Husky Exploration Drilling Project: Environmental Impact Statement

Appendices

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APPENDIX A

Final EIS Guidelines

Canadian Environmental Assessment Agency | Agence canadienne d'évaluation environnementale

GUIDELINES FOR THE PREPARATION OF AN ENVIRONMENTAL IMPACT STATEMENT

pursuant to the

Canadian Environmental Assessment Act, 2012

Husky Energy Exploration Drilling Project

Husky Oil Operations Ltd.

May 31, 2018

Canada

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DISCLAIMER

This document is not a legal authority, nor does it provide legal advice or direction; it provides information only, and must not be used as a substitute for the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) or its regulations. In the event of a discrepancy, CEAA 2012 and its regulations prevail. Portions of CEAA 2012 have been paraphrased in this document, but will not be relied upon for legal purposes.

Abbreviations and Short Forms

CEAA 2012	*Canadian Environmental Assessment Act*, *2012*
Agency	Canadian Environmental Assessment Agency
EA	environmental assessment
EIS	environmental impact statement
VC	valued component

Part 1 - Key Considerations

1. INTRODUCTION

The purpose of this document is to identify for the proponent the minimum information requirements for the preparation of an Environmental Impact Statement (EIS) for a designated project[1] to be assessed pursuant to the *Canadian Environmental Assessment Act, 2012* (CEAA 2012). This document specifies the nature, scope and extent of the information required. Part 1 of this document defines the scope of the environmental assessment (EA) and provides guidance and general instruction that must be taken into account in preparing the EIS. Part 2 outlines the information that must be included in the EIS.

Section 5 of CEAA 2012 describes the environmental effects that must be considered in an EA, including changes to the environment and effects of changes to the environment. The factors that are to be considered in an EA are described under section 19 of CEAA 2012. The Canadian Environmental Assessment Agency (the Agency) will use the proponent's EIS and other information received during the EA process to prepare a report that will inform the issuance of a decision statement by the Minister of Environment and Climate Change. Therefore the EIS must include a full description of the changes the project will cause to the environment that may result in adverse effects on areas of federal jurisdiction (i.e. section 5 of CEAA 2012) including changes that are directly linked or necessarily incidental to any federal decisions that would permit the project to be carried out. The EIS must also include a list of key mitigation measures that the proponent proposes to undertake in order to avoid or minimize any adverse environmental effects of the project. It is the responsibility of the proponent to provide sufficient data and analysis on potential changes to the environment to ensure a thorough evaluation of the environmental effects of the project by the Agency.

2. GUIDING PRINCIPLES

2.1. Environmental assessment as a planning and decision making tool

Environmental assessment (EA) is a process to predict environmental effects of proposed projects before they are carried out. An EA:

- identifies potential adverse environmental effects;
- proposes measures to mitigate adverse environmental effects;
- predicts whether there will be significant adverse environmental effects, after mitigation measures are implemented; and
- includes a follow-up program to verify the accuracy of the EA and the effectiveness of the mitigation measures.

2.2. Public participation

One of the purposes identified in CEAA 2012 is to ensure that opportunities are provided for meaningful public participation during an EA. CEAA 2012 requires that the Agency provide the public with an opportunity to participate in the EA. For EAs led by the Agency the public has an opportunity to comment on the draft EA report. Additional opportunities for participation may also be provided.

1 In this document, "project" has the same meaning as "designated project" as defined in CEAA 2012.

Meaningful public participation is best achieved when all parties have a clear understanding of the proposed project as early as possible in the review process. The proponent is required to provide current information about the project to the public and especially to the communities likely to be most affected by the project.

2.3. Engagement with Indigenous groups

A key objective of CEAA 2012 is to promote communication and cooperation with Aboriginal peoples which includes First Nations, Inuit and Métis. The proponent is expected to engage with potentially affected groups, beginning as early as possible in the project planning process.

The proponent shall provide potentially affected groups with opportunities to learn about the project and its potential effects and to make their concerns known about the project's potential effects and discuss measures to mitigate those effects. The proponent is strongly encouraged to work with potentially affected groups to establish an engagement approach. The proponent will make reasonable efforts to integrate Aboriginal traditional knowledge into the assessment of environmental effects. For more information on incorporating Aboriginal traditional knowledge, refer to Part 1, Section 4.2.2 of these guidelines.

In order to fulfill the Crown's constitutional obligations to consult with potentially impacted groups, the Agency integrates its legal obligation for consultation and accommodation in the EA process. The information gathered by the proponent during its engagement with groups helps to contribute to the Crown's understanding of any potential adverse impacts on potential or established Aboriginal or treaty rights protected under section 35 of the *Constitution Act*, *1982* ("section 35 Aboriginal rights") including title and related interests, and the effectiveness of measures proposed to avoid or minimize those impacts.

2.4. Application of the precautionary approach

In documenting the analyses included in the EIS, the proponent will demonstrate that all aspects of the project have been examined and planned in a careful and precautionary manner in order to avoid significant adverse environmental effects.

3. SCOPE OF THE ENVIRONMENTAL ASSESSMENT

3.1. Designated project

On September 2, 2016, Husky Oil Operations Ltd., the proponent of the Husky Energy Exploration Drilling Project provided a project description to the Agency. Based on the project description, the Agency determined that an EA is required under CEAA 2012. Following a request from the proponent, exploration licences 1151 and 1152 were added to the Project subject to environmental assessment on March 27, 2017. On March 23, 2018, exploration licence 1134 was removed from the Project based on a transfer of ownership and on April 27, 2018, exploration licence 1121 was removed from the Project as it had expired. On May 31, 2018, exploration licence 1155 was added to the Project subject to environmental assessment following a request from the proponent.

Based on the project description and subsequent submissions, the Agency determined that the EA will include the following project components:

- the mobilization, operation and demobilization of Mobile Offshore Drilling Units designed for year-round operations for the drilling, testing and abandonment of up to ten wells within exploration licences operated by Husky Oil Operations Ltd. (exploration licences 1151, 1152 and 1155), including consideration of any proposed safety exclusion zones. Drilling may occur in various water depths under consideration, with various types of drilling units, and with multiple drilling units operating simultaneously, if applicable;
- vertical seismic profiling surveys and in-water work to support the specific exploration wells under consideration (excluding surveys potentially required to support the conduct of the EA [e.g. environmental baseline surveys] and surveys related to the broader delineation of resources; and
- the loading, refuelling and operation of marine support vessels (i.e. for re-supply and transfer of materials, fuel, and equipment and on-site safety during drilling activities and transport between the supply base and Mobile Offshore Drilling Unit(s)) and helicopter support (i.e. for crew transport and delivery of light supplies and equipment) including transportation to the Mobile Offshore Drilling Unit.

Note: If the proponent acquires and becomes the operator of new exploration licences and submits corresponding information to the Agency, the Agency will consider on a case-by-case basis whether those exploration licences may be added to the Project subject to environmental assessment.

3.2. Factors to be considered

Scoping establishes the parameters of the EA and focuses the assessment on relevant issues and concerns. Part 2 of this document specifies the factors to be considered in the EA, including the factors listed in subsection 19(1) of CEAA 2012:

- environmental effects of the project, including the environmental effects of malfunctions or accidents that may occur in connection with the project and any cumulative environmental effects that are likely to result from the project in combination with other physical activities that have been or will be carried out;
- the significance of the effects referred to above;
- comments from the public;
- mitigation measures that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project;
- the requirements of the follow-up program in respect of the project;
- the purpose of the project;
- alternative means of carrying out the project that are technically and economically feasible and the environmental effects of any such alternative means;
- any change to the project that may be caused by the environment; and
- the results of any relevant regional study pursuant to CEAA 2012.

3.2.1. Changes to the environment

Environmental effects occur as interactions between actions (the carrying out of the project or decisions made by the federal government in relation to the project) and receptors in the environment, and subsequently between components of the environment (e.g. change in water quality that may affect fish).

Under CEAA 2012, an examination of environmental effects that result from changes to the environment as a result of the project being carried out or as a result of the federal government exercising any power duty or function that would allow the project to be carried out must be considered in the EIS.

In scoping the potential changes to the environment that may occur, the proponent should consider any potential changes in the physical environment such as changes to air quality, water quality and quantity, and physical disturbance of land that could reasonably be expected to occur.

3.2.2. Valued components to be examined

Valued components (VCs) refer to environmental biophysical or human features that may be impacted by a project. The value of a component not only relates to its role in the ecosystem, but also to the value people place on it. For example, it may have been identified as having scientific, social, cultural, economic, historical, archaeological or aesthetic importance.

The proponent must conduct and focus its analysis on VCs as they relate to **section 5 of CEAA 2012,** including the ones identified in Section 6.2 (Part 2) of these guidelines that may be affected by changes in the environment, as well as species at risk and their critical habitat as per the requirement outlined in section 79 of the *Species at Risk Act*. Section 5 of CEAA 2012 defines environmental effects as:

- a change that may be caused to fish and fish habitat, marine plants and migratory birds;
- a change that may be caused to the environment on federal lands, in another province or outside Canada;
- with respect to Aboriginal peoples, an effect of any change that may be caused to the environment on:
  - ✓ health and socio-economic conditions;
  - ✓ physical and cultural heritage;
  - ✓ the current use of lands and resources for traditional purposes; or
  - ✓ any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.
- for projects requiring a federal authority to exercise a power or perform a duty or function under another Act of Parliament:
  - ✓ a change, other than the ones mentioned above, that may be caused to the environment and that is directly linked or necessarily incidental to the exercise of the federal power or the performance of a duty or function; and
  - ✓ the effect of that change, other than the effects mentioned above, on:
    - o health and socio-economic conditions,
    - o physical and cultural heritage, or
    - o any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.

The list of VCs presented in the EIS will be completed according to the evolution and design of the project and reflect the knowledge acquired through public consultation and engagement with Indigenous groups.

The EIS will describe what methods were used to predict and assess the adverse environmental effects of the project on these valued components.

The VCs will be described in sufficient detail to allow the reviewer to understand their importance and to assess the potential for environmental effects arising from the project activities. The EIS will provide a rationale for selecting specific VCs and for excluding any VCs or information specified in these guidelines. Challenges may arise regarding particular exclusions, so it is important to document the information and the criteria used to justify the exclusion of a particular VC or piece of information. Justification may be based on, for example, primary data collection, computer modelling, literature references, public participation or engagement with Indigenous groups, or expert input or professional judgement. The EIS will identify those VCs, processes, and interactions that either were identified to be of concern during any workshops or meetings held by the proponent or that the proponent considers likely to be affected by the project. In doing so, the EIS will indicate to whom these concerns are important (i.e. the public or Indigenous groups) and the reasons why, including environmental, cultural, historical, social, economic, recreational, and aesthetic considerations, and traditional knowledge. If comments are received on a component that has not been included as a VC, these comments will be summarized and the rationale for excluding the component will address the comments.

3.2.3. Spatial and temporal boundaries

The spatial and temporal boundaries used in the EA may vary depending on the VC and will be considered separately for each VC, including for VCs related to the current use of lands and resources for traditional purposes by Aboriginal peoples, or other environmental effects referred to under paragraph 5(1)(*c*) of CEAA 2012. The proponent is encouraged to consult with the Agency, federal and provincial government departments and agencies, local government and Indigenous groups, and take into account public comments when defining the spatial and temporal boundaries used in the EIS.

The EIS will describe the spatial boundaries, including local and regional study areas, of each VC to be used in assessing the potential adverse environmental effects of the project and provide a rationale for each boundary. Spatial boundaries will be defined taking into account the appropriate scale and spatial extent of potential environmental effects, community knowledge and Aboriginal traditional knowledge, current or traditional land and resource use by Indigenous groups, ecological, technical, social and cultural considerations.

The temporal boundaries of the EA will span all phases of the project determined to be within the scope of this EA as specified under section 3.1 above. If effects are predicted after project decommissioning, this should be taken into consideration in defining boundaries. Community knowledge and Aboriginal traditional knowledge should factor into decisions around defining temporal boundaries.

If the temporal boundaries do not span all phases of the project, the EIS will identify the boundaries used and provide a rationale.

4. PREPARATION AND PRESENTATION OF THE ENVIRONMENTAL IMPACT STATEMENT

4.1. Guidance

The proponent is encouraged to consult relevant Agency policy and guidance[2] on topics to be addressed in the EIS, and to liaise with the Agency during the planning and development of the EIS. The proponent is also encouraged to consult relevant guidance from other federal departments.

Submission of regulatory and technical information necessary for federal authorities to make their regulatory decisions during the conduct of the EA is at the discretion of the proponent. Although that information is not necessary for the EA decision, the proponent is encouraged to submit it concurrent with the EIS. While the EIS must outline applicable federal authorizations required for the project to proceed, the proponent must provide information relevant to the regulatory role of the federal government. It should be noted that the issuance of these other applicable federal legislative, regulatory and constitutional requirements are within the purview of the relevant federal authorities, and are subject to separate processes post EA decision.

4.2. Use of information

4.2.1. Government expert advice

Section 20 of CEAA 2012 requires that every federal authority with specialist or expert information or knowledge with respect to a project subject to an EA must make that information or knowledge available to the Agency. The Agency will advise the proponent of the availability of pertinent information or knowledge or expert and specialist knowledge received from other federal authorities or other levels of government so that it can be incorporated into the EIS.

4.2.2. Community knowledge and Aboriginal traditional knowledge

Sub-section 19(3) of CEAA 2012 states that "the environmental assessment of a designated project may take into account community knowledge and Aboriginal traditional knowledge". For the purposes of these guidelines, community knowledge and Aboriginal traditional knowledge refers to knowledge acquired and accumulated by a local community or an Indigenous group.

The proponent will incorporate into the EIS the community knowledge and Aboriginal traditional knowledge to which it has access or that is acquired through public participation and engagement with Indigenous groups, in keeping with appropriate ethical standards and obligations of confidentiality. The proponent will integrate Aboriginal traditional knowledge into all aspects of its assessment including both methodology (e.g. establishing spatial and temporal boundaries, defining significance criteria) and analysis (e.g. baseline characterization, effects prediction, development of mitigation measures).

Agreement should be obtained from Indigenous groups regarding the use, management and protection of their existing traditional knowledge information during and after the EA. For more information on how Aboriginal traditional knowledge can be obtained and incorporated in the preparation of the EIS, please refer to the Agency's reference guide entitled "Considering Aboriginal traditional knowledge in environmental assessments conducted under the *Canadian Environmental Assessment Act, 2012*".

4.2.3. Existing information

[2] Visit the Canadian Environmental Assessment Agency website: https://www.canada.ca/en/environmental-assessment-agency/services/policy-guidance.html

In preparing the EIS, the proponent can use existing information relevant to the project, if applicable. When relying on existing information to meet requirements of the EIS Guidelines, the proponent will either include the information or provide a summary directly in the EIS and clearly direct the reader to where the information can be found (i.e. through cross-referencing). When relying on existing information to support the effects assessment, the proponent will provide a rationale to support the use of the information in relation to the specific project, separate factual lines of evidence from inference, and state any limitations on the inferences or conclusions that can be drawn from the existing information. In such circumstances, the proponent will clearly describe potential or known data or knowledge gaps, and describe how such gaps have been addressed in the assessment of the project.

4.2.4. Confidential information

In implementing CEAA 2012, the Agency is committed to promoting public participation in the EA of projects and providing access to the information on which EAs are based. All documents prepared or submitted by the proponent or any other stakeholder in relation to the EA are included in the Canadian Environmental Assessment Registry and made available to the public on request. For this reason, the EIS will not contain information that:

- is sensitive or confidential (i.e. financial, commercial, scientific, technical, personal, cultural or other nature), that is treated consistently as confidential, and the person affected has not consented to the disclosure; or
- may cause substantial harm to a person or specific harm to the environment through its disclosure.

The proponent will consult with the Agency regarding whether specific information requested by these guidelines should be treated as confidential.

4.3. Study strategy and methodology

The proponent is expected to respect the intent of these guidelines and to consider the environmental effects that are likely to arise from the project (including situations not explicitly identified in these guidelines), the technically and economically feasible mitigation measures that will be applied, and the significance of any residual effects. Except where specified by the Agency, the proponent has the discretion to select the most appropriate methods to compile and present data, information and analysis in the EIS as long as they are justifiable and replicable.

It is possible these guidelines may include matters which, in the judgement of the proponent, are not relevant or significant to the project. If such matters are omitted from the EIS, the proponent will clearly indicate it in the EIS, and provide a justification so the Agency, federal authorities, Indigenous groups, the public and any other interested party have an opportunity to comment on this decision. Where the Agency disagrees with the proponent's decision, it will require the proponent to provide the specified information.

The assessment will include the following general steps:

- ✓ identifying the activities and components of the project;
- ✓ predicting potential changes to the environment;
- ✓ predicting and evaluating the likely effects on identified VCs;
- ✓ identifying technically and economically feasible mitigation measures for any significant adverse environmental effects;
- ✓ determining any residual environmental effects;
- ✓ considering cumulative effects of the project in combination with other physical activities that have been or will be carried out; and
- ✓ determining the potential significance of any residual environmental effect following the implementation of mitigation measures.

For each VC, the EIS will describe the methodology used to assess project-related effects. The EIS could include an analysis of the pathway of the effects of environmental changes on each VC. The EIS will document where and how scientific, engineering, community knowledge and Aboriginal traditional knowledge were used to reach conclusions. Assumptions will be clearly identified and justified. All data, models and studies will be documented such that the analyses are transparent and reproducible. All data

collection methods will be specified. The uncertainty, reliability, sensitivity and conservativeness of models used to reach conclusions must be indicated.

The EIS will identify all significant gaps in knowledge and understanding related to key conclusions, and the steps to be taken by the proponent to address these gaps. Where the conclusions drawn from scientific, engineering and technical knowledge are inconsistent with the conclusions drawn from Aboriginal traditional knowledge, the EIS will present each perspective on the issue and a statement of the proponent's conclusions.

The EIS will include a description of the environment (both biophysical and human), including the components of the existing environment and environmental processes, their interrelations as well as the variability in these components, processes and interactions over time scales appropriate to the likely effects of the project. The description will be sufficiently detailed to characterize the environment before any disturbance to the environment due to the project and to identify, assess and determine the significance of the potential adverse environmental effects of the project. These data should include results from studies done prior to any physical disruption of the environment due to project related activities. The information describing the existing environment may be provided in a stand-alone chapter of the EIS or may be integrated into clearly defined sections within the effects assessment of each VC. This analysis will include environmental conditions resulting from historical and present activities in the local and regional study areas.

If the baseline data have been extrapolated or otherwise manipulated to depict environmental conditions in the study areas, modelling methods and equations will be described and will include calculations of margins of error and other relevant statistical information, such as confidence intervals and possible sources of error. The proponent will provide the references used in creating their approach to baseline data gathering, including identifying where appropriate, the relevant federal or provincial standards. The proponent is encouraged to discuss the timeframe and considerations for its proposed baseline data with the Agency prior to submitting its EIS.

In describing and assessing effects to the physical and biological environment, the proponent will take an ecosystem approach that considers both scientific and community knowledge and Aboriginal traditional knowledge and perspectives regarding ecosystem health and integrity. The proponent will consider the resilience of relevant species populations, communities and their habitats. The assessment of environmental effects on Aboriginal peoples, pursuant to paragraph 5(1)(*c*) of CEAA 2012, will undergo the same rigour and type of assessment as any other VC (including setting of spatial and temporal boundaries, identification and analysis of effects, identification of mitigation measures, determination of residual effects, identification and a clear explanation of the methodology used for assessing the significance of residual effects and assessment of cumulative effects).

The proponent will consider the use of both primary and secondary sources of information regarding baseline information, changes to the environment and the corresponding effect on health, socio-economics, physical and cultural heritage and the current use of lands and resources for traditional purposes. Primary sources of information could include traditional land use studies, socio-economic studies, heritage surveys or other relevant studies conducted specifically for the project and its EIS. Often these studies and other types of relevant information are obtained directly from Indigenous groups. Secondary sources of information could include previously documented information on the area, not collected specifically for the purposes of the project, or desk-top or literature-based information. The proponent will provide Indigenous groups the opportunity to review and provide comments on the information used for describing and assessing effects on Aboriginal peoples (further information on

engaging with Indigenous groups is provided in Part 2, Section 5 of this document). Where there are discrepancies in the views of the proponent and Indigenous groups on the information to be used in the EIS, the EIS will document these discrepancies and the rationale for the proponent's selection of information.

The assessment of the effects of each of the project components and physical activities, in all phases, will be based on a comparison of the biophysical and human environments between the predicted future conditions with the project and the predicted future conditions without the project. In undertaking the environmental effects assessment, the proponent will use best available information and methods. All conclusions will be substantiated. Predictions will be based on clearly stated assumptions. The proponent will describe how each assumption has been tested. With respect to quantitative models and predictions, the EIS will document the assumptions that underlie the model, the quality of the data and the degree of certainty of the predictions obtained.

4.4. Presentation and organization of the environmental impact statement

To facilitate the identification of the documents submitted and their placement in the Canadian Environmental Assessment Registry, the title page of the EIS and its related documents will contain the following information:

- project name and location
- title of the document, including the term "environmental impact statement"
- subtitle of the document
- name of the proponent
- date of submission of the EIS

The EIS will be written in clear, precise language. A glossary defining technical words, acronyms and abbreviations will be included. The EIS will include charts, diagrams, tables, maps and photographs, where appropriate, to clarify the text. Perspective drawings that clearly convey the various components of the project will also be provided. Wherever possible, maps will be presented in common scales and datum to allow for comparison and overlay of mapped features.

For purposes of brevity and to avoid repetition, cross-referencing within the EIS is preferred. For example, the EIS may make reference to information that has already been presented in other sections of the document, rather than repeating it. Detailed studies (including all relevant and supporting data and methodologies) will be provided in separate appendices and will be referenced by appendix, section and page in the text of the main document. The EIS will explain how information is organized in the document. This will include a table of contents with a list of all tables, figures, and photographs referenced in the text. A complete list of supporting literature and references will also be provided. A table of concordance, which cross references the information presented in the EIS with the information requirements identified in the EIS Guidelines, will be provided. The proponent will provide copies of the EIS and its summary for distribution, including paper and electronic versions in an unlocked, searchable PDF format, as directed by the Agency.

4.5. Summary of the environmental impact statement

The proponent will prepare a summary of the EIS in both of Canada's official languages (French and English) to be provided to the Agency at the same time as the EIS that will include the following:

- a concise description of all key components of the project and related activities;
- a summary of the engagement with Indigenous groups, and the participation of the public and government agencies, including a summary of the issues raised and the proponent's responses;
- an overview of expected changes to the environment;
- an overview of the key environmental effects of the project, as described under section 5 of CEAA 2012, and proposed technically and economically feasible mitigation measures;
- an overview of how factors under paragraph 19(1) of CEAA 2012 were considered;
- the proponent's conclusions on the residual environmental effects of the project, and the significance of those effects, after taking into account the mitigation measures.

The summary is to be provided as a separate document and should be structured as follows:

1. Introduction and EA context
2. Project overview
3. Alternative means of carrying out the project
4. Public participation
5. Engagement with Indigenous Groups
6. Summary of environmental effects assessment for each valued component, including:
    a. description of the baseline
    b. anticipated changes to the environment
    c. anticipated effects
    d. mitigation measures
    e. significance of residual effects
7. Follow-up and monitoring programs proposed

The summary will have sufficient details for the reader to understand the project, any potential environmental effects, proposed mitigation measures, and the significance of the residual effects. The summary will include key maps illustrating the project location and key project components.

Part 2 – Content of the Environmental Impact Statement

1. INTRODUCTION AND OVERVIEW

1.1. The proponent

In the EIS, the proponent will:

- provide contact information (e.g. name, address, phone, fax, email);
- identify itself and the name of the legal entity(ies) that would develop, manage and operate the project;
- describe corporate and management structures;
- specify the mechanism used to ensure that corporate policies will be implemented and respected for the project; and
- identify key personnel, contractors, and/or sub-contractors responsible for preparing the EIS.

1.2. Project overview

The EIS will describe the project, key project components and associated activities, scheduling details, the timing of each phase of the project and other key features. If the project is part of a larger sequence of projects, the EIS will outline the larger context.

The overview is to identify the key components of the project, rather than providing a detailed description, which will follow in Section 3 below.

1.3. Project location

The EIS will contain a description of the geographical setting in which the project will take place. This description will focus on those aspects of the project and its setting that are important in order to understand the potential environmental effects of the project. The following information will be included:

- the Universal Transverse Mercator (UTM) projection coordinates of the main project site;
- current resource use in the area;
- distance of the project facilities and components to any federal lands;
- the environmental significance and value of the geographical setting in which the project will take place and the surrounding area;
- environmentally sensitive areas, such as national, provincial and regional parks, ecological reserves, fishery closure areas, vulnerable marine ecosystems, ecologically and biologically significant areas and habitats of federally or provincially listed species at risk and other sensitive areas;
- description of local and Indigenous communities; and
- traditional territories and/or consultation areas, treaty lands, and Indian Reserve lands.

1.4. Regulatory framework and the role of government

The EIS will identify:

- any federal power, duty or function that may be exercised that would permit the carrying out (in whole or in part) of the project or associated activities;
- legislation and other regulatory approvals that are applicable to the project at the federal, provincial, regional and municipal levels;
- government policies, resource management plans, planning or study initiatives pertinent to the project and/or EA and their implications;
- any treaty, self-government or other agreements between federal or provincial governments and Indigenous groups that are pertinent to the project and/or EA;
- any relevant land use plans, or land zoning; and
- regional, provincial and/or national objectives, standards or guidelines that have been used by the proponent to assist in the evaluation of any predicted environmental effects.

2. PROJECT JUSTIFICATION AND ALTERNATIVES CONSIDERED

2.1. Purpose of the project

The EIS will describe the purpose of the project by providing the rationale for the project, explaining the background, the problems or opportunities that the project is intended to satisfy and the stated objectives from the perspective of the proponent. If the objectives of the project are related to broader private or public sector policies, plans or programs, this information will also be included.

The EIS will also describe the predicted environmental, economic and social benefits of the project. This information will be considered in assessing the justifiability[3] of any significant adverse residual environmental effects as defined in section 5 of CEAA 2012, if such effects are identified.

2.2. Alternative means of carrying out the project

The EIS will identify and consider the environmental effects of alternative means of carrying out the project that are technically and economically feasible. The proponent will complete the following procedural steps for addressing alternative means:

- Identify the alternative means to carry out the project.
- Identify the effects of each technically and economically feasible alternative means.
- Select the approach for the analysis of alternative means (i.e. identify a preferred means or bring forward alternative means).
- Assess the environmental effects of the alternative means.

In its alternative means analysis, the proponent will address, at a minimum, the following project components:

- choice of drilling fluid (i.e. water-based drilling mud or synthetic-based drilling mud);

[3] See subsection 52(2) of CEAA 2012.

- choice of drilling unit (i.e. drillship or semi-submersible);
- management of drilling wastes (i.e. disposal on seabed or into water column, recover and ship to shore, re-inject);
- water management and location of the final effluent discharge points; and
- alternative ways to light the platform at night (or flare at night when testing the well), to reduce attraction and associated mortality of birds, such as by installing flare shields.

The *Offshore Waste Treatment Guidelines*[4] include minimum performance targets for concentrations and volumes of waste material in discharges resulting from offshore exploration and development. Offshore operators are expected to take all reasonable measures to minimize the volumes of waste materials generated by their operations, and to minimize the quantity of substances of potential environmental concern contained within these waste materials. The EIS should include a discussion on how wastes and potential associated toxic substances would be minimized. The proponent should also discuss any alternatives that would enable it to achieve these objectives and adopt best practices in waste management and treatment.

The *Offshore Chemical Selection Guidelines for Drilling & Production Activities on Frontier Lands*[5] provide a framework for the selection of chemicals in support of offshore operations. The guidelines outline minimum expectations on the selection of lower toxicity chemicals; recognizing that variations to the selection process described in the guidelines may be required in areas where increased risk to the environment has been identified. With the objective of minimizing potential environmental impacts of discharges to the marine environment, the proponent should identify the quantity and type of chemicals (or constituents) that may be used in support of the proposed project that are:

- included on the *Canadian Environmental Protection Act's* List of Toxic Substances;
- not included on the OSPAR[1] Pose Little or No Risk to the Environment (PLONOR) list of chemicals and have a PARCOM[2] Offshore Chemical Notification Scheme Hazard Rating of A, B or purple, orange, blue, or white; or
- not included on the PLONOR list of chemicals and have not been assigned a PARCOM Offshore Chemical Notification Scheme Hazard Rating.

Alternatives to the use of the above-listed chemicals (e.g. through alternative means of operating or use of less-toxic alternatives) should be discussed in the EIS.

For further information regarding the "purpose of" and "alternative means", please consult the Agency's Operational Policy Statement entitled "Addressing "Purpose of" and "Alternative Means" under the Canadian Environmental Assessment Act, 2012".

The Agency recognizes that projects may be in the early planning stages when the EIS is being prepared. Where the proponent has not made final decisions concerning the placement of project infrastructure, the technologies to be used, or that several options may exist for various project components, the proponent

[4] National Energy Board, Canada-Nova Scotia Offshore Petroleum Board and Canada-Newfoundland and Labrador Offshore Petroleum Board. *Offshore Waste Treatment Guidelines*. December 2010. Available from: www.cnlopb.ca

[5] National Energy Board, Canada-Nova Scotia Offshore Petroleum Board and Canada-Newfoundland Offshore Petroleum Board. *Offshore Chemical Selection Guidelines for Drilling & Production Activities on Frontier Lands*. April 2009. Available from: www.cnlopb.ca

[1] Oslo and Paris Commissions

[2] Paris Commission

shall conduct an environmental effects analysis at the same level of detail for each of the various options available (alternative means) within the EIS.

3. PROJECT DESCRIPTION

3.1. Project components

The EIS will describe the project, by presenting the project components, associated and ancillary works, and other characteristics that will assist in understanding the environmental effects. This will include:

- maps, at an appropriate scale, of the project location;
- project components;
- boundaries and UTM coordinates of the proposed exploration licences (1151, 1152 and 1155);
- the major existing infrastructure;
- adjacent land and resource uses; and
- any important environmental features.

If the project is part of a larger sequence of projects, the proponent will outline the larger context and present the relevant references, if available.

In its EIS, the proponent will describe:

- the Mobile Offshore Drilling Units and/or drill ships and their operations (drilling, testing, abandonment) in locations and water depths under consideration;
- the size and types of vessels that will be used including navigation activities (i.e. routes, number and frequency of trips) and icebreaking activities (time of year, frequency, duration, expected start and end dates);
- helicopters, including routes, number and frequency of trips;
- vertical seismic profiling or any other in-water works to support the specific exploration wells under consideration, but excluding surveys potentially required to support the conduct of the EA (e.g. environmental baseline surveys) and surveys related to the broader delineation of resources;
- reagent requirements and uses (e.g. volumes, storage, types);
- petroleum products (e.g. source, volume, storage);
- the nature, composition and fate (e.g. areal extent) of drilling wastes (e.g. muds, cuttings) at various water depths and at various stages of drilling, including during riserless drilling and drilling with the marine riser in place, using dispersion modeling;
- the management or disposal of wastes (e.g. type and constituents of waste, quantity, treatment and method of disposal) including:
    - ✓ drilling muds, drill solids;
    - ✓ bilge and ballast water;
    - ✓ deck drainage;
    - ✓ cooling water;
    - ✓ fire control system test water;

- ✓ operational discharges from subsea systems and the installation of subsea systems;
- ✓ sewage and food wastes;
- ✓ well treatment or testing fluids; and
- ✓ other operational discharges.

- contributions to atmospheric emissions, including emissions profile (i.e. type, rate and source) for activities including routine or upset flaring, routine drilling, testing, shipping etc.;
- sources and extent of light, heat and noise;
- transfers of bulk materials (e.g. mud) and fuel;
- number of employees and transportation of employees;
- drinking and industrial water requirements (source, quantity required, need for water treatment);
- energy supply (source, quantity); and
- waste disposal (types of waste, methods of disposal, quantity).

3.2. Project activities

The EIS will include descriptions of the drilling, testing and decommissioning, suspension or abandonment of exploration wells associated with the proposed project.

This will include descriptions of the activities to be carried out during each phase, the location of each activity, expected outputs and an indication of the activity's magnitude and scale. Water depths for potential drill sites will be specified.

Although a complete list of project activities should be provided, the emphasis will be on activities with the greatest potential to have environmental effects. Sufficient information will be included to predict environmental effects and address concerns identified by the public and Indigenous groups. Highlight activities that involve periods of increased environmental disturbance or the release of materials into the environment.

The EIS will include a summary of the changes that have been made to the project since originally proposed, including the benefits of these changes to the environment, Indigenous groups, and the public.

The EIS will include a schedule including time of year, frequency, and duration for all project activities.

The information will include a description of:

3.2.1. Drilling and testing activities

- operation of the Mobile Offshore Drilling Unit and/or drill ships, including:
  - ✓ drilling at various water depths and in locations under consideration
  - ✓ well flow testing
  - ✓ waste management
  - ✓ water management
- vertical seismic profile surveys;
- equipment requirements (type, quantity); and
- storage and management of hazardous materials, fuels and residues.

3.2.2. Supply and servicing

- vessel support, including loading, refuelling and operation of marine support vessels (i.e. for transfer, re-supply and on-site safety during drilling activities) and.
- helicopter support (i.e. crew transport and delivery of supplies and equipment).

3.2.3. Decommissioning, suspension or abandonment of wells

- the preliminary outline of a well decommissioning, suspension and abandonment plan for wells at varying water depths

4. PUBLIC PARTICIPATION AND CONCERNS

The EIS will describe the ongoing and proposed public participation activities that the proponent will undertake or that it has already conducted on the project. It will provide a description of efforts made to distribute project information and provide a description of information and materials that were distributed during the consultation process. The EIS will indicate the methods used, where the consultation was held, the persons and organizations consulted, the concerns voiced and the extent to which this information was incorporated in the design of the project as well as in the EIS. The EIS will provide a summary of key issues raised related to the project and its potential effects to the environment as well as describe any outstanding issues and ways to address them.

5. ENGAGEMENT WITH INDIGENOUS GROUPS AND CONCERNS RAISED

For the purposes of developing the EIS, the proponent will engage with Indigenous groups that may be affected by the project, to obtain their views on:

- effects of changes to the environment on Aboriginal peoples (health and socio-economic conditions; physical and cultural heritage, including any structure, site or thing that is of historical, archaeological, paleontological or architectural significance; and current use of lands and resources for traditional purposes) pursuant to paragraph 5(1)(*c*) of CEAA 2012; and
- potential adverse impacts of the project on potential or established section 35 rights, including title and related interests, in respect of the Crown's duty to consult, and where appropriate, accommodate Aboriginal peoples.

With respect to the effects of changes to the environment on Aboriginal peoples as per paragraph 5(1)(c) of CEAA 2012, the assessment requirements are outlined in sections 6.1.8 and 6.3.7 below.

With respect to potential adverse impacts of the project on potential or established section 35 rights, including title and related interests, the EIS will document for the groups identified in Section 5.1 below (or in subsequent correspondence from the Agency):

- potential or established section 35 rights[6], including title and related interests, when this information is directly provided by a group to the proponent, the Agency or is available through public records, including:

[6] The 2011 *Updated Guidelines for Federal Officials to Fulfill the Duty to Consult (the Guidelines)* defines Aboriginal rights as: practices, traditions and customs integral to the distinctive culture of the Aboriginal group claiming the right that existed prior to contact with the Europeans (Van de Peet). In the context of Métis groups, Aboriginal rights means practices, traditions, and customs integral to the distinctive culture of the Métis group that existed prior to effective European control, that is, prior to the

- ✓ geographical extent, nature, frequency and timing of the practice or exercise of the right; and,
- ✓ maps and data sets (e.g. fish catch numbers);

- potential adverse impacts of each of the project components and physical activities, in all phases, on potential or established section 35 rights, including title and related interests. This assessment is to be based on a comparison of the exercise of the identified rights, title and related interests between the predicted future conditions with the project and the predicted future conditions without the project. Include the perspectives of potentially impacted groups where these were provided to the proponent by the groups;
- measures identified to accommodate potential adverse impacts of the project on the potential or established section 35 rights, including title and related interests. These measures will be written as specific commitments that clearly describe how the proponent intends to implement them, and may go beyond mitigation measures that are developed to address potential adverse environmental effects;
- potential adverse impacts on potential or established section 35 rights, including title and related interests that have not been fully mitigated or accommodated as part of the EA and associated engagement with Indigenous groups. The proponent will also take into account the potential adverse impacts that may result from the residual and cumulative environmental effects. Include the perspectives of potentially affected groups where these were provided to the proponent by the groups.

The information sources, methodology and findings of the assessment of paragraph 5(1)(*c*) effects under CEAA 2012 may be used to inform the assessment of potential adverse impacts of the project on potential or established section 35 rights, including title and related interests. However, there may be distinctions between the adverse impacts on potential or established section 35 rights, including title and related interests and paragraph 5(1)(*c*) effects under CEAA 2012. The proponent will carefully consider the potential distinction between these two aspects and, where there are differences, will include the relevant information in its assessment.

In terms of gathering views from potentially affected groups with respect to both environmental effects of the project and the potential adverse impacts of the project on potential or established section 35 rights, including title and related interests, the EIS will document:

- VCs suggested by groups for inclusion in the EIS, whether they were included, and the rationale for any exclusions;
- specific suggestions raised by each group for mitigating the effects of changes to the environment on Aboriginal peoples or accommodating potential adverse impacts of the project on potential or established section 35 rights, including title and related interests;
- views expressed by each group on the effectiveness of the mitigation or accommodation measures;

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time when Europeans effectively established political and legal control in the claimed area (*Powley*). Generally, these rights are fact and site specific. For greater certainty, the Guidelines also define Aboriginal title as an Aboriginal right. Visit the Indigenous and Northern Affairs Canada website at: http://www.aadnc-aandc.gc.ca/eng/1100100014664/1100100014675

- from the proponent's perspective, any potential cultural, social and/or economic impacts or benefits to each group identified that may arise as a result of the project. Include the perspectives of potentially affected groups where these were provided to the proponent by the groups;
- any other comments, specific issues and concerns raised by potentially affected groups and how they were responded to or addressed;
- changes made to the project design and implementation directly as a result of discussions with potentially affected groups;
- where and how Aboriginal traditional knowledge was incorporated into the environmental effects assessment (including methodology, baseline conditions and effects analysis for all VCs) and the consideration of potential adverse impacts on potential or established section 35 rights, including title and related interests, and related mitigation measures; and
- any additional issues and concerns raised by potentially affected groups in relation to the environmental effects assessment and the potential adverse impacts of the project on potential or established section 35 rights, including title and related interests.

The Agency recommends the proponent create a tracking table of key issues raised by each group, including the concerns raised related to the project, proposed mitigation measures, and where appropriate, a reference to the proponent's analysis in the EIS. Information provided related to potential adverse impacts on potential or established section 35 rights will be considered by the Crown in meeting its common law duty to consult obligations as set out in the *Updated Guidelines for Federal Officials to Fulfill the Duty to Consult* (2011).

5.1. Indigenous groups and engagement activities

With respect to engagement activities, the EIS will document:

- the engagement activities undertaken with each group prior to the submission of the EIS, including the date and means of engagement (e.g. meeting, mail, telephone);
- any future planned engagement activities; and
- how engagement activities by the proponent allowed groups to understand the project and evaluate its effects on their communities, activities, potential or established section 35 rights, including title and related interests.

In preparing the EIS, the proponent will ensure that groups have access to timely and relevant information on the project and how the project may adversely impact them. The proponent will structure its engagement activities to provide adequate time for groups to review and comment on the relevant information. Engagement activities are to be appropriate to the groups' needs, arranged through discussions with the groups and in keeping with established consultation protocols, where available. The EIS will describe all efforts, successful or not, taken to solicit the information required from groups to support the preparation of the EIS.

The proponent will ensure that views of groups are recorded and that groups are provided with opportunities to validate the interpretation of their views. The proponent will keep detailed tracking records of its engagement activities, recording all interactions with groups, the issues raised by each group and how the proponent addressed the concerns raised. The proponent will share these records with the Agency.

For the groups listed below, the proponent will ensure they are notified about key steps in the EIS development process and of opportunities to provide comments on key EA documents and/or information to be provided regarding their community. The proponent will ensure these groups are reflected in the baseline information and assessment of potential environmental effects as described under paragraph 5(1)(c) of CEAA 2012 and/or impacts to potential or established section 35 rights, including title and related interests, in the EIS. These groups include:

- *the Labrador Inuit (Nunatsiavut Government),*
- *the Labrador Innu (Innu Nation),*
- *the NunatuKavut Community Council,*

The groups referenced above may change as more is understood about the environmental effects or potential impacts on rights of the project and/or if the project or its components change during the EA. The Agency reserves the right to alter the list of groups that the proponent will engage with as additional information is gathered during the EA.

In addition, for the purposes of good governance, the proponent should also provide information to and discuss potential environmental effects from the Project, as described under section 5(1)(c) of CEAA 2012, with the Qalipu Mi'kmaq First Nation Band and the Miawpukek First Nation.

Upon receipt of knowledge or information of potential effects or adverse impacts to a group not listed above, the proponent shall provide that information to the Agency at the earliest opportunity.

6. EFFECTS ASSESSMENT

6.1. Project setting and baseline conditions

Based on the scope of the project described in Section 3 (Part 1), the EIS will present baseline information in sufficient detail to enable the identification of how the project could affect the VCs and an analysis of those effects. Should other VCs be identified during the conduct of the EA, the baseline condition for these components will also be described in the EIS. To determine the appropriate spatial boundaries to describe the baseline information, refer to Section 3.2.3 (Part 1) of these guidelines. As a minimum, the EIS will include a description of the following environmental components.

6.1.1. Atmospheric environment

The EIS will describe the atmospheric environment and climate at the project site and within areas that could be affected by routine project operations or accidents and malfunctions, such as:

- ambient air quality in the project areas and in the airshed likely to be affected by the project, including consideration of the following contaminants: total suspended particulates (TSP), fine particulates smaller than 2.5 microns ($PM_{2.5}$), respirable particulates of less than 10 microns (PM_{10}), carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOCs), hydrogen sulfide (H_2S) and any other potentially toxic air pollutants;
- identify and quantify existing greenhouse gas emissions[7] by individual pollutant measured as kilotonnes of CO_2 equivalent per year in the project study areas;

[7] Greenhouse gas emissions include: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

- direct and indirect sources of air emissions;
- current provincial/territorial/federal limits for greenhouse gas emission targets; and
- information on the variation in weather conditions over the project area using historical records of relevant meteorological parameters, including the following:
    - ✓ precipitation (rain and snow);
    - ✓ air temperature (mean, maximum and minimum temperatures);
    - ✓ wind speed and direction;
    - ✓ freezing spray;
    - ✓ lightning; and
    - ✓ visibility.

Particular attention should also be given to the analysis of extreme meteorological events that have the potential to result in adverse effects on the project (e.g. high wind events).

Relevant marine climate data sources should be consulted, including but not limited to data from Environment and Climate Change Canada moored weather buoys and any offshore platforms operating in the Eastern Newfoundland Strategic Environmental Assessment (SEA) area. Data from the International Comprehensive Atmosphere Ocean Dataset (ICOADS), the United States of America National Oceanographic and Atmospheric Administration (NOAA) database of tropical cyclone activity in the North Atlantic, NOAA's Climate Forecast System Reanalysis (CFSR), and the Canadian Lightning Detection Network.

6.1.2. Marine environment

The EIS will describe the marine environment within areas that could be affected by routine project operations or by accidents and malfunctions, including:

- marine water quality (e.g. water temperature, turbidity, salinity and pH);
- marine geology and geomorphology (i.e. bottom sediments, including quality, thickness, grain size, and mobility);
- physical oceanography including surface and subsurface current patterns, current velocities, waves, storm surges, long shore drift processes, tidal patterns, and tide gauges levels for the site, in proximity to the site, and along the shipping routes with consideration of predicted climate change effects;
- available bathymetric information (e.g. maximum and mean water depths) for the site and along shipping routes if applicable;
- ice climate in the regional study area, including ice formation and thickness, breakup and movement;
- ice conditions along the shipping routes with consideration of predicted climate change and its possible effect on the timing of ice formation in the future;
- fast-ice characteristics, including its surface area and seasonal stability along the shipping routes;
- marine plants, including all benthic and detached algae, marine flowering plants, brown algae, red algae, green algae and phytoplankton;

- acoustic environment (ambient noise levels from natural sources, shipping, seismic surveys, and other sources), including information on geographic extent and temporal variations and how the acoustic environment may be affected by the project.

When describing the baseline marine environment, relevant data sources should be consulted. In addition to data sources discussed under Atmospheric Environment and Climate (some of which contain marine data), the proponent should consult MSC50 Wind and Wave Hindcast Data, and long term gridded hourly wind and wave measurements for the North Atlantic.

6.1.3. Fish and fish habitat

The EIS will describe fish and fish habitat within areas that could be affected by routine project operations or by accidents and malfunctions, including:

- a characterization of fish populations on the basis of species and life stage, including information on the surveys carried out (e.g. location of sampling stations, catch methods, date of catches, species, catch per-unit effort) and the source of data available (e.g. government and historical databases, commercial fishing data);
- a description of primary and secondary productivity in affected water bodies with a characterisation of seasonal variability;
- a list of any fish or invertebrate species at risk that are known to be present; and
- benthic flora and fauna and their associated habitat, including sensitive features such as corals and sponges (Note: a benthic habitat survey (ROV / camera), including transects of seafloor in the area of the well locations, may be required).

Emphasis will be placed on the waters likely to be affected by the project and their physical characteristics, water and sediment quality. Hence, for all areas in which effects are anticipated, the EIS will describe the biophysical water and sediment characteristics, including:

- a description of the physical and biological characteristics of the fish and fish habitat likely to be directly or indirectly affected by the project;
- maps, at a suitable scale, indicating the surface area of potential or confirmed fish habitats and a description of these habitats as determined by water depths, type of substrate (sediments), aquatic vegetation, and potential use (i.e. spawning, rearing, nursery, feeding, overwintering, migration routes, etc.). Where appropriate, this information should be linked to water depths (bathymetry) to identify the extent of a water body's littoral / photic zone;
- quality, thickness, grain size and mobility of bottom sediments; and
- a discussion of sea bottom stability at the project site.

Any sampling survey methods used by the proponent will be described in order to allow experts to ensure the quality of the information provided. If previous studies on the habitat in the study area were conducted, they are to be submitted with the EIS.

6.1.4. Migratory birds and their habitat[8]

The EIS will describe migratory and non-migratory marine birds and their habitat at the project site and within areas that could be affected by routine project operations or accidents and malfunctions.

Migratory birds are protected under the *Migratory Birds Convention Act* (MBCA) and associated regulations. Preliminary data from existing sources will be gathered, including information such as:

- birds and their habitats that are found or are likely to be found in the study area. This description may be based on existing sources, but supporting evidence is required to demonstrate that the data used are representative of the avifauna and habitats found in the study area. The existing data must be supplemented by surveys, if required;
- abundance, distribution, and life stages of migratory and non-migratory birds likely to be affected in the project area based on existing information, or surveys, as appropriate, to provide current field data;
- year-round migratory bird use of the area (e.g. winter, spring migration, breeding season, fall migration), based on preliminary data from existing sources and surveys to provide current field data if appropriate; and
- areas of concentration of migratory birds, such as for breeding, feeding or resting.

Other relevant datasets should be consulted, such as those available from the Canadian Wildlife Service (e.g. Eastern Canadian Seabirds at Sea (ECSAS), Programme intégré de recherches sur les oiseaux pélagiques (PIROP)), the Atlantic Canada Conservation Data Centre (ACCDC), recovery strategies, management plans, Newfoundland and Labrador Department of Environment and Climate Change Wildlife Division, previous petroleum operations in the area and university or other research programs, if available.

6.1.5. Species at Risk

The EIS will describe federal species at risk and their habitat at the project site and within areas that could be affected by routine project operations or accidents and malfunctions, such as:

- a list of all potential or known federally listed species at risk that may be affected by the project, using existing data and literature as well as surveys to provide current field data;
- a list of all federal species designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) for listing on Schedule 1 of the *Species at Risk Act*. This will include those species in the risk categories of extirpated, endangered, threatened and of special concern[9];
- any published studies that describe the regional importance, abundance and distribution of species at risk including management plans, recovery strategies or plans. The existing data must be supplemented by surveys, if required; and

[8] Surveys should be designed in light of the available references and recommendations in Environment and Climate Change Canada's document entitled "*Guidance for the Preparation of an Environmental Impact Statement and Useful References*" (2016) (available from the Department of Environment and Climate Change Canada), and in the Canadian Wildlife Service's Technical Report No. 508, *A Framework for the Scientific Assessment of Potential Project Impacts on Birds* (Hanson et al. 2009). Appendix 3 of the Framework provides examples of project types and recommended techniques for assessing impacts on migratory birds.

[9] Proponents are encouraged to consult COSEWIC's annual report for a listing of the designated wildlife species: http://www.sararegistry.gc.ca/default.asp?lang=En&n=AA7D4CE8-1

- residences, seasonal movements, movement corridors, habitat requirements, key habitat areas, identified and proposed critical habitat and/or recovery habitat (where applicable) and general life history of species at risk that may occur in the project area, or be affected by the project.

The following information sources on species at risk and species of conservation concern should be among those consulted:

- ✓ Species at Risk Act Registry (www.sararegistry.gc.ca);
- ✓ COSEWIC;
- ✓ Relevant government agencies;
- ✓ Local naturalist and interest groups; and
- ✓ Indigenous groups and First Nations.

6.1.6. Marine mammals

The EIS will describe marine mammals and their habitat at the project site and within areas that could be affected by routine project operations or accidents and malfunctions, such as:

- marine mammal species that may be present, the times of year they are present, the ranges of the species and their migration patterns, and
- important areas in the vicinity of the drilling sites or supply routes (e.g. for mating, breeding, feeding and nursing of young) or that could be impacted by the project (e.g. acoustics, spills, etc.).

6.1.7. Marine turtles

The EIS will describe marine turtles and their habitat at the project site and within areas that could be affected by routine project operations or accidents and malfunctions, such as:

- marine turtle species that may be present, the times of year they are present, the ranges of the species and their migration patterns; and
- important areas in the vicinity of the drilling sites or supply routes (e.g. for mating, breeding, and feeding) or that could be impacted by the project (e.g. routine discharges, spills, etc.).

6.1.8. Indigenous peoples

With respect to potential effects on Indigenous peoples and the related VCs, baseline information will be provided for ***each group*** identified in Section 5 (Part 2) of these guidelines (and any groups identified after these guidelines are finalized). Baseline information will describe and characterize the elements in paragraph 5(1)(*c*) of CEAA 2012 based on the spatial and temporal scope selected for the EA according to the factors outlined in Part 1, Section 3.3.3 of this document. Baseline information will also characterize the regional context of each of the elements of paragraph 5(1)(*c*) of CEAA 2012 to support the assessment of project related effects and cumulative effects. Baseline information will be sufficient to provide a comprehensive understanding of the current state of each VC.

Baseline information for current use of lands and resources for traditional purposes will focus on the traditional activity (e.g. fishing) and include a characterization of all attributes of the activity that can be affected by environmental change. This includes not only identifying species of importance, but also assessing the quality and quantity of preferred traditional resources and locations, timing (e.g. seasonality, access restrictions, distance from community), ambient/sensory environment (e.g. noise, air

quality, visual landscape, presence of others) and cultural environment (e.g. historical/generational connections, preferred areas). As applicable, specific aspects that will be considered include, but are not limited to:

- current use of lands and resources for traditional purposes, including:
  - ✓ location of traditional territory (including maps where available);
  - ✓ commercial and traditional fishing activity within the project's potential zone of influence, including licences and maps;
  - ✓ fish, wildlife, birds, plants or other natural resources of importance for traditional use;
  - ✓ places where fish, wildlife, birds, plants or other natural resources are harvested, including places that are preferred;
  - ✓ access and travel routes for conducting traditional practices;
  - ✓ frequency, duration or timing of traditional practices; and
  - ✓ cultural values associated with the area affected by the project and the traditional uses identified.
- any Project components and a description of any activities (e.g. exclusion zones) that may affect commercial fisheries or other uses;
- human health[10], primarily with respect to potential contamination of food sources;
- location of reserves and communities; and
- physical and cultural heritage[11] (including any site, structure or thing of archaeological, paleontological, historical or architectural significance).

Any other baseline information that supports the analysis of predicted effects on Indigenous peoples will be included as necessary. The EIS will also indicate how input from groups, including Aboriginal traditional knowledge, was used in establishing the baseline conditions related to health and socio-economics, physical and cultural heritage and current use of lands and resources for traditional purposes.

6.1.9. Other changes to the environment arising as a result of a federal decision or due to changes on federal lands, in another province or outside Canada

Should there be the potential for a change to the environment arising as a result of a federal decision(s), or on federal lands, lands in another province or lands outside Canada, the EIS will include baseline information on the environmental component likely to be affected (if this information is not already covered in other subsections of these guidelines).

6.1.9.1. Special areas

The EIS will describe special areas (e.g. species at risk critical habitat that has been designated and that has been proposed or that may be under consideration, Important Bird Areas, Migratory Bird Sanctuaries,

[10] The proponent should refer to Health Canada's *Useful Information for Environmental Assessments* document in order to include the appropriate baseline information relevant to human health. This document can be obtained at http://www.publications.gc.ca/site/eng/481782/publication.html

[11] Heritage resources to be considered will include but not be limited to, physical objects (e.g. middens, culturally-modified trees, historic buildings), sites or places (e.g. burial sites, sacred sites, cultural landscapes) and attributes (e.g. language, beliefs).

ecological reserves, etc.) at the project site and within areas that could be affected by routine project operations or accidents and malfunctions, such as:

- Ecologically and Biologically Significant Areas (e.g. The Southeast Shoal and Tail of the Banks, The Northeast Shelf and Slope, Lily Canyon-Carson Canyon and The Virgin Rocks)
- Fishery Closure Areas (e.g. Northwest Atlantic Fisheries Organization Coral Closures, Orphan Knoll Seamount)
- Preliminary Representative Marine Areas (South Grand Bank Area)

The EIS will describe the distances between the edge of the project area (i.e. drill sites and shipping routes) and special areas. It shall state the rationale for designating specific areas as "special" (i.e. the defining environmental features of the special area).

6.1.9.2. Human environment

With respect to potential effects on the human environment, non-Indigenous people and the related VCs, baseline information will describe and characterize the following that could be affected by routine project operations or accidents and malfunctions. At a minimum, this should include:

- any federal lands, lands located outside the province or Canada that may be affected by the project operations or by accidents and malfunctions;
- the current and historical use of waters that may be affected by routine project operations or by accidents and malfunctions, including:
  - ✓ current commercial and recreational fishing activity, including licence holders and species fished;
  - ✓ other ocean uses (e.g. shipping, research, oil and gas, military, ocean infrastructure [e.g. subsea cable]);
- the location of and proximity of any permanent, seasonal or temporary residences or camps that could be affected by routine project operations or accidents and malfunctions;
- health[12] and socio-economic conditions that could be affected by routine project operations or accidents and malfunctions, including the functioning and health of the socio-economic environment, encompassing a broad range of matters that affect communities in the study area in a way that recognizes interrelationships, system functions and vulnerabilities;
- physical and cultural heritage, including structures, sites or things of historical, archaeological, paleontological or architectural significance that could be affected by routine project operations or accidents and malfunctions;
- the rural and urban settings that could be affected by routine project activities or accidents and malfunctions; and
- any project components and activities (e.g. exclusion zones) that may affect commercial or recreational fisheries or other uses.

The EIS should also discuss the potential to encounter unexploded ordnance (UXOs), based on consultation with the Department of National Defence.

[12] The proponent should refer to Health Canada's *Useful Information for Environmental Assessments* document in order to include the appropriate baseline information relevant to human health. This document can be obtained at http://www.publications.gc.ca/site/fra/9.700511/publication.html

6.2. Predicted changes to the physical environment

The EA will include a consideration of the predicted changes to the environment as a result of the project being carried out or as a result of any powers, duties or functions that are to be exercised by the federal government in relation to the project. These predicted changes to the environment are to be considered in relation to each phase of the project (e.g. drilling, testing, decommissioning, suspension, abandonment) and are to be described in terms of the magnitude, geographic extent, duration and frequency, and whether the environmental changes are reversible or irreversible.

The EIS will include stand-alone sections that summarise those changes that may be caused by the project on the components of the environment listed in paragraph 5(1)(a) of CEAA 2012, namely fish and fish habitat, aquatic species and migratory birds.

The EIS will include a stand-alone section that summarises any change the project may cause to the environment that may occur on federal lands or lands outside the province in which the project is to be located (including outside of Canada).

In situations where the project requires one or more federal decisions identified in section 5(2), the EIS will also include a stand-alone section that describes any change that may be caused by the project on the environment that is directly linked or necessarily incidental to these decisions (e.g. changes to commercial fishing).

6.3. Predicted effects on valued components

Based on the predicted changes to the environment identified in Section 6.2 above, the proponent is to assess the environmental effects of the project on the following VCs. All interconnections between VCs and between changes to multiple VCs will be described:

6.3.1. Fish and fish habitat

- the identification of any potential adverse effects to fish and fish habitat as defined in subsection 2(1) of the *Fisheries Act*, including the calculations of any potential habitat loss (temporary or permanent) in terms of surface areas (e.g. spawning grounds, juvenile, rearing and feeding areas), and in relation to availability and significance. The assessment will include a consideration of:
  - ✓ effects on water quality including changes to chemical composition, temperature, oceanographic conditions, etc.;
  - ✓ the geomorphological changes and their effects on hydrodynamic conditions and fish habitats (e.g. modification of benthic habitat including corals and sensitive habitat, area affected by drilling waste, disturbance to water column);
  - ✓ the modifications of hydrological and hydrometric conditions on fish habitat and on the fish species' life cycle activities (e.g. reproduction, juvenile, rearing, and feeding, movements);
  - ✓ any potential imbalances in the food web in relation to baseline conditions;
  - ✓ underwater noise and vibration emissions from project activities (i.e. drilling, vertical seismic profiling, offshore supply vessel operation, well abandonment) and how it may affect fish health and behaviour;
  - ✓ effects on the primary and secondary productivity of water bodies and how project-related effects may affect fish food sources;

- the effects of changes to the aquatic environment on fish and their habitat, including:
  - ✓ the anticipated changes in the composition and characteristics of the populations of various fish species, including shellfish and forage fish including mortality of fish, eggs and larvae; environment and species (e.g. corals, plants);
  - ✓ any modifications in migration or local movements during and after project activities (e.g. vertical seismic profiling, drilling);
  - ✓ any modifications and use of habitats by federally or provincially listed fish species;
- a discussion of the effects of drilling waste disposal on marine benthos and other components of the aquatic environment, recognizing that the disposal of these wastes is expected to be a primary cause of effect on benthos;
- a discussion of the length of time it would take for the benthic environment to return to baseline conditions in water depths within which the Project would occur;
- a discussion of how project timing correlates to key fisheries windows and any potential effects resulting from overlapping periods; and
- a discussion of how data examining the deposition of drilling-related wastes (e.g. fluid, mud residues, cuttings) and acoustic monitoring data would be collected during and after drilling operations and how this would be used to verify effects predictions.

6.3.2. Marine plants

- effects on marine plants, including all benthic and detached algae, marine flowering plants, brown algae, red algae, green algae and phytoplankton.

6.3.3. Marine mammals

- effects on marine mammals, including but not limited to:
  - ✓ mortality and other effects from vessel collisions or disturbance; and
  - ✓ direct and indirect effects caused by increased disturbance (e.g. noise, light, vibrations) including mortality, physical injury and behavioural changes (e.g. habitat avoidance, disruption to feeding behaviour, deviation in migration routes, communication masking, discomfort and behavioural disturbance).

6.3.4. Marine turtles

- effects on marine turtles, including but not limited to:
  - ✓ mortality and other effects from vessel collisions or disturbance; and
  - ✓ direct and indirect effects caused by increased disturbance (e.g. noise, light, vibrations) including mortality, physical injury and behavioural changes (e.g. habitat avoidance, disruption to feeding behaviour, deviation in migration routes, communication masking, discomfort and behavioural disturbance).

6.3.5. Migratory birds

- direct and indirect adverse effects on migratory birds, including population level effects that could be caused by all project activities, including but not limited to:
  - ✓ noise disturbance from seismic equipment including both direct effects (physiological), or indirect effects (foraging behaviour of prey species);
  - ✓ physical displacement as a result of vessel presence (e.g. disruption of foraging activities);
  - ✓ night-time illumination levels from lights and flares during different weather conditions and seasons and during different project activities (e.g. drilling, well testing) and associated nocturnal disturbance (e.g. increased opportunities for predators, attraction to the drilling unit and vessels and subsequent collision or exposure to vessel-based threats, incineration in flares, disruption of normal activities);
  - ✓ exposure to spilled contaminants (e.g. fuel, oils) and operational discharges (e.g. deck drainage, gray water, black water);
  - ✓ attraction of, and increase in, predator species as a result of waste disposal practices (i.e. sanitary and food waste) and the presence of incapacitated/dead prey near the Mobile Offshore Drilling Unit or support vessels;
  - ✓ physical harm or mortality from flaring on the drilling unit or other vessel based threats;
  - ✓ collision risk with the drilling unit and other project infrastructure;
  - ✓ the effects of oil spills in the nearshore or that reach land on landbird species;
  - ✓ change in marine habitat quality from drill muds and cuttings and sedimentation; and
  - ✓ indirect effects caused by increased disturbance (e.g. noise, light, presence of workers), relative abundance movements and changes in migratory bird habitat.

6.3.6. Species at risk

- the potential effects of the project on federally listed species at risk and those species listed by the Committee on the Status of Endangered Wildlife in Canada classified as extirpated, endangered, threatened or of special concern (flora and fauna) and their critical habitat, including:
  - ✓ alteration of habitat (including critical habitat) features;
  - ✓ direct and indirect effects from noise, vibrations and increased exposure to contaminants of concern;
  - ✓ a discussion of migration patterns of federal species at risk and related effects (e.g. displacement, increased risk of collision); and
  - ✓ direct and indirect effects on the survival or recovery of federally listed species (list species).

6.3.7. Indigenous peoples

With respect to Indigenous peoples, a description and analysis of how changes to the environment caused by the project will affect the following activities exercised by each Indigenous group, as applicable to the proposed project:

- current use of lands and resources for traditional purposes. This assessment will characterize the effects on the use or activity (e.g. fishing) as a result of the underlying changes to the

environment (i.e. how will the activity change if the project proceeds). The underlying changes to the environment will also be described, including, but not limited to:

- ✓ any changes to resources (fish, birds, or other natural resources) used for traditional purposes (e.g. fishing, use of sacred sites);
- ✓ effects on food, social, ceremonial, and commercial fishing;
- ✓ a discussion of how drilling activities correlates to key fisheries windows, and any potential impacts resulting from overlapping periods;
- ✓ changes related to species important to Indigenous people's current use of resources, including changes to key habitat;
- ✓ any changes or alterations to access into the areas used for traditional purposes and commercial fishing, including implementation of exclusion zones;
- ✓ any changes to the environment that affect cultural value or importance associated with traditional uses or areas affected by the project (e.g. values or attributes of the area that make it important as a place for inter-generational teaching of language or traditional practices, communal gatherings, integrity of preferred traditional practice areas);
- ✓ how timing of project activities (e.g. drilling, flaring) have the potential to interact with the timing of traditional practices, and any potential effects resulting from overlapping periods;
- ✓ consideration of the regional context for traditional use and the value of the project area in that regional context, including alienation of lands from traditional use;
- ✓ any changes to environmental quality (e.g. air, water), the sensory environment (e.g. noise, light, visual landscape), or perceived disturbance of the environment (e.g. fear of contamination of water or country foods) that could detract from use of the area or lead to avoidance of the area;
- ✓ an assessment of the potential to return affected areas to pre-project conditions to support traditional practices;

- human health, focusing on effects on health outcomes or risks in consideration of, but not limited to, potential changes in water quality (recreational and cultural uses), availability of country foods (e.g. marine species), and noise exposure. When risks to human health due to changes in one or more of these components are predicted, a complete Human Health Risk Assessment (HHRA) examining all exposure pathways for pollutants of concern may be necessary to adequately characterize potential risks to human health. Where adverse health effects are predicted, any incidental effects such as effects on current use of lands and resources for traditional purposes will also be assessed. The proponent must provide a justification if it determines that an assessment of the potential for contamination of country foods is not required or if some contaminants are excluded from the assessment;
- socio-economic conditions, including, but not limited to:
    - ✓ the use of navigable waters
    - ✓ commercial fishing (e.g. catch rates, exclusion zones, gear damage or loss, well abandonment, marketability of seafood products) and food security
    - ✓ commercial outfitters
    - ✓ recreational use
- physical and cultural heritage, and structures, sites or things of historical, archaeological, paleontological or architectural significance to groups, including, but not limited to:
    - ✓ the loss or destruction of physical and cultural heritage

- ✓ changes to access to physical and cultural heritage
- ✓ changes to the cultural value or importance associated with physical and cultural heritage

- other effects of changes to the environment on groups should be reflected as necessary.

6.3.8. Other valued components that may be affected as a result of a federal decision[13] or due to effects on federal lands, another province or outside Canada[14]

If there is the potential for a change to the environment arising as a result of a federal decision(s), for example an authorization under section 138(1) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act* or section 35 of the *Fisheries Act*, the EIS should include a description of the specific project components for which a federal authorisation/decision is required, and an assessment of any other VCs (not already covered in other subsections of these guidelines) that may be affected by the changes to the environment caused by these specific project components. If there is the potential for the project to result in environmental changes on federal lands (or waters), another province, or another country, then VCs of importance not already identified should be included. For example, if the project will result in the generation of greenhouse gas emissions, the EIS should include a description of the project's greenhouse gas emissions in a regional, provincial, national or international context if applicable. Suggested VCs are noted below for this project.

6.3.8.1. Air quality and greenhouse gas emissions

- comparison of anticipated air quality concentration against the *Canadian Ambient Air Quality Standards* (CAAQS) for fine particulate matter or other relevant federal and/or provincial criteria for other contaminants of potential concern;
- description of all methods and practices (e.g. control equipment) that will be implemented to minimize and control atmospheric emissions throughout the project life cycle. If the best available technologies are not included in the project design, the proponent will need to provide a rationale for the technologies selected;
- an estimate of the direct greenhouse gas emissions associated with all phases of the project (i.e. including drilling, well testing and marine and helicopter transportation) as well as any mitigation measures proposed to minimize greenhouse gas emissions. This information is to be presented by individual pollutant and should also be summarized in CO_2 equivalent per year. The proponent is responsible for the following:
  - ✓ provide an estimate of the contribution of the project emissions at the local, provincial and federal scale, and indicate the category into which the project falls in terms of the relative magnitude of its contribution to greenhouse gas emissions (project with low, medium or high emission rates);
  - ✓ justify all estimated emissions and emission factors used;
  - ✓ provide the estimation or derivation method, and disclose and describe all assumptions and emission intensity factors used;

[13] sub-section 5(2) of CEAA 2012
[14] paragraph 5(1)(b) of CEAA 2012

- ✓ compare and assess the level of estimated emissions to the regional, provincial and federal emission targets;
- ✓ provide information related to the project's electrical demand and sources of electrical power for equipment, i.e. the project's main source and any other additional sources (generators, etc.), as appropriate;

- changes in ambient noise levels; and
- changes in night-time light levels.

6.3.8.2. Commercial fisheries

- effects of changes to the environment on commercial fishing activities (e.g. effects on fished species affecting fisheries success, displacement from fishing areas (e.g. exclusion zones), gear loss or damage);
- a discussion of how drilling activities correlates to key commercial fisheries windows, and any potential impacts resulting from overlapping periods;
- effects from subsea infrastructure that could be left in place (e.g. wellheads) following abandonment; and
- changes to habitat of commercial fish species (e.g. noise, water and sediment quality).

6.3.8.3. Special areas

- effects on special areas, including, but not limited to:
  - ✓ use of dispersants, and
  - ✓ change to habitat quality (e.g. noise, light, water, sediment quality).

6.3.8.4. Human environment

- effects of changes to the environment on health and socio-economic conditions, physical and cultural heritage and any structure, site or thing that is of historical, archaeological, paleontological, or architectural value, including, but not limited to the following, as applicable:
  - ✓ recreational activities;
  - ✓ other ocean uses;
  - ✓ socio-economic conditions;
  - ✓ human health;
  - ✓ physical and cultural heritage (e.g. shipwrecks);
  - ✓ rural and urban settings that could be affected by routine activities and/or accidents and malfunctions.

6.4. Mitigation measures

Every EA conducted under CEAA 2012 will consider measures that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project. Under CEAA 2012, mitigation measures includes measures to eliminate, reduce or control the adverse environmental effects of a designated project, as well as restitution for damage to the environment through replacement,

restoration, compensation or other means. Measures will be specific, achievable, measurable and verifiable, and described in a manner that avoids ambiguity in intent, interpretation and implementation. Mitigation measures may be considered for inclusion as conditions in the EA decision statement and/or in other compliance and enforcement mechanisms provided by other authorities' permitting or licensing processes.

As a first step, the proponent is encouraged to use an approach based on the avoidance and reduction of the effects at the source. Such an approach may include the modification of the design of the project or relocation of project components.

The EIS will describe the standard mitigation practices, policies and commitments that constitute technically and economically feasible mitigation measures and that will be applied as part of standard practice regardless of location. The EIS will then describe the project's environmental protection plan and its environmental management system, through which the proponent will deliver this plan. The plan will provide an overall perspective on how potentially adverse effects would be minimized and managed over time. The EIS will further discuss the mechanisms the proponent would use to require its contractors and sub-contractors to comply with these commitments and policies and with auditing and enforcement programs.

The EIS will then describe mitigation measures that are specific to each environmental effect identified. Mitigation measures will be written as specific commitments that clearly describe how the proponent intends to implement them and the environmental outcome the mitigation measure is designed to address. The EIS will describe mitigation measures in relation to species and/or critical habitat listed under the *Species at Risk Act*. These measures will be consistent with any applicable recovery strategy and action plans.

The EIS will specify the actions, works, minimal disturbance footprint techniques, best available technology, corrective measures or additions planned during the project's various phases to eliminate or reduce the significance of adverse effects. The EIS will also present an assessment of the effectiveness of the proposed technically and economically feasible mitigation measures. The reasons for determining if the mitigation measure reduces the significance of an adverse effect will be made explicit. The proponent is also encouraged to identify mitigation measures for effects that are adverse although not significant.

The EIS will indicate what other technically and economically feasible mitigation measures were considered, and explain why they were rejected. Trade-offs between cost savings and effectiveness of the various forms of mitigation measures will be justified. The EIS will identify who is responsible for the implementation of these measures and the system of accountability.

Where mitigation measures are proposed to be implemented for which there is little experience or for which there is some question as to their effectiveness, the potential risks and effects to the environment should those measures not be effective will be clearly and concisely described. In addition, the EIS will identify the extent to which technological innovations will help mitigate environmental effects. Where possible, it will provide detailed information on the nature of these measures, their implementation, management and the requirements of the follow-up program.

Adaptive management is not considered as a mitigation measure, but if the follow-up program (refer to Section 8 below) indicates that corrective action is required, the proposed approach for managing the action should be identified.

6.5. Significance of residual effects

After having established the technically and economically feasible mitigation measures, the EIS will present any residual environmental effects of the project on the VCs identified in Section 6.3 above. The residual effects, even if very small or deemed insignificant, will be described.

The EIS will then provide a detailed analysis of the significance of the residual environmental effects that are considered adverse following the implementation of mitigation measures, using guidance described in Section 4 of the Agency's Operational Policy Statement, *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects under the Canadian Environmental Assessment Act, 2012*[15].

The EIS will identify the criteria used to assign significance ratings to any predicted adverse effects. It will contain clear and sufficient information to enable the Agency, technical and regulatory agencies, Indigenous groups, and the public to review the proponent's analysis of the significance of effects. The EIS will document the terms used to describe the level of significance.

The following criteria should be used in determining the significance of residual effects:

- magnitude
- geographic extent
- timing
- duration
- frequency
- reversibility
- ecological and social context[16]
- existence of environmental standards, guidelines or objectives for assessing the effect

In assessing significance against these criteria the proponent will, where possible, use relevant existing regulatory documents, environmental standards, guidelines, or objectives such as prescribed maximum levels of emissions or discharges of specific hazardous agents into the environment. The EIS will contain a section which explains the assumptions, definitions and limits to the criteria mentioned above in order to maintain consistency between the effects on each VC.

Where significant adverse effects are identified, the EIS will set out the probability (likelihood) that they will occur, and describe the degree of scientific uncertainty related to the data and methods used within the framework of this environmental analysis.

[15] Visit the Canadian Environmental Assessment Agency's website at: https://www.canada.ca/en/environmental-assessment-agency.html

[16] The ecological and social context within which potential environmental effects may occur should be taken into account when considering the key criteria above in relation to a particular VC, as the context may help better characterize whether adverse effects are significant.

6.6. Other effects to consider

6.6.1. Effects of potential accidents or malfunctions

The failure of certain works caused by equipment malfunctions, human error or exceptional natural events (e.g. earthquake, hurricane, submarine landslide) could cause major environmental effects. The proponent will therefore conduct an analysis of the risks of accidents and malfunctions, determine their effects, and present preliminary emergency response measures.

Taking into account the lifespan of different project components, the proponent will identify the probability of potential accidents and malfunctions related to the project, including an explanation of how those events were identified, potential consequences (including the environmental effects as defined in section 5 of CEAA 2012), the plausible worst case scenarios for each accident and malfunction type and the environmental effects of these scenarios. The EIS will identify the measures to be put in place to prepare, prevent for and respond to all such scenarios (e.g. contingency and emergency procedures). The EIS will also describe the existing mechanisms and arrangements with response organizations for emergency response within the spatial extent of the project.

This assessment will include an identification of the magnitude of an accident and/or malfunction, including the quantity, mechanism, rate, form and characteristics of the contaminants and other materials likely to be released into the environment during the accident and malfunction events and would potentially result in an adverse environmental effect as defined in section 5 of CEAA 2012. The spatial boundaries will identify the areas that could potentially be affected by a worst-case scenario for each accident type.

The EIS will describe the safeguards that have been established to protect against such occurrences and the contingency and emergency response procedures that would be put in place if such events do occur.

Of particular concern with exploration drilling in the marine environment is the potential for accidental spills. This includes both low-probability, large-scale events (e.g. blowouts, either surface, sub-sea or underground) and relatively smaller-volume spills that may occur more frequently. These incidents may affect, among other things, the health and survival of plankton, fish eggs and larvae, juvenile and adult fish, marine mammals, marine birds, marine turtles, and marine invertebrates in the affected area, which may include special areas and areas of high ecological significance. Fishing activity, including fishing by Indigenous peoples, and the commercial marketability of seafood products harvested in the Newfoundland and Labrador offshore may also be adversely affected by a spill or blowout. The effects of accidental spills and blowouts will therefore require assessment in the EIS, including fate and behaviour modelling, and hydrologic trajectory modelling for worst-case large-scale spill scenarios that may occur, including any assumptions, limitations, and formulated hypotheses, accompanied by supporting documentation of methodologies and the cumulative results of the modelling.. Results should be reported in a manner that illustrates the effects of varying weather and oceanographic conditions that may occur throughout the year, and should include a projection for spills originating at the site and followed until the slick volume is reduced to a negligible amount or until a shoreline is reached. Spill scenarios should also consider potential worst–cases, including when species at risk and high concentrations of marine birds or fish are present or for areas important for reproduction. A discussion on water depth and its effect on blow-out rate and spill trajectory modelling assumptions must be provided. Where well locations have not yet been identified, points of origin selected for spill trajectory models should be conservative (e.g.

selecting a potential location within the proposed drilling area that is closest to a sensitive feature or that could result in greatest effects).

Based on the results of the spill modelling and analysis in the EIS, an emergency response plan (e.g. oil spill contingency plan) for spills (small and large) and blowouts will be required. At a minimum, an outline of the emergency response plan along with key commitments is required in the EIS. Depending on the outcomes of the effects analysis, specific detail on key components of the plan will be required in the EIS. The proponent should commit to finalizing the plan in consultation with regulators prior to the application of permits. The EIS shall include a discussion on the use, availability (including nearest location), timing (testing and mobilizing) and feasibility of a capping stack to stop a blowout and resultant spills. If dispersants are to be used, the proponent shall consider associated environmental effects in the EIS (e.g. effects on marine life) and provide a plan for their use. The environmental effects of other measures outlined in the emergency response plan should also be considered (e.g. effects from burns). A pre-incident Net Environmental Benefit Analysis (NEBA) shall be undertaken to help guide the development of the response methods and plans. The EIS shall include the means by which design and/or operational procedures, including follow-up measures, will be implemented to mitigate significant adverse effects from malfunctions and/or accidental events.

The potential to encounter shallow gas pockets, and associated implications, should also be discussed.

The EIS should also consider effects of accidents in the near-shore environment (e.g. spills and ship groundings, as applicable) and of spills reaching shore; including effects on species at risk and their critical habitat, colonial nesters and concentrations of birds, and their habitat. The proponent will also demonstrate what long-term actions it would be prepared to undertake to remediate spill-affected lands and waters.

The EIS should include a summarization of the nature, extent and magnitude of spills, and accidental releases related to existing production installations and past exploration drilling programs in the Newfoundland and Labrador offshore. Comparisons with similar settings (e.g. in the Ormen Lange field in Norway and elsewhere) would also be meaningful for deep water drilling where there is very low probability but very high consequences associated with landsliding.

6.6.2. Effects of the environment on the project

The EIS will take into account how local conditions and natural hazards, such as severe and/or extreme weather conditions and external events (e.g. icebergs, seismic events and submarine landslide potential), could adversely affect the project and how this in turn could result in effects to the environment (e.g. extreme environmental conditions result in malfunctions and accidental events) with consideration of predicted climate change effects. These events will be considered in different probability patterns (e.g. 5-year event vs. 100-year event).

The EIS will provide details of planning, design and construction strategies intended to minimize the potential environmental effects of the environment on the project.

6.6.3. Cumulative effects assessment

The proponent will identify and assess the project's cumulative effects using the approach described in the Agency's Operational Policy Statement entitled *Addressing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012* and the guide entitled *Technical Guidance for*

Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012[17].

Cumulative effects are defined as changes to the environment due to the project combined with the existence of other past, present and reasonably foreseeable physical activities. Cumulative effects may result if:

- the implementation of the project may cause direct residual adverse effects on the VC, taking into account the application of technically and economically feasible mitigation measures; and,
- the same VC may be affected by other past, present and future physical activities[18].

