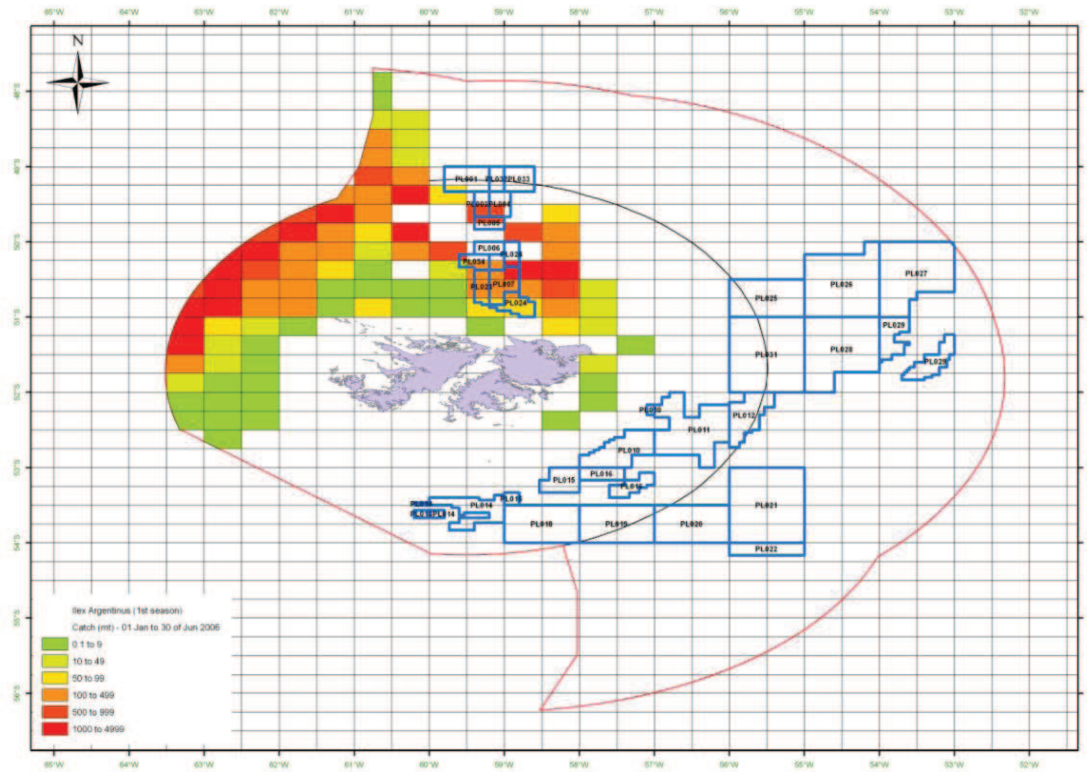

Figure 5.30 Illex argentinus catches (tonnes) by grid for Season 1 (Jan–Jun 2006)

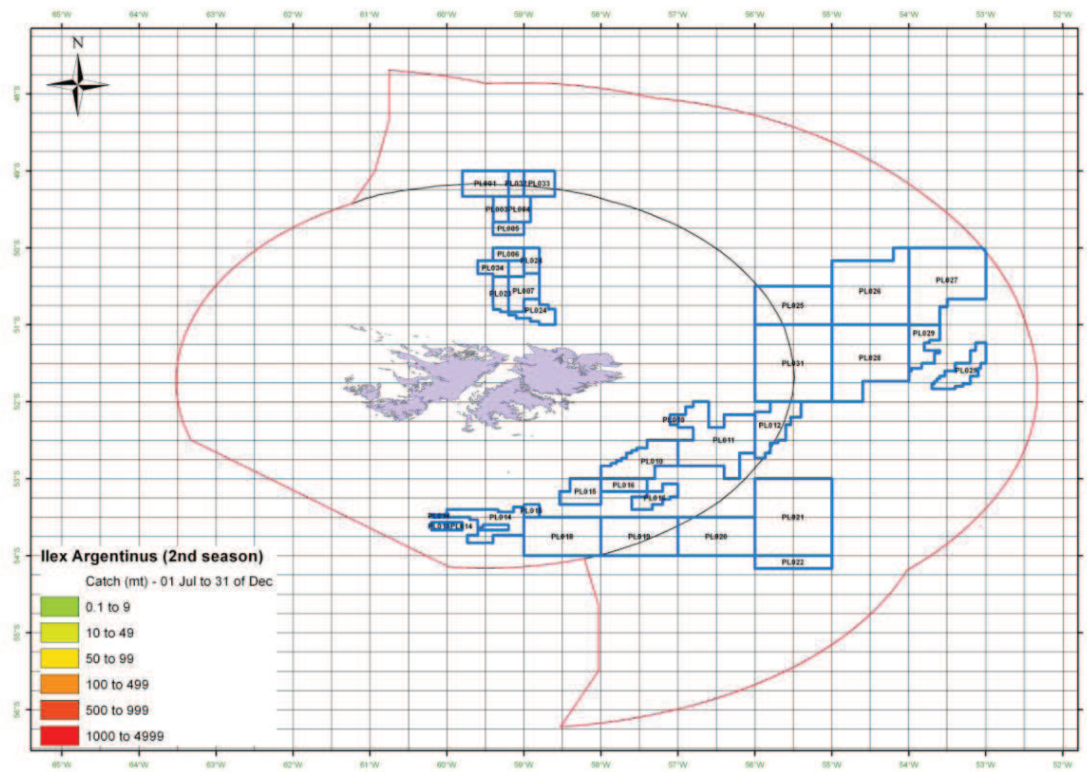

Figure 5.31 Illex argentinus catches (tonnes) by grid for Season 2 (Jul–Jun 2006)

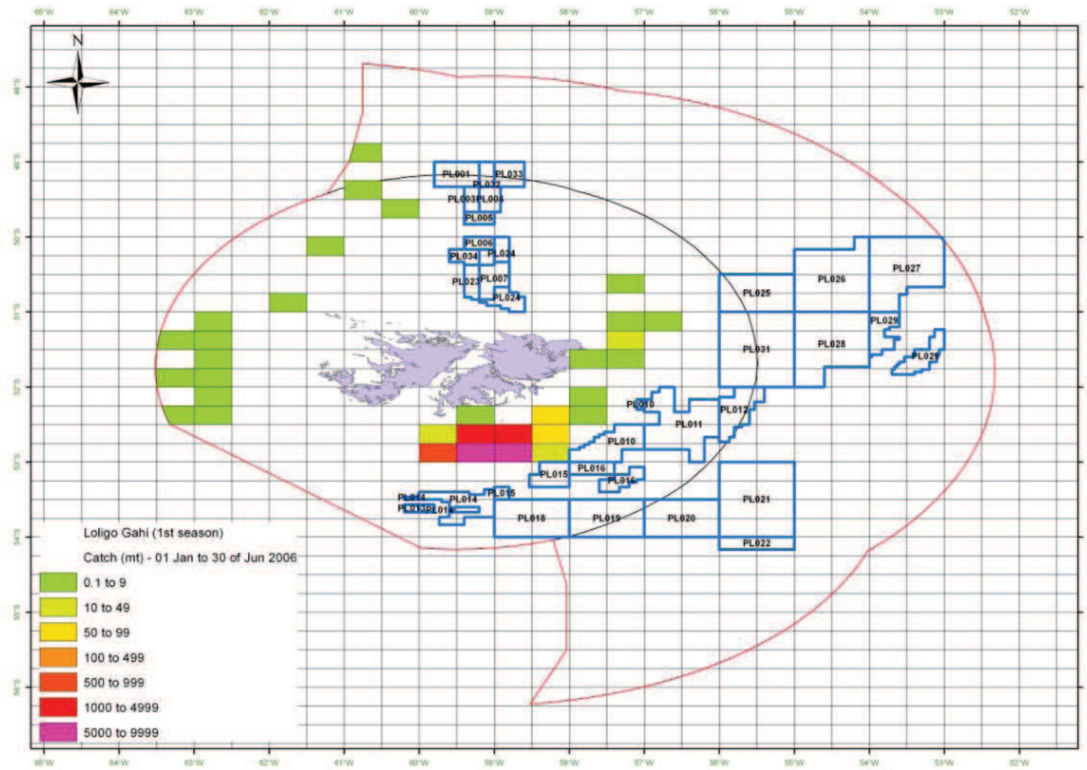

Figure 5.32 Loligo gahi catches (tonnes) by grid square for Season 1 (Jan–Jun 2006)

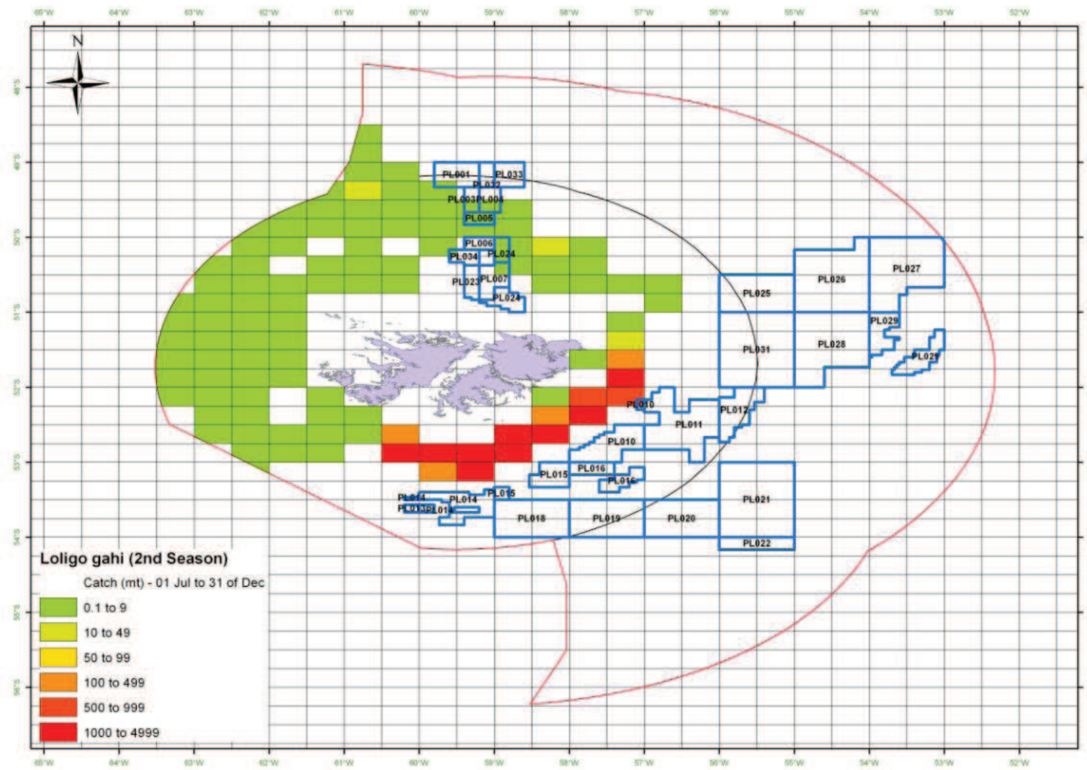

Figure 5.33 Loligo gahi catches (tonnes) by grid square for Season 2 (Jul–Dec 2006)

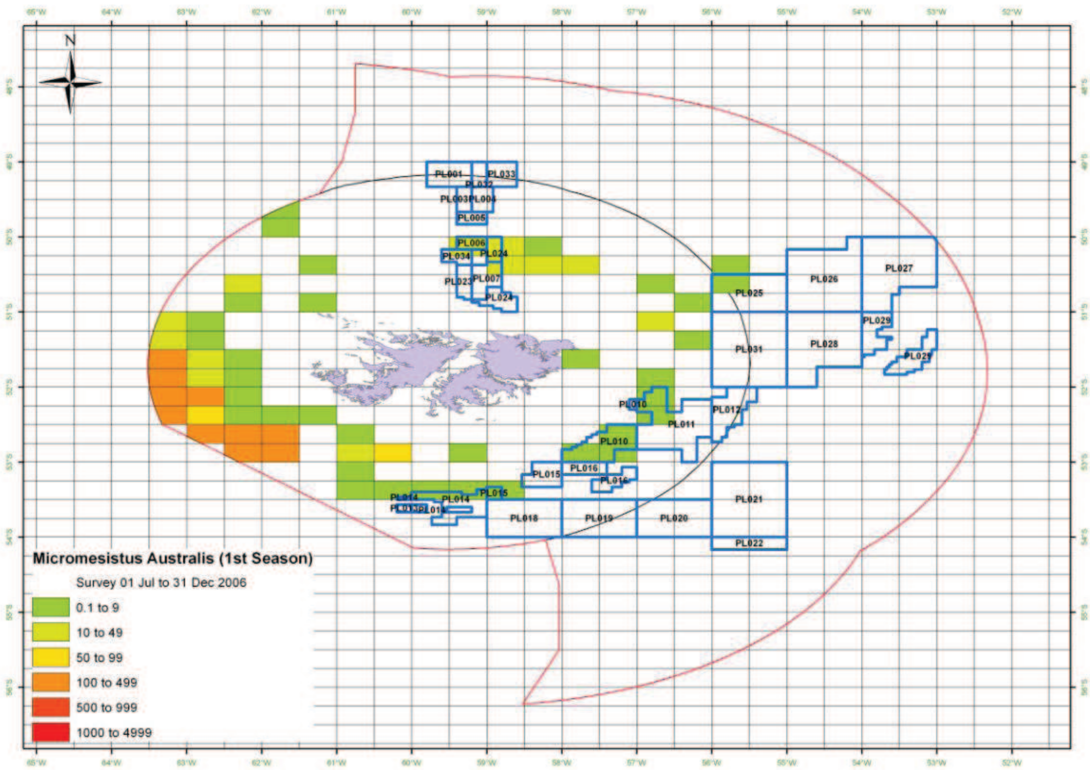

Figure 5.34 Micromesistius australis catches (tonnes) by grid square for Season 1 (Jan–Jun 2006)

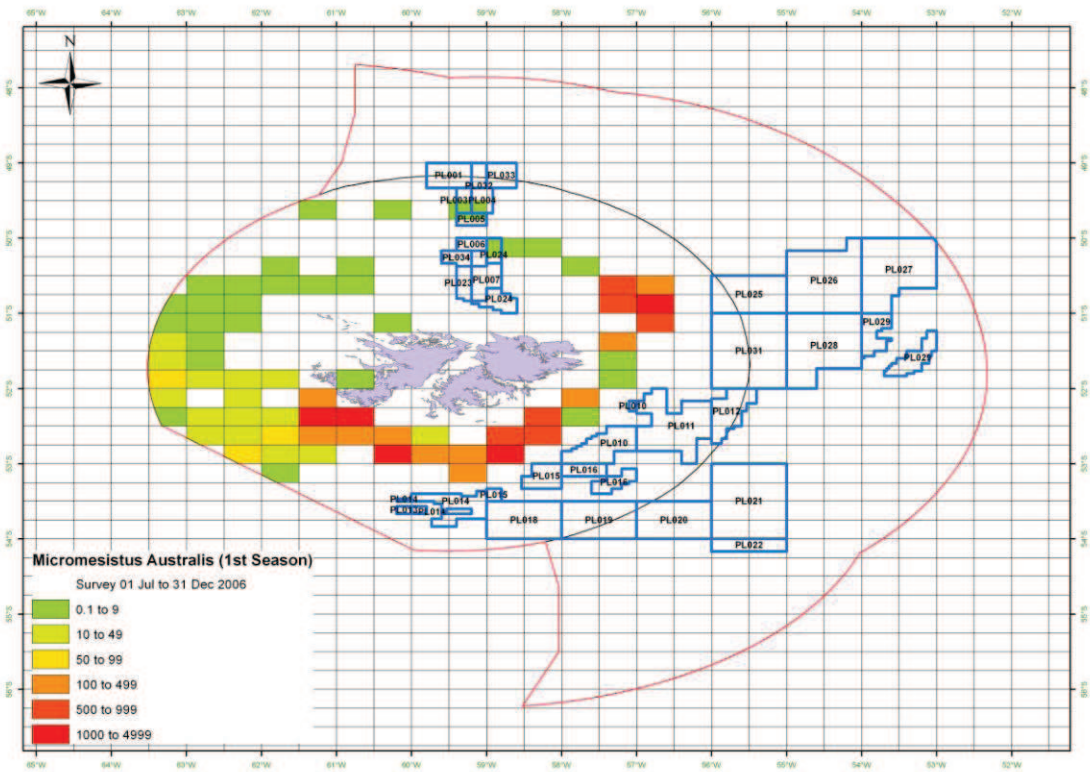

Figure 5.35 Micromesistius australis catches (tonnes) by grid square for Season 2 (Jul–Dec 2006)

The above figures demonstrate that the licence area to the south-east of the Falklands has no recorded Illex catch throughout the year. There is a low level of catch on the landward side of the licence blocks close to the eastern shore of East Falklands which may have minor significance for vessel movements to and from the proposed operations in the first half of the year.

There is also no recorded Loligo catch within the licence area throughout the year, although there is again fishing activity on the landward side of the licence blocks close to the southern and eastern coasts of East Falklands which may be impacted by vessel movements to and from the licence area. Near shore Loligo fishery to the east of the Falklands is most intense in the second half of the year between July and December.

There is no recorded catch of southern blue whiting in the licence area throughout the year.

5.3.2 Marine Archaeology

Numerous ships wrecks lie in the Falklands' waters including 19 registered shipwrecks (six from the World War One battle of the Falkland Islands) and other designated war graves which cannot be disturbed (Figure 5.36).

Stanley harbour contains wrecks of wooden ships constructed in the 19th century, including the Lady Elizabeth and the Jhelum, which are considered important examples of ship construction of this period.

There are two listed wrecks within the licence area, although no identified wrecks or significant marine artefacts are currently specified within the proposed survey locations. There risk of encountering shipwrecks at the proposed operational locations is extremely small due to the considerable water depth and low level of seabed disturbance. The Hydrographic Office identification number / name, co-ordinates and depths of the wrecks are (*ERT, 1997; FIG, 2008*) presented in Table 5.4.

Table 5.4. Marine Wreck Locations

Wreck	Location	
	Latitude	Longitude
Within the Borders &Southern **Licence Areas**		
SMS Leipzig	-53 38 34.3781	-56 31 2.6080
SMS Nurenburg	-53 14 47.4865	-55 37 11.6317
Outside the Borders &Southern **Licence Areas**		
Baden	-52 17 15.7440	-57 20 14.8323
Gneisenau	-52 33 9.9049	-56 11 32.2810
HMS Antelope	-52 02 3.6451	-59 43 41.2890
HMS Ardent	-51 33 33.5224	-59 04 9.1386
HMS Coventry	-51 07 55.6134	-59 43 11.1419
Santa Isabel	-52 23 46.2691	-57 14 55.7152
Scharnhorst	-52 27 53.6516	-56 07 3.4636
2	-52 00 38.2382	-58 21 12.4858
3	-51 53 4.6758	-58 16 43.7152
4	-51 41 14.8595	-57 48 54.1981
5	-51 42 3.4288	-57 42 5.2655
6	-51 29 59.9435	-59 09 34.4775
9	-50 44 7.6692	-54 28 49.5420
10	-52 13 31.4690	-53 54 14.1888
11	-52 03 30.1614	-56 59 33.1460
12	-52 02 13.5400	-57 35 48.2348
13	-52 18 13.2903	-58 32 27.3286

5.3.3 Communications

There are no recorded pipelines or cables in the vicinity of the licence areas.

Mobile phone reception is now available within the Falkland Islands and is provided by Cable & Wireless.

5.3.4 Security

The Falklands are defended by a British military garrison comprising air, sea and land assets, backed by reinforcement capability if required. The Strategic Defence Review concluded that the composition of the land force in the Falklands was appropriate to ensure the security of the Falklands. Since 1982 the Falklands have had a relatively large British military presence, with up to 2000 personnel living at the Mount Pleasant air base complex which was constructed in the mid 1980s. As well as military personnel, civilian employees of the MoD and contractors responsible for the provision and maintenance of services live at the base.

A Royal Navy River Class offshore patrol vessel (currently HMS Clyde) is permanently stationed in the Falklands at the East Cove military port located at Mare Harbour, and there are regular visits from the Atlantic Patrol Task (South) warship (either a destroyer or frigate), accompanied by an RFA support vessel, throughout the year. Air defence is provided by Royal Air Force interceptors, which are supported by VC-10 tankers, Hercules C-130s and Sea King search and rescue helicopters. Logistical support for the garrison is also provided by various civilian contractors operating Sikorsky S-61 helicopters based at Mount Pleasant, and a tug and small cargo vessel based at East Cove.

There are a number of wildlife avoidance areas around the Falklands. These are demonstrated in Figure 5.37 above. This map is adapted from information provided by the Defence Geographic Centre (part of the UK MoD) and is used primarily for the identification of avoidance areas for the use of military personnel. This map is under review and should not be taken as definitive for operational purposes. Any updates to the avoidance areas will be incorporated into operational management plans as they become available.

Wildlife avoidance areas currently apply primarily to military flights and use of helicopters, although they will be equally applicable to helicopter movements to and from any vessels or drill units operating offshore the Falkland Islands. These areas are shown in full on map GSGS 5563, Falkland Islands range and avoidance areas, Edition 4, as produced by the UK Ministry of Defence (classified). The map has three categories of wildlife sensitive wildlife sites, which have specific regulations.

Known sensitive breeding sites of penguins and seals

Not to be over-flown by helicopters below 500 feet (150 metres). There are numerous sites identified across the Falkland Islands.

Very sensitive areas with high risk of bird strike

Not to be over-flown by any aircraft below 1,500 feet (460 metres) except where operationally necessary. These sites include Volunteer Point, the Kidney/Cochon/Mt Low area, Sea Lion Island, Elephant Cays Group, Eddystone Rock, Port Egmont Cays Group, Keppel Island/Saunders Island, West Point/Grave Cove area, 2nd, 3rd and 4th Passage Islands, the Jason Islands Group, the Governor/Staats/Tea Island group, the Channel/Barclay/Fox New Island group and Bird Island.

New Island and Bird Island

Should be avoided by helicopter below 500 feet at night due to prions and petrels which are nocturnal September and April.

Falklands Conservation and the Environmental Planning Department have made a number of recommended changes to the range and avoidance areas map, including formalising regulations concerning landing distances, updating the sensitive areas and revising the comments on sensitive species associated with the map.

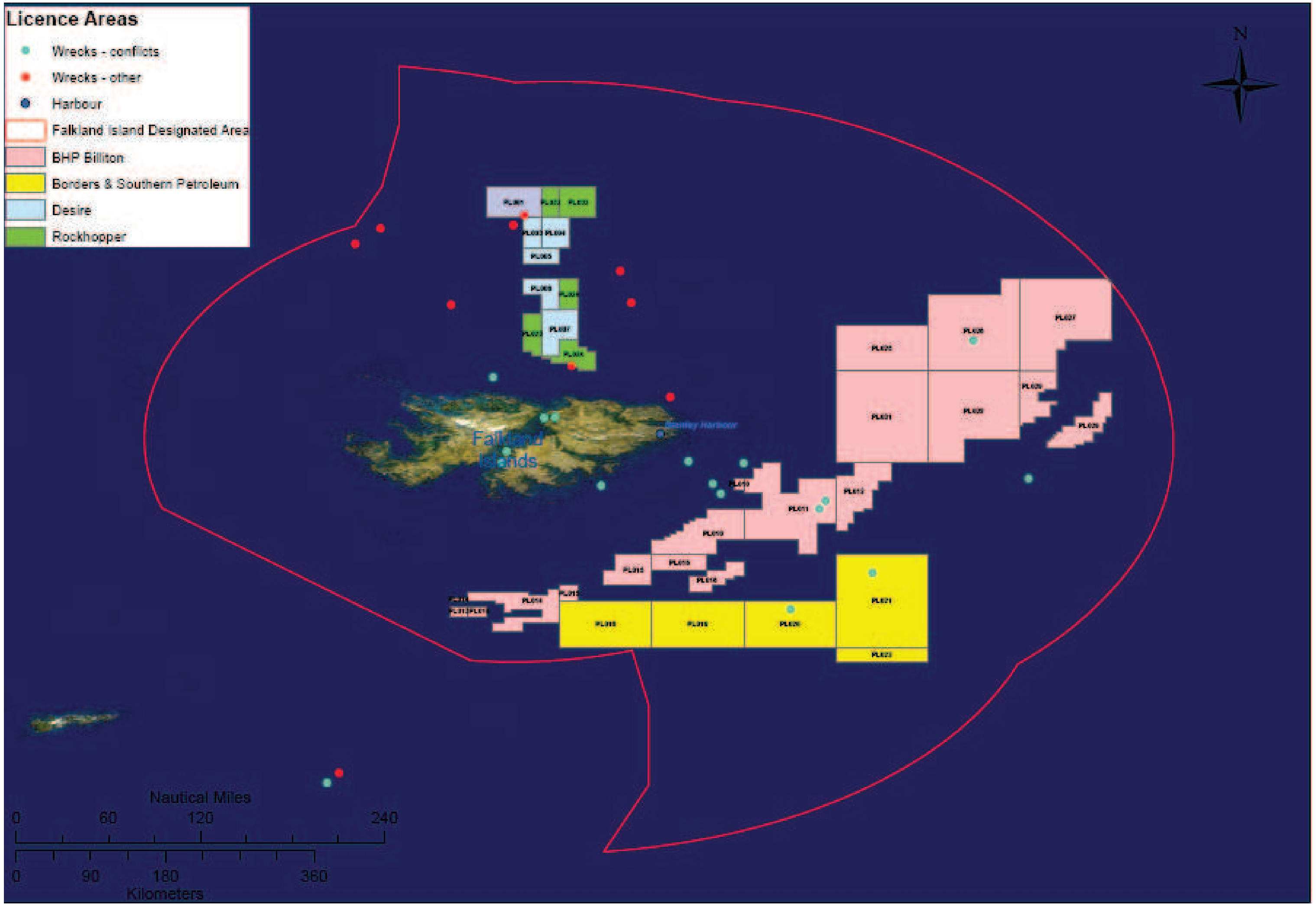

Figure 5.36 Known Shipwrecks in the Falklands Region

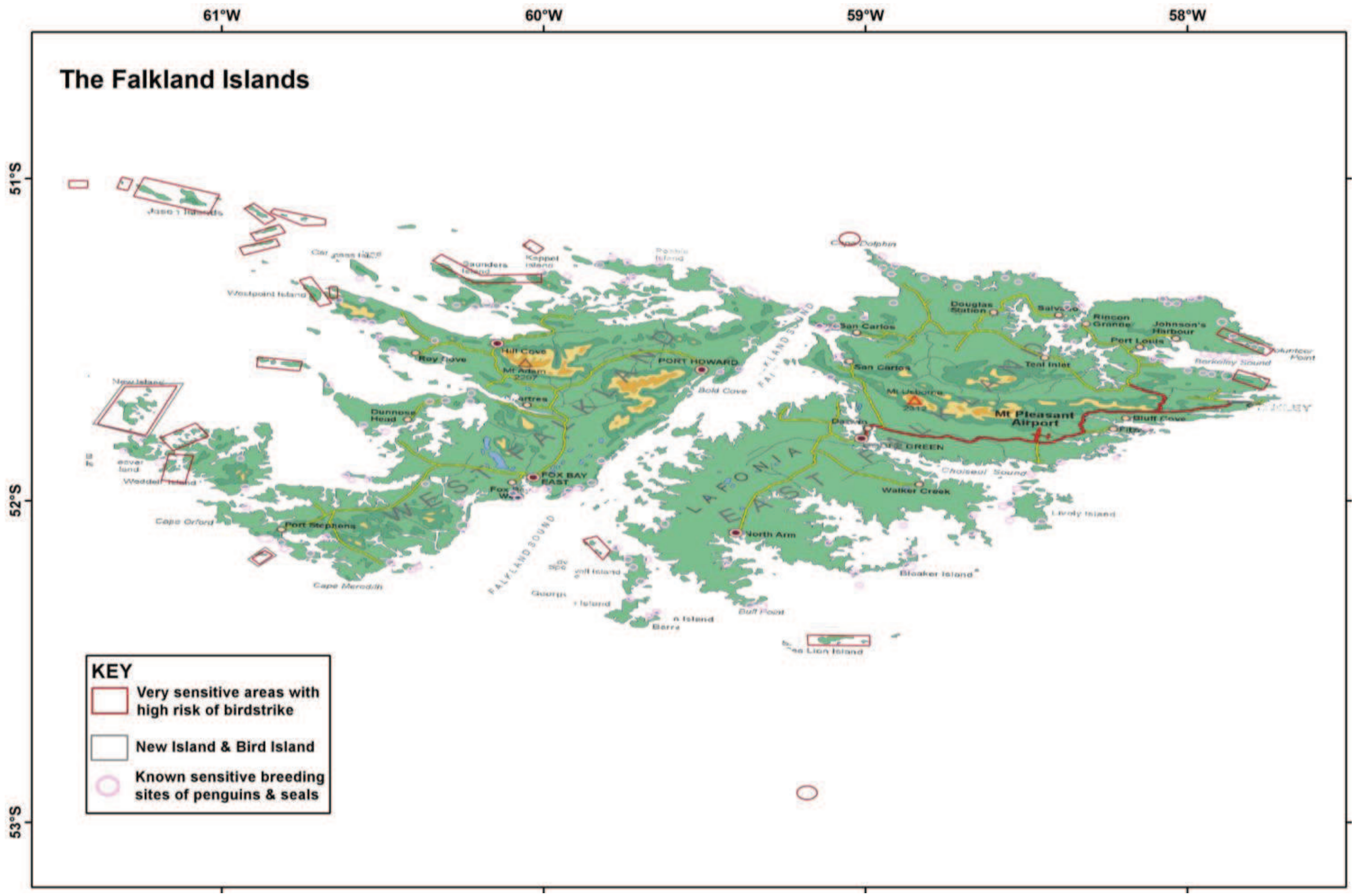

Figure 5.37 ***Identified ecologically sensitive areas to impacts from aircraft and helicopter activity*** *© Crown copyright material is reproduced with the permission of the Controller of HMSO. Adapted from the "Falkland Islands Range and Avoidance Areas" map provided by the Defence Geographic Centre, part of the UK Ministry of Defence.*

5.3.5 Navigation and Maritime Transport

Levels of shipping are low with no major shipping lanes within the licence areas.

Freight is transported to the Falklands from the UK and Chile by air and sea. The primary port is located in Stanley Harbour and known as FIPASS (Falklands Interim Port and Storage System). FIPASS, a floating system installed by the military after 1982 and purchased by the Falkland Islands Government in 1988, is currently operated by Byron McKay Port Services Ltd.

A commercial wharf is also located in Stanley harbour in close proximity to most retail and commercial operations, and provides a 4 m draft with limited warehousing, storage areas, water and fuel supplies.

The FIG is reviewing options for port development. A feasibility study has been undertaken in order to identify a suitable site to construct a new port.

Freight is transported locally by road or sea. Workboat Services Ltd provides a coastal shipping service. A recently introduced container feeder service by South American Atlantic Service Ltd services the ports of Montevideo (Uruguay) and Punta Arenas (Chile). The UK Ministry of Defence provides a 35 day sailing from the UK, which offers freight facility to the FIC (Falkland Islands Company Ltd.) and through the FIC to the local civilian community.

5.3.6 Waste Management Capability

There is very limited capacity of storing, managing and/or processing waste on the Islands. There is a government operated landfill, and the Islands do have the ability to recycle glass and aluminium but not plastic, paper or metal.

Used oil can be taken to a few waste oil burners via bowser or drums (e.g. Stanley Growers) and there is an independent incinerator at the slaughterhouse that could be available. Used batteries go to the landfill while some parts of vehicle batteries are recycled. The rest is stored for future export shipment.

5.3.7 Oil Industry Infrastructure

No permanent offshore oil industry infrastructure is currently in place. Shore based resources and infrastructure used for the previous drilling campaign, such as FIPASS and helicopter links, are likely to be utilised again for future drilling programmes.

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6 Environmental Hazards, Effects and Mitigation Measures

6.1 Introduction

The methodology used for environmental impact assessment follows the sequence summarised in Figure 6.1, with consultations incorporated into every phase.

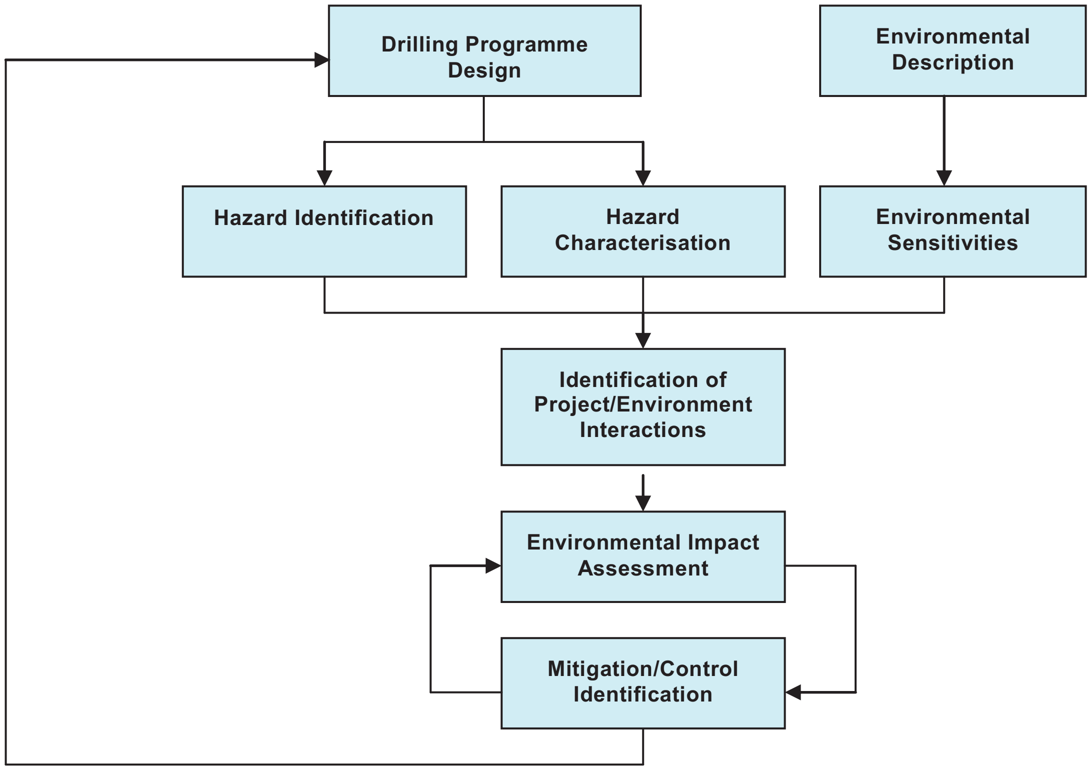

Figure 6.1 Methodology for Environmental Impact Assessment

The main supporting information required for an assessment includes a description of both the project (Section 4) and the environment in which it will take place (Section 5). In this section, the interactions between the project and the environment are identified and an environmental impact assessment is undertaken by establishing a matrix of hazards against environmental sensitivities.

The results of this qualitative risk assessment exercise are presented in the form of a matrix that highlights areas where some interaction is expected and provides a measure of the expected significance based on the criteria provided in Table 6.1. This qualitative scale helps to rank issues on a relative basis and identify areas where additional control measures may be required.

Table 6.1. Assessment of Significance of Effect or Hazard (from UKOOA, 1998)

1	**Severe** Change in ecosystem leading to long term (>10 years) damage and poor potential for recovery to a normal state. Likely to effect human health. Long term loss or change to users or public finance.
2	**Major** Change in ecosystem or activity over a wide area leading to medium term (>2 years) damage but with a likelihood of recovery within 10 years. Possible effect on human health. Financial loss to users or public.
3	**Moderate** Change in ecosystem or activity in a localised area for a short time, with good recovery potential. Similar scale of effect to existing variability but may have cumulative implications. Potential effect on health but unlikely, may cause nuisance to some users.
4	**Minor** Change which is within scope of existing variability but can be monitored and/or noticed. May affect behaviour but not a nuisance to users or public.
5	**Negligible** Changes which are unlikely to be noticed or measurable against background activities. Negligible effects in terms of health or standard of living.
	None No interaction and hence no change expected.
B	**Beneficial** Likely to cause some enhancement to ecosystem or activity within existing structure. May help local population.

6.2 Identification of Interactions

Table 6.2 summarises the interactions between the proposed exploration wells and the sensitivities of the local and regional environment during the proposed drilling period. A measure of the expected significance for each of the interactions has been derived based on the criteria provided in Table 6.1, above. The significance level assumes that the mitigation measures, identified for each of the hazards in the following sections, have been implemented.

Table 6.2. Potential Hazards and Associated Impacts from the Proposed Drilling Operations

Hazard	Water & Air		Flora & Fauna							Socio-economic								Other		
	Water Quality	Air Quality	Plankton	Seabed Fauna	Fish Spawning	Offshore Sea Birds	Coastal Birds	Marine Mammals	Sensitive Coastal Sites	Fishing	Shipping	Military Activity	Pipelines, Wells & Cables	Drilling & Support Crews	Dredging	Archaeology	Tourism / Leisure	Land Use	Sediments	Resource Use
Physical Presence										5	5						5			4
Seabed Disturbance				4												5			4	
Noise & Vibration					4	4	5	4												
Atmospheric Emissions		4																		
Marine Discharges	5		5	4	5															
Solid Waste									5									3		
Minor Loss of Containment	4		4		5	4		5		4	5						5			
Major Loss of Containment	3		3		3	2	3	4	3	3	3						3			

Key to Significance of Effect (see Table 4.1 for definitions)

1 Severe	2 Major	3 Moderate	4 Minor	5 Negligible	None

6.3 Design Control Measures

Environmental performance has been a key consideration in option selection and through the design process. Environmental studies and controls, implemented during the design stage of the project, ensure that additional control and mitigation measures required during the operational phases of the project are limited.

The major design controls include:

- Extensive planning prior to commencing operations to ensure that no strains are placed on current onshore capacities.
- Mud selection: use of WBM as the preferred option for the well sections with careful selection of components to reduce potential environmental effects.
- Waste: currently, any solid waste, excluding drill cuttings, that can be returned to shore for appropriate disposal will be skipped and shipped to the Falkland Islands. If the waste management capacity does not exist on the Islands, then the waste will be stored and shipped to an appropriate facility at an alternate destination by a licensed waste management contractor.
- Management procedures will be in place to ensure environmental controls are operating effectively and efficiently. These are detailed in Section 7 of this EIS.

- Oil Spill Contingency Plan (OSCP) and emergency response procedures will be in place. These will be submitted to FIG for approval prior to commencement of the drilling operations.

The environmental impact assessment undertaken for each phase of the project uses the design basis, with its integral design controls, as the benchmark for assessing potential impacts and identifying any additional control or mitigation methods required.

6.4 Physical Presence

There is no subsea infrastructure, such as cables or pipelines, in the areas of proposed wells, and so no interference is expected.

Drilling the proposed exploration wells will not result in any significant obstruction to other marine activities (e.g. fishing and/or shipping operations) whilst the drilling rig is operational, as the proposed drilling locations are outside of the key fishing areas and there are no known shipping lanes passing through the proposed well sites. However there is some fishing activity to the landward side of the licence blocks. Vessel collision risk is minor and the following mitigation measures will be implemented:

- A safety exclusion zone that will be established during the drilling operations, and the presence of project related vessels will minimise the risk of vessel collision.
- The planned activities will be promulgated in advance through Notice to Mariners, Navtex and VHF broadcast for the duration of the operations.
- The British Military will also be continually informed of Borders & Southern's proposed activities.

Resource consumption from acquisition of drilling consumables and equipment (casing, cement, mud, and chemicals) is assessed to be of low importance as it is unlikely that these resources will be sourced form the Falkland Islands, and are more likely to be sourced from elsewhere. The remote drilling location will require sufficient materials, equipment, spares and contingency supplies to be ordered in advance and shipped prior to rig mobilisation. Reordering and transporting replacement parts or additional materials during drilling will be financially and logistically impractical.

Fuel consumption throughout the drilling campaign is considered to be of minor importance to the Falkland Islands as it is likely that the fuel will be sourced from the Islands. The consumption of helifuel, aviation fuel for flights, diesel and marine fuel oil is an operational necessity, although fuel consumption can be minimised by a regular programme of maintenance and servicing. Advanced planning will be undertaken and should help to ensure flights and transfers are kept to a minimum, however regular crew changes are a necessity both for operational and health and safety reasons.

Water for drilling and domestic use is assessed to be of low importance to the Falkland Islands as some of it will be sourced from the sea and used as untreated seawater, some seawater will be treated in the desalination plant onboard the rig and a portion will be sourced locally in the Falkland Islands. However, if potable water has to be sourced from the Falkland Islands, it can be loaded outside peak times to minimise any impacts to the local community. In addition, water needs have been discussed with local authorities, and with adequate advance planning can be provided without effect to local needs.

6.5 Seabed Disturbance

6.5.1 Anchoring

Borders & Southern plan to use either a drill ship, or a 5^{th}-6^{th} generation DP semi-submersible rig for the proposed drilling programme. In the unlikely scenario of anchors being deployed there will be a direct impact on seabed surface. The impact is assessed to be minor as the benthic survey results revealed a homogenous benthic environment, typical of Magellan faunal area, and no habitats of conservation value were discovered. The small footprint (when compared to the legs of a jack-up rig, for example) and short duration of the drilling programme will limit potential impacts to the seafloor. It is anticipated that once the rig moves off location seabed communities will recover relatively quickly.

6.5.2 Deposition of Drill Cuttings

The main potential source of seabed disturbance from the Darwin East and Stebbing wells will be caused by the deposition of drill cuttings on the seabed in the vicinity of the drilling locations. The major physical waste product of a drilling operation is the generation of rock cuttings together with fine solids from the centrifuges. Other waste products include the discharge of drilling muds with the cuttings and cement during cementing of well casings.

Model Set-up and Assumptions

It is estimated that drilling the Darwin East exploration well will generate a maximum total of 1337.3 tonnes of cuttings associated with WBM while the Stebbing well will generate approximately 1331.3 tonnes of cuttings associated with WBM. These cuttings will be discharged to the sea, where the mud and cuttings will sink to the seabed and be deposited there in a pattern that reflects the nature of the cuttings' particle size distribution, the water depth and the water movements at the time of discharge.

The deposition of the cuttings and mud on the seabed has been modelled to gauge the potential pattern of deposition and to allow an estimation of the effect this could have on the benthic fauna. The Pollution Risk Offshore Technical Evaluation System (PROTEUS) model (version 1.5), developed by BMT Cordah (UK based environmental consultancy and information systems company), was used to carry out the modelling. Details on the model set up and the way in which the model works are provided in Appendix G.

To simulate residual water movements in the area, due to the lack of background current data in the modelling programme, the current override function was used in the model. This applies a 'blanket' background surface current speed and direction throughout the duration of the model run. The model assumes the input current to be true at the surface, and interpolates the currents as slowly diminishing down through the water column in accordance with the current shear effect (the effect of friction between the moving water mass and the seabed slowing the moving water down). Using the Acoustic Doppler Current Profiler (ADCP) measurements from the metocean mooring deployed in the vicinity of the proposed Darwin East and Stebbing well locations over the period between November 2007 and January 2008, the minimum observed current speed and calculated residual observed surface current direction (refer to Section 5.) were used as the 'current override' inputs for the model. The minimum observed current speed was used due to the fact that a slower current speed will give rise to less dispersion of the discharged cuttings, and hence represent a worst case scenario for the cuttings deposition i.e. give rise to the thickest deposition on the seabed. The residual surface current direction was used to represent the net drift of the cuttings over the duration of the model run.

Darwin East– Results

The results from the model are illustrated in Figures 6.2-6.3, which show that discharged material settles in a relatively circular pattern around the discharge location under the influence of the input current data. Figures 6.2 displays cuttings pile thickness contour plots with a thickness range from 0.01 to 1. millimetres (mm). The maximum cuttings pile thickness found was 1.1 mm, which occurred at the drilling location itself. This is likely to be the result of the top-hole well sections (the 36" and 26" sections) being discharged directly to the seabed. This is because when cuttings are deposited directly at the seabed, they have a limited chance to move through the water column and disperse away from the point of release, resulting in a thicker deposition.

The circular-shaped pile has a diameter of approximately 175 metres when measured to the 1 mm thickness contour. The cuttings pile in general (measured to the 0.01mm thickness contour) measures 2.4 x 1.3 kilometres at its longest and widest points, respectively. The cuttings are deposited along a north-east to south-west oriented axis, drifting away from the drilling location in a north-easterly direction. This is the result of the current characteristics input into the model and shows the effect of residual current direction in the area on the discharged cuttings. The widespread and very thin deposition observed is likely to be the result of the mid and bottom-hole well sections (17½" and 12¼" sections) being discharged overboard the rig. This is because when cuttings are discharged overboard, they can remain suspended in the water column for a significant period of time under the influence of the surface and bottom currents, before settling through the water column and finally being deposited on the seabed. This often results in more widespread deposition of the cuttings and a much less thick deposition of cuttings in general. In the case of the Darwin East well, the water depths in the area are significant (2,010 metres at the drilling location), meaning the time over which the particles would settle to the seabed would likely be very great. As such, it is likely that the majority of cuttings, particularly smaller particles that require less energy to be entrained, would have been dispersed over a very great distance, and after settling on the seabed, their thickness would be so small that it would be undetectable against the normal sediment regimes of the area.

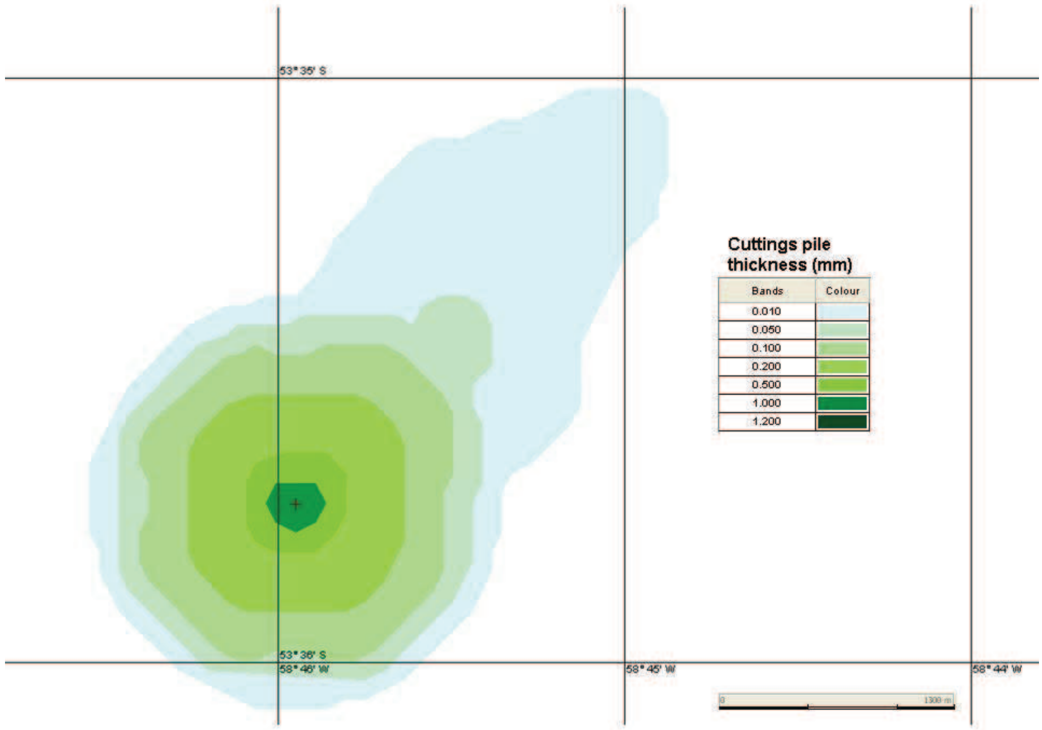

Figure 6.2 Predicted cuttings deposition on the seabed around the proposed Darwin East drilling location showing detailed view of the cuttings pile

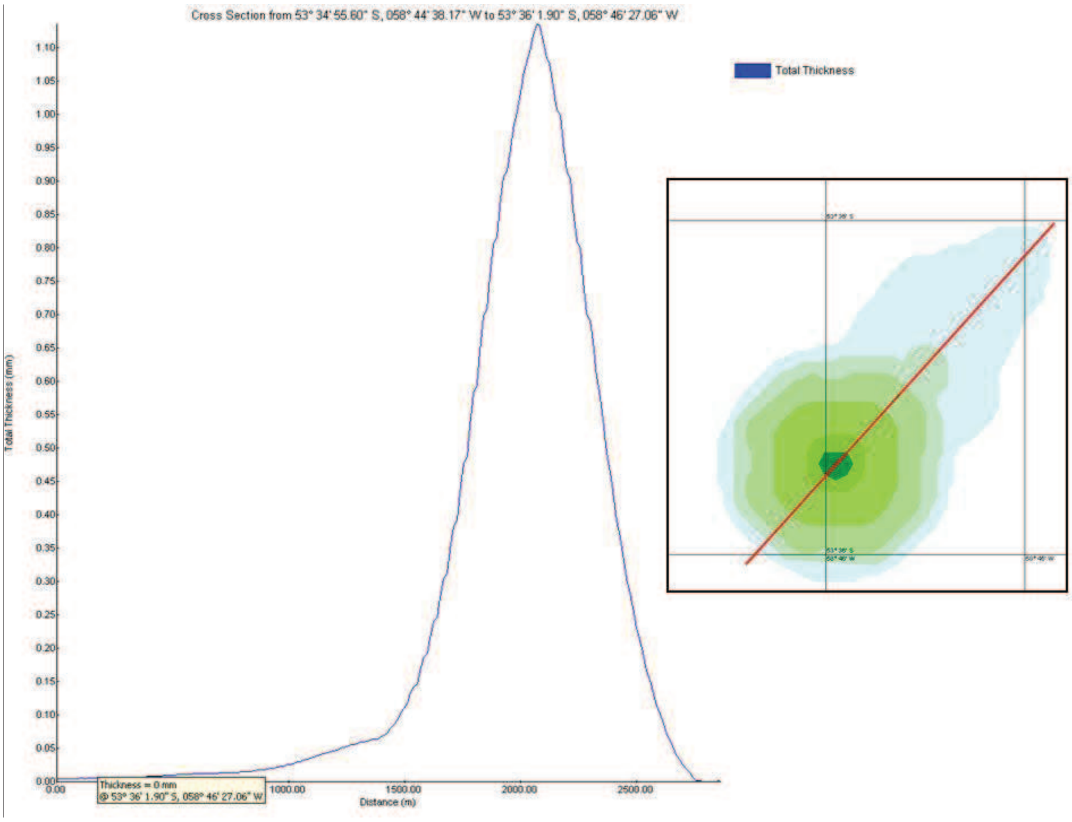

Figure 6.3 Cross section through the centre of the Darwin East drilling location along the long axis of the cuttings pile

Stebbing Well – Results

Similar to the cuttings pile dispersion modelled for the Darwin East well the results from the modelling at the Stebbing site (illustrated in Figure 6.3) show that discharged material settles in a elliptical pattern around the discharge location under the influence of the input current data. Cuttings pile thickness ranged between 0.01 to 1.9 millimetres (mm).

On consideration of the contour plots in Figures 6.4-6.5, it can be seen that the majority of cuttings are located in a circular-shaped pile centred on the drilling location. This circular-shaped pile has a diameter of approximately 497 metres when measured to the 1 mm thickness contour. It can also be seen that the cuttings pile closest to the well location is the thickest. This is likely to be the result of the top-hole well sections (the 36” and 26” sections) being discharged directly to the seabed, for the same reasons as stated above for the Stebbing well.

The cuttings pile in general (measured to the 0.01mm thickness contour) measures 2.0 x 1.3 kilometres at its longest and widest points, respectively. The cuttings are deposited along a north-north-east to south-south-west oriented axis, drifting away from the drilling location in a north-north-easterly direction. This is the result of the current characteristics input into the model (current in direction of bearing 040^{o}). The widespread and very thin deposition observed is likely to be the result of the mid and bottom-hole well sections (17½” and 12¼” sections) being discharged overboard the rig, for the same reasons as stated above for the Darwin East well.

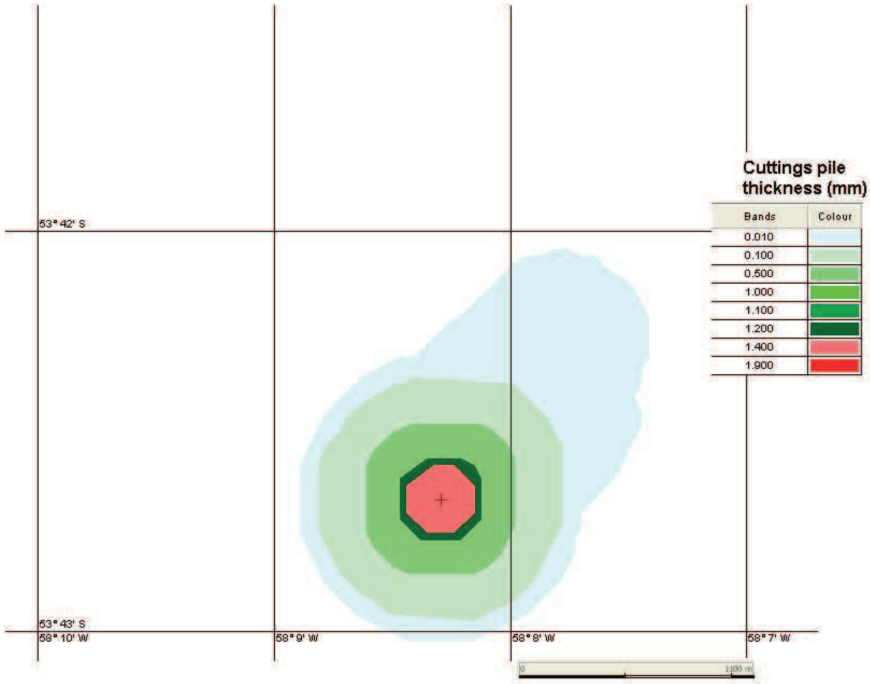

Figure 6.4 Predicted cuttings deposition on the seabed around the proposed Stebbing drilling location showing detailed view of the cuttings pile.

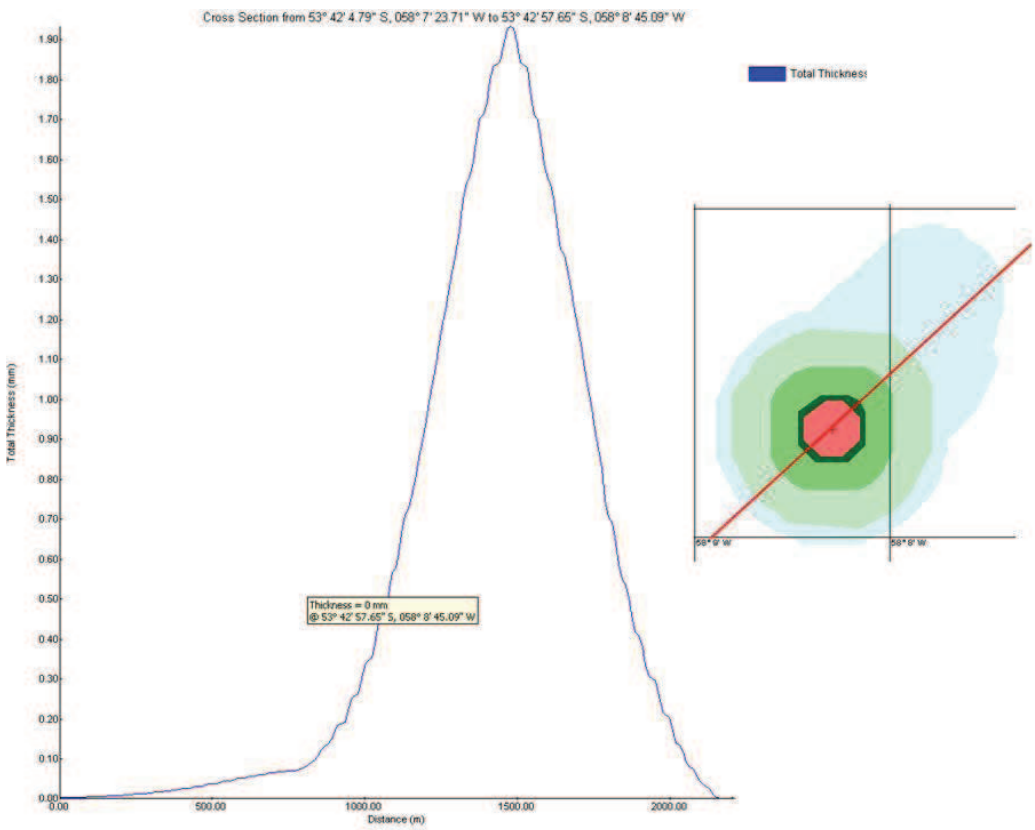

Figure 6.5 Cross section through the centre of the Stebbing drilling location along the long axis of the cuttings pile.

Conclusions

The deposition of cuttings and fine solids described above has the potential to directly affect the seabed fauna via smothering effect and changes in the sediment grain size and chemistry. Studies have shown that impacts from smothering can occur where the depth of cuttings is one millimetre or more (*Bakke et al., 1986*).

At the Darwin East well location, the cuttings pile thickness insignificantly exceeds 1 mm in a small area surrounding the drilling location of a radius of approximately 175 metres. This represents an area of approximately 0.6 km^2. At the Stebbing well location, the cuttings pile thickness slightly exceeds 1 mm to a distance of approximately 497 metres, approximately 1.6 km^2. A reduction in existing faunal representation may be expected due to smothering effects in the immediate vicinity of the wells, however the overall impact will be minor due to localised scale of the impact and absence of habitats of conservation value (*Benthic Solutions, 2009*).

As there are no toxic components within the discharge of the vast majority of cuttings, the impacted area will begin to recover soon after drilling operations have ceased. Recolonisation of the impacted area can take place in a number of ways including mobile species moving in from the edges of the area, juvenile recruitment from the plankton or from burrowing species digging back to the surface.

A study of the development drilling in the Pompano field in deep water in the Gulf of Mexico (*Fechelm et al, 1998*) has assessed the dispersion of Synthetic-based Drilling Muds (SBM) cuttings from two platforms in water depths of 393 metres and 565 metres. The cuttings from these multi-well developments totalled 7,659 bbl (ca. 980 tonnes) of SBM Petrofree LE (90% LAO, 10% Ester), although mud weight discharged has not been estimated. The dispersion of these cuttings was surveyed, and results indicated that no cuttings pile was observed at either location. Instead there was a thin 'veneer' of cuttings dispersed over a large area in a patchy fashion, the thickest patches were 20-25cm deep. Chemical analyses indicated that most of the fluid was observed along transects in the direction of the surface and mid-level currents rather than in the direction of bottom currents. Maximum measured SBM concentrations were recorded close to the platform (100m) and were in the order of 30-50,000µg/g in the top 2cm of sediment. Benthic abundance was highest in sediment along the same transect that had high SBM concentrations. ROV video was used to count demersal megafauna (primarily fish). Neither benthic fauna nor demersal fish abundance appeared to have been adversely affected by the SBM cuttings discharge.

Other evidence of cuttings dispersion exists from the UKCS. In 1987 a benthic environmental survey was undertaken at a single well site, located within a water depth of around 140 metres, in the Central North Sea (*AUMS, 1987*). The well had been drilled five years prior to the survey using a WBM and a total of approximately 800 tonnes of cuttings had been deposited on the seabed. The results of the survey indicated that, with the exception of a slightly elevated barium concentration, levels of sediment metals and hydrocarbons were similar to background. The analysis of the benthic fauna indicated that, even at sites closest to the wellhead, full recovery of the impacted sediments had taken place. This well site was revisited by Oil and Gas UK (formerly UKOOA) in 2005 and results now show that the area is completely consistent with background conditions (*Hartley Anderson Ltd, 2005*).

In addition, field studies in the United States of America have shown that recovery of benthic communities impacted with water based drilling discharges is likely to be very rapid (i.e. within a few months) (*Neff, 1982*).

Given this evidence, the shallowness of the predicted cuttings deposition and the action of movement of the bottom currents, it is likely that any cuttings will soon become mixed with the natural sediments and will eventually be dispersed.

6.6 Noise and Vibration

Sound is readily transmitted underwater and there is potential for sound produced from the exploration drilling to cause detrimental effects to marine animals. Because of the low loss characteristic of underwater sound transmission compared with underwater light transmission, the use of sound has developed evolutionary as the predominant long-range sensory modality for marine mammals. The use of underwater sound is therefore very important for marine mammals (e.g. seals, whales, porpoises and dolphins) in order to navigate, communicate and forage effectively. The introduction of additional (man-made) noise into the marine environment could potentially interfere with these animals' ability to determine the presence of other individuals, predators, prey and underwater features and obstructions. This could therefore cause short-term behavioural changes and, in more extreme cases, cause auditory damage. In addition, underwater sound may also cause behavioural changes in other animals such as fish and cephalopods.

The impact of noise generated during the drilling of exploration wells depends on ambient noise levels; the strength of the sound source; the sound transmission conditions of the receiving environment, and the proximity of animals to the noise in relation to their ability to detect such sound frequencies and their sensitivities to particular sound levels and frequencies.

Naturally occurring noise levels in the ocean as a result of wind and wave action may range from around 90 dB re 1µPa under very calm, low wind conditions to 110 dB re 1µPa under windy conditions. Certain aspects of the drilling campaign could generate noise in excess of ambient conditions.

6.6.1 Potential Impacts

Operational activities at the proposed well sites will generate noise, both above and below the sea surface, mainly during drilling activities. Noise is thought to have the potential to disturb animals in the area, particularly cetaceans.

Noise from offshore operations is produced over a relatively large frequency range, typically between 5- 4,000 Hertz (*Richardson et al., 1995).* Drill ships generate low frequency sounds in the range of 0.01 to 10 kHz**,** with received tonal levels between approximately 175 and 191 dB re 1 µPa-m (*Simmonds et al, 2003; Richardson et al, 1995; Evans & Nice, 1996*). The main sources of emitted noise include drill pipe operation, onboard machinery and thrusters noise. Drill ships are inherently louder than other types of rigs.

Typical subsea noise levels from offshore operations are shown in Table 6.3. The sound levels at a range of distances from various drilling facilities are also provided and have been estimated using the equation for spherical underwater noise spreading (*Evans & Nice, 1996; Richardson et al, 1995).*

Table 6.3. Sound sources from various offshore activities (adapted from: Evans & Nice, 1996; Richardson et al, 1995 and Simmonds et al, 2003)

Activity	Frequency range (kHz)	Average source level (dB re 1µPa-m)	Estimated received level at different ranges (km) by spherical spreading			
			0.1 km	1 km	10 km	100 km
High resolution geophysical survey; pingers, side-scan	10 to 200	<230	190	169	144	69
Low resolution geophysical seismic survey; seismic air gun	0.008 to 0.2	248	210	144	118	102
			208	187	162	87
Vertical Seismic Profiling	0.005 to 0.1	190	150	129	104	29
Production drilling	0.25	163	123	102	77	2
Jack-up drilling rig	0.005 to 1.2	85 to 127	45 to 87	24 to 66	<41	0
Semi-submersible rig	0.016 to 0.2	167 to 171	127 to 131	106 to 110	81 to 85	6 to 10
Drill ship	0.01 to 10	179 to 191	139 to 151	118 to 130	93 to 105	18 to 30
Large merchant vessel	0.005 to 0.9	160 to 190	120 to 150	99 to 129	74 to 104	<29
Super tanker	0.02 to 0.1	187 to 232	147 to 192	126 to 171	101 to 146	26 to 71

* (dB) The magnitude of the sound manifests itself as pressure, i.e. a force acting over a given area. It is expressed in terms of 'sound levels', which use a logarithmic scale of the ratio of the measured pressure to a reference pressure (Decibels (dB)). Level of underwater noise is reported in dB re 1µPa @ one metre in water.

Taking the average noise levels generated from drilling operations using a drill ship and a semi-submersible drilling rig and assuming a spherical propagation of noise from the source, it can be seen from Table 6.4 that background noise levels of 100dB will be reached within approximately 5 to 10 kilometres of the source.

6.6.2 Potential Impacts on Fish

Sound is perceived by fish through the ears and the lateral line (the acoustico-lateralis system) which is sensitive to vibration. In addition, some species of teleost or bony fish have a gas filled sack called a swimbladder that can also be used for sound detection. The swimbladder is sensitive to the pressure component of a sound wave, which it resonates as a signal that stimulates the ears (*Hawkins, 1993*). Some groups of fish, e.g. flatfish and elasmobranchs or cartilaginous fish such as sharks and rays, do not posses a swimbladder and so have a reduced hearing ability. Those species that are particularly sensitive to noise include the clupeids and gadoids (herring and cod families). *Turnpenny & Nedwell,* (*1994*) have measured sound pressure level thresholds for the onset of fish injuries (Figure 6.6).

Fish are generally sensitive to noises within the frequency range of 1 Hertz to 3,000 Hertz, however, it has been reported that they will respond consistently to very low, or very high frequency noises (*Knudsen et al. 1992, 1994*). Sounds in the range of 50 to 2,000 Hertz, such as the peak sound levels produced by many anthropogenic activities, only produce short-term startle response at the outset of sound production with subsequent habituation to noise (*Knudsen et al. 1992, 1994; Westerberg, 1999*).

Given the magnitude of sound levels expected to be generated during the proposed drilling activities, there will be a likely transient stunning effect and auditory damage to fish in an immediate vicinity of the drilling unit, but no physical injuries are expected. Physical damage will occur however for fish eggs and larvae, which have limited mobility and is the most sensitive to the noise. Few meters away from the source (drill ship or semi-submersible rig) these impacts will be negligible. During spawning, the impact will be minor due to localised area of impact.

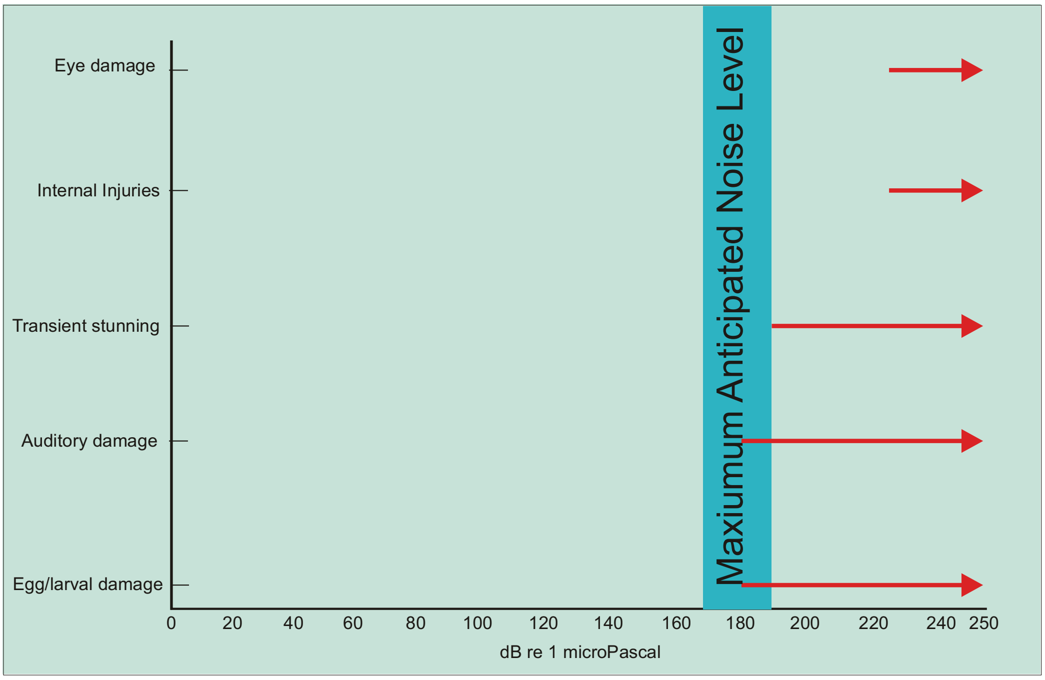

Figure 6.6. Sound Pressure Level Thresholds for the Onset of Fish Injuries (after Turnpenny & Nedwell, 1994)

6.6.3 Potential Impacts on Cetaceans

Based on the JNCC survey results (White et al., 2002) and on the MMO observations during 3D seismic survey within the Borders & Southern Licence area, the following species of cetacean can be found in the vicinity of the proposed drilling locations: long-finned pilot whale, hourglass dolphin, peale's dolphin, sei whale, killer whale, sperm whale, minke whale, baleen whale, blue whale (refer to Section 5.2.8). The only cetacean species recorded in significant numbers (>10 species over 3 months period) were finned pilot whale, fin whale and hourglass dolphin.

Cetaceans are unlikely to be significantly affected by the magnitude and frequency of noise produced during the planned offshore drilling operations (Richardson et al., 1995). The sound produced by drilling rigs and associated support shipping are all well below the injury thresholds for the functional hearing groups (i.e. low-, mid- and high-frequency cetaceans) for non-pulse sounds as established by Southall *et al*, 2007. Sounds produced might; however, evoke certain levels of behavioural response.

Zone of discomfort for marine is likely to be in a close proximity to the well. Davis (1990) suggests that auditory damage would occur if marine mammals were exposed to sounds greater than 120 dB for prolonged periods of time. To be exposed to such sound levels, the animal would have to be within 1 km of a drill ship during drilling activities. It is considered unlikely that marine mammals would remain close to such a noise source for any length of time (Richardson *et al*, 1995; Gordon *et al*, 2004).

While there are clearly major areas of uncertainty remaining, there has been relatively extensive behavioural observation of 'low-frequency cetaceans' exposed to non-pulse sources. The combined information from these generally indicates no (or very limited) responses at received sound levels of 90 to 120 dB re: 1 µPa and an increasing probability of avoidance and other behavioural effects in the 120 to 160 dB re: 1 µPa range (Southall et al, 2007). Assuming a 120 dB re: 1 µPa threshold, behavioural avoidance cetaceans is expected to the extend of 1 km from a a drill ship and less than 1 km from a semi-submersible drilling rig (Table 6.3).

Evidence suggests that dolphins and other toothed whales show considerable tolerance of drill rigs and support vessels (Richardson et al, 1995). Baleen whales have been reported within visual distance of drill ships off West Greenland (LGL, 2000) and bowhead whales have been observed to avoid an area with radius 10 kilometres around a drill-ship, corresponding to received sound levels of 115 dB re 1 µPa (Richardson et al, 1995). Sound levels produced from the proposed drilling programme are likely to be within 170-190dB range, this will be annulated to background levels within 5-10 kilometres of the source (depending on the drilling unit used - see Table 6.3).

Given the above, although cetaceans may be present in the vicinity of the drilling rig, the impacts of noise are estimated to be within a limited and short in duration (few months), and therefore minor overall.

6.6.4 Potential Impacts on Pinnipeds

Little is known of the at-sea distribution of Falkland Islands pinnipeds. Based on the JNCC survey results (White et al., 2002) it is possible that South American sea lions, South American fur seals and Southern elephant seals may be present within the vicinity of the proposed well location during the drilling period in low numbers.

Information on the effect of noise on pinnipeds is scarce (Davis et al., 1990). Noise can interfere with the ability of pinnipeds to explore their environment and communicate with each other (Reijnders et al., 1993). Furthermore, heavy noise generated from seismic operations, icebreakers and drilling operations might cause serious discomfort (Richardson et al., 1998).

Most pinniped species have peak sensitivities between 1 and 20 kHz. Some species, like the harbour seal, have best sensitivities over 10 kHz. Only the northern elephant seal has been shown to have good to moderate hearing below 1 kHz (Kastak and Schusterman, 1999). Some pinniped species are considered to be effectively double-eared in that they hear moderately well in two domains, air and water, but are not particularly acute in either. Others, however, are clearly best adapted for underwater hearing alone.

Responses of pinnipeds to noise disturbance vary depending on where the individual is when they encounter a novel noise source. Pinnipeds generally show reduced reaction distances to ships when the animals are in the water compared to when they are hauled out (Hammond et al., 2006). As the proposed wells are located some distance from the know haul-out sites and only low numbers of pinnipeds may be present in the water around the drilling rig (refer to Section 5.2.8), impacts from noise associated with drilling the proposed exploration wells are expected to be negligible.

6.6.5 Potential Impacts on Protected Birds

The majority of seabird species in the Falkland are observed in coastal and nearshore areas. Offshore seabirds are more likely to be found in higher numbers and hence more susceptible to noise during winter and spring seasons (June-November). It is possible that albatross will be present in the vicinity of the proposed wells.Petrels and shearwaters are known to be present in the vicinity of the exploration wells and include blue petrel, kerguelen petrel, Atlantic petrel, prion species, sooty shearwater and diving petrel, however, none of these species are considered to be present in significant numbers (refer to Section 5.2.9).

Of the penguin species recorded in the Falkland Islands, only rockhopper penguins and magellanic penguins have been observed at significant distance from the Falkland Islands and may therefore be present during the proposed drilling period.

Anticipated airborne noise from drilling activities is likely to be rapidly attenuated and, as a result, any impact to seabirds (i.e. displacement from the area) is likely to be much localized within the immediate vicinity of the drilling and will be temporary in nature.

Given the above, and the fact that the area in the vicinity of the proposed wells is not considered to be of particularly high sensitivity for seabirds, the impact of the proposed drilling activity on any birds which may be present in the area is considered to be negligible.

6.7 Atmospheric Emissions

The main sources of atmospheric emissions during drilling operations will result from diesel burnt for power generation for the drill rig and associated standby vessels.

Diesel burnt for power generation will give rise to minor emissions of carbon dioxide (CO_2), oxides of nitrogen (NOx), nitrogen dioxide (NO_2), sulphur dioxide (SOx) and unburned hydrocarbons (refer to Tables 6.4 and 6.5). These types of emissions are anticipated to disperse rapidly under most conditions to levels approaching background within a few tens of metres of their source. Although all such emissions will contribute to the overall pool of greenhouse and acidic gases in the atmosphere, local environmental and transboundary effects will be negligible. The overall, cumulative impact is estimated as minor.

Practical steps to limit atmospheric emissions that will be adopted during the drilling programme include advanced planning to ensure efficient operations, well maintained and operated power generation equipment and regular monitoring of fuel consumption.

Table 6.4. Predicted Atmospheric Emissions from Darwin East Well

Emissions[1]	Drill Rig[2]	Support Vessels[3]	Total
Carbon dioxide	3840.000	720.000	97.280
Carbon monoxide	18.840	3.533	0.158
Oxides of nitrogen	71.280	13.365	0.380
Nitrous oxide	0.264	0.050	0.007
Sulphur dioxide	4.800	0.900	0.122
Methane	0.216	0.041	0.003
Volatile organic chemicals	2.400	0.450	0.024

Note 1: Emission factors used from UKOOA 2002a based on methodology proposed by OGP

Note 2: Rig is estimated to consume @ 30 tonnes fuel/day for 40 days duration.

Note 3: 2 Support vessels (standby and supply vessels are estimated to consume @ 3 and 7 tonnes fuel/day, respectively) for 40 days duration.

Note 4: Atmospheric emissions for helicopter trips assumes flights for crew changes will occur 16 times (round trip) throughout the drilling programme. Fuel consumption is estimated at 5 tonnes per 1,000km with a return trip from Mt Pleasant Airport to the rig estimated at 380 km.

Table 6.5. Predicted Atmospheric Emissions from Stebbing Well

Emissions[1]	Drill Rig[2]	Support Vessels[3]	Total
Carbon dioxide	3360.000	672.000	96.320
Carbon monoxide	16.485	3.297	0.157
Oxides of nitrogen	62.370	12.474	0.376
Nitrous oxide	0.231	0.046	0.007
Sulphur dioxide	4.200	0.840	0.120
Methane	0.189	0.038	0.003
Volatile organic chemicals	2.100	0.420	0.024

Note 1: Emission factors used from UKOOA 2002a based on methodology proposed by OGP

Note 2: Rig is estimated to consume @ 30 tonnes fuel/day for 35 days duration.

Note 3: 2 Support vessels (standby and supply vessels are estimated to consume @ 3 and 7 tonnes fuel/day, respectively) for 40 days duration.

Note 4: Atmospheric emissions for helicopter trips assumes flights for crew changes will occur 14 times (round trip) throughout the drilling programme. Fuel consumption is estimated at 5 tonnes per 1,000km with a return trip from Mt Pleasant Airport to the rig estimated at 430 km.

6.8 Marine Discharges

Sources of marine discharges for the proposed wells are:

- Water based mud (WBM) and drill cuttings;
- Cement;
- Drainage water;
- Sewage.

These discharges are discussed in the following sections.

Borders & Southern are to employ several measure to reduce impacts to the marine environment from these discharges as detailed below:

- Planned use of water based mud (WBM) for all sections of the well with the selection of most environmentally benign mud and cement chemicals.
- Good housekeeping standards to be maintained on the rig to control the amount of hydrocarbons and other contaminants entering the drainage system. Appropriate drainage and sewage treatment systems will be on all rig/vessels. All discharges from the rig/supporting vessels will be treated and discharged according to the MARPOL Convention.
- All drilling chemicals to be assessed using the HOCNS methodology where appropriate, in accordance with the UK's Offshore Chemicals Regulations (OCR) 2002. Any chemicals with substitution warnings will be substituted where practicable.

Due to the low toxicity of the majority of the discharges and the anticipated dilution and dispersion, all impacts are predicted to be short-term and localised and assessed to be negligible.

6.8.1 Water Based Mud (WBM) and Drill Cuttings

WBM will be discharged as mud on cuttings and fine solids and, upon the completion of drilling each section of each well, the spent WBM will be discharged to sea. The drilling mud composition is essentially a brine solution, with naturally occurring barite and bentonite clay. Small amounts of chemicals are added to this to maintain the properties of the mud and to prevent damage to the well bore and the reservoir.

The main components of WBM will comprise natural products (for example, brine, bentonite and barite), which are biologically inert. The muds typically have a very low toxicity, with an LC_{50} of more than 50,000 parts per million (*Jones et al., 1986; Leuterman et al., 1989*). In fact, the WBM comprises approximately 90 percent water and the vast majority of WBM discharged for the well (approximately 96 percent) are classified under Annex 6 of the OSPAR convention (OSPAR, 1999) as substances, which are considered to Pose Little Or No Risk to the environment (PLONOR chemicals) (refer to Section 4.4.8).

Of the limited quantity of chemicals not classified as PLONOR and anticipated to be discharged along with the WBM, all are categorised as Category E or Gold (the lowest environmental risk category) under the UK Harmonised Offshore Chemical Notification Scheme (see Appendix B for a description of the UK Harmonised Offshore Chemical Notification Scheme, CHARM and Hazard Quotients).

Studies of the discharge of WBM into the water column in areas where currents are weak have found dilutions of 500 to 1,000 times within one to three metres of discharge *(Ray and Meek, 1980)*. Dilution will therefore be rapid and this, together with the low toxicity, indicates that any impacts within the water column will be undetectable shortly after discharge. Discharge of the WBM will not contribute to any impacts on the local seabed communities through toxicity, bioaccumulation, low biodegradability or other aspects such as the endocrine disruption.

In some cases drilling muds may be associated with elevated levels of heavy metals. However, a wide range of studies have shown that these are not bio-available and do not therefore result in any direct affects on marine fauna and flora (*Neff et al., 1989*).

6.8.2 Cement Chemicals

During drilling of the wells, some surface returns of cement and associated chemicals will be lost to the seabed in the immediate vicinity of the well. Only a small volume of cement will be lost from the well. The cement is comprised mostly of PLONOR chemicals (refer to Section 4.4.8).

All chemicals to be discharged which are non-PLONOR have a HQ band of GOLD or E (lowest environmental risk category) for the purposes of CHARM assessment. Any impacts will be very close to the wells in the same area affected by cuttings deposition (refer to Section 6.5.2).

6.8.3 Drainage Water and Sewage

Water generated from rig washdown and rainfall from the open deck areas may contain trace amounts of mud, lubricants and residual chemicals from small onboard leaks derived from activities such as re-fuelling of power packs or the laying down of dirty hoses or dope brushes etc. It should be stressed, however, that these would be relatively low volume discharges containing small residual quantities of contaminant. Borders & Southern will ensure that the rig is equipped with suitable containment, treatment and monitoring systems as part of the contract specification.

In addition, the Borders & Southern Drilling Representative will also ensure good housekeeping standards are maintained onboard the rig to minimise the amount of hydrocarbons and other contaminants entering the drainage systems. Liquid storage areas and areas that might otherwise be contaminated with oil are generally segregated from other deck areas to ensure that any contaminated drainage water can be treated or accidental spills contained. All the drains from the rig floor will be directed to a containment tank and the fluids processed/filtered to remove hydrocarbons (<15 parts per million hydrocarbons in water) as required under the MARPOL Convention and discharged to sea. Residual hydrocarbons will be routed to transit tanks for processing onshore.

An estimated 0.22 m^3/day of grey water and 0.10 m^3/day of black water will be generated by each person on board the drilling rig and support vessels (based on previous modelling and assumptions for offshore drilling operations (*BP, 2002*). Table 6.6 show the estimated volumes of grey and black water produced per drilling period (75 days) from the drilling of the exploration wells (assuming 100 persons onboard).

Table 6.6. Estimated quantities of grey and black water discharge during drilling period (75days)

Type of water	Volume (m^3)
Grey water produced (m^3)	1650
Black water produced (m^3)	750

A Marine Sanitation Device will be available on the drilling rig for treatment of sewage effluent. Sanitary wastes such as black (sewerage) and grey water (showers and washing facilities) will contain detergents and cleaning agents from toilets and showers, together with human waste. All black water is routed via sewage treatment systems before being discharged to sea.

Of note is that all discharges from the rig/supporting vessels will be treated and discharged according to the MARPOL Convention. In addition, all vessels, including the rig, will implement appropriate waste management plans.

6.9 Solid Wastes

Careful consideration is given to minimising the amount of waste generated and controlling its eventual disposal. It is acknowledged that waste disposal and treatment options in the Falklands are limited, and once a drill rig and drilling contractor have been chosen, the waste options will be assessed (in consultation with FIG) and a tailored project waste management plan will be developed and implemented.

Typically, 24 tonnes of general waste are generated per month from a single well drilling programme. Bulk wastes (e.g. garbage, scrap, etc.) generated on the drilling rig will be segregated by type, stored in covered, four tonne capacity skips. Periodically these will be transported to shore (either the Falklands, if practicable, or to an alternate location) and the waste recycled or disposed of in a controlled manner through authorised waste contractors. Borders & Southern will ensure that a waste management programme is implemented to minimise the amounts generated and to ensure material such as scrap metal, waste oil and surplus chemicals are sent for re-cycle or re-use as far as practicable. Other waste will be sent to authorised landfills or incineration facilities, depending on its precise nature, to the Falklands, if practicable, or an alternate location.

All discharges from the supporting vessels will be treated and discharged according to the MARPOL Convention (as relevant to the Atlantic Ocean). The MARPOL Convention prohibits discharge of any garbage or solid wastes (with the exception of macerated food waste) offshore.

All vessels, including the rig, will implement appropriate waste management plans and store and dispose of all solid wastes onshore accordingly. Procedures for dealing with special waste will be implemented in accordance with regulatory guidelines.

6.10 Loss of Containment

6.10.1 Potential Spill Scenarios

The main environmental risk associated with rig operations is a risk of accidental hydrocarbon release during drilling operations, mainly from fuel bunkering of diesel or a loss of well control.

Data recorded by the Department of Energy and Climate Change on oil spills on the UK Continental Shelf indicate that small spills are historically the most common during drilling operations, although these are still quite rare occurrences (Figure 6.7). The historical frequency is 0.15 'operational' spills per exploration well drilled on the UK Continental Shelf between 1994 and 1997 for all recorded spills of ten tonnes or less.

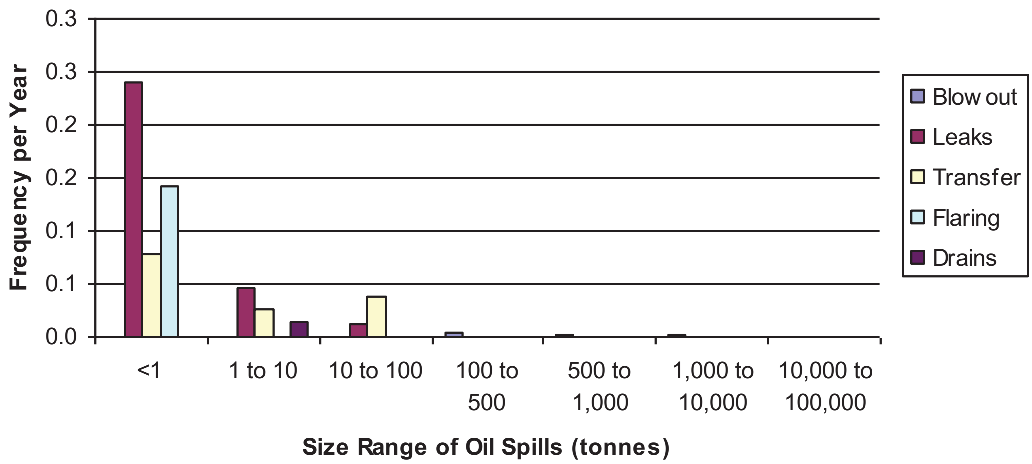

Figure 6.7 Frequency and Size of Oil Spills during Offshore Drilling Operations per Rig Per Year (data from UKCS and SINTEF Database)

Accidental diesel spills during bunkering are identified as a moderate risk but the expected volumes of hydrocarbon released would be generally small (0.6 tonnes) (*HSE, 1995*). Such a volume would disperse rapidly and will not impact along the coast.

The two main sources of potential spillages, from historical oil spill records are listed in Table 6.7 with the measures that being taken by Borders & Southern within the drilling programme to minimise or eliminate the risks. These are discussed further in the sections below along with response measures in the unlikely event that a large spill does occur. Further information on the likelihood of spills and the size and type of spill that may be expected from the proposed wells is also provided in Appendix H.

6.10.2 Worst Case Scenario

The worst-case scenario is considered to be from a major oil spill occurring as a result of a loss of well control or blow out. Historically, the worldwide frequency of blow outs is approximately 0.0063 per well, or 1 in every 159 wells (*Holand, 1997*). Statistics from the World Offshore Accident Data Bank (WOAD) indicate that worldwide the frequency of occurrence of blowouts from mobile drilling units is only of the order of 10 per 1000 unit years (*WOAD, 1998*). This is supported by data from the UK, where over 3500 exploration, appraisal and development wells have been drilled from 1997 to 2008 (includes mechanical sidetracks) with no major blow outs. The probability of a blow out during drilling in the exploration wells is therefore very low.

Table 6.7. Sources of Oil Spills and Control Measures Planned

Potential Source of Spill	Risk and Control Measures Taken
Fuel or other utility fluids (e.g. diesel, lubricants)	The rig will arrive on site fully bunkered, so refuelling should be minimised. If refuelling is undertaken at sea, a refuelling procedure will be implemented, and will contain measures such as the following: • Where practicable, re-fuelling and transfer of lubricants and other utility fluids will only be undertaken during daylight and in good weather conditions. Non-return valves will be installed on fuel transfer hoses, hoses will be tested and inspected as a part of a regular maintenance programme and operations will be supervised at all times from both the supply boat and drill rig. • Bunding is integral to the fuel, oil and liquid storage areas. • The rig will be equipped with sorbent clean-up materials and storage capacity for recovered oil and sorbent. The crew are trained in oil spill response actions. An oil spill contingency plan will be in place and will compliment the Falkland Islands national oil spill plan.
Loss of well control	Precautions to prevent loss of well control include: • shallow gas survey • appropriate well design and engineering, such as using a blowout preventer • well monitoring programme • conducting well control training and emergency drills.

6.10.3 Oil Spill Modelling

Oil spill modelling was carried out using the BMT (UK based environmental consultancy) Oil Spill Information System (OSIS) 4.2 software.

In the absence of tidal cycle data, the residual surface current speed and direction observed in the vicinity of the Darwin East and Stebbing wells was input into the OSIS model. This data was obtained from the ADCP current meter deployed during seismic survey (refer to Section 5.1.4). A blanket current of 0.31 knots in the direction of bearing 041 degrees was input into the model. This prevailing current speed and direction is in general agreement with the prevailing currents observed in the area of the well at the time of year, according to the Admiralty pilot for the Falkland Islands area.

For the trajectory modelling, a 30 knot onshore wind was chosen to represent a worst case scenario, as outlined in the UK's guidance notes relating to The Merchant Shipping (Oil Pollution Preparedness, Response Co-operation Convention) Regulations 1998, produced by the Department of Energy and Climate Change.

For the stochastic modelling scenarios, averaged wind rose data for the months of December, January and February were selected from prevailing wind data recorded in 2007 and 2008 for the general vicinity of the project location (refer to Section 5.1.5). The averaged wind rose data indicated that the predominant wind direction is from the west and south west, which is in agreement with the Met Ocean data for the Falkland Islands area.

