JWEL PROJECT NO. 1468

WHITE ROSE
BASELINE ENVIRONMENTAL
CHARACTERIZATION DESIGN

JULY 2000

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BASELINE ENVIRONMENTAL
CHARACTERIZATION DESIGN

PREPARED FOR

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1.0 INTRODUCTION

1.1 Background

Husky Oil Operations Limited (Husky Oil), with its joint-venturer Petro-Canada, is in the process of seeking approval from the Canada-Newfoundland Offshore Petroleum Board (C-NOPB) to develop the White Rose oilfield on the Grand Banks offshore Newfoundland. The field is approximately 350 km east southeast of St. John's Newfoundland and 50 km from both the Terra Nova and Hibernia fields (Figure 1.1-1).

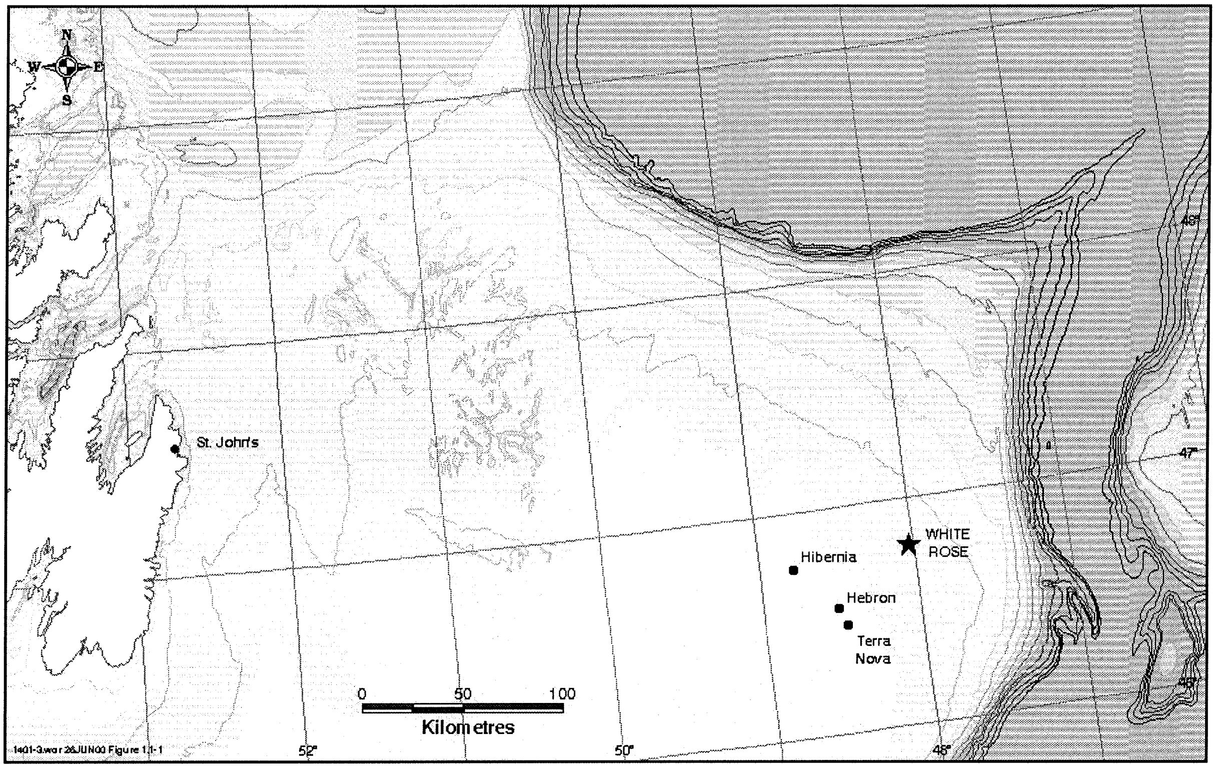
In July of 2000, Husky Oil will submit to the C-NOPB a Development Application (DA) consisting of a Canada-Newfoundland Benefits Plan, a Development Plan, an Environmental Impact Statement (EIS), a Socio-Economic Impact Statement (SEIS), a Safety Risk Assessment, and a summary document, consistent with the Canada-Newfoundland Offshore Accord Acts and Regulations and the Development Application Guidelines (C-NOPB 1988). The EIS and SEIS combined will provide the C-NOPB and the Department of Fisheries and Oceans (DFO), Environment Canada (EC) and Industry Canada (IC), the identified federal Responsible Authorities, with a full assessment of the effects of the proposed White Rose oilfield development on the environment, as required by the *Canadian Environmental Assessment Act* (CEAA). Both the regulatory agencies and the public will have an opportunity to review the DA.

As part of its planning for its DA, Husky Oil undertook an extensive public consultation program. One of the clear messages throughout meetings with the regulatory agencies, stakeholders and the public was the importance of protecting the environment, and the value of an environmental effects monitoring (EEM) program to determine whether there were any effects of the project.

Husky Oil commits in its EIS to develop a comprehensive Environmental Effects Monitoring (EEM) program for the marine receiving environment. The EEM program will test the effects predictions made in the EIS, and will be designed to detect changes in the marine receiving environment, and determine whether the changes are caused by the White Rose project. The focus of the EEM program will be the interaction of the environment with project discharges, such as drill cuttings, produced water, and grey waters. Of particular interest are temporal and spatial patterns.

In order to demonstrate the existing conditions prior to the introduction of project discharges, it is important to conduct a thorough baseline characterization program. This document outlines the design of a baseline characterization program that Husky Oil intends to conduct during the summer of 2000. The data collected will provide the basis for temporal comparisons during the operational EEM program. The data will also be used to confirm previous data collected at the White Rose site, and provide information about natural variability that will be used to determine the best design for the operational EEM program.

Figure 1.1-1 Location of the White Rose Oilfield



Husky Oil has the advantage of using the lessons learned from not only the North Sea and the Gulf of Mexico, where offshore oil and gas development has been ongoing for decades, but can now build on the extremely valuable experiences of Hibernia, operating on the Grand Banks for over two years (with a baseline from 1994, and two years of operational EEM data (1998 and 1999)) and Terra Nova, which completed its baseline in 1998. This Baseline Characterization program complements those of both Hibernia and Terra Nova, and will contribute to a regional understanding of the Grand Banks marine environment. It will also allow spatial and temporal analysis of the cumulative effects of the offshore industry on the regional situation. Husky Oil is committed to the regional approach to monitoring in order to better understand how the marine environment is responding to a developing offshore oil and gas industry.

1.2 Scope

This baseline characterization design focuses on those attributes of the environment that may be affected by the development, drilling and production activities. The attributes chosen must not only interact with project discharges, but must also provide measurable data that can be used to make effective environmental management decisions. An EEM program designed for response to accidental events will be provided to the C-NOPB and other appropriate agencies under separate cover.

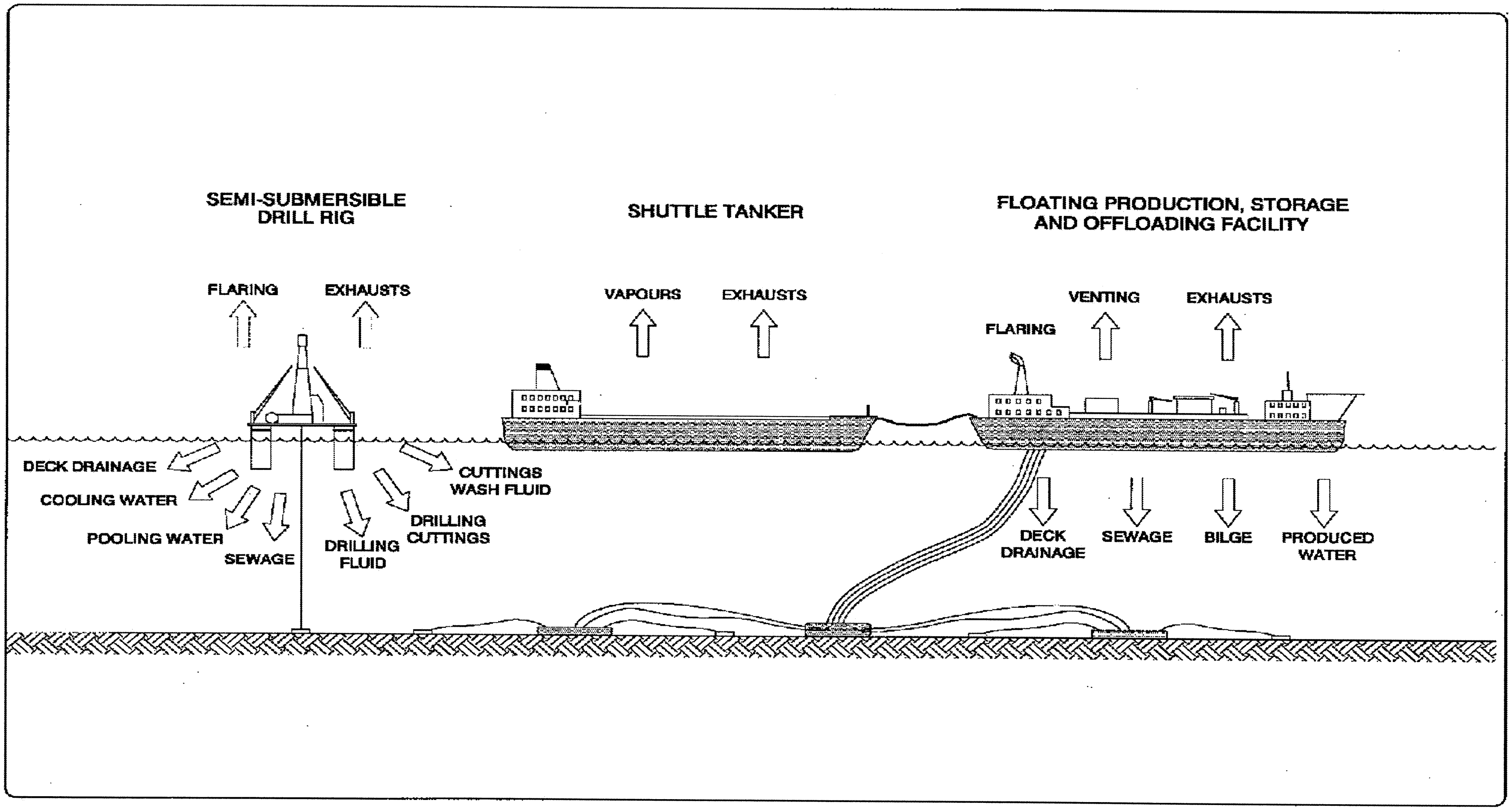
1.3 Operational Discharges

Unlike the typical fixed platform configuration of many offshore drill sites, drilling and production will occur simultaneously during development of the White Rose oilfield from the multiple well centres. Also, development of the wells of each glory hole will not be completed in a consecutive order. During the drilling and production operations of the White Rose oilfield, the platforms will generate a number of waste products which will be discharged into the aquatic environment from multiple point sources (Figure 1.3-1). These discharges will include:

- drill cuttings;
- produced water;
- well testing;
- flaring;
- deck drainage;
- cooling water; and
- domestic waste.

The ship-shape floating production, storage and offloading (FPSO) facility is a point source of produced water, flaring, deck drainage, and domestic waste, and is also a source of venting, exhaust emissions, and bilge discharge. Exhaust gases will be emitted from generators, engines and heaters onboard the FPSO, and small amounts of gas may also be vented through flame arresters on storage tanks on the production facility. Gases will contain traces of nitrous oxides, carbon monoxide and sulphur dioxide, and unburned hydrocarbons. The drill centres will be point sources of drill cuttings.

Figure 1.3-1 Possible Sources of Discharge from White Rose Project



1.4 Baseline Survey Design Methodology

1.4.1 Framework

This baseline characterization design was developed based upon experience with the Hibernia and Tera Nova EEM programs, as well as with North Sea and Gulf of Mexico approaches to monitoring that have been implemented for the offshore oil industry. The first step is to define the expectations and goals based upon input from regulators, public concerns and the scientific community. The extensive public consultation effort undertaken by Husky Oil identified a number of key issues associated with operational discharges and the marine environment, as summarized in Table 1.4-1.

Table 1.4-1 Summary of Issues and Concerns

Issues and Concerns
Concern about potential for a blowout, oil spill (all volumes) or chemical spill at the site or during transportation, and resulting effects of such accidents.
Dumping of bilge water by ocean-going vessels.
Cumulative effects of chronic oil pollution on the Grand Banks.
Effects of project operations and any accidents on traditional, current and future fisheries, including consideration of underutilized species and species under moratoria.
Cumulative effects of multiple offshore developments and related activities on fishery activities.
Fish tainting, real or perceived, and effects on fisheries.
Effects of the project on the biophysical environment due to release of drill cuttings and produced water, air pollution, sewage disposal and aircraft operation.
Vessel traffic and routing, and environmental effects.
Difficulties in distinguishing actual effects of offshore oil development from natural changes in the environment.
Need for representative baseline information for the White Rose site; concern about the appropriateness of using information from the Terra Nova reports.
Assessing long-term and cumulative effects of all users of the Grand Banks, such as other oil and gas activities, fishers, cable operators, research surveys and other vessels.
Need for environmental protection and monitoring plans.
Environmental management system that addresses pollution prevention, monitoring, auditing of the management system, environmental training, chemical selection and management, fisheries liaison and compensation for project-related damage.
Characterization of (information on) fish habitat conditions at the White Rose site.
Locations of species using the potentially affected area, including consideration of life stages.
Effect of project activities, including cumulative effects, on fish health and productivity, and amount of habitat affected.
Effect of any oil spill and planned discharges on fish and fish habitat.
Monitoring programs for fish and fish habitat.
Fish habitat compensation strategies and options.
Benthic communities.
Need for a monitoring process for all aspects of the project, including structures, operations, benefits and effects, with auditing of components.
Frequency of compliance monitoring.
Environmental effects monitoring for routine and accidental events, and compliance monitoring.
Monitoring parameters (marine birds, fish health/productivity, fish taint, fish habitat and marine environmental quality) and selection rationale.
Linking monitoring hypotheses to testable hypotheses.
Need for baseline studies and site-specific data.
Need to integrate monitoring programs with other projects such as Hibernia and Terra Nova.
Distinguishing "signal" from "noise" in monitoring programs.
Tying monitoring results to environmental management.
Independent/peer review of monitoring results.

If the White Rose project is approved, a separate Accidental Events EEM program will be designed and submitted to the C-NOPB six months prior to the beginning of development drilling. A compliance monitoring plan for each stage of development, including drilling and production, will also be submitted to the C-NOPB for approval six months prior to the start of those activities. Therefore those issues are not concerned in this document.

Based on the issues identified during the public and regulatory consultation, and knowledge of the Hibernia and Terra Nova projects, the baseline characterization program was designed. A sampling grid was developed that required scientific judgement in the choice of measurements and the level of spatial and temporal resolutions of the baseline monitoring.

1.4.2 Monitoring Questions

The baseline survey is designed to characterize existing conditions at the White Rose site. From these data questions will be formulated into testable hypotheses for the future EEM program. Based upon the concerns expressed for the effect of the project on the environment, combined with regulatory requirements and based on scientific expertise and experience with the offshore oil industry, the baseline characterization program focuses on:

- sediment quality;
- water quality; and
- biota.

Testable hypotheses will be developed for any or all of these categories for the future EEM program. Development of null hypotheses is considered to be a critical step in the development of EEM objectives and are comprised of three elements (Thomas 1992):

- spatial scale over which differences should be observed;
- temporal scale; and
- resolution scale (i.e., the magnitude of the smallest change that the program must detect at the specified level of statistical significance) or effects significance criteria.

1.4.3 Measurements

Measurements will be concentrated within the nearfield area around the three glory holes where changes are expected to be most likely. Stations also extend out to 20 km on the Grand Banks to provide control sites beyond the distance at which farfield effects have been reported in the North Sea (Olsgård and Gray 1995).

1.4.4 Detectable Change Concept

The goal of a monitoring program design should be to detect specific types and degree of change in the resources studied, in variables associated with them, or in model validation or increasing the knowledge of natural processes (NRC 1990). The biological, chemical and physical measurements identified in this baseline survey were selected in order to monitor the most appropriate candidate attributes at the White Rose site. A candidate attribute was considered appropriate for monitoring if it is of importance to the public or government regulators.

The expected magnitude of change, the nature of change and necessity for detection expected must be considered in the sampling strategy. Often regulatory standards identify the information, in some cases it can be predicted from preexisting data and in other situations it is developed from the baseline survey. Understanding the natural variability is required for defining meaningful change. If variability is large, it can mask environmental responses to project discharges. The baseline survey is designed to quantify natural variability and, using Power Analyses, help design the operational EEM program.

1.5 Design Team

Kathy Penney, M.Sc., is the Jacques Whitford Regional Vice President, Newfoundland and Labrador. She has extensive experience in all aspects of project management, environmental impact assessment, environmental effects monitoring design, and resource inventory and analysis. Ms. Penney was actively involved in the design of the Baseline Characterization and the Operational EEM for both Hibernia and Terra Nova offshore oil projects. She has been the project manager for the Hibernia and Terra Nova programs. Ms. Penney was seconded to Petro-Canada as the Environment Lead for the Terra Nova project from pre-approval to post-sanction, a period of over a year. She is presently managing a multi-disciplinary consultant team preparing the Husky White Rose DA for submission to the C-NOPB.