VCs that would not be affected by the project or would be affected positively by the project can, therefore, be omitted from the cumulative effects assessment. A cumulative effect on an environmental component may, however, be important even if the assessment of the project's effects on this component reveals that the effects of the project are minor.

In its EIS, the proponent will:

- Identify and provide a rationale for the VCs that will constitute the focus of the cumulative effects assessment, focussing the cumulative effects assessment on the VCs most likely to be affected by the project and other project and activities. To this end, the proponent must consider, without limiting itself thereto, the following components likely to be affected by the project:
  - ✓ fish and fish habitat,
  - ✓ migratory birds,
  - ✓ marine mammals and marine turtles,
  - ✓ species at risk,
  - ✓ marine plants,
  - ✓ special areas,
  - ✓ commercial fisheries,
  - ✓ Indigenous peoples,
  - ✓ air quality and greenhouse gases, and
  - ✓ human environment.
- Identify and justify the spatial and temporal boundaries for the cumulative effect assessment for each VC selected. The boundaries for the cumulative effects assessments will generally be different for each VC considered. These cumulative effects boundaries will also generally be larger than the boundaries for the corresponding project effects.
- Identify the sources of potential cumulative effects. Specify other projects or activities that have been or that are likely to be carried out that could cause effects on each selected VC within the boundaries defined, and whose effects would act in combination with the residual effects of the project. This assessment may consider the results of any relevant study conducted by a committee established under section 73 or 74 of CEAA 2012.

[17] Visit the Canadian Environmental Assessment Agency's website at: https://www.canada.ca/en/environmental-assessment-agency.html

[18] These terms are defined in the Canadian Environmental Assessment Agency's *Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012*, Draft, December 2014 – https://www.canada.ca/en/environmental-assessment-agency/services/policy-guidance/technical-guidance-assessing-cumulative-environmental-effects-under-canadian-environmental-assessment-act-2012.html

- Assess the cumulative effects on each VC selected by comparing the future scenario with the project and without the project. Effects of past activities (activities that have been carried out) will be used to contextualize the current state of the VC. In assessing the cumulative effects on current use of lands and resources for traditional purposes, the assessment will focus on the cumulative effects on the relevant activity (e.g. fishing).
- Describe the mitigation measures that are technically and economically feasible. The proponent shall assess the effectiveness of the measures applied to mitigate the cumulative effects. In cases where measures exist that are beyond the scope of the proponent's responsibility that could be effectively applied to mitigate these effects, the proponent will identify these effects and the parties that have the authority to act. In such cases, the EIS will summarize the discussions that took place with the other parties in order to implement the necessary measures over the long term.
- Determine the significance of the cumulative effects; and
- Develop a follow-up program to verify the accuracy of the assessment or to dispel the uncertainty concerning the effectiveness of mitigation measures for certain cumulative effects.

The proponent is encouraged to consult with key stakeholders and Indigenous groups prior to finalizing the choice of VCs and the appropriate boundaries to assess cumulative effects.

7. SUMMARY OF ENVIRONMENTAL EFFECTS ASSESSMENT

The EIS will contain a table summarizing the following key information:

- potential environmental effects on valued components;
- proposed mitigation measures to address the effects identified above; and
- potential residual effects and the significance of the residual environmental effects.

The summary table will be used in the EA Report prepared by the Agency. An example of a format for the key summary table is provided in Appendix 1 of this document.

In a second table, the EIS will summarize all key mitigation measures and commitments made by the proponent which will more specifically mitigate any significant adverse effects of the project on VCs (i.e. those measures that are essential to ensure that the project will not result in significant adverse environmental effects).

8. FOLLOW-UP AND MONITORING PROGRAMS

A follow-up program is designed to verify the accuracy of the effects assessment and to determine the effectiveness of the measures implemented to mitigate the adverse effects of the project. Considerations for developing a follow-up program include:

- whether the project will impact environmentally sensitive areas/VCs or protected areas or areas under consideration for protection;
- the nature of Indigenous and public concerns raised about the project;
- the accuracy of predictions;
- whether there is a question about the effectiveness of mitigation measures or the proponent proposes to use new or unproven techniques and technology;

- the nature of cumulative environmental effects;
- the nature, scale and complexity of the program; and
- whether there was limited scientific knowledge about the effects in the EA.

The goal of a monitoring program is to ensure that proper measures and controls are in place in order to decrease the potential for environmental degradation during all phases of project development, and to provide clearly defined action plans and emergency response procedures to account for human and environmental health and safety.

8.1. Follow-up program

The duration of the follow-up program shall be as long as required to evaluate the effectiveness of the mitigation measures.

The EIS shall present a preliminary follow-up program and shall include:

- objectives of the follow-up program and the VCs targeted by the program;
- list of elements requiring follow-up;
- number of follow-up studies planned as well as their main characteristics (list of parameters to be measured, planned implementation timetable, etc.);
- intervention mechanism used in the event that an unexpected deterioration of the environment is observed;
- mechanism to disseminate follow-up results among the concerned populations;
- accessibility and sharing of data for the general population;
- opportunity for the proponent to include the participation of Indigenous groups and stakeholders on the affected territory, during the development and implementation of the program; and
- involvement of local and regional organizations in the design, implementation and evaluation of the follow-up results as well as any updates, including a communication mechanism between these organizations and the proponent.

The discussion / description of follow-up and monitoring programs relative to the currently proposed drilling program should include a short summary of the design and results/outcomes of monitoring programs that have been undertaken for previously assessed and/or completed offshore exploration drilling programs in similar environments and how these will be factored into the verification of impact predictions and design of the follow up and monitoring for the current exploration drilling program.

8.2. Monitoring

The proponent will prepare an environmental monitoring program for all phases of the project.

Specifically, the environmental impact statement shall present an outline of the preliminary environmental monitoring program, including the:

- identification of the interventions that pose risks to one or more of the environmental and/or valued components and the measures and means planned to protect the environment;
- identification of regulatory instruments that include a monitoring program requirement for the valued components;

- description of the characteristics of the monitoring program where foreseeable (e.g. location of interventions, planned protocols, list of measured parameters, analytical methods employed, schedule, human and financial resources required);
- description of the proponent's intervention mechanisms in the event of the observation of non-compliance with the legal and environmental requirements or with the obligations imposed on contractors by the environmental provisions of their contracts;
- guidelines for preparing monitoring reports (number, content, frequency, format) that will be sent to the authorities concerned; and
- plans to engage Indigenous groups in monitoring, where appropriate.

Appendix 1 Example - Summary Table of Environmental Assessment

Valued Component affected	Area of federal jurisdiction[19] (√)	Project Activity	Potential effects	Proposed mitigation	Residual effect	*Magnitude*	*Geographical Extent*	*Timing*	*Duration*	*Frequency*	*Reversibility*	*Ecological context*	*Other criteria used to determine significance*[20]	Significance of residual adverse effect
Fish and fish habitat														
Migratory birds														
Species at risk														
Current use of land and resource for traditional purpose	**√** 5(1)(c)(iii)													
Any other VCs identified														

[19] Indicate by a check mark which valued components can be considered "environmental effects" as defined in section 5 of CEAA 2012, and specify which subsection of section 5 is relevant. For example, for the VC "current use of lands and resources for traditional purposes", the appropriate cell would indicate, section 5(1)(c)(iii) of CEAA 2012.

[20] The ecological and social context within which potential environmental effects may occur should be taken into account when considering the key criteria above in relation to a particular VC, as the context may help better characterize whether adverse effects are significant.

APPENDIX B

White Rose Extension Project Environmental Assessment Air Emissions Study (Stantec 2012)

Husky Energy

White Rose Extension Project

Air Emissions Study

June 2012

Husky Energy SUNCOR ENERGY nalcor energy

Air Emissions Study – White Rose Extension Project

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1.0 INTRODUCTION

1.1 White Rose Extension Project Overview

Husky Oil Operations Limited (Husky) is leading the development of the White Rose Extension Project (WREP), on behalf of the WREP proponents: Husky, Suncor Energy Inc. and Nalcor Energy – Oil and Gas Inc. The White Rose field and satellite extensions are located in the Jeanne d'Arc Basin, approximately 350 km east of Newfoundland and Labrador. The WREP involves the development of West White Rose via one of two options:

- Wellhead platform (WHP) in the West White Rose pool plus up to three future subsea drill centres (Option 1); and
- Subsea drill centre development in the West White Rose pool plus up to three additional future subsea drill centres (Option 2).

Primary infrastructure will be located within a 1 km radius of 724,080 m easting; 5,187,208 m northing (NAD 83, Zone 22) (refer to Figure 1-1 below).



Figure 1-1 White Rose Extension Project Proposed Location within the Jeanne d'Arc Basin, Offshore Eastern Newfoundland and Labrador

To aid in determining the potential environmental effects that the WREP could have on the atmospheric environment, an emissions inventory and dispersion modelling study were conducted. The methodology used to complete the study and the results obtained are presented here.

1.2 Air Contaminants of Interest

The primary air emissions of interest to this study include the following:

- Criteria Air Contaminants (CACs):
  - Carbon monoxide (CO);
  - Nitrogen dioxide (NO_2);
  - Sulphur dioxide (SO_2);
  - Total Suspended Particulate Matter (TSP);
  - Particulate matter less than 10 microns in diameter (PM_{10});
  - Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$); and
  - Volatile Organic Compounds (VOCs).
- Greenhouse gases (GHGs):
  - Carbon Dioxide (CO_2);
  - Nitrous Oxide (N_2O); and
  - Methane (CH_4).

1.3 Report Organization

This Air Emissions and Dispersion Modelling Study was developed in support of the environment assessment for the WREP and is presented in nine sections:

- Section 1.0 provides a general introduction to the WREP
- Section 2.0 describes the air pollution regulations relevant to the WREP
- Section 3.0 provides a description of the WREP activities by WREP phase and provides an inventory of emissions
- Section 4.0 provides the modelling methodology, model input parameters and assumptions
- Section 5.0 provides the results of the air dispersion modelling based on the operation of the proposed concrete gravity structure (CGS)
- Section 6.0 provides a summary of the results obtained
- Section 7.0 provides closure on this report

- Section 8.0 provides references used to prepare this study
- Section 9.0 provides acronyms used in this report

Additional supporting documentation is provided in the Appendices.

2.0 AIR QUALITY REGULATIONS

Air quality related to the operation of the WREP will be assessed in the context of potential WREP-related air emissions and the ground-level concentrations of these contaminants, as well as potential emissions of GHG emissions.

The federal government has set objectives for air quality, which are taken into account by federal agencies in project review, including the Canada Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB). The Newfoundland and Labrador provincial government have also set limits for air quality, which are defined in the *Air Pollution Control Regulations*.

The National Ambient Air Quality (NAAQ) Objectives and the Newfoundland and Labrador *Air Pollution Control Regulations* for specified CACs are presented in Table 2-1. In terms of the WREP, the Newfoundland and Labrador Maximum Permissible Ground Level Concentrations would be applicable to the Nearshore Project Area and the NAAQ Objectives would be applicable to the Offshore Project Area, due to its offshore jurisdiction. As the Newfoundland and Labrador *Air Pollution Control Regulations* are essentially the same as the NAAQ Objectives (except for the fact that the Province of Newfoundland and Labrador has adopted regulations pertaining to PM_{10} and $PM_{2.5}$), these will be referenced throughout this study.

Table 2-1 *Newfoundland and Labrador Air Pollution Control Regulations* and *Canadian Environmental Protection Act* National Ambient Air Quality Objectives

Pollutant and units (alternative units in brackets)	Averaging Time Period	Newfoundland and Labrador	Canada			
		Maximum Permissible Ground Level Concentration	Canada Wide Standards	Ambient Air Quality Objectives		
				Maximum Desirable	Maximum Acceptable	Maximum Tolerable
Nitrogen dioxide µg/m^3 (ppb)	1 hour	400 (213)	-	-	400 (213)	1,000 (532)
	24 hour	200 (106)	-	-	200 (106)	300 (160)
	Annual	100 (53)	-	60 (32)	100 (53)	-
Sulphur dioxide µg/m^3 (ppb)	1 hour	900 (344)	-	450 (172)	900 (344)	-
	3 hour	600 (228)				
	24 hour	300 (115)	-	150 (57)	300 (115)	800 (306)
	Annual	60 (23)	-	30 (11)	60 (23)	-
Total Suspended Particulate Matter µg/m^3	24 hour	120	-	-	120	400
	Annual	60	-	60	70	-
$PM_{2.5}$ µg/m^3	24 hour	25	30 (by 2010) Based on the 98th percentile ambient measurement annually, averaged over 3 consecutive years	-	-	-
PM_{10} µg/m^3	24 hour	50	-	-	-	-
Carbon Monoxide mg/m^3 (ppm)	1 hour	35 (31)	-	15 (13)	35 (31)	-
	8 hour	15 (13)	-	6 (5)	15 (13)	20 (17)

3.0 WHITE ROSE EXTENSION PROJECT EMISSIONS

At present there are two options in consideration for the execution of the WREP.

Option 1, the WHP development option, will include construction, fabrication, installation, commissioning, development drilling, operations and maintenance and decommissioning activities. The WHP will consist of a concrete gravity structure (CGS), with a topsides consisting of drilling facilities, wellheads and support services (including accommodations), utilities, flare boom and a helideck. The WHP will be tied back to the *SeaRose* floating production, storage and offloading (*FPSO*) vessel via existing subsea infrastructure

Option 2, the subsea drill centre, will comprise an excavated subsea drill centre into which subsea well infrastructure will be placed. Drilling of the wells will be accomplished via a mobile offshore drilling unit (MODU). The subsea drill centre will be tied back to the *SeaRose FPSO* by existing subsea infrastructure.

The relevant difference, in terms of the Atmospheric Environment, between these two options, is that the emissions of Option 1 include an onshore component and exposure of people to the emissions from this component. Option 2 involves the use of an existing vessel, with only minor nearshore and onshore emissions from mobilization tasks. Although the diesel equipment on board the drilling rig is likely of an older technology, and less clean-burning than gas, the temporary operation at an offshore location would likely be lower in the integrated exposure concentration to the general population. The following sub-sections outline the activities that would occur during the construction, operation, maintenance and decommissioning of the proposed WREP (Option 1 – WHP and Option 2 – Subsea Drill Centres).

3.1 Construction and Installation Phase

3.1.1 Activities

3.1.1.1 Option 1 – Wellhead Platform

The construction of the WHP will consist of a number of onshore and nearshore activities. The CGS will be constructed in a purpose-built graving dock at Argentia. This construction site will require general excavating and grading on land, the excavation of the graving dock, dewatering and disposal, CGS construction, shoreline and channel dredging, CGS and topsides tow-out and mating at a deep-water site.

Upon the completion of the topsides mating, the platform will be towed to its offshore location for installation and commissioning.

During the construction, installation and commissioning of the WHP, air emissions could be expected from the

- Operation of site clearing and grading equipment
- Earth-moving equipment during the excavation of the graving dock

- Concrete production, and from the dredging equipment during shoreline and channel dredging.

For all onshore construction activities, power will be supplied from the existing grid; however, there will be an emergency generator located on site.

During CGS and topsides tow-out and mating, air emissions will result from the operation of various tugs and supply vessels, the crane heavy-lift vessel and the topsides stand-by generator. Air emissions will also result from the operation of the ocean-going tug boats that will tow the CGS to its offshore location within the White Rose field and from the operation of the dual-fueled turbines (two 10 megawatt (MW) turbines and one spare) on the CGS during platform installation and commissioning. During the installation and commissioning of the platform, the turbines will operate on diesel fuel.

3.1.1.2 Option 2 – Subsea Drill Centre

There is no nearshore component associated with this option. The offshore construction and installation of the subsea drill centres will involve dredging a subsea drill centre, installation of subsea infrastructure, installation of flowlines to connect the new infrastructure with existing infrastructure and modifications to existing infrastructure.

3.1.2 Equipment and Emissions

As FEED work for the WREP has not yet been conducted, the amount and type of equipment that will be in use during the construction, installation and commissioning of the WHP has been estimated during the early pre-Feed stage.

3.1.2.1 Option 1 – Wellhead Platform

As previously discussed, the WHP development option will involve a number of onshore activities that will be conducted at the onshore construction site located in Argentia. Prior to initiating the onshore construction of the graving dock, the proposed site will require excavating and grading.

A list of the estimated equipment, quantities, horsepower and hours of operation to be used during the preparation of the proposed onshore construction site is presented in Table 3-1.

Table 3-1 Equipment Requirements Conceptual Graving Dock Facility for Concrete Gravity Structure Construction - Argentia Site

Activity	Equipment Type	Function	Fuel Type	Horse-power (hp)	No of Pieces	Months of Operation	Hours per month	Total Hours
Mobilization and Demobilization	Lowbed Trucking	Move Equipment	Diesel	250-300	4	2	80	640
	Loader (CAT 980)	Material Handling	Diesel	275	2	2	150	600
	Forklift	Material Handling	Diesel		1	2	168	336
Site Clearing	Excavator (CAT 350)	Clearing	Diesel	285	2	1	168	336
	Loader (CAT 980)	Material Handling	Diesel	275	1	1	168	168
	Dozer (CAT D9)	Clearing	Diesel	370	1	1	168	168
	Haul Trucks	Materials Hauling	Diesel	250-300	2	1	168	336
Mass Excavation	Excavator (375)	Excavation	Diesel	428	2	5	480	4,800
	Dozer (CAT D9)	Push material	Diesel	370	3	5	480	7,200
	Loader (CAT 980)	Material Handling	Diesel	275	1	5	200	1,000
	Loader (CAT 988)	Material Handling	Diesel	400	1	5	480	2,400
	Motor Grader (CAT 14G)	Grade roads	Diesel	200	1	5	480	2,400
	Haul Trucks (CAT 773)	Materials Hauling	Diesel	650	9	5	480	21,600
Wall Construction	Cranes (150 ton)	Hoisting	Diesel	400-500	1	2	480	960
	Hydraulic Vibratory Hammer	Install sheetpile	Diesel	700	1	1	480	480
Final Grading	Dozer (CAT D9)	Push material	Diesel	370	2	1	168	336
	Motor Grader	Grade roads	Diesel	200	1	1	168	168
General Service	Light Plants	Night work	Diesel	25	8	6	220	10,560
	Compressor	air supply	Diesel	75-150	3	6	220	3,960
	Generators	electrical Supply	Diesel	50-100	2	6	480	5,760
	Pickups		Gasoline	250-350	8	7	220	12,320
	Service Trucks		Gasoline	350-450	2	7	220	3,080
	Water Truck		Diesel	250	1	7	480	3,360
Note: Equipment list does not include CGS construction or shoreline/channel dredging								

The operation of the equipment listed in Table 3-1 will result in emissions of various CACs and GHGs. These emissions were estimated using the equipment inventory provided in Table 3-1 and emission factors acquired from United States Environmental Protection Agency (US EPA), Non-Road Program (US EPA 2010), as well as Table 3.3-

2, “Emissions Factors for Uncontrolled Gasoline and Diesel Industrial Engines” from the US EPA AP-42. In addition to the operation of the above equipment, emissions of CACs will result from the transportation of materials and personnel to the site. The emissions from the transportation of materials and personnel are calculated using emission factors from Transport Canada’s “Urban Transportation Emission Calculator (UTEC), which can be found at: http://www.tc.gc.ca/programs/environment/UTEC/CacEmissionFactors.aspx.

The estimated emissions based on site excavation and grading for CGS construction and material transport are presented in Table 3-2.

Table 3-2 Emissions Estimates for Graving Dock Facility Preparation for Concrete Gravity Structure Construction

Activity	Total Emissions (tonnes)					
	CO	**NO_X**	**CO_2**	**SO_2**	**PM**	**THC(A)**
Mobilization and Demobilization	0.45	1.21	103.1	0.15	0.06	0.08
Site Clearing	0.53	1.71	162.6	0.23	0.10	0.08
Mass Excavation	41.6	115.9	10,838	15.5	6.20	4.22
Wall Construction	1.33	5.75	506.5	0.87	0.15	0.17
Final Grading	0.32	0.91	84.7	0.12	0.05	0.04
General Service	2.40	3.29	354.0	0.49	0.44	0.36
Transportation	8.14	1.37	460.9	0.007	0.035	0.454
TOTAL	**46.6**	**128.7**	**12,049**	**17.3**	**7.01**	**4.97**

Note: does not include emissions related to GCS construction or shoreline/channel dredging
(A) THC = total hydrocarbon
Assumptions:
1) When a range of Hp was given, the highest value was used as a conservative estimate
2) Assumed diesel sulphur content is 0.4 wt%
3) Conservatively assumed 100% load factor (i.e., operating at engine capacity)

In addition to the list of equipment in Table 3-2, various pieces of construction equipment will also be used to construct a number of support facilities (including, but not limited to, offices, sheds, storage areas). At this stage of WREP design, the equipment to be used to implement the above activities is undetermined. Emissions from the operation of such equipment will be similar to those identified in Table 3-2 and will, for the most part, result from the combustion of diesel used to fuel the equipment.

The CGS will be constructed within the dry dock and will require the production of approximately 55,000 m^3 of concrete via an onsite concrete batching plant. Construction of the CGS will occur over a period of 20 to 24 months. Emissions related to the production of approximately 55,000 m^3 of concrete have been estimated and are presented in Table 3-3. Emission factors were acquired from the US EPA, Non-Road Program (US EPA 2010).

Table 3-3 Emission Estimates Resulting from Concrete Production

Equipment	Hp Assumed	Total hr	Total hp-hr	Total Emissions (tonnes)					
				CO	NO_X	CO_2	SO_2	PM	THC(A)
Conc. Plant (150 cubic yard/hr)	250	480	120,000	0.168	0.748	73.6	0.046	0.046	0.040
Conc. Truck	300	1,000	300,000	0.364	1.61	160.7	0.113	0.113	0.100
Conc. Pump (assume 75 m^3/hr)	150	735	110,250	0.210	0.718	68.5	0.054	0.054	0.043
TOTAL	**-**	**-**	**-**	**0.741**	**3.07**	**302.9**	**0.426**	**0.213**	**0.183**

(A) THC = total hydrocarbon

Assumptions:

1) Estimations are based on total concrete required. Any additional time that the plant is running has not been included
2) Equipment list is a rough approximation of equipment required
3) Horsepower has been assumed and emission factors are from the US EPA non-road program
4) Calculated time running for concrete pump based on total concrete production
5) Assumed concrete truck runs for 1,000 hours

Prior to the flooding of the dry-dock for CGS tow-out to the deep-water construction site, land-based excavation equipment and a coastal dredger will be used to remove the shoreline berm. Emission estimates for these activities will be small in comparison with the rest of the WREP. Whereas construction includes substantial grading and preparation, this task involves the removal of one end of the facility, a task that is small in comparison with the original construction. Emissions will result from the combustion of diesel fuel in the equipment engines and will occur over a short duration.

During the tow-out of the CGS and topside mating at the deep-water construction site, air emissions will result from the operation of a number of tug boats and vessels, including a single- or dual-crane heavy-lift vessel. Following topsides mating, the WHP will be towed to its offshore location via four ocean-going tugs. The transport is expected to take approximately 12 to 15 days. The emissions related to the marine transport component of the construction phase of the WREP are presented in Table 3-4. Emission factors were acquired from the US EPA (US EPA 2005).

The WHP development option may also involve the development of up to three subsea drill centres, which would require a dredger as with the subsea drill centre development option. Typical emissions from the operation of a dredger include TPM, PM_{10}, $PM_{2.5}$, CO, SO_2 and NO_X. The emissions resulting from the operation of a typical dredger are presented in Table 3.5. The emission factors used to calculate the emissions presented below were acquired from the US EPA's "Analysis of Commercial Marine Vessel Emissions and Fuel Consumption" (2000b).

Table 3-4 Emissions Related to the Tow-out of the Concrete Gravity Structure and Topsides Mating

Vessel	Quantity	hp Assumed	kW	Hr/Day Assumed	Days Running	Total Hr	Total kW-hr	Total Emissions (tonnes)						
								CO	NO_X	CO_2	SO_2	PM_{10}	$PM_{2.5}$	THC(A)
Heavy Lift Transportation Vessel	1	12,000	8,948	24	4	96	859,046	0.945	12.0	557.6	9.88	0.619	0.498	0.430
Tugs	4	15,000	11,185	24	4	96	1,073,808	1.18	15.0	697.0	12.4	0.773	0.623	0.537
Dual Crane Heavy Lift Vessel	1	33,000	24,608	24	240	5,760	141,742,637	155.9	1,984	91,997	1,630	102.1	82.2	70.9
Accommodation Vessel	1	670	500	24	240	5,760	2,877,805	3.17	40.3	1,868	33.1	2.07	1.67	1.44
Assistant Tug	1	5,000	3,728	24	240	5,760	21,476,157	23.6	300.7	13,939	247.0	15.5	12.5	10.7
Supply Boat	1	5,000	3,728	4	32	128	477,248	0.525	6.68	309.8	5.49	0.344	0.277	0.239
Tugs	4	17,000	12,677	24	15	360	4,563,683	5.02	63.9	2962.0	52.5	3.29	2.65	2.28
TOTAL	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**190**	**2,423**	**112,330**	**1,990**	**125**	**100**	**87**

(A) THC = total hydrocarbons

Assumptions:

1) Unless otherwise specified, vessels are running at 100%, 24 hours/day
2) Assumed the heavy lift transport vessel hp to be 12,000 Hp based on similar vessel found at http://www.jumboshipping.nl/jc_fleet_j1800.asp
3) Assumed dual crane heavy lift vessel hp to be 33,000 hp, based on similar ship found at http://hmc.heerema.com/About/Fleet/Thialf/tabid/378/Default.aspx
4) Assumed accommodation vessel hp to be 670 hp, based on similar vessel found at http://www.workboatsinternational.com/stc536.html
5) Assumed medium speed engines (rpm greater than 130 and typically over 400)

Table 3-5 Estimated Emissions of Critical Air Contaminants from the Operation of a Trailing Suction Hopper Dredger for a Subsea Drill Centre

Equipment	Air Emissions (tonnes/year)						
	CO	NO_X	SO_2	CO_2	TPM	PM_{10}	$PM_{2.5}$
Trailing Suction Hopper Dredger	10.8	43.4	46.4	2,923	0.97	0.94	0.51

Following tow-out of the platform to its offshore location, the facility will be installed and commissioned.

3.1.2.2 Option 2 – Subsea Drill Centres

As discussed above, the offshore construction and installation of the subsea drill centres will involve a number of activities. These activities will be conducted using a trailing suction hopper dredger vessel, along with other supporting vessels, to assist with installing the new infrastructure and laying the new flowlines. The operation of such vessels will result in emissions of various CACs and GHGs and will be similar to those presented in Tables 3-4 and 3.5.

3.1.3 Summary

A summary of the calculated emissions for WREP construction, onshore and nearshore, are presented in Table 3-6. These emissions represent the activities that will be required to construction the WHP. Emissions related to the construction and installation of the subsea drill centres would be smaller in magnitude and related to marine vessel operation only.

Table 3-6 Summary of Emission Estimates based on Construction and Installation

Activity	Total Emissions (tonnes)							
	CO	NO_X	CO_2	SO_2	PM	THC (A)	CH_4	N_2O
Mobilization and Demobilization	0.451	1.21	103.14	0.154	0.064	0.084	-	-
Site Clearing	0.527	1.71	162.64	0.234	0.098	0.085	-	-
Mass Excavation	41.6	115.9	10,838.4	15.5	6.20	4.22	-	-
Wall Construction	1.33	5.75	506.52	0.871	0.153	0.171	-	-
Final Grading	0.319	0.912	84.65	0.118	0.050	0.042	-	-
General Service	2.40	3.29	354.0	0.495	0.442	0.362	-	-
Transportation	8.14	1.37	460.9	0.007	0.035	0.454	0.026	0.041
Concrete Production	0.689	2.87	283.1	0.398	0.199	0.183	-	-
Marine Emissions	190.4	2,423	112,330	1,990	124.6	86.5	-	-
Trailing Suction Hopper Dredger	10.8	43.4	2,923	46.4	0.97	-	-	-
TOTAL	**257**	**2,599**	**128,046**	**2,054**	**133**	**92.1**	**0.03**	**0.04**

(A) THC = total hydrocarbon

3.2 Operation Phase

3.2.1 Activities

3.2.1.1 Option 1 – Wellhead Platform

The operation of the WHP will involve drilling, completions, well interventions and transport of the product to the *SeaRose FPSO*. Power to operate all equipment located on the platform will be generated from the operation of three dual-fuelled turbine generators (two operational, one spare).

3.2.1.2 Option 2 – Subsea Drill Centre

The operation and maintenance of the subsea drill centres with involve drilling, via the use of a MODU, completions and well interventions. The subsea drill centre will produce crude that will be directly transported back to the *SeaRose FPSO* for processing.

3.2.2 Equipment and Emissions

3.2.2.1 Option 1 – Wellhead Platform

The major sources of air emissions during the operation and maintenance of the WHP include the following:

- Power generation
- Operation of vessels
- Operation of helicopters
- Flaring
- Maintenance activities (i.e., welding, solvent use)
- Fugitive emissions (i.e., leaking valves, pump seals, compressor seals, flanges/ connectors and pressure relief valves).

During normal operations of the WHP, a support vessel will be on stand-by for the platform 365 days/year and at least one supply vessel will also be in operation 365 days/year, travelling between the east coast of Newfoundland and the offshore WREP site, transferring supplies. Helicopters will also routinely travel between the east coast of Newfoundland and the offshore WREP site to transport employees to and from work, approximately three round trip flights per week. Typical emissions from the operation of vessel and helicopter engines include CO, NO_X, SO_2, TSP, PM_{10}, $PM_{2.5}$ and CO_2.

Emissions related to the operation of the supply and support vessels were calculated using emission factors acquired from Table 2-10 in the US EPA “Best Practices in Preparing Port Emission Inventories, 2005”, and Table 5.1 in the US EPA “Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data” (US EPA 2000b). Emissions related to the operation of helicopters were calculated using emission factors

acquired from Table 3-15 in the EMEP/EEA "Emission Inventory Guidebook, 2009" and Table 13.2 of the Climate Registry, "Default Emission Factors". These emissions are presented in Table 3-7.

Table 3-7 Emissions from the Operation of Helicopters and Supply and Support Vessels

Activity	Total Emissions (tonnes/year)							
	CO	NO_X	CO_2	SO_2	PM	THC	CH_4	N_2O
Operation of Support Vessel	80.5	1,024	47,485	841.4	52.7	36.6	0 (A)	0 (A)
Operation of Helicopters	6.10	0.41	402.6	0.16	0 (B)	0[b]	0.01	0.04

(A) Emission factors for CH_4 and N_2O could not be found, but have been determined to be minimal
(B) Emission factors for PM and THC could not be found. These emissions should be minimal

Power generation will be supplied via three 10 MW dual-fueled turbine generators (two operational and one spare) during normal operation. During the installation of the WREP, the turbines will operate on diesel fuel. Once the facility is fully operational, the turbines will operate on 95 percent fuel gas and 5 percent diesel. The fuel gas will be supplied from the North Drill Centre. The fuel gas composition analysis is provided in Table 3-8.

Table 3-8 Fuel Gas Composition Analysis

Gas Component	Mole Fraction
CO	0.0001
H_2	trace
He	0.0001
O_2	0.0028
N_2	0.0135
CO_2	0.0208
H_2S	0
C_1	0.8509
C_2	0.0554
C_3	0.0318
iC_4	0.0045
nC_4	0.0106
iC_5	0.0025
nC_5	0.0031
C_6	0.0021
C_7	0.0011
C_8	0.0007
C_9	trace
C_{10}	0
TOTAL	**1**

Source: Husky Energy 2011

The turbine generators will supply all power requirements for the topside components of the WHP. The primary emissions from the combustion of produced gas in the turbines include NO_X, CO, SO_2, TSP, PM_{10} and $PM_{2.5}$. The fuel gas composition analysis, as presented in Table 3-8, indicates that there is no hydrogen sulphide (H_2S) present in the gas; therefore, the combustion of this fuel will not result in emissions of SO_2 or H_2S. However, as the turbines will operate approximately 5 percent of the time on diesel fuel, some SO_2 emissions will occur and have been considered during power generation.

Emissions related to the operation of the two 10 MW dual-fueled turbine generators were calculated using emission factors acquired from the US EPA AP-42 Chapter 3.1 Stationary Gas Turbines (US EPA 2000) and assuming a 34 percent efficiency (shaft plus electrical) for normal operations. The emission estimates are presented in Table 3-9.

Table 3-9 Emissions from Power Generation during Operation (WHP)

Activity	Total Emissions (tonnes/year)							
	CO	NO_X	CO_2	SO_2	PM	THC[(A)]	CH4	N_2O
Power Generation	61.8	276.3	89,645	3.88	5.49	0.99	6.52	2.27
(A) THC = total hydrocarbon								

The flare system is an essential component of the pressure relief and safety system of the WHP. The flare system will be designed to prevent over-pressurization of equipment during process upset conditions and to dispose of associated gas produced during emergency situations (i.e., blowdown). The air emissions during flaring include CO, NO_X, TSP, PM_{10} and $PM_{2.5}$. A small amount of fuel gas will be continuously used for flare pilots during the operation of the WHP; however, the associated air emissions will be minimal. This background flaring represents flaring associated with normal operations. The flare emissions during normal operation were estimated using flare gas properties and volumes and US EPA AP-42 emission factors for industrial flaring (Chapter 13.5) (US EPA 1991) and natural gas combustion in external combustion sources (Chapter 1.4) (US EPA 1998). The flaring emission estimates resulting from flaring during normal operations are presented in Table 3-10.

Table 3-10 Flaring Emissions Resulting from Normal Operation

Activity	Total Emissions (tonnes/year)							
	CO	NO_X	CO_2	SO_2	TPM	THC[(A)]	CH_4	N_2O
Normal Operations - Flaring	35.0	6.44	11,139	0	719.6	13.3	0.01	0.01
(A) THC = total hydrocarbon								

However, during a system blowdown, greater volumes of gas are required to be flared over short periods of time. Approximately 7,400 m^3 of gas could be flared following a WHP blowdown (Husky Energy 2012). The estimated emissions related to a WHP blowdown are provided in Table 3-11. These emissions were calculated using emission factors provided in AP-42 Chapter 13.5, Industrial Flares (US EPA 1991) and assuming

that the release would occur over a 10 minute period. In total, approximately 12 blowdowns could occur within any given year.

Table 3-11 Flaring Emissions Resulting from a Blowdown

Activity	Total Emissions (tonnes/year)				
	CO	NO_X	TPM	PM_{10}	$PM_{2.5}$
Flaring - Wellhead Blowdown	0.00044	0.097	0.011	0.011	0.011

In addition to the above estimated emissions, minor amounts of TSP and VOCs will be emitted during various routine maintenance activities, including welding, grinding and solvent use. Fugitive releases of VOCs can also result from such sources as leaking valves, pumps seals, compressor seals, flanges/connectors, pressure relief valves and ventilation exhausts, which are considered minor and intermittent sources.

3.2.2.2 Option 2 – Subsea Drill Centre

During the operation of the subsea drill centre development option, emissions of CACs will result from the operation of the MODU. Typical emissions related to the operation of a MODU are presented in Table 3-12. The data (for CO, NO_X and SO_2) presented in Table 3-12 was acquired from the 2012 emissions report by the GSF Grand Banks MODU provided to Stantec by Husky. Emissions data pertaining to particulate matter were calculated using fuel usage and emission factors acquired from the US EPA AP-42, Chapter 3.4, Large Stationary Diesel and All Stationary Dual-fuel Engines (US EPA 1996b).

Table 3-12 Representative Annual Mobile Offshore Drilling Unit Criteria Air Contaminant Emissions

CO	75.6
NO_X	284.6
SO_2	18.0
TPM	6.20
PM_{10}	5.10
$PM_{2.5}$	4.26

3.2.3 Summary

A summary of the estimated emissions released from the operation of the WHP are provided in Table 3-13.

Table 3-13 Summary of Emission Estimates based on Operation

Activity	Total Emissions (tonnes/year)							
	CO	**NO_X**	**CO_2**	**SO_2**	**PM**	**THC**	**CH_4**	**N_2O**
Operation of Support Vessel	80.5	1,024	47,485	841.4	52.7	36.6	0[a]	0[a]
Operation of Helicopters	6.10	0.41	402.6	0.16	0[b]	0[b]	0.01	0.04
Power Generation	61.8	276.3	89,645	3.88	5.49	0.99	6.52	2.27
Normal Operations - Flaring	35.0	6.44	11,139	-	719.6	13.3	0.01	0.01
TOTAL	**183**	**1,307**	**148,672**	**845**	**778**	**51**	**6.5**	**2.3**

(A), (B) Emission factors for CH_4 and N_2O PM and THC were not obtained, but they are assumed to be minimal in comparison to other sources.

The emissions released from the operation of the subsea drill centre, during drilling via a MODU, are presented in Table 3-12.

4.0 DISPERSON MODELLING METHODOLOGY

4.1 Model Selection and Approach

Air dispersion modelling was conducted for the operation of the WHP and the MODU to predict ground level concentrations of those contaminants of interest to the WREP that could then be compared to provincial and national guidelines.

The proposed WREP is located within the Jeanne d'Arc Basin and is therefore regulated by the C-NLOPB. There is no one specified dispersion model required for use by the C-NLOPB or Environment Canada. In the past, these agencies have, for the most part, accepted submissions based on:

- SCREEN3
- ISCST3, ISCLT3
- AERMOD
- CALPUFF
- Others on a case by case basis.

The Newfoundland and Labrador Department of Environment and Conservation (NLDEC) have developed a guidance document for dispersion modelling, *Guideline for Plume Dispersion Modelling* (NLDEC 2012). The document outlines those models approved by the NLDEC for the purpose of determining compliance with the provincial ambient air quality standards, the Newfoundland and Labrador *Air Pollution Control Regulations*. The province's preferred model, when the following conditions are present, is that of CALPUFF:

- Long range transport (>50 km)
- Overwater and coastal interaction effects
- Temporal analysis required.

Although regulated by the C-NLOPB, Husky has chosen to carry out the Air Emissions Study for the WREP using the province's preferred model, CALPUFF.

CALPUFF is a non-steady state Gaussian puff dispersion model that allows for and includes the following:

- Variable and curved pollutant trajectories
- Variable meteorological conditions
- Spatial variability to winds and turbulence fields
- Retention of previous hour emissions

- Calm and low wind speed conditions
- Causality effects
- Chemical removal
- Wet and dry deposition
- Building downwash
- Plume fumigation
- Complex terrain algorithms.

There are three major components to the CALPUFF model, CALMET (meteorological modelling package with both diagnostic and prognostic wind field generators), CALPUFF (a Gaussian puff dispersion model) and CALPOST (post processing program), as well as a series of pre-processors related to geophysical and meteorological parameters.

Specifics pertaining to the model domain, data pre-processing, CALMET, CALPUFF and CALPOST are described in detail in the following sub-sections. Copies of the CALMET and CALPUFF input files for one modelling scenario have been included in Appendix A.

4.2 Model Domain

4.2.1 Computational Grid

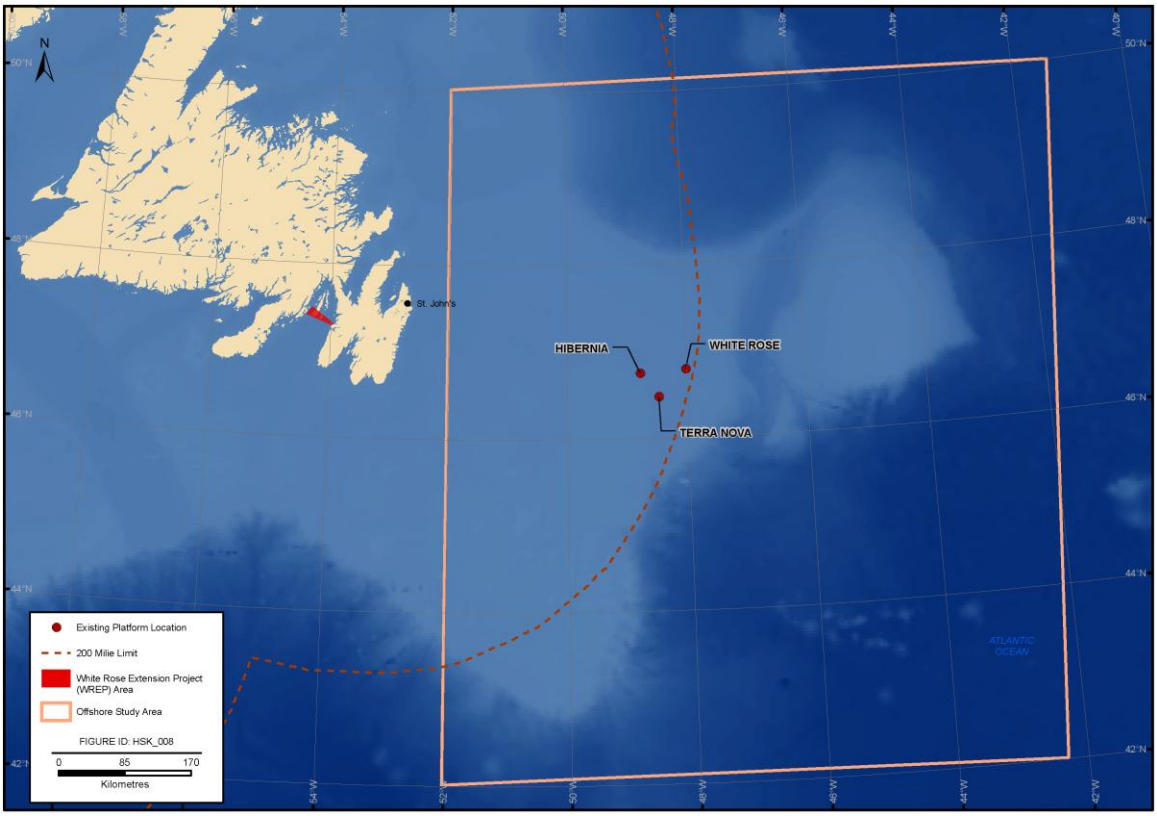
The modelling domain, or computational grid, selected for this study consisted of a 85 km by 85 km grid area centered at the following coordinate (NAD 83, Zone 22): 700,080 m easting; 5,187,208 m northing, with cells spaced 1 km apart.

4.2.2 Receptor Grid

A sampling grid (set of gridded receptors) was positioned within the computational grid covering a domain of 76 km by 76 km. To avoid potential boundary effects, the sampling grid was set in a few kilometres from the edge of the computational grid (90 km by 90 km). The spacing of the sampling grid was set to 500 m and receptor height was set to sea-level.

In addition to the sampling grid, a nested grid of receptors was centred on the proposed WHP location (724,080 m easting; 5,187,208 m northing). The nested grid extended approximately 2 km from the proposed WREP location, with receptor spacings of 50 m within 500 m of the WHP, 100 m spacing's between 500 and 1,000 m and 200 m spacing's within 2,000 m from the WHP. The receptor height of the nested grid was at sea-level.

Three discrete receptors were also incorporated into each model run and they represent the locations of the existing offshore platforms located within the Jeanne d'Arc Basin (Hibernia, Terra Nova and the existing *SeaRose FPSO*). The height of the platforms was set at 30 m above sea-level to represent the first deck. The locations of these platforms and the Offshore Project Area are presented in Figure 4-1.



Note: The modelling domain, or computational grid, selected for this study consisted of a 85 km by 85 km grid area centered at the following coordinate (NAD 83, Zone 22): 700,080 m easting; 5,187,208 m northing

Figure 4-1 Nearshore Project and Offshore Study Areas and Location of Existing Platforms

4.3 Geophysical Pre-processing

4.3.1 Overview

To initialize the CALMET model, terrain elevation and land use data depicting the geophysical conditions in the selected modelling domain are required, simplified by the fact that the entire model domain is over the ocean. Terrain elevation data are used in CALMET in various model algorithms to characterize meteorological phenomena such as up- and down-slope flows and the steering of winds by terrain such as a river valley. In addition to the terrain elevation data, the CALMET model uses surface parameters such as surface roughness length, albedo, Bowen ratio, leaf area index, soil heat flux and anthropogenic heat flux to estimate meteorological parameters such as surface heat flux and mechanical turbulence. In the model's geophysical pre-processor MAKEGEO, values for each of these surface parameters are specified based on input land use categories.

4.3.2 Terrain Data

The Offshore Project Area is located offshore eastern Newfoundland and Labrador within the Atlantic Ocean. All elevations within the modelling domain are therefore at sea level.

4.3.3 Land Use

Land use is the classification of the different land types such as urban, forested, wetland, agricultural. Different land classifications can have localized influences on the meteorology of a region and in turn can influence plume dispersion. CALMET requires land use data in order to help characterize the meteorology of the region.

Land use data processed by the geophysical pre-processor were collected from Global Land Cover Characterization (version 2) (30 arcsecond).

4.4 CALMET

4.4.1 Overview

CALMET is the meteorological model that pre-processes meteorological data for input into the CALPUFF model. CALMET develops three-dimensional (3-D) gridded hourly wind and temperature fields, as well as two-dimensional fields such as mixing heights.

Options exist in CALMET to create an initial guess field either by interpolating observation data or by using output from a prognostic meteorological model, such as the NCAR/PSU mesoscale modelling system (MM4/MM5). The prognostic model data are usually run over a very large domain with much coarser resolution than that applied with CALMET. The advantage of using CALMET is that it can be used to interpolate the prognostic data to develop a 3-D fine-scale first guess field of wind speeds and directions.

Typically, observations from the nearest representative upper air and surface stations are used alone or in conjunction with an initial guess field generated from a prognostic meteorological model. Alternatively, prognostic meteorological model data can also be used as the primary source of the meteorological input for processing by CALMET, as was the case here.

The version of CALMET used in this study, which also represents the newest version, is that of 6.334 (Level 110421).

4.4.2 Meteorological Data and Grid

As discussed above, the modelling domain is offshore, with the sources located in the Atlantic Ocean approximately 350 km from land. As such, there are no national surface meteorological stations in close proximity of the primary modelling area that would be considered representative of the meteorological conditions near the sources.

As a result, a Mesoscale Metrological Model (version 5) (MM5) dataset was procured from TRC Solutions for use in the study. The data set consisted of one year (2006) of MM5 data at 12 km resolution. The meteorological domain that was set up within CALMET (version 6.334 – level 110421) consisted of a 85 km by 85 km grid with 1 km spacings, centred at the following coordinate (NAD 83 Zone 22): 700,080 m easting; 5,187,208 m northing.

The vertical wind component within CALMET is defined at vertical cell faces. For this study the metrological grid was built using 10 vertical cell faces and 11 vertical cell heights, which are presented in Table 4-1.

Table 4-1 Vertical Cell Faces and Heights as Incorporated into CALMET

Cell Face	Cell Face Height (m)
1	0
2	20
3	40
4	80
5	160
6	320
7	640
8	1,200
9	2,000
10	3,000

4.5 CALPUFF

4.5.1 Overview

The following description of the CALPUFF model's major model algorithms and options are excerpts from the CALPUFF model's user manual.

The CALPUFF model is a non-steady-state Gaussian puff dispersion model which incorporates simple chemical transformation mechanisms, wet and dry deposition, complex terrain algorithms and building downwash. The CALPUFF model is suitable for estimating ground-level air quality concentrations on both local and regional scales, from tens of metres to hundreds of kilometres. It can accommodate arbitrarily varying point sources and gridded area source emissions. Most of the algorithms contain options to treat the physical processes at different levels of detail depending on the model application.

The major features and options of the CALPUFF model are summarized briefly as follows, including some that are only relevant to land, but are included for completeness:

- Sub-grid Scale Complex Terrain: The complex terrain module in CALPUFF is based on the approach used in the Complex Terrain Dispersion Model (CTDMPLUS). Plume impingement on sub-grid scale hills is evaluated using a dividing streamline (Hd) to determine which pollutant material is deflected around the sides of a hill (below Hd) and which material is advected over the hill (above Hd). Individual puffs are split into up to three sections for these calculations.

- Puff Sampling Functions: A set of accurate and computationally efficient puff sampling routines are included in CALPUFF that solve many of the computational difficulties with applying a puff model to near-field releases. For near-field applications during rapidly varying meteorological conditions, an elongated puff (slug) sampling function can be used. An integrated puff approach is used during less demanding conditions. Both techniques reproduce continuous plume results exactly under the appropriate steady state conditions.

- Wind Shear Effects: CALPUFF contains an optional puff splitting algorithm that allows vertical wind shear effects across individual puffs to be simulated. Differential rates of dispersion and transport occur on the puffs generated from the original puff, which under some conditions can substantially increase the effective rate of horizontal growth of the plume.

- Building Downwash: The Huber-Snyder and Schulman-Scire downwash models are both incorporated into CALPUFF. An option is provided to use either model for all stacks, or make the choice on a stack-by-stack and wind sector-by-wind sector basis. Both algorithms have been implemented in such a way as to allow the use of wind direction specific building dimensions.

- Over-water and Coastal Interaction Effects: Because the CALMET meteorological model contains both over-water and over-land boundary layer algorithms, the effects of water bodies on plume transport, dispersion and deposition can be simulated with CALPUFF. The puff formulation of CALPUFF is designed to handle spatial changes in meteorological and dispersion conditions, including the abrupt changes that occur at the coastline of a major body of water.

- Dispersion Coefficients: Several options are provided in CALPUFF for the computation of dispersion coefficients, including the use of turbulence measurements (σ_v and σ_w), the use of similarity theory to estimate σ_v and σ_w from modelled surface heat and momentum fluxes, or the use of Pasquill-Gifford (PG) or McElroy-Pooler (MP) dispersion coefficients, or dispersion equations based on the Complex Terrain Dispersion Model (CTDM). Options are provided to apply an averaging time correction or surface roughness length adjustment to the PG coefficients.

The Lakes Environmental CALPUFF View Model Version 6.4 (CALPUFF Version 6.42 – Level 110325) was used for this study for modelling as it contains the latest CALPUFF model released by TRC in April 2011.

Unless otherwise specified, the model was run in the default mode.

4.5.2 Air Contaminants

The following contaminants were modelled in regards to combustion related sources:

- SO_2
- TSP
- PM_{10}
- $PM_{2.5}$
- NO_2
- CO.

Ground level concentrations have been predicted for all these listed air contaminants.

4.5.3 Source Inputs

Five scenarios were modelled:

- Normal WHP operation;
- Normal operation of a MODU;
- Accidental flaring as a result of a wellhead blowdown;
- Cumulative operation of the proposed WHP with the existing platforms (White Rose, Hibernia and Terra Nova) and the proposed Hebron Platform; and
- Cumulative operation of the MODU with the existing platforms (White Rose, Hibernia and Terra Nova) and the proposed Hebron Platform.

The sources of emissions to be modelled include point sources from the oil and gas production installations (offshore platforms), including the turbines and flares.

Other sources of emissions related to platform operations, as discussed above, include the operation of helicopters, supply vessels, maintenance activities and fugitive sources. These sources have been included in the WREP's emission inventory, presented in Section 3.0, but have not been incorporated into the dispersion modelling scenarios.

The model input parameters for the normal operation of the WREP and MODU (Scenarios 1 and 2) are presented in Table 4-2. For the purposes of this study, typical stack parameter values have been selected for use. Upon final design of the WREP these values may differ. Emission factors for turbine emissions were acquired from Chapter 3.1 of the US EPA AP-42 (2000). Stack gas exit velocity and temperature for the flare was determined using guidance published by Alberta Environment (2003).

As discussed in Section 3.2.2, there is potential for approximately 12 blowdowns to occur per year. During a single blowdown event approximately 7,400 m^3 of gas is released from the flare. This type of flaring usually occurs over a short period of time and for calculation purposes a 10-minute release rate has been assumed for this study. Emission factors for flaring were acquired from the US EPA AP-42 Chapter 13.1 Industrial Flaring (1991) for releases of CO and NO_X and from Chapter 3.1 Stationary Gas Turbines (2000) for particulate matter, as per guidance published in the Canadian Petroleum Products Institute Code of Practice (2007). The fuel gas heating value was assumed to be the same as that for natural gas, 1,050 BTU/scf (US EPA 1985). As the flaring period is less than 1 hour (assumed 10 minutes), the predictions or releases are converted to a 1-hour equivalent in order to be compared with regulatory standards. For this study, the guidance published by Alberta Environment (2003) was used, and involved dividing the emission factors calculated for a 10-minute release period by six to represent the actual release over a 1-hour period, which would therefore allow for direct comparison of the predicted 1-hour results with the 1-hour standards.

Table 4-2 Stack Physical Properties and Emission Rates for Normal Platform Operation (Scenarios 1 and 2)

Source	Source Location		Stack Height (m)	Stack Diameter (m)	Stack Gas Exit Velocity (m/s)	Stack Gas Exit Temp. (K)	NO_X Emission Rate (g/s)	CO Emission Rate (g/s)	SO_2 Emission Rate (g/s)	TPM Emission Rate (g/s)	PM_{10} Emission Rate (g/s)	$PM_{2.5}$ Emission Rate (g/s)
	UTM X (m)	UTM Y (m)										
Option 1 - WHP												
Turbine	724,040	5,187,202	71.0	2.00	31.5	427	4.41	0.99	0.062	0.087	0.083	0.078
Turbine	724,050	5,187,202	71.0	2.00	31.5	427	4.41	0.99	0.062	0.087	0.083	0.078
Normal Flaring	724,150	5,187,202	126 (A)	16.7 (A)	2.00	727	0.20	1.11	NA	0.022	0.022	0.022
Option 2 – Subsea Drill Centres												
MODU Stack 1	724,076	5,187,229.	3	1	30	413	2.16	0.571	0.008	0.049	0.040	0.034
MODU Stack 2	724,078	5,187,227	3	1	30	413	2.16	0.571	0.008	0.049	0.040	0.034
MODU Stack 3	724,080	5,187,225	3	1	30	413	2.16	0.571	0.008	0.049	0.040	0.034
MODU Stack 4	724,082	5,187,223	3	1	30	413	2.16	0.571	0.008	0.049	0.040	0.034

(A) Flare height and diameter equivalent values estimated using the Alberta Flare Model for purge gas (AENV 2008)

The emission rates used for modelling scenario three (accidental flaring), based on the above noted assumptions, are presented in Table 4-3. The stack physical parameters for the flare were provided in Table 4-2.

Table 4-3 Emission Rates for a Single Flare Blowdown Event (Scenario 3)

Source	NO_X Emission Rate (g/s)	CO Emission Rate (g/s)	TPM Emission Rate (g/s)	PM_{10} Emission Rate (g/s)	$PM_{2.5}$ Emission Rate (g/s)
Flare (Blowdown)	2.24	0.0103	0.25	0.25	0.25

The fourth and fifth operational scenarios modelled were the cumulative effects from the operation of the existing three platforms, Hibernia, Terra Nova and the *SeaRose FSPO* and the proposed platform, Hebron, with the operation of the Project (WHP and MODU). Emissions data for the existing platforms were acquired from the National Pollutant Release Inventory database (2012), and are presented in Table 4-4. These data represent normal operations for all platforms. Detailed geometric information for sources other than those of the Project was not available. The input data used for the Project was previously provided in Table 4-2.

4.5.4 Downwash

The US EPA Building Profile Input Program (BPIP) model was used to estimate building downwash effects based on stack and platform information provided by Husky. The results of BPIP were then imported into CALPUFF. BPIP input information was not available for all facilities (i.e Hiberia, Terra Nova, SeaRose, Hebron).

The latest version of BPIP incorporated into CALPUFF allows for non-solid spaces underneath platform structures, when running the ISC downwash method. This version therefore allows for a representative approximation of windflow around offshore platforms and was used in this study.

4.6 CALPOST

4.6.1 Overview

CALPOST is the CALPUFF postprocessor designed to report concentration or wet/dry deposition flux results based on the hourly data contained in the CALPUFF output file. CALPOST Version 6.292 – Level 110406 was used to process the output file from the CALPUFF runs.

Table 4-4 Cumulative Emissions Data (Scenarios 4 and 5)

Source	Source Location		Stack Height (m)	Stack Diameter (m)	Stack Gas Exit Velocity (m/s)	Stack Gas Exit Temp. (K)	NO_X Emission Rate (g/s)	CO Emission Rate (g/s)	SO_2 Emission Rate (g/s)	TPM Emission Rate (g/s)	PM_{10} Emission Rate (g/s)	$PM_{2.5}$ Emission Rate (g/s)
	UTM X	UTM Y										
SeaRose FSPO	727,640	5,185,950	47	3	31.5	700	32.6	19.6	-	4.28	4.28	4.28
Hibernia	669,345	5,179,740	47	3	31.5	700	77.6	14.3	-	3.93	3.87	3.87
Terra Nova	693,516	5,149,900	47	3	31.5	700	63.8	21.8	-	6.63	6.60	6.63
Hebron	692,954	5,158,532	47	3	31.5	700	196.0	11.1	-	1.15	1.15	1.15

4.6.2 Post Processing

The contaminants and averaging periods modelled in this study are represented in Table 4-5.

Table 4-5 Contaminants Modelled and Averaging Periods

Air Contaminant	Averaging Period
TSP	1 hour, 24 hour, annual
PM_{10}	1 hour, 24 hour
$PM_{2.5}$	1 hour, 24 hour
NO_2	1 hour, 24 hour, annual
CO	1 hour, 8 hour
SO_2	1 hour, 3 hour, 24 hour, annual

4.6.3 Nitrogen Oxide to Nitrogen Dioxide Conversion

Nitrogen oxides (NO_X) are produced in most combustion processes, and almost entirely made up of nitric oxide (NO) and NO_2. These are both emitted in combustion processes and together, they are often referred to as nitrogen oxides. Only NO_2 is a CAC and regulated. NO, the dominant form at the stack, converts to NO_2 by oxidation in the atmosphere. The oxidation of NO to form NO_2 in the free atmosphere is a complex reaction, but is most directly accomplished by the reaction with ozone.

Dispersion modelling studies sometimes conservatively assume that all NO_X being emitted from a source is converted into NO_2. This approach is very conservative, as only a portion of the NO_X actually converts to NO_2. However, for this study, as the predicted NO_X concentrations are relatively low, the conservative assumption of complete conversion of NO_X to NO_2 was made.

5.0 DISPERSION MODELLING RESULTS

5.1 Normal Operation – Wellhead Platform

The maximum predicted 1-hour ground level concentrations at each of the three discrete installations for CO, NO_2, SO_2, TPM, PM_{10} and $PM_{2.5}$ during normal operation of the proposed WHP are listed in Table 5-1.

Table 5-1 Maximum Predicted 1-Hour Ground Level Concentrations under Normal Wellhead Platform Operation

Receptor	UTM		CO (µg/m^3)	NO_2 (µg/m^3)	SO_2 (µg/m^3)	TPM (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)
	Easting (m)	Northing (m)						
White Rose	727708	5186021	1.7	7.5	0.10	0.15	0.14	0.13
Hibernia	669419	5179807	0.17	0.68	0.01	0.014	0.013	0.012
Terra Nova	693372	5149964	0.18	0.78	0.01	0.016	0.0148	0.014
NL Regulatory Limit	-	-	35,000	400	900	-	-	-

The maximum predicted 3-hour ground level concentrations at each of the three discrete installations for SO_2 during normal operation of the proposed WHP is listed in Table 5-2.

Table 5-2 Maximum Predicted 3Hour Ground Level Concentrations for Normal Wellhead Platform Operation

Receptor	UTM		SO_2 (µg/m^3)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	0.10
Hibernia	669419	5179807	0.007
Terra Nova	693372	5149964	0.005
NL Regulatory Limit	-	-	600

The maximum predicted 8-hour ground level concentrations at each of the three discrete installations for CO during normal operation of the proposed WHP is shown in Table 5-3.

Table 5-3 Maximum Predicted 8-Hour Ground Level Concentrations under Normal Wellhead Platform Operation

Receptor	UTM		CO (µg/m^3)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	1.47
Hibernia	669419	5179807	0.083
Terra Nova	693372	5149964	0.069
NL Regulatory Limit	-	-	15,000

The maximum predicted 24-hour ground level concentrations at each of the three discrete installations for NO_2, SO_2, TPM, PM_{10} and $PM_{2.5}$ during normal operation of the proposed WHP are listed in Table 5-4.

Table 5-4 Maximum Predicted 24-Hour Ground Level Concentrations under Normal Wellhead Platform Operation

Receptor	UTM		NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
	Easting (m)	Northing (m)					
White Rose	727708	5186021	0.70	0.052	0.073	0.070	0.066
Hibernia	669419	5179807	0.11	0.002	0.002	0.002	0.002
Terra Nova	693372	5149964	0.17	0.002	0.003	0.003	0.003
NL Regulatory Limit	-	-	200	300	120	50	25

The maximum predicted annual ground level concentrations at each of the three discrete installations for NO_2, SO_2 and TPM during normal operation of the proposed WHP are shown in Table 5-5.

Table 5-5 Maximum Predicted Annual Ground Level Concentrations under Normal Wellhead Platform Operation

Receptor	UTM		NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)
	Easting (m)	Northing (m)			
White Rose	727708	5186021	0.20	0.003	0.004
Hibernia	669419	5179807	0.004	0.0001	0.0001
Terra Nova	693372	5149964	0.005	0.0001	0.0001
NL Regulatory Limit	-	-	100	60	60

5.2 Normal Operation Mobile Offshore Drilling Unit

The maximum predicted 1-hour ground level concentrations at each of the three discrete installations for CO, NO_2 and SO_2 during normal operation of the MODU are listed in Table 5-6.

Table 5-6 Maximum Predicted 1-Hour Ground Level Concentrations under Normal Mobile Offshore Drilling Unit Operation

Receptor	UTM		CO ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
	Easting (m)	Northing (m)						
White Rose	727708	5186021	6.5	24.5	1.26	0.56	0.45	0.39
Hibernia	669419	5179807	0.21	0.81	0.042	0.02	0.01	0.01
Terra Nova	693372	5149964	0.30	1.12	0.058	0.03	0.02	0.02
NL Regulatory Limit	-	-	35,000	400	900	-	-	-

The maximum predicted 3-hour ground level concentrations at each of the three discrete installations for SO_2 during normal MODU operation is listed in Table 5-7.

Table 5-7 Maximum Predicted 3-Hour Ground Level Concentrations for Normal Mobile Offshore Drilling Unit Operation

Receptor	UTM		SO_2 (µg/m^3)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	0.98
Hibernia	669419	5179807	0.026
Terra Nova	693372	5149964	0.049
NL Regulatory Limit	-	-	600

The maximum predicted 8-hour ground level concentrations at each of the three discrete installations for CO during normal MODU operation is shown in Table 5-8.

Table 5-8 Maximum Predicted 8-Hour Ground Level Concentrations under Normal Mobile Offshore Drilling Unit Operation

Receptor	UTM		CO (µg/m^3)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	3.8
Hibernia	669419	5179807	0.072
Terra Nova	693372	5149964	0.14
NL Regulatory Limit	-	-	15,000

The maximum predicted 24-hour ground level concentrations at each of the three discrete installations for NO_2 and SO_2 during normal MODU operation are listed in Table 5-9.

Table 5-9 Maximum Predicted 24-Hour Ground Level Concentrations under Normal Mobile Offshore Drilling Unit Operation

Receptor	UTM		NO_2 (µg/m^3)	SO2 (µg/m^3)	TPM (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)
	Easting (m)	Northing (m)					
White Rose	727708	5186021	8.1	0.42	0.18	0.15	0.13
Hibernia	669419	5179807	0.16	0.008	0.004	0.003	0.003
Terra Nova	693372	5149964	0.27	0.014	0.006	0.005	0.004
NL Regulatory Limit	-	-	200	300	120	50	25

The maximum predicted annual ground level concentrations at each of the three discrete installations for NO_2 and SO_2 during normal MODU operation are shown in Table 5-10.

Table 5-10 Maximum Predicted Annual Ground Level Concentrations under Normal Mobile Offshore Drilling Unit Operation

Receptor	UTM		NO_2 (µg/m^3)	TPM (µg/m^3)	SO2 (µg/m^3)
	Easting (m)	Northing (m)			
White Rose	727708	5186021	0.57	0.013	0.029
Hibernia	669419	5179807	0.005	0.0001	0.0003
Terra Nova	693372	5149964	0.009	0.0002	0.0005
NL Regulatory Limit	-	-	100	60	60

5.3 Wellhead Blowdown

The maximum predicted 1-hour ground level concentrations at each of the three discrete installations for CO, NO_2, SO_2, TPM, PM_{10} and $PM_{2.5}$ during a wellhead blowdown of the proposed WHP are included in Table 5-11.

Table 5-11 Maximum Predicted 1-Hour Ground Level Concentrations for a Blowdown

Receptor	UTM		CO ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
	Easting (m)	Northing (m)						
White Rose	727708	5186021	1.7	7.5	0.10	0.15	0.14	0.13
Hibernia	669419	5179807	0.15	0.68	0.0096	0.014	0.013	0.012
Terra Nova	693372	5149964	0.18	0.78	0.011	0.016	0.015	0.014
NL Regulatory Limit	-	-	35,000	400	900	-	-	-

The maximum predicted 3-hour ground level concentrations at each of the three discrete installations for SO_2 during a wellhead blowdown of the proposed WHP are listed in Table 5-12.

Table 5-12 Maximum Predicted 3-Hour Ground Level Concentrations for a Blowdown

Receptor	UTM		SO_2 ($\mu g/m^3$)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	0.10
Hibernia	669419	5179807	0.007
Terra Nova	693372	5149964	0.005
NL Regulatory Limit	-	-	600

The maximum predicted 8-hour ground level concentrations at each of the three discrete installations for CO during a wellhead blowdown of the proposed WHP are shown in Table 5-13.

Table 5-13 Maximum Predicted 8-Hour Ground Level Concentrations for a Blowdown

Receptor	UTM		CO ($\mu g/m^3$)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	1.5
Hibernia	669419	5179807	0.07
Terra Nova	693372	5149964	0.059
NL Regulatory Limit	-	-	15,000

The maximum predicted 24-hour ground level concentrations at each of the three discrete installations for NO_2, SO_2, TPM, PM_{10} and $PM_{2.5}$ during a wellhead blowdown of the proposed WHP are in Table 5-14.

Table 5-14 Maximum Predicted 24-hour Ground Level Concentrations for a Blowdown

Receptor	UTM		NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
	Easting (m)	Northing (m)					
White Rose	727708	5186021	3.7	0.052	0.073	0.070	0.065
Hibernia	669419	5179807	0.10	0.002	0.002	0.002	0.002
Terra Nova	693372	5149964	0.16	0.002	0.003	0.003	0.003
NL Regulatory Limit	-	-	200	300	120	50	25

The maximum predicted annual ground level concentration at each of the three discrete installations for NO_2,, SO_2 and TPM during a wellhead blowdown of the proposed WHP are listed in Table 5-15.

Table 5-15 Maximum Predicted Annual Ground Level Concentrations for a Blowdown

Receptor	UTM		NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)
	Easting (m)	Northing (m)			
White Rose	727708	5186021	0.20	0.003	0.004
Hibernia	669419	5179807	0.004	0.0001	0.0001
Terra Nova	693372	5149964	0.005	0.0001	0.0001
NL Regulatory Limit	-	-	100	60	60

5.4 Cumulative Effects – Normal Operation of the Wellhead Platform

The maximum predicted 1-hour ground level concentrations at each of the three discrete installations for CO, NO_2, SO_2, TPM, PM_{10} and $PM_{2.5}$ for the cumulative WHP operation are shown in Table 5-16.

Table 5-16 Maximum Predicted 1-Hour Ground Level Concentrations for Cumulative WHP Operation

Receptor	UTM		CO ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
	Easting (m)	Northing (m)						
White Rose	727708	5186021	1.83	12.8	0.10	0.50	0.50	0.49
Hibernia	669419	5179807	3.1	15.0	0.01	0.69	0.69	0.69
Terra Nova	693372	5149964	1.9	34.3	0.01	0.37	0.37	0.37
NL Regulatory Limit	-	-	35,000	400	900	-	-	-

The maximum predicted 3-hour ground level concentrations at each of the three discrete installations for SO_2 for the cumulative WHP operation are listed in Table 5-17.

Table 5-17 Maximum Predicted 3-Hour Ground Level Concentrations for Cumulative Wellhead Platform Operation

Receptor	UTM		SO_2 ($\mu g/m^3$)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	0.10
Hibernia	669419	5179807	0.007
Terra Nova	693372	5149964	0.005
NL Regulatory Limit	-	-	600

The maximum predicted 8-hour ground level concentrations at each of the three discrete receptors for CO for the cumulative operational scenario are included in Table 5-18.

Table 5-18 Maximum Predicted 8-Hour Ground Level Concentrations for Cumulative Operation

Receptor	UTM		CO ($\mu g/m^3$)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	1.5
Hibernia	669419	5179807	0.71
Terra Nova	693372	5149964	1.43
NL Regulatory Limit	-	-	15,000

The maximum predicted 24-hour ground level concentrations at each of the three discrete installations for NO_2, SO_2, TPM, PM_{10} and $PM_{2.5}$ for the cumulative WHP operation scenario are shown in Table 5-19.

Table 5-19 Maximum Predicted 24-Hour Ground Level Concentrations for Cumulative Wellhead Platform Operation

Receptor	UTM		NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
	Easting (m)	Northing (m)					
White Rose	727708	5186021	4.8	0.052	0.073	0.070	0.067
Hibernia	669419	5179807	3.9	0.002	0.068	0.068	0.068
Terra Nova	693372	5149964	18.0	0.002	0.11	0.11	0.11
NL Regulatory Limit	-	-	200	300	120	50	25

The maximum predicted annual ground level concentrations at each of the three discrete installations for NO_2, SO_2 and TPM for the cumulative WHP operation are listed in Table 5-20.

Table 5-20 Maximum Predicted Annual Ground Level Concentrations for Cumulative Wellhead Platform Operation

Receptor	UTM		NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)
	Easting (m)	Northing (m)			
White Rose	727708	5186021	0.50	0.0028	0.013
Hibernia	669419	5179807	0.15	0.0001	0.005
Terra Nova	693372	5149964	0.54	0.0001	0.01
NL Regulatory Limit	-	-	100	60	60

5.5 Cumulative Effects – Normal Operation of the Mobile Offshore Drilling Unit

The maximum predicted 1-hour ground level concentrations at each of the three discrete installations for CO, NO_2 and SO_2 for the cumulative operation of the MODU are shown in Table 5-21.

Table 5-21 Maximum Predicted 1-Hour Ground Level Concentrations for Cumulative Mobile Offshore Drilling Unit Operation

Receptor	UTM		CO ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
	Easting (m)	Northing (m)						
White Rose	727708	5186021	6.23	23.6	1.59	0.57	0.50	0.49
Hibernia	669419	5179807	3.14	15.0	0.056	0.69	0.69	0.69
Terra Nova	693372	5149964	1.94	34.3	0.076	0.37	0.37	0.37
NL Regulatory Limit	-	-	35,000	400	900	-	-	-

The maximum predicted 3-hour ground level concentrations at each of the three discrete installations for SO_2 for the cumulative MODU operation are listed in Table 5-22.

Table 5-22 Maximum Predicted 3-Hour Ground Level Concentrations for Cumulative Mobile Offshore Drilling Unit Operation

Receptor	UTM		SO_2 ($\mu g/m^3$)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	1.2
Hibernia	669419	5179807	0.034
Terra Nova	693372	5149964	0.065
NL Regulatory Limit	-	-	600

The maximum predicted 8-hour ground level concentrations at each of the three discrete installations for CO for the cumulative MODU operation are included in Table 5-23.

Table 5-23 Maximum Predicted 8-Hour Ground Level Concentrations for Cumulative Mobile Offshore Drilling Unit Operation

Receptor	UTM		CO ($\mu g/m^3$)
	Easting (m)	Northing (m)	
White Rose	727708	5186021	3.7
Hibernia	669419	5179807	0.70
Terra Nova	693372	5149964	1.4
NL Regulatory Limit	-	-	15,000

The maximum predicted 24-hour ground level concentrations at each of the three discrete installations for NO_2 and SO_2 for the cumulative MODU operation are shown in Table 5-24.

Table 5-24 Maximum Predicted 24-Hour Ground Level Concentrations for Cumulative Mobile Offshore Drilling Unit Operation

Receptor	UTM		NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	TPM ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
	Easting (m)	Northing (m)					
White Rose	727708	5186021	8.0	0.54	0.18	0.15	0.13
Hibernia	669419	5179807	3.9	0.011	0.07	0.07	0.07
Terra Nova	693372	5149964	18.1	0.018	0.11	0.11	0.11
NL Regulatory Limit	-	-	200	300	120	50	25

The maximum predicted annual ground level concentrations at each of the three discrete installations for NO_2 and SO_2 for the cumulative MODU operation are listed in Table 5-25.

Table 5-25 Maximum Predicted Annual Ground Level Concentrations for Cumulative Mobile Offshore Drilling Unit Operation

Receptor	UTM		NO_2 (µg/m^3)	TPM (µg/m^3)	SO_2 (µg/m^3)
	Easting (m)	Northing (m)			
White Rose	727708	5186021	0.85	0.021	0.037
Hibernia	669419	5179807	0.15	0.005	0.0004
Terra Nova	693372	5149964	0.54	0.010	0.0006
NL Regulatory Limit	-	-	100	60	60

Concentration maps for NO_2 for each time period for each modelling scenario are provided in Appendix B.

The cumulative effects analysis may be underestimated as downwash may be present in the other platforms, as is evident in the concentration mapping for the proposed WHP. If the downwash is of a comparable amount, then the cumulative effect due to the operation of the proposed WREP with the existing and planned platforms would likely still meet the Newfoundland and Labrador *Air Pollution Control Regulations* and NAAQ Objectives.

5.6 Greenhouse Gas Emissions (Wellhead Platform and Subsea Drill Centre)

A summary of the estimated GHGs during the operation of the proposed WHP and MODU are provided in Table 5-26.

Table 5-26 Estimated Greenhouse Gas Emissions for Operation

Activity	CO_2 (t/yr)	CH_4 (t/yr)	N_20 (t/yr)	$CO2_{eq}$ (tonnes/year)
Option 1 - WHP				
Operation of Support Vessel	47,485	-	-	47,485
Operation of Helicopters	403	0.01	0.04	416
Power Generation	89,645	6.52	2.27	90,486
Normal Operations - Flaring	11,139	0.01	0.01	11,142
TOTAL	**148,672**	**6.54**	**2.32**	**149,529**
Option 2 – MODU				
MODU	**14,800**	**0.83**	**1.01**	**15,132**

A comparison of the estimated GHG emissions for the operation of the WHP and MODU, and the emissions from the other platforms in operation as reported to Environment Canada for the 2010 reporting year, is provided in Table 5-27. These include the Terra Nova, Hibernia and *Sea Rose FPSO* platforms.

Table 5-27 2010 Greenhouse Gas Emissions Data by Platform

Facility	GHG Emissions (tonnesCO_{2eq}/year)			
	CO_2	CH_4	N_2O	Total
Terra $Nova_1$	569,634	22,976	11,616	604,227
Hibernia[1]	491,117	31,121	4,644	526,882
Sea Rose FPSO[1]	394,690	27,691	9,405	431,786
WHP Operation	148,672	137	719	149,529
MODU Operation	14,800	17.4	313	15,132
[1]Environment Canada 2012b				

As presented in Table 5-27, the emissions from the proposed WHP and the MODU are significantly less than the other platforms currently in operation.

6.0 SUMMARY

Generally the air emissions related to the operation of the proposed WREP (Options 1 and 2) would meet the NAAQ Objectives as well as the Newfoundland and Labrador *Air Pollution Control Regulations*.

7.0 CLOSING

This report has been prepared by Stantec Consulting Ltd. (Stantec) with the input and assistance of Husky Oil Operations Limited for the sole benefit of Husky. The report may not be relied upon by any other person, entity, other than for its intended purposes, without the express written consent of Stantec and Husky.