Given the above, the following scenarios have been modelled:

- The weathering of small 10 tonnes crude spill with a 30 knot onshore wind towards the Falkland Island from Darwin East and Stebbing wells;
- The weathering of the full rig inventory (1000 tonnes) instantaneous diesel spill with a 30 knot onshore wind towards the Falkland Islands from the Darwin East and Stebbing wells;
- The weathering of a well blow out (293 tonnes release over 24 hours) with a 30 knot onshore wind towards the Falkland Island from Darwin East and Stebbing wells;

- The weathering of a well blow out (293 tonnes release over 24 hours) with a 30 knot onshore wind towards the Beauchene Island from Darwin East and Stebbing wells;

The results of the modelling are summarised in Tables 6.8.-6.9

Table 6.8. OSIS Modelling Results for Darwin East Well

Oil Type	Spill Size	Scenario	Met-ocean Conditions	Fate of Spill	Figure
Diesel	1,000 tonnes (instantaneous release)	Loss of full rig inventory	Trajectory 30 knot onshore wind towards Falkland Islands	The spill plume fully disperses after 9 hours at a distance of 124 km from the Falkland Island shore and 64 km from the coast of Beauchene Island. No beaching occurs.	X
32 ^{0}API crude	10 tonnes (instantaneous release)	Partial loss of reservoir fluid	Trajectory 30 knot onshore wind towards Falkland Islands	The spill plume fully disperses after 20 hours at a distance of 103 km from the Falkland Islands shore.	X
32 ^{0}API crude	293 tonnes over 24 hours	Well blowout	Trajectory 30 knot onshore wind towards Falkland Islands	The spill plume makes contact with the south coast of the Falkland Islands after approximately 70 hours resulting in a final beaching volume of 118 tonnes	X
32 ^{0}API crude	293 tonnes over 24 hours	Well blowout	Trajectory 30 knot onshore wind towards Beauchene Island	The spill plume makes contact with the south coast of the Beauchene Island shore after approximately 33 hours with 180 tonnes of oil being beached in total.	6.8
32 ^{0}API crude	293 tonnes over 24 hours	Well blowout	Stochastic Typical weather conditions with 'prevailing' currents	There is a 0% total probability of the spill beaching on the coast of the Falkland Islands The data also suggests that the spill will not beach on either Sea lion or Beauchene islands.	6.9

Table 6.9. OSIS Modelling Results for Stebbing Well

Oil Type	Spill Size	Scenario	Met-ocean Conditions	Fate of Spill	Figure
Diesel	1,000 tonnes (instantaneous release)	Loss of full rig inventory	Trajectory 30 knot onshore wind towards Falkland Islands	The spill plume fully disperses after 9 hours at a distance of 156 km from the Falkland islands shore and 99 km from the coast of Beauchene Island. No beaching occurs.	X
25^o API crude	10 tonnes (instantaneous release)	Partial loss of reservoir fluid	Trajectory 30 knot onshore wind towards Falkland Islands	The spill plume makes contact with the south coast of the Falkland Islands shore after approximately 81 hours resulting in a final beaching volume of 12.28 tonnes.	6.10
25^o API crude	293 tonnes over 24 hours	Well blowout	Trajectory 30 knot onshore wind towards Falkland Islands	The spill plume beaches on the south coast of the Falkland Islands shore after approximately 95 hours resulting in a final beaching volume of 467 tonnes.	X
25^o API crude	293 tonnes over 24 hours	Well blowout	Trajectory 30 knot onshore wind towards Beauchene Island	The spill plume makes contact with the south coast of the Beauchene Island shore after approximately 50 hours with 760 tonnes of oil being beached in total.	6.11
25^o API crude	10 tonnes over 24 hours	Partial loss of reservoir fluid	Stochastic Typical weather conditions with 'prevailing' currents	There is a 0% total probability of beaching (on the Falkland islands. The model also suggests that the spill will not beach on either Sea lion or Beauchene islands.	X
25o API crude	293 tonnes over 24 hours	Well blowout	Stochastic Typical weather conditions with 'prevailing' currents	There is a 0% total probability of beaching (on the Falkland islands. The model also suggests that the spill will not beach on either Sea lion or Beauchene islands.	6.12

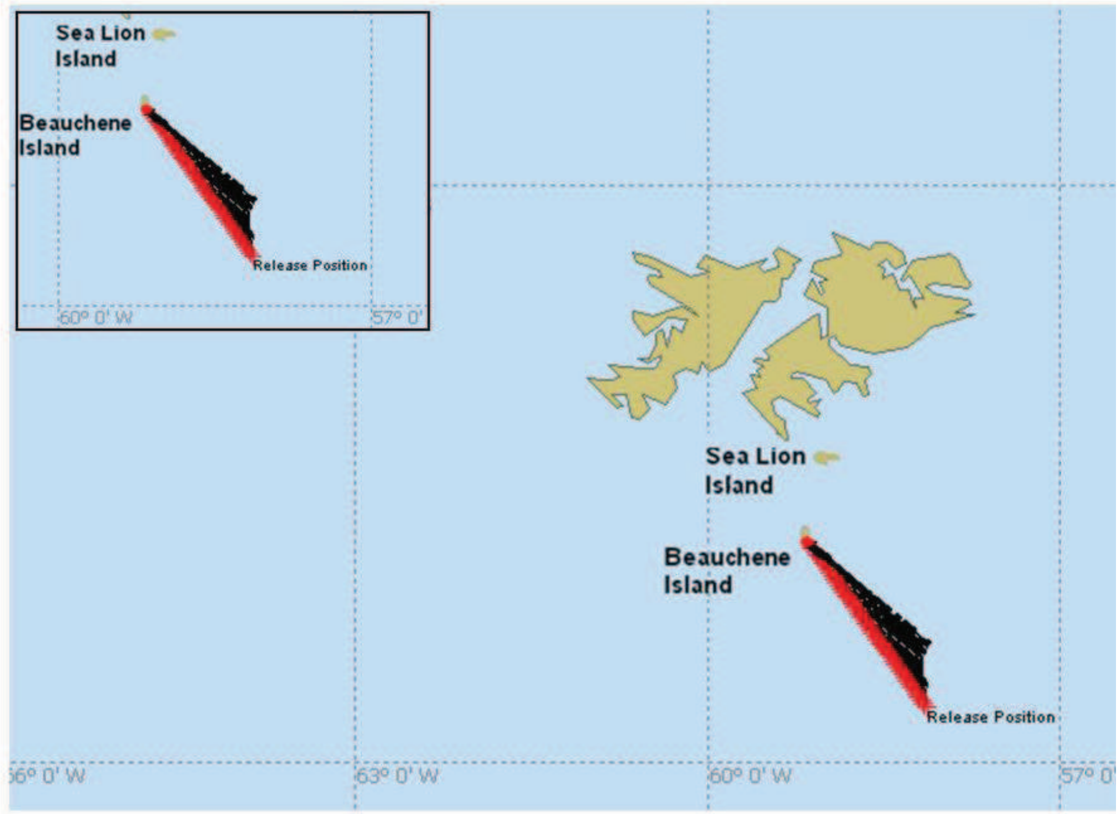

Figure 6.8 Trajectory model run of well blowout (293 tonnes, 32o API) released over a 24 hour period at the Darwin East well location under worst case 30 knot onshore wind conditions towards Beauchene Island

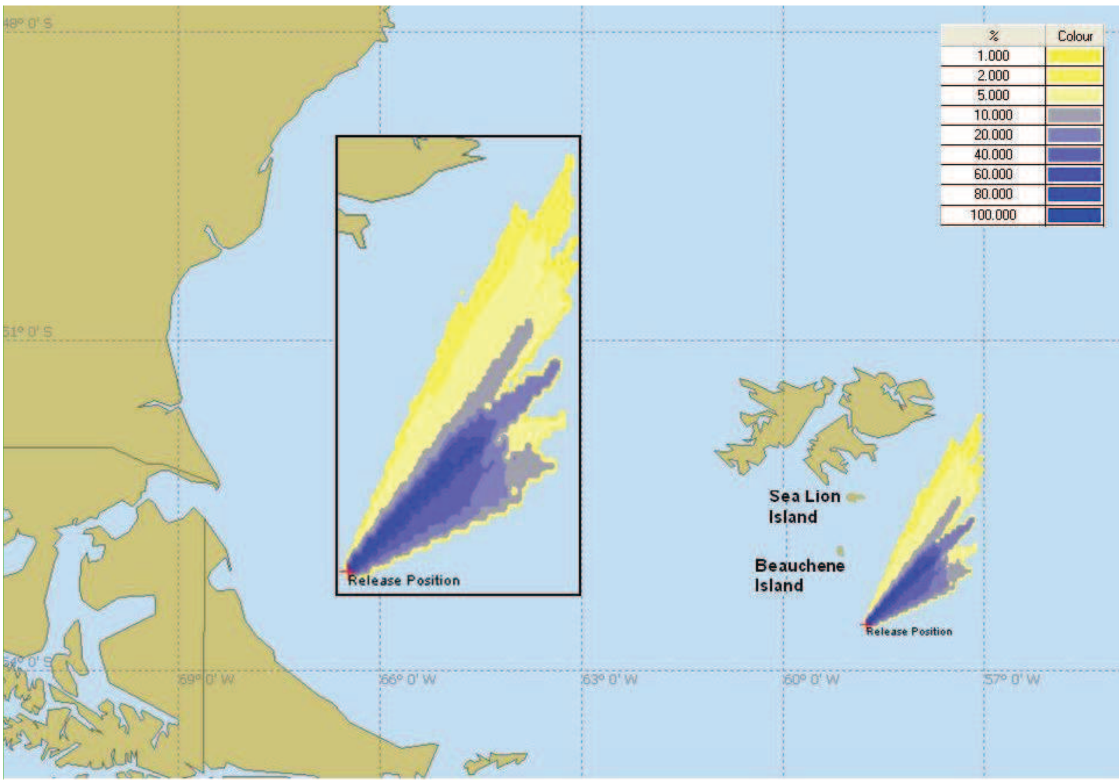

Figure 6.9 Stochastic model run of a well blow out (293 tonnes, 32o API) released over a 24 hour period at the Darwin East well location under typical wind conditions

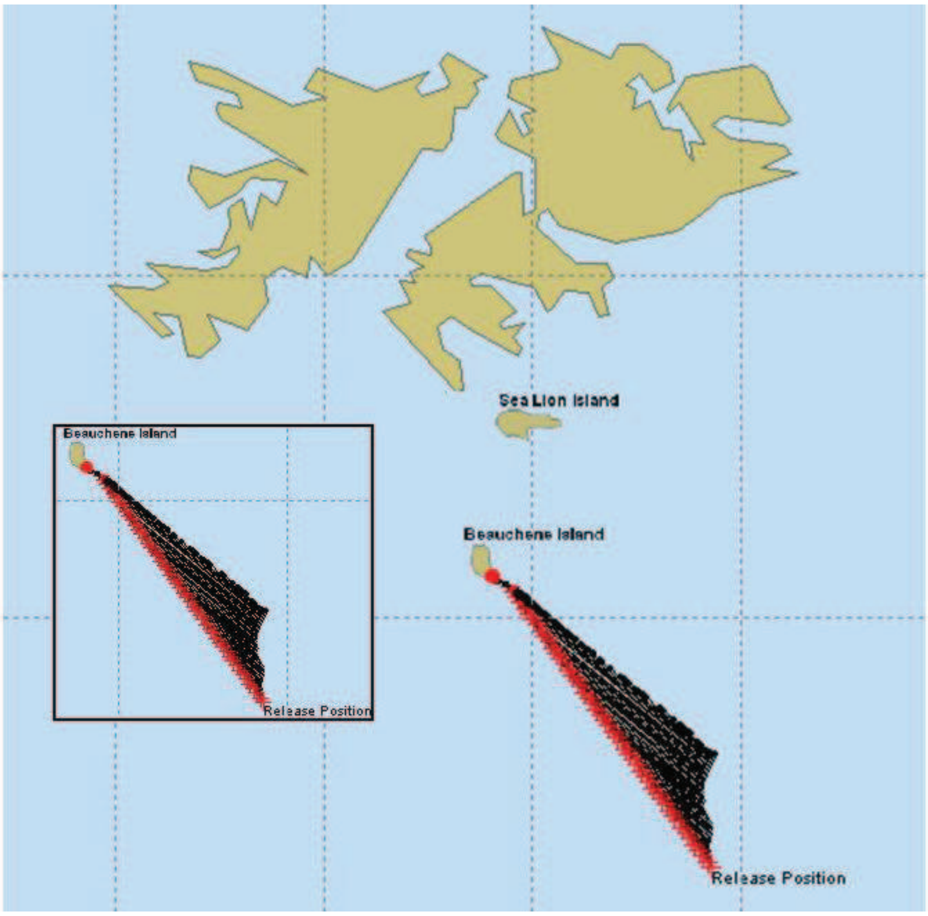

Figure 6.10 Trajectory model run of well blowout (293 tonnes, 25o API) released over a 24 hour period at the Stebbing well location under worst case 30 knot onshore wind conditions towards Beauchene Island

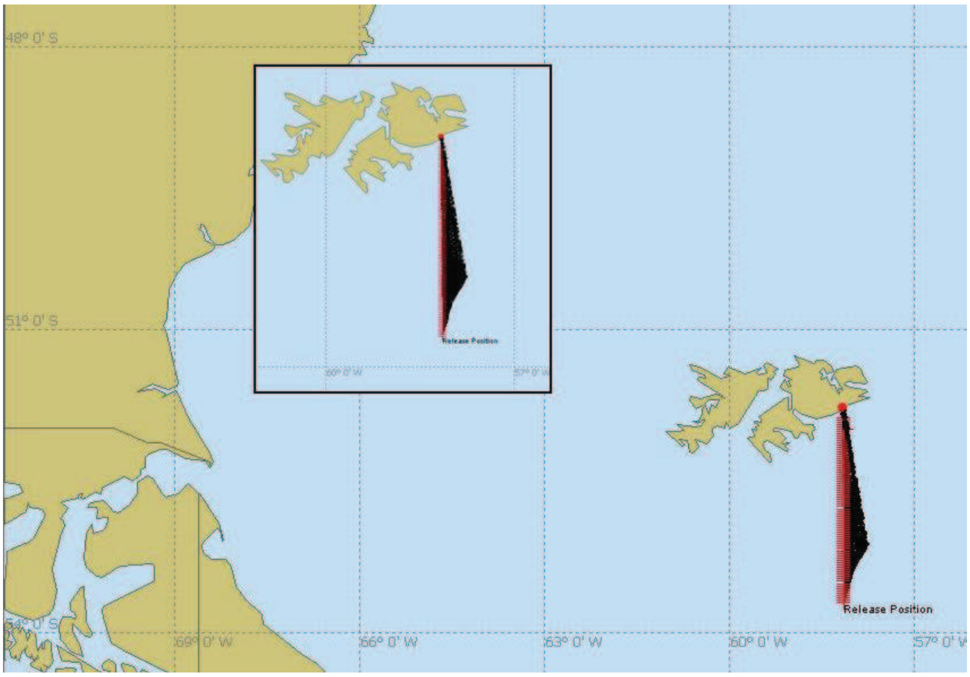

Figure 6.11 Trajectory model run of partial loss of reservoir fluid (10 tonnes crude, 32° API) instantaneously released at the Stebbing exploration well location under worst case 30 knot onshore wind conditions towards Falkland Islands

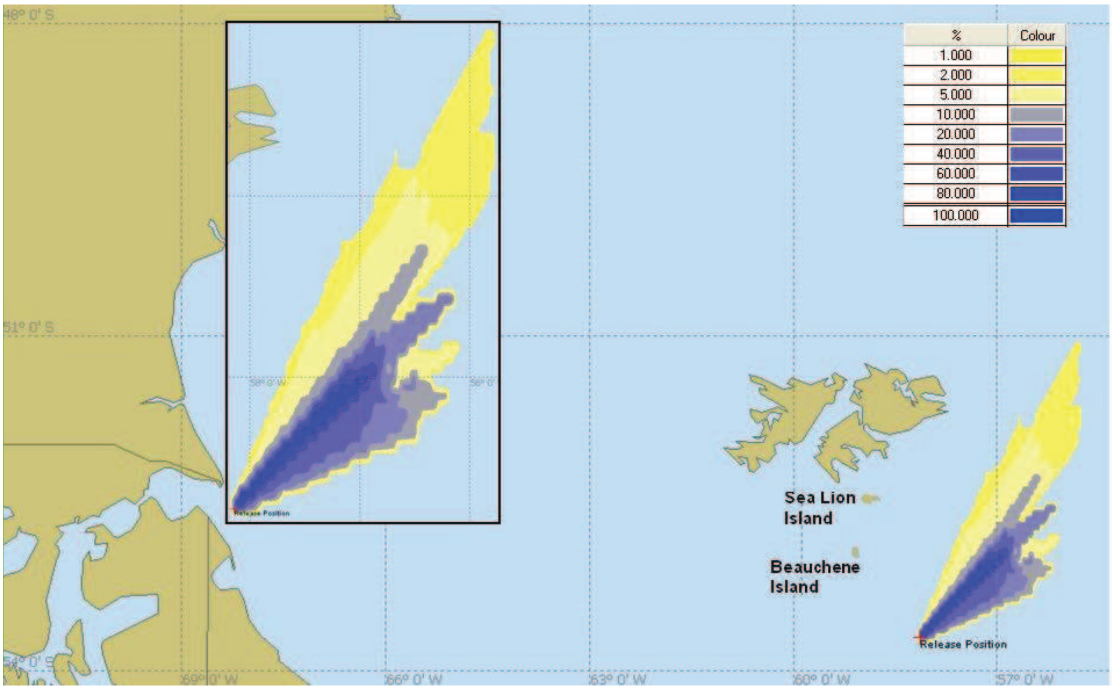

Figure 6.12 Stochastic model run from a well blow out (293 tonnes, 25o API) released over a 24 hour period at the Stebbing well location under typical wind conditions

A comprehensive series of trajectory (unlikely worst case) and stochastic (under typical weather conditions) modelling simulations were undertaken to establish the worst case and likely trajectories of resultant spill plumes from the Darwin East and Stebbing well locations.

With respect to the Darwin East well, the modelling results suggest that neither a full inventory loss of diesel fuel aboard the drilling rig (1,000 tonnes), or a partial loss of reservoir hydrocarbons from the well (10 tonnes) would result in a spill beaching at either the Beauchene Island or the Falkland Island locations. The modelling data suggests that a 1000 tonne diesel spill would disperse after 9 hours at a distance of 124 km from the Falkland Island shore and 64 km from the coast of Beauchene Island, whereas the partial loss of reservoir fluid from the well would fully disperses after 20 hours at a distance of 103 km from the Falkland island shore.

In the event of a well blow out at the Darwin East location under the unlikely constant 30 knot wind blowing towards the shore, oil would beach on the Beauchene Island after 33 hours and on the southern coast of the Falkland Islands after 70 hours resulting in a final beaching of 180 and 118 tonnes of crude, respectively. However, when the stochastic model is run under typical weather conditions, the modelling results suggest that there would be a 0 percent total probability of the spill plume beaching on the Falkland Islands. The data also suggests that the potential spill would not beach along the coast of Sea lion or Beauchene islands.

With regard to the Stebbing Well, the modelling results suggest that a full inventory loss of diesel fuel aboard the drilling rig (1,000 tonnes) would not result in a spill beaching at either the Beauchene Island or the Falkland island locations. The modelling data suggests that a 1000 tonne diesel spill would disperse after 9 hours at a distance of 156 km from the Falkland Islands shore and 99 km from the Coast of Beauchene Island. Following a partial loss of reservoir hydrocarbons from the well (10 tonnes) the resultant spill plume would beach on the south coast of the Falkland Islands shore after approximately 81 hours resulting in a final beaching volume of 12.28 tonnes.

In the event of a well blow out at the Stebbing well location under the unlikely constant 30 knot wind blowing towards shore, the resultant spill plume would beach on the Beauchene Island after 50 hours and on the southern coast of the Falkland islands after 95 hours resulting in a final beaching volume of 760 and 467 tonnes of crude, respectively. The stochastic run for the Stebbing well was run for both a 10 tonne crude spill and a full well blow out (293 tonnes), the total probability of the spill beaching on the Falkland Islands in both instances was shown to be zero percent (0%). The data also suggests that the resultant plume would not impact either the Sea lion Island or the Beauchene island.

The above mentioned beaching probabilities under typical weather conditions are considered to be low and therefore is unlikely to occur. In addition, it should be noted that historically, the worldwide frequency of blow outs is approximately 0.0063 per well, or 1 in every 159 wells *(Holand, 1997)*. Statistics from the World Offshore Accident Data Bank (WOAD) indicate that worldwide the frequency of occurrence of blowouts from mobile drilling units is only of the order of 10 per 1000 unit years *(WOAD, 1998)*. This is supported by data from the UK, where over 3500 exploration, appraisal and development wells have been drilled from 1997 to 2008 (includes mechanical sidetracks) with no major blow outs. The probability of a blow out during drilling of the Darwin East or the Stebbing exploration well is therefore very low.

6.10.4 Potential Impacts

The potential hydrocarbon spills during the proposed drilling programme may impact Falklands sensitive environment, including:

- Offshore seabirds and Internationally Important seabird colonies of the southern coast of Falklands main land and Beauchene Islands (refer to Section 5.2.9-5.2.12).
- Southern Falklands coast sites designated as National nature Reserves (refer to Section 5.2.12).
- Marine mammals, particularly pinniped colonies along the coastal zone (refer to Section 5.2.8).
- Fishing resources (refer to Section 5.3.1).
- Tourism (refer to Section 5.3.1)

As identified by the oil spill modelling, there is a low probability of hydrocarbons beaching under typical weather conditions, however oil slick will impact the wildlife offshore (Table 6.10).

Although diesel spills will not impact the coastline, their toxic effect on the wildlife in a close proximity to a spill will be significant (Table 6.10).

The greatest environmental sensitivity to oils spills would be the presence of vulnerable seabird populations, particularly between June and November and in January. The magnitude of any impact will, however, be dependent on the percentage of bird population present at the time of any oil spill event. The proposed exploration wells are located away from the identified areas of highest seabird vulnerability (refer to Section 5.2.10). Highest vulnerability tends to be associated with the inshore waters around the Falklands Islands, largely due to the presence of resident species with a predominantly coastal distribution such as the endemic Falklands Steamer duck, imperial shag and gentoo penguin. The Patagonian Shelf waters to the north and west of the Falklands, which support high densities of black-browed albatrosses and royal albatrosses year-round are also associated with high vulnerability areas, but again these are remote from the proposed drilling location. The seabird vulnerability during the proposed drilling period in the area immediately surrounding the well locations is rated as low to medium during the proposed drilling period.

Table 6.10. Summary of potential impacts from hydrocarbon spills

	Comments
Plankton	Oil is toxic to a wide range of planktonic organisms. Those living near the sea surface are particularly at risk, as water-soluble components leach from floating oil. Although oil spills may kill individuals, the effects on whole plankton communities generally appear to be short-term. Following an oil spill incident, plankton biomass may fall dramatically, due either to animal deaths or avoidance of the area. However, after only a few weeks, populations often return to previous levels, through a combination of high reproductive rates and immigration from outside the effected area.
Benthos	Effects on the benthos include acute toxicity and possible organic enrichment. Offshore impacts are likely to be minimal, and influenced by water depth and local hydrography. Shallow inshore areas and the shoreline are susceptible to heavy mortalities if coated with hydrocarbons. Recovery times are variable, dependant on many environmental factors, and may be in the region of 1 to 10+ years.
Fish	Lethal effects may occur in adult fish species with hydrocarbon levels of above one part per million. Larvae tend to be more susceptible and lethal effects may occur above 0.1 parts per million. Sub-lethal effects may be observed at low parts per billion concentrations; this can result in behavioural changes or narcosis (*Baker et al, 1990*). There is no definitive evidence that suggests that oil pollution has significant effects on adult fish populations in the open sea. Fish eggs and larvae are relatively immobile and under slicks there may be heavy mortalities that are exacerbated by the use of dispersants (*Swan et al, 1994*). Where oil is trapped in seabed sediments, sediment communities and demersal fish may be adversely affected. Offshore any such accumulations tend to be localised close to the spill source. Such deposits are relatively transient, disappearing as the release stops or the slick passes. As the oil weathers (typically weeks/months), these effects diminish.
Marine Mammals	It has been rare for cetaceans to be affected following a spill; they may be able to avoid affected areas and are not believed to be susceptible to the physical impacts of oil and oil emulsion lowering their resistance to the cold. Contact with oil may cause irritation of the skin and mucus membranes. Volatile hydrocarbon fractions may also cause respiratory problems. Pinnipeds are susceptible to oiling and the contamination of food sources, particularly in the coastal areas around their colonies, where their density is highest.
Birds	Species of birds that spend much of their time on the sea surface are particularly vulnerable to spills. Oiling of the plumage destroys its integrity as insulation and allows the animals to die of hypothermia or by drowning. Concentrations of birds are most vulnerable to oil pollution during the breeding season near their colonies and at other times of the year over the feeding grounds. Evidence suggests that in most cases spills are unlikely to have long term effects overall on bird populations unless a substantial portion of the population is restricted to the immediate area of the spill (*Dunnet 1982, Leppakoski 1973*). The impact on breeding colonies and bird populations depends upon the existence of a reservoir of young non-breeding adults from which they can be replenished and the reproductive rate of the impacted species. There is no evidence that oil spills have permanently damaged any seabird populations, but any small indigenous populations, or species that are clustered into a few dense colonies could potentially be at risk.
Fisheries	Fish exposed to oil may become tainted by oil-derived substances. It is of particular concern in caged fish and shellfish culture. Fin-fish rarely become tainted in the open environment, as they are able to avoid the affected area. However, major spills can result in loss of fishing days and exclusion zones and bans on certain species lasting several years may be enforced. Shellfish mortalities may occur if organisms are smothered by settling oil. Only low levels of oil in seawater may cause tainting in shellfish, which may be commercial damaging to shellfish fisheries. This is more common in filter feeding shellfish, principally bivalves, as they take up fine oil droplets from the water column. Media coverage together with public perception can also damage fisheries.
Tourism	Coastal tourism is vulnerable to the effects of major oil spills e.g. reduced amenity value. The impact would be influenced by a number of factors including media coverage and public perception.

6.10.5 Mitigation Measures

A number of measures will be implemented by Borders & Southern to reduce the risk of oil spills from the drilling rig and associated vessels and minimise the impact of any spill that may occur:

- Managing potential drilling hazards, such as shallow gas, and following established drilling safety standards to minimise the risk of control loss.
- Comprehensive operational planning and risk assessment and provision of suitable specification equipment for drilling (BOP etc).
- Oil Spill Contingency Plan will be implemented.
- All vessels and the drilling rig will comply with IMO/MCA codes for prevention of oil pollution and vessels will have onboard Shipboard Oil Pollution Emergency Plans (SOPEPs);
- As far as possible, support vessels with an established track record of operating in the Atlantic Margin and familiar with weather and operating conditions in the area will be used;
- Approach procedures and poor weather operational restrictions for visiting vessels and transfer operations at the drilling rig;
- Audits of the drilling rig and vessels including detailed list of contract requirements in terms of spill prevention procedures that must be in place;
- Regular maintenance and inspection of equipment and high spill risk points (in particular bunkering hoses, bunds, storage tank valves etc.);
- Lube and hydraulic oil will be stored in tanks or sealed drums which pose a minimal risk of spillage. In addition, drums and storage tanks for hydrocarbons will be well secured and stored in bunded areas, all of which will be properly maintained and inspected;
- Procedures in place for bunker transfer to minimise the risk of spillage;
- Use of bulk handling methods and non return valves for diesel transfer to reduce the risk of spillage;
- Availability of oil spill kits on board the rig and vessels to clean up any deck spills or leaks and suitable storage and disposal procedures for waste oil.
- Training of personnel with respects to the handling and deployment of oil spill recovery equipment.
- Collaboration with the national OSCP and availability of near-shore defences (i.e. booms), as well as trained personnel, spill surveillance services etc.
- Availability of spill response kits on the rig and vessels for initial spill response.

Even with comprehensive prevention measures in place, the residual risk of a spill remains, and integral to any Borders & Southern operation is the formulation of detailed and fully tested contingency response plans appropriate to the local environment. An approved Oil Spill Contingency Plan (OSCP) will be in place for the proposed drilling operations, including onshore and offshore plans.

6.11 Cumulative Impacts

The potential for cumulative impacts will arise from the drilling operation itself during which time the rig and support vessels will pose an additional shipping hazard in the area and from the legacy it will leave in terms of atmospheric greenhouse gases and the cuttings and mud discharged. However it is not anticipated that the short-term exploratory drilling campaign will significantly, or permanently, add to these existing cumulative impacts.

The rig will be shared by a number of operators, each drilling their respective wells in a programmed sequence, therefore there is unlikely to be any temporal overlap in operations. In addition, the wells being planned by other operators are located a considerable distance from each other, so the likelihood of any spatial overlap of impacts from different drilling operations must be considered to be remote.

Cumulative solid waste generation from the drilling campaign will be minimised and managed through the implementation of a Waste Management Plan, a separate document which will define specific waste handling/disposal routes and procedures.

In summary, cumulative environmental effects from the planned exploration programme offshore the Falkland Islands are unlikely given the short term nature of the wells, the fact that they will be plugged and abandoned and that exploration activities are planned over a wide area. Over time, impacts from drilling will be undetectable so there is no cumulative impact. Positive socio-economic effects are possible over time as they will be concentrated in a single location (Stanley) for all drilling operations both to the north and south of the island.

7 Management Framework

7.1 Introduction

Borders and Southern Petroleum Plc operates under an integrated Health Safety and Environmental Management System (HSE MS).

HSE management procedures are incorporated into relevant business functions which reinforce the Company philosophy that management of HSE issues is an integral part of Borders and Southern's business activities.

The application of the HSE MS during the drilling of the proposed exploration wells offshore the Falkland Islands will ensure that the Borders and Southern HSE Policy (Figure 7.1) is followed and that the Company's responsibilities under all relevant regulations are met.

borders&southern petroleum plc

HSE Policy Statement

Borders and Southern Petroleum plc is committed to effective corporate governance. Maintaining high standards of Health, Safety and Environmental (HSE) protection throughout its operations is an integral part of this and is achieved through:

- Strong leadership and clearly defined responsibilities and accountabilities for HSE at all levels of the organisation;
- Selection of competent personnel to manage activities;
- Compliance with regulatory and other applicable requirements, or where regulations do not exist, application of industry standards;
- Identifying, assessing and managing HSE risks and preventing pollution;
- Developing specific plans to identify, assign responsibilities, schedule and track HSE activities within each project;
- Selecting competent contractors and ensuring that they are effectively managed;
- Preparing and testing response plans to ensure that any incident can be quickly and efficiently controlled, reported and investigated to prevent recurrence;
- Continual improvement of HSE performance through monitoring, regular reporting and periodic audits;
- Periodic management reviews to identify and implement improvements to our HSE systems.

This policy is implemented through our HSE Management System and is used to guide all our activities. It will not be compromised by other business priorities.

Howard Obee
Chief Executive Officer

Date: 4/2/10

Figure 7.1 Borders and Southern HSE Policy

7.2 The Borders and Southern Health, Safety and Environment Management System

Borders and Southern's business comprises acquisition of acreage and exploration for oil and gas. Operational activities include geological and geophysical surveys, design, construction, and testing of wells and assessment of hydrocarbon reserves. In the future it is anticipated that this may lead on to field development and production operations.

The HSE MS establishes the main requirements and provides the framework for managing HSE issues within the business. It ensures:

- Clear assignment of responsibilities;
- Efficient and cost effective planning and operations;
- Effective management of HSE risks;
- Compliance with legislation; and
- Continuous improvement.

The system structure is illustrated in Figure 7.2. At the top, the HSE policy demonstrates the commitment and intentions of the Company. The HSE MS provides guidance on the implementation of policy requirements across the Company. At the second level are the project specific HSE Plans and Procedures; these provide the specifics of how things are done within each project. At the base of the structure are the Bridging Documents linking Borders and Southern's system with its contractors' HSE Operating Systems/Procedures.

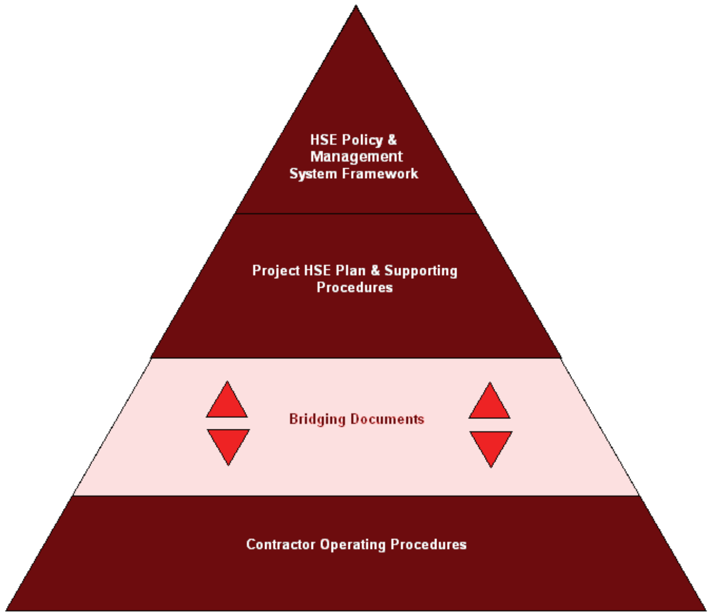

Figure 7.2 HSE Management System Structure

The HSE Management System is consistent with existing international models for health, safety and environmental management (e.g. ISO14001, OHSAS 18001, OGP). The system is structured around an 'organize, plan, do, review and adjust' process, with a feedback loop to assure continual improvement in performance. The system can be visualised as illustrated in Figure 7.3. It is made up of a number of elements and requirements and is relevant throughout the business lifecycle.

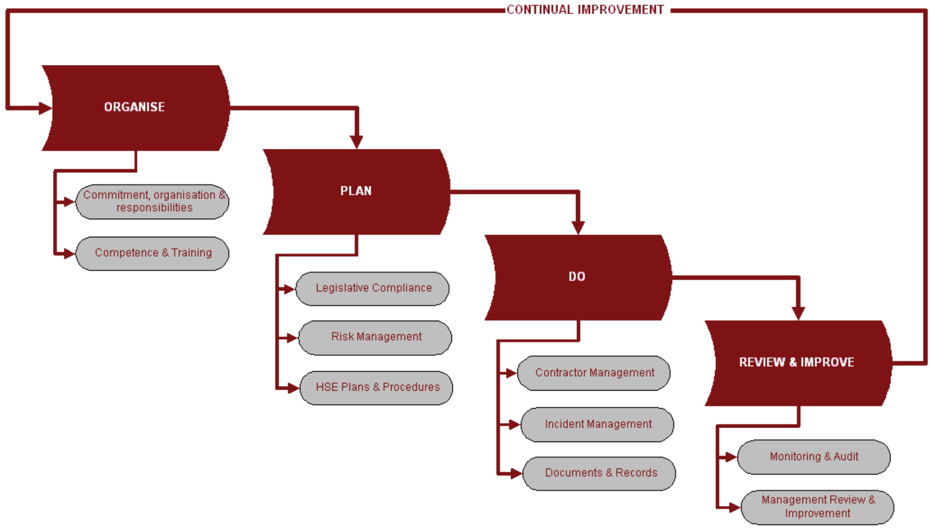

Figure 7.3 HSE Management System Framework

Organise: The system is driven through commitment and organisation. Broad HSE goals are established and responsibilities clearly defined. HSE expectations are communicated through internal and external networks. Personnel are selected that have the appropriate qualifications, experience and skills to meet their responsibilities.

Plan: Regulatory requirements and potential hazards and risks associated with planned activities are identified and appropriate measures to conform/control are incorporated in a project HSE Plan. Significant changes made to the Plan are subject to a risk review.

Do: Competent contractors are selected and managed to undertake specialist tasks, following agreed procedures. Effective response plans to emergencies are developed. Incidents are reported and investigated and lessons learned used to improve performance.

Review and Improve: Routine monitoring is undertaken to assess and, where necessary, improve HSE performance. Periodic audits are conducted to ensure the effective functioning and continued suitability of the management system. Management review the system annually, identify areas for improvement and build these into the following year's work plans.

7.3 Falklands HSE Management Framework

The Borders and Southern management system is not certified and, as Borders and Southern does not undertake operations itself, is based on the supervision and administration of contractors. The HSE Policy Statement and management system set out Borders and Southern's priority goals, expectations and commitments and how these will be applied within the framework outlined in figure 7.4 below:

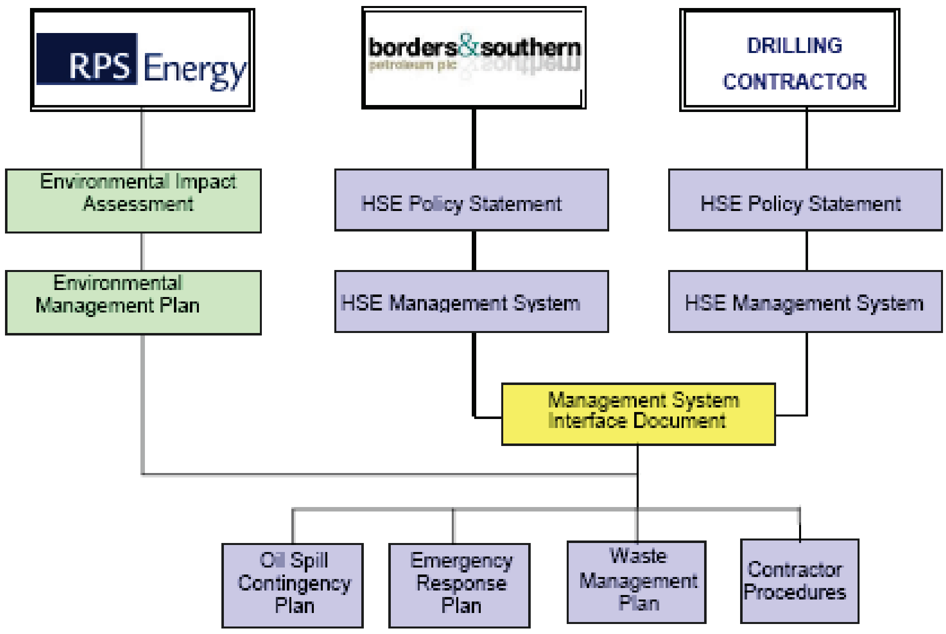

Figure 7.4 HSE Management Control for drilling operations

As outlined above, HSE management of the Project will be conducted within a comprehensive framework comprising of:

- Borders and Southern's Health, Safety and Environmental Policy Statement
- Borders and Southern's Health, Safety and Environmental Management System (HSE MS)
- Drilling contractors Management HSE Policy Statement
- Drilling contractors Well Management Safety Management System
- Management System Interface and Bridging Documents
- Drilling contractor operational controls and specific HSE procedures Included within these document are:
  - Policy, Standards and Procedures
  - Safety Management
  - Emergency Response
  - Environmental Considerations
  - Risk Management
  - Quality Assurance
  - Organisation
  - Document Control

7.4 Management System Interface Document

In order to ensure that operational and emergency primacy, interfaces and procedures are clearly defined, a review of Borders and Southern and contractors management systems will be undertaken resulting in a Management System Interface Document (MSID).

The MSID will be prepared in accordance with the Step Change In Safety 'Health and Safety Management System Interfacing' guidelines. The MSID document will have the following objectives:

- To identify interface issues and define roles and responsibilities
- To define reporting requirements
- To identify normal operational procedures for this well (see note 1 below)

- To identify interfaces and procedures in the event of an incident

The Management System Interface Document will be developed and implemented when contractors are finalised and their existing systems are known.

7.5 Oil Spill Contingency Plan

A dedicated oil spill contingency plan (OSCP) will be developed in support of the proposed drilling campaign in the North Falkland Basin. It will be developed when the contract for the drill rig and crew has been awarded, and will be based on the results of the oil spill modeling scenarios. The OSCP will provide for a multi-tier response dependent on the scale and type of spill. At the most extreme end of the scale (Tier 3) the OSCP will rely on mobilising specialist aircraft and personnel from Oil Spill Response Limited (OSR) in the UK to provide aerial dispersant spraying capability. The OSCP will also correspond with the plans of the FIG and its national oil spill contingency plans.

7.6 Borders and Southern Crisis and Emergency Management Plan

The Borders and Southern Crisis and Emergency Plan describes procedures and arrangements in place for the effective management of any incident or emergency which has the capability to become a crisis for the Company. The Crisis and Emergency Management Plan (C&EMP) forms an integral part of Borders and Southern Integrated Management System (IMS) and meets the requirements of Standard 5: Incident Management.

Implementation of the Crisis and Emergency Management Plan is intended to supplement the Management system Interface Document and is supported by the individual emergency management procedures associated with the rig, supply vessels and onshore emergency response units.

7.7 Falklands Waste Management Plan

The purpose of this Borders and Southern Waste Management Pan is to provide practical guidance on the disposal of all wastes generated from Borders and Southern drilling operations offshore the Falkland Islands.

Implementation of the Waste Management Plan is intended to supplement the Borders and Southern HSE plan, Management system Interface Document and is supported by the individual waste management plans associated with the rig, supply vessels and onshore waste management contractors.

7.8 Environmental Management Plan

In order to ensure that appropriate mitigation measures, identified following the EIA process, are implemented during the planning and drilling of the proposed exploration wells, an Environmental Management Plan (EMP) has been prepared (refer to Tables 5.1 and 5.2).

The Register identifies actions required, assigns responsibilities and sets target dates for completion. The register will act as a ‘live’ document to track progress through to cessation of drilling activities. It will provide guidance for the drilling contractor and can also be used by Borders and Southern to monitor contractor performance with regard to environmental issues. Should monitoring indicate unacceptable environmental performance, the EMR provides a mechanism to initiate remedial action.

Table 7.1. Environmental Management Plan

ROUTINE OPERATIONS				
Hazard & Effect(s)	**Proposed Mitigation**	**Required Actions**	**Responsible**	**Completion**
Cement, Drill Cuttings & Drill Fluids Smothering & toxic effects on benthic communities in the immediate vicinity of the well.	Planned use of Water Based Mud.		Drilling Manager	
	Selection of most environmentally benign mud & cement chemicals where possible. WBM comprised mainly of chemicals considered to pose little or no risk to the environment.	Liaise with mud suppliers to ensure appropriate chemical selection	Mud Man & Borders and Southern Company Man	
	Planned use of Water Based Mud.	Verify appropriate functioning		
	Cuttings & mud treatment equipment to ensure the separation of WBM from cuttings before discharged to sea with cuttings.			
	Management procedures to ensure optimal performance of cuttings treatment equipment & continuous mud mass balance maintained during drilling.	Continuous monitoring of mud mass balance.	Mud Man & Borders and Southern Company Man	
Physical Presence Restrictions on fishing & shipping.	Exclusion zone surrounding the drill rig (500 metres) implemented monitored & patrolled by a standby/supply vessels.	Ensure continuous 'on site' monitoring from standby vessel.	OIM / Borders and Southern Company Man	
	Drill rig to carry relevant navigational & communication aids.	Ensured during contracting process/ Pre operation inspection to ensure all vessels meet required standard.	Procurement/ Borders and Southern Company Man	
	Accommodation of needs for environmental monitoring and liaison with fishing industries	In order to minimise disruption to the drilling and other users of the sea: • Determine the extent of local fishing activities. • Establish contact with Fisheries Department.	Borders and Southern	
		Verify procedures for notifying local interests (including tourism industry.	Borders and Southern	
	Notifying other users. Ensure that other users are aware of the forthcoming drilling operation	Liaise with Fisheries Department at FIG, local fisheries interests, tourism industry, as well as the British Military.	Borders and Southern	
		Issue Radio Navigation Warnings and Notices to Mariners as appropriate.	OIM	

ROUTINE OPERATIONS

Hazard & Effect(s)	Proposed Mitigation	Required Actions	Responsible	Completion
Atmospheric Emissions Localised emissions from power generation (rig, supply / standby vessels & helicopter operations will affect air quality.	Regular maintenance of engines, compressors and generators. Use of non ozone depleting fire fighting foam. Batch processing waste to minimise operational time of incinerator, if one is available onboard the rig. Incineration of non-hazardous combustible waste only. Regular monitoring of fuel consumption. It is currently proposed to test the wells. Well testing operations will occur as follows: 30 minute flow period, 2 hours shut in for Pressure Build Ups (PBU), 8 hours flow period, 8 hours shut in for PBU, and 12 hours flow period. This programme will be subject to the well results and reservoir conditions. During the well test up to up to 8,000stb/d of oil or 25MMscf/d of gas will be flared dependant on the reservoir fluids encountered and if the reservoir is found to be capable of delivering these rates. Volume flared will be kept to a practical minimum.	Review of drilling contractor procedures prior to contact award Monitoring to ensure appropriate procedures are adhered to. Volumes flared will be kept to a practical minimum.	Procurement/ HSE Manager Borders and Southern Company Man Drilling Manager	
Solid Wastes Wastes will include galley wastes, scrap metal, waste oil & surplus chemicals.	Borders and Southern will ensure that the rig has an appropriate system of waste management in place and Develop and implement a waste management plan Garbage will be processed in a compactor & stored in a designated area on the rig. Other wastes will be stored in suitable containers & periodically these will be transported to shore. Material such as scrap metal, waste oil & surplus chemicals will be far as practicable, sent for re-cycle or re-use and will be disposed of in a controlled manner through authorised waste contractors. All galley wastes separated & ground to less than one inch in diameter before being discharged overboard.	Review of Drilling contractors waste management procedures Review waste management facilities onshore Falkland's and develop plan around availability of facilities and duty of car principles. Pre operation inspection to ensure onshore waste disposal facilities meet required Borders and Southern standards. 'On site' monitoring to ensure appropriate procedures adhered to. 'On site' monitoring to ensure appropriate procedures adhered to.	Procurement/ HSE Manager Borders and Southern Company Man Borders and Southern Company Man Borders and Southern Company Man	

ROUTINE OPERATIONS				
Hazard & Effect(s)	**Proposed Mitigation**	**Required Actions**	**Responsible**	**Completion**
Drainage & Sewage Water from rig wash down may contain trace amounts of drill fluid, lubricants & residual chemicals. There will be discharge of sewage & grey water.	Borders and Southern will ensure that good housekeeping measures are implemented to minimise the amount of mud & associated chemicals entering the rig drainage system. Marine Sanitation Device on rig for treatment of sewage effluent. All discharges from the rig & supporting vessels will be treated & discharged in according to the MARPOL convention.	Ensured during contracting process The Marine Sanitation Device and discharge inspected daily to ensure that no pollution or non permitted discharge occurring Pre operation inspection to ensure all vessels meet required MARPOL standards. 'On site' monitoring to ensure good housekeeping measured adhered to.	Procurement/ HSE Manager Maintenance Borders and Southern Company Man Borders and Southern Company Man	
Ballast water Spread of invasive species from the rigs ballast water	Borders and Southern will ensure that the rig has in place an appropriate Ballast water management plan A ballast handling plan for a ballast voyage should be prepared in advance, in a similar manner to the preparation of a cargo plan for a loaded voyage, and with the same degree of thoroughness. This pre-planning is necessary in order to maintain safety in case compliance with ballast exchange or other ballast water treatment or control options is required. • Mid Ocean Ballast exchange prior to arrival. • No discharge of 'high risk' ballast water in Falklands' waters. • Ballast water exchange to take place in open waters.	Ensure an IMO developed ballast water management plan is implemented for rig move. Mid Ocean Ballast exchange prior to arrival on location. Ensure Ballast water logs are maintained and kept up top date.	Borders and Southern HSE Manager Rig Barge Engineer	

Table 7.2. Management Plan - Mitigation Measures (Non-Routine Operations)

NON ROUTINE OPERATIONS				
Hazard/Effect(s)	**Proposed Mitigation**	**Required Actions**	**Responsible**	**Completion**
Spill of Hydrocarbons Potential impacts on marine fauna and flora / seabirds/ & other sea users.	*Unburnt hydrocarbons during testing* Volume flared will be kept to a practical minimum.	Well test procedures	OIM	-
	Fuel base oil or other utility fluids (e.g. diesel, lubricants) Any re-fuelling required will only be undertaken during daylight, if practicable, and in good weather conditions. Non-return valves will be installed on fuel transfer hoses, and operations will be supervised at all times from both the supply boat and drill rig.	Pre operation inspection to ensure refuelling system and procedures meet required standards. 'On site' monitoring to ensure appropriate procedures adhered to.	Borders and Southern Company Man Borders and Southern Company Man	
	Loss of rig (ship collision) Dedicated personnel to keep watch for incoming vessels. Standby vessel monitoring exclusion zone. Drill rig will carry all relevant navigational & communication aids. Notification of planned drilling programme with all relevant maritime authorities and representative fishing organisations.	Ensure continuous 'on site' monitoring from standby vessel. Ensure during pre-spud checks Pre operation inspection to ensure vessels meet required standard. Notification of Drilling Programme	OIM Procurement Borders and Southern Company Man HSE Manager	
	Risk of a loss of well control Minimised through details of mud programme, detailed study of the known geological conditions of the area, BOP design, and use, appropriate training and drills and good drilling practice.	Well monitoring equipment to detect influx from reservoir. Observation of drills and reaction times by Borders and Southern representatives. Pressure detection service provided by Mud-logging contractor. Blowout preventors tested on installation and routinely during operations.	Senior Toolpusher Borders and Southern Company Man Senior Toolpusher Borders and Southern Company Man Senior Toolpusher Borders and Southern Company Man	

NON ROUTINE OPERATIONS				
Hazard/Effect(s)	**Proposed Mitigation**	**Required Actions**	**Responsible**	**Completion**
	Spill Response (For all spills) The support vessel will be equipped with 5 m3 of chemical dispersant and spray system, able to treat up to 100 tonnes of oil, with a contact rate of approximately 10 tonnes per hour. Oil Spill Contingency Plan in place providing guidance on actions to be taken in event of spill. Managing potential drilling hazards, such as shallow gas, and following established drilling safety standards to minimize the risk of control loss. Availability of dispersants and spill response kits on the rig and vessels for initial spill response. Operational controls covering materials loading, transfer, and storage Supervision of all loading / bunkering operations. Loading / bunkering during suitable weather conditions and light levels only. All oil stored in tanks or drums on board the vessel in accordance with maritime safety requirements.	Ensured during contracting process & pre-op inspection to ensure all spill kits present and meet required standard. Establishing comprehensive Oil Spill Response Planning. Training of key personnel in oil spill response. All spills reported Consultation with the Fisheries Department and ongoing communications with all concerned parties regarding spill response.	Procurement/ Borders and Southern Company Man Borders and Southern Company Man / OIM	

8 Conclusion

The Patagonian Shelf, on which the Falkland Islands positioned, is of regional and global significance for marine resources. It comprises rich assemblages of seabirds, marine mammals, fish, squid and plankton populations.

A consortium of oil companies drilled six wells in the North Falkland Basin during 1998. As a result of this drilling programme a number of environmental studies were commissioned, focussing primarily on the North Falkland Basin. In comparison, the environment of the South Falkland Basin remains understudied.

In order to obtain more detailed baseline information, Borders & Southern conducted environmental surveys in 2008 / 2009 to acquire current data, water column profiles, sediment analysis, and to identify benthic habitats and geo hazards. The results were compared with the survey data collected by BHP Billiton in the neighbouring licence blocks.

This EIS makes a thorough assessment of the potential impacts that may arise from drilling the proposed Darwin East and Stebbing wells in the South Falkland Basin. The key environmental risks associated with the proposed drilling programme include drill cuttings disposal, waste disposal and use of resources (i.e. fuel). Oil spill modelling indicated that no oil beaching would occur in the unlikely even of a well blowout under typical weather conditions. However, crude oil released during blowout may have a major impact on the offshore seabirds. Diesel spills will not impact the coastline and offshore wildlife is likely to be affected only in a close proximity to the spill. It can be concluded that the highest risk of pollution during the drilling programme is from large oil spills. These are highly unlikely events however, and can be effectively controlled through prevention, preparedness and response.

Mitigation measures have been proposed for all impacts with the emphasis on those deemed to be of high to medium significance. This will allow operations to proceed without any significant long lasting impacts to the marine or coastal environment of the Falkland Islands. To successfully implement the proposed mitigation measures the focus is now on ensuring the operations follow established procedures, key personnel are trained in emergency response such as oil spill response, joint exercises are run with the Falkland Islands oil spill response plan, all personnel receive basic environmental awareness training and contingency plans are in place to prevent any environmental incidents from occurring.

The operations specific addendum to this EIS will be produced when the drilling programme is finalised to further detail the environmental management, operational controls and employee training necessary to keep impacts to ALARP (as low as reasonably practicable) levels. It is not expected that the operational aspects described in this EIS would change significantly. Should there be any operational changes likely to cause a significant change to the assessment of impacts, they will be incorporated within the operational addendum.

Correspondence with the Falkland Islands Government (FIG) has highlighted interaction with the relevant authorities is required on important issues such as waste management on the Islands and the incorporation of the national oil spill contingency plan with project specific plans. FIG has commissioned OSR to make some recommendations regarding the national oil spill response and a consultant from OSR visited the Islands in 2008 and submitted a report for consideration by FIG. FIG also continues to review the situation regarding onshore waste management and is seeking ways to better deal with waste onshore, commensurate with the resources available.

Socio-economic aspects of the oil and gas industry have been deliberately limited at the request of the FIG to avoid overlaps with existing studies.

In conclusion, despite the high sensitivity and international importance of the Falkland Islands' waters, there is clear dedication to carrying out these operations to a high environmental standard. Given the current operational commitments and proposed mitigation measures, it is considered that the proposed operations can be undertaken without significant impacts to the Falkland Islands' environment.

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Appendix A: Drilling Operations – Supporting Information

The Drilling Rig

The exploitation of hydrocarbons requires the construction of a conduit between the surface and the reservoir. This is achieved by the drilling process. Offshore wells are typically drilled by mobile drilling units of which there are three broad designs currently in use: drill ship, semi-submersible drilling rig and jack-up drilling rig. The proposed wells will be drilled using either drill ship or a DP 5th-6th generation drill rig.

Drill-ship: A drill-ship is a ship equipped with a drilling rig and station-keeping equipment such as anchor chains or a DP-system and thrusters. Drill-ships normally carry larger payloads than semi-submersible rigs and due to their mobility and ability to carry large amounts of drilling equipment, drill-ships are well suited to operate in remote areas. Drill-ships may have the capacity to operate in water depths ranging from 100m to ultra deep water in excess of 2000m, but the capacity of each individual drill-ship depends on the specifications and equipment of the individual unit. A drill-ship is required to have a DP system to operate in ultra deep water.

Semi-submersible rig: A semi-submersible rig is a floating unit that is supported primarily on large pontoon structures submerged below the sea surface. The operating decks are typically elevated 30m above the pontoons on large steel columns. Semi-submersible rigs are usually anchored to the seabed with six to twelve anchor chains, or kept in place by a dynamic positioning (DP) system, which is a computer controlled thruster system used to maintain the rig position. Semi-submersible rigs can be used for drilling, work-over operations, and as production platforms, depending on their equipment. Modern semi-submersible rigs, with DP systems, have the capacity to operate in deep water in excess of 1500m. In addition, semi-submersible rigs are flexible concerning operating water depth and have the capacity to work in medium water and some shallow water fields. A schematic diagram of a semi-submersible rig is given in Figure A.1 below.

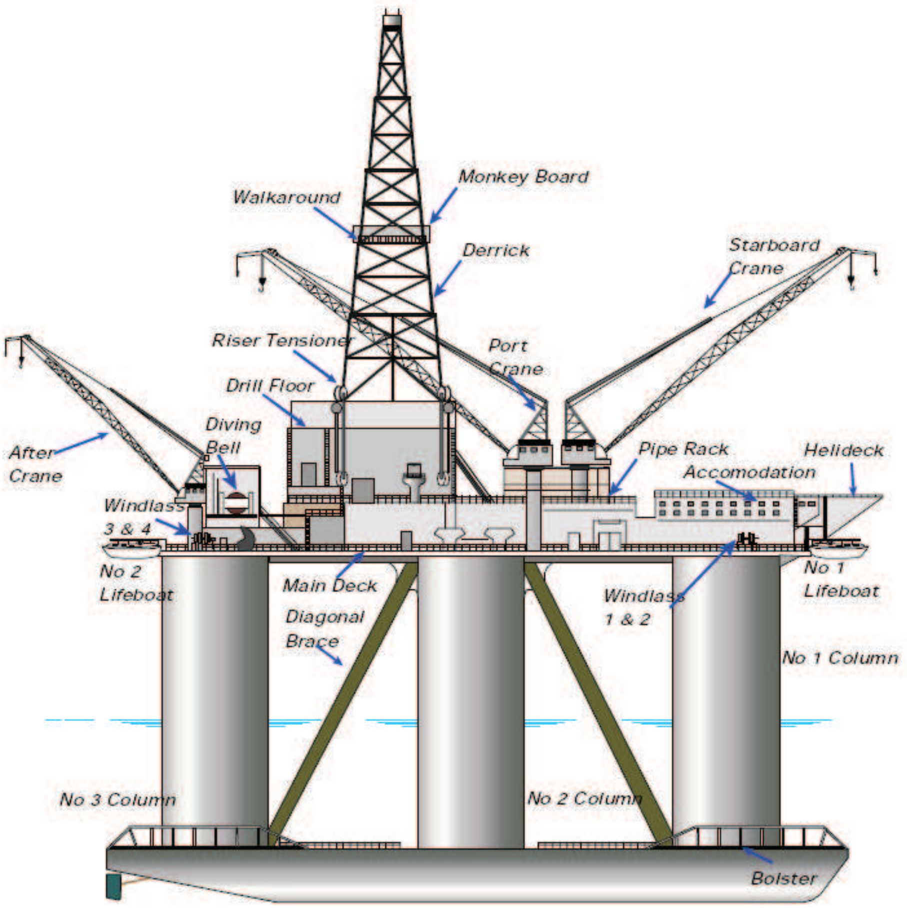


Figure A.1 A typical Semi-Submersible Rig Layout

To support the drilling operation, the following systems and services are usually located on a rig:

- Bulk Storage – is provided for fuel oil, bulk mud and cement, liquid mud, drill water and potable water;
- Pipe and Materials Storage – covered storage is provided for sacked material, drilling equipment, spares, etc. and deck storage for drill pipe and casing;
- Helideck – normally rated for a Sikorsky S-61 helicopter or equivalent;
- Craneage – two cranes provided for loading/off loading equipment / supplies from supply vessels;
- Emergency Systems – this includes life saving appliances, fire detection and protection equipment, combustible gas detection systems and life vessels; and
- Environmental Protection – sewage treatment unit, blow-out preventer (BOP) system, cuttings cleaning equipment and hazardous and non-hazardous drainage systems, which collect rainwater and/or any minor spills to a drains tank for treatment prior to discharge to sea, or allow transfer to tote tanks for shipment to shore and disposal by licensed waste disposal contractors.

Drilling Mud

During drilling operations a fluid known as drilling mud is pumped through the drill string down to the drilling bit and once a conductor tube or riser is set is place, is returned to the rig, in the space (or annulus) between the drill string and the casing (Figure A.2).

Drilling mud is essential to the operation. It performs the following functions:

- The hydrostatic pressure generated by the mud's weight controls the downhole pressure and prevents formation fluids from entering the well bore;
- It removes the rock cuttings from the bottom of the hole and carries them to the surface and when circulation is interrupted it suspends the drill cuttings in the hole;
- It lubricates and cools the drill bit and string; and
- It deposits an impermeable cake on the wall of the well bore effectively sealing and stabilising the formations being drilled.

The mud is recycled and maintained in good condition throughout the operation. The mud and suspended cuttings are processed on the rig through screens called "shale shakers" to maximise recovery of the mud. The recovered mud is then passed through a desander to remove sand particles and, if necessary, subsequent treatment is provided by a centrifuge or desilter. This additional equipment removes the fine colloidal solids, the particles too small to be removed by the conventional equipment, which if allowed to build up can make the mud too viscous.

Three major types of mud are typically used in offshore drilling:

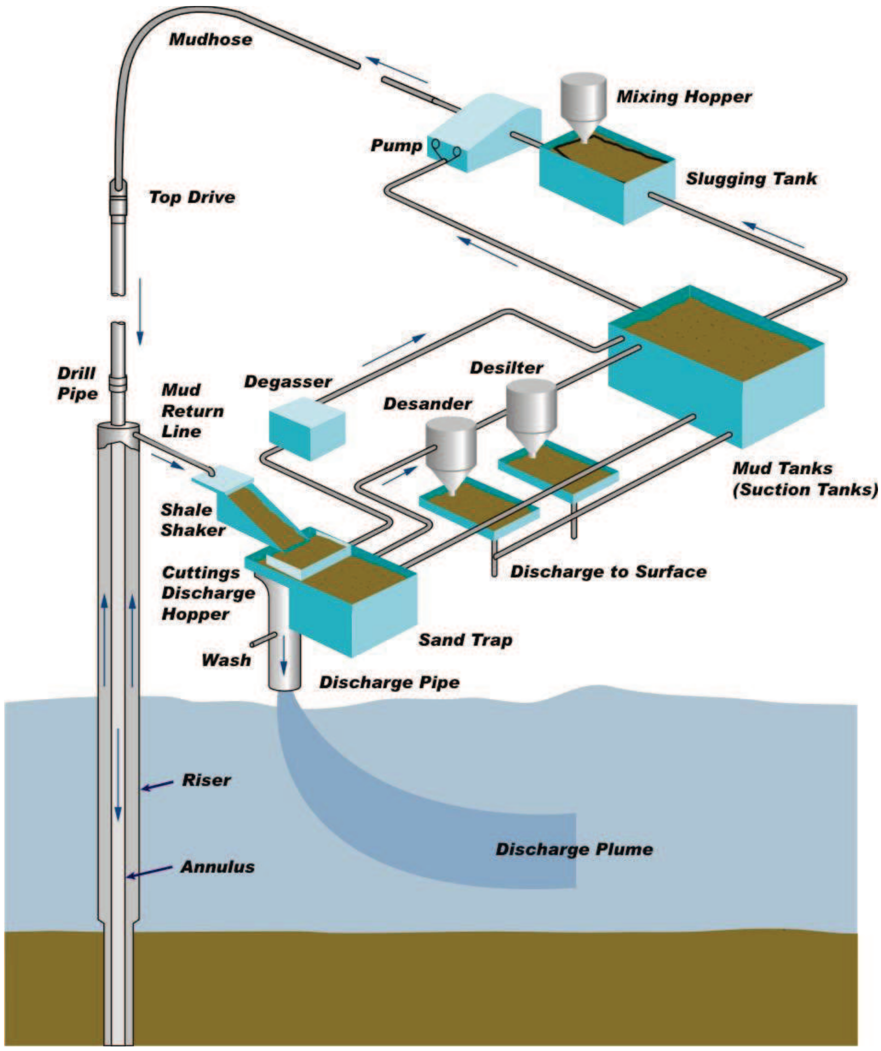
- Water based mud (WBM) – water forms the continuous phase of the mud (up to 90 percent by volume);
- Low toxicity oil based mud (LTOBM) – base oils, refined from crude oil, form the continuous phase of the mud; and
- Synthetic based mud (SBM) – the continuous phase is refined from a number of organic compounds chosen because they act like base oil but are selected to be more biodegradable.

The base muds form a viscous gel to which a variety of additives may be added for various reasons, including:

- Fluid loss control. The layer of mud on the wall of the wellbore retards the passage of liquid into the surrounding rock formation. Bentonite is the principal material for fluid loss control although additional additives such as starch and cellulose, both naturally occurring substances, are also used.

- Lost circulation. Naturally occurring fibrous, filamentous, granular or flake materials are used to stop lost circulation when the drill bit enters a porous or fractured formation. Typical materials include ground nut shells and mica.
- Lubricity. Normally the drilling mud alone is sufficient to adequately lubricate and cool the bit. However, under extreme loading, other lubricants are added to prevent the drill string from becoming stuck. No oil based chemicals will be required for Borders & Southern drilling programme.
- pH control. Caustic and lime are used to control the alkalinity of the mud to a pH of 9 to 10. This ensures the optimum performance of the polymers in the mud and controls bacterial activity.
- Pressure control. Barite is generally used as a weighting agent to control downhole pressure.

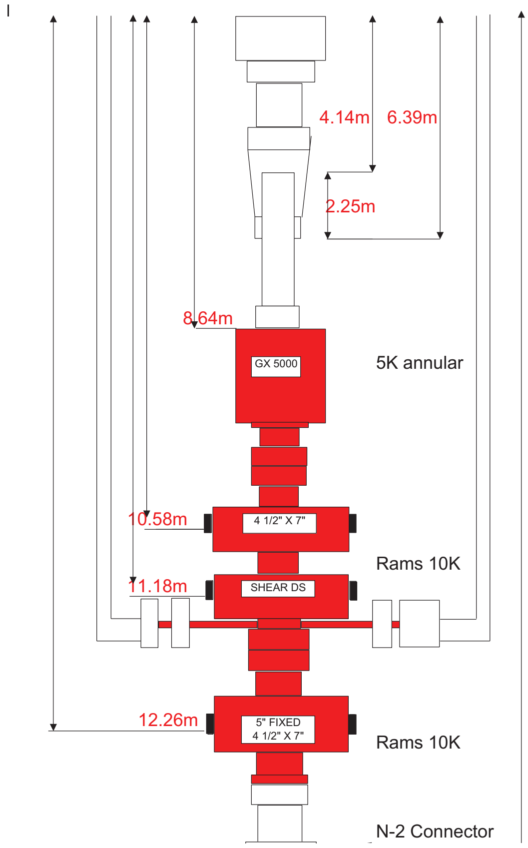
Figure A.2. A Typical Mud Recycling System, once Marine Riser is in Place.



Well Control and Blow out Prevention

In addition to careful monitoring and control of the fluid system and the installation of casing in each section of the well, a blow-out preventer stack, abbreviated to BOP, consisting of a series of individual preventers will be installed on the wellhead at the seafloor, after the surface casing has been installed (Figure A.3).

The function of the BOP is to prevent uncontrolled flow from the well by positively closing in the well-bore, if flow from the well-bore is detected. The BOP is made up of a series of hydraulically operated rams and would be operated in an emergency on the drill rig.



The well is not anticipated to encounter any zones of abnormal pressure and the BOP will be rated for pressures well in excess of those expected to be encountered in the well.

During drilling operations small amounts of BOP fluid are typically discharged every two weeks, during testing of the BOP.

Figure A.3. A typical Blow-Out Preventer Stack

Appendix B: HOCNS & HMCS

Until recently the control of offshore chemical discharges was controlled under the Offshore Chemical Notification Scheme (OCNS). Within the UK, the OCNS has been succeeded by The Offshore Chemicals Regulations 2002, which introduced a new approach to the consideration of chemical use and their discharge, the Harmonised Mandatory Control Scheme (HMCS). Both the OCNS and the HMCS are discussed below.

Offshore Chemical Notification Scheme (OCNS)

The Offshore Chemical Notification Scheme (OCNS) requires that all chemicals used in offshore exploration and production be tested using standard test protocols. Chemicals are then classified based on their biological properties e.g. toxicity and biodegradability. The OCNS scheme was adopted in the UK in 1979 and formed the basis of the Oslo and Paris Commissions (OSPARCOM) Harmonised Offshore Chemical Notification Format (HOCNF) which was established under cover of the Paris Commission Decision 96/3. The objectives of the OCNS and HOCNF are to regulate and manage chemical use by the oil and gas industry and consequently to prevent unacceptable damage to the marine environment through the operational or accidental discharge of chemicals.

The scheme was originally voluntary in the UK and all chemicals were given an OCNS Category ranging from 0 to 4. The system was later altered to harmonise the system with those operated by other countries bordering the North Sea. The HOCNS classifies all chemicals into five groups, A to E with Category A chemicals being the most toxic and least biodegradable and Category E chemicals considered to be the least harmful to the offshore environment.

In addition to being placed into one of the five HOCNS categories, substances known or expected to cause tainting of fish tissue or substances known or expected to cause endocrine disruption, if lost or discharged, will be identified with a special taint or endocrine disrupter (ED) warning.

Chemicals are categorised on the basis of a series of laboratory tests with particular reference to their ecotoxicological effect, the biodegradability of the chemical and the potential for bioaccumulation in marine species. The ecotoxicological data used to classify the toxicity of chemicals are the results of laboratory tests on aquatic indicator organisms. Acute toxicity is assessed and expressed as either:

- An LC50 – the concentration of the test substance in sea water that kills 50 percent of the test batch; and
- An EC50 – the concentration with a specified sub-lethal effect on 50 percent of the test batch.

The HOCNS grouping for a chemical is determined by comparing the results of toxicity tests for that chemical with the toxicity data given in Table B.1.

Table B.1. HOCNS Grouping Toxicity values (ppm) (Source: CEFAS, 2007)

HOCNS Grouping	A	B	C	D	E
Results for aquatic toxicity data (ppm)	<1	>1-10	>10-100	>100-1,000	>1,000
Results for sediment toxicity data (ppm)	<10	>10-100	>100-1,000	>1,000-10,000	>10,000

Aquatic toxicity - refers to the *Skeletonema costatum* EC_{50}, *Acartia tonsa* LC_{50}, and *Scophthalmus maximus* (juvenile turbot) LC_{50} test

Sediment toxicity - refers to the *Corophium volutator* LC_{50} test.

The categorisation also takes into account the chemicals potential to bio-accumulate and biodegrade and other aspects such as potential endocrine disruption. The bioaccumulation potential and biodegradation rate relates to the fate of a chemical within the marine environment. Bioaccumulation potential describes the net result of uptake, distribution, biodegradation and elimination of a substance within an organism, subsequent to exposure but within the environment. The partition coefficient between octanol and water (expressed as Log P_{ow}) is used as an indication of the potential for a substance to be bioaccumulated. A high value indicates a tendency to accumulate in lipophilic (“oil liking”) phases such as the fatty tissues of organisms, suspended particles or sediments. However, because of biodegradation and elimination processes, a high Log

P_{ow} does not necessarily imply bioaccumulation will occur. The classification outlined in Table B.2 is generally used to describe bioaccumulation potential.

Table B.2. Classification of Bioaccumulation Potential

Bioaccumulation Potential	Log P_{OW}
Low	<2
Medium	2-4
High	>4

Biodegradation of a substance refers to primary breakdown of the substance by living organisms, normally bacteria. A substance is considered readily biodegradable if 60 percent or more is broken down in 28 days during a biodegradation tests. Values below this are considered not to be readily biodegradable.

Harmonised Mandatory Control Scheme (HMCS)

The OSPAR Decision introducing an HMCS for the use and discharge of chemicals offshore came into force through the Offshore Chemicals Regulations 2002. The regulatory regime requires operators to obtain a permit to use and discharge chemicals in the course of oil and gas exploration and production operations offshore.

The OSPAR Decision and its supporting Recommendations entered into force on 16 January 2001. The Decision requires offshore chemicals to be ranked according to their calculated Hazard Quotients relating to each chemical discharge under standardised platform conditions (HQ = ratio of Predicted Environmental Concentration (PEC) to Predicted No Effect Concentration (PNEC). It also obliges authorities to use the CHARM "hazard assessment" module as the primary tool for ranking. In the UK this is carried out by a multidisciplinary team at the CEFAS Burnham Laboratory. From this information, operators assess and select their chemical need, calculating PEC:PNECs for actual conditions of use (utilising the CHARM module as appropriate) and bearing in mind the objective of the HMCS to identify substances of concern for substitution and ranking of others to support moves towards the use of less harmful substances. Inorganic chemicals and organic chemicals with functions for which the CHARM model has no algorithms will continue to be ranked using the existing HOCNS hazard groups defined above.

A series of ranked lists are maintained on the CEFAS web site which use a banding system to rank organic chemicals of similar function according to PEC: PNEC "Hazard Quotients" calculated using the CHARM model. The band definitions are given in Table B.3.

Table B.3. Classification of Bioaccumulation Potential

HQ Banding	HQ Value
Gold	0>x<1
Silver	1=<x<30
White	30=<x<100
Blue	100=<x<300
Orange	300=<x<1000
Purple	1000=<x

The minimum data set of actual values and the parameters used by CEFAS to calculate them are disclosed to chemical suppliers on "templates". The suppliers then pass these on to operators to enable the calculation of site-specific risk assessments (RQs) for any chemicals they may want to use. Some chemicals are generated and or used in-situ on offshore installations, e.g. Sodium Hypochlorite, and don't fall under the remit of any one supplier.

The properties of substances on the OSPAR List of Substances/Preparations Used and Discharged Offshore, Which Pose Little Or No Risk to the Marine Environment (PLONOR) are sufficiently well known that the UK Regulatory Authorities do not require them to be tested. This list is reviewed annually and the notification requirements for these chemicals are given in the PLONOR document.

Appendix C: Benthic Survey – Benthic Solutions Limited, 2009

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Borders & Southern PLC

REGIONAL BENTHIC ENVIRONMENTAL SURVEY OF THE BURDWOOD BANK, SOUH FALKLAND BASIN

FINAL REPORT

Client: **Borders and Southern Plc**

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Project Reference: BSL0811
Survey Dates: 16.11 to 21.11.2008
Date of Report: 07.10.2009

ABSTRACT

In November 2008, Borders and Southern PLC, commissioned Benthic Solutions Limited, to carry out a field environmental survey over a regional area of the Burdwood Bank and South Falkland Basin, encapsulating several prospect areas. This included analysis and interpretation of benthic sample data acquired during the field acquisition program. Field operations were undertaken by Benthic Solutions personnel from the supply vessel MV *Luma* (operated out of southern Chile), using a combination of large box corer, double grab sampler and 3m gravity corer. Benthic sampling was undertaken at a total of 23 stations relating to an even spread of samples over several prospect areas, specific bathymetric features and the regional area as a whole.

The objectives of this study were as follows:

- To analyse and interpret macrofaunal communities at all stations and provide a regional baseline and context from which to reference specific well locations;
- To analyse and interpret physico-chemical samples at all stations and provide a regional baseline and context from which to reference specific well locations;
- To utilise the above sediment and biological data to delineate potentially environmentally sensitive seabed features within the Prospect Area. In particular, the presence of sensitive habitats such as biogenic reefs (such as *Lophelia* and *Madrepora* corals) and cold water seep communities.
- To carry out a cursory assessment of the shallow geology in order to identify general soil conditions and the possible presence of gas hydrates.
- To carry out a cursory assessment of the water column structure to identify any variation in the water masses passing over this regional area.

A detailed habitat assessment cannot be carried out without the provision of additional acoustic datasets. The review of the bathymetric features identified from the 3D seismic data was able to identify clear seabed features which were targeted for environmental sampling. The benthic survey revealed that the seabed habitat and sediments varied across the regional area due to localised geological changes and possible hydrodynamic differences relating to depositional and non-depositional sedimentation. The majority for the survey revealed mixed substrates predominantly made up of fine sands, but with additional admixtures from glacial derived gravels in varied quantities. One station revealed the presence of outcropping bedrock whilst another revealed eroded stiff clays at the surface. Geographically, stations towards the north and east of the survey area showed a finer, more homogeneous substrate based on sandy silts. This may highlight the presence of lower boundary currents in this area.

Particle size analysis confirmed sediment variability with irregular size distributions recorded from coarse gravels (some as large as cobbles 25cm across) to clays,

although the mean sediment sizes only ranged from poorly sorted very fine sands to very poorly sorted medium sand. The variability in sediment classes is best demonstrated when looking at the proportion of sediment fines (i.e. particle below 63µm relating to silts and clays), which ranged from 8.8% to 79%. The higher percentages revealed a clear pattern of distribution towards the northwest part of the survey areas (the main part of the South Falkland Basin). With the exception of a slightly elevated sorting of sediments related to the northern flank of the Burdwood Bank, other important sedimentary factors, such as the proportion of coarser substrates, showed no pattern of distribution within the survey area.

The macrofaunal analysis revealed a community expected for the Magellan faunal area. Whilst similar to that of the Northern Boreal Region, the fauna is characterised by a low diversity in the echinoderms and a very high crustacean diversity. The overall faunal abundance and richness remained quite high and consistent throughout, although statistically the distribution of this community did not appear to alter significantly with either physical or chemical changes recorded at these sites. There were almost no correlations between univariate and other environmental parameters. This is further confirmed by multivariate analyses, which equally showed a relatively diverse faunal population, with only marginal separation into different faunal groups by similarity. These also gave poor correlations to other environmental parameters.

The dominant macrofaunal population for the region was based on that of a mobile surface dwelling polychaete, the Onuphid *Rhamphobranchium ehlersi*, Nematodes and surface or shallow burrowing crustacean, such as a tenaid in the family Apseudidae and the amphipods *Urothoe sp*, and Phoxocephaloidea sp.C (eyeless). This pattern of dominance by an onuphid polycheate and crustacea was also shared by other surveys in both the North Falkland Basin and along the East Falkland Margin (BSL 2008 and FSL 2009a-d, respectively). Other common fauna present within the benthos of the Burdwood Bank were large cypridoidea ostracods and a number of forams, with both groups clearly playing an important role within macrofaunal community even though they would typically fall into the meiofaunal range or be discounted for other reasons.

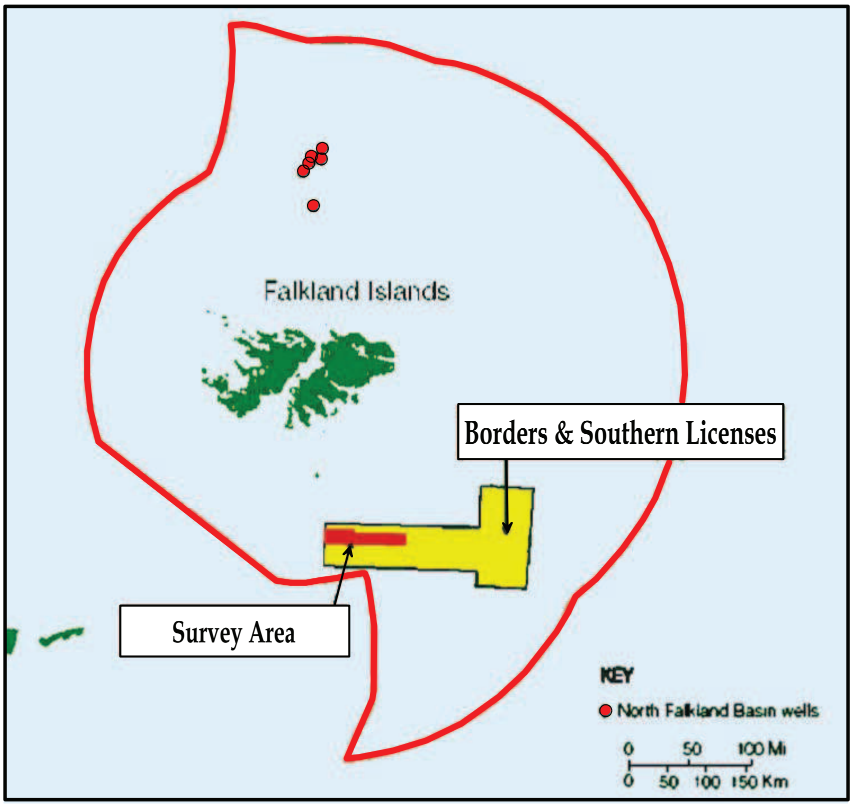
Seabed sampling revealed a significant presence of epifaunal species associated with the regular deposits of glacial drop-stones, with one site also showing bedrock exposure and another showing an eroded clay surface. These substrata indicate a non-depositional environment allowing a significant epifaunal population to exist. Epifaunal species were dominated by three major groups of cnidera, porifera, and bryozoa. The key groups were cnideran Octocorals, which were well represented, with one stoloniferous species (*aff Sarcodictyon*) and four prominent Gorgonarians, *Melitodes sp, Pleurocoralloides sp, Callozostron carlottae* and *Stachyodes sp.*, and a madreporan coral *Lophelia*. Live material of *Lophelia* was only recorded from a single sample along with some dead fragments from one site. The discovery of *Lophelia* is important as this location is generally outside its expected temperature range, with ambient seabed water temperatures of only 2.5°C. Although almost ubiquitous along the Atlantic continental slopes between 300 and 2000m, this branched hard corals is usually of conservational interest when developed into extensive biogenic reefs which can induce high localised diversity. This level of development was not recorded during this study. Other common epifaunal groups were many species of bryozoa and sponges which were frequently recorded encrusting or as upright branched forms. No environmentally sensitive species or other habitats considered to be of conservational value were recorded during this regional survey.

Chemical analysis was broken into organic and inorganic components. The latter consisted predominantly of heavy & trace metals. Results of these were all within ranges expected for uncontaminated deep water sediments, comparing closely with similar surveys in the Falklands locality. Levels exhibited a typical pattern of distribution associated with granulometric parameters. Results of the organic analysis also indicated an association with the sediment parameters but with a particularly high correlation with sediment fines, in particular silts. This relationship is normal, and usually relates to natural variability in localised hydrodynamics and rates of sedimentation in the water column. These results indicated a generally non-depositional environment throughout, but particularly to the east of the survey area.

Analysis of the sediment hydrocarbons (total hydrocarbons (THC), aliphatics and polycyclic aromatic hydrocarbons(PAH)), all showed a background signature of non-biogenic material within the survey area. The overall level of hydrocarbons was relatively low with a maximum THC concentration of 24$\mu g.g^{-1}$, approximately an order of magnitude higher than would typically be expected for an uncontaminated sediment at this water depth. The pattern of elevated hydrocarbons towards the west could either suggest a low level plume distribution of material within the prevailing current or it could represent the geographical distribution of a viable source interval and associated natural hydrocarbon seepage. A regional comparison of stations surveyed up to 420km to the northeast confirmed the presence of this material, albeit in trace amounts, confirming a regional concentration towards the south and west of the combined survey areas. Detailed analysis of both the saturate and aromatic fractions revealed this material to probably be thermogenic in origin, possibly immature, and may relate to natural hydrocarbon seepage.

Water quality profiles revealed a consistent water mass throughout the region with a density related upper layer, caused by solar heating, in the surface 100m. Seabed salinity and temperatures were consistent at 34.7 practical salinity units and 2.3°C.

LOCATION MAP



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GLOSSARY OF ABBREVIATIONS

ACP	Antarctic Circumpolar Current	ORP	Oxidative Reductive Potential
BSL	Benthic Solutions Limited	OSPAR	Oslo and Paris Commission
CPI	Carbon Preference Index	PAH	Polycyclic Aromatic Hydrocarbons
CTD	Conductivity/temperature/depth	PPB	Parts Per Billion
dw	Dry Weight	PPM	Parts Per Million
GC	Gas Chromatography	PRIMER	Plymouth Routines in Multivariate Ecological Research
GC-FID	Gas Chromatography - Flame Ionisation Detection	PSU	Practical Salinity units (approx $^{o}/_{oo}$)
ICP-MS	Inductively Coupled Plasma Mass Spectrometry	REDOX	Reductive Oxidative Potential
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry	RDL	Redox Discontinuity Layer
IMS	Industrial Methylated Spirit	SD	Standard Deviation
LAT	Lowest Astronomical Tide	TOC	Total Organic Carbon
LOI	Loss on Ignition	TOM	Total Organic Matter
GC-MS	Gas Chromatography Mass Spectrometry	THC	Total Hydrocarbons
mg.kg^{-1}	milligrams per kilogram or PPM	UCM	Unresolved Complex Mixture
MSL	Mean Sea Level	UKOOA	United Kingdom Offshore Operators Association
ng.g^{-1}	nanograms per gram or PPB	µg.g^{-1}	micrograms per gram or PPM
nMDS	Non-Metric Multidimensional Scaling	WAS	Wilson Auto-Siever
NPD	Naphalene, Phenanthrene, Anthracene and Dibenziothene		

1. SCOPE OF WORK

1.1. Introduction

Benthic survey operations previously undertaken for Oil & Gas exploration in the Falkland Islands were previously carried out in the North Falkland Basin in 1998. These surveys were based upon a generic localised cruciform template with samples set at predetermined distances from a central well location and out to a small radius of around 1km with very few regional reference locations established. A later review of the results showed that most of the survey areas indicated homogeneous localised habitats with consistent sediment and biological parameters. However, inter-field variations were greater, with a slow change in sediment type, and as a result, physico-chemistry and associated biological communities with decreasing depth and proximity to the shelf break. Additional geophysical datasets similarly showed consistent and relatively benign survey areas dominated by sedimentation, with the greatest variance exhibited in the deeper waters where historical glacial activities had created some sediment changes through iceberg keel scarring and patches of gravel deposits. No sensitive habitats, or features of conservational importance were recorded (i.e. cold water corals, geological or biogenic reefs, or gas escape features with authigenic structures). A very recent survey of the North Falkland Basin was carried out in the summer of 2008. This survey, undertaken by Benthic Solutions Limited on behalf of Desire Petroleum, Rockhopper Petroleum and Arcadia, followed a quite different strategy based on lessons learned from the 1998 assessments of a similar area. Rather than concentrating all of the sampling effort into a relatively small and probably homogeneous area surrounding each possible well location, a regional program was employed where samples were spread out over a larger grid area. Supplemented with some localised sites, this strategy established a greater understanding of individual prospect areas in the context of the Continental Shelf and upper slope as a whole. The full results of this study were still in production at the time of the present study.

For the South Falkland Basin, the prospect area falls into quite a different sediment type to that previously studied in the North. Located in much deeper waters, the Borders and Southern prospect area needed to be sampled in a more pragmatic and efficient way in order to maximise the knowledge of the region as whole and provide a context for individual sites and habitats within it. No detailed well locations were known at the time of the study with only target areas available. As little or nothing is known of the regional sediment variations within the South Falkland Basin, a pragmatic approach to sampling was employed whereby most sample stations were positioned based on a large scale grid coverage of the area with some additional sites selected based on potential habitat changes as identified by bathymetric features. A similar strategy was also employed immediately after this survey along the eastern Contintental Margin at several sites on the continental slope bor BHP petroleum (FSL 2009a-d).

Overall, the number of samples acquired and processed was 23 stations, based on four prospective target areas. There positions were based on the following strategy (Figure 1).

Regional Area Grid:	A regional area grid was established to provide a large scale separation of sites across the entire area based on an approximate separation of around 15km. As the regional survey area overlaps with selected target areas (see below) a number of these sites have been rationalised to reduce sampling effort. A total of 9 regional sites was proposed for the full survey area (101km x 19.3km) (NB. The northeast corner of the prospect was not sampled due to the extreme water depth and its distance from the closest target area).
Target Area Grid	Following a review of the bathymetric features and a selection of the target areas within the prospect, areas were further sampled to provide additional information relating to a closer proximity to a possible well location. At the time of site selection these areas were based on the following target leads and have been selected to represent bathymetric highs, sedimentary basins, shelf breaks and escarpments or other unknown features. Sites are separated as follows: Target Lead A = 3 sites Target Lead F = 4 sites Target Lead G = 4 sites Target Lead L (Blocks 1-3) = 3 sites Total of 14 target based locations
Intelligent Sampling:	Once sampling operations had commenced, unusual or unexpected sediment changes were to be reviewed during the survey work and the bathymetric rendering of the seabed (from the 3D seismic) re-evaluated if required. If necessary, up to 2 additional sample sites were to be established to confirm/ground truth this revised interpretation, based on a intelligent site selection.

The overall scope of work, therefore for the South Falkland Basin was between 23 to 25 sites. Proposed sites are outlined in Table 1.1 and Figure 1.1. In the event of extensive inclement sea conditions or unfavourable surface geology preventing the completion of the survey, sample sites were prioritised.

1.2. Benthic Survey Strategy

As water depths were expected to range from between 1200 and 2100metres, benthic sampling was to be undertaken using a large 0.25m^2 box corer sampler constructed of stainless steel, whilst a second large grab sampler was to be used in the event of limited penetration (such as compacted sands) or if insufficient surface material was recovered by the corer. Both devices were designed to completely enclose the sample on recovery and provide inspection/sub-sampling access to the samples surface without disturbing the integrity of the sediment layering. Recovered material was to be processed onboard over a 500µm aperture using a *Wilson Auto-siever*, or were to be sub-sampled for physico-chemical determination after the sample had been described and photographed.

For each of the 23 proposed sample locations, three separate sub-samples were to be acquired, two of these were to be analysed for sediment macrofauna and one for physico-chemical determination. For the larger 0.25m^2 samplers, all sub-samples could be acquired from a single successful deployment, however an additional deployment would be required for an oversized grab sampler (0.2m^2), thereby allowing an additional third replicate to be acquired and processed for sediment macrofauna when this sampler was used.

All recovered samples were to be assessed under strict quality control criteria prior to acceptance and subsequent processing. On recovery, with the exception of sediment biology, all samples were to be immediately frozen and stored (< -18^{o}C) for later transportation (frozen) to the proposed laboratory, or for storage on demobilisation. This material was to remain frozen during transportation back to the analytical laboratories. The following physico-chemical analyses were to be undertaken following demobilisation, using UK guidelines. Previous experience of these techniques and processing low level uncontaminated marine sediments was essential.

- Full Particle size distribution (phi scale, includes the <63µm fraction);
- Total organic matter (by loss on ignition);
- Total organic carbon and carbonates;
- Total petroleum hydrocarbons (TPH) by GC-FID;
- Saturate hydrocarbons (nC_{10} – nC_{35}) by GC-FID;
- Polycyclic aromatic hydrocarbons (2-6 ring & alkyl derivatives);
- Heavy & trace metals (double analysis following both aqua regia and HF digest by ICP or AAS for Ba, Cd, Cr, As, Cu, Ni, Zn, V, Pb, Al, Fe, Sr) and Hg (by cold vapour or ICPMS).
- Duplicate or triplicate Macrofaunal determination (over 500µm)

1.3. Three Metre Gravity Coring

As nothing was known of the surface geology in the region and some concerns remained over the stability of the superficial substrates, particularly if carbonate oozes were encountered, an additional 3 metre gravity corer was taken to provide additional geotechnical samples on up to 6 proposed sites (Table 1.1).

1.4. Water Profiling Strategy

Two or three replicate water quality profiles were to be undertaken down to full depth within the geographical extremes of the survey area. Water profiles were to be collected using a continuous reading water quality profiler or CTD depth rated to 3000m. This was to be fitted with sensors to obtain and record measurements throughout the water column from sea surface down to the seabed. The probe was to be pre-programmed and set to recording mode and lowered at an approximate rate of ca. 60m/sec to allow the sensors to equilibrate. The sampling frequency of the instrument is normally set at 1 second (maximum frequency). Data will be recorded during both down and up casts.

Figure 1.1. *Summary of Proposed Sample Locations and Prospect Areas*

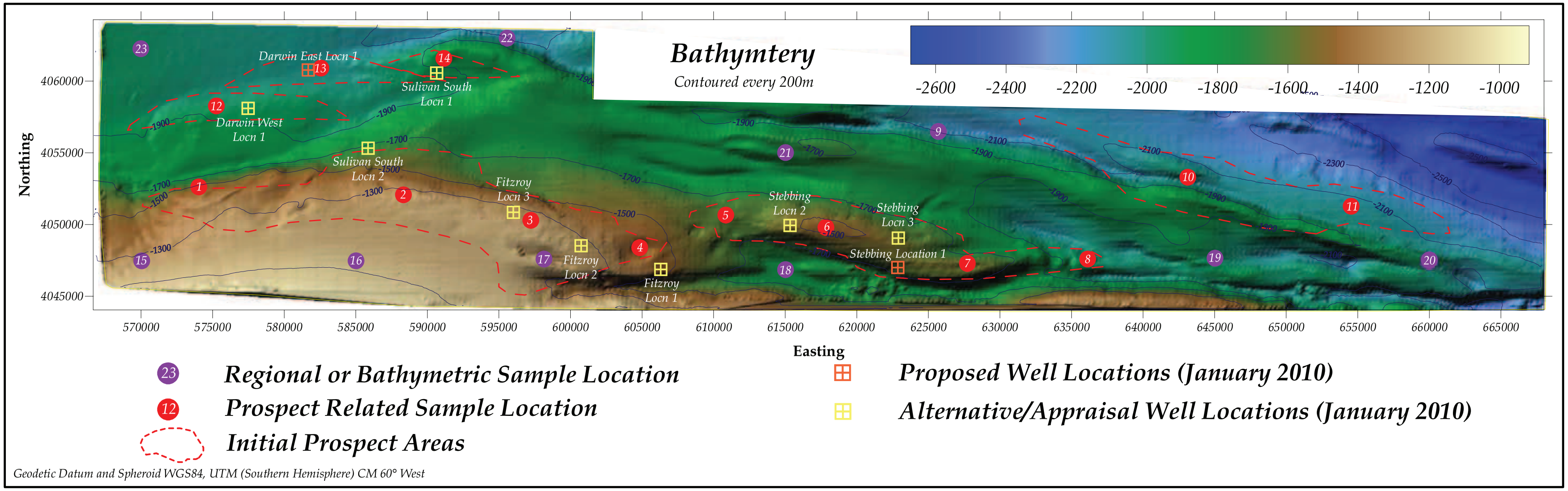


Table 1.2 *Prospective Well Locations as Supplied by Borders and Southern (Summer 2009).*

Well Name	Easting	Northing	Latitude	Longitude	Well Type
Darwin East Locn 1	581679	4060778	-53 degs 35 mins 43.6581 secs	-58 degs 45 mins 57.0275 secs	Primary Well Location
Darwin West Locn 1	577481	4058098	-53 degs 37 mins 12.6555 secs	-58 degs 49 mins 42.9271 secs	Alternative / Appraisal
Stebbing Location 1	622870	4047005	-53 degs 42 mins 40.1689 secs	-58 degs 08 mins 17.8985 secs	Primary Well Location
Stebbing Location 2	615341	4049940	-53 degs 41 mins 11.4263 secs	-58 degs 15 mins 12.2928 secs	Alternative / Appraisal
Stebbing Location 3	622905	4049053	-53 degs 41 mins 33.9048 secs	-58 degs 08 mins 18.9148 secs	Alternative / Appraisal
Fitzroy Location 1	606307	4046872	-53 degs 42 mins 57.5602 secs	-58 degs 23 mins 20.7607 secs	Alternative / Appraisal
Fitzroy Location 2	600743	4048519	-53 degs 42 mins 08.2586 secs	-58 degs 28 mins 26.0938 secs	Alternative / Appraisal
Fitzroy Location 3	596008	4050857	-53 degs 40 mins 55.8410 secs	-58 degs 32 mins 46.8244 secs	Alternative / Appraisal
Sulivan South Locn 1	590651	4060570	-53 degs 35 mins 45.0778 secs	-58 degs 37 mins 48.9188 secs	Alternative / Appraisal
Sulivan South Locn 2	585859	4055321	-53 degs 38 mins 37.7888 secs	-58 degs 42 mins 04.3001 secs	Alternative / Appraisal

Water profile sensors will be as follows:

- Conductivity (mS/cm)
- Temperature (° C)
- Depth (m)
- Calculated Salinity (psu or °/₀₀)
- Calculated Density (g/cm³)
- Calculated Sound Velocity (m/sec)

Table 1.1 Summary of Proposed Sample Location and Priority

Sample Station	UTM		Geographical Positions		Add. samples Cores/profiles	Sample Priority
	Easting	Northing	Latitude (South)	Longitude (West)		
1	574060	4052639	-53° 40′ 11.05	-58° 52′ 44.40	-	Medium
2	588304	4052086	-53° 40′ 20.97	-58° 39′ 47.88	-	Medium
3	597166	4050307	-53° 41′ 12.86	-58° 31′ 43.11	-	High
4	604366	4048414	-53° 42′ 09.09	-58° 25′ 08.47	3m Core	High
5	610839	4050647	-53° 40′ 52.07	-58° 19′ 18.51	3m Core	High
6	617898	4049857	-53° 41′ 12.06	-58° 12′ 52.86	3m Core / profile	High
7	627725	4047300	-53° 42′ 26.43	-58° 03′ 53.68	-	High
8	636143	4047580	-53° 42′ 09.72	-57° 56′ 15.31	-	Medium
9	625685	4056465	-53° 37′ 31.82	-58° 05′ 58.23	-	Medium
10	643135	4053308	-53° 38′ 57.78	-57° 50′ 03.79	3m Core/profile	Low
11	654614	4051256	-53° 39′ 52.36	-57° 39′ 35.44	-	Low
12	575260	4058240	-53° 37′ 09.23	-58° 51′ 43.91	3m Core	High
13	582512	4060886	-53 °35′ 39.69	-58° 45′ 11.83	3m Core / profile	High
14	591172	4061608	-53° 35′ 11.17	-58° 37′ 21.68	-	Medium
15	570000	4047500	-53° 42′ 59.32	-58° 56′ 21.41	-	Low
16	585000	4047500	-53° 42′ 51.30	-58° 42′ 43.35	-	Medium
17	598119	4047557	-53° 42′ 41.18	-58° 30′ 48.04	-	High
18	615000	4046813	-53° 42′ 52.83	-58° 15′ 26.70	-	High
19	645000	4047670	-53° 41′ 58.23	-57° 48′ 12.81	-	Low
20	660000	4047500	-53° 41′ 47.96	-57° 34′ 35.28	-	Low
21	615000	4055000	-53° 38′ 28.04	-58° 15′ 37.62	-	Medium
22	595555	4063011	-53° 34′ 22.98	-58° 33′ 24.94	-	Low
23	570000	4062250	-53° 35′ 02.12	-58° 56′ 33.37	-	High

Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

More accurate positions relating to prospect well locations were supplied by Borders and Southern immediately prior to submission of this interpretive report. These are all located relatively close to existing sample locations which can be used to describe likely conditions for each site. However, given the late availability of this information, these well locations will not be discussed further in this report.