Ellen Tracy, B.Sc., is a marine biologist at Jacques Whitford Environment Limited in St. John's. Ms. Tracy has worked on several offshore oil and gas-related projects including, among others, the White Rose oilfield Development Application preparation support for Husky Oil Operations Limited, a review of drilling waste management options for the Canadian Association of Petroleum Producers, preparation of the environmental protection plan for the drilling and production phases of the Terra Nova development, preparation of a compliance monitoring plan for the production phase of the Terra Nova development, and environmental effects monitoring program design for Terra Nova and Hibernia developments, including baseline characterization design. Ms. Tracy's experience on the above projects included project management and client and regulatory liaison.

Elisabeth DeBlois, Ph.D., (Principal, CHART) has 20 years experience in fisheries and marine ecology. She gained formal training in fisheries at McGill University, working on capelin population dynamics in Conception Bay Newfoundland (Ph.D. 1992). She studied cod migration and distribution on the Grand Banks as a Post-Doctoral fellow at the Department of Fisheries and Oceans (Newfoundland region).

Her other topics of research have involved a review of the current status of fisheries recruitment research; a series of analyses of fisheries catch data (abundance, distribution, CPUE; cash landing); analysis of cod shoaling behaviour relative to food concentration as well as to trawling activity; review of acoustic scattering models for fish, review and recommendation of technical and statistical methodologies involved in Canadian trawl/acoustic fisheries surveys; and a description of the potential stock structure of Scotian Shelf flatfish as inferred from ichthyoplankton distribution. Dr. DeBlois used this information to complete an analysis of the commercial fisheries component of the White Rose Development Application Socio-Economic Impact Statement. Dr. DeBlois maintain contact with a number of colleagues within government and research institutions and has easy access to current information on DFO and Memorial University data holdings and availability.

Michael D. Paine, Ph.D., is the principal of Paine, Ledge and Associates (PLA) in North Vancouver, BC. He brings to the project team considerable expertise on marine environmental monitoring program design, including the design of the Terra Nova baseline characterization program, implementation, and data analysis; uptake and effects of hydrocarbons; and crude oil effects on fish. Dr. Paine has published 14 refereed journal articles, and has authored or co-authored over 40 reports for government and industry. Dr. Paine, while with PLA and with EVS Consultants (1989-1993), has been involved in several long-term marine EEM programs. The Alcan marine monitoring program has been conducted since the late 1980s off the Alcan aluminum smelter in Kitimat, BC. Hydrocarbons, especially in sediments, are major contaminants of concern. The Capital Region District (CRD) in Victoria, BC, and surrounding municipalities, manages several sewage treatment plants. Discharges from those plants, and their effects on marine biota in the Strait of Juan de Fuca, have been the subject of several EVS and PLA projects in the 1990s. Dr. Paine has also been involved in other marine EEM programs, examining impacts from combined sewer outfalls, and DDT and PCB in sediments off the California coast. He has been involved in numerous freshwater EEM programs and related projects, including several conducted in the Alberta Oil Sands area. He was Pollution Monitoring Task Manager for a large international project to improve marine monitoring capabilities in southeast Asian countries. Dr. Paine has also provided statistical guidance and review to industry and government for monitoring impacts from mines, pulp and paper mills, hydrophobic organic compounds, and pesticides.

David Pinsent M.Sc. (Marine Ecology) is an Intermediate Scientist and Project Manager with JWEL in St. John's. In over 4 years with JWEL, Mr. Pinsent has designed, conducted and authored several marine baseline and environmental effects monitoring (EEM) programs in the oil and mining industries. Most recently, he was a co-author on the Hibernia EEM Report and the Terra Nova EEM Baseline Characterization Report. Mr. Pinsent was a member of the team which designed the Terra Nova and Newfoundland Transshipment EEM programs. He has also designed and authored environmental effects monitoring programs for Voisey's Bay Nickel Company (VBNC), and Public Works and Government Services Canada (PWGSC). Mr Pinsent has designed, conducted and authored baseline studies for the Newfoundland Transshipment Terminal and the Argentia Nickel Smelter/Refinery projects. Mr. Pinsent was a senior author in the environmental assessment documents for the Voisey's Bay Mine/Mill, the Argentia Nickel Smelter/Refinery and the Newfoundland Transshipment Terminal project. Mr. Pinsent was also an advisor to VBNC during their environmental assessment panel hearings.

Jim Dempsey, B.Sc. has 25 years experience as a marine environmental consultant and has worked in all of Canada's oceans as well as both coasts of the USA. He has worked in the offshore oil and gas sector since 1977 and is familiar with marine operations supporting E&P activities. With a combined scientific background in marine biology, oceanography, and ice/icebergs, he has a fundamental understanding of the fate and effects of marine pollution in general, and oil spills in particular. In addition to offshore applications, Mr. Dempsey has had considerable experience in shoreline assessment and mapping. Mr. Dempsey has worked on the Hibernia EEM and Terra Nova baseline characterization programs and is the designated client representative for the Terra Nov EEM project.

2.0 BACKGROUND

2.1 Characteristics of the Grand Banks

The Grand Banks ecosystem is a complex and dynamic system that has been subject to a number of human-induced and environmental changes over the past 15 years. The collapse of several fish populations (for example, Northern cod) led to the closing of most major ground fisheries in the early 1990s and a shift in harvesting effort to lesser-fished species such as shrimp, crab, scallops and clams. Changes in water mass characteristics, such as temperature and salinity, were also observed between 1985 (Mobil 1985) and 1995 (Petro-Canada 1995). In 1997, the Grand Banks became an oil-producing region. Currently, there is one producing oilfield (Hibernia) on the Grand Banks and a second (Terra Nova) soon to begin production.

2.2 Physical Environment

As a result of its climatic and oceanic conditions, and as a result of its susceptibility to seasonal intrusions of ice, the Project area is situated in one of the harshest operating environments in the world.

2.2.1 Atmospheric Environment

The marine climate at the White Rose oilfield is similar to that at the Hibernia and Terra Nova fields. Mean monthly air temperatures range from –1.6 °C in February to 13.7 °C in August (Table 2.2-1). Winds in the area are primarily from the west in winter, and from the southwest during the summer months, and have been recorded at speeds of up to m/s (85 kts) (Table 2.2-2).

Table 2.2-1 Monthly Air Temperature Statistics

Month	Temperature (°C)			Standard Deviation
	Minimum	Maximum	Mean	
January	-10	6.7	-0.6	2.8
February	-9.2	5.6	-1.6	2.7
March	-17.3	7.7	-0.3	3.5
April	-5.6	9.5	2.3	2.1
May	-4.4	9.6	3.7	2.4
June	-1.2	13.1	6.8	2.4
July	0.9	17	11.3	2.1
August	7.8	20	13.7	2.3
September	4.2	17.5	11.9	2.4
October	-1	14.9	7.2	2.9
November	-4.1	12.5	3	2.4
December	-13.5	8.6	0.2	3

Data source: Husky Oil/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
Source: Husky 2000a

Table 2.2-2 Extremes at White Rose Location Using AES40 Grid Point 5622 (46.875N, 48.3333W) All Months and Years Combined

Return Period (years)	Wave (m)			Wind (m/s)				
	Significant Wave Height	Maximum Wave Height	Associated Spectral Peak Period	1-h Mean	10-min Mean	1-min Mean	15-s Mean	3-s Mean
1	10.5	19.7	13.5	23.6	25.0	28.8	31.2	33.7
10	12.7	23.8	14.9	27.7	29.4	33.8	36.6	39.6
25	13.5	25.2	15.4	28.8	30.5	35.1	38.0	41.2
50	14.1	26.3	15.8	29.7	31.5	36.2	39.2	42.5
100	14.7	27.4	16.1	30.5	32.3	37.2	40.3	43.6
Source: Husky 2000a								

2.2.2 Oceanic Environment

The White Rose site is located in a water depth of approximately 120 m. In the immediate vicinity, the bottom relief is relatively featureless, but steep slopes occur to the north and east on the edges of the Grand Banks.

At the White Rose site in 1999, monthly maximum combined wave heights ranged from 5.5 m (September) to 12.5 m (December) (Table 2.2-2).

Mean monthly sea surface temperatures at White Rose range from -0.6°C (February) to 13.3°C (August) (Table 2.2-3). Mean monthly values for water salinity range from 31.51 to 32.99 ‰. At the surface, the warmest water temperatures are in July and August and the coldest are in February, while the lowest salinity is in August and the highest in February. At water depths of 50 and 100 m, the salinity and temperature variations are smaller, with temperatures usually between -0.6°C and 2°C, and salinity between 32.6 and 33.5 ‰.

Table 2.2-3 Monthly Sea Surface Temperature Statistics

Month	Temperature (°C)			Standard Deviation
	Minimum	Maximum	Mean	
January	-2.2	1.4	-0.4	0.7
February	-2.4	1.6	-0.6	0.7
March	-2.3	2.3	-0.3	0.9
April	-2.2	7.2	1	1.3
May	-1	7.2	2.6	1.8
June	0	12	5.9	1.7
July	5	15.6	10.1	1.9
August	8.5	18.4	13.3	2.2
September	6	21.4	12.2	1.9
October	2.2	12.7	7.4	2.2
November	0	7.1	3.2	1.3
December	-2.6	4	0.7	1
Data source:	Husky Oil/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88) Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)			
Source: Husky 2000a				

Oceanic currents at White Rose are comprised of semi-diurnal and diurnal tidal currents, direct wind driven currents, inertial currents, geostrophic currents, and low frequency mesoscale currents resulting from such potential features as meteorological disturbances, meanders and eddies, and propagation of continental shelf waves. Data for the site indicate that monthly maximum surface current speeds range from 36.0 cm/sec (January) to 89.9 cm/sec (September), and that there is no preferred direction for surface currents in the area (Table 2.2-4).

2.2.3 Sea Ice and Icebergs

As a result of its location on the eastern slope of the continental shelf, the White Rose site is susceptible to seasonal incursions of ice. Both sea ice and icebergs are present in this marine environment. The White Rose area lies close to the extreme southern limit of the regional ice pack, and sea ice is usually loosely packed and pressure free. Most of the ice coverage in the area ranges from 30 cm to 100 cm in thickness, and is primarily comprised of either young or first year ice.

Table 2.2-4 Current Data for the White Rose Site

Well Site	Period	Max. Speed (cm/sec)	Mean Velocity (cm/sec)	Direction
Near Surface Currents				
White Rose N-30	Aug – Oct, 1999	89.9	5.0	Southeast
White Rose A-17	Jun – Aug, 1999	28.6	8.4	Northeast
White Rose L-08	Mar – Jun, 1999	45.7	2.7	Northwest
White Rose E-09	May – July, 1988	45.2	7.5	Southeast
White Rose J-49	Aug – Nov, 1985	61.7	4.9	South
White Rose L-61	Dec – Feb, 1985	36.0	6.4	Northeast
White Rose N-22	Jul – Oct, 1984	82.0	19.0	Southwest
Trave E-87	Nov – Jan, 1984	55.0	8.1	South
Trave E-87	Feb – Mar, 1984	40.0	11.1	Southeast
Mid-Depth Currents				
White Rose N-30	Aug – Oct, 1999	40.8	10.6	Northeast
White Rose L-08	Mar – Jun, 1999	29.4	3.8	South
White Rose A-90	Jul – Aug, 1988	24.7	3.4	Southeast
White Rose E-09	May - July, 1988	39.0	5.9	Southeast
White Rose E-09	Jan – Feb 1988	35.0	3.5	Southeast
Whites Rose E-09	Sept – Oct, 1987	32.6	9.0	Southwest
White Rose J-49	Aug – Nov, 1985	43.7	2.6	Southeast
White Rose N-22	Jul – Nov, 1984	31.0	1.8	Southeast
Trave E-87	Feb – Mar, 1983	31.0	7.5	South
Trave E-87	Nov – Jan, 1983	46.0	5.0	Southeast
Near-Bottom Currents				
White Rose L-08	Mar – Jun, 1999	27.6	2.8	Southeast
White Rose A-90	Jul – Aug, 1988	25.2	2.3	Southeast
White Rose E-09	May- Jul, 1988	32.6	3.7	Southwest
White Rose E-09	Jan – Feb, 1988	34.5	3.7	Southeast
White Rose J-49	Aug – Nov, 1985	50.6	2.0	Southeast
Trave E-87	Nov – Jan, 1983	39.0	6.6	Southeast
Trave E-87	Feb – Mar, 1987	32.0	5.9	Southeast
Source: Husky 2000a				

Table 2.2-5 Icing and Iceberg Criteria

Theoretical Superstructure Icing Accumulation on 5 cm Cylinder	10-Year Return	100-Year Return
Glaze and Rime Icing (mm)	72	169
Spray Icing (mm)	316	514
Icebergs Sightings	**Mean**	**Maximum**
One Degree Grid	67	268
Mass (t)	220,000	--
Speed (km/h)	0.77	9.8
Sea Ice Occurrence	**Mean Concentration**	**Average Number of Weeks**
Within 25 km	54 to 57 % coverage	2.3 to 2.6
Source: Husky 2000b		

The principal origins of the icebergs that reach the White Rose location are the 100 tidewater glaciers of West Greenland. Between 10,000 and 15,000 icebergs are calved each year, primarily from 20 major glaciers between the Jacobshaven and Humboldt glaciers. These glaciers account for 85 percent of the icebergs that reach the Grand Banks. According to the International Ice Patrol, the number of icebergs reaching the Grand Banks each year has varied from a low of 0 in 1966 to a high of 2,202 in 1984, with the average over the last 10 years being approximately 900 icebergs. Of these, only a small proportion will pass through the White Rose area. Over the last 10 years, the average yearly number of icebergs sighted in the 1^0 grid containing White Rose has been 47. The number of icebergs peaks in May, but is at relatively high levels from March to June.

2.3 Biological Environment

The Grand Banks ecosystem is a complex and dynamic system, driven by numerous physical, chemical, biological and anthropogenic influences. This section provides, as well as an overview of important ecological relationships on the Grand Banks.

2.3.1 Commercial Fish and Fish Habitat

Benthos refers to plants and animals that live in or on the sea bottom. At least 370 species of polychaete, echinoderm, crustacean and mollusc occur on the Grand Banks. Numerically, polychaetes are the most abundant infaunal taxa, and echinoderms and bivalves are dominant in terms of biomass (Hutcheson et al. 1981). Crustaceans are the dominant hyperbenthic animal. Commercially important members include clam, scallop, lobster, shrimp and crab. The composition of the benthic community is highly related to substrate type and water depth. Deep water and northern areas of the banks contain Arctic/ sub-Arctic assemblages. Temperate species are characteristic of shallow water and southerly portions of the banks.

A variety of pelagic and groundfish species occur in the White Rose area. Fish serve not only as an important food source for humans, but are also important ecologically as predators and food for other species as well.

The White Rose site is located within NAFO Unit Area 3Lt. Recent years have seen a significant increase in the value of commercial fish landings in the area, with landings valued at $1.74 million in 1998. During that year, snow crab comprised 98 percent of this landed value, followed distantly by porbeagle shark and Atlantic cod. Other species that are or have been important to fishing activity in the project area and adjacent region include Iceland scallop, northern shrimp, Stimpton's surf clam, yellowtail flounder, various species of shark, Greenland halibut, American Plaice, Atlantic halibut, various redfish species, capelin, swordfish, bluefish and bigeye tuna, American lobster, Atlantic salmon, witch flounder, short-finned squid, haddock, grenadier, and Atlantic herring.

A number of additional species have also been identified as potential commercial fish species in the area. These include various species of wolffish and skate, monkfish (or goosefish), white hake and winter flounder.

There appears to have been a recent shift in the species composition on the Grand Banks, with a decline in a number of species in addition to northern cod.

2.3.2 Sea-associated Birds

The Grand Banks and the southeastern coast of Newfoundland are very important areas for over 60 species of sea-associated birds, including puffins, guillemots, razorbills, murres, gulls, jaegers, storm-peterls, shearwaters and phalaropes. Of these 60 species, approximately 18 are pelagic, nine of which nest in the study area. There are several million of these nesting birds, and there are millions of annual visitors that forage on the Grand Banks. In addition, a wide variety of coastal species, including gulls, terns, cormorants, waterfowl and shorebirds frequent the shoreline areas of the study area. Sea-associated birds in the study area eat a variety of prey, including capelin, copepods, amphipods and short-finned squid, and different species forage at different water depths. Several endangered or threatened bird species also occur in or near the area, including harlequin ducks, piping plovers, ivory gulls, manx shearwaters, and common black-headed gulls. Marine birds are important predators on plankton, benthos and fish.

2.3.3 Marine Mammals and Sea Turtles

Eighteen species of marine mammals are known to occur in the study area, including 14 species of whales and dolphins and four species of seals. A few additional species may also occur, but these are not considered important components of the ecosystem because of their rarity. Although most species are seasonal inhabitants, the waters of the Grand Banks and surrounding areas are important feeding grounds for some.