This report was undertaken exclusively for the purpose outlined herein and is limited to the scope and purpose specifically expressed in this report. This report cannot be used or applied under any circumstances to another location or situation or for any other purpose without further evaluation of the data and related limitations. Any use of this report by a third party, or any reliance on decisions made based upon it, are the responsibility of such third parties. Stantec accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

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This report presents the best professional judgment of Stantec personnel available at the time of its preparation. Stantec reserves the right to modify the contents of this report, in whole or in part, to reflect any new information that becomes available. If any conditions become apparent that differ substantially from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

8.0 REFERENCES

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9.0 ACRONYMS

Term	Description
BPIP	Building Profile Input Program
Btu/scf	British thermal units per standard cubic feet
CAC	Criteria Air Contaminants
CGS	Concrete gravity structure
CH_4	Methane
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CO	Carbon monoxide
CO_2	Carbon dioxide
FEED	Front End Engineering Design
FPSO	Floating production, storage and offloading facility
GHG	Greenhouse gas
hr	hour
H_2S	Hydrogen sulphide
Hp	Horsepower
Kw	Kilowatt
m/s	metres per second
MW	Megawatt
N_2O	Nitrous oxide
NAAQ	National Ambient Air Quality
NLDEC	Newfoundland and Labrador Department of Environment and Conservation
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
PM_{10}	Particulate matter less than 10 microns in diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
s	seconds
SO_2	Sulphur dioxide
THC	Total hydrocarbons
TSP	Total suspended particulate matter
US EPA	United States Environmental Protection Agency
VOC	Volatile organic compounds
WHP	Wellhead platform
WREP	White Rose Extension Project

APPENDIX A

CALPUFF Input Files

```
                                  1_CALMET_operation.INP
CALMET.INP      2.1              Hour Start and End Times with Seconds
MM5 Data for Offshore NL


---------------- Run title (3 lines) ------------------------------------------

                    CALMET MODEL CONTROL FILE
                    -------------------------

--------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names


Subgroup (a)
------------
Default Name  Type           File Name
------------  ----           ---------
GEO.DAT       input    ! GEODAT = operationnoship_geo\GEO.DAT !
SURF.DAT      input    ! SRFDAT = operationnoship_met\SURF.DAT !
CLOUD.DAT     input    * CLDDAT = *
PRECIP.DAT    input    ! PRCDAT = operationnoship_met\PRECIP.DAT !
WT.DAT        input    * WTDAT = *

CALMET.LST    output   ! METLST = CALMET.LST !
CALMET.DAT    output   ! METDAT = CALMET.DAT !
PACOUT.DAT    output   * PACDAT = *

All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = F !
         F = UPPER CASE

NUMBER OF UPPER AIR & OVERWATER STATIONS:

    Number of upper air stations (NUSTA)  No default     ! NUSTA = 0 !
    Number of overwater met stations
                                  (NOWSTA) No default     ! NOWSTA = 0 !

NUMBER OF PROGNOSTIC and IGF-CALMET FILEs:

    Number of MM4/MM5/3D.DAT files
                                  (NM3D) No default       ! NM3D = 12 !

    Number of IGF-CALMET.DAT files
                                  (NIGF)   No default     ! NIGF = 0 !

                       !END!
--------------------------------------------------------------------------------
Subgroup (b)
--------------------------------
Upper air files (one per station)
--------------------------------
Default Name  Type       File Name
------------  ----       ---------

--------------------------------------------------------------------------------
Subgroup (c)
-----------------------------------------
Overwater station files (one per station)
-----------------------------------------
Default Name  Type       File Name
------------  ----       ---------
```

```
------------------------------------------------------------------------------
Subgroup (d)
------------------------------------------------
MM4/MM5/3D.DAT files (consecutive or overlapping)
------------------------------------------------
Default Name  Type       File Name
------------  ----       ---------
MM41.DAT     input   1  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_jan.m3d!    !END!
MM42.DAT     input   2  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_feb.m3d!    !END!
MM43.DAT     input   3  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_march.m3d!    !END!
MM44.DAT     input   4  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_april.m3d!    !END!
MM45.DAT     input   5  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_may.m3d!    !END!
MM46.DAT     input   6  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_june.m3d!    !END!
MM47.DAT     input   7  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_july.m3d!    !END!
MM48.DAT     input   8  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_aug.m3d!    !END!
MM49.DAT     input   9  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_sept.m3d!    !END!
MM410.DAT     input   10  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_oct.m3d!    !END!
MM411.DAT     input   11  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_nov.m3d!    !END!
MM412.DAT     input   12  ! M3DDAT=..\..\METDAT~1\TILESN~1\NL_dec.m3d!    !END!

------------------------------------------------------------------------------
Subgroup (e)
------------------------------------------------
IGF-CALMET.DAT files (consecutive or overlapping)
------------------------------------------------
Default Name  Type       File Name
------------  ----       ---------
* IGFDATFILES = *
------------------------------------------------------------------------------
Subgroup (f)
----------------
Other file names
----------------

Default Name  Type       File Name
------------  ----       ---------
DIAG.DAT      input      * DIADAT = *
PROG.DAT      input      * PRGDAT = *

TEST.PRT      output     * TSTPRT = *
TEST.OUT      output     * TSTOUT = *
TEST.KIN      output     * TSTKIN = *
TEST.FRD      output     * TSTFRD = *
TEST.SLP      output     * TSTSLP = *
DCST.GRD      output     * DCSTGD = *

------------------------------------------------------------------------------
NOTES: (1) File/path names can be up to 70 characters in length
       (2) Subgroups (a) and (f) must have ONE 'END' (surrounded by
           delimiters) at the end of the group
       (3) Subgroups (b) through (e) are included ONLY if the corresponding
           number of files (NUSTA, NOWSTA, NM3D, NIGF) is not 0, and each must have
           an 'END' (surround by delimiters) at the end of EACH LINE

                          !END!


------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------
```

```
                          1_CALMET_operation.INP
Starting date:    Year   (IBYR)  --    No default   ! IBYR = 2005 !
                  Month  (IBMO)  --    No default   ! IBMO = 12 !
                  Day    (IBDY)  --    No default   ! IBDY = 30 !
Starting time:    Hour   (IBHR)  --    No default   ! IBHR = 0 !
                  Second (IBSEC) --    No default   ! IBSEC = 0 !

Ending date:      Year   (IEYR)  --    No default   ! IEYR = 2006 !
                  Month  (IEMO)  --    No default   ! IEMO = 12 !
                  Day    (IEDY)  --    No default   ! IEDY = 31 !
Ending time:      Hour   (IEHR)  --    No default   ! IEHR = 20 !
                  Second (IESEC) --    No default   ! IESEC = 0 !

 UTC time zone         (ABTZ) -- No default       ! ABTZ = UTC-0300 !
    (character*8)
    PST = UTC-0800, MST = UTC-0700 , GMT = UTC-0000
    CST = UTC-0600, EST = UTC-0500

Length of modeling time-step (seconds)
Must divide evenly into 3600 (1 hour)
(NSECDT)                          Default:3600     ! NSECDT = 3600 !
                                  Units: seconds

Run type            (IRTYPE) -- Default: 1       ! IRTYPE = 1 !

   0 = Computes wind fields only
   1 = Computes wind fields and micrometeorological variables
       (u*, w*, L, zi, etc.)
   (IRTYPE must be 1 to run CALPUFF or CALGRID)

Compute special data fields required
by CALGRID (i.e., 3-D fields of W wind
components and temperature)
in additional to regular            Default: T    ! LCALGRD = T !
fields ? (LCALGRD)
(LCALGRD must be T to run CALGRID)

 Flag to stop run after
 SETUP phase (ITEST)              Default: 2       ! ITEST = 2 !
 (Used to allow checking
 of the model inputs, files, etc.)
 ITEST = 1 - STOPS program after SETUP phase
 ITEST = 2 - Continues with execution of
             COMPUTATIONAL phase after SETUP


Test options specified to see if
they conform to regulatory
values? (MREG)                    No Default        ! MREG = 0 !

   0 = NO checks are made
   1 = Technical options must conform to USEPA guidance
             IMIXH    -1       Maul-Carson convective mixing height
                               over land; OCD mixing height overwater
             ICOARE   0        OCD deltaT method for overwater fluxes
             THRESHL  0.0      Threshold buoyancy flux over land needed
                               to sustain convective mixing height growth
             ISURFT   > 0      Pick one representative station, OR
                      -2       in NOOBS mode (ITPROG=2) average all
                               surface prognostic temperatures to get
                               a single representative surface temp.
             IUPT     > 0      Pick one representative station, OR
                      -2       in NOOBS mode (ITPROG>0) average all surface
                               prognostic temperatures to get a single
```

```
!END!

--------------------------------------------------------------------------------

INPUT GROUP: 2 -- Map Projection and Grid control parameters
--------------

     Projection for all (X,Y):
     -------------------------

     Map projection
     (PMAP)                    Default: UTM    ! PMAP = UTM !

         UTM :  Universal Transverse Mercator
         TTM :  Tangential Transverse Mercator
         LCC :  Lambert Conformal Conic
          PS :  Polar Stereographic
          EM :  Equatorial Mercator
        LAZA :  Lambert Azimuthal Equal Area

     False Easting and Northing (km) at the projection origin
     (Used only if PMAP= TTM, LCC, or LAZA)
     (FEAST)                   Default=0.0     ! FEAST = 0 !
     (FNORTH)                  Default=0.0     ! FNORTH = 0 !

     UTM zone (1 to 60)
     (Used only if PMAP=UTM)
     (IUTMZN)                  No Default      ! IUTMZN = 22 !

     Hemisphere for UTM projection?
     (Used only if PMAP=UTM)
     (UTMHEM)                  Default: N      ! UTMHEM = N !
         N   :  Northern hemisphere projection
         S   :  Southern hemisphere projection

     Latitude and Longitude (decimal degrees) of projection origin
     (Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
     (RLAT0)                   No Default      ! RLAT0 = 0.00N !
     (RLON0)                   No Default      ! RLON0 = 0.00E !

         TTM :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         LCC :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         PS  :  RLON0 identifies central (grid N/S) meridian of projection
                RLAT0 selected for convenience
         EM  :  RLON0 identifies central meridian of projection
                RLAT0 is REPLACED by 0.0N (Equator)
         LAZA:  RLON0 identifies longitude of tangent-point of mapping plane
                RLAT0 identifies latitude of tangent-point of mapping plane

     Matching parallel(s) of latitude (decimal degrees) for projection
     (Used only if PMAP= LCC or PS)
     (XLAT1)                   No Default      ! XLAT1 = 30.00N !
     (XLAT2)                   No Default      ! XLAT2 = 60.00N !

         LCC :  Projection cone slices through Earth's surface at XLAT1 and XLAT2
         PS  :  Projection plane slices through Earth at XLAT1
                (XLAT2 is not used)

     ----------
```

Note: Latitudes and longitudes should be positive, and include a letter N,S,E, or W indicating north or south latitude, and east or west longitude. For example,
35.9 N Latitude = 35.9N
118.7 E Longitude = 118.7E

Datum-region

The Datum-Region for the coordinates is identified by a character string. Many mapping products currently available use the model of the Earth known as the World Geodetic System 1984 (WGS-84). Other local models may be in use, and their selection in CALMET will make its output consistent with local mapping products. The list of Datum-Regions with official transformation parameters is provided by the National Imagery and Mapping Agency (NIMA).

NIMA Datum - Regions(Examples)

WGS-84	WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
NAS-C	NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
NAR-C	NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
NWS-84	NWS 6370KM Radius, Sphere
ESR-S	ESRI REFERENCE 6371KM Radius, Sphere

Datum-region for output coordinates
(DATUM) Default: WGS-84 ! DATUM = WGS-84 !

Horizontal grid definition:

Rectangular grid defined for projection PMAP,
with X the Easting and Y the Northing coordinate

No. X grid cells (NX) No default ! NX = 85 !
No. Y grid cells (NY) No default ! NY = 85 !

Grid spacing (DGRIDKM) No default ! DGRIDKM = 1 !
Units: km

Reference grid coordinate of
SOUTHWEST corner of grid cell (1,1)

X coordinate (XORIGKM) No default ! XORIGKM = 658.6500 !
Y coordinate (YORIGKM) No default ! YORIGKM = 5139.6660 !
Units: km

Vertical grid definition:

No. of vertical layers (NZ) No default ! NZ = 10 !

Cell face heights in arbitrary
vertical grid (ZFACE(NZ+1)) No defaults
Units: m

! ZFACE =
0.00,20.00,40.00,80.00,160.00,320.00,640.00,1200.00,2000.00,3000.00,4000.00 !

!END!

```
--------------------------------------------------------------------------------

INPUT GROUP: 3 -- Output Options
--------------


    DISK OUTPUT OPTION

       Save met. fields in an unformatted
       output file ?              (LSAVE)  Default: T     ! LSAVE = T !
       (F = Do not save, T = Save)

       Type of unformatted output file:
       (IFORMO)                            Default: 1    ! IFORMO = 1 !

            1 = CALPUFF/CALGRID type file (CALMET.DAT)
            2 = MESOPUFF-II type file     (PACOUT.DAT)


    LINE PRINTER OUTPUT OPTIONS:

       Print met. fields ?  (LPRINT)       Default: F     ! LPRINT = F !
       (F = Do not print, T = Print)
       (NOTE: parameters below control which
              met. variables are printed)

       Print interval
       (IPRINF) in hours                   Default: 1     ! IPRINF = 1 !
       (Meteorological fields are printed
        every  6  hours)


       Specify which layers of U, V wind component
       to print (IUVOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T)        Defaults: NZ*0
       * IUVOUT = *
       ------------------------


       Specify which levels of the W wind component to print
       (NOTE: W defined at TOP cell face --  6  values)
       (IWOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T & LCALGRD=T)
       -----------------------------------
                                           Defaults: NZ*0
        * IWOUT = *


       Specify which levels of the 3-D temperature field to print
       (ITOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T & LCALGRD=T)
       -----------------------------------
                                           Defaults: NZ*0
        * ITOUT = *

       Specify which meteorological fields
       to print
       (used only if LPRINT=T)             Defaults: 0 (all variables)
       -----------------------
```

```
   Variable            Print ?
                     (0 = do not print,
                      1 = print)
   --------          ----------------

! STABILITY = 0 ! - PGT stability class
! USTAR = 0 ! - Friction velocity
! MONIN = 0 ! - Monin-Obukhov length
! MIXHT = 0 ! - Mixing height
! WSTAR = 0 ! - Convective velocity scale
! PRECIP = 0 ! - Precipitation rate
! SENSHEAT = 0 ! - Sensible heat flux
! CONVZI = 0 ! - Convective mixing ht.


 Testing and debug print options for micrometeorological module

    Print input meteorological data and
    internal variables (LDB)          Default: F       ! LDB = F !
    (F = Do not print, T = print)
    (NOTE: this option produces large amounts of output)

    First time step for which debug data
    are printed (NN1)                 Default: 1       ! NN1 = 1 !

    Last time step for which debug data
    are printed (NN2)                 Default: 1       ! NN2 = 1 !

    Print distance to land
    internal variables (LDBCST)       Default: F       ! LDBCST = F !
    (F = Do not print, T = print)
    (Output in .GRD file DCST.GRD, defined in input group 0)

 Testing and debug print options for wind field module
 (all of the following print options control output to
  wind field module's output files: TEST.PRT, TEST.OUT,
  TEST.KIN, TEST.FRD, and TEST.SLP)

    Control variable for writing the test/debug
    wind fields to disk files (IOUTD)
    (0=Do not write, 1=write)         Default: 0       ! IOUTD = 0 !

    Number of levels, starting at the surface,
    to print (NZPRN2)                 Default: 1       ! NZPRN2 = 1 !

    Print the INTERPOLATED wind components ?
    (IPR0) (0=no, 1=yes)              Default: 0       ! IPR0 = 0 !

    Print the TERRAIN ADJUSTED surface wind
    components ?
    (IPR1) (0=no, 1=yes)              Default: 0       ! IPR1 = 0 !

    Print the SMOOTHED wind components and
    the INITIAL DIVERGENCE fields ?
    (IPR2) (0=no, 1=yes)              Default: 0       ! IPR2 = 0 !

    Print the FINAL wind speed and direction
    fields ?
    (IPR3) (0=no, 1=yes)              Default: 0       ! IPR3 = 0 !

    Print the FINAL DIVERGENCE fields ?
```

```
        (IPR4) (0=no, 1=yes)              Default: 0       ! IPR4 = 0 !

        Print the winds after KINEMATIC effects
        are added ?
        (IPR5) (0=no, 1=yes)              Default: 0       ! IPR5 = 0 !

        Print the winds after the FROUDE NUMBER
        adjustment is made ?
        (IPR6) (0=no, 1=yes)              Default: 0       ! IPR6 = 0 !

        Print the winds after SLOPE FLOWS
        are added ?
        (IPR7) (0=no, 1=yes)              Default: 0       ! IPR7 = 0 !

        Print the FINAL wind field components ?
        (IPR8) (0=no, 1=yes)              Default: 0       ! IPR8 = 0 !

!END!


-------------------------------------------------------------------------------

INPUT GROUP: 4 -- Meteorological data options
--------------

    NO OBSERVATION MODE              (NOOBS)  Default: 0     ! NOOBS = 2 !
          0 = Use surface, overwater, and upper air stations
          1 = Use surface and overwater stations (no upper air observations)
              Use MM4/MM5/3D.DAT for upper air data
          2 = No surface, overwater, or upper air observations
              Use MM4/MM5/3D.DAT for surface, overwater, and upper air data

    NUMBER OF SURFACE & PRECIP. METEOROLOGICAL STATIONS

       Number of surface stations   (NSSTA)  No default     ! NSSTA = 0 !

       Number of precipitation stations
       (NPSTA=-1: flag for use of MM5/3D.DAT precip data)
                                    (NPSTA)  No default     ! NPSTA = -1 !

    CLOUD DATA OPTIONS
       Gridded cloud fields:
                                  (ICLOUD)  Default: 0     ! ICLOUD = 3 !
       ICLOUD = 0 - Gridded clouds not used
       ICLOUD = 1 - Gridded CLOUD.DAT generated as OUTPUT
       ICLOUD = 2 - Gridded CLOUD.DAT read as INPUT
       ICLOUD = 3 - Gridded cloud cover from Prognostic Rel. Humidity
                    at 850mb (Teixera)
       ICLOUD = 4 - Gridded cloud cover from Prognostic Rel. Humidity
                    at all levels (MM5toGrads algorithm)

    FILE FORMATS

       Surface meteorological data file format
                                   (IFORMS)  Default: 2     ! IFORMS = 2 !
       (1 = unformatted (e.g., SMERGE output))
       (2 = formatted   (free-formatted user input))

       Precipitation data file format
                                   (IFORMP)  Default: 2     ! IFORMP = 2 !
       (1 = unformatted (e.g., PMERGE output))
       (2 = formatted   (free-formatted user input))
```

```
      Cloud data file format
                                (IFORMC)  Default: 2     ! IFORMC = 1 !
      (1 = unformatted - CALMET unformatted output)
      (2 = formatted   - free-formatted CALMET output or user input)

!END!


------------------------------------------------------------------------------

INPUT GROUP: 5 -- Wind Field Options and Parameters
--------------


    WIND FIELD MODEL OPTIONS
      Model selection variable (IWFCOD)     Default: 1      ! IWFCOD = 1 !
         0 = Objective analysis only
         1 = Diagnostic wind module

      Compute Froude number adjustment
      effects ? (IFRADJ)                    Default: 1      ! IFRADJ = 1 !
      (0 = NO, 1 = YES)

      Compute kinematic effects ? (IKINE)   Default: 0      ! IKINE = 0 !
      (0 = NO, 1 = YES)

      Use O'Brien procedure for adjustment
      of the vertical velocity ? (IOBR)     Default: 0      ! IOBR = 0 !
      (0 = NO, 1 = YES)

      Compute slope flow effects ? (ISLOPE) Default: 1      ! ISLOPE = 1 !
      (0 = NO, 1 = YES)

      Extrapolate surface wind observations
      to upper layers ? (IEXTRP)            Default: -4     ! IEXTRP = 1 !
      (1 = no extrapolation is done,
       2 = power law extrapolation used,
       3 = user input multiplicative factors
           for layers 2 - NZ used (see FEXTRP array)
       4 = similarity theory used
       -1, -2, -3, -4 = same as above except layer 1 data
           at upper air stations are ignored

      Extrapolate surface winds even
      if calm? (ICALM)                      Default: 0      ! ICALM = 0 !
      (0 = NO, 1 = YES)

      Layer-dependent biases modifying the weights of
      surface and upper air stations (BIAS(NZ))
        -1<=BIAS<=1
      Negative BIAS reduces the weight of upper air stations
        (e.g. BIAS=-0.1 reduces the weight of upper air stations
      by 10%; BIAS= -1, reduces their weight by 100 %)
      Positive BIAS reduces the weight of surface stations
        (e.g. BIAS= 0.2 reduces the weight of surface stations
      by 20%; BIAS=1 reduces their weight by 100%)
      Zero BIAS leaves weights unchanged (1/R**2 interpolation)
      Default: NZ*0
! BIAS = 0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0 !

      Minimum distance from nearest upper air station
      to surface station for which extrapolation
      of surface winds at surface station will be allowed
```

```
   (RMIN2: Set to -1 for IEXTRP = 4 or other situations
    where all surface stations should be extrapolated)
                                        Default: 4.    ! RMIN2 = 4 !

   Use gridded prognostic wind field model
   output fields as input to the diagnostic
   wind field model (IPROG)             Default: 0     ! IPROG = 14 !
   (0 = No, [IWFCOD = 0 or 1]
    1 = Yes, use CSUMM prog. winds as Step 1 field, [IWFCOD = 0]
    2 = Yes, use CSUMM prog. winds as initial guess field [IWFCOD = 1]
    3 = Yes, use winds from MM4.DAT file as Step 1 field [IWFCOD = 0]
    4 = Yes, use winds from MM4.DAT file as initial guess field [IWFCOD = 1]
    5 = Yes, use winds from MM4.DAT file as observations [IWFCOD = 1]
    13 = Yes, use winds from MM5/3D.DAT file as Step 1 field [IWFCOD = 0]
    14 = Yes, use winds from MM5/3D.DAT file as initial guess field [IWFCOD = 1]
    15 = Yes, use winds from MM5/3D.DAT file as observations [IWFCOD = 1]

   Timestep (seconds) of the prognostic
   model input data   (ISTEPPGS)        Default: 3600   ! ISTEPPGS = 3600 !


   Use coarse CALMET fields as initial guess fields (IGFMET)
   (overwrites IGF based on prognostic wind fields if any)
                                        Default: 0      ! IGFMET = 0 !

RADIUS OF INFLUENCE PARAMETERS

   Use varying radius of influence      Default: F      ! LVARY = F !
   (if no stations are found within RMAX1,RMAX2,
    or RMAX3, then the closest station will be used)

   Maximum radius of influence over land
   in the surface layer (RMAX1)         No default      ! RMAX1 = 0 !
                                        Units: km
   Maximum radius of influence over land
   aloft (RMAX2)                        No default      ! RMAX2 = 0 !
                                        Units: km
   Maximum radius of influence over water
   (RMAX3)                              No default      ! RMAX3 = 0 !
                                        Units: km


OTHER WIND FIELD INPUT PARAMETERS

   Minimum radius of influence used in
   the wind field interpolation (RMIN)  Default: 0.1    ! RMIN = 0.1 !
                                        Units: km
   Radius of influence of terrain
   features (TERRAD)                    No default      ! TERRAD = 40 !

                                        Units: km
   Relative weighting of the first
   guess field and observations in the
   SURFACE layer (R1)                   No default      ! R1 = 0 !
   (R1 is the distance from an          Units: km
   observational station at which the
   observation and first guess field are
   equally weighted)

   Relative weighting of the first
   guess field and observations in the
   layers ALOFT (R2)                    No default      ! R2 = 0 !
   (R2 is applied in the upper layers   Units: km
```

```
   in the same manner as R1 is used in
   the surface layer).

   Relative weighting parameter of the
   prognostic wind field data (RPROG)    No default      ! RPROG = 0 !
   (Used only if IPROG = 1)              Units: km
   ------------------------

   Maximum acceptable divergence in the
   divergence minimization procedure
   (DIVLIM)                              Default: 5.E-6  ! DIVLIM = 5E-6 !

   Maximum number of iterations in the
   divergence min. procedure (NITER)     Default: 50     ! NITER = 50 !

   Number of passes in the smoothing
   procedure (NSMTH(NZ))
   NOTE: NZ values must be entered
        Default: 2,(mxnz-1)*4 ! NSMTH = 2,9*4 !

   Maximum number of stations used in
   each layer for the interpolation of
   data to a grid point (NINTR2(NZ))
   NOTE: NZ values must be entered       Default: 99.    ! NINTR2 = 10*99 !

   Critical Froude number (CRITFN)       Default: 1.0    ! CRITFN = 1 !

   Empirical factor controlling the
   influence of kinematic effects
   (ALPHA)                               Default: 0.1    ! ALPHA = 0.1 !

   Multiplicative scaling factor for
   extrapolation of surface observations
   to upper layers (FEXTR2(NZ))          Default: NZ*0.0
   ! FEXTR2 = 10*0 !
   (Used only if IEXTRP = 3 or -3)


BARRIER INFORMATION

   Number of barriers to interpolation
   of the wind fields (NBAR)             Default: 0      ! NBAR = 0 !

   Level (1 to NZ) up to which barriers
   apply (KBAR)                          Default: NZ     ! KBAR = 10 !

   THE FOLLOWING 4 VARIABLES ARE INCLUDED
   ONLY IF NBAR > 0
   NOTE: NBAR values must be entered     No defaults
         for each variable               Units: km

      X coordinate of BEGINNING
      of each barrier (XBBAR(NBAR))      ! XBBAR =  !
      Y coordinate of BEGINNING
      of each barrier (YBBAR(NBAR))      ! YBBAR =  !

      X coordinate of ENDING
      of each barrier (XEBAR(NBAR))      ! XEBAR =  !
      Y coordinate of ENDING
      of each barrier (YEBAR(NBAR))      ! YEBAR =  !


DIAGNOSTIC MODULE DATA INPUT OPTIONS
```

```
Surface temperature (IDIOPT1)         Default: 0      ! IDIOPT1 = 0 !
   0 = Compute internally from
       hourly surface observations or prognostic fields
   1 = Read preprocessed values from
       a data file (DIAG.DAT)

   Surface met. station to use for
   the surface temperature (ISURFT)   Default: -1    ! ISURFT = -1 !
   (Must be a value from 1 to NSSTA,
    or -1 to use 2-D spatially varying
       surface temperatures,
    or -2 to use a domain-average prognostic
       surface temperatures (only with ITPROG=2))
   (Used only if IDIOPT1 = 0)
   -------------------------

Temperature lapse rate used in the    Default: 0     ! IDIOPT2 = 0 !
   computation of terrain-induced
   circulations (IDIOPT2)
   0 = Compute internally from (at least) twice-daily
       upper air observations or prognostic fields
   1 = Read hourly preprocessed values
       from a data file (DIAG.DAT)

   Upper air station to use for
   the domain-scale lapse rate (IUPT) Default: -1    ! IUPT = -1 !
   (Must be a value from 1 to NUSTA,
    or -1 to use 2-D spatially varying lapse rate,
    or -2 to use a domain-average prognostic
       lapse rate (only with ITPROG>0))
   (Used only if IDIOPT2 = 0)
   -------------------------

   Depth through which the domain-scale
   lapse rate is computed (ZUPT)      Default: 200.  ! ZUPT = 200 !
   (Used only if IDIOPT2 = 0)         Units: meters
   -------------------------

Initial Guess Field Winds
(IDIOPT3)                             Default: 0     ! IDIOPT3 = 0 !
   0 = Compute internally from
       observations or prognostic wind fields
   1 = Read hourly preprocessed domain-average wind values
       from a data file (DIAG.DAT)

   Upper air station to use for
   the initial guess winds (IUPWND)   Default: -1    ! IUPWND = -1 !
   (Must be a value from -1 to NUSTA, with
   -1 indicating 3-D initial guess fields,
   and IUPWND>1 domain-scaled (i.e. constant) IGF)
   (Used only if IDIOPT3 = 0 and noobs=0)
   -------------------------------------

   Bottom and top of layer through
   which the domain-scale winds
   are computed
   (ZUPWND(1), ZUPWND(2))        Defaults: 1., 1000. ! ZUPWND= 1.0, 1.00 !
   (Used only if IDIOPT3 = 0, NOOBS>0 and IUPWND>0)    Units: meters
   -------------------------

Observed surface wind components
for wind field module (IDIOPT4)  Default: 0     ! IDIOPT4 = 0 !
```

```
      0 = Read WS, WD from a surface
          data file (SURF.DAT)
      1 = Read hourly preprocessed U, V from
          a data file (DIAG.DAT)

   Observed upper air wind components
   for wind field module (IDIOPT5)  Default: 0     ! IDIOPT5 = 0 !
      0 = Read WS, WD from an upper
          air data file (UP1.DAT, UP2.DAT, etc.)
      1 = Read hourly preprocessed U, V from
          a data file (DIAG.DAT)

   LAKE BREEZE INFORMATION

      Use Lake Breeze Module  (LLBREZE)
                                      Default: F      ! LLBREZE = F !

       Number of lake breeze regions (NBOX)           ! NBOX = 0 !

    X Grid line 1 defining the region of interest
                                                      ! XG1 =  !
    X Grid line 2 defining the region of interest
                                                      ! XG2 =  !
    Y Grid line 1 defining the region of interest
                                                      ! YG1 =  !
    Y Grid line 2 defining the region of interest
                                                      ! YG2 =  !

     X Point defining the coastline (Straight line)
               (XBCST)  (KM)   Default: none    ! XBCST =  !

     Y Point defining the coastline (Straight line)
               (YBCST)  (KM)   Default: none    ! YBCST =  !

     X Point defining the coastline (Straight line)
               (XECST)  (KM)   Default: none    ! XECST =  !

     Y Point defining the coastline (Straight line)
               (YECST)  (KM)   Default: none    ! YECST =  !


   Number of stations in the region     Default: none ! NLB =  !
   (Surface stations + upper air stations)

   Station ID's  in the region   (METBXID(NLB))
   (Surface stations first, then upper air stations)
     ! METBXID =  !

!END!


------------------------------------------------------------------------------

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters
--------------

    EMPIRICAL MIXING HEIGHT CONSTANTS

      Neutral, mechanical equation
      (CONSTB)                          Default: 1.41   ! CONSTB = 1.41 !
      Convective mixing ht. equation
      (CONSTE)                          Default: 0.15   ! CONSTE = 0.15 !
      Stable mixing ht. equation
```

```
   (CONSTN)                            Default: 2400.   ! CONSTN = 2400 !
   Overwater mixing ht. equation
   (CONSTW)                            Default: 0.16    ! CONSTW = 0.16 !
   Absolute value of Coriolis
   parameter (FCORIOL)                 Default: 1.E-4   ! FCORIOL = 0.0001 !
                                       Units: (1/s)

SPATIAL AVERAGING OF MIXING HEIGHTS

   Conduct spatial averaging
   (IAVEZI)  (0=no, 1=yes)             Default: 1       ! IAVEZI = 1 !

   Max. search radius in averaging
   process (MNMDAV)                    Default: 1       ! MNMDAV = 1 !
                                       Units: Grid
                                              cells
   Half-angle of upwind looking cone
   for averaging (HAFANG)              Default: 30.     ! HAFANG = 30 !
                                       Units: deg.
   Layer of winds used in upwind
   averaging (ILEVZI)                  Default: 1       ! ILEVZI = 1 !
   (must be between 1 and NZ)


CONVECTIVE MIXING HEIGHT OPTIONS:
   Method to compute the convective
   mixing height(IMIHXH)               Default: 1       ! IMIXH = -1 !
       1: Maul-Carson for land and water cells
      -1: Maul-Carson for land cells only -
          OCD mixing height overwater
       2: Batchvarova and Gryning for land and water cells
      -2: Batchvarova and Gryning for land cells only
          OCD mixing height overwater

   Threshold buoyancy flux required to
   sustain convective mixing height growth
   overland (THRESHL)                  Default: 0.0     ! THRESHL = 0 !
   (expressed as a heat flux           units: W/m3
    per meter of boundary layer)


   Threshold buoyancy flux required to
   sustain convective mixing height growth
   overwater (THRESHW)                 Default: 0.05    ! THRESHW = 0.05 !
   (expressed as a heat flux           units: W/m3
    per meter of boundary layer)


   Option for overwater lapse rates used
   in convective mixing height growth
   (ITWPROG)                           Default: 0       ! ITWPROG = 0 !
   0 : use SEA.DAT lapse rates and deltaT (or assume neutral
       conditions if missing)
   1 : use prognostic lapse rates (only if IPROG>2)
       and SEA.DAT deltaT (or neutral if missing)
   2 : use prognostic lapse rates and prognostic delta T
       (only if iprog>12 and 3D.DAT version# 2.0 or higher)

   Land Use category ocean in 3D.DAT datasets
   (ILUOC3D)                           Default: 16      ! ILUOC3D = 16 !
   Note: if 3D.DAT from MM5 version 3.0, iluoc3d = 16
         if MM4.DAT,           typically iluoc3d = 7
```

```
OTHER MIXING HEIGHT VARIABLES

   Minimum potential temperature lapse
   rate in the stable layer above the
   current convective mixing ht.          Default: 0.001  ! DPTMIN = 0.001 !
   (DPTMIN)                               Units: deg. K/m
   Depth of layer above current conv.
   mixing height through which lapse      Default: 200.   ! DZZI = 200 !
   rate is computed (DZZI)                Units: meters

   Minimum overland mixing height         Default:  50.   ! ZIMIN = 50 !
   (ZIMIN)                                Units: meters
   Maximum overland mixing height         Default: 3000.  ! ZIMAX = 3000 !
   (ZIMAX)                                Units: meters
   Minimum overwater mixing height        Default:   50.  ! ZIMINW = 50 !
   (ZIMINW) -- (Not used if observed      Units: meters
   overwater mixing hts. are used)
   Maximum overwater mixing height        Default: 3000.  ! ZIMAXW = 3000 !
   (ZIMAXW) -- (Not used if observed      Units: meters
   overwater mixing hts. are used)


OVERWATER SURFACE FLUXES METHOD and PARAMETERS
      (ICOARE)                            Default: 10      ! ICOARE = 0 !
       0: original deltaT method (OCD)
      10: COARE with no wave parameterization (jwave=0, Charnock)
      11: COARE with wave option jwave=1 (Oost et al.)
          and default wave properties
     -11: COARE with wave option jwave=1 (Oost et al.)
          and observed wave properties (must be in SEA.DAT files)
      12: COARE with wave option 2 (Taylor and Yelland)
           and default wave properties
     -12: COARE with wave option 2 (Taylor and Yelland)
          and observed wave properties (must be in SEA.DAT files)

      Note:  When ICOARE=0, similarity wind profile stability PSI functions
             based on Van Ulden and Holtslag (1985) are substituted for
             later formulations used with the COARE module, and temperatures
             used for surface layer parameters are obtained from either the
             nearest surface station temperature or prognostic model 2D
             temperatures (if ITPROG=2).


      Coastal/Shallow water length scale (DSHELF)
      (for modified z0 in shallow water)
      ( COARE fluxes only)
                                    Default : 0.        ! DSHELF = 0 !
                                    units: km

       COARE warm layer computation (IWARM)             ! IWARM = 0 !
       1: on - 0: off (must be off if SST measured with
       IR radiometer)               Default: 0

       COARE cool skin layer computation (ICOOL)        ! ICOOL = 0 !
       1: on - 0: off (must be off if SST measured with
       IR radiometer)               Default: 0

RELATIVE HUMIDITY PARAMETERS

   3D relative humidity from observations or
   from prognostic data? (IRHPROG)       Default:0      ! IRHPROG = 1 !
```

```
          0 = Use RH from SURF.DAT file
              (only if NOOBS = 0,1)
          1 = Use prognostic RH
              (only if NOOBS = 0,1,2)

    TEMPERATURE PARAMETERS

       3D temperature from observations or
       from prognostic data? (ITPROG)        Default:0        ! ITPROG = 2 !

          0 = Use Surface and upper air stations
              (only if NOOBS = 0)
          1 = Use Surface stations (no upper air observations)
              Use MM5/3D.DAT for upper air data
              (only if NOOBS = 0,1)
          2 = No surface or upper air observations
              Use MM5/3D.DAT for surface and upper air data
              (only if NOOBS = 0,1,2)

       Interpolation type
       (1 = 1/R ; 2 = 1/R**2)                Default:1         ! IRAD = 1 !

       Radius of influence for temperature
       interpolation (TRADKM)                Default: 500.     ! TRADKM = 500 !
                                             Units: km

       Maximum Number of stations to include
       in temperature interpolation (NUMTS)  Default: 5        ! NUMTS = 5 !

       Conduct spatial averaging of temp-
       eratures (IAVET)  (0=no, 1=yes)       Default: 1        ! IAVET = 1 !
       (will use mixing ht MNMDAV,HAFANG
        so make sure they are correct)

       Default temperature gradient          Default: -.0098 ! TGDEFB = -0.0098 !
       below the mixing height over          Units: K/m
       water (TGDEFB)

       Default temperature gradient          Default: -.0045 ! TGDEFA = -0.0045 !
       above the mixing height over          Units: K/m
       water (TGDEFA)

       Beginning (JWAT1) and ending (JWAT2)
       land use categories for temperature                   ! JWAT1 = 999 !
       interpolation over water -- Make                      ! JWAT2 = 999 !
       bigger than largest land use to disable

    PRECIP INTERPOLATION PARAMETERS

       Method of interpolation (NFLAGP)      Default: 2       ! NFLAGP = 2 !
        (1=1/R,2=1/R**2,3=EXP/R**2)
       Radius of Influence  (SIGMAP)         Default: 100.0 ! SIGMAP = 100 !
        (0.0 => use half dist. btwn          Units: km
         nearest stns w & w/out
         precip when NFLAGP = 3)
       Minimum Precip. Rate Cutoff (CUTP)    Default: 0.01 ! CUTP = 0.01 !
        (values <CUTP = 0.0 mm/hr)          Units: mm/hr
!END!
```

INPUT GROUP: 7 -- Surface meteorological station parameters

```
--------------

     SURFACE STATION VARIABLES
     (One record per station --  12  records in all)


           1     2
        Name     ID     X coord.   Y coord.    Time   Anem.
                          (km)       (km)       zone   Ht.(m)
       ------------------------------------------------------------

-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Six digit integer for station ID

!END!


--------------------------------------------------------------------------------

INPUT GROUP: 8 -- Upper air meteorological station parameters
--------------

     UPPER AIR STATION VARIABLES
     (One record per station --  3  records in all)

           1     2
        Name    ID      X coord.   Y coord.  Time zone
                          (km)       (km)
        ---------------------------------------------

-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!


--------------------------------------------------------------------------------

INPUT GROUP: 9 -- Precipitation station parameters
--------------

     PRECIPITATION STATION VARIABLES
     (One record per station --  2  records in all)
     (NOT INCLUDED IF NPSTA = 0)

          1          2
        Name   Station    X coord.  Y coord.
                 Code       (km)      (km)
        ------------------------------------


-------------------
```

```
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Six digit station code composed of state
        code (first 2 digits) and station ID (last
        4 digits)

!END!
```

```
MM5 Data for Offshore NL
Project Case

---------------- Run title (3 lines) ------------------------------------------

                    CALPUFF MODEL CONTROL FILE
                    --------------------------

--------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names

--------------
Default Name  Type          File Name
------------  ----          ---------
CALMET.DAT    input    ! METDAT = CALMET.DAT !
    or
ISCMET.DAT    input    * ISCDAT = *
    or
PLMMET.DAT    input    * PLMDAT = *
    or
PROFILE.DAT   input    ! PRFDAT = PROFILE.DAT !
SURFACE.DAT   input    * SFCDAT = *
RESTARTB.DAT  input    * RSTARTB = *
--------------------------------------------------------------------------------
CALPUFF.LST   output   ! PUFLST = ..\operation\CALPUFF.LST !
CONC.DAT      output   ! CONDAT = CONC.DAT !
DFLX.DAT      output   ! DFDAT = DFLX.DAT !
WFLX.DAT      output   ! WFDAT = WFLX.DAT !

VISB.DAT      output   ! VISDAT = VISB.DAT !
TK2D.DAT      output   * T2DDAT = *
RHO2D.DAT     output   * RHODAT = *
RESTARTE.DAT  output   * RSTARTE = *
--------------------------------------------------------------------------------
Emission Files
--------------
PTEMARB.DAT   input    * PTDAT = *
VOLEMARB.DAT  input    * VOLDAT = *
BAEMARB.DAT   input    * ARDAT = *
LNEMARB.DAT   input    * LNDAT = *
--------------------------------------------------------------------------------
Other Files
-----------
OZONE.DAT     input    * OZDAT = *
VD.DAT        input    * VDDAT = *
CHEM.DAT      input    * CHEMDAT = *
AUX           input    * AUXEXT = *
(Extension added to METDAT filename(s) for files
 with auxiliary 2D and 3D data)
H2O2.DAT      input    * H2O2DAT = *
NH3Z.DAT      input    * NH3ZDAT = *
HILL.DAT      input    * HILDAT = *
HILLRCT.DAT   input    * RCTDAT = *
COASTLN.DAT   input    * CSTDAT = *
FLUXBDY.DAT   input    * BDYDAT = *
BCON.DAT      input    * BCNDAT = *
DEBUG.DAT     output   * DEBUG = *
MASSFLX.DAT   output   * FLXDAT = *
MASSBAL.DAT   output   * BALDAT = *
FOG.DAT       output   * FOGDAT = *
RISE.DAT      output   * RISDAT = *
PFTRAK.DAT    output   * TRKDAT = *
```

```
--------------------------------------------------------------------------------
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = F !
         F = UPPER CASE
NOTE: (1) file/path names can be up to 132 characters in length


Provision for multiple input files
----------------------------------
     Number of CALMET.DAT Domains (NMETDOM)
                                     Default: 1       ! NMETDOM = 1 !

     Number of CALMET.DAT files (NMETDAT)
     (Total for ALL Domains)
                                     Default: 1       ! NMETDAT = 1 !

     Number of PTEMARB.DAT files for run (NPTDAT)
                                     Default: 0       ! NPTDAT = 0 !

     Number of BAEMARB.DAT files for run (NARDAT)
                                     Default: 0       ! NARDAT =  0  !

     Number of VOLEMARB.DAT files for run (NVOLDAT)
                                     Default: 0       ! NVOLDAT =  0  !

!END!

-------------
Subgroup (0a)
-------------
  Provide a name for each CALMET domain if NMETDOM > 1
  Enter NMETDOM lines.
                                    a,b
Default Name             Domain Name
------------             ------------
* DOMAINLIST = *


  The following CALMET.DAT filenames are processed in sequence
  if NMETDAT > 1

  Enter NMETDAT lines, 1 line for each file name.

                                    a,c,d
Default Name  Type          File Name
------------  ----          ---------
 none         input    * METDAT=     *   *END*

-------------
    a
     The name for each CALMET domain and each CALMET.DAT file is treated
     as a separate input subgroup and therefore must end with an input
     group terminator.
    b
     Use DOMAIN1= to assign the name for the outermost CALMET domain.
     Use DOMAIN2= to assign the name for the next inner CALMET domain.
     Use DOMAIN3= to assign the name for the next inner CALMET domain, etc.
      ------------------------------------------------------------------
      |   When inner domains with equal resolution (grid-cell size)     |
      |   overlap, the data from the FIRST such domain in the list will  |
      |   be used if all other criteria for choosing the controlling     |
      |   grid domain are inconclusive.                                  |
```

```
     ----------------------------------------------------------------------
    c
     Use METDAT1= to assign the file names for the outermost CALMET domain.
     Use METDAT2= to assign the file names for the next inner CALMET domain.
     Use METDAT3= to assign the file names for the next inner CALMET domain, etc.
    d
     The filenames for each domain must be provided in sequential order


-------------
Subgroup (0b)
-------------

  The following PTEMARB.DAT filenames are processed in sequence if NPTDAT>0

Default Name  Type          File Name
------------  ----          ---------
* PTDATLIST = *


-------------
Subgroup (0c)
-------------

  The following BAEMARB.DAT filenames are processed in sequence if NARDAT>0

Default Name  Type          File Name
------------  ----          ---------
* ARDATLIST = *


-------------
Subgroup (0d)
-------------

  The following VOLEMARB.DAT filenames are processed in sequence if NARDAT>0

Default Name  Type          File Name
------------  ----          ---------
* VOLDATLIST = *

------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

    Option to run all periods found
    in the met. file     (METRUN)   Default: 0       ! METRUN = 1 !

         METRUN = 0 - Run period explicitly defined below
         METRUN = 1 - Run all periods in met. file

     Starting date:    Year   (IBYR)  --    No default   ! IBYR = 2006 !
                       Month  (IBMO)  --    No default   ! IBMO = 12 !
                       Day    (IBDY)  --    No default   ! IBDY = 30 !
     Starting time:    Hour   (IBHR)  --    No default   ! IBHR = 0 !
                       Minute (IBMIN) --    No default   ! IBMIN = 0 !
                       Second (IBSEC) --    No default   ! IBSEC = 0 !

     Ending date:      Year   (IEYR)  --    No default   ! IEYR = 2006 !
                       Month  (IEMO)  --    No default   ! IEMO = 12 !
                       Day    (IEDY)  --    No default   ! IEDY = 31 !
     Ending time:      Hour   (IEHR)  --    No default   ! IEHR = 19 !
```

```
                  Minute (IEMIN) --    No default   ! IEMIN = 0 !
                  Second (IESEC) --    No default   ! IESEC = 0 !

(These are only used if METRUN = 0)

Base time zone:          (ABTZ)  --    No default   ! ABTZ = UTC-0300 !
 (character*8)
The modeling domain may span multiple time zones.  ABTZ defines the
base time zone used for the entire simulation.  This must match the
base time zone of the meteorological data.
Examples:
    Los Angeles, USA          = UTC-0800
    New York, USA             = UTC-0500
    Santiago, Chile           = UTC-0400
    Greenwich Mean Time (GMT) = UTC+0000
    Rome, Italy               = UTC+0100
    Cape Town, S.Africa       = UTC+0200
    Sydney, Australia         = UTC+1000

Length of modeling time-step (seconds)
Equal to update period in the primary
meteorological data files, or an
integer fraction of it (1/2, 1/3 ...)
Must be no larger than 1 hour
(NSECDT)                          Default:3600     ! NSECDT = 3600 !
                                  Units: seconds

Number of chemical species (NSPEC)
                                  Default: 5       ! NSPEC = 6 !

Number of chemical species
to be emitted  (NSE)              Default: 3       ! NSE = 6 !

Flag to stop run after
SETUP phase (ITEST)               Default: 2       ! ITEST = 2 !
(Used to allow checking
of the model inputs, files, etc.)
      ITEST = 1 - STOPS program after SETUP phase
      ITEST = 2 - Continues with execution of program
                  after SETUP

Restart Configuration:

   Control flag (MRESTART)        Default: 0       ! MRESTART = 0 !

      0 = Do not read or write a restart file
      1 = Read a restart file at the beginning of
          the run
      2 = Write a restart file during run
      3 = Read a restart file at beginning of run
          and write a restart file during run

   Number of periods in Restart
   output cycle (NRESPD)          Default: 0       ! NRESPD = 0 !

      0 = File written only at last period
     >0 = File updated every NRESPD periods

Meteorological Data Format (METFM)
                                  Default: 1       ! METFM = 1 !

      METFM = 1 - CALMET binary file (CALMET.MET)
      METFM = 2 - ISC ASCII file (ISCMET.MET)
```

```
          METFM = 3 - AUSPLUME ASCII file (PLMMET.MET)
          METFM = 4 - CTDM plus tower file (PROFILE.DAT) and
                      surface parameters file (SURFACE.DAT)
          METFM = 5 - AERMET tower file (PROFILE.DAT) and
                      surface parameters file (SURFACE.DAT)

     Meteorological Profile Data Format (MPRFFM)
            (used only for METFM = 1, 2, 3)
                                    Default: 1       ! MPRFFM = 1 !

          MPRFFM = 1 - CTDM plus tower file (PROFILE.DAT)
          MPRFFM = 2 - AERMET tower file (PROFILE.DAT)

     PG sigma-y is adjusted by the factor (AVET/PGTIME)**0.2
     Averaging Time (minutes) (AVET)
                                    Default: 60.0    ! AVET = 60 !
     PG Averaging Time (minutes) (PGTIME)
                                    Default: 60.0    ! PGTIME = 60 !


!END!


--------------------------------------------------------------------------------

INPUT GROUP: 2 -- Technical options
--------------


     Vertical distribution used in the
     near field (MGAUSS)                  Default: 1     ! MGAUSS = 1 !
        0 = uniform
        1 = Gaussian

     Terrain adjustment method
     (MCTADJ)                             Default: 3     ! MCTADJ = 3 !
        0 = no adjustment
        1 = ISC-type of terrain adjustment
        2 = simple, CALPUFF-type of terrain
            adjustment
        3 = partial plume path adjustment

     Subgrid-scale complex terrain
     flag (MCTSG)                         Default: 0     ! MCTSG = 0 !
        0 = not modeled
        1 = modeled

     Near-field puffs modeled as
     elongated slugs? (MSLUG)             Default: 0     ! MSLUG = 0 !
        0 = no
        1 = yes (slug model used)

     Transitional plume rise modeled?
     (MTRANS)                             Default: 1     ! MTRANS = 1 !
        0 = no  (i.e., final rise only)
        1 = yes (i.e., transitional rise computed)

     Stack tip downwash? (MTIP)           Default: 1     ! MTIP = 1 !
        0 = no  (i.e., no stack tip downwash)
        1 = yes (i.e., use stack tip downwash)

     Method used to compute plume rise for
     point sources not subject to building
```

```
downwash? (MRISE)                    Default: 1     ! MRISE = 1 !
   1 = Briggs plume rise
   2 = Numerical plume rise

Method used to simulate building
downwash? (MBDW)                     Default: 1     ! MBDW = 1 !
   1 = ISC method
   2 = PRIME method

Vertical wind shear modeled above
stack top? (MSHEAR)                  Default: 0     ! MSHEAR = 0 !
   0 = no  (i.e., vertical wind shear not modeled)
   1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT)     Default: 0     ! MSPLIT = 0 !
   0 = no (i.e., puffs not split)
   1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM)      Default: 1     ! MCHEM = 0 !
   0 = chemical transformation not
       modeled
   1 = transformation rates computed
       internally (MESOPUFF II scheme)
   2 = user-specified transformation
       rates used
   3 = transformation rates computed
       internally (RIVAD/ARM3 scheme)
   4 = secondary organic aerosol formation
       computed (MESOPUFF II scheme for OH)
   5 = user-specified half-life with or
       without transfer to child species
   6 = transformation rates computed
       internally (Updated RIVAD scheme with
       ISORROPIA equilibrium)
   7 = transformation rates computed
       internally (Updated RIVAD scheme with
       ISORROPIA equilibrium and CalTech SOA)

Aqueous phase transformation flag (MAQCHEM)
(Used only if MCHEM = 6, or 7)       Default: 0     ! MAQCHEM = 0 !
   0 = aqueous phase transformation
       not modeled
   1 = transformation rates and wet
       scavenging coefficients adjusted
       for in-cloud aqueous phase reactions
       (adapted from RADM cloud model
        implementation in CMAQ/SCICHEM)

Liquid Water Content flag (MLWC)
(Used only if MAQCHEM = 1)           Default: 1     ! MLWC = 1 !
   0 = water content estimated from cloud cover
       and presence of precipitation
   1 = gridded cloud water data read from CALMET
       water content output files (filenames are
       the CALMET.DAT names PLUS the extension
       AUXEXT provided in Input Group 0)

Wet removal modeled ? (MWET)         Default: 1     ! MWET = 0 !
   0 = no
   1 = yes

Dry deposition modeled ? (MDRY)      Default: 1     ! MDRY = 0 !
   0 = no
```

```
   1 = yes
   (dry deposition method specified
    for each species in Input Group 3)


Gravitational settling (plume tilt)
modeled ? (MTILT)                    Default: 0     ! MTILT = 0 !
   0 = no
   1 = yes
   (puff center falls at the gravitational
    settling velocity for 1 particle species)

Restrictions:
    - MDRY  = 1
    - NSPEC = 1  (must be particle species as well)
    - sg    = 0  GEOMETRIC STANDARD DEVIATION in Group 8 is
                 set to zero for a single particle diameter

Method used to compute dispersion
coefficients (MDISP)                 Default: 3     ! MDISP = 3 !

   1 = dispersion coefficients computed from measured values
       of turbulence, sigma v, sigma w
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.
   5 = CTDM sigmas used for stable and neutral conditions.
       For unstable conditions, sigmas are computed as in
       MDISP = 3, described above.  MDISP = 5 assumes that
       measured values are read

Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
(Used only if MDISP = 1 or 5)        Default: 3     ! MTURBVW = 3 !
   1 = use sigma-v or sigma-theta measurements
       from PROFILE.DAT to compute sigma-y
       (valid for METFM = 1, 2, 3, 4, 5)
   2 = use sigma-w measurements
       from PROFILE.DAT to compute sigma-z
       (valid for METFM = 1, 2, 3, 4, 5)
   3 = use both sigma-(v/theta) and sigma-w
       from PROFILE.DAT to compute sigma-y and sigma-z
       (valid for METFM = 1, 2, 3, 4, 5)
   4 = use sigma-theta measurements
       from PLMMET.DAT to compute sigma-y
       (valid only if METFM = 3)

Back-up method used to compute dispersion
when measured turbulence data are
missing (MDISP2)                     Default: 3     ! MDISP2 = 3 !
(used only if MDISP = 1 or 5)
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.
```

```
[DIAGNOSTIC FEATURE]
Method used for Lagrangian timescale for Sigma-y
(used only if MDISP=1,2 or MDISP2=1,2)
(MTAULY)                              Default: 0     ! MTAULY = 0 !
   0 = Draxler default 617.284 (s)
   1 = Computed as Lag. Length / (.75 q) -- after SCIPUFF
  10 <Direct user input (s)             -- e.g., 306.9


[DIAGNOSTIC FEATURE]
Method used for Advective-Decay timescale for Turbulence
(used only if MDISP=2 or MDISP2=2)
(MTAUADV)                             Default: 0     ! MTAUADV = 0 !
   0 = No turbulence advection
   1 = Computed (OPTION NOT IMPLEMENTED)
  10 <Direct user input (s)   -- e.g., 800


Method used to compute turbulence sigma-v &
sigma-w using micrometeorological variables
(Used only if MDISP = 2 or MDISP2 = 2)
(MCTURB)                              Default: 1     ! MCTURB = 1 !
   1 = Standard CALPUFF subroutines
   2 = AERMOD subroutines

PG sigma-y,z adj. for roughness?      Default: 0     ! MROUGH = 0 !
(MROUGH)
   0 = no
   1 = yes

Partial plume penetration of          Default: 1     ! MPARTL = 1 !
elevated inversion modeled for
point sources?
(MPARTL)
   0 = no
   1 = yes

Partial plume penetration of          Default: 1     ! MPARTLBA = 1 !
elevated inversion modeled for
buoyant area sources?
(MPARTLBA)
   0 = no
   1 = yes

Strength of temperature inversion     Default: 0     ! MTINV = 0 !
provided in PROFILE.DAT extended records?
(MTINV)
   0 = no (computed from measured/default gradients)
   1 = yes

PDF used for dispersion under convective conditions?
                                      Default: 0     ! MPDF = 0 !
(MPDF)
   0 = no
   1 = yes

Sub-Grid TIBL module used for shore line?
                                      Default: 0     ! MSGTIBL = 0 !
(MSGTIBL)
   0 = no
   1 = yes
```

```
Boundary conditions (concentration) modeled?
                                        Default: 0     ! MBCON = 0 !
(MBCON)
   0 = no
   1 = yes, using formatted BCON.DAT file
   2 = yes, using unformatted CONC.DAT file

Note:  MBCON > 0 requires that the last species modeled
       be 'BCON'.  Mass is placed in species BCON when
       generating boundary condition puffs so that clean
       air entering the modeling domain can be simulated
       in the same way as polluted air.  Specify zero
       emission of species BCON for all regular sources.

Individual source contributions saved?
                                        Default: 0     ! MSOURCE = 0 !
(MSOURCE)
   0 = no
   1 = yes


Analyses of fogging and icing impacts due to emissions from
arrays of mechanically-forced cooling towers can be performed
using CALPUFF in conjunction with a cooling tower emissions
processor (CTEMISS) and its associated postprocessors.  Hourly
emissions of water vapor and temperature from each cooling tower
cell are computed for the current cell configuration and ambient
conditions by CTEMISS. CALPUFF models the dispersion of these
emissions and provides cloud information in a specialized format
for further analysis. Output to FOG.DAT is provided in either
'plume mode' or 'receptor mode' format.

Configure for FOG Model output?
                                        Default: 0     ! MFOG = 0 !
(MFOG)
   0 = no
   1 = yes  - report results in PLUME Mode format
   2 = yes  - report results in RECEPTOR Mode format


Test options specified to see if
they conform to regulatory
values? (MREG)                          Default: 1     ! MREG = 0 !

   0 = NO checks are made
   1 = Technical options must conform to USEPA
       Long Range Transport (LRT) guidance
                   METFM    1 or 2
                   AVET     60. (min)
                   PGTIME   60. (min)
                   MGAUSS   1
                   MCTADJ   3
                   MTRANS   1
                   MTIP     1
                   MRISE    1
                   MCHEM    1 or 3 (if modeling SOx, NOx)
                   MWET     1
                   MDRY     1
                   MDISP    2 or 3
                   MPDF     0 if MDISP=3
                            1 if MDISP=2
                   MROUGH   0
                   MPARTL   1
```

```
MPARTLBA 0
SYTDEP   550. (m)
MHFTSZ   0
SVMIN    0.5 (m/s)

!END!
```

INPUT GROUP: 3a, 3b -- Species list

Subgroup (3a)

The following species are modeled:

```
! CSPEC =          NOX !            !END!
! CSPEC =           CO !            !END!
! CSPEC =          SO2 !            !END!
! CSPEC =          TPM !            !END!
! CSPEC =         PM10 !            !END!
! CSPEC =         PM25 !            !END!
```

GROUP SPECIES NAME (Limit: 12 Characters in length)	MODELED (0=NO, 1=YES)	EMITTED (0=NO, 1=YES)	Dry DEPOSITED (0=NO, 1=COMPUTED-GAS, 2=COMPUTED-PARTICLE, 3=USER-SPECIFIED)	OUTPUT NUMBER (0=NONE, 1=1st CGRUP, 2=2nd CGRUP, 3= etc.)
NOX	1	1	1	0
CO	1	1	1	0
SO2	1	1	1	0
TPM	1	1	2	0
PM10	1	1	2	0
PM25	1	1	2	0

```
!END!
```

Note: The last species in (3a) must be 'BCON' when using the boundary condition option (MBCON > 0). Species BCON should typically be modeled as inert (no chem transformation or removal).

Subgroup (3b)

The following names are used for Species-Groups in which results for certain species are combined (added) prior to output. The CGRUP name will be used as the species name in output files. Use this feature to model specific particle-size distributions by treating each size-range as a separate species. Order must be consistent with 3(a) above.

```
------------------------------------------------------------------------------


INPUT GROUP: 4 -- Map Projection and Grid control parameters
--------------

     Projection for all (X,Y):
     -------------------------

     Map projection
     (PMAP)                    Default: UTM    ! PMAP = UTM !

         UTM :  Universal Transverse Mercator
         TTM :  Tangential Transverse Mercator
         LCC :  Lambert Conformal Conic
          PS :  Polar Stereographic
          EM :  Equatorial Mercator
        LAZA :  Lambert Azimuthal Equal Area

     False Easting and Northing (km) at the projection origin
     (Used only if PMAP= TTM, LCC, or LAZA)
     (FEAST)                   Default=0.0     ! FEAST = 0 !
     (FNORTH)                  Default=0.0     ! FNORTH = 0 !

     UTM zone (1 to 60)
     (Used only if PMAP=UTM)
     (IUTMZN)                  No Default      ! IUTMZN = 22 !

     Hemisphere for UTM projection?
     (Used only if PMAP=UTM)
     (UTMHEM)                  Default: N      ! UTMHEM = N !
         N   :  Northern hemisphere projection
         S   :  Southern hemisphere projection

     Latitude and Longitude (decimal degrees) of projection origin
     (Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
     (RLAT0)                   No Default      ! RLAT0 = 0N !
     (RLON0)                   No Default      ! RLON0 = 0E !

         TTM :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         LCC :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         PS  :  RLON0 identifies central (grid N/S) meridian of projection
                RLAT0 selected for convenience
         EM  :  RLON0 identifies central meridian of projection
                RLAT0 is REPLACED by 0.0N (Equator)
         LAZA:  RLON0 identifies longitude of tangent-point of mapping plane
                RLAT0 identifies latitude of tangent-point of mapping plane

     Matching parallel(s) of latitude (decimal degrees) for projection
     (Used only if PMAP= LCC or PS)
     (XLAT1)                   No Default      ! XLAT1 = 30N !
     (XLAT2)                   No Default      ! XLAT2 = 60N !

         LCC :  Projection cone slices through Earth's surface at XLAT1 and XLAT2
         PS  :  Projection plane slices through Earth at XLAT1
                (XLAT2 is not used)

     ----------
```

Note: Latitudes and longitudes should be positive, and include a letter N,S,E, or W indicating north or south latitude, and east or west longitude. For example,
35.9 N Latitude = 35.9N
118.7 E Longitude = 118.7E

Datum-region

The Datum-Region for the coordinates is identified by a character string. Many mapping products currently available use the model of the Earth known as the World Geodetic System 1984 (WGS-84). Other local models may be in use, and their selection in CALMET will make its output consistent with local mapping products. The list of Datum-Regions with official transformation parameters is provided by the National Imagery and Mapping Agency (NIMA).

NIMA Datum - Regions(Examples)

WGS-84	WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
NAS-C	NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
NAR-C	NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
NWS-84	NWS 6370KM Radius, Sphere
ESR-S	ESRI REFERENCE 6371KM Radius, Sphere

Datum-region for output coordinates
(DATUM) Default: WGS-84 ! DATUM = WGS-84 !

METEOROLOGICAL Grid (outermost if nested CALMET grids are used):

Rectangular grid defined for projection PMAP,
with X the Easting and Y the Northing coordinate

No. X grid cells (NX)	No default	! NX = 85 !
No. Y grid cells (NY)	No default	! NY = 85 !
No. vertical layers (NZ)	No default	! NZ = 10 !
Grid spacing (DGRIDKM)	No default Units: km	! DGRIDKM = 1 !
Cell face heights (ZFACE(nz+1))	No defaults Units: m	

! ZFACE = 0.0, 20.0, 40.0, 80.0, 160.0, 320.0, 640.0, 1200.0, 2000.0, 3000.0, 4000.0 !

Reference Coordinates
of SOUTHWEST corner of
grid cell(1, 1):

X coordinate (XORIGKM)	No default	! XORIGKM = 658.6500 !
Y coordinate (YORIGKM)	No default Units: km	! YORIGKM = 5139.6660 !

COMPUTATIONAL Grid:

The computational grid is identical to or a subset of the MET. grid. The lower left (LL) corner of the computational grid is at grid point (IBCOMP, JBCOMP) of the MET. grid. The upper right (UR) corner of the computational grid is at grid point (IECOMP, JECOMP) of the MET. grid.

The grid spacing of the computational grid is the same as the MET. grid.

X index of LL corner (IBCOMP) (1 <= IBCOMP <= NX)	No default	! IBCOMP = 1 !
Y index of LL corner (JBCOMP) (1 <= JBCOMP <= NY)	No default	! JBCOMP = 1 !
X index of UR corner (IECOMP) (1 <= IECOMP <= NX)	No default	! IECOMP = 85 !
Y index of UR corner (JECOMP) (1 <= JECOMP <= NY)	No default	! JECOMP = 85 !

SAMPLING Grid (GRIDDED RECEPTORS):

The lower left (LL) corner of the sampling grid is at grid point (IBSAMP, JBSAMP) of the MET. grid. The upper right (UR) corner of the sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid. The sampling grid must be identical to or a subset of the computational grid. It may be a nested grid inside the computational grid. The grid spacing of the sampling grid is DGRIDKM/MESHDN.

Logical flag indicating if gridded receptors are used (LSAMP) (T=yes, F=no)	Default: T	! LSAMP = T !
X index of LL corner (IBSAMP) (IBCOMP <= IBSAMP <= IECOMP)	No default	! IBSAMP = 5 !
Y index of LL corner (JBSAMP) (JBCOMP <= JBSAMP <= JECOMP)	No default	! JBSAMP = 5 !
X index of UR corner (IESAMP) (IBCOMP <= IESAMP <= IECOMP)	No default	! IESAMP = 80 !
Y index of UR corner (JESAMP) (JBCOMP <= JESAMP <= JECOMP)	No default	! JESAMP = 80 !
Nesting factor of the sampling grid (MESHDN) (MESHDN is an integer >= 1)	Default: 1	! MESHDN = 1 !

!END!

INPUT GROUP: 5 -- Output Options

FILE	DEFAULT VALUE	VALUE THIS RUN
Concentrations (ICON)	1	! ICON = 1 !
Dry Fluxes (IDRY)	1	! IDRY = 0 !
Wet Fluxes (IWET)	1	! IWET = 0 !

```
2D Temperature (IT2D)              0                    ! IT2D = 0 !
2D Density (IRHO)                  0                    ! IRHO = 0 !
Relative Humidity (IVIS)           1                    ! IVIS = 0 !
 (relative humidity file is
  required for visibility
  analysis)
Use data compression option in output file?
(LCOMPRS)                          Default: T           ! LCOMPRS = F !

*
 0 = Do not create file, 1 = create file


 QA PLOT FILE OUTPUT OPTION:

    Create a standard series of output files (e.g.
    locations of sources, receptors, grids ...)
    suitable for plotting?
    (IQAPLOT)                      Default: 1           ! IQAPLOT = 1 !
      0 = no
      1 = yes

 DIAGNOSTIC PUFF-TRACKING OUTPUT OPTION:

    Puff locations and properties reported to
    PFTRAK.DAT file for postprocessing?
    (IPFTRAK)                      Default: 0           ! IPFTRAK = 0 !
      0 = no
      1 = yes, update puff output at end of each timestep
      2 = yes, update puff output at end of each sampling step

 DIAGNOSTIC MASS FLUX OUTPUT OPTIONS:

    Mass flux across specified boundaries
    for selected species reported?
    (IMFLX)                        Default: 0           ! IMFLX = 0 !
      0 = no
      1 = yes (FLUXBDY.DAT and MASSFLX.DAT filenames
               are specified in Input Group 0)

    Mass balance for each species
    reported?
    (IMBAL)                        Default: 0           ! IMBAL = 0 !
      0 = no
      1 = yes (MASSBAL.DAT filename is
           specified in Input Group 0)


 NUMERICAL RISE OUTPUT OPTION:

    Create a file with plume properties for each rise
    increment, for each model timestep?
    This applies to sources modeled with numerical rise
    and is limited to ONE source in the run.
    (INRISE)                       Default: 0           ! INRISE = 0 !
      0 = no
      1 = yes (RISE.DAT filename is
               specified in Input Group 0)


 LINE PRINTER OUTPUT OPTIONS:

    Print concentrations (ICPRT)   Default: 0           ! ICPRT = 0 !
```

```
Print dry fluxes (IDPRT)          Default: 0         ! IDPRT = 0 !
Print wet fluxes (IWPRT)          Default: 0         ! IWPRT = 0 !
(0 = Do not print, 1 = Print)

Concentration print interval
(ICFRQ) in timesteps              Default: 1         ! ICFRQ = 1 !
Dry flux print interval
(IDFRQ) in timesteps              Default: 1         ! IDFRQ = 1 !
Wet flux print interval
(IWFRQ) in timesteps              Default: 1         ! IWFRQ = 1 !

Units for Line Printer Output
(IPRTU)                           Default: 1         ! IPRTU = 3 !
                  for              for
              Concentration    Deposition
      1 =        g/m**3          g/m**2/s
      2 =       mg/m**3         mg/m**2/s
      3 =       ug/m**3         ug/m**2/s
      4 =       ng/m**3         ng/m**2/s
      5 =      Odour Units

Messages tracking progress of run
written to the screen ?
(IMESG)                           Default: 2         ! IMESG = 2 !
  0 = no
  1 = yes (advection step, puff ID)
  2 = yes (YYYYJJJHH, # old puffs, # emitted puffs)
```

SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS

SPECIES /GROUP	---- CONCENTRATIONS ---- PRINTED?	SAVED ON DISK?	------ DRY FLUXES ------ PRINTED?	SAVED ON DISK?	------ WET FLUXES ------ PRINTED?	SAVED ON DISK?	-- MASS FLUX -- SAVED ON DISK?
NOX =	1,	1,	1,	0,	1,	0,	!
CO =	1,	1,	1,	0,	1,	0,	!
SO2 =	1,	1,	1,	0,	1,	0,	!
TPM =	1,	1,	1,	0,	1,	0,	!
PM10 =	1,	1,	1,	0,	1,	0,	!
PM25 =	1,	1,	1,	0,	1,	0,	!

Note: Species BCON (for MBCON > 0) does not need to be saved on disk.

OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

```
Logical for debug output
(LDEBUG)                          Default: F     ! LDEBUG = F !

First puff to track
(IPFDEB)                          Default: 1     ! IPFDEB = 1 !
```

```
       Number of puffs to track
       (NPFDEB)                                  Default: 1     ! NPFDEB = 1000 !

       Met. period to start output
       (NN1)                                     Default: 1     ! NN1 = 1 !

       Met. period to end output
       (NN2)                                     Default: 10    ! NN2 = 10 !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
-------------------------

---------------
Subgroup (6a)
---------------
       Number of terrain features (NHILL)        Default: 0     ! NHILL = 0 !

       Number of special complex terrain
       receptors  (NCTREC)                       Default: 0     ! NCTREC = 0 !

       Terrain and CTSG Receptor data for
       CTSG hills input in CTDM format ?
       (MHILL)                                   No Default     ! MHILL = 2 !
       1 = Hill and Receptor data created
           by CTDM processors & read from
           HILL.DAT and HILLRCT.DAT files
       2 = Hill data created by OPTHILL &
           input below in Subgroup (6b);
           Receptor data in Subgroup (6c)

       Factor to convert horizontal dimensions  Default: 1.0   ! XHILL2M = 1.0 !
       to meters (MHILL=1)

       Factor to convert vertical dimensions    Default: 1.0   ! ZHILL2M = 1.0 !
       to meters (MHILL=1)

       X-origin of CTDM system relative to      No Default     ! XCTDMKM = 0.0 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

       Y-origin of CTDM system relative to      No Default     ! YCTDMKM = 0.0 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------

                      1 **
     HILL information

HILL            XC         YC       THETAH  ZGRID  RELIEF    EXPO 1    EXPO 2   SCALE
1    SCALE 2    AMAX1      AMAX2
 NO.           (km)       (km)      (deg.)   (m)     (m)       (m)       (m)       (m)
      (m)       (m)        (m)
----            ----       ----      ------  -----  ------    ------    ------
```

Subgroup (6c)

COMPLEX TERRAIN RECEPTOR INFORMATION

XRCT (km)	YRCT (km)	ZRCT (m)	XHH

1

Description of Complex Terrain Variables:
- XC, YC = Coordinates of center of hill
- THETAH = Orientation of major axis of hill (clockwise from North)
- ZGRID = Height of the 0 of the grid above mean sea level
- RELIEF = Height of the crest of the hill above the grid elevation
- EXPO 1 = Hill-shape exponent for the major axis
- EXPO 2 = Hill-shape exponent for the major axis
- SCALE 1 = Horizontal length scale along the major axis
- SCALE 2 = Horizontal length scale along the minor axis
- AMAX = Maximum allowed axis length for the major axis
- BMAX = Maximum allowed axis length for the major axis

XRCT, YRCT = Coordinates of the complex terrain receptors
- ZRCT = Height of the ground (MSL) at the complex terrain Receptor
- XHH = Hill number associated with each complex terrain receptor (NOTE: MUST BE ENTERED AS A REAL NUMBER)

**

NOTE: DATA for each hill and CTSG receptor are treated as a separate input subgroup and therefore must end with an input group terminator.

INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases

SPECIES NAME	DIFFUSIVITY (cm**2/s)	ALPHA STAR (dimensionless)	REACTIVITY	MESOPHYLL RESISTANCE (s/cm)	HENRY'S LAW COEFFICIENT

* DRYGAS = *

!END!

INPUT GROUP: 8 -- Size parameters for dry deposition of particles

For SINGLE SPECIES, the mean and standard deviation are used to compute a deposition velocity for NINT (see group 9) size-ranges, and these are then averaged to obtain a mean deposition velocity.

For GROUPED SPECIES, the size distribution should be explicitly specified (by the 'species' in the group), and the standard deviation for each should be entered as 0. The model will then use the deposition velocity for the stated mean diameter.

SPECIES NAME	GEOMETRIC MASS MEAN DIAMETER (microns)	GEOMETRIC STANDARD DEVIATION (microns)

```
* DRYPART = *
!END!
```

INPUT GROUP: 9 -- Miscellaneous dry deposition parameters

```
     Reference cuticle resistance (s/cm)
     (RCUTR)                          Default: 30    ! RCUTR = 30 !
     Reference ground resistance  (s/cm)
     (RGR)                            Default: 10    ! RGR = 10 !
     Reference pollutant reactivity
     (REACTR)                         Default: 8     ! REACTR = 8 !

     Number of particle-size intervals used to
     evaluate effective particle deposition velocity
     (NINT)                           Default: 9     ! NINT = 9 !

     Vegetation state in unirrigated areas
     (IVEG)                           Default: 1     ! IVEG = 1 !
        IVEG=1 for active and unstressed vegetation
        IVEG=2 for active and stressed vegetation
        IVEG=3 for inactive vegetation

!END!
```

INPUT GROUP: 10 -- Wet Deposition Parameters

Scavenging Coefficient -- Units: (sec)**(-1)

Pollutant	Liquid Precip.	Frozen Precip.

```
* WETDEPOS = *
!END!
```

INPUT GROUP: 11a, 11b -- Chemistry Parameters

Subgroup (11a)

Several parameters are needed for one or more of the chemical transformation mechanisms. Those used for each mechanism are:

Mechanism (MCHEM)	MOZ	BCK O3	MNH3	MAVG NH3	BCK NH3	RNIT E1	RNIT E2	RNIT E3	MH2O2	BCK H2O2	BCK PRAC	OFRAC	VCNX	NDEC AY
0 None	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1 MESOPUFF II	X	X	.	.	X	X	X	X	.	.	.	.	.	.
2 User Rates	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3 RIVAD	X	X	.	.	X	.	.	.	.	.	.	.	.	.
4 SOA	X	X	.	.	.	.	.	.	.	.	X	X	X	.
5 Radioactive Decay	.	.	.	.	.	.	.	.	.	.	.	.	.	X
6 RIVAD/ISORRPIA	X	X	X	X	X	X	.	.	X	X	.	.	.	.
7 RIVAD/ISORRPIA/SOA	X	X	X	X	X	X	.	.	X	X	X	X	.	.

Ozone data input option (MOZ) Default: 1 ! MOZ = 1 !
(Used only if MCHEM = 1,3,4,6 or 7)
0 = use a monthly background ozone value
1 = read hourly ozone concentrations from
the OZONE.DAT data file

Monthly ozone concentrations in ppb (BCKO3)
(Used only if MCHEM = 1,3,4,6, or 7 and either
MOZ = 0, or
MOZ = 1 and all hourly O3 data missing)
Default: 12*80.
! BCKO3 = 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00 !

Ammonia data option (MNH3) Default: 0 ! MNH3 = 0 !
(Used only if MCHEM = 6 or 7)
0 = use monthly background ammonia values (BCKNH3) - no vertical variation
1 = read monthly background ammonia values for each layer from
the NH3Z.DAT data file

Ammonia vertical averaging option (MAVGNH3)
(Used only if MCHEM = 6 or 7, and MNH3 = 1)
0 = use NH3 at puff center height (no averaging is done)
1 = average NH3 values over vertical extent of puff
Default: 1 ! MAVGNH3 = 1 !

Monthly ammonia concentrations in ppb (BCKNH3)
(Used only if MCHEM = 1 or 3, or
if MCHEM = 6 or 7, and MNH3 = 0)
Default: 12*10.
! BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00 !