2. FIELD OPERATIONS

The field environmental survey was undertaken by Benthic Solutions Limited from the Chilean supply vessel MV *Luma,* mobilised from Punta Arenas in the Magellan Straits. The field acquisition was based upon a benthic sampling campaign and water quality profiling over a regional area of the Burdwood Bank, located in the South Falkland Basin. The timing of the mobilisation, field survey and demobilisation are summarised in Table 2.1.

Table 2.1 Chronological Sequence of Field Operations for the Regional Benthic Environmental Survey, Burdwood Bank, South Falkland Basin

Dates	Activity	Data acquired for this report
10-12.11.2008	Travel	Personnel travel to Southern Chile
13-14.11.2008	Mobilisation, transit and Sampling	Mobilisation of survey equipment onboard the vessel. Test configurations sail for survey area.
15.11.2008	Transit	Magellan straits to Burdwood Bank
16.11.2008	Transit Sampling Standby	Transit to first site and setup for sampling Box coring at 1 station (23) Standby due to inclement weather conditions
17.11.2008	Standby Sampling	Standby due to inclement weather conditions Gravity coring at 2 stations (12 & 13)
18.11.2008	Sampling	Box coring at 3 stations (5, 10 and 18) Gravity coring at 3 stations (4, 5 and 10) Water quality profile (10)
19.11.2008	Sampling	Van Veen grab 7 stations (7,8,9,10,11,19 and 20)
20.11.2008	Sampling	Van Veen grab 7 stations (2, 3, 4, 6, 16, 17 and 21), Gravity coring at 1 station (6)
21.11.2008	Sampling Transit	Box coring at 2 stations (1 and 15) Van Veen grab at 4 stations (12, 13, 14 and 21) Water quality profiles (6 and 13)
22.11.2008	Transit	Burdwood Bank to Magellan straits
23.11.2008	Transit	Burdwood Bank to Magellan straits
24.11.2008	Transit Demobilisation	Vessel arrives and demobilises in Punta Arenas.
25-26.11.2008	Travel	Personnel and samples travel back to the UK

2.1 Benthic Environmental Sampling

Benthic samples were acquired using a combination of sampling devices. Whilst this was not an ideal method, it was a strategic option; the unusual and variable nature of the surface geology encountered at the site necessitated a flexible approach, without which little or no material would have been recovered at many of the locations. As little or nothing was known about the surface geology prior to the survey, the possibility of challenging surface sediments for sampling was expected at the time of the mobilisation. Consequently, Benthic Solutions Limited had prepared contingency measures in the way of an alternative sampling device (a unique double Van Veen grab sampler designed and built by Benthic Solutions Limited) in addition to the larger box corer which was deployed as the primary sampler. In the event, both samplers were used to good effect with sandy and stiff clay sampled by grab and silts, sands and fine gravels sampled via box corer. Details of the sampling equipment are as follows:

USNEL Box Corer

The primary seabed sampler was a 0.25m^2 USNEL type box corer, requiring only a single good sample to be recovered at each of the proposed locations. Pre-deployment procedures included the cleaning of the inner stainless steel box, cable and blocks to be generally grease free. A record of the samplers touch down at deployment depth was monitored by means of an offset load cell which recorded tension on the cable and could be zeroed immediately prior to sampling. Samples were subject to quality control on retrieval and were retained in the following circumstances:

- Water above sample was undisturbed;
- Spade closure complete allowing no sediment washout;
- Penetration of the box was sufficient to maintain a seal at the base of the core;
- Sampler was retrieved perfectly upright and had not fouled in any way;
- Inspection/access doors had closed properly enclosing the sample;
- No disruption of the sample through striking the side of the vessel;
- Sample were taken inside the acceptable target range;
- The sample was acceptable to the principle scientist.

For each sample, the whole core was inspected, described, photographed and sub-sampled for two 0.1m^2 replicates, which were processed onboard using a *Wilson* Auto-siever over a 500µm aperture mesh. Key observations from samples were colour, sediment classification, layering (including RDLs), smell (including the presence of H_2S), obvious fauna and evidence of bioturbation. The separation of the macrofaunal samples was undertaken following area segregation and siphoning the supernatant surface waters prior to sediment extractions down to a depth of 20cm (Figure 2.2). The remainder of the core sample (0.05m^2) was surface sub-sampled for Physico-chemistry.

An additional hand core (89mm id) was also taken to preserve the surface structure of the samples for possible later geotechnical analysis. This was pushed into the full penetration of the box core, and complete core extracted and stored upright.

Double Van Veen Grab

Where a box corer was not able to acquire a sample due to the sediment type (usually compacted sands or shallow stiff clays), the surface sediments were acquired using the alternative sampler. This was a double Van Veen grab sampler. This devise has two samplers in a ballasted frame and acquires a seabed sample area of 2 x 0.1m^2 on each deployment. Pre-deployment procedures included the cleaning of the inner stainless grab buckets, cable and blocks so that they were generally grease-free. As with the corer, touch down at deployment depth was monitored by means of an offset load cell measuring the tension on the cable. Samples were subject to quality control on retrieval and were retained in the following circumstances:

- Water above sample was undisturbed;
- Bucket closure complete allowing no sediment washout;
- Penetration of the grab was sufficient to maintain a seal at the base;
- Sampler was retrieved perfectly upright and had not fouled in any way;
- Sampler access doors had closed properly enclosing the sample;
- No disruption of the sample through striking the side of the vessel;
- Sample was taken within the acceptable target range;
- The sample was acceptable to the principle scientist.

On retrieval, the whole sample was inspected, described and photographed prior to processing. A total of three 0.1m^2 replicates, were processed onboard using a *Wilson* Auto-siever over a 500µm aperture mesh. Key observations from samples were colour, sediment classification, layering (including RDLs), smell (including the presence of H_2S), obvious fauna and evidence of bioturbation and evidence of anthropogenic debris (Figure 2.2). The remaining sample (0.1m^2) was sub-sampled for Physico-chemistry.

<u>Sample Processing</u>

Sub-sampling of physico-chemistry was undertaken from both samplers with the following material retrieved:

- 2 x Surface 2cm scrape for Hydrocarbon analysis (one spare);
- 2 x Surface 2cm sectioned from core tube for heavy & trace metals (one spare);
- 2 x surface 2cm for PSA , TOM & TOC (one spare).

The preservation of materials were undertaken using the following standard techniques. All physico-chemical samples were stored in appropriate containers (i.e. glass for hydrocarbons, and plastics for metals and PSA) and immediately frozen and stored (< -18^{o}C) for later transportation (frozen) to the laboratory on demobilisation. Faunal samples were fixed and stained in 5% buffered formalin and a vital stain (Rose Bengal) for storage and transportation. This material was later transferred to IMS. All biological samples were double-labelled, with internal tags. On samples that retained minor amounts of clays a small amount of additional di-sodium hexametaphosphate was included within the fixative onboard to induce clay separation during storage. Sample positions are given in Table 2.2, and plotted in Figure 2.1. Photographs from the field sampling operations are given in Figure 2.2 and from the samples in Appendix VI.

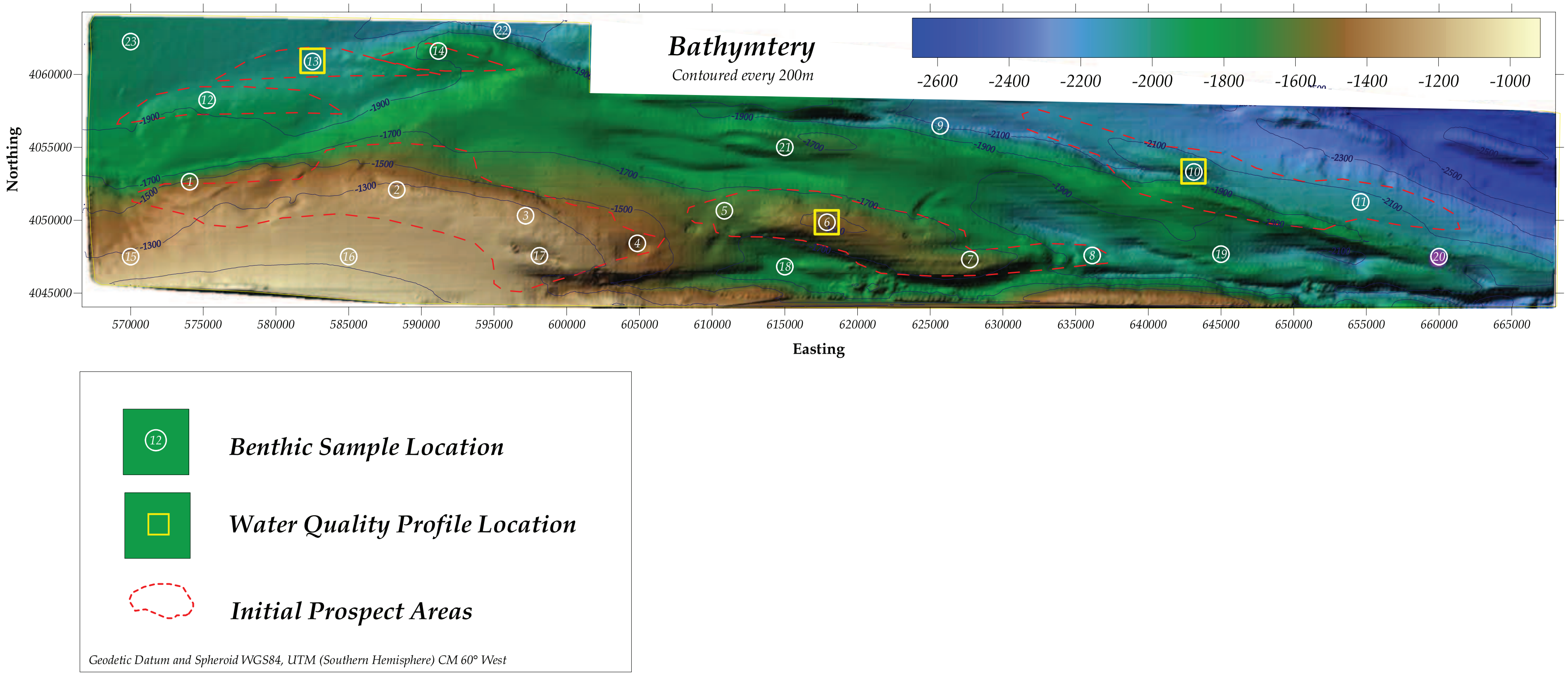
In the event sampling was successfully carried out at 22 out of the 23 stations using a combination of the samplers. Only station 9, which indicated a very stiff eroded clay surface provided no material for future processing (other than a superficial scrape). The striking of bedrock or pockets of intermittent sand meant that no biological replicates were recovered for station 17, whilst only a single biological replicate was obtained for both stations 7 and 10 due to either limited surface material or coarse gravels, respectively. Little or no gravity core material was recovered at station 4, 6 and 10 due to hard substrates. Other sites achieved penetrations from 0.43 to 1.9m.

Table 2.2 *Actual Sampling Locations*

Station	Gear	Depth	Latitude (S)*	Longitude (W)*	Attempts (corer penetration)	BIO (0.1m reps)	Chem	Water Profile (depth)
1	VV	1389	53.67024	58.87858	2	3	YES	-
2	VV	1246	53.67253	58.66227	4	3	YES	-
3	VV	1214	53.68705	58.53043	2	3	YES	-
4	VV	1450	53.70281	58.41076	3	4	YES	-
	GC	1420-26	53.70283	58.41521	2(0m)	-	-	-
5	BC	1540	53.68107	58.32085	1	2	YES	-
	GC	1540	53.68084	58.32080	1 (43cm)	-	-	-
6	VV	1428	53.68777	58.21582	2	3	YES	1476m
	GC	1423	53.68713	58.21501	1 (10cm)	-	-	-
7	VV	1534	53.70763	58.06586	3	1	YES	-
8	BC	1910	53.70294	57.93796	2	1	YES	-
8	VV				1	2	-	-
9	BC	-	-	-	1	-	-	-
10	BC	1980	53.64964	57.83362	1	-	YES	2061m
	VV				1	1	-	-
	GC	1980	53.65042	57.83298	1 (10cm)	-	-	-
11	VV	2008	53.66388	57.66093	2	3	YES	-
12	BC	1840	53.62044	58.86038	6	2	YES	-
	GC	1880	53.61948	58.86153	3 (1.9m)	-	-	-
13	BC	2050	53.59457	58.75221	1	2	YES	2043m
	GC	1946	53.59409	58.75421	1 (43cm)	-	-	-
14	BC	1800	53.58669	58.62292	1	2	YES	-
15	VV	1180	53.71698	58.94008	5	2	YES	-
16	VV	1108	53.71426	58.71249	2	3	YES	-
17	VV	1161	53.71214	58.51492	2	-	YES	-
18	BC	1745	53.71549	58.25585	2	2	YES	-
19	VV	1927	53.70006	57.80361	2	2	YES	-
20	VV	1955	53.69691	57.57647	1	1	YES	-
	BC	1955	53.69684	57.57616	1	1	YES	-
21	VV	1694	53.64173	58.26114	3	3	YES	-
22	BC	2010	53.57386	58.55610	1	2	YES	-
23	BC	1870	53.58556	58.94219	3	2	YES	-
False Target	VV	1200	53.7245	58.52842	1	-	PSA Only	-

Where: BC = Box corer, VV = Van Veen Grab, GC = 3m gravity corer, Chem = Surface particle size analysis, total organic carbon, carbonates, total organic matter heavy & trace metals, and sediment hydrocarbons. Bio Reps = number of 0.1m² Macrofaunal replicates sieved above 500µm.
** = WGS84, Datum.*

Figure 2.1. *Actual Environmental Sample Locations*



2.2 Water Quality Profiling

As little is known about the water column in the deeper waters of the proposed prospect area, three replicate water quality profiles were undertaken within the regional survey area over a three day period. These replicate profiles provide a general snap-shot of the water column structure for the duration of the survey.

Water profiles were collected using a MIDAS CTD continuous reading water quality profiler depth rated to 6000m. This was fitted with sensors to record measurements throughout the water column from sea surface down to the seabed. The probe was pre-programmed and set to recording mode and lowered at an approximate rate of ca. 65m/min. This was a sufficient time to allow the onboard sensors (conductivity, temperature and pressure) to equilibrate to ambient conditions during the cast. The sampling frequency of the instrument was set to 1 reading per second. Data was recorded during both down and up casts. A total of three data casts were acquired (stations 6, 10 and 13) with the depths and positions shown in Table 2.2.

Profile sensors and derived parameters are as follows:

- Conductivity: mS/cm
- Temperature: ^{o} C
- Depth: Metres
- Density: g/cm^3 calculated
- Sound Velocity: m/sec calculated
- Salinity: ppt calculated

2.3. Survey Geodesy

The geodetic parameters used were as follows: -

Table 2.3 Survey Geodetic Parameters

Global Positioning System Geodetic Parameters	
Datum:	World Geodetic System 1984 (WGS84)
Spheroid:	World Geodetic System 1984 (WGS84)
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	$^1/_f$ = 298.2572235630
Local Datum Geodetic Parameters	
Datum:	World Geodetic System 1984 (WGS84)
Spheroid:	World Geodetic System 1984 (WGS84)
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	$^1/_f$ = 298.2572235630
Project Projection Parameters	
Grid Projection:	Transverse Mercator, Southern Hemisphere
UTM Zone:	N/A
Central Meridian:	60° 00′ 00″ West
Latitude of Origin:	00° 00′ 00″ S
False Easting:	500 000 m
False Northing:	10 000 000 m
Scale factor on Central Meridian:	0.9996
Units:	Metre

Figure 2.2 *Environmental Survey Operations at the South Falkland Basin*

(A) MV Luma mobilising in Punta Arenas. (B) Deployment of a CTD profiler. (C) The unique Benthic Solutions Double Grab (0.2m²). (D) Biological templates and core sub-sampling from the box corer. (E) 3m Gravity Corer. (F) Deployment of the USNEL Box corer. (G) Example of decapod *Peltarion spinosulum* recovered from one of the box core samples.

3. SAMPLE ANALYSES

The recovered benthic samples were sorted and correctly stored prior to demobilisation and transportation of the material to the correct laboratory. All physico-chemical samples were immediately frozen on recovery and hand–carried back to the UK, to be returned to a laboratory freezer within 48hours. This material was analysed at the following laboratories with all remaining material held by Benthic Solutions Limited for back-up:

- Benthic Solutions Limited: Particle size & macrofaunal analysis.
- TES Bretby: Chemical analysis

A summary of the analytical methodologies applied for this study are as follows:

3.1. Particle Size Distribution

The samples recovered from each site were analysed by Benthic Solutions Limited. The complete sub-sample was dried and passed through stainless steel sieves with mesh apertures of 8000, 4000, 2000µm with a nesting receiver. In most cases almost the entire sample would pass through the sieve stack, but any material retained on the sieve, such as small shells and shell fragments and stones were removed, weighed and recorded.

The sediment particle size distributions below 2000µm were determined using a Malvern Mastersizer 2000 particle sizer according to Standard Operating Procedures (SOP). The results obtained by a sizer have been previously validated by comparison with independent assessment by wet sieving (Hart, 1996). The range of sieve sizes, together with their Wentworth classifications, is given in Table 3.1.

The separate assessments of the fractions above and below 2000µm were combined using a computer programme. This followed a manual input of the dry sieve results for fractions 16-8mm, 8-4mm and 4-2mm and sub-2mm fractions and the electronic data captured by the Mastersizer below 2000µm.

This method defines the particle size distributions in terms of phi mean, Median, fraction percentages (i.e. coarse sediments, sands and fines), sorting (mixture of sediment sizes) and skewness (weighting of sediment fractions above and below the mean sediment size; Folk 1954).

Graphic Mean (M) - a very valuable measure of average particle size in phi units (Folk & Ward, 1957).

$$M = \frac{\phi 16 + \phi 50 + \phi 84}{3}$$

where *M = The graphic mean particle size in phi*
ø = the phi size of the 16th, 50th and 84th percentile of the sample

Table 3.1 ***Phi and Sieve Apertures with Wentworth Classifications***

Aperture in microns	Aperture in Phi Unit	Sediment Description	
2000	-1	Granule	Gravel
1400	-0.5	Very Coarse Sand	
1000	0		
710	0.5	Coarse Sand	Sands
500	1		
355	1.5	Medium Sand	
250	2		
180	2.5	Fine Sand	
125	3		
90	3.5	Very Fine Sand	
63	4		
44	4.5	Coarse Silt	Fines (Silts)
31.5	5		
22	5.5	Medium Silt	
15.6	6		
11	6.5	Fine Silt	
7.8	7		
5.5	7.5	Very Fine Silt	
3.9	8		
2	9	Clay	Fines (Clays)
1	10		

Sorting (D) – the inclusive graphic standard deviation of the sample is a measure of the degree of sorting (Table 3.2).

$$D = \frac{\phi 84 + \phi 16}{4} + \frac{\phi 95 + \phi 5}{6.6}$$

where *D = the inclusive graphic standard deviation*
ø = the phi size of the 84th, 16th, 95th and 5th percentile of the sample

Table 3.2 *Sorting Classifications*

Sorting Coefficient (Graphical Standard Deviation)	Sorting Classifications
0.00 < 0.35	Very well sorted
0.35 < 0.50	Well sorted
0.50 < 0.71	Moderately well sorted
0.71 < 1.00	Moderately sorted
1.00 < 2.00	Poorly sorted
2.00 < 4.00	Very poorly sorted
4.00 +	Extremely poorly sorted

Skewness (S) – the degree of asymmetry of a frequency or cumulative curve (Table 3.3).

$$S = \frac{ø84 + ø16 - (ø50)}{2(ø84 - ø16)} + \frac{ø95 + ø5 - 2(ø50)}{2(ø95 - ø5)}$$

where *S = the skewness of the sample*
ø = the phi size of the 84th, 16th, 50th, 95th and 5th percentile of the sample

Table 3.3 *Skewness Classifications*

Skewness Coefficient	Mathematical Skewness	Graphical Skewness
+1.00 > +0.30	Strongly positive	Strongly coarse skewed
+0.30 > +0.10	Positive	Coarse skewed
+0.10 > -0.10	Near symmetrical	Symmetrical
-0.10 > -0.30	Negative	Fine skewed
-0.30 > -1.00	Strongly negative	Strongly fine skewed

Graphic Kurtosis (K) – The degree of peakedness or departure from the 'normal' frequency or cumulative curve (Table 3.4).

$$S = \frac{ø95 - ø5}{2.44(ø75 - ø25)}$$

where *K = Kurtosis*
ø = the phi size of the 95th, 5th, 75th and 25th percentile of the sample

Table 3.4 *Kurtosis Classifications*

Kurtosis Coefficient	Kurtosis Classification	Graphical meaning
0.41 < 0.67	Very Platykurtic	Flat-peaked; the ends are better sorted than the centre
0.67 < 0.90	Platykurtic	
0.90 < 1.10	Mesokurtic	Normal; bell shaped curve
1.11 < 1.50	Leptokurtic	Curves are excessively peaked; the centre is better sorted than the ends.
1.50 < 3.00	Very Leptokurtic	
3.00 +	Extremely Leptokurtic	

3.2. Sediment Total Organic Matter (TOM) and Organic Carbon (TOC)

TOM was analysed using 1g of air dried and ground sample (<200µm) placed in a crucible and dried in an oven at 50±2.5°C until constant weight was achieved. The final sample weight was recorded to the nearest 0.1% and the sample was allowed to cool in a desiccator. The sample was then placed in an muffle furnace and heated to 440±25°C for 4 hours. The crucible was removed from the furnace and allowed to cool to room temperature in a desiccator. The crucible was then reweighed and the percentage loss on ignition calculated.

TOC was analysed using a combustion method (5310B, AWWA/APHA, 20th Ed., 1999 / DIN EN 13137, accredited to ISO 17025). This method is used for total carbon analysis of dried, crushed rock powder and environmental soil samples. The samples are previously treated with 10% HCl to obtain material containing only organic carbon compounds.

The Carbon Analyser heats the sample in a flow of oxygen and any carbon present is converted to carbon dioxide which is measured by infra-red absorption. The percentage carbon is then calculated with respect to the original sample weight. The range for the method is 0.01 - 100%.

3.3. Hydrocarbon Concentrations (Total hydrocarbon Concentrations and Aliphatics)

This method details the solvent extraction of sediment samples to quantify the toluene equivalent organic contaminants present and to prepare samples for further analysis by Gas Chromatography (GC) and GC-Mass Spectrometry (GC-MS).

3.3.1. General Precautions

High purity solvents were used throughout. Solvent purity was assessed by evaporating an appropriate volume to 1ml and analysing the concentrate by GC for general hydrocarbons, target n-alkanes and aromatics. All glassware and extraction sundries were cleaned prior to use by thorough rinsing with hydrocarbon-free deionised water followed by two rinses with dichloromethane. All glassware was heated in a high temperature oven at 450 degrees C for 6 hours.

3.3.2. Extraction Procedure for Hydrocarbons

Each analytical sample (15 ± 0.1g) was spiked with a internal standard solution containing the following components: aliphatics - heptamethylnonane, 1-chlorooctadecane and squalane; aromatics - naphthalene-d8, anthracene-d10 and pyrene-d10. The sample was then wet vortex extracted using 3 successive aliquots of DCM/Methanol. The extracts were combined and water partitioned to remove the Methanol and any excess water from the sample.

Solvent extracts were chemically dried and then reduced to approximately 1ml using a Kuderna Danish evaporator with micro Snyder.

3.3.3. Column fractionation for Aliphatic and Aromatic Fractions

The concentrated extract was transferred to a pre-conditioned flash chromatography column containing approximately 1g of activated Silica gel. The compounds were eluted with 3ml of Pentane/DCM (2:1). An aliquot of the extract was then taken and analysed for total hydrocarbon (THC) content and individual n-alkanes by large volume injection GC-FID and one taken to be analysed for PAHs by GC-MS-SIM.

3.3.4. Quality Control Samples

The following quality control samples were prepared with the batches of sediment samples:

i A method blank comprising 15 ± 0.1g of baked anhydrous sodium sulphate (organic free) treated as a sample.

ii A matrix matched standard sample consisting of 15 ± 0.1 g baked sand spiked with USEPA(16) PAHs + Dibenzothiophene and Florida mix and treated as sample.

iii A sample duplicate - any one sample from the batch, dependent upon available sample mass, analysed in duplicate.

3.3.5. Hydrocarbon Analysis

Analysis of total hydrocarbons and aliphatics was performed by using a Agilent 6890 with an FID detector. PAHs, DBT and alkylated derivative analysis was performed by GC-MS to UK offshore specifications (DTI, 1993) using selected-ion monitoring mode (SIM). Appropriate column and GC conditions were used to provide sufficient chromatographic separation of all analytes and the required sensitivity.

3.3.6. Calibration and Calculation

GC techniques require the use of internal standards in order to obtain quantitative results. The technique requires addition of non-naturally occurring compounds to the sample, allowing correction for varying recovery .

Target analytes concentrations are calculated by comparison to the nearest eluting internal standards. A relative response factor was applied to correct the data for the differing responses of target analytes and internal standards. Response factors were established prior to running samples, from solutions containing USEPA(16) PAHs + Dibenzothiophene for the GCMS, Florida mix (even n-Alkanes nC10-nC40) for individual GCFID targets and a Diesel/Mineral Oil mix for total oil determination.

The assumption is made that the alkylated PAHs have a similar response to that of the non-alkylated parent, as the full range of such compounds is not commercially available. Method blanks and spiked matrix samples were analysed with each batch of samples. Calibration check standards are analysed before and after every batch and the response factors compared with the initial calibration. The sample concentration is calculated using the response factors from the continuing calibration. Detection limits are based on the levels at which the laboratory is confident of the instruments ability to measure concentrations accurately.

The mean detection limits used for the sediment total hydrocarbons and n-alkanes were:

1. n-alkanes — $1ng.g^{-1}$ (ppb)
2. PAHs — $1ng.g^{-1}$ (ppb)
3. Total Hydrocarbon — $100ng.g^{-1}$ (ppb)

3.4. Heavy & Trace Metal Concentrations

Sediment samples were homogenised and a 50g portion was air dried at room temperature. Each sample was then ground down to a fine powder (<100µm) by hand using a mortar and pestle. A clean blank sand sample was hand ground prior to preparation of the field samples to identify the presence of any trace metals in the system.

3.4. Heavy & Trace Metal Concentrations (TES Bretby)

Sediment samples were homogenised and a 50g portion of each sample was air dried at room temperature. Each sample was then ground down to a fine powder (<100µm) by hand using a metal free mortar and pestle. A clean sand sample was hand ground prior to preparation of the field samples as a blank.

3.4.1. Sample Digestion Procedure

Acid Leachable Metals (Mn, Fe, Ba, Sr , Al, Cr, Cu, Ni, Zn, Mn, V, As, Pb ,Cd)

Approximately 1g of the sediment was accurately weighed out and transferred to a beaker and wet with approximately 20ml of distilled water. Hydrochloric acid (6ml) and Nitric acids (2ml) were added, and the covered sample left to digest for 4 hours in a steam bath. After digestion, the sample was filtered through a Whatman 542 filter paper into a 100ml standard flask. The watch-glass and beaker were rinsed thoroughly, transferring the washings to the filter paper. The filter paper was rinsed until the volume was approximately 90ml. The filter funnel was rinsed into the flask and then the flask was made up to a 100ml volume and mixed well. The filtrate was the analysed by ICP-OES and/or ICP-MS.

Total Metals by ICPOES (Hydrofluoric /Boric acid Extractable Metals - Fe, Ba, Sr & Al.)

Approximately 0.20g of the sediment sample was accurately weighed out and placed in a PTFE bottle and 2.5mls of Hydrofluoric acid was added. The bottle was then placed in an oven at 105±5°C for approximately 30 minutes and then allowed to air cool in a fume cupboard. A further 65mls of 4% Boric acid was then added to the bottle and the contents are then mixed thoroughly and placed in a polypropylene flask. The solution was then made up to 100ml with deionised water and analysed by ICP-OES.

Total Metals by ICPMS (Hydrofluoric /Nitric acid Extractable Metals - Cr, Cu, Ni, Zn, As, Pb, Sn, V & Cd)

Approximately 0.10g of the sediment sample was accurately weighed out and placed in a PTFE bottle. Approximately 1ml of Hydrofluoric acid, 1ml of nitric acid and 1 ml of water were added and the bottle placed in an oven at 105±5°C for approximately 60 minutes. The bottle was then allowed to air cool in a fume cupboard. The extract was transferred to a plastic beaker and evaporated to dryness. The residue was then cooled and dissolved in 2 ml of nitric acid. This was transferred to a 100ml volumetric flask and made up to volume with deionised water. The metals concentrations in the extract were determined by ICP-MS

The mean detection limits are given in Table 3.5 for acid leachable (AL) and hydrofluoric acid (HF) digestions.

Table 3.5 ***Heavy Metals - Mean Detection Limits (MDL)***

Analyte	Unit	MDL	
		AL	HF
Ni	$\mu g.g^{-1}$	1	5
V	$\mu g.g^{-1}$	1	5
Al	$\mu g.g^{-1}$	10	10
Zn	$\mu g.g^{-1}$	5	5
Fe	$\mu g.g^{-1}$	5	10
Cu	$\mu g.g^{-1}$	1	5
Ba	$\mu g.g^{-1}$	5	5
Cr	$\mu g.g^{-1}$	1	5
As	$\mu g.g^{-1}$	1	1
Cd	$\mu g.g^{-1}$	1	1
Pb	$\mu g.g^{-1}$	1	1
Sn	$\mu g.g^{-1}$	10	0.5
Hg	$\mu g.g^{-1}$	0.01	0.01

ICPMS ICPOES

Mercury Digestion Procedure

Approximately 1g of the sediment was accurately weighed out and transferred to a beaker. Hydrogen peroxide (10ml of 30 volumes) was added, and the covered sample left to digest for 0.5 hour in the fume cupboard. 10ml of nitric acid was added and the sample placed on the hotplate for 1 hour.

After digestion, the sample was filtered through a Whatman 542 filter paper into a 100ml standard flask. The watch-glass and beaker were rinsed thoroughly, transferring the washings to the filter paper. The filter paper was rinsed until the volume was approximately 90ml. The filter funnel was rinsed into the flask and then the flask was made up to 100ml volume and mixed well. The filtrate was the analysed by ICP-MS.

3.4.2. Analytical Methodology

Inductively Coupled Plasma Optical Emission Spectrometry

Calibration
The instrument is calibrated using dilutions of the 1ml=10mg spectroscopic solutions. The final calibration solutions are matrix matched with the relevant acids. The calibration line consists of 5 standards. Specific metal wavelengths are given in table 3.6.

Inductively Coupled Plasma- Mass Spectrometry

Calibration
The instrument is calibrated using dilutions of the 1ml=10mg spectroscopic solutions. The calibration line consists of 7 standards. The atomic masses used are as given in table 3.6.

The analytes are scaled against internal standards to take account of changes in plasma conditions as a result of matrix differences for standards and samples. The internal standards have a similar mass and ionisation properties to the target metals.

Table 3.6. Element Selection Criteria using ICP

Element	ICPOES (nano metre)	ICP-MS (atomic mass)
As	189.04	75
Ba	233.53	-
Cd	226.50	111
Cr	267.72	52
Pb	220.35	208
Hg	-	80
Ni	231.60	60
V	290.88	51
Zn	213.86	66

3.5. Faunal Analysis

All macrofaunal determination was carried out using a laboratory operated by Benthic Solutions Limited. The senior taxonomist was involved with previous macrofaunal identification undertaken in the Falklands region (FOSA 1998, Fisheries Inshore EIA in 2000, Regional North Falkland Basin in 2008). Benthic sediment samples were thoroughly washed with freshwater on a 500µm sieve to remove traces of formalin, placed in gridded, white trays and then hand sorted by eye followed by binocular microscope to remove all fauna. Sorted organisms were preserved in 70% Industrial Methylated Spirit (IMS) and 5% glycerol. Where possible, all organisms were identified to species level according appropriate keys for the region. This includes specialist patagonian material obtained from German cruises carried out in the 1970's. Colonial and encrusting organisms were recorded by presence alone and where colonies could be identified as a single example these were also recorded, although these data have been removed from the analyses of the material. The presence of anthropogenic components were also recorded where relevant.

Benthic Solutions is committed to total quality control from the start of a project to its completion. All samples taken or received by the company were given a unique identification number. All analytical methods were carried out according to recognised standards for marine analyses. All taxonomic staff are fully qualified to post-doctorate level. Documentation is maintained that indicates the stage of analysis that each sample has reached. A full reference collection of all specimens has been retained for further clarification of putative species groups where/if required. BSL is a participant in the NMBAQC quality assurance scheme.

Digital datasets are kept for all sites in the form of excel spreadsheets (by sample and by station) on BSL's archive computer. This system is duplicated onto a second archive drive in case of electronic failure. These data will be stored in this way for a minimum of 3 years, or transferred to storage disk (data CD or DVD).

All taxa were distinguished to species level and identified to at least family level where possible, although as little is known of about the area, many of the species were separated putatively. Whilst some of the groups were only partially separated in this document, ongoing analysis with further site-specific well sites will increase our knowledge of the area and a more definitive faunal matrix will be provided at a later point in time. Nomenclature for species names were allocated either when identity was confirmed, allocated as "cf." when apparently identifying to a known species but confirmation was not possible (for example, incomplete specimens or descriptions), or allocated as "aff." when close to but distinct from a described species. The terms "indet." refers to being unable to identify to a lower taxon and "juv" as a juvenile to that species, genus or family. Species lists for 22 stations (48 samples (1 to 3 replicates per station)), together with univariate parameters for both sample replicates and stations, are given within Appendix V.

3.5.1 Data Standardisation and Analyses

In accordance to OSPAR Commission (2004) guidelines, all species falling into juvenile, colonial, planktonic of meiofaunal taxa are excluded from the full analyses within the dataset (this is discussed further within the text of section 4.6). This helps to reduce the variability of data undertaken during different periods within the year, or where minor changes may occur or where some groups may only be included in a non-quantitative fashion, such as presence/absence. Certain taxa, such as the Nematodes, normally associated with meiofauna, were included where individuals greater than 10mm were recorded. The following primary and univariate parameters were calculated for each all data by stations and sample (Table 3.8).

Table 3.8. Primary and Univariate Parameter Calculations

Variable	Parameter	Formula	Description
Total Species	S	Number of species recorded	Species richness
Total Individuals	N	Number of individuals recorded	Sample abundance
Shannon-Weiner Index	H(s)	$H(s) = -\sum_{i=1}^{s} (Pi)(\log_2 Pi)$ where s = number of species & Pi = proportion of total sample belonging to *i*th species.	Diversity: using both richness and equitability, recorded in log 2.
Simpsons Dominance	1-Lambda	$Lambda = \sum \left(\frac{ni(ni-1)}{N(N-1)} \right)$ where ni = number of individuals in the *i*th species & N = total number of individuals	Evenness, related to dominance of most common species (simpson 1949)
Pielou's Equitability	J	$J = \frac{H(s)}{(\log S)}$ where s = number of species & H(s) = Shannon-Weiner diversity index.	Evenness or distribution between species (Pielou, 1969)
Margalefs Richness	D_{Mg}	$D_{Mg} = \frac{(S-1)}{(\log N)}$ where s = number of species & N = number of individuals.	Richness derived from number of species and total number of individuals (Clifford & Stevenson, 1975)

In addition to univariate methods of analysis, data for both sample replicates and stations were analysed using multivariate techniques. These serve to reduce complex species-site data to a form that is visually interpretable. A multivariate analyses was based on transformed data (double square root) to detect any improved relationships when effects of dominance were reduced. The basis for multivariate analyses was based upon the software PRIMER (Plymouth Routines In Multivariate Ecological Research).

Similarity Matrices and Hierarchical Agglomerative Clustering
A similarity matrix is used to compare every individual sample replicate and/or stations with each other. The coefficient used in this process is based upon Bray Curtis (Bray & Curtis, 1957), considered to be the most suitable for community data. These are subsequently assigned into groups of replicates and/or stations according to their level of similarity and clustered together based upon a Group Average Method into a dendrogram of similarity.

Non-Metric Multidimensional Scaling (nMDS): nMDS is currently widely used in the analysis of spatial and temporal change in benthic communities (e.g. Warwick & Clarke, 1991). The recorded observations from data were exposed to computation of triangular matrices of similarities between all pairs of samples. The similarity of every pair of sites was computed using the Bray-Curtis index on transformed data. Clustering was by a hierarchical agglomerative method using group average sorting, and the results are presented as a dendrogram and as a two-dimensional ordination plot. The degree of distortion involved in producing an ordination gives an indication of the adequacy of the nMDS representation and is recorded as a stress value as outline in Table 3.9.

Table 3.9. Inference from nMDS Stress Values

nMDS Stress	Adequacy of Representation for Two-Dimensional Plot
≤0.05	Excellent representation with no prospect of misinterpretation.
>0.05 to 0.1	Good ordination with no real prospect of a misleading interpretation.
>0.1 to 0.2	Potentially useful 2-d plot, though for values at the upper end of this range too much reliance should not be placed on plot detail; superimposition of clusters should be undertaken to verify conclusions.
>0.2 to 0.3	Ordination should be treated with scepticism. Clusters may be superimposed to verify conclusions, but ordinations with stress values >2.5 should be discarded. A 3-d ordination may be more appropriate.
>0.3	Ordination is unreliable with points close to being arbitrarily placed in the 2-d plot. A 3-d ordination should be examined.

SIMPER: the nMDS clustering program is used to analyse differences between sites. SIMPER enables those species responsible for differences to be identified by examining the contribution of individual species to the similarity measure. As all sites grouped within a single cluster, this program was subsequently not used.

3.6. Environmental Data Presentation using Contouring Software

To aid in the interpretation and presentation of the environmental information acquired for this report, both hydrographic and environmental variables were processed using contouring and 3D surface mapping software (Surfer v8). This software allows a digital terrain model (DTM), or grid, to be interpolated from irregularly spaced geographical information (XYZ data). When large quantities of data are used (such as in swathe bathymetry), the level of interpolation is limited only to small spaces in between the data points. However, when processing environmental variables only 39 stations were sampled and analysed during the benthic survey. In this instance a diagrammatic circle of a 2000m diameter has been used to colour illustrate the parameter level at each relevant site. It should be remembered that this is done for presentation purposes only and that these data values are "not representative" for the whole of the geographical area covered by the circle.

3.7. Data Comparisons and Historical Datasets

During the interpretation, data comparisons have been made to previous survey data from the North Falkland Basin surveyed for Desire, Rockhopper and Arcadia (BSL 2008) and surveys carried out on the east Falkland continental margin Slope in 2009 by BHP Petreoluem (Fugro 2009a-d). Sources used in this comparison are outlined below in Table 3.10:

Table 3.10. Historical Datasets used for Comparison in the Survey Area

Source and Year	Contractor	Region and Comment
AFEN 1996-2000	NOC	Northeast Atlantic from 100-2000 metres water depth. Three cruises.
BSL 2008	Benthic Solutions	Regional benthic environmental survey program for Desire, Rockhopper and arcadia in the North Falkland Basin.
Fugro 2009a	Fugro Surveys Limited	Benthic Survey as Toroa sites for BHP Petroleum
Fugro 2009b		Benthic Survey as Nimrod sites for BHP Petroleum
Fugro 2009c		Benthic Survey as Loligo sites for BHP Petroleum
Fugro 2009d		Benthic Survey as Endeavour sites for BHP Petroleum

Other referenced data will be based on standard North Sea and Northeast Atlantic levels as published by mean and 95th percentile values for background sediments (UKOOA, 2001).

4. DISCUSSION

A summary of the regional geological and bathymetric conditions is given below. This is taken from a general review of the geology south of the Falklands, and in particular the area around the Burdwood Bank, South Falkland Basin and South and eastern continental margin. Most previous survey activities have been undertaken to the north of the islands in relation to the North Falkland Basin and Continental Shelf (Gardline 1998a-h and BSL 2008), although recent survey activities have been undertaken by BHP petroleum along the eastern continental margin, north of the proposed survey area (FSL 2009a-d).

4.1. Regional Geological and Bathymetry

The South Falkland Basin is located immediately south of the Falkland Islands and is bounded by the Malvinas Basin to the west, the Falkland Plateaux to the east and the Burdwood Bank to the south. The continental margin to the south of the Falkland Islands developed as a passive coastal margin bordering the developing Weddell sea during the late Jurassic and continued in this plate setting for much of the Cretaceous. During the late Cretaceous and early Tertiary plate movements that had initially created the Andean orogeny caused the subduction of the western Weddell oceanic plate, loading the continental plate to the south of the Falkland Islands. Loading created a foreland basin that was filled with sediments from both the emergent Falkland Islands and the developing thrust front. The northward movement of the Burdwood Bank initiated the inversion of the foreland basin creating a series of prograding north-vergent stack of blind and emergent thrusts seen along the southern margin of the South Falkland Basin.

The Falkland Islands themselves comprise of a series of Pre-Cambrian to Permo-Carboniferous aged rocks. Traversing south across the continental margin these 'basement' sequences can be seen to subcrop the seabed until onlapped by the late Jurassic and Cretaceous passive margin sequences (Figure 4.1). Downdip these extensional passive margin sequences are buried beneath a prograding wedge of Tertiary sediments that infilled the developing foreland basin. Moving further south the tectonic front that marks the northern progress of the thrust sheets is expressed by a series of north-vergent stack of blind and emergent thrusts. The thrust front forms a series of elongate east-west oriented thrust tip anticlines. The magnitude of the uplift increases to the south stepping the seabed up from the foreland deep to eventually plateaux at the Burdwood Bank were the seabed shallows to just 200m.

The inversion of the foreland basin in the south has led to the development of vast elongate thrust tip anticlines. The uplift led to subsequent erosion of sediments from the crest of the anticlines. The seabed in the south is therefore comprised of exposed older Tertiary sequences along the anticline crests and younger more recent eroded sediments in the troughs Further south across the Burdwood Bank it is anticipated that Cretaceous sequences subcrop the seabed. Moving northwards away from the thrusts the seabed represents the undeformed forland basin filled with the more recent sediment detritus. Seismic character of the sediments indicate that sediment infill is derived mostly from erosion of the hinterlands. Significant thrusting and uplift is thought to have ceased around 5 to 10 millions years ago. The lack of sediment drape over the undulating seabed topography either indicates low pelagic productivity or sufficient water column movement to prevent pelagic sediment accumulation.

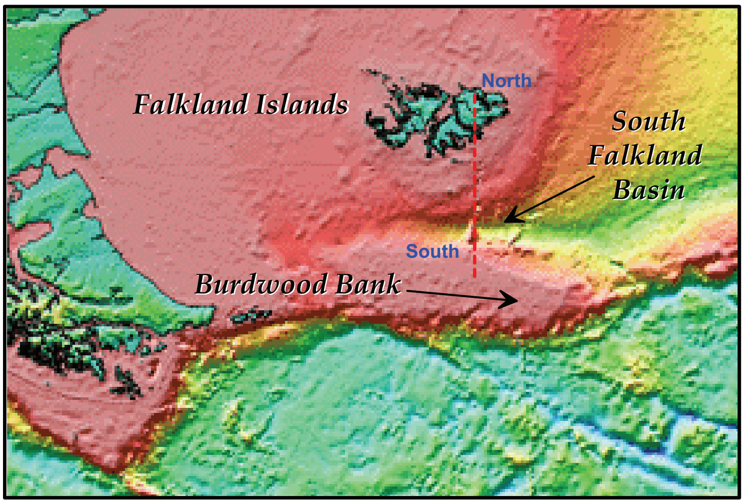
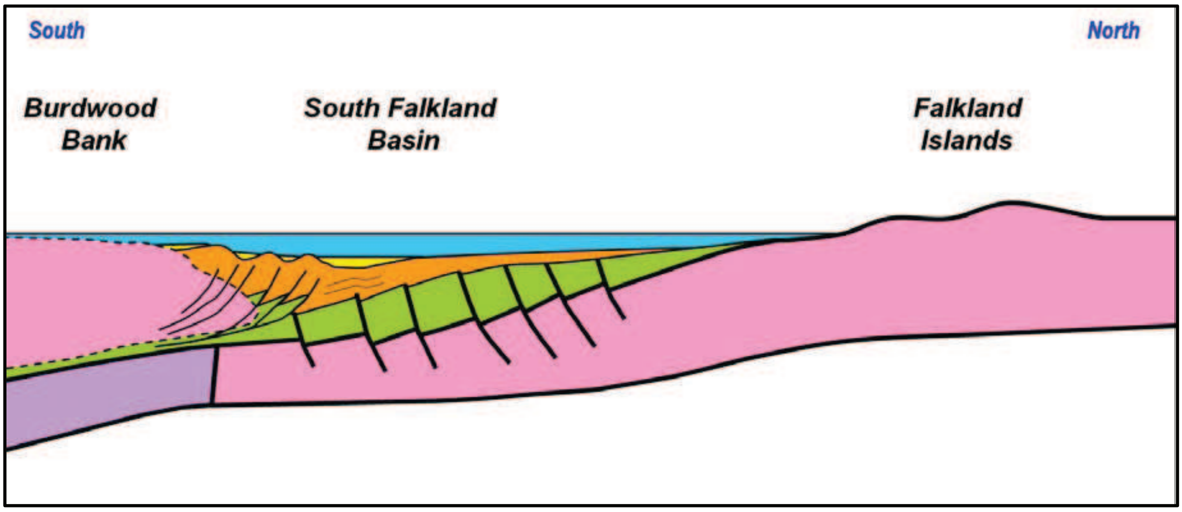


Figure 4.1.
Regional Bathymetry and Geological Context of the Burdwood Bank and South Falkland Basin

Geological Legend

- Recent sediments
- Upper Cretaceous and Tertiary sequences
- Jurassic and Cretaceous sequences
- Continental crust and basement rocks
- Oceanic crust

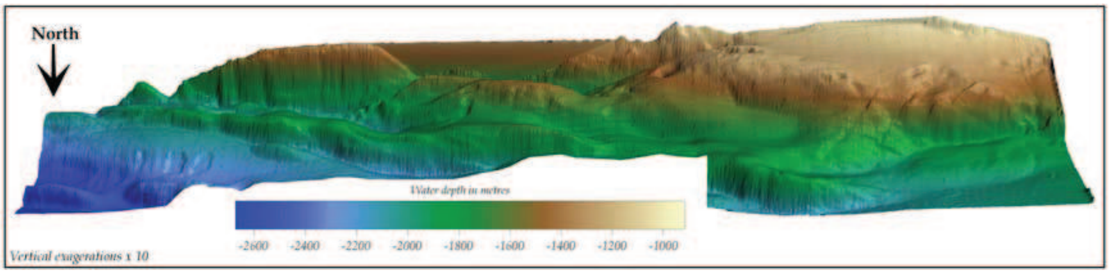


Borders and Southern acreage occupies the area between the northern boundary of the Burdwood Bank and the undeformed foreland basin. The benthic survey area comprises an undulating seabed topography formed by thrust cored anticlines and relatively flat seabed areas above the undeformed foreland basin. These geological features can clearly be seen in a geographical representation of the regional bathymetry represented as an isometric view from the north (Figure 4.2). This was produced by processing the surface return from the 3D seismic data. A number of these features (such as small banks produced by the thrust anticlines, uneven areas within the main bank, and undeformed areas within the basin) have been targeted during the environmental survey program in addition to sites covering the prospect areas (see figure 2.1).

Currently, there have been no sampling operations carried out in this area, with all previous survey activities limited to the North Falkland Basin (Gardline 1998 a-f, BSL 2008). Neighbouring blocks to the northwest of the Burdwood Bank area were recently surveyed using a combination of broad acoustic (swathe bathymetry), seabed sampling and some minor seabed video (acquired at two sites using ROV;

FSL 2009a-d). Of the four areas surveyed, locations varied from 75m Northeast (Toroa) in approximately 650m water depth, to 424km northeast (Endeavour) in approximately 1,350m water depth, with two further sites in between (Nimrod and Loligo). Results relating to the Toroa and the Loligo location indicated different sediments that were similar to those exhibited at the Burdwood Bank and will be used for comparative purposes within this document where relevant. Furthermore, as some of the environmental variables recorded at the Burdwood Bank indicate a large regional pattern of distribution, comparative results recovered at all sites along the eastern Falkland margin are used to represent these patterns.

Figure 4.2. Isometric View of Bathymetry at Burdwood Bank Regional Survey Area



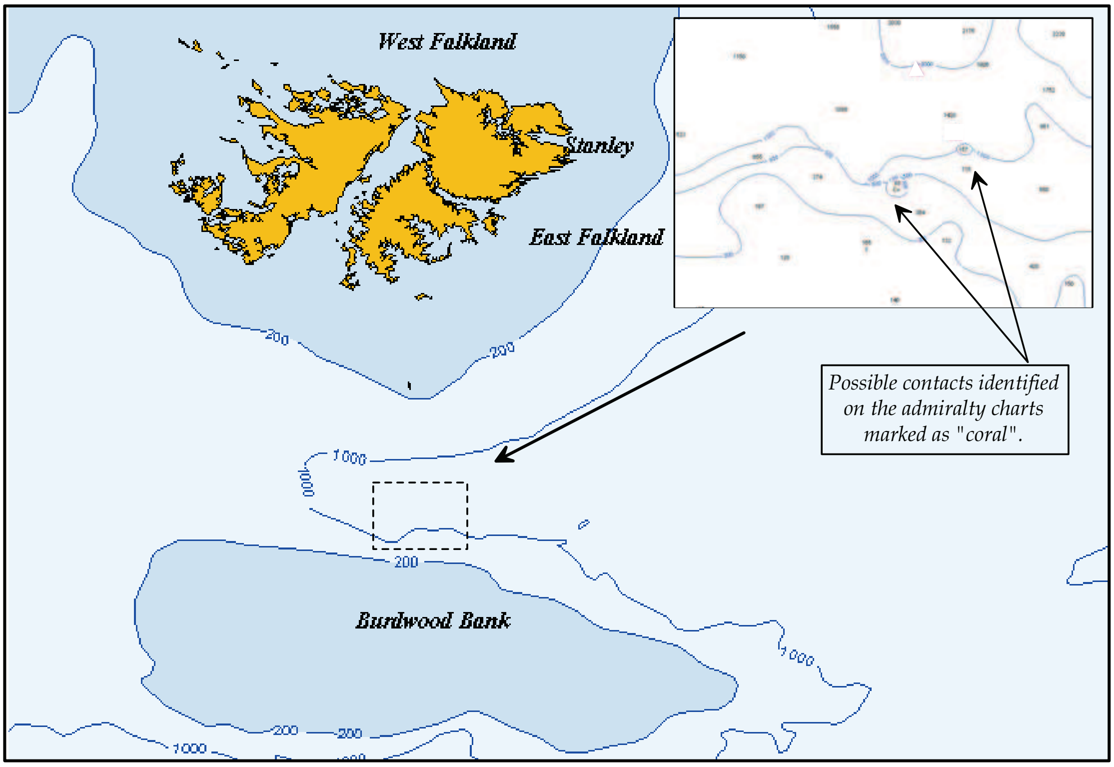
In addition to the benthic communities, an appreciation of the habitat types recorded on the Burdwood Bank and within the South Falkland Basin is important, particularly if these are considered to be of conservational importance. Legislation into the protection of certain marine habitats has altered dramatically in recent years and now constitutes a very central aspect to any environmental assessment for offshore developments. As little is known of the seabed in this area the current baseline will also be assessed for sensitive, or potentially internationally important habitats. Examples that might be encountered in Falkland waters are as follows:

- Coldwater seep communities often associated with active pock marks (escaping gases and fluids);
- Chemosynthetic structures associated with methane derived authigenic carbonates with active gas seeps;
- Biogenic reefs associated with coldwater corals (*Lophelia* and *Madrepora*), octocorals, demosponges, mollusc beds (*Modiolus*) or polychaete concretions (*Sabelleria);*
- Rocky reefs (seamounts and volcanic outcrops) which may have an affect on current circulation and provide a hard substrate in an otherwise soft sediment environment.

No evidence of these features have been recorded from this area. However, some of the geological profiles indicated the possible presence of gas hydrates close to the surface. Also the detailed regional bathymetry (figure 4.2), shows the presence of possible rock outcropping through a slight irregularity within the surface textures in certain areas.

The admiralty charts of the area identified a couple of very steep bathymetric rises to the south of the current survey area, but still on the northern side of the Burdwood Bank (Figure 4.3). As these show very steep contours from 500 and 1000m shoaling to 88 and 157m, respectively and annotated with a "coral" sediment type these were additionally investigated during the current survey operations. No evidence of these feature existed with the 88m features recording a measured water depth of 1200m and a homogeneous sand recovered. Consequently, these are thought to be erroneous on the charts.

Figure 4.3. Regional Contacts Identified on Admiralty Charts, in the South Falkland Basin



4.2 Particle Size Distribution

Analytical results of all the processed samples, along with observations made within the field indicated that the seabed within the regional survey area showed considerable variability in sediment distributions relative to location on the Burdwood Bank or within the South Falkland Basin. Overall mean particle sizes varied from poorly sorted very fine sands at station 4 (a small indentation on the northern edge of the Burdwood Bank), to very poorly sorted medium sand at station 7 (on a small bathymetric rise in the central area ; Figure 4.4 to 4.6). The distribution of mean sediment sizes ranged from medium silt around 24µm (station 23) to medium sand 355µm (station 19), with significant variability between these averages throughout the area. The total mean for all survey stations was very fine sand (160µm, SD 130µm) but with a large percentage variance of 81.2%. This is the percentage of the standard deviation to the mean. No significant pattern of distribution is evident other than lower mean particle size in the northwest region of the survey area (i.e. stations 12, 13, 14 and 23).

Table 4.1. *Summary of Surface Particle Size Distribution*

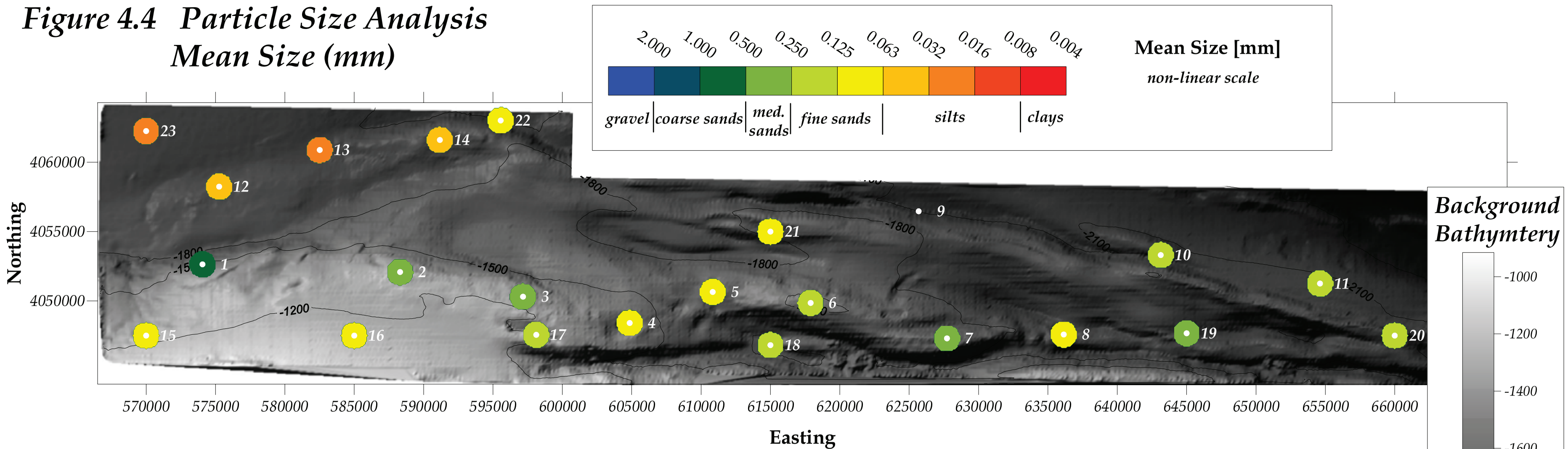
Station	Mean Size		Median	Sorting	Skewness	Kurtosis	% Fines	% Sands	% Gravel
	mm	Phi							
Station 1	0.564	0.83	0.437	2.36	-0.10	1.30	8.8%	71.1%	20.2%
Station 2	0.276	1.86	0.351	2.26	0.29	1.58	15.9%	76.3%	7.8%
Station 3	0.328	1.61	0.282	3.23	-0.01	0.91	20.9%	52.9%	26.3%
Station 4	0.109	3.19	0.116	1.21	0.29	1.63	18.7%	81.1%	0.2%
Station 5	0.068	3.89	0.093	2.52	0.21	1.15	38.6%	57.7%	3.7%
Station 6	0.128	2.97	0.167	2.59	0.16	1.63	24.3%	65.4%	10.3%
Station 7	0.276	1.86	0.130	3.27	-0.31	2.05	23.1%	58.5%	18.3%
Station 8	0.093	3.43	0.120	1.75	0.39	1.55	25.3%	71.5%	3.2%
Station 10	0.169	2.56	0.240	2.03	0.43	1.43	20.0%	76.7%	3.3%
Station 11	0.172	2.54	0.197	2.51	0.08	1.71	21.0%	66.0%	13.1%
Station 12	0.036	4.79	0.048	1.98	0.32	1.01	59.7%	40.3%	0.0%
Station 13	0.031	4.99	0.036	1.93	0.18	0.97	67.3%	32.7%	0.0%
Station 14	0.061	4.03	0.078	3.07	0.08	1.08	46.6%	43.9%	9.5%
Station 15	0.063	3.98	0.091	1.70	0.50	1.45	32.4%	67.6%	0.0%
Station 16	0.101	3.31	0.111	1.31	0.34	1.64	22.1%	77.8%	0.1%
Station 17	0.202	2.31	0.229	1.60	0.27	1.31	13.8%	83.6%	2.6%
Station 18	0.138	2.86	0.150	1.26	0.37	1.77	14.2%	85.8%	0.0%
Station 19	0.335	1.58	0.427	2.31	0.34	1.18	15.6%	79.1%	5.3%
Station 20	0.180	2.48	0.171	2.63	-0.06	1.91	21.0%	63.7%	15.3%
Station 21	0.070	3.83	0.101	2.07	0.35	1.06	35.5%	60.3%	4.2%
Station 22	0.093	3.42	0.116	2.93	0.14	0.86	42.1%	53.1%	4.9%
Station 23	0.024	5.41	0.026	1.88	0.15	1.07	79.0%	21.0%	0.0%
Survey	**0.16**	**3.08**	**0.17**	**2.20**	**0.20**	**1.38**	**0.30**	**0.63**	**0.07**
St Dev	**0.13**	**1.181**	**0.116**	**0.611**	**0.195**	**0.341**	**0.185**	**0.17**	**0.0758**
% variance	**81.2%**	**38.4%**	**68.9%**	**27.8%**	**97.6%**	**24.8%**	**61.2%**	**27.1%**	**112.4%**
Toroa 2009a	**0.031**	**5.00**	**-**	**1.54**	**-**	**-**	**77.8%**	**22.2%**	**0.0%**
Loligo 2009c	**1.743**	**1.02**	**-**	**1.02**	**-**	**-**	**16.7%**	**57.5%**	**25.7%**
North Falklands 2008	**156.5**	**2.74**	**1.46**	**0.27**	**1.39**	**-**	**17.4%**	**81.5%**	**1.1%**

The use of mean sediment sizes is very limited due to the variability within the distributions of size classes encountered for individual stations. These reflect a notable variability in the surface geology across the survey area. This is highlighted by the general variability in sediment sorting throughout the survey area (Figure 4.6). The clearest separation of sizes classes is recorded within the proportion of sediment fines (i.e. particle below 63µm relating to silts and clays). For this parameters, the proportion of fines varied from 8.8% recorded at Station 1 (northern edge of the Burdwood Bank) to 79% recorded at stations 23 (northwest extreme of the survey area; Figure 4.7). Furthermore, unlike the mean sediment type, the survey revealed a clear pattern of distribution with increased fines found at the five stations in the northwest (Stations 12-14, 22 and 23) which all showed elevated fines above 43%. Bathymetrically, all of these stations fall north of the Burdwood Bank northern slope and relate to a sedimentary basin in the north of the survey area. Elsewhere, the percentage fines were typically between 15 and 35% (mean 30%, SD 18.5%).

Similar to percentage fines, the proportion of gravels (coarser sediments larger than 2mm) was also quite variable, but without any significant pattern of distribution (Figure 4.8). This fraction varied from an undetectable percentage (recorded for five 5 stations), to a moderate 26.3%, recorded Station 3 (northern slope of the Burdwood Bank). The presence of small rounded glacial gravels were recorded at most sites (Figure 4.9a), although the proportion of these were low or absent within the basin to the northwest (stations 12, 13 and 23) and along the northern slope of the Burdwood Bank slope at stations 15, 16 and 17. At some stations, these drop stones were quite large with cobble examples recorded at stations 1 and 10 (Figures 4.9b and 4.9c respectively). The greatest concentration of glacial drops stones was recorded along the base of the Burdwood Bank (station 1-3) or on top of localised bathymetric highs (such as stations 6 and 8). Other coarse materials were related to either bedrock, recorded in area of variable topography at station 17 (Figure 4.9d), or a large amount of gravel sized carbonates recorded at station 2 (Figure 4.9e). For the latter, this predominantly biogenic material indicated the presence of a possible contourite substrate, where slightly lower density carbonate fragments are winnowed into localised mounds of sediment aggregations by the prevailing currents.

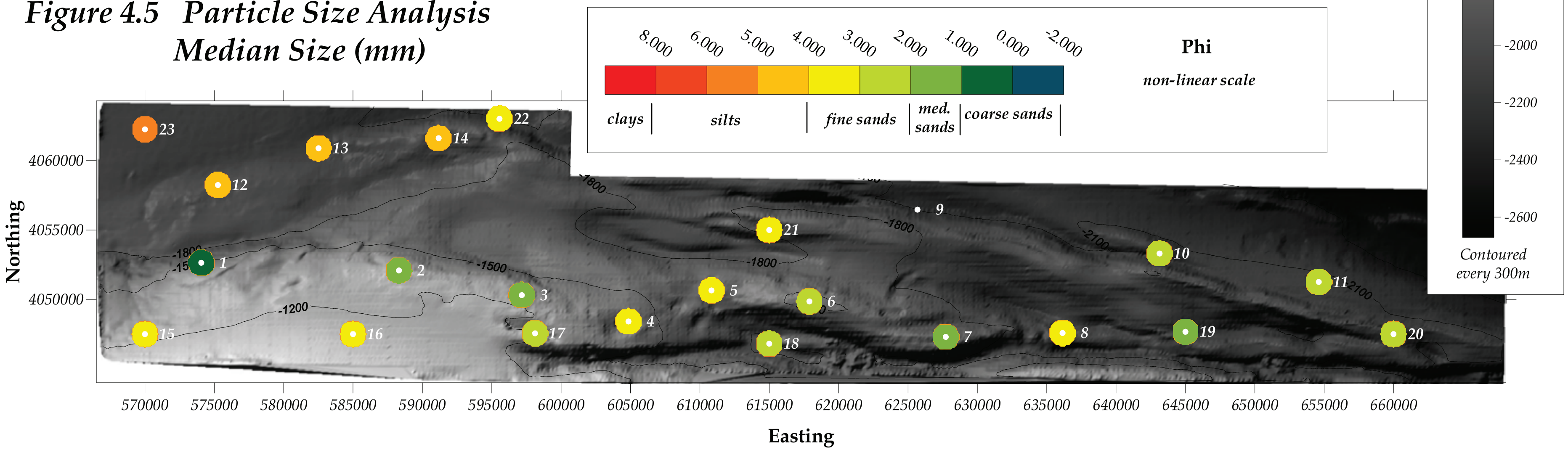
It should be noted that owing to the nature of the survey operations, the sampling of mixed sediment substrates has a tendency to bias sample results towards the finer components. This is due to the fact that coarse sediment patches are problematic during recovery due to interference to the samplers operation and due to the relatively small sub-sample obtained for laboratory analysis. Field observations and photographs of the samples (Appendix VI) showed that this may have occurred on stations 1, 10 and 17. Nevertheless, “no sample” attempts were relatively rare and the majority of gravel fractions where below the granule to small pebble size range allowing them to be recorded during normal operations.

Figure 4.4 Particle Size Analysis Mean Size (mm)



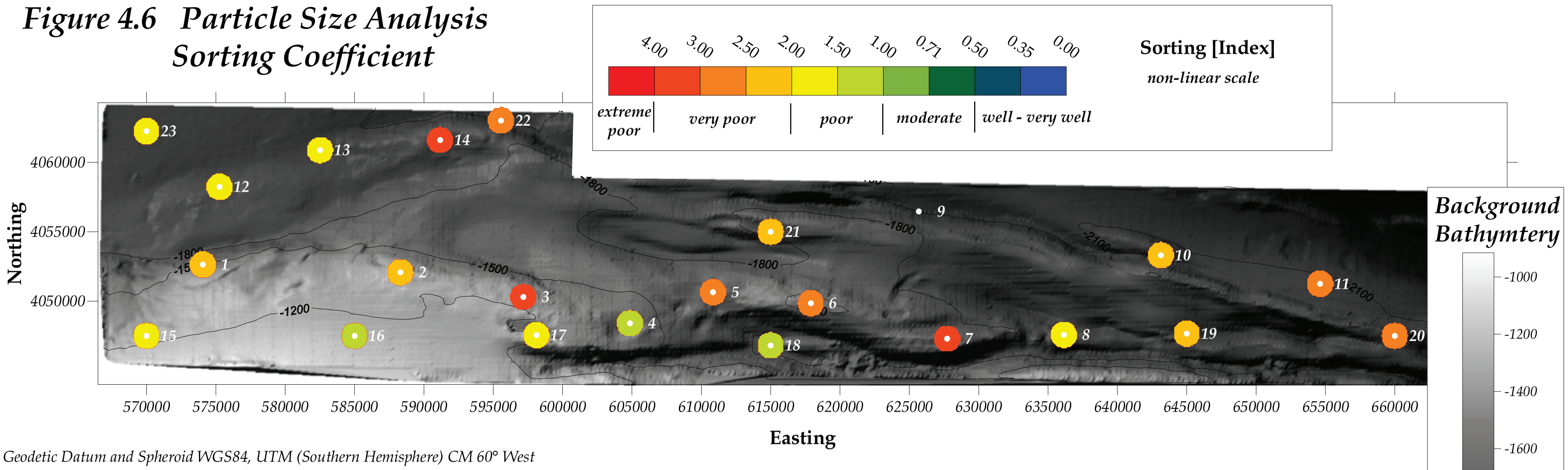
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.5 Particle Size Analysis Median Size (mm)



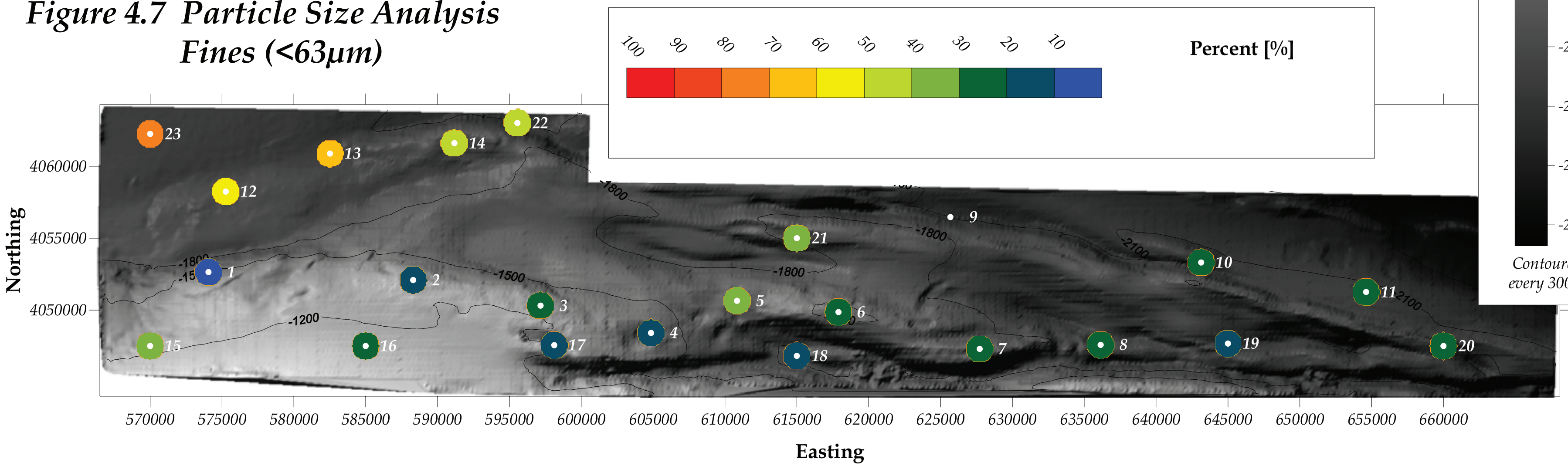
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.6 Particle Size Analysis Sorting Coefficient



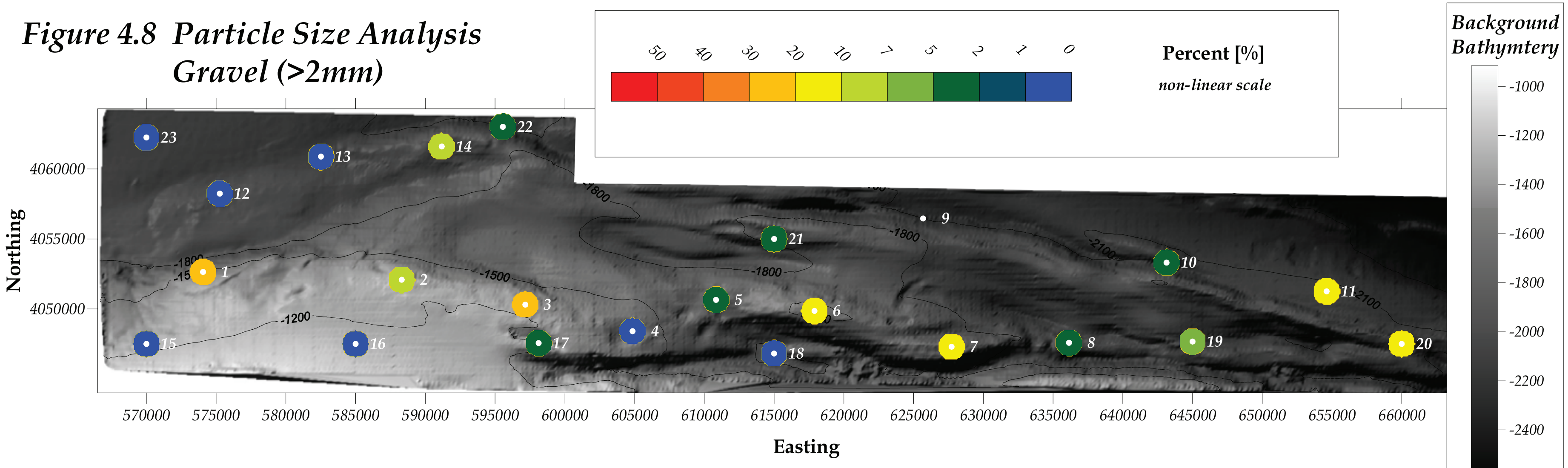
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.7 Particle Size Analysis Fines (<63µm)

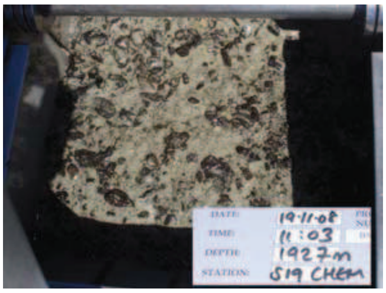


Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.8 Particle Size Analysis Gravel (>2mm)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

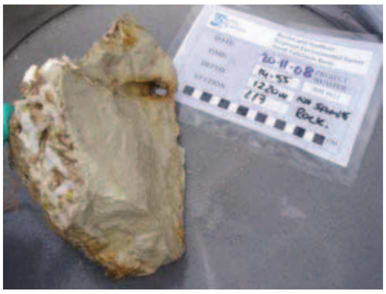


(a) Example of Small surface drop stones (Station 19).

(c) Cobble drop stones (Station 1)

(b) Bedrock (clay-stone?) at Station 17

(d) Large cobble drop stone (Station 10)

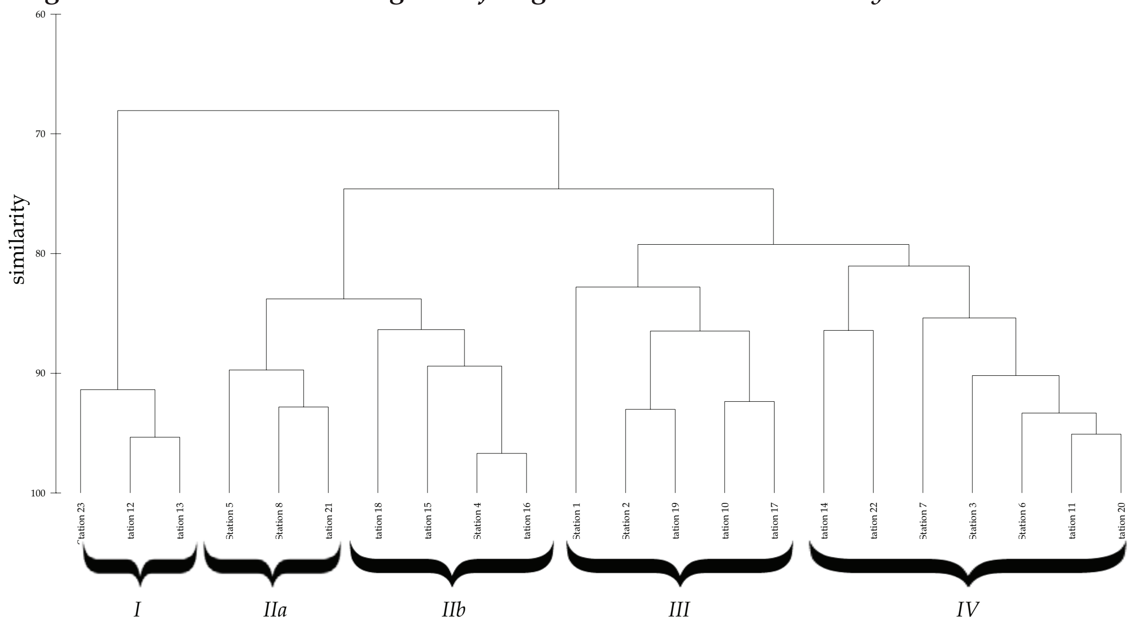


(e) Possible contourite of mobile broken shell and echinoid spines (Station 2)

Figure 4.9 Examples of Coarse Sediments Recovered from Selected Stations

Further to assessing the proportion of sediment size extremes (i.e. gravels and fines), the full distribution of all samples were broken down into size classes at half phi intervals and compared to each other using a multivariate analysis to identify similarities between sediment types. Multivariate analyses were undertaken using the Plymouth Routines in Multivariate Ecological Research (PRIMER). Data for the percentage composition within each size class were clustered into a similarity matrix using a Bray Curtis similarity measure and presented as a dendrogram (Figure 4.10). These data separate the sediments into 5 clusters, two of which can be considered to be sub-clusters of cluster 2. These are described further below and presented as size class distributions for Figure 4.11.

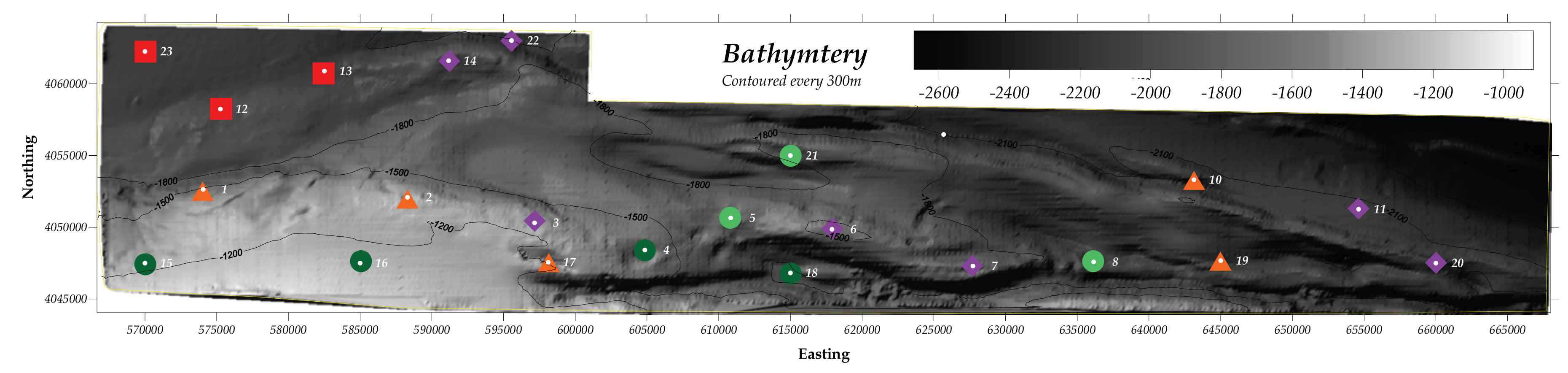
Figure 4.10. *Dendrogram of Regional Sediment Similarity*



The most distinct particle size distribution (Cluster I) was exhibited at 3 of the 22 stations analysed, clustering at a 92% similarity. The mean distribution for all of these sites (presented as a red line/square in Figure 4.11) are classed as silty sands and exhibited a finely skewed distribution around fine sands and coarse silts, with some clays (12%) and minimal sediments above medium sands (3.5%). These stations all relate to a sedimentary regime typical of the low energy environment found within the western end of the South Falkland Basin.

Cluster 2 is separated into two further sub-clusters containing 3 and 4 stations respectively. Both sub-clusters show a similar normal distribution around fine sand, although the level of sorting in the silty sands of sub-cluster 2b (dark green line/ circle in Figure 4.11) is significantly higher than the slightly gravely silty sands of sub-cluster 2a (light green dotted line/circle). As a consequence the proportions of the outer size classes, such as coarse sands (> 500µm) and silts and clays (<63µm) decreases from 5.8 and 33% in Cluster 2a, to 0.1% and 21.8% for Cluster 2b, respectively (Figure 4.11). Cluster 2 is located through the central part of the area, with sub-cluster 2b stations positioned in the slightly shallower part of the bank where the sediments are better reworked by the prevailing currents.

Clusters III and IV, are represented by spatially more disparate sites within the area and reflect the variable levels of heterogeneity exhibited by the sediments throughout the survey area. Both are representative of slightly silty gravely sands. Cluster III, represented by 5 sites, showed very poorly sorted sediments peaking around medium sand (250µm), but with significant proportions of coarser sands and gravels (31.5%) and moderate silts and clays (20.9%). Cluster IV, represented by 7 sites, showed a similar shaped distribution to cluster III but centred on fine sand (125µm). As a result the proportion of sediments above coarser sands was markedly lower (14.8%), whilst silts and clays were marginally higher (28.4%). These clusters are respectively represented by an orange line/triangle, or purple line/diamond on Figure 4.11. Geographically, there appears to be no real pattern of distribution reflecting the variability of localised sediment conditions throughout the main part of the survey area.



LEGEND

- PSA Cluster 1 (Sandy silts)
- PSA Cluster 2a (Slightly gravely silty sands)
- PSA Cluster 2b (Silty sands)
- PSA Cluster 3 (Slightly silty gravely coarse sands)
- PSA Cluster 4 (Slightly silty gravelly fine sands)

Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

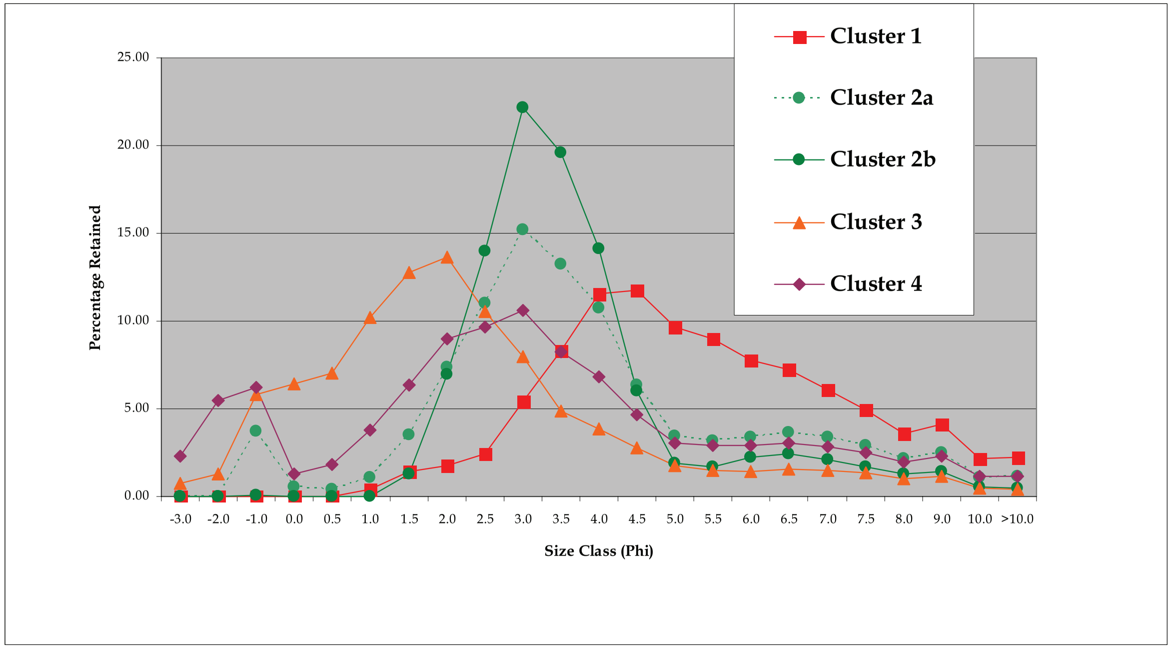


Figure 4.11

Distribution of Grouped Stations Based on Particle Size Distributions (separated at the 80% similarity level using Bray Curtis)

The overall granulometric results of this survey showed a significant variability in the sediment habitats north of the Burdwood Bank. Whilst the presence of glacial deposits over the surface sediments would indicate a low depositional regime for much of the area since the end of the Pleistocene, the uneven coverage and grading of much of these coarser fractions would suggest that localised surface sediments may remain quite variable and subject to ongoing oceanographic influences. Sites located in the northwest of the surface area indicated a notably finer sedimentary habitat indicative of a lower energy regime in the western end of the South Falkland Basin. This is different for the field observations made at station 9 (in the eastern end of this basin), which indicated the presence of stiff clays at the surface with no overlying Holocene material. This would indicate an eroded surface and a more a significantly more rigorous boundary hydrodynamic. Station 17, located in area of slight bathymetric variability, indicating the presence of surface cropping bedrock.

The variability of these sediments at the Burdwood Bank is comparable to results from similar surveys carried out by BHP Petroleum along the length of the east Falkland continental margin (FSL 2009a-d), but covering a much larger survey area. Samples taken at the Toroa and Loligo sites, showed a similar range of sediment types, but are 75 or 365km northeast of the current location, respectively. Toroa, located on the upper part of the continental slope in approximately 650m of water (FSL 2009a) indicated sandy silts and a generally depositional environment similar to that recorded in the northwest of the current study. The mixed glacial deposits or intermittent bedrock exposure, as recorded at station 17, was, however, recorded at the Loligo sites (FSL 2009c) in approximately 1450m water depth. These can be compared to the relatively homogeneous Holocene sands found in the North Falkland Basin throughout the Continental Shelf, where sediments were either slightly silty sands, or where glacial deposits are exposed, slightly gravely medium to fine sands.

Significant variations within the sediment granulometry has had a marked impact on the chemical but only partial impact on the biological components recorded within the sediments. As such, particle size parameters are the most dominant, statistically correlating with a significant number of other environmental factors including several metals and many organic components (in particular the PAHs and allkanes) often at the 99% confidence level (Pearsons' $P<0.01$). Many of these correlations will be an artefact of auto-correlation against key parameters, with the mean & median particle sizes, %fines, silts and clays and sorting coefficient being the most dominant.

4.3. Total Organic Matter, Organic Carbon, Carbonates and Redox Potential

Total organic matter (TOM) was measured as a percentage of the total sample weight, and represents the combustible constituent within the sediments Table 4.2 and Figure 4.12. TOM is made up from a mixture of different organic materials, but is predominantly naphthenic materials (such as carboxylic acids and humic substances) which play an important role within the benthic community as a potential food source to deposit feeding organisms. This has led to the suggestion that variation in benthic communities is, in part, caused by the availability of organic materials (Snelgrove & Butman, 1994). Furthermore, organic matter is also an important scavenger of other chemical components, such as heavy metals and some hydrocarbon compounds (McDougall, 2000). Overall, the proportion of total organic matter by loss on ignition (LOI) is generally considered to be a coarse indicator in sediments as it is subject to errors such as over-estimation of organic content, due to loss of non-organic substances on ignition (i.e. volatile oxides and carbonates, and the bodies of living organisms).

The level of total organic matter (TOM) was consistent ranging from 2.52 to 4.58% (mean 3.5%, SD 0.61). Spatially, the samples showed only a weak pattern of distribution relating to slightly higher concentrations in the northwest region. This would normally be associated with the increased proportion of sediment fines in this area (as indicative of greater sedimentation), although this parameter did not statistically correlate with this fraction in the granulometry. In fact, TOM only weakly correlated with the metals copper, iron and nickel, water depth and sediment sorting. This latter correlation is due to the fact that organic matter is predominantly related to the rate of sedimentation (detrital rain), with lower concentrations expected in the shallower sandier areas where surface sediments indicate some mobility and increased sediment sorting ($P<0.05$).

The overall level of TOM, however was low when compared to other studies in a similar depth and sediment type. Examples to the northeast are the sandy silts of Toroa at 6.0% (FSL 2009a), or the mixed gravely sands at Loligo 5.3% (FSL 2009c). Areas with lower TOM values were the shallower reworked sands recorded on the north Falkland Continental Shelf, at only 1.66% (BSL 2008), or 1.3%, recorded at a similar continental margin, recorded in the northern hemisphere (by the Atlantic Frontier Environmental Network in the Northeast Atlantic).

In addition to total organic matter, the sediments were also analysed for total organic carbon (TOC; Figure 4.12) and inorganic carbon (i.e. carbonates). The total mean values exhibited proportions of 0.31 and 2.06%, respectively. TOC represented around 9.1% of all organics present, a similar level to that recorded at other sites in the east Falkland Continental margin (5.1-8.1%, FSL 2009a & c), but notably lower than that recorded on the north Falkland Continental Shelf (28.1%, BSL 2008). Overall, this level remained relatively consistent, which statistically correlated to the proportion of sediments fines (silts, clays and mean size, $P<0.01$). Consequently a slight pattern of distribution can be observed in Figure 4.12, indicating slightly higher concentrations in the more depositional sediments in the northwest of the survey area.

The proportion of carbonates were not recorded elsewhere in the east Falkland Continental margin, but averaged around 0.56% on the north Falklands Continental Shelf (BSL 2008). As the current study is notably higher, these results would suggest a background influence from inorganic carbonate material, probably related to shell, and the tests of zooplankton and benthic organisms. The highest level of carbonates recorded at 3.73% was recorded at station 2, which indicated the reworked sediment (possible contourite) of biogenic material including broken shell, and sea urchin spines (as shown in Figure 4.9e).

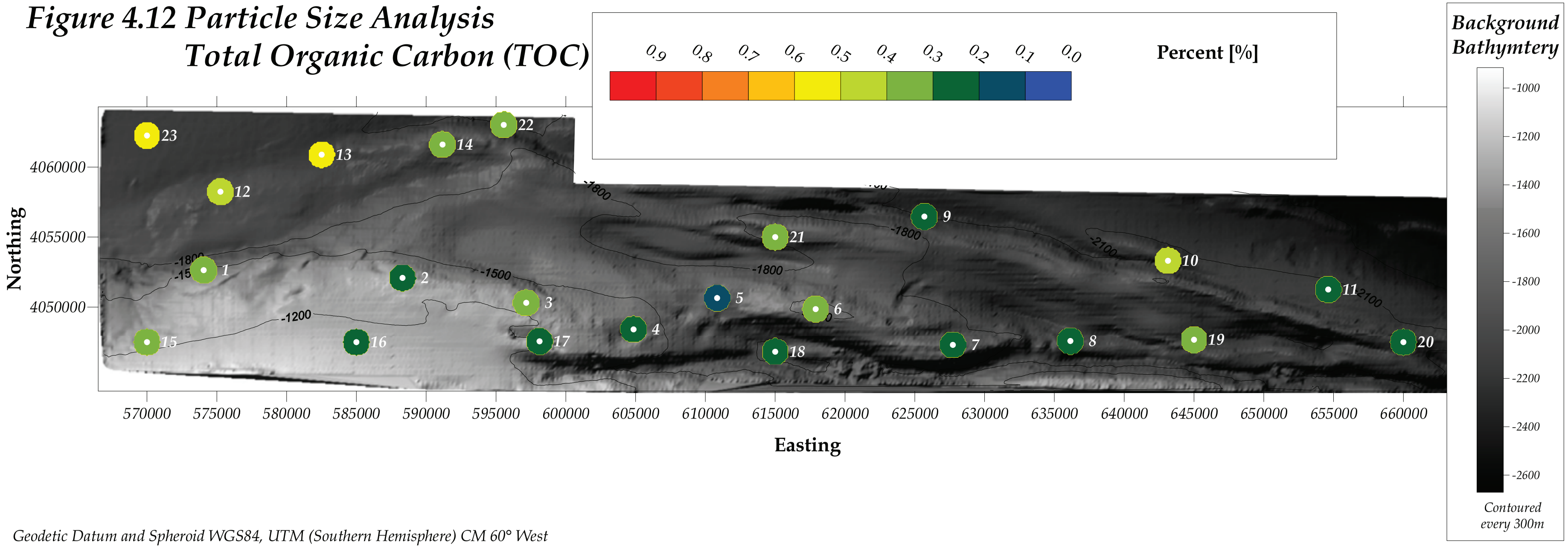
Overall, the presence of pelagic sediments from the deposition of planktonic materials (flocculants and detrital rain) is relatively low, with sediments indicative of granular reworked materils, predominantly sands and glacio-marine gravels. This is indicative of an erosional (or certainly non-depositional) hydrosdynamic regime across the survey area. This will prevent the natural formation of calcareous or silaceous oozes by the deposition of detrial skeletal material from the water column (foraminifera and coccolithophores, or diatoms respectively), commonly found in deep water sediments where the primary productivity of the overlying water mass is expected to be high.

Table 4.2. Summary of Moisture and Organic Components

Station	Moisture Content %	Total Organic Matter %	Total Organic Carbon (%)	Total Carbonates (%)	Proportion TOC (%)	Redox Potential (mV)	
						1cm	5cm
Station 1	32.6	4.28	0.31	1.73	7.2%	228	219
Station 2	31.9	3.38	0.22	3.73	6.5%	197	176
Station 3	27.2	3.69	0.32	2.49	8.7%	274	199
Station 4	27.6	2.57	0.26	1.5	10.1%	222	182
Station 5	34.1	3.45	0.18	2.7	5.2%	259	244
Station 6	31.2	3.97	0.33	2.37	8.3%	262	229
Station 7	33.3	2.71	0.27	1.97	10.0%	275	322
Station 8	35.6	3.08	0.22	1.76	7.1%	297	219
Station 10	28.7	4.24	0.4	2.29	9.4%	200	-
Station 11	27.8	3.95	0.23	2.14	5.8%	174	185
Station 12	39.7	3.09	0.46	1.97	14.9%	226	151
Station 13	45.1	3.55	0.51	2.12	14.4%	234	179
Station 14	31	4.43	0.35	1.56	7.9%	251	182
Station 15	31.4	3.00	0.36	1.7	12.0%	237	207
Station 16	27.8	2.52	0.29	1.48	11.5%	217	188
Station 17	27.4	2.64	0.21	1.39	8.0%	231	204
Station 18	30.2	2.83	0.24	1.51	8.5%	182	172
Station 19	26.3	3.76	0.31	3.6	8.2%	168	115
Station 20	26.1	3.63	0.23	2.46	6.3%	212	221
Station 21	34.5	3.75	0.31	1.73	8.3%	225	213
Station 22	33.3	4.58	0.32	1.37	7.0%	257	215
Station 23	33	3.9	0.6	1.99	15.4%	361	368
Survey Mean	31.6%	3.5%	0.31%	2.06%	9.1%	235.86	209.05
St Dev	4.57%	0.61%	0.10%	0.63%	0.03%	43.6	54.0
% variance	14.4%	17.5%	32.5%	30.5%	31.3%	18.5%	25.8%
Toroa 2009	**-**	**6.0%**	**0.73%**	**-**	**8.1%**	**-**	**-**
Loligo 2009	**-**	**5.3%**	**0.27%**	**-**	**5.1%**	**-**	**-**
North Falklands 2008	**21.6%**	**1.66%**	**0.46%**	**0.56%**	**28.1%**	**408**	**373**

Field measurement of the oxygenation reduction potential (ORP) of the surface sediments was carried out at both 1 and 5 cm depths directly from the grab samples onboard. Although generally considered to be only a coarse indication of sediment oxygen, these results show strongly positive voltages synonymous with well oxygenated sediments. This would reflect low microbial activity within the sediments and support the low organic concentrations recorded at each of the sites and low temperature (at around 2.3°C) with subsequent high dissolved oxygen concentration of the waters recorded immediately above the seabed (see section 4.7).