Six species of baleen whales occur in the area: humpback, blue, fin, sei, minke, and possibly North Atlantic right whales. Although nearly all of these species experienced declining in numbers due to whaling, it is likely that some are recovering. However, the humpback, blue and fin whales are still listed as vulnerable, and the North American right whale is listed as endangered. In addition, eight species of odontocetes (toothed whales) are found in the region, which range from the largest living odontocete, the sperm, to one of the smallest whales, the harbour porpoise. Most of these marine mammals occur seasonally in the study area and little is known regarding their distribution and population size in these waters. Of the toothed whales found in the study area, the harbour porpoise is listed as threatened and a population of the northern bottlenose whale is considered vulnerable. In addition, grey, harp, hooded and harbour seals occur in the study area at various time of year. The main diet of seals consists of fish, and invertebrates such as squid and shrimp.

Three species of sea turtle (leatherback, loggerhead, and Kemp's ridley) are also known to occur in the area. The leatherback turtle is listed as endangered by COSEWIC (1999) and by the United States National Marine Fisheries Service (NMFS) and Fish and Wildlife Service (FWS), Kemp's Ridley is also listed as endangered and the loggerhead turtle is listed as threatened by NMFS and FWS.

2.4 Substrate

The Grand Banks are largely underlain by crystalline and meta-sedimentary rocks of the Avalon terrain, which contain structural fabrics imposed by Caledonian and Hercynian deformation episode. The White Rose field is located on the eastern margin of the Jeanne d' Arc Basin. Side scan sonar images of the White Rose area (Fugro Jacques GeoSurveys 1999a; 1999b; Nortec Jacques GeoSurveys 1998) indicate that the surficial geology is a thin veneer of fine to medium grained sand over a coarser substrate, consisting of gravel and gravelly sand. Variable concentrations of benthic organisms (such as, starfish, brittle stars, bivalves, etc.), as well as cobbles, are present. The only seabed features are related to seabed disruption by iceberg scouring, or by the dragging of otter trawl "doors" during fishing activities. The seabed is relatively stable, with relatively little sedimentary transport within the region. The White Rose area is one of relatively low seismic activity.

The stratigraphic section penetrated by the wells drilled in the White Rose region contains Tertiary to Late Jurassic age rocks. Of the formations penetrated, only the South Mara, Avalon, Eastern Shoals and Hibernia sections have any reservoir-quality sandstones. The oldest rocks penetrated in the White Rose region are from the Voyager Formation in the White Rose N-22 well.

The Egret Member is the main source rock for the hydrocarbons in the White Rose area and has been penetrated in the A-90 well. Oil bearing, overpressured sandstones, probably the Tempest Member were penetrated in the E-09 well.

The Aptian-aged Avalon Formation is the primary reservoir in the White Rose Field. In general, the Avalon is a marginal marine, shoreface succession through much of the field. The Avalon is dominated by very fine to fine-grained sandstones, siltstones and shales, and ranges from 0 to 400 m in thickness. The main sandstone accumulations occur in the southeastern portion of the field with the E-09, L-08 and A-17 wells (South White Rose Pool) exhibiting thicknesses of up to 350 m of sandstone. The Avalon Formation is absent in the White Rose A-90 and Trave E-87 wells.

Substrate type and characteristics in the White Rose area are based on data collected from glory holes constructed for subsea well protection at the Terra Nova site (C-CORE 1999), and site-specific surveys conducted for Husky Oil's drilling programs in the White Rose area. This information is summarized in Table 2.4-1.

Table 2.4-1 Substrate Profiles and Description

Substrate Stratigraphy	Profile Name and Description			
	Terra Nova Glory Holes			White Rose Site Surveys (Husky Oil, May, 1997, March 1999)
	0-90 Glory Hole (BIO & Seabed Exploration, April 1996)	1998 SW Glory Hole (Seacore)	Terra Nova Project Summary	
Sand	0 to 1.5 m loose sand with small stones	0-1.6 m[1] sand or sand and gravel and cobbles	0-2 m sand and sand and gravel	0 to 3 m fine/ medium sand, relatively hard packed
Clay or Hard Pan	1.5 to 2.3 m variable thickness, grey-green well-cemented, "shelly" mudstone (southwest); dark grey, stiff massive mud (north)		2 to 4 m hard pan	
Sand and Gravel (and Cobbles)			4-5.5 m sand, gravel and cobbles/boulder; Friction Angle=44°, Cohesion = 0 kPa	2 to 10 m coarse sand and gravel
Layered Clay and Sand with Cobbles/ Boulders	2.3 to 8.0 m fine grained sand with clay matrix, numerous stones (good initial strength)		5.5 to 9.5 m layered clay and sand with cobbles/boulders; Friction Angle=42°, Cohesion = up to 28 kPa	
Clay with Cobbles	8.0 to 9.8 m stiff grey/green clay		9.5 to 16.5 m clay with cobbles and boulders high to low plasticity	10 to 700 m claystone

[1] No data below 1.6 m
Source: Husky 2000b

2.5 Chemical Environment

The concentration of dissolved oxygen in seawater strongly influences the abundance and distribution of marine life. The concentration in the Grand Banks water column has been reported to be fairly uniform during the spring with a mean surface value of approximately 8 ml/L, decreasing to approximately 7 ml/L near the bottom. Similar results were reported by a mid-spring 1993 survey of the Grand Banks. The reported range for suspended particulate matter in the Grand Banks water column is 0.01 to 2.77 mg/L and is within ranges reported for other ocean environments. Water samples collected at the Terra Nova oilfield site displayed a mean value of total suspended solids of 2.26 mg/L at the surface and 2.17 mg/L near the bottom. The results of sampling for trace metals on the Grand Banks indicate the area is typical of open water areas. Polycyclic aromatic hydrocarbon concentrations for seawater samples collected at the Terra Nova Oilfield site were below detection limits in water column samples; however, other hydrocarbons were detected. The source of the hydrocarbons was suggested to be from atmospheric fallout of aromatic compounds rather than near by point-source emissions.

Sediments on the Grand Banks are generally homogeneous, both physically and chemically. On a regional scale the seabed is relatively homogenous, and comprised of sand and gravel. Hydrocarbons are ubiquitous in marine sediments and are commonly found in marine phytoplankton. On the Grand Banks, hydrocarbon levels are generally at very low background concentrations.

3.0 EXPECTATIONS AND GOALS OF THE MONITORING PROGRAM

EEM is conducted to assess the status of the marine environment, detect changes in this status, test effects predictions made during the assessment process, assess the effectiveness of implemented mitigation, and provide an early warning of any undesirable change resulting from the effects of activities at the site. Baseline characterization of the environment provides information on the existing status of the marine environment. In this case, baseline conditions refer to the existing environmental conditions at the White Rose oilfield after preliminary exploration and prior to development.

The goal of the baseline characterization program is to provide a foundation of information upon which the future EEM programs can be structured. The baseline characterization survey is intended to be as broad based as possible, and may include attributes and stations that will not be carried into an EEM program. Baseline conditions on the Grand Banks in the White Rose area need to be characterized so that any changes can be detected and related to project discharges following well development and production in 2001/2002. The overall objective of the monitoring studies is to provide useful information in management decision making (NRC 1990). To achieve this, the monitoring plan must establish scientifically defensible, statistically valid, cost-effective sampling and analytical programs. Formulating monitoring objectives requires consideration of public concerns, regulatory requirements and scientific issues.

3.1 Identification of Public Concerns

The following issues concerning monitoring were raised during the public consultations for the White Rose EIS (Husky Oil 2000) (Table 3.1-1):

Table 3.1-1 Summary of Issues and Concerns

Issues and Concerns
Concern about potential for a blowout, oil spill (all volumes) or chemical spill at the site or during transportation, and resulting effects of such accidents.
Dumping of bilge water by ocean-going vessels.
Cumulative effects of chronic oil pollution on the Grand Banks.
Effects of project operations and any accidents on traditional, current and future fisheries, including consideration of underutilized species and species under moratoria.
Cumulative effects of multiple offshore developments and related activities on fishery activities.
Fish tainting, real or perceived, and effects on fisheries.
Effects of the project on the biophysical environment due to release of drilling muds and produced water, air pollution, sewage disposal and aircraft operation.
Vessel traffic and routing, and environmental effects.
Difficulties in distinguishing actual effects of offshore oil development from natural changes in the environment.
Need for representative baseline information for the White Rose site; concern about the appropriateness of using information from the Terra Nova reports.
Assessing long-term and cumulative effects of all users of the Grand Banks, such as other oil and gas activities, fishers, cable operators, research surveys and other vessels.
Need for environmental protection and monitoring plans.

Issues and Concerns
Environmental management system that addresses pollution prevention, monitoring, auditing of the management system, environmental training, chemical selection and management, fisheries liaison and compensation for project-related damage.
Characterization of (information on) fish habitat conditions at the White Rose site.
Locations of species using the potentially affected area, including consideration of life stages.
Effect of project activities, including cumulative effects, on fish health and productivity, and amount of habitat affected.
Effect of any oil spill and planned discharges on fish and fish habitat.
Monitoring programs for fish and fish habitat.
Fish habitat compensation strategies and options.
Benthic communities.
Need for a monitoring process for all aspects of the project, including structures, operations, benefits and effects, with auditing of components.
Frequency of compliance monitoring.
Environmental effects monitoring for routine and accidental events, and compliance monitoring.
Monitoring parameters (marine birds, fish health/productivity, fish taint, fish habitat and marine environmental quality) and selection rationale.
Linking monitoring hypotheses to testable hypotheses.
Need for baseline studies and site-specific data.
Need to integrate monitoring programs with other projects such as Hibernia and Terra Nova.
Distinguishing "signal" from "noise" in monitoring programs.
Tying monitoring results to environmental management.
Independent/peer review of monitoring results.

3.2 Identification of Regulatory Requirements

3.2.1 Legislated Requirements

The C-NOPB guidelines (1988) provide the direction necessary for addressing the regulatory requirements of the *Canada-Newfoundland Atlantic Accord Implementation Act* and the *Canada-Newfoundland Atlantic Accord Implementation Newfoundland Act*. The C-NOPB guidelines and CEAA set out the regulatory requirements for a DA and a federal environmental assessment, respectively. They established the initial scope for the DA and related assessment.

The White Rose project is subject to CEAA. The C-NOPB is responsible for issuing a production licence for the project, and thereby "has the administration of federal lands and …disposes of those lands or any interest in those lands…for the purpose of enabling the project to be carried out" within the meaning of paragraph 5(1)(c) of CEAA. The C-NOPB therefore requires an environmental assessment under CEAA, and is a responsible authority respecting the project.

DFO had determined that the project may result in harmful alteration, disruption or destruction of fish habitat under authority respecting the project. Similarly, EC has determined that the construction of glory holes during the project and the deposition of spoils upon the surrounding seabed likely will require a Disposal at Sea Permit under the *Canadian Environmental Protection Act*, and that EC is a responsible authority. Finally, IC had determined that the radio equipment on the production installation will require its approval pursuant to Section 5(1)(f) on the *Radiocommunications Act,* and that therefore it is a responsible authority respecting the proposed project as well. The project is subject to a comprehensive study level of assessment under CEAA, since it falls within the *Comprehensive Study List Regulations*, Part IV, Oil and Gas Projects, Section 11.

3.2.2 C-NOPB Scoping Document

The scoping document issued by the C-NOPB on June 28, 2000 is the principle regulatory tool providing specific direction for the content of the DA, and environmental and socio-economic assessment. It was reviewed for issues and concerns to be addressed in the assessment and development application documents.

The scoping document states that Husky Oil must consider the factors outlined in Section 16 of the CEAA and matters listed in the appropriate sections of C-NOPB guidelines (1988), as well as issues and concerns identified during its regulatory, stakeholder and public consultation. Issues and concerns noted in the scoping document related to the marine receiving environment include:

- cumulative environmental effects, including fishing activities, marine bird hunting, marine transportation, Hibernia and Terra Nova projects, and approved or reasonably foreseeable petroleum exploration activity;
- environmental assessment methodology and testable hypotheses;
- marine resources, including marine and/or migratory birds, marine fish, shellfish, marine mammals, benthic and water-column fish habitat;
- marine use, including present structures and operations, and commercial fisheries;
- discharges and emissions, including electromagnetic emissions from radio equipment, planned project discharges to the marine environment and reinjection of produced water and drill cuttings;
- accidental events, including blowouts, oil spills, chronic oil pollution and spill response;
- environmental management, including policies for pollution prevention, environmental effects and compliance monitoring, management system auditing, training, chemical selection and management, fisheries liaison, compensation strategies for damage to fisheries and other affected parties, fish habitat compensation and environmental emergency response; and
- environmental effects monitoring, including program characteristics, parameters and hypotheses, baseline information, integration with other programs, independent/peer review of results, linking results to the environmental management system, and habitat compensation and post-dredging monitoring.

3.3 Identification of Scientific Issues

Husky Oil has consulted with knowledgeable stakeholders and the appropriate regulatory agencies over the course of its two-year planning for the White Rose oilfield development. All scientific issues raised during that process were addressed in the EIS.

The scientific issues to be addressed by the baseline survey were confirmed following a review of current scientific literature on the effects of offshore oil production. The discharge of drilling muds, cuttings and other fluids associated with drilling may result in toxic effects or the accumulation of contaminants in marine sediment and biota. The toxicity of operational discharges and the accumulation of contaminants have been studied in the North Sea (Addy et al. 1984), off Sable Island (Yunker and Drinnan 1987), and by such institutions as Environment Canada (1994) and GESAMP (1993). Recent research has also identified the smothering of benthos by drill cuttings as a potential concern associated with offshore oil production (Davies et al. 1984).

Studies in the North Sea and elsewhere in the 1980s, raised concerns about the environmental effects of the original oil-based muds (OBMs) with a high aromatic content and drove the development of the synthetic base fluids in the 1990s. Industry developed synthetic-based muds (SBMs) as a base drilling fluid to replicate the performance characteristics of traditional OBMs, which were based on diesel and mineral oil. The SBMs were developed to have lower environmental impact and greater worker safety through lower toxicity, elimination of PAHs, faster biodegradability, lower bioaccumulation potential, and, in some drilling situations, less drilling waste volume.

SBMs have borne the regulatory legacy of the effects of OBMs used in the 1970s and 80s, particularly in the North Sea, where they were in very common use. Regulators have been cautious to relax the stringent management and discharge regulations imposed for OBM cuttings despite the fact that the science seems to indicate that the environmental effects associated with SBM cuttings are more restricted in area, less toxic, and last for a shorter period of time. The SBM family of drilling fluids and cuttings have been the subject of extensive testing and examination by regulators in Europe and the United States to determine the most appropriate management systems for their areas of jurisdiction. The evolution of the regulations is requiring the Industry to adopt more rigorous drilling fluid management systems and undertake more extensive research, development, and monitoring programs to assess the environmental effects associated with the discharge of coated cuttings before approvals are received.

The pressure that has driven the regulations and resulted in the new technologies has also resulted in the development of a new collaborative relationship between regulators and the Industry. The regulators have recognized that the approach to finding an acceptable solution to environmental issues, such as disposal of SBM cuttings, requires inputs from all stakeholders to ensure that the operational and financial effects of a regulation are fully understood and evaluated before final decisions are made. Formal and informal relationships have been established between Industry and regulatory bodies in the United States, Australia, and the UK and Norwegian sectors of the North Sea to address, among other issues, the management of synthetic drilling fluids and the resulting cuttings. In Norway, the oil industry association has been an active contributor to an innovative and strategic consultative forum (MILJØSOK), which is the alliance between the Norwegian industry and government to create an open dialogue between the stakeholders on measures to better meet environmental challenges. One of the first issues this forum considered was disposal options for cuttings. In Australia, the national environment agency has developed strong relations with the national oil and gas industry association to develop multiple use solutions that address issues associated with competing resource interests. In the United States, the recent work by the Environmental Protection Agency (USEPA 1999) to develop new effluent limitations, guidelines and standards for synthetic based drilling fluids involved an extensive cooperative work program with the Industry.

The regulators in the various jurisdictions have developed two different models for addressing the SBM cuttings issue. In developing regulations, regulators have borrowed very freely from the experience and results in other jurisdictions. Internationally, the North Sea drill cuttings management initiatives driven by the regional OSPAR Convention and its predecessor organizations is widely used as a guide. The North Sea is unique because it is a semi-enclosed water body surrounded by heavily populated industrialized countries, each with a sector of the North Sea to manage. Consequently, the collective pressures to regulate materials such as drill cuttings are greater than in areas such as Australia, Canada, and the United States which are governed by their own national legislation, and are signatories to regional marine environmental management conventions, which add additional regulatory pressure. The result has been the development of a regulatory system that has established rigorous standards to which all operators are expected to conform.

In Australia and the United States, a flexible system for the management and discharge of SBM cuttings is evolving. Industry and the regulatory agencies have developed a holistic approach to the SBM cuttings management issue to ensure that all the technical, financial and environmental consequences are thoroughly evaluated before a final decision about a disposal strategy is made. It relies heavily on the concepts of best available technology and best environmental management practices to achieve the desired objective. It places a strong onus on the operator to carefully manage the drilling program and be accountable for the result, and it gives the regulators the option of tightening up controls if the desired results are not being achieved.

This regulatory model provides flexibility in considering new SBMs or environmental monitoring technologies, or new environmental effects information, to modify cuttings management requirements to assure maximum environmental protection at the most effective cost. It is important to emphasize that this model does not necessarily mean a departure from appropriate environmental protection goals. It simply defines a regulatory objective and allows the operator to make operation specific decisions.