Nighttime SO2 loss rate in %/hour (RNITE1)
(Used only if MCHEM = 1, 6 or 7)
This rate is used only at night for MCHEM=1
and is added to the computed rate both day
and night for MCHEM=6,7 (heterogeneous reactions)

```
                                    Default: 0.2          ! RNITE1 = 0.2 !

    Nighttime NOx loss rate in %/hour (RNITE2)
    (Used only if MCHEM = 1)
                                    Default: 2.0          ! RNITE2 = 2 !

    Nighttime HNO3 formation rate in %/hour (RNITE3)
    (Used only if MCHEM = 1)
                                    Default: 2.0          ! RNITE3 = 2 !

    H2O2 data input option (MH2O2)    Default: 1          ! MH2O2 = 1 !
    (Used only if MCHEM = 6 or 7, and MAQCHEM = 1)
       0 = use a monthly background H2O2 value
       1 = read hourly H2O2 concentrations from
           the H2O2.DAT data file

    Monthly H2O2 concentrations in ppb (BCKH2O2)
    (Used only if MQACHEM = 1 and either
       MH2O2 = 0 or
       MH2O2 = 1 and all hourly H2O2 data missing)
                                    Default: 12*1.
    ! BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00,
1.00 !


  --- Data for SECONDARY ORGANIC AEROSOL (SOA) Options
      (used only if MCHEM = 4 or 7)

      The MCHEM = 4 SOA module uses monthly values of:
           Fine particulate concentration in ug/m^3 (BCKPMF)
           Organic fraction of fine particulate     (OFRAC)
           VOC / NOX ratio (after reaction)         (VCNX)

      The MCHEM = 7 SOA module uses monthly values of:
           Fine particulate concentration in ug/m^3 (BCKPMF)
           Organic fraction of fine particulate     (OFRAC)

      These characterize the air mass when computing
      the formation of SOA from VOC emissions.
      Typical values for several distinct air mass types are:

         Month    1    2    3    4    5    6    7    8    9   10   11   12
                 Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

      Clean Continental
         BCKPMF   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
         OFRAC  .15  .15  .20  .20  .20  .20  .20  .20  .20  .20  .20  .15
         VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

      Clean Marine (surface)
         BCKPMF  .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
         OFRAC  .25  .25  .30  .30  .30  .30  .30  .30  .30  .30  .30  .25
         VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

      Urban - low biogenic (controls present)
         BCKPMF  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.
         OFRAC  .20  .20  .25  .25  .25  .25  .25  .25  .20  .20  .20  .20
         VCNX     4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.

      Urban - high biogenic (controls present)
         BCKPMF  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.
         OFRAC  .25  .25  .30  .30  .30  .55  .55  .55  .35  .35  .35  .25
         VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.
```

```
     Regional Plume
        BCKPMF  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
        OFRAC  .20  .20  .25  .35  .25  .40  .40  .40  .30  .30  .30  .20
        VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

     Urban - no controls present
        BCKPMF 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
        OFRAC  .30  .30  .35  .35  .35  .55  .55  .55  .35  .35  .35  .30
        VCNX     2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.

     Default: Clean Continental
     ! BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00,
1.00 !
     ! OFRAC = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20,
0.15 !
     ! VCNX = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00,
50.00, 50.00 !

 --- End Data for SECONDARY ORGANIC AEROSOL (SOA) Options


     Number of half-life decay specification blocks provided in Subgroup 11b
     (Used only if MCHEM = 5)
     (NDECAY)                                    Default: 0      ! NDECAY = 0 !

!END!


--------------
Subgroup (11b)
--------------

     Each species modeled may be assigned a decay half-life (sec), and the
associated
     mass lost may be assigned to one or more other modeled species using a mass
yield
     factor. This information is used only for MCHEM=5.

     Provide NDECAY blocks assigning the half-life for a parent species and mass
yield
     factors for each child species (if any) produced by the decay.
     Set HALF_LIFE=0.0 for NO decay (infinite half-life).

                              a            b
        SPECIES      Half-Life   Mass Yield
         NAME          (sec)       Factor
        -------      ---------   ----------
* SPECHLLIST = *

--------
    a
     Specify a half life that is greater than or equal to zero for 1 parent species
     in each block, and set the yield factor for this species to -1
    b
     Specify a yield factor that is greater than or equal to zero for 1 or more
child
     species in each block, and set the half-life for each of these species to -1

     NOTE: Assignments in each block are treated as a separate input
           subgroup and therefore must end with an input group terminator.
           If NDECAY=0, no assignments and input group terminators should appear.
```

```
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
---------------

     Horizontal size of puff (m) beyond which
     time-dependent dispersion equations (Heffter)
     are used to determine sigma-y and
     sigma-z (SYTDEP)                          Default: 550.   ! SYTDEP = 550 !

     Switch for using Heffter equation for sigma z
     as above (0 = Not use Heffter; 1 = use Heffter
     (MHFTSZ)                                  Default: 0      ! MHFTSZ = 0 !

     Stability class used to determine plume
     growth rates for puffs above the boundary
     layer (JSUP)                              Default: 5      ! JSUP = 5 !

     Vertical dispersion constant for stable
     conditions (k1 in Eqn. 2.7-3)  (CONK1)    Default: 0.01   ! CONK1 = 0.01 !

     Vertical dispersion constant for neutral/
     unstable conditions (k2 in Eqn. 2.7-4)
     (CONK2)                                   Default: 0.1    ! CONK2 = 0.1 !

     Factor for determining Transition-point from
     Schulman-Scire to Huber-Snyder Building Downwash
     scheme (SS used for Hs <Hb + TBD * HL)
     (TBD)                                     Default: 0.5    ! TBD = 0.5 !
        TBD <0   ==> always use Huber-Snyder
        TBD = 1.5 ==> always use Schulman-Scire
        TBD = 0.5 ==> ISC Transition-point

     Range of land use categories for which
     urban dispersion is assumed
     (IURB1, IURB2)                            Default: 10     ! IURB1 = 10 !
                                                        19     ! IURB2 = 19 !

     Site characterization parameters for single-point Met data files ---------
     (needed for METFM = 2,3,4,5)

        Land use category for modeling domain
        (ILANDUIN)                             Default: 20     ! ILANDUIN = 20 !

        Roughness length (m) for modeling domain
        (ZOIN)                                 Default: 0.25   ! ZOIN = .25 !

        Leaf area index for modeling domain
        (XLAIIN)                               Default: 3.0    ! XLAIIN = 3.0 !

        Elevation above sea level (m)
        (ELEVIN)                               Default: 0.0    ! ELEVIN = .0 !

        Latitude (degrees) for met location
        (XLATIN)                               Default: -999.  ! XLATIN = -999.0 !

        Longitude (degrees) for met location
        (XLONIN)                               Default: -999.  ! XLONIN = -999.0 !

     Specialized information for interpreting single-point Met data files -----

        Anemometer height (m) (Used only if METFM = 2,3)
```

```
   (ANEMHT)                                  Default: 10.    ! ANEMHT = 10.0 !

   Form of lateral turbulance data in PROFILE.DAT file
   (Used only if METFM = 4,5 or MTURBVW = 1 or 3)
   (ISIGMAV)                                 Default: 1      ! ISIGMAV = 1 !
       0 = read sigma-theta
       1 = read sigma-v

   Choice of mixing heights (Used only if METFM = 4)
   (IMIXCTDM)                                Default: 0      ! IMIXCTDM = 0 !
       0 = read PREDICTED mixing heights
       1 = read OBSERVED mixing heights

Maximum length of a slug (met. grid units)
(XMXLEN)                                     Default: 1.0    ! XMXLEN = 1 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XSAMLEN)                                    Default: 1.0    ! XSAMLEN = 1 !

Maximum Number of slugs/puffs release from
one source during one time step
(MXNEW)                                      Default: 99     ! MXNEW = 99 !

Maximum Number of sampling steps for
one puff/slug during one time step
(MXSAM)                                      Default: 99     ! MXSAM = 99 !

Number of iterations used when computing
the transport wind for a sampling step
that includes gradual rise (for CALMET
and PROFILE winds)
(NCOUNT)                                     Default: 2      ! NCOUNT = 2 !

Minimum sigma y for a new puff/slug (m)
(SYMIN)                                      Default: 1.0    ! SYMIN = 1 !

Minimum sigma z for a new puff/slug (m)
(SZMIN)                                      Default: 1.0    ! SZMIN = 1 !

Maximum sigma z (m) allowed to avoid
numerical problem in calculating virtual
time or distance.  Cap should be large
enough to have no influence on normal events.
Enter a negative cap to disable.
(SZCAP_M)                                    Default: 5.0e06 ! SZCAP_M = 5000000
!

Default minimum turbulence velocities sigma-v and sigma-w
for each stability class over land and over water (m/s)
(SVMIN(12) and SWMIN(12))

                  ----------  LAND  ----------       ---------  WATER  ----------
   Stab Class :    A    B    C    D    E    F         A    B    C    D    E    F
                  ---  ---  ---  ---  ---  ---       ---  ---  ---  ---  ---  ---
Default SVMIN : .50, .50, .50, .50, .50, .50,      .37, .37, .37, .37, .37, .37
Default SWMIN : .20, .12, .08, .06, .03, .016,     .20, .12, .08, .06, .03,
.016

      ! SVMIN = 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37,
0.37 !
      ! SWMIN = 0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06,
0.03, 0.016 !
```

```
     Divergence criterion for dw/dz across puff
     used to initiate adjustment for horizontal
     convergence (1/s)
     Partial adjustment starts at CDIV(1), and
     full adjustment is reached at CDIV(2)
     (CDIV(2))                                  Default: 0.0,0.0  ! CDIV = 0, 0 !

     Search radius (number of cells) for nearest
     land and water cells used in the subgrid
     TIBL module
     (NLUTIBL)                                  Default: 4      ! NLUTIBL = 4 !

     Minimum wind speed (m/s) allowed for
     non-calm conditions. Also used as minimum
     speed returned when using power-law
     extrapolation toward surface
     (WSCALM)                                   Default: 0.5    ! WSCALM = 0.5 !

     Maximum mixing height (m)
     (XMAXZI)                                   Default: 3000.  ! XMAXZI = 3000 !

     Minimum mixing height (m)
     (XMINZI)                                   Default: 50.    ! XMINZI = 50 !

     Default wind speed classes --
     5 upper bounds (m/s) are entered;
     the 6th class has no upper limit
     (WSCAT(5))                       Default   :
                                      ISC RURAL : 1.54, 3.09, 5.14, 8.23, 10.8
(10.8+)

                                Wind Speed Class :  1     2     3     4     5
                                                    ---   ---   ---   ---   ---
                                         ! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.8 !

     Default wind speed profile power-law
     exponents for stabilities 1-6
     (PLX0(6))                        Default   : ISC RURAL values
                                      ISC RURAL : .07, .07, .10, .15, .35, .55
                                      ISC URBAN : .15, .15, .20, .25, .30, .30

                                 Stability Class :  A     B     C     D     E     F
                                                    ---   ---   ---   ---   ---   ---
                                           ! PLX0 = 0.07, 0.07, 0.1, 0.15, 0.35, 0.55 !

     Default potential temperature gradient
     for stable classes E, F (degK/m)
     (PTG0(2))                        Default: 0.020, 0.035
                                         ! PTG0 = 0.02, 0.035 !

     Default plume path coefficients for
     each stability class (used when option
     for partial plume height terrain adjustment
     is selected -- MCTADJ=3)
     (PPC(6))                    Stability Class :  A     B     C     D     E     F
                                    Default  PPC : .50,  .50,  .50,  .50,  .35,  .35
                                                   ---   ---   ---   ---   ---   ---
                                          ! PPC = 0.5, 0.5, 0.5, 0.5, 0.35, 0.35 !

     Slug-to-puff transition criterion factor
     equal to sigma-y/length of slug
     (SL2PF)                                Default: 10.        ! SL2PF = 10 !
```

```
Puff-splitting control variables ------------------------

  VERTICAL SPLIT
  --------------

  Number of puffs that result every time a puff
  is split - nsplit=2 means that 1 puff splits
  into 2
  (NSPLIT)                          Default:   3        ! NSPLIT = 3 !

  Time(s) of a day when split puffs are eligible to
  be split once again; this is typically set once
  per day, around sunset before nocturnal shear develops.
  24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
  0=do not re-split    1=eligible for re-split
  (IRESPLIT(24))                    Default:  Hour 17 = 1
  ! IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !

  Split is allowed only if last hour's mixing
  height (m) exceeds a minimum value
  (ZISPLIT)                         Default: 100.       ! ZISPLIT = 100 !

  Split is allowed only if ratio of last hour's
  mixing ht to the maximum mixing ht experienced
  by the puff is less than a maximum value (this
  postpones a split until a nocturnal layer develops)
  (ROLDMAX)                         Default: 0.25       ! ROLDMAX = 0.25 !


  HORIZONTAL SPLIT
  ----------------

  Number of puffs that result every time a puff
  is split - nsplith=5 means that 1 puff splits
  into 5
  (NSPLITH)                         Default:   5        ! NSPLITH = 5 !

  Minimum sigma-y (Grid Cells Units) of puff
  before it may be split
  (SYSPLITH)                        Default:  1.0       ! SYSPLITH = 1 !

  Minimum puff elongation rate (SYSPLITH/hr) due to
  wind shear, before it may be split
  (SHSPLITH)                        Default:  2.        ! SHSPLITH = 2 !

  Minimum concentration (g/m^3) of each
  species in puff before it may be split
  Enter array of NSPEC values; if a single value is
  entered, it will be used for ALL species
  (CNSPLITH)                        Default:  1.0E-07   ! CNSPLITH = 0 !

Integration control variables ----------------------

  Fractional convergence criterion for numerical SLUG
  sampling integration
  (EPSSLUG)                         Default:   1.0e-04  ! EPSSLUG = 0.0001 !

  Fractional convergence criterion for numerical AREA
  source integration
  (EPSAREA)                         Default:   1.0e-06  ! EPSAREA = 1E-6 !

  Trajectory step-length (m) used for numerical rise
```

```
      integration
      (DSRISE)                          Default:   1.0      ! DSRISE = 1 !

      Boundary Condition (BC) Puff control variables ------------------------

      Minimum height (m) to which BC puffs are mixed as they are emitted
      (MBCON=2 ONLY).  Actual height is reset to the current mixing height
      at the release point if greater than this minimum.
      (HTMINBC)                         Default:   500.     * HTMINBC = *

      Search radius (km) about a receptor for sampling nearest BC puff.
      BC puffs are typically emitted with a spacing of one grid cell
      length, so the search radius should be greater than DGRIDKM.
      (RSAMPBC)                         Default:   10.      * RSAMPBC = *

      Near-Surface depletion adjustment to concentration profile used when
      sampling BC puffs?
      (MDEPBC)                          Default:   1        * MDEPBC = *
         0 = Concentration is NOT adjusted for depletion
         1 = Adjust Concentration for depletion

!END!


--------------------------------------------------------------------------------


INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters
---------------------------------

---------------
Subgroup (13a)
---------------

     Number of point sources with
     parameters provided below      (NPT1)  No default  ! NPT1 = 3 !

     Units used for point source
     emissions below                (IPTU)  Default: 1  ! IPTU = 1 !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (13d)        (NSPT1) Default: 0  ! NSPT1 = 0 !

     Number of point sources with
     variable emission parameters
     provided in external file      (NPT2)  No default  ! NPT2 = 0 !

     (If NPT2 > 0, these point
     source emissions are read from
     the file: PTEMARB.DAT)

!END!

---------------
```

Subgroup (13b)
---

a

POINT SOURCE: CONSTANT DATA
---

b

c

Source No.	X Coordinate (km)	Y Coordinate (km)	Stack Height (m)	Base Elevation (m)	Stack Diameter (m)	Exit Vel. (m/s)	Exit Temp. (deg. K)	Bldg. Dwash	Emission Rates
1	SRCNAM = SRC_1								
1	X = 724.040	5187.202	71.0	0.0	2.0	31.5	427.0	2.0	4.406, 0.988, 0.062, 0.087, 0.083, 0.078
1	ZPLTFM =	30.0							
1	FMFAC =	1.0	!END!						
2	SRCNAM = SRC_2								
2	X = 724.050	5187.202	71.0	0.0	2.0	31.5	427.0	2.0	4.406, 0.988, 0.062, 0.087, 0.083, 0.078
2	ZPLTFM =	30.0							
2	FMFAC =	1.0	!END!						
3	SRCNAM = SRC_3								
3	X = 724.150	5187.202	126.31	0.0	16.67	2.0	727.0	2.0	0.204, 1.111, 0, 0.022, 0.022, 0.022
3	ZPLTFM =	30.0							
3	FMFAC =	1.0	!END!						

---

a
Data for each source are treated as a separate input subgroup
and therefore must end with an input group terminator.

SRCNAM is a 12-character name for a source
(No default)

X is an array holding the source data listed by the column headings
(No default)

SIGYZI is an array holding the initial sigma-y and sigma-z (m)
(Default: 0.,0.)

FMFAC is a vertical momentum flux factor (0. or 1.0) used to represent the effect of rain-caps or other physical configurations that reduce momentum rise associated with the actual exit velocity.
(Default: 1.0 -- full momentum used)

ZPLTFM is the platform height (m) for sources influenced by an isolated structure that has a significant open area between the surface and the bulk of the structure, such as an offshore oil platform. The Base Elevation is that of the surface (ground or ocean), and the Stack Height is the release height above the Base (not above the platform). Building heights entered in Subgroup 13c must be those of the buildings on the platform, measured from the platform deck. ZPLTFM is used only with MBDW=1 (ISC downwash method) for sources with building downwash.
(Default: 0.0)

b
0. = No building downwash modeled
1. = Downwash modeled for buildings resting on the surface
2. = Downwash modeled for buildings raised above the surface (ZPLTFM > 0.)
NOTE: must be entered as a REAL number (i.e., with decimal point)

c
An emission rate must be entered for every pollutant modeled.
Enter emission rate of zero for secondary pollutants that are
modeled, but not emitted. Units are specified by IPTU
(e.g. 1 for g/s).

Subgroup (13c)

BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH

Source No. — a

Effective building height, width, length and X/Y offset (in meters) every 10 degrees. LENGTH, XBADJ, and YBADJ are only needed for MBDW=2 (PRIME downwash option)

```
   1 ! SRCNAM = SRC_1 !
   1 ! HEIGHT  =   28.27,   28.27,   28.27,   28.27,   28.27,   36.07,
                   36.07,   36.07,   36.07,   36.07,   36.07,   36.07,
                   36.07,   28.27,   28.27,   28.27,   28.27,   28.27,
                   28.27,   28.27,   28.27,   28.27,   28.27,   36.07,
                   36.07,   36.07,   36.07,   36.07,   36.07,   36.07,
                   36.07,   28.27,   28.27,   28.27,   28.27,   28.27 !
   1 ! WIDTH   =   30.30,   37.73,   44.01,   48.95,   52.41,   50.80,
                   52.11,   51.85,   50.00,   51.85,   52.11,   50.80,
                   47.94,   48.95,   44.01,   37.73,   30.30,   21.95,
                   30.30,   37.73,   44.01,   48.95,   52.41,   50.80,
                   52.11,   51.85,   50.00,   51.85,   52.11,   50.80,
                   47.94,   48.95,   44.01,   37.73,   30.30,   21.95 !
!END!
   2 ! SRCNAM = SRC_2 !
   2 ! HEIGHT  =   28.27,   28.27,   28.27,   28.27,   36.07,   36.07,
                   36.07,   36.07,   36.07,   36.07,   36.07,   36.07,
                   36.07,   28.27,   28.27,   28.27,   28.27,   28.27,
                   28.27,   28.27,   28.27,   28.27,   36.07,   36.07,
                   36.07,   36.07,   36.07,   36.07,   36.07,   36.07,
                   36.07,   28.27,   28.27,   28.27,   28.27,   28.27 !
   2 ! WIDTH   =   30.30,   37.73,   44.01,   48.95,   47.94,   50.80,
                   52.11,   51.85,   50.00,   51.85,   52.11,   50.80,
                   47.94,   48.95,   44.01,   37.73,   30.30,   21.95,
                   30.30,   37.73,   44.01,   48.95,   47.94,   50.80,
                   52.11,   51.85,   50.00,   51.85,   52.11,   50.80,
                   47.94,   48.95,   44.01,   37.73,   30.30,   21.95 !
!END!
   3 ! SRCNAM = SRC_3 !
   3 ! HEIGHT  =    0.00,    0.00,    0.00,   36.07,   36.07,   36.07,
                   36.07,   36.07,   36.07,   36.07,   36.07,   36.07,
                   36.07,   36.07,    0.00,    0.00,    0.00,    0.00,
                    0.00,    0.00,    0.00,   36.07,   36.07,   36.07,
                   36.07,   36.07,   36.07,   36.07,   36.07,   36.07,
                   36.07,   36.07,    0.00,    0.00,    0.00,    0.00 !
   3 ! WIDTH   =    0.00,    0.00,    0.00,   43.63,   47.94,   50.80,
                   52.11,   51.85,   50.00,   51.85,   52.11,   50.80,
                   47.94,   43.63,    0.00,    0.00,    0.00,    0.00,
                    0.00,    0.00,    0.00,   43.63,   47.94,   50.80,
```

```
                  52.11,   51.85,   50.00,   51.85,   52.11,   50.80,
                  47.94,   43.63,    0.00,    0.00,    0.00,    0.00 !
!END!
```

---

a
Building height, width, length, and X/Y offset from the source are treated as a separate input subgroup for each source and therefore must end with an input group terminator. The X/Y offset is the position, relative to the stack, of the center of the upwind face of the projected building, with the x-axis pointing along the flow direction.

Subgroup (13d)
---

a
POINT SOURCE: VARIABLE EMISSIONS DATA

Use this subgroup to describe temporal variations in the emission rates given in 13b. Factors entered multiply the rates in 13b. Skip sources here that have constant emissions. For more elaborate variation in source parameters, use PTEMARB.DAT and NPT2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0

- 0 = Constant
- 1 = Diurnal cycle (24 scaling factors: hours 1-24)
- 2 = Monthly cycle (12 scaling factors: months 1-12)
- 3 = Hour & Season (4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)
- 4 = Speed & Stab. (6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12
- 5 = Temperature (12 scaling factors, where temperature classes have upper bounds (C) of: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)

---
a
Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters

Subgroup (14a)

Number of polygon area sources with parameters specified below (NAR1) No default ! NAR1 = 0 !

```
     Units used for area source
     emissions below           (IARU)       Default: 1  ! IARU = 1 !
           1 =        g/m**2/s
           2 =       kg/m**2/hr
           3 =       lb/m**2/hr
           4 =     tons/m**2/yr
           5 =     Odour Unit * m/s  (vol. flux/m**2 of odour compound)
           6 =     Odour Unit * m/min
           7 =     metric tons/m**2/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (14d)        (NSAR1) Default: 0  ! NSAR1 = 0 !

     Number of buoyant polygon area sources
     with variable location and emission
     parameters (NAR2)                       No default  ! NAR2 = 0 !
     (If NAR2 > 0, ALL parameter data for
     these sources are read from the file: BAEMARB.DAT)

!END!

---------------
Subgroup (14b)
---------------
                                   a
          AREA SOURCE: CONSTANT DATA
          --------------------------
                                                              b
Source           Effect.    Base      Initial    Emission
 No.             Height   Elevation   Sigma z     Rates
                   (m)       (m)        (m)
-------          ------    ------     --------   ---------


--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.
    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IARU
     (e.g. 1 for g/m**2/s).

---------------
Subgroup (14c)
---------------

           COORDINATES (km) FOR EACH VERTEX(4) OF EACH POLYGON
           ---------------------------------------------------
Source                                                          a
 No.       Ordered list of X followed by list of Y, grouped by source
------     ------------------------------------------------------------


--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.
```

Subgroup (14d)

AREA SOURCE: VARIABLE EMISSIONS DATA [a]

Use this subgroup to describe temporal variations in the emission rates given in 14b. Factors entered multiply the rates in 14b. Skip sources here that have constant emissions. For more elaborate variation in source parameters, use BAEMARB.DAT and NAR2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0

- 0 = Constant
- 1 = Diurnal cycle (24 scaling factors: hours 1-24)
- 2 = Monthly cycle (12 scaling factors: months 1-12)
- 3 = Hour & Season (4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)
- 4 = Speed & Stab. (6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12
- 5 = Temperature (12 scaling factors, where temperature classes have upper bounds (C) of: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)

---

[a] Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters

Subgroup (15a)

Number of buoyant line sources with variable location and emission parameters (NLN2) No default ! NLN2 = 0 !

(If NLN2 > 0, ALL parameter data for these sources are read from the file: LNEMARB.DAT)

Number of buoyant line sources (NLINES) No default ! NLINES = 0 !

Units used for line source emissions below (ILNU) Default: 1 ! ILNU = 1 !

- 1 = g/s
- 2 = kg/hr
- 3 = lb/hr
- 4 = tons/yr
- 5 = Odour Unit * m**3/s (vol. flux of odour compound)
- 6 = Odour Unit * m**3/min
- 7 = metric tons/yr

Number of source-species
combinations with variable
emissions scaling factors
provided below in (15c) (NSLN1) Default: 0 ! NSLN1 = 0 !

Maximum number of segments used to model
each line (MXNSEG) Default: 7 ! MXNSEG = 7 !

The following variables are required only if NLINES > 0. They are
used in the buoyant line source plume rise calculations.

Number of distances at which transitional rise is computed	Default: 6	! NLRISE = 6 !
Average building length (XL)	No default (in meters)	* XL = *
Average building height (HBL)	No default (in meters)	* HBL = *
Average building width (WBL)	No default (in meters)	* WBL = *
Average line source width (WML)	No default (in meters)	* WML = *
Average separation between buildings (DXL)	No default (in meters)	* DXL = *
Average buoyancy parameter (FPRIMEL)	No default (in m**4/s**3)	* FPRIMEL = *

!END!

Subgroup (15b)

BUOYANT LINE SOURCE: CONSTANT DATA

Source No.	Beg. X Coordinate (km)	Beg. Y Coordinate (km)	End. X Coordinate (km)	End. Y Coordinate (km)	Release Height (m)	Base Elevation (m)	Emission Rates[a]

---

a
Data for each source are treated as a separate input subgroup
and therefore must end with an input group terminator.

b
An emission rate must be entered for every pollutant modeled.
Enter emission rate of zero for secondary pollutants that are
modeled, but not emitted. Units are specified by ILNTU
(e.g. 1 for g/s).

Subgroup (15c)
---

[a]

BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA

Use this subgroup to describe temporal variations in the emission rates given in 15b. Factors entered multiply the rates in 15b. Skip sources here that have constant emissions.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0

0 =	Constant	
1 =	Diurnal cycle	(24 scaling factors: hours 1-24)
2 =	Monthly cycle	(12 scaling factors: months 1-12)
3 =	Hour & Season	(4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)
4 =	Speed & Stab.	(6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12
5 =	Temperature	(12 scaling factors, where temperature classes have upper bounds (C) of: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)

---

[a] Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters

Subgroup (16a)

Number of volume sources with parameters provided in 16b,c (NVL1) No default ! NVL1 = 0 !

Units used for volume source emissions below in 16b (IVLU) Default: 1 ! IVLU = 1 !

1 =	g/s
2 =	kg/hr
3 =	lb/hr
4 =	tons/yr
5 =	Odour Unit * m**3/s (vol. flux of odour compound)
6 =	Odour Unit * m**3/min
7 =	metric tons/yr

Number of source-species combinations with variable emissions scaling factors provided below in (16c) (NSVL1) Default: 0 ! NSVL1 = 0 !

```
     Number of volume sources with
     variable location and emission
     parameters                    (NVL2)     No default  ! NVL2 = 0 !

     (If NVL2 > 0, ALL parameter data for
      these sources are read from the VOLEMARB.DAT file(s) )

!END!

---------------
Subgroup (16b)
---------------
                                        a
           VOLUME SOURCE: CONSTANT DATA
           ----------------------------
                                                                        b
         X           Y        Effect.    Base     Initial    Initial    Emission
     Coordinate  Coordinate   Height   Elevation  Sigma y    Sigma z     Rates
        (km)        (km)        (m)       (m)       (m)        (m)
     ----------  ----------   ------    ------    --------   --------   --------


--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IVLU
     (e.g. 1 for g/s).

---------------
Subgroup (16c)
---------------
                                                 a
          VOLUME SOURCE: VARIABLE EMISSIONS DATA
          --------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 16b.  Factors entered multiply the rates in 16b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use VOLEMARB.DAT and NVL2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                 Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)
```

---

a
Data for each species are treated as a separate input subgroup
and therefore must end with an input group terminator.

INPUT GROUPS: 17a, 17b, 17c -- Non-gridded (discrete) receptor information

---

Subgroup (17a)

Number of non-gridded receptors (NREC) No default ! NREC = 1083 !

Group names can be used to assign receptor locations in
Subgroup 17c and thereby provide an identification that
can be referenced when postprocessing receptors. The
default assignment name X is used when NRGRP = 0.

Number of receptor group names (NRGRP) Default: 0 ! NRGRP = 0 !

!END!

Subgroup (17b)

Provide a name for each receptor group if NRGRP>0.
Enter NRGRP lines.

a,b

Group Name

---

* RGRPNAMLIST = *

---

a
Each group name provided is treated as a separate input subgroup
and therefore must end with an input group terminator.
b
Receptor group names must not include blanks.

Subgroup (17c)

---

a

NON-GRIDDED (DISCRETE) RECEPTOR DATA

Receptor No.	c Group Name	X Coordinate (km)	Y Coordinate (km)	Ground Elevation (m)	Height Above Ground (m)	b	
1	! X =	669.345,	5179.811,	0.0,	30.0 !		!END!
2	! X =	727.708,	5186.021,	0.0,	30.0 !		!END!
3	! X =	693.372,	5149.964,	0.0,	30.0 !		!END!
4	! X =	723.580,	5186.708,	0.0,	0.0 !		!END!
5	! X =	723.630,	5186.708,	0.0,	0.0 !		!END!
6	! X =	723.680,	5186.708,	0.0,	0.0 !		!END!

```
 7 ! X =       723.730,     5186.708,          0.0,          0.0 !   !END!
 8 ! X =       723.780,     5186.708,          0.0,          0.0 !   !END!
 9 ! X =       723.830,     5186.708,          0.0,          0.0 !   !END!
10 ! X =       723.880,     5186.708,          0.0,          0.0 !   !END!
11 ! X =       723.930,     5186.708,          0.0,          0.0 !   !END!
12 ! X =       723.980,     5186.708,          0.0,          0.0 !   !END!
13 ! X =       724.030,     5186.708,          0.0,          0.0 !   !END!
14 ! X =       724.080,     5186.708,          0.0,          0.0 !   !END!
15 ! X =       724.130,     5186.708,          0.0,          0.0 !   !END!
16 ! X =       724.180,     5186.708,          0.0,          0.0 !   !END!
17 ! X =       724.230,     5186.708,          0.0,          0.0 !   !END!
18 ! X =       724.280,     5186.708,          0.0,          0.0 !   !END!
19 ! X =       724.330,     5186.708,          0.0,          0.0 !   !END!
20 ! X =       724.380,     5186.708,          0.0,          0.0 !   !END!
21 ! X =       724.430,     5186.708,          0.0,          0.0 !   !END!
22 ! X =       724.480,     5186.708,          0.0,          0.0 !   !END!
23 ! X =       724.530,     5186.708,          0.0,          0.0 !   !END!
24 ! X =       724.580,     5186.708,          0.0,          0.0 !   !END!
25 ! X =       723.580,     5186.758,          0.0,          0.0 !   !END!
26 ! X =       723.630,     5186.758,          0.0,          0.0 !   !END!
27 ! X =       723.680,     5186.758,          0.0,          0.0 !   !END!
28 ! X =       723.730,     5186.758,          0.0,          0.0 !   !END!
29 ! X =       723.780,     5186.758,          0.0,          0.0 !   !END!
30 ! X =       723.830,     5186.758,          0.0,          0.0 !   !END!
31 ! X =       723.880,     5186.758,          0.0,          0.0 !   !END!
32 ! X =       723.930,     5186.758,          0.0,          0.0 !   !END!
33 ! X =       723.980,     5186.758,          0.0,          0.0 !   !END!
34 ! X =       724.030,     5186.758,          0.0,          0.0 !   !END!
35 ! X =       724.080,     5186.758,          0.0,          0.0 !   !END!
36 ! X =       724.130,     5186.758,          0.0,          0.0 !   !END!
37 ! X =       724.180,     5186.758,          0.0,          0.0 !   !END!
38 ! X =       724.230,     5186.758,          0.0,          0.0 !   !END!
39 ! X =       724.280,     5186.758,          0.0,          0.0 !   !END!
40 ! X =       724.330,     5186.758,          0.0,          0.0 !   !END!
41 ! X =       724.380,     5186.758,          0.0,          0.0 !   !END!
42 ! X =       724.430,     5186.758,          0.0,          0.0 !   !END!
43 ! X =       724.480,     5186.758,          0.0,          0.0 !   !END!
44 ! X =       724.530,     5186.758,          0.0,          0.0 !   !END!
45 ! X =       724.580,     5186.758,          0.0,          0.0 !   !END!
46 ! X =       723.580,     5186.808,          0.0,          0.0 !   !END!
47 ! X =       723.630,     5186.808,          0.0,          0.0 !   !END!
48 ! X =       723.680,     5186.808,          0.0,          0.0 !   !END!
49 ! X =       723.730,     5186.808,          0.0,          0.0 !   !END!
50 ! X =       723.780,     5186.808,          0.0,          0.0 !   !END!
51 ! X =       723.830,     5186.808,          0.0,          0.0 !   !END!
52 ! X =       723.880,     5186.808,          0.0,          0.0 !   !END!
53 ! X =       723.930,     5186.808,          0.0,          0.0 !   !END!
54 ! X =       723.980,     5186.808,          0.0,          0.0 !   !END!
55 ! X =       724.030,     5186.808,          0.0,          0.0 !   !END!
56 ! X =       724.080,     5186.808,          0.0,          0.0 !   !END!
57 ! X =       724.130,     5186.808,          0.0,          0.0 !   !END!
58 ! X =       724.180,     5186.808,          0.0,          0.0 !   !END!
59 ! X =       724.230,     5186.808,          0.0,          0.0 !   !END!
60 ! X =       724.280,     5186.808,          0.0,          0.0 !   !END!
61 ! X =       724.330,     5186.808,          0.0,          0.0 !   !END!
62 ! X =       724.380,     5186.808,          0.0,          0.0 !   !END!
63 ! X =       724.430,     5186.808,          0.0,          0.0 !   !END!
64 ! X =       724.480,     5186.808,          0.0,          0.0 !   !END!
65 ! X =       724.530,     5186.808,          0.0,          0.0 !   !END!
66 ! X =       724.580,     5186.808,          0.0,          0.0 !   !END!
67 ! X =       723.580,     5186.858,          0.0,          0.0 !   !END!
68 ! X =       723.630,     5186.858,          0.0,          0.0 !   !END!
69 ! X =       723.680,     5186.858,          0.0,          0.0 !   !END!
```

```
 70 ! X =       723.730,     5186.858,          0.0,          0.0 !   !END!
 71 ! X =       723.780,     5186.858,          0.0,          0.0 !   !END!
 72 ! X =       723.830,     5186.858,          0.0,          0.0 !   !END!
 73 ! X =       723.880,     5186.858,          0.0,          0.0 !   !END!
 74 ! X =       723.930,     5186.858,          0.0,          0.0 !   !END!
 75 ! X =       723.980,     5186.858,          0.0,          0.0 !   !END!
 76 ! X =       724.030,     5186.858,          0.0,          0.0 !   !END!
 77 ! X =       724.080,     5186.858,          0.0,          0.0 !   !END!
 78 ! X =       724.130,     5186.858,          0.0,          0.0 !   !END!
 79 ! X =       724.180,     5186.858,          0.0,          0.0 !   !END!
 80 ! X =       724.230,     5186.858,          0.0,          0.0 !   !END!
 81 ! X =       724.280,     5186.858,          0.0,          0.0 !   !END!
 82 ! X =       724.330,     5186.858,          0.0,          0.0 !   !END!
 83 ! X =       724.380,     5186.858,          0.0,          0.0 !   !END!
 84 ! X =       724.430,     5186.858,          0.0,          0.0 !   !END!
 85 ! X =       724.480,     5186.858,          0.0,          0.0 !   !END!
 86 ! X =       724.530,     5186.858,          0.0,          0.0 !   !END!
 87 ! X =       724.580,     5186.858,          0.0,          0.0 !   !END!
 88 ! X =       723.580,     5186.908,          0.0,          0.0 !   !END!
 89 ! X =       723.630,     5186.908,          0.0,          0.0 !   !END!
 90 ! X =       723.680,     5186.908,          0.0,          0.0 !   !END!
 91 ! X =       723.730,     5186.908,          0.0,          0.0 !   !END!
 92 ! X =       723.780,     5186.908,          0.0,          0.0 !   !END!
 93 ! X =       723.830,     5186.908,          0.0,          0.0 !   !END!
 94 ! X =       723.880,     5186.908,          0.0,          0.0 !   !END!
 95 ! X =       723.930,     5186.908,          0.0,          0.0 !   !END!
 96 ! X =       723.980,     5186.908,          0.0,          0.0 !   !END!
 97 ! X =       724.030,     5186.908,          0.0,          0.0 !   !END!
 98 ! X =       724.080,     5186.908,          0.0,          0.0 !   !END!
 99 ! X =       724.130,     5186.908,          0.0,          0.0 !   !END!
100 ! X =       724.180,     5186.908,          0.0,          0.0 !   !END!
101 ! X =       724.230,     5186.908,          0.0,          0.0 !   !END!
102 ! X =       724.280,     5186.908,          0.0,          0.0 !   !END!
103 ! X =       724.330,     5186.908,          0.0,          0.0 !   !END!
104 ! X =       724.380,     5186.908,          0.0,          0.0 !   !END!
105 ! X =       724.430,     5186.908,          0.0,          0.0 !   !END!
106 ! X =       724.480,     5186.908,          0.0,          0.0 !   !END!
107 ! X =       724.530,     5186.908,          0.0,          0.0 !   !END!
108 ! X =       724.580,     5186.908,          0.0,          0.0 !   !END!
109 ! X =       723.580,     5186.958,          0.0,          0.0 !   !END!
110 ! X =       723.630,     5186.958,          0.0,          0.0 !   !END!
111 ! X =       723.680,     5186.958,          0.0,          0.0 !   !END!
112 ! X =       723.730,     5186.958,          0.0,          0.0 !   !END!
113 ! X =       723.780,     5186.958,          0.0,          0.0 !   !END!
114 ! X =       723.830,     5186.958,          0.0,          0.0 !   !END!
115 ! X =       723.880,     5186.958,          0.0,          0.0 !   !END!
116 ! X =       723.930,     5186.958,          0.0,          0.0 !   !END!
117 ! X =       723.980,     5186.958,          0.0,          0.0 !   !END!
118 ! X =       724.030,     5186.958,          0.0,          0.0 !   !END!
119 ! X =       724.080,     5186.958,          0.0,          0.0 !   !END!
120 ! X =       724.130,     5186.958,          0.0,          0.0 !   !END!
121 ! X =       724.180,     5186.958,          0.0,          0.0 !   !END!
122 ! X =       724.230,     5186.958,          0.0,          0.0 !   !END!
123 ! X =       724.280,     5186.958,          0.0,          0.0 !   !END!
124 ! X =       724.330,     5186.958,          0.0,          0.0 !   !END!
125 ! X =       724.380,     5186.958,          0.0,          0.0 !   !END!
126 ! X =       724.430,     5186.958,          0.0,          0.0 !   !END!
127 ! X =       724.480,     5186.958,          0.0,          0.0 !   !END!
128 ! X =       724.530,     5186.958,          0.0,          0.0 !   !END!
129 ! X =       724.580,     5186.958,          0.0,          0.0 !   !END!
130 ! X =       723.580,     5187.008,          0.0,          0.0 !   !END!
131 ! X =       723.630,     5187.008,          0.0,          0.0 !   !END!
132 ! X =       723.680,     5187.008,          0.0,          0.0 !   !END!
```

```
133 ! X =       723.730,     5187.008,          0.0,          0.0 !   !END!
134 ! X =       723.780,     5187.008,          0.0,          0.0 !   !END!
135 ! X =       723.830,     5187.008,          0.0,          0.0 !   !END!
136 ! X =       723.880,     5187.008,          0.0,          0.0 !   !END!
137 ! X =       723.930,     5187.008,          0.0,          0.0 !   !END!
138 ! X =       723.980,     5187.008,          0.0,          0.0 !   !END!
139 ! X =       724.030,     5187.008,          0.0,          0.0 !   !END!
140 ! X =       724.080,     5187.008,          0.0,          0.0 !   !END!
141 ! X =       724.130,     5187.008,          0.0,          0.0 !   !END!
142 ! X =       724.180,     5187.008,          0.0,          0.0 !   !END!
143 ! X =       724.230,     5187.008,          0.0,          0.0 !   !END!
144 ! X =       724.280,     5187.008,          0.0,          0.0 !   !END!
145 ! X =       724.330,     5187.008,          0.0,          0.0 !   !END!
146 ! X =       724.380,     5187.008,          0.0,          0.0 !   !END!
147 ! X =       724.430,     5187.008,          0.0,          0.0 !   !END!
148 ! X =       724.480,     5187.008,          0.0,          0.0 !   !END!
149 ! X =       724.530,     5187.008,          0.0,          0.0 !   !END!
150 ! X =       724.580,     5187.008,          0.0,          0.0 !   !END!
151 ! X =       723.580,     5187.058,          0.0,          0.0 !   !END!
152 ! X =       723.630,     5187.058,          0.0,          0.0 !   !END!
153 ! X =       723.680,     5187.058,          0.0,          0.0 !   !END!
154 ! X =       723.730,     5187.058,          0.0,          0.0 !   !END!
155 ! X =       723.780,     5187.058,          0.0,          0.0 !   !END!
156 ! X =       723.830,     5187.058,          0.0,          0.0 !   !END!
157 ! X =       723.880,     5187.058,          0.0,          0.0 !   !END!
158 ! X =       723.930,     5187.058,          0.0,          0.0 !   !END!
159 ! X =       723.980,     5187.058,          0.0,          0.0 !   !END!
160 ! X =       724.030,     5187.058,          0.0,          0.0 !   !END!
161 ! X =       724.080,     5187.058,          0.0,          0.0 !   !END!
162 ! X =       724.130,     5187.058,          0.0,          0.0 !   !END!
163 ! X =       724.180,     5187.058,          0.0,          0.0 !   !END!
164 ! X =       724.230,     5187.058,          0.0,          0.0 !   !END!
165 ! X =       724.280,     5187.058,          0.0,          0.0 !   !END!
166 ! X =       724.330,     5187.058,          0.0,          0.0 !   !END!
167 ! X =       724.380,     5187.058,          0.0,          0.0 !   !END!
168 ! X =       724.430,     5187.058,          0.0,          0.0 !   !END!
169 ! X =       724.480,     5187.058,          0.0,          0.0 !   !END!
170 ! X =       724.530,     5187.058,          0.0,          0.0 !   !END!
171 ! X =       724.580,     5187.058,          0.0,          0.0 !   !END!
172 ! X =       723.580,     5187.108,          0.0,          0.0 !   !END!
173 ! X =       723.630,     5187.108,          0.0,          0.0 !   !END!
174 ! X =       723.680,     5187.108,          0.0,          0.0 !   !END!
175 ! X =       723.730,     5187.108,          0.0,          0.0 !   !END!
176 ! X =       723.780,     5187.108,          0.0,          0.0 !   !END!
177 ! X =       723.830,     5187.108,          0.0,          0.0 !   !END!
178 ! X =       723.880,     5187.108,          0.0,          0.0 !   !END!
179 ! X =       723.930,     5187.108,          0.0,          0.0 !   !END!
180 ! X =       723.980,     5187.108,          0.0,          0.0 !   !END!
181 ! X =       724.030,     5187.108,          0.0,          0.0 !   !END!
182 ! X =       724.080,     5187.108,          0.0,          0.0 !   !END!
183 ! X =       724.130,     5187.108,          0.0,          0.0 !   !END!
184 ! X =       724.180,     5187.108,          0.0,          0.0 !   !END!
185 ! X =       724.230,     5187.108,          0.0,          0.0 !   !END!
186 ! X =       724.280,     5187.108,          0.0,          0.0 !   !END!
187 ! X =       724.330,     5187.108,          0.0,          0.0 !   !END!
188 ! X =       724.380,     5187.108,          0.0,          0.0 !   !END!
189 ! X =       724.430,     5187.108,          0.0,          0.0 !   !END!
190 ! X =       724.480,     5187.108,          0.0,          0.0 !   !END!
191 ! X =       724.530,     5187.108,          0.0,          0.0 !   !END!
192 ! X =       724.580,     5187.108,          0.0,          0.0 !   !END!
193 ! X =       723.580,     5187.158,          0.0,          0.0 !   !END!
194 ! X =       723.630,     5187.158,          0.0,          0.0 !   !END!
195 ! X =       723.680,     5187.158,          0.0,          0.0 !   !END!
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196 ! X =       723.730,     5187.158,          0.0,          0.0 !   !END!
197 ! X =       723.780,     5187.158,          0.0,          0.0 !   !END!
198 ! X =       723.830,     5187.158,          0.0,          0.0 !   !END!
199 ! X =       723.880,     5187.158,          0.0,          0.0 !   !END!
200 ! X =       723.930,     5187.158,          0.0,          0.0 !   !END!
201 ! X =       723.980,     5187.158,          0.0,          0.0 !   !END!
202 ! X =       724.030,     5187.158,          0.0,          0.0 !   !END!
203 ! X =       724.080,     5187.158,          0.0,          0.0 !   !END!
204 ! X =       724.130,     5187.158,          0.0,          0.0 !   !END!
205 ! X =       724.180,     5187.158,          0.0,          0.0 !   !END!
206 ! X =       724.230,     5187.158,          0.0,          0.0 !   !END!
207 ! X =       724.280,     5187.158,          0.0,          0.0 !   !END!
208 ! X =       724.330,     5187.158,          0.0,          0.0 !   !END!
209 ! X =       724.380,     5187.158,          0.0,          0.0 !   !END!
210 ! X =       724.430,     5187.158,          0.0,          0.0 !   !END!
211 ! X =       724.480,     5187.158,          0.0,          0.0 !   !END!
212 ! X =       724.530,     5187.158,          0.0,          0.0 !   !END!
213 ! X =       724.580,     5187.158,          0.0,          0.0 !   !END!
214 ! X =       723.580,     5187.208,          0.0,          0.0 !   !END!
215 ! X =       723.630,     5187.208,          0.0,          0.0 !   !END!
216 ! X =       723.680,     5187.208,          0.0,          0.0 !   !END!
217 ! X =       723.730,     5187.208,          0.0,          0.0 !   !END!
218 ! X =       723.780,     5187.208,          0.0,          0.0 !   !END!
219 ! X =       723.830,     5187.208,          0.0,          0.0 !   !END!
220 ! X =       723.880,     5187.208,          0.0,          0.0 !   !END!
221 ! X =       723.930,     5187.208,          0.0,          0.0 !   !END!
222 ! X =       723.980,     5187.208,          0.0,          0.0 !   !END!
223 ! X =       724.030,     5187.208,          0.0,          0.0 !   !END!
224 ! X =       724.130,     5187.208,          0.0,          0.0 !   !END!
225 ! X =       724.180,     5187.208,          0.0,          0.0 !   !END!
226 ! X =       724.230,     5187.208,          0.0,          0.0 !   !END!
227 ! X =       724.280,     5187.208,          0.0,          0.0 !   !END!
228 ! X =       724.330,     5187.208,          0.0,          0.0 !   !END!
229 ! X =       724.380,     5187.208,          0.0,          0.0 !   !END!
230 ! X =       724.430,     5187.208,          0.0,          0.0 !   !END!
231 ! X =       724.480,     5187.208,          0.0,          0.0 !   !END!
232 ! X =       724.530,     5187.208,          0.0,          0.0 !   !END!
233 ! X =       724.580,     5187.208,          0.0,          0.0 !   !END!
234 ! X =       723.580,     5187.258,          0.0,          0.0 !   !END!
235 ! X =       723.630,     5187.258,          0.0,          0.0 !   !END!
236 ! X =       723.680,     5187.258,          0.0,          0.0 !   !END!
237 ! X =       723.730,     5187.258,          0.0,          0.0 !   !END!
238 ! X =       723.780,     5187.258,          0.0,          0.0 !   !END!
239 ! X =       723.830,     5187.258,          0.0,          0.0 !   !END!
240 ! X =       723.880,     5187.258,          0.0,          0.0 !   !END!
241 ! X =       723.930,     5187.258,          0.0,          0.0 !   !END!
242 ! X =       723.980,     5187.258,          0.0,          0.0 !   !END!
243 ! X =       724.030,     5187.258,          0.0,          0.0 !   !END!
244 ! X =       724.080,     5187.258,          0.0,          0.0 !   !END!
245 ! X =       724.130,     5187.258,          0.0,          0.0 !   !END!
246 ! X =       724.180,     5187.258,          0.0,          0.0 !   !END!
247 ! X =       724.230,     5187.258,          0.0,          0.0 !   !END!
248 ! X =       724.280,     5187.258,          0.0,          0.0 !   !END!
249 ! X =       724.330,     5187.258,          0.0,          0.0 !   !END!
250 ! X =       724.380,     5187.258,          0.0,          0.0 !   !END!
251 ! X =       724.430,     5187.258,          0.0,          0.0 !   !END!
252 ! X =       724.480,     5187.258,          0.0,          0.0 !   !END!
253 ! X =       724.530,     5187.258,          0.0,          0.0 !   !END!
254 ! X =       724.580,     5187.258,          0.0,          0.0 !   !END!
255 ! X =       723.580,     5187.308,          0.0,          0.0 !   !END!
256 ! X =       723.630,     5187.308,          0.0,          0.0 !   !END!
257 ! X =       723.680,     5187.308,          0.0,          0.0 !   !END!
258 ! X =       723.730,     5187.308,          0.0,          0.0 !   !END!
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259 ! X =       723.780,     5187.308,          0.0,          0.0 !   !END!
260 ! X =       723.830,     5187.308,          0.0,          0.0 !   !END!
261 ! X =       723.880,     5187.308,          0.0,          0.0 !   !END!
262 ! X =       723.930,     5187.308,          0.0,          0.0 !   !END!
263 ! X =       723.980,     5187.308,          0.0,          0.0 !   !END!
264 ! X =       724.030,     5187.308,          0.0,          0.0 !   !END!
265 ! X =       724.080,     5187.308,          0.0,          0.0 !   !END!
266 ! X =       724.130,     5187.308,          0.0,          0.0 !   !END!
267 ! X =       724.180,     5187.308,          0.0,          0.0 !   !END!
268 ! X =       724.230,     5187.308,          0.0,          0.0 !   !END!
269 ! X =       724.280,     5187.308,          0.0,          0.0 !   !END!
270 ! X =       724.330,     5187.308,          0.0,          0.0 !   !END!
271 ! X =       724.380,     5187.308,          0.0,          0.0 !   !END!
272 ! X =       724.430,     5187.308,          0.0,          0.0 !   !END!
273 ! X =       724.480,     5187.308,          0.0,          0.0 !   !END!
274 ! X =       724.530,     5187.308,          0.0,          0.0 !   !END!
275 ! X =       724.580,     5187.308,          0.0,          0.0 !   !END!
276 ! X =       723.580,     5187.358,          0.0,          0.0 !   !END!
277 ! X =       723.630,     5187.358,          0.0,          0.0 !   !END!
278 ! X =       723.680,     5187.358,          0.0,          0.0 !   !END!
279 ! X =       723.730,     5187.358,          0.0,          0.0 !   !END!
280 ! X =       723.780,     5187.358,          0.0,          0.0 !   !END!
281 ! X =       723.830,     5187.358,          0.0,          0.0 !   !END!
282 ! X =       723.880,     5187.358,          0.0,          0.0 !   !END!
283 ! X =       723.930,     5187.358,          0.0,          0.0 !   !END!
284 ! X =       723.980,     5187.358,          0.0,          0.0 !   !END!
285 ! X =       724.030,     5187.358,          0.0,          0.0 !   !END!
286 ! X =       724.080,     5187.358,          0.0,          0.0 !   !END!
287 ! X =       724.130,     5187.358,          0.0,          0.0 !   !END!
288 ! X =       724.180,     5187.358,          0.0,          0.0 !   !END!
289 ! X =       724.230,     5187.358,          0.0,          0.0 !   !END!
290 ! X =       724.280,     5187.358,          0.0,          0.0 !   !END!
291 ! X =       724.330,     5187.358,          0.0,          0.0 !   !END!
292 ! X =       724.380,     5187.358,          0.0,          0.0 !   !END!
293 ! X =       724.430,     5187.358,          0.0,          0.0 !   !END!
294 ! X =       724.480,     5187.358,          0.0,          0.0 !   !END!
295 ! X =       724.530,     5187.358,          0.0,          0.0 !   !END!
296 ! X =       724.580,     5187.358,          0.0,          0.0 !   !END!
297 ! X =       723.580,     5187.408,          0.0,          0.0 !   !END!
298 ! X =       723.630,     5187.408,          0.0,          0.0 !   !END!
299 ! X =       723.680,     5187.408,          0.0,          0.0 !   !END!
300 ! X =       723.730,     5187.408,          0.0,          0.0 !   !END!
301 ! X =       723.780,     5187.408,          0.0,          0.0 !   !END!
302 ! X =       723.830,     5187.408,          0.0,          0.0 !   !END!
303 ! X =       723.880,     5187.408,          0.0,          0.0 !   !END!
304 ! X =       723.930,     5187.408,          0.0,          0.0 !   !END!
305 ! X =       723.980,     5187.408,          0.0,          0.0 !   !END!
306 ! X =       724.030,     5187.408,          0.0,          0.0 !   !END!
307 ! X =       724.080,     5187.408,          0.0,          0.0 !   !END!
308 ! X =       724.130,     5187.408,          0.0,          0.0 !   !END!
309 ! X =       724.180,     5187.408,          0.0,          0.0 !   !END!
310 ! X =       724.230,     5187.408,          0.0,          0.0 !   !END!
311 ! X =       724.280,     5187.408,          0.0,          0.0 !   !END!
312 ! X =       724.330,     5187.408,          0.0,          0.0 !   !END!
313 ! X =       724.380,     5187.408,          0.0,          0.0 !   !END!
314 ! X =       724.430,     5187.408,          0.0,          0.0 !   !END!
315 ! X =       724.480,     5187.408,          0.0,          0.0 !   !END!
316 ! X =       724.530,     5187.408,          0.0,          0.0 !   !END!
317 ! X =       724.580,     5187.408,          0.0,          0.0 !   !END!
318 ! X =       723.580,     5187.458,          0.0,          0.0 !   !END!
319 ! X =       723.630,     5187.458,          0.0,          0.0 !   !END!
320 ! X =       723.680,     5187.458,          0.0,          0.0 !   !END!
321 ! X =       723.730,     5187.458,          0.0,          0.0 !   !END!
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322 ! X =       723.780,     5187.458,          0.0,          0.0 !   !END!
323 ! X =       723.830,     5187.458,          0.0,          0.0 !   !END!
324 ! X =       723.880,     5187.458,          0.0,          0.0 !   !END!
325 ! X =       723.930,     5187.458,          0.0,          0.0 !   !END!
326 ! X =       723.980,     5187.458,          0.0,          0.0 !   !END!
327 ! X =       724.030,     5187.458,          0.0,          0.0 !   !END!
328 ! X =       724.080,     5187.458,          0.0,          0.0 !   !END!
329 ! X =       724.130,     5187.458,          0.0,          0.0 !   !END!
330 ! X =       724.180,     5187.458,          0.0,          0.0 !   !END!
331 ! X =       724.230,     5187.458,          0.0,          0.0 !   !END!
332 ! X =       724.280,     5187.458,          0.0,          0.0 !   !END!
333 ! X =       724.330,     5187.458,          0.0,          0.0 !   !END!
334 ! X =       724.380,     5187.458,          0.0,          0.0 !   !END!
335 ! X =       724.430,     5187.458,          0.0,          0.0 !   !END!
336 ! X =       724.480,     5187.458,          0.0,          0.0 !   !END!
337 ! X =       724.530,     5187.458,          0.0,          0.0 !   !END!
338 ! X =       724.580,     5187.458,          0.0,          0.0 !   !END!
339 ! X =       723.580,     5187.508,          0.0,          0.0 !   !END!
340 ! X =       723.630,     5187.508,          0.0,          0.0 !   !END!
341 ! X =       723.680,     5187.508,          0.0,          0.0 !   !END!
342 ! X =       723.730,     5187.508,          0.0,          0.0 !   !END!
343 ! X =       723.780,     5187.508,          0.0,          0.0 !   !END!
344 ! X =       723.830,     5187.508,          0.0,          0.0 !   !END!
345 ! X =       723.880,     5187.508,          0.0,          0.0 !   !END!
346 ! X =       723.930,     5187.508,          0.0,          0.0 !   !END!
347 ! X =       723.980,     5187.508,          0.0,          0.0 !   !END!
348 ! X =       724.030,     5187.508,          0.0,          0.0 !   !END!
349 ! X =       724.080,     5187.508,          0.0,          0.0 !   !END!
350 ! X =       724.130,     5187.508,          0.0,          0.0 !   !END!
351 ! X =       724.180,     5187.508,          0.0,          0.0 !   !END!
352 ! X =       724.230,     5187.508,          0.0,          0.0 !   !END!
353 ! X =       724.280,     5187.508,          0.0,          0.0 !   !END!
354 ! X =       724.330,     5187.508,          0.0,          0.0 !   !END!
355 ! X =       724.380,     5187.508,          0.0,          0.0 !   !END!
356 ! X =       724.430,     5187.508,          0.0,          0.0 !   !END!
357 ! X =       724.480,     5187.508,          0.0,          0.0 !   !END!
358 ! X =       724.530,     5187.508,          0.0,          0.0 !   !END!
359 ! X =       724.580,     5187.508,          0.0,          0.0 !   !END!
360 ! X =       723.580,     5187.558,          0.0,          0.0 !   !END!
361 ! X =       723.630,     5187.558,          0.0,          0.0 !   !END!
362 ! X =       723.680,     5187.558,          0.0,          0.0 !   !END!
363 ! X =       723.730,     5187.558,          0.0,          0.0 !   !END!
364 ! X =       723.780,     5187.558,          0.0,          0.0 !   !END!
365 ! X =       723.830,     5187.558,          0.0,          0.0 !   !END!
366 ! X =       723.880,     5187.558,          0.0,          0.0 !   !END!
367 ! X =       723.930,     5187.558,          0.0,          0.0 !   !END!
368 ! X =       723.980,     5187.558,          0.0,          0.0 !   !END!
369 ! X =       724.030,     5187.558,          0.0,          0.0 !   !END!
370 ! X =       724.080,     5187.558,          0.0,          0.0 !   !END!
371 ! X =       724.130,     5187.558,          0.0,          0.0 !   !END!
372 ! X =       724.180,     5187.558,          0.0,          0.0 !   !END!
373 ! X =       724.230,     5187.558,          0.0,          0.0 !   !END!
374 ! X =       724.280,     5187.558,          0.0,          0.0 !   !END!
375 ! X =       724.330,     5187.558,          0.0,          0.0 !   !END!
376 ! X =       724.380,     5187.558,          0.0,          0.0 !   !END!
377 ! X =       724.430,     5187.558,          0.0,          0.0 !   !END!
378 ! X =       724.480,     5187.558,          0.0,          0.0 !   !END!
379 ! X =       724.530,     5187.558,          0.0,          0.0 !   !END!
380 ! X =       724.580,     5187.558,          0.0,          0.0 !   !END!
381 ! X =       723.580,     5187.608,          0.0,          0.0 !   !END!
382 ! X =       723.630,     5187.608,          0.0,          0.0 !   !END!
383 ! X =       723.680,     5187.608,          0.0,          0.0 !   !END!
384 ! X =       723.730,     5187.608,          0.0,          0.0 !   !END!
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385 ! X =       723.780,     5187.608,          0.0,          0.0 !   !END!
386 ! X =       723.830,     5187.608,          0.0,          0.0 !   !END!
387 ! X =       723.880,     5187.608,          0.0,          0.0 !   !END!
388 ! X =       723.930,     5187.608,          0.0,          0.0 !   !END!
389 ! X =       723.980,     5187.608,          0.0,          0.0 !   !END!
390 ! X =       724.030,     5187.608,          0.0,          0.0 !   !END!
391 ! X =       724.080,     5187.608,          0.0,          0.0 !   !END!
392 ! X =       724.130,     5187.608,          0.0,          0.0 !   !END!
393 ! X =       724.180,     5187.608,          0.0,          0.0 !   !END!
394 ! X =       724.230,     5187.608,          0.0,          0.0 !   !END!
395 ! X =       724.280,     5187.608,          0.0,          0.0 !   !END!
396 ! X =       724.330,     5187.608,          0.0,          0.0 !   !END!
397 ! X =       724.380,     5187.608,          0.0,          0.0 !   !END!
398 ! X =       724.430,     5187.608,          0.0,          0.0 !   !END!
399 ! X =       724.480,     5187.608,          0.0,          0.0 !   !END!
400 ! X =       724.530,     5187.608,          0.0,          0.0 !   !END!
401 ! X =       724.580,     5187.608,          0.0,          0.0 !   !END!
402 ! X =       723.580,     5187.658,          0.0,          0.0 !   !END!
403 ! X =       723.630,     5187.658,          0.0,          0.0 !   !END!
404 ! X =       723.680,     5187.658,          0.0,          0.0 !   !END!
405 ! X =       723.730,     5187.658,          0.0,          0.0 !   !END!
406 ! X =       723.780,     5187.658,          0.0,          0.0 !   !END!
407 ! X =       723.830,     5187.658,          0.0,          0.0 !   !END!
408 ! X =       723.880,     5187.658,          0.0,          0.0 !   !END!
409 ! X =       723.930,     5187.658,          0.0,          0.0 !   !END!
410 ! X =       723.980,     5187.658,          0.0,          0.0 !   !END!
411 ! X =       724.030,     5187.658,          0.0,          0.0 !   !END!
412 ! X =       724.080,     5187.658,          0.0,          0.0 !   !END!
413 ! X =       724.130,     5187.658,          0.0,          0.0 !   !END!
414 ! X =       724.180,     5187.658,          0.0,          0.0 !   !END!
415 ! X =       724.230,     5187.658,          0.0,          0.0 !   !END!
416 ! X =       724.280,     5187.658,          0.0,          0.0 !   !END!
417 ! X =       724.330,     5187.658,          0.0,          0.0 !   !END!
418 ! X =       724.380,     5187.658,          0.0,          0.0 !   !END!
419 ! X =       724.430,     5187.658,          0.0,          0.0 !   !END!
420 ! X =       724.480,     5187.658,          0.0,          0.0 !   !END!
421 ! X =       724.530,     5187.658,          0.0,          0.0 !   !END!
422 ! X =       724.580,     5187.658,          0.0,          0.0 !   !END!
423 ! X =       723.580,     5187.708,          0.0,          0.0 !   !END!
424 ! X =       723.630,     5187.708,          0.0,          0.0 !   !END!
425 ! X =       723.680,     5187.708,          0.0,          0.0 !   !END!
426 ! X =       723.730,     5187.708,          0.0,          0.0 !   !END!
427 ! X =       723.780,     5187.708,          0.0,          0.0 !   !END!
428 ! X =       723.830,     5187.708,          0.0,          0.0 !   !END!
429 ! X =       723.880,     5187.708,          0.0,          0.0 !   !END!
430 ! X =       723.930,     5187.708,          0.0,          0.0 !   !END!
431 ! X =       723.980,     5187.708,          0.0,          0.0 !   !END!
432 ! X =       724.030,     5187.708,          0.0,          0.0 !   !END!
433 ! X =       724.080,     5187.708,          0.0,          0.0 !   !END!
434 ! X =       724.130,     5187.708,          0.0,          0.0 !   !END!
435 ! X =       724.180,     5187.708,          0.0,          0.0 !   !END!
436 ! X =       724.230,     5187.708,          0.0,          0.0 !   !END!
437 ! X =       724.280,     5187.708,          0.0,          0.0 !   !END!
438 ! X =       724.330,     5187.708,          0.0,          0.0 !   !END!
439 ! X =       724.380,     5187.708,          0.0,          0.0 !   !END!
440 ! X =       724.430,     5187.708,          0.0,          0.0 !   !END!
441 ! X =       724.480,     5187.708,          0.0,          0.0 !   !END!
442 ! X =       724.530,     5187.708,          0.0,          0.0 !   !END!
443 ! X =       724.580,     5187.708,          0.0,          0.0 !   !END!
444 ! X =       723.080,     5186.208,          0.0,          0.0 !   !END!
445 ! X =       723.180,     5186.208,          0.0,          0.0 !   !END!
446 ! X =       723.280,     5186.208,          0.0,          0.0 !   !END!
447 ! X =       723.380,     5186.208,          0.0,          0.0 !   !END!
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448 ! X =       723.480,     5186.208,          0.0,          0.0 !   !END!
449 ! X =       723.580,     5186.208,          0.0,          0.0 !   !END!
450 ! X =       723.680,     5186.208,          0.0,          0.0 !   !END!
451 ! X =       723.780,     5186.208,          0.0,          0.0 !   !END!
452 ! X =       723.880,     5186.208,          0.0,          0.0 !   !END!
453 ! X =       723.980,     5186.208,          0.0,          0.0 !   !END!
454 ! X =       724.080,     5186.208,          0.0,          0.0 !   !END!
455 ! X =       724.180,     5186.208,          0.0,          0.0 !   !END!
456 ! X =       724.280,     5186.208,          0.0,          0.0 !   !END!
457 ! X =       724.380,     5186.208,          0.0,          0.0 !   !END!
458 ! X =       724.480,     5186.208,          0.0,          0.0 !   !END!
459 ! X =       724.580,     5186.208,          0.0,          0.0 !   !END!
460 ! X =       724.680,     5186.208,          0.0,          0.0 !   !END!
461 ! X =       724.780,     5186.208,          0.0,          0.0 !   !END!
462 ! X =       724.880,     5186.208,          0.0,          0.0 !   !END!
463 ! X =       724.980,     5186.208,          0.0,          0.0 !   !END!
464 ! X =       725.080,     5186.208,          0.0,          0.0 !   !END!
465 ! X =       723.080,     5186.308,          0.0,          0.0 !   !END!
466 ! X =       723.180,     5186.308,          0.0,          0.0 !   !END!
467 ! X =       723.280,     5186.308,          0.0,          0.0 !   !END!
468 ! X =       723.380,     5186.308,          0.0,          0.0 !   !END!
469 ! X =       723.480,     5186.308,          0.0,          0.0 !   !END!
470 ! X =       723.580,     5186.308,          0.0,          0.0 !   !END!
471 ! X =       723.680,     5186.308,          0.0,          0.0 !   !END!
472 ! X =       723.780,     5186.308,          0.0,          0.0 !   !END!
473 ! X =       723.880,     5186.308,          0.0,          0.0 !   !END!
474 ! X =       723.980,     5186.308,          0.0,          0.0 !   !END!
475 ! X =       724.080,     5186.308,          0.0,          0.0 !   !END!
476 ! X =       724.180,     5186.308,          0.0,          0.0 !   !END!
477 ! X =       724.280,     5186.308,          0.0,          0.0 !   !END!
478 ! X =       724.380,     5186.308,          0.0,          0.0 !   !END!
479 ! X =       724.480,     5186.308,          0.0,          0.0 !   !END!
480 ! X =       724.580,     5186.308,          0.0,          0.0 !   !END!
481 ! X =       724.680,     5186.308,          0.0,          0.0 !   !END!
482 ! X =       724.780,     5186.308,          0.0,          0.0 !   !END!
483 ! X =       724.880,     5186.308,          0.0,          0.0 !   !END!
484 ! X =       724.980,     5186.308,          0.0,          0.0 !   !END!
485 ! X =       725.080,     5186.308,          0.0,          0.0 !   !END!
486 ! X =       723.080,     5186.408,          0.0,          0.0 !   !END!
487 ! X =       723.180,     5186.408,          0.0,          0.0 !   !END!
488 ! X =       723.280,     5186.408,          0.0,          0.0 !   !END!
489 ! X =       723.380,     5186.408,          0.0,          0.0 !   !END!
490 ! X =       723.480,     5186.408,          0.0,          0.0 !   !END!
491 ! X =       723.580,     5186.408,          0.0,          0.0 !   !END!
492 ! X =       723.680,     5186.408,          0.0,          0.0 !   !END!
493 ! X =       723.780,     5186.408,          0.0,          0.0 !   !END!
494 ! X =       723.880,     5186.408,          0.0,          0.0 !   !END!
495 ! X =       723.980,     5186.408,          0.0,          0.0 !   !END!
496 ! X =       724.080,     5186.408,          0.0,          0.0 !   !END!
497 ! X =       724.180,     5186.408,          0.0,          0.0 !   !END!
498 ! X =       724.280,     5186.408,          0.0,          0.0 !   !END!
499 ! X =       724.380,     5186.408,          0.0,          0.0 !   !END!
500 ! X =       724.480,     5186.408,          0.0,          0.0 !   !END!
501 ! X =       724.580,     5186.408,          0.0,          0.0 !   !END!
502 ! X =       724.680,     5186.408,          0.0,          0.0 !   !END!
503 ! X =       724.780,     5186.408,          0.0,          0.0 !   !END!
504 ! X =       724.880,     5186.408,          0.0,          0.0 !   !END!
505 ! X =       724.980,     5186.408,          0.0,          0.0 !   !END!
506 ! X =       725.080,     5186.408,          0.0,          0.0 !   !END!
507 ! X =       723.080,     5186.508,          0.0,          0.0 !   !END!
508 ! X =       723.180,     5186.508,          0.0,          0.0 !   !END!
509 ! X =       723.280,     5186.508,          0.0,          0.0 !   !END!
510 ! X =       723.380,     5186.508,          0.0,          0.0 !   !END!
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511 ! X =       723.480,     5186.508,          0.0,          0.0 !   !END!
512 ! X =       723.580,     5186.508,          0.0,          0.0 !   !END!
513 ! X =       723.680,     5186.508,          0.0,          0.0 !   !END!
514 ! X =       723.780,     5186.508,          0.0,          0.0 !   !END!
515 ! X =       723.880,     5186.508,          0.0,          0.0 !   !END!
516 ! X =       723.980,     5186.508,          0.0,          0.0 !   !END!
517 ! X =       724.080,     5186.508,          0.0,          0.0 !   !END!
518 ! X =       724.180,     5186.508,          0.0,          0.0 !   !END!
519 ! X =       724.280,     5186.508,          0.0,          0.0 !   !END!
520 ! X =       724.380,     5186.508,          0.0,          0.0 !   !END!
521 ! X =       724.480,     5186.508,          0.0,          0.0 !   !END!
522 ! X =       724.580,     5186.508,          0.0,          0.0 !   !END!
523 ! X =       724.680,     5186.508,          0.0,          0.0 !   !END!
524 ! X =       724.780,     5186.508,          0.0,          0.0 !   !END!
525 ! X =       724.880,     5186.508,          0.0,          0.0 !   !END!
526 ! X =       724.980,     5186.508,          0.0,          0.0 !   !END!
527 ! X =       725.080,     5186.508,          0.0,          0.0 !   !END!
528 ! X =       723.080,     5186.608,          0.0,          0.0 !   !END!
529 ! X =       723.180,     5186.608,          0.0,          0.0 !   !END!
530 ! X =       723.280,     5186.608,          0.0,          0.0 !   !END!
531 ! X =       723.380,     5186.608,          0.0,          0.0 !   !END!
532 ! X =       723.480,     5186.608,          0.0,          0.0 !   !END!
533 ! X =       723.580,     5186.608,          0.0,          0.0 !   !END!
534 ! X =       723.680,     5186.608,          0.0,          0.0 !   !END!
535 ! X =       723.780,     5186.608,          0.0,          0.0 !   !END!
536 ! X =       723.880,     5186.608,          0.0,          0.0 !   !END!
537 ! X =       723.980,     5186.608,          0.0,          0.0 !   !END!
538 ! X =       724.080,     5186.608,          0.0,          0.0 !   !END!
539 ! X =       724.180,     5186.608,          0.0,          0.0 !   !END!
540 ! X =       724.280,     5186.608,          0.0,          0.0 !   !END!
541 ! X =       724.380,     5186.608,          0.0,          0.0 !   !END!
542 ! X =       724.480,     5186.608,          0.0,          0.0 !   !END!
543 ! X =       724.580,     5186.608,          0.0,          0.0 !   !END!
544 ! X =       724.680,     5186.608,          0.0,          0.0 !   !END!
545 ! X =       724.780,     5186.608,          0.0,          0.0 !   !END!
546 ! X =       724.880,     5186.608,          0.0,          0.0 !   !END!
547 ! X =       724.980,     5186.608,          0.0,          0.0 !   !END!
548 ! X =       725.080,     5186.608,          0.0,          0.0 !   !END!
549 ! X =       723.080,     5186.708,          0.0,          0.0 !   !END!
550 ! X =       723.180,     5186.708,          0.0,          0.0 !   !END!
551 ! X =       723.280,     5186.708,          0.0,          0.0 !   !END!
552 ! X =       723.380,     5186.708,          0.0,          0.0 !   !END!
553 ! X =       723.480,     5186.708,          0.0,          0.0 !   !END!
554 ! X =       724.680,     5186.708,          0.0,          0.0 !   !END!
555 ! X =       724.780,     5186.708,          0.0,          0.0 !   !END!
556 ! X =       724.880,     5186.708,          0.0,          0.0 !   !END!
557 ! X =       724.980,     5186.708,          0.0,          0.0 !   !END!
558 ! X =       725.080,     5186.708,          0.0,          0.0 !   !END!
559 ! X =       723.080,     5186.808,          0.0,          0.0 !   !END!
560 ! X =       723.180,     5186.808,          0.0,          0.0 !   !END!
561 ! X =       723.280,     5186.808,          0.0,          0.0 !   !END!
562 ! X =       723.380,     5186.808,          0.0,          0.0 !   !END!
563 ! X =       723.480,     5186.808,          0.0,          0.0 !   !END!
564 ! X =       724.680,     5186.808,          0.0,          0.0 !   !END!
565 ! X =       724.780,     5186.808,          0.0,          0.0 !   !END!
566 ! X =       724.880,     5186.808,          0.0,          0.0 !   !END!
567 ! X =       724.980,     5186.808,          0.0,          0.0 !   !END!
568 ! X =       725.080,     5186.808,          0.0,          0.0 !   !END!
569 ! X =       723.080,     5186.908,          0.0,          0.0 !   !END!
570 ! X =       723.180,     5186.908,          0.0,          0.0 !   !END!
571 ! X =       723.280,     5186.908,          0.0,          0.0 !   !END!
572 ! X =       723.380,     5186.908,          0.0,          0.0 !   !END!
573 ! X =       723.480,     5186.908,          0.0,          0.0 !   !END!
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574 ! X =       724.680,     5186.908,          0.0,          0.0 !   !END!
575 ! X =       724.780,     5186.908,          0.0,          0.0 !   !END!
576 ! X =       724.880,     5186.908,          0.0,          0.0 !   !END!
577 ! X =       724.980,     5186.908,          0.0,          0.0 !   !END!
578 ! X =       725.080,     5186.908,          0.0,          0.0 !   !END!
579 ! X =       723.080,     5187.008,          0.0,          0.0 !   !END!
580 ! X =       723.180,     5187.008,          0.0,          0.0 !   !END!
581 ! X =       723.280,     5187.008,          0.0,          0.0 !   !END!
582 ! X =       723.380,     5187.008,          0.0,          0.0 !   !END!
583 ! X =       723.480,     5187.008,          0.0,          0.0 !   !END!
584 ! X =       724.680,     5187.008,          0.0,          0.0 !   !END!
585 ! X =       724.780,     5187.008,          0.0,          0.0 !   !END!
586 ! X =       724.880,     5187.008,          0.0,          0.0 !   !END!
587 ! X =       724.980,     5187.008,          0.0,          0.0 !   !END!
588 ! X =       725.080,     5187.008,          0.0,          0.0 !   !END!
589 ! X =       723.080,     5187.108,          0.0,          0.0 !   !END!
590 ! X =       723.180,     5187.108,          0.0,          0.0 !   !END!
591 ! X =       723.280,     5187.108,          0.0,          0.0 !   !END!
592 ! X =       723.380,     5187.108,          0.0,          0.0 !   !END!
593 ! X =       723.480,     5187.108,          0.0,          0.0 !   !END!
594 ! X =       724.680,     5187.108,          0.0,          0.0 !   !END!
595 ! X =       724.780,     5187.108,          0.0,          0.0 !   !END!
596 ! X =       724.880,     5187.108,          0.0,          0.0 !   !END!
597 ! X =       724.980,     5187.108,          0.0,          0.0 !   !END!
598 ! X =       725.080,     5187.108,          0.0,          0.0 !   !END!
599 ! X =       723.080,     5187.208,          0.0,          0.0 !   !END!
600 ! X =       723.180,     5187.208,          0.0,          0.0 !   !END!
601 ! X =       723.280,     5187.208,          0.0,          0.0 !   !END!
602 ! X =       723.380,     5187.208,          0.0,          0.0 !   !END!
603 ! X =       723.480,     5187.208,          0.0,          0.0 !   !END!
604 ! X =       724.680,     5187.208,          0.0,          0.0 !   !END!
605 ! X =       724.780,     5187.208,          0.0,          0.0 !   !END!
606 ! X =       724.880,     5187.208,          0.0,          0.0 !   !END!
607 ! X =       724.980,     5187.208,          0.0,          0.0 !   !END!
608 ! X =       725.080,     5187.208,          0.0,          0.0 !   !END!
609 ! X =       723.080,     5187.308,          0.0,          0.0 !   !END!
610 ! X =       723.180,     5187.308,          0.0,          0.0 !   !END!
611 ! X =       723.280,     5187.308,          0.0,          0.0 !   !END!
612 ! X =       723.380,     5187.308,          0.0,          0.0 !   !END!
613 ! X =       723.480,     5187.308,          0.0,          0.0 !   !END!
614 ! X =       724.680,     5187.308,          0.0,          0.0 !   !END!
615 ! X =       724.780,     5187.308,          0.0,          0.0 !   !END!
616 ! X =       724.880,     5187.308,          0.0,          0.0 !   !END!
617 ! X =       724.980,     5187.308,          0.0,          0.0 !   !END!
618 ! X =       725.080,     5187.308,          0.0,          0.0 !   !END!
619 ! X =       723.080,     5187.408,          0.0,          0.0 !   !END!
620 ! X =       723.180,     5187.408,          0.0,          0.0 !   !END!
621 ! X =       723.280,     5187.408,          0.0,          0.0 !   !END!
622 ! X =       723.380,     5187.408,          0.0,          0.0 !   !END!
623 ! X =       723.480,     5187.408,          0.0,          0.0 !   !END!
624 ! X =       724.680,     5187.408,          0.0,          0.0 !   !END!
625 ! X =       724.780,     5187.408,          0.0,          0.0 !   !END!
626 ! X =       724.880,     5187.408,          0.0,          0.0 !   !END!
627 ! X =       724.980,     5187.408,          0.0,          0.0 !   !END!
628 ! X =       725.080,     5187.408,          0.0,          0.0 !   !END!
629 ! X =       723.080,     5187.508,          0.0,          0.0 !   !END!
630 ! X =       723.180,     5187.508,          0.0,          0.0 !   !END!
631 ! X =       723.280,     5187.508,          0.0,          0.0 !   !END!
632 ! X =       723.380,     5187.508,          0.0,          0.0 !   !END!
633 ! X =       723.480,     5187.508,          0.0,          0.0 !   !END!
634 ! X =       724.680,     5187.508,          0.0,          0.0 !   !END!
635 ! X =       724.780,     5187.508,          0.0,          0.0 !   !END!
636 ! X =       724.880,     5187.508,          0.0,          0.0 !   !END!
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637 ! X =       724.980,     5187.508,          0.0,          0.0 !   !END!
638 ! X =       725.080,     5187.508,          0.0,          0.0 !   !END!
639 ! X =       723.080,     5187.608,          0.0,          0.0 !   !END!
640 ! X =       723.180,     5187.608,          0.0,          0.0 !   !END!
641 ! X =       723.280,     5187.608,          0.0,          0.0 !   !END!
642 ! X =       723.380,     5187.608,          0.0,          0.0 !   !END!
643 ! X =       723.480,     5187.608,          0.0,          0.0 !   !END!
644 ! X =       724.680,     5187.608,          0.0,          0.0 !   !END!
645 ! X =       724.780,     5187.608,          0.0,          0.0 !   !END!
646 ! X =       724.880,     5187.608,          0.0,          0.0 !   !END!
647 ! X =       724.980,     5187.608,          0.0,          0.0 !   !END!
648 ! X =       725.080,     5187.608,          0.0,          0.0 !   !END!
649 ! X =       723.080,     5187.708,          0.0,          0.0 !   !END!
650 ! X =       723.180,     5187.708,          0.0,          0.0 !   !END!
651 ! X =       723.280,     5187.708,          0.0,          0.0 !   !END!
652 ! X =       723.380,     5187.708,          0.0,          0.0 !   !END!
653 ! X =       723.480,     5187.708,          0.0,          0.0 !   !END!
654 ! X =       724.680,     5187.708,          0.0,          0.0 !   !END!
655 ! X =       724.780,     5187.708,          0.0,          0.0 !   !END!
656 ! X =       724.880,     5187.708,          0.0,          0.0 !   !END!
657 ! X =       724.980,     5187.708,          0.0,          0.0 !   !END!
658 ! X =       725.080,     5187.708,          0.0,          0.0 !   !END!
659 ! X =       723.080,     5187.808,          0.0,          0.0 !   !END!
660 ! X =       723.180,     5187.808,          0.0,          0.0 !   !END!
661 ! X =       723.280,     5187.808,          0.0,          0.0 !   !END!
662 ! X =       723.380,     5187.808,          0.0,          0.0 !   !END!
663 ! X =       723.480,     5187.808,          0.0,          0.0 !   !END!
664 ! X =       723.580,     5187.808,          0.0,          0.0 !   !END!
665 ! X =       723.680,     5187.808,          0.0,          0.0 !   !END!
666 ! X =       723.780,     5187.808,          0.0,          0.0 !   !END!
667 ! X =       723.880,     5187.808,          0.0,          0.0 !   !END!
668 ! X =       723.980,     5187.808,          0.0,          0.0 !   !END!
669 ! X =       724.080,     5187.808,          0.0,          0.0 !   !END!
670 ! X =       724.180,     5187.808,          0.0,          0.0 !   !END!
671 ! X =       724.280,     5187.808,          0.0,          0.0 !   !END!
672 ! X =       724.380,     5187.808,          0.0,          0.0 !   !END!
673 ! X =       724.480,     5187.808,          0.0,          0.0 !   !END!
674 ! X =       724.580,     5187.808,          0.0,          0.0 !   !END!
675 ! X =       724.680,     5187.808,          0.0,          0.0 !   !END!
676 ! X =       724.780,     5187.808,          0.0,          0.0 !   !END!
677 ! X =       724.880,     5187.808,          0.0,          0.0 !   !END!
678 ! X =       724.980,     5187.808,          0.0,          0.0 !   !END!
679 ! X =       725.080,     5187.808,          0.0,          0.0 !   !END!
680 ! X =       723.080,     5187.908,          0.0,          0.0 !   !END!
681 ! X =       723.180,     5187.908,          0.0,          0.0 !   !END!
682 ! X =       723.280,     5187.908,          0.0,          0.0 !   !END!
683 ! X =       723.380,     5187.908,          0.0,          0.0 !   !END!
684 ! X =       723.480,     5187.908,          0.0,          0.0 !   !END!
685 ! X =       723.580,     5187.908,          0.0,          0.0 !   !END!
686 ! X =       723.680,     5187.908,          0.0,          0.0 !   !END!
687 ! X =       723.780,     5187.908,          0.0,          0.0 !   !END!
688 ! X =       723.880,     5187.908,          0.0,          0.0 !   !END!
689 ! X =       723.980,     5187.908,          0.0,          0.0 !   !END!
690 ! X =       724.080,     5187.908,          0.0,          0.0 !   !END!
691 ! X =       724.180,     5187.908,          0.0,          0.0 !   !END!
692 ! X =       724.280,     5187.908,          0.0,          0.0 !   !END!
693 ! X =       724.380,     5187.908,          0.0,          0.0 !   !END!
694 ! X =       724.480,     5187.908,          0.0,          0.0 !   !END!
695 ! X =       724.580,     5187.908,          0.0,          0.0 !   !END!
696 ! X =       724.680,     5187.908,          0.0,          0.0 !   !END!
697 ! X =       724.780,     5187.908,          0.0,          0.0 !   !END!
698 ! X =       724.880,     5187.908,          0.0,          0.0 !   !END!
699 ! X =       724.980,     5187.908,          0.0,          0.0 !   !END!
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700 ! X =       725.080,     5187.908,          0.0,          0.0 !   !END!
701 ! X =       723.080,     5188.008,          0.0,          0.0 !   !END!
702 ! X =       723.180,     5188.008,          0.0,          0.0 !   !END!
703 ! X =       723.280,     5188.008,          0.0,          0.0 !   !END!
704 ! X =       723.380,     5188.008,          0.0,          0.0 !   !END!
705 ! X =       723.480,     5188.008,          0.0,          0.0 !   !END!
706 ! X =       723.580,     5188.008,          0.0,          0.0 !   !END!
707 ! X =       723.680,     5188.008,          0.0,          0.0 !   !END!
708 ! X =       723.780,     5188.008,          0.0,          0.0 !   !END!
709 ! X =       723.880,     5188.008,          0.0,          0.0 !   !END!
710 ! X =       723.980,     5188.008,          0.0,          0.0 !   !END!
711 ! X =       724.080,     5188.008,          0.0,          0.0 !   !END!
712 ! X =       724.180,     5188.008,          0.0,          0.0 !   !END!
713 ! X =       724.280,     5188.008,          0.0,          0.0 !   !END!
714 ! X =       724.380,     5188.008,          0.0,          0.0 !   !END!
715 ! X =       724.480,     5188.008,          0.0,          0.0 !   !END!
716 ! X =       724.580,     5188.008,          0.0,          0.0 !   !END!
717 ! X =       724.680,     5188.008,          0.0,          0.0 !   !END!
718 ! X =       724.780,     5188.008,          0.0,          0.0 !   !END!
719 ! X =       724.880,     5188.008,          0.0,          0.0 !   !END!
720 ! X =       724.980,     5188.008,          0.0,          0.0 !   !END!
721 ! X =       725.080,     5188.008,          0.0,          0.0 !   !END!
722 ! X =       723.080,     5188.108,          0.0,          0.0 !   !END!
723 ! X =       723.180,     5188.108,          0.0,          0.0 !   !END!
724 ! X =       723.280,     5188.108,          0.0,          0.0 !   !END!
725 ! X =       723.380,     5188.108,          0.0,          0.0 !   !END!
726 ! X =       723.480,     5188.108,          0.0,          0.0 !   !END!
727 ! X =       723.580,     5188.108,          0.0,          0.0 !   !END!
728 ! X =       723.680,     5188.108,          0.0,          0.0 !   !END!
729 ! X =       723.780,     5188.108,          0.0,          0.0 !   !END!
730 ! X =       723.880,     5188.108,          0.0,          0.0 !   !END!
731 ! X =       723.980,     5188.108,          0.0,          0.0 !   !END!
732 ! X =       724.080,     5188.108,          0.0,          0.0 !   !END!
733 ! X =       724.180,     5188.108,          0.0,          0.0 !   !END!
734 ! X =       724.280,     5188.108,          0.0,          0.0 !   !END!
735 ! X =       724.380,     5188.108,          0.0,          0.0 !   !END!
736 ! X =       724.480,     5188.108,          0.0,          0.0 !   !END!
737 ! X =       724.580,     5188.108,          0.0,          0.0 !   !END!
738 ! X =       724.680,     5188.108,          0.0,          0.0 !   !END!
739 ! X =       724.780,     5188.108,          0.0,          0.0 !   !END!
740 ! X =       724.880,     5188.108,          0.0,          0.0 !   !END!
741 ! X =       724.980,     5188.108,          0.0,          0.0 !   !END!
742 ! X =       725.080,     5188.108,          0.0,          0.0 !   !END!
743 ! X =       723.080,     5188.208,          0.0,          0.0 !   !END!
744 ! X =       723.180,     5188.208,          0.0,          0.0 !   !END!
745 ! X =       723.280,     5188.208,          0.0,          0.0 !   !END!
746 ! X =       723.380,     5188.208,          0.0,          0.0 !   !END!
747 ! X =       723.480,     5188.208,          0.0,          0.0 !   !END!
748 ! X =       723.580,     5188.208,          0.0,          0.0 !   !END!
749 ! X =       723.680,     5188.208,          0.0,          0.0 !   !END!
750 ! X =       723.780,     5188.208,          0.0,          0.0 !   !END!
751 ! X =       723.880,     5188.208,          0.0,          0.0 !   !END!
752 ! X =       723.980,     5188.208,          0.0,          0.0 !   !END!
753 ! X =       724.080,     5188.208,          0.0,          0.0 !   !END!
754 ! X =       724.180,     5188.208,          0.0,          0.0 !   !END!
755 ! X =       724.280,     5188.208,          0.0,          0.0 !   !END!
756 ! X =       724.380,     5188.208,          0.0,          0.0 !   !END!
757 ! X =       724.480,     5188.208,          0.0,          0.0 !   !END!
758 ! X =       724.580,     5188.208,          0.0,          0.0 !   !END!
759 ! X =       724.680,     5188.208,          0.0,          0.0 !   !END!
760 ! X =       724.780,     5188.208,          0.0,          0.0 !   !END!
761 ! X =       724.880,     5188.208,          0.0,          0.0 !   !END!
762 ! X =       724.980,     5188.208,          0.0,          0.0 !   !END!
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763 ! X =       725.080,     5188.208,          0.0,          0.0 !   !END!
764 ! X =       722.080,     5185.208,          0.0,          0.0 !   !END!
765 ! X =       722.280,     5185.208,          0.0,          0.0 !   !END!
766 ! X =       722.480,     5185.208,          0.0,          0.0 !   !END!
767 ! X =       722.680,     5185.208,          0.0,          0.0 !   !END!
768 ! X =       722.880,     5185.208,          0.0,          0.0 !   !END!
769 ! X =       723.080,     5185.208,          0.0,          0.0 !   !END!
770 ! X =       723.280,     5185.208,          0.0,          0.0 !   !END!
771 ! X =       723.480,     5185.208,          0.0,          0.0 !   !END!
772 ! X =       723.680,     5185.208,          0.0,          0.0 !   !END!
773 ! X =       723.880,     5185.208,          0.0,          0.0 !   !END!
774 ! X =       724.080,     5185.208,          0.0,          0.0 !   !END!
775 ! X =       724.280,     5185.208,          0.0,          0.0 !   !END!
776 ! X =       724.480,     5185.208,          0.0,          0.0 !   !END!
777 ! X =       724.680,     5185.208,          0.0,          0.0 !   !END!
778 ! X =       724.880,     5185.208,          0.0,          0.0 !   !END!
779 ! X =       725.080,     5185.208,          0.0,          0.0 !   !END!
780 ! X =       725.280,     5185.208,          0.0,          0.0 !   !END!
781 ! X =       725.480,     5185.208,          0.0,          0.0 !   !END!
782 ! X =       725.680,     5185.208,          0.0,          0.0 !   !END!
783 ! X =       725.880,     5185.208,          0.0,          0.0 !   !END!
784 ! X =       726.080,     5185.208,          0.0,          0.0 !   !END!
785 ! X =       722.080,     5185.408,          0.0,          0.0 !   !END!
786 ! X =       722.280,     5185.408,          0.0,          0.0 !   !END!
787 ! X =       722.480,     5185.408,          0.0,          0.0 !   !END!
788 ! X =       722.680,     5185.408,          0.0,          0.0 !   !END!
789 ! X =       722.880,     5185.408,          0.0,          0.0 !   !END!
790 ! X =       723.080,     5185.408,          0.0,          0.0 !   !END!
791 ! X =       723.280,     5185.408,          0.0,          0.0 !   !END!
792 ! X =       723.480,     5185.408,          0.0,          0.0 !   !END!
793 ! X =       723.680,     5185.408,          0.0,          0.0 !   !END!
794 ! X =       723.880,     5185.408,          0.0,          0.0 !   !END!
795 ! X =       724.080,     5185.408,          0.0,          0.0 !   !END!
796 ! X =       724.280,     5185.408,          0.0,          0.0 !   !END!
797 ! X =       724.480,     5185.408,          0.0,          0.0 !   !END!
798 ! X =       724.680,     5185.408,          0.0,          0.0 !   !END!
799 ! X =       724.880,     5185.408,          0.0,          0.0 !   !END!
800 ! X =       725.080,     5185.408,          0.0,          0.0 !   !END!
801 ! X =       725.280,     5185.408,          0.0,          0.0 !   !END!
802 ! X =       725.480,     5185.408,          0.0,          0.0 !   !END!
803 ! X =       725.680,     5185.408,          0.0,          0.0 !   !END!
804 ! X =       725.880,     5185.408,          0.0,          0.0 !   !END!
805 ! X =       726.080,     5185.408,          0.0,          0.0 !   !END!
806 ! X =       722.080,     5185.608,          0.0,          0.0 !   !END!
807 ! X =       722.280,     5185.608,          0.0,          0.0 !   !END!
808 ! X =       722.480,     5185.608,          0.0,          0.0 !   !END!
809 ! X =       722.680,     5185.608,          0.0,          0.0 !   !END!
810 ! X =       722.880,     5185.608,          0.0,          0.0 !   !END!
811 ! X =       723.080,     5185.608,          0.0,          0.0 !   !END!
812 ! X =       723.280,     5185.608,          0.0,          0.0 !   !END!
813 ! X =       723.480,     5185.608,          0.0,          0.0 !   !END!
814 ! X =       723.680,     5185.608,          0.0,          0.0 !   !END!
815 ! X =       723.880,     5185.608,          0.0,          0.0 !   !END!
816 ! X =       724.080,     5185.608,          0.0,          0.0 !   !END!
817 ! X =       724.280,     5185.608,          0.0,          0.0 !   !END!
818 ! X =       724.480,     5185.608,          0.0,          0.0 !   !END!
819 ! X =       724.680,     5185.608,          0.0,          0.0 !   !END!
820 ! X =       724.880,     5185.608,          0.0,          0.0 !   !END!
821 ! X =       725.080,     5185.608,          0.0,          0.0 !   !END!
822 ! X =       725.280,     5185.608,          0.0,          0.0 !   !END!
823 ! X =       725.480,     5185.608,          0.0,          0.0 !   !END!
824 ! X =       725.680,     5185.608,          0.0,          0.0 !   !END!
825 ! X =       725.880,     5185.608,          0.0,          0.0 !   !END!
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826 ! X =       726.080,     5185.608,          0.0,          0.0 !   !END!
827 ! X =       722.080,     5185.808,          0.0,          0.0 !   !END!
828 ! X =       722.280,     5185.808,          0.0,          0.0 !   !END!
829 ! X =       722.480,     5185.808,          0.0,          0.0 !   !END!
830 ! X =       722.680,     5185.808,          0.0,          0.0 !   !END!
831 ! X =       722.880,     5185.808,          0.0,          0.0 !   !END!
832 ! X =       723.080,     5185.808,          0.0,          0.0 !   !END!
833 ! X =       723.280,     5185.808,          0.0,          0.0 !   !END!
834 ! X =       723.480,     5185.808,          0.0,          0.0 !   !END!
835 ! X =       723.680,     5185.808,          0.0,          0.0 !   !END!
836 ! X =       723.880,     5185.808,          0.0,          0.0 !   !END!
837 ! X =       724.080,     5185.808,          0.0,          0.0 !   !END!
838 ! X =       724.280,     5185.808,          0.0,          0.0 !   !END!
839 ! X =       724.480,     5185.808,          0.0,          0.0 !   !END!
840 ! X =       724.680,     5185.808,          0.0,          0.0 !   !END!
841 ! X =       724.880,     5185.808,          0.0,          0.0 !   !END!
842 ! X =       725.080,     5185.808,          0.0,          0.0 !   !END!
843 ! X =       725.280,     5185.808,          0.0,          0.0 !   !END!
844 ! X =       725.480,     5185.808,          0.0,          0.0 !   !END!
845 ! X =       725.680,     5185.808,          0.0,          0.0 !   !END!
846 ! X =       725.880,     5185.808,          0.0,          0.0 !   !END!
847 ! X =       726.080,     5185.808,          0.0,          0.0 !   !END!
848 ! X =       722.080,     5186.008,          0.0,          0.0 !   !END!
849 ! X =       722.280,     5186.008,          0.0,          0.0 !   !END!
850 ! X =       722.480,     5186.008,          0.0,          0.0 !   !END!
851 ! X =       722.680,     5186.008,          0.0,          0.0 !   !END!
852 ! X =       722.880,     5186.008,          0.0,          0.0 !   !END!
853 ! X =       723.080,     5186.008,          0.0,          0.0 !   !END!
854 ! X =       723.280,     5186.008,          0.0,          0.0 !   !END!
855 ! X =       723.480,     5186.008,          0.0,          0.0 !   !END!
856 ! X =       723.680,     5186.008,          0.0,          0.0 !   !END!
857 ! X =       723.880,     5186.008,          0.0,          0.0 !   !END!
858 ! X =       724.080,     5186.008,          0.0,          0.0 !   !END!
859 ! X =       724.280,     5186.008,          0.0,          0.0 !   !END!
860 ! X =       724.480,     5186.008,          0.0,          0.0 !   !END!
861 ! X =       724.680,     5186.008,          0.0,          0.0 !   !END!
862 ! X =       724.880,     5186.008,          0.0,          0.0 !   !END!
863 ! X =       725.080,     5186.008,          0.0,          0.0 !   !END!
864 ! X =       725.280,     5186.008,          0.0,          0.0 !   !END!
865 ! X =       725.480,     5186.008,          0.0,          0.0 !   !END!
866 ! X =       725.680,     5186.008,          0.0,          0.0 !   !END!
867 ! X =       725.880,     5186.008,          0.0,          0.0 !   !END!
868 ! X =       726.080,     5186.008,          0.0,          0.0 !   !END!
869 ! X =       722.080,     5186.208,          0.0,          0.0 !   !END!
870 ! X =       722.280,     5186.208,          0.0,          0.0 !   !END!
871 ! X =       722.480,     5186.208,          0.0,          0.0 !   !END!
872 ! X =       722.680,     5186.208,          0.0,          0.0 !   !END!
873 ! X =       722.880,     5186.208,          0.0,          0.0 !   !END!
874 ! X =       725.280,     5186.208,          0.0,          0.0 !   !END!
875 ! X =       725.480,     5186.208,          0.0,          0.0 !   !END!
876 ! X =       725.680,     5186.208,          0.0,          0.0 !   !END!
877 ! X =       725.880,     5186.208,          0.0,          0.0 !   !END!
878 ! X =       726.080,     5186.208,          0.0,          0.0 !   !END!
879 ! X =       722.080,     5186.408,          0.0,          0.0 !   !END!
880 ! X =       722.280,     5186.408,          0.0,          0.0 !   !END!
881 ! X =       722.480,     5186.408,          0.0,          0.0 !   !END!
882 ! X =       722.680,     5186.408,          0.0,          0.0 !   !END!
883 ! X =       722.880,     5186.408,          0.0,          0.0 !   !END!
884 ! X =       725.280,     5186.408,          0.0,          0.0 !   !END!
885 ! X =       725.480,     5186.408,          0.0,          0.0 !   !END!
886 ! X =       725.680,     5186.408,          0.0,          0.0 !   !END!
887 ! X =       725.880,     5186.408,          0.0,          0.0 !   !END!
888 ! X =       726.080,     5186.408,          0.0,          0.0 !   !END!
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889 ! X =       722.080,     5186.608,          0.0,          0.0 !   !END!
890 ! X =       722.280,     5186.608,          0.0,          0.0 !   !END!
891 ! X =       722.480,     5186.608,          0.0,          0.0 !   !END!
892 ! X =       722.680,     5186.608,          0.0,          0.0 !   !END!
893 ! X =       722.880,     5186.608,          0.0,          0.0 !   !END!
894 ! X =       725.280,     5186.608,          0.0,          0.0 !   !END!
895 ! X =       725.480,     5186.608,          0.0,          0.0 !   !END!
896 ! X =       725.680,     5186.608,          0.0,          0.0 !   !END!
897 ! X =       725.880,     5186.608,          0.0,          0.0 !   !END!
898 ! X =       726.080,     5186.608,          0.0,          0.0 !   !END!
899 ! X =       722.080,     5186.808,          0.0,          0.0 !   !END!
900 ! X =       722.280,     5186.808,          0.0,          0.0 !   !END!
901 ! X =       722.480,     5186.808,          0.0,          0.0 !   !END!
902 ! X =       722.680,     5186.808,          0.0,          0.0 !   !END!
903 ! X =       722.880,     5186.808,          0.0,          0.0 !   !END!
904 ! X =       725.280,     5186.808,          0.0,          0.0 !   !END!
905 ! X =       725.480,     5186.808,          0.0,          0.0 !   !END!
906 ! X =       725.680,     5186.808,          0.0,          0.0 !   !END!
907 ! X =       725.880,     5186.808,          0.0,          0.0 !   !END!
908 ! X =       726.080,     5186.808,          0.0,          0.0 !   !END!
909 ! X =       722.080,     5187.008,          0.0,          0.0 !   !END!
910 ! X =       722.280,     5187.008,          0.0,          0.0 !   !END!
911 ! X =       722.480,     5187.008,          0.0,          0.0 !   !END!
912 ! X =       722.680,     5187.008,          0.0,          0.0 !   !END!
913 ! X =       722.880,     5187.008,          0.0,          0.0 !   !END!
914 ! X =       725.280,     5187.008,          0.0,          0.0 !   !END!
915 ! X =       725.480,     5187.008,          0.0,          0.0 !   !END!
916 ! X =       725.680,     5187.008,          0.0,          0.0 !   !END!
917 ! X =       725.880,     5187.008,          0.0,          0.0 !   !END!
918 ! X =       726.080,     5187.008,          0.0,          0.0 !   !END!
919 ! X =       722.080,     5187.208,          0.0,          0.0 !   !END!
920 ! X =       722.280,     5187.208,          0.0,          0.0 !   !END!
921 ! X =       722.480,     5187.208,          0.0,          0.0 !   !END!
922 ! X =       722.680,     5187.208,          0.0,          0.0 !   !END!
923 ! X =       722.880,     5187.208,          0.0,          0.0 !   !END!
924 ! X =       725.280,     5187.208,          0.0,          0.0 !   !END!
925 ! X =       725.480,     5187.208,          0.0,          0.0 !   !END!
926 ! X =       725.680,     5187.208,          0.0,          0.0 !   !END!
927 ! X =       725.880,     5187.208,          0.0,          0.0 !   !END!
928 ! X =       726.080,     5187.208,          0.0,          0.0 !   !END!
929 ! X =       722.080,     5187.408,          0.0,          0.0 !   !END!
930 ! X =       722.280,     5187.408,          0.0,          0.0 !   !END!
931 ! X =       722.480,     5187.408,          0.0,          0.0 !   !END!
932 ! X =       722.680,     5187.408,          0.0,          0.0 !   !END!
933 ! X =       722.880,     5187.408,          0.0,          0.0 !   !END!
934 ! X =       725.280,     5187.408,          0.0,          0.0 !   !END!
935 ! X =       725.480,     5187.408,          0.0,          0.0 !   !END!
936 ! X =       725.680,     5187.408,          0.0,          0.0 !   !END!
937 ! X =       725.880,     5187.408,          0.0,          0.0 !   !END!
938 ! X =       726.080,     5187.408,          0.0,          0.0 !   !END!
939 ! X =       722.080,     5187.608,          0.0,          0.0 !   !END!
940 ! X =       722.280,     5187.608,          0.0,          0.0 !   !END!
941 ! X =       722.480,     5187.608,          0.0,          0.0 !   !END!
942 ! X =       722.680,     5187.608,          0.0,          0.0 !   !END!
943 ! X =       722.880,     5187.608,          0.0,          0.0 !   !END!
944 ! X =       725.280,     5187.608,          0.0,          0.0 !   !END!
945 ! X =       725.480,     5187.608,          0.0,          0.0 !   !END!
946 ! X =       725.680,     5187.608,          0.0,          0.0 !   !END!
947 ! X =       725.880,     5187.608,          0.0,          0.0 !   !END!
948 ! X =       726.080,     5187.608,          0.0,          0.0 !   !END!
949 ! X =       722.080,     5187.808,          0.0,          0.0 !   !END!
950 ! X =       722.280,     5187.808,          0.0,          0.0 !   !END!
951 ! X =       722.480,     5187.808,          0.0,          0.0 !   !END!
```