Figure 4.12 Particle Size Analysis
Total Organic Carbon (TOC)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

As the ORP values remained well above 0mV at all sites for the lower depth, it can be surmised that the redox discontinuity layer (RDL; or the point where free oxygen disappears) was deeper than the 5cm depth measured at all of the sites. As expected, these values are marginally lower (less oxygenated) than those recorded during in shallower sandier sediments on the North Falkland Continental Shelf (BSL 2008).

4.4. Sediment Hydrocarbons

4.4.1. Total Petroleum Hydrocarbons

Results for hydrocarbon analysis are summarised and tabulated as total hydrocarbon concentrations, total n-alkane and homologue ratios in Table 4.3, with individual alkanes (nC_{10}-nC_{37}) listed in Table 4.4. The analytical gas chromatograms (examples given in Figure 4.14 and Appendix II) show the aliphatic hydrocarbon traces for each station, labelled with every fourth n-alkane, the isoprenoid hydrocarbon, Pristane (IP18) and the internal standards hepta-methylnonane (A), 1-chlorooctadecane (B) and squalane (C).

The total hydrocarbons (THC) concentrations of the sediments, measured by integration of all non-polarised components within the GC trace, showed moderate background concentrations at most sites sampled ranging from 6.4 to 24.1µg.g^{-1} (ppm, Table 4.3 & Figure 4.13). The mean for the whole survey area was 12.8µg.g^{-1} (SD 5). These levels are moderately high, and well above the range expected for uncontaminated similar sediments in the Northeast Atlantic (ca. 2.9µg.g^{-1} AFEN 2000). These can also be compared to sediments means from sites along the East Falkland Continental Margin (FSL 2009a & c) and from the North Falkland Continental Shelf (BSL 2008). In the former, the shallow sandy substrates indicated a mean background THC of 4.3µg.g^{-1}, whilst the closer neighbouring sites of Toroa and Loligo, 75 to 380km northeast of the current site, indicated mean THC concentrations of 8.7 and 3.0µg.g^{-1}, respectively (FSL 2009a & c).

Within the survey area, the levels of total hydrocarbons indicated a pattern of distribution, where elevated levels were recorded to the west of the site, predominantly to the northwest. This pattern is partially due to a significant correlation with the sediment fines, which showed an association with the mean sediment size and clays, and in particular the proportion of silts (2-63µm, $P<0.001$). This is a common relationship as hydrocarbons are deposited into the sediments via a natural pelagic sedimentation processes and will be found in higher concentrations where fines are allowed to settle to the seabed. Other significant correlations were total organic carbon, a probable auto-correlation with sediment fines, saturate and polycyclic aromatic hydrocarbons (all $P<0.001$). The latter are discussed in greater detail later in this section.

The mean level of unresolved compounds was generally very high constituting between 88.6 and 91.9% of the total hydrocarbons recorded within the survey area. This component is likely to represent complex organic materials that are ubiquitous within the sediments in this area,. These are a residual component of weathered materials; a combination from both natural autochthonous and allochthonous sources. A discussion on the possible origins of these hydrocarbons is carried out by breaking down the total hydrocarbons concentration into speciated aliphatic and aromatic fractions. These are reviewed in the next sections.

4.4.2. Saturate Alkanes

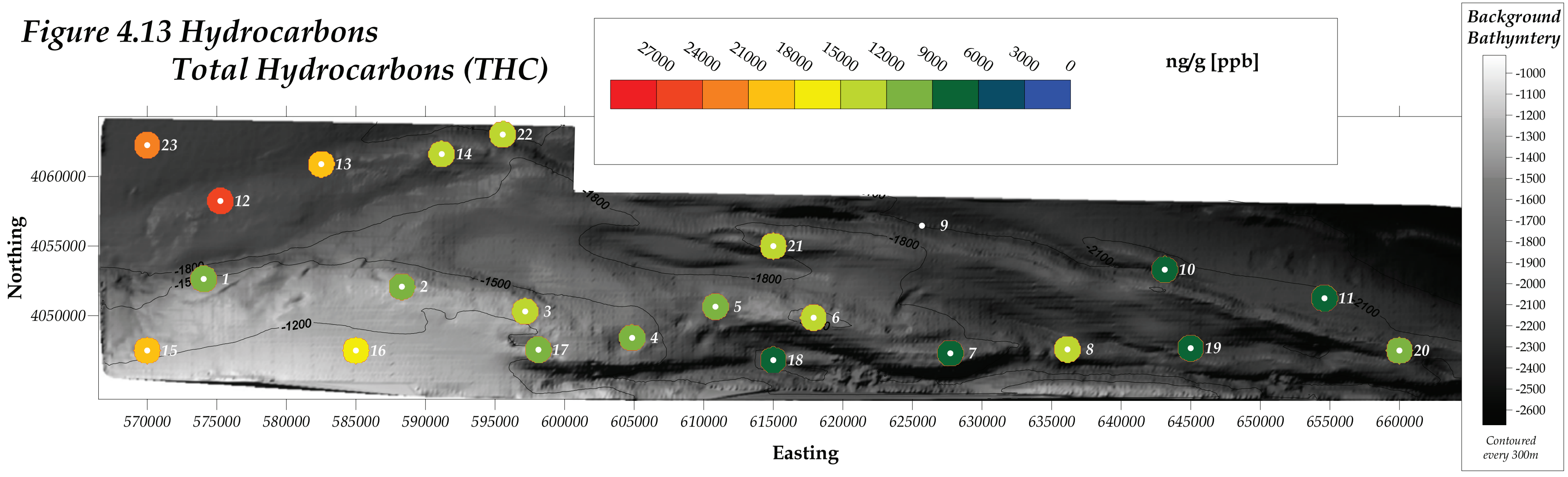
All of the sample stations were analysed for n-alkanes using gas chromatography with flame ionisation detection (GC-FID). The results are summarised in Table 4.3 and individually listed in Table 4.4, which gives a breakdown of consecutive n-alkane content from nC_{10} through to nC_{37}, together with the isoprenoid hydrocarbons Pristane (Pr) and Phytane (Ph).

Table 4.3. Summary Hydrocarbon Concentrations

Station	THC ($ng.g^{-1}$)	Total n-alkanes ($ng.g^{-1}$)	Carbon Preference Index	Pristane/ phytane Ratio	P/B ratio	Alkane proportion (%)	Total PAHs ($ng.g^{-1}$)	NPD PAHs ($ng.g^{-1}$)
Station 1	10,745	1,052	1.06	4.04	1.17	9.8	227.9	135.8
Station 2	9,138	801	1.08	4.05	1.03	8.8	178.3	99.0
Station 3	12,763	1,135	1.01	4.23	1.20	8.9	244.8	142.3
Station 4	10,744	1,090	1.04	5.16	1.45	10.1	240.9	127.3
Station 5	9,158	958	1.10	4.73	1.22	10.5	220.8	119.6
Station 6	13,698	1,114	1.17	4.15	1.01	8.1	310.3	169.2
Station 7	8,251	877	1.05	4.62	1.15	10.6	207.7	116.4
Station 8	13,036	1,268	1.02	4.99	1.26	9.7	324.4	174.4
Station 10	6,406	709	1.00	5.12	0.94	11.1	144.1	79.1
Station 11	8,574	783	1.15	4.14	1.01	9.1	164.2	92.0
Station 12	24,066	2,136	1.06	5.46	1.03	8.9	555.7	289.4
Station 13	20,200	1,893	1.08	5.91	1.24	9.4	478.0	254.7
Station 14	13,811	1,388	1.06	5.42	1.15	10.0	329.5	183.3
Station 15	18,382	1,554	1.03	5.49	1.20	8.5	385.1	196.3
Station 16	15,597	1,254	1.11	4.89	1.15	8.0	328.7	160.2
Station 17	11,206	999	1.01	4.67	1.42	8.9	228.0	121.6
Station 18	8,042	722	1.02	4.70	1.17	9.0	182.4	101.0
Station 19	7,768	775	1.05	4.89	1.07	10.0	213.3	120.4
Station 20	9,285	1,060	1.04	5.00	1.42	11.4	270.7	160.6
Station 21	14,203	1,171	0.99	5.21	1.14	8.2	328.8	179.2
Station 22	13,308	1,250	1.03	4.84	1.32	9.4	368.6	202.0
Station 23	23,917	2,100	1.06	5.34	1.30	8.8	602.6	322.2
Survey Mean	**12,832**	**1186**	**1.06**	**4.87**	**1.18**	**9.5**	**297**	**161**
St Dev	**5004**	**413**	**0.05**	**0.52**	**0.14**	**1.05**	**122.5**	**62.9**
% variance	**39.0%**	**34.8%**	**4.4%**	**10.6%**	**11.8%**	**10.0%**	**41.2%**	**39.0%**
Toroa 2009	**8,700**	**240**	**1.12**	**4.09**	**-**	**2.7**	**224**	**166**
Loligo 2009	**3,000**	**100**	**1.07**	**3.11**	**-**	**3.3**	**119**	**102**
North Falklands 2008	**4299**	**208.2**	**1.88**	**1.01**	**0.16**	**5.1**	**0.6**	**0.5**

As with the proportion of total hydrocarbons, the total n-alkane concentrations were moderately high ranging from 709 to 2,100$ng.g^{-1}$ (mean 1,186, SD 413) and exhibiting a similar pattern of distribution (statistically n-alkanes correlated very highly with THC and all of the fine sediment parameters; $P<0.001$). Furthermore, the level of alkanes were also notably higher than recorded at the neighbouring sites along the east Falkland Continental Margin or in shallower waters on the North Falklands Continental Shelf. Here, the respective mean concentration of total alkanes were 100,

Figure 4.13 Hydrocarbons
Total Hydrocarbons (THC)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

240 and 208 ng.g^{-1} (FSL 2009a, c and BSL 2008), up to an order of magnitude lower than the present study. The proportion of alkanes to total hydrocarbons was also elevated, with 9.5% of the organics represented by saturate homologous series during the current study compared to between 2.7 and 5.1% at these other Falkland sites. These results point to a background impact to the sediments by a relatively consistent input of saturate hydrocarbons.

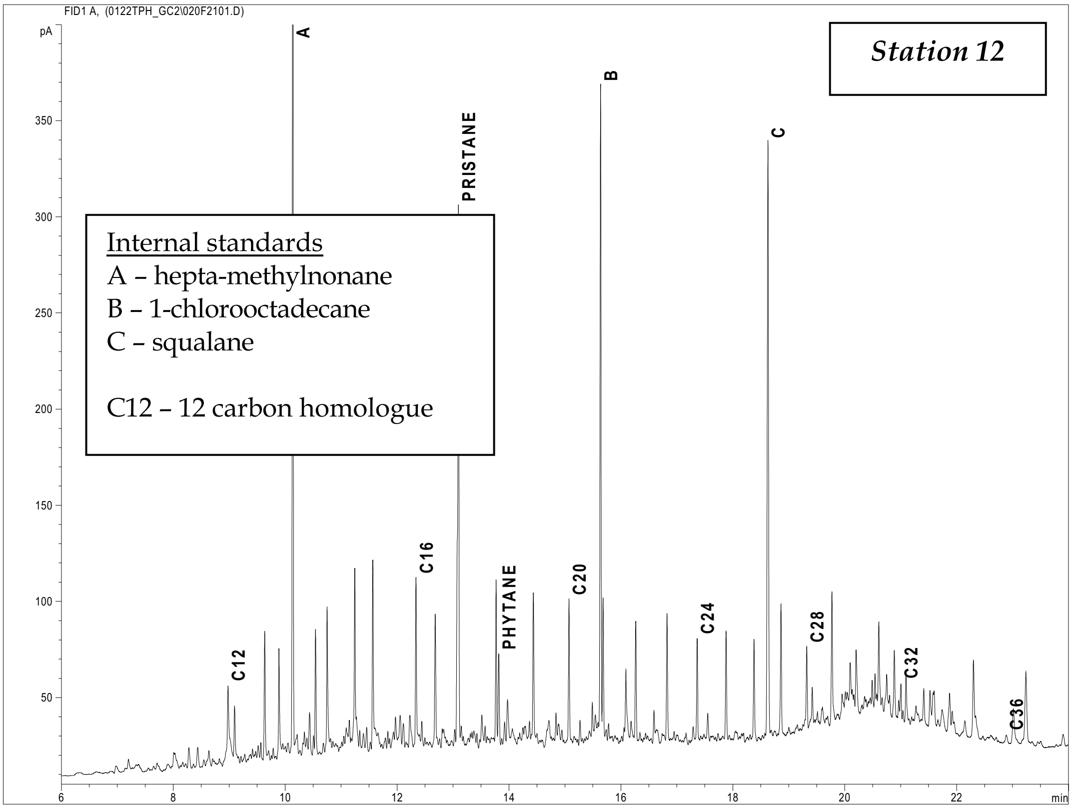
On inspection of the individual gas chromatograms (Appendix II) all stations indicated similar forms with the presence of both biogenic and thermogenic hydrocarbon material. Figure 4.14 shows two example stations relating to sites with the highest and one of the lowest THC recorded levels (stations 12 and 20 respectively). A similar GC-trace recorded at a neighbouring site 75km Northeast of the current survey (Toroa stations 4, FSL 2009a) is also shown.

The baseline of most stations indicated a relatively 'noisy' trace indicative of unresolved complex mixtures (UCM) throughout the full range of the chromatogram. A breakdown of this signature is as follows:

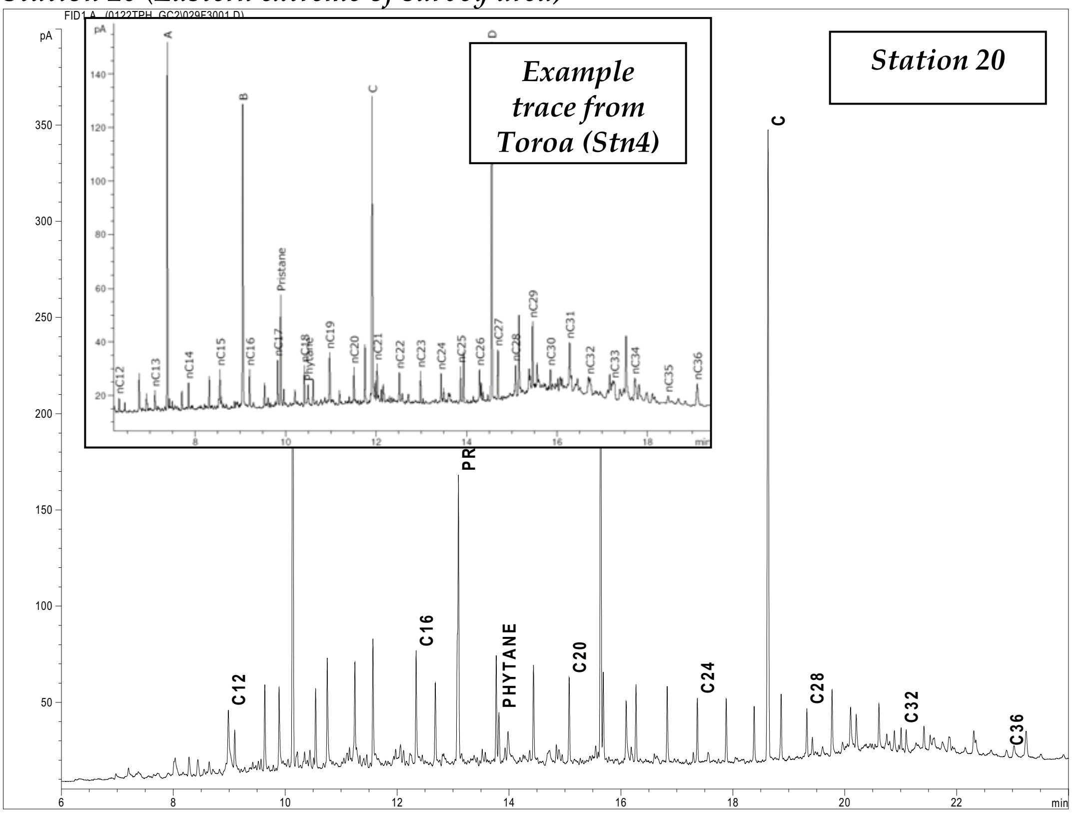
Terrestrial: Within the range nC_{26} to nC_{34}, a consistent UCM envelope peaking at nC_{32} indicates the presence heavily weathered biogenic material along with a slight pattern of elevated concentrations in each of the odd numbered homologues in this range. This distribution is consistent with the presence of terrestrial derived n-alkanes from the wax cuticles of higher plants, which typically comprise the long-chain, odd carbon number n-alkanes (nC_{25-33}) (Eglinton *et al.*, 1962), whereas marine organisms (phyto- and zooplankton) preferentially synthesize short-chain, odd carbon number (nC_{15-21}) (Blumer *et al*, 1971). Terrestrial matter is often evident in marine sediments, particularly inshore sediments, although it has also been observed from samples in remote areas like the northeast Atlantic Margin (McDougall, 2000), having entered the marine environment through run-off and aeolian processes from adjacent land masses.

Thermogenic: All GC traces indicated a background UCM in the much lower and broader range spanning nC_{10} to nC_{24} indicative of weathered hydrocarbons in a diesel range. This is indicative of low level thermogenic material and is recorded throughout the survey area, including the GC–trace of the neighbouring sample 75km northeast. Moreover, the peaks representing the individual homologues clearly showed a pattern of elevation over a similar range, peaking at nC_{15} (nC_{17} for the neighbouring site, FSL 2009a). This pattern may be indicative of immature oils from a source rock. As this material is also recordable in the neighbouring surveys as far as to 430km northeast, the source of this material must be considerable and long term. The regional pattern of this material is discussed in more detail further in section 4.4.4.

Figure 4.14. Example Gas Chromatograms for Saturate Hydrocarbons Analysis for the South Falkland Basin (Stations 12 and 20)



Station 20 (Eastern extreme of survey area)



A closer inspection of the different proportions of n-alkanes recorded can sometimes identify trends within the data or refine information on the source from which the different organic components derive. The following ratios were also calculated and assessed:

Carbon Preference Index (CPI):

The carbon preference index is calculated as follows;

$$CPI = \frac{\text{odd homologues } (nC_{11} \text{ to } nC_{35})}{\text{even homologues } (nC_{10} \text{ to } nC_{34})}$$

The carbon preference index (CPI), is associated with the preference of biogenic n-alkanes (i.e. that of a preference for odd-carbon numbered homologues, particularly around nC_{27}-nC_{33}; Sleeter *et al*., 1980), derived from fatty acids, alcohols, esters and land plant waxes. The CPI was calculated for all sites and ranged from 0.99 to 1.17 (mean 1.06; SD 0.05). This is a consistent low level with little or no dominance by biogenic (in particular, terrestrial aliphatic) compounds. This compares closely to the neighbouring site along the east Falkland Continental Margin which also indicated ratios close to unity (1.12 and 1.07; FSL 2009 a & c), but not with results from the north Falklands Contintental Shelf which showed a much higher mean of 1.88 (BSL 2008). These low concentrations, along with the very high consistency within the data, points to a clear dominant source in the origin of saturates in this area. Where a low level background signature of terrestrial influences are often recorded in coastal and sedimentary areas, results in the current study and elsewhere along the eastern margin suggest that terrestrial influences are relatively minimal given the open ocean environment and lack of nearby land masses where higher plant material might dominate the organic signature. In addition to this, the very small terrestrial influences that are seen are partially masked by a larger thermogenic signature where there is no carbon preference. The absence of this feature on the north Falklands Continental Shelf, further confirms that this background source is peculiar to the south or eastern continental slope and not elsewhere around the Falklands. Statistically, CPI did not correlate to any other parameter (including the sediments granulometry) confirming that as a ratio, these result reflect the balance of saturate homologues within the whole area, rather than localised elevations due to varying sediment types.

Petrogenic/Biogenic or (P/B) Ratio:

$$P/B \text{ Ratio} = \frac{P = \text{sum of } nC_{10} \text{ to } nC_{20}}{B = \text{sum of } nC_{21} \text{ to } nC_{35}}$$

The P/B ratio compares the lighter, more petrogenic aliphatics with the heavier, and more biogenic aliphatics. Results were calculated for all stations showing a consistently high, thermogenic ratio ranging from 0.94 to 1.45 (Mean, 1.18) with no pattern of distribution. This ratio was not calculated for the neighbouring sites, but was a consistently low, biogenic mean of 0.16 recorded on the North Falkland Continental Shelf, or a moderate biogenic ratio of 0.73 recorded in similar sediments in the Northeast Atlantic (AFEN 2000). As with the CPI, the PB ratio clearly reflects a petrogenic influence, where significant quantities of lighter weight materials have been recorded on a regional scale. Again, statistically, the PB ratio failed to correlate with any of the sediment parameters.

The Pristane/Phytane Ratio

Pristane and phytane are both isoprenoidal alkanes commonly found as constituents within crude oils. However, in biogenic environments, only pristane is found with phytane generally absent or only present at low levels in uncontaminated natural systems (Blumer and Snyder, 1965). A presence of both isoprenoids at similar levels is typically taken as an indication of petroleum contamination.

The Pristane/Phytane ratio indicated high, but consistent ratios ranging from 4.04 to 5.91 (mean 4.87; Figure 4.15). This would typically indicate a generally biogenic origin, although it should be noted that Pristane/Phytane ratio can often be difficult to interpret due to its erratic nature and should be used mainly to substantiate other interpretations. The use of the ratio in interpretative discourse is open to criticism, mainly owing to the natural occurrence of phytane in some older sediments and the confusing variation of sedimentary pristane induced by the variability of phytoplankton numbers (Blumer & Synder, 1965). Furthermore as phytane concentrations can often be undetectable, this often renders this ratio useless (as was the case for 22 samples on the North Falkland Basin. However, in this case, the concentration of phytane is very high ranging from 25 to 104ng.g-1 (mean 39ng.g-1) which is unlikely to come from any biogenic source. Consequently, the high ratios here are produced by an even higher concentration of pristine. These are at exceptional levels ranging from 120 to 556ng.g-1 (mean 246ng.g-1). This is expected to be the result from a combination of sources relating to background thermogenic material (as per the phytane) and a further natural biogenic enhancement from pelagic detrital material, found in high concentration from planktonic crustacea (such as *Calanus*), which are rich in the overlying waters of the south Atlantic. Statistically, the Pristine/Phytane ratio correlates strongly with sediment fines and total organic carbon, confirming the parameters link with the sedimentary material.

Figure 4.15 Hydrocarbons Pristane/Phytane Ratio

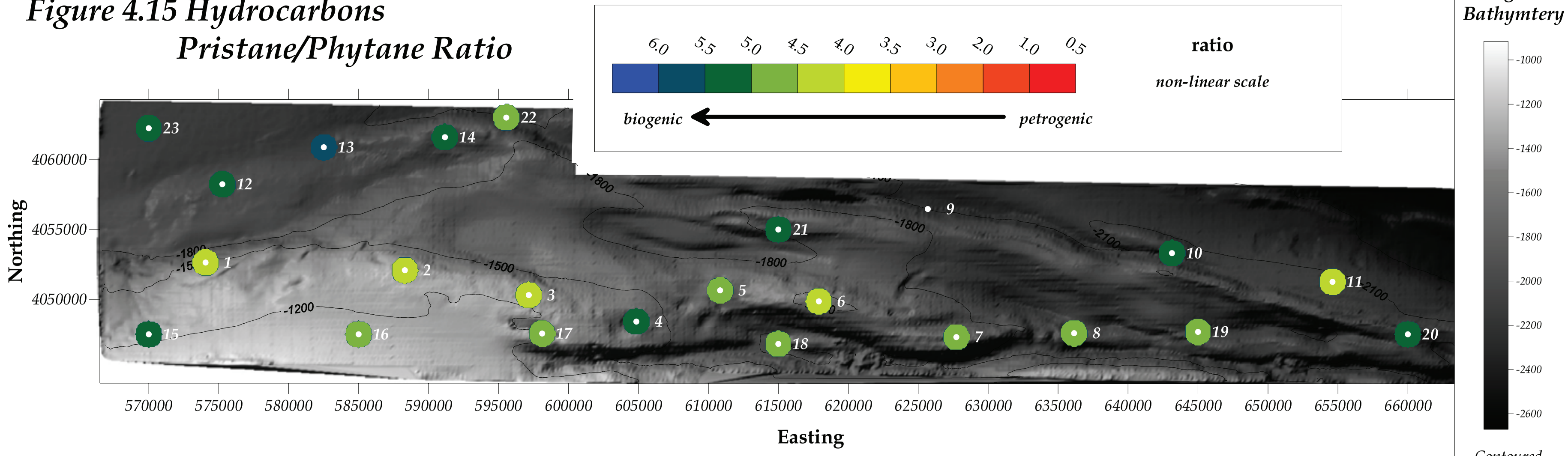


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Table 4.4. Total Aliphatic Concentrations (ng.g^{-1})

Station	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Stn 8	Stn10	Stn11	Stn12
nC10	8.9	6.2	13.1	9.7	4.7	7.0	6.9	4.2	6.2	9.9	10.2
nC11	13.4	7.7	2.3	5.0	3.8	2.4	11.0	19.0	9.7	6.6	17.9
nC12	16.8	16.1	6.5	15.3	14.7	11.4	19.9	23.1	17.9	5.9	44.7
nC13	21.5	12.3	27.3	28.8	25.0	26.6	15.9	30.5	15.8	22.4	46.9
nC14	71.5	55.2	94.1	97.2	81.1	69.1	68.1	102.9	49.8	61.2	158.2
nC15	96.3	62.0	117.0	112.5	96.5	99.7	76.6	117.7	58.9	66.9	175.1
nC16	66.3	42.0	70.5	76.4	58.8	75.2	49.1	84.8	43.0	41.2	122.8
nC17	74.5	61.6	72.0	74.3	61.1	78.7	55.5	77.6	12.5	43.0	127.5
pristane	199.4	144.4	179.3	234.9	176.5	205.3	167.3	257.3	143.6	161.3	465.4
nC18	67.9	49.7	76.4	79.7	62.5	61.4	56.8	86.4	42.1	48.6	132.6
phytane	49.3	35.6	42.4	45.5	37.3	49.4	36.2	51.6	28.1	38.9	85.3
nC19	61.9	43.5	66.3	75.6	59.5	67.4	51.1	81.3	43.9	47.4	128.6
nC20	68.9	50.1	73.6	71.9	58.6	60.5	57.5	79.4	44.9	39.5	121.0
nC21	41.5	41.5	58.5	41.4	42.3	55.5	33.6	56.5	28.7	41.5	89.0
nC22	36.8	30.8	48.5	36.6	34.7	45.2	31.8	49.8	24.5	28.2	79.9
nC23	39.9	28.9	49.2	37.3	35.5	48.8	31.7	50.4	23.3	29.8	84.9
nC24	35.5	29.8	42.5	33.2	33.3	42.2	29.9	46.2	24.5	29.3	73.9
nC25	43.2	33.5	41.2	33.5	32.6	48.8	33.5	46.6	33.1	30.7	77.5
nC26	37.4	30.1	42.4	35.7	33.9	46.2	32.3	48.2	27.1	28.6	77.6
nC27	47.0	37.3	52.9	45.3	45.2	60.6	44.7	59.9	34.2	39.1	105.8
nC28	29.0	22.2	35.8	29.5	28.5	34.3	27.8	38.7	22.0	26.5	61.5
nC29	45.5	37.4	46.7	48.3	48.9	60.6	47.7	56.0	43.5	45.9	112.0
nC30	24.3	21.2	23.8	20.7	20.2	28.6	20.7	25.9	16.9	20.7	61.3
nC31	24.0	23.3	24.3	25.9	25.1	33.3	28.1	26.2	24.1	26.3	76.7
nC32	15.3	12.0	10.9	9.8	11.2	13.3	11.3	12.0	10.2	7.4	35.5
nC33	19.1	14.7	7.5	14.4	14.4	15.0	13.5	13.0	13.7	10.4	31.2
nC34	21.8	10.8	12.3	8.6	7.2	8.9	7.2	18.4	19.4	11.8	52.8
nC35	10.3	2.9	4.5	12.4	10.3	1.9	3.8	2.8	9.5	5.6	17.8
nC36	10.2	9.5	13.0	9.9	6.4	9.4	9.0	8.6	6.8	5.6	7.0
nC37	3.2	8.9	1.8	1.8	2.3	2.5	2.6	2.2	3.2	3.1	6.2
THC	**10,745**	**9,138**	**12,763**	**10,744**	**9,158**	**13,699**	**8,251**	**13,036**	**6,406**	**8,574**	**24,066**
Total n-alkanes	**1,052**	**801**	**1,135**	**1,090**	**958**	**1,114**	**877**	**1,268**	**709**	**783**	**2,136**

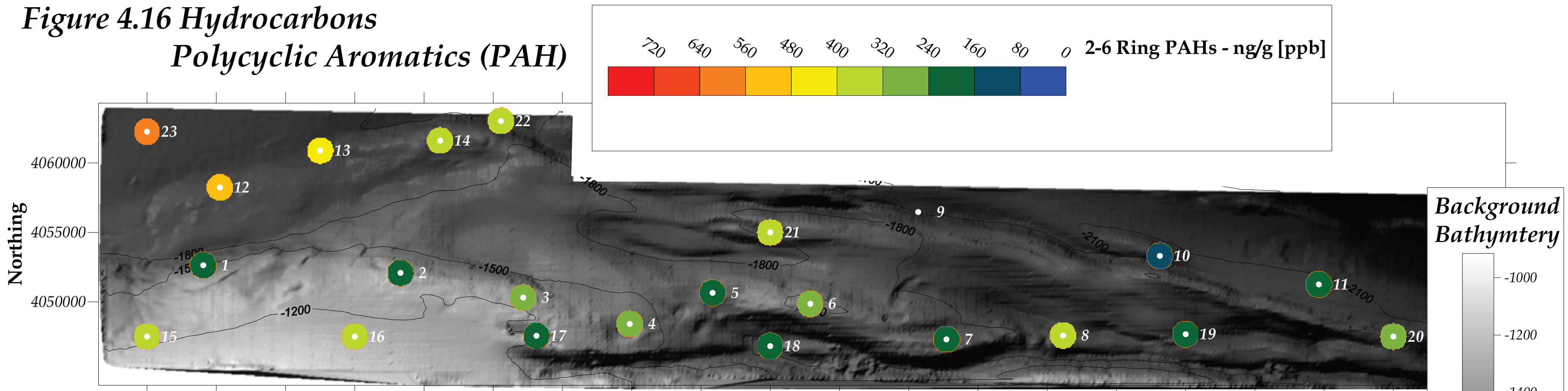
Table 4.4. Cont. *Total Aliphatic Concentrations (ng.g-1)*

Station	Stn13	Stn14	Stn15	Stn16	Stn17	Stn18	Stn19	Stn20	Stn21	Stn22	Stn23
nC10	3.7	7.3	4.1	6.1	4.2	3.8	6.2	4.8	8.8	22.2	2.8
nC11	29.5	20.4	13.2	9.9	13.7	5.6	11.2	23.2	16.6	20.1	20.9
nC12	27.9	37.9	31.9	21.1	23.1	21.4	19.4	24.9	25.2	34.7	20.7
nC13	43.4	33.2	35.8	28.0	24.7	15.5	17.0	31.5	29.7	34.8	42.7
nC14	145.7	104.5	123.5	94.9	86.6	51.6	57.8	98.6	94.6	103.7	152.3
nC15	172.1	116.8	143.0	115.5	98.1	64.9	67.3	101.2	104.9	112.0	195.9
nC16	121.6	83.1	100.0	79.2	69.7	45.2	45.8	71.6	71.5	76.7	140.0
nC17	126.3	79.6	101.3	77.3	65.6	38.4	32.7	59.1	57.7	75.9	140.6
pristane	468.9	302.4	365.6	277.9	209.6	166.0	169.1	199.1	252.3	237.6	556.1
nC18	130.9	89.1	104.8	85.4	72.2	52.1	51.3	74.2	76.9	83.4	163.2
phytane	79.3	55.8	66.5	56.8	44.9	35.3	34.6	39.8	48.5	49.1	104.1
nC19	127.7	87.0	96.0	80.3	66.5	46.4	46.1	68.8	71.7	75.2	155.8
nC20	120.7	83.2	93.5	72.6	62.4	45.2	45.4	63.5	66.9	72.6	151.8
nC21	73.3	55.8	63.4	60.4	46.4	33.1	36.6	46.4	47.3	56.4	88.6
nC22	65.9	50.1	58.4	48.6	37.0	25.8	29.8	37.5	42.6	46.4	74.9
nC23	70.4	52.7	60.8	50.2	37.3	25.3	29.9	37.4	44.9	47.9	77.5
nC24	61.1	48.3	53.7	44.9	34.0	23.4	29.0	35.3	40.1	42.7	69.7
nC25	62.4	49.4	52.5	55.8	32.1	34.5	32.4	34.1	41.0	44.9	70.9
nC26	63.9	51.6	54.2	44.0	37.7	26.2	28.7	33.1	40.8	42.0	72.7
nC27	87.0	65.5	75.1	61.5	36.6	33.6	37.4	41.2	54.5	56.4	103.3
nC28	41.6	39.6	43.5	34.3	22.6	22.1	23.4	27.2	32.8	33.8	58.3
nC29	88.8	69.2	73.7	60.7	42.0	35.5	42.7	41.2	56.4	56.7	100.7
nC30	35.6	29.0	26.4	25.7	19.3	13.5	17.3	20.6	28.2	26.0	53.7
nC31	47.5	38.6	37.3	26.9	20.7	18.5	22.9	24.6	33.4	28.0	42.6
nC32	30.0	23.6	18.1	15.1	9.2	8.2	8.6	13.1	12.1	11.2	16.8
nC33	25.2	21.3	17.2	15.2	10.0	8.2	11.6	15.2	13.7	16.0	22.1
nC34	50.1	19.4	43.5	19.6	14.0	15.5	11.5	7.4	38.5	15.4	30.7
nC35	20.9	18.7	13.6	13.3	5.5	3.7	6.4	12.3	9.8	10.4	16.3
nC36	11.5	5.8	11.7	4.1	5.2	4.0	4.1	7.4	9.3	4.9	10.9
nC37	8.0	6.8	4.2	3.4	2.9	1.2	3.0	4.9	1.2	<1	3.9
THC	**20,200**	**13,811**	**18,382**	**15,598**	**11,206**	**8,042**	**7,768**	**9,285**	**14,203**	**13,308**	**23,917**
Total n-alkanes	**1,893**	**1,388**	**1,554**	**1,254**	**999**	**722**	**775**	**1,060**	**1,171**	**1,250**	**2,100**

4.4.3. Polycyclic Aromatic Hydrocarbons (PAH)

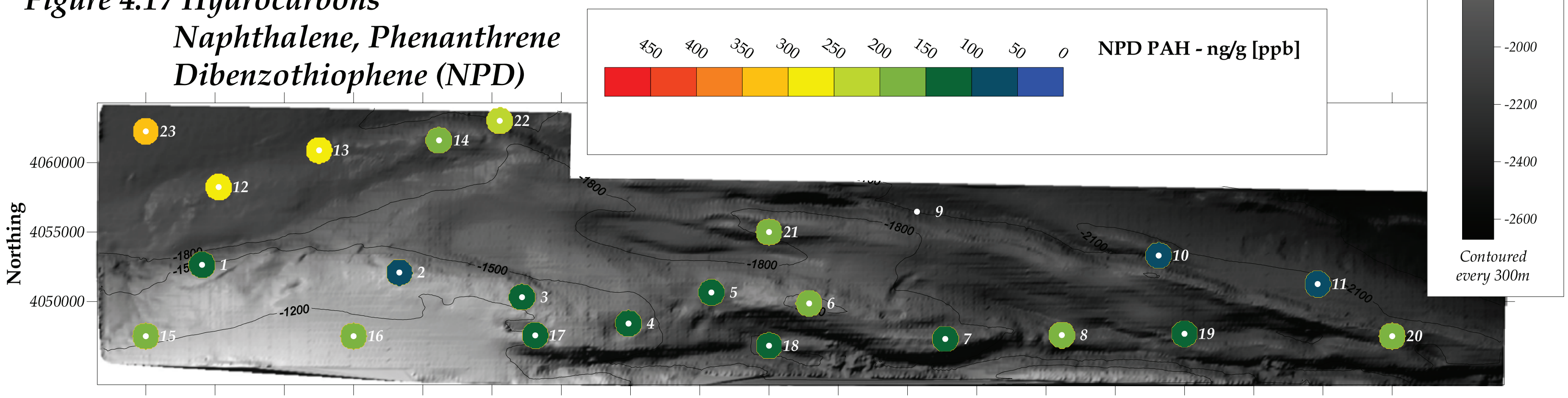
Quantitative polycyclic aromatic hydrocarbons were analysed at each station using Gas Chromatography-Mass Spectrometry (GC-MS). Results of the single ion current (SIC) analyses are summarised in Table 4.3, and detailed in Table 4.5, showing concentrations for both parent compounds and their alkyl derivatives. A summary of PAH distributions are given in Appendix III. The polycyclic aromatic hydrocarbons listed under the United States Environmental Protection Agency, for the 16 priority pollutants for air, water and sediment quality are listed in Table 4.6. The EPA 16 are used globally in assessments of contamination relating to both environmental and human health studies.

Figure 4.16 Hydrocarbons Polycyclic Aromatics (PAH)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.17 Hydrocarbons Naphthalene, Phenanthrene Dibenzothiophene (NPD)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Total PAH concentrations were at moderate to high background concentrations throughout the survey area ranging from 144 to 602ng.g^{-1} (mean 297ng.g^{-1}, SD 122; Figure 4.16). This can be compared to means of 224 and 119 at the neighbouring east Falkland Continental Margin sites (FSL, 2009a & c) or a maximum of 16.5ng.g^{-1} recorded on the North Falkland Continental Shelf (BSL 2009).

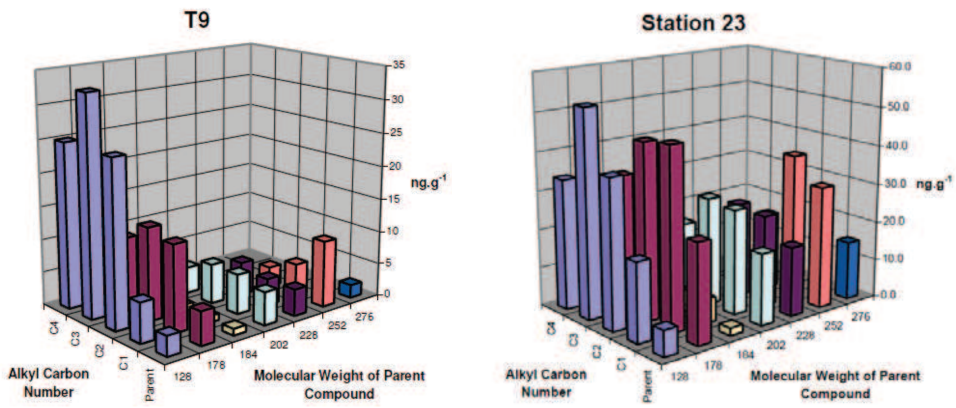
Polyaromatic hydrocarbons and their alkyl derivatives have been recorded in a wide range of marine sediments (Laflamme & Hites, 1978) with the majority of compounds produced from what is thought to be pyrolytic sources. These are the combustion of organic material such as forest fires (Youngblood & Blumer, 1975), the burning of fossil fuels and, in the case of offshore oilfields, flare stacks, etc. The resulting PAHs, rich in the heavier weight 4-6 ring aromatics, are normally transported to the sediments via atmospheric fallout or river runoff. Another PAH source is petroleum hydrocarbon, often associated with localised drilling activities. These are rich in the lighter, more volatile 2 and 3 ring PAHs (NPD; naphthalene (128), phenanthrene, anthracene (178) and dibenzothiophene (DBT) with their alkyl derivatives).

Statistically, these elevated levels of PAHs showed close correlations with that of the fine sediment parameters suggesting that sedimentation and sediment retention are important factors in the residency of these compounds. However, total PAH also showed a very high correlation with that of total hydrocarbons and saturates ($P<0.001$), confirming them to be from the same non-biogenic or pyrolytic source.

As with total PAH, the NPD fraction showed a very similar pattern of thermogenic material with high levels ranging from 79 to 322ng.g^{-1} (mean 161ng.g^{-1}, SD63; Figure 4.17). NPD also showed a similar statistical correlation with the fine sediments. However, a comparison of the NPD/4-6 ratio revealed a different correlation relative to the proportion of coarser sediments and the poor level of sorting. All ratios were high, ranging from 0.95 to 1.47 (mean 1.22), but this fraction had a greater impact in areas of mixed sediments. The exact reason for this is uncertain, although a ubiquitous background of heavy weight PAHs of pyrolytic origin in an area remote from terrestrial fires and large land-masses is likely to be very limited.

Further information on the source(s) of PAH in the sediment may be obtained from a study of their alkyl homologue distributions (i.e. the degree of methyl, ethyl, substitution of the parent compounds). Pyrolytically derived PAH are predominantly unalkylated whereas thermogenic derived PAHs are formed at relatively low temperatures (<150°C), and contains mainly alkylated species. The distribution of parent 2 - 6 ring PAH compounds also reflects whether the source is petrogenic or pyrolytic. The trend is represented graphically in Appendix III. These are three-dimensional plots which show the PAH concentrations, the parent compound distribution and the alkyl homologue distribution of the aromatic material in each of the sediments analysed. These show PAHs of clear thermogenic origin with significant alkylated aromatics throughout the 2-6 ring range. Furthermore, the proportion of the parent to alkylated concentrations remained the same at almost all stations irrelevant to the overall concentration. This confirms the same source dominating the PAHs at all sites. This consistency can also be seen in the parent to alkylated compounds in samples from the neighbouring site of Toroa, 75km to the northeast (Figure 4.18). Allowing for slight differences in the laboratory analysis, the representation of the lighter 2-3 ring parent and alkylated compounds is very similar.

Figure 4.18 Comparison of parent and alkylated PAHs Between The Burdwood Bank (Station 23) and Toroa (Station T9; FSL 2009a)



These results can be better demonstrated by comparing the proportion of parent compounds with that of the proportion of naphthalenes, phenanthrenes and dibenzothiophenes (Figure 4.19). This also shows a generally petrogenic origin, although very minor pyrolytic material may be present. Proportionally, the slightly lower proportion of NPD may be explained by an immaturity within the thermogenic oils.

Figure 4.19 PAH Source Assignment for the Burdwood Bank Sediments.

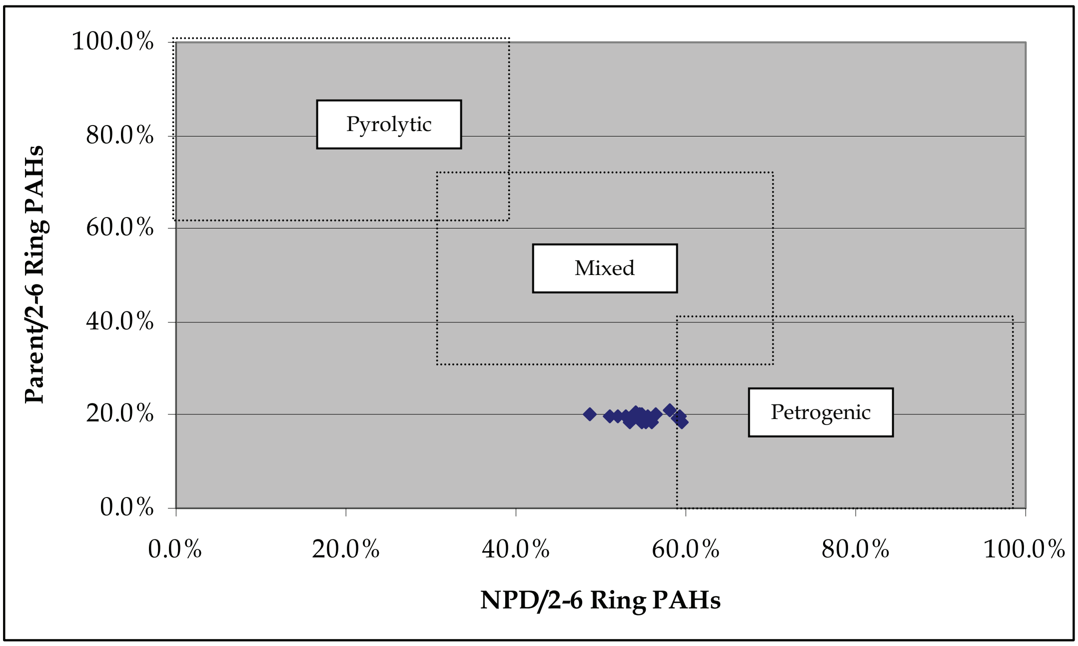


Table 4.5. *Polycyclic Aromatic Hydrocarbon Concentrations (Single Ion Currents, ng.g^{-1})*

Station	Stn1	Stn2	Stn3	Stn4	Stn5	Stn6	Stn7	Stn8	Stn10	Stn11	Stn12
Naphthalene	2.3	1.8	2.7	2.2	2.5	3.4	2.3	3.0	1.6	1.8	5.7
C1 Naphthalenes	8.9	6.4	10.5	8.2	8.1	11.1	7.9	11.1	5.5	6.1	17.9
C2 Naphthalenes	17.8	12.4	20.3	16.1	15.2	21.1	15.2	21.7	10.1	11.8	33.4
C3 Naphthalenes	20.2	14.1	19.6	20.1	18.4	26.0	17.7	28.0	12.1	13.7	45.4
C4 Naphthalenes	12.3	8.5	11.4	12.2	10.9	17.3	11.8	18.1	7.4	8.7	30.1
Sum Naphthalenes	**61**	**43**	**64**	**59**	**55**	**79**	**55**	**82**	**37**	**42**	**133**
Phenanthrene / Anthracene	12.8	10.1	16.2	11.2	10.3	14.1	10.5	14.7	7.2	8.6	22.1
C1 178	21	16	24	20	19	26	18	26	13	16	40
C2 178	20	16	20	19	18	26	16	24	12	13	44
C3 178	13	9	12	12	12	16	11	18	7	8	34
Sum 178	**67**	**51**	**72**	**62**	**59**	**81**	**56**	**82**	**40**	**45**	**140**
Dibenzthiophene	<1	<1	<1	<1	<1	1	<1	1	<1	<1	2
C1 Dibenzthiophenes	3	2	2	2	2	3	2	3	1	2	6
C2 Dibenzthiophenes	3	2	2	3	2	3	2	3	1	2	5
C3 Dibenzthiophenes	2	1	1	2	1	2	1	3	<1	1	3
Sum Dibenzthiophenes	**8**	**4**	**6**	**7**	**6**	**9**	**5**	**10**	**3**	**5**	**17**
Fluoranthene / pyrene	7	5	7	8	7	9	6	10	4	5	16
C1 202	9	7	9	10	9	13	8	13	5	7	24
C2 202	9	7	10	11	10	14	8	15	6	7	24
C3 202	7	5	6	8	6	10	6	10	4	5	18
Sum 202	**31**	**24**	**33**	**37**	**32**	**45**	**28**	**48**	**20**	**23**	**82**
Benzanthracene / chrysene	6	5	8	8	7	10	5	10	4	4	16
C1 228	8	7	8	9	8	11	8	13	6	6	22
C2 228	8	7	9	9	8	11	8	12	5	6	25
Sum 228	**22**	**19**	**25**	**26**	**23**	**32**	**20**	**35**	**15**	**16**	**64**
Benzfluoranthenes / benzopyrenes	12	10	14	15	13	18	11	17	7	9	32
C1 252	12	11	13	15	13	18	13	19	10	10	33
C2 252	7	7	7	9	8	11	8	13	5	6	21
Sum 252	**31**	**27**	**34**	**39**	**34**	**48**	**33**	**49**	**22**	**25**	**86**
Aranthanthrenes / indeno- pyrene / benzperylene	3	3	4	4	5	7	4	7	3	3	15
C1 276	3	3	4	4	3	5	3	5	3	3	11
C2 276	2	3	3	3	3	4	3	5	3	2	8
Sum 276	**9**	**9**	**11**	**12**	**12**	**16**	**10**	**17**	**8**	**8**	**35**
Sum of all fractions	**228**	**178**	**245**	**241**	**221**	**310**	**208**	**324**	**144**	**164**	**556**
Sum of NPD fraction	**136**	**99**	**142**	**127**	**120**	**169**	**116**	**174**	**79**	**92**	**289**

Table 4.5. cont. *Polycyclic Aromatic Hydrocarbon Concentrations*

(Single Ion Currents, $ng.g^{-1}$)

Station	Stn13	Stn14	Stn15	Stn16	Stn17	Stn18	Stn19	Stn20	Stn21	Stn22	Stn23
Naphthalene	5.1	3.5	3.1	2.9	2.0	1.8	2.7	3.3	3.7	3.8	6.6
C1 Naphthalenes	15.8	11.6	10.9	9.7	7.8	6.6	9.1	10.8	12.5	12.9	20.3
C2 Naphthalenes	31.2	22.0	22.4	18.2	15.4	12.4	15.6	20.5	22.3	24.8	38.3
C3 Naphthalenes	42.8	29.5	30.3	25.1	19.6	15.9	17.7	22.8	26.0	31.1	53.4
C4 Naphthalenes	27.4	17.5	20.0	16.7	11.4	10.3	10.6	13.5	17.8	18.5	33.7
Sum Naphthalenes	**122**	**84**	**87**	**73**	**56**	**47**	**56**	**71**	**82**	**91**	**152**
Phenanthrene / Anthracene	21.5	16.8	16.9	13.1	10.5	8.2	12.1	16.8	16.6	18.4	25.4
C1 178	36	28	29	25	19	15	19	29	27	33	46
C2 178	37	27	31	22	18	15	17	23	26	30	45
C3 178	24	17	20	17	12	11	11	14	16	19	35
Sum 178	**118**	**89**	**97**	**77**	**59**	**49**	**59**	**83**	**86**	**100**	**152**
Dibenzthiophene	2	1	1	1	<1	<1	<1	<1	1	1	2
C1 Dibenzthiophenes	5	3	4	3	2	2	2	2	4	4	6
C2 Dibenzthiophenes	5	3	4	4	2	2	2	2	4	3	6
C3 Dibenzthiophenes	3	3	3	2	2	1	1	2	2	2	4
Sum Dibenzthiophenes	**14**	**10**	**12**	**10**	**6**	**5**	**5**	**7**	**11**	**11**	**18**
Fluoranthene / pyrene	15	9	13	11	7	6	7	8	11	12	18
C1 202	21	13	19	16	9	8	8	10	14	15	27
C2 202	21	14	18	16	11	8	8	10	14	15	28
C3 202	15	10	12	12	7	5	6	8	9	12	19
Sum 202	**72**	**46**	**61**	**54**	**34**	**28**	**30**	**35**	**48**	**54**	**92**
Benzanthracene / chrysene	14	10	12	10	6	5	7	7	10	12	18
C1 228	19	12	16	13	8	7	7	9	12	14	24
C2 228	18	12	16	13	9	7	7	9	12	14	24
Sum 228	**52**	**33**	**45**	**36**	**24**	**19**	**21**	**26**	**33**	**40**	**66**
Benzfluoranthenes / benzopyrenes	24	17	21	19	13	10	11	15	17	21	31
C1 252	29	20	27	24	15	11	12	15	20	22	37
C2 252	21	13	14	14	9	7	8	8	13	13	20
Sum 252	**74**	**50**	**63**	**57**	**37**	**27**	**31**	**38**	**50**	**56**	**89**
Aranthanthrenes / indeno- pyrene / benzperylene	11	6	8	9	4	3	4	4	7	7	15
C1 276	8	6	6	6	5	2	4	4	6	6	11
C2 276	6	4	6	6	3	2	3	3	5	5	8
Sum 276	**25**	**16**	**20**	**21**	**12**	**8**	**11**	**12**	**18**	**17**	**34**
Sum of all fractions	**478**	**330**	**385**	**329**	**228**	**182**	**213**	**271**	**329**	**369**	**603**
Sum of NPD fraction	**255**	**183**	**196**	**160**	**122**	**101**	**120**	**161**	**179**	**202**	**322**

Table 4.6. ***Polycyclic Aromatic Hydrocarbon Concentrations (US EPA Priority Pollutants, ng.g^{-1})***

PAH	*Mass*	Stn1	Stn2	Stn3	Stn4	Stn5	Stn6	Stn7	Stn8	Stn10	Stn11	Stn12
Naphthalene	**128**	2.3	1.8	2.7	2.2	2.5	3.4	2.3	3.0	1.6	1.8	5.7
Acenaphthylene	**152**	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthene	**154**	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.8
Fluorene	**166**	1.1	<1	<1	1.2	1.2	1.6	<1	1.5	<1	<1	2.4
Phenanthrene	**178**	12.8	10.1	16.2	11.2	10.3	14.1	10.5	13.6	7.2	8.6	20.9
Dibenzothiophene	**184**	<1	<1	<1	<1	<1	1.1	<1	1.0	<1	<1	1.9
Anthracene	**178**	<1	<1	<1	<1	<1	<1	<1	1.1	<1	<1	1.2
Fluoranthene	**202**	1.8	1.4	2.1	2.3	2.0	2.7	1.8	2.6	1.2	1.5	4.6
Pyrene	**202**	4.7	3.8	5.2	5.4	4.9	6.3	4.2	7.1	2.9	3.7	11.3
Benzo[a]anthracene	**228**	<1	<1	1.1	1.4	1.4	2.0	<1	1.8	<1	<1	4.0
Chrysene	**228**	5.6	5.0	6.8	6.2	5.7	7.8	5.0	7.8	4.0	4.4	12.5
Benzo[b]fluoranthene	**252**	3.6	3.1	3.5	4.3	3.2	5.5	3.3	4.5	1.7	2.8	8.8
Benzo[k]fluoranthene	**252**	1.4	<1	1.7	1.6	1.6	1.9	1.1	2.0	1.0	<1	4.1
Benzo[a]pyrene	**252**	1.4	1.0	1.4	1.8	1.5	1.9	1.2	1.9	<1	1.0	3.4
Indeno[123,cd]pyrene	**276**	<1	<1	<1	<1	1.0	1.2	<1	1.3	<1	<1	2.2
Dibenzo[a,h]anthracene	**278**	<1	<1	<1	<1	<1	<1	<1	1.2	<1	<1	1.9
Benzo[ghi]perylene	**276**	3.3	3.4	4.0	4.1	4.3	5.4	3.5	5.0	2.5	3.1	11.1

Table 4.6.cont. *Polycyclic Aromatic Hydrocarbon Concentrations (US EPA Priority Pollutants, ng.g^{-1})*

PAH	*Mass*	Stn13	Stn14	Stn15	Stn16	Stn17	Stn18	Stn19	Stn20	Stn21	Stn22	Stn23
Naphthalene	**128**	5.1	3.5	3.1	2.9	2.0	1.8	2.7	3.3	3.7	3.8	6.6
Acenaphthylene	**152**	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthene	**154**	1.6	1.0	1.3	1.1	<1	<1	<1	<1	1.1	1.2	2.0
Fluorene	**166**	2.2	1.7	1.7	1.5	1.0	1.1	<1	1.2	1.5	2.1	3.6
Phenanthrene	**178**	19.7	16.8	15.4	13.1	10.5	8.2	12.1	16.8	15.2	18.4	23.7
Dibenzothiophene	**184**	1.6	1.3	1.4	1.1	<1	<1	<1	<1	1.4	1.4	2.0
Anthracene	**178**	1.8	<1	1.6	<1	<1	<1	<1	<1	1.4	<1	1.7
Fluoranthene	**202**	4.3	2.7	3.6	3.1	2.1	1.8	2.1	2.2	3.7	3.2	5.4
Pyrene	**202**	10.3	6.5	9.1	7.6	5.0	4.3	4.9	5.4	7.2	8.4	13.0
Benzo[a]anthracene	**228**	2.9	1.7	2.6	1.9	<1	1.0	1.1	<1	1.8	2.7	3.3
Chrysene	**228**	11.3	7.8	9.6	8.5	6.1	4.4	5.6	7.3	8.1	9.5	14.5
Benzo[b]fluoranthene	**252**	5.9	4.6	5.4	5.0	3.7	2.5	3.0	4.1	4.6	6.0	8.9
Benzo[k]fluoranthene	**252**	2.9	1.8	2.7	2.0	1.5	1.2	<1	1.7	1.5	2.6	3.0
Benzo[a]pyrene	**252**	2.9	1.8	2.5	2.3	1.5	1.3	1.3	1.4	2.0	2.1	3.8
Indeno[123,cd]pyrene	**276**	1.7	<1	1.2	1.8	<1	<1	<1	<1	1.2	1.1	2.3
Dibenzo[a,h]anthracene	**278**	1.8	<1	1.0	1.1	<1	<1	<1	<1	<1	<1	2.3
Benzo[ghi]perylene	**276**	7.7	5.9	5.5	6.3	3.7	2.6	3.9	4.0	5.4	5.6	10.4

4.4.4. Regional Distribution of Sediment Hydrocarbons

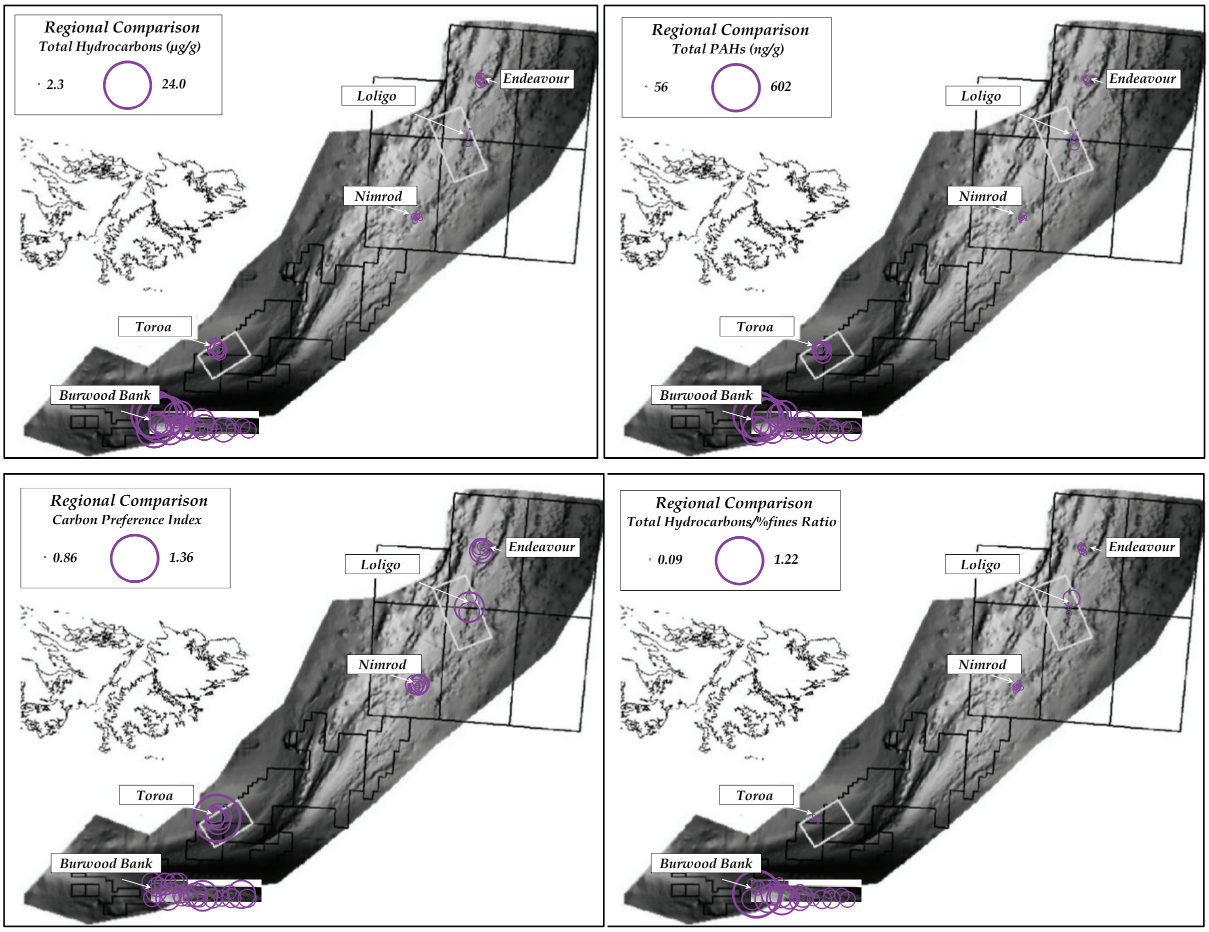
Data recovered from the current survey has been compared to similar organic sediment results acquired by BHP Billiton along the East Falkland Margin (FSL 2009a-d). These data were acquired at four prospect areas as outlined in Table 4.7. Sediments from these sites were processed in the United Kingdom following a very similar protocol to that outlined in this study making them very compatible for comparison. Regional bubble plots comparing the sediment organics are summarised in Figure 4.20.

Table 4.7 Vicinity of BHP Billiton Prospect Areas, East Falkland Margin

Site	Easting*	Northing*	Range(km)**	Bearing (°)**
Toroa	630930	4123122	74.8	199
Nimrod	820598	4247129	289.0	228
Loligo	869701	4323178	377.3	224
Endeavour	881325	4376192	424.4	220

* mean central positions calculated from sample locations
** from mean central area of the current survey

Figure 4.20 Regional Comparison of Organics



Regional concentration of Total Hydrocarbons (A) and Total PAHs (B) clearly show an increased concentration in the southwest, with marginal elevations at the Toroa and eastern Burdwood Bank stations, and significant elevations at stations in the west. The regional distribution pattern could either result from a plume of material emanating from west of the South Falkland Basin, being carried along the prevailing Malvinas Current, or it could represent the regional distribution of a viable source interval with associated natural hydrocarbon seeps. The Carbon Preference Index (CPI) is applied for the full saturate range and will identify difference in the proportion of alochthonous based biogenic material from that of marine based autochthonous material, petrogenic in particular (C). Results show a consistent ratio along the whole length of the continental shelf, showing that despite the elevations, the material producing the background THC values are broadly from a similar origin. The final figure (D), is the THC normalised against the proportion of fines within the sediment (i.e. <63µm) to remove bias from sites with increased sedimentation. Results here, show that although the proportion elevations recorded at the stations 12, 13 and 23 have been reduced, there remains a clear pattern of increased THC influence within the substrate to the west of the site.

4.5. Heavy and Trace Metal Concentrations

Results for heavy and trace metal analysis are given in Table 4.8. All of the heavy and trace metals analysed (Al, Ba, Sr, As, Fe, Cd, Cr, Cu, Hg, Ni, Pb, V and Zn), with the exception of mercury (Hg), underwent a double aqua regia followed by a hydrofluoric (HF) digestion and extraction, to provide sub-digestion values (sometimes reported as "bioavailable") in addition to total sediment metals.

Metals occur naturally in the marine environment, and are widely distributed in both dissolved and sedimentary forms. Some are essential to marine life while others may be toxic to numerous organisms (Paez-Osuna & Ruiz-Fernandez, 1995). Rivers, coastal discharges, and the atmosphere – the principal route by which lead enters offshore areas (Schaule & Patterson, 1983) – are the principal modes of entry for metals to the marine environment, with anthropogenic input occurring primarily as components of industrial and municipal wastes.

Historically, it is important to establish baseline levels for several heavy and trace metals where found in elevated concentrations within drilling fluids or produced waters discharged by Oil & Gas installations, both through intentional additives (such as metal based salts and organo-metallic compounds in the fluids) as well as impurities within the mud systems. Metals most characterised by offshore contamination to the sediments are barium, chromium, lead and zinc (Neff, 2005), although these may vary greatly dependant upon the constituents used.

Trace metal contaminants in the marine environment tend to form associations with the non-residual phases of mineral matter, such as iron and manganese oxides and hydroxides, metal sulphides, organics, and carbonates. Metals associated with these non-residual phases are prone to various environmental interactions and transformations (physical, chemical and biological) potentially increasing their biological availability (Tessier *et al*, 1979). Residual trace metals are defined as those which are part of the silicate matrix of the sediment and that are located mainly in the lattice structures of the component minerals. Non-residual trace metals are not part of the silicate matrix and have been incorporated into the sediment from aqueous solution by processes such as adsorption and organic complexes and may include trace metals originating from sources of pollution. Therefore, in monitoring trace metal contamination of the marine environment, it is important to distinguish these more mobile metals from the residual metals held tightly in the sediment lattice (Chester & Voutsinou, 1981), which are of comparatively little environmental significance.

The question of biolavailability of metals to marine organisms is a complex one, as sediment granulometry and the interface between waters and sediment all affect the bioavailability and subsequently toxicity. Therefore, even if a metal is found in higher concentrations it does not necessarily follow that this will have a detrimental effect on the environment, if present in an insoluble state. Historically, several extraction techniques have been applied to metal analysis in the past, with the most common applying to an HF/perchloric extraction for total metals, and a weaker nitric or aqua regia extraction for bioavailable metals. The latter techniques have shown close correlation to metal burdens in the tissues of benthic organisms (Luoma and Davies, 1983; Bryan and Langston, 1992). However the overall extent to which a particular digests reflects bioavailability is still not fully understood. Sometime the concentrations of some metals, like barium, typically recorded in areas where previous drilling activities have occurred, are so high that full dissolution cannot be guaranteed even with hydrofluoric acid digestions, necessitating a further fusion technique. This was not required for the baseline sediments on this study.

Of the metals analysed, the crustal or matrix metals aluminium (Al; Figure 4.21) and iron (Fe, Figure 4.22) indicated significantly high and slightly variable concentrations with means of 40.8 and 58.0 $mg.g^{-1}$, respectively. These levels reflect the naturally high level of these residual metals in the sediment of this region. This variability indicated a weak pattern of distribution, with elevated levels within the more granular sediment towards the east. This was statistically correlated with coarser sands, gravels, mean size, organic matter and the metals nickel and zinc. Iron is also an important metal as it is often associated with other elements, such as Arsenic (As) to which they adsorb. Arsenic weakly correlated to iron, exhibiting slight variability ranging from 2 to 22.1$\mu g.g^{-1}$. Both Al and Fe indicating similar variability at other sites around the Falklands, the mean concentration for iron at Loligo was 110$mg.g^{-1}$, for example (FSL 2009c).

Barium remains the most abundant metal found in drilling related discharges due to its use as a weighting agent within the drilling mud program in the form of barite ($BaSO_4$). Consequently, it is often used as an indicator to the effects of drilling related discharges. For this baseline survey, natural barium levels remained relatively high and variable throughout the area ranging from 265$\mu g.g^{-1}$ to 2,420$\mu g.g^{-1}$ (mean 782$\mu g.g^{-1}$), with no obvious pattern of distributions (Figure 4.22). This variability reflects the natural changes in concentrations relative to the natural sediment changes at these locations, the majority of which (89.2%) remaining soluble to a weaker acid digestion and available to the marine fauna. This high percentage is slightly unusual as Barium, a matrix bound metal, is generally found in an insoluble sulphate form, considered as non-toxic (Gerrard et al, 1999) and is rarely of toxicological concern. Statistically, barium failed to correlate with any other parameter with the exception of the PB ratio ($P<0.05$). Again, this is slightly unusual in that natural barium levels typically shows a strong granulometric link and consequently auto-correlates strongly to other metals, in particular the crustal metals such aluminium and iron. Overall results in the current survey are marginally higher than those recorded at the neighbouring sites at 236, 329 and 407µg.g^{-1}, for the North Falkland Continental Shelf, Loligo and Toroa, respectively (BSL, 2008 & FSL 2009a & c).

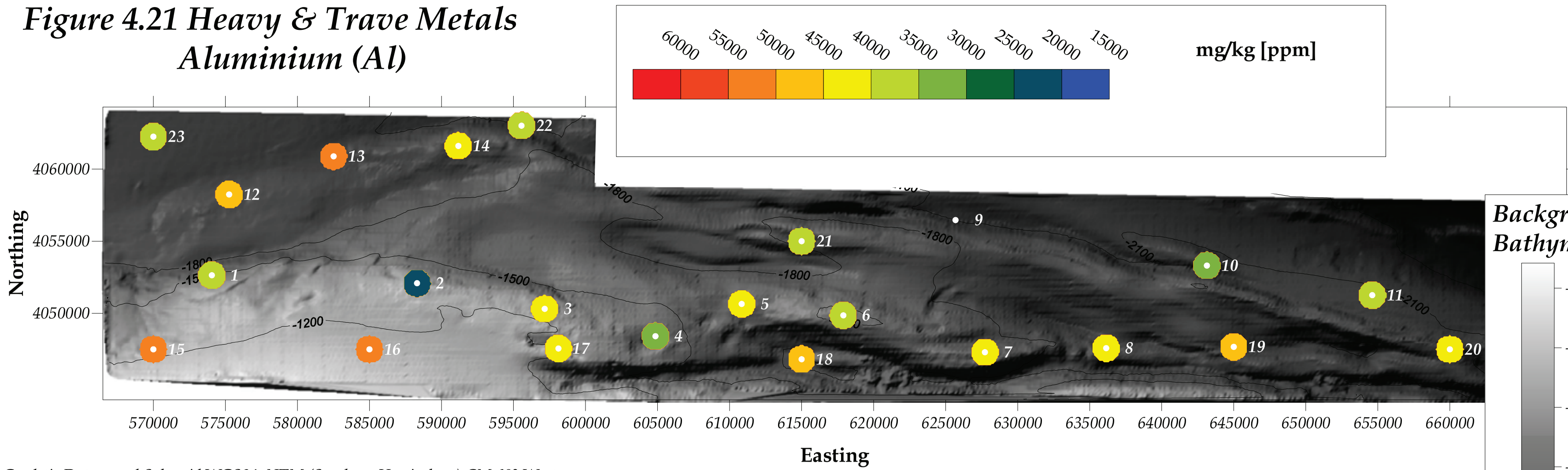
Strontium is a similar metal to barium as is also often associated with drilling related discharges. Here, natural levels were slightly less variable, and no pattern of distribution recorded, correlating only weakly with carbonates ($P<0.05$). Overall, total levels ranged from 102 to 479 µg.g^{-1} (mean 281 µg.g^{-1}), with around 80% soluble to the weaker extraction method.

The concentration of lead (Pb; Figure 4.24) was also low, but slightly variable (mean 9µg.g^{-1} (SD 3.1). This was marginally higher than previously recorded at neighbouring sites (ranging from 5.8 to 6.7 µg.g^{-1}), but exhibited a slightly weak pattern of distribution correlating with zinc and several of the hydrocarbon components (PAH, NPD and total hydrocarbons).
Other metals that showed correlations with different environmental parameters were copper (Cu, Figure 4.24) and nickel (Ni; Figure 4.26), although these showed opposite distributions. Copper, which had a total mean of 14.6µg.g^{-1} (SD 2.9), showed a strong correlation with the finer sediments, sorting and TOM. Nickel, with a mean of 8.4µg.g^{-1} (SD 1.4), however, correlated with the proportion of gravels, mean size and TOM. In both cases, overall concentrations were generally low and within the range recorded at neighbouring sites around the Falklands.

All of the remaining metals analysed show generally low level concentrations expected for an uncontaminated offshore environment. Both mercury (Hg) and cadmium (Cd) remained at, or below detectable limits for the tests. Chromium (Cr) ranged from 32.1 to 61 µg.g^{-1} (mean 44.3µg.g^{-1}) and within the range previously recorded in the Falklands 25.8 to 139µg.g^{-1} (BSL 2008). The last remaining metal of vanadium (V) remained relatively consistent around a mean of 59.3 (SD 7.3), and was marginally higher than previously recorded in the north Falklands Continental Shelf 28.9 to 49µg.g^{-1}.

When comparing the key elements with those of the OSPAR background reference concentrations (BRCs) values, the seven key metals cadmium, chromium, copper, mercury, nickel, lead and zinc all gave concentrations below OSPAR BRCs with the exception of cadmium which could not be determined to a low enough resolution. There remains some debate as to toxicity of cadmium to marine and terrestrial organisms. Some papers describe cadmium as "very toxic" (Muniz et al 2004), whilst others consider this metals to have no negative effects (McLeese et al, 1987). Other attempts to quantify the critical level of cadmium toxification were carried out by Buchman (1999) and suggested 'probable effect level' of around 4.2mg.kg^{-1}. Cadmium remained below 1µg.g^{-1} for all samples analysed.

Figure 4.21 Heavy & Trave Metals Aluminium (Al)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

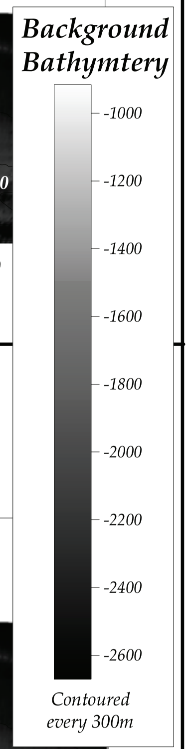
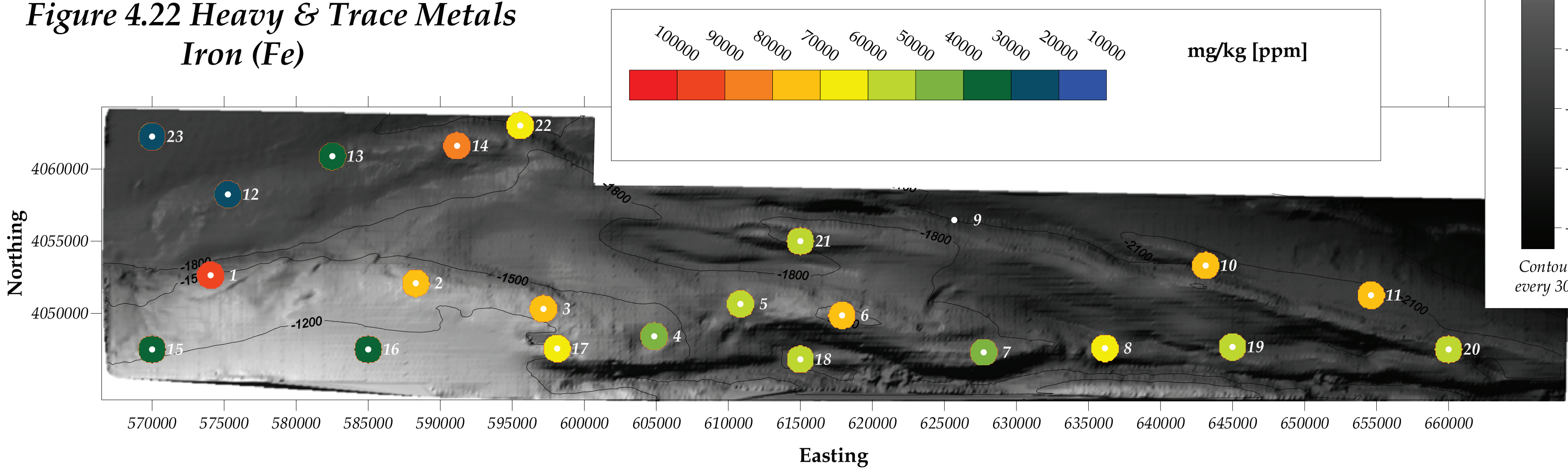
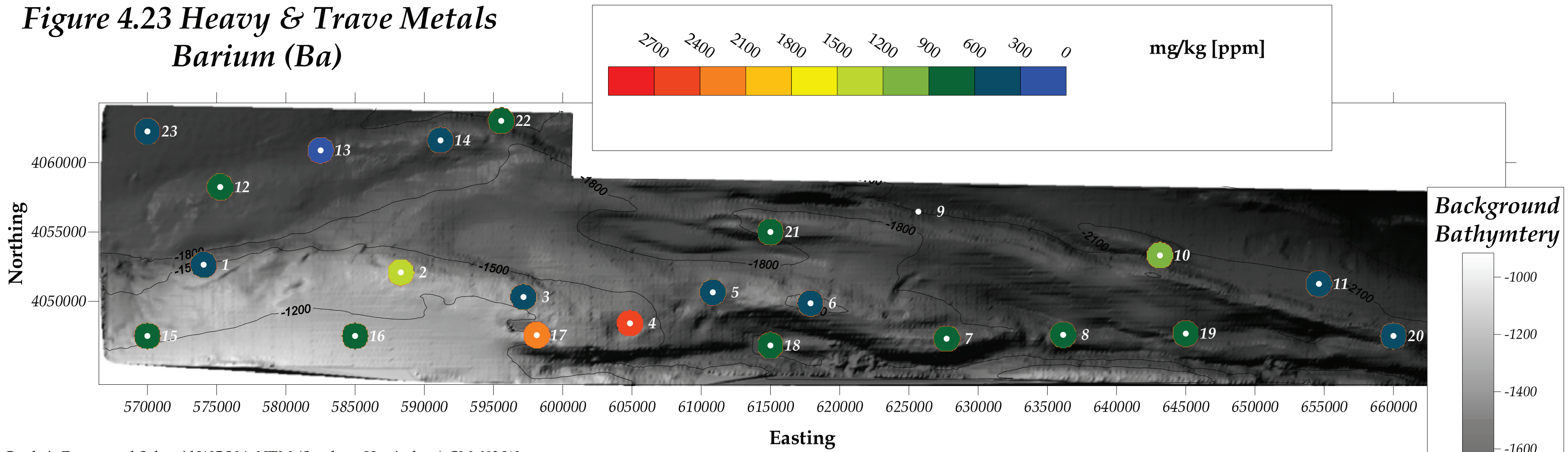


Figure 4.22 Heavy & Trace Metals Iron (Fe)



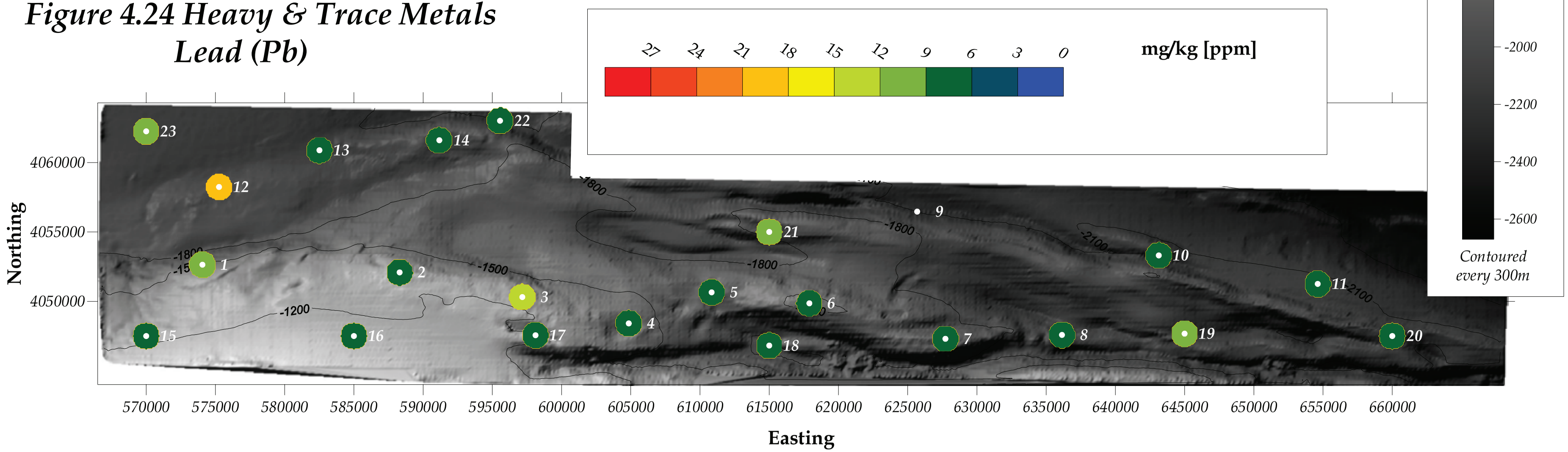
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.23 Heavy & Trave Metals Barium (Ba)



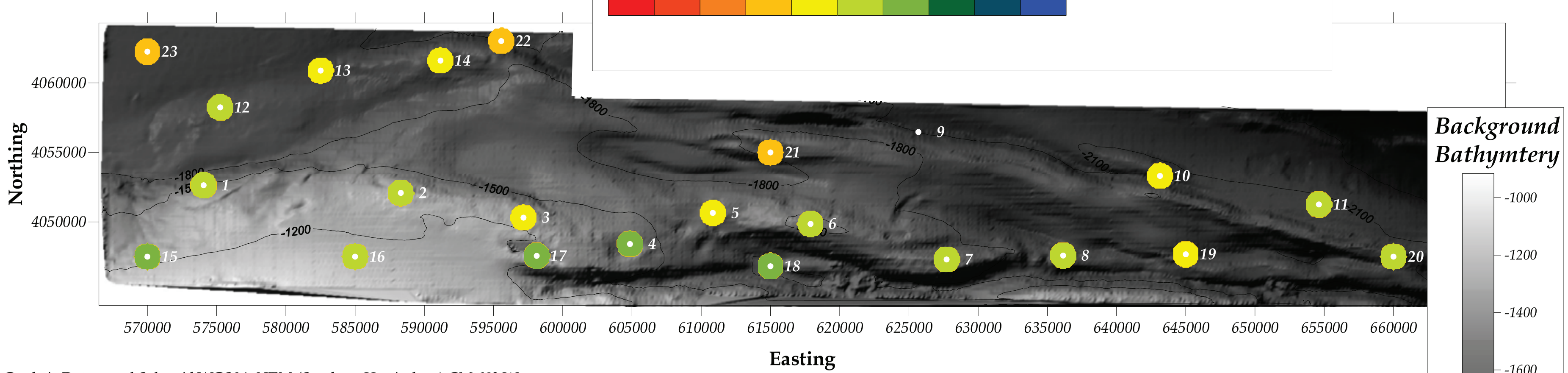
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.24 Heavy & Trace Metals Lead (Pb)



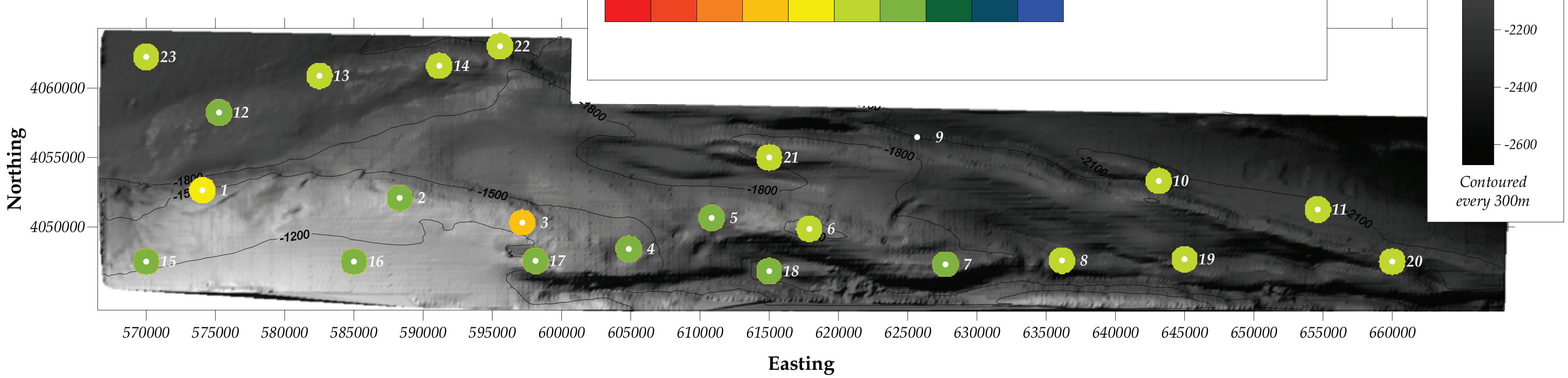
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.25 Heavy & Trave Metals Copper (Cu)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.26 Heavy & Trace Metals Nickel (Ni)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Table 4.8. Total Heavy & Trace Metal Concentrations (µg.g^{-1} or ppm)

Station	Arsenic		Barium		Cadmium		Chromium		Copper		Lead		Hg
	HF	AR	HF	AR	HF	AR	HF	AR	HF	AR	HF	AR	
Station 1	22.1	26.4	460	402	<1	<1	38.7	40.6	13.8	11.3	11	7.2	0.1
Station 2	12.8	18.6	1240	1250	<1	<1	34.1	43	14	9.2	6.6	5.8	<0.1
Station 3	20.2	18.9	494	315	<1	<1	35.7	24.3	16.1	10.2	13.7	8.4	<0.1
Station 4	7.1	7.1	2420	2690	<1	<1	46	47.2	11.4	7.7	6.5	3.1	<0.1
Station 5	7	7.8	520	378	<1	<1	40.8	41.2	15.2	13	8.1	3.9	0.2
Station 6	12.1	12.4	560	431	<1	<1	54	53.8	14.3	11.1	7.6	4.9	0.1
Station 7	4.8	5.5	637	511	<1	<1	39.2	38.3	13.5	10.1	8.8	3.6	0.1
Station 8	6.5	6.3	698	654	<1	<1	55.9	57.6	13.1	8.9	7.1	3.3	<0.1
Station 10	9	10.3	952	855	<1	<1	44.4	51.6	15.9	13.2	7.7	6	<0.1
Station 11	7	7	437	286	<1	<1	61	59.7	14.4	10.7	6.8	4.5	0.1
Station 12	4.3	3.4	602	352	<1	<1	30.1	17.9	13.9	9.8	20.6	4.7	0.2
Station 13	28	2.2	265	438	<1	<1	57.8	60.1	16.5	15	7.9	4.2	0.2
Station 14	14.9	14.3	493	355	<1	<1	66.6	60.3	17.1	12.6	8	4.6	0.1
Station 15	3.9	3.6	659	576	<1	<1	32.1	23.4	9	7.4	7.4	3.9	<0.1
Station 16	4.9	3.7	631	600	<1	<1	34.7	22.8	12.1	5.4	8.7	3.7	<0.1
Station 17	11.4	11.8	2320	2390	<1	<1	39.7	37.7	11.4	8.4	8.4	5.5	<0.1
Station 18	7.8	7.5	741	596	<1	<1	45.6	44.8	11.4	7.4	7.9	3.5	<0.1
Station 19	7.3	7.2	701	550	<1	<1	35.1	25.1	16	13.6	9.5	6.8	0.1
Station 20	6.9	6.7	554	483	<1	<1	42.1	41.1	13	13.4	7.2	4.3	<0.1
Station 21	6	8.3	619	413	<1	<1	60	53.2	20	13.7	10	5.7	0.2
Station 22	9	12.9	638	446	<1	<1	50	45.8	20	13.5	8	6.3	0.2
Station 23	2	1.8	568	384	<1	<1	30	21.7	20	19.4	10	5.5	0.3
Survey	9.8	9.3	782	698	-	-	44.3	41.4	14.6	11.1	9.0	5.0	0.16
St Dev	6.5	6.1	548	633	-	-	10.9	13.7	2.9	3.2	3.1	1.4	0.07
%variance	66.1	65.9	70.1	90.8	-	-	24.5	33.2	20.0	28.3	34.2	27.9	42.2
Bioavailabilit	94.7%		89.2%		-		93.6%		76.1%		55.4%		-
Toroa 2009	**1.0**	**1.0**	**407**	**108**	**0.9**	**0.12**	**25.8**	**18**	**17.0**	**12.2**	**5.8**	**2.7**	**<0.1**
Loligo	**2.0**	**2.1**	**329**	**138**	**0.8**	**-**	**139**	**39.6**	**20.0**	**11.8**	**6.7**	**4.5**	**<0.1**
North Falklands 2008	**3.6**	**3.0**	**236**	**18.7**	**0.4**	**<1**	**26.9**	**20.5**	**5.5**	**8.7**	**5.8**	**2.3**	**0.01**
OSPAR BRC	**-**		**-**		**0.2**		**60**		**20**		**25**		**0.05**

HF = Total metals by hydrofluoric extraction
AR = "bioavailable" metals by aqua regia extraction

Table 4.8. cont. *Total Heavy & Trace Metal Concentrations (µg.g⁻¹ or ppm)*

Station	Nickel		Strontium		Vanadium		Zinc		Aluminium		Iron	
	HF	AR	HF	AR	HF	AR	HF	AR	HF	AR	HF	AR
Station 1	10.9	11.8	263	222	66.3	61.2	71.4	78.8	35200	8540	99700	91600
Station 2	7.2	7.5	479	462	56.2	58.2	58.3	55.4	21200	7890	71000	70500
Station 3	12.1	12.1	228	165	73.7	48.6	64.8	55.5	41900	8170	76900	54500
Station 4	7	7.3	288	235	56.6	43.9	55.5	51.4	34800	8970	41300	41800
Station 5	7.6	8.6	329	272	54.9	41.1	53.6	50.4	41200	9000	56200	46300
Station 6	8.9	9	300	225	55.3	38.7	70.2	52.5	36200	7020	78700	60300
Station 7	7.1	7.8	280	239	53	38	46.3	46.8	43500	9470	43300	36800
Station 8	8.9	8.1	296	214	58.1	44.2	58.4	52.6	42000	8490	60400	45900
Station 10	9.4	10.2	330	247	47.9	42.7	65.6	69	32200	7230	76900	72200
Station 11	9.2	9	239	179	63.1	45.6	57.2	54.2	35600	8830	71900	64800
Station 12	7.4	6.5	279	188	56.2	25.9	73	46	48000	8780	29000	19200
Station 13	8.8	9.5	120	242	55.6	33.8	49.4	44.1	50500	1230	30900	23300
Station 14	9.1	8.3	235	175	80.8	55.4	66.2	58.4	40000	8650	82500	73100
Station 15	7.3	7.1	249	185	57.8	32.6	49.3	47.3	53400	9000	39600	28100
Station 16	6.8	6.4	241	157	59.1	30.4	60.1	45.8	52000	8140	39200	28200
Station 17	7.6	9.3	264	206	62.9	51.5	65.3	64.7	42900	9620	64800	53100
Station 18	7.1	7.3	243	165	58.6	45.1	61.4	52.9	48500	1000	56500	43900
Station 19	9.8	10.6	296	227	62.8	36.1	56.4	50.3	46900	9740	54800	43100
Station 20	9	9.6	336	287	55.7	37.5	56.7	48.6	40900	8080	57200	45100
Station 21	8	8.4	406	319	50	43.6	60	48.2	37200	8940	54800	47500
Station 22	8	9.4	221	161	60	56.6	70	66	35100	1120	69100	72300
Station 23	8	9.2	278	233	60	33.9	60	47.5	39800	1290	21700	21400
Survey	8.4	8.8	281	227	59.3	42.9	60.4	53.9	40863	9134	58018	49227
St Dev	1.4	1.5	70	67.6	7.3	9.4	7.4	8.7	7438	1446	19671	19319
%variance	16.1	17.4	25.0	29.7	12.2	22.0	12.2	16.1	18.2	15.8	33.9	39.2
Bioavailable	Ca. 100%		80.7%		72.4%		89.3%		22.4%		84.8%	
Toroa 2009	**10.5**	**36.1**	-	-	**49.0**	**19.5**	**38.5**	**39.8**	**59418**	**7263**	**22380**	**13983**
Loligo	**13.0**	**23.9**	-	-	**32.3**	**19.5**	**43.7**	**36.7**	**30267**	**4827**	**110867**	**23600**
North Falklands 2008	**6.4**	**7.1**	**195**	**79.8**	**28.9**	**14.5**	**27.4**	**16.0**	**35,297**	**6,402**	**15,160**	**11,440**
OSPAR BRC	**45**		-		-		**90**		-		-	

HF = Total metals by hydrofluoric extraction
AR = "bioavailable" metals by aqua regia extraction

4.6. Macrofaunal Analysis

Macrofaunal analysis was carried out on forty eight replicates (from 21 sites) over the regional survey area. The sediments showed a variable seabed ranging from sandy silts in the northwest to silty gravely sands and occasional bedrock exposure. Macrofaunal samples were all processed in the field using a 500µm mesh size. Subsequent macrofaunal taxonomy was carried out to the lowest practical level available, given the timing of the report, although some material has not been fully described due to limited information on some groups for the South Atlantic. Of the identified fauna to date, a total of 3,194 individuals/colonies were identified from the 48 samples analysed. Faunal data for each sample are listed in Appendix V, whilst univariate analyses are summarised in Tables 4.10 & 4.11. Of the 318 species/groups recorded, 233 were infaunal, consisting of 86 annelids accounting for 36.5% of the total taxa (42.0% of individuals). The molluscs were represented by 34 species (14.3% or 9.5% of individuals), the crustaceans by 79 species (33.9% or 26.5% of individuals) and the echinoderms by 12 species (5.1%, or 2.5% of individuals), while all other groups (cnidaria, nemertea, nematoda, platyhelminths, sipuncula, pycnogonida, brachiopoda, foraminifera, enteropneusta and chordata) accounted for the remaining 22 species (9.2%, or 16.5% of individuals). A distribution of the different taxa is presented in Figure 4.27 and 4.28 by replicate and Figure 4.29 and 4.30 by station, showing abundance (i.e. number of individuals in each phyla) and richness (i.e. number of species in each phyla), respectively.