This approach also has the added benefit of forming associations between the regulatory agencies and the Industry where there is a mutual recognition and understanding of the environmental issues and goals, and the management methodologies most appropriate for the desired outcome. A common understanding about the limitations of the available cuttings management and measurement technologies can influence the direction of regulations and assure that unreasonably restrictive regulations do not have unintended side effects. In this model, all the stakeholders have a vested interest in, and ownership of the result.

3.4 Monitoring Objectives

The EEM Program is intended to provide the prime means to determine and quantify project-induced change in the surrounding environment. Where such change occurs, the EEM Program will enable the evaluation of effects and, therefore, will assist in identifying the appropriate modifications to, or mitigation of, production activities or discharges.
Objectives to be met in the development and application of the EEM plan are as follows:

- to test whether the impact of discharges into the aquatic environment is within the bounds predicted by the EIS;
- to fulfil regulatory information requirements and address legitimate public concerns;
- to provide feedback to the Husky Oil such that the information may be used in project management;
- to synthesize, interpret and analyze data such that it is scientifically defensible;
- to be cost-effective, making optimal use of personnel, technology and equipment;
- to present the results in a format which can be understood by the general public; and
- to use the results to modify operational practices and procedures where/when necessary.

4.0 MONITORING STRATEGY

4.1 Selection of Candidate Attributes

Candidate attributes were selected for the baseline survey on the basis of four criteria: valued ecosystem components (VECs) identified in the White Rose EIS (Husky Oil 2000); those attributes raised by the regulators; the scientific expertise of study team members; and, the logistics of undertaking the studies.

Attributes selected for consideration included the following:

- sediment quality;
- benthic macroinvertebrates;
- fish/shellfish;
- water quality;
- marine mammals; and
- seabirds.

4.1.1 Water Quality

Water quality was determined not to qualify as a candidate attribute for the baseline survey. Given the high degree of water column mixing, the scientific consensus is that taking snapshot sampling of this highly variable attribute would not provide value to determining cause and effect of project discharges. The essence of effects monitoring is repeatability, a trait virtually unobtainable by monitoring water quality offshore because the same water cannot be measured twice. Compliance monitoring during the production phase to meet C-NOPB discharge regulations, Offshore Waste Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996), for produced water, deck drainage and drill cuttings will be undertaken at laboratory facilities onboard the FPSO. However, Husky Oil will sample basic water quality parameters such as chemistry, conductivity and temperature at depth, and chlorophyll content during the baseline characterization program.

4.1.2 Marine Mammals

Because underwater noise propagates for long distances, the potential zone of influence around a particular noise source can be many tens of kilometres in radius. The zone of influence of underwater noise at White Rose includes zones around the development area, shipping routes between the supply base and the drilling rig or FPSO, and the helicopter flight routes between St. John's Airport and the White Rose Field.

Marine mammals typically are more tolerant of fixed location noise sources, like the semi-submersible drill rig and FPSO planned for use in the White Rose development, than moving sources.

Baleen whales exhibit variable reactions (avoidance response in relation to distance from the noise source) to noise created by drilling rigs, but these reactions are likely related to the received sound level of the noise source. Some baleen whales are less responsive to noise, and habituation may occur, so that in time, whales may occur closer to drilling structures (e.g., bowhead whales in Richardson et al. 1985a; 1985b; 1990). Behavioural reactions would be limited to a very small area (a few 100 m) around a semi-submersible rig because noise levels are low (Richardson et al. 1995). Baleen whales may show little reaction or slow, inconspicuous avoidance reactions to boats and supply vessels that are moving slowly on a steady course. If the vessel changes course and/or speed, whales likely will swim rapidly away. Avoidance is strongest when the vessel travels directly toward the whale.

Toothed whales show variable reactions to aircraft overflights; some dive or swim away, while others exhibit no reaction (see Petro-Canada 1995). Some baleen species, like minke, bowhead and right whales reacted to aircraft overflights at altitudes of 150 to 300 m by diving, changing dive patterns or leaving the area (Leatherwood et al. 1982; Watkins and Moore 1983; Payne et al. 1983; Richardson et al. 1985b; 1985c). Belugas, dolphins, and other toothed whales show considerable tolerance of drill rigs and their support vessels, particularly when there are not negative consequences from close approach to the activities (Richardson et al. 1995).

Seals hauled out for pupping or moulting are very sensitive to aircraft disturbance (Richardson et al. 1995). It is highly unlikely that there will be overflights of seals that are pupping or moulting as few, if any, seals will be hauled out (either on ice or land) along the flight route to White Rose during these critical times or at other times of the year.

The issue of noise effects upon marine mammals was raised during public consultation. There is an important whale feeding ground on the Southeast Shoal, which is approximately 250 km from the White Rose site. There appears to be sufficient data available in the literature (e.g., Richardson et al. 1995) to provide input into acoustic models.

Husky Oil has committed to follow-up monitoring of marine mammals in the event of an oil spill. This will be included in an EEM program specifically designed for response to accidental events (e.g., large oil spill) which will be submitted to C-NOPB and other appropriate agencies six months prior to the onset of development drilling.

4.1.3 Sea-associated Birds

The issue of most concern with sea-associated birds is the potential for effects due to an accidental oil spill. Oil spill prevention and preparedness are operational issues for the White Rose oilfield. Commitments have been made in the EIS to dedicated sea-associated bird surveys of mortality in the event of an oil spill. Spill effects monitoring will be addressed in the Oil Pollution Emergency Plan to be developed for the White Rose project.

There is considerable information available on the sea-associated bird populations in the Marine Birds Gazetteer (Lock et al. 1994). This atlas is specific to vulnerability of sea-associated birds and waterfowl to oil pollution. Monitoring of effects to sea-associated birds should be addressed in the Oil Pollution Emergency Plan and that a dedicated team would be responsible for this attribute if an oil spill were to occur. A single survey cruise during baseline monitoring is too brief to establish background levels.

In addition, Husky Oil has committed to logging any bird mortalities that may arise from accidental collisions with the FPSO or within the flare during discharge.

A sea-associated bird census could be conducted from operational supply vessels. Husky Oil has previously conducted sea-associated bird and marine mammal surveys from offshore supply vessels (Wiese and Montevechi 1999) and has committed to continuing logging observations.

Husky Oil has committed to follow-up monitoring of sea-associated birds in the event of an oil spill. This will be included in an EEM program specifically designed for response to accidental events (e.g., large oil spill) which will be submitted to C-NOPB and other appropriate agencies six months prior to the onset of development drilling.

4.1.4 Sediment Quality

Husky Oil has committed in the EIS to monitor oils in the sediments and their effects on benthic organisms. The regulators have identified oil contamination of sediments and effects on benthic organisms as a key indicator of sediment quality and the scientific community has routinely monitored sediment quality as part of their monitoring programs. Sediments are the ultimate sink for persistent chemicals and particulate matter emitted from the well development and production. Sediment monitoring is preferred as sediments provide short term and long term historical accounts of activities, accumulate contaminants to a much higher concentration than water, allow contaminant gradients to be established and give a degree of kinematic variability that is lower compared to the water column.

4.1.5 Benthic Macroinvertebrates

Benthic macroinvertebrates depend upon the seafloor for food resources and habitat. As most of these animals are sedentary or sessile, they can provide a record of intermittent and chronic contamination effects over the life of the offshore project. Using a variety of feeding strategies, benthic organisms feed upon particulates as they rain down through the water column (suspension feeders) or feed directly upon the sediments (deposit feeders) making them vulnerable to accumulation of contaminants. The EIS did not identify public concern for benthic community assemblages; however, environmental regulators have expressed concern for the effects of oil on benthic animals and the scientific community has, since the 1970s, monitored the effect upon the infauna benthic community (Hartley 1979; Kingston 1987; Daan et al. 1992; Olsgård and Gray 1995; Green and Montagna 1996; Kennicutt et al. 1996). The epifaunal benthic community has also been quantified on the Grand Banks (Schneider et al. 1987).

4.1.6 Fish/Shellfish

The Grand Banks fishery was central to the economy and society of Newfoundland. Groundfish stocks have collapsed and remain under a fishing moratorium established in 1992. Stock recovery is slower than expected and its future health remains uncertain. Reduced fish stocks has affected selection of candidate species for baseline characterization. Flatfish are typically used for contamination studies, and American plaice will be used to compare results with the other existing EEM programs (Hibernia and Terra Nova). In addition, the abundance of snow crab (a commercially-important species) in the White Rose area also makes it an ideal candidate attribute.

The public, along with the regulators, has expressed considerable concern for fish stocks in regard to tainting of flesh, effect on migratory fish stocks and effect on spawning and rearing grounds from hydrocarbon releases. On the East Coast of Canada, in the Gulf of Mexico and the North Sea, researchers have studied hydrocarbon fate and effects upon groundfish and shellfish (Paine et al. 1988; Dey et al. 1983; Payne et al. 1983; Neff et al. 1985; Berthou et al. 1987; Strickland and Chassan 1989). Development of the White Rose oilfield has the potential to result in effects on fish species from drilling and operational discharges. The White Rose EIS states that a program to monitor tainting in fish will be implemented and the DFO position statement (DFO 1997) recommends that a well designed tainting detection program should be initiated around development sites for assurance purposes. Furthermore, the DFO position statement identifies bioaccumulation as an issue; the baseline survey will determine if appropriate species are available and in sufficient numbers to enable body burden analyses. Since in-situ bioaccumulation studies have not proven successful in offshore environments, it is considered an experimental technique and will not be considered for the White Rose EEM.

4.2 Detectable Change

An adequate measure of spatial or temporal variability for any one of the potential candidate attributes has not been established within the White Rose region of the Grand Banks. Variability in the baseline survey data will be used to evaluate suitable measures of detectable change. Any highly variable parameter is not a suitable indicator of detectable change.

On possible measure of detectable change is expressed in terms of the maximum acceptable effects levels (MAELs). MAEL, as defined in the context of the White Rose project, is essentially a means of determining the maximum acceptable effect that could occur at a specific distance from project and be attributed to operations of the project. MAELs may be measured by water column concentrations of contaminants, pore water concentrations, sediment matrix concentrations or bioassessment testing. The use of biological effects tests for the MAELs is preferred over the use of measured chemical concentrations, since the linkage between effects and causes (as defined by chemical concentrations) is not well defined and may generate erroneous conclusions.

Baseline data will be examined and this information will help to determine what would be considered a detectable change.

4.3 Sampling Design

Sampling and statistical analyses will occur at micro- and macro-scales within the nearfield and farfield regions to address zones of influence (ZOI). The nearfield is that region described by the immediate influence of the drill centres and considered the area encompassed by all three glory holes. The farfield region is the area further out along the transects outside the nearfield area. The design considers nearfield effects from the drill centres which preliminary modeling has predicted to be local and farfield effects from waterborne and sediment transported contaminants. The ZOI for the discharges and the parameters being measured are anticipated to differ based upon published literature. For example, the ZOI for hydrocarbons may differ from the ZOIs for suspended particulate matter and metals.

The sampling design focuses upon the seabed because sediments are the ultimate sink for persistent chemicals in the marine environment. The two most common chemical contaminants associated with offshore oil platforms are hydrocarbons and metals. Chemical contaminants in sediments can affect environmental quality in two ways:

- adversely affect the natural productive capacity of sediments; and
- potentially release contaminants to other phases of the environment, such as the water column and biota.

In addition to chemicals, discharge of particulate matter is also associated with offshore oil activities (GESAMP 1993). Particulates released from the platform and from drilling can alter the physical characteristics of sediments and thereby adversely affect the productive capacity of sediments.

Methods to assess the quality of sediments and associated fauna have evolved from basic chemical analysis to complex studies which combine physical, chemical and biological testing. Five general types of testing are currently used:

- sediment chemical and physical testing;
- sediment toxicity testing;
- tissue chemistry testing (bioaccumulation);
- benthic infaunal community structure; and
- benthic fish pathology.

Useful information can be obtained from independent chemical and biological testing, however, reliance on any single test as a descriptor of sediment quality is not recommended (Chapman et al. 1991). An innovative approach which combines three of the above tests is the sediment quality triad (SQT). The

SQT incorporates concurrently obtained (synoptic) measures of sediment chemistry and physical description, sediment toxicity, and benthic infaunal community structure to determine environmental degradation (e.g., Long and Chapman 1985; Chapman et al. 1987, Chapman 1992). Integration of results from these three measures greatly increases the value of the overall study results. The SQT approach has recently been applied to assess the pollution status of sediments near offshore oil platforms in the North Sea (Chapman 1992) and in the Gulf of Mexico (Chapman et al. 1991; Chapman and Power 1990; Green and Montagna 1996). The project team has applied the SQT approach in the Alcan and Victoria (BC) marine monitoring programs, the Voisey's Bay Mine/Mill baseline characterization and the Hibernia EEM and Terra Nova baseline characterization programs.

SQT may be a suitable approach for assessing baseline sediment quality at the White Rose oilfield. Husky Oil has committed in the EIS to monitoring oils in sediments and their effects on benthic communities. Evaluation and selection of sediment quality tests to use in the baseline characterization would be based on existing information in the primary literature, experience at the Hibernia and Terra Nova sites and on existing conditions at the White Rose oilfield available from the proponent and regulators.

SQT variables (chemistry, toxicology, benthic communities) will be assessed at the micro-scale; fish and/or shellfish contamination and condition will be assessed at the macro-scale.

4.3.1 Micro-scale Sampling Design

The proposed micro-scale sampling design must provide baseline information on natural spatial variation of the SQT and supplementary variables, and provide a temporal control for post-operational effects assessments. Therefore, the sampling design or grid includes more sample stations than will probably be required for post-operational sampling and effects assessment.

The White Rose project is similar to Terra Nova in that there is not a single point source (for example, a fixed platform connected to all drill centres), but four - the three glory holes plus the FPSO. With a single point source, sample stations can be selected at increasing distances from the source along several radii or transects, as in the Hibernia baseline and EEM program (JWE 1995; JWEL 1998; see also Green and Montagna 1996). Other approaches are possible; most would use a general linear model (ANOVA and/or regression) to test for effects of distance or direction from the point source on candidate attributes. Various levels of replication have been used in past studies. For example, many North Sea studies have replicated within stations; the GOOMEX studies replicated within box cores, and also used radii as blocks, another form of replication (Kennicutt et al. 1996).

ANOVA approaches are not feasible for the White Rose project. First, with four point sources, distance and direction cannot be defined relative to a single point. One could select n stations at each of one or more distances and/or directions from any drill centre. However, each of those stations would not be equidistant from other drill centres and from the FPSO, which might also affect the station. Furthermore, during early operational years, all drill centres will not be equal because the number of wells drilled will differ among them. A completely crossed design, with one or more stations at each possible combination of distance or direction from each drill centre and the FPSO, and number of wells drilled, would be impossible to construct. Even if a completely crossed design were possible, the number of stations required would be too large to be feasible. Therefore, distance from the various sources, and the number of wells drilled, must be used as independent (i.e, X) variables in a regression approach rather than as factors in an ANOVA approach. This type of approach is described in more detail in Section 4.3.1.2. Ellis and Schneider (1997) compare the regression and ANOVA approaches for assessing impacts from offshore oil projects, demonstrating that the regression approach is generally superior when the zone of influence is unknown.

For all statistical analyses in the baseline survey, stations will be the fundamental units of replication, although replication within stations may occur for some attributes for practical reasons. The SQT variables must be measured on the same replicate units (i.e., be synoptic) (Chapman et al. 1987) and cannot be measured synoptically on any level lower than station. For example, one box core (i.e., replicate within station) will not provide sufficient sediment for analyses of all three SQT variables; removal of the surface 2 to 5 cm for chemistry or toxicology from one or more cores would also remove most of the benthic invertebrates. Therefore, correlations among the SQT variables can only be calculated using stations as individual observations. In any study, most of the costs for collecting and analyzing samples should be allocated to increasing replication at the highest level possible (Cuff and Coleman 1979; Green et al. 1993). Subsampling within stations can increase the precision of station values (i.e., means of those subsamples (Keough and Mapstone 1995)), and will be used when the costs of subsampling are low (e.g., as for chemical analyses of composites).

4.3.1.1 Sampling Stations

The design includes a survey grid centered on the FPSO and a second series of stations centered on the proposed location of glory holes. This design will accommodate a 1.5-km movement of glory holes should proposed location change. The design creation is described below.

The original distance series (Figure 4.3-1) was rejected in favor the series presented below (Figure 4.3-2). This new series provides the same coverage but with fewer (56 versus 72) stations. Stations along the grid axes were then removed to generate a staggered series (Table 4.3-1), again reducing number of stations, this time by half (n=28). Following this, 18 of the deleted stations were reallocated along a 1-km radius around each glory hole (n=6 additional stations per glory hole) (Table 4.3-2), for a total count of 46 stations (Figure 4.3-3).