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 952 ! X =       722.680,     5187.808,          0.0,          0.0 !   !END!
 953 ! X =       722.880,     5187.808,          0.0,          0.0 !   !END!
 954 ! X =       725.280,     5187.808,          0.0,          0.0 !   !END!
 955 ! X =       725.480,     5187.808,          0.0,          0.0 !   !END!
 956 ! X =       725.680,     5187.808,          0.0,          0.0 !   !END!
 957 ! X =       725.880,     5187.808,          0.0,          0.0 !   !END!
 958 ! X =       726.080,     5187.808,          0.0,          0.0 !   !END!
 959 ! X =       722.080,     5188.008,          0.0,          0.0 !   !END!
 960 ! X =       722.280,     5188.008,          0.0,          0.0 !   !END!
 961 ! X =       722.480,     5188.008,          0.0,          0.0 !   !END!
 962 ! X =       722.680,     5188.008,          0.0,          0.0 !   !END!
 963 ! X =       722.880,     5188.008,          0.0,          0.0 !   !END!
 964 ! X =       725.280,     5188.008,          0.0,          0.0 !   !END!
 965 ! X =       725.480,     5188.008,          0.0,          0.0 !   !END!
 966 ! X =       725.680,     5188.008,          0.0,          0.0 !   !END!
 967 ! X =       725.880,     5188.008,          0.0,          0.0 !   !END!
 968 ! X =       726.080,     5188.008,          0.0,          0.0 !   !END!
 969 ! X =       722.080,     5188.208,          0.0,          0.0 !   !END!
 970 ! X =       722.280,     5188.208,          0.0,          0.0 !   !END!
 971 ! X =       722.480,     5188.208,          0.0,          0.0 !   !END!
 972 ! X =       722.680,     5188.208,          0.0,          0.0 !   !END!
 973 ! X =       722.880,     5188.208,          0.0,          0.0 !   !END!
 974 ! X =       725.280,     5188.208,          0.0,          0.0 !   !END!
 975 ! X =       725.480,     5188.208,          0.0,          0.0 !   !END!
 976 ! X =       725.680,     5188.208,          0.0,          0.0 !   !END!
 977 ! X =       725.880,     5188.208,          0.0,          0.0 !   !END!
 978 ! X =       726.080,     5188.208,          0.0,          0.0 !   !END!
 979 ! X =       722.080,     5188.408,          0.0,          0.0 !   !END!
 980 ! X =       722.280,     5188.408,          0.0,          0.0 !   !END!
 981 ! X =       722.480,     5188.408,          0.0,          0.0 !   !END!
 982 ! X =       722.680,     5188.408,          0.0,          0.0 !   !END!
 983 ! X =       722.880,     5188.408,          0.0,          0.0 !   !END!
 984 ! X =       723.080,     5188.408,          0.0,          0.0 !   !END!
 985 ! X =       723.280,     5188.408,          0.0,          0.0 !   !END!
 986 ! X =       723.480,     5188.408,          0.0,          0.0 !   !END!
 987 ! X =       723.680,     5188.408,          0.0,          0.0 !   !END!
 988 ! X =       723.880,     5188.408,          0.0,          0.0 !   !END!
 989 ! X =       724.080,     5188.408,          0.0,          0.0 !   !END!
 990 ! X =       724.280,     5188.408,          0.0,          0.0 !   !END!
 991 ! X =       724.480,     5188.408,          0.0,          0.0 !   !END!
 992 ! X =       724.680,     5188.408,          0.0,          0.0 !   !END!
 993 ! X =       724.880,     5188.408,          0.0,          0.0 !   !END!
 994 ! X =       725.080,     5188.408,          0.0,          0.0 !   !END!
 995 ! X =       725.280,     5188.408,          0.0,          0.0 !   !END!
 996 ! X =       725.480,     5188.408,          0.0,          0.0 !   !END!
 997 ! X =       725.680,     5188.408,          0.0,          0.0 !   !END!
 998 ! X =       725.880,     5188.408,          0.0,          0.0 !   !END!
 999 ! X =       726.080,     5188.408,          0.0,          0.0 !   !END!
1000 ! X =       722.080,     5188.608,          0.0,          0.0 !   !END!
1001 ! X =       722.280,     5188.608,          0.0,          0.0 !   !END!
1002 ! X =       722.480,     5188.608,          0.0,          0.0 !   !END!
1003 ! X =       722.680,     5188.608,          0.0,          0.0 !   !END!
1004 ! X =       722.880,     5188.608,          0.0,          0.0 !   !END!
1005 ! X =       723.080,     5188.608,          0.0,          0.0 !   !END!
1006 ! X =       723.280,     5188.608,          0.0,          0.0 !   !END!
1007 ! X =       723.480,     5188.608,          0.0,          0.0 !   !END!
1008 ! X =       723.680,     5188.608,          0.0,          0.0 !   !END!
1009 ! X =       723.880,     5188.608,          0.0,          0.0 !   !END!
1010 ! X =       724.080,     5188.608,          0.0,          0.0 !   !END!
1011 ! X =       724.280,     5188.608,          0.0,          0.0 !   !END!
1012 ! X =       724.480,     5188.608,          0.0,          0.0 !   !END!
1013 ! X =       724.680,     5188.608,          0.0,          0.0 !   !END!
1014 ! X =       724.880,     5188.608,          0.0,          0.0 !   !END!
```

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1015 ! X =       725.080,     5188.608,          0.0,          0.0 !   !END!
1016 ! X =       725.280,     5188.608,          0.0,          0.0 !   !END!
1017 ! X =       725.480,     5188.608,          0.0,          0.0 !   !END!
1018 ! X =       725.680,     5188.608,          0.0,          0.0 !   !END!
1019 ! X =       725.880,     5188.608,          0.0,          0.0 !   !END!
1020 ! X =       726.080,     5188.608,          0.0,          0.0 !   !END!
1021 ! X =       722.080,     5188.808,          0.0,          0.0 !   !END!
1022 ! X =       722.280,     5188.808,          0.0,          0.0 !   !END!
1023 ! X =       722.480,     5188.808,          0.0,          0.0 !   !END!
1024 ! X =       722.680,     5188.808,          0.0,          0.0 !   !END!
1025 ! X =       722.880,     5188.808,          0.0,          0.0 !   !END!
1026 ! X =       723.080,     5188.808,          0.0,          0.0 !   !END!
1027 ! X =       723.280,     5188.808,          0.0,          0.0 !   !END!
1028 ! X =       723.480,     5188.808,          0.0,          0.0 !   !END!
1029 ! X =       723.680,     5188.808,          0.0,          0.0 !   !END!
1030 ! X =       723.880,     5188.808,          0.0,          0.0 !   !END!
1031 ! X =       724.080,     5188.808,          0.0,          0.0 !   !END!
1032 ! X =       724.280,     5188.808,          0.0,          0.0 !   !END!
1033 ! X =       724.480,     5188.808,          0.0,          0.0 !   !END!
1034 ! X =       724.680,     5188.808,          0.0,          0.0 !   !END!
1035 ! X =       724.880,     5188.808,          0.0,          0.0 !   !END!
1036 ! X =       725.080,     5188.808,          0.0,          0.0 !   !END!
1037 ! X =       725.280,     5188.808,          0.0,          0.0 !   !END!
1038 ! X =       725.480,     5188.808,          0.0,          0.0 !   !END!
1039 ! X =       725.680,     5188.808,          0.0,          0.0 !   !END!
1040 ! X =       725.880,     5188.808,          0.0,          0.0 !   !END!
1041 ! X =       726.080,     5188.808,          0.0,          0.0 !   !END!
1042 ! X =       722.080,     5189.008,          0.0,          0.0 !   !END!
1043 ! X =       722.280,     5189.008,          0.0,          0.0 !   !END!
1044 ! X =       722.480,     5189.008,          0.0,          0.0 !   !END!
1045 ! X =       722.680,     5189.008,          0.0,          0.0 !   !END!
1046 ! X =       722.880,     5189.008,          0.0,          0.0 !   !END!
1047 ! X =       723.080,     5189.008,          0.0,          0.0 !   !END!
1048 ! X =       723.280,     5189.008,          0.0,          0.0 !   !END!
1049 ! X =       723.480,     5189.008,          0.0,          0.0 !   !END!
1050 ! X =       723.680,     5189.008,          0.0,          0.0 !   !END!
1051 ! X =       723.880,     5189.008,          0.0,          0.0 !   !END!
1052 ! X =       724.080,     5189.008,          0.0,          0.0 !   !END!
1053 ! X =       724.280,     5189.008,          0.0,          0.0 !   !END!
1054 ! X =       724.480,     5189.008,          0.0,          0.0 !   !END!
1055 ! X =       724.680,     5189.008,          0.0,          0.0 !   !END!
1056 ! X =       724.880,     5189.008,          0.0,          0.0 !   !END!
1057 ! X =       725.080,     5189.008,          0.0,          0.0 !   !END!
1058 ! X =       725.280,     5189.008,          0.0,          0.0 !   !END!
1059 ! X =       725.480,     5189.008,          0.0,          0.0 !   !END!
1060 ! X =       725.680,     5189.008,          0.0,          0.0 !   !END!
1061 ! X =       725.880,     5189.008,          0.0,          0.0 !   !END!
1062 ! X =       726.080,     5189.008,          0.0,          0.0 !   !END!
1063 ! X =       722.080,     5189.208,          0.0,          0.0 !   !END!
1064 ! X =       722.280,     5189.208,          0.0,          0.0 !   !END!
1065 ! X =       722.480,     5189.208,          0.0,          0.0 !   !END!
1066 ! X =       722.680,     5189.208,          0.0,          0.0 !   !END!
1067 ! X =       722.880,     5189.208,          0.0,          0.0 !   !END!
1068 ! X =       723.080,     5189.208,          0.0,          0.0 !   !END!
1069 ! X =       723.280,     5189.208,          0.0,          0.0 !   !END!
1070 ! X =       723.480,     5189.208,          0.0,          0.0 !   !END!
1071 ! X =       723.680,     5189.208,          0.0,          0.0 !   !END!
1072 ! X =       723.880,     5189.208,          0.0,          0.0 !   !END!
1073 ! X =       724.080,     5189.208,          0.0,          0.0 !   !END!
1074 ! X =       724.280,     5189.208,          0.0,          0.0 !   !END!
1075 ! X =       724.480,     5189.208,          0.0,          0.0 !   !END!
1076 ! X =       724.680,     5189.208,          0.0,          0.0 !   !END!
1077 ! X =       724.880,     5189.208,          0.0,          0.0 !   !END!
```

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 1078 ! X =       725.080,     5189.208,          0.0,           0.0 !   !END!
 1079 ! X =       725.280,     5189.208,          0.0,           0.0 !   !END!
 1080 ! X =       725.480,     5189.208,          0.0,           0.0 !   !END!
 1081 ! X =       725.680,     5189.208,          0.0,           0.0 !   !END!
 1082 ! X =       725.880,     5189.208,          0.0,           0.0 !   !END!
 1083 ! X =       726.080,     5189.208,          0.0,           0.0 !   !END!