With the exception of species that have been intentionally grouped into higher taxonomic levels (e.g. Nematoda, Nemertea etc.), the majority of adult specimens were identified to species level where possible. Some of the complicated polychaete and amphipod species have yet to be fully separated and have been intentionally grouped into a higher taxonomic level based on information available a the time of the survey. Furthermore, some groups have been separated into putative species where they are considered to be distinct, but cannot be named. Of the 235 separated quantitative infaunal taxa/groups used in this report approximately 42 of these were recorded to species (excluding juveniles and fragmented species), along with a further 85 identified to genus and 38 to putative species level. This is equivalent to around 70.3% of the taxon. The remaining specimens were placed in higher taxonomic groups such as family or order, accounted for the remaining 29.8% of the taxon. Few juvenile species were recorded throughout the survey area possibly reflecting the early spring timing of the sampling, or due to the limited knowledge known about many of the species. Juveniles are often excluded from community analyses due to their high mortality prior to reaching maturity and difficulties in distinguishing species of the same genus. Consequently, they tend to induce a recruitment spike at certain times of the year due to rapid settlement and colonisation, but are essentially a ephemeral part of the population masking the underlying trends within the mature adults

A similar survey on the North Falklands Continental Shelf also acquired over a regional area but in shallower more homogeneous sediments indicated a higher species abundance but notably lower species richness (BSL 2008). For this survey the species abundance was equivalent to around 2,150 ind.m^2, compared to 660 ind.m^2 for the Burdwood Bank, whilst species richness increased from 210 taxa in 78 samples to 318 taxa from 48 samples. Both results highlight the differences in the habitat, with deeper and more variability substrates encountered at the Burdwood Bank. When compared to deeper neighbouring sites (i.e. Toroa and Loligo; FSL 2009a & c) in the East Falkland Margin, the faunal population at these locations varied from around 404 to 390 ind.$m^{2,}$ and a species richness of around 110 to 78 species, but from fewer samples. This is respectively equivalent to 21 and 18 species per sample compared to almost 32 species per sample at the Burdwood Bank. Proportionally, the separation of the different phyla look broadly similar between the current survey and that of the North Falkland Basin; that of a polycheate dominance (around 48%), but also a very significant crustacean population (35%) and a low echinoderm population (<5%). However, this distribution was slightly different in the East Falkland Margin which indicated a marginally lower crustacean population of around 24 to 11%. Echinoderms were similarly poorly represented at 6 to 0.6% echinoderms for these areas, respectively.

Other macrofaunal groups not included in the multivariate analyses are the epifaunal species (such as poriphera, hydroidea and bryozoa) and some damaged specimens. Overall, these groups accounted for a further 83 different groups or 26% of the community recorded. These have been separated from the main matrix or recorded as presence/ absence and not included in the multivariate analysis. These have been listed separately in Appendix V.

Figure 4.27. Proportion of Individual Abundance by Main Group and Replicate

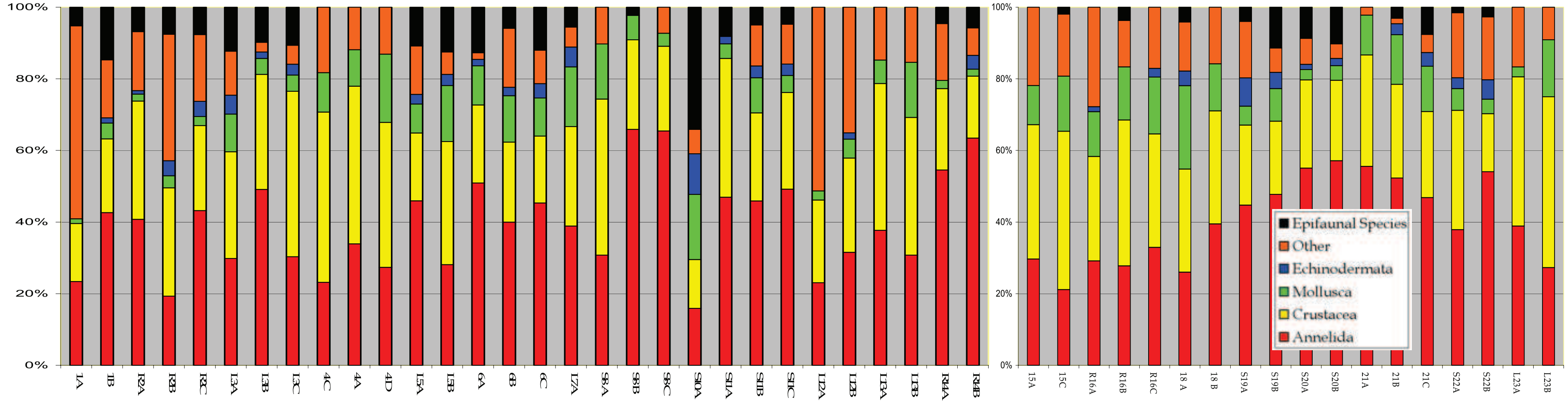


Figure 4.28. Proportion of Individual Richness by Main Group and Replicate

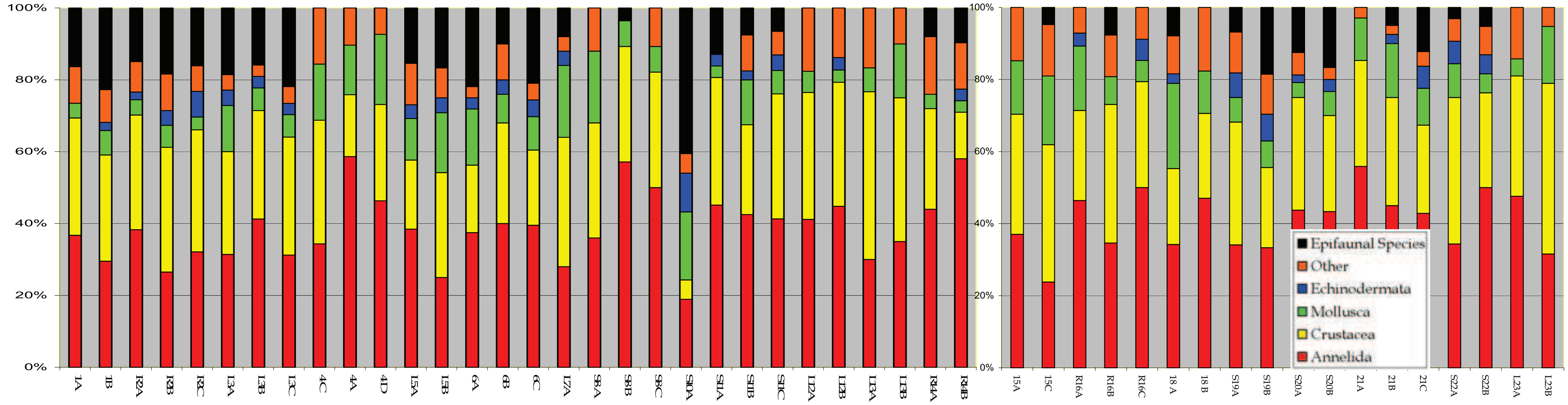


Figure 4.29. ***Proportion of Individual Abundance by Main Group and Replicate***

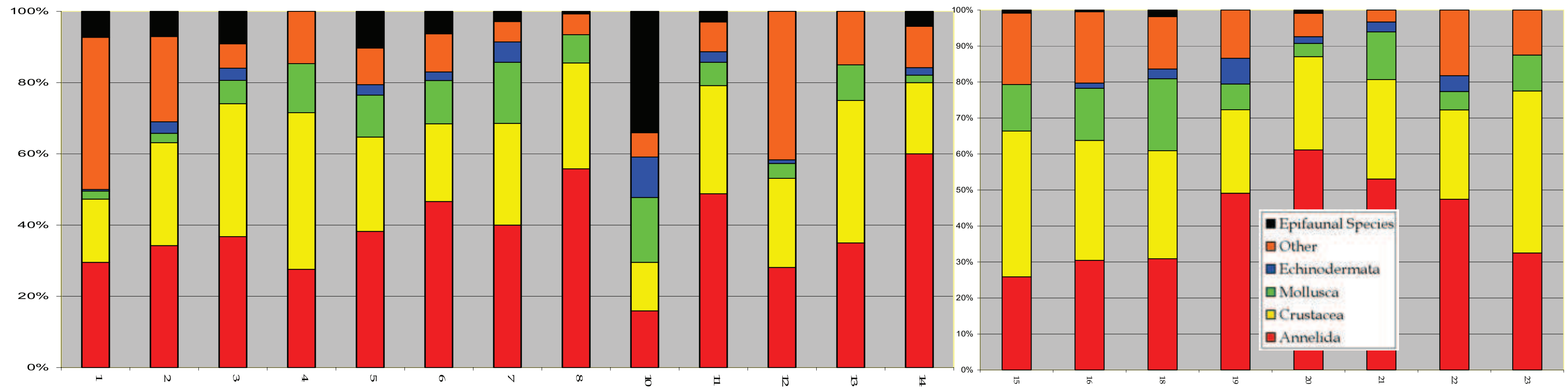
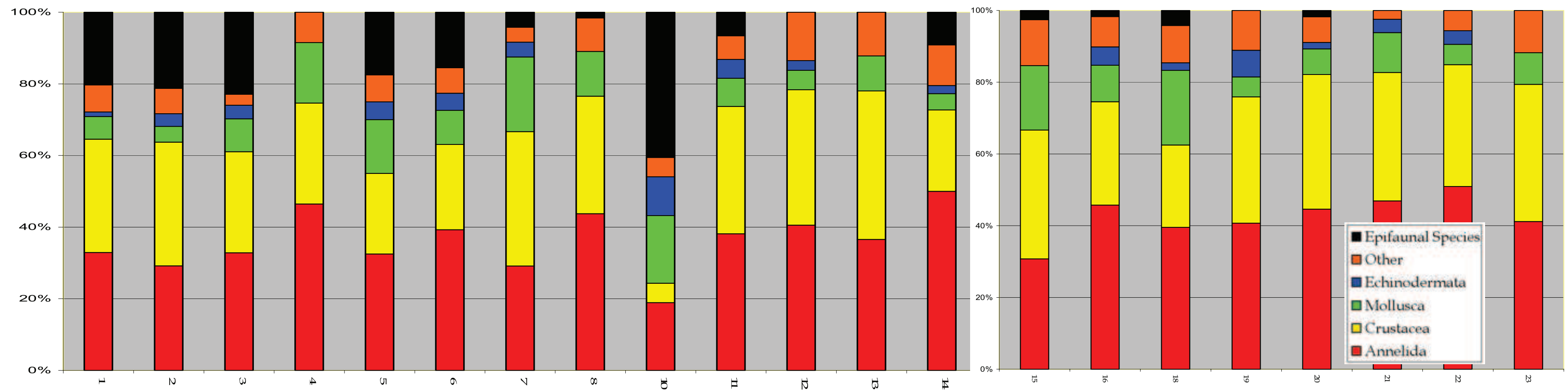


Figure 4.30. ***Proportion of Individual Richness by Main Group and Replicate***



4.6.1. Infaunal Trends

The benthic fauna of the Falkland Islands belongs to the Magellan faunal area, made up of the sea areas around the southern part of South America (e.g. of the Coasts of Argentina and Chile, and the subantarctic area to the south). In many aspects it is comparable to the Northern Boreal Region; it is however characterised by a very high diversity within the crustacea, with many groups well represented. For this preliminary regional assessment the level of analysis has concentrated on the key separation of groups in order to identify trends within the biological community with that of the physical habitats in this deep water environment. Further analysis of this material is expected to refine a greater number of specimens to species level; although our knowledge of the fauna is much more limited than that of the northern Atlantic and European waters, with the use of specialist taxonomic knowledge to resolve some of the groups and a definite identification and description of hitherto unrecognised species.

The top five numerically dominant species across the regional survey area were, in order, the polycheate *Rhamphobranchium ehlersi*, Nematodes, Ostracods, and the amphipods *Urothoe* sp and a further gammarid Phoxocephaloidea sp.C (eyeless). However, the distribution of these key species alter slightly on a regional scale. This is explained further during the multivariate analyses (see section 4.6.4).

A measure of the overall dominance pattern in the sampling area was achieved by ranking the top species per station according to abundance, giving a rank score of 10 to the most abundant species, decreasing to 1 for the tenth most abundant species, and summing these scores for all 21 sites to provide an overall dominance score (Eleftheriou & Basford, 1989) for each species. The top 10 species are shown in Table 4.9. This ranking closely matches the numerical ranking for the species overall for the top five species although the bottom order indicated considerable variation. This suggests that the proportion of these species remained relatively inconsistent across the survey area with clear habitat changes and subsequent sub-communities existing for different sediment types or areas.

Table 4.9. Overall Species Ranking (Top 10 Species)

Overall Top 15 Rank	Species/Taxon	Total rank score (out of 210)	Numerical Abundance (48 replicates)	Numerical Ranking
1	*Rhamphobranchium ehlersi*	151	258	1
2	Nematoda spp.	98	241	2
3	*Urothoe sp.*	62	86	3
4	Phoxocephaloidea sp.C (eyeless)	62	72	4
5	Nemertea spp.	52	50	6
6	*Galathowenia sp*	48	50	10
7	*Aricidea c.f. oculata*	44	68	7
8	Oligochaeta Tubificidae	43	57	8
9	*Aff Scoloplos sp*	36	34	14
10	Caulleriella spp	34	36	11

Comments relating to individual infaunal groups recorded during the survey are as follows:

Polychaeta: The dominant species in this survey proved to be the quill worm *Rhamphobranchium ehlersi* with up to 14 specimens recorded in a sample, and many specimens achieving a size of several cm (Figure 4.31). A related species, *Nothria conchylega*, has its tube attached to hard substrate, and several instances of this species were also recorded.

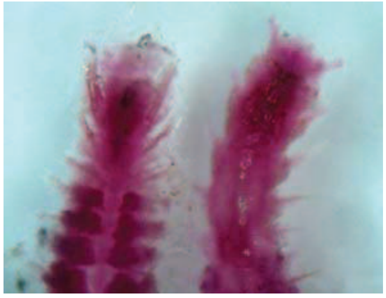


Figure 4.31. The dominant polychaete Rhamphobranchium ehlersi

Another prominent species was the eyeless nereimorph species *Ceratocephale* due to its size. Other errant and not infrequent species were the paddle worms *Mystides* and *Eteone, Glycera capitata* and the Nephtyd species *Aglaophamus.*

Amongst the sedentary Polychaeta was the Family Paraonidae, with *Aricidea* spp and *Levinsenia* featuring prominently. There were a considerable number of species of *Aricidea* described, and the existence of species complexes (i.e. several species within this genus) is likely, although in many instances, identification was limited to the anterior ends only.

Another Polychaete family of note was the Sabellidae, and especially the subfamily Fabriciidae, with the Genera *Jasmineira*, *Chone* and *Euchone.* These and their tubes were regularly encountered throughout the study area in nearly all samples. Other prominent large specimens were *Spiochaetopterus* sp, with tubes of several cm length, *Lumbrineris* sp, and *Maldane sarsi* subspecies. It should be noted that a number of species recorded are bipolar and are commonly recorded in European waters. A wide distribution of some polychaete fauna should not be surprising given the often lengthy planktonic life of polychaete larva. There were no obvious differences in the biology of these species nor in those species which share their generic status within the northern boreal region. Species with a very wide geographical and vertical distribution in the Atlantic and elsewhere are:

Glycera capitata	*Notomastus latericeus*
Nothria conchylega	*Ophelina cylindricaudata*
Levinsenia gracilis	*Scalibregma inflatum*
Spiophanes bombyx	*Melinna cristata*
Maldane sarsi	*Terebellides stroemi*
Chaetozone setosa	

Crustacea: This Class of Arthropoda produced more than a quarter of the species recorded, with the bulk provided by Amphipoda, Isopoda, Tanaidacea and Cumaceans in that order. However some of the minor groups were not without interest. One specimen of Cephalocarida, a minute ancient group of interstitial crustaceans was identified on the base of its turgor extremities; superficially it resembles a polychaete worm.

The largest group and the most difficult taxonomically was comprised of the Amphipods. Most common were species belonging to the families Phoxocephalidae and Lysiannassidae, followed by *Ampelisca* species. Frequent were also Stenothoidae, and *Urothoe* spp. (Figure 4.32).

Figure 4.32. The dominant crustacean Urothoe sp.

The Isopoda provided a large number of species, virtually all well recognized Deep Sea genera. While it proved relatively easy to identify to Genus, this could not be taken through to species except in few circumstances. Typical deep Sea Genera are: *Macrostylis, Nannoniscus, Haploniscus, Ischnomesus, Haplomesus, Heteromesus, Desmosoma, Janirella, Spinianirella* and *Abyssinaria.*

The Family Serolidae, typical of Antarctic and sub-antarctic waters, was represented by three specimens of two species of *Serolis*., the second one characterized by a couple of bands of small spines across some thoracic segments and numerous small spines on the telson, and neither featured in the key to Atlantic Bathyal Isopoda.

Next in numbers proved to be the Tanaidacea with nine species; of interest was the species denominated as "long body". This featured an extremely elongated body, with each segment or somite being several times as long as wide.

Cumaceans were not infrequent, and similar to the fauna of the shallower survey. Decapods were not recorded. Rather than a damaged example of the crab *Peltarion spinosulum* recovered in one of the box corer samples which was discarded (pictured in Figure 2.2G).

Mollusca: This phylum is represented by 34 species, with Bivalvia the largest class. Here *Pecten (aff Similipecten*) and *Dacrydium sp* are prominent (Figure 4.33); both are byssus-attached species and could therefore be considered epifaunal. The same applies to *Lima sp*. and *Bathyarca* *sp*. Most species and specimens were small, rarely more than 1mm across, with the exception of *Pecten* which grew to several mm.

Gastropoda achieved a larger size, with some specimens reaching 2 cm in length. No species was very common, and most are predatory. More prominent were members of the Class Scaphopoda (elephant tusk shells), and Solenogastres, worm like molluscs without a shell.

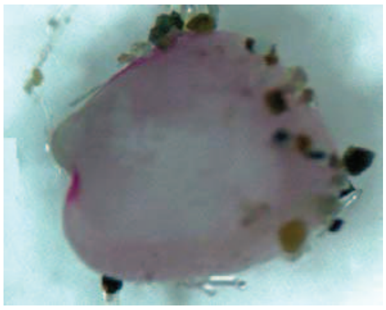


Figure 4.33. The bivalve mollusc Dacrydium sp.

Echinoderms: The abundance and richness of echinoderms was very low. The thirteen species recorded were dominated by ophiuroids with nine species. *Astrotoma agassissi* belongs to the order Euryalida, with arms articulating vertically as well as horizontally, all others belong to the order Ophiurida. *Astrotoma* was found clinging to the branches of the Gorgonarian *Pleurocoralloides* (typical behaviour for this group) and can therefore be considered to represent sites with greater epifaunal coverage (i.e. areas with bedrock or larger glacial drop-stones). Two very small specimens of a stalked Crinoid were also recorded on one station, both belonging to the Family Bathycrinidae.

No Asteroidea (starfish) and only one fragmented specimen of a spatangoid irregular sea urchin were recorded during the survey. One dendrochirote Holothurion (*Psolus*) and two species of synaptid Holothurians were recorded. One synaptid species was characterized by an absence of calcareous deposits, with only the mouth ring and tentacle bases indicating its systematic status; the third species belonged to the Family Microtrochidae, with wheel like deposits in the skin. This family is confined to polar seas and deep water.

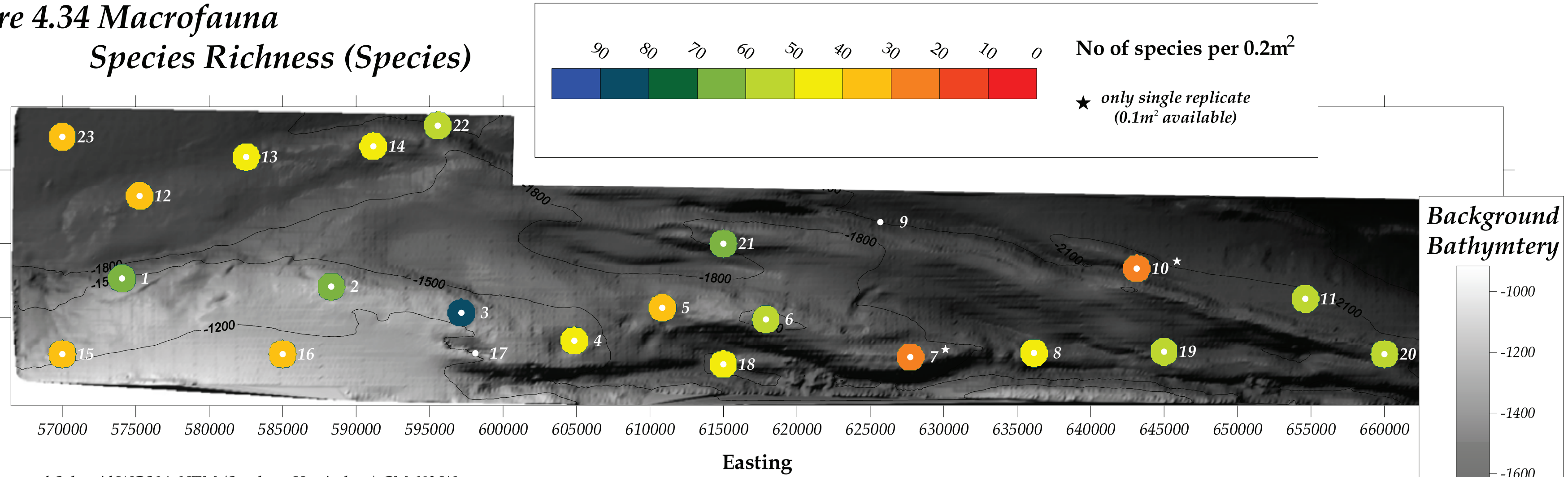
<u>4.6.2. Univariate Parameters</u>

The primary and univariate parameters are listed for individual macrofaunal replicates, together with aggregated stations in Table 4.10 (by replicate) and Table 4.11 (by stations), respectively. The total number of individuals varied from 27 to 146 per $0.1m^2$ (60 to 206 by station ($0.2m^2$)) and taxa varied from 17 to 57 per $0.1m^2$ (22 to 87 by station ($0.2m^2$)), with the greatest abundance in taxa and highest number of individuals recorded in the central western area on the northern edge of the Burdwood Bank (Figures 4.34 and 4.35). The lowest values, by station, related to stations 7 and 10 where only a single replicate could be recovered. No other pattern of distribution was recorded with very little correlation with other sediment parameters. With the exception of a weak correlation between abundance and median size and parent to total PAHs ($P<0.05$), no relationships were recorded. This highlights the variability of the habitat and the complex relationship between the number and abundance of species with varying sediment types.

The Shannon-Weiner diversity values were generally quite high, but slightly variable ranging from 3.08 to 5.35 by replicate or 4.18 to 6.03 (mean 4.86, SD 0.47) for all stations. No significant pattern of distribution was recorded (Figure 4.36). Consequently, statistically, diversity correlated with very few other parameters, showing no relationship with sediments granulometry or depth and a very weak correlation with parent/total PAHs ($P<0.05$). The Pielou's Equitability indices showed a similar pattern by station, ranging from 0.70 to 0.95 (Mean 0.89, SD 0.06), indicating a variable species dominance across the sampling template. Margalef's Index (Species Richness) varied between 6.24 and 16.23 (mean 9.81, SD 2.46). Both parameters were influenced by the single replicates recovered at stations 7 and 10. Lastly, the Simpson's evenness ranged from 0.83 to 0.98 (mean 0.95, SD 0.03; Figure 4.37). As with diversity, neither richness, evenness nor dominance parameters indicated any pattern of distribution separating them from the varied granulometric parameters. This is slightly unusual, as this would tend to suggest that whilst the infaunal communities may alter, the magnitude of this in this area and varied sediment type is relatively small, and the generally limited dominance of key species throughout.

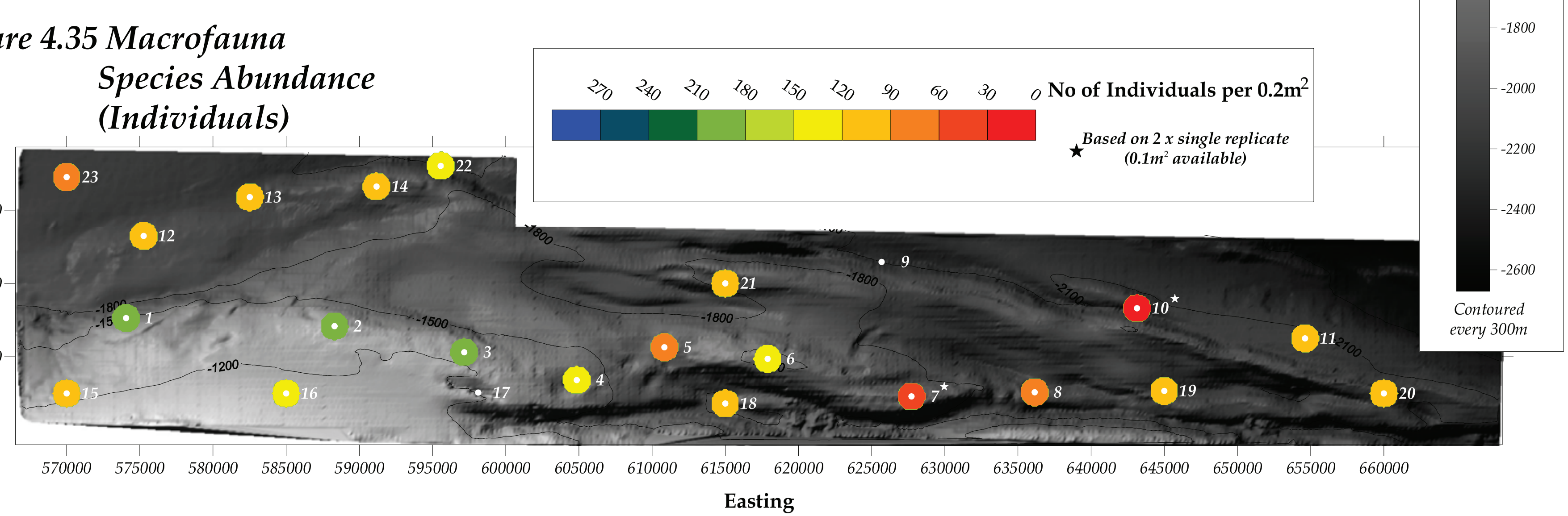
A comparison with the neighbouring sites on the North Falkland Basin, showed that although the faunal abundance and richness was greater in the shallower survey, the homogeneity of the sandy substrates meant that both diversity and dominance were lower (BSL 2008). For the East Falkland Margin, the biology recorded at the Toroa and Loligo sites were quite different, with the latter representative of a much more varied and coarser sediment, whilst silts predominated in the shallower Toroa site (FSL 2009a & c). The mean abundance and richness per $0.2m^2$ was around 40 and below 21 for both sites compared to 112 and 47 in the present study. Both surveys indicated significantly lower abundance and richness when compared to the present survey, which similarly resulted in a poor species diversity. However, whilst the species dominance of Loligo was similarly poor, the Toroa results were similar to that of the present study (at 0.95), indicative of a relatively even spread within the most common species at this site. Like the current study, the dominant community composition was very similar, and well presented by similar species or groups. Where the Onuphid polycheates *Rhamphobranchium ehlersi* and amphipods *Urothoe sp. and* Phoxocephaloidea sp.C (eyeless) dominated in the current study, Toroa was similarly dominated by another Onuphid polycheate, *Onuphis pseudoiridescens,* along with *a* Haustoriidae sp. 1 amphipod, whilst Loligo was dominated by yet another Onuphid polycheate *Kinbergonuphis oligobranchiata.* The communities at these two sites were similar, exhibiting a non-dominated abundance structure to the community with some overlap in species distributions. Nevertheless, despite these similarities the two different communities were clearly distinct from each other, presumably due to the quite different sediments recorded for each.

Figure 4.34 Macrofauna Species Richness (Species)



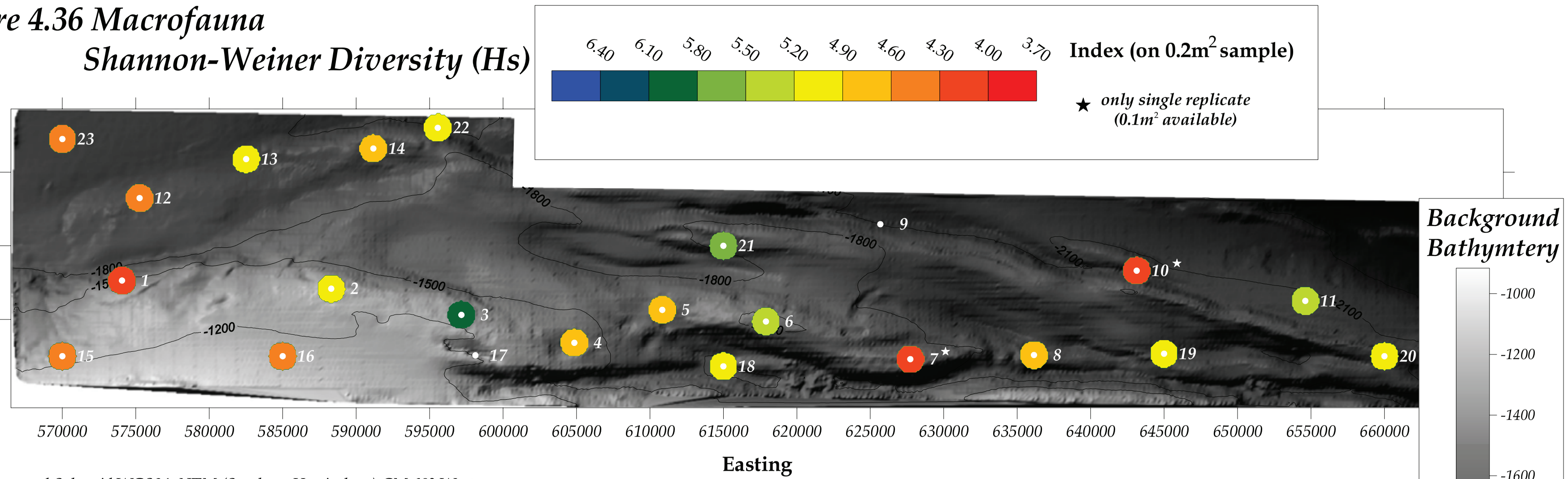
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.35 Macrofauna Species Abundance (Individuals)



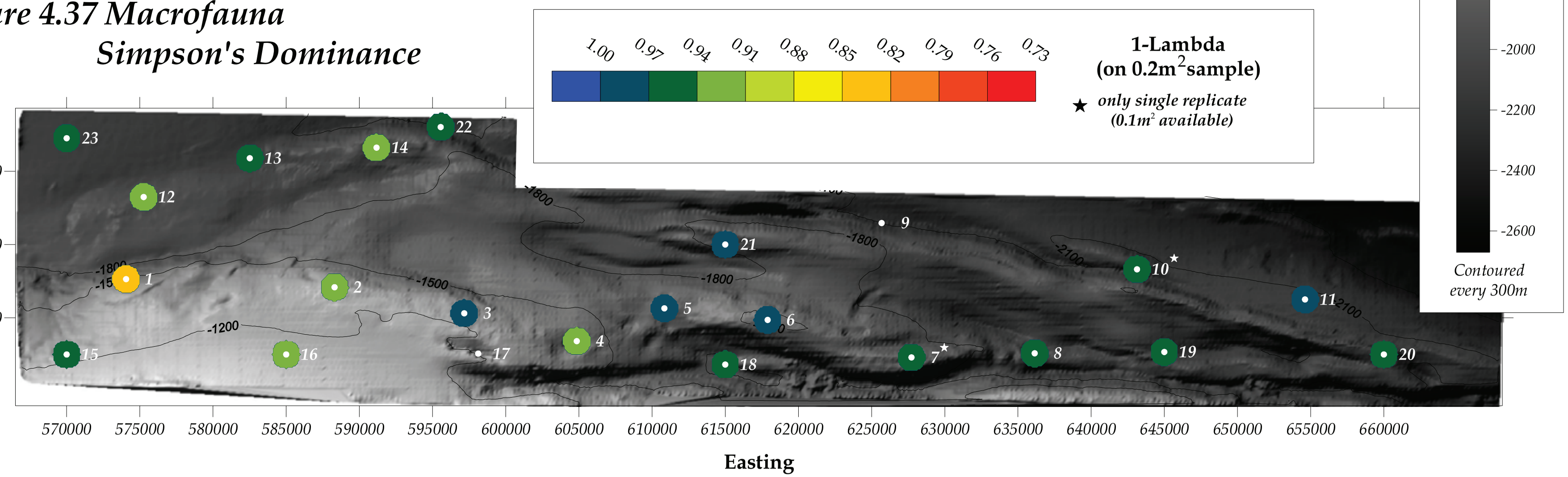
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.36 Macrofauna
Shannon-Weiner Diversity (Hs)



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Figure 4.37 Macrofauna
Simpson's Dominance



Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

Table 4.10. Univariate Faunal Parameters (0.1m² replicates)

Station	Number of Species (S)	Number of Individuals (N)	Richness (Margalef)	Evenness (Pielou's Evenness)	Shannon-Wiener Diversity	Simpsons
Sample 1A	41	146	8.026	0.6251	3.349	0.7168
Sample 1B	34	58	8.127	0.9014	4.586	0.9480
Sample 2A	40	96	8.544	0.8664	4.611	0.9450
Sample 2B	40	110	8.297	0.8130	4.327	0.8931
Sample 2C	46	108	9.611	0.8841	4.883	0.9555
Sample 3A	57	100	12.160	0.9451	5.513	0.9804
Sample 3B	52	100	11.070	0.9390	5.353	0.9778
Sample 3C	50	118	10.270	0.9081	5.125	0.9655
Sample 4A	29	59	6.867	0.8703	4.228	0.9287
Sample 4C	31	81	6.827	0.8580	4.251	0.9210
Sample 4D	41	84	9.028	0.8579	4.596	0.9271
Sample 5A	22	33	6.006	0.9630	4.294	0.9716
Sample 5B	19	27	5.461	0.9601	4.078	0.9687
Sample 6A	24	47	5.974	0.9207	4.221	0.9510
Sample 6B	45	80	10.040	0.9394	5.159	0.9763
Sample 6C	33	65	7.666	0.9541	4.813	0.9740
Sample 7A	23	34	6.239	0.9451	4.275	0.9643
Sample 8A	25	39	6.551	0.9261	4.301	0.9555
Sample 8B	27	43	6.913	0.8819	4.193	0.9214
Sample 8C	28	55	6.738	0.8973	4.314	0.9421
Sample 10A	22	29	6.236	0.9532	4.251	0.9680
Sample 11A	27	45	6.830	0.9593	4.561	0.9727
Sample 11B	37	58	8.866	0.9610	5.007	0.9806
Sample 11C	43	60	10.260	0.9372	5.085	0.9723
Sample 12A	17	39	4.367	0.7548	3.085	0.7854
Sample 12B	29	57	6.925	0.9239	4.489	0.9593
Sample 13A	30	61	7.054	0.9309	4.568	0.9634
Sample 13B	20	39	5.186	0.9389	4.058	0.9541
Sample 14A	23	42	5.886	0.9221	4.171	0.9443
Sample 14B	28	49	6.938	0.8945	4.300	0.9379
Sample 15A	27	64	6.252	0.9072	4.314	0.9499
Sample 15C	20	51	4.832	0.8829	3.816	0.9216
Sample 16A	28	72	6.313	0.8527	4.099	0.9143
Sample 16B	24	52	5.821	0.8810	4.039	0.9306
Sample 16C	34	82	7.489	0.8867	4.511	0.9476
Sample 18A	35	70	8.003	0.9272	4.756	0.9669
Sample 18B	17	38	4.399	0.9216	3.767	0.9346
Sample 19A	41	73	9.323	0.9244	4.952	0.9677
Sample 19B	22	39	5.732	0.8947	3.99	0.9312
Sample 20A	42	63	9.896	0.9413	5.076	0.9734
Sample 20B	25	44	6.342	0.8486	3.941	0.8953
Sample 21A	34	45	8.669	0.9768	4.969	0.9869
Sample 21B	38	63	8.930	0.9495	4.983	0.9764
Sample 21C	43	73	9.789	0.9538	5.176	0.9802
Sample 22A	31	65	7.187	0.8940	4.429	0.9466
Sample 22B	36	72	8.184	0.9048	4.678	0.9558
Sample 23A	21	36	5.581	0.9429	4.142	0.9603
Sample 23B	19	44	4.757	0.9041	3.840	0.9345

Table 4.11. Univariate Faunal Parameters (0.2m^2 station)

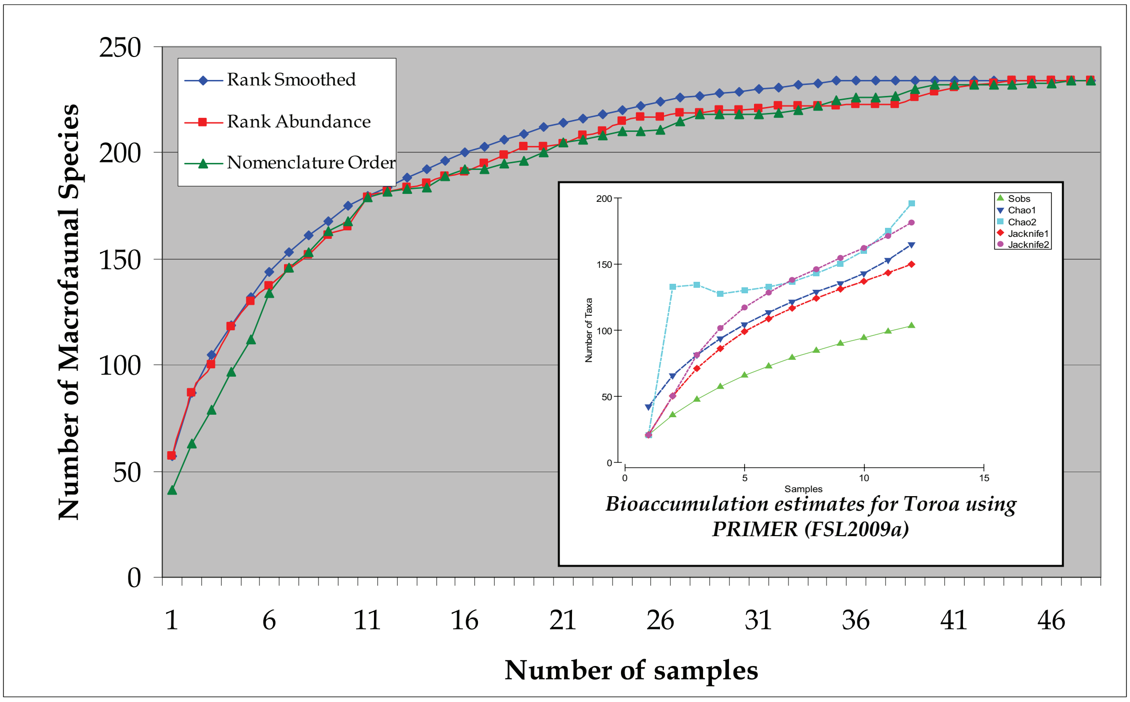
Station	Number of Species (S)	Number of Individuals (N)	Richness (Margalef)	Evenness (Pielou's Evenness)	Shannon-Wiener Diversity	Simpsons Dominance
Station 1	63	204	11.660	0.6997	4.182	0.8289
Station 2	67	206	12.390	0.8132	4.933	0.9307
Station 3	87	200	16.230	0.9362	6.032	0.9849
Station 4	48	140	9.511	0.8326	4.650	0.9260
Station 5	32	60	7.571	0.9472	4.736	0.9718
Station 6	56	127	11.350	0.9170	5.325	0.9729
Station 7*	23	34	6.239	0.9451	4.275	0.9643
Station 8	45	82	9.985	0.8914	4.896	0.9518
Station 10*	22	29	6.236	0.9532	4.251	0.9680
Station 11	50	103	10.570	0.9460	5.339	0.9783
Station 12	37	96	7.887	0.8718	4.542	0.9349
Station 13	41	100	8.686	0.9213	4.936	0.9671
Station 14	40	91	8.646	0.8722	4.642	0.9372
Station 15	38	115	7.798	0.8593	4.509	0.9452
Station 16	38	124	7.676	0.8533	4.478	0.9364
Station 17	-	-	-	-	-	-
Station 18	46	108	9.611	0.9015	4.980	0.9630
Station 19	54	112	11.230	0.8989	5.173	0.9604
Station 20	55	107	11.560	0.8845	5.114	0.9475
Station 21	62	108	13.030	0.9465	5.635	0.9832
Station 22	53	137	10.570	0.8733	5.002	0.9515
Station 23	34	80	7.531	0.8840	4.497	0.9487
Survey Mean	**47.19**	**112.52**	**9.81**	**0.89**	**4.86**	**0.95**
St Dev	**15.28**	**47.60**	**2.46**	**0.06**	**0.47**	**0.03**
% variance	**32.4%**	**42.3%**	**25.1%**	**6.6%**	**9.7%**	**3.4%**
Toroa 2009	**20.7**	**40.7**	**5.3**	**0.92**	**3.96**	**0.95**
Loligo 2009	**17.6**	**39**	**4.6**	**0.86**	**3.44**	**0.89**
North Falklands 2008	**64.8**	**430.1**	**10.609**	**0.802**	**4.814**	**0.933**

4.6.3. Species Richness and Bioaccumulation Curves

An expectation of the overall faunal population was assessed by collectively looking at the bioaccumulation of species against the 48 replicates taken. These are presented in the form of a bioaccumulation curve plotted by sample nomenclature, rank abundance or re-ordered (smoothed) rank abundance and is given in Figure 4.38. Results show that the population reaches asymptote at around 230 species, with only a slow incremental increase based on further replicates beyond this. Assuming a statistically representative population is around 2/3rds of the total community, this level (ca. 157 species), would be achieved in an approximate sample area of 0.8 to 0.9m^2 (i.e. 8 or 9 replicates).

This result can be compared to a similar plot produced for the Toroa site 75km north using PRIMER computer software (Figure 4.38 inset). The PRIMER package provides a comparison between observations and community calculations using various algorithms (Chao1, Chao2, Jacknife1 and Jacknife2 formulae; Chao 2005). As the data were produced from much fewer samples, the graphs indicated a rather more conservative theoretical population with estimates of 150 to 196 estimated from the 103 species observed.

Figure 4.38 Bioaccumulation of Species Recorded at the Burdwood Bank



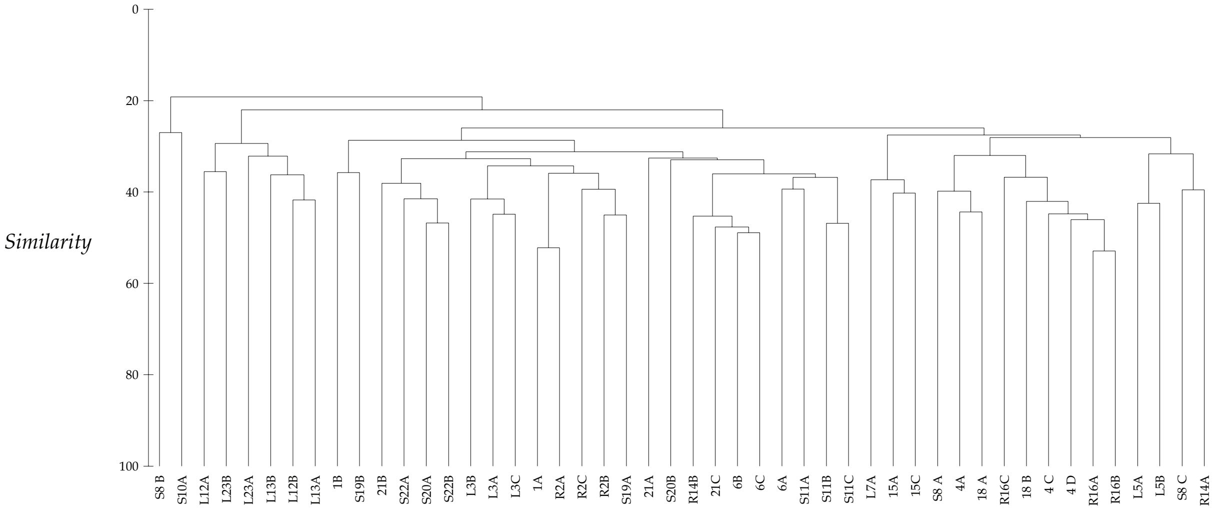
4.6.4. Multivariate Analyses

To provide a more thorough examination of the macrofaunal community, multivariate analyses was performed upon the data for both the replicate and aggregated stations using Plymouth Routines in Multivariate Ecological Research software (PRIMER; Clarke & Warwick 1994) to illustrate data trends. Unlike univariate parameter, multivariate analyses preserve the identity of the different species by assigning a similarity or dissimilarity between the samples. The analyses were undertaken on double square-root transformed data, as these data gave a clearest interpretation.

4.6.4.1. Dendrogram – Group Average Method

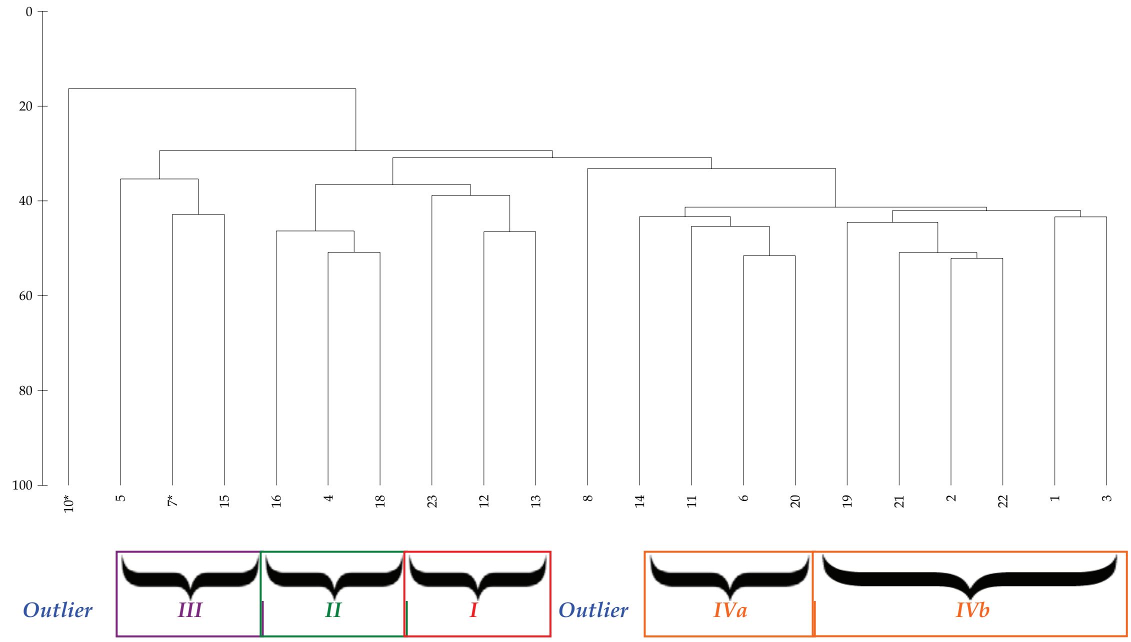
The similarity dendrogram is given for all replicates in Figure 4.39. This diagram shows that intra-station relationships are relatively poor compared to Inter-station variability. Consequently, many of the replicates fail to cluster with other replicates from the same stations, with all replicates generally showing a 30 to 50 similarity. No clear separation of grouped replicates is evident, with the exception of stations 12, 13 and 23, all located in the northwest part of the survey area. Although these were only 30 to 40% similar, as a group these stations were only 24% similar to any other stations. These data confirm a high intra-station variability overall.

Figure 4.39. ***Dendrogram of Macrofaunal Replicates***



By combining the replicate dataset, a similarity dendrogram is also given for all stations (Figure 4.40). Because of the variability in the number of replicates recovered at many of the sites due to the variation in sampler used , pooled station results are based on a duplicate replicate combination (0.2m^2) where available. The exceptions are stations 7 and 10 as only a single replicate was recovered during the field operations. Unlike the replicates, the increased surface area of the stations show a separation of the sites into more defined groups. The similarities between these groups are still relatively weak (at around 30-40%), whilst the inter-station similarities are also relatively weak generally clustering around a 45 to 55% similarity level. The clusters separate into five groups and 2 outlier sites (of stations 8 and 10) Cluster I is represented by station 12, 13 and 23 in the northwest corner of the site, Cluster II is represented by stations 4, 16 and 18 along the upper part of the Burdwood Bank. Cluster III are disparate stations 5, 7 and 15, whilst Cluster IV is separated into two sub-groups relating to 6, 11, 14 and 20 (Cluster IVa) and stations 1, 2, 3, 19, 21 and 22 (Cluster IVb). These larger groups were also dispersed throughout the survey area. A graphical representation of these different groups is shown in figure 4.41.

Figure 4.40. ***Dendrogram of Macrofaunal Stations***



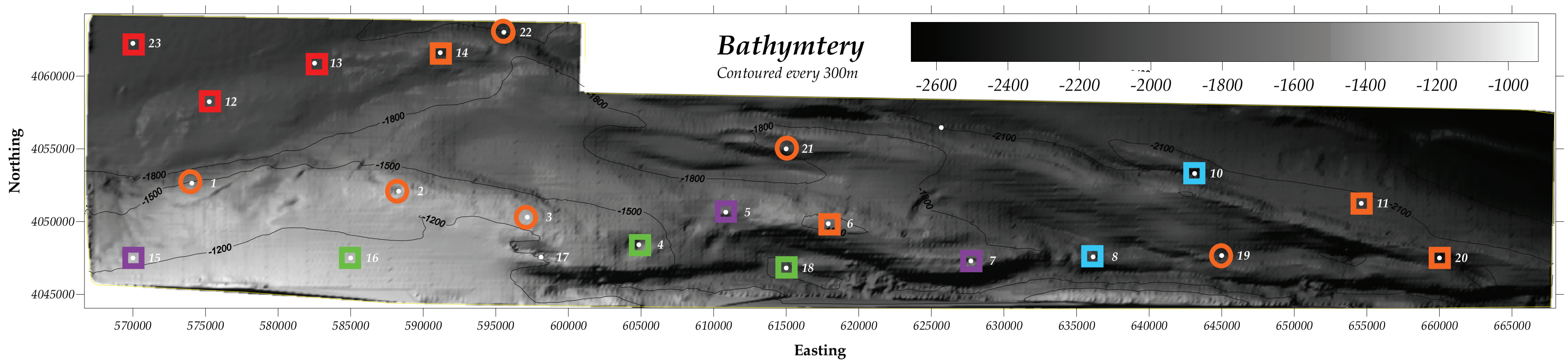


Figure 4.41

Distribution of Grouped Stations Based on Macrofaunal Populations (separated at the 35% similarity level using Bray Curtis)

LEGEND

- *Faunal Cluster I*
- *Faunal Cluster II*
- *Faunal Cluster III*
- *Faunal Cluster IVa*
- *Faunal Cluster IVb*
- *Faunal Outlier Sites*

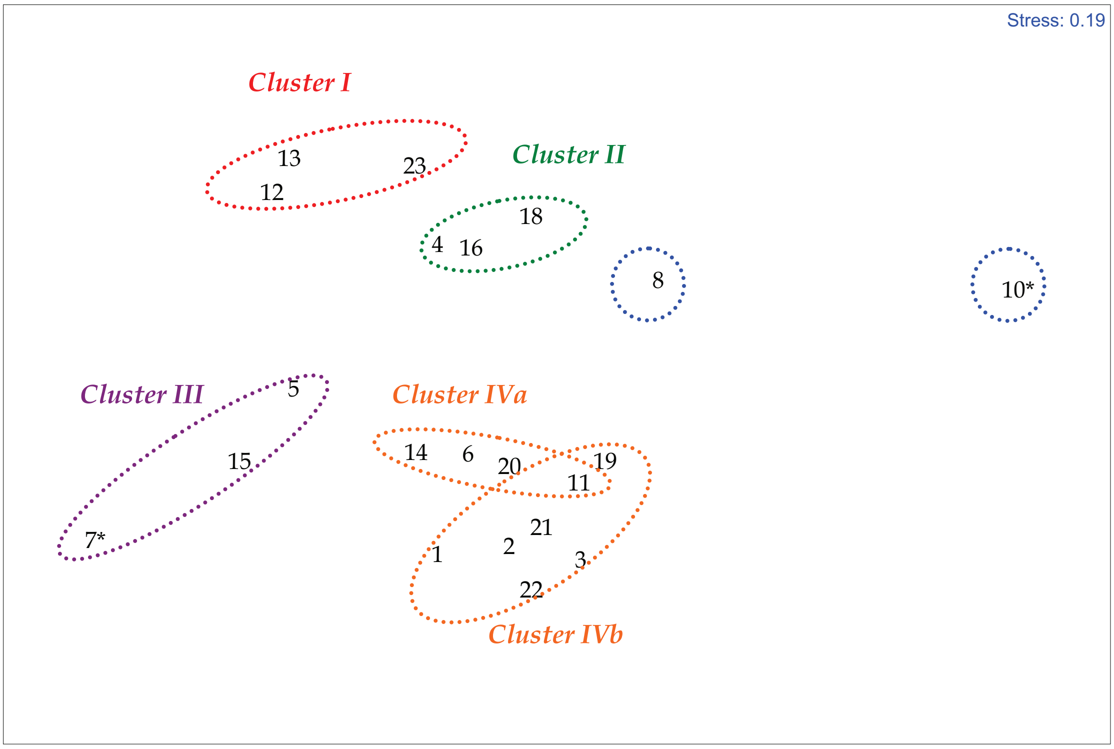
Geodetic Datum and Spheroid WGS84, UTM (Southern Hemisphere) CM 60° West

4.6.4.2. MDS Ordination Plot

The above similarities were presented into a 2-dimensional representation where the two axes of similarity are shown. This multi-dimensional scaling (MDS) ordination is presented in Figure 4.42 for all 21 stations, with the separation of the 5 clusters represented.

Although clear separation has occurred amongst many of the groups, the stress values recorded within the statistical representations was moderately at 0.19. Consequently, the ordination should be treated with care with further statistical comparisons made to confirm that these separations are representative. This is a result of high intra station variability and that the separations of grouped stations are generally weak. Ultimately, these data may be subject to slight over interpretation and possible miss-representation if not supported by other trends or correlations within the data. This is partially due to the lack granulometric correlations with the faunal parameters, even though significant variability in habitat regimes was recorded throughout the survey area.

Figure 4.42. MDS Ordination Plot by Station



The separation of the five clusters is one based on subtle community variations related to localised environmental factors. The geographical locations of the five clusters are shown in Figure 4.41 over the survey area. This shows that only the more depositional finer sediments recorded in the northwest area (stations 12, 13 and 23) all cluster together. All other stations and clusters are more dispersed suggesting that these populations are responding to localised changes rather than larger regional ones. Statistical analysis of the MDS axis shows a significant correlation with the proportion of sands for the X-axis (along with the metal Zn). The Y-axis however, correlates strongly with the proportion of silts, mean phi size, TOC and many of the hydrocarbon concentrations (PAH, NPD, THC, alkanes, pristane and phytane; $P<0.01$) and is the main cause of separation within the clusters.

Using SIMPER, a summary of the top five species (in rank order) responsible for the separation of the Clusters is given in Table 4.12. Their similarity contribution is also presented. Grouped similarities are all very weak clustering at only 38 to 43% similarity. The soft sandy silts recorded at Cluster I in the northwest is populated by small crustacea dominated by a Tanaid and two amphipods (*Urothoe sp*. and Phoxocephaloidea sp.C) all contributing to the top five species grouping for these stations. The tanaid and *Urothoe* sp are the most responsible for these stations separating from most other clusters, with the exception of Cluster II.

Table 4.12. SIMPER Results Showing the Top Five Characterising Species in the Main Faunal Clusters

Species	Average Abundance	Average Similarity	Contribution	Cumulative Contribution
Cluster I (Similarity 41.4%)				
Tanaidae sp (Apseudidae)	6	3.29	7.95	7.95
Nematoda spp.	6.67	3.11	7.51	15.46
Galathowenia sp	6	3.09	7.47	22.93
Urothoe sp.	6	3.08	7.44	30.37
Phoxocephaloidea sp.C (eyeless)	5	3.01	7.26	37.64
Cluster II (similarity 47.8%)				
Ostracoda spp.	22	3.81	7.95	7.95
Urothoe sp.	7.67	2.87	5.99	13.94
Rhamphobranchium ehlersi	7	2.77	5.78	19.73
"Snail" shaped Foram	9.67	2.72	5.69	25.41
Phoxocephaloidea sp.C (eyeless)	4.33	2.59	5.40	30.82
Cluster III (similarity 37.9%)				
Rhamphobranchium ehlersi	4.67	3.69	9.74	9.74
Ostracoda spp.	7.33	3.58	9.46	19.21
Nematoda spp.	2.67	3.5	9.25	28.46
Terebellides stroemi	1	2.86	7.55	36.01
Stenothoidae sp I	2	2.86	7.55	43.56
Cluster IV (similarity 42.9%)				
Rhamphobranchium ehlersi	15.1	2.73	6.36	6.36
Ostracoda spp.	3.5	1.85	4.32	10.67
Nematoda spp.	17.4	1.62	3.77	14.45
Nemertea spp.	3.3	1.47	3.43	17.87
Aricidea c.f. oculata	2.7	1.42	3.32	21.19
Outlier Site 8 (single location)				
Rhamphobranchium ehlersi	15	-	-	-
Macrostylis sp	4	-	-	-
Aff Scoloplos sp	3	-	-	-
Scyphozoa polyp	2	-	-	-
Spiophanes bombyx	2	-	-	-
Outlier Site 10 (single location)				
Paradeliscidae sp	5	-	-	-
Pecten sp.(Similipecten?)	2	-	-	-
Nemertea spp.	2	-	-	-
Psolus sp	2	-	-	-
Rhamphobranchium ehlersi	1	-	-	-

nc = not calculated for a single station

Cluster II, is predominantly made up of silty reworked sands with an absence of gravels. Fauna here was fairly ubiquitous for many of the other sites with the Onophid polycheate *Rhamphobranchium ehlersi* and the two amphipods recorded in Cluster I also dominant. However, this site indicated the presence of several foraminifera forms, which were generally absent or in low numbers at all other stations. These include both the "egg" and "snail" forms. Also responsible for this clusters separation are the molluscs *Mactra sp* and *Aff Diplodonta sp.* Cluster III is a relatively poor faunal community existing in variable sediment types. The population is relatively consistent with other species within the area (including those of Cluster IV, with the Onophid *Rhamphobranchium ehlersi*, Nematoda sp and Ostracoda sp, present in both groups. The separation of Cluster III from that of Cluster IV, a typically silty gravely coarse sand, was due to the absence of an ampharetid polycheate, the sipunculid *Golfingia sp.* and a mollusc *Dacrydium sp*, and the presence of the mollusc *aff. Thyasira*, the polychaete *Lumbrineris c.f.antarctica* and the oligochaete Tubificidae in Cluster IV.

4.6.5. Environmental Variables

Environmental variables were analysed using a number of different ways in order to relate significant relationships between abiotic and biotic factors. Tests include ordination using both Pearson's product moment analysis (PPM) which provides 2 dimensional comparisons between each of the environmental variables, and BIO-ENV (PRIMER) which provides a step-wise comparison of grouped environmental factors which best match the sample patterns seen within the faunal assemblages.

Step-wise, the grouped environmental variables showed a significant correlation between a number of parameters which, although possibly highlight inter-parameter relationships, may act to auto-correlate a number of the variables when using a more multi-dimensional technique. PPM correlations showed that the sediment parameters, in particular the sediment size, proportion of fines, silts and clays, sorting coefficient, and total organic carbon showed strong correlations with the metals copper, iron, nickel, most hydrocarbon parameters but no univariate faunal parameters (at $P<0.01$ & 0.001; Appendix VIII). The highest environmental correlation across parameter types of unrelated groups was percentage silts and the organics, pristine, or polycyclic aromatics (NPD or PAH) at 0.877 to 0.890. This is a very significant correlations of $P<0.0001$.

BIO-ENV was used to correlate a number of these variables with that of the similarity dendrogram created for the stations and a single or grouped environmental variable which gave the greatest correlation. Using Bray-Curtis similarity and Euclidian distance for environmental variables (square root transformed) and using Spearman's Rank Correlation the individual parameters: % gravels, medium sands and Zinc gave the greatest correlations (0.41 and 0.3, respectively) both below a significant level $P>0.05$. However, grouped together the environmental variables % gravels, medium sands along with either Zinc, sorting coefficient or moisture content all gave weak, but significant correlations of 0.455 to 0.467 ($P<0.05$). What is interesting, is that none of the granulometric fines (silts, clays, mean sizes etc.) which would be typically associated with the faunal distribution, showed any correlations with the community. Only the presence of gravels and the coarser sediment types, such as medium sands, made any such impact.

4.6.6. Summary of Macrofaunal Results

The benthic fauna of the Falkland Islands belongs to the Magellan faunal area (made up of the sea areas around the southern part of South America) and the northern Antarctic. Whilst this is generally comparable to the Northern Boreal Region, the fauna is characterised by a very high diversity in certain groups, such as crustacea, (with amphipods, in particular *Urothoe* sp, common over most sites, including the shallower sediments on the North Falklands Continental Shelf), or low diversity in the echinoderms. Univariate parameters indicated generally high and consistent levels across the regional survey area as all sites gave moderate to high species richness, diversity and evenness throughout. Statistically, univariate parameters indicated almost no correlations with either the granulometric or other environmental variables for the survey. This would generally suggest a consistent regional population where significant changes in sediment factors, in particular the proportion of fines and coarser deposits, make only subtle changes to the population. Multivariate analyses, equally confirmed a relatively diverse faunal population, but with relatively low levels of similarity between samples and stations. Separation of the stations into clustered groups of similarity was very limited and generally restricted to four poorly defined groups where similarity between stations also remained poor. With the exception of three sites, relating to the softer finer sediments in the northwest, none of these clusters indicated any geographical pattern of distribution.

The dominant macrofaunal population for the regions was based on that of a mobile surface dwelling polychaete, the Onuphid *Rhamphobranchium ehlersi*, Nematodes, and surface or shallow burrowing crustacean, such as a tenaid in the family Apseudidae, a couple of amphipods *Urothoe sp*, and Phoxocephaloidea sp.C (eyeless). Other common fauna present within the benthos were ostracods and a number of forams. Many of these groups (such as the Ostracods (mostly cypridoidea), forams and nematodes) are not usually included within the macrofaunal analysis normally due to their size (typically falling in the meiofaunal range). However, as very little is known about the sediments in this area and many of these species were clearly large enough (some as large as 5mm) to constitute an important role within benthic ecosystem, these additional groups have been included within the analysis for completeness.

Whilst polychaetes dominated the macrofaunal population overall, the most abundant annelid recorded during the survey was the onuphid *Rhamphobranchium ehlersi*. Unlike most polychaete species which live within the surface substrate, the omnivorous onuphids live within a sediment encrusted mucous tube which it physically drags across the surface of the seabed. Comparison with the macrofaunal population with the neighbouring sites in the eastern Falkland Continental Margin equally showed other onuphid species

Figure 4.43 ROV image of Onuphid polycheate at Toroa (75km NE; FSL 2009a)

Onuphis pseudoiridescens, at Toroa 75km Northeast (FSL 2009a) and *Kinbergonuphis oligobranchiata* at Loligo site 345km northeast (FSL 2009c). To date, the former species has only been recorded from the south-west Atlantic (including in the vicinity of the Falkland islands) and from the south-east Pacific coast of Chile (Rozbaczylo *et al*, 2006). Onuphids were also recorded during ROV footage at the Toroa site (Figure 4.43).

R.ehlersi in the present study is a different genus to *Onuphis*, but in the same family. This genus is characterised by special long setae in the first three chaetigers (bristle-bearing segment), with a different shape of hooks on the end. A general search of taxonomic records revealed at least six different onuphid species for the Magellan Province, with a further example *Nothria (Onophis) conchylega* which is in the same family and with a near cosmopolitan distribution, also recorded on the Burdwood Bank.

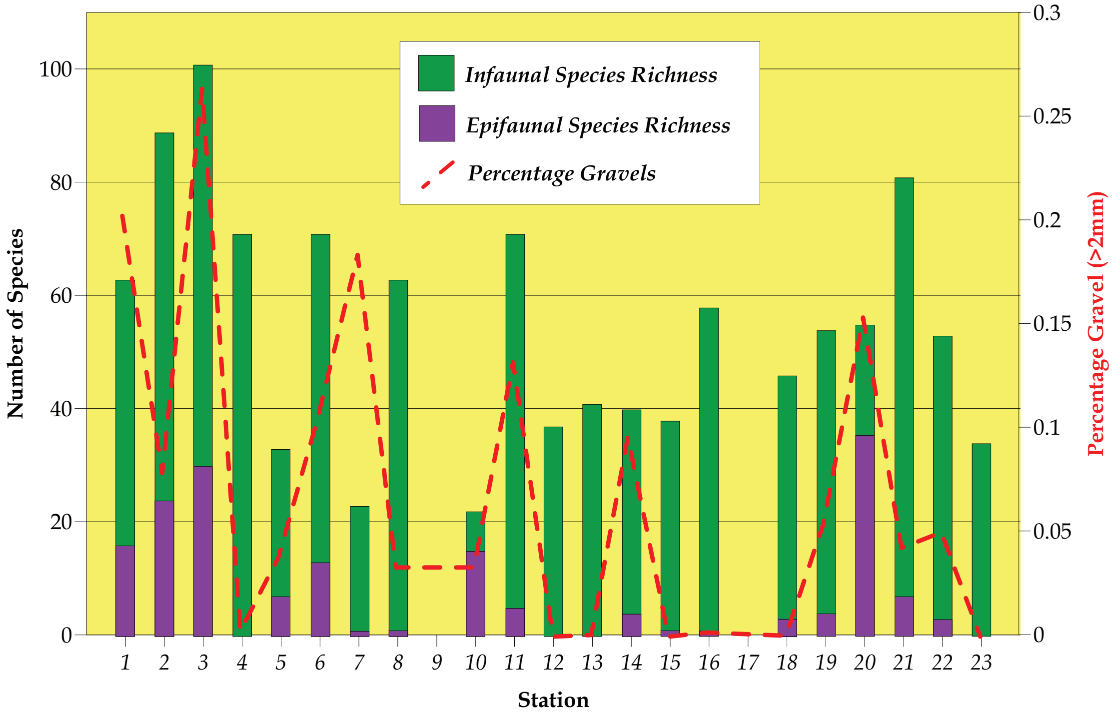
As with the univariate parameters, correlations between the environmental parameters and the multivariate trends groups indicated little or no significance, with only a very weak pattern relative to the proportion of gravels and/or medium sands within the sediments. Consequently, whilst there is significant variability recorded between sediment types throughout the survey area, this has had only a marginal impact on the faunal community which appears to be quite diverse throughout the whole survey area. Consequently, whilst environmental factors show very significant distributions relative to the granulometric properties of the sediments, the faunal population does not.

Overall, no environmentally sensitive species or habitats considered to be of conservational value were recorded within the macrofaunal analysis during the regional survey operations.

4.6.7. Epifaunal Results

Many of the sites sampled indicated the presence of some coarser admixtures within the sediments relating to gravels ranging from granules through to large cobbles (25cm) sized fractions. Consequently, a number of sites indicated the presence of epifaunal species which have been identified qualitatively. Observations made during the sampling and the resulting particle size analysis undertaken on recovered material showed that 7 out of the 23 stations surveyed indicated gravels greater than 10% or the evidence of outcropping bedrock at the surface. Furthermore, most of the sites indicated a generally non-depositional environment, meaning that epifaunal species are able to become established on low lying harder substrates. Figure 4.44, shows a comparison of both epifaunal and infaunal species at each station along with the proportion of gravel content present for that station. For the most part, this shows a direct relationship of increased epifaunal with gravels, or low epifaunal species where gravels were absent.

Figure 4.44 *Epifaunal Species Richness vs Gravels*



Brief comments on the dominant epifauna recorded from three major groups, (Cnidera, Porifera, and Bryozoa), are outlined below:

Cnideria: Amongst the Cnidera, hydroidea were the least prominent and only represented by small colonies of widespread or cosmopolitan genera. However the Octocorals were well represented, with one stoloniferous species (*aff Sarcodictyon*) and four prominent Gorgonarians, *Melitodes sp, Pleurocoralloides sp, Callozostron carlottae* and *Stachyodes sp*. The fifth species was too fragmentary to identify. *Pleurocoralloides* is characterized by a strongly calcified central column, and is related to the precious coral of the Mediterranean. *Callozostron* was the most common species of this group and was characterized by scaly branches and spined calyces.

The madreporan coral *Lophelia* was recorded in a couple of samples, however live tissue was only found in one specimen in one sample, (that of 1B). A couple of dead fragments were found in a couple of other samples near this station. Branched hard corals are of conservational interest as they are able to develop into extensive thickets creating large biogenic reefs which can be highly diverse, but extremely fragile. Madrepora are azooxanthellate coral species which do not rely on symbiotic algae to obtain nutrients, allowing growth to occur in dark and cold water environments well below the photic zone. However, as a result, they are very slow growing, developing by as little as 6mm a year. Consequently, larger reef structures which can be tens of metres high can take thousands of year to develop. This appears not to be the case for the current study as only a small example of this species and other hard corals were recorded, although the presence of this species does confirm the potential for more developed reefs to exist within the general survey area.

Although no extensive reefs were encountered, evidence from the Loligo area, located in a slightly shallower water depths (around 1350m) and a similar sediment type, taken by sampling and ROV operations showed sporadic, and at times, fairly extensive coverage from low level corals on some of the harder substrates (example in Figure 4.45; FSL 2009c). Box core samples similarly showed fragments of *Lophelia pertusa*, although no live specimens were recovered. Existing ecological data for *L. pertusa* suggest that its range would not extend to the Falkland slope due to the low seabed temperature recorded (2.9°C). ICES (2002) state that *L. pertusa* prefers oceanic waters with a temperature of between 4°C and 12°C and a relatively high tidal flow (to facilitate filter feeding). Consequrntly, the coral identified from Loligo and in the present study may reflect an antarctic variant to this madreporan species or may simply extend the temperature range of the existing *L.pertusa* species, although stunting its development beyond minor isolated thickets due to temperature limitations.

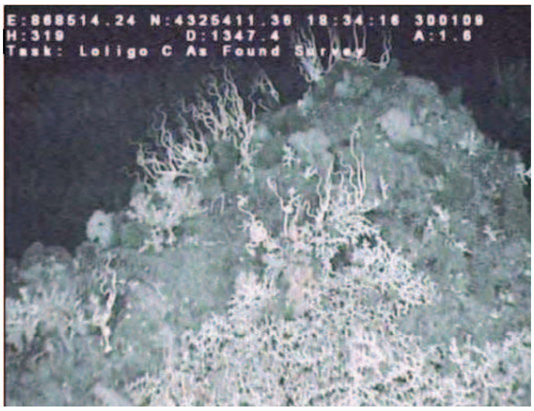


Figure 4.45 ROV image of ophiuroids and branched hard corals at Loligo (350kmkm NE; FSL 2009c)

Porifera: In addition to Cnideria, the phyla Porifera (sponges) were also well represented at a number of sites. Hexactinellidae were recorded only in fragmentary form, although the presence of numerous spicules in the sediments belonging to this class indicates that they are more common than indicated from the samples. This also applied to the Tetraxonida, where only one species was recorded with one specimen of *Tetilla*. Also of interest was the lithistid sponge *Gastropharella* sp. These sponges, a polyphyletic group, have a virtually solid skeleton of "Desmas" with a compliment of other spicules, in this case Tylota.

A common sponge genus throughout the deeper waters of the Atlantic is *Asbestopluma sp*, was well represented in the current study. These sponges are upright branching forms without the normal canal system and rely on a carnivorous mode of feeding. Their microscleres (anisochelae) catch small crustaceans which are then surrounded by tissue and digested.

The other genera recorded, generally related to the small encrusting patches on stones and were rarely massive, were also commonly represented in the sponge fauna of the Atlantic and elsewhere. Identification of these species was done on the base of internal characteristics of spicule shape and arrangement.

Bryozoa: Bryozoa were frequently recorded and found encrusting, as upright branches or flexible colonies. It is currently not practical to identify the Class Cyclostomata in detail as this group is awaiting revision and it also proved impossible to ascribe definite generic status to many of Cheilostomata with the keys available for this area. In this instance, affinities to existing Genera was used to define individual taxa. Where a definite species name is given this implies that the genus was represented with only one species or the species has otherwise defining characteristics. Some of these genera are also found in the northern hemisphere (e.g. *Escharoides, Fenestrulina, Escharina, Escharella, Rhynchozoon, Plesiothoa* and *Smittoidea).*

Only three species were ascribed to the Class Ctenostomata. Of interest was aff. *Metalcyonidium*, forming an upside down cone on a stalk devoid of zooids. This is reminiscent of *Metalcyonidium spp* found infrequently in the deep waters of the North Atlantic. With 38 taxa this group was well represented, frequent and diverse. Its composition aided by a lengthy larval lifespan which encourages dispersal. Amongst the other groups common colonies of the Pterobranchia *Rhabdopleura* were recorded with a typical black stolon and annulated tubes containing the zooids covering whole stones.

Overall the fauna was very rich and diverse, typical of the depth regime.

Crustacea In addition to the free-living infaunal species, the frequent occurrence of Cirripedia, the stalked Barnacle *Scalpellum* sp. and the acorn barnacle *Verruca sp*. was recorded, both being unusual for Deep Sea and Antarctic waters. These were clearly associated with stations where coarse gravels were present. Some copepoda appeared within samples which were neither epifaunal nor benthic but accidental pelagic specimens. These were related to the Euphausiacea (or Krill) and were probably caught by the sampler during the descent, or have been introduced to the samples thought he sea water processing phase of the operations.

4.7. Water Quality Sampling

In addition to the benthic sampling, water quality profiles were also acquired at a number of locations (station 6, 10 and 13) to provide the water column structure and identify the presence or variation of certain water masses between stations.

Results from the water quality profiles are summarised in Table 4.13 and Figure 4.46. For each profile, data was acquired on both the decent and accent (down and up-cast), with the variation in the two datasets indicative of the equilibration of the sensors. Raw data suggests that the system was deployed at a sufficient speed for the sensors to equilibrate to the change in ambient conditions. Sensor extremes are presented in Table 4.13 all profiles.

Figure 4.46 *Profiles of the Water Column at the Burdwood Bank*

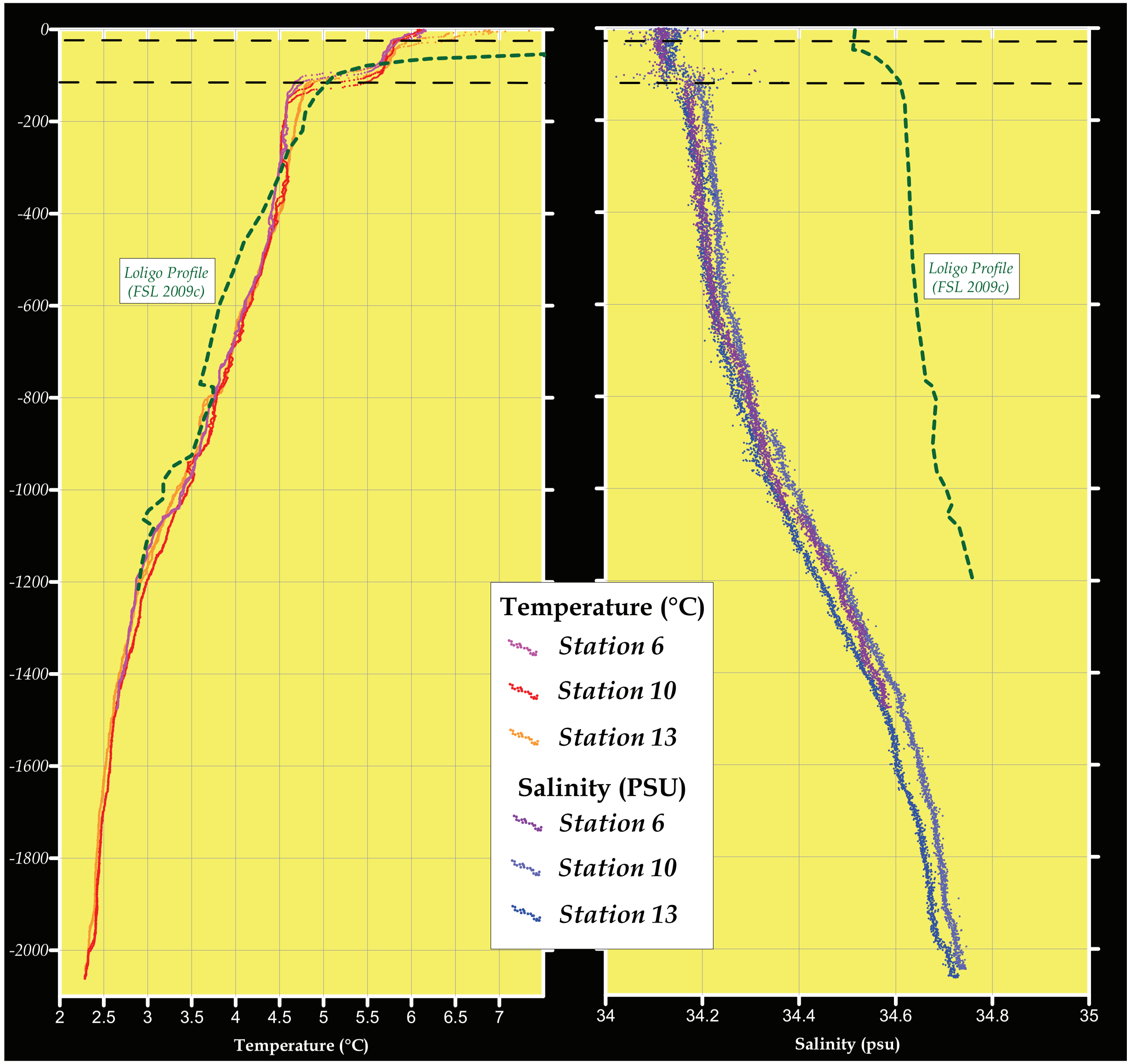


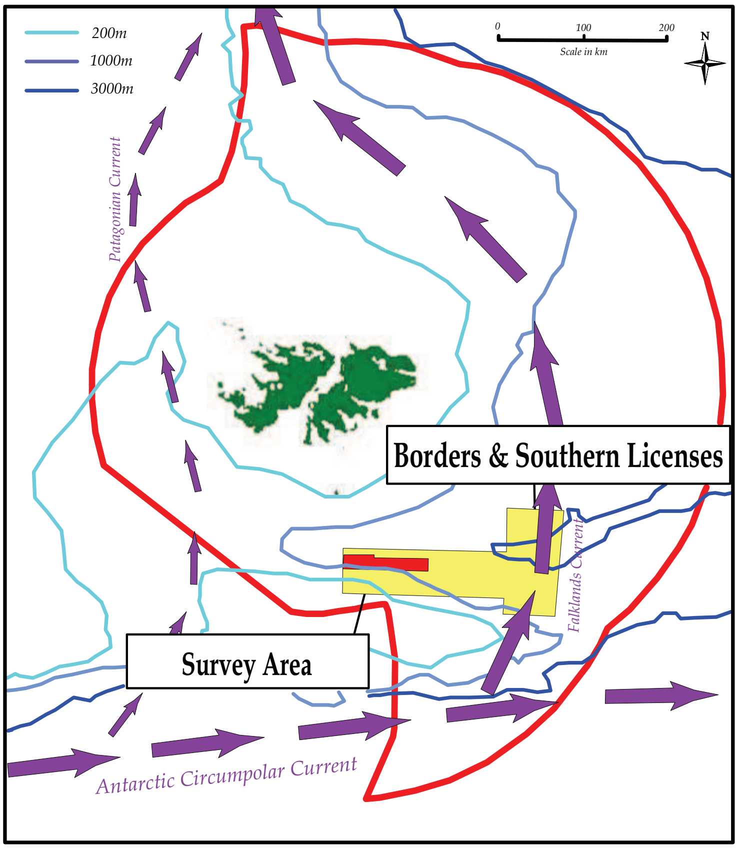
Table 4.13 *Summary of Water Quality Profiles*

Parameter	Station 6		Station 10		Station 12	
	Min	Max	Min	Max	Min	Max
Deployment (Date) Deployment (Time)	20/11/08 06:17:19	20/11/08 06:59:51	18/11/08 23:43:59	19/11/08 00:37:57	21/11/08 16:36:12	21/11/08 17:36:54
Depth (m)	0	1476	0	2061	0	2043
Temperature (°C)	2.65	6.16	2.28	6.12	2.29	7.07
Conductivity (mS/cm)	31.65	33.74	31.64	33.70	31.64	34.51
Salinity (PSU)	34.04	34.59	33.98	34.73	33.53	34.75
Density (g/cm³)	1026.8	1034.4	1026.8	1037.3	1026.2	1037.2
Speed of Sound(m/sec)	1470.2	1484.7	1470.5	1493.2	1470.8	1492.9

** Results for the dissolved oxygen sensor gave unstable results and have subsequently not been presented.*

Water column profiles are shown for the full depth of ca. 2100m (Figure 4.46) for all three profiles. All three profiles showed similar patterns even taking into account the shallower nature (by 600m) of the station 6, or the fact that stations 10 and 13 were at opposite ends of the survey area. Consequently, these results show that the overlying water masses are essentially the same for all three sites surveyed.

Figure 4.47 *General Current Circulation at the Proposed Survey Area*



The general water circulations in the survey area is dominated by the Antarctic Circumpolar Current (ACC), which is located to the south of the Falklands in the Antarctic Polar Front or Antarctic Convergence where surface waters to the south meet warmer surface waters from the north. Travelling from west to east, the ACC passes around CapeHorn and then splits into two weaker current passing either side of the Falklands. These two northern components (collectively called the Malvinas current) are separated by the eastern flow following the southern edge of the Burdwood Bank before turning north to follow the eastern Falklands Continental Margin (Figure 4.47). The water masses influencing this site are therefore a result of this deviation of the ACC northwards, although it is unknown exactly how the current will affect the survey area within the South Falkland Basin, slightly west of this deviation. Evidence from the survey showed that softer deposited material only occurred in the northwest (Stations 12, 13 and 23), whilst elsewhere the seabed was either actively eroded (Station 9) or were non-depositional sediments. This would suggest that stronger currents exist to the north and east of the survey area. A residual flow of water is expected to be from the south and west. This is supported by admiralty charts which show a surface flow ENE across the basin at velocities of up to 1.5 knots. It is also thought that the current has significant non-zero bottom velocities, a claim that was directly verified by Harkema and Weatherly (1989, as cited in Garzoli 1993). Their bottom current meters measured velocities of up to 10 cm s^{-1} (Garzoli 1993). Based on hydrographic data, it is believed that the Malvinas Current has a strong barotropic component and that it is well-mixed (Vivier and Provost 1999).

The water profile results showed a consistent vertical structure within the water column with specific layering recorded at the following depths:

Layer I Surface 20-40m

This is a typical density structure with solar heated water of between 6 and 7°C falling to 5.5°C. Surface salinity remained constant at around 34.1 practical salinity units (PSU: equivalent to parts per thousand). Surface Freshwater influences are minimal due to the lack of significant landmasses nearby and the consistent feed of residual current from the Southern Ocean, south and west of the survey area. As the survey was carried out in the spring period (November), the solar induced thermocline has yet to be fully developed. This is demonstrated by comparing results from the Loligo site taken 350km northeast, a month or so later, which showed a notably warmer surface layer

Layer II from 40m to around 100m

This marks the base of the main surface thermocline and halocline. The temperature remains above 4.8°C, whilst the salinity indicated little or no change at around 34.1 to 34.15 psu. The base of this layer is marked by a rapid temperature change of approximately 1°C, and a slight rise in salinity to around 34.2 psu. A comparison with the Loliogo profiles taken slightly later into the summer, showed that the depth of this layer was also around 100m, but the layer itself merges directly into surface layer 1 as outlined above.

Layer III from ~100m to the seabed

The remainder of the water column indicates normal density structure with a slow entrainment of temperature from the warmer upper layers with that of the underlying water mass. Here the temperature and salinity changes by a constant rate decreasing from 4.6 to around 2.3°C and increasing from 34.2 to 34.7psu over the

1900m depth change. This water mass reflects the main flow of water from the Southern Ocean, flowing from the south and west, and is not expected to alter seasonally. This is partially supported by the profile from the Loligo project which indicated a similar temperature profile, although some fluctuations were recorded within this profile which are interpreted as an artefact of the sampling and the fact the profile was periodically halted to take water samples at selected depths. The Loligo salinity profile was also marginally higher throughout (0.4psu), although this may reflect a further artefact with a variation between the instruments used between the two studies.