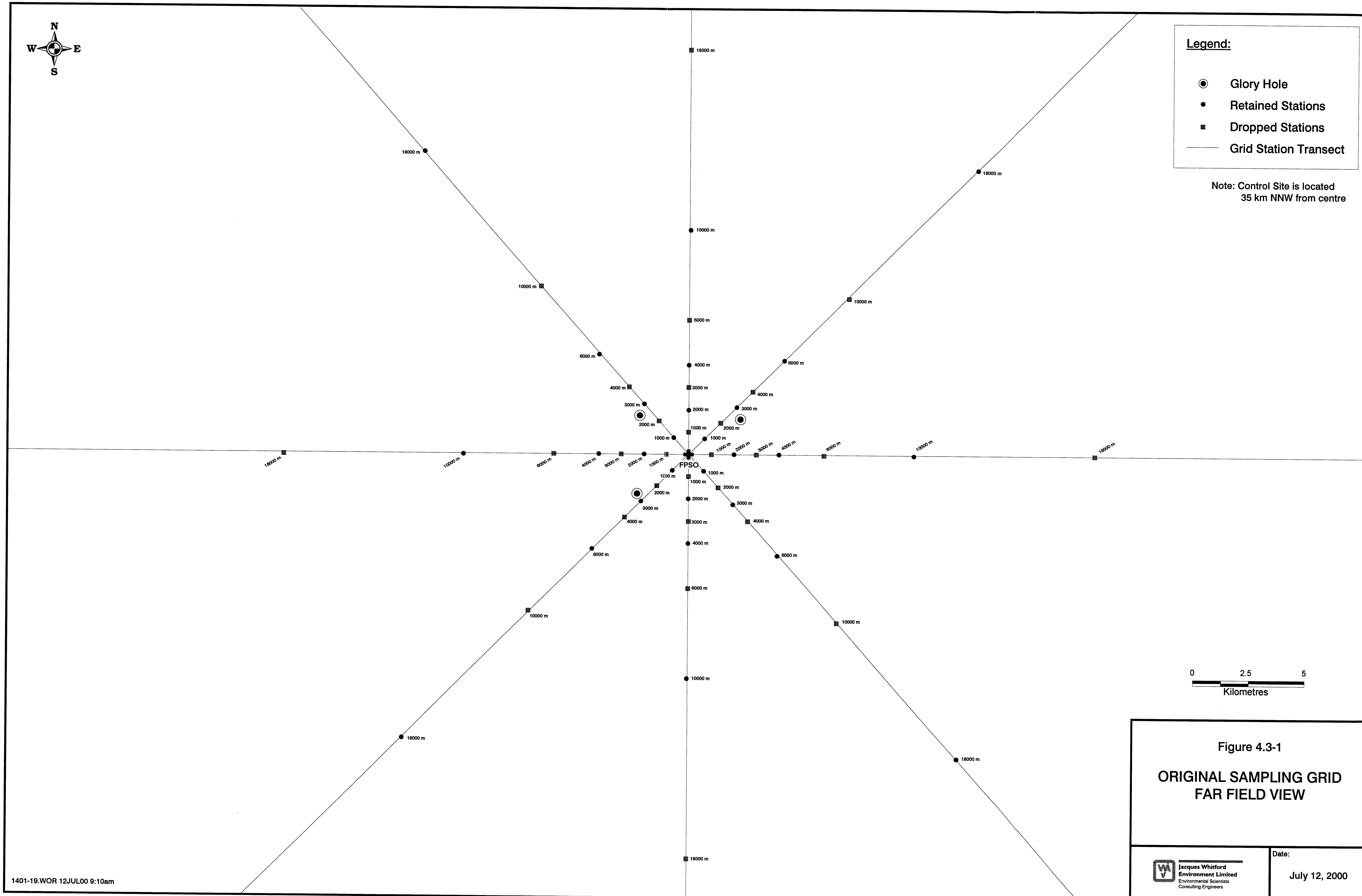


Figure 4.3-1

ORIGINAL SAMPLING GRID FAR FIELD VIEW

Jacques Whitford Environment Limited
Environmental Scientists
Consulting Engineers

Date: July 12, 2000

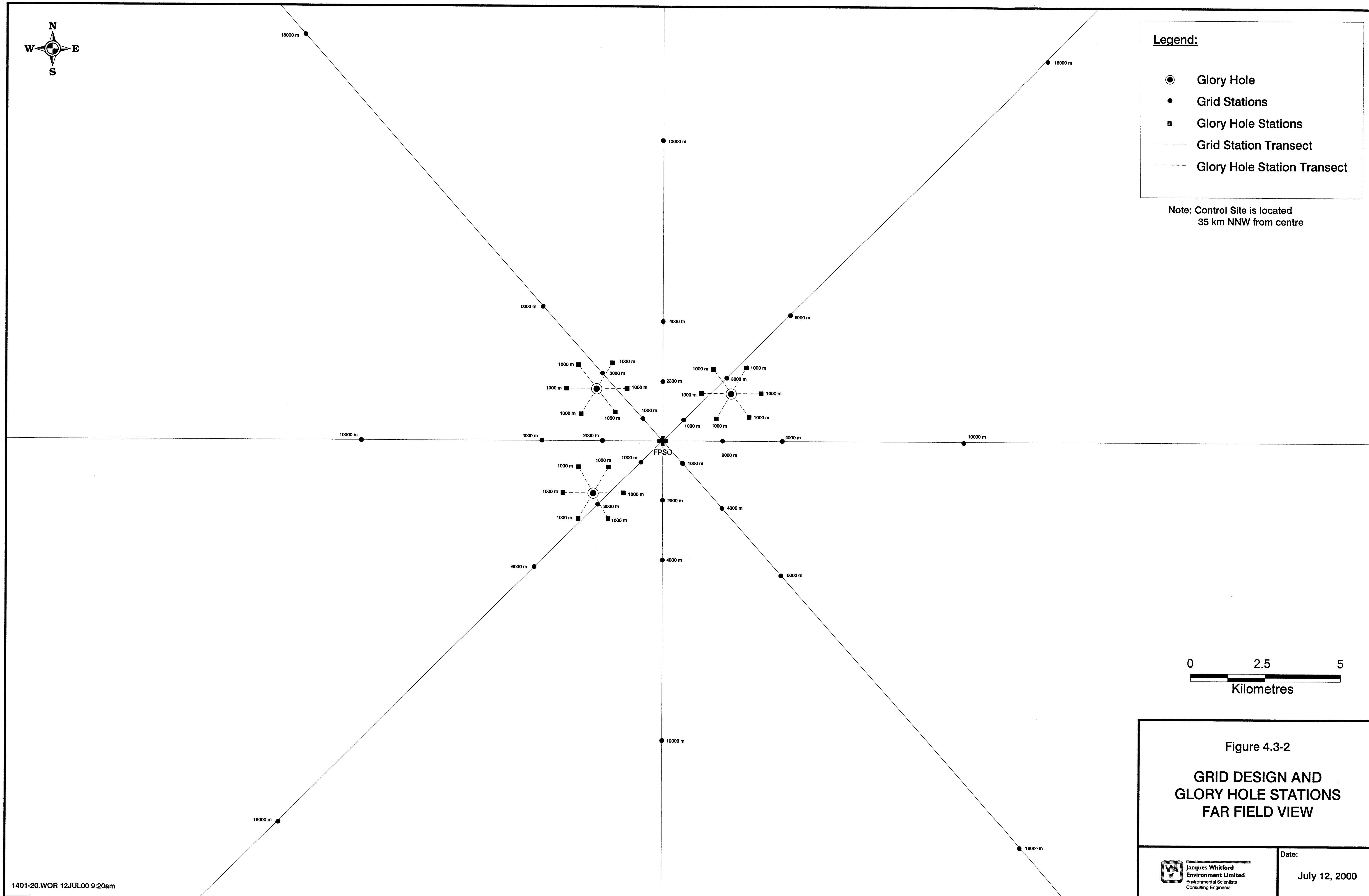


Figure 4.3-2

GRID DESIGN AND GLORY HOLE STATIONS FAR FIELD VIEW

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Environmental Scientists
Consulting Engineers

Date: July 12, 2000

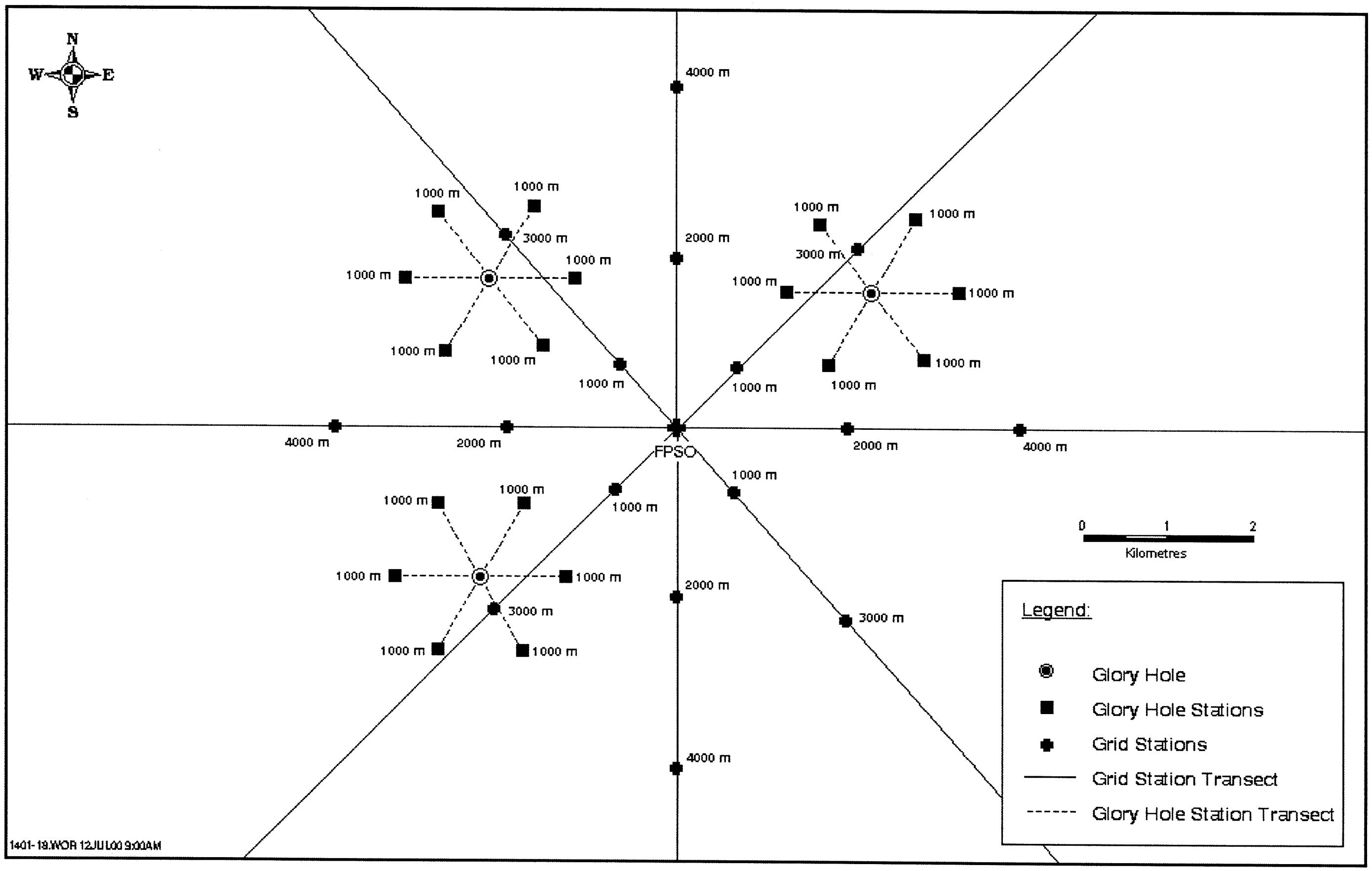
Table 4.3-1 Staggered Distance Series (excluding glory hole stations)

Distance (km)	N	NE	E	SE	S	SW	W	NW
1		X		X		X		X
2	X		X		X		X	
3		X		X		X		X
4	X		X		X		X	
6		X		X		X		X
10	X		X		X		X	
18		X		X		X		X
Total	3	4	3	4	3	4	3	4

Table 4.3-2 Distance to Nearest Glory hole

Distance	Number Stations
≤1 km	21
>1-2 km	5
>2-5 km	11
>5-10 km	5
>10-20 km	4
Total number of stations	**46**

Figure 4.3-3 Grid Design and Glory Hole Stations – Near Field View



4.3.1.2 Statistical Analyses

Baseline statistical analyses will focus on describing patterns of spatial variability, and on examining variance at different levels of replication. The most important analyses for all SQT variables will be construction of a semi-variogram, a standard tool for geostatistics and spatial analyses. Differences (=semi-variances) in responses (attributes) between all possible pairs of stations are plotted against the distances between those stations. Any EEM program will relate SQT variables (contamination and effects) to distance from one or more sources, with a correlation considered evidence of effects. However, for many variables, differences between stations increase naturally with distance. Such a relationship might confound effects assessment, although there are methods of removing or estimating that confounding influence in operational EEM programs (for example, Chapman et al. 1996). For the baseline program, the primary objective will simply be to determine if a relationship between differences and distances exists for candidate attributes. The two-dimensional spatial patterns of SQT variables will also be illustrated graphically.

Descriptions of statistical analyses for operational EEM are not required for a baseline program, but are described below because the sampling design and regression approach represent a departure from traditional monitoring approaches based on ANOVA or multivariate methods. For reasons listed above, the basic form of statistical analyses for EEM will be regressions of response (SQT) variables against various independent variables. The simplest relationship would be between the response and distance from the nearest active drill centre, probably the primary independent variable of interest. This relationship may exist after all wells have been drilled, if contamination and effects diminish rapidly with distance. However, other independent variables such as distance to the second (third,...) nearest active drill centre will probably be required, especially for inbound stations potentially affected by several sources (such as, in the centre of the sampling gird in Figure 4.3-3). As these independent variables are added, the initial approach of regressing responses to distance loses meaning. At that point, chemical concentrations should replace other independent variables, which are effectively surrogates for contamination, for analyses of biological and toxicological variables.

The regression approach allows changes in well location to be incorporated into the analysis. The drill centres may be moved from the locations shown in Figure 4.3-3; only a few or even no wells may be drilled at some centres; new and less environmentally damaging drilling techniques may be developed and used. The important point is that almost any eventuality can be incorporated into the flexible regression approach provided that a large and representative set of stations is sampled. Initially, the regression approach can also incorporate baseline data, by expressing operational responses as the measured value minus baseline for that station. Analyzing multi-year operational data would be more complex but is, in principle, possible.

Another advantage of the regression approach is that both distance and level of contaminant can be incorporated into an analysis, potentially increasing sensitivity and reducing sampling effort. The regression approach can be used to predict the values of X at which effects corresponding to the MAEL occur, even if that particular value of *X* was not sampled. This is the same approach used in lethal level calculations (LC_{50}, EC_{50}, etc.) in toxicology. With multiple *X*, the process becomes complex and probably less meaningful, since the MAEL may theoretically occur at many different combinations of the various *X*. Many of these combinations may not exist in the real world, so again, it may be more useful to use chemical concentrations instead of distances as the *X*. Similarly, regressions can be used to predict values of the response for combinations of the independent variables which exist but were not sampled, which will likely prove more useful.

Relationships among SQT attributes in the operational EEM program will also be analyzed according to the basic correlative, multivariate approach(es) outlined in Green et al. (1993), Chapman et al. (1996), and Green and Montagna (1996). Baseline analyses will be largely restricted to evaluating and comparing those approaches.

5.0 SAMPLING DESIGN

The basic strategy of this baseline survey is to take measurements of the deposition, movement and fate/impact of discharged waste from the drill centres and FPSO. Several types of monitoring studies will be used:

- nearfield and farfield benthic monitoring of chemistry, toxicity and community assemblage; and
- nearfield and farfield monitoring of fish and shellfish for contamination.

Sampling for benthic community characterization, sediment chemistry and sediment toxicity are coordinated to apply the SQT approach.

5.1 Benthic Community

5.1.1 Purpose and Objective

The characterization of benthic community variability during a baseline survey will allow an evaluation of its usefulness as a candidate attribute. A baseline study establishes current conditions against which future conditions may be compared if benthic community analyses are determined to be an appropriate monitoring tool. The composition of infaunal and epibenthic communities will be analyzed to determine if there is attenuation with distance from each glory hole. The purpose of this component is to characterize the benthic community to allow the determination through EEM whether any changes occur in population density or benthic community composition within projects ZOI.

Infaunal community analysis will be used in conjunction with sediment chemistry and toxicity results to provide an integrated assessment of sediment quality, toxicity and effects on biota.

5.1.2 Questions

Baseline data collection is essential to any EEM program. The following are a list of questions which the combined baseline survey and EEM program will address:

- Are there sufficient numbers of benthic organisms to provide statistically sound data?
- Has benthic population density and species relative abundance changed with distance from each drill site and, if so, can these changes be correlated with sediment chemistry (or tracers) and toxicity?
- Has the benthic community composition in the nearfield and farfield changed from the observed baseline?
- Has the species composition changed relative to each glory hole and the FPSO and, if so, can these changes be correlated with sediment chemistry (or tracers) and toxicity?
- How long after commencement of drilling was the first change in benthic communities realized?

- Are changes in the benthic community composition consistent or prolonged with time?
- Are communities from adjacent stations more similar than those from stations further apart?
- Do the farfield reference stations differ from the nearfield stations in benthic community composition?
- Are benthic communities useful as a candidate attribute?