-------------
    a
     Data for each receptor are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     Receptor height above ground is optional.  If no value is entered,
     the receptor is placed on the ground.
    c
     Receptors can be assigned using group names provided in 17b.  If no
     group names are used (NRGRP=0) then the default assignment name X
     must be used.
```

APPENDIX B

Concentration Maps

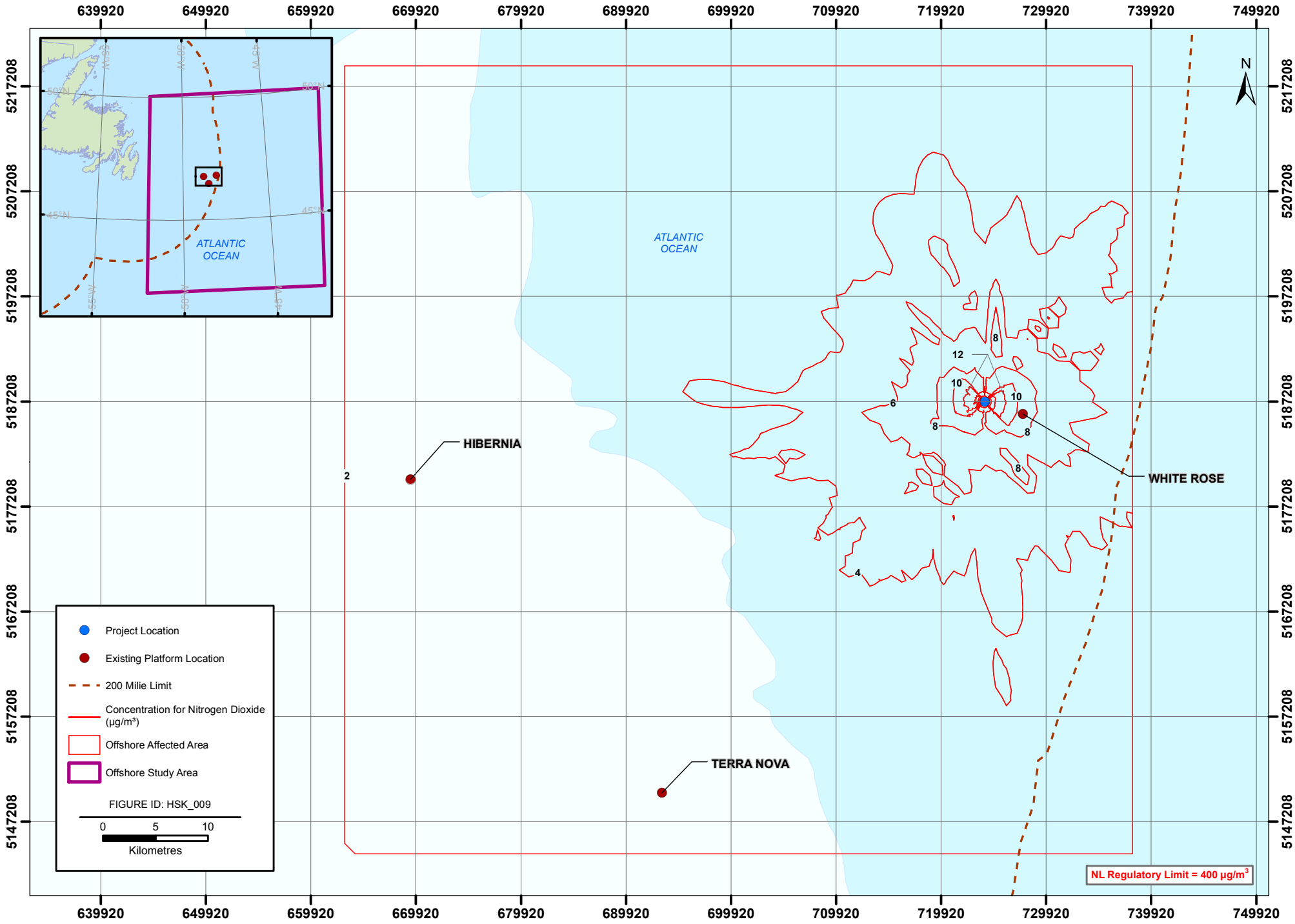


Figure B1 Maximum Predicted 1-hour Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – Normal WHP Operation

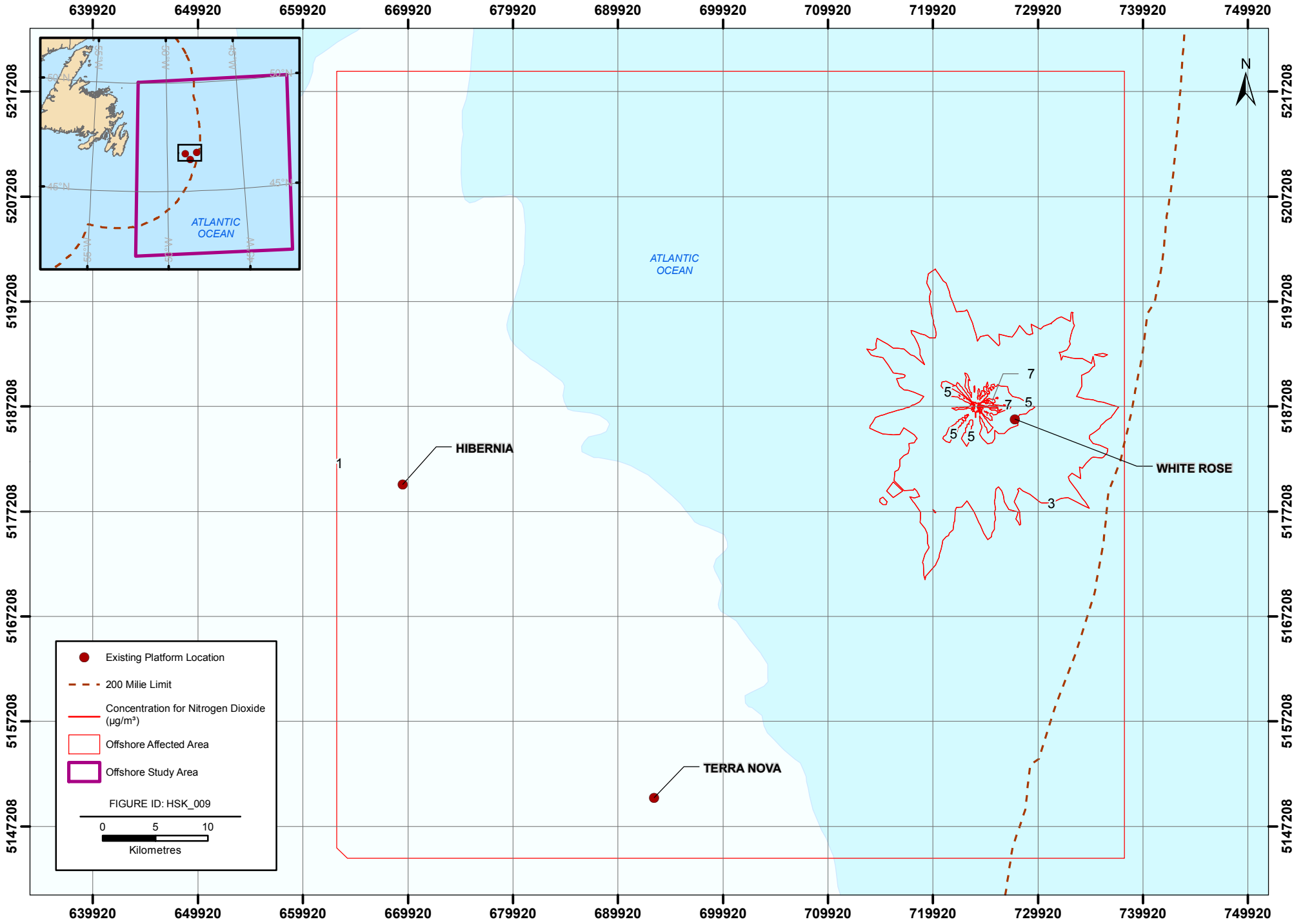


Figure B2 Maximum Predicted 24-hour Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – Normal Project Operation

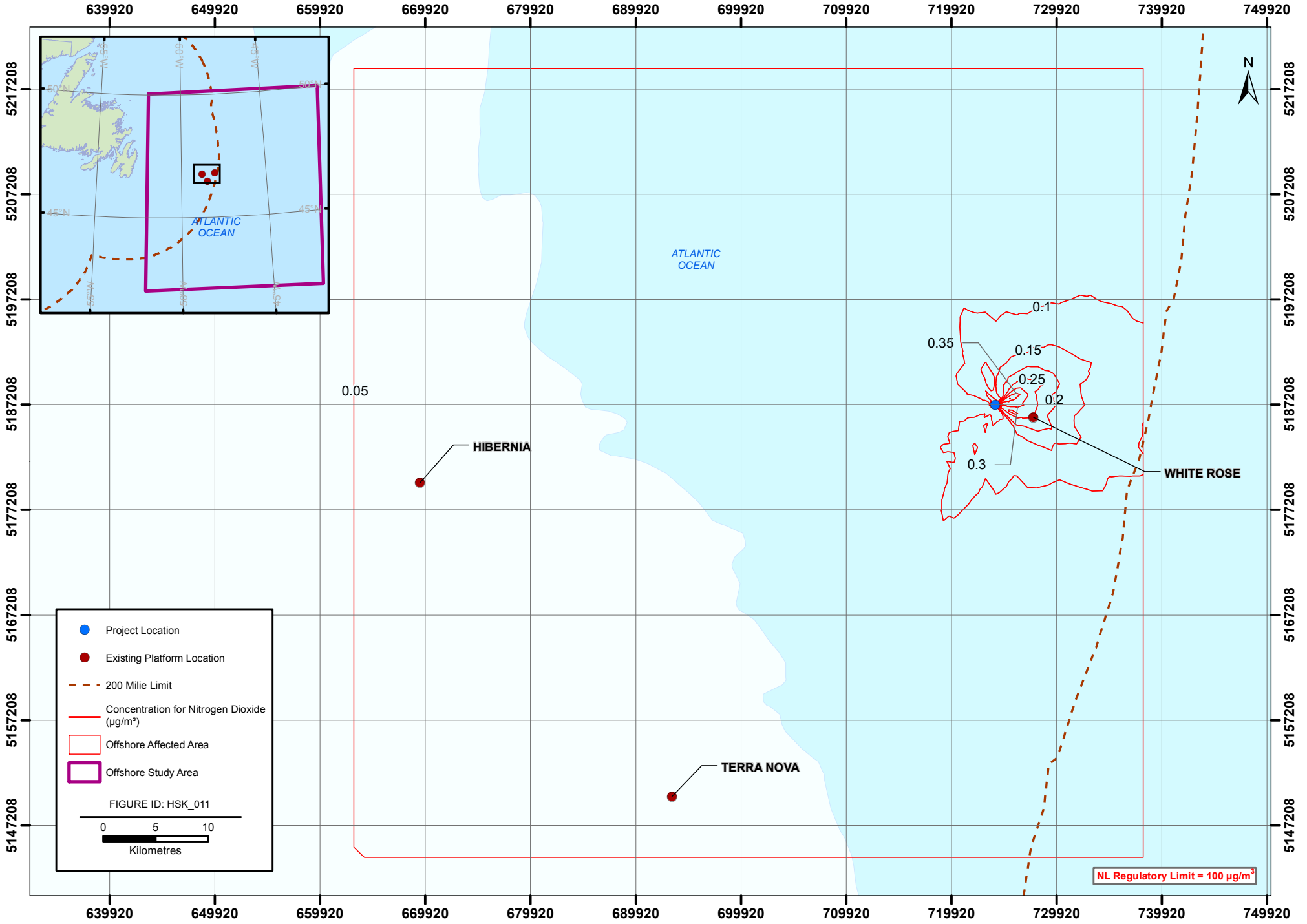


Figure B3 Maximum Predicted Annual Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – Normal WHP Operation

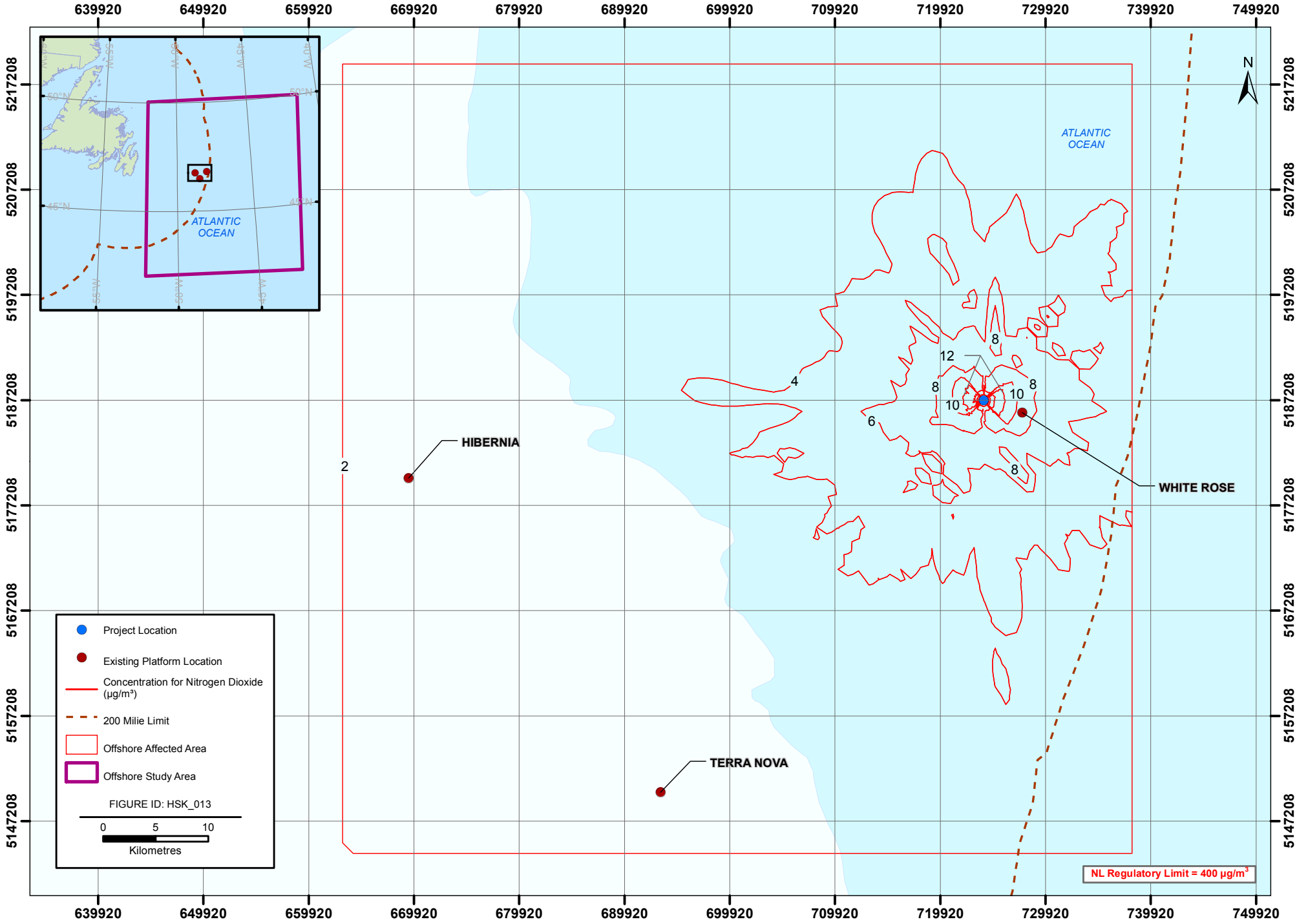


Figure B4 Maximum Predicted 1-hour Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – WHP Blowdown

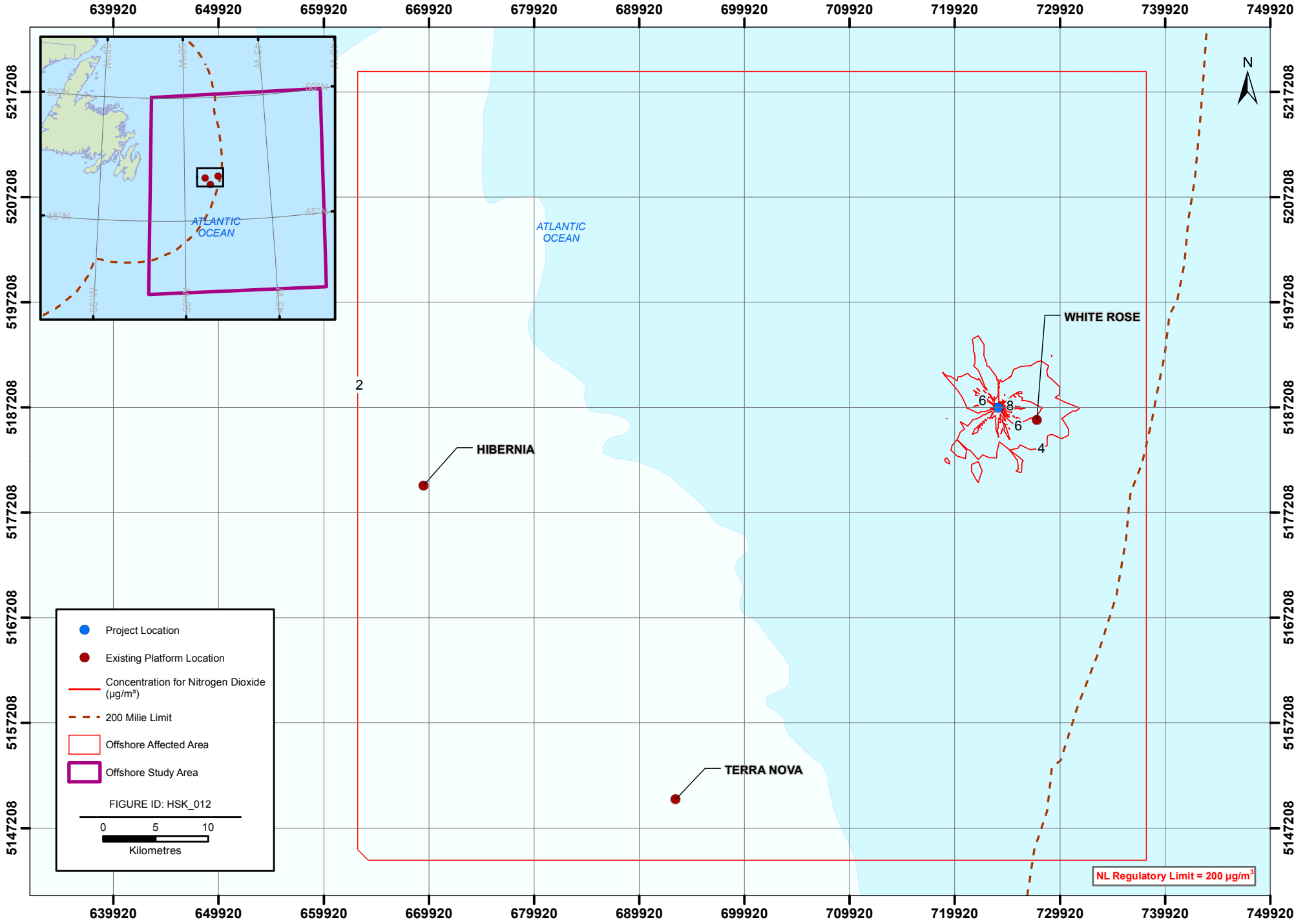


Figure B5 Maximum Predicted 24-hour Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – WHP Blowdown

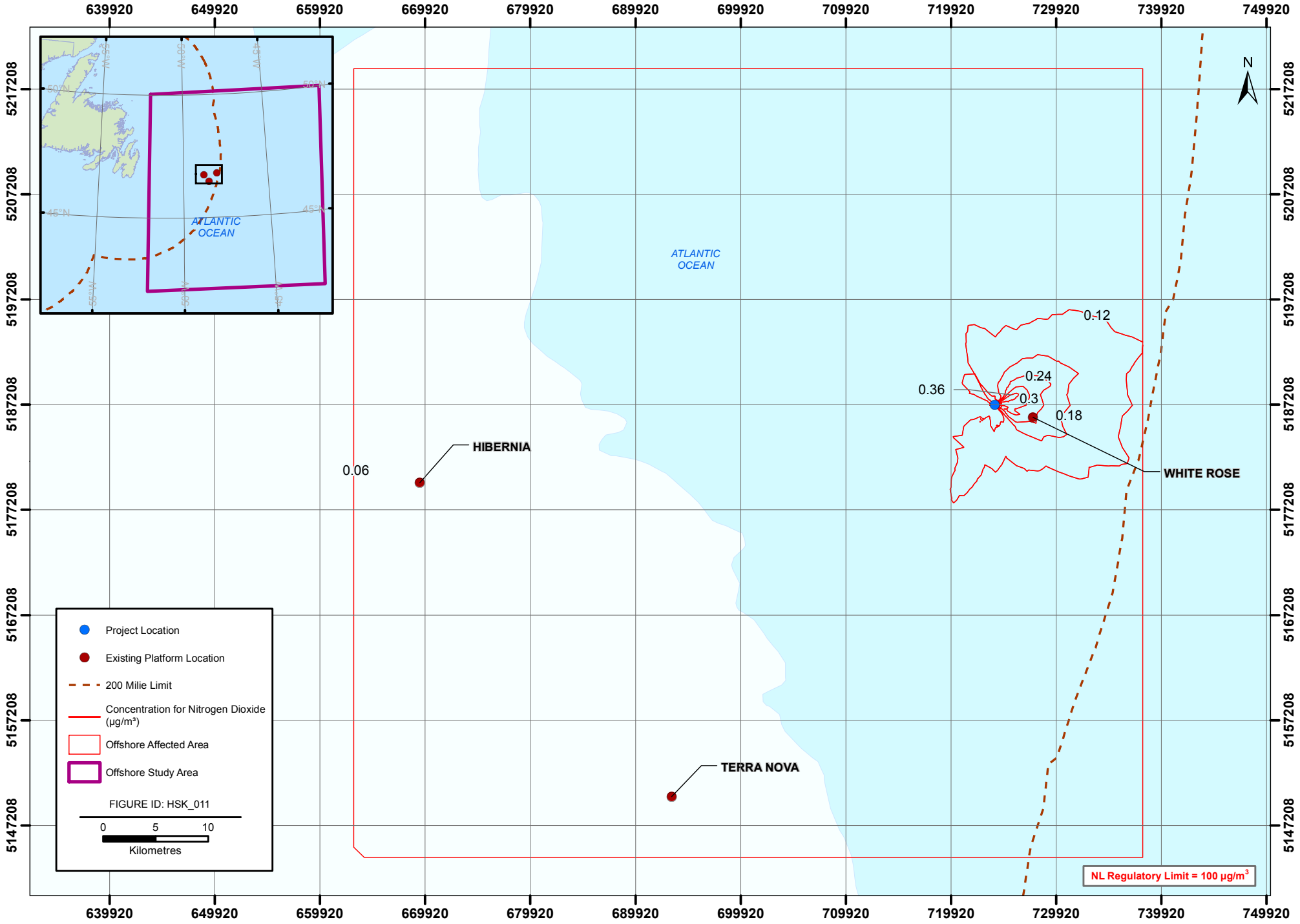


Figure B6 Maximum Predicted Annual Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – WHP Blowdown

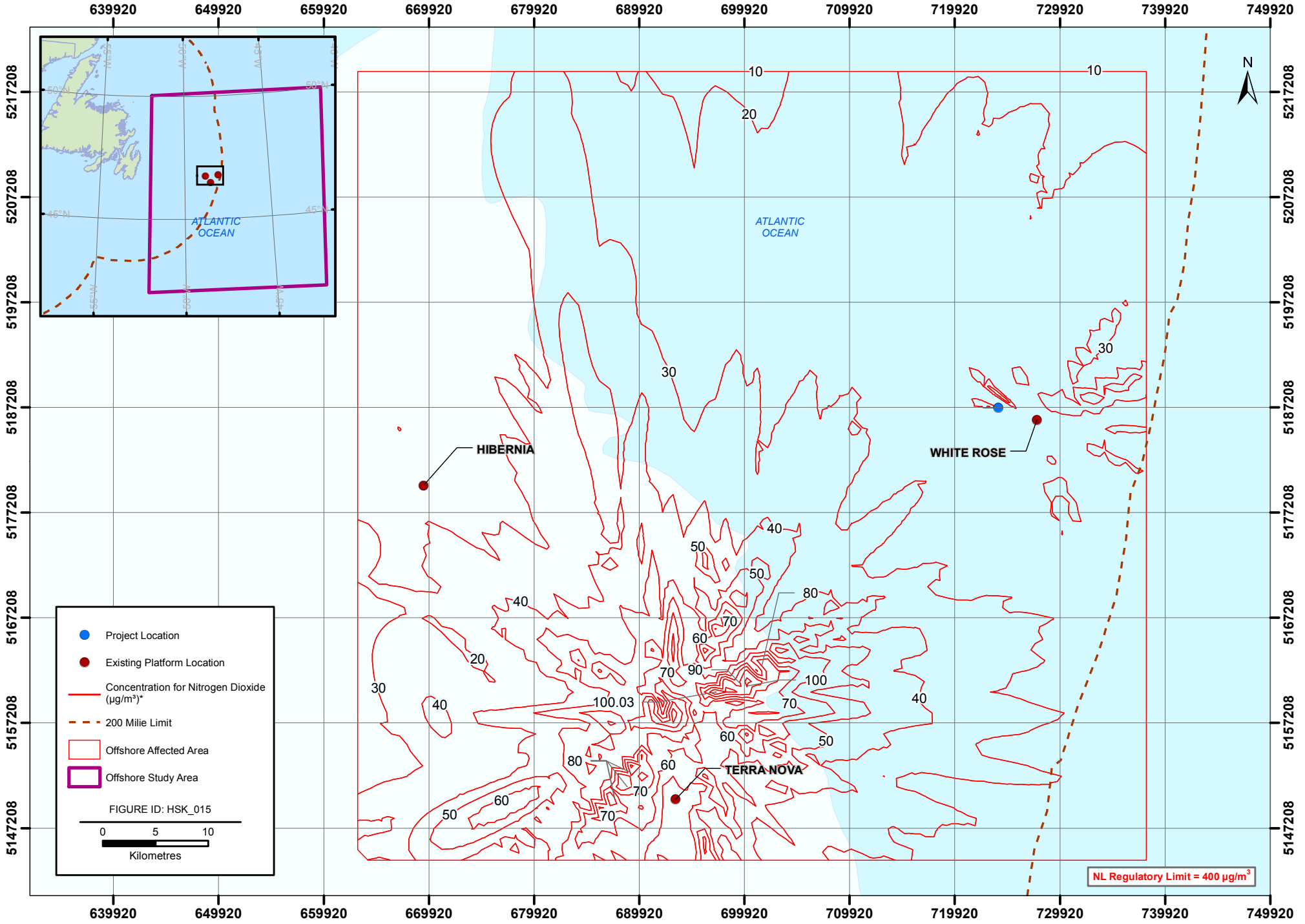


Figure B7 Maximum Predicted 1-hour Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – Cumulative Operation WHP

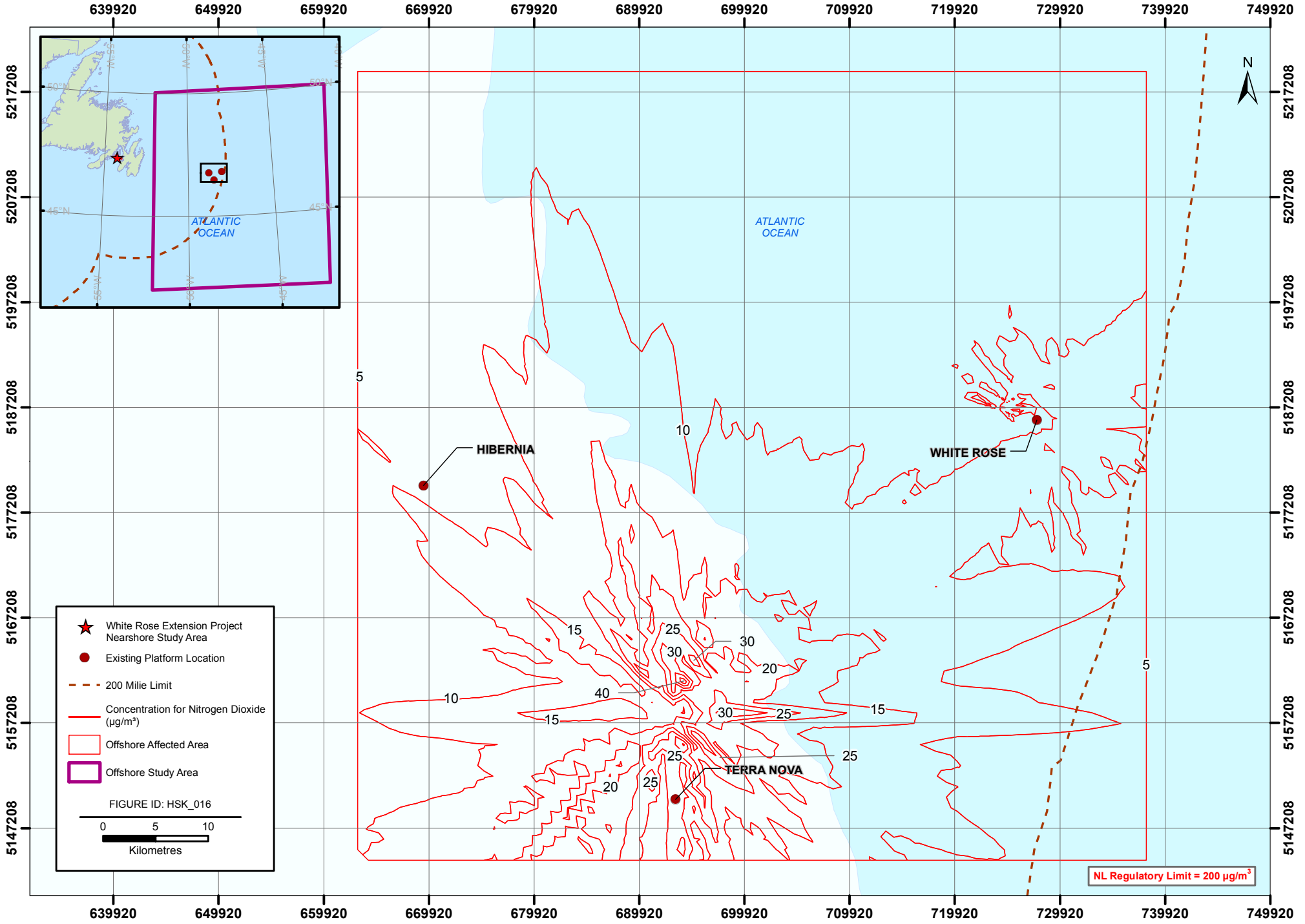


Figure B8 Maximum Predicted 24-hour Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – Cumulative Operation WHP

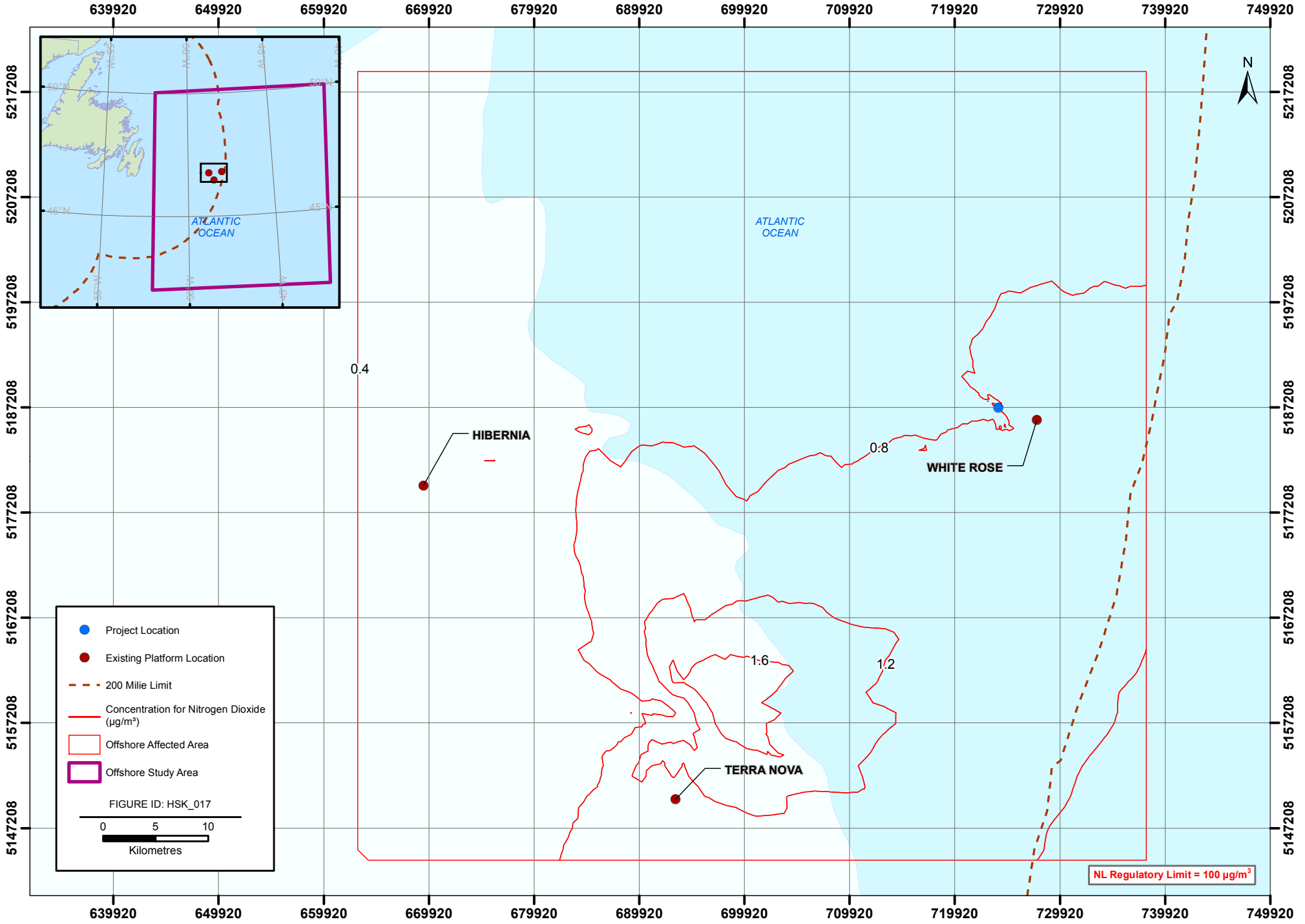


Figure B9 Maximum Predicted Annual Ground Level Concentration for Nitrogen Dioxide (NO_2), µg/m^3 – Cumulative Operation WHP

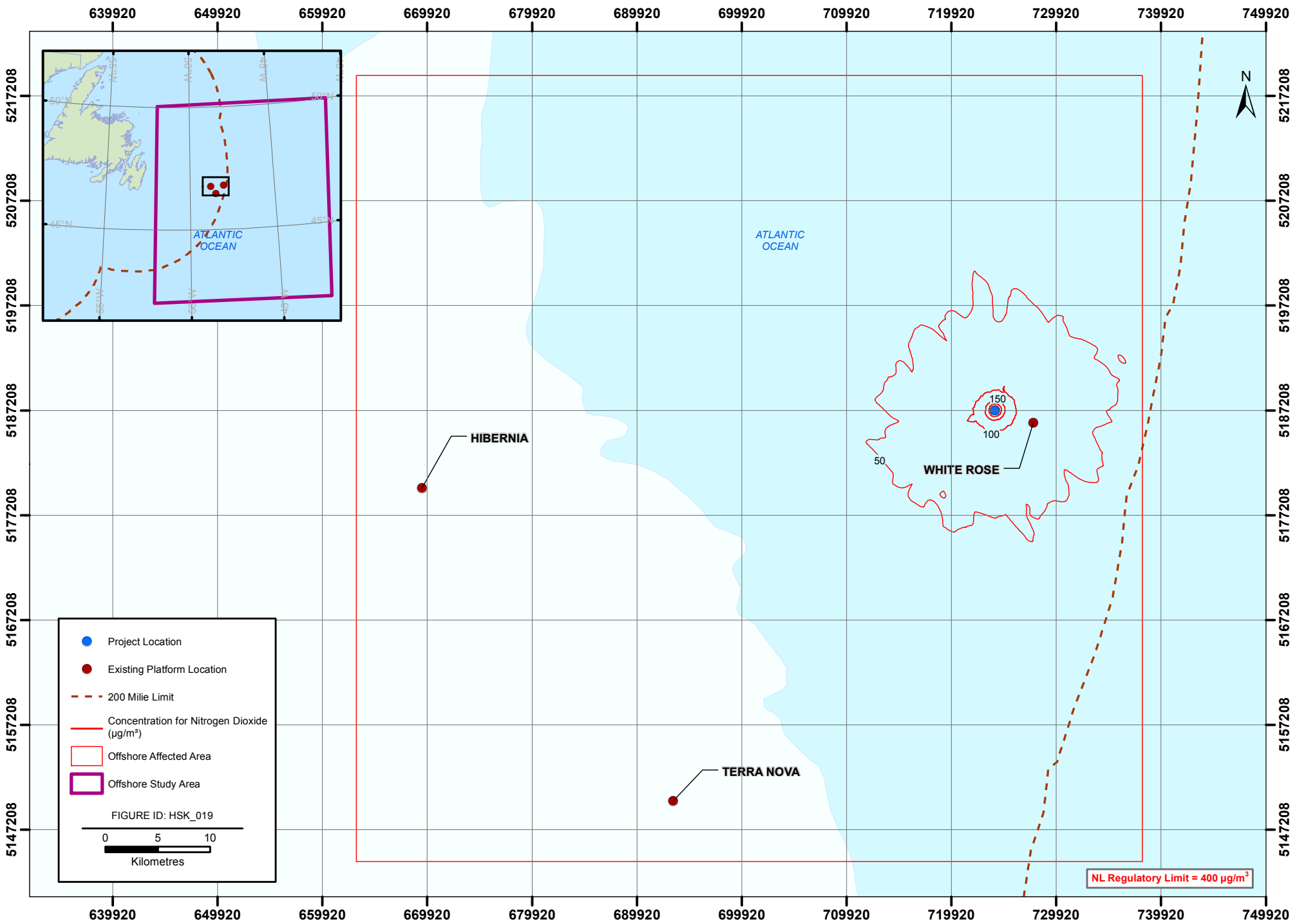


Figure B10 Maximum Predicted 1-hr Ground Level Concentration for Nitrogen Dioxide (NO_2), ug/m^3 – Normal Operation MODU

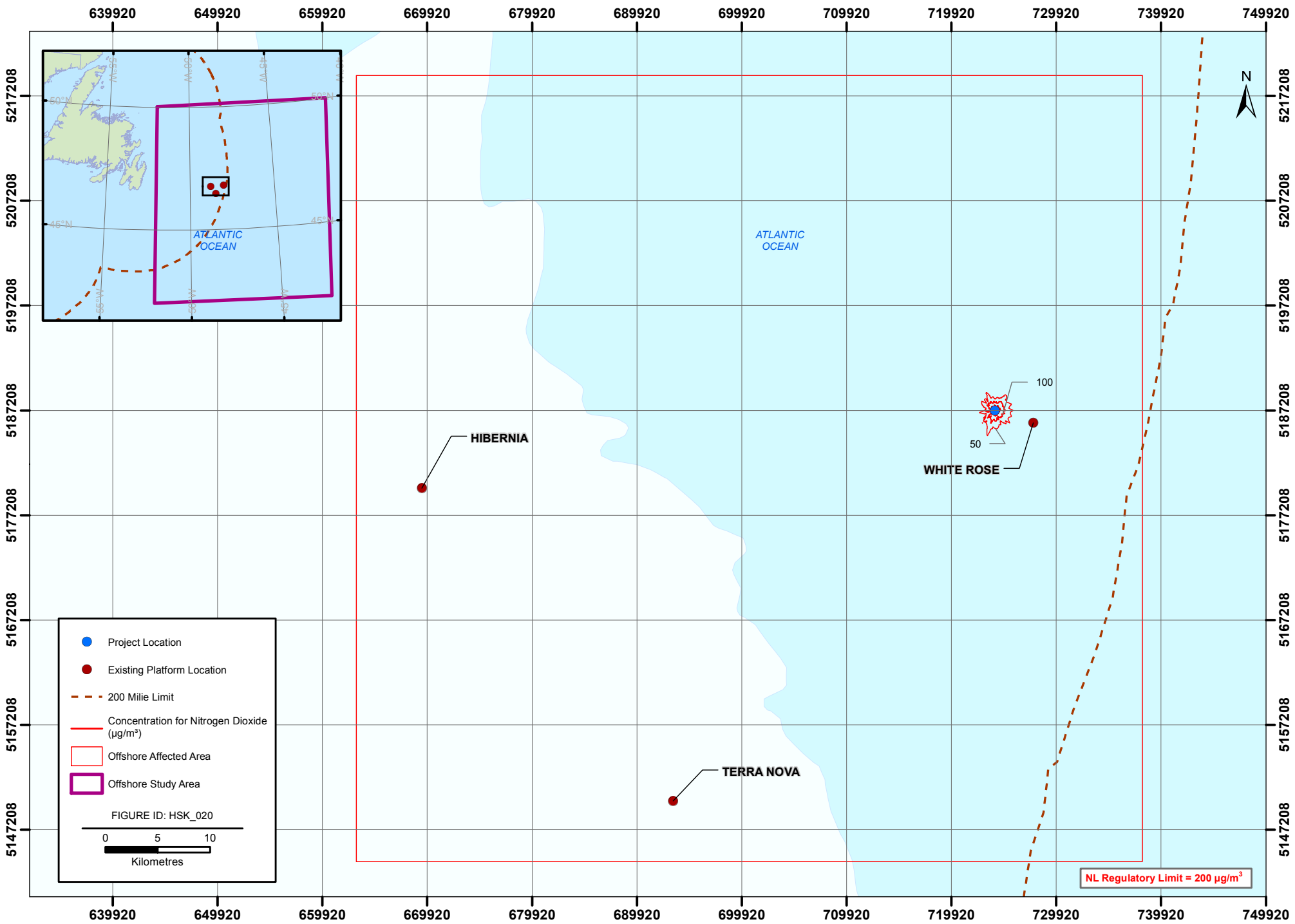


Figure B11 Maximum Predicted 24-hr Ground Level Concentration for Nitrogen Dioxide (NO_2), ug/m^3 – Normal Operation MODU

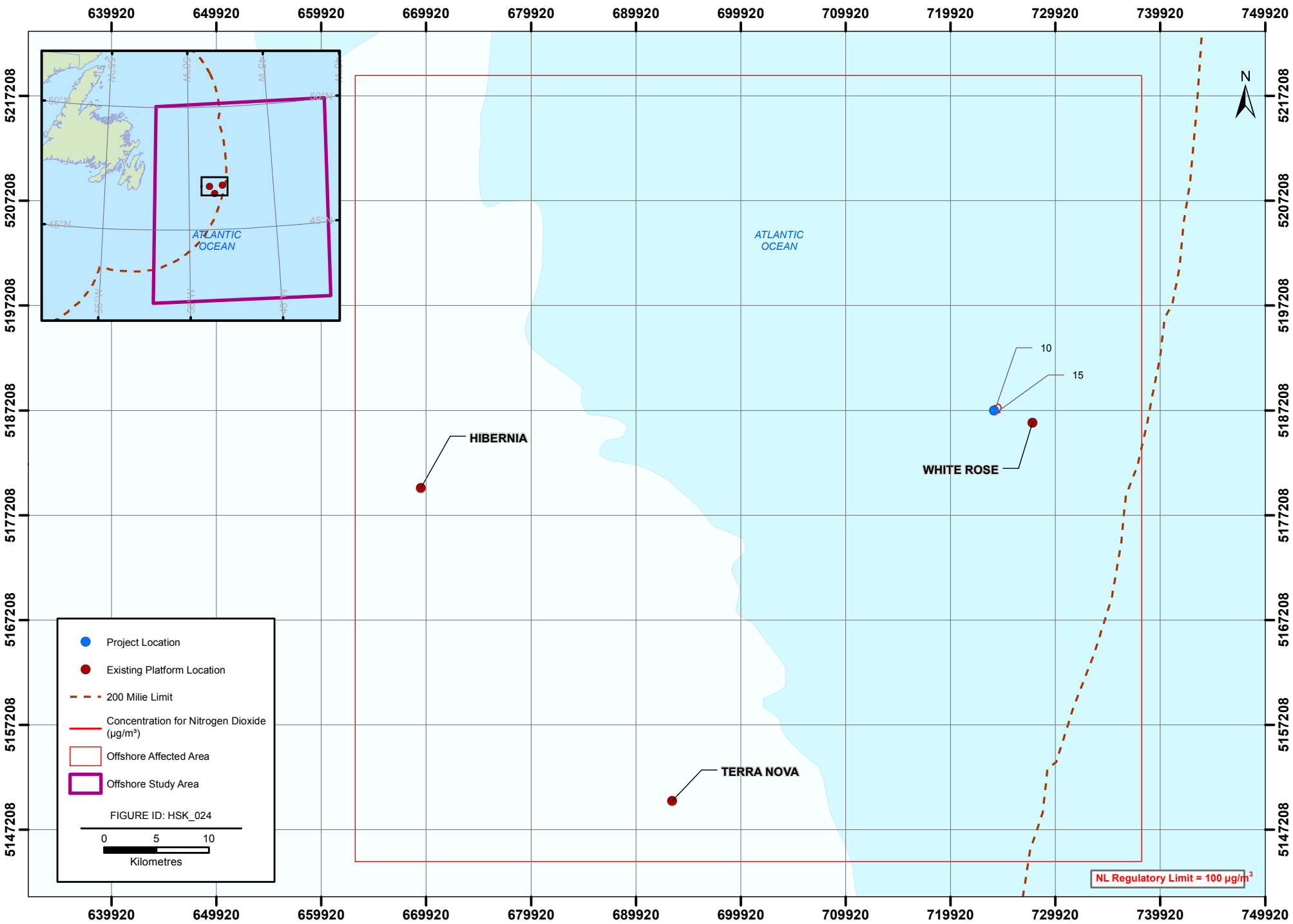


Figure B12 Maximum Predicted Annual Ground Level Concentration for Nitrogen Dioxide (NO_2), ug/m^3 – Normal Operation MODU

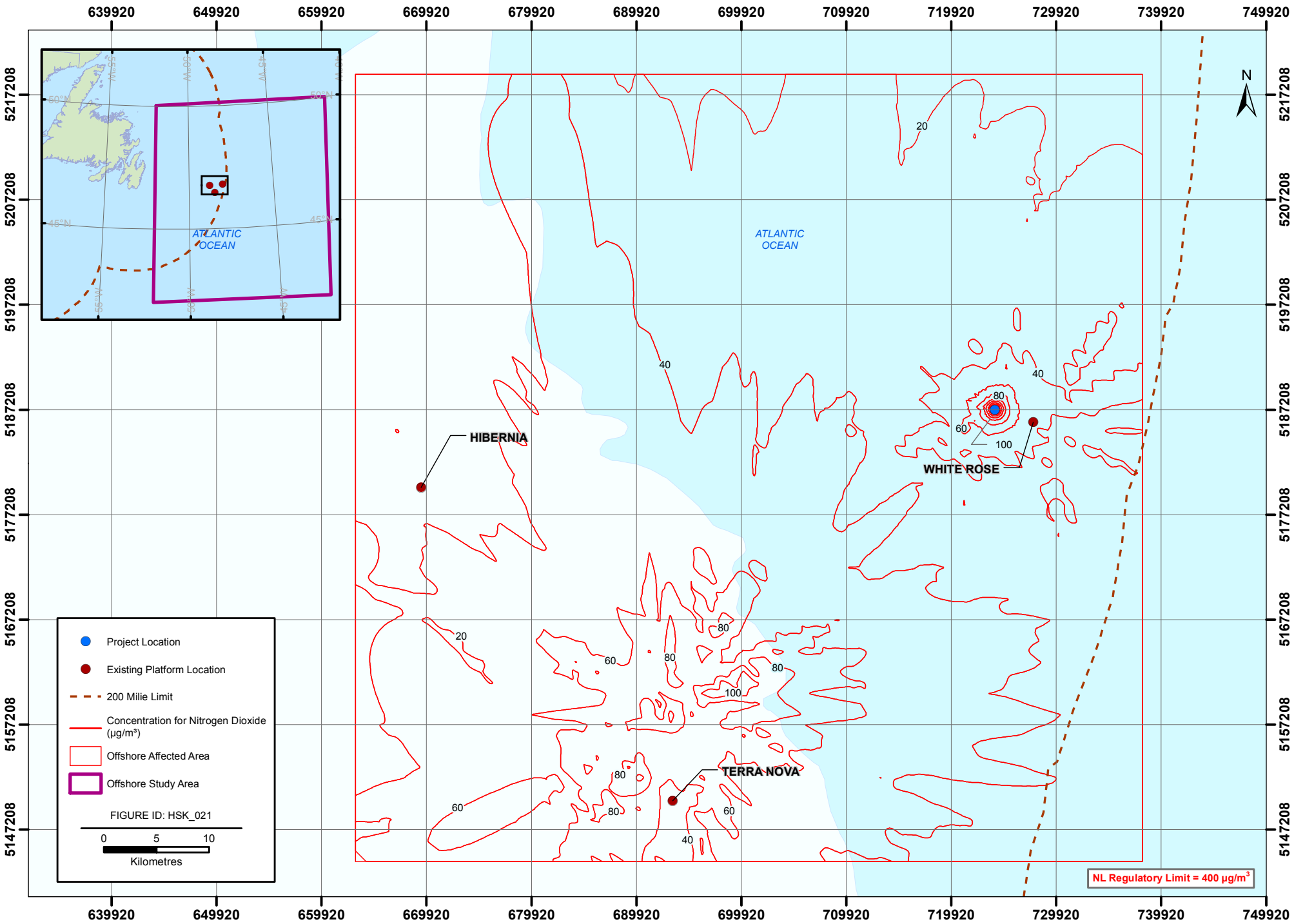


Figure B13 Maximum Predicted 1-hr Ground Level Concentration for Nitrogen Dioxide (NO_2), ug/m^3 – Cumulative Operation MODU

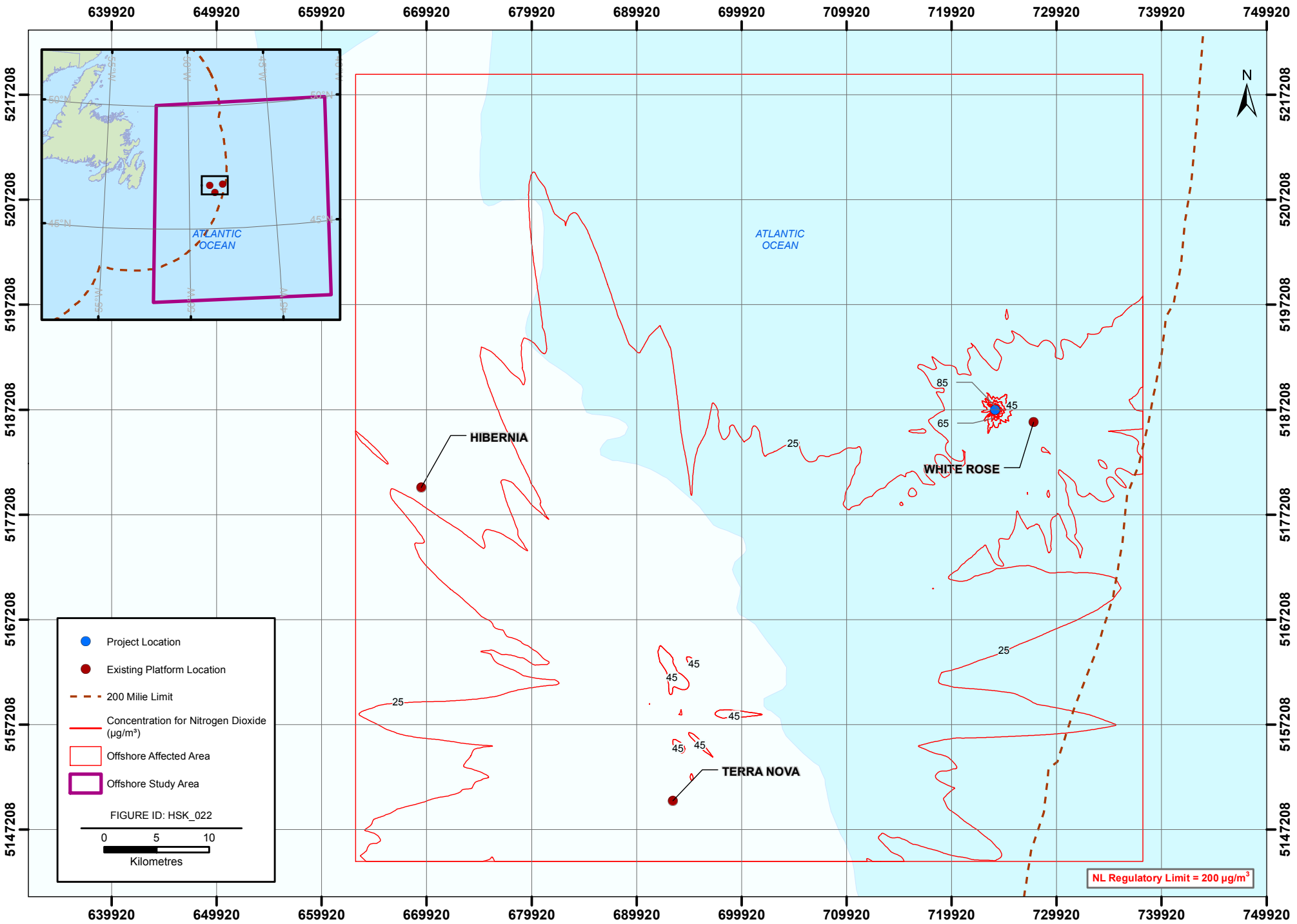


Figure B14 Maximum Predicted 24-hr Ground Level Concentration for Nitrogen Dioxide (NO_2), ug/m^3 – Cumulative Operation MODU

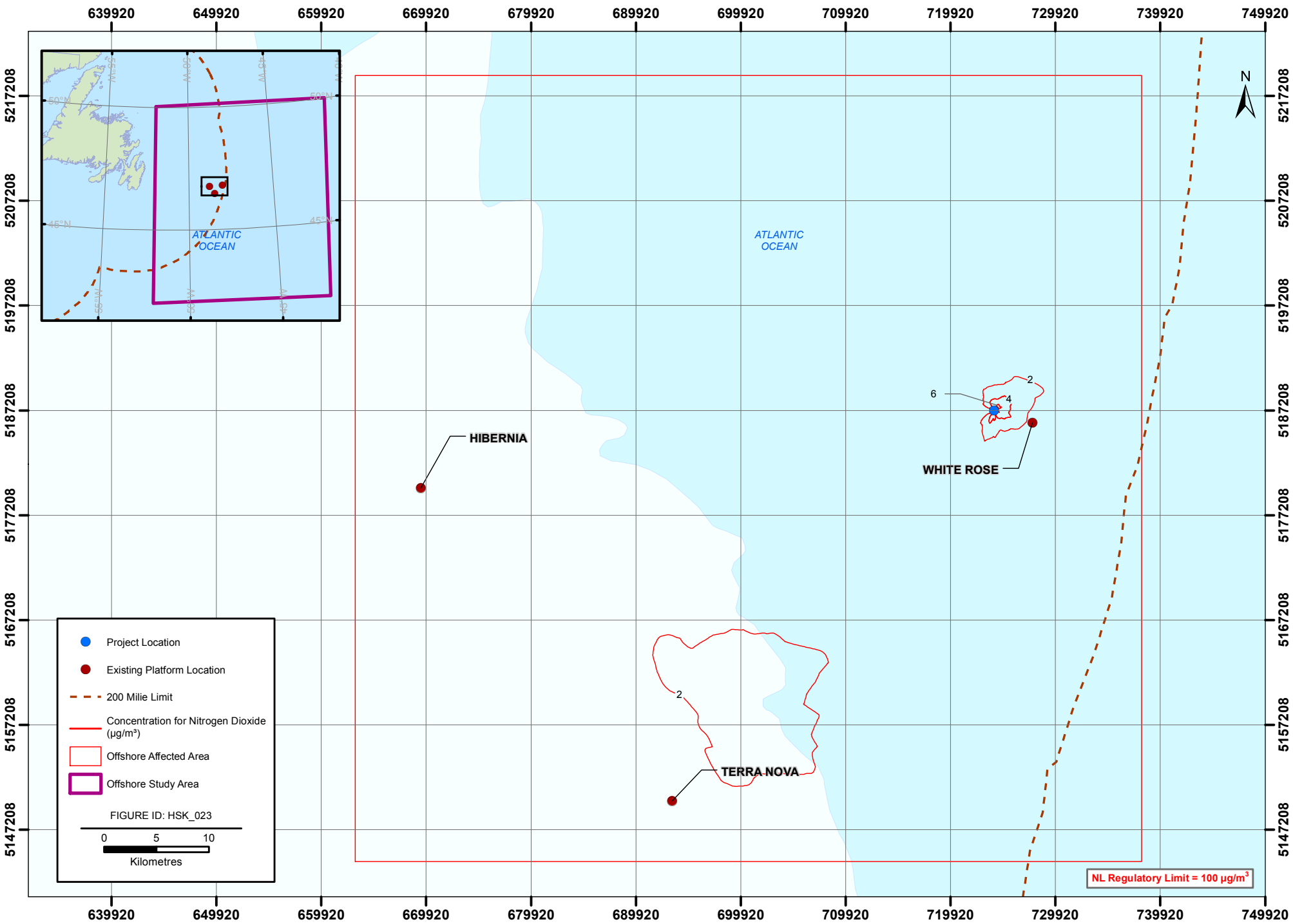


Figure B15 Maximum Predicted Annual Ground Level Concentration for Nitrogen Dioxide (NO_2), ug/m^3 – Cumulative Operation MODU

APPENDIX C

White Rose Extension Project Environmental Assessment
Underwater Sournd Propagation (JASCO 2012)

Husky Energy

White Rose Extension Project

Underwater Sound Propagation

June 2012

Husky Energy SUNCOR ENERGY nalcor energy

Underwater Sound Propagation Assessment for the Environmental Assessment of the White Rose Extension Project

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Executive Summary

JASCO Applied Sciences carried out an underwater sound propagation assessment to estimate distances to sound level thresholds around potential underwater acoustic sources resulting from the Husky Oil Operation Ltd. White Rose Extension Project (WREP). Depending upon the options selected, the different phases of WREP may consist of: the construction of a concrete gravity structure (CGS) at Argentia, NL; the transportation of the CGS from Argentia to the White Rose Field site (Grand Banks, offshore Newfoundland); and drilling from a wellhead platform or subsea drill centre in the White Rose field.

This report presents the assessment of underwater sound fields resulting from dredging and blasting operations at three sites near Argentia Harbour, Placentia Bay, and from dredging, drilling, support vessel, and helicopter operations at the White Rose site. Distances to level thresholds from blasting activities are provided as un-weighted and M-weighted sound exposure levels of 120 to 210 dB re 1 $\mu Pa^2 \cdot s$; distances to level thresholds from all sources (impulsive and continuous) are provided as un-weighted and M-weighted rms sound pressure levels of 120 to 200 dB re 1 µPa.

1.0 Introduction

1.1 Overview

JASCO Applied Sciences (JASCO) conducted an underwater sound propagation assessment for the Environmental Assessment of the Husky Oil Operation Ltd. (Husky) White Rose Extension Project (WREP). Depending upon the options selected, the different phases of WREP may consist of: the construction of a concrete gravity structure (CGS) at Argentia, NL; the transportation of the CGS from Argentia to the White Rose field site (Grand Banks, offshore Newfoundland); and drilling from a wellhead platform (WHP) or subsea drill centre in the White Rose field. The CGS and topsides will be joined in Placentia Bay, NL.

JASCO modelled underwater sound propagation around potential underwater acoustic sources resulting from the WREP, to estimate distances to sound level thresholds. The modelled sources represent: dredging and blasting activities near Argentia Harbour, Placentia Bay; operations that may be required to transport the CGS from the construction site in Argentia; and dredging, drilling, support vessel and helicopter activities at the White Rose Field site. Distances to sound level thresholds were estimated for water temperature profiles representative of months that are the most (February) and least (August) conducive to long-range sound propagation, accounting for source directivity and the range-dependent environmental properties in the area.

This report presents the modelled results in two formats. Tables present maximum and 95 percent distances to sound level thresholds. Sound-field contour maps present the directivity and range to various sound level thresholds. Distances to level thresholds from blasting activities (impulsive sources) are provided as un-weighted and M-weighted sound exposure levels (SELs) of 200 through 120 dB re 1 $\mu Pa^2 \cdot s$. Distances to level thresholds from all sources (impulsive and continuous) are provided as un-weighted and M-weighted root-mean-square sound pressure level (rms SPLs) of 200 through 120 dB re 1 µPa.

1.2 Acoustic Metrics

Underwater sound amplitude is measured in decibels (dB), relative to a standard reference pressure of 1 µPa. The rms SPL is commonly used to evaluate the loudness or effects of continuous noise sources. The rms SPL (dB re 1 µPa, ANSI symbol L_p) is the rms pressure level over the time window, T:

$$L_p = 10 \log_{10} \left(\frac{1}{T} \int_T p^2(t) dt \Big/ p_o^2 \right) \quad (1)$$

where T is the time interval in seconds. The rms SPL can be thought of as a measure of the average pressure or as the "effective" pressure over the duration of an acoustic event. For impulsive noise such as the sound from an explosion, T is the duration of one acoustic pulse. Because T is used as a divisor, pulses that are more spread out in time have a lower rms SPL for the same total acoustic energy.

The SEL (dB re 1 $\mu Pa^2 \cdot s$, ANSI symbol L_E) is also commonly used to quantifying loudness of impulsive sources. It is the time integral of the squared pressure over a fixed-time window containing the entire pulse, T:

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_o p_o^2\right) \quad (2)$$

where T_o is a reference time interval of 1 s. The per-pulse SEL is measured in units of dB re 1 μPa·√s or equivalently dB re 1 μPa^2·s. This measure represents the total energy delivered over the duration of an acoustic event at a receiver location. The SEL is related to sound energy (or exposure) rather than sound pressure. SEL can be a metric that describes the sound level for a single sound pulse or a cumulative metric, if applied over a period containing multiple pulses.

For continuous sources, *T* is set to 1 s to calculate the rms SPL, making it equivalent to the SEL.

1.3 Acoustic Impact Criteria

1.3.1 Marine Mammal Frequency Weighting

The potential for underwater noise to impact marine species depends on how well the species can hear the sounds produced (Southall et al. 2007). Noises are less likely to disturb or injure animals if they are at frequencies outside the animals' hearing range. For non-injurious sound levels, frequency weighting based on audiograms may be applied to weight the importance of sound levels at particular frequencies in a manner reflective of the receiver's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

Based on a review of literature on marine mammal hearing and on physiological and behavioural responses to anthropogenic sound, Southall et al. (249) proposed standard marine mammal frequency weighting (M-weighting) functions for five functional hearing groups of marine mammals:

- Low-frequency cetaceans (LFCs) - mysticetes (baleen whales)
- Mid-frequency cetaceans (MFCs) - some odontocetes (toothed whales)
- High-frequency cetaceans (HFCs) - odontocetes specialized for using high-frequencies
- Pinnipeds in water - seals, sea lions and walrus
- Pinnipeds in air (not addressed here).

The amount of discount applied by M-weighting functions for less-audible frequencies is lower than that indicated by the corresponding audiograms for member species of these hearing groups. The rationale for applying a smaller discount is due in part to an observed characteristic of mammalian hearing, whereby perceived equal-loudness curves have increasingly less rapid roll-off outside the most sensitive hearing frequency range as sound levels increase. This is the reason that C-weighting curves for humans, used for assessing effects of loud sounds such as blasts, are flatter than A-weighting curves used for quiet to mid-level sounds. Additionally, out-of-band frequencies, although less audible, can still cause physical injury if pressure levels are high enough. Therefore, the M-weighting functions are intended to be applied primarily at high sound levels where impacts such as temporary or permanent hearing threshold shifts may occur. The use of M-weighting should be considered

precautionary (in the sense of overestimating the potential impact), particularly when applied to lower level impacts such as onset of behavioural response. Figure 1-1 shows the decibel frequency weighting of the M-weighting functions for each functional hearing group underwater.

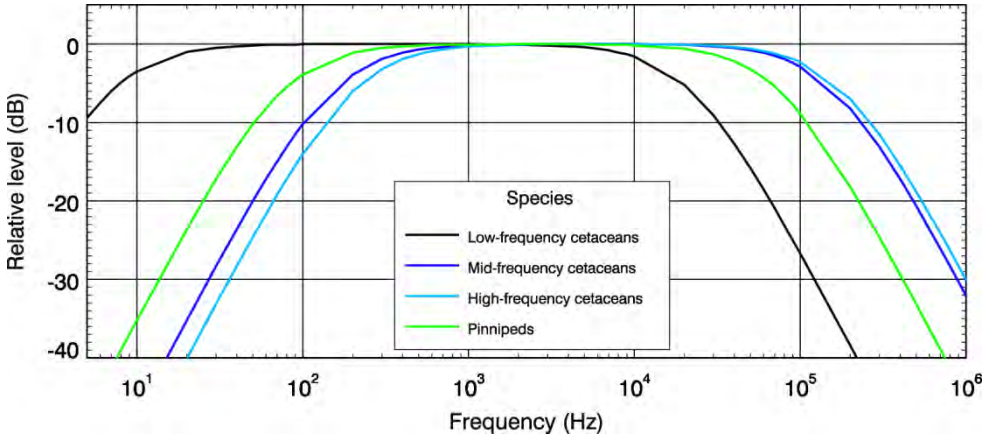


Figure 1-1 Standard M-weighting functions for low-, mid-, and high-frequency cetaceans and for pinnipeds in water

These functions have unity gain (0 dB) through the passband and the high and low frequency roll-offs are approximately −12 dB per octave. The amplitude response of the M-weighting functions is defined in the frequency domain by:

$$G(f) = -20\log_{10}\left[\left(1+\frac{f_{lo}^{2}}{f^{2}}\right)\left(1+\frac{f^{2}}{f_{hi}^{2}}\right)\right] \qquad (3)$$

The roll-off and passband of these functions are controlled by parameters f_{lo} and f_{hi}, estimated upper and lower hearing limits specific to each functional hearing group (Table 1-1).

Table 1-1 Low- and high-frequency cut-off parameters of M-weighting functions for each marine mammal functional hearing group

Functional Hearing group	f_{lo} (Hz)	f_{hi} (Hz)
Low-frequency cetaceans (LFC)	7	22 000
Mid-frequency cetaceans (MFC)	150	160 000
High-frequency cetaceans (HFC)	200	180 000
Pinnipeds (in water)	75	75 000

1.3.2 Exposure Criteria

Canada's received-level standards for potential effects of noise on marine mammals are based on criteria developed by the US National Marine Fisheries Service (NMFS), which proposed values of rms SPL as impact criteria. For impulsive sound sources, a broadband received rms SPL of 160 dB re 1 µPa or greater is estimated to cause disruption of behavioural patterns (i.e., harassment) to marine mammals (Marine Mammal Protection Act [MMPA] 2007). Furthermore, concerns about temporary and/or permanent hearing impairment

to cetaceans exist at a broadband received rms SPL of 180 dB re 1 µPa or greater. This level is higher (190 dB re 1 µPa) for pinnipeds in water (Marine Mammal Protection Act [MMPA] 2007). This harassment criterion (the most cautionary injury impact criterion) was thought to be well understood by the public and easily calculated from standard propagation models (NMFS 2005). Expressed in rms units, the criterion accounts for not only the energy of the pulse, but also the length of the pulse (see Equation 1). The disadvantage of such a criterion is that it does not account for important attributes of exposure such as exposure duration, sound frequency composition and pulse repetition rate. Also, these exposure levels are calculated using un-weighted acoustic signals (i.e., the criterion does not account for the different hearing ability of animals at different frequencies).

1.3.3 Southall Criteria

The Noise Criteria Group, sponsored by NMFS, was established in 2005 to address shortcomings of the 180 to 160 dB re 1 µPa rms SPL criteria. The goals of the Noise Criteria Group were to review literature on marine mammal hearing and marine mammal behavioural and physiological responses to anthropogenic noise, and to propose new noise exposure criteria. In 2007, the findings were published by an assembly of experts (Southall *et al.* 2007). The publication introduced new threshold levels, now commonly referred to as the "Southall criteria".

These so-called "dual-criteria" are based on both zero-to-peak (peak) SPL of acoustic waves, expressed in dB re 1 µPa, and total SEL, expressed in dB re 1 $\mu Pa^2 \cdot s$. A received sound exposure is assumed to cause injury if it exceeds either the peak SPL or SEL criterion, or both. The peak SPL is not frequency weighted, whereas the SEL is M-weighted for the given marine mammal group (see Section 1.3.1).

Different levels were established for cetaceans and pinnipeds, with the levels for pinnipeds being lower than for cetaceans. During the calculations of SEL, the length of the pulse is not considered, only the total energy released during the pulse event (see Equation 2).

Table 1-2 Southall criteria for injury and behavioural disturbance

Marine Mammal Hearing Group	Injury		Behavioural disturbance	
	Peak SPL (dB re 1 µPa)	SEL (dB re 1 $\mu Pa^2 \cdot s$)	Peak SPL (dB re 1 µPa)	SEL (dB re 1 $\mu Pa^2 \cdot s$)
Low-frequency cetaceans (LFC)	230	198 (M_{LFC})	224	183 (M_{LFC})
Mid-frequency cetaceans (MFC)	230	198 (M_{MFC})	224	183 (M_{MFC})
High-frequency cetaceans (HFC)	230	198 (M_{HFC})	224	183 (M_{HFC})
Pinnipeds in water	218	186 (M_{Pinn})	212	171 (M_{Pinn})
Source: Southall *et al.* 2007 Note: The peak SPL criterion is un-weighted (i.e., flat weighted), whereas the SEL criterion is M-weighted for the given marine mammal functional hearing group				

2.0 Methods

The various operations involved in the WREP were divided into nearshore and offshore operations:

- The nearshore operations include blasting and dredging required for transporting the CGS from Argentia Harbour to a mating site in Placentia Bay; and

- The offshore operations include dredging in the White Rose field, drilling at the WHP or subsea drill centre, and the use of a support vessel and a helicopter around the WHP.

Several complementary acoustic models were used to predict the underwater acoustic field associated with the studied operations. First, the source levels representing each operation (or acoustic source) were estimated, either through modelling with Conventional Weapons Effects software (ConWep, v2.0 released August 1992, Hyde 1988) for blasting, or from levels recorded for surrogate sources (Section 2.2). Next, sound was propagated through the underwater environment using one or multiple propagation models (Section 2.3). The choice of propagation model depended mainly on the source's location (in-ground, in-water, or in-air) and its frequency spectrum. Finally, marine mammal frequency weighting (M-weighting; see Section 1.3.1) for four functional hearing groups was applied to weight the importance of received sound levels at particular frequencies.

2.1 Modelled Scenarios

Dredging is planned for three locations near Argentia, Placentia Bay, to facilitate the transportation of the CGS to sea. If the sediment is too hard for suction dredging, blasting may be used. Nearshore dredging operations were modelled at three locations along the CGS tow track (see Figure 2-1). Blasting was modelled on-shore, 50 m from the water line close to Site A (i.e., inside the limits of the proposed construction pit), and at the south end of Corridor 1. Offshore operations were modelled at one site - White Rose field, where the WHP or subsea drill centre will be located (Figure 2-2). The dredging operations, were modelled, as well as various operations associated with the WHP or subsea drill centre itself (drilling, support vessel and helicopter operations).

Nine scenarios were modelled in total (Table 2-1), and each scenario was modelled for the oceanographic regime during two months: February and August (see Section 2.4).

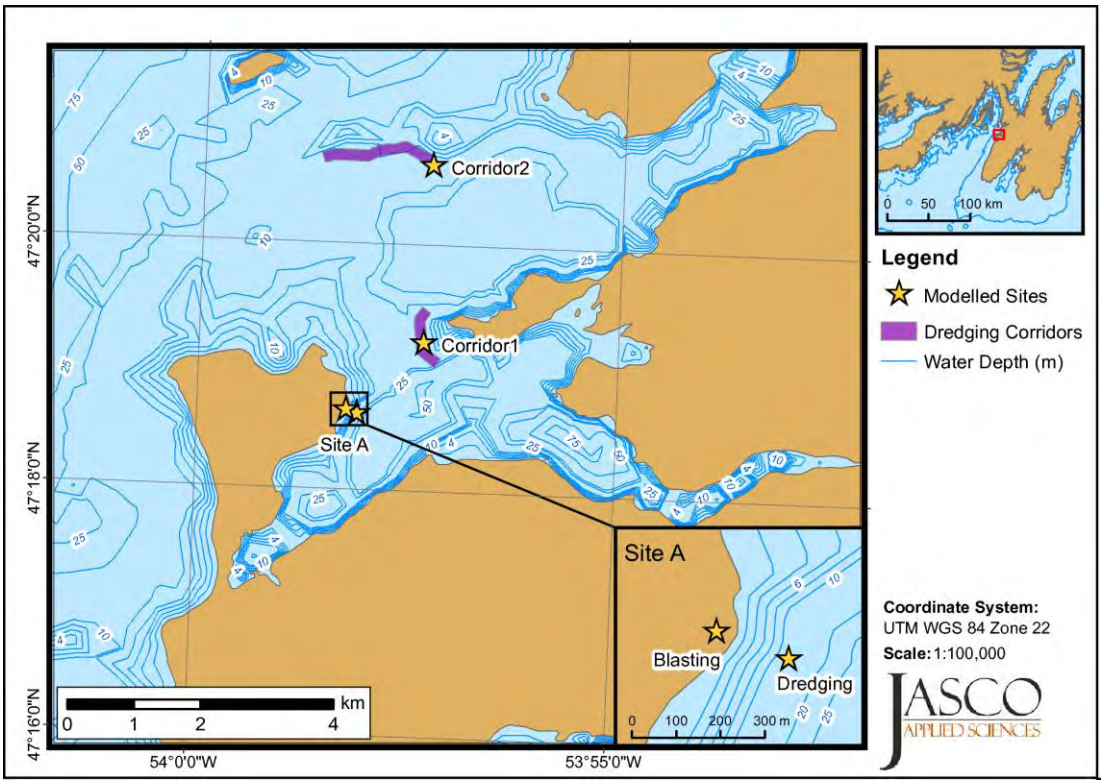


Figure 2-1 Overview of modelled sites near Argentia Harbour, Placentia Bay, NL, Canada

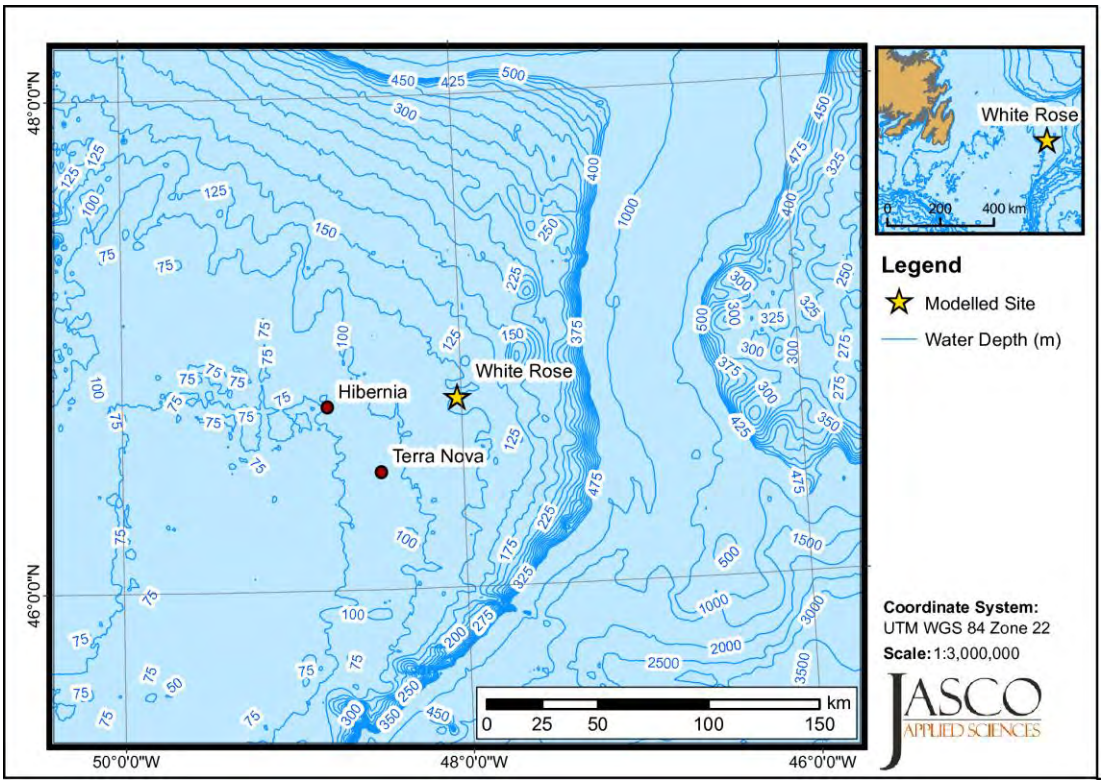


Figure 2-2 Overview of modelled site at the White Rose field, offshore Newfoundland, Canada

Table 2-1 Location and sound sources of each modelled scenario and the propagation model employed

Scenario	Location	Source	UTM Coordinates (m), Zone 22	Water depth (m)	Model
Nearshore					
1	Site A	1. Blasting (on-shore)	275500 E, 5244000 N	0	RAM-S
2	Site A	3. Dredging, cutter suction dredge	275663 E, 5243937 N	14.2	MONM
3	Corridor 1	2. Blasting (in water)	276672 E, 5244988 N	14.6	RAM-S
4	Corridor 1	4. Dredge, trailing suction hopper dredge	276672 E, 5244988 N	14.6	MONM
5	Corridor 2	4. Dredge, trailing suction hopper dredge	276825 E, 5247656 N	14.5	MONM
Offshore					
6	White Rose Field	4. Dredge, trailing suction hopper dredge	727202 E, 5184225 N	128.3	MONM
7	White Rose Field	5. Drilling	727202 E, 5184225 N	128.3	MONM
8	White Rose Field	6. Support vessel	727202 E, 5184225 N	128.3	MONM
9	White Rose Field	7. Helicopter	727202 E, 5184225 N	128.3	Young's equation

2.2 Acoustic Sources

The main sources of underwater acoustic noise from the WREP are expected to be generated during blasting, dredging and drilling . Lower acoustic levels are expected from the use of support vessels and helicopter. The source specifications relating to underwater acoustic modelling are summarized in Table 2-2. The method used to model the 1/3-octave band source levels are detailed in Sections 2.2.1 to 2.2.5.

Table 2-2 Acoustic source specifications

Source	Operation	Source Depth	BB SL (dB re 1 µPa @ 1 m)	Frequency range (kHz)	Propagation Model	Location
1	Blasting, on-shore	20 m below sea level	243.5	0.01–2	RAM-S	Site A
2	Blasting, off-shore	2 m below seafloor	243.5	0.01–2	RAM-S	Corridor 1
3	Dredging, cutter suction dredge	5 m, 1 m above seafloor (A)	189.3	0.01–10	MONM	Site A
4	Dredging, trailing suction hopper dredge	5 m, 1 m above seafloor (A)	195.4	0.01–10	MONM	Corridors 1 & 2, White Rose Field
5	Drilling	36 m	162.3	0.01–10	MONM	White Rose Field
6	Support vessel	5 m	182.5	0.01–10	MONM	White Rose Field
7	Helicopter	91 m above sea surface	169.7	0.01–10	N/A	White Rose Field

Note: The source depths are in metres (m)

(A) Dredging was modelled as two point sources, a low-frequency source close to the surface and the high-frequency source close to the seafloor (see details in Section 2.2.2

2.2.1 Sources 1 and 2: Blasting

Blasting operations may be performed to facilitate dredging if hard substrate is encountered. For this operation, explosive charges would be installed in pre-drilled holes at a few metres depth in the ground. At the time of modelling it was unknown if the blasting operation will be required; therefore, neither the contractor nor the specifics of the blasting operation were available. JASCO relied on previous experience modelling blasting (Matthews *et al.* 2010, Zykov *et al.* 2010) for selecting realistic parameters.

Blast overpressure levels at a receiver were modelled with the ConWep software. These levels were then back-propagated to estimate the source levels at a reference distance of 1 m. ConWep predicts ground-shock overpressures for specified charge sizes and detonation depths below the ground surface (Hyde 1988). It includes a database of the yield and detonation rates for various explosive compounds, including pentolite and trinitrotoluene (TNT). ConWep employs empirical equations developed on the basis of numerous experiments conducted by the US Army (TM 5-855-1 1986). For ground-shock modelling, ConWep predicts the peak pressure and peak pressure time-history curve (P-T history curve) envelope.

The input parameters for ConWep include the type and weight of the explosive charge, geometry of the blast (charge depth, distance and depth to the receiver) and geoacoustic parameters of the substrate (density, and P-wave speed and attenuation coefficient).

The P-T history curve was computed for a receiver located 40 m from the charge. Reflections from all other layers were excluded from modelling at this stage. The amplitude of the P-T curve was then back-propagated to 1 m assuming spherical spreading loss of $20\log_{10}(R/1\text{ m})$, where R is the distance at which the original P-T curve was estimated (i.e., 40 m).

The overpressure signature was modelled for a blast charge of 5 kg of pentolite, which is equivalent to 7.1 kg of TNT (Figure 2-3). The physical properties of the backfill sediments were set to simulate till (see Section 2.4.1): 2 000 m/s P-wave speed; and 2 000 kg/m^3 density. The acoustic wave excited by a blast is characterized by an instantaneous rise of pressure, followed by exponential decay. The frequency spectrum of such signal is more or less flat, i.e., the acoustic energy is distributed evenly among the frequency bands. The rms SPL and SEL metrics were calculated for the acoustic pulse at 1 m using Equations 1 and 2, respectively. The characteristics of the acoustic pulse from a 5 kg charge of pentolite are summarized in Table 2-3.

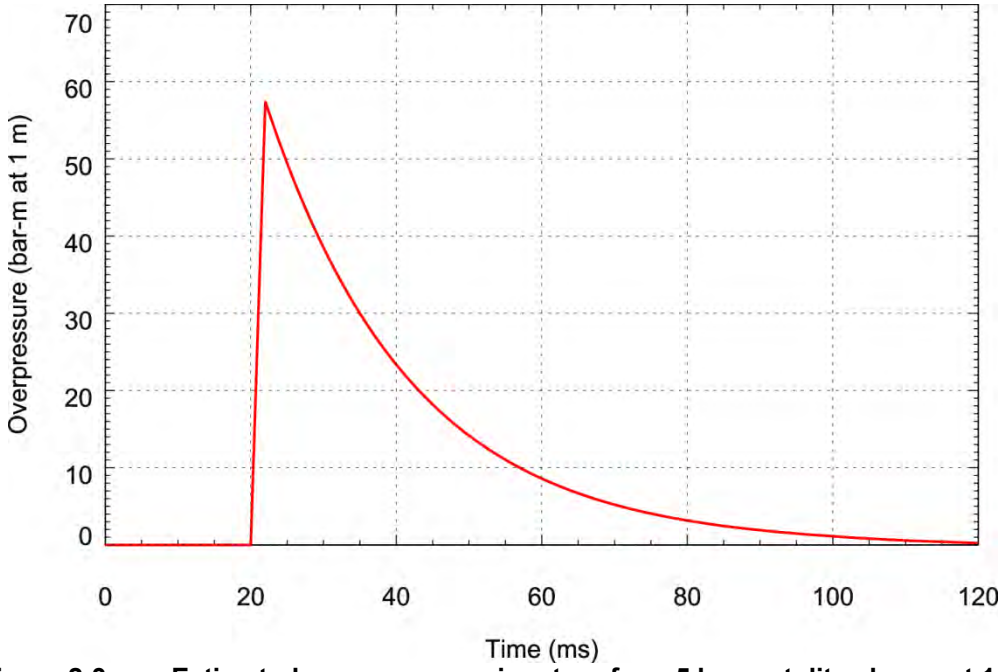


Figure 2-3 Estimated overpressure signature for a 5 kg pentolite charge at 1 m

Table 2-3 Estimated sound levels of the acoustic pulse produced by detonation of 5 kg of pentolite

Distance from source (m)	Zero-to-peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SEL (dB re 1 µPa^2·s)
40	219.1	211.4	199.3
1	255.1	243.5	231.5

The modelling of the acoustic wave propagation from the blast was performed in 24 1/3-octave bands (10 Hz to 2 kHz). The SEL in each band was calculated as 217.5 dB re 1 $\mu Pa^2 \cdot s$ by distributing the acoustic energy evenly through the bands.

2.2.2 Source 3 and 4: Suction Dredges

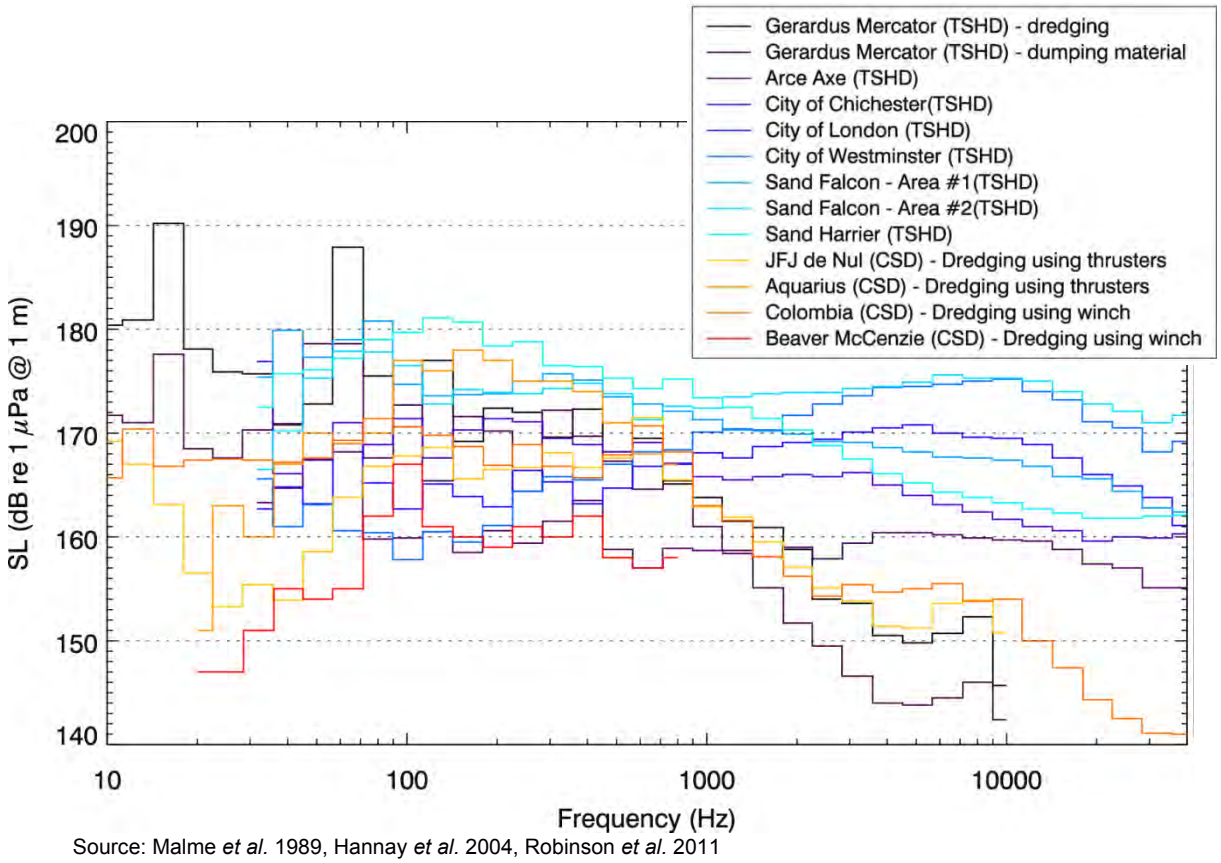
Suction dredges use a wide pipe (up to 1 m in diameter) and a high power pump to suck water and bottom material into a hopper or onto the shore. A cutter head may be used to help loosen sediment. The pipe with a cutter head or drag head can be steered using cables and winches or thrusters. Generally, a cutter suction dredge (CSD) vessel uses legs (also known as spuds) and swings between anchors instead of using a propulsion system. In contrast, a trailing suction hopper dredge (TSHD) vessel moves using its main propulsion system (propeller and/or thrusters).

During dredging operations, the main sources of underwater sound are the vessel's propulsion system and onboard machinery, the displacement of material by the suction head at the seafloor and the displacement of material through the suction pipe. Robinson et al. (2011) recorded six TSHD in several operational modes. His study shows that sound levels below 1 kHz are associated mainly with the vessel itself, while sound levels above 1 kHz are associated mainly with the dragging/abrasion of sediment passing through the drag head, suction pipe and pump. Beamforming analysis of recorded dredging noise from a number of TSHDs also shows that sound above a frequency of 2 kHz can be associated with the operations of the dredge pump and dredger head close to the seafloor (Robinson et al. 2011). Thus, suction dredges may be represented by a low-frequency source (< 1 to 2 kHz) close to the water surface and a higher-frequency source (> 2 kHz) close to the seafloor.

Various suction dredge spectra are presented in Figure 2-4; the known dredge specifications are summarized in Table 2-4. Generally, the source levels for TSHD, which uses the vessel's propulsion system, are higher than for CSD at < 1 kHz. This is in accordance with the Robinson et al. (2011) study.

While it is expected that a CSD will be used at Site A and a TSHD will be used for the dredging of Corridors 1 and 2, the exact specifications of the suction dredges to be used in the WREP are unknown. Thus, two source level spectra were constructed based on the source levels of the reference spectra in Figure 2-4. For each 1/3-octave band below 1 kHz, the source level for the CSD was set to the maximum level of all reference CSDs and the source level for the TSHD was set to the maximum level of all reference TSHDs. For each 1/3-octave band above 1 kHz, the source level for both the CSD and TSHD was set to the maximum level of all reference dredges (Figure 2-5).

In accordance with Robinson et al. (2011), the source depths of the suction dredges were set to 5 m depth for frequencies below 2 kHz and 1 m above the seafloor for frequencies above 2 kHz.



Source: Malme *et al.* 1989, Hannay *et al.* 2004, Robinson *et al.* 2011

Figure 2-4 Comparison of published source levels from trailing suction hopper dredges and cutter suction dredges

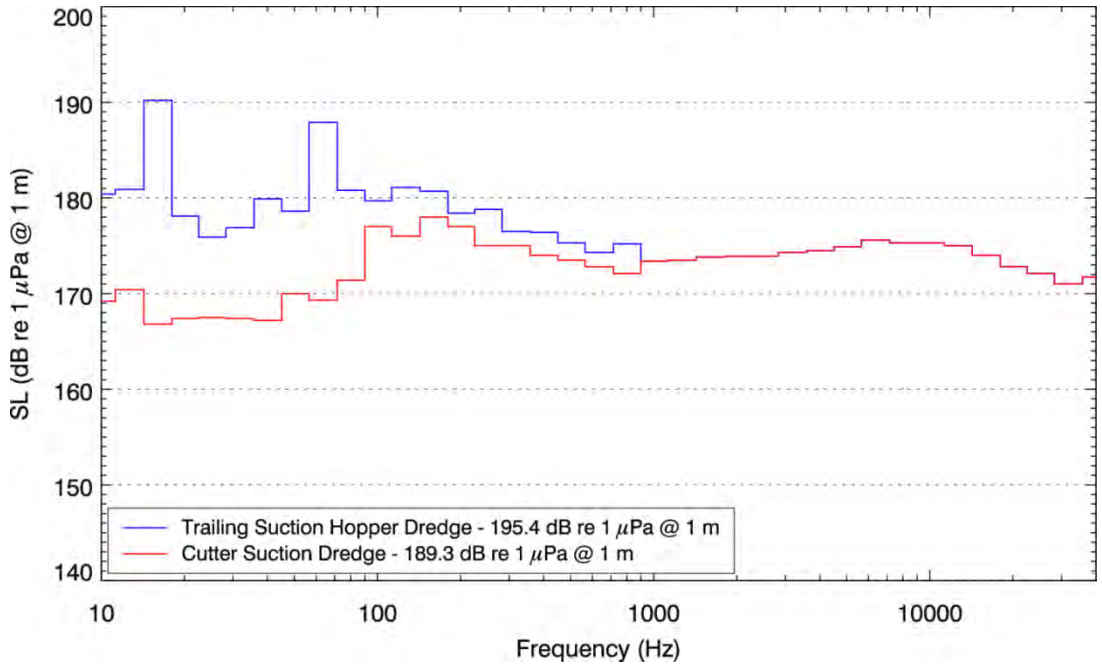


Figure 2-5 Estimated source levels for the modelled trailing suction hopper dredge and the cutter suction dredge

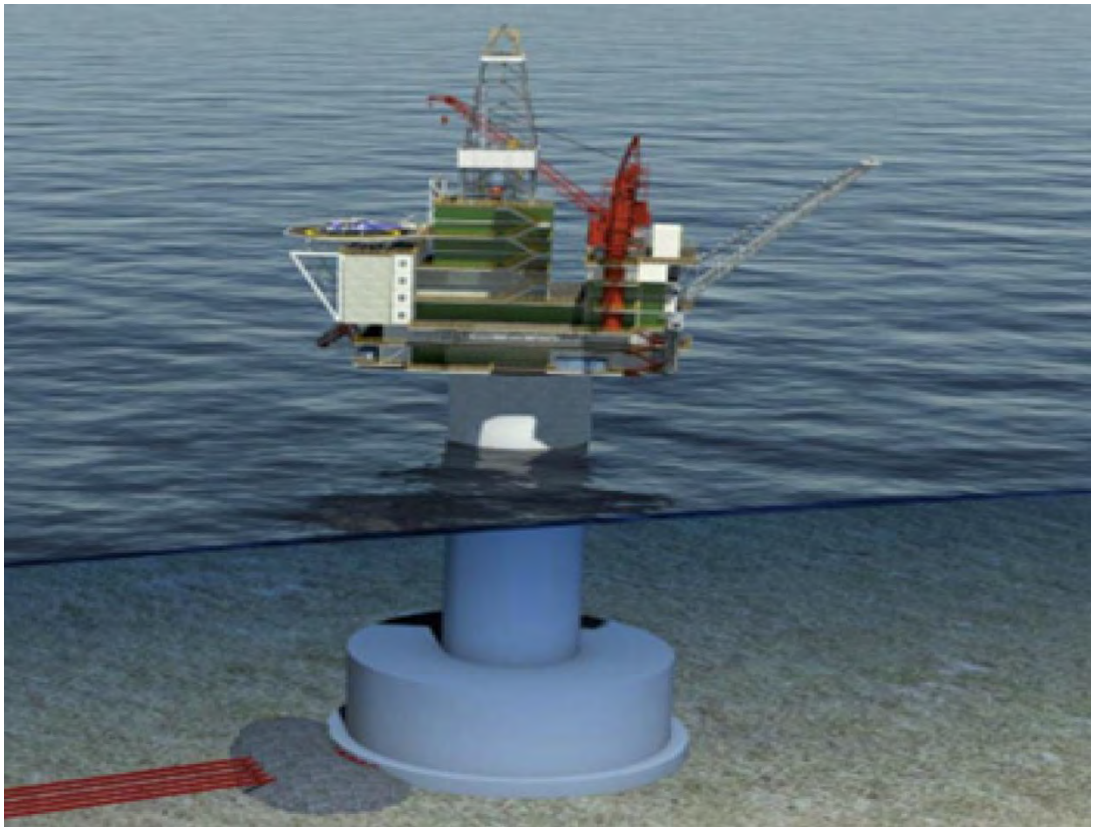
Table 2-4 Specifications of the reference dredges

Dredge	Type	Dimension (m)	Size/ tonnage	Max dredge depth (m)	Other specifications	Reference
Sand Harrier	TSHD	99	4671 t	33	Pump power: 1591 kW	Robinson et al. 2011
Sand Falcon	TSHD	120	8359 t	50	Pump power: 1100 and 1631 kW (2 pumps)	Robinson et al. 2011
Arco Axe	TSHD	98.3	5000 t	48	Pump power: 1100 kW	Robinson et al. 2011
City of Chichester	TSHD	72	2300 t	35	Pump power: 700 kW	Robinson et al. 2011
City of London	TSHD	99.9	4750 t	46	Pump power: 1100 kW	Robinson et al. 2011
City of Westminster	TSHD	99.7	5200 t	46	Pump power: 1100 kW	Robinson et al. 2011
Gerardus Mercator	TSHD	152.9 × 29 × 11.51	hopper size: 18 000 m³	112	Suction pumps, double-walled 2 × 3000 kW Discharge pumps power 14 000 kW Submerged dredgepump 3200 kW Main engines 2 × 9450 kW Shaft generators 2 × 4500 kW Auxiliary engines 3 × 924 kW Harbour engine 320 kW Jet pumps 2 × 1000 kW Bow thrusters 2 × 1000 kW	Hannay et al. 2004 http://www.sakhalinenergy.com/en/documents/doc_33_cea_tbl4-7.pdf
JFJ de Nul	CSD	124.4 × 27.8 × 6.51	unknown	35	Cutter head controlled by thruster Cutter drive power 6000 kW Submerged dredge pump on cutter ladder 3 800 kW Inboard dredge pumps 2 × 6000 kW Propulsion 2 × 3800 kW Total installed power 27 190 kW	Hannay et al. 2004 http://www.sakhalinenergy.com/en/documents/doc_33_cea_tbl4-7.pdf
Aquarius	CSD	107 × 19 × 4.85	unknown	25	12 889 kW Cutter head controlled by thruster	Malme et al. 1989
Columbia	CSD	49 × 13.4 × 2.14	unknown	18	Pipe diameter: 0.66 m Cutter power: 375 kW Total power: 3954 kW Cutter head controlled by winch	Zykov et al. 2007

Dredge	Type	Dimension (m)	Size/ tonnage	Max dredge depth (m)	Other specifications	Reference
Beaver MacKenzie	CSD	86.5 × 15.44 × 4	2148.5 t	45	Pipe Diameter: 0.85 m 1500 hp on ladder; 1700 hp on discharge; 1500 hp on jet pump Cutter head controlled by winch	Malme et al. 1989

2.2.3 Source 5: Drilling Platform

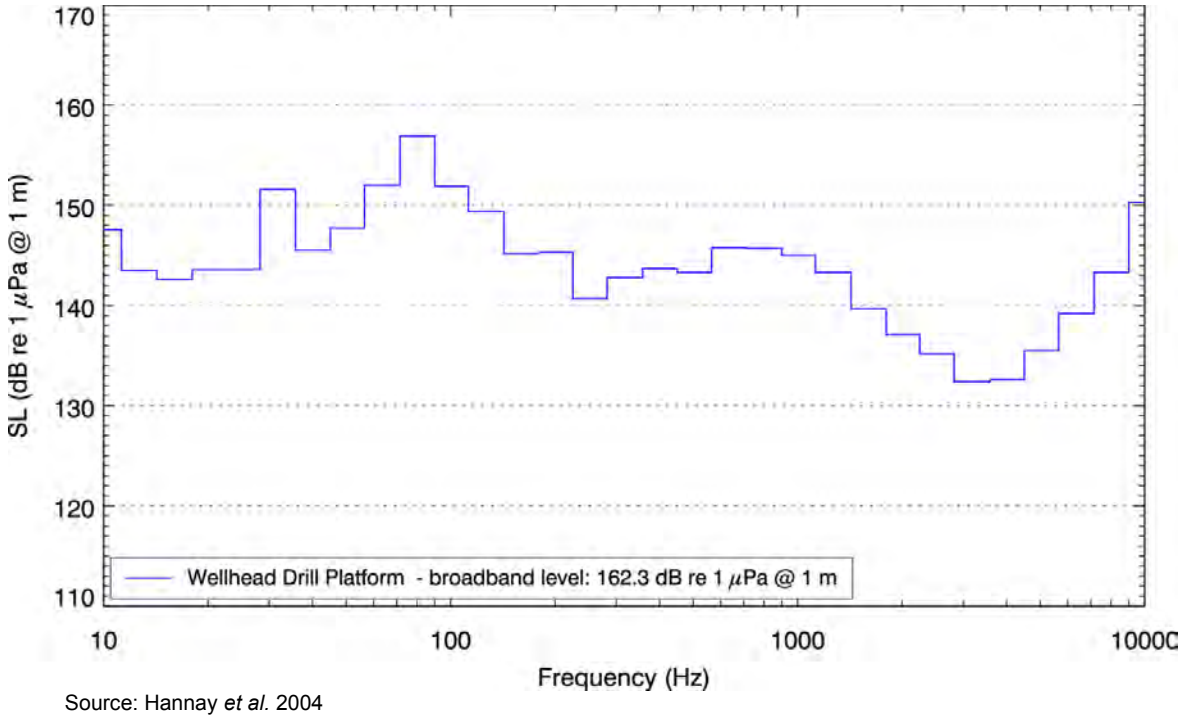
The planned WHP consists of a CGS with a topside that includes drilling facilities, wellheads and support services (i.e., accommodations, utilities, flare boom and helideck) (Figure 2-6). Although underwater sound levels from multiple types of drilling installations (e.g., drillships, semi-submerged platforms, fixed multi-legged platforms and drilling islands) are publicly available, recordings of drilling operations from a WHP are limited (Gales 1982, Malme *et al.* 1989, Richardson *et al.* 1995, Blackwell *et al.* 2004, Hannay *et al.* 2004). In general, drillships produce higher sound levels than fixed multi-legged platforms (Gales 1982), whereas drilling islands produce the lowest sound levels (Blackwell et al. 2004).



Source: Husky Energy 2012

Figure 2-6 Example of a wellhead platform with a concrete gravity structure

In this study, source levels for the drilling operations at the WHP were estimated from JASCO recordings of the *Molikpaq* platform while drilling (Hannay et al. 2004). The *Molikpaq* drilling platform is a 111 m wide, caisson-retained platform (i.e., ballast is filled with sand), located 16 km offshore northeast Sakhalin, Russia. Received levels from these recordings were back-propagated assuming spherical spreading loss, to conservatively estimate the source levels (Figure 2-7).



Source: Hannay *et al.* 2004

Figure 2-7 Estimated 1/3-octave band source levels for drilling operations at the modelled wellhead platform, based on source levels for the caisson-retained *Molikpaq* platform

Sound may come from multiple locations on the platform, including the machinery outside the water, resonances along the caisson and the drill within the seafloor. The depth of the source influences sound propagation by creating a cut-off frequency in the spectrum. This cut-off frequency can be seen as a low-frequency (or high-pass) filter; sound propagating at frequencies below the cut-off value is highly attenuated since the source depth is less than one-quarter of the frequency wavelength. To produce a cautionary estimate of distances to sound level thresholds, sound from the drilling operations was modelled as a point source located at 36 m depth, equal to one-quarter of the wavelength of the lowest modelled frequency, which is 144 m at 10 Hz. This source depth minimizes the attenuation of low frequencies and promotes long-range propagation.

2.2.4 Source 6: Support Vessel

Tugs often work at high-power output rates. As such, the cavitation process of the propeller blades and/or the use of jet thrusters are the main sources of underwater sound. The intensity of these sources is generally related to the vessel's total horsepower (Hannay et al. 2004).

At the time of this study, the support vessel at the White Rose field was expected to be a tug with a power of approximately 5 000 HP. Since the exact vessel was undetermined, a reference vessel recorded by JASCO, the *Neftegaz 22* (Hannay et al. 2004), was chosen to represent the support vessel based on its total horsepower. The *Neftegaz 22* specifications are:

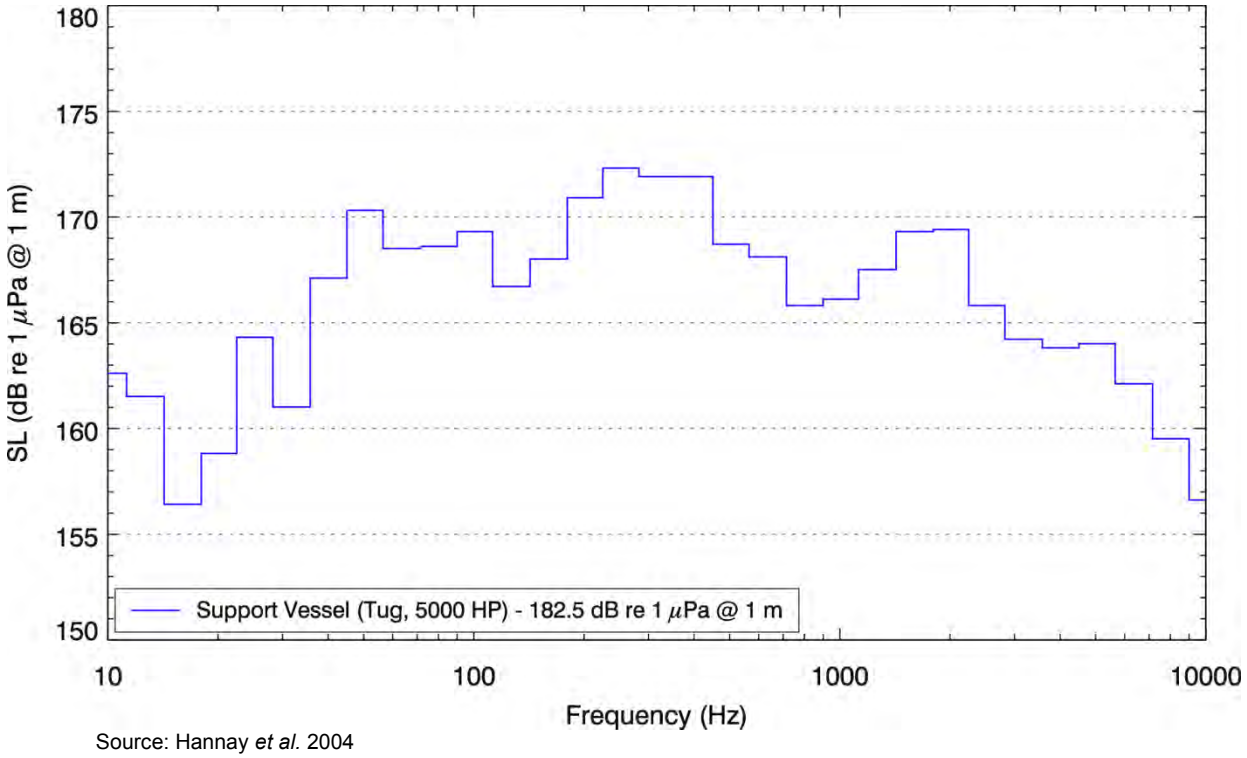
- Type: anchor handling tug supply

- Built: 1985, Poland
- Deadweight: 1 397 metric tonnes
- Length overall: 81 m
- Breath: 16 m
- Draft: 4.9 m (loaded light)
- Engines: 2×6 ZL 40/48
- Total break-horsepower (BHP): 7 200
- Maximum speed: 26 km/h (14 knots)

The 1/3-octave band source levels of the modelled support vessel were adjusted for the difference in total horsepower (THP) between the two vessels (-1.5 dB) using the following equation:

$$SL = SL_{ref} + 10\log\left(\frac{THP}{THP_{ref}}\right) = SL_{ref} + 10\log\left(\frac{5000\ HP}{7200\ HP}\right) \quad (4)$$

The final spectrum for the modelled support vessel is presented in Figure 2-8.



Source: Hannay *et al.* 2004

Figure 2-8 Estimated source levels for the support vessel based on the surrogate tug, *Neftegaz 22*

Since the propulsion system and the onboard machinery (propagating through the hull) is generally the sound source in tug operations, the depth of the modelled source was set to 5 m, a conservatively large estimate of the vessel draft.

The depth of the source influences sound propagation by creating a cut-off frequency in the spectrum. This cut-off frequency can be seen as a low-frequency (or high-pass) filter; sound propagating at frequencies below the cut-off value is highly attenuated since the source depth is less than one-quarter of the frequency wavelength. The cut-off frequency for a source depth of 5 m is approximately 73 Hz (based on the average underwater sound speed at the White Rose site). Since lower frequencies generally propagate further from a source, a similar vessel with a shallower draft (e.g., 3.5 m, leading to a cut-off frequency of approximately 103 Hz) would result in shorter distances to sound level thresholds.

2.2.5 Source 7: Helicopter

At the time of this study, the type of helicopter to be used for the WREP was unknown. JASCO recordings of a Bell 206 and a Bell 212 helicopter were used to estimate source levels. These helicopters were recorded during low-speed fly pass, and spectrum levels were backpropagated to the reference distance of 1 m, assuming spherical spreading loss of $20\log_{10}(R/1\text{ m})$, where R is the distance between the receiver and the helicopter. The helicopter specifications and 1/3-ocatve band spectrum are presented in Table 2-5 and Figure 2-9. Note that the standard reference pressure for underwater acoustics (1 µPa) differs from in-air acoustics (20 µPa). However, the source levels for the recorded helicopters are presented in reference to 1 µPa for comparison purposes. For cautionary results, the assessment of underwater received levels from the helicopter was modelled using the highest source levels (i.e., the Bell 206 helicopter).

Table 2-5 Specifications of reference helicopters

Type	Specifications/Comments
Bell 206	• Length: 12.11 m • Rotor diameter: 10.16 m • Height: 2.83 m • Disc area: 81.1 m² • Powerplant: 1 × Allison 250-C20J turboshaft, 420 shp (310 kW) • Maximum speed: 130 knots (224 km/h)
Bell 212	• Length: 17.43 m • Rotor diameter: 14.64 m • Height: 3.83 m • Disc area: 168.3 m² • Powerplant: 1 × Pratt & Whitney Canada PT6T-3 or −3B turboshaft, 1800 shp (1342 kW) • Maximum speed: 120 knots (223 km/h)

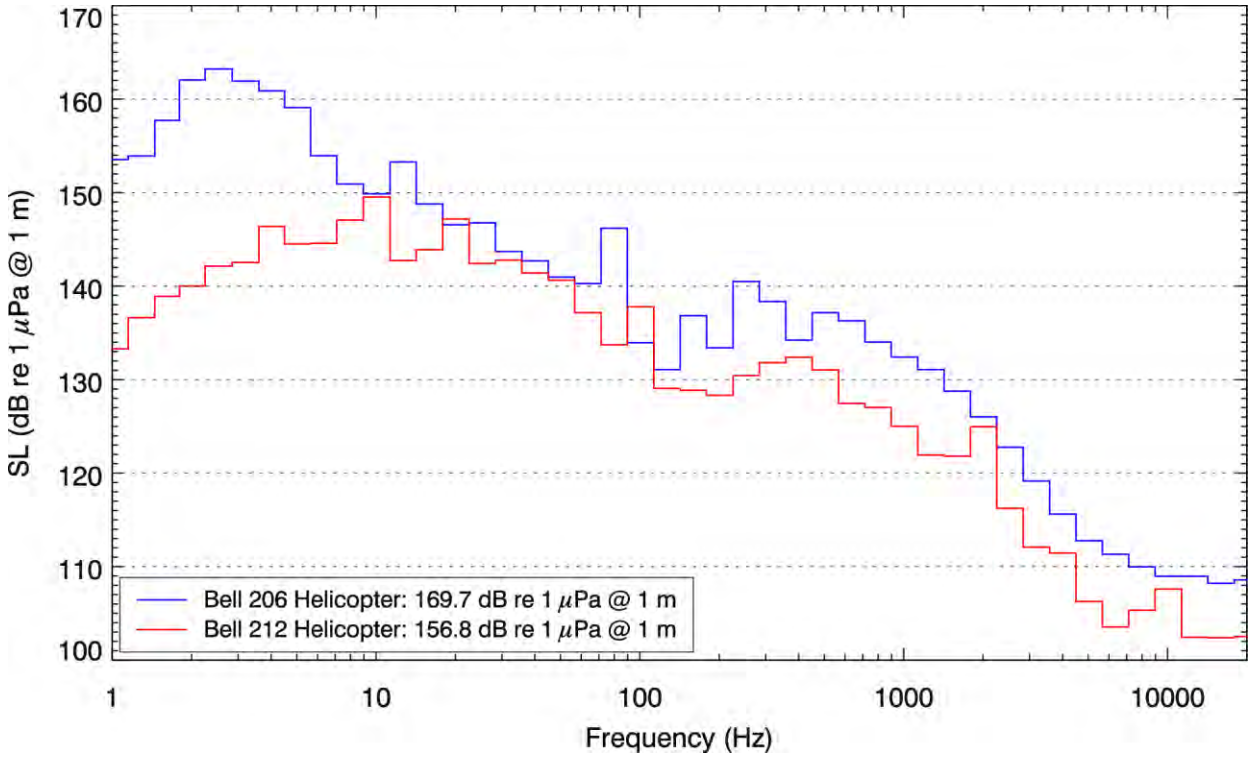


Figure 2-9 Calculated 1/3-octave band source levels for Bell 206 and Bell 212 helicopter

2.3 Sound Propagation Models

Sound was propagated through the underwater environment using one or multiple propagation models. The selection of an appropriate propagation model was mainly based on the source's location (in-ground, in-water or in-air) and its frequency spectrum.

2.3.1 Source 1 and 2: Blasting

Blasting operations are performed by detonating explosive charges placed in the ocean-floor sediments. For modelling purposes, an explosion is considered to be an in-ground point source.

Marine sediment is an elastic medium that, unlike water, supports the propagation of shear waves. Simplified acoustic wave propagation models (e.g., Range-dependent Acoustic Model (RAM)) do not account for the existence of shear waves in the sediments. Shear waves are excluded from the models for a speedier modelling process. Exclusion of shear waves from the modelling is justifiable for an in-water source, and the observed reduction in the accuracy of the solution is acceptable. However, propagation modelling of an in-ground source without considering the presence of shear waves in the sediments can lead to an unacceptable loss of accuracy.

2.3.1.1 Range-dependent Acoustic Model with Shear Waves

Sound propagating from an explosive charge was modelled with RAM-S (Collins 1993). RAM-S is an extension of RAM that incorporates the propagation of shear waves in the sediments.

RAM-S incorporates five geoacoustic properties of the sediment layer: P-wave speed and attenuation, S-wave speed and attenuation, as well as sediment density. All five properties, as well as water depth and sound speed profiles in the water column, can be defined as a range-dependent vertical profile (i.e., each parameter varies with depth and distance from the source). RAM-S computes acoustic fields in three dimensions by modelling transmission loss along 2-D vertical radial planes covering a 360° swath from the source, an approach commonly referred to as N×2-D. RAM-S model results have been validated against controlled acoustic propagation experiments in a laboratory (Collis et al. 2007).

2.3.1.2 Model Parameters

In this study, sound transmission loss was modelled at the centre frequencies of 1/3-octave bands between 10 Hz and 2 kHz, for a total of 24 bands. This frequency range includes the important bandwidths of noise emissions for the blasting operation. The 2-D radial planes were evenly spaced covering a 360° swath with a separation angle of 2.5°, for a total of N=144 radials. The range step size along each radial was variable depending on the modelled frequency. For the frequency range from 10 to 63 Hz, the step size was 5 m; for the 80 Hz to 250 Hz range, 2 m; and for the 320 Hz to 2 kHz range, 1 m. Sound was modelled to a maximum range of 75 km at both Site A and Corridor 1.

2.3.1.3 Estimating 90 Percent Root-mean-square Sound Pressure Level from Sound Exposure Levels

Existing safety radius regulations for impulsive sound sources are based on the rms SPL metric. An objective definition of pulse duration is needed when measuring the rms level for a pulse. Following suggestions by Malme et al. (1986), Greene (1997) and McCauley et al. (1998), pulse duration is conventionally taken to be the interval during which 90 percent of the pulse energy is received. Although one can measure the 90 percent rms SPL in situ, this metric is generally difficult to model because the adaptive integration period, implicit in the definition of the 90 percent rms SPL, is sensitive to the specific multipath arrival pattern from the source and can vary greatly with distance from the source or with depth of the receiver. To predict the 90 percent rms SPL, it is necessary to model the full waveform of acoustic pressure, but full-waveform modelling for large-depth, range-dependent environments can be prohibitive due to the extensive time required to run the model.

In various studies where the rms SPL, SEL and pulse duration have been measured for individual airgun pulses, the offset between rms SPL and SEL is typically 5 to 15 dB, with considerable variation depending on water depth and geoacoustic environment (Greene 1997, McCauley *et al.* 1998, Blackwell *et al.* 2007, MacGillivray *et al.* 2007). Generally, the measured SEL to rms SPL offsets are larger at closer distances, where the pulse duration is short ($\ll$ 1 s), and smaller at farther distances, where the pulse duration tends to increase because of propagation effects.

In this study, JASCO's full-waveform acoustic propagation model FWRAM was used to determine range-dependent estimates of rms SPL and SEL for a small set of representative propagation directions.

FWRAM conducts time-domain calculations and is therefore appropriate for computing time-averaged rms SPLs for impulsive sources. The model computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments using the parabolic equation (PE) approach to solving the acoustic wave equation. Like RAM-S, FWRAM accounts for range-varying properties of the acoustic environment. It uses the same environmental inputs (bathymetry, water sound speed profile and seabed geoacoustic profile). However, FWRAM computes pressure waveforms via Fourier synthesis[1] of the modelled acoustic transfer function in closely spaced frequency bands.

Range-dependent rms SPL-SEL conversion functions were calculated from the resulting rms SPL-SEL offsets and applied to the set of SEL predictions from RAM-S. This approach combines accurate pulse length information available from FWRAM with the greater computational efficiency of RAM-S.

The chosen propagation directions were along the azimuth where sound propagates farthest from the source (without traveling to land) (i.e., 015° east of UTM north at Site A and 310° at Corridor 1). The site-specific offset functions used in this study are presented in Figures 2-10 and 2-11.

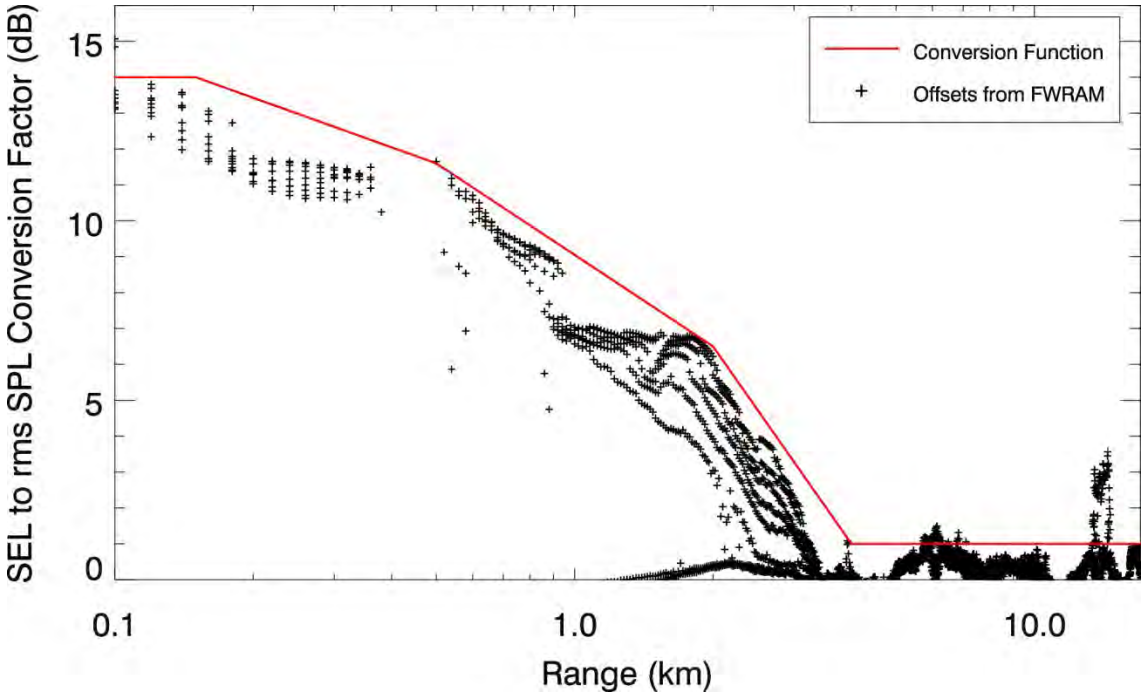


Figure 2-10 Offset of SELs to rms SPLs modelled for Site A

[1] Fourier synthesis is the operation of rebuilding a function from simpler pieces (Fourier series).

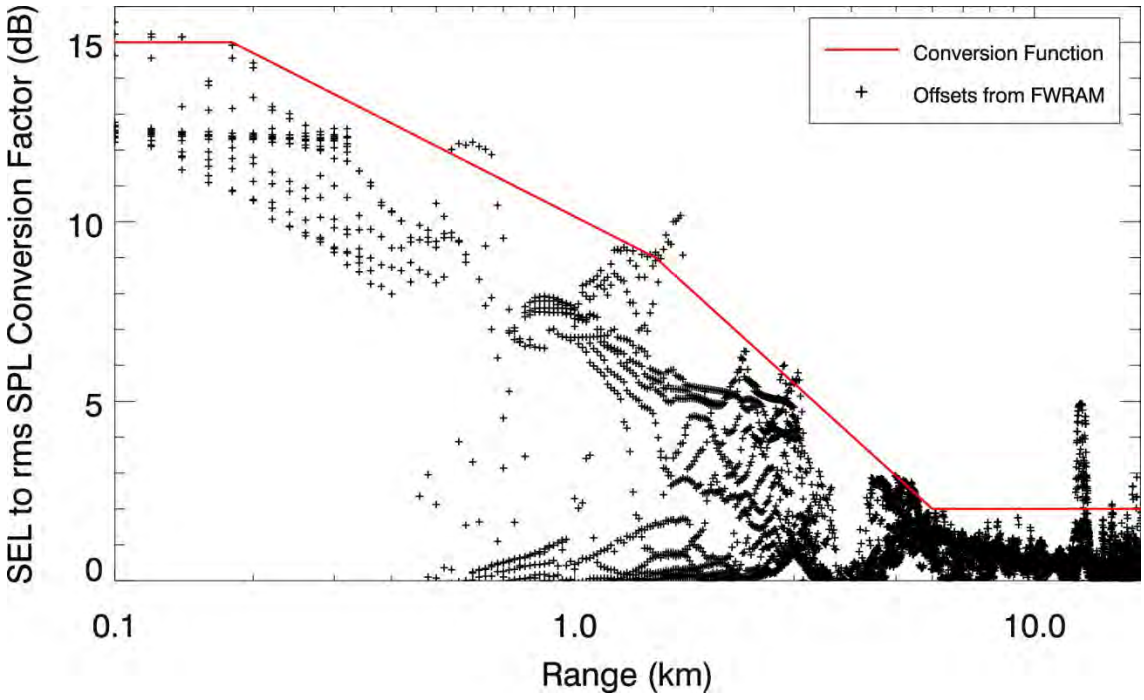


Figure 2-11 Offset of SELs to rms SPLs modelled for Corridor 1

2.3.2 Sources 3 to 6: Dredging, Drilling and Support Vessel

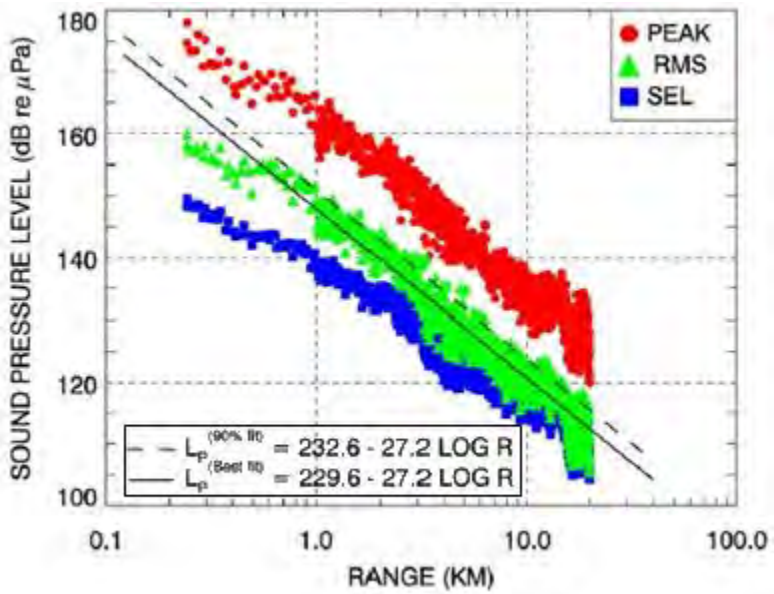
The acoustic propagation model used to model the acoustic sources at frequencies below 10 kHz is JASCO's Marine Operations Noise Model (MONM). MONM computes received SEL for impulsive sources. For a continuous source, such as a vessel, dredge or drill rig, MONM outputs rms SPLs.

MONM computes acoustic fields in three dimensions by modelling transmission loss along 2-D vertical radial planes covering a 360° swath from the source (*N*×2-D). MONM fully accounts for depth and/or range dependence of several environmental parameters, including bathymetry and the sound speed profiles in the water column and the sub-bottom. It also accounts for the additional reflection loss due to partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces. It includes wave attenuations in all layers. The acoustic environment is sampled at a fixed range step within the radial planes.

MONM handles frequency dependence by computing acoustic transmission loss at the centre frequencies of 1/3-octave bands. It treats sound propagation through a wide-angled PE solution at frequencies ≤ 2 kHz and through a ray-tracing solution at frequencies > 2 kHz. Third-octave band received levels are computed by subtracting band transmission loss values from the corresponding directional source levels. Broadband received levels are then computed by summing the received band levels.

MONM's sound level predictions have been extensively validated against experimental data (Hannay and Racca 2005, Aerts *et al.* 2008, Funk *et al.* 2008, Ireland *et al.* 2009, O'Neill *et al.* 2010, Warner *et al.* 2010). An inherent variability in measured sound levels is caused by temporal variability in the environment (and the variability in the signature

of repeated acoustic impulses for non-continuous sources); sample sound source verification results are presented in Figure 2-12. While MONM's predictions correspond to the averaged received levels, cautionary estimates of the threshold radii are obtained by shifting the best fit line (solid line, Figure 2-12) upward so that the trend line encompasses 90 percent of all the data (dashed line, Figure 2-12).



Source: Ireland *et al.* 2009

Solid line is the least squares best fit to rms SPL. Dashed line is the best fit line increased by 3.0 dB to exceed 90 percent of all rms SPL values (90th percentile fit)

Figure 2-12 Peak and rms SPL and per-shot SEL versus range from a 20 in^3 airgun array

In the regions of the Beaufort and Chukchi Seas, sound source verification results show that this 90th percentile best-fit is, on average, 3 dB higher than the original best fit line for sources in water depths greater than 20 m (Aerts *et al.* 2008, Funk *et al.* 2008, Ireland *et al.* 2009, O'Neill *et al.* 2010). Consequently, a safety factor of 3 dB was added to the predicted received levels to provide cautionary results reflecting the inherent variability of sound levels in the modelled area.

2.3.2.1 Marine Operations Noise Model: Range-dependent Acoustic Model

At frequencies up to 2 kHz, MONM treats sound propagation in range-varying acoustic environments through a wide-angled PE solution to the acoustic wave equation. The PE method used by MONM is based on a version of the Naval Research Laboratory's RAM, which has been modified to account for an elastic seabed. The PE method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins 1993).