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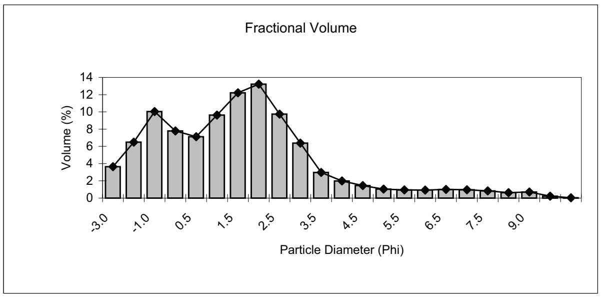
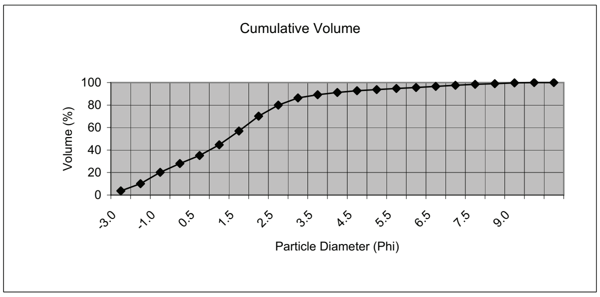
APPENDIX I: Particle Size Distribution

Sample No.:	Station 1	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 15:51

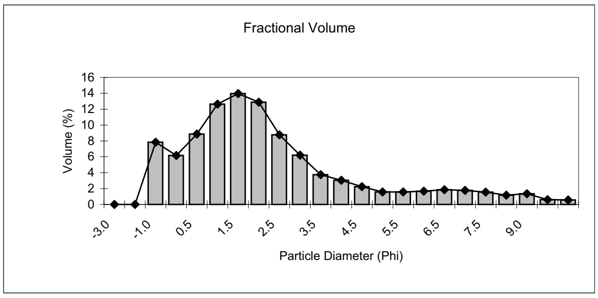


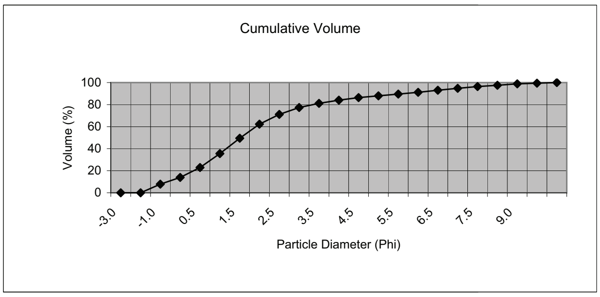


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	3.65	3.7	Pebble
4.000	-2.0	6.49	10.1	
2.000	-1.0	10.03	20.2	Granule
1.000	0.0	7.79	28.0	V.Coarse Sand
0.710	0.5	7.13	35.1	Coarse Sand
0.500	1.0	9.63	44.7	
0.355	1.5	12.21	56.9	Medium Sand
0.250	2.0	13.23	70.2	
0.180	2.5	9.75	79.9	Fine Sand
0.125	3.0	6.37	86.3	
0.900	3.5	2.97	89.2	V.Fine Sand
0.063	4.0	1.98	91.2	
0.044	4.5	1.46	92.7	Coarse Silt
0.032	5.0	1.04	93.7	
0.022	5.5	0.94	94.7	Medium Silt
0.016	6.0	0.92	95.6	
0.011	6.5	1.01	96.6	Fine silt
0.008	7.0	0.97	97.6	
0.006	7.5	0.84	98.4	V.Fine Silt
0.004	8.0	0.63	99.0	
0.002	9.0	0.71	99.7	Coarse Clay
0.001	10.0	0.23	100.0	Medium Clay
<0.001	>10.0	0.03	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.564	2.464	0.83
Median	0.437		1.19
Sorting	**Value**	**Inference**	
Coefficient	2.36	Very Poorly Sorted	
Skewness	-0.10	Negative (Fine)	
Kurtosis	1.30	Leptokurtic	
% Fines	8.77%	Coarse Sand	
% Sands	71.05%		
% Gravel	20.18%		

Sample No.:	Station 2	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:21

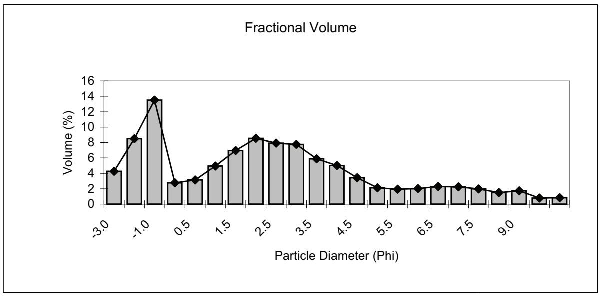


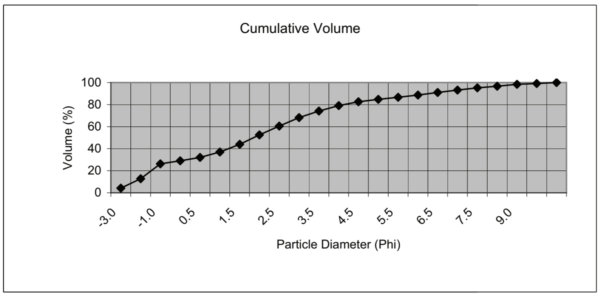


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	7.84	7.8	Granule
1.000	0.0	6.16	14.0	V.Coarse Sand
0.710	0.5	8.86	22.9	Coarse Sand
0.500	1.0	12.63	35.5	
0.355	1.5	13.96	49.5	Medium Sand
0.250	2.0	12.87	62.3	
0.180	2.5	8.77	71.1	Fine Sand
0.125	3.0	6.21	77.3	
0.900	3.5	3.75	81.1	V.Fine Sand
0.063	4.0	3.04	84.1	
0.044	4.5	2.24	86.3	Coarse Silt
0.032	5.0	1.57	87.9	
0.022	5.5	1.56	89.5	Medium Silt
0.016	6.0	1.66	91.2	
0.011	6.5	1.85	93.0	Fine silt
0.008	7.0	1.77	94.8	
0.006	7.5	1.54	96.3	V.Fine Silt
0.004	8.0	1.17	97.5	
0.002	9.0	1.35	98.8	Coarse Clay
0.001	10.0	0.60	99.4	Medium Clay
<0.001	>10.0	0.56	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.276	0.924	1.86
Median	0.351		1.51
Sorting	**Value**	**Inference**	
Coefficient	2.26	Very Poorly Sorted	
Skewness	0.29	Positive(Coarse)	
Kurtosis	1.58	Very Leptokurtic	
% Fines	15.90%	Medium Sand	
% Sands	76.26%		
% Gravel	7.85%		

Sample No.:	Station 3	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:41

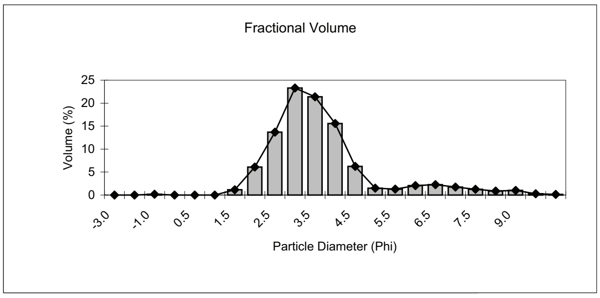


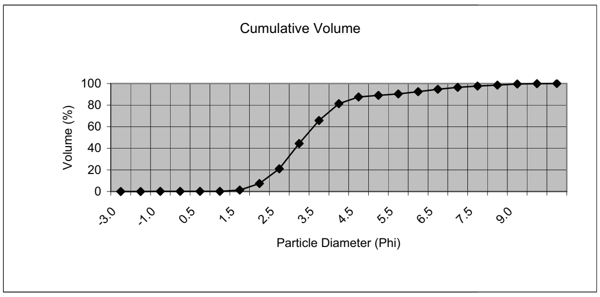


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	4.25	4.3	Pebble
4.000	-2.0	8.49	12.7	
2.000	-1.0	13.51	26.3	Granule
1.000	0.0	2.75	29.0	V.Coarse Sand
0.710	0.5	3.13	32.1	Coarse Sand
0.500	1.0	4.94	37.1	
0.355	1.5	6.95	44.0	Medium Sand
0.250	2.0	8.54	52.6	
0.180	2.5	7.92	60.5	Fine Sand
0.125	3.0	7.75	68.2	
0.900	3.5	5.89	74.1	V.Fine Sand
0.063	4.0	5.01	79.1	
0.044	4.5	3.43	82.6	Coarse Silt
0.032	5.0	2.13	84.7	
0.022	5.5	1.93	86.6	Medium Silt
0.016	6.0	2.03	88.6	
0.011	6.5	2.30	90.9	Fine silt
0.008	7.0	2.24	93.2	
0.006	7.5	1.98	95.2	V.Fine Silt
0.004	8.0	1.50	96.7	
0.002	9.0	1.72	98.4	Coarse Clay
0.001	10.0	0.78	99.2	Medium Clay
<0.001	>10.0	0.84	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.328	2.814	1.61
Median	0.282		1.83
Sorting	**Value**	**Inference**	
Coefficient	3.23	Very Poorly Sorted	
Skewness	-0.01	Symmetrical	
Kurtosis	0.91	Mesokurtic	
% Fines	20.87%	Medium Sand	
% Sands	52.88%		
% Gravel	26.25%		

Sample No.:	Station 4	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:52

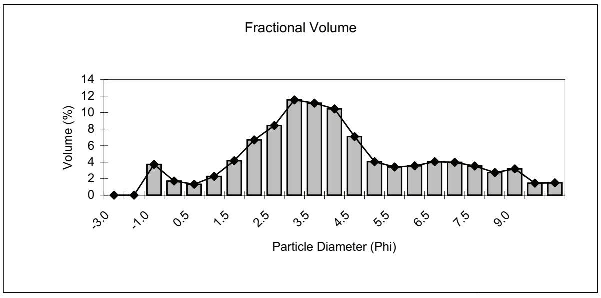


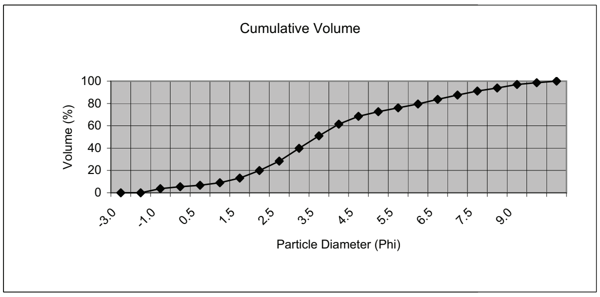


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.18	0.2	Granule
1.000	0.0	0.00	0.2	V.Coarse Sand
0.710	0.5	0.00	0.2	Coarse Sand
0.500	1.0	0.01	0.2	
0.355	1.5	1.16	1.3	Medium Sand
0.250	2.0	6.08	7.4	
0.180	2.5	13.67	21.1	Fine Sand
0.125	3.0	23.29	44.4	
0.900	3.5	21.39	65.8	V.Fine Sand
0.063	4.0	15.56	81.3	
0.044	4.5	6.24	87.6	Coarse Silt
0.032	5.0	1.50	89.1	
0.022	5.5	1.30	90.4	Medium Silt
0.016	6.0	2.06	92.4	
0.011	6.5	2.25	94.7	Fine silt
0.008	7.0	1.76	96.4	
0.006	7.5	1.26	97.7	V.Fine Silt
0.004	8.0	0.89	98.6	
0.002	9.0	1.01	99.6	Coarse Clay
0.001	10.0	0.29	99.9	Medium Clay
<0.001	>10.0	0.12	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.109	0.100	3.19
Median	0.116		3.11
Sorting	**Value**	**Inference**	
Coefficient	1.21	Poorly Sorted	
Skewness	0.29	Positive(Coarse)	
Kurtosis	1.63	Very Leptokurtic	
% Fines	18.68%	V.Fine Sands	
% Sands	81.14%		
% Gravel	0.18%		

Sample No.:	Station 5	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:55

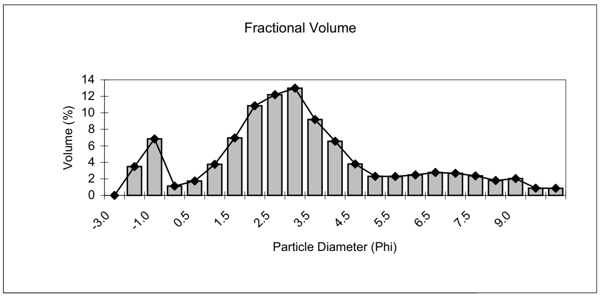


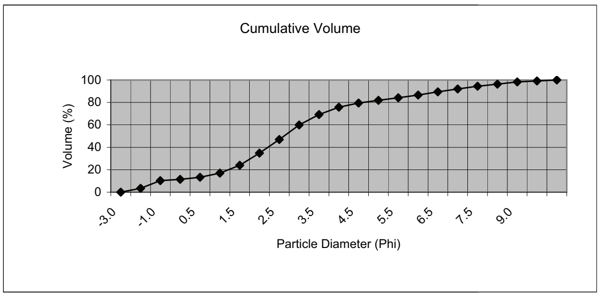


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	3.72	3.7	Granule
1.000	0.0	1.72	5.4	V.Coarse Sand
0.710	0.5	1.31	6.7	Coarse Sand
0.500	1.0	2.27	9.0	
0.355	1.5	4.17	13.2	Medium Sand
0.250	2.0	6.68	19.9	
0.180	2.5	8.44	28.3	Fine Sand
0.125	3.0	11.55	39.9	
0.900	3.5	11.14	51.0	V.Fine Sand
0.063	4.0	10.44	61.4	
0.044	4.5	7.10	68.5	Coarse Silt
0.032	5.0	4.06	72.6	
0.022	5.5	3.42	76.0	Medium Silt
0.016	6.0	3.55	79.6	
0.011	6.5	4.05	83.6	Fine silt
0.008	7.0	3.97	87.6	
0.006	7.5	3.54	91.1	V.Fine Silt
0.004	8.0	2.73	93.9	
0.002	9.0	3.19	97.0	Coarse Clay
0.001	10.0	1.46	98.5	Medium Clay
<0.001	>10.0	1.49	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.068	0.405	3.89
Median	0.093		3.42
Sorting	**Value**	**Inference**	
Coefficient	2.52	Very Poorly Sorted	
Skewness	0.21	Positive(Coarse)	
Kurtosis	1.15	Leptokurtic	
% Fines	38.57%	V.Fine Sands	
% Sands	57.72%		
% Gravel	3.72%		

Sample No.:	Station 6	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:49

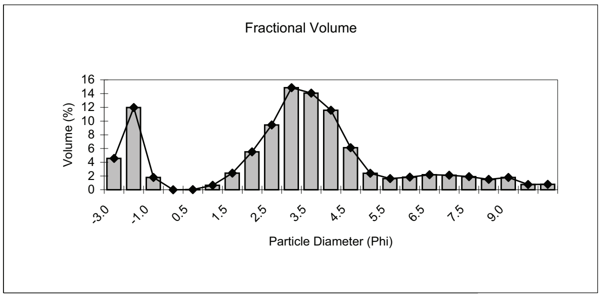


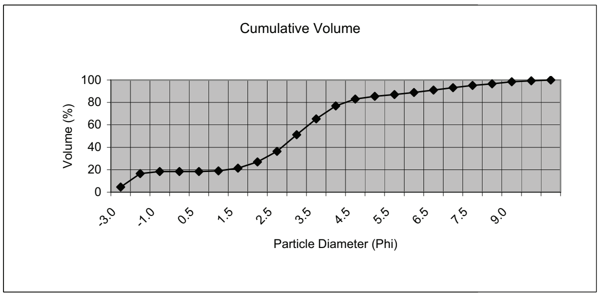


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	3.48	3.5	
2.000	-1.0	6.84	10.3	Granule
1.000	0.0	1.13	11.5	V.Coarse Sand
0.710	0.5	1.74	13.2	Coarse Sand
0.500	1.0	3.77	17.0	
0.355	1.5	6.97	23.9	Medium Sand
0.250	2.0	10.87	34.8	
0.180	2.5	12.19	47.0	Fine Sand
0.125	3.0	12.99	60.0	
0.900	3.5	9.18	69.2	V.Fine Sand
0.063	4.0	6.56	75.7	
0.044	4.5	3.80	79.5	Coarse Silt
0.032	5.0	2.31	81.8	
0.022	5.5	2.29	84.1	Medium Silt
0.016	6.0	2.48	86.6	
0.011	6.5	2.77	89.4	Fine silt
0.008	7.0	2.68	92.1	
0.006	7.5	2.37	94.4	V.Fine Silt
0.004	8.0	1.81	96.3	
0.002	9.0	2.04	98.3	Coarse Clay
0.001	10.0	0.87	99.2	Medium Clay
<0.001	>10.0	0.84	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.128	1.241	2.97
Median	0.167		2.58
Sorting	**Value**	**Inference**	
Coefficient	2.59	Very Poorly Sorted	
Skewness	0.16	Positive(Coarse)	
Kurtosis	1.63	Very Leptokurtic	
% Fines	24.28%	Fine Sand	
% Sands	65.40%		
% Gravel	10.33%		

Sample No.:	Station 7	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 15:45

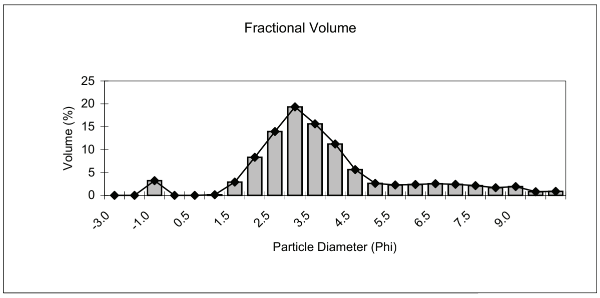


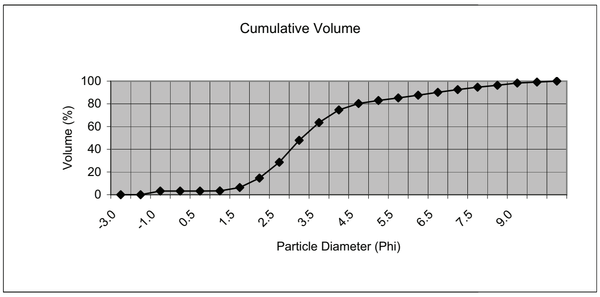


Aperture (μm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	4.57	4.6	Pebble
4.000	-2.0	11.97	16.5	
2.000	-1.0	1.80	18.3	Granule
1.000	0.0	0.00	18.3	V.Coarse Sand
0.710	0.5	0.01	18.4	Coarse Sand
0.500	1.0	0.65	19.0	
0.355	1.5	2.42	21.4	Medium Sand
0.250	2.0	5.51	26.9	
0.180	2.5	9.44	36.4	Fine Sand
0.125	3.0	14.86	51.2	
0.900	3.5	14.07	65.3	V.Fine Sand
0.063	4.0	11.58	76.9	
0.044	4.5	6.13	83.0	Coarse Silt
0.032	5.0	2.41	85.4	
0.022	5.5	1.63	87.1	Medium Silt
0.016	6.0	1.84	88.9	
0.011	6.5	2.18	91.1	Fine silt
0.008	7.0	2.13	93.2	
0.006	7.5	1.91	95.1	V.Fine Silt
0.004	8.0	1.52	96.6	
0.002	9.0	1.80	98.4	Coarse Clay
0.001	10.0	0.78	99.2	Medium Clay
<0.001	>10.0	0.78	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.276	3.132	1.86
Median	0.130		2.95
Sorting	**Value**	**Inference**	
Coefficient	3.27	Very Poorly Sorted	
Skewness	-0.31	Very Negative(fine)	
Kurtosis	2.05	Very Leptokurtic	
% Fines	23.11%	Medium Sand	
% Sands	58.55%		
% Gravel	18.35%		

Sample No.:	Station 8	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:32

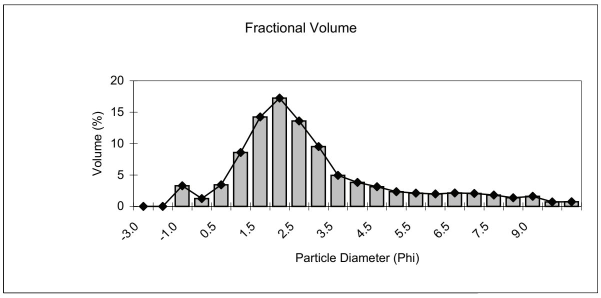


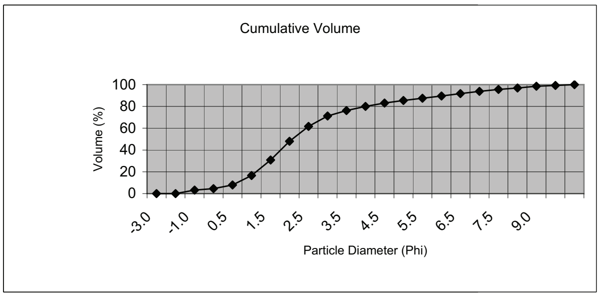


Aperture (μm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	3.23	3.2	Granule
1.000	0.0	0.00	3.2	V.Coarse Sand
0.710	0.5	0.00	3.2	Coarse Sand
0.500	1.0	0.13	3.4	
0.355	1.5	2.91	6.3	Medium Sand
0.250	2.0	8.33	14.6	
0.180	2.5	13.95	28.5	Fine Sand
0.125	3.0	19.32	47.9	
0.900	3.5	15.63	63.5	V.Fine Sand
0.063	4.0	11.21	74.7	
0.044	4.5	5.62	80.3	Coarse Silt
0.032	5.0	2.63	83.0	
0.022	5.5	2.27	85.2	Medium Silt
0.016	6.0	2.38	87.6	
0.011	6.5	2.56	90.2	Fine silt
0.008	7.0	2.41	92.6	
0.006	7.5	2.13	94.7	V.Fine Silt
0.004	8.0	1.67	96.4	
0.002	9.0	1.93	98.3	Coarse Clay
0.001	10.0	0.81	99.1	Medium Clay
<0.001	>10.0	0.88	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.093	0.146	3.43
Median	0.120		3.06
Sorting	**Value**	**Inference**	
Coefficient	1.75	Poorly Sorted	
Skewness	0.39	Very Positive (Coarse)	
Kurtosis	1.55	Very Leptokurtic	
% Fines	25.29%	V.Fine Sands	
% Sands	71.48%		
% Gravel	3.23%		

Sample No.:	Station 10	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:29

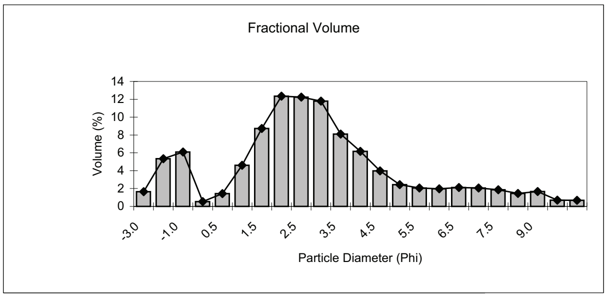


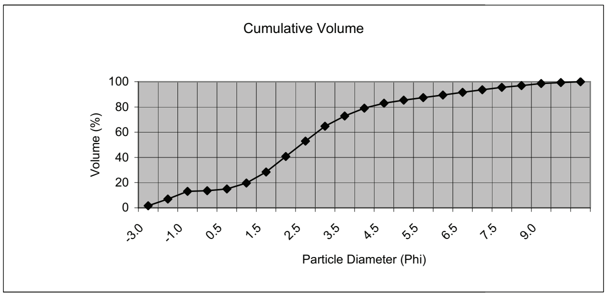


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	3.29	3.3	Granule
1.000	0.0	1.24	4.5	V.Coarse Sand
0.710	0.5	3.45	8.0	Coarse Sand
0.500	1.0	8.58	16.6	
0.355	1.5	14.24	30.8	Medium Sand
0.250	2.0	17.25	48.1	
0.180	2.5	13.61	61.7	Fine Sand
0.125	3.0	9.54	71.2	
0.900	3.5	4.95	76.2	V.Fine Sand
0.063	4.0	3.81	80.0	
0.044	4.5	3.14	83.1	Coarse Silt
0.032	5.0	2.35	85.5	
0.022	5.5	2.12	87.6	Medium Silt
0.016	6.0	2.00	89.6	
0.011	6.5	2.14	91.7	Fine silt
0.008	7.0	2.06	93.8	
0.006	7.5	1.81	95.6	V.Fine Silt
0.004	8.0	1.38	97.0	
0.002	9.0	1.60	98.6	Coarse Clay
0.001	10.0	0.72	99.3	Medium Clay
<0.001	>10.0	0.73	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.169	0.335	2.56
Median	0.240		2.06
Sorting	**Value**	**Inference**	
Coefficient	2.03	Very Poorly Sorted	
Skewness	0.43	Very Positive (Coarse)	
Kurtosis	1.43	Leptokurtic	
% Fines	20.03%	Fine Sand	
% Sands	76.67%		
% Gravel	3.29%		

Sample No.:	Station 11	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 15:42

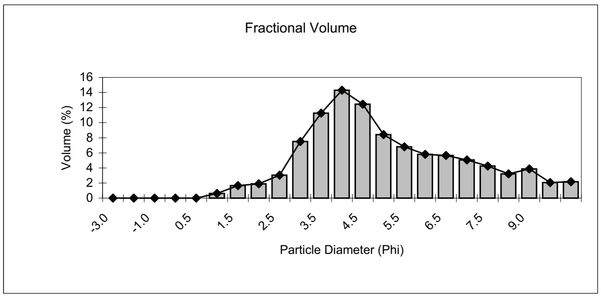


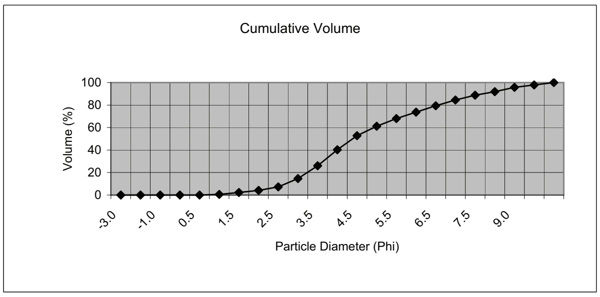


Aperture (mmm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	1.6	1.6	Pebble
4.000	-2.0	5.3	7.0	
2.000	-1.0	6.1	13.1	Granule
1.000	0.0	0.5	13.6	C, Coarse S
0.710	0.5	1.4	15.0	Coarse Sand
0.500	1.0	4.6	19.6	
0.355	1.5	8.7	28.4	Medium Sand
0.250	2.0	12.4	40.7	
0.180	2.5	12.2	53.0	Fine Sand
0.125	3.0	11.8	64.8	
0.900	3.5	8.1	72.9	V.Fine Sand
0.063	4.0	6.2	79.0	
0.044	4.5	4.0	83.0	Corse Silt
0.032	5.0	2.4	85.4	
0.022	5.5	2.1	87.5	Medium Silt
0.016	6.0	2.0	89.5	
0.011	6.5	2.1	91.6	Fine Silt
0.008	7.0	2.1	93.6	
0.006	7.5	1.9	95.5	V.Fine Silt
0.004	8.0	1.5	97.0	
0.002	9.0	1.7	98.6	Coarse Clay
0.001	10.0	0.7	99.3	Medium Clay
<0.001	>10.0	0.7	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.172	1.899	2.54
Median	0.197		2.34
Sorting	**Value**	**Inference**	
Coefficient	2.5	Very Poorly Sorted	
Skewness	0.1	Symmetrical	
Kurtosis	1.7	Very Leptokurtic	
% Fines	0.2	Fine Sand	
% Sands	0.7		
% Gravel	0.1		

Sample No.:	Station 12	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 15:54

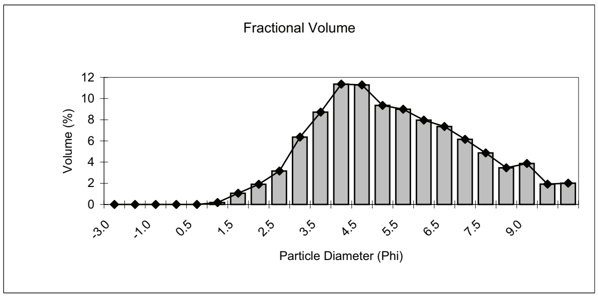


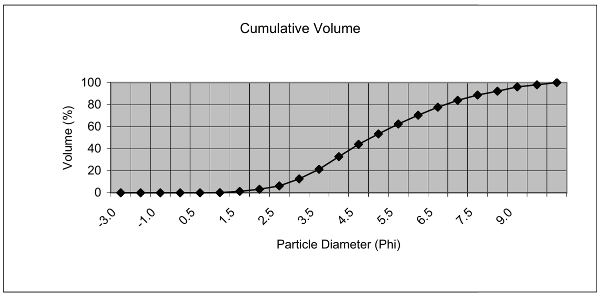


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	0.62	0.6	
0.355	1.5	1.66	2.3	Medium Sand
0.250	2.0	1.89	4.2	
0.180	2.5	3.04	7.2	Fine Sand
0.125	3.0	7.50	14.7	
0.900	3.5	11.26	26.0	V.Fine Sand
0.063	4.0	14.30	40.3	
0.044	4.5	12.46	52.7	Coarse Silt
0.032	5.0	8.42	61.1	
0.022	5.5	6.79	67.9	Medium Silt
0.016	6.0	5.79	73.7	
0.011	6.5	5.66	79.4	Fine silt
0.008	7.0	5.06	84.4	
0.006	7.5	4.26	88.7	V.Fine Silt
0.004	8.0	3.21	91.9	
0.002	9.0	3.86	95.8	Coarse Clay
0.001	10.0	2.06	97.8	Medium Clay
<0.001	>10.0	2.16	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.036	0.081	4.79
Median	0.048		4.38
Sorting	**Value**	**Inference**	
Coefficient	1.98	Poorly Sorted	
Skewness	0.32	Very Positive (Coarse)	
Kurtosis	1.01	Mesokurtic	
% Fines	59.74%	Coarse Silt	
% Sands	40.27%		
% Gravel	0.00%		

Sample No.:	Station 13	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:35

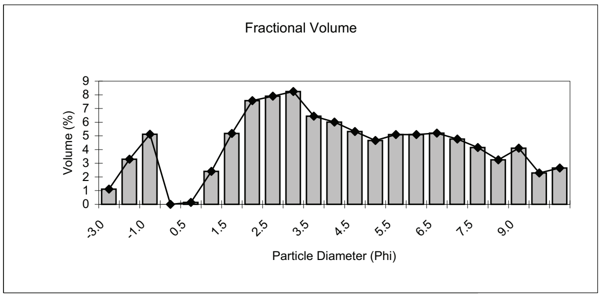


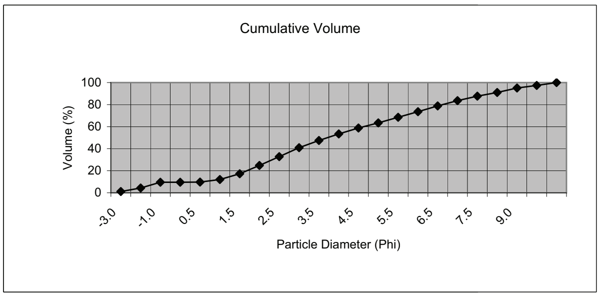


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	0.19	0.2	
0.355	1.5	1.05	1.2	Medium Sand
0.250	2.0	1.91	3.1	
0.180	2.5	3.15	6.3	Fine Sand
0.125	3.0	6.36	12.7	
0.900	3.5	8.72	21.4	V.Fine Sand
0.063	4.0	11.36	32.7	
0.044	4.5	11.28	44.0	Coarse Silt
0.032	5.0	9.36	53.4	
0.022	5.5	9.00	62.4	Medium Silt
0.016	6.0	7.97	70.3	
0.011	6.5	7.37	77.7	Fine silt
0.008	7.0	6.15	83.9	
0.006	7.5	4.87	88.7	V.Fine Silt
0.004	8.0	3.46	92.2	
0.002	9.0	3.87	96.1	Coarse Clay
0.001	10.0	1.93	98.0	Medium Clay
<0.001	>10.0	2.01	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.031	0.074	4.99
Median	0.036		4.80
Sorting	**Value**	**Inference**	
Coefficient	1.93	Poorly Sorted	
Skewness	0.18	Positive(Coarse)	
Kurtosis	0.97	Mesokurtic	
% Fines	67.26%	Coarse Silt	
% Sands	32.74%		
% Gravel	0.00%		

Sample No.:	Station 14	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 16:15



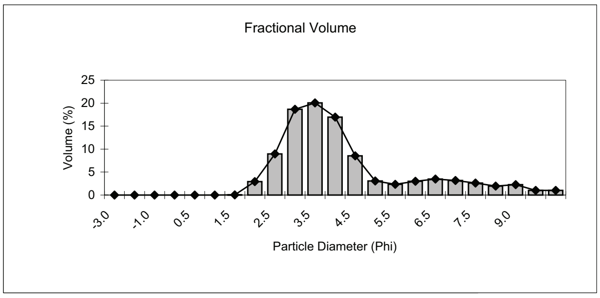


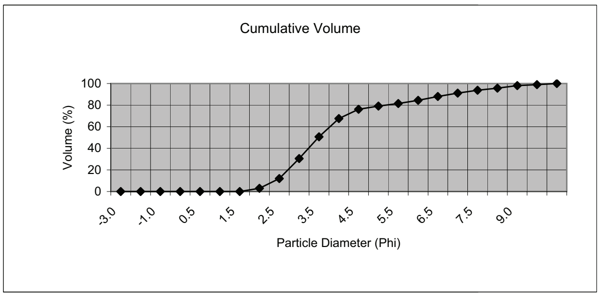
Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	1.11	1.1	Pebble
4.000	-2.0	3.30	4.4	
2.000	-1.0	5.12	9.5	Granule
1.000	0.0	0.00	9.5	V.Coarse Sand
0.710	0.5	0.14	9.7	Coarse Sand
0.500	1.0	2.41	12.1	
0.355	1.5	5.18	17.3	Medium Sand
0.250	2.0	7.57	24.8	
0.180	2.5	7.90	32.7	Fine Sand
0.125	3.0	8.24	41.0	
0.900	3.5	6.44	47.4	V.Fine Sand
0.063	4.0	6.01	53.4	
0.044	4.5	5.32	58.7	Coarse Silt
0.032	5.0	4.66	63.4	
0.022	5.5	5.10	68.5	Medium Silt
0.016	6.0	5.10	73.6	
0.011	6.5	5.21	78.8	Fine silt
0.008	7.0	4.76	83.6	
0.006	7.5	4.14	87.7	V.Fine Silt
0.004	8.0	3.25	91.0	
0.002	9.0	4.10	95.1	Coarse Clay
0.001	10.0	2.29	97.4	Medium Clay
<0.001	>10.0	2.65	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.061	1.220	4.03
Median	0.078		3.67

Sorting	Value	Inference
Coefficient	3.07	Very Poorly Sorted
Skewness	0.08	Symmetrical
Kurtosis	1.08	Mesokurtic
% Fines	46.58%	Coarse Silt
% Sands	43.89%	
% Gravel	9.53%	

Sample No.:	Station 15	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:44



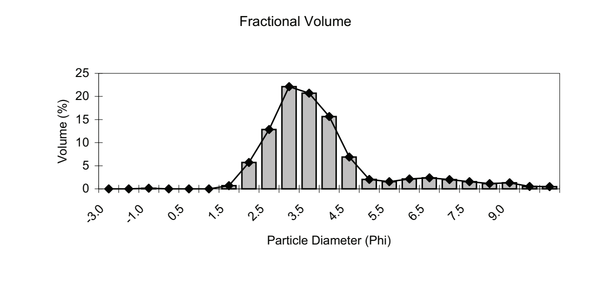


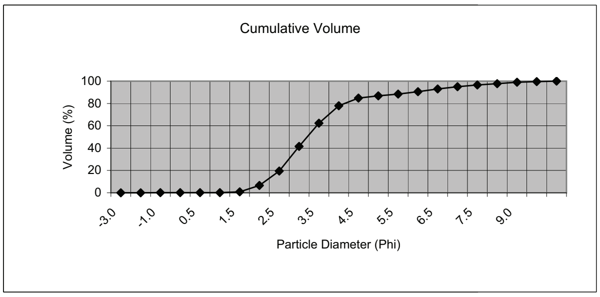
Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	0.00	0.0	
0.355	1.5	0.05	0.1	Medium Sand
0.250	2.0	2.93	3.0	
0.180	2.5	8.94	11.9	Fine Sand
0.125	3.0	18.66	30.6	
0.900	3.5	20.05	50.6	V.Fine Sand
0.063	4.0	16.95	67.6	
0.044	4.5	8.52	76.1	Coarse Silt
0.032	5.0	3.06	79.2	
0.022	5.5	2.34	81.5	Medium Silt
0.016	6.0	3.01	84.5	
0.011	6.5	3.48	88.0	Fine silt
0.008	7.0	3.16	91.2	
0.006	7.5	2.62	93.8	V.Fine Silt
0.004	8.0	1.97	95.7	
0.002	9.0	2.27	98.0	Coarse Clay
0.001	10.0	1.00	99.0	Medium Clay
<0.001	>10.0	0.99	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.063	0.087	3.98
Median	0.091		3.46

Sorting	Value	Inference
Coefficient	1.70	Poorly Sorted
Skewness	0.50	Very Positive (Coarse)
Kurtosis	1.45	Leptokurtic
% Fines	32.41%	V.Fine Sands
% Sands	67.59%	
% Gravel	0.00%	

Sample No.:	Station 16	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:46

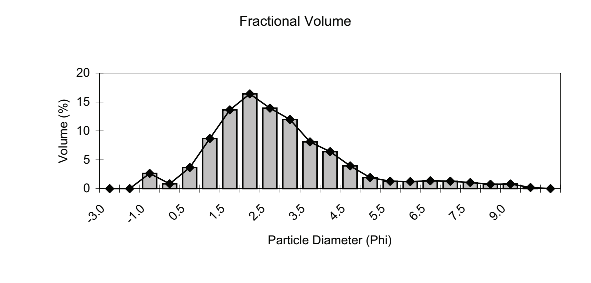


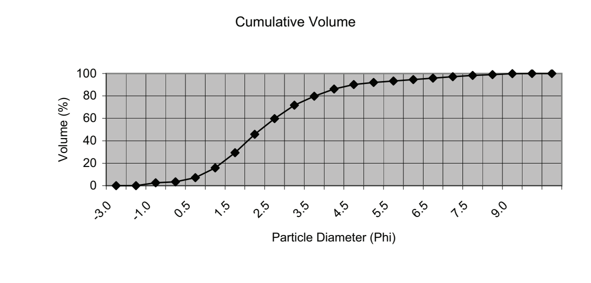


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.13	0.1	Granule
1.000	0.0	0.00	0.1	V.Coarse Sand
0.710	0.5	0.00	0.1	Coarse Sand
0.500	1.0	0.00	0.1	
0.355	1.5	0.71	0.8	Medium Sand
0.250	2.0	5.72	6.6	
0.180	2.5	12.86	19.4	Fine Sand
0.125	3.0	22.11	41.5	
0.900	3.5	20.72	62.3	V.Fine Sand
0.063	4.0	15.66	77.9	
0.044	4.5	6.90	84.8	Coarse Silt
0.032	5.0	2.05	86.9	
0.022	5.5	1.57	88.4	Medium Silt
0.016	6.0	2.15	90.6	
0.011	6.5	2.39	93.0	Fine silt
0.008	7.0	2.01	95.0	
0.006	7.5	1.57	96.5	V.Fine Silt
0.004	8.0	1.15	97.7	
0.002	9.0	1.31	99.0	Coarse Clay
0.001	10.0	0.52	99.5	Medium Clay
<0.001	>10.0	0.48	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.101	0.098	3.31
Median	0.111		3.18
Sorting	**Value**	**Inference**	
Coefficient	1.31	Poorly Sorted	
Skewness	0.34	Very Positive (Coarse)	
Kurtosis	1.64	Very Leptokurtic	
% Fines	22.08%	V.Fine Sands	
% Sands	77.79%		
% Gravel	0.13%		

Sample No.:	Station 17	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 15:57

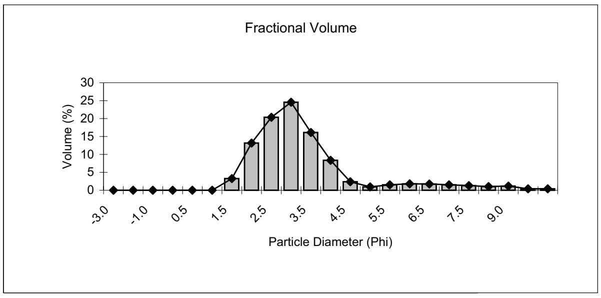


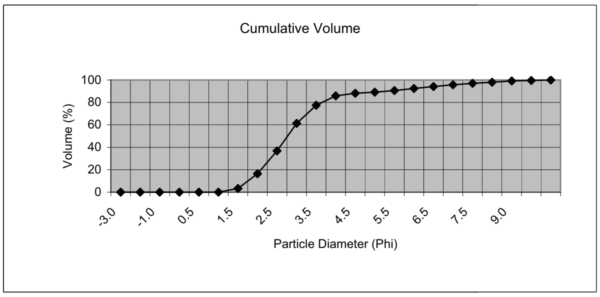


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	2.62	2.6	Granule
1.000	0.0	0.82	3.4	V.Coarse Sand
0.710	0.5	3.66	7.1	Coarse Sand
0.500	1.0	8.66	15.8	
0.355	1.5	13.63	29.4	Medium Sand
0.250	2.0	16.40	45.8	
0.180	2.5	13.94	59.7	Fine Sand
0.125	3.0	11.98	71.7	
0.900	3.5	8.09	79.8	V.Fine Sand
0.063	4.0	6.39	86.2	
0.044	4.5	3.94	90.1	Coarse Silt
0.032	5.0	1.92	92.1	
0.022	5.5	1.28	93.3	Medium Silt
0.016	6.0	1.22	94.6	
0.011	6.5	1.37	95.9	Fine silt
0.008	7.0	1.27	97.2	
0.006	7.5	1.05	98.2	V.Fine Silt
0.004	8.0	0.75	99.0	
0.002	9.0	0.81	99.8	Coarse Clay
0.001	10.0	0.19	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.202	0.303	2.31
Median	0.229		2.13
Sorting	**Value**	**Inference**	
Coefficient	1.60	Poorly Sorted	
Skewness	0.27	Positive(Coarse)	
Kurtosis	1.31	Leptokurtic	
% Fines	13.80%	Fine Sand	
% Sands	83.58%		
% Gravel	2.62%		

Sample No.:	Station 18	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:24

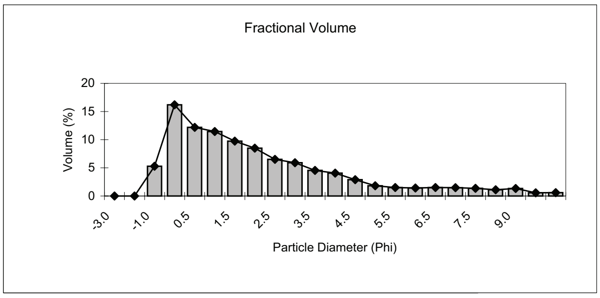


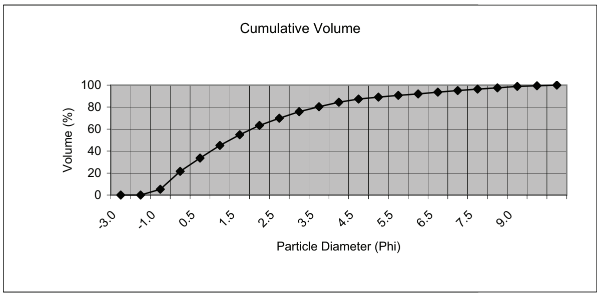


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	0.00	0.0	
0.355	1.5	3.27	3.3	Medium Sand
0.250	2.0	13.17	16.4	
0.180	2.5	20.37	36.8	Fine Sand
0.125	3.0	24.56	61.4	
0.900	3.5	16.13	77.5	V.Fine Sand
0.063	4.0	8.33	85.8	
0.044	4.5	2.37	88.2	Coarse Silt
0.032	5.0	0.93	89.1	
0.022	5.5	1.50	90.6	Medium Silt
0.016	6.0	1.79	92.4	
0.011	6.5	1.74	94.2	Fine silt
0.008	7.0	1.50	95.7	
0.006	7.5	1.31	97.0	V.Fine Silt
0.004	8.0	1.04	98.0	
0.002	9.0	1.17	99.2	Coarse Clay
0.001	10.0	0.42	99.6	Medium Clay
<0.001	>10.0	0.39	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.138	0.122	2.86
Median	0.150		2.73
Sorting Coefficient	Value 1.26	Inference: Poorly Sorted	
Skewness	0.37	Very Positive (Coarse)	
Kurtosis	1.77	Very Leptokurtic	
% Fines	14.17%	Fine Sand	
% Sands	85.83%		
% Gravel	0.00%		

Sample No.:	Station 19	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:57



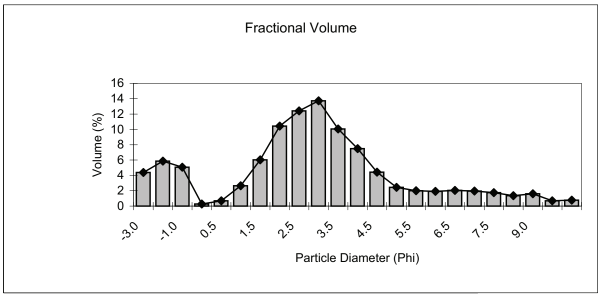


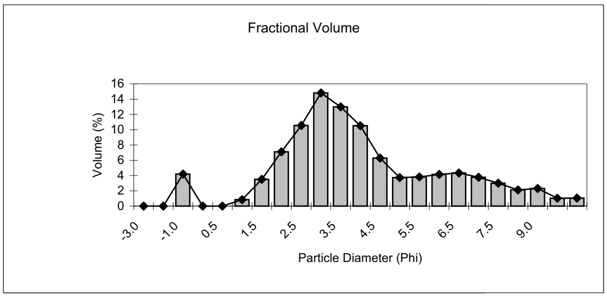
Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	5.28	5.3	Granule
1.000	0.0	16.20	21.5	V.Coarse Sand
0.710	0.5	12.18	33.7	Coarse Sand
0.500	1.0	11.45	45.1	
0.355	1.5	9.75	54.9	Medium Sand
0.250	2.0	8.50	63.4	
0.180	2.5	6.51	69.9	Fine Sand
0.125	3.0	5.92	75.8	
0.900	3.5	4.55	80.3	V.Fine Sand
0.063	4.0	4.05	84.4	
0.044	4.5	2.91	87.3	Coarse Silt
0.032	5.0	1.82	89.1	
0.022	5.5	1.51	90.6	Medium Silt
0.016	6.0	1.41	92.0	
0.011	6.5	1.51	93.6	Fine silt
0.008	7.0	1.48	95.0	
0.006	7.5	1.36	96.4	V.Fine Silt
0.004	8.0	1.10	97.5	
0.002	9.0	1.34	98.8	Coarse Clay
0.001	10.0	0.58	99.4	Medium Clay
<0.001	>10.0	0.59	100.0	Fine Clay

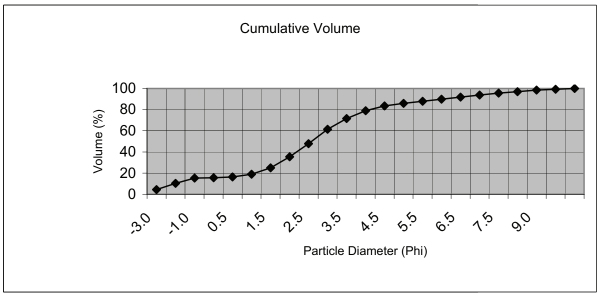
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.335	0.803	1.58
Median	0.427		1.23
Sorting Coefficient	Value 2.31	Inference: Very Poorly Sorted	
Skewness	0.34	Very Positive (Coarse)	
Kurtosis	1.18	Leptokurtic	
% Fines	15.61%	Medium Sand	
% Sands	79.12%		
% Gravel	5.28%		

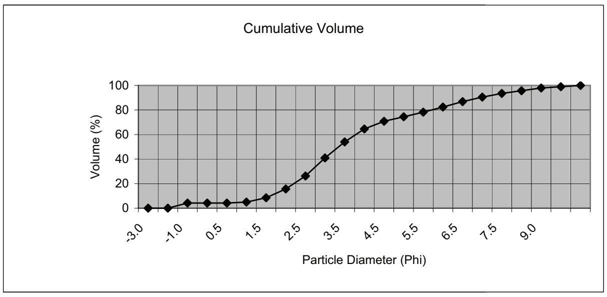
Sample No.:	Station 20	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:38

Sample No.:	Station 21	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 13:27









Station 20

Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	4.38	4.4	Pebble
4.000	-2.0	5.85	10.2	
2.000	-1.0	5.07	15.3	Granule
1.000	0.0	0.27	15.6	V.Coarse Sand
0.710	0.5	0.69	16.3	Coarse Sand
0.500	1.0	2.65	18.9	
0.355	1.5	6.02	24.9	Medium Sand
0.250	2.0	10.42	35.4	
0.180	2.5	12.41	47.8	Fine Sand
0.125	3.0	13.72	61.5	
0.900	3.5	10.05	71.5	V.Fine Sand
0.063	4.0	7.49	79.0	
0.044	4.5	4.43	83.5	Coarse Silt
0.032	5.0	2.45	85.9	
0.022	5.5	2.01	87.9	Medium Silt
0.016	6.0	1.92	89.8	
0.011	6.5	2.05	91.9	Fine silt
0.008	7.0	1.96	93.8	
0.006	7.5	1.75	95.6	V.Fine Silt
0.004	8.0	1.37	96.9	
0.002	9.0	1.60	98.5	Coarse Clay
0.001	10.0	0.69	99.2	Medium Clay
<0.001	>10.0	0.76	100.0	Fine Clay

Station 21

Aperture (mmm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.0	0.0	Pebble
4.000	-2.0	0.0	0.0	
2.000	-1.0	4.2	4.2	Granule
1.000	0.0	0.0	4.2	C, Coarse S
0.710	0.5	0.0	4.2	Coarse Sand
0.500	1.0	0.8	5.0	
0.355	1.5	3.5	8.5	Medium Sand
0.250	2.0	7.1	15.6	
0.180	2.5	10.6	26.2	Fine Sand
0.125	3.0	14.8	41.0	
0.900	3.5	13.0	54.0	V.Fine Sand
0.063	4.0	10.5	64.5	
0.044	4.5	6.3	70.8	Corse Silt
0.032	5.0	3.7	74.5	
0.022	5.5	3.8	78.3	Medium Silt
0.016	6.0	4.1	82.4	
0.011	6.5	4.3	86.8	Fine Silt
0.008	7.0	3.8	90.5	
0.006	7.5	3.0	93.5	V.Fine Silt
0.004	8.0	2.1	95.6	
0.002	9.0	2.3	97.9	Coarse Clay
0.001	10.0	1.0	99.0	Medium Clay
<0.001	>10.0	1.0	100.0	Fine Clay

Station 20

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.180	2.648	2.48
Median	0.171		2.55

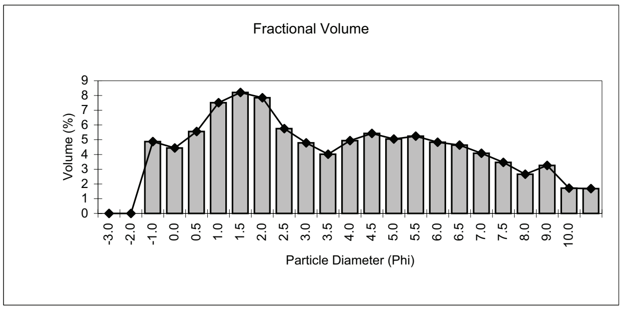
Sorting	Value	Inference
Coefficient	2.63	Very Poorly Sorted
Skewness	-0.06	Symmetrical
Kurtosis	1.91	Very Leptokurtic
% Fines	20.98%	Fine Sand
% Sands	63.72%	
% Gravel	15.30%	

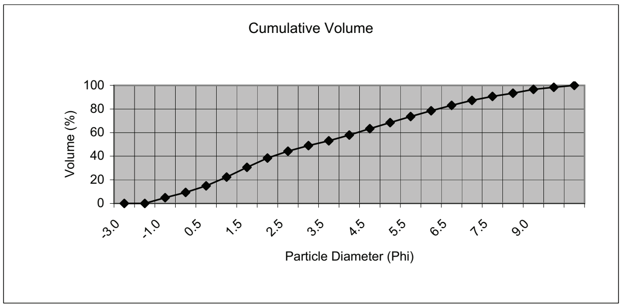
Station 21

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.070	0.175	3.83
Median	0.101		3.31

Sorting	Value	Inference
Coefficient	2.1	Very Poorly Sorted
Skewness	0.3	Very Positive (Coarse)
Kurtosis	1.1	Mesokurtic
% Fines	0.4	V.Fine Sands
% Sands	0.6	
% Gravel	0.0	

Sample No.:	Station 22	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 15:48

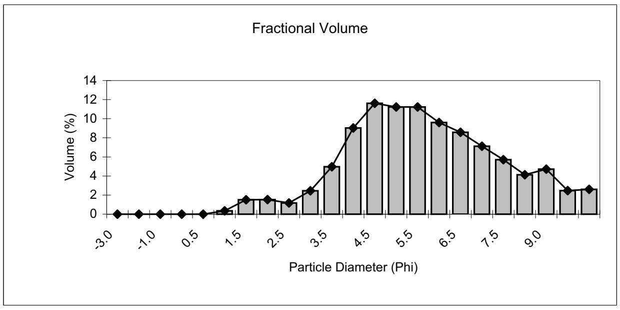


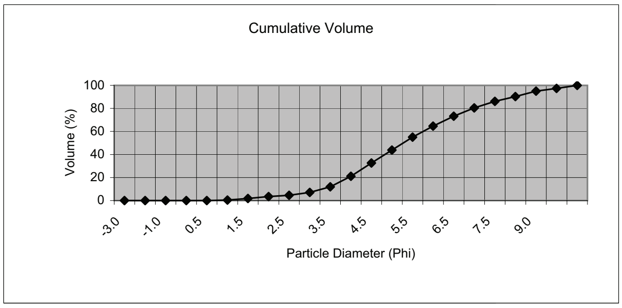


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	4.88	4.9	Granule
1.000	0.0	4.45	9.3	V.Coarse Sand
0.710	0.5	5.56	14.9	Coarse Sand
0.500	1.0	7.51	22.4	
0.355	1.5	8.21	30.6	Medium Sand
0.250	2.0	7.85	38.5	
0.180	2.5	5.76	44.2	Fine Sand
0.125	3.0	4.78	49.0	
0.900	3.5	4.02	53.0	V.Fine Sand
0.063	4.0	4.94	58.0	
0.044	4.5	5.43	63.4	Coarse Silt
0.032	5.0	5.05	68.4	
0.022	5.5	5.24	73.7	Medium Silt
0.016	6.0	4.83	78.5	
0.011	6.5	4.64	83.1	Fine silt
0.008	7.0	4.08	87.2	
0.006	7.5	3.46	90.7	V.Fine Silt
0.004	8.0	2.66	93.3	
0.002	9.0	3.26	96.6	Coarse Clay
0.001	10.0	1.72	98.3	Medium Clay
<0.001	>10.0	1.69	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.093	0.663	3.42
Median	0.116		3.11
Sorting	**Value**	**Inference**	
Coefficient	2.93	Very Poorly Sorted	
Skewness	0.14	Positive(Coarse)	
Kurtosis	0.86	Platykurtic	
% Fines	42.05%	V.Fine Sands	
% Sands	53.07%		
% Gravel	4.88%		

Sample No.:	Station 23	Operator	Ian Wilson
Source Data:	Borders & Southern	Date&Time:	06/02/2009 16:18

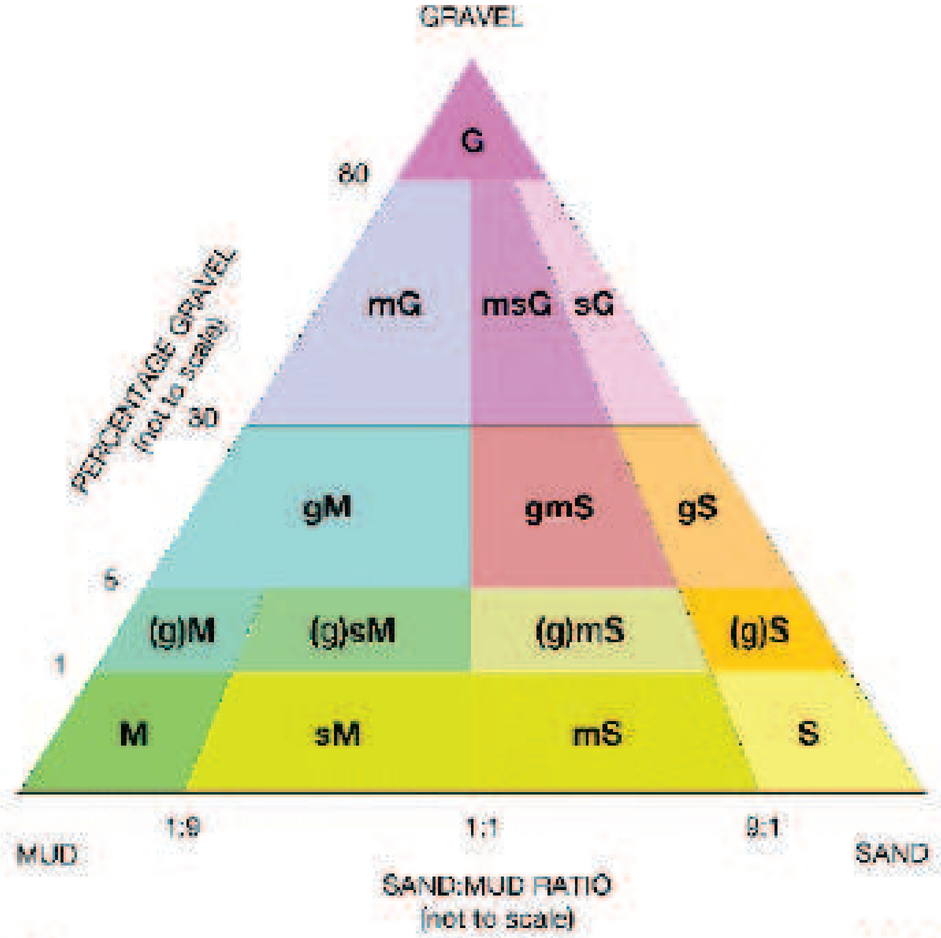




Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	0.35	0.4	
0.355	1.5	1.52	1.9	Medium Sand
0.250	2.0	1.53	3.4	
0.180	2.5	1.18	4.6	Fine Sand
0.125	3.0	2.45	7.0	
0.900	3.5	4.97	12.0	V.Fine Sand
0.063	4.0	9.03	21.0	
0.044	4.5	11.61	32.6	Coarse Silt
0.032	5.0	11.23	43.9	
0.022	5.5	11.23	55.1	Medium Silt
0.016	6.0	9.61	64.7	
0.011	6.5	8.57	73.3	Fine silt
0.008	7.0	7.11	80.4	
0.006	7.5	5.71	86.1	V.Fine Silt
0.004	8.0	4.14	90.2	
0.002	9.0	4.72	94.9	Coarse Clay
0.001	10.0	2.46	97.4	Medium Clay
<0.001	>10.0	2.60	100.0	Fine Clay

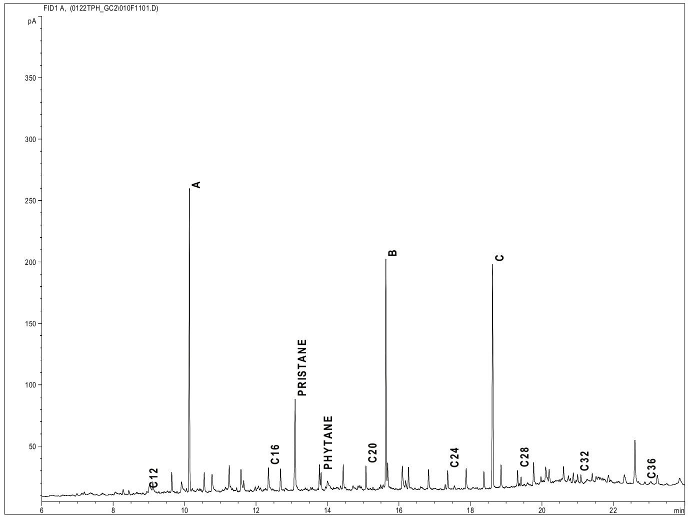
Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.024	0.058	5.41
Median	0.026		5.25
Sorting	**Value**	**Inference**	
Coefficient	1.88	Poorly Sorted	
Skewness	0.15	Positive(Coarse)	
Kurtosis	1.07	Mesokurtic	
% Fines	78.98%	Medium Silt	
% Sands	21.02%		
% Gravel	0.00%		

Modified Folk Classification

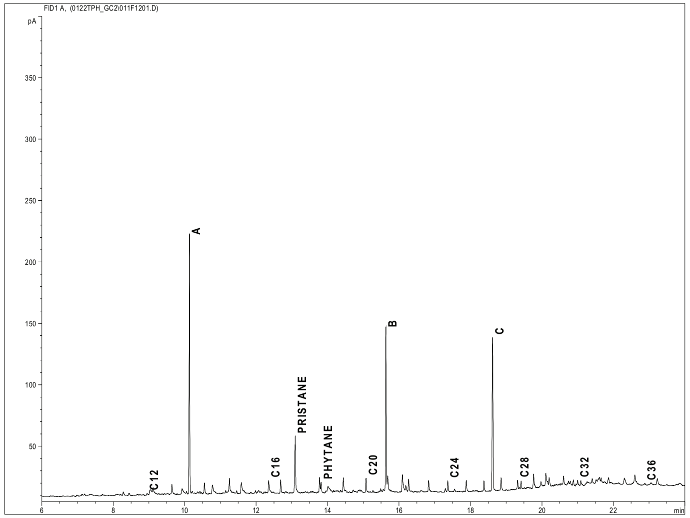


M	Mud
sM	Sandy mud
(g)M	Slightly gravelly mud
(g)sM	Slightly gravelly sandy mud
gM	Gravelly mud
S	Sand
mS	Muddy sand
(g)S	Slightly gravelly sand
(g)mS	Slightly gravelly muddy sand
gmS	Gravelly muddy sand
gS	Gravelly sand
G	Gravel
mG	Muddy gravel
msG	Muddy sandy gravel
sG	Sandy gravel

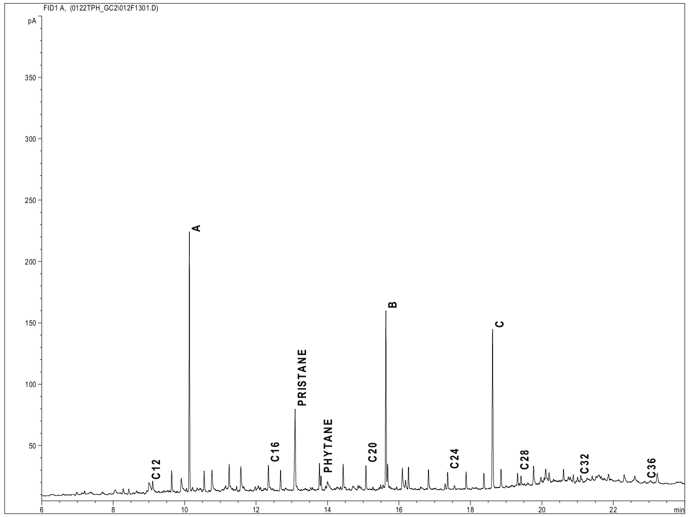
APPENDIX II: GC-FID Traces



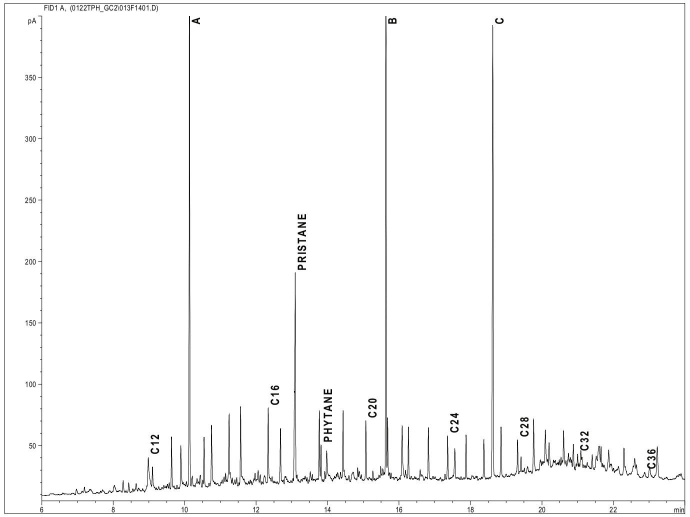
Station 1



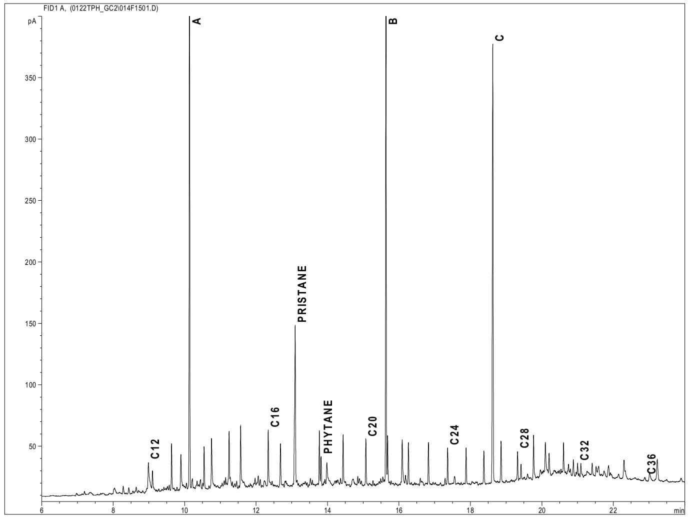
Station 2



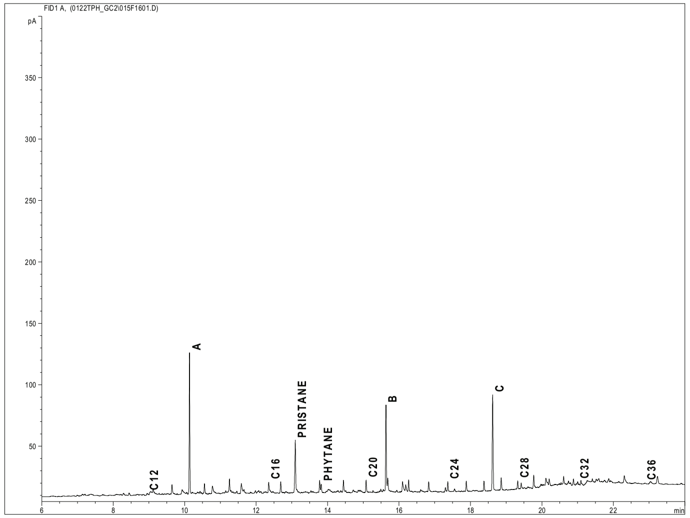
Station 3



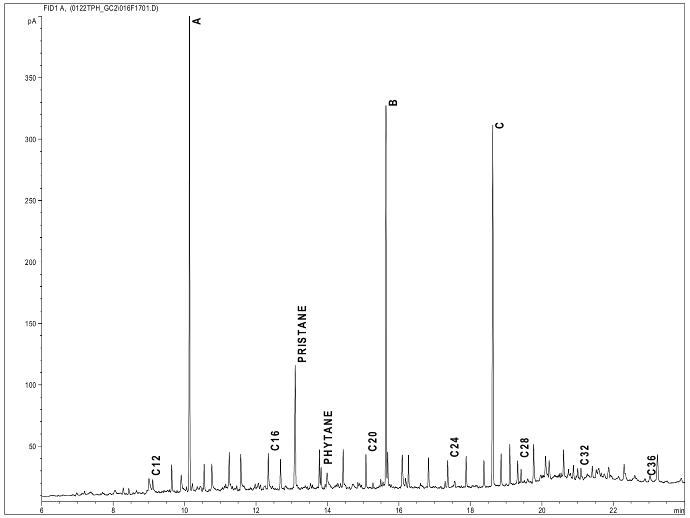
Station 4



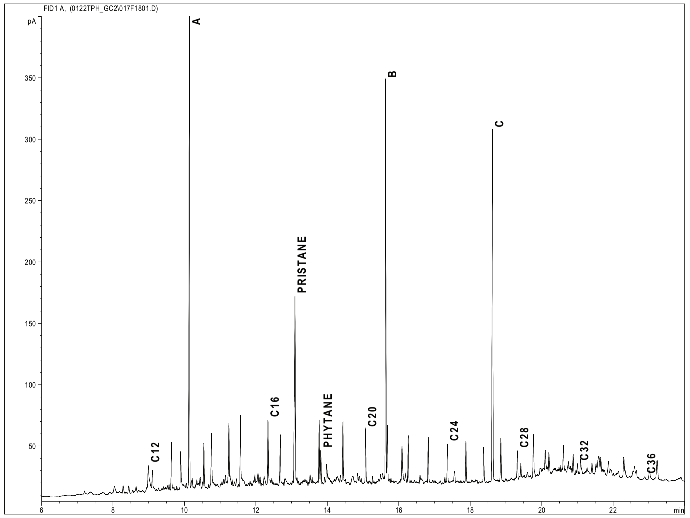
Station 5



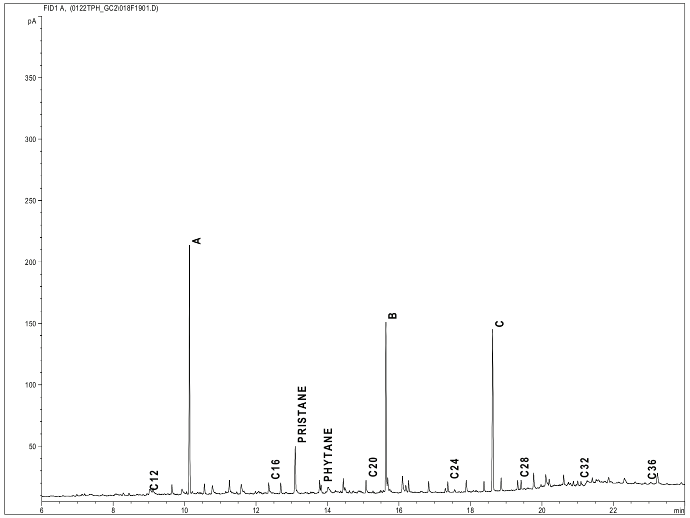
Station 6



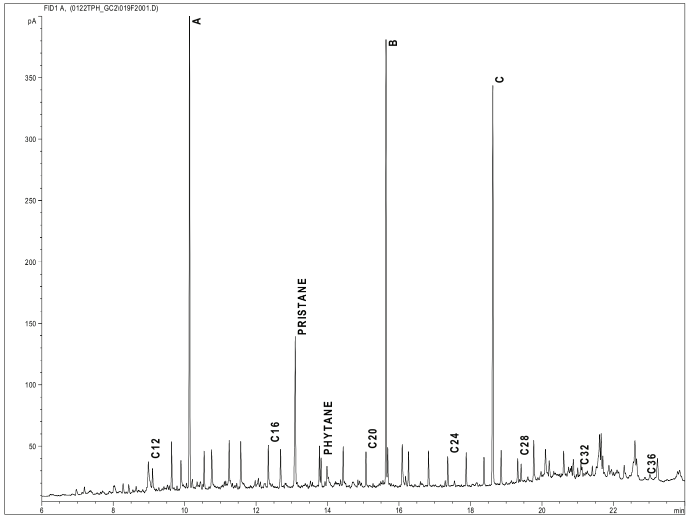
Station 7



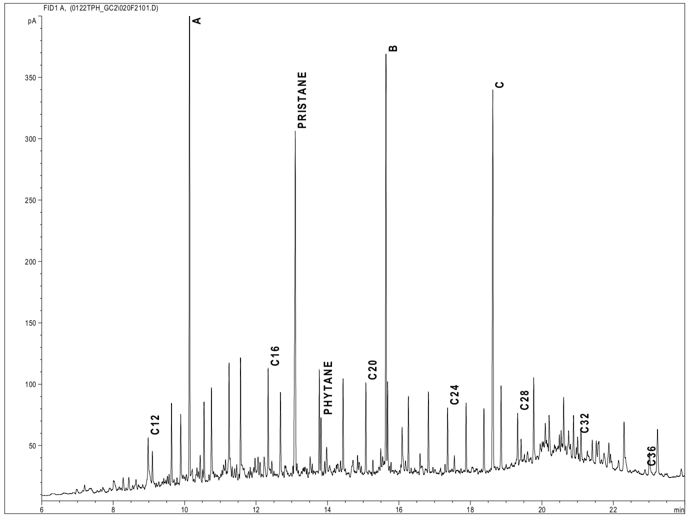
Station 8



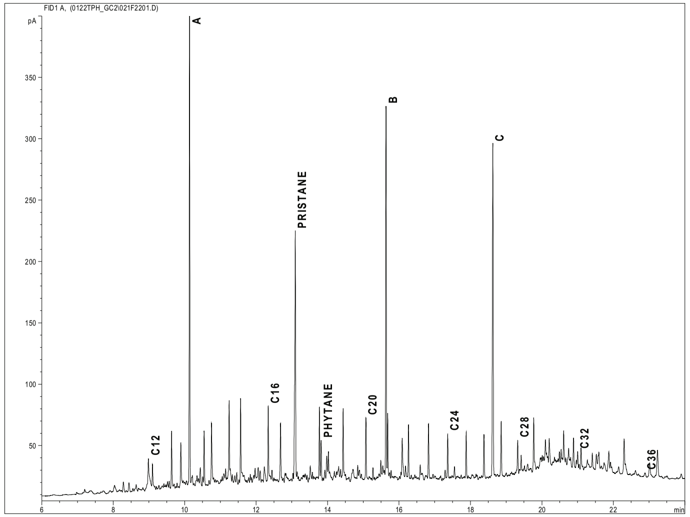
Station 10



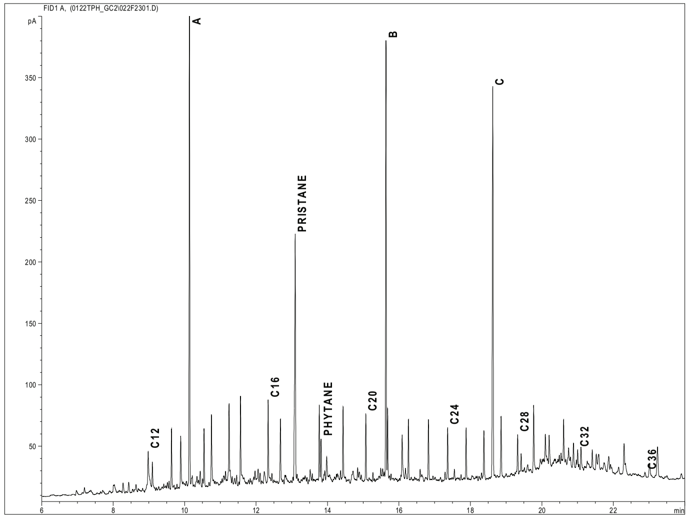
Station 11



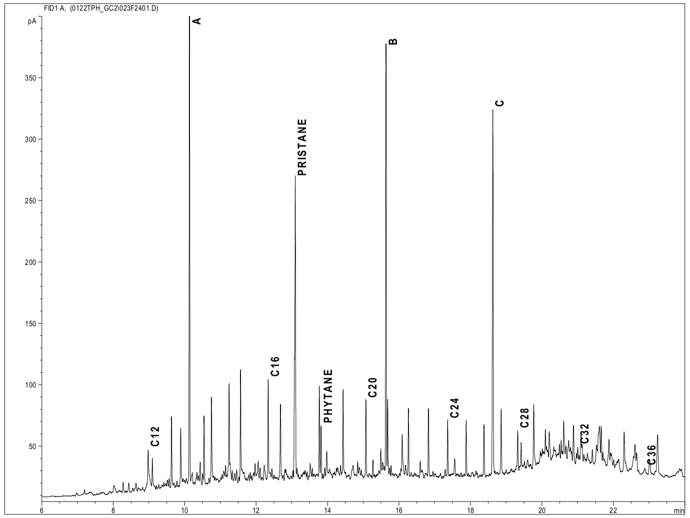
Station 12



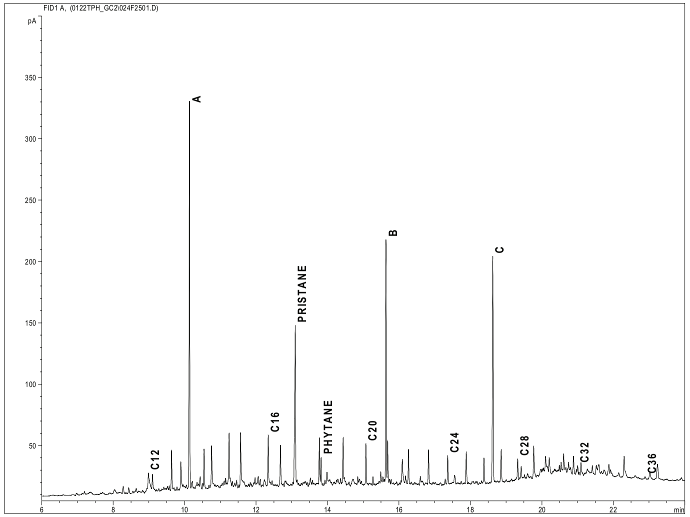
Station 13



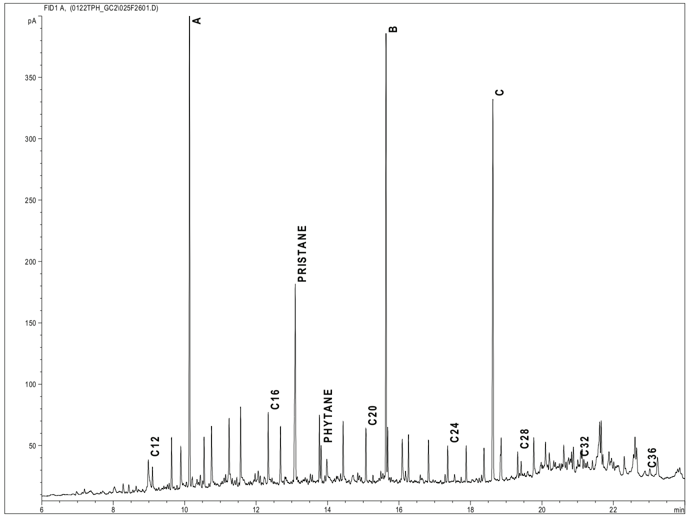
Station 14



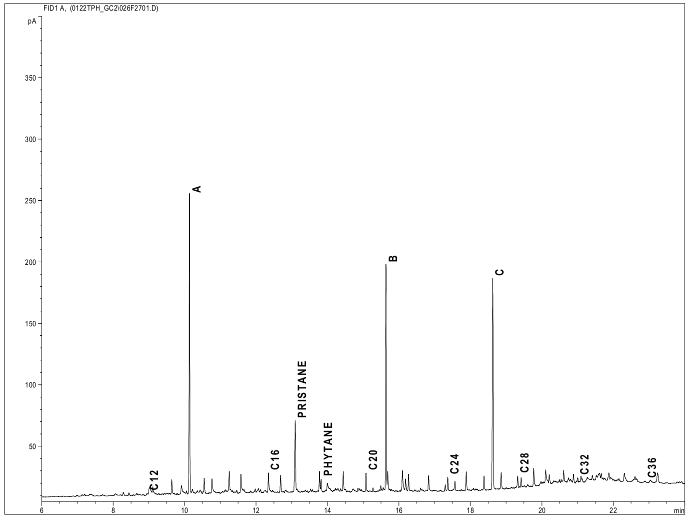
Station 15



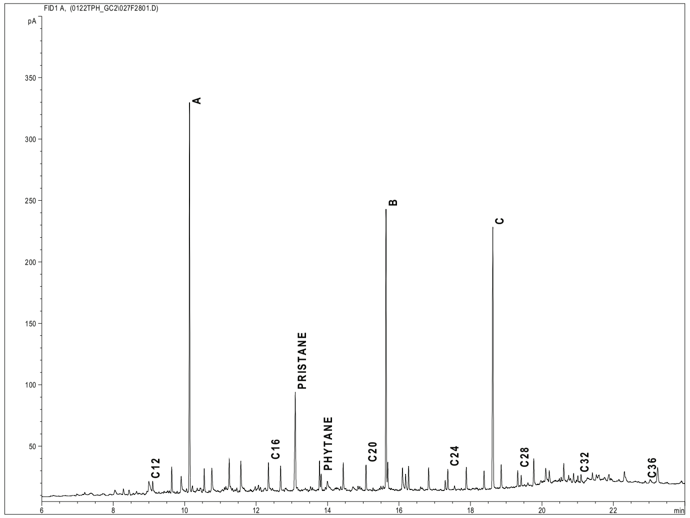
Station 16



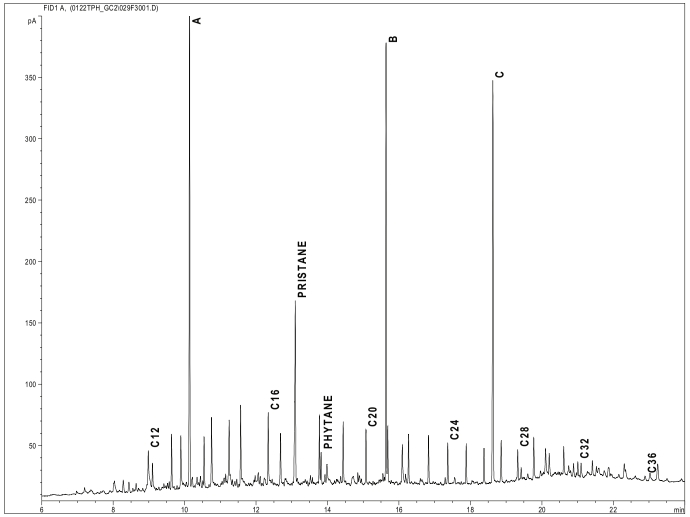
Station 17



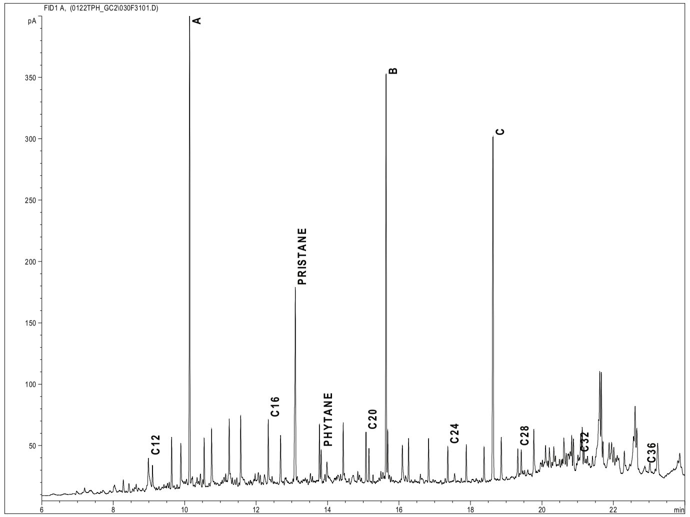
Station 18



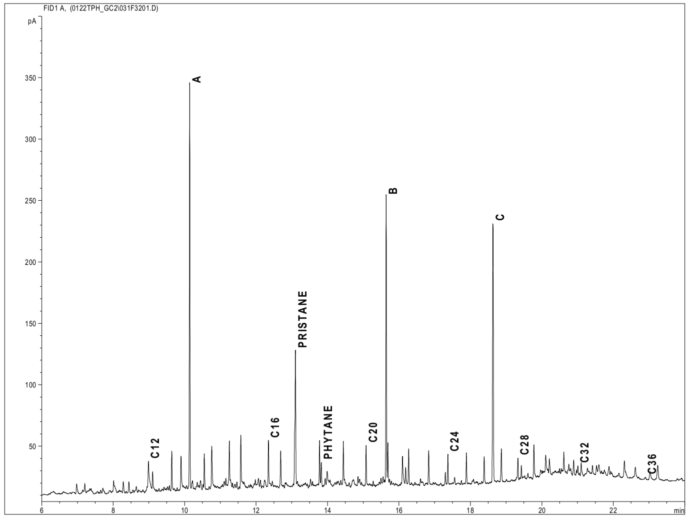
Station 19



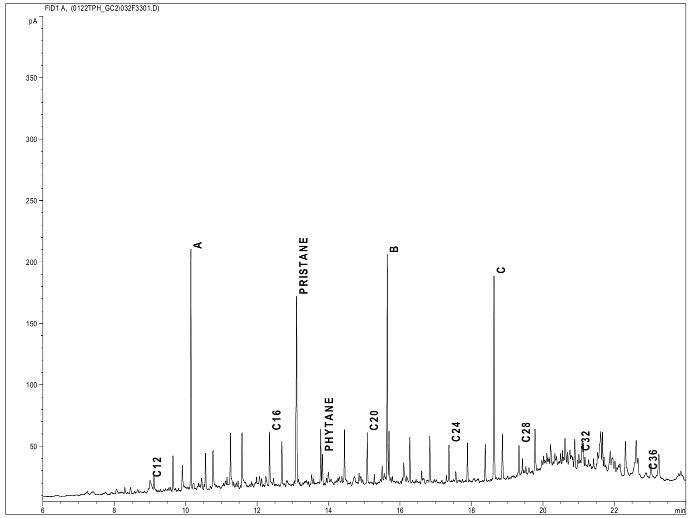
Station 20



Station 21

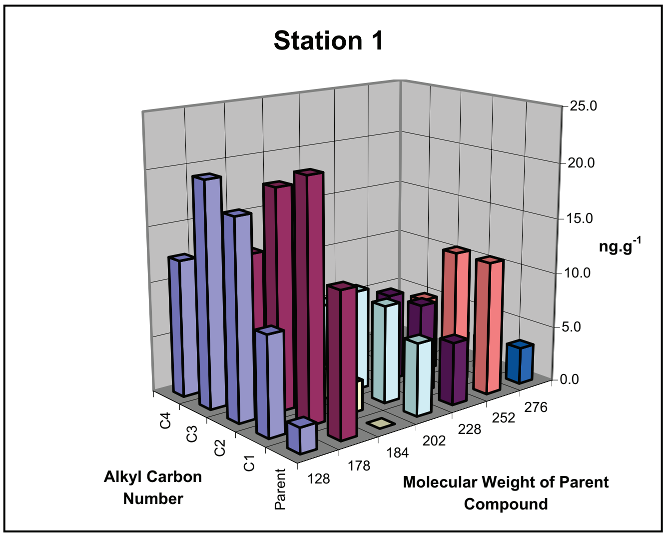


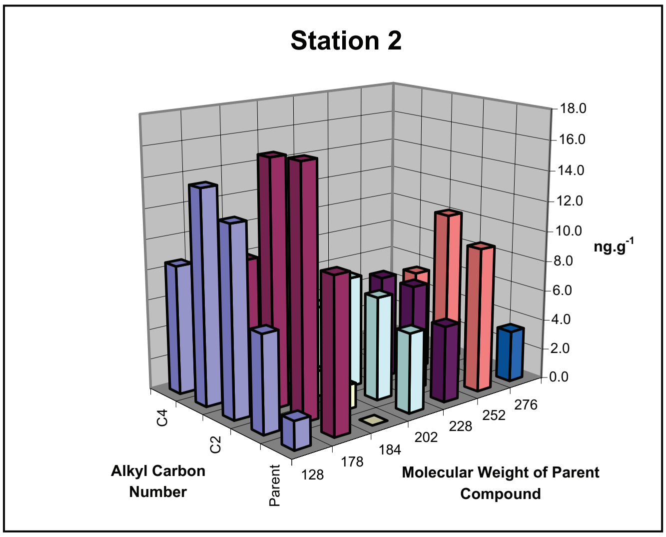
Station 22

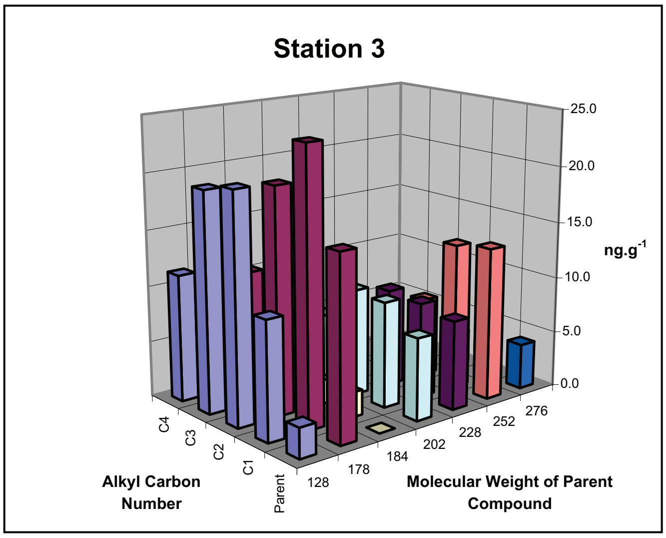


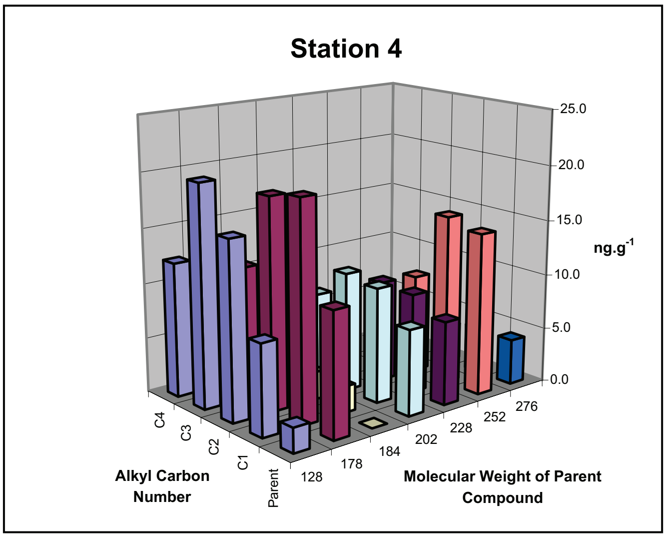
Station 23

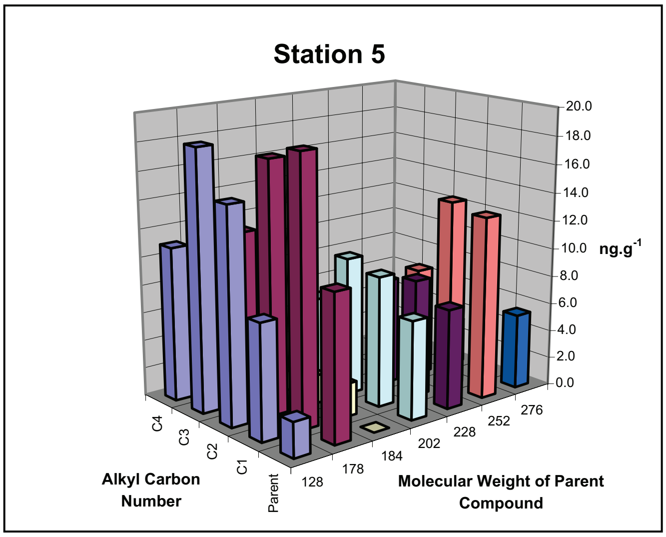
APPENDIX III: Polycyclic Aromatic Hydrocarbons

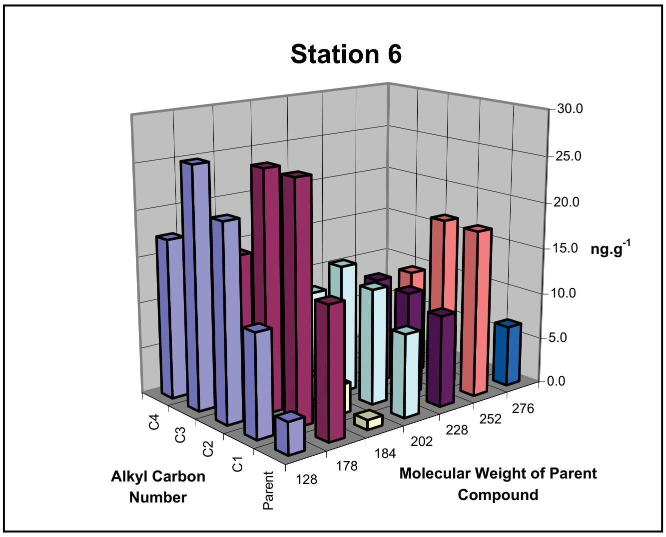

Station 1
25.0
20.0
15.0
10.0
5.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

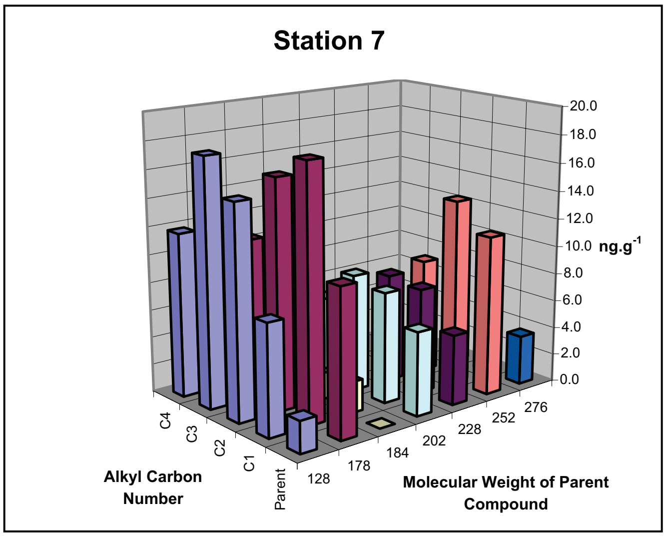

Station 2
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ng.g-1
C4
C2
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

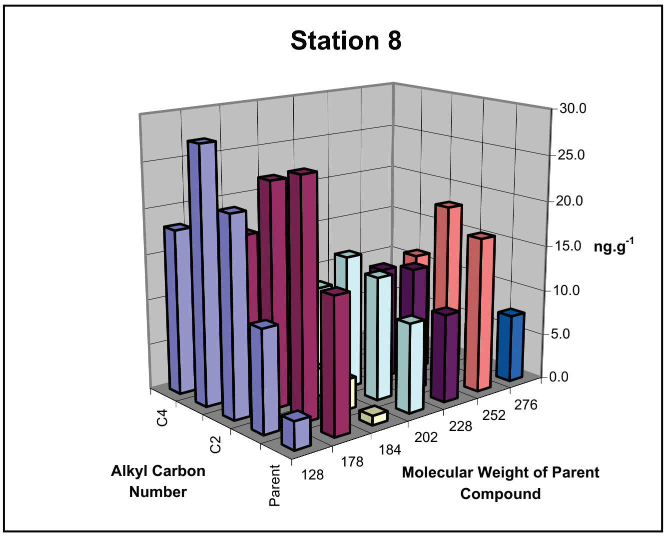

Station 3
25.0
20.0
15.0
10.0
5.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

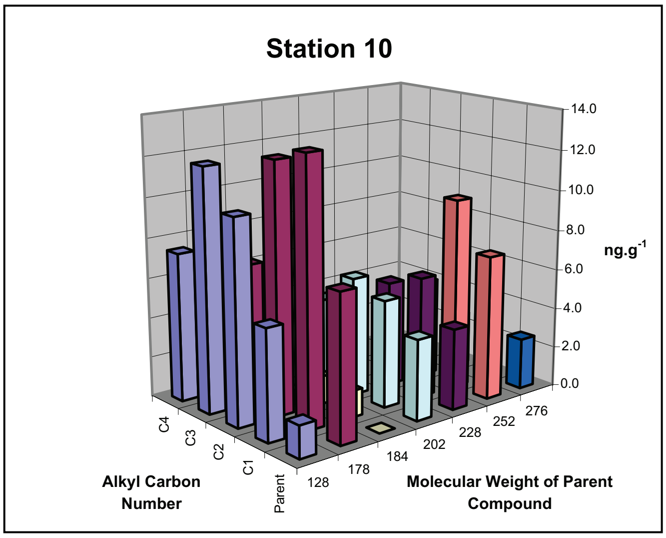

Station 4
25.0
20.0
15.0
10.0
5.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

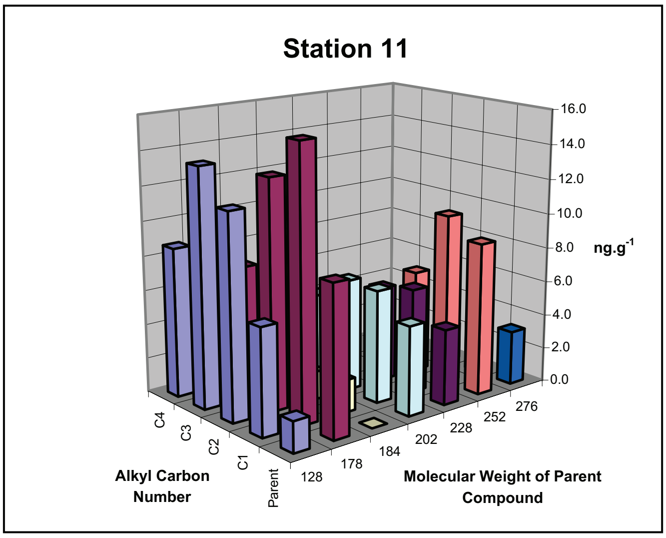

Station 5
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

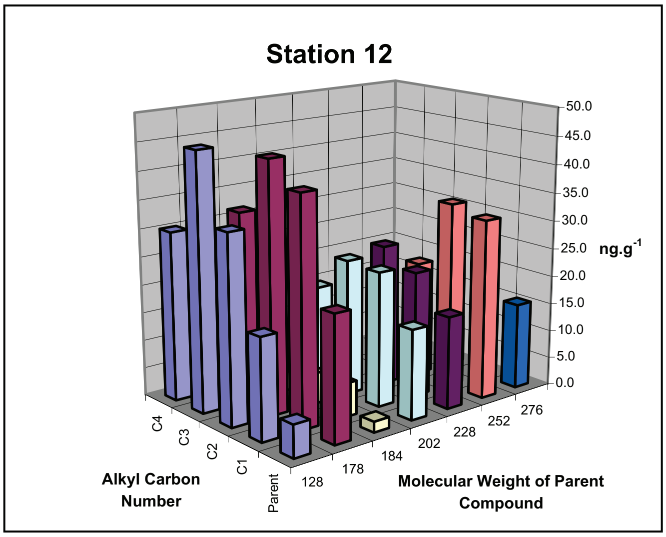

Station 6
30.0
25.0
20.0
15.0
10.0
5.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