5.1.3 Measurement

Infaunal benthic communities will be sampled using a large-volume Pouliot box corer. The corer is largely stainless steel with some components of galvanized steel and nylon. This device is designed to collect an undisturbed seabed sediment sample over a 0.0625 m2 area. Each sample will be approximately 37 cm in diameter and 10 to 15 cm in depth, with little vertical compression. The volume of each sample will be recorded to allow standardization by depth. A photograph will be taken of the surface of each marine sediment core for characterization purposes.

A winch and cable aboard the host vessel is used to lower and raise the corer to retrieve the sediment sample. Two complete grabs will be collected at each station in order to ensure that sufficient numbers of organisms are collected per station. As each core box is released from the sample device, it is visually examined to determine whether a sufficient amount of sediment was collected (25 to 45 cm deep), and to ensure the integrity of the core was maintained. If the sample is judged to be insufficient in terms of sample volume (sediment depth) or due to evidence of sediment being disturbed, the core will be discarded. Only acceptable cores are retained.

There will be no subsampling for benthic community biomonitoring. All samples will be kept in 10 percent buffered formalin until they are sieved (0.5 mm sieve) and sorted at the laboratory (see Section 5.5.3.3). Both samples for each station will be quantified and identified to the lowest possible taxa. Samples will be sorted separately.

5.1.4 Data Analysis

Statistical analyses of infauna will involve comparison of variables among stations, using variance among box cores as the error term. Standard formulae will be used to calculate the added variance among stations (e.g., Snedecor and Cochran 1980). If that variance is large, then there probably is little to be gained from additional replication (i.e., more box cores) within stations. However, if variance among stations is small, additional replication within stations may be useful in operational EEM. This will be especially true if few organisms are collected per core. When abundances are low, variances, even on a relative scale, are often heterogeneous and may not meet the assumptions of parametric statistics (Green 1989), based on normal error. The baseline data will be used to evaluate three solutions: (1) randomization to compute confidence intervals and Type I error; (2) non-normal error structures; and (3) compositing of samples. Data collected according to the layout in Figure 4.3-2 will allow calculation of whether effect levels reported in the literature will be detectable at White Rose. If the variability is too high at baseline levels, then the place of benthic community biomonitoring in future White Rose EEM programs will need to be reconsidered.

The baseline infaunal data will also be used to evaluate the effectiveness of various multivariate techniques. The standard approach will be similar to that used in the pulp and paper EEM (Environment Canada 1995), except that non-metric multidimensional dimensional scaling (NMDS) will replace canonical correspondence analysis (CCA) (Clarke 1993 describes NMDS). Use of NMDS scores, which are composite variables, in statistical analyses can often increase power and sensitivity even when abundances are low.

Statistical analyses of epifauna will be different from analyses of infauna, because abundances of the former are measured continuously along transects rather than at selected point locations. Schneider et al. (1987) describe the basic approach, which is effectively a form of spatial analysis. Haining (1990) and Webster (1985) provide general reviews of spatial analysis.

5.2 Sediment Chemistry

Determination of sediment quality has evolved from basic chemical analysis, which was the traditional test of choice for offshore monitoring programs, to complex tests involving chemical, physical and biological parameters. Reliance upon a single test as a descriptor of sediment quality is not recommended for this program (Chapman et. al. 1991). Instead an innovative approach will be taken which combines all three testing media in the SQT.

5.2.1 Purpose and Objective

Sediment chemistry will focus on priority pollutants associated with known discharges which can influence the bioavialability of pollutants and the distribution and composition of benthic organisms, such as carbon content and particle size. The baseline survey will establish background conditions, including the possibility of characterization of changes to sediment chemistry resulting from exploratory drilling. Full hydrocarbon and metal suites will characterize the sediment chemistry. The purpose of this component is to establish baseline conditions to enable future EEM programs to detect short- or long-term changes in sediment relative to the glory holes and FPSO and provide data on spatial extent of changes.

5.2.2 Questions

The following are a list of questions which the baseline survey will enable the future environmental effects monitoring program to address:

- Have the concentrations of contaminants in sediment changed relative to each glory hole and if so, can these changes be correlated with sediment toxicity or benthic community composition?
- What is the spatial scale of detectable effect?
- How long after drilling commences does the first indication of contaminant accumulation occur?
- Have the sediments become more anoxic, such that the thickness of the sediment anoxic layer decreased near the glory holes?
- Are changes in the sediment contaminant levels consistent or prolonged with time?
- Are sediment contaminant levels from adjacent stations more similar than those from stations further apart?
- Are sediment contaminants found at farfield sites attributable to the project site?
- Do the reference stations differ from the nearfield stations in sediment contamination?
- Have the sediment contaminant levels in the nearfield and farfield changed from the observed baseline conditions?
- Is sediment chemistry suitable as a candidate attribute?

5.2.3 Measurement

At each sampling station, a composite sample from the two cores used for benthic community biomonitoring will comprise the sediment sample for chemical analysis. Approximately 125 mL of sediment from each infaunal core will be scooped from the top layer then composited into a single sample for chemical analysis. A 250-mL sample will also be taken from the toxicity grab at each station which will be archived for possible future analysis (i.e., fingerprinting). The 250-mL composite sample will be analyzed for particle size, metals (barium, cadmium, copper, lead, zinc, chromium, aluminum, nickel, lithium, iron, mercury and vanadium), total organic hydrocarbon, total inorganic carbon, redox potential (in the field), total hydrocarbon, aliphatic hydrocarbons, n-C12/pristane to n-C18/phytane ratio, suite of 17 polycyclic aromatic hydrocarbons (PAHs) (including naphthalene, dibenzo(a,h)anthracene and phenanthrene) and light and high end chains of hydrocarbon (e.g., C6-C32-35). Analysis will be conducted at a CAEAL certified laboratory.

Numerous studies have shown that barium is a suitable tracer for dispersion of well-based contaminants in sediments.

If hydrocarbons are found in the study area sediments during the baseline survey, hydrocarbon fingerprinting will be conducted on the archived samples. This technique uses GCMS and biological marker compounds (including steroidal and triterpenoidal alkanes) against a base oil of known source, most logically White Rose, Terra Nova or Hibernia crude oil.

5.2.4 Data Analysis

No data analysis will be performed upon chemical data beyond the regression analyses outlined in Section 4.1. To make effective use of resources, there will be no within-station replication of sediment sampling for chemical analysis.

5.3 Sediment Toxicity Testing

5.3.1 Purpose and Objective

Sediment toxicity testing links chemical and physical affects to biotic changes by acting as a measure of bioavailability to sediment-dwelling (infaunal) animals. Animals are exposed to sediment under controlled conditions to determine if the exposure causes adverse effects on the animals. Because there is no organism for toxicity testing that represents all animals, a range of organisms representing different trophic levels and taxonomic groups is used in standardized tests. Standardized methods include both lethal and sublethal endpoints and the use of appropriate controls (e.g., negative and positive controls). Sediment toxicity tests with appropriate test animals are recognized and accepted as effective tools to determine the biological significance of contamination found in coastal sediments.

Sediment toxicity testing would use standardized and accepted Environment Canada procedures and would consider testing interstitial water as well as whole sediment. Should White Rose sediment be a highly porous sediment as was observed at the Hibernia site, elutriate preparation would be a consideration for some of the sediment toxicity testing. If a decision is made to use elutriate, all tests will be done with elutriate in order to better be able to compare results. Tests would include sublethal and lethal endpoints. Candidate tests include amphipod survival, echinoderm fertilization (using interstitial water or an elutriate), and bacterial luminescence.

The objective of measuring baseline sediment toxicity conditions at the White Rose oilfield is to allow a comparison of toxicity of chemical contaminants associated with production releases. The baseline data will help detect and measure changes in the sediment quality, particularly toxicity during the production phase of the White Rose project. The baseline survey will use three toxicity assays to determine the biological significance and state of the sediment health.

5.3.2 Questions

The baseline survey will determine " What is the baseline sediment toxicity in the area of the future White Rose project?".

The baseline data should be collected in such a manner that there is sufficient information on which the following questions can be formulated and addressed by an environmental effects monitoring program:

- Is there sufficient pore water available to conduct chronic toxicity tests?
- Has the sediment toxicity in the nearfield and farfield changed from the observed baseline conditions?
- What is the spatial scale of detectable toxic effects?
- Has the sediment toxicity changed relative to each glory hole and, if so, can these changes be correlated with sediment chemistry or benthic community composition?
- Are the sediment toxicity results due to anthropogenic influences or are they a result of natural processes?
- How long after drilling commences was the first change in sediment toxicity realized?
- Are changes in sediment toxicity consistent or prolonged over time?
- Are sediment toxicity from adjacent stations more similar than those from stations further apart?
- Will sediment toxicity be a suitable tool to make meaningful inferences with respect to sediment quality and the effects related to the White Rose project?
- Is the level or degree of sediment toxicity which results in an irreversible or significant effect on biological organisms (i.e., what are the ecological implications)?
- Is sediment toxicity a suitable candidate attribute?

In conjunction with null hypothesis development at the EEM stage, the development of proposed effects significance criteria or MAELs will be considered. The development of MAELs must be scientifically attainable, achievable with known, practical, and cost-effective techniques, and should define the significance of an environmental effect. Guidelines developed by Environment Canada will be used to evaluate the sediment toxicity data for bacterial bioluminescence and amphipod assays. Echinoid fertilization will use mean percent fertilization in the 100 percent elutriate (assuming pore water will not be obtainable as was the case for the Hibernia Baseline EEM program) rather than the IC25. The mean percent fertilization in 100 percent would then be the variable analyzed in the proposed regression approach, described in Section 4.3.1.2.

5.3.3 Measurement

A battery of sediment toxicity tests will used to determine biological significance and and the state of the baseline sediment. Sediment toxicity is one of the three components in the SQT used to assess sediment quality. The rational of this approach is that healthy sediment provides habitat that supports a diverse and abundant community structure and is non-toxic, whereas toxic sediment resulting from the accumulation of contaminants will result in a different community structure. The battery of toxicity tests uses organisms from several trophic levels, produces conclusive data in a short period of time ($\leq$10 days), and monitors both lethal and sublethal effects. The battery is comprised of the following sediment toxicity assays:

- amphipod (*Rhepoxynius abronius*) survival;
- echinoid (*Lytechinius pictus*) fertilization; and
- luminescent bacteria assays (Microtox™).

5.3.3.1 Amphipod Survival Assay

The amphipod survival assay will be conducted according to Environment Canada protocols (1992a) using the marine amphipod *Rhepoxynius abronius*. The amphipod survival assay exposes amphipods to the sediment samples for a period of 10 days, after which survival in the five lab replicates is examined and compared to either a control or reference sediment (control station sediment).

5.3.3.2 Echinoid Fertilization Assay

The echinoid fertilization assay will be conducted as per Environment Canada protocols using the white sea urchin, *Lytechinius pictus*. This assay can be done on pore water or an elutriate; if pore water is difficult to collect, as was seen at Hibernia (HMDC 1994) the elutriate will be used. Since the two are not comparable, a choice will be made early in the program and the method will remain throughout the EEM.

A deviation from the standard dilution series (100, 50, 25, 12.5 and 6.25 percent) is proposed, with the assay examining only the 100 percent and control samples. The fertilization assay will collect gametes and conduct the test as per Environment Canada guidelines, except the number of dilutions would be limited to the 100 percent. This would not allow for data analysis to be conducted in the traditional method through the use of NOEC (no-observed-effect-concentration), LOEC (lowest-observed-effect-concentration), TEC (threshold effect concentration), IC25 and IC50 (the fertilization inhibition concentrations). The deviation from standard protocol is due to cost considerations and the statistical and experimental design of the program which will be further detailed in Section 5.4.6.

5.3.3.3 Luminescent Bacteria Assay

A strain of marine bacteria (*Vibrio fischeri*) is used to determine the toxicity of samples. The bacterium emits light as a result of normal metabolic activities. The light is measured with a photo detector under specific conditions and reduction of light production at 5, 15 or 30 minutes is taken as a measure of toxicity (Environment Canada 1992c). The sediment or solid phase would be examined for toxicity using Microtox™ analysis.

5.3.4 Data Analysis

The spatial patterns for the toxicological endpoints will be examined using procedures outlined in Section 4.3.1.2 (e.g., semi-variograms). Amphipod survival, Microtox™ IC50 and echinoid percent fertilization in 100 percent elutriate can be compared among stations in ANOVA, with variance among laboratory replicates used as the error term. The objective would be to estimate the variance components - among stations and among laboratory replicates (i.e., as in Section 5.1.6). Both variance components should be small. Low variance among lab replicates indicates good laboratory practice, and responses should not vary widely among stations and should be similar to control responses. Therefore, there should be no need to increase the number of laboratory replicates in the future. However, the baseline variance among those replicates can be used as a benchmark for evaluating the same variance, and laboratory quality control, in future studies.

Over the life of the White Rose program, amphipod survival and echinoid percent fertilization should be expressed as percentages of control responses, since those responses will fluctuate somewhat over time.

In addition to the above analyses, the results for the sediment toxicity assays will be evaluated according to interpretation guidelines developed by Environment Canada (K. Doe, pers. comm.). The criteria are as follows:

Microtox™ Solid-Phase Assay:

- 10-minute IC50 of >5,000 mg/L (as dry solids) is non-toxic;
- 10-minute IC50 within a range of 1,000 to 5,000 mg/L (as dry solids) is marginally toxic; and
- 10-minute IC50 of <1,000 mg/L (as dry solids) is toxic.

Amphipod Survival Test (*R. abronius*):

- sediments are toxic if the endpoint (mortality) is more than 20 percent lower and statistically different from the mortality caused by the reference sample; and
- sediments are toxic if the endpoint (mortality) is more than 30 percent lower and statistically different from the mortality caused by the control sample.

The Environment Canada guideline for echinoid fertilization can not be used due to modifications in the protocol. It is a very expensive test and the sampling program was designed in such a way that distance from the source is evaluated. Furthermore, more information is gained from this experimental design. The reasoning behind the program design for echinoid fertilization is that the IC25 is useful for regulatory purposes, to set standards and allow rapid comparison of toxicity among sediment samples. Because the IC25 is based on more replicates, it will usually be more precise than the mean percent fertilization in 100 percent elutriate. However, in field EEM programs, the IC25 is not always cost-effective or even meaningful when many stations are sampled and tested. The IC25 indicates the elutriate concentration at which percent fertilization is reduced to 25 percent less than that for controls or reference sediments. The IC25 is a measure of toxicity, with a lower value indicating a more toxic sediment. However, elutriate concentrations have no obvious meaning in the field; even pore water concentrations can only be 100 percent. It would be more meaningful to express an IC25 in terms of distances from one or more sources or in terms of concentrations of one or more chemicals (e.g., as discussed in Section 4.1.1.2). To do that, one needs only the percent fertilization in 100 percent pore water for each station. Effectively, an IC25 would be calculated for the entire study area, in meaningful terms, rather than for each station in terms of percent elutriate or pore water.

5.4 Fish and Shellfish Body Burden and Taint

5.4.1 Purpose and Objective

This program component is intended to establish baseline levels of tissue chemical contaminants and organoleptic evaluations for the White Rose site. Tainting and bioaccumulation are the two effects which are traditional EEM components and are components of the Hibernia EEM and Terra Nova baseline characterization program (HMDC 1994; HMDC 1995a; HMDC 1996). Bioaccumulation will likely also be considered an essential component for any EEM program for the White Rose project. The White Rose EIS (Husky 2000a) states that a program to monitor tainting in fish will be implemented and the DFO position statement (DFO 1997) recommends that a well designed tainting program should be initiated around development sites for assurance purposes. Furthermore, the DFO position statement recognizes that bioaccumulation could be an issue of greater concern than tainting, particularly in light of recent North Sea study conclusions. However, the ideal or suitable candidate species for these attributes must be determined. Existing knowledge (video) from the White Rose area suggest that shellfish would be as or more available than any non-migratory finfish. The White Rose project has the potential to result in measurable impacts on biota due to routine discharges of:

- oil-based drilling muds and cuttings; and
- platform produced water.

Potential effects on biota from these discharges are hydrocarbon and/or trace metal bioaccumulation and tainting. The baseline data will allow a comparison with which to detect and measure changes in tissue contaminants and taint during the drilling and production of the White Rose project.

5.4.2 Questions

The baseline survey will try to determine what biological species are present in sufficient numbers to be used as a monitoring tool for body burden and taint. Ideally a fish species of commercial importance will be selected as a Candidate Monitoring Target (CMT).

The data collected during the baseline survey at the White Rose site will be used to formulate a series of question which will lead to the establishment of testable hypothesis and the development of proposed effects significance criteria or MAELs.

The baseline survey should provide sufficient information from which the following questions may be formulated and answered:

- Has the contaminant level in the candidate species in the farfield and nearfield areas changed from the observed baseline conditions?
- Has the organoleptic evaluations or taint determinations of the candidate species in the farfield and nearfield areas changed from the observed baseline conditions?
- Is there a correlation or discernable relationship between contaminant levels in the candidate species and the organoleptic evaluation?
- Are we able to use organoleptic evaluations to make meaningful inferences regarding the contaminant levels and the effects related to the White Rose project?
- Are we able to use contaminant levels to make meaningful inferences regarding the organoleptic evaluations and the effects related to the White Rose project?
- What is the level or degree of contaminant levels which results in significant effects on the biological organisms?
- Are changes in organoleptic evaluations and body burden contaminant levels consistent or prolonged over time?
- Have the organoleptic evaluations or body burden contaminant levels changed relative to each glory hole and, if so, can these changes be correlated with the SQT?
- Which species is most suitable as a candidate monitor?