2.3.2.2 Marine Operations Noise Model: BELLHOP

At frequencies between 2 and 10 kHz, MONM treats sound propagation in range-varying acoustic environments through ray-series approximation of the acoustic wave equation using the BELLHOP acoustic ray-trace model (Porter and Liu 1994).

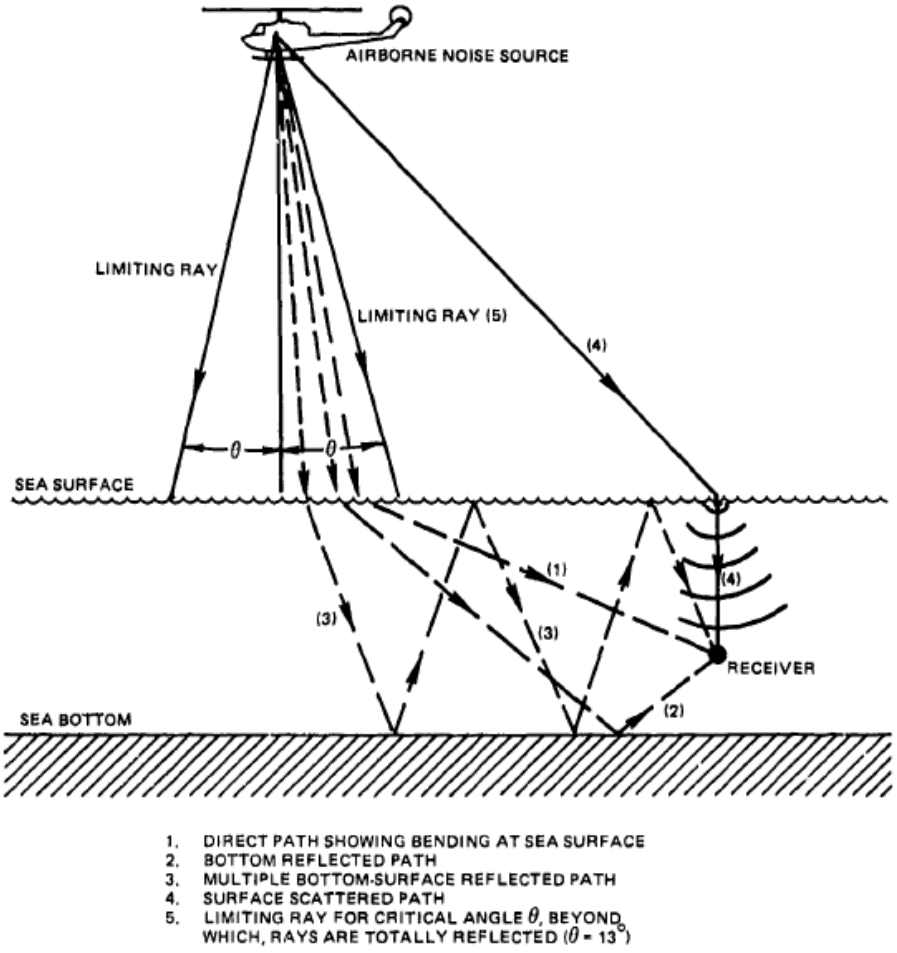
BELLHOP models transmission loss in the ocean using the Gaussian beam tracing technique. In addition to other types of attenuation, BELLHOP accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water (Fisher and Simmons 1977). This type of attenuation is important for frequencies higher than 5 kHz and cannot be neglected without noticeable effect on the modelling results at longer distances from the source (may be > 3 dB at approximately 10 km from the source for frequencies ≥ 5 kHz).

2.3.2.3 Model Parameters

In this study, sound transmission loss was modelled at the centre frequencies of 1/3-octave bands between 10 Hz and 10 kHz. This frequency range includes the important bandwidths of noise emissions for the modelled dredging, drilling and support vessel operations. The 2-D radial planes were evenly spaced covering a 360° swath with a separation angle of 2.5°, for a total of N=144 radials. At all frequencies the range step size along each radial was 5 m. Sound was modelled to a range of 25 km at Sites A, Corridor 1 and Corridor 2, and 50 km at the White Rose field site.

2.3.3 Source 7: Helicopter

The large difference in acoustic impedance between air and water limits the amount of sound energy that can penetrate the sea surface and propagate underwater. According to Snell's law, sound propagating at angles > 13° from vertical will be totally reflected at the sea surface ((5) in Figure 2-13). Some sound energy may penetrate the water at angles > 13° in conditions of high sea state (Lubard and Hurdle 1976), or via scattering ((4) in Figure 2-13); however, most of the received energy far from the source is transmitted through direct- and bottom-reflected paths ((1) to (3) in Figure 2-13).



Source: Gales 1982, based on Urick 1972

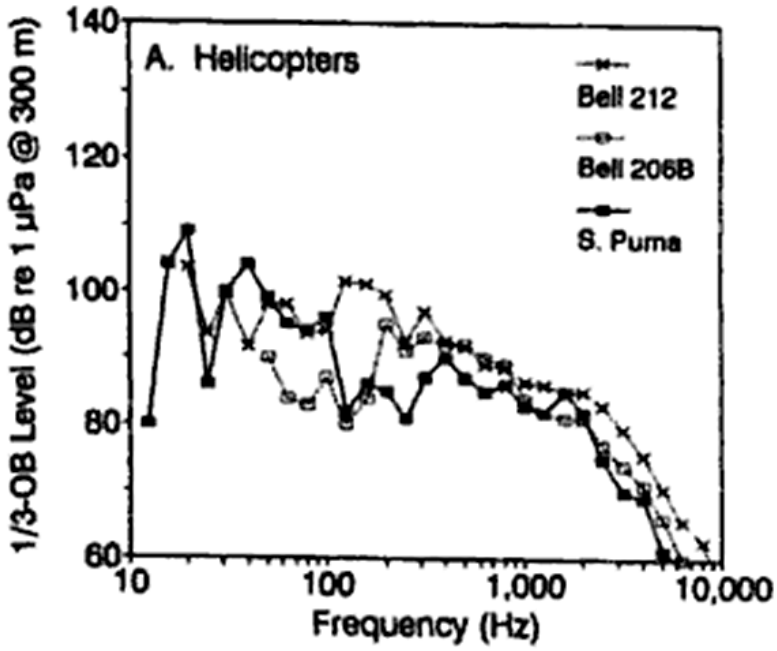
Figure 2-13 Ray-path diagram for air-water propagation from an airborne source

Received underwater sound levels strongly depend on the altitude of the aircraft and the water depth. Received levels tend to be higher in shallow environments with a reflective bottom; however, reported underwater received levels for helicopters are low (Urick 1972, Young 1973, Greene 1985, Richardson and Malme 1993, Richardson *et al.* 1995). For example, Greene (1985) reports:

- Recorded levels of no higher than 111 dB re 1 µPa at 9 m below the surface, directly under a Bell 212 helicopter flying at an altitude of 305 m

- Recorded levels no higher than 111 dB re 1 µPa at 9 m below the surface, at a lateral distance of 50 m from a Sikorsky 61 helicopter flying at an altitude of 152 m.

Richardson (1995) also presents relatively low levels for three types of helicopters flying at an altitude of 300 m (see Figure 2-14).



Source: Richardson *et al.* 1995, Figure 6.4

Figure 2-14 Derived 1/3-octave band levels at the water surface, directly below helicopters flying at an altitude of 300 m

2.3.3.1 Young's Model

Underwater received levels from an airborne source may be estimated using Young's equation (1973), which produces results consistent with empirical data (Richardson et al. 1995). Young's equation estimates underwater acoustic (broadband) levels from an airborne source though the computation of a virtual source. This virtual source accounts for the changes in sound speed and path angles due to changes in impedance between air and water.

2.3.3.2 Model Parameters

In this report, distances to the 120 dB re 1 µPa (rms SPL) threshold were estimated using Young's tabulated transmission loss levels for an airborne source at 91 m (300 ft), corrected for expected averaged sound speed in water at the White Rose field (1 441 m/s in February, 1 471 m/s in August). Distances to other level thresholds (i.e., ≥ 130 dB re 1 µPa) were estimated assuming spherical spreading. This is a valid assumption since the distances to the 120 dB re 1 µPa are estimated to be less than half the water depth.

2.4 Environmental Parameters

2.4.1 Nearshore: Site A, Corridors 1 and 2

Water depths throughout the Argentia Harbour and Placentia Bay areas were obtained from soundings and bathymetric contour data from navigational charts (Canadian Hydrographic Services 2012). The data sets were merged and re-gridded, using bilinear

interpolation, onto a Universal Transverse Mercator (UTM) Zone 22 coordinate projection with a horizontal resolution of 25 × 25 m.

The bottom geology and the geoacoustic properties within Argentia Harbour and Placentia Bay were obtained from reports by C-CORE provided by Stantec (Halliday 2012, Halliday and Cuff 2012) and from published literature (Catto et al. 1997). Generally, the surficial sediments in the area include layers of medium to fine-grained sand and gravel, underlain by till or bedrock. The thickness of surficial layers increases to the southwest, from outcrops of till in the north to 8 m of sand west of Site A.

The geoacoustic properties were estimated following equations by Hamilton (1980) and Buckingham (2005). Three geoacoustic profiles were developed to represent the geoacoustic conditions for:

- Onshore blasting operations near Site A (Table 2-6)
- The fine-grained sand found at and around Site A (Table 2-7)
- The medium-grained sand found at and around Corridors 1 and 2 (Table 2-8).

The geoacoustic profile for modelling of blasting operations has no top layer of soft sediments (sand or gravel), since the blasting operation will be performed once highly-compacted sediments are encountered (till or bedrock) and the blast charges will be placed in sediment that is difficult to remove with the dredge alone.

Table 2-6 Geoacoustic profile for onshore blasting operation near Site A

Sediment	Depth (m)	Density (g/cm^3)	Compressional sound speed (m/s)	Compressional sound attenuation (dB/λ)	Shear sound speed (m/s)	Shear sound attenuation (dB/λ)
Till	0 to 40	2.1 to 2.3	2000 to 2500	1.0	400	0.4
	40 to 100	2.3 to 2.6	2500 to 3000	1.0 to 0.3	400	0.4
	100 to 255	2.6 to 2.6	3000	0.3	400	0.4
Precambrian Bedrock	> 255	2.60	5500	0.28	400	0.4

Table 2-7 Geoacoustic profile for Site A

Sediment	Depth (m)	Density (g/cm^3)	Compressional sound speed (m/s)	Compressional sound attenuation (dB/λ)	Shear sound speed (m/s)	Shear sound attenuation (dB/λ)
Sand and Gravel	0 to 1	2.0	1606 to 1723	0.30 to 0.40	200	2.0
	1 to 6	2.04-2.10	1723 to 2000	0.40 to 1.00		
Till	6 to 255	2.10-2.60	2000 to 5500	1.00 to 0.28		
Precambrian Bedrock	> 255	2.60	5500	0.28		

Table 2-8 Geoacoustic profile for Corridors 1 and 2

Sediment	Depth (m)	Density (g/cm^3)	Compressional sound speed (m/s)	Compressional sound attenuation (dB/λ)	Shear sound speed (m/s)	Shear sound attenuation (dB/λ)
Sand and Gravel	0 to 1	2.0	1650 to 1805	0.60	250	3.0
	1 to 6	2.08-2.10	1805 to 2000	0.60 to 1.00		
Till	6 to 255	2.10-2.60	2000 to 5500	1.00 to 0.28		
Precambrian Bedrock	> 255	2.60	5500	0.28		

Underwater sound speed profiles for Argentia Harbour and Placentia Bay were downloaded from the US Naval Oceanographic Office's Generalized Digital Environmental Model (GDEM) database (Teague et al. 1990). The latest release of the GDEM database (version 3.0) provides average monthly profiles of temperature and salinity for the world's oceans on a latitude/longitude grid with 0.25° resolution. GDEM profiles are provided at 78 fixed depths to a maximum depth of 6800 m. They are based on historical observations of global temperature and salinity from the US Navy Master Oceanographic Observational Data Set (MOODS).

Temperature-salinity profiles were extracted from the GDEM database for the appropriate season and source location and were converted to speed of sound in seawater (*c*, m/s) using the equations of Coppens (1981):

$$\begin{aligned} c(z,T,S) &= 1449.05 + 45.7t - 5.21t^2 - 0.23t^3 \\ &\quad + (1.333 - 0.126t + 0.009t^2)(S-35) + \Delta \\ \Delta &= 16.3Z + 0.18Z^2 \\ Z &= (z/1000)(1 - 0.0026\cos(2\phi)) \\ t &= T/10 \end{aligned} \quad (5)$$

where *z* is water depth (m), *T* is temperature (°C), *S* is salinity (psu) and Φ (Phi) is latitude (radians). The resulting monthly sound speed profiles are shown in Figure 2-15. The sound fields were modelled using two profiles: that with the most constant sound speed (February) and that which is most downward refracting (August).

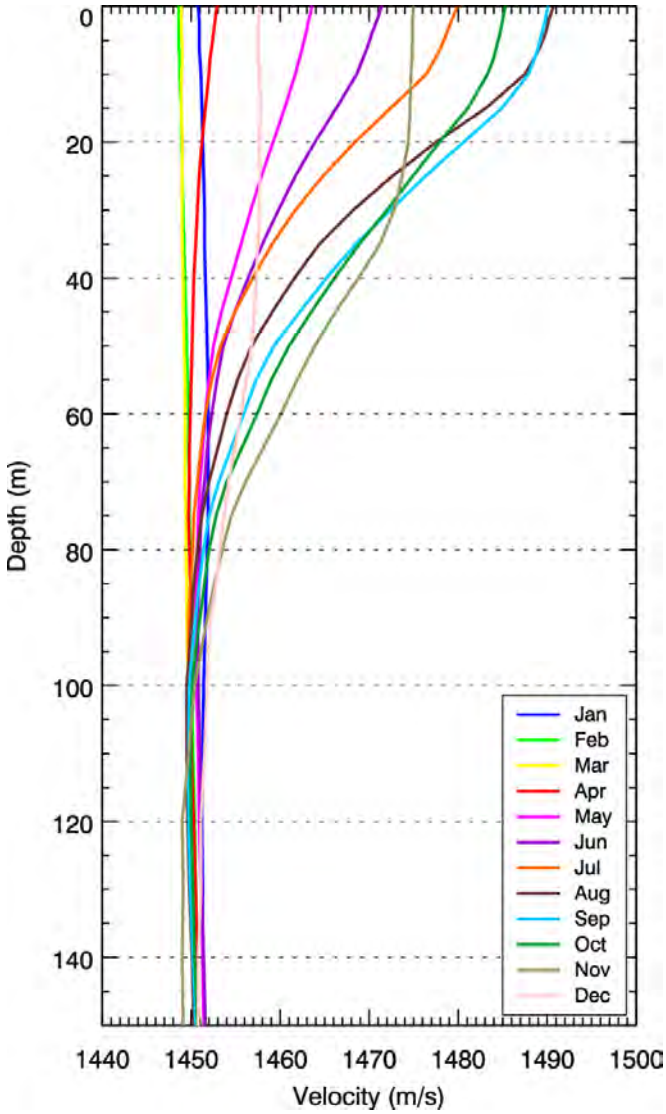


Figure 2-15 Predicted monthly mean sound speed profiles for the nearshore sites: Site A and Corridors 1 and 2

2.4.2 Offshore: White Rose Field

Water depths throughout the White Rose field were obtained from *SRTM30+* (v6.0), a global topography and bathymetry grid with a resolution of 30 arc-seconds or approximately 1 km (Rodriguez et al. 2005). At the studied latitude, the *SRTM30+* grid cell size is approximately 640 × 925 m. The bathymetry data were extracted and re-gridded, using bilinear interpolation, onto a UTM Zone 22 coordinate projection with a horizontal resolution of 500 × 500 m.

The surficial sedimentology in the area of the Jeanne D'Arc Basin, on the northern Grand Banks offshore Newfoundland, has been documented by numerous investigators. The generic geoacoustic profile representing this area (Table 2-9) was developed from information reported by Mosher and Sonnichsen (1992), King and Sonnichsen (2000), Divins (2010) and Abid et al. (2004). The geological stratification is composed of a surficial layer of sand and gravel, which overlays an acoustically-reflective layer of silty to fine sand. It is also characterized by a shallow acoustic basement of unconsolidated tertiary sediment extending for tens of kilometres below the seafloor. Following this profile, the geoacoustic parameters were estimated based on values reported by Ellis and Hughes (1989) and Osler (1994).

Table 2-9 Geoacoustic profile for the White Rose field in Jeanne D'Arc Basin

Sediment	Depth (m)	Density (g/cm^3)	Compressional sound speed (m/s)	Compressional sound attenuation (dB/λ)	Shear sound speed (m/s)	Shear sound attenuation (dB/λ)
Sand and Gravel	0 to 5	1.9 to 2.0	1800 to 1900	0.36 to 0.475	200	3.0
Silty Sand to Fine Sand	5 to 50	1.8 to 2.0	1650 to 1900	0.66 to 0.475		
Sand to Sandy Till	50 to 255	2.0 to 2.1	1900 to 2100	0.475 to 1.0		
Tertiary Bedrock	> 255	2.2	2100	0.21		

Underwater sound speed profiles representing the conditions at the White Rose field were downloaded from the GDEM database (Teague et al. 1990). Temperature-salinity profiles were extracted from the GDEM database and converted to speed of sound in seawater (Figure 2-16; see Section 2.4.1). The sound fields were modelled using two profiles: the most constant sound speed (February); and that which is most downward refracting (August).

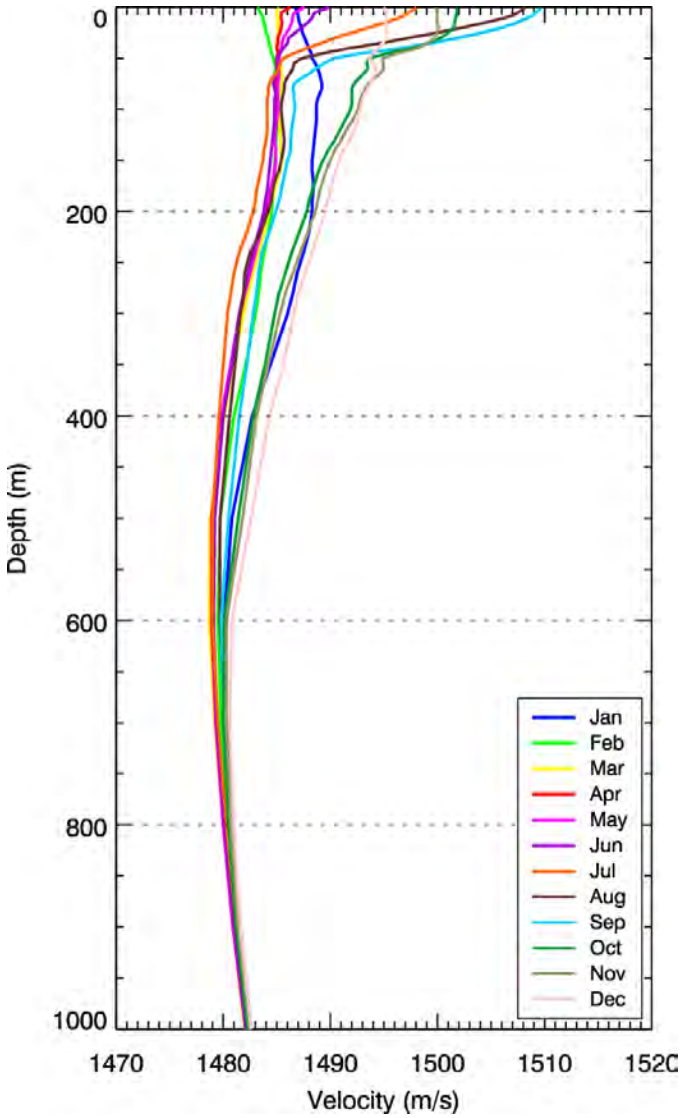


Figure 2-16 Predicted monthly mean sound speed profiles for the offshore site, White Rose field

3.0 Results

The underwater sound fields predicted by the propagation models were sampled such that the received sound level at a surface sampling location is taken as the maximum value occurring over the entire water column. The predicted distances to specific SEL and rms SPL thresholds were computed from these "maximum-over-depth" sound fields. Two distances, relative to the source, are reported for each sound level:

- R_{max}, the maximum range at which the given sound level was encountered in the modelled sound field

- $R_{95\%}$, the maximum range at which the given sound level was encountered after exclusion of the 5 percent farthest such points.

This $R_{95\%}$ definition is meaningful in terms of impact on marine mammals because, regardless of the geometric shape of the noise footprint for a given sound level threshold, $R_{95\%}$ is the predicted range that encompasses at least 95 percent of the animals that could be exposed to sound at or above that level.

The modelled results are presented as tables of R_{max} and $R_{95\%}$ to specified maximum-over-depth SEL (only for impulsive sources (i.e., from blasting activities)) and rms SPL thresholds, and as contour maps of maximum-over-depth sound field showing the directivity in sound propagation. While R_{max} and $R_{95\%}$ are highly relevant, they may vary depending on the location of the source within the modelled area. By considering the distances to the sound level thresholds in combination with the maps of the propagated sound field, better predictions can be made for the variations occurring in realistic scenarios.

3.1 Nearshore: Site A, Corridors 1 and 2

3.1.1 Scenario 1: Site A, Source 1 (Blasting On-shore)

Modelled results for Scenario 1 represent noise from a single blast from 5 kg of pentolite, detonated on land, 20 m below the sea-level (Tables 3-1 to 3-4, Figures 3-1 and 3-2).

Table 3-1 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from an in-ground blast at Site A to modelled maximum-over-depth SEL thresholds with and without M-weighting

SEL (dB re 1 μPa^2·s)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	150	144	150	144	–	–	–	–	–	–
190	1 230	922	1 220	861	192	178	149	142	364	320
180	2 800	2 390	2 780	2 380	1 700	1 460	1 390	503	2 110	1 850
170	4 520	3 620	4 520	3 620	4 140	2 830	3 430	2 440	4 490	3 490
160	5 130	4 510	5 090	4 490	4 750	3 860	4 550	3 830	4 780	3 880
150	6 000	5 430	5 940	5 170	5 670	4 330	4 850	4 030	5 930	4 980
140	25 600	18 500	25 500	17 400	6 550	5 230	6 310	5 210	6 630	5 250
130	34 300	28 800	32 800	28 000	7 080	5 460	7 070	5 460	7 130	5 360
120	51 400	37 700	50 400	36 200	35 900	6 620	35 900	6 940	35 900	14 300

Table 3-2 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from an in-ground blast at Site A to modelled maximum-over-depth rms SPL thresholds with and without M-weighting

rms SPL (dB re 1 μPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
210	313	282	313	277	–	–	–	–	157	151
200	1 000	894	990	865	286	264	220	210	457	409
190	2 330	1 950	2 230	1 920	1 410	1 270	701	606	1 860	1 580
180	3 290	2 770	3 240	2 760	2 470	2 070	2 140	1 870	2 760	2 420
170	4 530	3 580	4 530	3 580	4 460	3 340	3 740	3 190	4 520	3 550
160	5 290	4 530	5 270	4 520	4 770	3 830	4 700	3 800	4 780	3 820
150	15 300	5 660	5 970	5 330	5 920	4 460	5 590	4 040	5 940	4 990
140	30 100	19 000	25 600	18 100	6 630	5 240	6 580	5 220	6 710	5 230
130	34 500	29 300	34 200	28 600	7 160	5 450	7 130	5 440	7 630	5 360
120	54 100	38 400	51 400	37 400	35 900	6 600	35 900	6 890	35 900	15 300

Table 3-3 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from an in-ground blast at Site A to modelled maximum-over-depth SEL thresholds with and without M-weighting

SEL (dB re 1 μPa^2·s)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	130	130	130	128	–	–	–	–	–	–
190	1 030	886	1 010	840	184	175	144	139	348	311
180	2 730	2 330	2 720	2 320	1 560	1 380	623	559	2 060	1 810
170	4 520	3 620	4 520	3 620	3 640	2 590	2 780	2 350	4 480	3 410
160	4 980	4 420	4 940	4 390	4 800	3 870	4 770	3 820	4 840	3 900
150	6 020	5 380	5 780	5 120	4 890	4 020	4 890	4 070	5 580	4 820
140	25 500	17 900	20 600	17 000	6 100	5 180	6 070	5 150	6 460	5 190
130	34 100	28 400	32 700	27 300	7 000	5 470	6 970	5 470	7 020	5 350
120	50 400	36 700	50 400	34 900	35 900	5 900	35 900	5 890	35 900	13 800

Table 3-4 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from an in-ground blast at Site A to modelled maximum-over-depth rms SPL thresholds with and without M-weighting

rms SPL (dB re 1 μPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
210	289	270	286	263	–	–	–	–	150	143
200	1 020	890	933	850	279	256	216	205	451	412
190	2 250	1 890	2 120	1 860	1 350	926	721	640	1 770	1 430
180	3 160	2 720	3 150	2 710	2 210	1 970	2 090	1 830	2 720	2 370
170	4 520	3 570	4 520	3 580	4 180	3 300	3 710	3 040	4 490	3 520
160	5 090	4 440	5 050	4 420	4 840	3 840	4 800	3 810	4 850	3 840
150	15 200	5 590	5 850	5 290	4 890	4 000	4 890	3 960	5 750	4 870
140	30 100	18 600	25 500	17 600	6 470	5 180	6 200	5 150	6 600	5 180
130	34 300	28 800	34 000	28 200	7 050	5 440	7 020	5 450	7 070	5 310
120	50 400	37 700	50 400	36 400	35 900	5 970	35 900	6 010	35 900	15 000

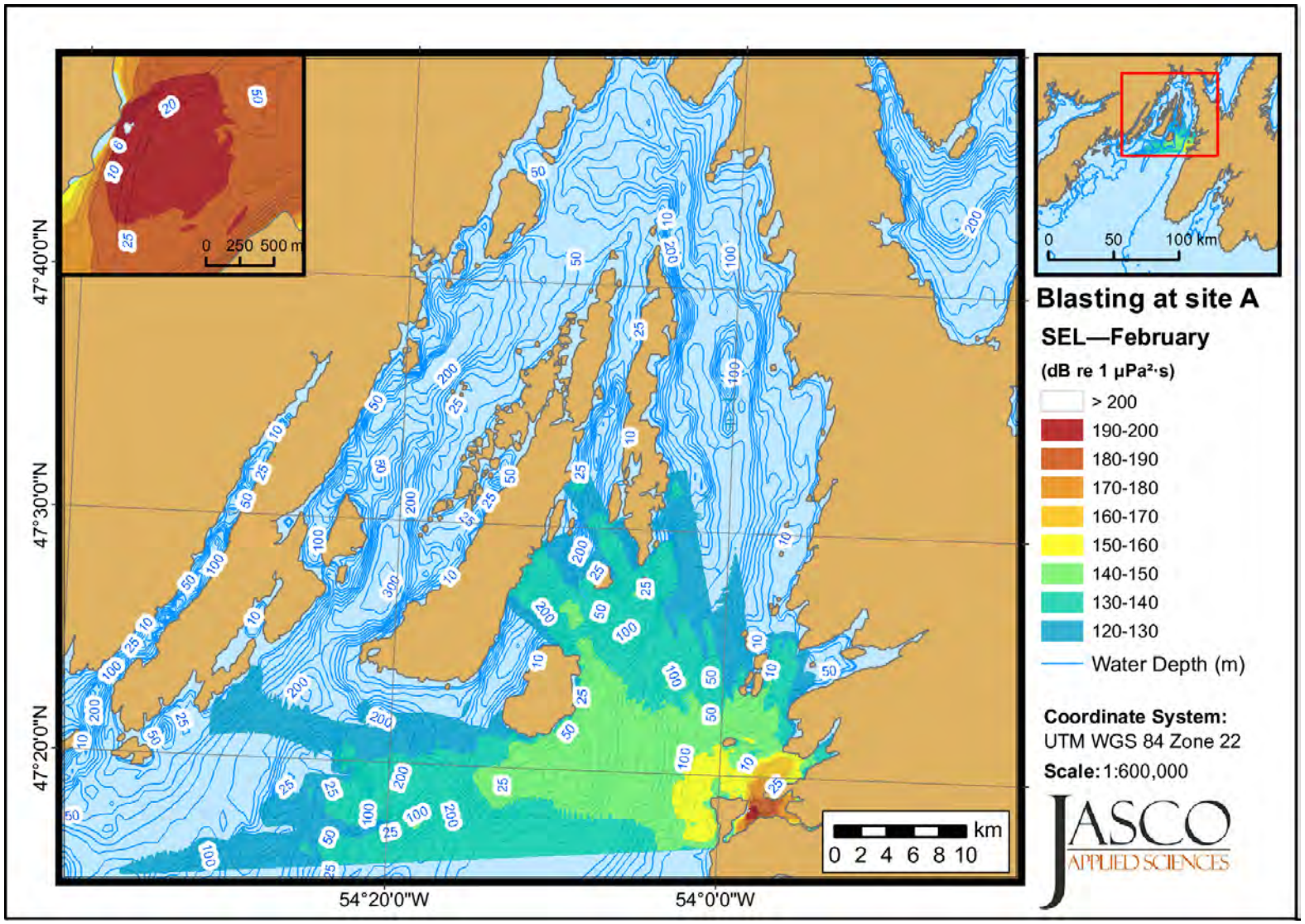


Figure 3-1 February: Received maximum-over-depth sound levels from an in-ground blast at Site A

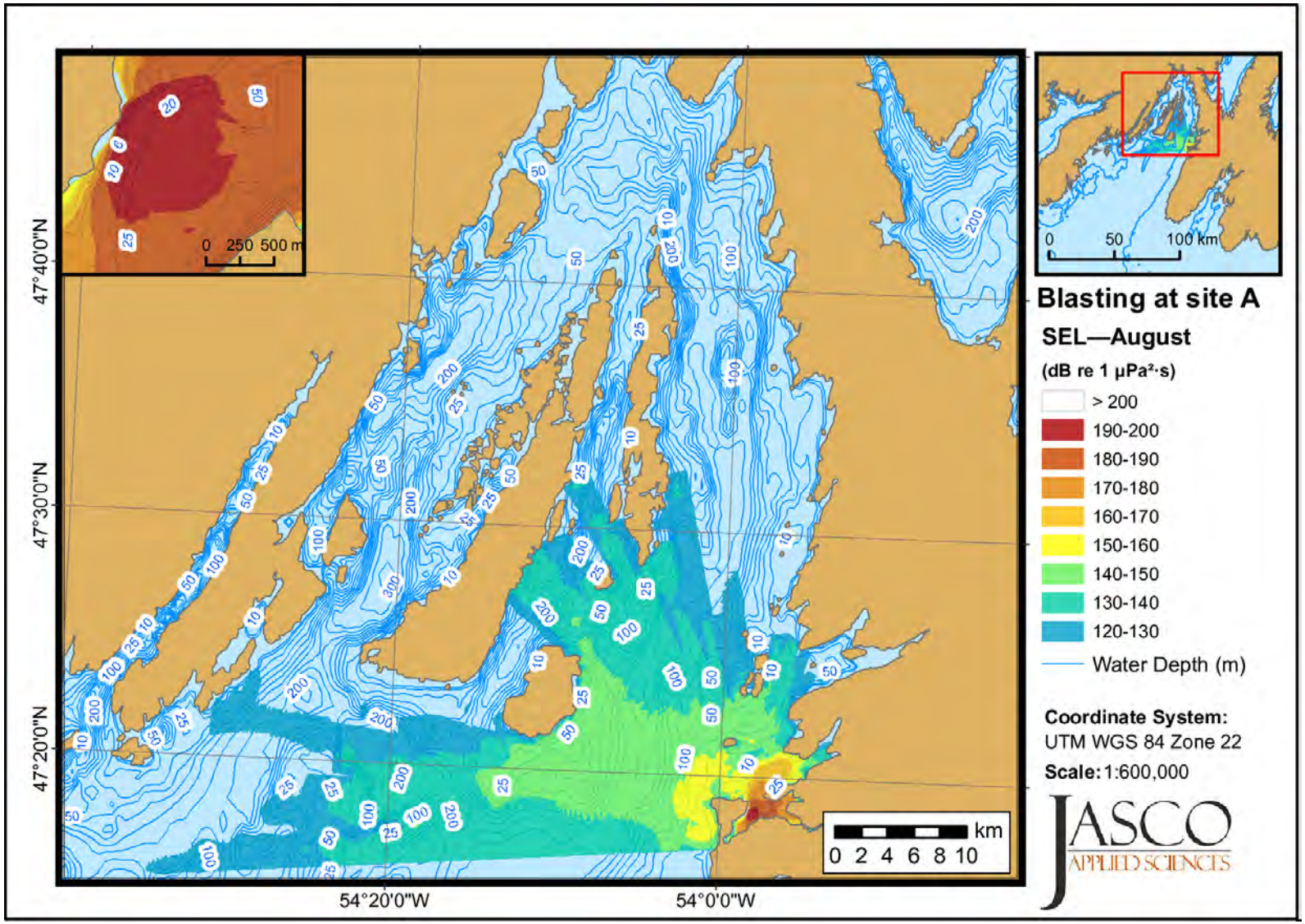


Figure 3-2 August: Received maximum-over-depth sound levels from an in-ground blast at Site A

3.1.2 Scenario 2: Site A, Source 3 (Cutter Suction Dredge)

Modelled results for Scenario 2 represent (continuous) noise from a cutter suction dredge operating at Site A (Tables 3-5 and 3-6, Figures 3-3 and 3-4).

Table 3-5 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the cutter suction dredge at Site A to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	–	–	–	–	–	–	–	–	–	–
180	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
170	22	22	22	22	16	16	14	14	21	21
160	163	139	160	136	112	97	110	90	140	117
150	1 357	1 109	1 311	1 087	706	515	692	476	1 165	616
140	3 530	2 598	3 530	2 515	3 528	2 115	3 259	2 063	3 530	2 293
130	8 375	5 506	8 371	5 480	8 371	5 428	7 939	5 383	8 375	5 480
120	15 991	13 777	15 991	13 768	15 991	13 707	15 991	13 651	15 991	13 762

Table 3-6 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the cutter suction dredge at Site A to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	–	–	–	–	–	–	–	–	–	–
180	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
170	22	22	22	21	14	14	14	11	20	18
160	160	125	160	121	105	92	100	86	135	106
150	863	635	862	616	601	471	526	435	740	546
140	2 509	2 027	2 503	2 022	2 370	1 900	2 309	1 872	2 443	1 970
130	5 698	4 931	5 698	4 934	5 624	4 775	5 624	4 494	5 679	4 888
120	8 371	6 629	8 371	6 627	8 371	6 396	8 371	6 258	8 371	6 569

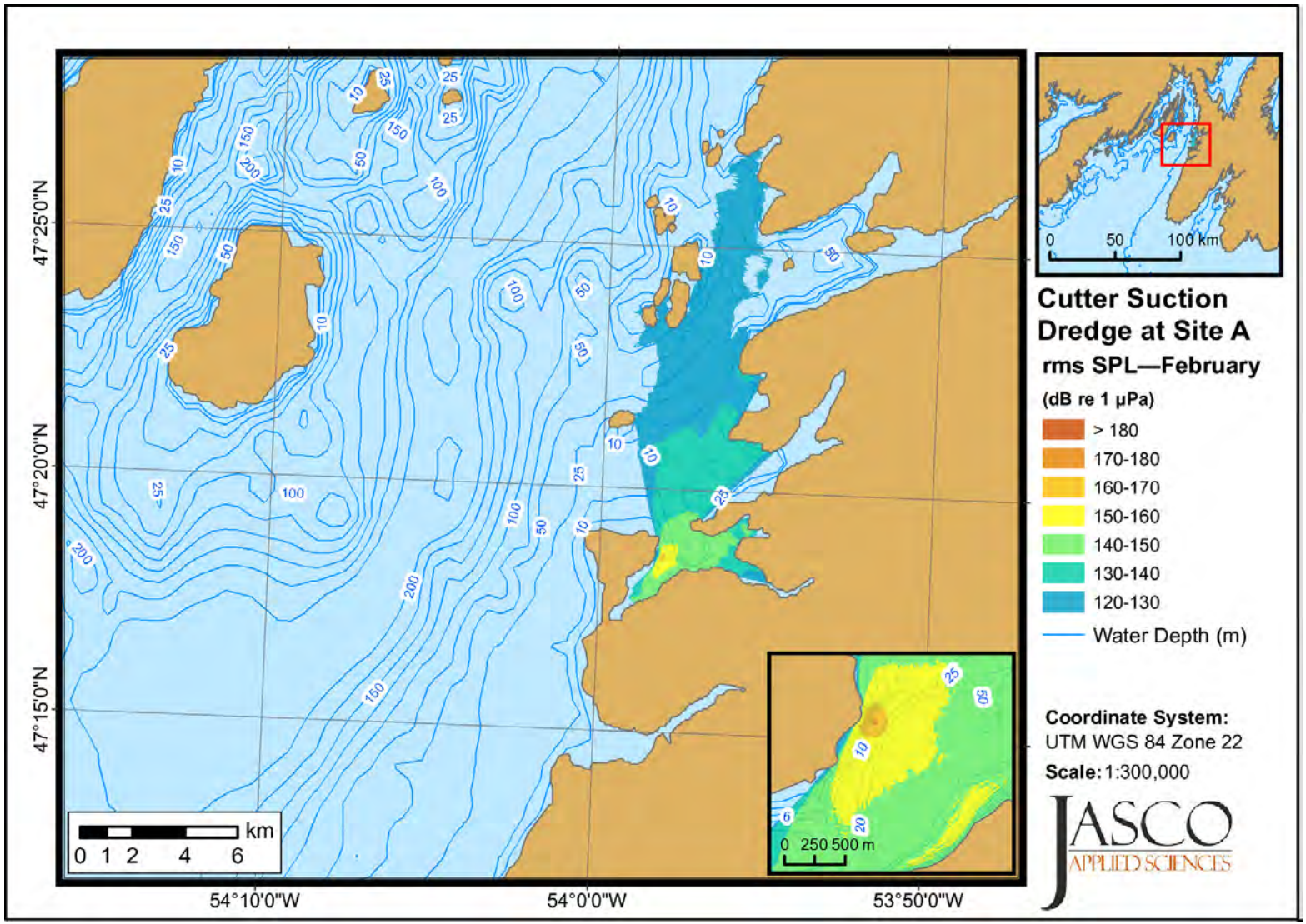


Figure 3-3 February: Received maximum-over-depth sound levels from the cutter suction dredge at Site A

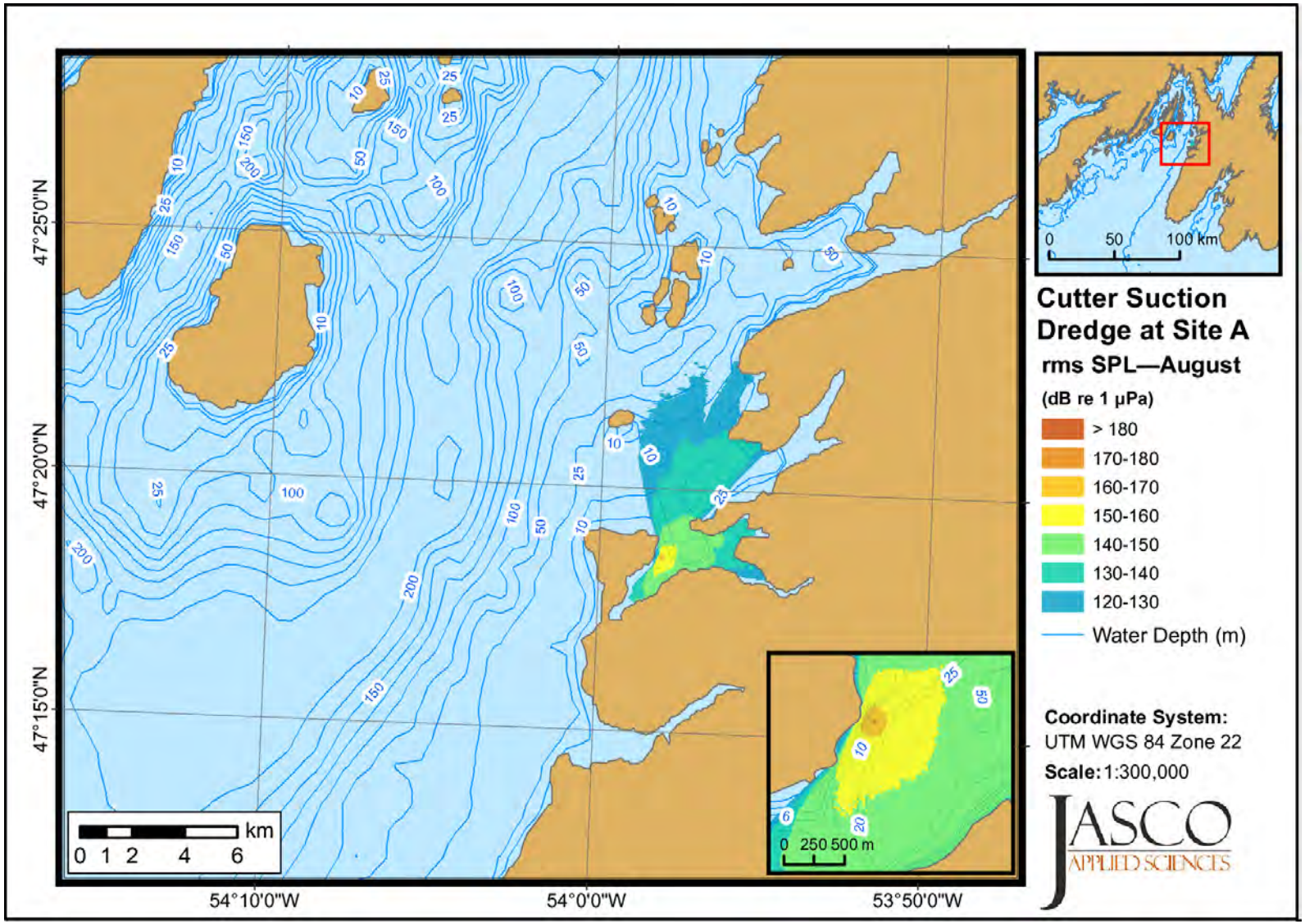


Figure 3-4 August: Received maximum-over-depth sound levels from the cutter suction dredge at Site A

3.1.3 Scenario 3: Corridor 1, Source 2 (Blasting in Water)

Modelled results for Scenario 3 represent noise from a single blast from 5 kg of pentolite, detonated at 2 m below the seafloor (Tables 3-7 to 3-10; Figures 3-5 and 3-6).

Table 3-7 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from an in-ground blast at Corridor 1 to modelled maximum-over-depth SEL thresholds with and without M-weighting

SEL (dB re 1 µPa^2·s)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
220	13	13	13	13	–	–	–	–	–	–
210	84	78	84	76	25	24	24	24	34	34
200	512	442	504	425	84	79	70	66	164	141
190	2 250	1 540	2 250	1 520	387	346	317	278	701	578
180	4 240	3 180	4 230	3 140	1 980	1 500	1 620	1 090	2 760	2 060
170	4 620	3 680	4 620	3 680	3 810	2 840	3 380	2 590	4 460	3 550
160	8 510	5 000	8 500	4 950	4 850	3 980	4 810	3 830	5 030	4 320
150	21 100	10 900	21 100	10 800	11 300	8 210	11 200	8 070	18 800	8 780
140	37 500	24 500	37 500	24 500	37 500	24 200	37 500	24 000	37 500	24 400
130	58 800	52 000	58 800	52 100	58 800	52 400	58 800	52 400	58 800	52 400
120	62 700	51 700	62 700	51 800	62 700	52 100	62 300	52 200	62 700	52 100

Table 3-8 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from an in-ground blast at Corridor 1 to modelled maximum-over-depth rms SPL thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
230	42	38	38	37	–	–	–	–	12	12
220	217	199	208	193	43	41	40	38	70	64
210	708	614	692	603	182	168	141	130	320	281
200	1 900	1 420	1 890	1 410	608	503	495	430	847	735
190	3 230	2 610	3 220	2 600	1 690	1 310	1 390	1 070	2 350	1 650
180	4 460	3 530	4 460	3 520	3 110	2 370	2 820	2 180	3 760	2 920
170	4 810	4 040	4 810	4 030	4 470	3 610	4 390	3 520	4 650	3 740
160	8 740	7 300	8 730	7 270	6 380	4 610	5 200	4 480	8 510	4 870
150	25 200	18 100	25 200	17 900	21 300	10 600	21 300	9 140	24 900	12 600
140	54 900	28 700	54 900	28 700	54 900	27 200	54 900	26 600	54 900	28 100
130	58 800	51 500	58 800	51 600	58 800	52 000	58 800	52 000	58 800	52 000
120	63 100	51 200	63 100	51 200	63 100	51 600	63 100	51 600	63 100	51 600

Table 3-9 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from an in-ground blast at Corridor 1 to modelled maximum-over-depth SEL thresholds with and without M-weighting

SEL (dB re 1 µPa^2·s)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
220	12	12	12	12	–	–	–	–	–	–
210	80	71	76	70	25	25	24	24	34	33
200	445	402	437	394	80	76	68	62	155	134
190	2 100	1 500	2 080	1 480	388	337	341	263	652	553
180	4 040	2 970	4 030	2 930	1 880	1 440	1 550	984	2 670	2 000
170	4 520	3 620	4 520	3 620	3 370	2 690	3 220	2 410	4 380	3 470
160	8 010	4 730	8 000	4 710	4 820	3 850	4 670	3 730	4 950	4 200
150	11 800	9 480	11 800	9 420	9 650	7 780	9 510	7 490	11 400	8 160
140	29 700	20 600	29 700	20 600	29 700	18 100	29 700	17 700	29 700	18 800
130	50 400	28 100	50 400	28 000	50 400	25 300	50 400	24 900	50 400	25 900
120	56 500	42 900	56 500	42 900	56 500	44 300	56 500	44 200	56 500	44 400

Table 3-10 August: Maximum (R_{max}, m) and 95 percent ($R9_{5\%}$, m) horizontal distances from an in-ground blast at Corridor 1 to modelled maximum-over-depth rms SPL thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
230	38	37	37	35	–	–	–	–	12	12
220	200	183	195	176	42	40	40	38	69	62
210	647	587	641	578	178	159	146	127	341	269
200	1 820	1 390	1 810	1 380	604	496	482	420	831	720
190	3 200	2 540	3 180	2 510	1 630	1 280	1 360	1 050	2 230	1 610
180	4 420	3 480	4 400	3 480	2 870	2 290	2 740	2 110	3 340	2 810
170	4 770	3 950	4 770	3 940	4 400	3 520	4 050	3 380	4 590	3 670
160	8 410	5 570	8 410	5 500	5 220	4 550	4 980	4 400	5 580	4 770
150	19 200	10 700	19 200	10 600	11 500	8 550	11 100	8 140	12 100	9 520
140	33 700	21 800	33 700	21 800	29 700	20 000	29 700	19 400	33 700	20 700
130	51 700	33 500	51 100	33 600	51 000	32 500	51 000	31 900	51 000	33 200
120	57 700	44 000	57 700	44 100	57 600	45 200	57 600	45 200	57 600	45 300

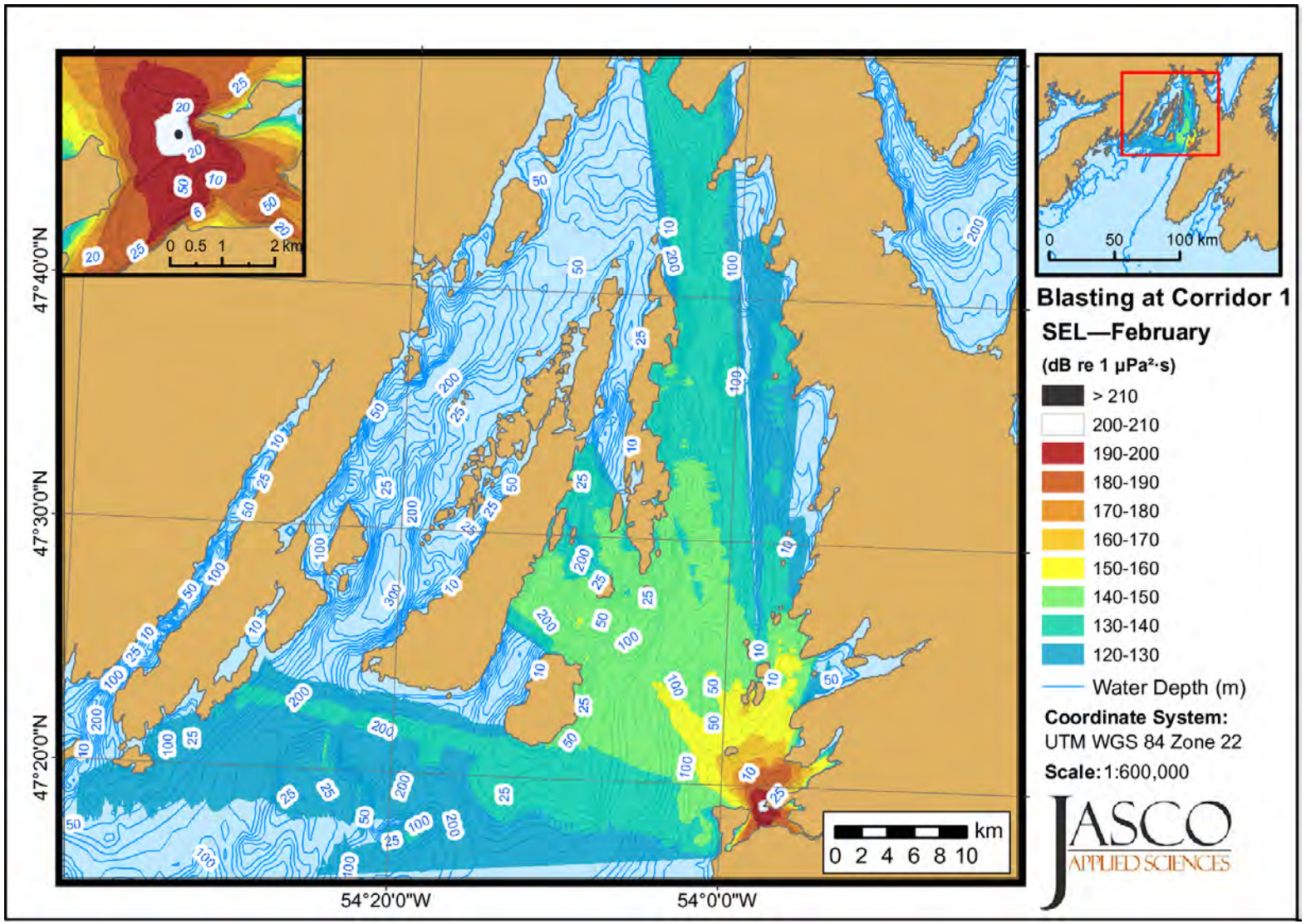


Figure 3-5 February: Received maximum-over-depth sound levels from an in-water blast at Corridor 1

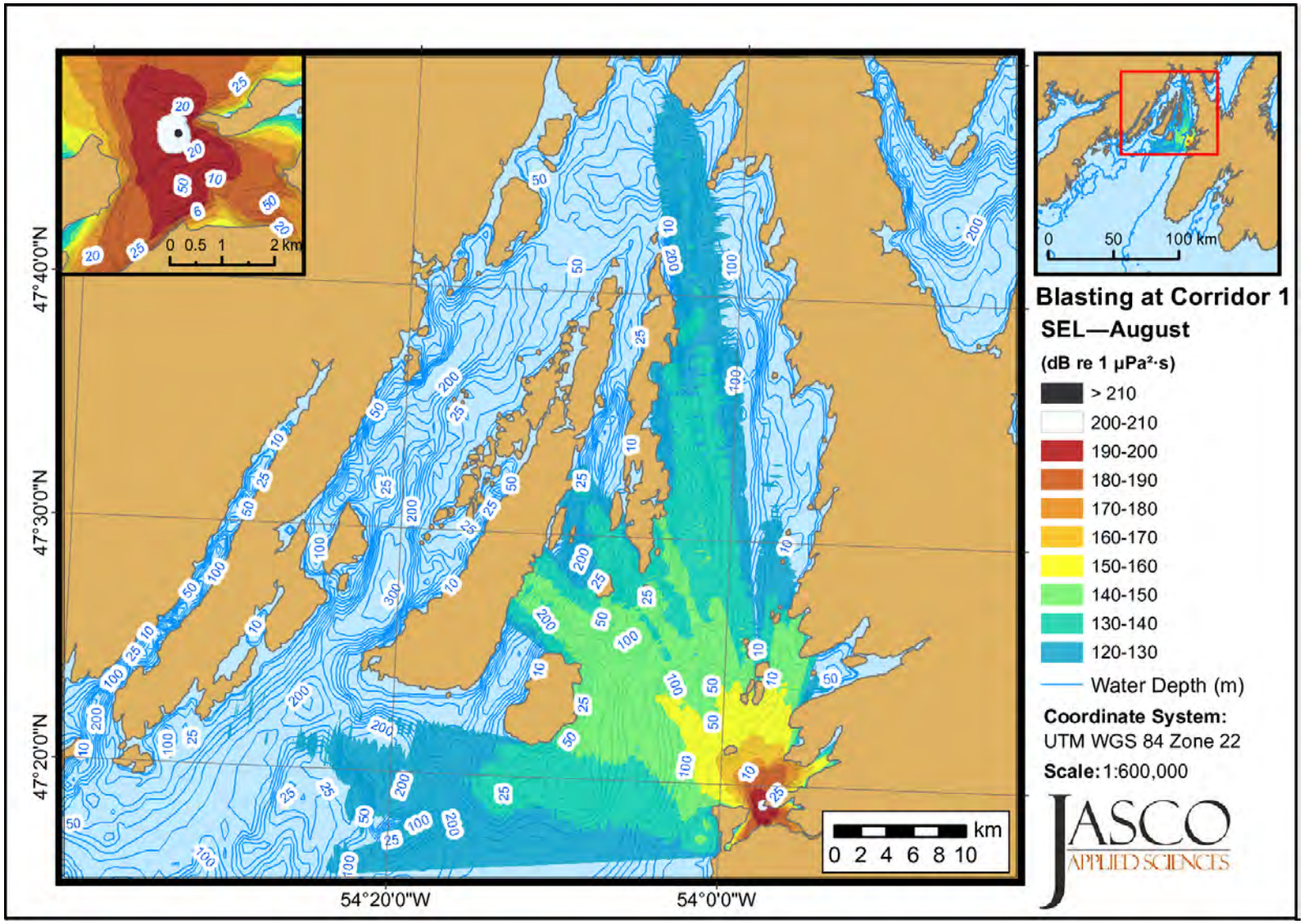


Figure 3-6 August: Received maximum-over-depth sound levels from an in-water blast at Corridor 1

3.1.4 Scenario 4: Corridor 1, Source 4 (Trailing Suction Hopper Dredge)

Modelled results for Scenario 4 represent (continuous) noise from a trailing suction hopper dredge operating in the southern section of Corridor 1 (Tables 3-11 and 3-12; Figures 3-7 and 3-8).

Table 3-11 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the trailing suction hopper dredge at Corridor 1 to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	< 5	< 5	< 5	< 5	–	–	–	–	–	–
180	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
170	45	43	43	42	16	16	15	14	27	25
160	284	248	282	244	125	111	115	96	180	154
150	1 546	988	1 505	977	802	631	676	559	945	792
140	3 942	3 236	3 941	3 216	3 836	2 878	3 794	2 748	3 939	3 108
130	8 779	5 056	8 776	4 973	8 776	4 807	8 776	4 735	8 776	4 947
120	24 927	18 239	24 925	18 242	24 886	17 751	24 884	17 344	24 925	18 114

Table 3-12 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the trailing suction hopper dredge at Corridor 1 to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	< 5	< 5	< 5	< 5	–	–	–	–	–	–
180	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
170	43	40	41	40	16	16	15	14	25	25
160	270	236	265	234	119	107	99	91	176	150
150	1 067	924	1 041	913	725	583	641	515	890	731
140	3 135	2 635	3 122	2 628	2 610	1 879	2 444	1 740	2 965	2 341
130	4 804	3 997	4 804	3 982	4 768	3 768	4 743	3 688	4 801	3 906
120	11 623	7 163	11 623	7 149	11 075	6 456	11 072	6 219	11 607	6 909

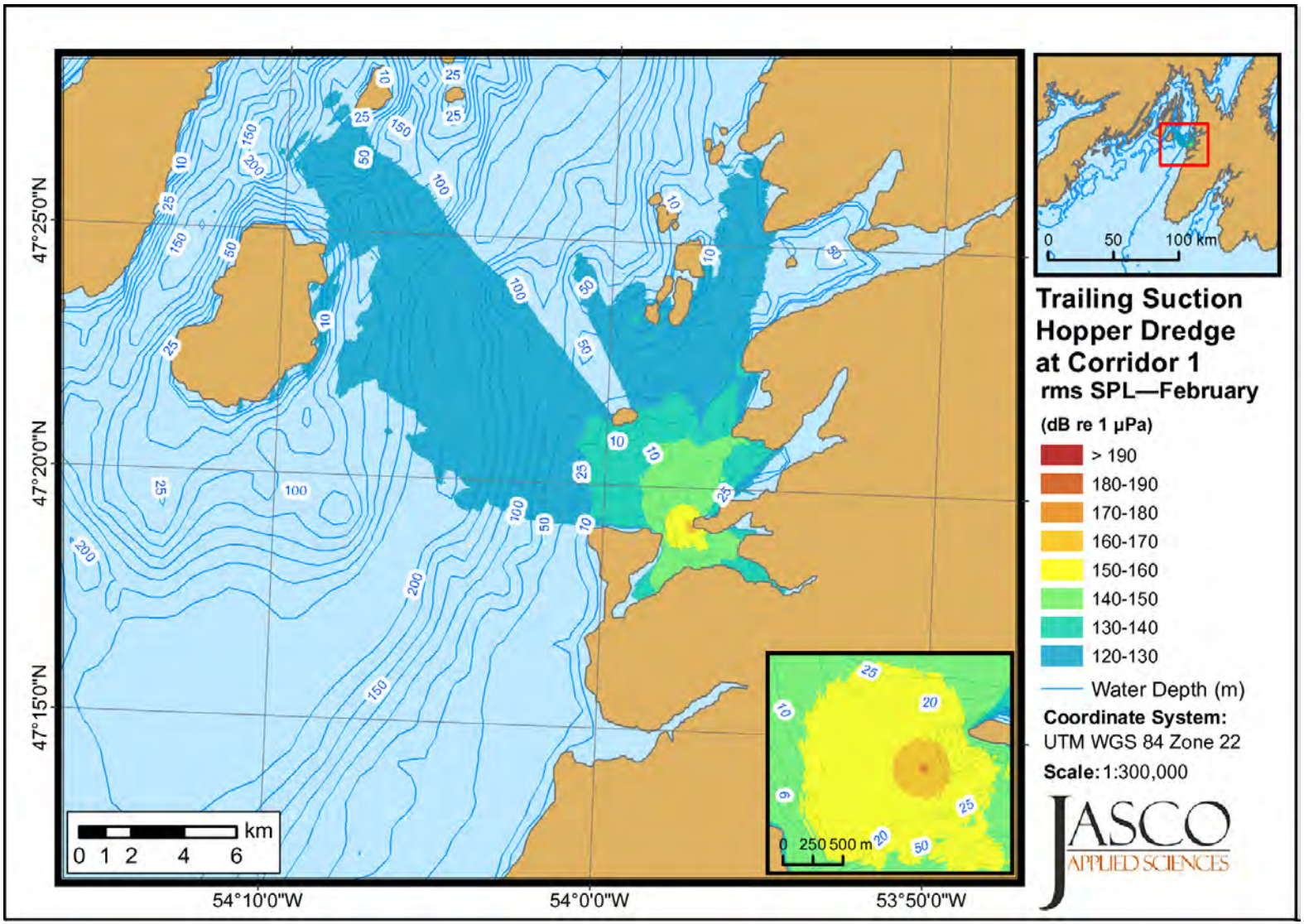


Figure 3-7 February: Received maximum-over-depth sound levels from the trailing suction hopper dredge at Corridor 1

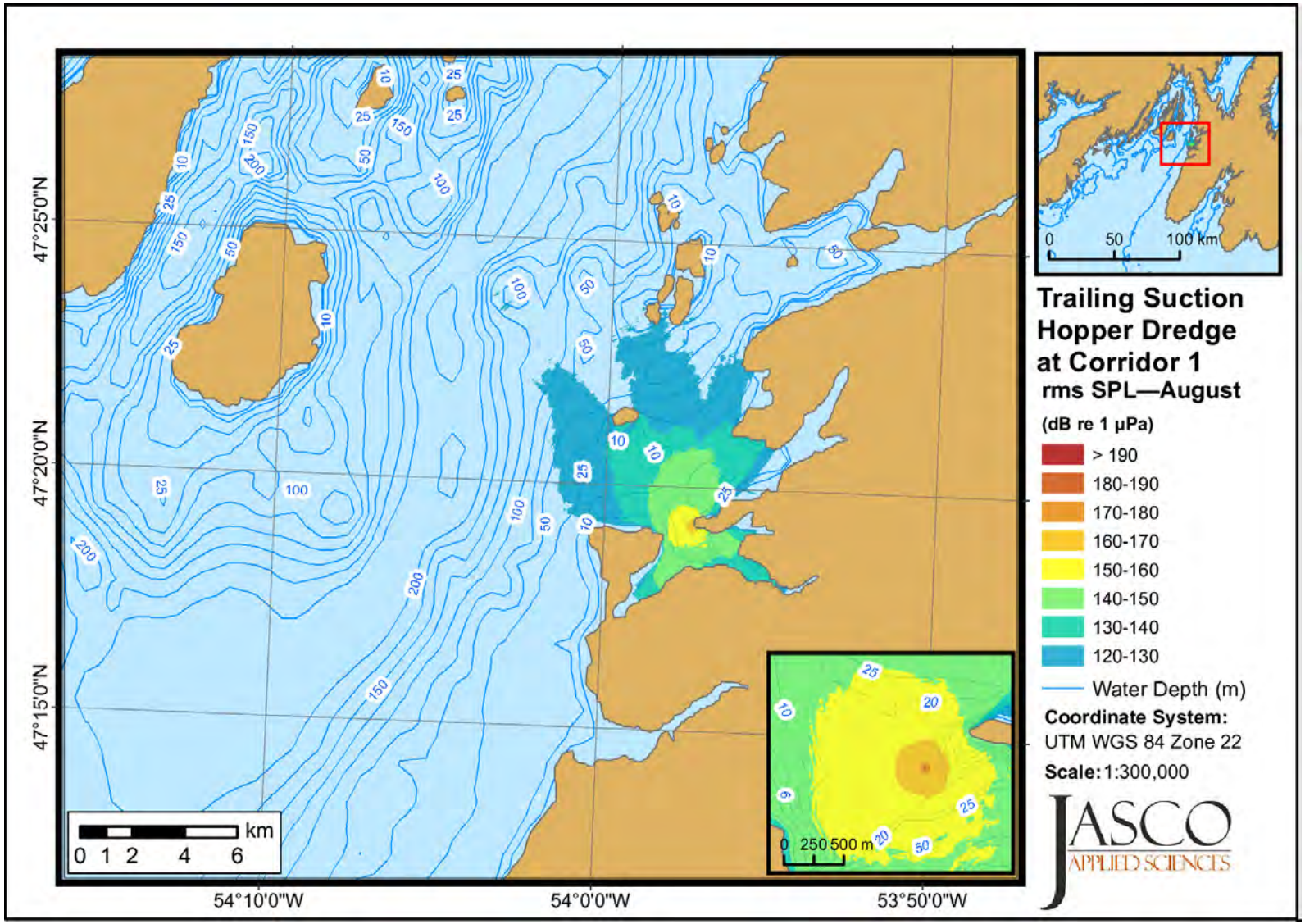


Figure 3-8 August: Received maximum-over-depth sound levels from the trailing suction hopper dredge at Corridor 1

3.1.5 Scenario 5: Corridor 2, Source 4 (Trailing Suction Hopper Dredge)

Modelled results for Scenario 5 represent (continuous) noise from a trailing suction hopper dredge operating in the eastern section of Corridor 2 (Tables 3-13 and 3-14; Figures 3-9 and 3-10).

Table 3-13 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the trailing suction hopper dredge at Corridor 2 to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	< 5	< 5	< 5	< 5	–	–	–	–	–	–
180	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
170	45	43	43	43	18	18	16	16	30	29
160	290	248	290	244	130	110	115	97	185	159
150	1 191	928	1 191	911	701	574	658	523	884	693
140	4 483	3 047	4 299	3 041	3 541	2 833	3 533	2 715	3 691	3 007
130	7 677	5 364	7 677	5 302	7 587	5 158	7 587	5 070	7 656	5 266
120	23 686	19 775	23 662	19 674	22 970	18 903	22 023	18 586	23 583	19 421

Table 3-14 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the trailing suction hopper dredge at Corridor 2 to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	< 5	< 5	< 5	< 5	–	–	–	–	–	–
180	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
170	43	41	42	40	18	16	14	14	29	27
160	271	232	266	227	114	105	103	90	172	149
150	1 028	869	1 026	853	636	518	568	474	792	645
140	3 345	2 727	3 345	2 719	2 828	2 166	2 690	2 089	3 156	2 434
130	5 770	4 200	5 770	4 174	5 751	3 816	5 301	3 699	5 768	4 052
120	16 436	7 498	16 426	7 322	15 060	6 376	15 055	6 228	16 241	6 688

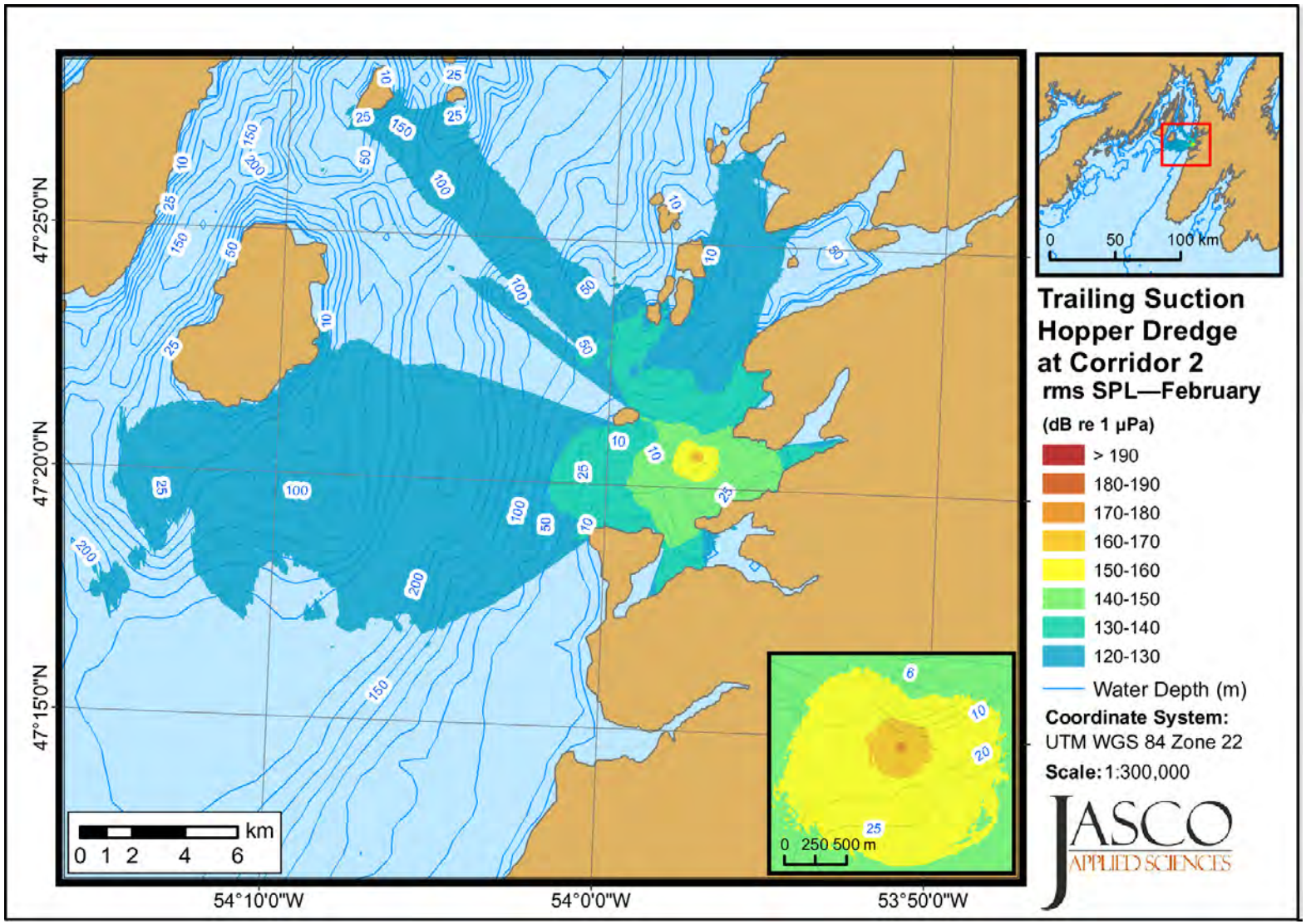


Figure 3-9 February: Received maximum-over-depth sound levels from the trailing suction hopper dredge at Corridor 2

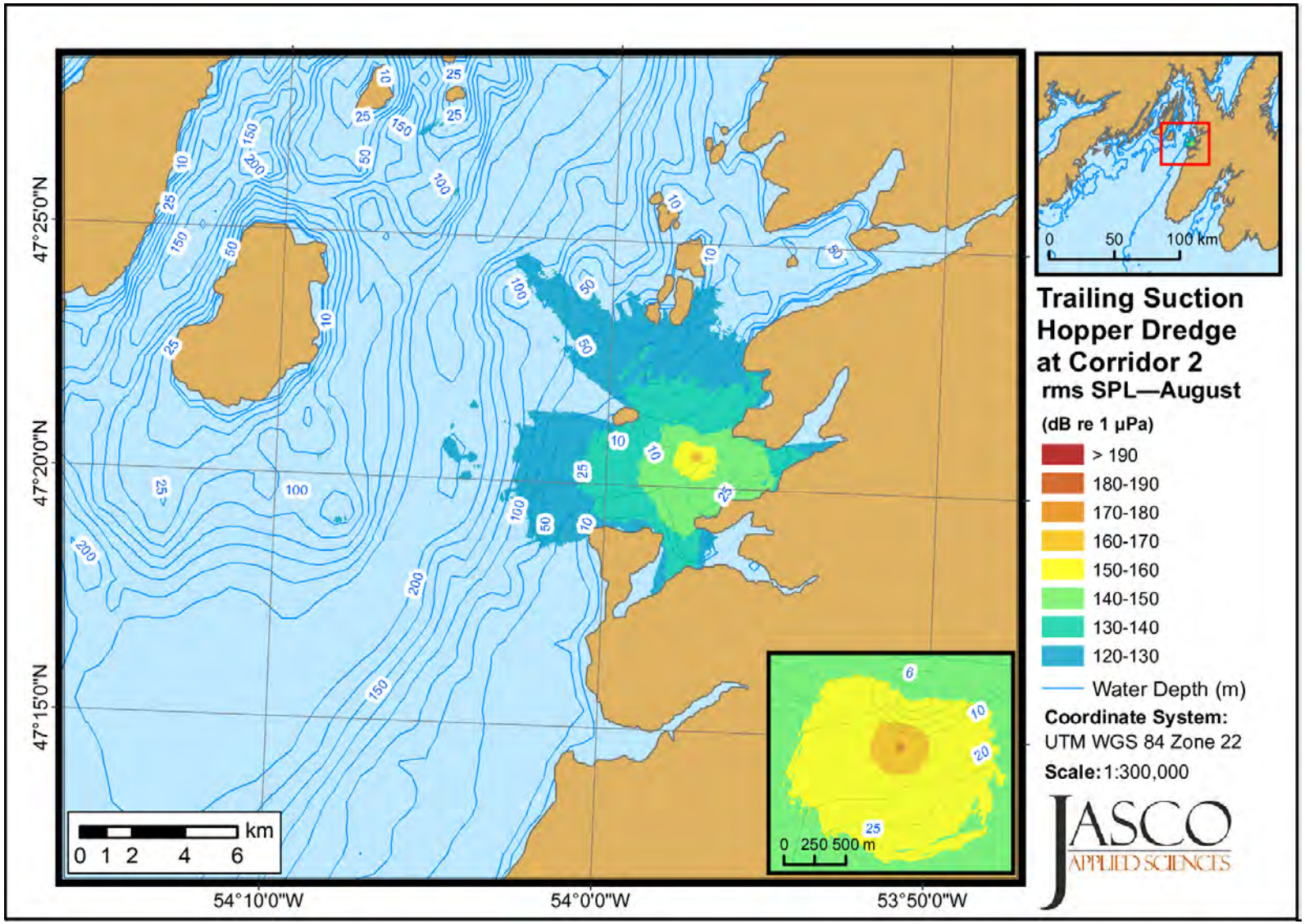


Figure 3-10 August: Received maximum-over-depth sound levels from the trailing suction hopper dredge at Corridor 2

3.2 Offshore: White Rose Field

3.2.1 Scenario 6: White Rose Field, Source 4 (Trailing Suction Hopper Dredge)

Modelled results for Scenario 6 represent (continuous) noise from a trailing suction hopper dredge operating at the White Rose field site (Tables 3-15 and 3-16; Figures 3-11 and 3-12).

Table 3-15 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the trailing suction hopper dredge at White Rose Field to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	< 5	< 5	< 5	< 5	–	–	–	–	–	–
180	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
170	22	22	22	22	11	11	10	10	16	16
160	95	89	92	89	42	41	36	35	56	54
150	565	461	549	455	250	240	224	216	367	336
140	3 787	2 954	3 691	2 909	2 060	1 563	1 869	1 340	2 698	2 065
130	14 933	12 211	14 933	12 109	11 148	8 715	9 631	8 526	13v678	10 182
120	49 604	39 812	49 600	39 328	49 600	34 491	48 165	33 747	49 600	37 250

Table 3-16 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the trailing suction hopper dredge at White Rose Field to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	< 5	< 5	< 5	< 5	–	–	–	–	–	–
180	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
170	22	22	22	22	11	11	11	11	16	16
160	95	90	93	89	41	40	36	36	55	54
150	546	485	545	457	271	258	240	209	390	354
140	3 801	2 864	3 780	2 824	2 414	1 635	1 852	1 490	3 126	2 184
130	13 957	10 989	13 909	10 917	10 523	8 419	10 338	7 632	12 462	9 622
120	37 346	28 189	37 346	28 022	32 294	23 825	30 270	22 726	33 591	26 120

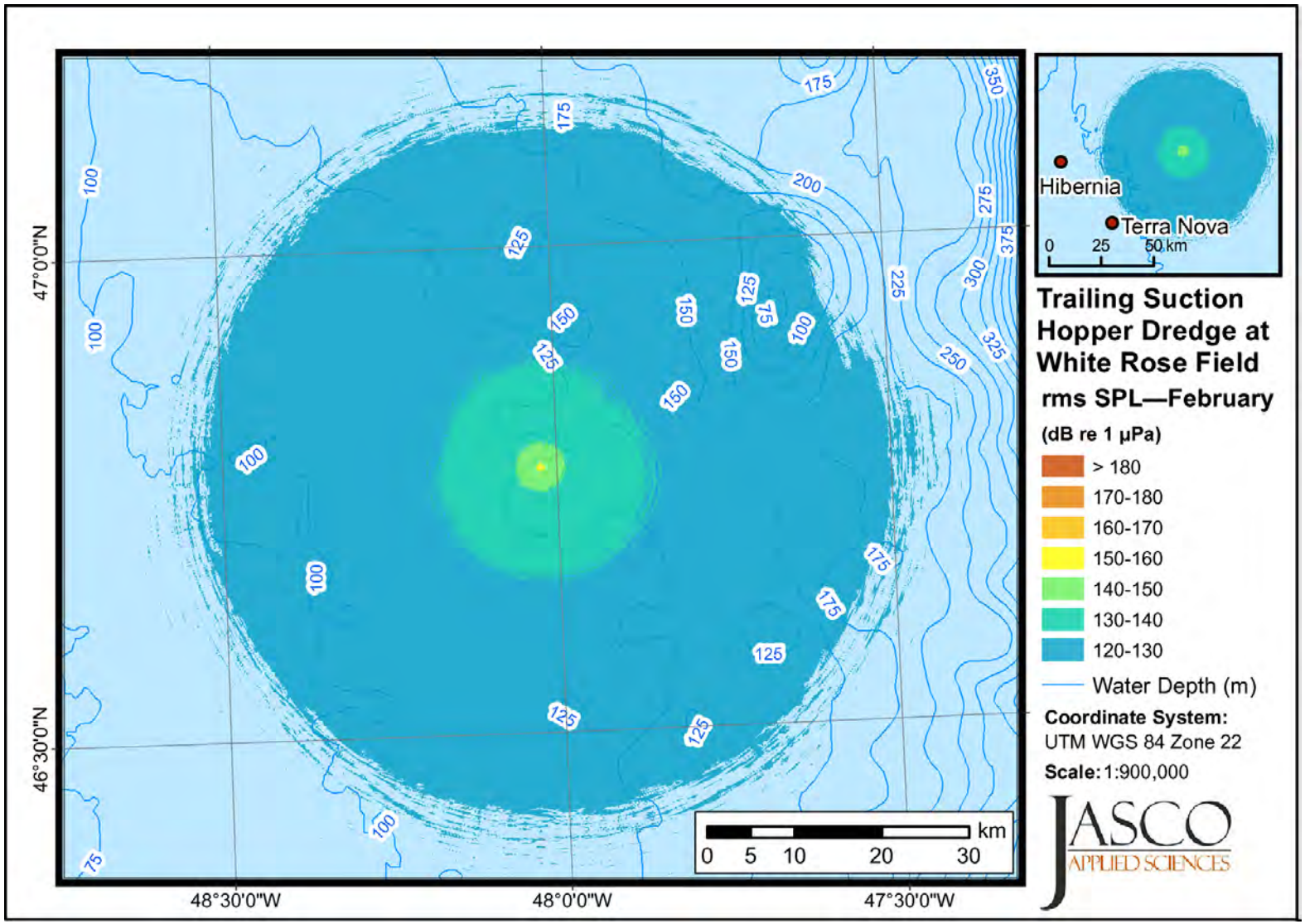


Figure 3-11 February: Received maximum-over-depth sound levels from the trailing suction hopper dredge at White Rose Field

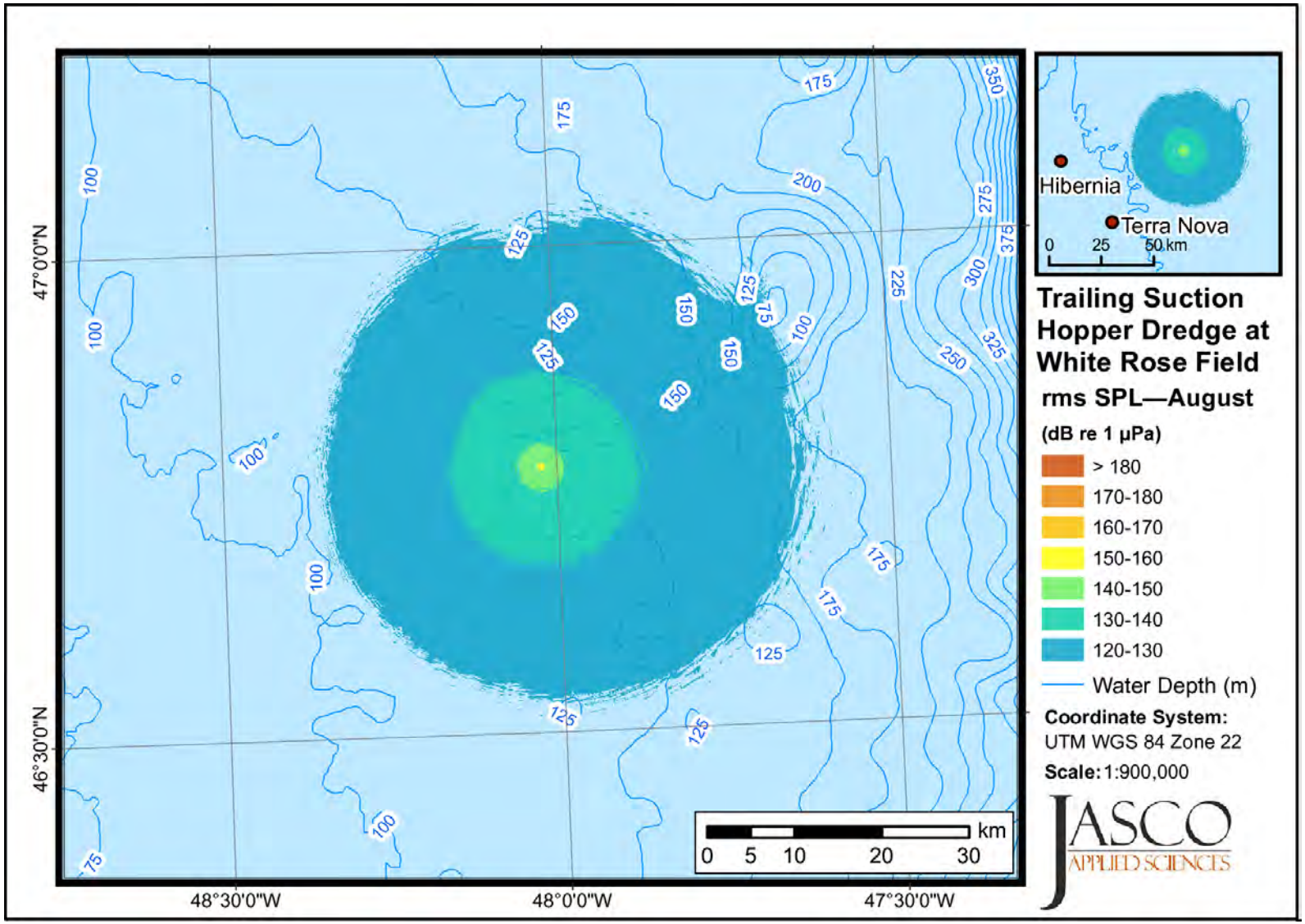


Figure 3-12 August: Received maximum-over-depth sound levels from the trailing suction hopper dredge at White Rose Field

3.2.2 Scenario 7: White Rose Field, Source 5 (Drilling Wellhead Platform)

Modelled results for Scenario 7 represent (continuous) noise from the drilling operations at the White Rose field (Tables 3-17 and 3-18; Figures 3-13 and 3-14).

Table 3-17 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the drilling platform at White Rose Field to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
170	–	–	–	–	–	–	–	–	–	–
160	< 5	< 5	< 5	< 5	–	–	–	–	–	–
150	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
140	18	18	18	18	7	7	7	7	11	11
130	97	95	96	94	32	32	29	29	47	47
120	720	584	699	565	205	178	145	139	306	266

Table 3-18 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the drilling platform at White Rose Field to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
170	–	–	–	–	–	–	–	–	–	–
160	< 5	< 5	< 5	< 5	–	–	–	–	–	–
150	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
140	18	18	18	18	7	7	7	7	11	11
130	97	94	96	93	32	32	30	29	51	50
120	858	677	850	666	186	173	155	139	326	297

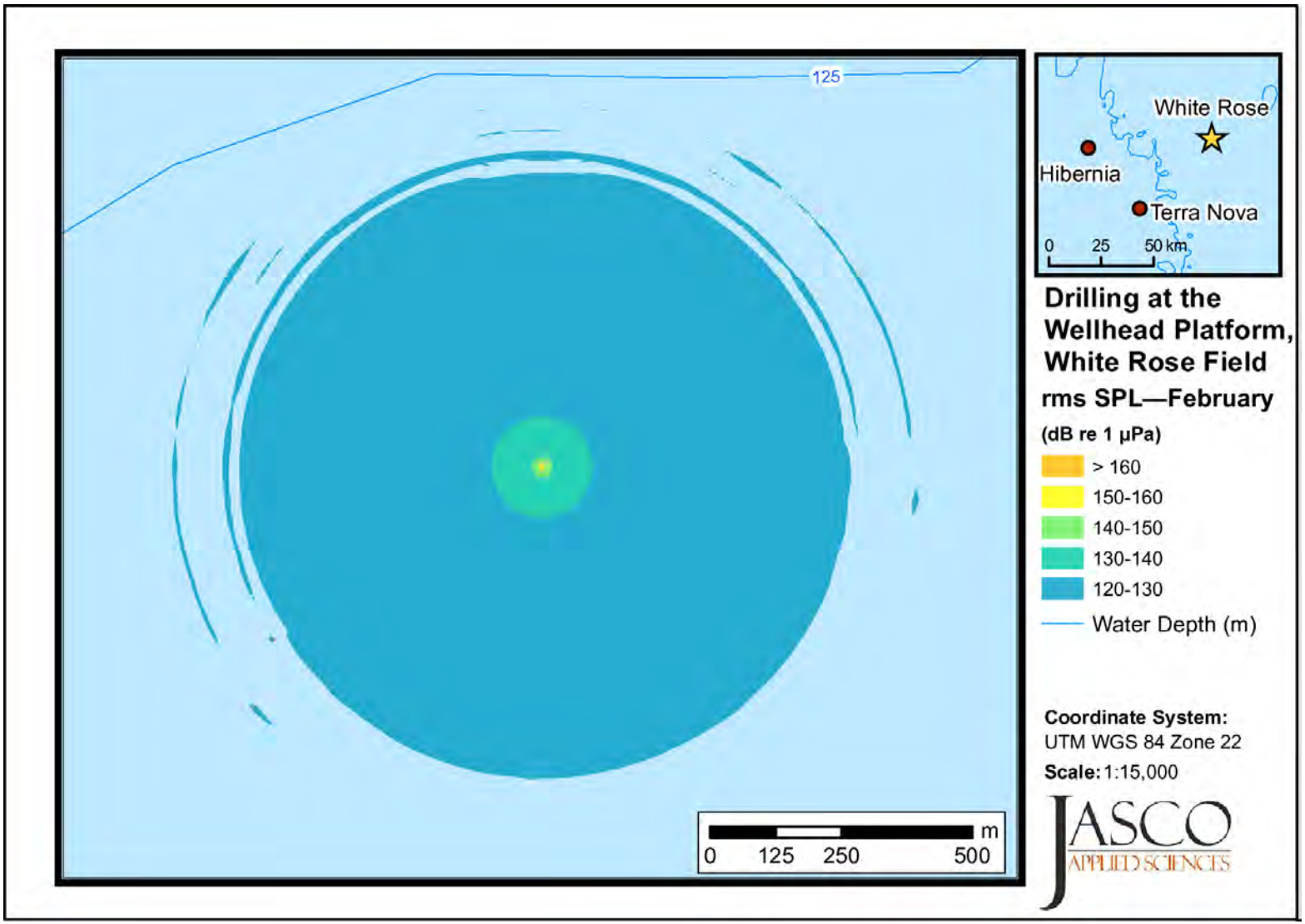


Figure 3-13 February: Received maximum-over-depth sound levels from the drilling platform at White Rose Field

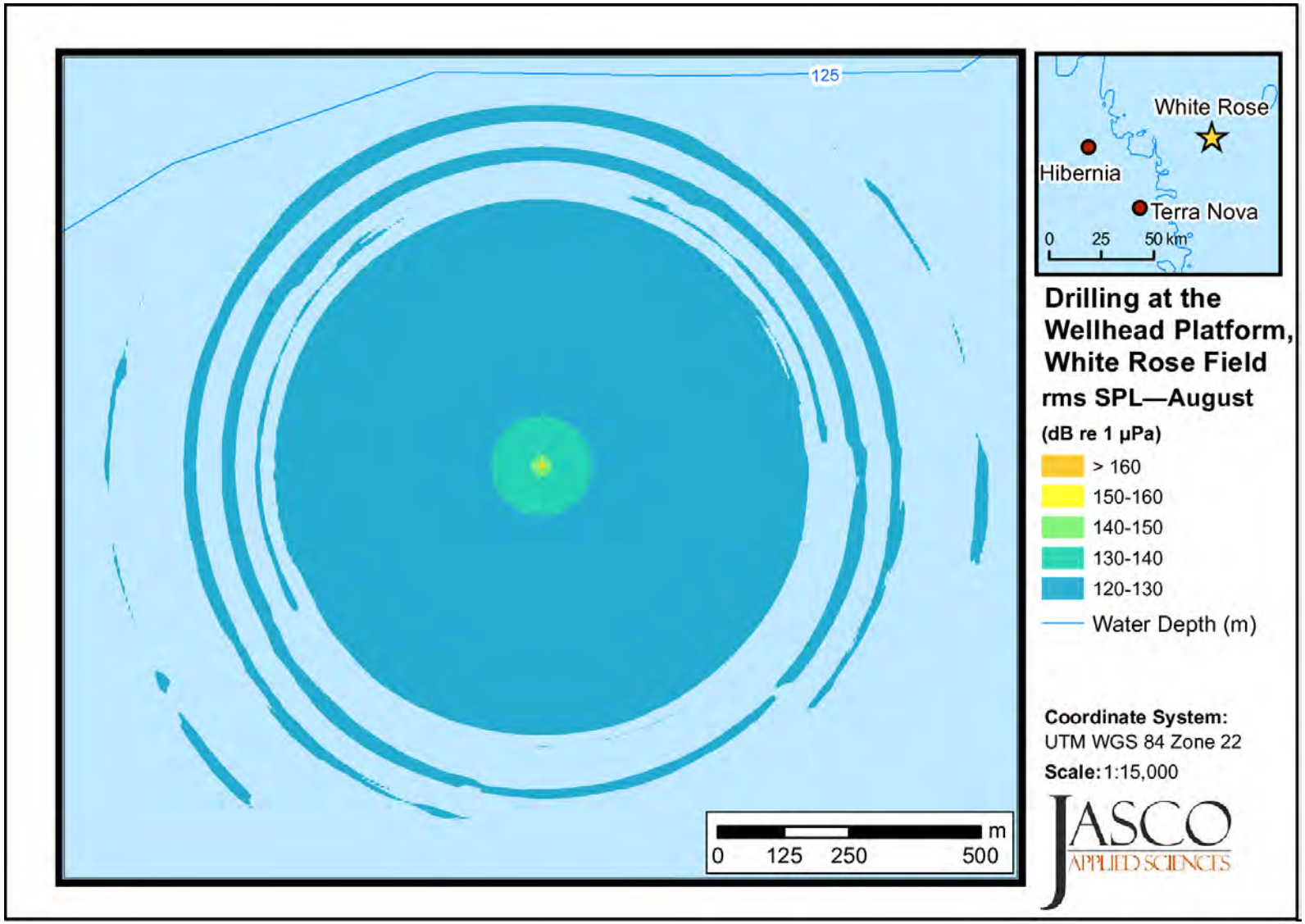


Figure 3-14 August: Received maximum-over-depth sound levels from the drilling platform at White Rose Field

3.2.3 Scenario 8: White Rose Field, Source 6 (Support Vessel)

Modelled results for Scenario 8 represent (continuous) noise from a support vessel (5 000 HP tug) operating at the White Rose field site (Tables 3-19 and 3-20; Figures 3-15 and 3-16).

Table 3-19 February: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the support vessel at White Rose Field to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	—	—	—	—	—	—	—	—	—	—
180	< 5	< 5	< 5	< 5	—	—	—	—	—	—
170	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
160	22	22	22	22	18	18	18	18	21	21
150	83	81	83	81	65	63	63	61	75	73
140	641	528	641	526	495	365	355	303	541	487
130	4 725	3 701	4 690	3 660	4 367	2 442	3 560	2 088	4 555	3 115
120	21 800	15 650	21 800	15 598	19 483	12 986	17 204	12 026	19 553	14 427

Table 3-20 August: Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from the support vessel at White Rose Field to modelled maximum-over-depth sound level thresholds with and without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted		LFC		MFC		HFC		Pinnipeds	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	—	—	—	—	—	—	—	—	—	—
180	< 5	< 5	< 5	< 5	—	—	—	—	—	—
170	7	7	7	7	< 5	< 5	< 5	< 5	< 5	< 5
160	22	22	22	22	18	18	18	18	22	22
150	81	79	81	79	64	62	61	60	73	71
140	600	533	600	532	536	437	440	378	552	517
130	5 155	3 567	5 155	3 546	4 431	2 882	3 374	2 554	5 036	3 215
120	19 927	13 759	19 927	13 730	16 356	11 877	15 219	11 007	19 040	13 064

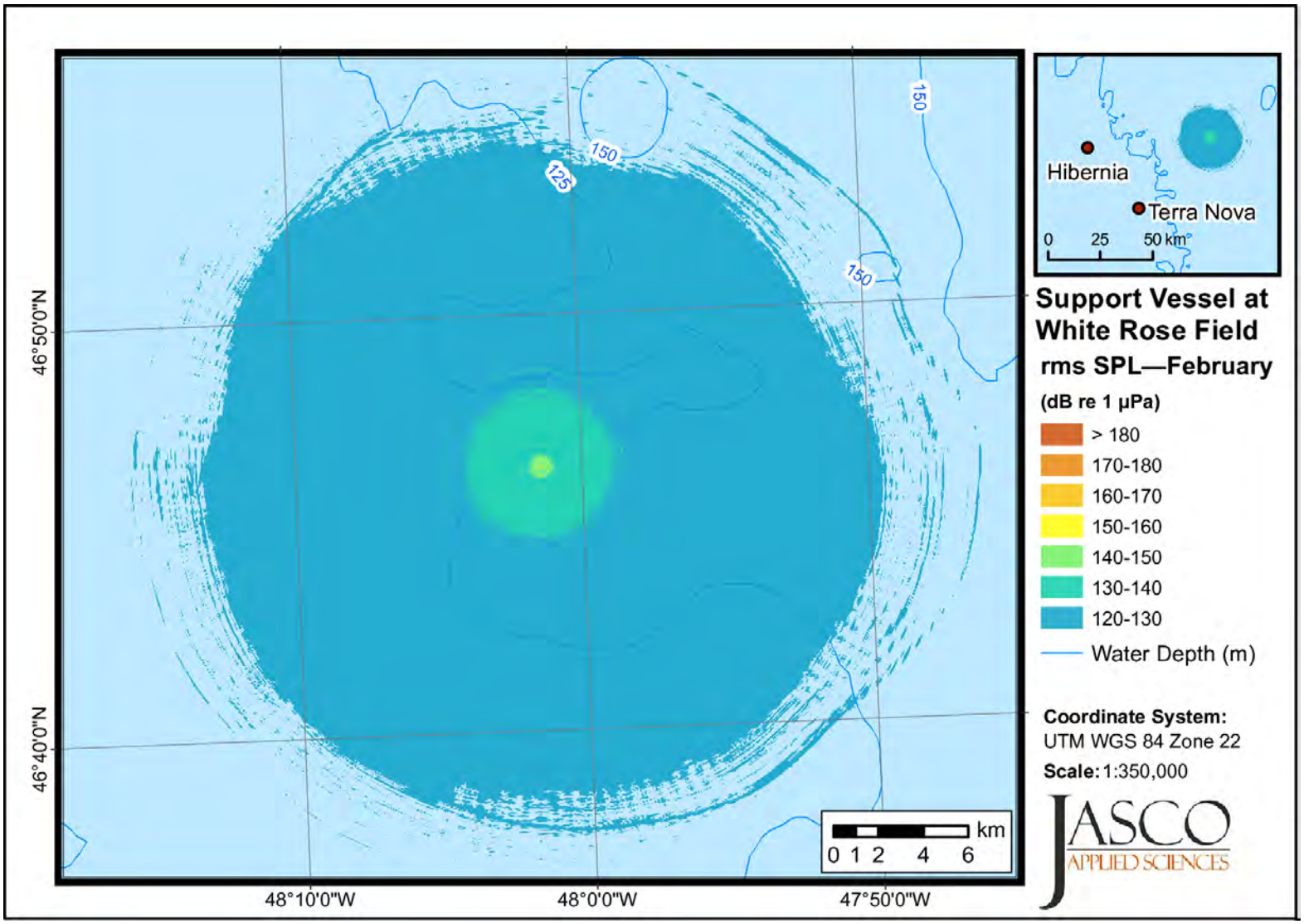


Figure 3-15 February: Received maximum-over-depth sound levels from the support vessel at White Rose Field

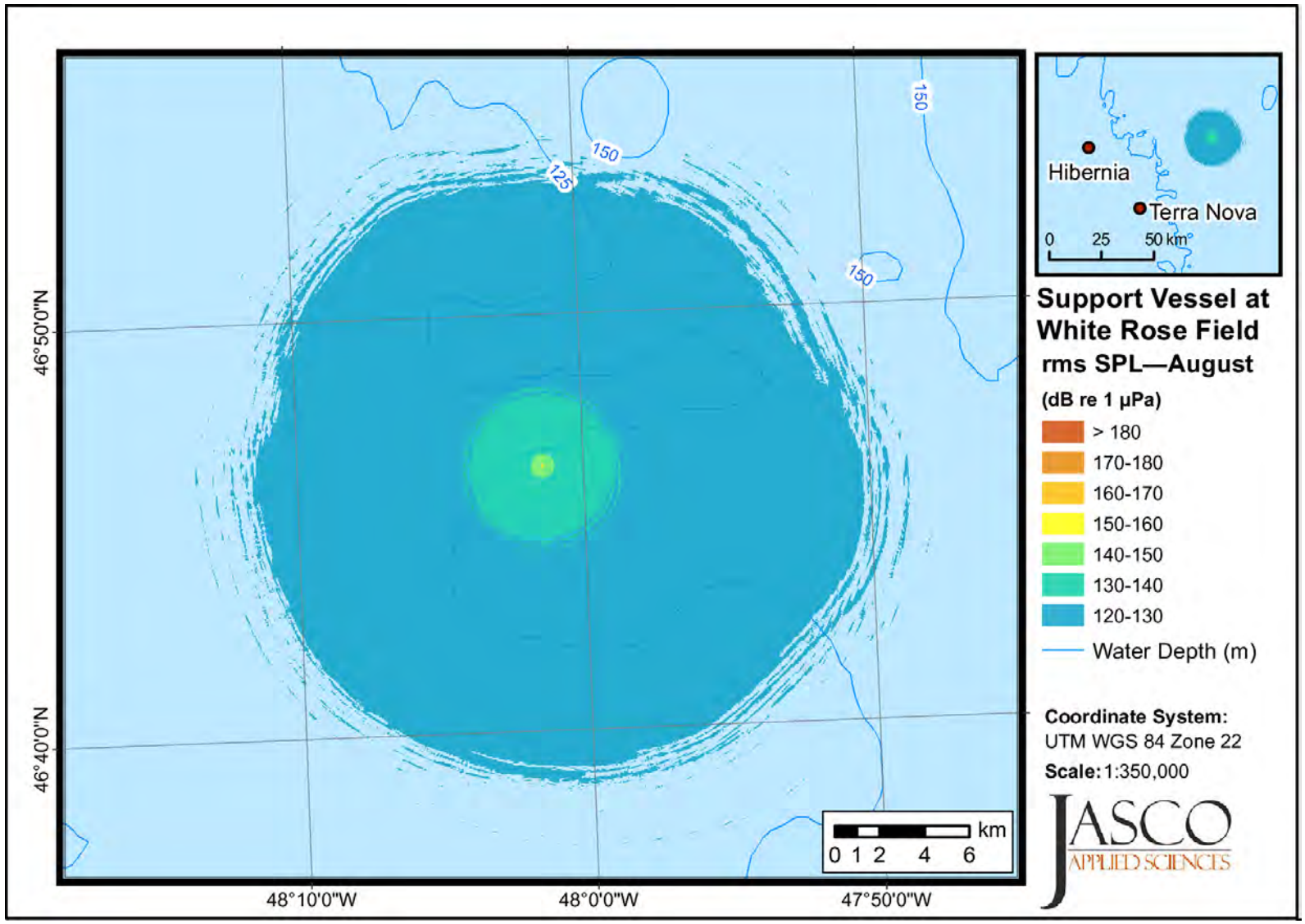


Figure 3-16 August: Received maximum-over-depth sound levels from the support vessel at White Rose Field

3.2.4 Scenario 9: White Rose Field, Source 7 (Helicopter)

Underwater received sound levels around a helicopter at an altitude of 91 m (300 ft) were estimated using the source levels from a Bell 206 helicopter and Young's (1973) model. Broadband received levels no higher than 157 dB re 1 µPa are estimated at 3 m below the surface, directly under the source, and broadband received levels no higher than 120 dB re 1 µPa, at a lateral distance of 61 m from the source (Table 3-21). Since the threshold of the 120 dB re 1 µPa rms SPL is reached at a lateral distance of less than half the water depth (128 m), distances to received sound level thresholds of 130 to 150 dB re 1 µPa were estimated assuming spherical spreading.

Table 3-21 Maximum (R_{max}, m) and 95 percent ($R_{95\%}$, m) horizontal distances from directly under the helicopter at White Rose Field to modelled maximum-over-depth sound level thresholds without M-weighting

rms SPL (dB re 1 µPa)	Un-weighted	
	R_{max}	$R_{95\%}$
170	—	—
160	< 3	< 3
150	6	6
140	10	10
130	26	26
120	61	61

The distances to the sound level thresholds are expected to vary by less than 1 m between the months. At short distances from the source (less than half the water depth (i.e., < 64 m)), M-weighting is not expected to substantially affect distances to sound level thresholds.

4.0 References

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5.0 Acronyms

Term	Description
BHP	break-horsepower
CGS	concrete gravity structure
ConWep	Conventional Weapons Effects Software
CSD	cutter suction dredge
FWRAM	Full-Waveform Acoustic Propagation Model (based on RAM)
GDEM	Generalized Digital Environmental Model
HFC	high-frequency cetacean functional hearing group
LFC	low-frequency cetacean functional hearing group
MFC	mid-frequency cetacean functional hearing group
MONM	Marine Operations Noise Model
MOODS	Master Oceanographic Observational Data Set
M-weighting	marine mammal frequency weighting
NMFS	(United States) National Marine Fisheries Service
PE	parabolic equation
RAM	Range-dependent Acoustic Model
RAM-S	Range-dependent Acoustic Model with Shear Waves
rms SPL	root-mean-square sound pressure level
SEL	sound exposure level
SPL	sound pressure level
THP	total horsepower
TNT	trinitrotoluene
TSHD	trailing suction hopper dredge
UTM	Universal Transverse Mercator
WHP	wellhead platform
WREP	White Rose Extension Project

APPENDIX D

Species Descriptions

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1.0 MARINE FISH

1.1 Groundfish

1.1.1 Atlantic Halibut

Atlantic halibut are distributed from north of Labrador to Virginia and are typically found along the slopes of the continental shelf. The species seasonally migrates between deep channels between banks in winter and shallow waters of the banks in summer (Neilson et al. 1987, Miller et al. 1991, Cargnelli et al. 1999, Sigourney et al. 2006, in COSEWIC 2011a). They prefer temperatures from 3°C to 5°C, and larger individuals move to deeper water in winter (DFO 2015c, in BP 2016). They prefer sand, gravel, or clay substrates. The species can grow to sizes of over 2.5 m in length and reach weights of over 300 kg. The Atlantic halibut is the largest and most commercially-valuable groundfish in the Atlantic Ocean (DFO 2009f, in BP 2016). This species preys on benthic organisms and shifts from invertebrates to fish as the halibut grows larger in size. Small halibut (<30 cm) feed on hermit crabs, shrimp, crabs, and mysids, while larger fish (>70 cm) consume various species of flatfish, redfish, and pollock (DFO 2013u, in BP 2016).

Females mature at 10 to 14 years with spawning occurring from December to June in deep water depths ranging from 300 to 700 m. Large females may lay up to several million eggs. The eggs are 3 to 4 mm in diameter and float freely in the ocean until they hatch 16 days later. Larvae are approximately 7 mm in length and survive on a yolk sac for four to five weeks until they begin feeding on plankton. Atlantic halibut may live up to 50 years, with a typical lifespan of 25 to 30 years (DFO 2009f, in BP 2016).

1.1.2 Barndoor Skate

The barndoor skate can be found from northeastern Florida to the Flemish Cap. In Canadian waters the species is most common on Georges Bank and on the western Scotian Shelf to Sable Island Bank, but is less common on the Grand Banks (COSEWIC 2010a). They can be found on soft mud, sand, and gravel bottoms in water depths from 35 to 350 m. Off Newfoundland the species has been documented up to water depths of 1,174 m (COSEWIC 2010a). Observations on the migration patterns of the species do not exist and information on the species life history is limited.

1.1.3 Black Dogfish

The black dogfish is a deep-water species found in temperate to boreal waters over the outer continental shelves and slopes of the North Atlantic Ocean. They have been observed at water depths up to 1,600 m, but are most common at depths of 550 to 1,000 m and temperatures between 3.5°C and 4.5°C. The black dogfish feeds on squid, benthic and pelagic crustaceans, shrimp, jellyfish, and fish species including redfish (FLMNH 2013a, in BP 2016).

Black dogfish reproduce year-round. Females are ovoviviparous giving birth to 4 to 40 pups that measure 13 to 19 cm in length. In Canadian waters they give birth in parts of the Laurentian Channel.

1.1.4 Haddock

Haddock is a member of the cod family found on both sides of the North Atlantic Ocean and are generally associated with broken ground, gravel, pebbles, clay, smooth hard sand, sticky sand of gritty consistency, and shell beds. They are most common in water depths from 50 to 250 m (DFO 2013p, in BP 2016). Haddock can be found from Greenland to Cape Hatteras. Juveniles are more common in the shallower banks and shoals with adults being found in the deeper basins and shelf edge locations (NOAA 2013h, in BP 2016). Haddock feed on a variety of benthic organisms including mollusks, polychaetes, crustaceans, echinoderms, and fish eggs. Adults sometimes feed on small fish including herring, skates, spiny dogfish, and a variety of groundfish, including other haddock (NOAA 2013h, in BP 2016).

Haddock is a fast-growing species, maturing from one to four years of age and generally living from three to seven years. In waters surrounding Newfoundland, the species can be found in high concentrations on the Southwest Slope of the Grand Banks Ecologically and Biologically Significant Area (EBSA) (Amec 2014). Spawning occurs from March to August over rock, sand, gravel, and mud bottom primarily on the Grand Banks in the Southwest Shelf Edge and Slope EBSA. Haddock are highly fecund, producing on average 850,000 eggs, with larger fish producing up to 3 million eggs (NOAA 2013h, in BP 2016). Eggs and larvae are pelagic until larvae reach a size of 25 mm before settling into deeper waters.

1.1.5 Greenland Halibut

Greenland halibut (turbot) are large, demersal flatfish that are distributed in Canadian waters from northern Labrador to the Grand Banks and occur in the Gulf of St. Lawrence (Healey 2010, in Husky Energy 2012a). Greenland halibut show a preference for temperatures between -0.5°C and 3°C (Healey 2010, in Husky Energy 2012a). They occur within the Study Area and are known to concentrate along the northeast edge of the Grand Banks and on the northeast Newfoundland Shelf. The Northeast Shelf and Slope EBSA in the Study area is known to support high concentrations of Greenland halibut in spring (DFO 2007b, in Husky Energy 2012a). Greenland halibut also occur less commonly along the southeast and southwest slopes of the Grand Banks and the Laurentian Channel (Bowering 2000, Kulka et al. 2003, Healey 2010, in Husky Energy 2012a). Greenland halibut are relatively common in the Project Area during the fall, but are distributed at the edge of the Grand Banks during spring.

During the late 1970s and much of the 1980s, this species was relatively abundant along the deep slopes, particularly in NAFO Division 2G, and in deep channels between banks (NAFO Division 2H, 2J, and 3K) (Healey 2010, in Husky Energy 2012a). Stocks reached a low in the 1990s and large, older fish were largely absent from catches. Several strong successive year-classes from 1993 to 1995 facilitated some recovery by the late 1990s. More recent surveys suggest there have been

weaker year-classes since that time, driving average or lower than average population estimates. The 2009 spring survey had the lowest estimates of biomass and abundance of Greenland halibut to date in NAFO Division 3LNO (Healey 2010, in Husky Energy 2012a).

Spawning generally occurs from July to October with a secondary peak in December (Junquera and Zamarro 2004). Eggs and larvae remain pelagic over deep waters until settling. As juveniles (<20 cm), Greenland halibut mainly feed on small crustaceans and squid, and as they grow (20 to 69 cm) they mainly feed on capelin. As large adults (>69 cm), Greenland halibut feed mainly on demersal fish (Bowering and Lilly 1992, in Husky Energy 2012a).

1.1.6 Monkfish

Monkfish can be found from the Northern Gulf of St. Lawrence to Cape Hatteras. They have been found inhabiting areas up to 800 m in water depth, but are most commonly found from 70 to 190 m (DFO 2010a, in Husky Energy 2012a). They prefer water temperatures ranging from 3°C to 9°C. Research has shown that they invade shallow waters of the banks in the summer and migrate to deeper waters in the winter. They are associated with deeper waters along the western Grand Bank (Amec 2014). Monkfish can grow to a size of over 1 m and have a lifespan of up to 12 years. Monkfish live on the ocean floor, typically on sand, mud, and shell substrates (NOAA 2013). They are opportunistic feeders preying upon anything that is available. Juveniles feed mostly on small fish, shrimp, and squid, while adults feed on fish (including other monkfish), crustaceans, mollusks, seabirds, and diving ducks (NOAA 2013).

Sexual maturity occurs between three and four years, with spawning typically occurring during the summer months (Horseman and Shackell 2009, in BP 2016). Females lay eggs in a veil, which is a clear, ribbon-like mucous sheet that can contain up to a million tiny pink eggs. Once the female sheds the veil, the sheet floats on the ocean's surface. The veil of eggs can measure 6 to12 m in length and be between 0.15 and 1.5 m wide (NOAA 2013i, in BP 2016).

1.1.7 Northern Sand Lance

Sand lance are known to be an important forage fish for many groundfish and pelagic fishes (e.g., capelin, cod, other sand lance, American plaice), as well as higher trophic levels (e.g., whales, harp seals, seabirds) (Bundy et al. 2000, in Husky Energy 2012a). Despite this, little is known about the biology and life history of sand lance. Sand lance are distributed from West Greenland to Cape Hatteras, but are concentrated on the Grand Banks where they are abundant, particularly on gravel substrate (Anderson et al. 1999, in Husky Energy 2012a).

EEM sampling in the Project Area has indicated sand lance are relatively abundant (5.1% to 7.1% of catches) at reference sites (Husky 2009, in Husky Energy 2012a), and sand lance larvae have been found to be abundant during pelagic surveys in August and September on the Grand Banks.

1.1.8 Pollock

Pollock is a member of the cod family. This fish is found from southern Labrador to Cape Hatteras, with major concentrations on the slopes of the Burgeo and St. Pierre Banks and the Southwest Shelf Edge and Slope EBSA. Adults live over a variety of substrate types including sand, mud, rock, and various types of vegetation (NOAA 2013j, in Amec 2014). Adults prefer a water depth range of 110 to 180 m (Amec 2014).

Adults mature at four to seven years and spawning occurs from September to March in Canadian waters. Spawning takes place on Burgeo and St. Pierre Banks. An average female produces 225,000 eggs which are buoyant and hatch in approximately nine days. Larvae measure 3 to 4 mm long upon hatching and grow rapidly. Larvae feed on copepods. Following the larval stage, young pollock move into shallow waters and feed on small crustaceans.

1.1.9 Sculpin

Several small sculpin species are found through much of the Study Area on the continental shelf and shallow slope. Within this area the highest concentrations occur on the eastern edge of the Grand Banks and along the Bonavista corridor. They are numerous (representing about 1 % of the fish captured in DFO research trawl surveys), and could therefore be ecologically important as predators on invertebrates (Scott and Scott 1988). Their life history and ecology is, however, not well studied (Scott and Scott 1988).

1.1.10 Witch Flounder

In the Study Area, witch flounder are concentrated in deep waters at the edge of the Grand Banks and occur on the southwestern Grand Banks (Kulka et al. 2003; Maddock-Parsons 2006, in Husky Energy 2012a). They occur at low densities within the Project Area during the spring and fall surveys, and are not known to undertake extensive migrations and may occur in this area year-round (Kulka et al. 2003, in Husky Energy 2012a).

Biomass and abundance estimates from DFO spring surveys in Division 3N have been at very low levels since 1984 (Maddock-Parsons 2006, in Husky Energy 2012a). Fall survey estimates are also low but lack a clear trend. There has been a moratorium on the harvest of this species since 1994 due to the low stock levels (Maddock-Parsons 2006, in Husky Energy 2012a).