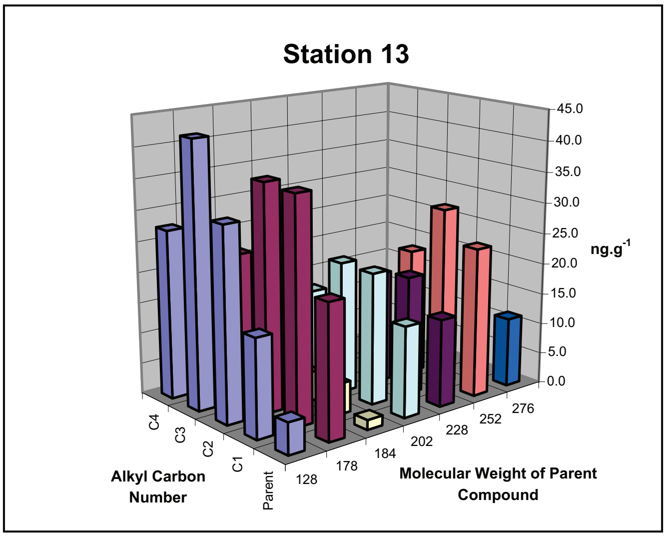




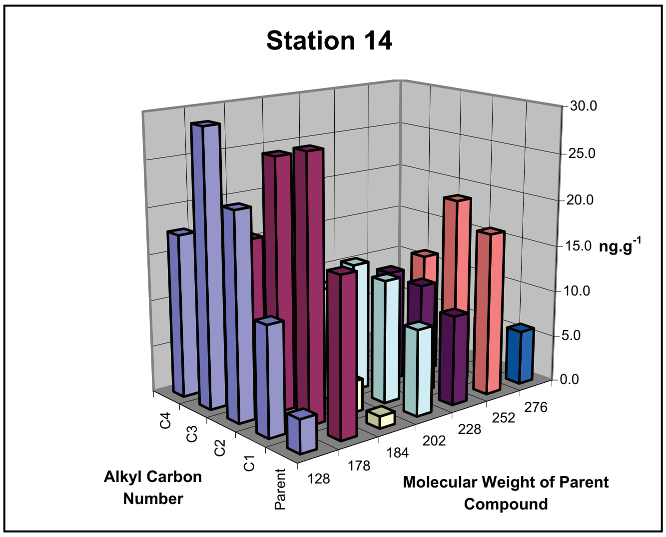


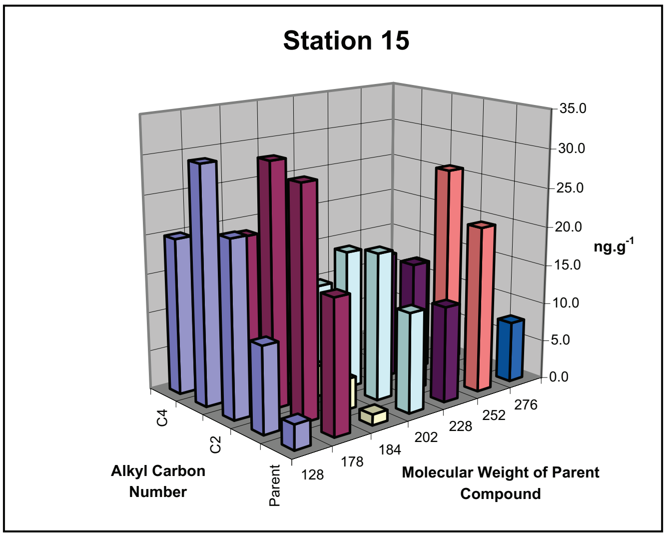


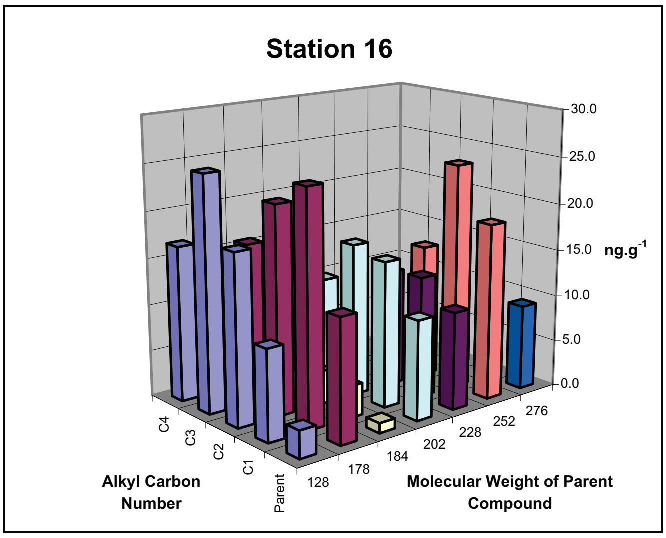


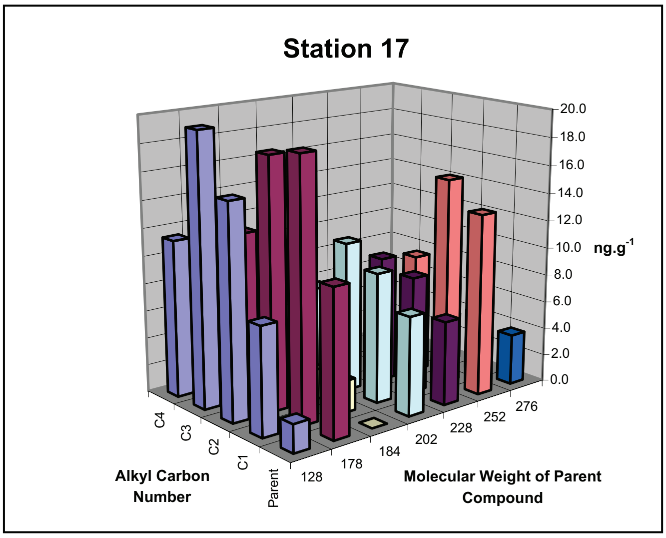


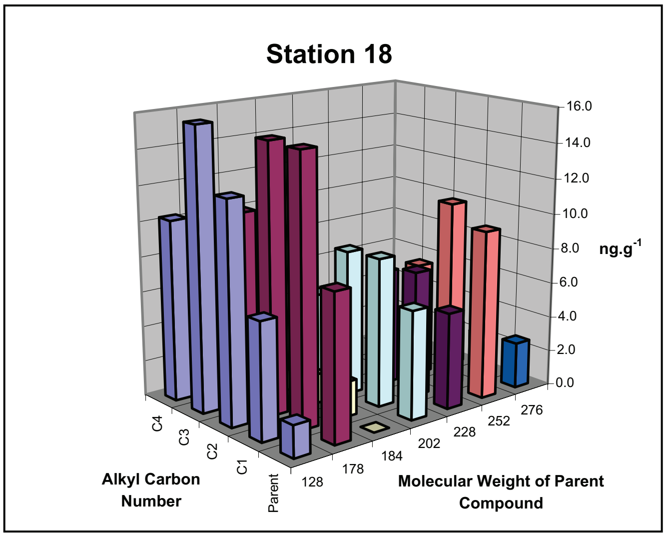
Appendix III

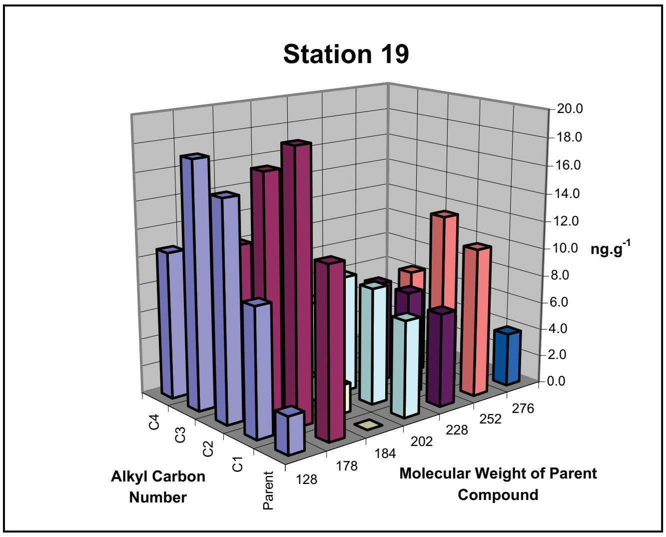

Station 14
30.0
25.0
20.0
15.0
10.0
5.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

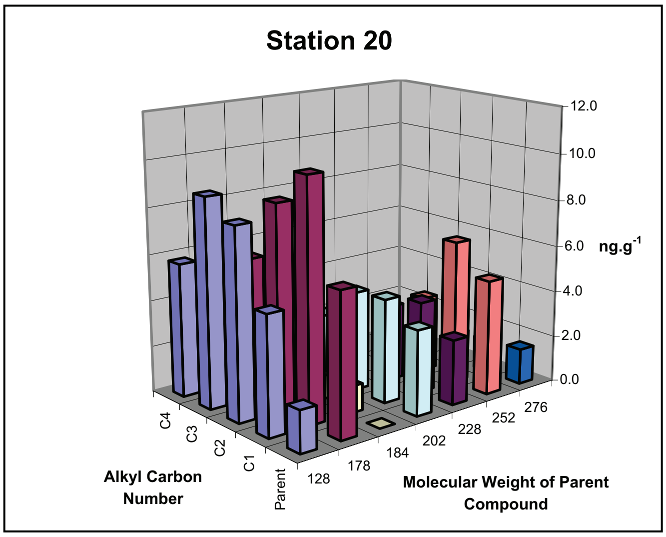

Station 15
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
ng.g-1
C4
C2
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


Station 16
30.0
25.0
20.0
15.0
10.0
5.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


Station 17
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


Station 18
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


Station 19
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound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8.0
6.0
4.0
2.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
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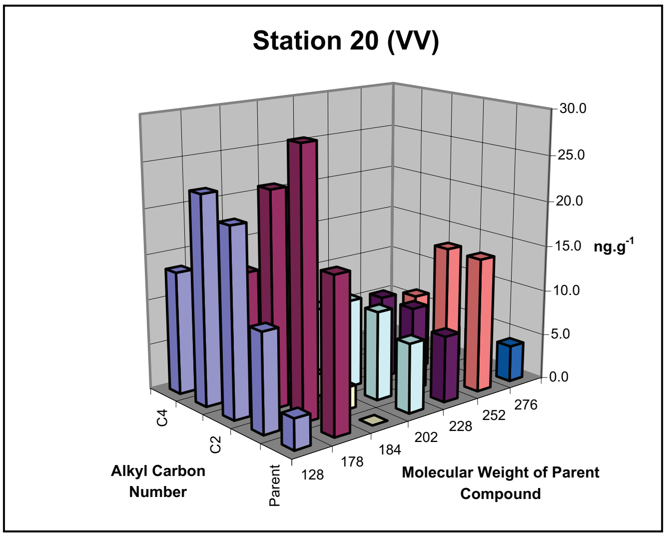
184
202
228
252
276
Molecular Weight of Parent Compound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0.0
ng.g-1
C4
C2
Parent
Alkyl Carbon Number
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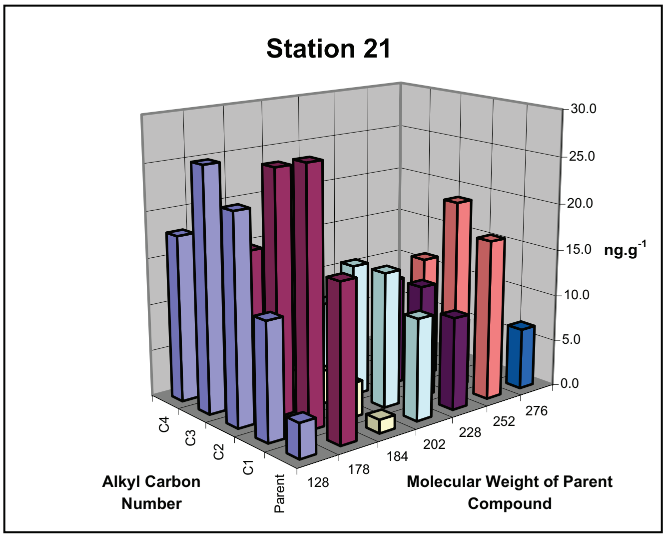
184
202
228
252
276
Molecular Weight of Parent Compound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5.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
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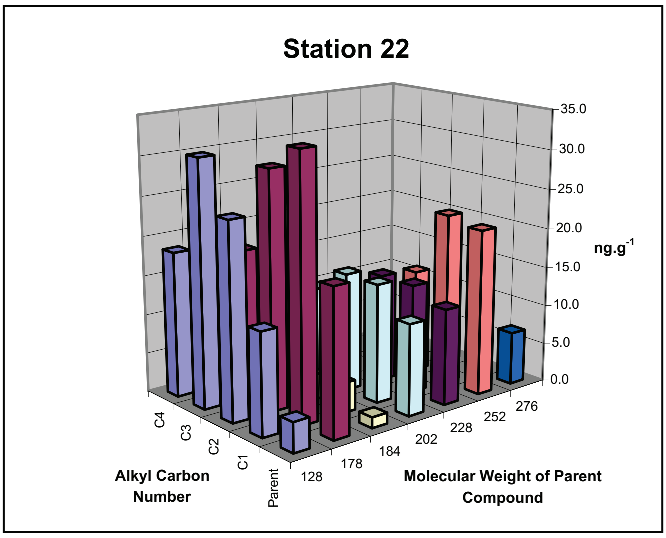
178
184
202
228
252
276
Molecular Weight of Parent Compound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C4
C3
C2
C1
Parent
Alkyl Carbon Number
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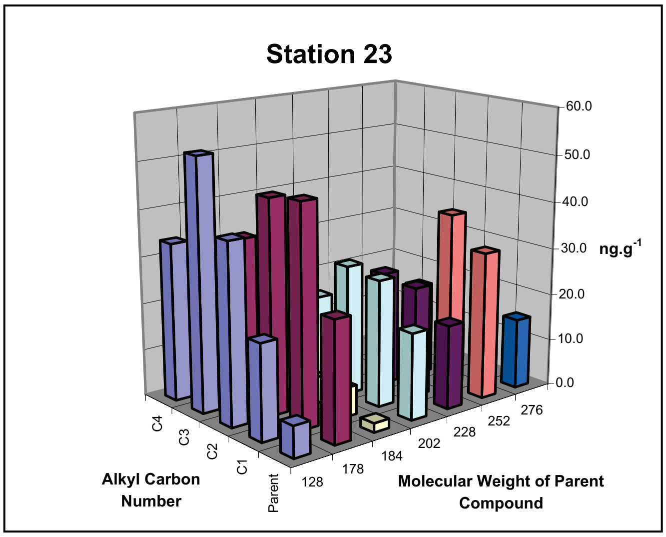
178
184
202
228
252
276
Molecular Weight of Parent Compound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20.0
10.0
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

APPENDIX IV: Sampling Log Sheets

Date	Number: Sample	Number: Station	*Water Depth (m bsl)	Fix #	Lat (S): dd	Lat (S): mm.mmm	Long (W): dd	Long (W): mm.mmm	Local Time (-3hrs GMT)	Penetration	Accept?	Fauna/GC container size	Photo: *in-situ*	Photo: sieve	RDL: mV (1cm/5cm/10cm)	RDL: °C (1cm/5cm/10cm)	Sediment Description: Sed. classification & colour	Sediment Description: Surface casts/tubes	Sediment Description: Stratification	Conspicuous Fauna/Comments	Additional comments regarding analyses	Comments and suggestions regarding faunal sample analysis
16.11.08	1BC	23	1964	24	53	34.936	58	56.596	11:45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Did not trip		
16.11.08	2BC	23	1964	26	53	35.027	58	56.455	14:28	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Did not trip		
16.11.08				27	53	35.002	58	56.424	14:28											Double drop/fix		
16.11.08	3BC	23	1870	28	53	35.134	58	56.531	16:09	54	FA, FB, CHEM	FA-1X0.25L; FB-1X0.25L	Y	N	361/368/nd	4.8/nd/nd	Light brown to olive grey. No sed description noted.	Tubes	Top 5cm lighter in colour	No obvious fauna		FA & FB both box core samples. Both good samples. **Site 23 - no priority order.**
16.11.08	4BC	L12	nd	nil					nd	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Did not trip		-
17.11.08	5GC	L12	2080	29	53	37.070	58	51.594	19:44	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No sample recovered.		-
17.11.08	6GC	L12	1880	31	53	37.183	58	51.708	20:50	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No pullout on loadcell. No sample recovered.		-
17.11.08	7GC	L12	1880	32	53	37.169	58	51.692	20:53	2.6m	1.9m recovery.	1 x sleeve (1.9mcore), 1 x bag (plug)	?	N/A	N/A	N/A	Grey/light brown core throughout. Possibly clay. Slight H2S smell at base.	N/A	Y - BUT likely double strike - 1) 0.6m & 2) 1.3m	Core deployed twice to seabed to obtain pullout.		-
17.11.08	8GC	L13	1946	33	53	35.645	58	45.253	22:26	1.5m	43cm recovery	1 x sleeve (core) only	?	N/A	N/A	N/A	Grey/light brown core throughout. Possibly clay.	N/A	N/A	None		-
18.11.08	9GC	L4	1436	34	53	42.223	58	24.716	01:04	0cm	N/A	N/A	?	N	N/A	N/A	N/A	N/A	N/A	No sample. Sleeve empty.		-
18.11.08	10GC	L4	1420	35	53	42.170	58	24.913	02:09	0cm	N/A	1 x bag (shell fragment) kept.	?	N/A	N/A	N/A	Single small shell fragment in core sleeve.	N/A	N/A	Core deployed to seabed twice. No sample recovered. Likely hard substrate, possibly clay.		-
18.11.08				36	53	42.175	58	24.921	02:10											Fix for 2nd seabed hit		-
18.11.08	11GC	L5	1540	37	53	40.850	58	19.248	08:23	43cm	38cm	1 x sleeve (38cmcore), 1 x bag (plug)	?	N/A	N/A	N/A	38cm fine muddy sand grading to courser sand with depth. Sand overlying stiff/weathered, dry blue/green clay (5cm plug in bottom of core).	N/A	38cm fine muddy sand grading to courser sand with depth. Sand overlying stiff/weathered, dry blue/green clay (5cm plug in bottom of core).	Core deployed to seabed twice.		-
18.11.08				38	53	40.849	58	19.225	08:23											Fix for 2nd seabed hit		-
18.11.08	12BC	L5	1540	39	53	40.864	58	19.251	09:55	40cm	FA, FB, CHEM	FA-1X1L; FB-1X1L	Y	FB only	259/244/192	8.4/5.9/5.3	Fairly cohesive fine-medium sandy mud. Some gravel also present.	Small tubes	N			FA & FB both box core samples. Both good samples. **Site 5 - no priority order.**
18.11.08	13BC	18	1745	40	53	42.917	58	15.403	11:57	<10cm	N	X	?	N	NR	NR	Compact muddy fine sand.	N	None observed.	Core deployed to seabed twice as no pullout observed. Core badly disturbed and small. Rejected.		-
18.11.08				41	53	42.920	58	15.398	11:57											Fix for 2nd seabed hit		-
18.11.08	14BC	18	1745	42	53	42.929	58	15.351	13:16	12cm	FA, FB, CHEM	FA-1X0.25L; FB-1X0.25L	Y	Y	182/172/155	6.1/5.5/6	Compact muddy fine sand.	Small poly tubes	N			FA and FB both box core samples. **18FA=good sample.** FB = entire box sample minus FA and chem. Note: **18FB = not quantitative.** Retained as qualitative sample only.
18.11.08	15GC	S10	1980	43	53	39.025	57	49.979	22:14	20cm	Y	1 x sleeve (20cmcore), 1 x bag (plug)	?	N	NR	NR	Grey sands over very stiff clays.	N	Y - surface sands over clay.	Some palynological material/debris present.		-
18.11.08	16BC	S10	1980	44	53	38.978	57	50.017	23:21	8cm	CHEM	-	Y	N/A	NR	NR	Muddy fine sand with some small, stiff clay fragments. Some gravel also present.	N	N			-
19.11.08	17VV	S10	1983	45	53	38.950	57	49.970	02:13	5cm 1 side only. 2nd side empty.	FA (slight wash out)	FA-2X2.5L & 2X1L	Y	Y	200/-/-	7.6/-/-	Mixed substrate. Small boulder in middle of bucket with ~5cm of muddy sediment comprising fine-medium sand with small amount of coarse sand, gravel and pebbles. Shell debris also present.	N	N	Sponges (cf Scypha), gorgonians, ophiuroids, erect bryozoans, encrusting bryozoans, soft corals.		FA (van veen sample) = slight wash out and small in size due to nature of sed. and weather conditions. **Site 10 priority order = FA. No FB or FC obtained.**
19.11.08	18VV	S11	2008	46	53	39.833	57	39.656	04:13	8cm	FA, CHEM	FA-1X1L	Y	N	174/185/-	7.4/6.2/-	Muddy mixed grade sand. Porrly sorted. Some gravel present also.	N	N	Lot of heave on vessel and wire snatching undoubtly affecting grab performance and sample quality.		FA (van veen sample) = good sample.
19.11.08	19VV	S11	2021	47	53	39.823	57	39.674	05:30	8cm	FB, FC	FB-1X1L; FC-1X1L	Y	Y	192/154/-	7.4/5.7/-	Muddy mixed grade sand. Poorly sorted. Some gravel present also.	N	N			FB & FC (van veen samples) = good samples. **Site 11 priority order=FA, FB, FC.**

19.11.08	20BC	S20	1955	48	53	41.810	57	34.570	07:23	20cm	FB, CHEM	FB-1X1L	Y	Y	212/221/217	6.4/5.5/5.3	Light brown compact medium sand with coarse sand and gravel.	N	N	Spade/box seal broken by presence of gravel. Slight wash out on side of core where FB was taken from. Chem area OK.		FB (box core sample) = slightly washed out.
19.11.08	21VV	S20	1955	49	53	41.815	57	34.588	09:13	8cm	FA, CHEM	FA-1X1L	Y	?	234/208/-	7.9/6.5/-	Light brown compact medium sand with coarse sand and gravel.	N	N			FA (van veen sample). Good sample, no wash out. **Site 20 priority order=FA, FB.**
19.11.08	22VV	S19	1927	50	53	42.004	57	48.217	11:03	10cm	FA, CHEM	FA-2X1L	Y	?	168/115/136	5.8/5.4/6.7	Thin layer of gravel and coarse sand over cohesive muddy fine sand.	N	Y	Sponges		FA (van veen sample) = good sample.
19.11.08	23VV	S19	1927	51	53	42.023	57	48.158	12:04	10cm 1 side only. 2nd side empty	FB	FB-1X1L	Y	?	NR	NR	Thin layer of gravel and coarse sand over cohesive muddy fine sand.	N	Y	1 side empty/clean		FB (van veen sample)=good sample. No FC obtained. **Site 19 no priority order.**
19.11.08	24BC	S8	1910	52	53	42.158	57	56.250	13:47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No sample. Corer leg fouled in jaws. Assume large heave prior to hitting seabed causing spade and leg to foul. Shackle weight missing, presumed lost.		-
19.11.08	25BC	S8	1910	53	53	42.176	57	56.278	15:15	20cm	FA, CHEM (partial washout for both)	FA-1X1L	Y	Y	297/219/-	5.7/-/-	Grey medium sand over olive green medium sand. Surface gravels. Slightly silty.	N	Colour only			FA=box core sample. Partial washout.
19.11.08	26VV	S8	1910	54	53	42.166	57	56.248	16:33	9&10cm	FB, FC	FB-1X1L; FC-1X1L	Y	Y	NR	NR	Grey medium sand over olive green medium sand. Surface gravels. Slightly silty.	N	Colour only	FB-sponges		FB & FC = van veen samples. Both good samples. **Site 8 priority order = FB, FC, FA.**
19.11.08	27BC	L7	1540	55	53	42.463	58	3.898	18:07	0cm	N	N/A	Y	N/A	N/A	N/A	Few grains of sand and some shell.	N	N	Hard bottom		-
19.11.08	28VV	L7	1534	56	53	42.458	58	3.952	19:45	11cm	FA	FA-1X1L	Y	Y	275/322/-	5.6/-/-	Black gravel on top of olive green medium sand.	N	Surface gravel.			FA (van veen sample) = good sample. **Site 7 priority order =FA. No FB or FC obtained.**
19.11.08	29VV	L7	1526	57	53	42.437	58	3.943	20:49	0cm	N	N/A	Y	BAG	N/A	N/A	Clay chippings or mud stone	N	No sed.	Outcrop/hard seabed. Clay scrape on outside of grab.		-
19.11.08	30BC	R9	2020	58	53	37.559	58	5.957	22:27	2cm	N	N/A	N/A	Y-BAG	N/A	N/A	Clay chippings or mud stone	N	No sed.	Clay scrape on corer. Box with 2cm pen. only. Clay outcropping/hard bottom present.		**No fauna samples obtained for site 9.**
20.11.08	31VV	R21	1694	59	53	38.504	58	15.668	00:20	15cm	FA, CHEM	FA-1X1L	Y	Y	225/213/198	6.8/6.0/6.3	Light brown, soft, fine sandy mud. Some coarse sand and gravel present. Poorly sorted.	Tubes	N			**Site 21 no priority order.** FA, FB, FC (all van veen). All good samples.
20.11.08	32VV	R21	1687	60	53	38.486	58	15.631	01:30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Did not trip		
20.11.08	33VV	R21	1689	61	53	38.506	58	15.582	02:24	15cm	FB, FC	FB-1X1L; FC-1X1L	Y	Y	NR	NR	Soft mud with some coarse sand and gravel.	Tubes	N			
20.11.08	34VV	6	1428	62	53	41.266	58	12.949	03:39	10cm	FA, CHEM	FA-1X1L	Y	Y	262/229/177	6.0/5.7/6.5	Soft mud with some coarse sand and gravel. Sand quite compact.	N	N	Rich in small polychaetes. BC not deployed here. Sediment too compact.		**Site 6 priority order FA, FB, FC.** All van veen. All good samples.
20.11.08	35VV	6	1430	63	53	41.204	58	12.816	04:35	12cm	FB, FC	FB-1X1L; FC-1X1L	Y	Y	NR	NR	Soft mud with some coarse sand and gravel. Sand quite compact.	N	N	Rich in small polychaetes.		
20.11.08	36GC	6	1423	64	53	41.228	58	12.901	06:37	10cm	5cm recovered	1xsleeve (core), 1xbag (plug)	Y-photo of core	N/A	NR	NR	Muddy fine sand (~5cm) overlying hard blue/green clay. Clay layer recovered very thin (<1cm).	N	Y			
20.11.08	37VV	4	1450	65	53	42.169	58	24.646	08:45	7cm	FC, CHEM	FC-1X1L	Y	Y	222/182/-	7.4/7.5/-	Light brown mudy fine sand. Compact.	N	N	No BC attempted as previous GC attempts showed shallow clay layer.		**Site 4 priority order FA, FC, FD, FB.** All van veen. FB small.
20.11.08	38VV	4	1450	66	53	42.163	58	24.755	09:41	5cm - 1 side only. Side 2 = water + few grains of clean gravel.	FB	FB-1X0.25L	Y- BUT photo incorrectly labelled 09:41 4FC. Should read 09:41 4FB.	Y	NR	NR	Light brown mudy fine sand. Compact.	N	N	Large amphipods notable		
20.11.08	39VV	4	1452	67	53	42.124	58	24.698	10:24	8cm	FA, FD	FA-1X0.25L; FD-1X0.25L	Y	Y	NR	NR	Light brown mudy fine sand. Compact.	N	N	Rich in small polychaetes.		
20.11.08	40VV	3	1214	68	53	41.223	58	31.826	12:06	9cm	FA, CHEM	FA-2X1L	Y	Y	274/199/-	7.5/7.7/-	No description	N	N			**Site 3 priority order FA, FB, FC.** All van veen, all good samples.
20.11.08	41VV	3	1220	69	53	41.216	58	31.816	13:11	8 & 7cm	FB(8), FC(7)	FB-1X1L; FC-1X1L	Y	Y	NR	NR	Light brown slightly muddy sand and angular gravels.	Epifauna	N	Faunally rich. Sponges, branched calcareous spp, Cirolis and other crustaceans.		

20.11.08	42VV	L17	1161	70	53	42.728	58	30.895	14:04	6 & <2cm	CHEM(6), side 2 = no sample	Rock sample 2x2.5L stacked & 1X0.25L	Y (+photos of epifauna)	N/A	231/204/-	7.6/-/-	Slightly muddy sand and fine mixed gravel. Some cobbles.	N	N	Epifauna on stones. Branched calcareous spp and sponges.		Retained samples not for quantitative analysis. **Kept for species interest only.**
20.11.08	43VV	L17	1210	71	53	42.686	58	30.951	14:55	0cm	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A			**No quantitative FA, FB or FC obtained from L17.**
20.11.08	44VV	False Target	1200	72	53	43.470	58	31.705	16:10	7&4cm	'BIO'(7); PSA/SPARE (4)	BIO-1X0.25L	Y	BIO - Y	NR	NR	Homogeneous fine sand, minor coarse sand.	N	N	Investigation of steep shoal to the south of L17. False position on chart.		'BIO' sample not for quantitative macro analysis. **Retained for species interest only.**
20.11.08	45VV	R16	1108	73	53	42.856	58	42.749	17:37	7&6cm	FA(7), CHEM(6)	FA-1X0.25L	Y	Y	217/188/-	6.7/-/-	Homogeous fine to medium sand. Minor coarse sand.	N	N	Crushed spatangoid.		
20.11.08	46VV	R16	1105	74	53	42.883	58	42.704	18:20	14&13cm	FB(14), FC(13)	FB-1X1L; FC-1X1L	Y	Y	X	X	Medium sand and silts.	N	5cm sand over silt			**Site 16 use FB, FC, FA as priority order** (IW).
20.11.08	47BC	R2	1259	75	53	40.371	58	39.794	19:36	5cm	N	N/A	Y	N	NR	NR	Sandy silt and coarse gravel.	N	?Possibly	Crinoid.		
				76	53	40.369	58	39.763												Fix for 2nd seabed hit		
20.11.08	48VV	R2	1246	77	53	40.352	58	39.736	20:35	8&7cm	FA(8), CHEM(7)	FA-1X2.5L	Y	Y	197/176/-	6.9/-/-	Coarse carbonate sands and shell (many urchin spines). Non-silcate sands.	N	Top 1cm = shell.			FA (van veen sample). Good sample.
20.11.08	49VV	R2	1248	78	53	40.368	58	39.767	22:42	4&3cm	N - too small and washed out	N/A	Y	N/A	N/A	N/A	Coarse carbonate sands and shell (many urchin spines). Non-silcate sands.	N	N	Sample too small, washed out. Not retained.		
21.11.08	50VV	R2	1244	79	53	40.331	58	39.751	23:35	9cm	FB, FC	FB-2X2.5L; FC-2X2.5L	Y	Y	NR	NR	Coarse carbonate sands and shell (many urchin spines). Non-silcate sands.	N	N			FB and FC (both van veen). Both good samples. **Site 2 priority order FA, FB, FC.**
21.11.08	51VV	15	1196	80	53	42.958	58	56.350	01:37	0cm	N-water only	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Water column trigger due to swell. Grab empty, water only.		
21.11.08	52VV	15	1175	81	53	43.025	58	56.545	02:20	0&12cm	FC(12); side 2 water only.	FC-1X0.25L	Y	Y	237/207/180	7.6/6.1/7.1	Soft fine sandy mud.	Tubes	N	2nd side empty/water only.		FC (van veen sample). Good sample.
21.11.08	53VV	15	1180	82	53	42.977	58	56.521	03:35	0cm	N-water only	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Water column trigger due to swell. Grab empty, water only.		
21.11.08	54VV	15	1180	83	53	43.064	58	56.512	04:57	0cm	N-water only	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Water column trigger due to swell. Grab empty, water only. Half winch speed used on deployment - this helped eliminate cable snatch but grab still recovered empty. Still too rough for BC.		
21.11.08	55VV	15	1180	85	53	43.019	58	56.405	06:22	10&5cm	FA(10), CHEM(5)	FA-1X0.25L	Y	Y	252/220/212	6.8/6.6/6.8	Soft fine sandy mud. Cohesive.	Tubes	N			FA (van veen sample)-good sample. **Site 15 priority order FC, FA. No FB obtained.**
21.11.08	56VV	1	1389	86	53	40.214	58	52.715	07:38	8&4cm	FA(8), CHEM(4)	FA-1X2.5L	Y	Y	228/219/173	6.4/5.8/7.5	Muddy medium sand with some coarse sand, gravel and pebbles. Compact.	N	N	Encrusting bryozoans, Porifera, corals.		FA (van veen sample). Good sample.
21.11.08	57VV	1	1414	87	53	40.232	58	52.765	08:31	5&3cm	FB(5), FC(3)	FB-1X2.5L; FC-2X2.5L	Y	Y	NR	NR	Mixed sediment comprising mud, fine, medium and coarse sands, gravels, pebbles and small cobbles.	N	N	Large corals, encrusting bryozoans.		FB (van veen sample). Good sample. FC retained as qualitative only (3cm). **Site 1 priority order FA, FB.**
21.11.08	58BC	12	1851	88	53	37.149	58	51.658	10:17	0cm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Did not trip		
21.11.08	59VV	12	1850	90	53	37.210	58	51.587	11:38	0cm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Did not trip. Brought onboard, trigger reset.		
21.11.08	60BC	12	1850	91	53	37.078	58	51.647	13:18	0cm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Did not trip. Bent trigger plate. Adjusted.		
	60BC	12	1850	92	53	37.091	58	51.626	13:18											Fix for 2nd seabed hit		
21.11.08	61BC	12	1840	93	53	37.226	58	51.623	15:05	45cm	FA, FB, CHEM, CORE (35cm)	FA-1X0.25L; FB-1X0.25L	Y	Y	226/151/-	5.0/-/-	Sand and silt. Soft and homogeneous.	N	RDL @ 5cm			FA and FB (both box core samples). Both good samples. **Site 12 priority order FA, FB.**
21.11.08	62BC	L13	2050	94	53	35.674	58	45.133	17:09	45cm	FA, FB, CHEM, CORE (36cm)	FA-1X0.25L; FB-1X0.25L	Y	Y	234/179/-	4.9/-/-	Homogeneous slightly sandy silts.	N	RDL @ 5cm	Few tubes, polychaetes.		FA and FB (both box core samples). Both good samples. **Site 13 priority order FA, FB.**
21.11.08	63BC	R14	1800	95	53	35.201	58	37.375	19:08	39cm	FA, FB, CHEM, CORE(30cm)	FA-1X1L; FB-1X1L	Y	Y	251/182/-	5.1/-/-	Silty sand with surface coarse sand and fine gravels.	N	Top 1cm = gravels.	Few polychaetes, crustacea and gastropoda.		FA and FB (both box core samples). Both good samples. **Site 14 priority order FA, FB.**
21.11.08	64BC	S22	2010	96	53	34.432	58	33.366	21:10	42cm	FA, FB, CHEM, CORE(34cm)	FA-2X1L; FB-2X1L	Y	Y	257/215/-	4.9/-/-	Silty sand with surface coarse sands and gravels.	N	Top 2cm = gravels			FA and FB (both box core samples). Both good samples. **Site 22 priority order FA, FB.**

APPENDIX V: Macrofaunal Species Lists

Macrofaunal Matrix

Comment	Species	1A	1B	R2A	R2B	R2C	L3A	L3B	L3C	4 C	4A	4 D	L5A	L5B	6A	6B	6C	L7A	S8 A	S8 B	S8 C	S10A	S11A	S11B	S11C
	Sample Replicates																								
	CNIDARIA																								
Ceriantharia	*Ceriantharia sp*			1												1									
Octocorallia	*Pennatulidae sp*															1									
Octocorallia	*Melitodes sp*												1												
Scyphozoa	Scyphozoa polyp																		2						
Anthozoa	Aff Gonactinia sp			1																					
Anthozoa	Actinaria sp						1																		
Anthozoa	Edwardsiidae sp.		1		1																			1	1
Anthozoa	Solitary Coral I																								
Anthozoa	Solitary Coral II (toothed rim)																					1			
	NEMERTEA																								
	Nemertea spp.	2	2	4	4	4	3	2	2	1			2	1		4	5				1	2		2	4
	NEMATODA																								
	Nematoda spp.	77	4	11	34	15	10		4	2	1	1	2	1		7	2	2			2				2
	SIPUNCULA																								
Sipunculidea	*Golfingia sp.*	2	4		2	2										1					1			3	
	TURBELLARIA																								
Turbellaria	Turbelleraria sp indet.	1																							
	ANNELIDA																								
Polychaeta	Euphrosine sp																								
Polychaeta	Dorvilleidae sp			1		1	2	2		1	2	1								1	1			1	1
Polychaeta	Polynoidae spp						1	1			1														
Polychaeta	cf Eunoe sp																						1		
Polychaeta	cf Leanira sp			1		1		1																	
Polychaeta	aff Pholoe	2					2																		
Polychaeta	*aff. Pisione sp*		1		1	1							1				1								1
Polychaeta	*Eteone spp*				1			1				1											1	2	
Polychaeta	*Mystides sp.*				1		2	2	1			1													
Polychaeta	*Glycera capitata*	2	1					1	2						1	1	2	1		1			2	2	1
Polychaeta	Syllidae sp.	1		2			2		2			1				1								1	1
Polychaeta	Pilargiidae sp	1																							
Polychaeta	Ceratocephale sp.			3	3	2					1													1	1
Polychaeta	Nereis sp		1																						
Polychaeta	*Aglaophamus sp.*			1						1		1		3		1									
Polychaeta	*Rhamphobranchium ehlersi*	10	12	14	3	12	1	5	9	2	1	2	1	1	7	6	4	5	3	12	10	1	5	5	9
Polychaeta	*Nothria conchylega*							1	1						1								1		1
Polychaeta	*Aff Scoloplos sp*							1			1		4			2			2	1	2	1		3	1
Polychaeta	*Aricidea sp.A*	1		1				1			1	1			1									1	
Polychaeta	*Aricidea c.f. oculata*	3		5		8	1	3	3	4		1			3	2	1	1		1			2		
Polychaeta	*Aricidea simplex*							2	2																
Polychaeta	*Aricidea strelzoni*																								
Polychaeta	*Paraonoidae spp.*					2														1					
Polychaeta	*Levinsenia gracilis*	2		1									1			1		1							1
Polychaeta	*Apistobranchus cf fragmentata*																								
Polychaeta	Spionidae sp.	1																			2				
Polychaeta	Minuspio sp						1	2								1						1			
Polychaeta	*Scolelepis sp.*					1			1								1			1		1			
Polychaeta	*Spiophanes bombyx*																			2		1			
Polychaeta	*Spiophanes c.f. soederstroemi*						1				1														
Polychaeta	*Laonice spp*											2								1					
Polychaeta	*Diplocirrus hirsutus*				1						1								1	1					
Polychaeta	*Flabelligera sp.*																2								
Polychaeta	*Pherusa sp*																								
Polychaeta	*Cossura sp.*						2		1				1			2	4								
Polychaeta	Maldanidae spp.						1			1	3	1	2		3	2	3		1	1	1		2	2	2
Polychaeta	*Eupraxilella antarctica*										1														
Polychaeta	*Maldane sarsi subsp*								1												1				1
Polychaeta	*Praxillella bransfieldensis*									1															
Polychaeta	*Praxilella c.f. antarctica*										1														
Polychaeta	*Rhodine cf loveni*							1		2		2			1										
Polychaeta	*Spiochaetopterus sp.*		1		2																				
Polychaeta	*Cirratulus sp*		1				1																		
Polychaeta	*Cirriformia sp.*	2			1																				
Polychaeta	*Caulleriella spp*	3	2	1	1	2		2	1	4	1				4	1	3	4	1						
Polychaeta	*Chaetozone setosa.*						2		1	1		1		1			1	1							1
Polychaeta	Tharyx fusiformis											1								2					
Polychaeta	Tharyx sp											1				1								1	
Polychaeta	Macrochaeta sp.																								
Polychaeta	*Notomastus aff latericeus*					1					1	1							1		1		1	1	
Polychaeta	*Travisia sp.*							1																	
Polychaeta	*Ophelina aff cylindricaudata*									1															
Polychaeta	*Ophelina nematoides*											1													
Polychaeta	*Ophelina breviata*															1									
Polychaeta	*Ophelia sp*													1							2				
Polychaeta	*Scalibregma inflatum*							2			1						1								
Polychaeta	*Scalibregma sp. II?*																								
Polychaeta	*Sternaspis sp*								1																
Polychaeta	*Ampharetinae spp*	1		2	1	3	1	4	5														1	1	1
Polychaeta	*Samytha sp*														2										
Polychaeta	*Amage sp.*	1	1			1	1												1	1				1	1
Polychaeta	*Melinna c.f.cristata*							1	2						2										
Polychaeta	*Streblosoma sp*					2									1	3	4								
Polychaeta	*Pista sp.*								1																
Polychaeta	*Terebellides stroemi*		2						1				1			3		1						1	
Polychaeta	Terebellidae fragment	1		1			2		1								1			1		1			
Polychaeta	Perkinsiniana antarc tica	1					4																		
Polychaeta	Sabella sp		1			1																	3		
Polychaeta	Sabellidae frag.	1					1		2																
Polychaeta	Fabricinidae sp.																				1				
Polychaeta	*Fabricola / Pseudofabricia sp*															1					1				
Polychaeta	*Jasmineira sp*		1					2												1			1	3	2
Polychaeta	*Chone sp*				3	2	2	5									1						1	1	3
Polychaeta	*Euchone pallida*	2	2	1			1	9													2		1		
Oligochaeta	Oligochaeta Tubificidae	1		4		4	2	2	2			2	3	2	2	1					3				1
Polychaeta	Serpulidae							1											1						
Polychaeta	*Phylo felix*			1							1										1				
Polychaeta	*Lumbrineris c.f.antarctica*			1												1	1			1			1	1	
Polychaeta	*Ninoe c.f. falklandica*																								
Polychaeta	*Galathowenia sp*		3		1			1		1	1		2			1			1		8	1			
Polychaeta	*Myriowenia cf. californicensis*																								
Polychaeta	*Polygordius sp.*						1					1	1	1			3								1
Polychaeta	*Sphaerodorum sp I*			1				1			1					2	1								1
Polychaeta	*Sphaerodorum sp II*											1													
Polychaeta	*c.f. Fauvelia?*																								
Pogonophora	*Siboglinum sp*				4	6																			
Pogonophora	*Pogonophora sp*			1		1																			

Macrofaunal Matrix

Comment	Species	1A	1B	R2A	R2B	R2C	L3A	L3B	L3C	4 C	4A	4 D	L5A	L5B	6A	6B	6C	L7A	S8 A	S8 B	S8 C	S10A	S11A	S11B	S11C
	Sample Replicates																								
	CRUSTACEA																								
Cephalocarida	Cephalocarida sp?																					1			
Cirripedia	Scalpellum sp.		1			1	2	2									1								
Cirripedia	Verruca sp				1			1																1	
Ostracoda	Ostracoda spp.	1	2	2	1	2	1	1	2	20	13	21	1	3	6	1	2	2	7	2	2		2	2	1
Copepoda	Copepoda indet	1	1			1		2	2	1						1	1								1
Amphipoda	*Phtisica ap*	1		3	2											1									
Amphipoda	*Amphipoda sp. A*							2																	1
Amphipoda	Stenothoidae sp I	2	1		2		1	3					1			1		1							1
Amphipoda	Stenothoidae sp II (wide rostrum)	4		1																					
Amphipoda	Stegocephalidae						1	1	3														1		
Amphipoda	aff Apherusa																								
Amphipoda	*Urothoe sp.*	1		1				5	3	5	8	3			1	2	3	1			3		2	1	1
Amphipoda	Podoceridae								3																
Amphipoda	Phoxocephaloidae sp. A																								
Amphipoda	Phoxocephaloidea sp. B																								
Amphipoda	Phoxocephaloidea sp.C (eyeless)		1	1				1	3	3	1	1	2	3	1				1					1	2
Amphipoda	Phoxocephalus sp eyeles, notched	3		1																			2	1	
Amphipoda	Metaphoxus											1									1				
Amphipoda	*Maera sp.*		1	12	9	1	3	6	5			1		1		2			1	1	1		1	3	
Amphipoda	*Leucothoidae*					1	2									2									1
Amphipoda	*Aff. Dexamine*			1																					
Amphipoda	*aff. Melitidae*					1			13																
Amphipoda	*Acanthozone sp*		1																						
Amphipoda	*Didymochelia spp*			1	2	1	1		2									1							
Amphipoda	Lysianassoidea sp. C	1																		1			1		
Amphipoda	Lysianassoidea sp. D									2										1					
Amphipoda	Lysianassoidea sp. F					3			1	1													3		
Amphipoda	Lysianassoidea sp. G	1				1								1			1	1	1				3		
Amphipoda	*Ampelisca sp. A*					1		1		1											1				
Amphipoda	*Ampelisca sp. B*																								
Amphipoda	*Ampelisca sp. C*	3					1		1						2	1	2		1				1		
Amphipoda	*Ampelisca sp. D*											1								2					
Amphipoda	*Ampelicca sp. E*																								
Amphipoda	Amphilochidae sp A											1													
Amphipoda	Photis sp				1		2	3								1									
Amphipoda	aff. Leptocheirus	2		2	3																				
Amphipoda	Paradeliscidae sp			4		6																5			
Amphipoda	*aff. Dulichia*	1			1		5		1		1												2		1
Amphipoda	*aff Laetmatophilus sp*								1																
Amphipoda	*aff Laetmatophilus sp II*					1																			
Amphipoda	*aff Xerodice sp*																								
Isopoda	*Gnathia praniza*		1					1																	
Isopoda	*Ilyarachna sp*					2	1		1									1			1				1
Isopoda	*Eurycope sp*			1																					
Isopoda	*Munna c.f. argentinae*					1	2																		
Isopoda	*Macrostylis sp*				1					1					1				4				1		1
Isopoda	*Nannoniscus sp*	1		2				1	2															3	
Isopoda	*Haploniscus sp*																				2				
Isopoda	*Ischnomesus sp*		1																1						
Isopoda	*Haplomesus c.f. insignis*																				1				
Isopoda	*Heteromesus sp.*						1																		
Isopoda	*Stylomesus sp*																								
Isopoda	*Desmosoma sp*							1	1							1								1	
Isopoda	*Janirella sp. (abyssorum?)*		1																	1					
Isopoda	*Janirella sp.II*						1	2	1																
Isopoda	*Spinianirella sp.*						4																		
Isopoda	*Abyssinaria sp.*						2																		
Isopoda	*Dynamenella sp*						1		1																1
Isopoda	*Cirolana sp.*				1			1								1									
Isopoda	*Cirolana sp II*					1																			
Isopoda	*Eurydice sp*																								
Isopoda	*Pseudanthura lateralis*	1	1	1	2		1	1	2				2		1										1
Isopoda	*Antarctura sp*								12																
Isopoda	*Serolis sp I*		1			1																			
Isopoda	*Serolis sp II*				1																				
Tanaidacea	*Tanaidae sp A*				2	1										3	2			1					
Tanaidacea	*Tanaidae sp B*				3			1		3			1	1										1	1
Tanaidacea	*Tanaidae sp C*																								
Tanaidacea	*Tanaidae sp D*				3		1										1		1						1
Tanaidacea	*Tanaidae sp E long body*	1		1		1			1			1				1	1	1						1	
Tanaidacea	*Archaeotanais hirsutus*					1														1					
Tanaidacea	*Tanaidae sp E*																								
Tanaidacea	*Tanaidae sp (Apseudidae)*	1					1			1															
Tanaidacea	*Tanaidae sp (Apseudidae)II*																								
Cumacea	*Eudorella sp.*									1															
Cumacea	*Leucon sp.*											1		1				1		1	1				
Cumacea	Bodotriidae sp										3	2													
Cumacea	aff. Iphinoe																								
Cumacea	Diastylidae sp A		1															1							1
Cumacea	*Campylaspis spp.*											1		1		1									
Eupausiacea	Euphausiacea				1																				1
	PYGNOGONIDA																								
	Anoplodactylidae sp	1			1																				
	MOLLUSCA																								
Caudofoveata	Caudofoveata						1	1																	
Solenogastres	Solenogastres	1		1								1										1		1	
Scaphopoda	Scaphopoda sp.		1							1	1			1	1				1			1		2	
Scaphopoda	aff. Cadulus						1																		
Gastropoda	Caecum sp.									2															
Gastropoda	Oenopota sp																		1						
Gastropoda	Skenea I									1								1							
Gastropoda	Skenea II																				1				
Gastropoda	Eulima sp						3																		
Gastropoda	*Polinices sp.high*																								
Gastropoda	*Polinices sp.flat*																								
Gastropoda	*Fusitronica sp I*																1	1							
Gastropoda	*Fusitronica sp II*																1					1			
Gastropoda	*Mitra/Vexilla sp*		1				1																		
Gastropoda	*Marginellidae sp.*	1																							
Gastropoda	*Retusa sp*																								
Bivalvia	Dacrydium sp.				1			1				2			1	1	2			1		1		1	1
Bivalvia	*Yoldiella / Ledella*		1								2			1											
Bivalvia	*aff. Bathyarca*			1	2	2			1																
Bivalvia	*Pecten sp.(Similipecten?)*						1		2			1		1	2	5	4		1			2	2	1	1
Bivalvia	*Lima sp*																								
Bivalvia	*Mysella spp*								1				1	2	1	4						1		1	
Bivalvia	*Cardiidae sp*																								1
Bivalvia	*Veneridae spp*						2	2										1							
Bivalvia	*Mactra sp*									4	2	2							2		1				
Bivalvia	*Mactra sp II, round*										1	1						2							
Bivalvia	*aff. Diplodonta sp*									1		3													
Bivalvia	*Aff. Mya*						1																		
Bivalvia	*Thracia c.f.meridonalis*											1													
Bivalvia	*Cuspidaria sp.*					1	1									1				2		1			
Bivalvia	*Poromya sp*																		1						
Bivalvia	*aff. Axinulus*						1	1	2			5			1										
Bivalvia	*aff. Thyasira*				1								1					1							
Bivalvia	*Bivalve dam.*												1												

Macrofaunal Matrix

Comment	Species	1A	1B	R2A	R2B	R2C	L3A	L3B	L3C	4 C	4A	4 D	L5A	L5B	6A	6B	6C	L7A	S8 A	S8 B	S8 C	S10A	S11A	S11B	S11C
	Sample Replicates																								
	ECHINODERMATA																								
Crinoidea	Bathycrinidae (stalked Crinoid)																							2	
Ophiuroidea	Astrotoma agassisi																					1			
Ophiuroidea	Amphiuridae sp		1	1		2	4																		
Ophiuroidea	Ophiactis sp												1												
Ophiuroidea	Ophiolepidae sp				4	1	1		1														1		
Ophiuroidea	Ophiacantha sp							1																	
Ophiuroidea	*Ophionephtys magellanica*																								1
Ophiuroidea	*Ophiozonella falklandica*						1		3								2	2							
Ophiuroidea	*Ophiomitrella falklandica*				1	1																1			
Echinoidea	*Spatangoid sp fragment*															1									
Holothurioidea	*Psolus sp*																					2			
Holothurioidea	*Synaptidae sp*																					1			1
Holothurioidea	*Myriotrochidae sp (Synaptid)*															1									
	ENTEROPNEUSTA																								
Enteropneusta	Enteropneusta sp.					1													1						
	FORAMINIFERA																								
	Foraminifera sp. B (long white)										2								1						
	"Snail Foram."									7		4													
	"egg"									4	4	6													
	"spiral"																							1	
	BRACHIOPODA																								
Terebratulida	Brachiopoda sp aff. Terebratulina							1	1						1										
	PISCES																								
	Gobiiform, not id.																								
	count	41	34	40	40	46	57	52	50	31	29	41	22	19	24	45	33	23	25	27	28	22	27	37	43
	sum	146	58	96	110	108	100	100	118	81	59	84	33	27	47	80	65	34	39	43	55	29	45	58	60
	number or replicate																								
	sum (m2)																								

Macrofaunal Matrix

Comment	Species	L12A	L12B	L13A	L13B	R14A	R14B	15A	15C	R16A	R16B	R16C	18 A	18 B	S19A	S19B	S20A	S20B	21A	21B	21C	S22A	S22B	L23A	L23B
	Sample Replicates																								
	CNIDARIA																								
Ceriantharia	*Ceriantharia sp*																								
Octocorallia	*Pennatulidae sp*							7	2																
Octocorallia	*Melitodes sp*																								
Scyphozoa	Scyphozoa polyp														2		1								
Anthozoa	Aff Gonactinia sp																								
Anthozoa	Actinaria sp																								
Anthozoa	Edwardsiidae sp.	1				2			1			1				1									
Anthozoa	Solitary Coral I														1								1		
Anthozoa	Solitary Coral II (toothed rim)																								
	NEMERTEA																								
	Nemertea spp.			1	1	2	1	1		2					3	1		2	1		1			1	
	NEMATODA																								
	Nematoda spp.	1	8	4	5	2	1	3			4	2	1		2		3			1	3	11	11	2	
	SIPUNCULA																								
Sipunculidea	*Golfingia sp.*						1								4	1	1					1	1		
	TURBELLARIA																								
Turbellaria	Turbelleraria sp indet.																								
	ANNELIDA																								
Polychaeta	Euphrosine sp															1									
Polychaeta	Dorvilleidae sp						1			1											1				
Polychaeta	Polynoidae spp																								
Polychaeta	cf Eunoe sp																								
Polychaeta	cf Leanira sp																						1		
Polychaeta	aff Pholoe																		1		1				
Polychaeta	*aff. Pisione sp*			5											1		1				1				
Polychaeta	*Eteone spp*											1					1	1	1			1			
Polychaeta	*Mystides sp.*																								
Polychaeta	*Glycera capitata*												1				3								
Polychaeta	Syllidae sp.									1					1						1				
Polychaeta	Pilargiidae sp																								
Polychaeta	Ceratocephale sp.		3		4							1			5		2	1		1				3	
Polychaeta	Nereis sp																								
Polychaeta	*Aglaophamus sp.*						1	1			1	1							1				1		
Polychaeta	*Rhamphobranchium ehlersi*					9	11	2	5	4	6	4	3	5	10	9	9	14	3	2	6	8	8		
Polychaeta	*Nothria conchylega*														1		1	1				1			
Polychaeta	*Aff Scoloplos sp*											1		1					1	5	4		3		1
Polychaeta	*Aricidea sp.A*							1		1	2				1					1				1	1
Polychaeta	*Aricidea c.f. oculata*		2			1	2	8	3	3	1	4					1	1		1			2		1
Polychaeta	*Aricidea simplex*							1		2					4					1				1	
Polychaeta	*Aricidea strelzoni*											3													
Polychaeta	*Paraonoidae spp.*																								
Polychaeta	*Levinsenia gracilis*			4		2											1			1			3		
Polychaeta	*Apistobranchus cf fragmentata*				1						1			1		1							1		
Polychaeta	Spionidae sp.																								
Polychaeta	Minuspio sp						1										1				1				
Polychaeta	*Scolelepis sp.*						1			2			2												
Polychaeta	*Spiophanes bombyx*														1				1		1			1	
Polychaeta	*Spiophanes c.f. soederstroemi*					1							1							3					
Polychaeta	*Laonice spp*													1						1					
Polychaeta	*Diplocirrus hirsutus*						1										1			1			1		
Polychaeta	*Flabelligera sp.*																								
Polychaeta	*Pherusa sp*		1									1													
Polychaeta	*Cossura sp.*														1				1	1	3		1	1	
Polychaeta	Maldanidae spp.	1	1	1		1	2	1		2		1		2		1	1		1		1				3
Polychaeta	*Eupraxilella antarctica*																								
Polychaeta	*Maldane sarsi subsp*																1	1					1		
Polychaeta	*Praxillella bransfieldensis*																							1	
Polychaeta	*Praxilella c.f. antarctica*																								
Polychaeta	*Rhodine cf loveni*									1				1											
Polychaeta	*Spiochaetopterus sp.*		1	1								1	1						1		3		2		
Polychaeta	*Cirratulus sp*																								
Polychaeta	*Cirriformia sp.*																			1		1			
Polychaeta	*Caulleriella spp*				1	2	3		1		1	2	1			1	1		1	1	1	1	1		
Polychaeta	*Chaetozone setosa.*	1	3																						
Polychaeta	Tharyx fusiformis	1	1	1																					
Polychaeta	Tharyx sp																				1				
Polychaeta	Macrochaeta sp.															2						3			
Polychaeta	*Notomastus aff latericeus*					1								3	2						2			1	
Polychaeta	*Travisia sp.*									1	1	1													
Polychaeta	*Ophelina aff cylindricaudata*																								
Polychaeta	*Ophelina nematoides*		1																						
Polychaeta	*Ophelina breviata*																	1						1	
Polychaeta	*Ophelia sp*																								
Polychaeta	*Scalibregma inflatum*			1				2	1								2							1	
Polychaeta	*Scalibregma sp. II?*																					1			
Polychaeta	*Sternaspis sp*																								
Polychaeta	*Ampharetinae spp*	2	1			1	1			1	1				3				2				3		1
Polychaeta	*Samytha sp*														1										
Polychaeta	*Amage sp.*							1				1	1												
Polychaeta	*Melinna c.f.cristata*			2			1					1													
Polychaeta	*Streblosoma sp*						1												1		1		1		
Polychaeta	*Pista sp.*																								
Polychaeta	*Terebellides stroemi*						1	1										1				2			
Polychaeta	Terebellidae fragment		1										1		1										
Polychaeta	Perkinsiniana antarc tica						1												1						
Polychaeta	Sabella sp																	1	1			2			
Polychaeta	Sabellidae frag.	2																					1		
Polychaeta	Fabricinidae sp.																								
Polychaeta	*Fabricola / Pseudofabricia sp*				1													1							
Polychaeta	*Jasmineira sp*												1			4	2			1					
Polychaeta	*Chone sp*							1											3	2			3		
Polychaeta	*Euchone pallida*														1	1				1	1				
Oligochaeta	Oligochaeta Tubificidae		1		3	2	2			1	1						1		1	6	1	4	5		
Polychaeta	Serpulidae																								
Polychaeta	*Phylo felix*		1			2						1	1	1			1	1	2	4			1		
Polychaeta	*Lumbrineris c.f.antarctica*				1		1					2				1	1	3	1		4		1		
Polychaeta	*Ninoe c.f. falklandica*			1																					
Polychaeta	*Galathowenia sp*	1	1	7	1	2	1		1	1			1		1		3				1	1		3	5
Polychaeta	*Myriowenia cf. californicensis*																								
Polychaeta	*Polygordius sp.*						1						3								1				
Polychaeta	*Sphaerodorum sp I*											1	2				2	1	1		1				
Polychaeta	*Sphaerodorum sp II*																								
Polychaeta	*c.f. Fauvelia?*																2								
Pogonophora	*Siboglinum sp*	1																							
Pogonophora	*Pogonophora sp*																								

Macrofaunal Matrix

Comment	Species	L12A	L12B	L13A	L13B	R14A	R14B	15A	15C	R16A	R16B	R16C	18 A	18 B	S19A	S19B	S20A	S20B	21A	21B	21C	S22A	S22B	L23A	L23B
	Sample Replicates																								
	CRUSTACEA																								
Cephalocarida	Cephalocarida sp?																								
Cirripedia	Scalpellum sp.														2		1					2	1		
Cirripedia	Verruca sp														1							4			
Ostracoda	Ostracoda spp.	1				1		5	11	9	10	5	7	7	1	4	1	2		2	3	3	2		1
Copepoda	Copepoda indet																1			1			2		
Amphipoda	*Phtisica ap*									1															
Amphipoda	*Amphipoda sp. A*																1								
Amphipoda	Stenothoidae sp I			1				4							1	1				1					
Amphipoda	Stenothoidae sp II (wide rostrum)			2																					
Amphipoda	Stegocephalidae					1																			
Amphipoda	aff Apherusa								1																
Amphipoda	*Urothoe sp.*	1	2	1	3		2	3	4	3	2	5	5			1		1			2			4	7
Amphipoda	Podoceridae																								
Amphipoda	Phoxocephaloidae sp. A																								
Amphipoda	Phoxocephaloidea sp. B																								
Amphipoda	Phoxocephaloidea sp.C (eyeless)	3		1	2			7	3	4	2	2		3	1		2	3		3	1	4	1	4	5
Amphipoda	Phoxocephalus sp eyeles, notched												2		1		1		2				1		
Amphipoda	Metaphoxus																								
Amphipoda	*Maera sp.*		1		1					1	1	3	3				2					1			1
Amphipoda	*Leucothoidae*							1																	
Amphipoda	*Aff. Dexamine*																								
Amphipoda	*aff. Melitidae*																								
Amphipoda	*Acanthozone sp*																								
Amphipoda	*Didymochelia spp*							1							1				1						
Amphipoda	Lysianassoidea sp. C									1											1				
Amphipoda	Lysianassoidea sp. D	1	1	1																					
Amphipoda	Lysianassoidea sp. F										1					1			1						
Amphipoda	Lysianassoidea sp. G						1		1												1			1	
Amphipoda	*Ampelisca sp. A*											1						1							
Amphipoda	*Ampelisca sp. B*										1					1			1	1					1
Amphipoda	*Ampelisca sp. C*					3	5					1					1			1	3				
Amphipoda	*Ampelisca sp. D*																								
Amphipoda	*Ampelicca sp. E*			1																					
Amphipoda	Amphilochidae sp A																								
Amphipoda	Photis sp																	1	2						
Amphipoda	aff. Leptocheirus																		1						
Amphipoda	Paradeliscidae sp																	1	1			1			
Amphipoda	*aff. Dulichia*																		1			1			
Amphipoda	*aff Laetmatophilus sp*																								
Amphipoda	*aff Laetmatophilus sp II*																								
Amphipoda	*aff Xerodice sp*											5													
Isopoda	*Gnathia praniza*																								
Isopoda	*Ilyarachna sp*								1				1		2		1								
Isopoda	*Eurycope sp*								1																
Isopoda	*Munna c.f. argentinae*										1														
Isopoda	*Macrostylis sp*			1	1	1							1				1		2						
Isopoda	*Nannoniscus sp*							1												1					1
Isopoda	*Haploniscus sp*		1	3	2			1																	
Isopoda	*Ischnomesus sp*			1					1																
Isopoda	*Haplomesus c.f. insignis*		1	2			1														1				
Isopoda	*Heteromesus sp.*					2														1					
Isopoda	*Stylomesus sp*				1							1											1		
Isopoda	*Desmosoma sp*																1			1	2	1			
Isopoda	*Janirella sp. (abyssorum?)*																								
Isopoda	*Janirella sp.II*																								
Isopoda	*Spinianirella sp.*																								
Isopoda	*Abyssinaria sp.*														1										
Isopoda	*Dynamenella sp*																								
Isopoda	*Cirolana sp.*							1																	
Isopoda	*Cirolana sp II*																					1			
Isopoda	*Eurydice sp*									2	2			1											
Isopoda	*Pseudanthura lateralis*		2		1						1	2	1		1										
Isopoda	*Antarctura sp*																1								
Isopoda	*Serolis sp I*																								
Isopoda	*Serolis sp II*																								
Tanaidacea	*Tanaidae sp A*		1												1					2		1		1	
Tanaidacea	*Tanaidae sp B*														1		1			1			1		
Tanaidacea	*Tanaidae sp C*																							1	
Tanaidacea	*Tanaidae sp D*			2											1							1	1	1	
Tanaidacea	*Tanaidae sp E long body*		1	1																					
Tanaidacea	*Archaeotanais hirsutus*														1					2			1		
Tanaidacea	*Tanaidae sp E*										1														
Tanaidacea	*Tanaidae sp (Apseudidae)*		4	5	4									1	1			1			2			3	2
Tanaidacea	*Tanaidae sp (Apseudidae)II*															1									
Cumacea	*Eudorella sp.*																1				1				2
Cumacea	*Leucon sp.*	2				1											1				1	1	1		1
Cumacea	Bodotriidae sp																					1			
Cumacea	aff. Iphinoe			3																					
Cumacea	Diastylidae sp A		1			1						1	1						2						
Cumacea	*Campylaspis spp.*																	1							
Eupausiacea	Euphausiacea	1																			1				
	PYGNOGONIDA																								
	Anoplodactylidae sp																								
	MOLLUSCA																								
Caudofoveata	Caudofoveata																								
Solenogastres	Solenogastres									1			1							2					
Scaphopoda	Scaphopoda sp.												1												1
Scaphopoda	aff. Cadulus							1					1								2				
Gastropoda	Caecum sp.																								
Gastropoda	Oenopota sp												1												
Gastropoda	Skenea I												1						1		1				
Gastropoda	Skenea II									1			1												
Gastropoda	Eulima sp																								
Gastropoda	*Polinices sp.high*				1																				
Gastropoda	*Polinices sp.flat*												1		1										
Gastropoda	*Fusitronica sp I*																1								
Gastropoda	*Fusitronica sp II*																			1					
Gastropoda	*Mitra/Vexilla sp*					1																			
Gastropoda	*Marginellidae sp.*																								
Gastropoda	*Retusa sp*																1								
Bivalvia	Dacrydium sp.														2	2		1		1	3	1	1		
Bivalvia	*Yoldiella / Ledella*				3								6												1
Bivalvia	*aff. Bathyarca*								1													1	2		
Bivalvia	*Pecten sp.(Similipecten?)*						1								1	2		1	1	2	2				
Bivalvia	*Lima sp*											1													
Bivalvia	*Mysella spp*							2	1										2	1	2				
Bivalvia	*Cardiidae sp*																								
Bivalvia	*Veneridae spp*								2										1						
Bivalvia	*Mactra sp*	1		1	2					1	1		4	3						2		2			
Bivalvia	*Mactra sp II, round*							3																	
Bivalvia	*aff. Diplodonta sp*			3						2	7	12		2											
Bivalvia	*Aff. Mya*																								
Bivalvia	*Thracia c.f.meridonalis*																								
Bivalvia	*Cuspidaria sp.*																								
Bivalvia	*Poromya sp*							1																	
Bivalvia	*aff. Axinulus*									4														1	5
Bivalvia	*aff. Thyasira*		3						4																
Bivalvia	*Bivalve dam.*																								

Macrofaunal Matrix

Comment	Species	L12A	L12B	L13A	L13B	R14A	R14B	15A	15C	R16A	R16B	R16C	18 A	18 B	S19A	S19B	S20A	S20B	21A	21B	21C	S22A	S22B	L23A	L23B
	Sample Replicates																								
	ECHINODERMATA																								
Crinoidea	Bathycrinidae (stalked Crinoid)																								
Ophiuroidea	Astrotoma agassisi																								
Ophiuroidea	Amphiuridae sp											1			1	1						1	3		
Ophiuroidea	Ophiactis sp																								
Ophiuroidea	Ophiolepidae sp						2						3		4										
Ophiuroidea	Ophiacantha sp																								
Ophiuroidea	*Ophionephtys magellanica*											1													
Ophiuroidea	*Ophiozonella falklandica*																			2	1				
Ophiuroidea	*Ophiomitrella falklandica*														1		1	1			1	1	1		
Echinoidea	*Spatangoid sp fragment*		1							1															
Holothurioidea	*Psolus sp*																				1				
Holothurioidea	*Synaptidae sp*															1									
Holothurioidea	*Myriotrochidae sp (Synaptid)*																								
	ENTEROPNEUSTA																								
Enteropneusta	Enteropneusta sp.																								
	FORAMINIFERA																								
	Foraminifera sp. B (long white)		5	1									5	1											4
	"Snail Foram."							3	6	18	1	11		3											
	"egg"		4	2							2		3	2											
	"spiral"	18	3										1											3	
	BRACHIOPODA																								
Terebratulida	Brachiopoda sp aff. Terebratulina					1	1																		
	PISCES																								
	Gobiiform, not id.			1																					
	count	17	29	30	20	23	28	27	20	28	24	34	35	17	41	22	42	25	34	38	43	31	36	21	19
	sum	39	57	61	39	42	49	64	51	72	52	82	70	38	73	39	63	44	45	63	73	65	72	36	44
	number or replicate																								
	sum (m2)																								

Macrofaunal Matrix

Comment	Species	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	20	21	22	23
		Stations (all samples)																				
	CNIDARIA																					
Ceriantharia	*Ceriantharia sp*		1				1															
Octocorallia	*Pennatulidae sp*						1								9							
Octocorallia	*Melitodes sp*					1																
Scyphozoa	Scyphozoa polyp								2									2	1			
Anthozoa	Aff Gonactinia sp		1																			
Anthozoa	Actinaria sp			1																		
Anthozoa	Edwardsiidae sp.	1	1								2	1		2	1	1		1				
Anthozoa	Solitary Coral I																	1			1	
Anthozoa	Solitary Coral II (toothed rim)									1												
	NEMERTEA		4																			
	Nemertea spp.	4	12	7	1	3	9		1	2	6		2	3	1	2		4	2	2		1
	NEMATODA																					
	Nematoda spp.	81	60	14	4	3	9	2	2		2	9	9	3	3	6	1	2	3	4	22	2
	SIPUNCULA																					
Sipunculidea	*Golfingia sp.*	6	4				1		1		3			1				5	1		2	
	TURBELLARIA																					
Turbellaria	Turbelleraria sp indet.	1																				
	ANNELIDA																					
Polychaeta	Euphrosine sp																	1				
Polychaeta	Dorvilleidae sp		2	4	4				2		2			1		1				1		
Polychaeta	Polynoidae spp			2	1																	
Polychaeta	cf Eunoe sp										1											
Polychaeta	cf Leanira sp		2	1																	1	
Polychaeta	aff Pholoe	2		2																2		
Polychaeta	*aff. Pisione sp*	1	2			1	1				1		5					1	1	1		
Polychaeta	*Eteone spp*		1	1	1						3					1			2	1	1	
Polychaeta	*Mystides sp.*		1	5	1																	
Polychaeta	*Glycera capitata*	3		3			4	1	1		5						1		3			
Polychaeta	Syllidae sp.	1	2	4	1		1				2					1		1		1		
Polychaeta	Pilargiidae sp	1																				
Polychaeta	Ceratocephale sp.		8		1						2	3	4			1		5	3	1		3
Polychaeta	Nereis sp	1																				
Polychaeta	*Aglaophamus sp.*		1		2	3	1							1	1	2				1	1	
Polychaeta	*Rhamphobranchium ehlersi*	22	29	15	5	2	17	5	25	1	19			20	7	14	8	19	23	11	16	
Polychaeta	*Nothria conchylega*			2			1				2							1	2		1	
Polychaeta	*Aff Scoloplos sp*			1	1	4	2		5	1	4					1	1			10	3	1
Polychaeta	*Aricidea sp.A*	1	1	1	2		1				1				1	3		1		1		2
Polychaeta	*Aricidea c.f. oculata*	3	13	7	5		6	1	1		2	2		3	11	8			2	1	2	1
Polychaeta	*Aricidea simplex*			4											1	2		4		1		1
Polychaeta	*Aricidea strelzoni*															3						
Polychaeta	*Paraonoidae spp.*		2						1													
Polychaeta	*Levinsenia gracilis*	2	1			1	1	1			1		4	2					1	1	3	
Polychaeta	*Apistobranchus cf fragmentata*												1			1	1	1			1	
Polychaeta	Spionidae sp.	1							2													
Polychaeta	Minuspio sp			3			1			1				1					1	1		
Polychaeta	*Scolelepis sp.*		1	1			1		1	1				1		2	2					
Polychaeta	*Spiophanes bombyx*								2	1								1		2		1
Polychaeta	*Spiophanes c.f. soederstroemi*			1	1									1			1			3		
Polychaeta	*Laonice spp*				2				1								1			1		
Polychaeta	*Diplocirrus hirsutus*		1		1				2					1					1	1	1	
Polychaeta	*Flabelligera sp.*						2															
Polychaeta	*Pherusa sp*											1				1						
Polychaeta	*Cossura sp.*			3		1	6											1		5	1	1
Polychaeta	Maldanidae spp.			1	5	2	8		3		6	2	1	3	1	3	2	1	1	2		3
Polychaeta	*Eupraxilella antarctica*				1																	
Polychaeta	*Maldane sarsi subsp*			1					1		1								2		1	
Polychaeta	*Praxillella bransfieldensis*				1																	1
Polychaeta	*Praxilella c.f. antarctica*				1																	
Polychaeta	*Rhodine cf loveni*			1	4		1									1	1					
Polychaeta	*Spiochaetopterus sp.*	1	2									1	1			1	1			4	2	
Polychaeta	*Cirratulus sp*	1		1																		
Polychaeta	*Cirriformia sp.*	2	1																	1	1	
Polychaeta	*Caulleriella spp*	5	4	3	5		8	4	1				1	5	1	3	1	1	1	3	2	
Polychaeta	*Chaetozone setosa.*			3	2	1	1	1			1	4										
Polychaeta	Tharyx fusiformis				1				2			2	1									
Polychaeta	Tharyx sp				1		1				1									1		
Polychaeta	Macrochaeta sp.																	2			3	
Polychaeta	*Notomastus aff latericeus*		1		2				2		2			1			3	2		2		1
Polychaeta	*Travisia sp.*			1												3						
Polychaeta	*Ophelina aff cylindricaudata*				1																	
Polychaeta	*Ophelina nematoides*				1							1										
Polychaeta	*Ophelina breviata*						1												1			1
Polychaeta	*Ophelia sp*					1			2													
Polychaeta	*Scalibregma inflatum*			2	1		1						1		3				2			1
Polychaeta	*Scalibregma sp. II?*																				1	
Polychaeta	*Sternaspis sp*			1																		
Polychaeta	*Ampharetinae spp*	1	6	10							3	3		2		2		3		2	3	1
Polychaeta	*Samytha sp*						2											1				
Polychaeta	*Amage sp.*	2	1	1					2		2				1	1	1					
Polychaeta	*Melinna c.f.cristata*			3			2						2	1		1						
Polychaeta	*Streblosoma sp*		2				8							1						2	1	
Polychaeta	*Pista sp.*			1																		
Polychaeta	*Terebellides stroemi*	2		1		1	3	1			1			1	1				1		2	
Polychaeta	Terebellidae fragment	1	1	3			1		1	1		1					1	1				
Polychaeta	Perkinsiniana antarc tica	1		4										1						1		
Polychaeta	Sabella sp	1	1								3								1	1	2	
Polychaeta	Sabellidae frag.	1		3								2									1	
Polychaeta	Fabricinidae sp.								1													
Polychaeta	*Fabricola / Pseudofabricia sp*						1		1				1						1			
Polychaeta	*Jasmineira sp*	1		2					1		6						1	4	2	1		
Polychaeta	*Chone sp*		5	7			1				5				1					5	3	
Polychaeta	*Euchone pallida*	4	1	10					2		1							2		2		
Oligochaeta	Oligochaeta Tubificidae	1	8	6	2	5	3		3		1	1	3	4		2			1	8	9	
Polychaeta	Serpulidae			1					1													
Polychaeta	*Phylo felix*		1		1				1			1		2		1	2		2	6	1	
Polychaeta	*Lumbrineris c.f.antarctica*		1				2		1		2		1	1		2		1	4	5	1	
Polychaeta	*Ninoe c.f. falklandica*												1									
Polychaeta	*Galathowenia sp*	3	1	1	2	2	1		9	1		2	8	3	1	1	1	1	3	1	1	8
Polychaeta	*Myriowenia cf. californicensis*																					
Polychaeta	*Polygordius sp.*			1	1	2	3				1			1			3			1		
Polychaeta	*Sphaerodorum sp I*		1	1	1		3				1					1	2		3	2		
Polychaeta	*Sphaerodorum sp II*				1																	
Polychaeta	*c.f. Fauvelia?*																		2			
Pogonophora	*Siboglinum sp*		10									1										
Pogonophora	*Pogonophora sp*		2																			

Macrofaunal Matrix

Comment	Species	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	20	21	22	23
	Stations (all samples)																					
	CRUSTACEA																					
Cephalocarida	Cephalocarida sp?									1												
Cirripedia	Scalpellum sp.	1	1	4			1											2	1		3	
Cirripedia	Verruca sp		1	1							1							1			4	
Ostracoda	Ostracoda spp.	3	5	4	54	4	9	2	11		5	1		1	16	24	14	5	3	5	5	1
Copepoda	Copepoda indet	2	1	4	1		2				1								1	1	2	
Amphipoda	*Phtisica ap*	1	5				1									1						
Amphipoda	*Amphipoda sp. A*			2							1								1			
Amphipoda	Stenothoidae sp I	3	2	4		1	1	1			1		1		4			2		1		
Amphipoda	Stenothoidae sp II (wide rostrum)	4	1										2									
Amphipoda	Stegocephalidae			5							1			1								
Amphipoda	aff Apherusa														1							
Amphipoda	*Urothoe sp.*	1	1	8	16		6	1	3		4	3	4	2	7	10	5	1	1	2		11
Amphipoda	Podoceridae			3																		
Amphipoda	Phoxocephaloidae sp. A																					
Amphipoda	Phoxocephaloidea sp. B																					
Amphipoda	Phoxocephaloidea sp.C (eyeless)	1	1	4	5	5	1		1		3	3	3		10	8	3	1	5	4	5	9
Amphipoda	Phoxocephalus sp eyeles, notched	3	1								3						2	1	1	2	1	
Amphipoda	Metaphoxus				1				1													
Amphipoda	*Maera sp.*	1	22	14	1	1	2		3		4	1	1			5	3		2		1	1
Amphipoda	*Leucothoidae*		1	2			2				1				1							
Amphipoda	*Aff. Dexamine*		1																			
Amphipoda	*aff. Melitidae*		1	13																		
Amphipoda	*Acanthozone sp*	1																				
Amphipoda	*Didymochelia spp*		4	3				1							1			1		1		
Amphipoda	Lysianassoidea sp. C	1							1		1					1				1		
Amphipoda	Lysianassoidea sp. D				2				1			2	1									
Amphipoda	Lysianassoidea sp. F		3	1	1						3					1		1		1		
Amphipoda	Lysianassoidea sp. G	1	1			1	1	1	1		3			1	1					1		1
Amphipoda	*Ampelisca sp. A*		1	1	1				1							1			1			
Amphipoda	*Ampelisca sp. B*															1		1		2		1
Amphipoda	*Ampelisca sp. C*	3		2			5		1		1			8		1			1	4		
Amphipoda	*Ampelisca sp. D*				1				2													
Amphipoda	*Ampelicca sp. E*												1									
Amphipoda	Amphilochidae sp A				1																	
Amphipoda	Photis sp		1	5			1												1	2		
Amphipoda	aff. Leptocheirus	2	5																	1		
Amphipoda	Paradeliscidae sp		10							5									1	1	1	
Amphipoda	*aff. Dulichia*	1	1	6	1						3									1	1	
Amphipoda	*aff Laetmatophilus sp*			1																		
Amphipoda	*aff Laetmatophilus sp II*		1																			
Amphipoda	*aff Xerodice sp*															5						
Isopoda	*Gnathia praniza*	1		1																		
Isopoda	*Ilyarachna sp*		2	2				1	1		1				1		1	2	1			
Isopoda	*Eurycope sp*		1												1							
Isopoda	*Munna c.f. argentinae*		1	2												1						
Isopoda	*Macrostylis sp*		1		1		1		4		2		2	1			1		1	2		
Isopoda	*Nannoniscus sp*	1	2	3							3				1					1		1
Isopoda	*Haploniscus sp*								2			1	5		1							
Isopoda	*Ischnomesus sp*	1							1				1		1							
Isopoda	*Haplomesus c.f. insignis*								1			1	2	1						1		
Isopoda	*Heteromesus sp.*			1										2						1		
Isopoda	*Stylomesus sp*												1			1					1	
Isopoda	*Desmosoma sp*			2			1				1								1	3	1	
Isopoda	*Janirella sp. (abyssorum?)*	1							1													
Isopoda	*Janirella sp.II*			4																		
Isopoda	*Spinianirella sp.*			4																		
Isopoda	*Abyssinaria sp.*			2														1				
Isopoda	*Dynamenella sp*			2							1											
Isopoda	*Cirolana sp.*		1	1			1								1							
Isopoda	*Cirolana sp II*		1																		1	
Isopoda	*Eurydice sp*															4	1					
Isopoda	*Pseudanthura lateralis*	2	3	4		2	1				1	2	1			3	1	1				
Isopoda	*Antarctura sp*			12															1			
Isopoda	*Serolis sp I*	1	1																			
Isopoda	*Serolis sp II*		1																			
Tanaidacea	*Tanaidae sp A*		3				5		1			1						1		2	1	1
Tanaidacea	*Tanaidae sp B*		3	1	3	2					2							1	1	1	1	
Tanaidacea	*Tanaidae sp C*																					1
Tanaidacea	*Tanaidae sp D*		3	1			1		1		1		2					1			2	1
Tanaidacea	*Tanaidae sp E long body*	1	2	1	1		2	1			1	1	1									
Tanaidacea	*Archaeotanais hirsutus*		1						1									1		2	1	
Tanaidacea	*Tanaidae sp E*															1						
Tanaidacea	*Tanaidae sp (Apseudidae)*	1		1	1							4	9				1	1	1	2		5
Tanaidacea	*Tanaidae sp (Apseudidae)II*																	1				
Cumacea	*Eudorella sp.*				1														1	1		2
Cumacea	*Leucon sp.*				1	1		1	2			2		1					1	1	2	1
Cumacea	Bodotriidae sp				5																1	
Cumacea	aff. Iphinoe												3									
Cumacea	Diastylidae sp A	1						1			1	1		1		1	1			2		
Cumacea	*Campylaspis spp.*				1	1	1												1			
Eupausiacea	Euphausiacea		1								1	1								1		
	PYGNOGONIDA																					
	Anoplodactylidae sp	1	1																			
	MOLLUSCA																					
Caudofoveata	Caudofoveata			2																		
Solenogastres	Solenogastres	1	1		1					1	1					1	1			2		
Scaphopoda	Scaphopoda sp.	1			2	1	1		1	1	2						1					1
Scaphopoda	aff. Cadulus			1											1		1			2		
Gastropoda	Caecum sp.				2																	
Gastropoda	Oenopota sp								1								1					
Gastropoda	Skenea I				1			1									1			2		
Gastropoda	Skenea II								1							1	1					
Gastropoda	Eulima sp			3																		
Gastropoda	*Polinices sp.high*												1									
Gastropoda	*Polinices sp.flat*																1	1				
Gastropoda	*Fusitronica sp I*						1	1											1			
Gastropoda	*Fusitronica sp II*						1			1										1		
Gastropoda	*Mitra/Vexilla sp*	1		1										1								
Gastropoda	*Marginellidae sp.*	1																				
Gastropoda	*Retusa sp*																		1			
Bivalvia	Dacrydium sp.		1	1	2		4		1	1	2							4	1	4	2	
Bivalvia	*Yoldiella / Ledella*	1			2	1							3				6					1
Bivalvia	*aff. Bathyarca*		5	1											1						3	
Bivalvia	*Pecten sp.(Similipecten?)*			3	1	1	11		1	2	4			1				3	1	5		
Bivalvia	*Lima sp*															1						
Bivalvia	*Mysella spp*			1		3	5			1	1				3					5		
Bivalvia	*Cardiidae sp*										1											
Bivalvia	*Veneridae spp*			4				1							2					1		
Bivalvia	*Mactra sp*				8				3			1	3			2	7			2	2	
Bivalvia	*Mactra sp II, round*				2			2							3							
Bivalvia	*aff. Diplodonta sp*				4								3			21	2					
Bivalvia	*Aff. Mya*			1																		
Bivalvia	*Thracia c.f.meridonalis*				1																	
Bivalvia	*Cuspidaria sp.*		1	1			1		2	1												
Bivalvia	*Poromya sp*								1						1							
Bivalvia	*aff. Axinulus*			4	5		1									4						6
Bivalvia	*aff. Thyasira*		1			1		1				3			4							
Bivalvia	*Bivalve dam.*					1																

Macrofaunal Matrix

Comment	Species	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	20	21	22	23
	Stations (all samples)																					
	ECHINODERMATA		1																			
Crinoidea	Bathycrinidae (stalked Crinoid)										2											
Ophiuroidea	Astrotoma agassisi									1												
Ophiuroidea	Amphiuridae sp	1	3	4												1		2			4	
Ophiuroidea	Ophiactis sp					1																
Ophiuroidea	Ophiolepidae sp		5	2							1			2			3	4				
Ophiuroidea	Ophiacantha sp			1																		
Ophiuroidea	*Ophionephtys magellanica*										1					1						
Ophiuroidea	*Ophiozonella falklandica*			4			2	2												3		
Ophiuroidea	*Ophiomitrella falklandica*		2							1								1	2	1	2	
Echinoidea	*Spatangoid sp fragment*						1					1				1						
Holothurioidea	*Psolus sp*									2										1		
Holothurioidea	*Synaptidae sp*									1	1							1				
Holothurioidea	*Myriotrochidae sp (Synaptid)*						1															
	ENTEROPNEUSTA																					
Enteropneusta	Enteropneusta sp.		1						1													
	FORAMINIFERA																					
	Foraminifera sp. B (long white)				2				1			5	1				6					4
	"Snail Foram."				11										9	30	3					
	"egg"				14							4	2			2	5					
	"spiral"										1	21					1					3
	BRACHIOPODA																					
Terebratulida	Brachiopoda sp aff. Terebratulina			2			1							2								
	PISCES																					
	Gobiiform, not id.												1									
	count	**63**	**90**	**100**	**70**	**32**	**70**	**23**	**63**	**22**	**71**	**37**	**41**	**40**	**38**	**58**	**46**	**54**	**55**	**81**	**53**	**34**
	sum	**204**	**319**	**318**	**224**	**60**	**192**	**34**	**137**	**29**	**163**	**96**	**100**	**91**	**115**	**206**	**108**	**112**	**107**	**181**	**137**	**80**
	number or replicate	**2**	**3**	**3**	**3**	**2**	**3**	**1**	**3**	**1**	**3**	**2**	**2**	**2**	**2**	**3**	**2**	**3**	**3**	**3**	**2**	**2**
	sum (m2)	**1020**	**1063**	**1060**	**747**	**300**	**640**	**340**	**457**	**290**	**543**	**480**	**500**	**455**	**575**	**687**	**540**	**373**	**357**	**603**	**685**	**400**

Macrofaunal Matrix

Comment	Species	1	2	3	4	5	6	7*	8	10*	11	12	13	14	15	16	18	19	20	21	22	23
		Stations (duplicate samples except station 7 and 10)																				
	CNIDARIA																					
Ceriantharia	*Ceriantharia sp*		1				1															
Octocorallia	*Pennatulidae sp*						1								9							
Octocorallia	*Melitodes sp*					1																
Scyphozoa	Scyphozoa polyp								2									2	1			
Anthozoa	Aff Gonactinia sp		1																			
Anthozoa	Actinaria sp			1																		
Anthozoa	Edwardsiidae sp.	1	1								1	1		2	1			1				
Anthozoa	Solitary Coral I																	1			1	
Anthozoa	Solitary Coral II (toothed rim)									1												
	NEMERTEA																					
	Nemertea spp.	4	8	5	1	3	4			2	2		2	3	1	2		4	2	1		1
	NEMATODA																					
	Nematoda spp.	81	45	10	3	3	7	2				9	9	3	3	4	1	2	3	1	22	2
	SIPUNCULA																					
Sipunculidea	*Golfingia sp.*	6	2				1				3			1				5	1		2	
	TURBELLARIA																					
Turbellaria	Turbelleraria sp indet.	1																				
	ANNELIDA																					
Polychaeta	Euphrosine sp																	1				
Polychaeta	Dorvilleidae sp		1	4	3				1		1			1		1						
Polychaeta	Polynoidae spp			2	1																	
Polychaeta	cf Eunoe sp										1											
Polychaeta	cf Leanira sp		1	1																	1	
Polychaeta	aff Pholoe	2		2																1		
Polychaeta	*aff. Pisione sp*	1	1			1							5					1	1			
Polychaeta	*Eteone spp*		1	1							3								2	1	1	
Polychaeta	*Mystides sp.*		1	4																		
Polychaeta	*Glycera capitata*	3		1			2	1	1		4						1		3			
Polychaeta	Syllidae sp.	1	2	2			1				1					1		1				
Polychaeta	Pilargiidae sp	1																				
Polychaeta	Ceratocephale sp.		6		1						1	3	4					5	3	1		3
Polychaeta	Nereis sp	1																				
Polychaeta	*Aglaophamus sp.*		1		1	3	1							1	1	1				1	1	
Polychaeta	*Rhamphobranchium ehlersi*	22	17	6	3	2	13	5	15	1	10			20	7	10	8	19	23	5	16	
Polychaeta	*Nothria conchylega*			1			1				1							1	2		1	
Polychaeta	*Aff Scoloplos sp*			1	1	4	2		3	1	3						1			6	3	1
Polychaeta	*Aricidea sp.A*	1	1	1	1		1				1				1	3		1		1		2
Polychaeta	*Aricidea c.f. oculata*	3	5	4	4		5	1	1		2	2		3	11	4			2	1	2	1
Polychaeta	*Aricidea simplex*			2											1	2		4		1		1
Polychaeta	*Aricidea strelzoni*																					
Polychaeta	*Paraonoidae spp.*								1													
Polychaeta	*Levinsenia gracilis*	2	1			1	1	1					4	2					1	1	3	
Polychaeta	*Apistobranchus cf fragmentata*												1			1	1	1			1	
Polychaeta	Spionidae sp.	1																				
Polychaeta	Minuspio sp			3			1			1				1					1			
Polychaeta	*Scolelepis sp.*								1	1				1		2	2					
Polychaeta	*Spiophanes bombyx*								2	1								1		1		1
Polychaeta	*Spiophanes c.f. soederstroemi*			1	1									1			1			3		
Polychaeta	*Laonice spp*								1								1			1		
Polychaeta	*Diplocirrus hirsutus*		1		1				2					1					1	1	1	
Polychaeta	*Flabelligera sp.*																					
Polychaeta	*Pherusa sp*											1										
Polychaeta	*Cossura sp.*			2		1	2											1		2	1	1
Polychaeta	Maldanidae spp.			1	4	2	5		2		4	2	1	3	1	2	2	1	1	1		3
Polychaeta	*Eupraxilella antarctica*				1																	
Polychaeta	*Maldane sarsi subsp*																		2		1	
Polychaeta	*Praxillella bransfieldensis*				1																	1
Polychaeta	*Praxilella c.f. antarctica*				1																	
Polychaeta	*Rhodine cf loveni*			1	2		1									1	1					
Polychaeta	*Spiochaetopterus sp.*	1	2									1	1				1			1	2	
Polychaeta	*Cirratulus sp*	1		1																		
Polychaeta	*Cirriformia sp.*	2	1																	1	1	
Polychaeta	*Caulleriella spp*	5	2	2	5		5	4	1				1	5	1	1	1	1	1	2	2	
Polychaeta	*Chaetozone setosa.*			2	1	1		1				4										
Polychaeta	Tharyx fusiformis								2			2	1									
Polychaeta	Tharyx sp						1				1											
Polychaeta	Macrochaeta sp.																	2			3	
Polychaeta	*Notomastus aff latericeus*				1				1		2			1			3	2				1
Polychaeta	*Travisia sp.*			1												2						
Polychaeta	*Ophelina aff cylindricaudata*				1																	
Polychaeta	*Ophelina nematoides*											1										
Polychaeta	*Ophelina breviata*						1												1			1
Polychaeta	*Ophelia sp*					1																
Polychaeta	*Scalibregma inflatum*			2	1								1		3				2			1
Polychaeta	*Scalibregma sp. II?*																				1	
Polychaeta	*Sternaspis sp*																					
Polychaeta	*Ampharetinae spp*	1	3	5							2	3		2		2		3		2	3	1
Polychaeta	*Samytha sp*						2											1				
Polychaeta	*Amage sp.*	2		1					2		1				1		1					
Polychaeta	*Melinna c.f.cristata*			1			2						2	1								
Polychaeta	*Streblosoma sp*						4							1						1	1	
Polychaeta	*Pista sp.*																					
Polychaeta	*Terebellides stroemi*	2				1	3	1			1			1	1				1		2	
Polychaeta	Terebellidae fragment	1	1	2					1	1		1					1	1				
Polychaeta	Perkinsiniana antarc tica	1		4										1						1		
Polychaeta	Sabella sp	1									3								1	1	2	
Polychaeta	Sabellidae frag.	1		1								2									1	
Polychaeta	Fabricinidae sp.																					
Polychaeta	*Fabricola / Pseudofabricia sp*						1						1						1			
Polychaeta	*Jasmineira sp*	1		2					1		4						1	4	2	1		
Polychaeta	*Chone sp*		3	7							2				1					5	3	
Polychaeta	*Euchone pallida*	4	1	10							1							2		1		
Oligochaeta	Oligochaeta Tubificidae	1	4	4		5	3					1	3	4		2			1	7	9	
Polychaeta	Serpulidae			1					1													
Polychaeta	*Phylo felix*		1		1							1		2			2		2	6	1	
Polychaeta	*Lumbrineris c.f.antarctica*		1				1		1		2		1	1				1	4	1	1	
Polychaeta	*Ninoe c.f. falklandica*												1									
Polychaeta	*Galathowenia sp*	3	1	1	2	2	1		1	1		2	8	3	1	1	1	1	3		1	8
Polychaeta	*Myriowenia cf. californicensis*																					
Polychaeta	*Polygordius sp.*			1		2								1			3					
Polychaeta	*Sphaerodorum sp I*		1	1	1		2										2		3	1		
Polychaeta	*Sphaerodorum sp II*																					
Polychaeta	*c.f. Fauvelia?*																		2			
Pogonophora	*Siboglinum sp*		4									1										
Pogonophora	*Pogonophora sp*		1																			

Macrofaunal Matrix

Comment	Species	1	2	3	4	5	6	7*	8	10*	11	12	13	14	15	16	18	19	20	21	22	23
		Stations (duplicate samples except station 7 and 10)																				
	CRUSTACEA																					
Cephalocarida	Cephalocarida sp?									1												
Cirripedia	Scalpellum sp.	1		4														2	1		3	
Cirripedia	Verruca sp		1	1							1							1			4	
Ostracoda	Ostracoda spp.	3	3	2	33	4	7	2	9		4	1		1	16	19	14	5	3	2	5	1
Copepoda	Copepoda indet	2		2	1		1												1	1	2	
Amphipoda	*Phtisica ap*	1	5				1									1						
Amphipoda	*Amphipoda sp. A*			2															1			
Amphipoda	Stenothoidae sp I	3	2	4		1	1	1					1		4			2		1		
Amphipoda	Stenothoidae sp II (wide rostrum)	4	1										2									
Amphipoda	Stegocephalidae			2							1			1								
Amphipoda	aff Apherusa														1							
Amphipoda	*Urothoe sp.*	1	1	5	13		3	1			3	3	4	2	7	5	5	1	1			11
Amphipoda	Podoceridae																					
Amphipoda	Phoxocephaloidae sp. A																					
Amphipoda	Phoxocephaloidea sp. B																					
Amphipoda	Phoxocephaloidea sp.C (eyeless)	1	1	1	4	5	1		1		1	3	3		10	6	3	1	5	3	5	9
Amphipoda	Phoxocephalus sp eyeles, notched	3	1								3						2	1	1	2	1	
Amphipoda	Metaphoxus																					
Amphipoda	*Maera sp.*	1	21	9		1	2		2		4	1	1			2	3		2		1	1
Amphipoda	*Leucothoidae*			2			2								1							
Amphipoda	*Aff. Dexamine*		1																			
Amphipoda	*aff. Melitidae*																					
Amphipoda	*Acanthozone sp*	1																				
Amphipoda	*Didymochelia spp*		3	1				1							1			1		1		
Amphipoda	Lysianassoidea sp. C	1							1		1					1						
Amphipoda	Lysianassoidea sp. D				2				1			2	1									
Amphipoda	Lysianassoidea sp. F				1						3					1		1		1		
Amphipoda	Lysianassoidea sp. G	1				1		1	1		3			1	1							1
Amphipoda	*Ampelisca sp. A*			1	1														1			
Amphipoda	*Ampelisca sp. B*															1		1		2		1
Amphipoda	*Ampelisca sp. C*	3		1			3		1		1			8					1	1		
Amphipoda	*Ampelisca sp. D*								2													
Amphipoda	*Ampelicca sp. E*												1									
Amphipoda	Amphilochidae sp A																					
Amphipoda	Photis sp		1	5			1												1	2		
Amphipoda	aff. Leptocheirus	2	5																	1		
Amphipoda	Paradeliscidae sp		4							5									1	1	1	
Amphipoda	*aff. Dulichia*	1	1	5	1						2									1	1	
Amphipoda	*aff Laetmatophilus sp*																					
Amphipoda	*aff Laetmatophilus sp II*																					
Amphipoda	*aff Xerodice sp*																					
Isopoda	*Gnathia praniza*	1		1																		
Isopoda	*Ilyarachna sp*			1				1							1		1	2	1			
Isopoda	*Eurycope sp*		1												1							
Isopoda	*Munna c.f. argentinae*			2												1						
Isopoda	*Macrostylis sp*		1		1		1		4		1		2	1			1		1	2		
Isopoda	*Nannoniscus sp*	1	2	1							3				1					1		1
Isopoda	*Haploniscus sp*											1	5		1							
Isopoda	*Ischnomesus sp*	1							1				1		1							
Isopoda	*Haplomesus c.f. insignis*											1	2	1								
Isopoda	*Heteromesus sp.*			1										2						1		
Isopoda	*Stylomesus sp*												1								1	
Isopoda	*Desmosoma sp*			1			1				1								1	1	1	
Isopoda	*Janirella sp. (abyssorum?)*	1							1													
Isopoda	*Janirella sp.II*			3																		
Isopoda	*Spinianirella sp.*			4																		
Isopoda	*Abyssinaria sp.*			2														1				
Isopoda	*Dynamenella sp*			1																		
Isopoda	*Cirolana sp.*		1	1			1								1							
Isopoda	*Cirolana sp II*																				1	
Isopoda	*Eurydice sp*															4	1					
Isopoda	*Pseudanthura lateralis*	2	3	2		2	1					2	1			1	1	1				
Isopoda	*Antarctura sp*																		1			
Isopoda	*Serolis sp I*	1																				
Isopoda	*Serolis sp II*		1																			
Tanaidacea	*Tanaidae sp A*		2				3		1			1						1		2	1	1
Tanaidacea	*Tanaidae sp B*		3	1	3	2					1							1	1	1	1	
Tanaidacea	*Tanaidae sp C*																					1
Tanaidacea	*Tanaidae sp D*		3	1					1				2					1			2	1
Tanaidacea	*Tanaidae sp E long body*	1	1				1	1			1	1	1									
Tanaidacea	*Archaeotanais hirsutus*								1									1		2	1	
Tanaidacea	*Tanaidae sp E*															1						
Tanaidacea	*Tanaidae sp (Apseudidae)*	1		1	1							4	9				1	1	1			5
Tanaidacea	*Tanaidae sp (Apseudidae)II*																	1				
Cumacea	*Eudorella sp.*				1														1			2
Cumacea	*Leucon sp.*					1		1	1			2		1					1		2	1
Cumacea	Bodotriidae sp				3																1	
Cumacea	aff. Iphinoe												3									
Cumacea	Diastylidae sp A	1						1				1		1			1			2		
Cumacea	*Campylaspis spp.*					1	1												1			
Eupausiacea	Euphausiacea		1									1										
	PYGNOGONIDA																					
	Anoplodactylidae sp	1	1																			
	MOLLUSCA																					
Caudofoveata	Caudofoveata			2																		
Solenogastres	Solenogastres	1	1							1	1					1	1			2		
Scaphopoda	Scaphopoda sp.	1			2	1	1		1	1	2						1					1
Scaphopoda	aff. Cadulus			1											1		1					
Gastropoda	Caecum sp.				2																	
Gastropoda	Oenopota sp								1								1					
Gastropoda	Skenea I				1			1									1			1		
Gastropoda	Skenea II															1	1					
Gastropoda	Eulima sp			3																		
Gastropoda	*Polinices sp.high*												1									
Gastropoda	*Polinices sp.flat*																1	1				
Gastropoda	*Fusitronica sp I*							1											1			
Gastropoda	*Fusitronica sp II*									1										1		
Gastropoda	*Mitra/Vexilla sp*	1		1										1								
Gastropoda	*Marginellidae sp.*	1																				
Gastropoda	*Retusa sp*																		1			
Bivalvia	Dacrydium sp.		1	1			2		1	1	1							4	1	1	2	
Bivalvia	*Yoldiella / Ledella*	1			2	1							3				6					1
Bivalvia	*aff. Bathyarca*		3												1						3	
Bivalvia	*Pecten sp.(Similipecten?)*			1		1	7		1	2	3			1				3	1	3		
Bivalvia	*Lima sp*																					
Bivalvia	*Mysella spp*					3	5			1	1				3					3		
Bivalvia	*Cardiidae sp*																					
Bivalvia	*Veneridae spp*			4				1							2					1		
Bivalvia	*Mactra sp*				6				2			1	3			2	7			2	2	
Bivalvia	*Mactra sp II, round*				1			2							3							
Bivalvia	*aff. Diplodonta sp*				1								3			9	2					
Bivalvia	*Aff. Mya*			1																		
Bivalvia	*Thracia c.f.meridonalis*																					
Bivalvia	*Cuspidaria sp.*			1			1		2	1												
Bivalvia	*Poromya sp*								1						1							
Bivalvia	*aff. Axinulus*			2			1									4						6
Bivalvia	*aff. Thyasira*		1			1		1				3			4							
Bivalvia	*Bivalve dam.*					1																

Macrofaunal Matrix

Comment	Species	1	2	3	4	5	6	7*	8	10*	11	12	13	14	15	16	18	19	20	21	22	23
	Stations (duplicate samples except station 7 and 10)																					
	ECHINODERMATA		1																			
Crinoidea	Bathycrinidae (stalked Crinoid)										2											
Ophiuroidea	Astrotoma agassisi									1												
Ophiuroidea	Amphiuridae sp	1	1	4														2			4	
Ophiuroidea	Ophiactis sp					1																
Ophiuroidea	Ophiolepidae sp		4	1							1			2			3	4				
Ophiuroidea	Ophiacantha sp			1																		
Ophiuroidea	*Ophionephtys magellanica*																					
Ophiuroidea	*Ophiozonella falklandica*			1				2												2		
Ophiuroidea	*Ophiomitrella falklandica*		1							1								1	2		2	
Echinoidea	*Spatangoid sp fragment*						1					1				1						
Holothurioidea	*Psolus sp*									2												
Holothurioidea	*Synaptidae sp*									1								1				
Holothurioidea	*Myriotrochidae sp (Synaptid)*						1															
	ENTEROPNEUSTA																					
Enteropneusta	Enteropneusta sp.								1													
	FORAMINIFERA																					
	Foraminifera sp. B (long white)				2				1			5	1				6					4
	"Snail Foram."				7										9	19	3					
	"egg"				8							4	2			2	5					
	"spiral"										1	21					1					3
	BRACHIOPODA																					
Terebratulida	Brachiopoda sp aff. Terebratulina			1			1							2								
	PISCES																					
	Gobiiform, not id.												1									
	count	75	81	109	60	41	69	23	52	22	64	46	50	51	47	52	52	63	67	72	67	40
	sum	204	207	200	140	60	127	34	82	29	103	96	100	91	115	124	108	112	107	108	137	80
	number or replicate																					
	sum (m2)																					

* = single replicate sample only

		1A	1B	R2A	R2B	R2C	L3A	L3B	L3C	4 C	4A	4 D	L5A	L5B	6vvA	6vvB	6vvC	L7A	S8 A	S8 B	S8 C	S10A
	CNIDARIA																					
Hydroidea	*Eudendrium sp.*																					
Hydroidea	*Lafoea sp*								P													
Hydroidea	*Campanularia sp.I*																					
Hydroidea	*Campanularia sp.II*	P		P																		
Hydroidea	*Lovenella sp*																					P
Hydroidea	*Sertularella sp*			P																		P
Hydroidea	*Aglaophenia sp*																					
Octocorallia	*aff. Sarcodictyum*														P		P	P				
Octocorallia	*cf Pleurocoralloides sp*							2														P
Octocorallia	*Callozostron carlottae*		P		P		2															P
Octocorallia	*Stachyodes sp.*		P																			
Octocorallia	*Gorgonaria spp*		P																			
Anthozoa	Lophelia (live)		P																			
Anthozoa	Lophelia (dead)		P		P	P																
	PTEROBRANCHIA																					
Pterobranchia	Rhabdopleura sp.		P			P			P													
Pterobranchia	c.f. Pterobranchia																					
Pterobranchia	Discorhabdus																					
	CHORDATA																					
Tunicata	*Eugyra sp.*									1												
	PORIFERA																					
Hexactinelida	Hexactinella frag.				P													1				
Hexactinelida	Hexactinella juv.																					
Tetractinomorpha	Tetilla sp.							P														
Lithistida	Gastropharella sp (Lithistida)																					P
Hadromerida	Suberites sp					P			P													P
Hadromerida	Quasilina sp													P			P					
Ceractinomorpha	Eurypon	P					P						P									
Ceractinomorpha	Eurypon sp II				P												P					
Ceractinomorpha	Halicnemia sp						P	P														
Ceractinomorpha	Tentorium sp.					P	P	P	P													
Ceractinomorpha	aff. Ulosa sp		P					P														
Ceractinomorpha	Asbestopluma sp.	P			P	P			P													P
Ceractinomorpha	Inflatella sp.							P														
Ceractinomorpha	Crella sp I						P															
Ceractinomorpha	Mycale sp.								P													
Ceractinomorpha	Isodictya sp	P																				
Ceractinomorpha	Antho sp.								P													
Ceractinomorpha	Crella sp II						P															
Ceractinomorpha	Plocamia sp			P																		
Ceractinomorpha	Microcionidae sp I																					
Ceractinomorpha	Microcionidae sp II			P																		
Ceractinomorpha	Axinellidae sp													P								
Ceractinomorpha	Halichondria sp								P													
Ceractinomorpha	Halichondria sp II							P														

		1A	1B	R2A	R2B	R2C	L3A	L3B	L3C	4 C	4A	4 D	L5A	L5B	6vvA	6vvB	6vvC	L7A	S8 A	S8 B	S8 C	S10A
	BRYOZOA																					
Cyclostomata	Crisia sp																					
Cyclostomata	Tubulipora sp							P														
Cyclostomata	Annectocyma sp			P											P							
Cyclostomata	aff. Idmidronea															P						
Cyclostomata	Hornera I					P	P		P								P					P
Cyclostomata	Hornera II						P		P													
Cyclostomata	Disporella sp							P														
Cyclostomata	Stomatopora sp	P	P		P		P		P						P	P	P					
Cheilostomata	Isosemiflustra sp												P									
Cheilostomata	Callopora "antler"					P		P						P	P		P					
Cheilostomata	Amphiblestrum sp																					
Cheilostomata	Caberea sp		P				P		P													
Cheilostomata	Notoplites sp.																			P		
Cheilostomata	Carbasea sp					P																
Cheilostomata	Cellaria sp. I	P												P	P							P
Cheilostomata	Cellaria sp. II	P				P		P														P
Cheilostomata	Cellarinella sp						P		P													
Cheilostomata	Bugulella sp	P	P										P	P		P	P					P
Cheilostomata	*Dendroperistomata projecta*																					
Cheilostomata	Cornucopina sp						P															
Cheilostomata	Smittoidea sp																P					
Cheilostomata	Escharoides sp																					
Cheilostomata	Escharella sp														P	P						
Cheilostomata	Escharella sp II																					P
Cheilostomata	aff Schizomavella						P															
Cheilostomata	Schizosomella sp								P													
Cheilostomata	Escharina sp				P	P																
Cheilostomata	Fenestrulina sp				P																	
Cheilostomata	Hippothoa sp														P	P	P					
Cheilostomata	Plesiothoa sp			P																		
Cheilostomata	Aff. Cellepora												P									
Cheilostomata	Stombypselosarnia sp																					P
Cheilostomata	Rhynchozoon fistulosum				P																	P
Cheilostomata	Icelozoon sp																					
Cheilostomata	Osthimosia sp			P																		
Ctenostomata	aff. Metalcyonidium														P		P					
Ctenostomata	aff Vesicularia																					P
Ctenostomata	Aff Walkeria sp																					
	BRACHIOPODA																					
Terebratulida	Brachiopoda sp aff. Terebratulina							1	1						1							
	PISCES																					
	Gobiiform, not id.																					