5.4.3 Measurement

Bivalves and shellfish are good candidate monitoring targets because they are sessile, benthic, filter or deposit feeders which are in close contact with the sediment and generally travel limited distances as compared to finfish. The species to be used for contaminant and organoleptic evaluation will be chosen after an evaluation of information collected from benthic trawls in the study area. The first choice of specimen would be snow crab, a population of sufficient size can be found in the nearfield of the White Rose and reference sites.

The use of a finfish species is not recommended based on the state of the current fishery and the inability to collect sufficient sample size during the Hibernia baseline EEM program (HMDC 1995), but is suggested as part of the baseline for comparison purposes with the Hibernia EEM and Terra Nova baseline characterization programs.

5.4.3.1 Contaminants

A minimum of five composited samples of snow crab tissue (legs) or a suitable tissue from an alternate species from nearfield at the White Rose site and a reference site will be examined for trace metals and a suite of hydrocarbons. The parameters to be analyzed are listed in Tables 5.4-1 and 5.4-2. In addition to the listed chemical parameters, lipid content, moisture, length, weight and age should be determined to aid in the interpretation of data.

Table 5.4-1 Trace Metal Candidate Parameters

Parameters
Barium (BA)
Cadmium (Cd)
Copper (Cu)
Lead (Pb)
Zinc (Zn)
Chromium (Cr)
Aluminium (Al)
Lithium (Li)
Iron (Fe)
Mercury (Hg)
As per PARCOM Guidelines (1989)

Table 5.4-2 Petroleum Hydrocarbon Candidate Parameters

Parameters*
Total Hydrocarbon Content (THC)
Aliphatic hydrocarbons
n-C_{12}/pristane to n-C_{18}/phytane ratio
Polycyclic Aromatic Hydrocarbons (PAHs)
• Acenaphthene
• Acenaphthylene
• Anthracene
• Benzo(a)anthracene
• Benzo(a)pyrene
• Benzo(e)pyrene
• Benxo(b)fluoranthene**
• Benzo(k)fluoranthene**
• Benzo(ghi)perylene
• Chrysene
• Dibenzo(a,h)anthracene
• Fluoranthene
• Fluorene
• Indeno (1,2,3-cd)pyrene
• Naphthalene
• Phenanthrene
• Pyrene
C6-C20
C21-C32
C6-C32
* As per PARCOM guidelines (1989) ** Unresolved double peaks.

Determination for trace metals will be by IP-MS with detection limits as follows:

- cadmium 0.05 mg/kg;
- lead 1 mg/kg;
- zinc 1 mg/kg;
- copper 1 mg/kg;
- chromium 1 mg/kg;
- iron 100 mg/kg;
- arsenic 1 mg/kg; and
- mercury 0.1 mg/kg.

Concentrations should be reported on a wet and dry weight basis.

Analyses for both petroleum hydrocarbons and a suite of 18 PAHs will be undertaken using gas chromatography-mass spectrometry (GC-MS), ensuring that sufficient clean up procedures have been undertaken to provide for competent analyses.

5.4.3.2 Organoleptic Evaluation (Taint)

Organoleptic sensory evaluation methods (taste panels) will be conducted to collect information on scallops with respect to "taint". The organoleptic sensory evaluation tools that will be used are the triangle test for the assessment of taint; hedonic scaling (affective/acceptance test) for the detection and measurement of flavour impairment if a determination of taint is made, and fingerprinting for identification of responsible party (if necessary).

The ASTM definition of taint as cited in Botta (1994) will be used for the White Rose program, and is considered to be an "off-flavour" and "undesirable flavour". Taint, as defined, may be due to spoilage or the presence of contaminants in the flesh. Taint, as defined, makes no reference as to whether the taint is pleasant or unpleasant. Therefore, any assessment of taint must incorporate procedures to detect and measure changes in flavour in conjunction with an assessment of flavour impairment. GESAMP (1993) recognizes this necessity and therefore, tainting is considered to be a possible effect of the impact of oil pollution in the marine environment.

Samples of tissue (crab legs) will be prepared by the casserole method. Frozen samples are to be thawed at room temperature for two hours. Samples will be enclosed in individual aluminum foil packets and cooked in a convection oven at 210ºC for 20 minutes. Fifteen-gram samples will be placed in each foil packet (prior to cooking) and labeled with a random three-digit code. Samples will be served at 35ºC.

Discriminative tests will be employed during organoleptic sensory evaluations to determine whether a product is tainted. The triangle test is the sensory evaluation tool most commonly employed because it is believed to be free of expectation error. It does not require any familiarity with the sensory properties of either the odd or the duplicate sample (Botta 1994).

The triangle test presents the panelists with a three-sample set (triangle) of coded samples and the panelist must identify the sample which is different from the other two in the set. Half the panelists will receive sets composed of two coded samples from treatment A and one coded from treatment B, whereas the other panelists will receive sets composed of one coded sample from treatment A and two coded from treatment B. Therefore, there are six possible orders in which the coded samples may be presented to the panelists (Botta 1994):

- ABB;
- AAB;
- ABA;

- BAA;
- BBA; and
- BAB.

Panelists for the triangle test should have the same level of qualification and each panelist should be given one familiarization session. Triangle tests used for the evaluation of fish tainting will be administered to 24 panelists typical of the general population of consumers. However, regardless of the size of panel, the number of panelists should be a multiple of six. Panelists involved in simple discriminate test such as the triangle test should not be trained (Botta 1994). Therefore, the taste panels will use naive panelists.

Acceptance (affective) tests are employed during organoleptic sensory evaluations to determine "acceptability" and will be used if the triangle test finds a determination of taint. The nine point hedonic scale (or even five or seven) is a useful sensory evaluation technique (Stone and Sidel 1985) by which the magnitude of preference (or attributes of stimuli) are made explicit by the participants (Land and Sheppard 1988). The simplicity of use, interest to participants, use with naive participants, flexibility over a wide range of applications, and applicability to a wide range of stimuli make this technique ideal for our purposes.

In the future with the onset of other oil production facilities, the time and expense to provide and maintain a group of trained panelists might be justified if the expense was shared by all groups. Presently, and for the baseline survey, the use of untrained panelists is recommended.

5.4.4 Location

Contaminant levels and organoleptic evaluations would be conducted on samples collected in the nearfield region of the White Rose site and from a reference site.

5.4.5 Data Analysis

5.4.5.1 Contaminants

Heavy metal and hydrocarbon related parameters will be analyzed in a length stratified manner. Comparison of body burden will be made with measurement variables such as body/tissue weight, age, etc. Data from a minimum of five samples from each of two sites (exposure and reference) will be subject to a Student t-test for comparison.

5.4.5.2 Taint

The triangle test datum is a value which represents the number of correct responses over the number of panelists. This value is compared to values in a standard table (Table 5.4-3) to determine the statistical significance of the result. A statistically significant result for the recommended panel size of 24 would require 13 correct responses (95 percent significance level).

Hedonic scaling assesses the magnitude of preference along a nine-point scale. The scale lends itself to the assignment of values (1 to 9) and statistical analysis of the data by Analysis of Variance (ANOVA).

The drawback to the use of the ANOVA is the assumption that each point of the scale is of equal size and value. Nevertheless, the ANOVA analysis allows for the detection of differences between sample locations while accounting for differences attributable to sample variability. Graphical presentation in the form of a frequency histogram aids in the interpretation and understanding of hedonic scaling results and should be used as an illustrative aid.

A determination of "taint" necessitates that a statistical difference for the triangle test and an unacceptable ranking for the hedonic scaling be obtained.

Table 5.4-3 Triangle Test, Difference Analyses

Number of tasters	Number of correct answers necessary to establish level of significance			Number of tasters	number of correct answers necessary to establish level of significance		
	5%	1%	0.1%		5%	1%	0.1%
7	5	6	7	57	27	29	31
8	6	7	8	58	27	29	32
9	6	7	8	59	27	30	32
10	7	8	9	60	28	30	33
11	7	8	9	61	28	30	33
12	8	9	10	62	28	31	33
13	8	9	10	63	29	31	34
14	9	10	11	64	29	32	34
15	9	10	12	65	30	32	35
16	10	11	12	66	30	32	35
17	10	11	13	67	30	33	36
18	10	12	13	68	31	33	36
19	11	12	14	69	31	34	36
20	11	13	14	70	32	34	37
21	12	13	15	71	32	34	37
22	12	14	15	72	32	35	38
23	13	14	16	73	33	35	38
24	13	14	16	74	33	36	39
25	13	15	17	75	34	36	39
26	14	15	17	76	34	36	39
27	14	16	18	77	34	37	40
28	15	16	14	78	35	37	40
29	15	17	19	79	35	38	41
30	16	17	19	80	35	38	41
31	16	18	19	81	36	38	41
32	16	18	20	82	36	39	42
33	17	19	20	83	37	39	42
34	17	19	21	84	37	40	43
35	18	19	21	85	37	40	43
36	18	20	22	86	38	40	44
37	18	20	22	87	38	41	44
38	19	21	23	88	39	41	44
39	19	21	23	89	39	42	45
40	20	22	24	90	39	42	45
41	20	22	24	91	40	42	46
42	21	22	25	92	40	43	46
43	21	23	25	93	40	43	46
44	21	23	25	94	41	44	47
45	22	24	26	95	41	44	47
46	22	24	26	96	42	44	48
47	23	25	27	97	42	45	48
48	23	25	27	98	42	45	49
49	23	25	28	99	43	46	49
50	24	26	28	100	43	46	49
51	24	26	29	200	80	84	89
52	25	27	29	300	117	122	127
53	25	27	29	400	152	158	165
54	25	27	30	500	188	194	202
55	26	28	30	1000	363	372	383
56	26	28	31	2000	709	722	737

Source: Larmond 1977.

5.5 Water Quality

Water will serve as the primary receiving environment for discharges during drilling and operations of the White Rose oilfield, and as a pathway to the sediment receiving environment and biological effects. As a result, a commitment was made in the White Rose EIS (Husky Oil 2000) to monitor water quality. Monitoring this variable will allow testing of effects predictions made in the EIS relative to produced water and drill cuttings.

Formation of two water layers with warmer water overlying a colder layer is a commonly observed seasonal structure in the study area. Lack of variation in water column profiles between stations is normal for this type of open ocean environment. Deeper water temperatures will be less variable over time than the upper layer, which is more heavily influenced by overlying weather systems and seasonal isolation. Seasonal variations may occur in the structure of the water column, however, there is no reason to expect large differences in water column structure between control and study areas.

Analysis of water quality is moderate in relation to information return. As a result of this evaluation, and commitments made in the EIS, water quality is included as a monitoring variable in the White Rose EEM program.

5.5.1 Purpose and Objective

Monitoring water quality near discharge sources may prove useful in indicating whether there are detectable effects to the water column within the initial dilution zone. However, it should be recognized that the utility of using water quality as a routine monitoring variable for offshore oil EEM programs is limited, due to rapid dilution and the difficulty in tracking movement of contaminants in a fluid medium (Boesch and Rabelais 1987).

Persistent discharges may be measurable in the water column using chemical and physical analysis, particularly in the immediate vicinity of discharge. Measuring phytoplankton density may provide an indication of biological changes in the water column resulting from project inputs.

5.5.2 Measurements and Data Analysis

Sample collection methods for water quality analysis used during the baseline data collection survey will be followed during EEM surveys.

5.5.2.1 Chemical Characteristics

Water samples will be obtained from three depths (near surface, just below the thermocline, and near-bottom) using Niskin-X samplers. Sample container and preservative required for the parameters to be analyzed are listed in Table 5.5-1. Variables to be measured are based on the main chemical constituents of discharges: trace metals, hydrocarbons and particulate matter. Parameters are listed in Table 5.5-2, along with method of analysis.

5.5.2.2 Physical Characteristics

Water column profiling for temperature (accuracy to nearest 0.01°C), dissolved oxygen (accuracy to nearest 0.1 mg/L), salinity (accuracy to nearest 0.01%), pH (accuracy to nearest 0.1 pH) and chlorophyll (accuracy to nearest 0.06 µg/L) will be performed at each water sampling station using a Sea-Bird™ 25 CTD meter. The position of the thermocline will also be determined using the Sea-Bird™ 25 CTD. Depths selected at surface, just below the thermocline and near bottom, will correspond with depths sampled for the water chemistry.

Table 5.5-1 Water Analysis Bottle Types and Preservatives

Parameter to be Analysed	Bottle (number and type)	Preservative
PAHs	2 x 1 litre glass bottles	none
Oil and Grease	2 x 124 ml glass bottles	none
TSS	2 x 500 ml plastic bottles	none
Mercury	1 x 125 ml glass bottle	potassium dicromate
Trace Metals	2 x 1 litre plastic bottles	10 drops nitric acid

Table 5.5-2 Trace Metal and Hydrocarbon Analysis in Seawater

Parameter	Limit of Quantitation	Method of Analysis
Total Suspended Solids	0.5 mg/L	Gravimetric
Arsenic	0.1 µg/L	ICP-MS
Cadmium	0.1 µg/L	ICP-MS
Chromium	0.5 µg/L	ICP-MS
Cobalt	0.1 µg/L	ICP-MS
Copper	0.1 µg/L	ICP-MS
Iron	1 µg/L	ICP-MS
Lead	0.1 µg/L	ICP-MS
Manganese	1 µg/L	ICP-MS
Nickel	1.5 µg/L	ICP-MS
Vanadium	1.5 µg/L	ICP-MS
Zinc	1 µg/L	ICP-MS
Mercury	0.05 µg/L	CVAAS
Naphthalene	0.05 µg/L	GC/MS
Perylene	0.01 µg/L	GC/MS
1-Methylnaphthalene	0.01 µg/L	GC/MS
2-Methylnaphthalene	0.02 µg/L	GC/MS
Acenaphthylene	0.01 µg/L	GC/MS
Acenaphthene	0.01 µg/L	GC/MS
Fluorene	0.01 µg/L	GC/MS
Phenanthrene	0.01 µg/L	GC/MS
Anthracene	0.01 µg/L	GC/MS
Fluoranthene	0.01 µg/L	GC/MS
Pyrene	0.01 µg/L	GC/MS
Benz(a)anthracene	0.01 µg/L	GC/MS
Chrysene	0.01 µg/L	GC/MS
Benzo(b)fluoranthene	0.01 µg/L	GC/MS
Benzo(k)fluoranthene	0.01 µg/L	GC/MS
Benzo(a)pyrene	0.01 µg/L	GC/MS
Indeno(1,2,3-cd)pyrene	0.01 µg/L	GC/MS
Dibenz(a,h)anthracene	0.01 µg/L	GC/MS
Benzo(g,h,i)perylene	0.01 µg/L	GC/MS
1-Chloronaphthalene	0.01 µg/L	GC/MS
2-Chloronaphthalene	0.01 µg/L	GC/MS
Oil & Grease	1 mg/L	IR
Vegetable Oil & Grease	1 mg/L	IR
Mineral Oil & Grease	1 mg/L	IR

Prior to the start of sampling at each station, the position, station depth and the thermocline (depth of temperature gradient) will be obtained. The procedure includes the following steps:

- determine depth of water column using the vessel's deep water hydrographic sounder;
- confirm CTD operation and preparation for deployment, including initializing prior to cast;

- deploy CTD using a hydrographic winch and cable;
- lower CTD to near bottom depth at a constant rate;
- retrieve CTD and download data using a laptop computer; and
- display station profile on screen and select appropriate depths.

5.5.2.3 Phytoplankton Density

The EEM program will look at vertical profiles of phytoplankton density using a CTD with attached fluorometer. Fluorescence characteristics of populations change overtime, therefore every fluorometric reading will be calibrated using a sample analyzed in the laboratory for phytoplankton density.

After an initial CTD cast, a Niskin water sampler will be deployed to collect samples at three depths at one station for use in calibrating fluorometer readings:

- near surface at 1 m below surface;
- depth of the upper limit of photosynthetically available radiation (PAR) extinction; and
- off-bottom at approximately 2 m above seabed.

Samples will be transferred to 500 mL plastic bottles and filtered within 30 minutes of collection. Prior to filtration, sample bottles will be gently inverted to ensure that they are homogeneous. Using a vacuum filtration apparatus, 50 mL of each sample will be gently filtered (less than 75 mm Hg vacuum pressure) onto a GF/F filter. After filtration, each filter pad will be placed into a labelled vial of 10 ml cold 90 percent acetone (one filter per vial). Filtration will not be carried out in direct sunlight to avoid degradation of chlorophyll pigments. Samples will be wrapped and stored in the dark at temperatures below -10ºC.

QA/QC procedures for the chlorophyll analysis will consisted of the collection and analysis of duplicate chlorophyll samples at selected stations.

Concentration of both chlorophyll-*a* and phaeopigments will be determined fluorometrically using standard fluorometric techniques described in Smith et al. (1981). The analyses will be conducted at an appropriate laboratory (such as by Satlantic Inc.), which will also review CTD chlorophyll data to provide post-sampling calibration of the fluorometer on the CTD. Regression analysis between laboratory measured chlorophyll-*a* (and phaeophytin pigment concentrations) from bottle samples and fluorometer measurements will be used to calibrate the fluorometer.

5.6 Fish Health

Fish health is a broad term that applies to a number of variables, including examination of tissues for pathological changes (histopathology), blood analysis (haematology), enzymatic indicators of exposure to pollutants or stress (e.g., Mixed-Function Oxygenase; MFO), and life history measures (e.g., age, size, growth and fecundity).

Histopathology is usually carried out on liver and gill tissues. The liver plays a major role in metabolism, excretion, digestion, and storage of various substances, including those toxic to the organism. Common liver disorders that result when fish are exposed to toxins are hepatocyte regenerative foci, hydropic vacualization, neoplasia, and necrosis. The gill epithelium of fish is the major site of gas exchange, acid-base balance, ionic regulations, and excretion of nitrogenous waste. Fish exposed to contaminants may show gill histological changes such as epithelium hyperplasia, fusion of gill lamellae, separation of respiratory epithelium from underlying tissue, and other lamellar lesions.

Due to the mobility to American plaice, caution must be used in interpreting the data as health effects may or may not be attributable to the White Rose oilfield development. As the project develops, consideration should be given to using health effects in a "regional monitoring plan" as opposed to the site-specific White Rose EEM program. However, the cost of assessing fish health indicators is moderate in relation to information return. As a result of this overall evaluation, fish health indicators are considered to be appropriate monitoring variables to include in the White Rose EEM program.

5.6.1 Purpose and Objective

Histopathology is a measure of long-term changes whereas haematology is a short-term indicator of health. Haematological assessment involves morphological analysis of blood samples for several different types of blood components such as neutrophils, lymphocytes, thromocytes, and polychromatocytes. Examining the cellular components of the blood to determine whether they are within normal range is a quick method to assess the general health of a fish.

MFO enzyme induction is an indicator of recent exposure to stress or pollutants. MFOs play an important role in detoxification by transforming foreign components into derivatives that are more easily eliminated from the organism. A series of oxidation reactions converts relatively insoluble inorganic components into water-soluble metabolites that may be further conjugated and excreted in urine or bile. Measurement of MFO activity is economical and sensitive, while at the same time relatively insensitive to any stress associated with animal collection. A number of field and laboratory studies have demonstrated that MFO enzyme induction is a useful index for assessing recent exposure to organic pollution. Flatfish have been used to assess fish health in EEM programs in the North Sea.

5.6.2 Measurements and Data Analysis

5.6.2.1 Mixed-Function Oxygenase Induction

Each liver sample will be thawed slightly on ice and a representative sample (approximately 1 gram) will be taken from the same location on each organ. Each liver will be homogenized in four volumes of 50 mM Tris buffer (1 g liver to 4 mls 50 mM Tris using ten passes of a glass ten Broek hand Homogenizer). The homogenate will be centrifuged at 9000 x g for 10 minutes a 4°C. The pellet will be discarded and the supernatant (now known as S9) transferred to Eppendorf microcentrifuge tubes and frozen in triplicate at -80°C until assayed. In the event that a top fat layer appears, it will be discarded. It is important that samples from each site are held under the same storage and assay conditions.

Ethoxy-resorufin o-deethylase (EROD) activity should be assayed fluorometrically as described by Pohl and Fouts (1980) and modified by Porter et al. (1989) using a fluorescence spectrophotometer. The reaction mixture, final volume 1.25 ml, will consist of 53 nmol Tris-Sucrose buffer (50 mM, pH 7.5), 50 ul of S9 liver, and 2.25 nmol 7 -ER (150 uM ethoxyresorufin). The reaction mixture will be started by the addition of 0.16 mg NADPH (1.25 mg/ml). After a 15-minute incubation at 27°C in a temperature-controlled waterbath, the reaction will be terminated by the addition of a 2.5 ml of ice-cold methanol. A methanol blank will be used and will contain the same components as the sample tubes except for the addition of NADPH. Assay tubes will be vortexed and the protein precipitate removed by centrifugation at 3600 x g for 5 minutes. The fluorescence of resorufin formed in the supernatant will be measured in cuvettes (1 cm path length) at 585 nm using an excitation wavelength of 550 nm (slit width of 0.5 mm). Enzyme activity is linear with time and protein concentration. The rate of enzyme activity in pmol/min/mg protein will be obtained from the regression of fluorescence against the standard concentrations of resorufin.

All liver samples, used for MFO analysis, will be treated and processed in the same manner so that any difference in MFO activity should only be due to sampling area and not affected by processing. Also, when the liver is homogenized and the S9 homogenate prepared, it is frozen in triplicate so that there are three identical tubes of homogenate for each liver sample. This is very important because EROD activity decreases as the tissue thaws. If this occurs inadvertently there are two other tubes of the same sample that can be used as backup.

5.6.2.2 Histopathology

Both liver and gill samples will be dehydrated in ethanol, cleared in chloroform, and embedded in paraffin wax. Samples will be sectioned at 6 microns and stained with Mayer's Haematoxylin and Eosin. Additional special stains may be done, if required, to assess various liver lesions. Each sample will be assessed microscopically and a colour photo taken of each section and any lesions observed.

Some of the more notable liver lesions to be looked for in the samples could include:

1. Non-specific necrosis
2. Nuclear pleomorphism
3. Megalocytic hepatosis
4. Eosinophilic foci
5. Basophilic foci
6. Clear cell foci
7. Hepatocellular carcinoma
8. Cholangioma
9. Cholangiofibrosis
10. Increase in mitotic activity
11. Macrophage aggregates

According to research carried out by the Toxicology Section (DFO, Science Branch, St. John's), there are generally six recognized stages used to read gill sections. It is important to note that the stages described below do not follow in any specific order. For example, a Stage 4 does not necessarily turn into a Stage 5; however, they range from the best (normal) to the worst (fusion) condition. These stages are as follows:

Stage 1 - Normal
Stage 2 - Distal hyperplasia
Stage 3 - Epithelium lifting
Stage 4 - Clubbing - Fibrosis
- Telangiectasis
Stage 5 - Basal hyperplasia
Stage 6 - Fusion

A colour photograph should be taken of each stage and any tissue abnormalities. One must keep in mind that the microscopic examination of gill sections is not a quantitative procedure, as all the gill lamellae do not conform to set patterns for each stage. Most times a judgement call is needed; consequently the skill and experience of the person reading the gills is crucial to the correct interpretation of the samples. Also, the presence and number of a variety of cells found in gill tissue should be recorded. These include hypertrophic epithelium cells, chloride cells, and mucus cells.

Similar quality control procedures should be used as with the MFO samples. For both liver and gill tissue, a sample should be taken from the same place on each tissue consistently. In addition, serial sections will be made for each histology sample. This means there will be four sections from the same sample on each slide. If an abnormality is found in a section, then the other three sections are checked for the same abnormality. If it is not found then the abnormality is considered an artifact of processing.

5.6.2.3 Haematology

Blood taken from each fish will also be used for haematological assessment. Using the EBM method, all cellular components should be assessed for abnormalities.

In terms of haematology analysis, standard routine procedures will be followed. Because blood cells do not disperse randomly on a slide when a blood smear is made, one must ensure that all sections of the slide are assessed. The EBM method is a standard procedure that ensures the entire slide is checked and that cells in one particular area (i.e., the middle or the edges) are not missed.

5.7 Quality Assurance and Quality Control

Quality assurance (QA) can be defined as a "set of operating principles that, if strictly followed during sample collection and analysis, will produce data of known and defensible quality whose analytical accuracy can be stated with a high level of accuracy" (APHA 1992). QA is comprised of two separate but interrelated activities: quality control and quality assessment (NRC 1990).

Quality control (QC) ensures that the data collected are of adequate quality, given the study objectives and the specific hypothesis to be tested. QC activities would include standardized protocols for sample collection and processing. The goals of QC are to ensure that: sampling, processing and analysis techniques are consistent; uncollected samples are minimized; data are comparable with similar data collected elsewhere; and study results can be reproduced (NRC 1990).

5.7.1 Quality Assurance Plan

To ensure that environmental baseline data for the White Rose project are accurate and defensible, a Quality Assurance Plan should be developed prior to sampling. QA/QC planning ensures high quality data are produced and substantiated. An effective QA plan includes organization, record keeping and standard operating procedures (SOPs) for such tasks as field surveys, sample handling, laboratory analyses and data management.

The following will be considered for inclusion in the QA Plan:

- identification of field teams and the responsibilities of each member;
- statement and prioritization of study objectives;
- description of survey area, including station locations, samples and station identifiers;
- identification of variables to be measured and corresponding containers and preservatives;
- identification of all QA/QC samples to be submitted with the samples;
- description of the sampling methods, including station positioning, sampling devices, replication and other special considerations;
- detailed program schedule including time, date and location of stations and field teams;
- storage and shipping procedures;
- identification of laboratories to which samples will be shipped;
- field team requirements;
- location and availability of alternate equipment;

- all equipment necessary to under take the program; and
- equipment checklists and manifests are prepared to ensure all required sampling equipment, supplies, spare parts and alternative equipment are available to the sampling program.

5.7.2 Sample Collection

The following are specific QA/QC methods that will be instituted for the White Rose Baseline Data Collection Survey.

5.7.2.1 Sample Station Location

Accurate positioning is essential to ensuring that stations can be plotted and reoccupied with a high degree of certainty. All locations will be fixed by Differential Geographical Positioning Systems (DGPS). All personnel using such devices will be trained in their proper use, care and limitations.

5.7.2.2 Sample Handling

- All stages of sampling handling will be carefully documented to ensure sample handling requirements are sustained to minimize against errors in collection, shipping and analyses of the samples.
- SOPs will be used to ensure all field personnel activities are conducted in the same manner regardless of the actual person conducting the activity.
- Sample programs will maintain integrity of sample from time of collection to data reporting. Chain of custody procedures ensure all the possession and handling of samples can be traced from collection to final disposition.
- Sample labels should be waterproof and securely fastened and contain the following information:
  - sample identification (identifier),
  - preservation technique,
  - date/time of collection,
  - location (depth and by identifier),
  - collectors ID, and
  - sample analysis required.
- Triplicate cores will be obtained from each marine sample location - two for infauna and sediment chemistry analyses, and the third for toxicity testing and archival.
- A 125-mL sample will be taken from each infauna/sediment chemistry core and combined for a total sample of 250-mL for hydrocarbon and total metals testing. This sample will be stored in a glass container at 4°C for shipping to the laboratory within two weeks of collection.
- The remainder of each infauna/sediment chemistry core, to a depth of 15 cm, will be stored in a food grade high density polyethylene bucket with O-ring seal and preserved with 10 to 20 percent

formalin, buffered with sodium borate. The buckets will be stored at ambient temperature for shipping to the laboratory.

- Whole fish (American plaice) will be frozen for fish health analysis.
- Liver and fillets (American plaice) and legs (snow crab) will be frozen for body burden analysis.
- Water samples will be stored in pre-labelled containers appropriate for the analyses to be conducted and stored at 4°C.
- Chain of custody forms will be filled out with information from the sample label and will accompany every sample shipped to a laboratory or consultant for analysis with each person who has custody signing off to ensure sample traceability.
- • Shipment manifests will accompany every sample shipped to a laboratory or consultant for analysis with the consigner and consignee signing off on the shipment.

5.7.2.3 Sample Shipment

- All samples will be shipped in such a manner to ensure that the samples are received at the appropriate destination (labs) within an acceptable holding time.
- Shipping containers will be in good shape and capable of handling rough treatment.
- Samples will be tightly packed:
  - dividers must separate glass; and
  - empty spaces must be filled so jars are secure.
- Leakproof containers will be used wherever appropriate.
- Sample request form and/or chain of custody forms will accompany all samples.

A chain of custody form will be filled out for each shipment. The original chain of custody will be placed inside shipping container in such a manner that it is protected and than can serve as a sample request form.

- A copy of the chain of custody form will be retained by shipper.
- Shipping containers will be sent by a courier who will provide a delivery slip.
  - This serves as a backup to the chain of custody.
  - This will confirm that the laboratory received the samples.
- All shipping charges should be prepaid to avoid rejection of shipment by consigner.

5.7.3 Laboratory Analysis

- The laboratory should provide proof of membership (in good standing) in CAEAL or be an recognized expert (benthic analysis).
- The laboratory must have an acceptable quality assurance/quality control program in place.

- The laboratory must have in place a corporate Safety and Environmental Protection Policies and Procedures.
- • The laboratory must be suitably equipped to meet the analytical requirements for the
- analyses undertaken.
- The laboratory should assign a specific staff member who will be responsible for the project and will act as liaison person with the client in terms of delivery of results, quality control of results and overall activities of the laboratory. This person shall be responsible for
  - sample reception,
  - maintenance of chain of custody,
  - maintenance of sample tracking logs,
  - distribution of samples for laboratory analyses,
  - subcontracting samples to other facilities,
  - supervision of labelling, log keeping, data reduction, and data transcription, and
  - storage and security of all samples, data and documents.
- The laboratory shall provide all necessary forms and documentation required for sample submission.
- The laboratory shall notify the client of inconsistencies between labels and sample request forms (Chain of Custody Forms).
- Prior to initiation of testing all parameters should be confirmed with the client.
- Data transfer shall be submitted by faxed results and by hard copy in mail and, where available, electronically.
- The client will not pay for samples which must be reanalyzed due to laboratory error.
- Originals of the following documents shall be sent to the client
  - chain of custody forms,
  - data report sheets, and
  - QA/QC control records and reports.

5.7.3.1 Analytical Laboratory

- The laboratory will be required to analyze samples on a 10 percent replicate basis or one replicate per batch, whichever is more frequent.
- Where available, Certified Reference Material (CRMs) should be run along side each batch of samples.
- The laboratory shall provide appropriate QA/QC reports or data for each set of samples analyzed. The reported data should include results of laboratory duplicates, reference samples, method blanks, and spike recovery. The laboratory should provide validation of these QA/QC data to demonstrate their acceptability.
- The laboratory shall provide full references for all methods used.

5.7.3.2 Toxicological Laboratory

- The toxicity results should be provided within two weeks of test conclusion. A full report should include bench data and related reference toxicant data. These assays shall be conducted as per procedures outlined in Environment Canada (1992a; 1992b; 1992c) and with modifications for the Echinoid Fertilization assay as described in Section 5.3.
- Where available, reference toxicants should be run along side each batch of samples.
- The laboratory will provide full references for all methods used.

5.7.3.3 Benthic Analysis

The infauna from two separate benthic grabs, at each station, are to be identified and quantified to the lowest possible taxonomic level. All field processed benthic samples will be sieved separately through 0.5-mm mesh sieves to remove residual sediment and shell hash, both of which will be measured. All organisms retained by the sieve will be transferred to individually labeled vials containing 70 percent ethanol. Organisms will be identified to species where possible, enumerated and the collective biomass determined for each sub-sample. All body fragments will be counted, but invertebrate heads will be used exclusively for species enumeration. Organisms will be returned to sample vials for archival. A reference collection and all original data sheets will be provided by the laboratory.

Identification of species will be undertaken by marine invertebrate taxonomists using stereo and compound microscopes. Numerous guides, recently published keys and papers (Abbott 1954; Appley et. al. 1980; Berrill 1959; Bousfield 1973; Cutler 1994; Gosner 1971; Grainger 1966; Hartman 1968; Light 1978; Miner 1950; Noyes 1980; Pettibone 1963; Pocklington 1989; Richardson 1909; Sars 1890; Watling 1979) will be used to aid in the identification of species. Keys appropriate to the geographic region of study will be used.

The samples will be processed randomly. For processing, the samples are poured on a sieve with a mesh size of 0.5 mm, then carefully washed using a water pressure low enough so that small or delicate animals are not damaged. Once the preservatives and fine-grained materials are removed, the animals are picked from the remaining sediment. Initially, the washed sample is placed in an enamel tray and the larger animals are picked out under 2X magnification. To pick the smaller animals, aliquots of sediment are placed in a petri dish and examined under a binocular microscope using at least 10X magnification. A count of heads is done when fragments are encountered, and the whole sample is examined this way. All animals are preserved in 70 percent alcohol and sieves are rinsed thoroughly between samples.

Approximately 10 percent of the samples are retained for re-examination to determine sorting efficiency. This should be recorded on a separate sheet and labelled "sorted debris". A reference collection should be maintained in the laboratory at the time of sorting, and a species list should be provided to the contractor. Transcription checks against the original records should be undertaken to guard against data entry errors or data misuse. Staining and mounting techniques should also be described.

To determine wet weight biomass, all animals are placed together on paper towels and blotted dry. The material is weighed in a tiered plastic weighing dish to 0.1 mg accuracy. The volume of gravel and shell hash should be recorded for infauna samples.

5.7.4 Data Management

Data management involves a number of systematic processes and protocols that are designed to provide a framework for providing quality environmental data with a high degree of credibility. The major components for a data management system used for environmental programs should include or consider items such as:

- data documentation (computer programs, and statistical, normalization and error control procedures);
- data recording (laboratory reports, field notebooks, field maps and auxiliary data records);
- data custody and transfer (chain of custody records, QA/QC procedures for authorizing changes to data, QA/QC documentation of transfer formats, data recording forms, and data verification and validation);
- data validation (data identification, transmittal errors, flagged or rejected data, data comparability, and data review and evaluation);
- data verification (sample results reported and checked for transmission errors, sample labels verified, cross-referencing field data sheets and laboratory results, data review, flagging and screening);
- data presentation (tables, graphs and figures); and
- data storage (digital format and hard copy).

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