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		S11A	S11B	S11C	L12A	L12B	L13A	L13B	R14A	R14B	15A	15C	R16A	R16B	R16C	18 A	18 B	S19A	S19B	S20A	S20B	21A	21B	21C	S22A	S22B	L23A	L23B
	CNIDARIA																											
Hydroidea	*Eudendrium sp.*															P												
Hydroidea	*Lafoea sp*	P																										
Hydroidea	*Campanularia sp.I*																											
Hydroidea	*Campanularia sp.II*																											
Hydroidea	*Lovenella sp*																											
Hydroidea	*Sertularella sp*																											
Hydroidea	*Aglaophenia sp*		P																									
Octocorallia	*aff. Sarcodictyum*																											
Octocorallia	*cf Pleurocoralloides sp*																											
Octocorallia	*Callozostron carlottae*																				1							
Octocorallia	*Stachyodes sp.*																											
Octocorallia	*Gorgonaria spp*											1		1														
Anthozoa	Lophelia (live)																											
Anthozoa	Lophelia (dead)																											
	PTEROBRANCHIA																											
Pterobranchia	Rhabdopleura sp.	P	P	P						P								P	P	P	P			P				
Pterobranchia	c.f. Pterobranchia																			P								
Pterobranchia	Discorhabdus																				P							
	CHORDATA																											
Tunicata	*Eugyra sp.*																											
	PORIFERA																											
Hexactinelida	Hexactinella frag.															1												
Hexactinelida	Hexactinella juv.															1												
Tetractinomorpha	Tetilla sp.																											
Lithistida	Gastropharella sp (Lithistida)																											
Hadromerida	Suberites sp																											
Hadromerida	Quasilina sp																											
Ceractinomorpha	Eurypon																											
Ceractinomorpha	Eurypon sp II																		P									
Ceractinomorpha	Halicnemia sp																											
Ceractinomorpha	Tentorium sp.																											
Ceractinomorpha	aff. Ulosa sp																											
Ceractinomorpha	Asbestopluma sp.																	P	P					P				
Ceractinomorpha	Inflatella sp.																											
Ceractinomorpha	Crella sp I																											
Ceractinomorpha	Mycale sp.																											
Ceractinomorpha	Isodictya sp																											
Ceractinomorpha	Antho sp.																											
Ceractinomorpha	Crella sp II																											
Ceractinomorpha	Plocamia sp																											
Ceractinomorpha	Microcionidae sp I																		P									
Ceractinomorpha	Microcionidae sp II																											
Ceractinomorpha	Axinellidae sp																											
Ceractinomorpha	Halichondria sp																											
Ceractinomorpha	Halichondria sp II																											

		S11A	S11B	S11C	L12A	L12B	L13A	L13B	R14A	R14B	15A	15C	R16A	R16B	R16C	18 A	18 B	S19A	S19B	S20A	S20B	21A	21B	21C	S22A	S22B	L23A	L23B
	BRYOZOA																											
Cyclostomata	Crisia sp																			P								
Cyclostomata	Tubulipora sp																											
Cyclostomata	Annectocyma sp																											
Cyclostomata	aff. Idmidronea																											
Cyclostomata	Hornera I																											
Cyclostomata	Hornera II																											
Cyclostomata	Disporella sp																											
Cyclostomata	Stomatopora sp								P	1										P	P			P				
Cheilostomata	Isosemiflustra sp																											
Cheilostomata	Callopora "antler"																											
Cheilostomata	Amphiblestrum sp																							P				
Cheilostomata	Caberea sp																											
Cheilostomata	Notoplites sp.																											
Cheilostomata	Carbasea sp																											
Cheilostomata	Cellaria sp. I																							P				
Cheilostomata	Cellaria sp. II																				P							
Cheilostomata	Cellarinella sp																											
Cheilostomata	Bugulella sp	P		P																P								
Cheilostomata	*Dendroperistomata projecta*													P														
Cheilostomata	Cornucopina sp																											
Cheilostomata	Smittoidea sp																											
Cheilostomata	Escharoides sp																	P	P									
Cheilostomata	Escharella sp																									P		
Cheilostomata	Escharella sp II																											
Cheilostomata	aff Schizomavella																											
Cheilostomata	Schizosomella sp																											
Cheilostomata	Escharina sp																											
Cheilostomata	Fenestrulina sp																											
Cheilostomata	Hippothoa sp								P																			
Cheilostomata	Plesiothoa sp																											
Cheilostomata	Aff. Cellepora																											
Cheilostomata	Stombypselosarnia sp																											
Cheilostomata	Rhynchozoon fistulosum																											
Cheilostomata	Icelozoon sp	P	P	P																					P			
Cheilostomata	Osthimosia sp																									P		
Ctenostomata	aff. Metalcyonidium																			P			P					
Ctenostomata	aff Vesicularia																											
Ctenostomata	Aff Walkeria sp									P													P	P				
	BRACHIOPODA																											
Terebratulida	Brachiopoda sp aff. Terebratulina								1	1																		
	PISCES																											
	Gobiiform, not id.						1																					

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		1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	20	21	22	23
	CNIDARIA																					
Hydroidea	*Eudendrium sp.*																P					
Hydroidea	*Lafoea sp*			P							P											
Hydroidea	*Campanularia sp.I*																					
Hydroidea	*Campanularia sp.II*	P	P																			
Hydroidea	*Lovenella sp*									P												
Hydroidea	*Sertularella sp*		P							P												
Hydroidea	*Aglaophenia sp*										P											
Octocorallia	*aff. Sarcodictyum*						P	P														
Octocorallia	*cf Pleurocoralloides sp*			P						P												
Octocorallia	*Callozostron carlottae*	P	P	P						P									P			
Octocorallia	*Stachyodes sp.*	P																				
Octocorallia	*Gorgonaria spp*	P													P	P						
Anthozoa	Lophelia (live)	P																				
Anthozoa	Lophelia (dead)	P	P																			
	PTEROBRANCHIA																					
Pterobranchia	Rhabdopleura sp.	P	P	P							P			P				P	P	P		
Pterobranchia	c.f. Pterobranchia																		P			
Pterobranchia	Discorhabdus																		P			
	CHORDATA																					
Tunicata	*Eugyra sp.*				P																	
	PORIFERA																					
Hexactinelida	Hexactinella frag.		P					P									P					
Hexactinelida	Hexactinella juv.																P					
Tetractinomorpha	Tetilla sp.			P																		
Lithistida	Gastropharella sp (Lithistida)									P												
Hadromerida	Suberites sp		P	P						P												
Hadromerida	Quasilina sp					P	P															
Ceractinomorpha	Eurypon	P		P		P																
Ceractinomorpha	Eurypon sp II		P				P											P				
Ceractinomorpha	Halicnemia sp			P																		
Ceractinomorpha	Tentorium sp.		P	P																		
Ceractinomorpha	aff. Ulosa sp	P		P																		
Ceractinomorpha	Asbestopluma sp.	P	P	P						P								P		P		
Ceractinomorpha	Inflatella sp.			P																		
Ceractinomorpha	Crella sp I			P																		
Ceractinomorpha	Mycale sp.			P																		
Ceractinomorpha	Isodictya sp	P																				
Ceractinomorpha	Antho sp.			P																		
Ceractinomorpha	Crella sp II			P																		
Ceractinomorpha	Plocamia sp		P																			
Ceractinomorpha	Microcionidae sp I																	P				
Ceractinomorpha	Microcionidae sp II		P																			
Ceractinomorpha	Axinellidae sp					P																
Ceractinomorpha	Halichondria sp			P																		
Ceractinomorpha	Halichondria sp II			P																		

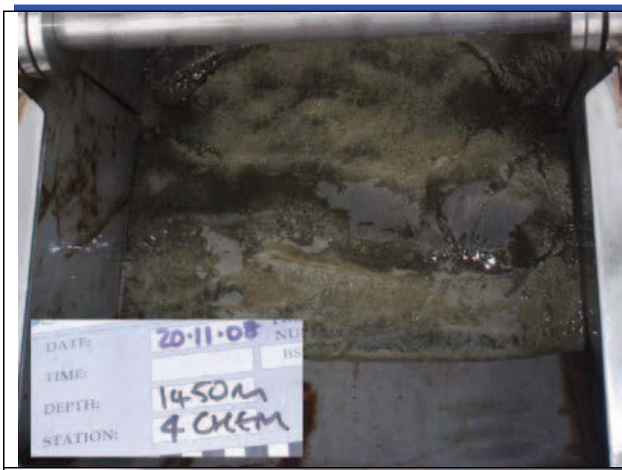
		1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	20	21	22	23
	BRYOZOA																					
Cyclostomata	Crisia sp																		P			
Cyclostomata	Tubulipora sp			P																		
Cyclostomata	Annectocyma sp		P				P															
Cyclostomata	aff. Idmidronea						P															
Cyclostomata	Hornera I		P	P			P			P												
Cyclostomata	Hornera II			P																		
Cyclostomata	Disporella sp			P																		
Cyclostomata	Stomatopora sp	P	P	P			P							P					P	P		
Cheilostomata	Isosemiflustra sp					P																
Cheilostomata	Callopora "antler"		P	P		P	P															
Cheilostomata	Amphiblestrum sp																			P		
Cheilostomata	Caberea sp	P		P																		
Cheilostomata	Notoplites sp.								P													
Cheilostomata	Carbasea sp		P																			
Cheilostomata	Cellaria sp. I	P				P	P			P										P		
Cheilostomata	Cellaria sp. II	P	P	P						P									P			
Cheilostomata	Cellarinella sp			P																		
Cheilostomata	Bugulella sp	P				P	P			P	P								P			
Cheilostomata	*Dendroperistomata projecta*															P						
Cheilostomata	Cornucopina sp			P																		
Cheilostomata	Smittoidea sp						P															
Cheilostomata	Escharoides sp																	P				
Cheilostomata	Escharella sp						P														P	
Cheilostomata	Escharella sp II									P												
Cheilostomata	aff Schizomavella			P																		
Cheilostomata	Schizosomella sp			P																		
Cheilostomata	Escharina sp		P																			
Cheilostomata	Fenestrulina sp		P																			
Cheilostomata	Hippothoa sp						P							P								
Cheilostomata	Plesiothoa sp		P																			
Cheilostomata	Aff. Cellepora					P																
Cheilostomata	Stombypselosarnia sp									P												
Cheilostomata	Rhynchozoon fistulosum		P							P												
Cheilostomata	Icelozoon sp										P										P	
Cheilostomata	Osthimosia sp		P																		P	
Ctenostomata	aff. Metalcyonidium						P												P	P		
Ctenostomata	aff Vesicularia									P												
Ctenostomata	Aff Walkeria sp													P						P		
	BRACHIOPODA																					
Terebratulida	Brachiopoda sp aff. Terebratulina			P			P							P								
	PISCES																					
	Gobiiform, not id.												P									
340 Taxa		16	23	31	1	8	15	2	1	15	5	0	1	5	1	2	3	5	9	7	3	0

APPENDIX VI: Sample Photograph

Station 1

Station 2

Station 3



Station 4

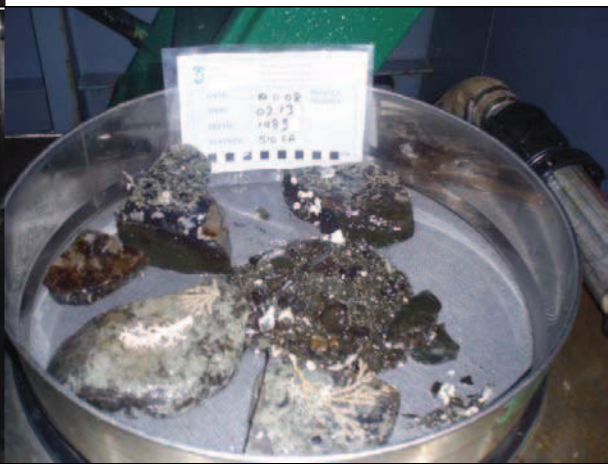
Station 5

Station 6

Station 7

Station 8

Station 9



Station 10

Station 11

Station 12

Station 13

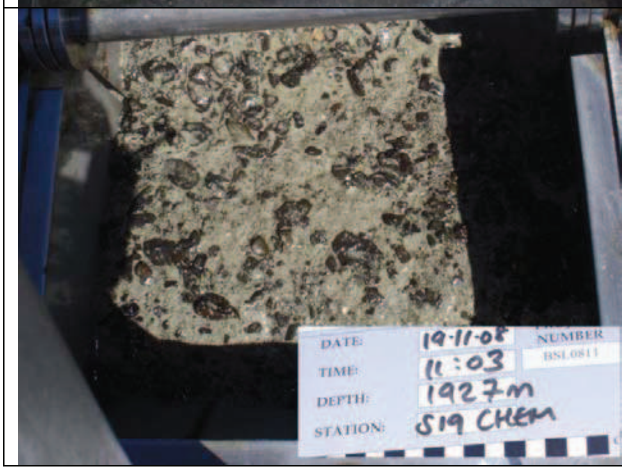
Station 14

Station 15

Station 16

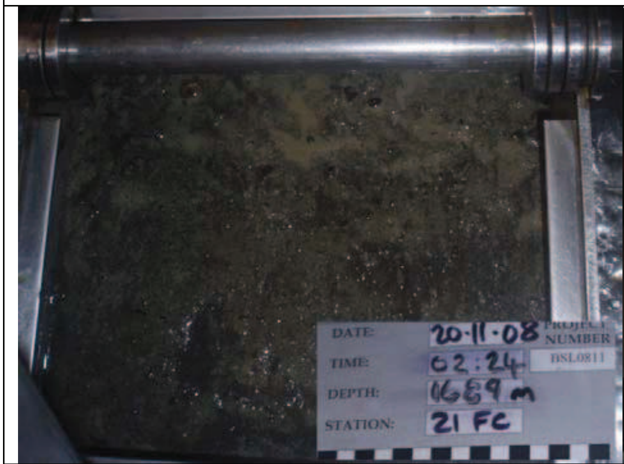
Station 17

Station 18



Station 19

Station 20



Station 21

Station 22

Station 23

		False Target

Additional Faunal and Sediment photographs

	Station 1 Epifauna
	Bedrock broken from the seabed at station 17
	Stations 10 close-up of epiafuna

APPENDIX VII: Pearson's Multivariate Correlations

Pearson Product Moment Correlation Coefficient	% Gravel	Coarse sands	Medum Sands	Fine sands	Silts	Clays	% Fines	Mean (mm)	Median (m)	Phi	Median (Phi)	Sorting	Skewness	Kurtosis	Total Organics	Organic Carbon	Inorganic Carbon	Moisture (%)	As-HF	Al-HF	Ba-HF	Cr-HF	Cu-HF	Fe-HF	Ni-HF	Pb-HF	Sr-HF	V-HF	Zn-HF
0811-1	20.18	24.55	25.43	21.07	7.80	0.97	8.8	0.564	0.437	0.83	1.19	2.36	-0.10	1.30	4.28	0.31	1.73	32.6	22.1	35200	460	38.7	13.8	99700	10.9	11	263	66.3	71.4
0811-R2	7.85	27.66	26.83	21.77	13.38	2.51	15.9	0.276	0.351	1.86	1.51	2.26	0.29	1.58	3.38	0.22	3.73	31.9	12.8	21200	1240	34.1	14	71000	7.2	6.6	479	56.2	58.3
0811-3	26.25	10.82	15.49	26.57	17.53	3.34	20.9	0.328	0.282	1.61	1.83	3.23	-0.01	0.91	3.69	0.32	2.49	27.2	20.2	41900	494	35.7	16.1	76900	12.1	13.7	228	73.7	64.8
0811-L4	0.18	0.01	7.23	73.90	17.26	1.42	18.7	0.109	0.116	3.19	3.11	1.21	0.29	1.63	2.57	0.26	1.5	27.6	7.1	34800	2420	46	11.4	41300	7	6.5	288	56.6	55.5
0811-L5	3.72	5.30	10.85	41.57	32.42	6.14	38.6	0.068	0.093	3.89	3.42	2.52	0.21	1.15	3.45	0.18	2.7	34.1	7	41200	520	40.8	15.2	56200	7.6	8.1	329	54.9	53.6
0811-6	10.33	6.64	17.84	40.93	20.52	3.75	24.3	0.128	0.167	2.97	2.58	2.59	0.16	1.63	3.97	0.33	2.37	31.2	12.1	36200	560	54	14.3	78700	8.9	7.6	300	55.3	70.2
0811-L7	18.35	0.66	7.93	49.95	19.74	3.37	23.1	0.276	0.130	1.86	2.95	3.27	-0.31	2.05	2.71	0.27	1.97	33.3	4.8	43500	637	39.2	13.5	43300	7.1	8.8	280	53	46.3
0811-S8	3.23	0.13	11.24	60.11	21.67	3.62	25.3	0.093	0.120	3.43	3.06	1.75	0.39	1.55	3.08	0.22	1.76	35.6	6.5	42000	698	55.9	13.1	60400	8.9	7.1	296	58.1	58.4
0811-S10	3.29	13.27	31.49	31.91	16.99	3.05	20.0	0.169	0.240	2.56	2.06	2.03	0.43	1.43	4.24	0.4	2.29	28.7	9	32200	952	44.4	15.9	76900	9.4	7.7	330	47.9	65.6
0811-S11	13.06	6.57	21.08	38.30	17.93	3.05	21.0	0.172	0.197	2.54	2.34	2.51	0.08	1.71	3.95	0.23	2.14	27.8	7	35600	437	61	14.4	71900	9.2	6.8	239	63.1	57.2
0811-L12	0.00	0.62	3.55	36.10	51.65	8.09	59.7	0.036	0.048	4.79	4.38	1.98	0.32	1.01	3.09	0.46	1.97	39.7	4.3	48000	602	30.1	13.9	29000	7.4	20.6	279	56.2	73
0811-L13	0.00	0.19	2.96	29.59	59.46	7.81	67.3	0.031	0.036	4.99	4.80	1.93	0.18	0.97	3.55	0.51	2.12	45.1	28	50500	265	57.8	16.5	30900	8.8	7.9	120	55.6	49.4
0811-R14	9.53	2.55	12.75	28.58	37.54	9.04	46.6	0.061	0.078	4.03	3.67	3.07	0.08	1.08	4.43	0.35	1.56	31	14.9	40000	493	66.6	17.1	82500	9.1	8	235	80.8	66.2
0811-15	0.00	0.00	2.98	64.60	28.16	4.26	32.4	0.063	0.091	3.98	3.46	1.70	0.50	1.45	3	0.36	1.7	31.4	3.9	53400	659	32.1	9	39600	7.3	7.4	249	57.8	49.3
0811-R16	0.13	0.00	6.43	71.36	19.77	2.31	22.1	0.101	0.111	3.31	3.18	1.31	0.34	1.64	2.52	0.29	1.48	27.8	4.9	52000	631	34.7	12.1	39200	6.8	8.7	241	59.1	60.1
0811-L17	2.62	13.14	30.03	40.41	12.80	1.01	13.8	0.202	0.229	2.31	2.13	1.60	0.27	1.31	2.64	0.21	1.39	27.4	11.4	42900	2320	39.7	11.4	64800	7.6	8.4	264	62.9	65.3
0811-18	0.00	0.00	16.44	69.39	12.19	1.98	14.2	0.138	0.150	2.86	2.73	1.26	0.37	1.77	2.83	0.24	1.51	30.2	7.8	48500	741	45.6	11.4	56500	7.1	7.9	243	58.6	61.4
0811-19	5.28	39.83	18.25	21.03	13.10	2.50	15.6	0.335	0.427	1.58	1.23	2.31	0.34	1.18	3.76	0.31	3.6	26.3	7.3	46900	701	35.1	16	54800	9.8	9.5	296	62.8	56.4
0811-20BC	15.30	3.61	16.44	43.67	17.92	3.05	21.0	0.180	0.171	2.48	2.55	2.63	-0.06	1.91	3.63	0.23	2.46	30.1	7.2	37000	545	48.8	15.6	56800	9	7.1	329	57.2	54.1
0811-R21	4.18	0.83	10.60	48.86	31.16	4.37	35.5	0.070	0.101	3.83	3.31	2.07	0.35	1.06	3.75	0.31	1.73	34.5	6	37200	619	60	20	54800	8	10	406	50	60
0811-S22	4.88	17.51	16.06	19.50	35.39	6.66	42.1	0.093	0.116	3.42	3.11	2.93	0.14	0.86	4.58	0.32	1.37	33.3	9	35100	638	50	20	69100	8	8	221	60	70
0811-23	0.00	0.35	3.05	17.63	69.20	9.78	79.0	0.024	0.026	5.41	5.25	1.88	0.15	1.07	3.9	0.6	1.99	33	2	39800	568	30	20	21700	8	10	278	60	60
% Gravel								0.706	0.504			0.765												0.600	0.680				
Coarse sands			0.645					0.690	0.874								0.614							0.495					
Medum Sands								0.589	0.741															0.781					
Fine sands														0.571															
Silts						0.926	0.999			0.885	0.906					0.796		0.683					0.505						
Clays							0.944			0.806	0.807					0.684		0.601					0.580						
% Fines										0.882	0.901					0.787		0.677					0.520						
Mean (mm)									0.904															0.599	0.550				
Median (m)																	0.528							0.638	0.530				
Phi											0.952					0.599		0.592											
Median (Phi)																0.626		0.633											
Sorting															0.579								0.477	0.448	0.499				
Skewness																													
Kurtosis																													
Total Organics																							0.723	0.552	0.609				0.435
Organic Carbon																		0.460					0.423						
Inorganic Carbon																											0.500		
Moisture (%)																													
As-HF																								0.435	0.581				
Al-HF																													
Ba-HF																													
Cr-HF																													
Cu-HF																													
Fe-HF																									0.595				0.497
Ni-HF																												0.499	
Pb-HF																													0.468
Sr-HF																													
V-HF																													
Zn-HF																													
PAH (2-6 ring)																													
NPD PAH fraction																													
NPD / 4-6 ringratio																													
Parent/PAH																													
Total Oil (ug/kg)																													
Total n alkanes																													
CPI (10-37)																													
Pristane																													
Phytane																													
Pr/Ph Ratio																													
%alkanes																													
PB ratio																													
Richness																													
Abundance																													
Richness																													
Evenness																													
Diversity																													
Dominance																													
Water Depth																													

Significant Correlations $P<0.05$ (>0.423)

Significant Correlations $P<0.01$ (>0.537)

Pearson Product Moment Correlation Coefficient	PAH (2-6 ring)	NPD PAH fraction	NPD / 4-6 ringratio	Parent/PAH	Total Oil (ug/kg)	Total n alkanes	CPI (10-37)	Pristane	Phytane	Pr/Ph Ratio	%alkanes	PB ratio	Richness	Abundance	Richness	Evenness	Diversity	Dominance	Water Depth
0811-1	227.9	135.8	1.47	18.6%	10745	1052	1.06	199.4	49.3	4.04	9.8%	1.17	63	204	11.66	0.6997	4.182	0.8289	1500
0811-R2	178.3	99.0	1.25	19.7%	9138	801	1.08	144.4	35.6	4.05	8.8%	1.03	88	314	15.13	0.8095	5.229	0.9426	1290
0811-3	244.8	142.3	1.39	21.1%	12763	1135	1.01	179.3	42.4	4.23	8.9%	1.20	100	318	17.18	0.923	6.132	0.9837	1250
0811-L4	240.9	127.3	1.12	19.7%	10744	1090	1.04	234.9	45.5	5.16	10.1%	1.45	70	224	12.75	0.8104	4.967	0.9265	1450
0811-L5	220.8	119.6	1.18	20.4%	9158	958	1.10	176.5	37.3	4.73	10.5%	1.22	32	60	7.571	0.9472	4.736	0.9718	1650
0811-6	310.3	169.2	1.20	20.0%	13698	1114	1.17	205.3	49.4	4.15	8.1%	1.01	70	192	13.12	0.8963	5.494	0.9732	1450
0811-L7	207.7	116.4	1.28	18.6%	8251	877	1.05	167.3	36.2	4.62	10.6%	1.15	23	34	6.239	0.9451	4.275	0.9643	1580
0811-S8	324.4	174.4	1.16	19.3%	13036	1268	1.02	257.3	51.6	4.99	9.7%	1.26	63	137	12.6	0.8748	5.229	0.9531	1950
0811-S10	144.1	79.1	1.22	18.5%	6406	709	1.00	143.6	28.1	5.12	11.1%	0.94	22	29	6.236	0.9532	4.251	0.968	2050
0811-S11	164.2	92.0	1.28	19.4%	8574	783	1.15	161.3	38.9	4.14	9.1%	1.01	71	163	13.74	0.924	5.682	0.9761	2080
0811-L12	555.7	289.4	1.09	19.6%	24066	2136	1.06	465.4	85.3	5.46	8.9%	1.03	37	96	7.887	0.8718	4.542	0.9349	1950
0811-L13	478.0	254.7	1.14	19.3%	20200	1893	1.08	468.9	79.3	5.91	9.4%	1.24	41	100	8.686	0.9213	4.936	0.9671	2050
0811-R14	329.5	183.3	1.25	19.4%	13811	1388	1.06	302.4	55.8	5.42	10.0%	1.15	40	91	8.646	0.8722	4.642	0.9372	1880
0811-15	385.1	196.3	1.04	19.6%	18382	1554	1.03	365.6	66.5	5.49	8.5%	1.20	38	115	7.798	0.8593	4.509	0.9452	1250
0811-R16	328.7	160.2	0.95	20.1%	15597	1254	1.11	277.9	56.8	4.89	8.0%	1.15	58	206	10.7	0.8271	4.845	0.9438	1150
0811-L17	228.0	121.6	1.14	18.7%	11206	999	1.01	209.6	44.9	4.67	8.9%	1.42							1200
0811-18	182.4	101.0	1.24	18.5%	8042	722	1.02	166.0	35.3	4.70	9.0%	1.17	46	108	9.611	0.9015	4.98	0.963	1550
0811-19	213.3	120.4	1.30	20.1%	7768	775	1.05	169.1	34.6	4.89	10.0%	1.07	54	112	11.23	0.8989	5.173	0.9604	1980
0811-20BC	107.2	63.2	1.44	19.5%	4010	474	0.97	120.2	25.3	4.76	11.8%	1.39	55	107	11.56	0.8845	5.114	0.9475	2010
0811-R21	328.8	179.2	1.20	20.1%	14203	1171	0.99	252.3	48.5	5.21	8.2%	1.14	81	181	15.39	0.9359	5.934	0.9836	1780
0811-S22	368.6	202.0	1.21	20.4%	13308	1250	1.03	237.6	49.1	4.84	9.4%	1.32	53	137	10.57	0.8733	5.002	0.9515	2000
0811-23	602.6	322.2	1.15	19.3%	23917	2100	1.06	556.1	104.1	5.34	8.8%	1.30	34	80	7.531	0.884	4.497	0.9487	1950
% Gravel			0.810																
Coarse sands			0.459																
Medum Sands			0.505																
Fine sands																			
Silts	0.877	0.882			0.810	0.856		0.890	0.851	0.693									0.444
Clays	0.761	0.777			0.677	0.740		0.739	0.701	0.603									0.505
% Fines	0.868	0.875			0.798	0.848		0.877	0.838	0.687									0.456
Mean (mm)			0.718																
Median (m)			0.619											0.427					
Phi	0.801	0.778			0.756	0.777		0.826	0.762	0.787									
Median (Phi)	0.809	0.792			0.758	0.795		0.846	0.790	0.760									
Sorting			0.616																
Skewness																			
Kurtosis																			
Total Organics			0.509																0.536
Organic Carbon	0.792	0.804			0.759	0.783		0.828	0.809	0.593									
Inorganic Carbon																			
Moisture (%)	0.610	0.620			0.564	0.624		0.600	0.553	0.496									
As-HF																			
Al-HF								0.440		0.517									
Ba-HF												0.452							
Cr-HF																			0.442
Cu-HF																			0.597
Fe-HF			0.638																
Ni-HF			0.695																
Pb-HF	0.470	0.481			0.507	0.506			0.426										
Sr-HF																			
V-HF																			
Zn-HF																			
PAH (2-6 ring)		0.996			0.975	0.979		0.961	0.967	0.625									
NPD PAH fraction					0.964	0.974		0.952	0.962	0.599									
NPD / 4-6 ringratio											0.494								
Parent/PAH													0.531	0.495	0.517		0.637		
Total Oil (ug/kg)						0.983		0.950	0.967	0.569									
Total n alkanes								0.968	0.970	0.632									
CPI (10-37)																			
Pristane									0.983	0.713									
Phytane										0.578									
Pr/Ph Ratio																			
%alkanes																			0.454
PB ratio																			
Richness														0.931	0.991		0.815		
Abundance															0.876		0.608		
Richness																	0.856		
Evenness																		0.903	
Diversity																		0.537	
Dominance																			
Water Depth																			

APPENDIX VIII: Service Warranty

SERVICE WARRANTY

This report, with its associated works and services, has been designed solely to meet the requirements of the contract agreed with you, our client. If used in other circumstances, some or all of the results may not be valid and we can accept no liability for such use. Such circumstances include different or changed objectives, use by third parties, or changes to, for example, site conditions or legislation occurring after completion of the work. In case of doubt, please consult Benthic Solutions Limited.

Appendix D – IUCN Red List Aves

Source: BirdLife International – www.birdlife.org

Viewed on 18th January 2010.

Species	Category
Coscoroba Swan *Coscoroba coscoroba*	LC
Black-necked Swan *Cygnus melancoryphus*	LC
Falkland Steamerduck *Tachyeres brachypterus*	LC
Flying Steamerduck *Tachyeres patachonicus*	LC
Upland Goose *Chloephaga picta*	LC
Kelp Goose *Chloephaga hybrida*	LC
Ruddy-headed Goose *Chloephaga rubidiceps*	LC
Crested Duck *Lophonetta specularioides*	LC
Chiloe Wigeon *Anas sibilatrix*	LC
Mallard *Anas platyrhynchos*	LC
Cinnamon Teal *Anas cyanoptera*	LC
Red Shoveler *Anas platalea*	LC
White-cheeked Pintail *Anas bahamensis*	LC
Speckled Teal *Anas flavirostris*	LC
Yellow-billed Pintail *Anas georgica*	LC
Silver Teal *Anas versicolor*	LC
Rosy-billed Pochard *Netta peposaca*	LC
King Penguin *Aptenodytes patagonicus*	LC
Gentoo Penguin *Pygoscelis papua*	NT
Chinstrap Penguin *Pygoscelis antarcticus*	LC
Southern Rockhopper Penguin *Eudyptes chrysocome*	VU
Macaroni Penguin *Eudyptes chrysolophus*	VU
Magellanic Penguin *Spheniscus magellanicus*	NT
Wandering Albatross *Diomedea exulans*	VU
Northern Royal Albatross *Diomedea sanfordi*	EN
Southern Royal Albatross *Diomedea epomophora*	VU
Light-mantled Albatross *Phoebetria palpebrata*	NT
Black-browed Albatross *Thalassarche melanophrys*	EN
Grey-headed Albatross *Thalassarche chrysostoma*	VU
Southern Giant-petrel *Macronectes giganteus*	LC
Northern Giant-petrel *Macronectes halli*	LC
Southern Fulmar *Fulmarus glacialoides*	LC
Antarctic Petrel *Thalassoica antarctica*	LC
Cape Petrel *Daption capense*	LC
Snow Petrel *Pagodroma nivea*	LC
Blue Petrel *Halobaena caerulea*	LC
Broad-billed Prion *Pachyptila vittata*	LC
Antarctic Prion *Pachyptila desolata*	LC
Thin-billed Prion *Pachyptila belcheri*	LC
Fairy Prion *Pachyptila turtur*	LC
Kerguelen Petrel *Lugensa brevirostris*	LC
Soft-plumaged Petrel *Pterodroma mollis*	LC
Atlantic Petrel *Pterodroma incerta*	EN
White-chinned Petrel *Procellaria aequinoctialis*	VU

Grey Petrel *Procellaria cinerea*	NT
Cory's Shearwater *Calonectris diomedea*	LC
Great Shearwater *Puffinus gravis*	LC
Sooty Shearwater *Puffinus griseus*	NT
Manx Shearwater *Puffinus puffinus*	LC
Little Shearwater *Puffinus assimilis*	LC
Wilson's Storm-petrel *Oceanites oceanicus*	LC
Grey-backed Storm-petrel *Garrodia nereis*	LC
Black-bellied Storm-petrel *Fregetta tropica*	LC
Magellanic Diving-petrel *Pelecanoides magellani*	LC
Common Diving-petrel *Pelecanoides urinatrix*	LC
White-tufted Grebe *Rollandia rolland*	LC
Great Grebe *Podiceps major*	LC
Silvery Grebe *Podiceps occipitalis*	LC
Maguari Stork *Ciconia maguari*	LC
Buff-necked Ibis *Theristicus caudatus*	LC
Black-crowned Night-heron *Nycticorax nycticorax*	LC
Cattle Egret *Bubulcus ibis*	LC
Cocoi Heron *Ardea cocoi*	LC
Great Egret *Casmerodius albus*	LC
Imperial Shag *Phalacrocorax atriceps*	LC
Rock Shag *Phalacrocorax magellanicus*	LC
Turkey Vulture *Cathartes aura*	LC
Crested Caracara *Caracara cheriway*	LC
Striated Caracara *Phalcoboenus australis*	NT
American Kestrel *Falco sparverius*	LC
Peregrine Falcon *Falco peregrinus*	LC
Cinereous Harrier *Circus cinereus*	LC
Sharp-shinned Hawk *Accipiter striatus*	LC
Red-backed Hawk *Buteo polyosoma*	LC
Plumbeous Rail *Pardirallus sanguinolentus*	LC
Yellow-legged Gallinule *Porphyrio martinica*	LC
White-winged Coot *Fulica leucoptera*	LC
Red-gartered Coot *Fulica armillata*	LC
Red-fronted Coot *Fulica rufifrons*	LC
Snowy Sheathbill *Chionis albus*	LC
Blackish Oystercatcher *Haematopus ater*	LC
Magellanic Oystercatcher *Haematopus leucopodus*	LC
Black-necked Stilt *Himantopus mexicanus*	LC
Two-banded Plover *Charadrius falklandicus*	LC
Rufous-chested Plover *Charadrius modestus*	LC
South American Snipe *Gallinago paraguaiae*	LC
Fuegian Snipe *Gallinago stricklandii*	NT
Hudsonian Godwit *Limosa haemastica*	LC
Whimbrel *Numenius phaeopus*	LC
Ruddy Turnstone *Arenaria interpres*	LC
Sanderling *Calidris alba*	LC
White-rumped Sandpiper *Calidris fuscicollis*	LC
Baird's Sandpiper *Calidris bairdii*	LC
Stilt Sandpiper *Calidris himantopus*	LC

Dolphin Gull *Leucophaeus scoresbii*	LC
Grey Gull *Larus modestus*	LC
Kelp Gull *Larus dominicanus*	LC
Brown-hooded Gull *Larus maculipennis*	LC
Franklin's Gull *Larus pipixcan*	LC
Common Tern *Sterna hirundo*	LC
Arctic Tern *Sterna paradisaea*	LC
Antarctic Tern *Sterna vittata*	LC
Southern Skua *Catharacta antarctica*	LC
South Polar Skua *Catharacta maccormicki*	LC
Parasitic Jaeger *Stercorarius parasiticus*	LC
Long-tailed Jaeger *Stercorarius longicaudus*	LC
Eared Dove *Zenaida auriculata*	LC
Austral Parakeet *Enicognathus ferrugineus*	LC
Dark-billed Cuckoo *Coccyzus melacoryphus*	LC
Barn Owl *Tyto alba*	LC
Short-eared Owl *Asio flammeus*	LC
White-collared Swift *Streptoprocne zonaris*	LC
Sick's Swift *Chaetura meridionalis*	LC
White-crested Elaenia *Elaenia albiceps*	LC
Patagonian Negrito *Lessonia rufa*	LC
Dark-faced Ground-tyrant *Muscisaxicola maclovianus*	LC
White-browed Ground-tyrant *Muscisaxicola albilora*	LC
Black-billed Shrike-tyrant *Agriornis montanus*	LC
Fire-eyed Diucon *Xolmis pyrope*	LC
Great Kiskadee *Pitangus sulphuratus*	LC
Eastern Kingbird *Tyrannus tyrannus*	LC
Blackish Cinclodes *Cinclodes antarcticus*	LC
Chilean Swallow *Tachycineta meyeni*	LC
Southern Rough-winged Swallow *Stelgidopteryx ruficollis*	LC
Barn Swallow *Hirundo rustica*	LC
Cliff Swallow *Petrochelidon pyrrhonota*	LC
Sedge Wren *Cistothorus platensis*	LC
Cobb's Wren *Troglodytes cobbi*	VU
Patagonian Mockingbird *Mimus patagonicus*	LC
Austral Thrush *Turdus falcklandii*	LC
House Sparrow *Passer domesticus*	LC
Correndera Pipit *Anthus correndera*	LC
Black-chinned Siskin *Carduelis barbata*	LC
Long-tailed Meadowlark *Sturnella loyca*	LC
White-bridled Finch *Melanodera melanodera*	LC

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Appendix F – IUCN Red List Cetaceans and Fish

Scientific Name	Common Name	IUCN Categorry
	Cetaceans	
Balaenoptera borealis	Sei whale	**Endangered**
Balaenoptera musculus	Blue whale	**Endangered**
Berardius arnuxii	Arnoux's beaked whale	Low Risk/Cons. Dependant
Cephalorhynchus commersonii	Commerson's dolphin	Data Deficient
Eubalaena australis	Southern right whale	Low Risk/Cons. Dependant
Hyperoodon planifrons	Southern bottlenose whale	Low Risk/Cons. Dependant
Lagenorhynchus australis	Peale's dolphin	Data Deficient
Lagenorhynchus obscurus	Dusky dolphin	Data Deficient
Lissodelphis peronii	Southern right whale	Data Deficient
Megaptera novaeangliae	Humpback whale	Vulnerable
Mesoplodon grayi	Gray's beaked whale	Data Deficient
Mesoplodon hectori	Hector's beaked whale	Data Deficient
Mesoplodon layardi	Layard's beaked whale	Data Deficient
Orcinus orca	Killer whale	Low Risk/Cons. Dependant
Phocoena dioptrica	Spectacled porpoise	Data Deficient
Physeter macrocephalus	Sperm whale	Vulnerable
Ziphius cavirostris	Cuvier's beaked whale	Data Deficient
	Fish	
Carcharhinus longimanus	Oceanic whitetip shark	Vulnerable
Cetorhinus maximus	Basking shark	Vulnerable

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Appendix G: Cuttings Modelling – The BMT PROTEUS Model

G.1 Introduction

The Pollution Risk Offshore Technical Evaluation System (PROTEUS) has been developed by BMT to predict the fate and impact of discharged drilling mud, cuttings and produced waters in the marine environment. It is based on a discrete particle representation concept which considers the physical, geochemical and biological mechanisms from which the fate and impact of drilling discharges can be predicted.

Development of PROTEUS has been sponsored by a consortium of oil companies and the UK Government under the 'Managing Impacts on the Marine Environment' (MIME) programme. The model is based on research conducted at world-leading institutions in the fields of dispersion physics, geochemistry and ecotoxicology.

G.2 Theory

The drilling mud and cuttings model uses a particle-tracking approach. The discharge is represented by the release of a discrete number of particles during each time step of the model simulation. Each particle has an individual size and density, determined by the model from input density distribution data. The model is provided with hydrodynamic data which is used in the simulation of particle advection and dispersion in three dimensions. The particles' size and density are used to determine the settling characteristics of the mud and cuttings.

G.3 Particle advection

The model can consider advection of particles by tidal and wind-induced currents. As well as advecting the particles, current shear through the water column acts to disperse particles. Current shear is calculated by the model using well-established equations described by van Veen, and as quoted in Bowden (1965) (see also van Dam and Louwersheir (1992)).

G.4 Particle diffusion

Turbulent diffusion processes (in this case, dispersion processes other than current shearing) are simulated using a random walk technique. At each time step, $\delta\tau$, individual particles are subject to a three dimensional random displacement, $\delta\vec{r}$. The scale of displacement in each dimension at each time step is determined by the following equation:

$$\delta r = \sqrt{2E\delta\tau}$$

where E is the diffusivity coefficient.

The direction in which particles move is determined using a random number generator subroutine based on Schrage's algorithm (*Bratley et al., 1983*). The random seeds used in Schrage's algorithm are altered at each time step.

G.5 Particle settling

In theory, particle settling is a function of a few quantifiable parameters, such as particle density, particle size and water density. The rate at which particles settle is termed the settling velocity. The distribution of particle sizes and densities within the discharged mud and cuttings is used to determine the distribution of particle settling velocities within the discharged material. At each model time step when discharge is occurring, the model releases a set of particles with a range of settling velocities in proportion to this distribution.

However, the settling of material in seawater is more complex than this theoretical approach. Experimental observations suggest that the mud dispersion is actually subject to very complicated flow phenomena which can make calculation of settling velocities more difficult. For instance, as discharge particle concentration increases, inter-particle collisions occur more frequently and cause enhanced flocculation and aggregation. This enhanced aggregation of particles may accelerate the descent of mud and cuttings discharges. Therefore, the settling speed is often multiplied by an acceleration factor, F, which is given by the following empirical formula:

$$F = 0.013.C^{\varepsilon}$$

where C is the local concentration of the fine particles. ε takes an empirical value of approximately 1.3. The factor is restricted to values between 1 and 100 according to Bowers and Goldenblatt (1978) and Brandsma *et al.* (1992).

Where water-based muds (WBM) are discharged, it is assumed that separation of the mud from the cuttings will occur fairly readily upon contact with the sea-water, and aggregation will be minimal. In this case the acceleration factor F, is not included. If synthetic oil-based muds (SOBM) are discharged, it is assumed that the mud will not disaggregate, and will therefore remain attached to the cuttings particles, settling at the same velocity as the cuttings to which they are attached.

G.6 Boundary conditions

Mud and cuttings particles are assumed stationary once they reach the seabed. Re-suspension can be considered only when information on erosion and sedimentation mechanisms at the seabed including critical hydrodynamic shear stresses around the discharge area is known. Thus, particle re-suspension is not considered in the model.

A symmetric reflection boundary condition is applied to particles which reach the sea surface. This boundary condition usually applies to fine particles which reach the surface through the random walk process.

G.7 Model output

The model predicts the deposition pattern of particles on the seabed. The number of particles per unit area is calculated and particle volume information is then used to determine the seabed thickness of drilling discharge.

G.8 Input parameters

The parameters input into the PROTEUS model for the Darwin East and Stebbing exploration wells were as follows:

Darwin East well input parameters

Section Size (inches)	Operation		Cuttings		Muds			Depth of Discharge (m)
	Duration (days)	Interval (days)	Density (sg)	Volume Discharged (m^3)	Density (sg)	Continuous Volume Discharged (m^3)	Batch Volume Discharged (m^3)	
36	3	0.5	2.6	39.4	1.5	39.4	0	Seabed
26	1.2	8.5	2.6	130.2	1.14	130.2	0	Seabed
17 $^1/_2$	5	4	2.6	318.2	1.38	318.2	0	10
12 ¼	3	9	2.6	26.6	1.74	26.6	0	10

All used automatic cuttings and mud PSDs.

Stebbing well input parameters

Section Size (inches)	Operation		Cuttings		Muds			Depth of Discharge (m)
	Duration (days)	Interval (days)	Density (sg)	Volume Discharged (m^3)	Density (sg)	Continuous Volume Discharged (m^3)	Batch Volume Discharged (m^3)	
36	3	0.5	2.6	39.4	1.44	39.4	0	Seabed
26	1	8	2.6	260.7	1.44	260.7	0	Seabed
17 $^1/_2$	2	3	2.6	139.7	1.14	139.7	0	10
12 ¼	6	14	2.6	72.2	1.32	72.2	0	10

All used automatic cuttings and mud PSDs.

In the absence of any site-specific particle size distributions (PSD), generic PSDs have been used for the modelling study (Figures G.1 and G.2). These size distributions have been compiled from a range of sampling programs undertaken for various projects in the North Sea. The particle settling velocities were derived analytically from the size distribution and densities, using the well established theories developed by Dyer (1986) and Sleath (1984), which have subsequently been analysed and are detailed by Bryden & Charles (1998).

Blanket current speed and direction data used for the model run at the discharge location for the Darwin East and Stebbing exploration wells are shown in Figure G.3.

Figure G.1. Particle Size Distributions (PSD) for drill cuttings from a toothed drill bit used in the modelling. Plot shows the cumulative distribution of solids (by diameter) within the drill cuttings.

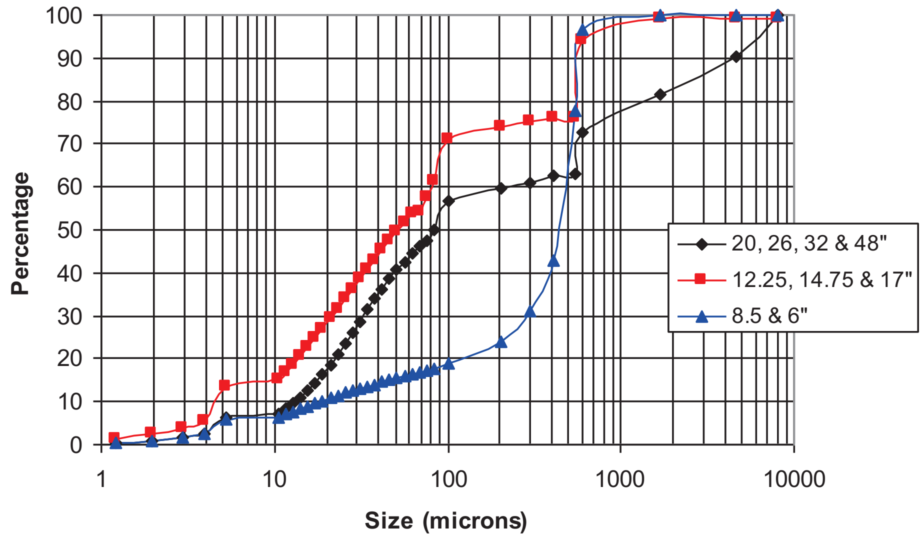

Figure G.2. Particle Size Distribution (PSD) for solid particles within drilling muds used in the modelling. Plot shows the cumulative distribution of solids by diameter.

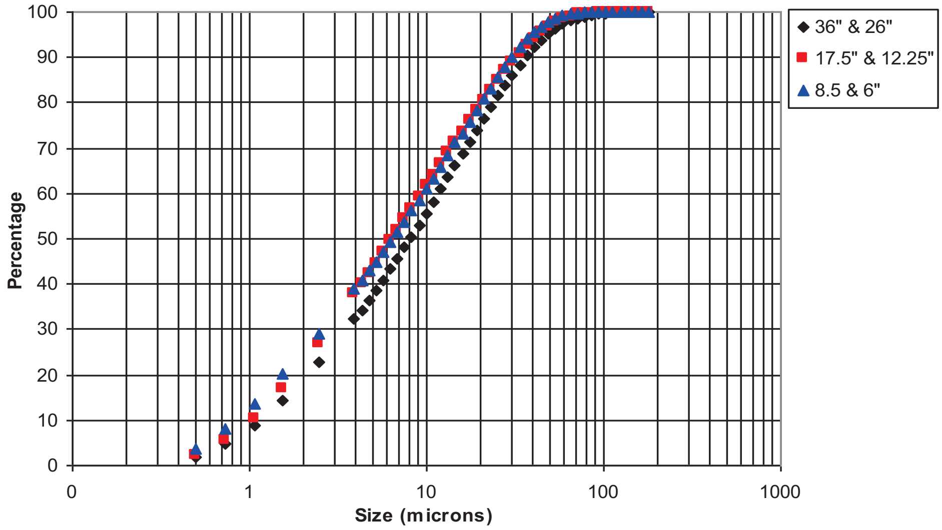

Figure G.3. Blanket (current override) current speed and direction input data for the Darwin East and Stebbing exploration well models.

	Darwin East	Stebbing
Current Speed	0.31	0.31
Current Direction	7	7

Appendix H: Oil Spill Modelling – The BMT OSIS Model

H.1 Introduction

The Oil Spill Information System (OSIS) is a state-of-the-art oil spill modelling system for the prediction of the trajectory, spreading, shoreline impact and weathering of marine oil spills. The system provides a total capability to predict the movement, spreading, weathering and coastal impact of oil spilt in the marine environment. Most importantly, the model has been extensively validated during scientific sea trials (through a licence exclusively held in the UK by AEA Technology) and real incidents (e.g. Braer, Sea Empress). The system has been the primary oil spill modelling system in the UK for many years and is used by the Maritime and Coastguard Agency, Oil Spill Response Ltd., Briggs Environmental Services, and most of the UK-based oil companies. It is also used internationally in areas such as SE Asia, Pacific Asia and the Caspian by many of the world's largest oil companies

H.2 Databases

OSIS relies on five primary database types to provide its model predictions. Four of these databases are pre-configured and stored in the system to provide maps, oceanographic information, bathymetric data and oil properties information. The fifth database is the weather database which is set-up by the user for the prevailing weather conditions at the time of the spill.

H.3 Mapping

The OSIS v 4 map databases contain information for display using the Geographical Information System (GIS) in OSIS. These maps may contain information on the coastline, bathymetry, coastal features, areas sensitive to oil spills, response information etc. Data can be imported from external applications using digital inter-change formats.

H.3.1 Oceanographic information

OSIS derives information on water movement from a sophisticated current data server which allows multiple data sources to be combined and integrated to provide water flows information on tidal and seasonal cycles. BMT Cordah's Digital Tidal Atlas can be then be used to visualise and manipulate this information.

To further refine the quality of the simulation results, OSIS has a manual override function, the 'Override currents' tab on the program which allows the user to input site specific current data.

H.3.2 Bathymetric Database

The requirement for bathymetric data within OSIS is satisfied by the bathymetric database which takes random bathymetric data input and stores it in a digital bathymetry model format.

H.3.3 Weather database

Prevailing wind data is a requisite feature of the OSIS model and along with prevailing currents contributes to the actual spill movements. OSIS models oil weathering based on the properties of the fresh oil. This information is entered via the model run manager which contains linked spreadsheets. These spreadsheets allow the user to setup multiple spills and associated weather data for running in a batch mode ideal for the multiple spill runs required during contingency planning.

The wind input data required differs depending on the type of modelling simulation that will be undertaken. If the modelling simulation is a trajectory run, then only the prevailing direction (s) and force (s) of the expected or worst case wind is required. Typical wind inputs are presented in Figure H1.

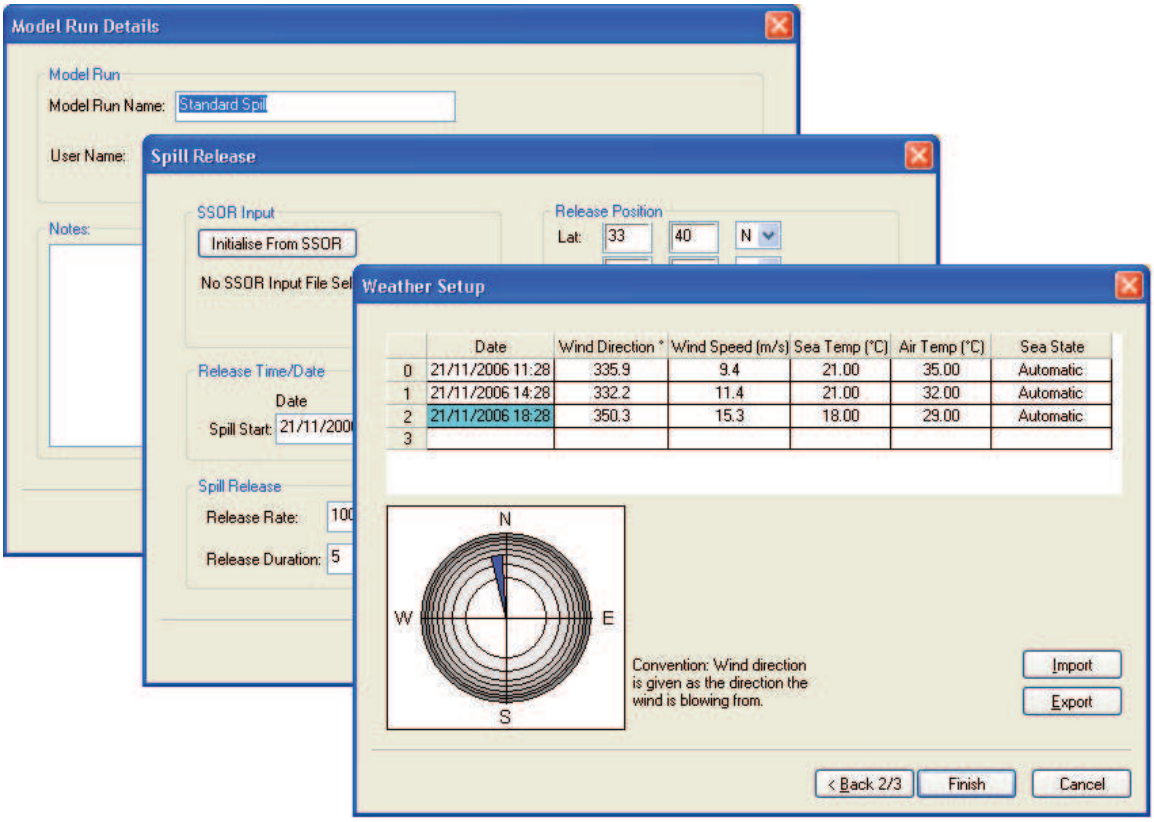

Figure H.1 Trajectory wind data set up

If the modelling simulation undertaken is a stochastic run then actual wind rose data representative of the location where the spill simulation is being run will be required. The wind data required should detail, direction, force and percentage of occurrence for wind activity in the modelling location. Typical data requirements can be seen in Figure H2.

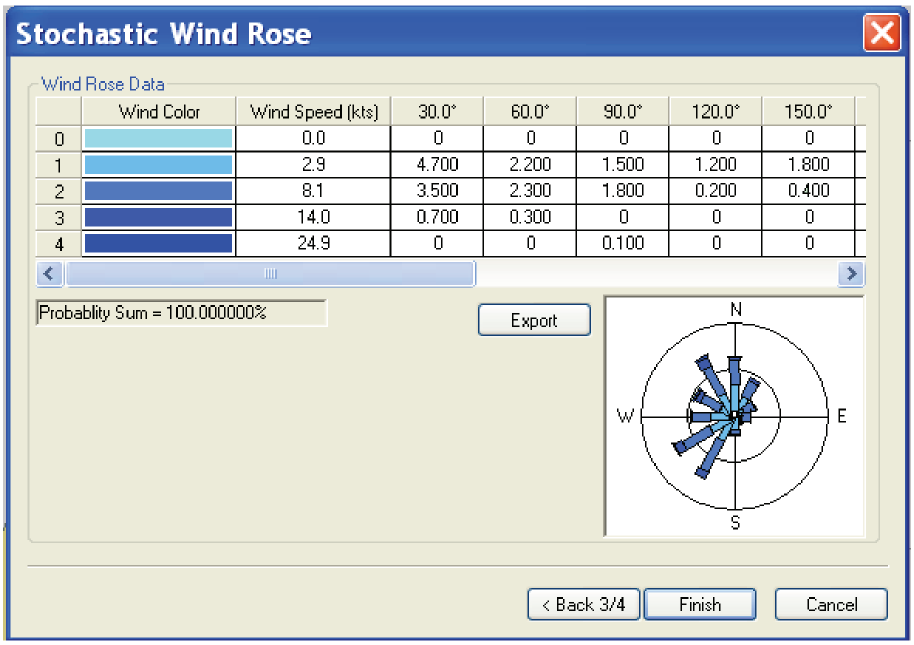

Figure H.2 Trajectory wind data set up

H.3.4 Oil Properties Database

OSIS models oil weathering based on the properties of the fresh oil. The oil properties database contains over 100 international oils and new oils may be added as required provided that the necessary oil analyses have been carried out. Information on the spill scenario is input using the Spill Data menu which allows definition of the volume, duration, diameter and depth of the spill as well as the oil type, tidal data to be used and the model run conditions; weather forecast is then added to the spill scenario based on the best available data including wind speed and direction, sea and air temperature, and sea state Typical spill data inputs are illustrated in Figure H3.

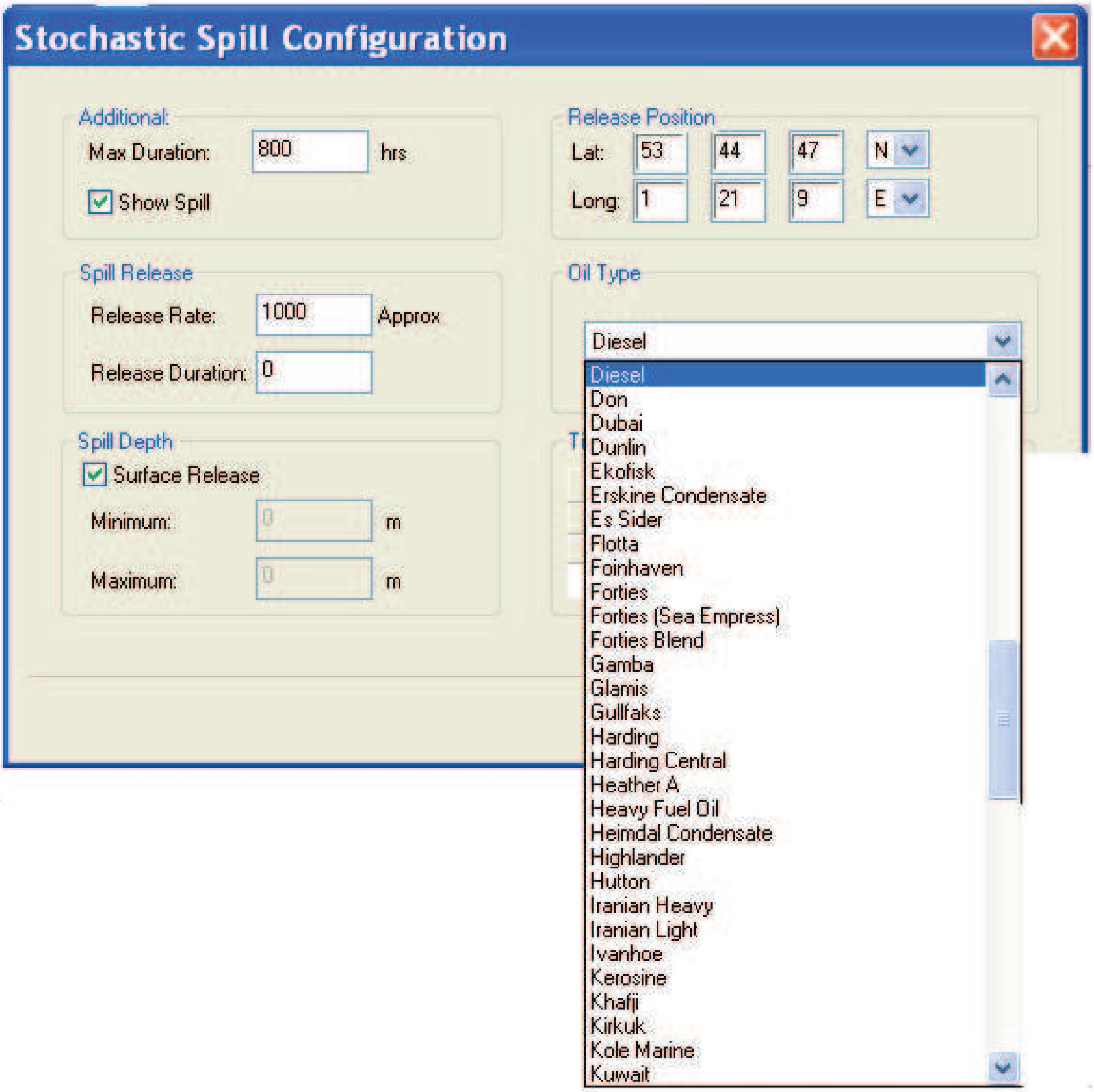

Figure H.3 Spill model inputs

During the spill run the user may utilise a number of options allowing the onscreen data to be analysed or adding supporting data. An example of this is the ability to visualise the current flow field and wind data under which the oil spill is being influenced. The user may also use the Spill Move option to reposition a spill on the basis of visual or remotely sensed observations.

H.4 Validation

Validation has been fundamental in the development of OSIS. It is one of the few models which have been validated against licensed oil spill sea trials. Its weathering algorithms have been developed through empirical work, not based on theoretical equations. Most of the oils in the OSIS database have been specifically laboratory-characterised to allow them to use the unique OSIS weathering model.

OSIS has been validated at sea against:

- 18 oil spill trials, up to three days in duration
- 10 different oil types
- Meteorological conditions from Beaufort scale 1-6

H.5 Metocean Data input

H.5.1 Introduction

This report provides a high level overview of the environmental resources that could potentially be impacted from possible spill scenarios associated with the proposed Borders and Southern drilling activities, south /east of the Falkland Islands in the South Atlantic.

The modelling data presented in this report has been was derived using BMT's Oil Spill Information System (OSIS) 4.0 model and recent met-ocean data1.

The following sections detail the prevailing met-ocean conditions in the vicinity of the proposed drilling locations and the likely trajectories of spills associated with the proposed operations. Both trajectory (conservative, absolute and worst case) and stochastic (under typical weather conditions) modelling scenarios were run to detail the possible and likely behaviour of the spills from the Darwin East and Stebbing well locations.

H.5.2 Currents

Outside the continental shelf, tidal influences are negligible and any water movement may be regarded as being from currents. Currents in the vicinity of the Falkland Islands may vary considerably depending on the prevailing weather and variations in temperature and density. In depths of less than 200 metres, a considerable part of the water movement is tidal and the proportion increases as the depths decrease.

The predominant current south of the Falkland Islands, between December and February, is in a north, north east direction, which occurs up to 50% of the time in the range of 0.28 to 0.34 knot. From June to August, currents are directed in a north easterly direction, with strengths of 1-1.5 knots and occur in this manner for approximately 75 percent or more of the time[2]. There is also a weaker current occurring less than 50 % of the time in a north, north westerly direction.

H.5.3 Wave Movements

The prevailing direction of wave movements varies throughout the year. However, in January wave swells tend to be most common and strongest from the south-westerly through westerly to northern directions. Whereas in July, wave swells tend to be predominantly from the southern to north-western directions.

H.5.4 Wind

Mean wind directions tend to be similar to that of the prevailing wave movements and as such are predominantly from a south-westerly to north-westerly direction throughout the year, with mean wind speeds typically varying from 15 to 17 knots. The number of days a month where gale force winds occur is roughly the same throughout the year ranging between 4 - 5 days, with a total of approximately 55 days a year experiencing such conditions. However, for trajectory runs which have been used to model worst case scenarios, a constant onshore 30 knot wind has been used. For Stochastic runs, site specific wind rose data has been inputted into the model.

[1] *United Kingdom Hydro-graphic Office, (2008) Admiralty Sailing Directions, South America Pilot, Volume II, NP 6.*
[2] Page 16 of *UKHO (2008)*

H.5.5 Temperature

Mean sea surface temperature varies throughout the year. In February, sea surface temperature in the region of the proposed drilling locations is approximately 6 to 10°C while in August it is relatively lower, ranging between 2 to 6 °C.

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Appendix I: Management Systems

I.1 Borders & Southern HSE Policy

borders&southern
petroleum plc

HSE Policy Statement

Borders and Southern Petroleum plc is committed to effective corporate governance. Maintaining high standards of Health, Safety and Environmental (HSE) protection throughout its operations is an integral part of this and is achieved through:

- Strong leadership and clearly defined responsibilities and accountabilities for HSE at all levels of the organisation;
- Selection of competent personnel to manage activities;
- Compliance with regulatory and other applicable requirements, or where regulations do not exist, application of industry standards;
- Identifying, assessing and managing HSE risks and preventing pollution;
- Developing specific plans to identify, assign responsibilities, schedule and track HSE activities within each project;
- Selecting competent contractors and ensuring that they are effectively managed;
- Preparing and testing response plans to ensure that any incident can be quickly and efficiently controlled, reported and investigated to prevent recurrence;
- Continual improvement of HSE performance through monitoring, regular reporting and periodic audits;
- Periodic management reviews to identify and implement improvements to our HSE systems.

This policy is implemented through our HSE Management System and is used to guide all our activities. It will not be compromised by other business priorities.

Howard Obee
Chief Executive Officer

Date: 4/2/10

I.2 Health, Safety and Environment Management System

1. Introduction

Purpose

This document describes the Health, Safety and Environmental (HSE) Management System of Borders and Southern Petroleum plc (referred to in this document as '**Borders and Southern**'). It outlines the HSE policy, the organisation structure and system for managing HSE within the Company.

Scope

Borders and Southern's business comprises acquisition of acreage and exploration for oil and gas. Operational activities include geological and geophysical surveys, design, construction, and testing of wells and assessment of hydrocarbon reserves. In the future it is anticipated that this will lead on to field development and production operations.

The HSE Management System establishes the main requirements and provides the framework for managing HSE issues within the business. It ensures:

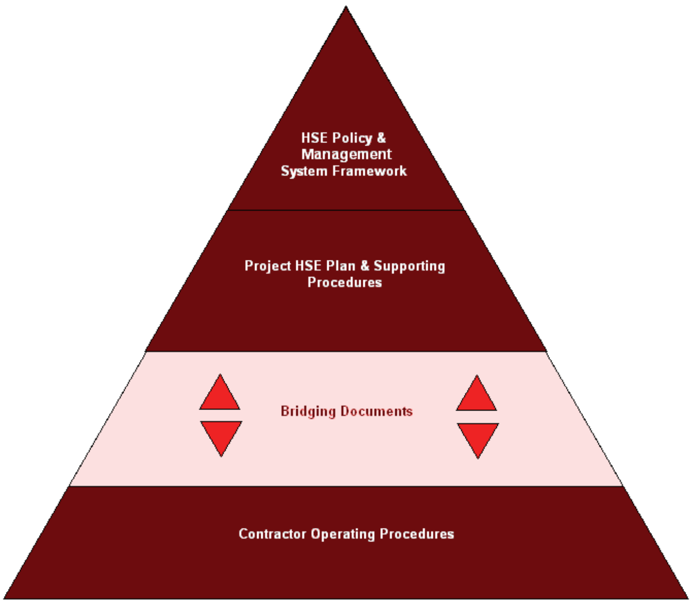
- Clear assignment of responsibilities;
- Efficient and cost effective planning and operations;
- Effective management of HSE risks;
- Compliance with legislation; and
- Continuous improvement.

The system is goals orientated and allows sufficient flexibility for each project to achieve these goals in a manner which best suits the business.

Structure

The system structure is illustrated in Figure 1.1. At the top, the HSE policy demonstrates the commitment and intentions of the Company. The HSE Management System Framework document provides guidance on the implementation of policy across the Company. At the second level are the project specific HSE Plans and Procedures; these provide the specifics of how each project is executed. At the base of the structure are the Bridging Documents linking Borders and Southern's system with its contractors' HSE Operating Systems/Procedures.

Figure 1.1. HSE Management System Structure

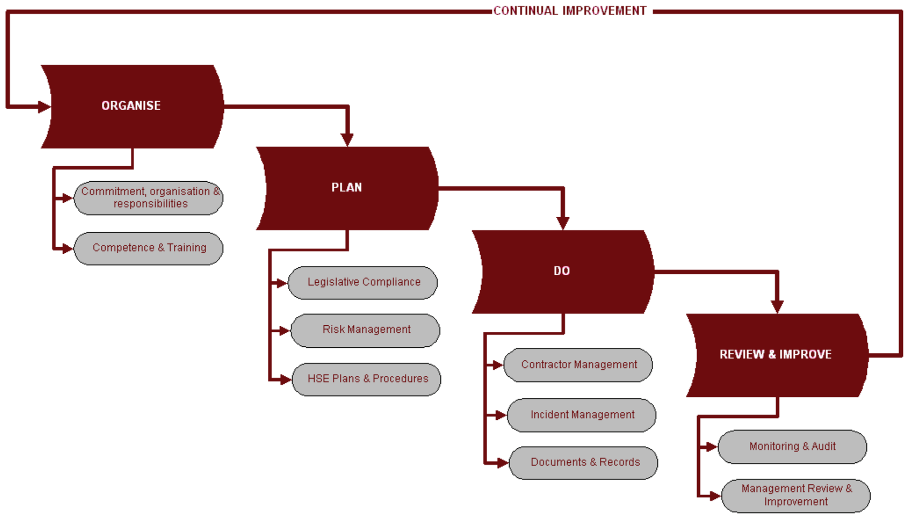


2. HSE Management System Framework

Process

The HSE Management System is consistent with existing international models for health, safety and environmental management (e.g. ISO14001, ISO 18001). The system is structured around an 'organise, plan, do, review' process, with a feedback loop to assure continual improvement in performance. The system can be visualised as illustrated in Figure 2.1. It is made up of a number of elements and requirements and is relevant throughout the business lifecycle.

Figure 2.1. HSE Management System Framework



Organise

The system is driven through commitment and organisation. Broad HSE goals are established and responsibilities clearly defined. HSE expectations are communicated through internal and external networks. Personnel are selected that have the appropriate qualifications, experience and skills to meet their responsibilities.

Plan

Regulatory requirements and potential hazards and risks associated with planned activities are identified and appropriate measures to conform/control are incorporated in a project HSE Plan. Significant changes made to the Plan are subject to a risk review.

Do

Competent contractors are selected and managed to undertake specialist tasks, following agreed procedures. Effective response plans to emergencies are developed. Incidents are reported and investigated and lessons learned used to improve performance.

Review & Improve

Routine monitoring is undertaken to assess and, where necessary, improve HSE performance. Periodic audits are conducted to ensure the effective functioning and continued suitability of the management system. Management review the system annually, identify areas for improvement and build these into the following year's work plans.

3. Organise

Element	Requirement
Commitment, Organisation & Responsibilities	• Management commitment to high HSE standards is documented in its HSE Policy (see Appendix 1). The Policy is: ♦ Signed and dated by the Managing Director; ♦ Communicated to staff, contractors and stakeholders; ♦ Reviewed periodically and where appropriate updated and re-issued. • Broad HSE goals are established by senior management for each operational project. These goals are set in the context of: ♦ Compliance with existing legislation; ♦ Meeting the commitments made in the HSE Policy; ♦ Managing the risks associated with planned activities. • Management at all levels provides visible and active leadership within the organisation promoting positive HSE culture and a common understanding of Borders and Southern's expectations. Active and visible leadership includes: ♦ Promotion of the Company's HSE Policy and project goals; ♦ Monitoring HSE at senior management meetings; ♦ Discussion of HSE performance by senior managers at operational locations; ♦ Senior management participation in HSE inspections and audits; ♦ Encouraging staff and contractors to identify possible hazards, raise HSE concerns and suggest improvements; ♦ Annual reviews by management of HSE performance. • Reporting relationships and responsibilities within the organisation are defined and personnel are briefed on the HSE risks associated with their work and of their specific HSE roles and responsibilities (see Appendix 2). • Internal communications (formal and informal) on HSE expectations are maintained by through the line management structure by: induction programmes for new hires/contractors, routine written/verbal/electronic means, periodic management meetings and site inductions, safety meetings, pre-spud/tour meetings, toolbox/tailgate talks. • External communications with contractors and stakeholders (e.g. government organisations, industry organisations, interest groups) are managed through a company representative delegated by the responsible Manager. Records of any commitments made during these communications are maintained. • Resourcing plans are developed through the annual and project budgeting processes, to ensure that sufficient resources are available to meet the requirements identified in the Company's HSE Policy and Management System.
Competence & Training	• Employees and consultants are selected on the basis that they are medically fit and have the qualifications, experience and skills to perform the tasks that they have been assigned. • Managers monitor the ongoing performance of their staff to ensure appropriate supervision and/or identify additional HSE training needs. • Competency and training needs are periodically reviewed and, where appropriate, additional training is provided for employees with specific HSE responsibilities (e.g. emergency response training).

4. Plan

<table>
<tr><th>Element</th><th>Requirement</th></tr>
<tr><td>Legislative Compliance</td><td>

Regulatory requirements for planned activities are identified, communicated and integrated into an activity or project HSE Plan.
A register of applicable HSE regulations is maintained.
Regulatory requirements are periodically reviewed to ensure that any new requirements are identified, communicated and the HSE Plan(s)/register updated.
</td></tr>
<tr><td>Risk Management</td><td>

Hazards and risks associated with operational activities are identified, evaluated and controlled to minimize adverse impacts.

Risks are identified and assessed using appropriate hazard identification/risk assessment methods. Potential sources of pollution and other impacts on the environment are evaluated through environmental impact assessments.
Risks are controlled to levels as low as reasonably practicable in order of preference – elimination > containment > procedural controls;
A register of identified risks and associated controls is maintained;
Information on significant risks and their controls are communicated to the workforce and where appropriate local communities and other stakeholders;
The effectiveness of the key controls is monitored.

Changes in organisation, operational programmes or procedures that may have an adverse HSE impact are identified, the potential risks assessed and, where necessary, controls and/or authorisations introduced to reduce risk to levels that are as low as reasonably practicable.
</td></tr>
<tr><td>HSE Plans</td><td>

A project HSE Plan describing how the HSE Management System is implemented for each operational project (i.e. seismic, drilling and, at the appropriate time, field development projects).
The HSE Plan addresses:

Project HSE goals and KPIs;
Organisation and specific HSE responsibilities;
Regulatory requirements;
Risk management programme;
Training needs;
Monitoring and reporting;
Audit programme;
Bridging arrangements.

Supporting procedures are developed where appropriate.
The Plan should be reviewed on completion to identify areas for improvement.
</td></tr>
</table>

5. Do

Element	Requirement

Contractor Management	• Good HSE performance is considered an integral part of contractor competence. Sufficient information to verify the contractors' ability to achieve high HSE standards is collected during the contractor qualification process.
	• Pre-contract HSE audits are undertaken on key facilities and their owners/operators, to verify effective HSE management systems, particularly:
	  ◆ Before leasing an operations office or shore-base;
	  ◆ Before undertaking a seismic survey;
	  ◆ Before chartering an aircraft;
	  ◆ Before contracting a drilling rig, or other major facility.
	• Appropriate HSE provisions are included in the contract terms and conditions to ensure that contractors' are obligated to meet Borders and Southern's HSE standards.
	• The Company's HSE expectations are communicated to contractors and responsibilities agreed. Where multiple contractors' are involved, formal bridging documents are developed to define responsibilities.
	• Contractors HSE performance is monitored during execution of the work, to ensure:
	  ◆ The work is being performed to the required standard;
	  ◆ Agreed responsibilities are being met;
	  ◆ Incidents/non-conformances are reported/investigated by the contractor;
	  ◆ Agreed recommendations for remedial action are executed and closed out in a timely manner.
	• Feedback on HSE performance is provided, where appropriate, to identify areas for improvement.

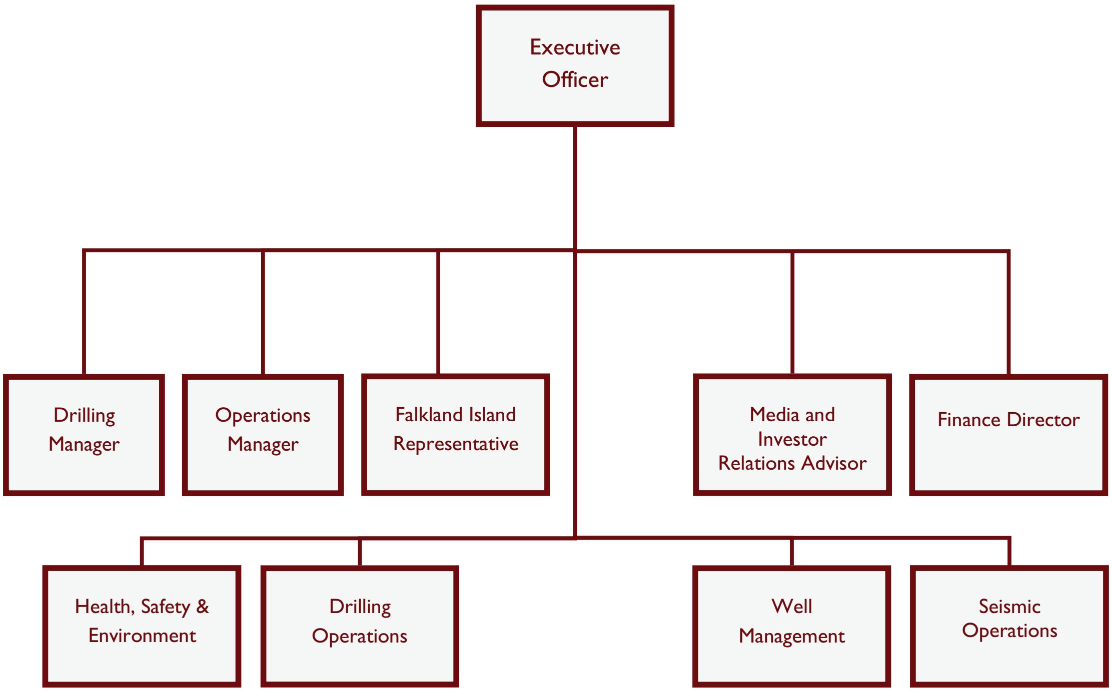
Incident Management	• Incident management plans are established to address potential operational emergencies, designate roles and responsibilities and identify the interface requirements with stakeholders (e.g. contractors, media, relatives, partners, insurers, shareholders or regulators). Points of contact and telephone numbers are included in the plan. Back-up equipment, resources and personnel are identified in the plans and appropriate mobilization procedures agreed. • The plans are communicated to personnel. Response personnel receive training to ensure they are competent to carry out their emergency roles. This is supplemented by periodic refresher training. • Periodic drills and training exercises are carried out. Significant findings are used to improve the plans. • Incidents and near misses are managed to bring under control, reported, investigated to an appropriate level and documented. Investigations are conducted to determine main causes, contributing factors, trends and measures needed to ensure the incident does not recur. Agreed actions are documented, tracked to completion and closed out. Significant findings are communicated to staff.

Documents & Records	• The issue and revision of key HSE documents are controlled to ensure they:
	  ◆ Can be located and are available in their current versions at all locations where operations essential to the effective functioning of the HSE MS are performed;
	  ◆ Are removed from circulation if obsolete and ensured against unintended use;
	  ◆ Are suitably identified as obsolete if they are retained for legal and/or knowledge preservation purposes.
	• Statutory records are maintained together with sufficient records to demonstrate compliance with the HSE Policy and Management System.

6. Review & Improve

Element	Requirement
Monitoring & Audit	• HSE performance is monitored on an ongoing basis. Results are reported and compared against the expectations set in the HSE Plan. • Non-compliances are reported through line management, and where appropriate to the regulatory authorities, investigated and appropriate corrective action taken by the responsible manager. Agreed actions are tracked to completion and close out. • Periodic HSE audits are undertaken on key activities. The scope and frequency of these audits is determined by risk to the company and documented in the HSE Plan. • Audit deficiencies are identified and action taken to rectify them. Audit findings are documented and records maintained. Agreed actions are tracked to close-out. Significant findings and agreed actions are communicated to staff.
Management Review & Improvement	• A management review of the HSE Management System is conducted on an annual basis to evaluate whether the system is working effectively and to identify and agree any improvements that might be necessary. The review includes: ♦ Progress against goals; ♦ Incident statistics; ♦ Audit results; ♦ Initiatives undertaken or planned; ♦ Overall improvements achieved; ♦ Agreement of recommended changes and improvements. • Agreed improvements are integrated into the project plans. The responsibility and timing is agreed and the plans executed in a timely manner.

Organisation and HSE Responsibilities



KEY RESPONSIBILITIES & ACCOUNTABILITIES	
Executive Officer	Accountable for implementation of HSE Policy and assurance that the organisation, processes and resources for implementation of the HSE Management System are in-place.
Operations Manager	Accountable to the Executive Officer for leading, aligning, communicating, resourcing, implementing and monitoring performance of the HSE Management System within their respective areas of activity.
Drilling Manager	Accountable to the Executive Officer for leading, aligning, communicating, resourcing, implementing and monitoring performance of the HSE Management System and reporting HSE concerns, issues and incidents.
Staff & Consultants	Accountable to their Line Manager for working in a safe and environmentally responsible manner, fully implementing the relevant requirements of the HSE Management System and reporting any HSE concerns, issues and incidents.