Witch flounder spawn on the Grand Banks between March and June (Maddock-Parsons 2006, in Husky Energy 2012a). Spawning has been reported near the Study Area in June (Ollerhead et al. 2004, in Husky Energy 2012a). Eggs are pelagic and hatch in seven to eight days at 8°C. Witch flounder larvae may be pelagic up to a year, before settling to the seafloor. The primary prey for witch flounder is decapod crustaceans and polychaetes (Methven 1999, in Husky Energy 2012a).

1.1.11 Yellowtail Founder

Yellowtail flounder are distributed from Labrador to Chesapeake Bay and are most frequently found on sandy substrates at water depths less than 100 m (Walsh 2000, in Husky Energy 2012a). Yellowtail flounder declined from the late 1980s to early 1990s, but since that time has shown stable and increasing population trends (Walsh et al. 2000, Maddock-Parsons 2009, in Husky Energy 2012a). Yellowtail flounder are most densely distributed in the warmer waters of the Tail of the Grand Banks and along the Laurentian Channel slope (Kulka et al. 2003, in Husky Energy 2012a), although historically their distribution also included the northern Grand Banks. This species is relatively sedentary and does not undergo migrations. Spawning occurs primarily on the central and southern areas of the Grand Banks, although it can occur in the northern area, and spawning is thought to occur between April and June (Ollerhead et al. 2004, Maddock-Parsons 2009, in Husky Energy 2012a). Yellowtail flounder eggs are deposited on the bottom and float to near the surface once fertilized (Scott and Scott 1988). Newly settled juveniles select mud- and sand-dominated substrate, and the Southeast Shoal of the Grand Banks is known to be an important nursery area for yellowtail flounder.

The yellowtail flounder diet on the Grand Banks is composed mainly of polychaetes and amphipods (Walsh 1992, Methven 1999, in Husky Energy 2012a). As yellowtail flounder historically occurred on the northern Grand Banks, it is likely they do occur in the Study Area, although it is not known to be an important habitat area (Walsh et al. 2000, in Husky Energy 2012a). The Southeast Shoal and Tail of the Grand Banks EBSA, which is located within the Study Area is an important spawning and nursery area for yellowtail flounder (DFO 2007b, in Husky Energy 2012a).

1.2 Pelagic Fish

1.2.1 Albacore Tuna

Albacore tuna are sparsely distributed along the Grand Banks. They enter Canadian waters in July and remain until November to feed. Spawning occurs from March to July in subtropical areas of the Atlantic Ocean and Mediterranean Sea. Females produce between 800,000 and 2.5 million buoyant eggs that hatch in one to two days. After hatching, the larvae grow quickly and remain in the spawning grounds until the second year when, during the spring, they begin their migration to the North American coast (NOAA 2013a, in BP 2016).

1.2.2 Atlantic Herring

Atlantic herring are found on both sides of the North Atlantic. In the northwest Atlantic, they are found from Labrador to Cape Hatteras (DFO 2015g, in BP 2016). They are common in shallow inshore waters or offshore from the surface to depths of 200 m. The species has a life expectancy of 15 years and matures at four years of age. Atlantic herring primarily feed on zooplankton, krill, and fish larvae (NOAA 2013b, in BP 2016).

Atlantic herring form massive schools prior to spawning and migrate to spawning grounds in both coastal waters and offshore banks (GMRI 2014, in BP 2016). In Newfoundland, herring spawn along the southwest coastal waters in the Gulf of St. Lawrence (Amec 2014). Females produce 30,000 to 200,000 eggs that are deposited on rock, gravel, and sand substrate. Schools of herring can produce so many eggs that an area of ocean floor becomes covered in a dense carpet of eggs several centimetres thick. The eggs hatch within seven to ten days and by late spring the larvae grow into juveniles foraging in large schools in the summer. Larvae are carried by ocean currents for approximately six months before becoming active swimmers (GMRI 2014, in BP 2016).

1.2.3 Atlantic Mackerel

Atlantic mackerel are pelagic schooling fish which occupy moderately deep water (70 to 200 m) along the Continental Shelf or in channels between banks. They can be found in Canadian coastal and inshore waters during the summer and fall only. They are sensitive to water temperatures and make migrations on a seasonal basis to feed and spawn. Mackerel mainly feed on crustaceans including copepods, krill, and shrimp, and opportunistically on squid and small fish (NOAA 2013c, in BP 2016).

The species has two major spawning groups with one group spawning in the Mid-Atlantic Bight (between Rhode Island and Virginia) from April to May and the second group spawning in June and July in the Gulf of St. Lawrence. It is possible that mackerel spawn in the coastal waters of southern Newfoundland. In 2009, egg surveys were conducted along the coast of Newfoundland which resulted in very low egg densities, suggesting that spawning on the coast of Newfoundland is low (DFO 2012). Spawning takes place close to shore with females releasing batches of eggs five to seven times during the spawning season. The eggs are buoyant and hatch within four to eight days (NOAA 2013c, in BP 2016).

1.2.4 Capelin

Typically, capelin winter offshore and will undergo extensive migrations to coastal areas during spring to spawn (Carscadden and Nakashima 1997, in Husky Energy 2012a). Timing of the inshore spawning of capelin in coastal Newfoundland can be highly variable, with temperature one of the prime factors in explaining variability (Carscadden et al. 2001; Regular et al. 2009, in Husky Energy 2012a). During periods when colder than normal temperatures prevail, spawning is delayed. In late spring and summer, capelin move to shallower bays to spawn on beaches, or alternatively, spawn offshore at depths up to 125 m (Nakashima and Wheeler 2002, in Husky Energy 2012a). Spawning may occur in a given location year after year, or only occur periodically in some locations (Nakashima and Wheeler 2002, in Husky Energy 2012a). Females may produce as many as 50,000 eggs at one time. Eggs attach to the substrate and remain in the sediment for 14 to 52 days, with hatching time triggered by temperature (Scott and Scott 1988, in Husky Energy 2012a).

After hatching, capelin larvae remain in the sediment up to five days, until ideal conditions (particularly an onshore wind) occur and enable the larvae to enter the water (Nakashima and

Wheeler 2002, in Husky Energy 2012a). If these conditions do not occur within five days, the yolk sac is depleted and there is a low rate of survival. Studies of juvenile capelin that remain in the shallow nearshore water have shown preference for eelgrass habitat in mud, sand, or gravel substrate. Adults are not known to have habitat preferences.

Adults undertake vertical migrations, staying in the lower water column during daylight and migrating toward the surface at night, except in autumn when they have a reverse vertical migration (migrate to the surface during the day) (Mowbray 2002, in Husky Energy 2012a).

1.2.5 Greenland Shark

The Greenland shark (*Somniosus microcephalus*) is the largest member of the dogfish family and can grow to over 6 m in length. It is distinctive in appearance with small dorsal fins, small pectoral fins and a rounded stout shape with a rounded snout. Greenland shark occurs in the North Atlantic Ocean and in the western Atlantic, ranges from Greenland and Baffin Island south to Newfoundland, Gulf of St. Lawrence and the Scotian Shelf. This species commonly occurs at depths ranging from surface waters to below 200 m (reported up to 1,280 m) (Yano et al. 2007, in Husky Energy 2012a) and prefers temperatures between 0.6°C and 12°C. In winter months, the Greenland shark is common in shallow surface waters, estuaries, and bays, but moves into deeper, cooler waters during summer (Scott and Scott 1988; Stokesbury et al. 2005, in Husky Energy 2012a).

There is little information available on the reproduction, life span and growth of Greenland shark as they are rarely sighted. They are known to be ovoviviparous. Females are thought to mature at approximately 450 cm and males at 300 cm (Yano et al. 2007, in Husky Energy 2012a). The diet of Greenland shark is diverse and includes capelin, halibut, herring, lumpfish, redfish, salmon, and marine mammals, including carrion. It is thought this species has few natural predators (Yano et al. 2007, in Husky Energy 2012a).

1.2.6 Lanternfish

Lanternfish are a family of small, pelagic fishes characterized by having light producing organs on their body (Scott and Scott 1988, in Amec 2014). They occur in oceans across the world from pole to pole in deep oceanic waters, where they perform vertical feeding migrations to feed on plankton. These species can be extremely abundant in deep-water habitats and form a critical prey base for commercially valued species such as cod, hake, tunas, salmon, and marine mammals (Scott and Scott 1988, in Amec 2014). In the Study Area, they represented only 2% of all the fish caught during DFO RV surveys, but are probably among the most abundant species in deeper areas not sampled by DFO surveys. This is supported by the fact that their highest densities from the trawl surveys were in the deep waters of the Flemish Pass.

1.2.7 Swordfish

Swordfish can be found along the Gulf Stream and as far north as the Grand Banks. They migrate into Canadian waters in the summer as part of their annual seasonal movement, following spawning in subtropical and tropical areas. Swordfish can be found along the Grand Banks and its slopes at the surface to depths of 500 m feeding in cooler, more productive waters. Swordfish feed on a variety of fish species as well as invertebrates including squid (NOAA 2013f, in BP 2016). Spawning takes place in the Sargasso Sea and in the Caribbean from December to March and off the southeast United States from April to August.

1.3 Invertebrates

1.3.1 Atlantic surf clam

Atlantic surf clams generally inhabit the inshore waters in burrows in silty to sandy substrates, though individuals have been found in water depths of 75 m (Duggan 1996, in BP 2016). Spawning occurs in the summer months of June through August (Gibson 2003, in BP 2016). The larvae remain planktonic for approximately two weeks before settling onto benthic habitats. Juveniles are motile covering short distances, whereas adults are predominantly sessile. Atlantic surf clams generally grow to marketable size in four to five years (Gibson 2003, in BP 2016).

1.3.2 Propeller Clam

Propeller clams can be found in high abundances on sandy bottoms of the Grand Banks (Kenchington et al. 2001, in Amec 2014). The species population is dominated by older individuals more than 100 years old (Kilada et al. 2009, in Amec 2014). They serve as a prey species for American plaice and Atlantic wolffish (Templeman 1984, in Amec 2014).

1.3.3 Pale Sea Urchin

The pale sea urchin can be found in high abundance on sandy and cobble benthic areas of the Grand Banks (Kenchington et al. 2001, in Amec 2014). The species can be found in deep waters to depths up to 1,600 m and are the dominant sea urchins in water depths > 60 m (Amec 2014).

1.3.4 Atlantic Sea Scallop

Atlantic sea scallop can be found from the South Coast of Newfoundland to Cape Hatteras, North Carolina. In Canada, this species is managed in six geographical zones called Scallop Fishing Areas, which range from the St. Pierre Bank off the south coast of Newfoundland to Georges Bank off the southern coast of Nova Scotia. They live in discrete, and sometimes large, aggregates (beds) on the seabed. They feed by filtering planktonic organisms from the water column and can live up to 20 years (DFO 2015j, NOAA 2013q, in BP 2016). Sea scallops are found densely concentrated on sandy, gravel bottoms and can be found in waters at depths as shallow as 10 m

and as deep as 384 m. The harvestable offshore concentrations are found on banks at depths between 35 to 120 m (DFO 2015).

Spawning occurs in the late summer to early fall with females producing hundreds of millions of eggs per year. Once eggs have hatched, the larvae drift in the water column for four to six weeks before settling on the seafloor, generally near existing scallop beds (DFO 2015j, NOAA 2013q, in BP 2016).

1.3.5 Iceland Scallop

Iceland scallops can be found from the subtidal zone to water depths up to 180 m. In Newfoundland they generally occur in water depths > 55 m on variable hard substrates including gravel and cobble (Amec 2014). In the Grand Banks area shell, stock is harvested from the Lilly Canyon/Carson Canyon area and the Western Slope of the Grand Banks (DFO 1997; Naidu 2001). The species is a broadcast spawner (mass spawning or synchronous spawning), spawning in April and May. The planktonic larvae remain in the water column for 10 weeks prior to settling to the bottom.

1.3.6 Northern Shrimp

Although several species of shrimp (family Penaedae and infraorder Caridean) occur in the Study Area, the predominant species is the northern or pink shrimp. Northern shrimp occur from Labrador to the Grand Banks and occur at water depths of 150 to 350 m (DFO 2011c, in Husky Energy 2012a). Northern shrimp prefer temperatures between 0°C and 4°C (Colbourne and Orr 2004, in Husky Energy 2012a). Northern shrimp are known to congregate during winter and spring, and to disperse in summer and early fall. This species is most abundant in the deeper slope waters of the Grand Banks during spring and migrates to shallower waters during the fall.

Larvae are released into the water column in April and May, and settle to the bottom from July to September. The reproductive cycles of most northern shrimp stocks are synchronous with the local spring phytoplankton bloom (Greene et al. 2009, Koeller et al. 2009, in Husky Energy 2012a). Spawning occurs in late summer and fall and females retain the fertilized eggs until the following spring when the eggs are released. The eggs hatch and larvae remain pelagic for a few months before settling to the benthos. Adult shrimp are benthic during the day and feed on detritus, phytoplankton, and small invertebrates. At night, the shrimp migrate vertically in the water column to feed in surface waters (Bundy et al. 2000, in Husky Energy 2012a). Shrimp are preyed upon by several species of fish such as Greenland halibut and Atlantic cod.

1.3.7 Snow Crab

In the offshore area, snow crabs are most common on mud and sand-mud substrate at temperatures of -0.5°C to 4.5°C, and water depths of 20 to 2,000 m (DFO 2005b, Dawe et al. 2010, in Husky Energy 2012a). Depth, temperature, and bottom substrate have all been correlated with densities of adult and juvenile crabs.

Mating is thought to occur at the end of the winter or in the spring, with spawning taking place in spring and early summer. Females carry fertilized eggs on their underbelly until the following year and released when water temperatures are suitable (Moriyasu and Lanteigne 1998, in Husky Energy 2012a). Larvae are pelagic and may be planktonic for months until settlement. Newly hatched larvae are approximately 3 mm long. They immediately rise to the surface, where the currents carry them before they settle back on the bottom, most probably at a different place than where they hatched. During this period, they go through three different larval stages before adopting the regular shape of crabs and settle to the seafloor at 3 mm wide across the shell. Larvae complete development on the seafloor (DFO 2005b, in Husky Energy 2012a). Benthic snow crabs feed on polychaetes, echinoderms, and molluscs.

Snow crabs are not known to undertake migrations and are thought to have a small range, owing to their relatively sedentary life style. Analyses of the spatial distribution of snow crab catches during annual fall DFO surveys indicate that there have been gradual spatial shifts of densities for most size groups, as well as annual and area-specific changes in survey catch rates (Dawe et al. 2010, in Husky Energy 2012a). Large and small crabs overlap in spatial distribution. Snow crabs occur in the Study Area but are more common along the slope of the Grand Banks on fine substrate (Dawe and Taylor 2003, in Husky Energy 2012a). Snow crabs are collected as part of the existing White Rose EEM biological sampling program. They were uncommon during DFO RV in 2010 and 2011 in NAFO Division 3L (northern Grand Banks). DFO RV surveys suggest the exploitable (i.e., mature) biomass of snow crab has declined since 1996 and the pre-recruit index is expected to remain low (DFO 2005b, in Husky Energy 2012a).

1.4 Species at Risk

1.4.1 Acadian Redfish

The Acadian redfish live primarily in cool waters (3°C to 8°C) along the slopes of banks and deep water channels in depths ranging from 100 to 700 m (Amec 2014). The Southwest Shelf Edge and Slope EBSA is an important spawning area for redfish. Migratory movement information is unknown for the species given they cannot be tagged (gas bladder ruptures when brought to the surface). Dispersal and migration is believed to be limited; however, the species can be found in a wide range of habitats and is known to use rocks and anemones as protection from predators.

The Acadian redfish reaches sexual maturity very late and has highly successful abundance every 5 to 12 years (COSEWIC 2010c, in Husky Energy 2012a). They are a slow-growing species that can attain an age up to 75 years. Females are ovoviviparous, keeping fertilized eggs inside until the larvae have hatched. Breeding occurs between September and December and larval extrusion occurs in the spring. Larvae may be present in the water column May to August, feeding on copepods and fish eggs, and can be found over the Grand Banks, Flemish Cap, and their slopes. At the larval stage, Acadian redfish feed on the eggs of fish and invertebrates until they reach juvenile and adult stages where they will feed on copepods, euphausiids, and fish (COSEWIC 2010c, in Husky Energy 2012a). Abundance estimates for the mature population of Acadian redfish are based on scientific surveys conducted by DFO. The Acadian redfish has shown a substantial

(>95%) decline over one to two generations in areas where they were historically abundant, although in some areas abundance indices have been stable or increasing since the mid-1990s (COSEWIC 2010c, in Husky Energy 2012a). The abundance indices for this species fluctuate widely, but show no overall trends.

1.4.2 American Eel

American eels can be found in Canadian freshwater, estuarine, coastal, and marine environments from Niagara Falls to Labrador and have a very complex life history (DFO 2013j, in BP 2016). Mature Silver eels spawn in the Sargasso Sea with hatching occurring from March to October and peaking in August. Larvae are transparent and willow-shaped and are transported to North American coastal waters by the Gulf Stream (COSEWIC 2012c, in BP 2016). After approximately 7 to 12 months, larvae enter the Continental Shelf area and become glass eels taking on an eel shape while remaining transparent. As glass eels migrate towards freshwater coastal streams they are known as elvers and will run into the freshwater streams, peaking from April to June in Newfoundland. Elvers eventually transform into yellow eels, which is the major growth phase for the species. Yellow eels will spend years maturing in freshwater streams and coastal areas before making a major transformation to return to the Sargasso Sea to spawn. Yellow eels will remain in coastal areas or freshwater on average for 9 to 22 years before metamorphosing both morphologically and physiologically into silver eels (COSEWIC 2012c, in BP 2016). Newfoundland silver eels begin their outmigration to the Sargasso Sea in November travelling over 2,000 km to spawn for the only time during their life.

The population of American eels was examined using time-series data to estimate the percent change in indices of abundance from the 1950s to the 2000s. This examination resulted in an almost uniformly negative (-7.1% to -96.2%) trend within the species North American western range, while trends were mixed within the eastern portion of its range (COSEWIC 2012a).

Available fisheries-independent indices of eel abundance in Newfoundland are composed of electrofishing surveys conducted for salmonids at Northeast Brook (1984 to 1996) and Highlands River (1980 to 1981; 1993 to1999), as well as surveys conducted at salmonid counting fences in Conne River (1986 to 2008) and Western Arm Brook (1994 to 2008). The data from Northeast Brook and Highlands River indicates a substantial negative trend; this index of eel abundance declined approximately 88% from 1984 to 1996 and approximately 95% from 1980 to 1999. The more recent time series from Conne River and Western Arm Brook show variable counts of eels. The average annual count for 2003-2008 was greater at Conne River but lower at Western Arm Brook, and neither trend was statistically significant (COSEWIC 2012a).

1.4.3 American Plaice

The American plaice is a benthic marine flatfish with a laterally compressed body. The geographic limits of the Newfoundland and Labrador population of American plaice is from Hudson Strait and Cape Chidley southeast to the Grand Banks and west to Cape Ray (COSEWIC 2009b, in BP 2016). The species is closely associated with the seafloor and commonly found in water depths of 100 to

300 m where soft or sandy sediments are present (DFO 2013i, in BP 2016). Females are batch spawners and spawn batches of eggs for up to one month during April. On the Flemish Cap, spawning occurs in early April. On the Grand Banks spawning occurs later in April. The Southeast Shoal, Tail of the Banks, and Virgin Rocks EBSAs are important spawning grounds for the species. Eggs and larvae are pelagic and may be present in the water column between May and June (COSEWIC 2009b, in Husky Energy 2012a).

American plaice prefer water temperatures ranging from 0.5°C to 1.5°C. They are opportunistic feeders consuming a variety of prey items such as polychaetes, echinoderms, molluscs, crustaceans, and small fish. Throughout their Canadian range, American plaice are limited to local movements made in response to seasonal changes in temperatures or prey availability (COSEWIC 2009b, in Husky Energy 2012a).

1.4.4 Atlantic Bluefin Tuna

Atlantic bluefin tuna are highly migratory, with long and varied routes. Bluefin tuna are distributed throughout the North Atlantic Ocean, occupying waters up to a depth of 200 m from Newfoundland to the Gulf of Mexico (Maguire and Lester 2012, in BP 2016) and can usually be found in Canadian waters in the summer. They have a life expectancy up to 20 years, maturing at about eight years of age. Spawning takes place in the Gulf of Mexico and the Mediterranean Sea. Females produce up to 10 million eggs in a year that are fertilized in the water column by males and hatch after two days.

Important prey items for the species include: herring, mackerel, capelin, silver hake, white hake, and squid. However; they are opportunistic and will feed on jellyfish, salps, and demersal and sessile fish and invertebrate species (NOAA 2013e, in BP 2016).

Adult bluefin tuna enter Canadian waters from June to October and can be found over the continental shelf off Newfoundland (Amec 2014). Bluefin tuna are pelagic species and can tolerate a wide range of temperatures due to their ability to regulate their own body temperatures.

Population estimates for the Atlantic bluefin tuna (mature population) show an initial steep decline from 1970 into the 1990s, with a small increase until the late 1990s, followed by a steady decline to the last data point in 2010 (COSEWIC 2011a, in BP 2016).

1.4.5 Atlantic Cod

Atlantic cod can generally be found in coastal, nearshore, and offshore areas from water depths of a few metres to 500 m. Atlantic cod have been observed spawning in both offshore and inshore waters at all times of the year depending on location (COSEWIC 2010d, in BP 2016). Peak spawning has been observed during the spring and occurring in batches. Eggs and larvae are pelagic and float on the surface and drift with the oceanographic conditions at the time of spawning. Each

female will produce several million eggs, with usually only one egg surviving to maturity. Eggs and larvae may be present in the upper water column of the Grand Banks year-round.

Juvenile cod to the age of four prefer habitats that provide protection and cover such as nearshore waters with eelgrass or areas with rock and coral (COSEWIC 2010d, in BP 2016). For the first few weeks of life, Atlantic cod reside in the upper 10 to 50 m of the ocean. Prey availability and temperature are the primary factors determining habitat selection for cod.

Newfoundland and Labrador Population

Cod from this population range from north of Cape Chidley (off the northern tip of Labrador) to the southeast Grand Banks (COSEWIC 2010). Although cod are generally found in water temperatures ranging from 2ºC to 11ºC, cod in some areas of Newfoundland can withstand temperatures as low as -1.5ºC. Cod can survive these cold temperatures and prevent the formation of ice crystals in the blood by producing plasma antifreeze proteins that improve freeze resistance. Fish from this population reproduce for the first time at the age of five to seven years. The Newfoundland and Labrador population of Atlantic cod contained 75% to 80% of all of the Atlantic cod in Canadian waters in the early 1960s (COSEWIC 2010). The Newfoundland and Labrador population has a three generation ratio of decline of 97% to 99%.

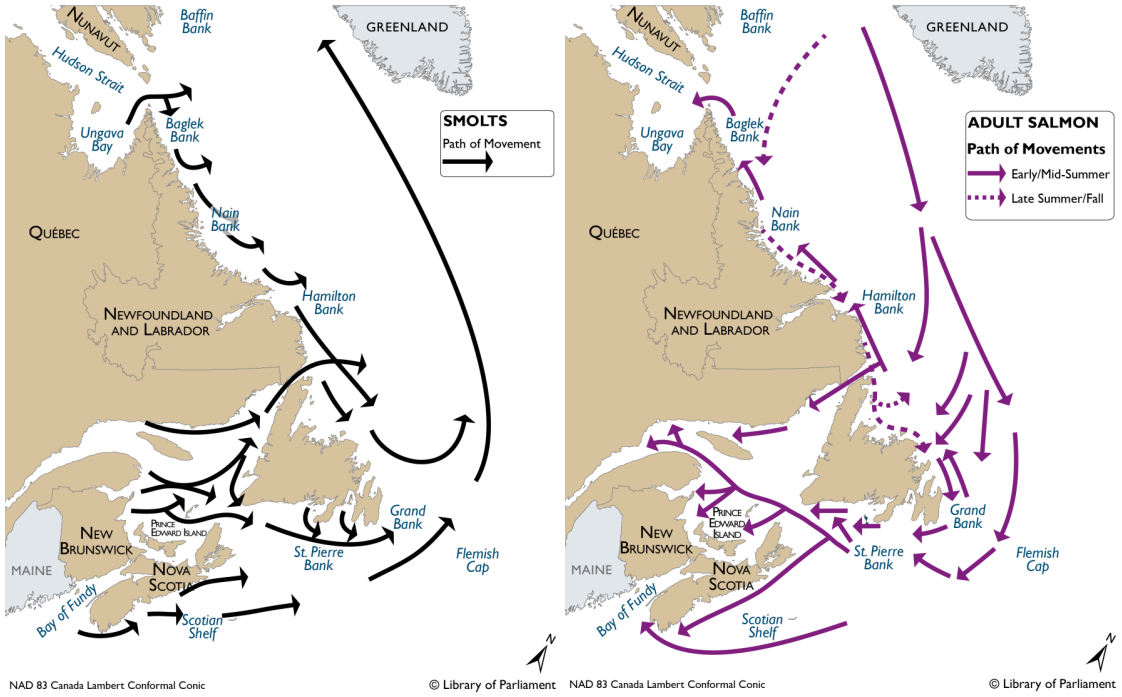
1.4.6 Atlantic Salmon

Adult salmon return from the ocean to freshwater rivers to spawn after a feeding stage at sea from May to November. Female salmon deposit eggs in gravel nests usually in gravel riffle sections of streams in October and November. Following spawning, anadromous adults return to sea either immediately after spawning or remain in freshwater until the following spring (COSEWIC 2010b). Fertilized eggs incubate in nests over the winter and begin to hatch in April and remaining in the gravel riverbed for several weeks while living off a large yolk sac. Once the yolk sac has been absorbed, free swimming fry begin to actively feed and remain in freshwater for one to eight years before they begin a behavioural and physiological transformation and migrate to sea as smolts.

Atlantic salmon smolts leave their natal rivers of Atlantic Canada and eastern Quebec in the spring and migrate to summer/fall feeding areas in the Labrador Sea gyre, the western coast of Greenland, and the eastern Grand Banks via the Strait of Belle Isle or waters off the eastern Newfoundland Coast (Figure 1; Reddin 2006). Migration routes are generally thought to follow the dominant surface water currents. Overwintering distribution is not well-defined but is generally believed to encompass an area from the southern Labrador Sea, to the eastern edge of the Scotian shelf (COSEWIC 2010b). Available literature suggests that the Labrador Sea is the primary overwintering area (Reddin 2006; DFO 2013).

Migration back to freshwater, in the summer and fall, generally follows ocean currents back toward coastal environments and onward to natal rivers. The distribution and migration patterns of Atlantic salmon are influenced by the age structure of the population. Salmon of various ages may be found during the ocean life cycle, and those ages influence migratory patterns so that at

any given time, there are individuals in a population inhabiting ocean environments (COSEWIC 2010b). Post-smolts (salmon that have not yet spent a winter at sea) exit rivers in May/June to feed in the summer/fall and overwinter. Following their first winter, those salmon are termed one sea-winter (1SW) salmon. One sea-winter salmon may migrate back to their natal rivers to spawn the following summer or they may migrate to ocean foraging grounds and overwinter for another season. Those that remain are known as two sea-winter (2SW) salmon and these individuals return to spawn the following summer. Fish that are successful at spawning typically overwinter in freshwater and return to the ocean the following spring. Thus, at any given time there are multiple age classes of salmon expected to be using ocean environments.



Source: The Standing Committee on Fisheries and Oceans 2017

Figure 1 General Ocean Distribution and Migratory Patterns of Canadian Atlantic Salmon

1.4.7 Atlantic Wolffish

Atlantic wolffish occurs in Newfoundland waters with a higher concentration around the Southeast Shoal and the Tail of the Banks EBSAs. In Newfoundland, they are typically found inhabiting the seafloor in water depths of <100 to 400 m at temperatures ranging from -0.5°C to 6.5°C (COSEWIC 2012b, in Amec 2014). Juvenile and adult Atlantic wolffish can be found on a variety of substrates. Atlantic wolffish feed on mostly invertebrates (85%) including whelks, sea urchins, hermit crabs, crabs, and scallops. A smaller portion of their diet consists of fish with their main prey being redfish (COSEWIC 2012b, in Amec 2014).

Atlantic wolffish make short migrations to spawning grounds, which are generally boulder and cave habitat in shallow waters, during the fall (COSEWIC 2012b, in Amec 2014). Eggs/larvae may be present on the seafloor in fall to early winter. The eggs are deposited in crevices on rocky substrates and are guarded by males until they hatch. Juvenile Atlantic wolffish are capable of wide dispersion, while adults are sedentary (COSEWIC 2012b, in Amec 2014). The number of Atlantic wolffish individuals in Canadian waters is estimated to exceed 49 million, with over 5 million mature individuals (COSEWIC 2012b, in Amec 2014). In Canadian waters, the abundance of mature individuals has declined by 87% since 1970, while the abundance of immature individuals has increased over the same period (LGL 2014, in BP 2016).

1.4.8 Basking Shark

Basking sharks are believed to have a life span of 50 years, with males maturing between 12 to 16 years of age and females maturing between 16 to 20 years of age (COSEWIC 2009c, in Husky Energy 2012a). Males and females pair up in the summer, presumably to mate. Females have a gestation period of 2.6 to 3.5 years and give birth to about six pups with an average length at birth of 1.5 to 2 m. The species feeds on zooplankton that congregate in oceanic fronts.

They can be found throughout the North Atlantic with observations in coastal waters of Newfoundland and near the mouth of the Bay of Fundy. There is limited information regarding population sizes and trends, with total population estimates for Atlantic Canada ranging from a conservative estimate of 4,918 individuals to 10,125 individuals (COSEWIC 2009c, in Husky Energy 2012a).

Habitat requirements have not been investigated in Canada, but it is believed that the basking shark lives primarily in oceanic front locations where their main food source, zooplankton, congregates (COSEWIC 2009c, in Husky Energy 2012a). Tagging studies have shown the species occupying surface waters to depths of over 1,200 m.

1.4.9 Blue Shark

Blue sharks are widespread, highly migratory and can be found worldwide in temperate and tropical oceans, generally in the offshore surface water (COSEWIC 2006a, in BP 2016). Blue sharks typically mate in the spring to early summer (COSEWIC 2006a, in BP 2016). The female may store sperm for months to years while waiting for ovulation to occur. The gestation period lasts 9 to 12 months, with birth usually occurring in the spring to fall. Blue sharks are viviparous (bearing live young) with an average litter size of 26 pups. The length of newborn pups averages 40 to 50 cm, taking four to five years to mature to a length of 193 to 210 cm. Abundance indices based on catch rates in or near Canadian waters show varying declining rates of blue sharks between near 0% to 53% since the mid-1990s (COSEWIC 2006a, in BP 2016). Blue sharks are opportunistic predators and feed on bony fish, squid, birds, and marine mammal carrion.

Blue sharks are commonly found in offshore waters in depths up to 350 m during summer and fall from June to October. Blue sharks can be found in water temperatures between 5.6°C to 28°C

but prefer temperatures of 8°C to 16°C. Temperature is believed to be a primary factor in migration (COSEWIC 2006a, in BP 2016). Canadian waters provide habitat for primarily immature individuals although mature species are occasionally observed (COSEWIC 2006a, in BP 2016).

1.4.10 Cusk

Cusk occurs rarely in the deep waters along the edge of the continental shelf off Newfoundland and Labrador. They prefer water depths of 200 to 600 m, inhabit benthic area consisting of a hard and rocky seabed, and feed on invertebrate species.

Cusk are a slow-growing and later-maturing species with males maturing at five years and females at seven (SARA 2013b, in BP 2016). Spawning occurs between May and August with females laying from 100,000 to over a million eggs. The eggs are buoyant and hatch 4 mm larvae that remain buoyant until settling to the bottom at a size of 50 to 60 mm. Population trends for the species indicate a decline of 93.4% from 1970 to 2001 (COSEWIC 2003, in BP 2016).

1.4.11 Deepwater Redfish

Deepwater redfish have similar life history characteristics as the Acadian redfish, with the major difference being that they release their larvae 15 to 25 days earlier (COSEWIC 2010c, in BP 2016). They are closely associated with the seafloor and commonly found inhabiting waters deeper than the Acadian redfish. The deepwater redfish extends from the Grand Banks to Baffin Bay and includes the Gulf of St. Lawrence, Laurentian Channel, and the Labrador Sea (COSEWIC 2010c, in BP 2016). They can be found in a wide range of habitats, using rocks and anemones as protection from predators. Commonly found inhabiting waters 350 to 500 m deep, the species can be found on the edge of the banks and in deep channels from the Labrador Sea to Sable Island. Redfish are considered semi-pelagic because they make long daily vertical migration (COSEWIC 2010c, in BP 2016). Migratory movement information is unknown because they cannot be tagged (gas bladder ruptures when brought to the surface). It is believed that once they have settled to the seafloor, dispersal is limited (COSEWIC 2010c, in BP 2016). Given the impossibility of rapidly differentiating between deepwater redfish and Acadian redfish, particularly in commercial catches, redfish stock assessments have always been done for all species combined (COSEWIC 2010c, in BP 2016). The deepwater redfish has shown a substantial (>95%) decline over one to two generations in areas where they were historically abundant, although in some areas abundance indices have been stable or increasing since the mid-1990s (COSEWIC 2010c, in BP 2016). The abundance indices for this species fluctuate widely, but show no overall trends.

1.4.12 Northern Wolffish

Northern wolffish range from northeast Newfoundland and across the North Atlantic with occasional occurrences on the Scotian Shelf (COSEWIC 2012d, in BP 2016). In Newfoundland, the species can be found in the deep waters (150 to 1000 m) of the Grand Banks and Flemish Cap in spring and fall. Before the decline of the northern wolffish, they were caught on substrates of all types. Today they are most often found on sand and shell hash (COSEWIC 2012d, in Amec 2014).

Scientific surveys from all parts of the western Atlantic range indicate declines in the abundance of Northern Wolffish over the past 20 years. From 1978 to 1994, abundance in the primary range off northeastern Newfoundland declined by 98%. The number of locations where the species has been historically found have also declined.

The northern wolffish is a benthopelagic species, feeding on benthic crustaceans and invertebrates, but lives in the open ocean (COSEWIC 2012d, in BP 2016). Spawning occurs in the later portion of the year, with females laying upwards of 27,000 demersal eggs. The species matures at five years of age or older. They are a non-schooling, non-migratory species which are territorial and make nests in which they guard their eggs.

1.4.13 Porbeagle Shark

Porbeagle sharks are a pelagic species that can be found from the coast to the open sea; however, they are known to commonly inhabit continental shelves and ocean basins at depths up to 700 m. They have also been found closer to shore, although this is more occasional (SARA 2013a, in BP 2016). Generally, porbeagle sharks in Canadian waters can be found at temperatures ranging from 5°C to 10°C, with little variation from one season to the next, suggesting that they travel about to remain in the cold waters they prefer (SARA 2013a, in BP 2016).

Male porbeagle sharks mature at eight years with females maturing at 13 years and have a life expectancy of 25 to 46 years. Mating occurs from late September to November and females are ovoviviparous having a gestation period of eight to nine months. Females leave the Continental Shelf in December travelling at great depths (>500 m), swimming up to 2,500 km to the Sargasso Sea (DFO 2013e, in BP 2016). Females give birth here in March and April inhabiting the deep, cool waters. The young start appearing in Atlantic Canadian waters in June and July. It is believed that the young sharks "hitch a ride north" on the deep cool sections of the Gulf Stream (DFO 2013e, in BP 2016).

Immature porbeagle sharks inhabit the Scotian Shelf with mature individuals migrating along the shelf waters to mating grounds located on the Grand Banks, off the mouth of the Gulf of St. Lawrence, and on Georges Bank from September to November. There is a population which undertakes extensive annual migrations and from January to February; this population can be found in the Gulf of Maine, Georges Bank, and the Southern Scotian Shelf. By the spring they can be found on the edge of the Scotian Shelf and in offshore basins. In the summer and fall, they can be found off the southern coast of Newfoundland and in the Gulf of St. Lawrence (Campana et al. 2013, in BP 2016).

The most recent population estimate for this species in 2009 was thought to be approximately 197,000 to 207,000 individuals, which included 11,000 to 14,000 spawning females (COSEWIC 2014b, in BP 2016). Since 1961, the abundance of this species has declined by 56% to 70%. This decline has been reduced over the last decade, due to a reduction in this fishery.

1.4.14 Roughhead Grenadier

The roughhead grenadier is a benthopelagic species that is closely associated with the seafloor. They are commonly found in water depths of 200 to 2,000 m on or near the continental slope of the Newfoundland and Labrador Shelves, the northeastern slope of the Grand Banks and off the Flemish Cap; however, they have been observed from Davis Strait to the southern Grand Banks. The species is an opportunistic predator feeding on invertebrates, small fish, and squid (COSEWIC 2007a, in BP 2016).

Roughhead grenadier are a slow-growing and late-maturing fish species with a long life cycle and low population turnover rate. Females mature at approximately 13 to 15 years of age. Spawning may occur within the southern Grand Banks during the winter and early spring, although it is possible that the species spawns year-round. Females lay over 25,000 pelagic eggs over a lengthy spawning period (COSEWIC 2007a, in BP 2016).

1.4.15 Roundnose Grenadier

The roundnose grenadier is a continental slope species with the deeper part of its geographic range not well surveyed (COSEWIC 2008a, in BP 2016). It is more abundant in the northern portion of its Canadian range including Labrador and Northeast Newfoundland shelves and Davis Strait. It is closely associated with the seafloor and commonly found inhabiting waters 800 to1,000 m in depth but has been found in water depths of up to 2,600 m.

Like the roughhead grenadier, the roundnose grenadier is a relatively long-lived, slow-growing species. Females reach maturity at about 10 years of age and have been reported with a maximum age of 60 years (COSEWIC 2008a, in BP 2016). Spawning is believed to occur year-round with peaks at different times for different areas. Females will spawn 12,000 to 25,000 pelagic eggs.

Roundnose grenadier have been observed moving up and down continental slopes, moving to deeper water in the winter and shallower water in the summer. They have also been observed to carry out diurnal vertical migrations of 1000 m off the bottom. The species feeds in the water column on a variety of prey items including: copepods, amphipods, squid, and small fish (COSEWIC 2008a, in BP 2016).

1.4.16 Shortfin Mako

The shortfin mako is a pelagic species that migrates north following food stocks (i.e., mackerel, herring, and tuna) during the late summer and fall. The species prefers warm-water temperatures ranging from 17°C to 22°C and is typically associated with Gulf Stream waters and occurring at depths from the surface to 500 m (COSEWIC 2006f, in BP 2016). It is rarely found in waters with temperatures less than 16°C.

The species can reach lengths of over 4 m. Females mature at 2.7 to 3 m at an average age of 17 years old. Females are ovoviviparous and have litters of 4 to 25 pups after a 15- to 18-month

gestation period and have an estimated three-year parturition cycle. Pups are born at a length of 70 cm. Shortfin makos have a lifespan ranging from 25 to 45 years (COSEWIC 2006f, in BP 2016). There are no reliable population-level stock estimates available for the shortfin mako in the North Atlantic. Trend estimates, based on declines in catch rates in the entire Northwest Atlantic, suggest that the shortfin mako populations may have decreased by up to 50% in the past 15 to 30 years (COSEWIC 2006f, in BP 2016).

1.4.17 Smooth Skate

The smooth skate can be found from the Grand Banks to South Carolina. In Canadian waters it is common from the Grand Banks along the Scotian Shelf and into the Gulf of Maine area. The species has been recorded at shallowest and deepest water depths of 25 and 1,436 m, respectively; however, densest concentrations occur between 150 and 550 m (COSEWIC 2012g, in BP 2016). They can be found over a relatively narrow range of temperatures ranging from -1.3°C to 15.7°C (BIO 2013a, in BP 2016). Smooth skates prefer soft mud substrates consisting of silts and clay, but they have also been found on sand, shell hash, gravel, and pebble substrates. Smooth skates primarily feed on small crustaceans, and will eat fish once they reach later (largest) stages of their life.

The smooth skate is a slow-growing, late-maturing and long-lived species that is capable of spawning year-round with no known observed peak in spawning rates. Smooth skates are generally slow to reproduce, producing 40 to 100 egg capsules per year. Females mature at an average age of 11 years. Females will lay an egg capsule on the benthic substrate. Larval smooth skates develop in the egg capsule in one to two years before hatching (BIO 2013a, in BP 2016). The estimate for the Laurentian-Scotian population of smooth skates is approximately 5,704,000 individuals (COSEWIC 2012g, in BP 2016). The estimate for the Funk Island population is 320,000 individuals (COSEWIC 2012g, in BP 2016).

1.4.18 Spiny Dogfish

Spiny dogfish are widely distributed in boreal to warm temperate waters, spread over continental and insular shelves and upper slopes of the Pacific and Atlantic Oceans (Kulka 2006, in Husky Energy 2012a). This small shark is commonly distributed over the continental shelf of temperate regions, and is most abundant in waters 5°C to 15°C (Kulka 2006, in Husky Energy 2012a). The Atlantic population extends from Labrador to Cape Hatteras and is most abundant south of Nova Scotia; however, there are areas of concentration around Newfoundland and Labrador, including on the eastern edge of the Grand Banks.

There are indications of a local inshore/offshore migration pattern (Kulka 2006, in Husky Energy 2012a). The distribution of spiny dogfish is patchy as they can form dense aggregations, causing high variability in survey indices. The absence of young juveniles, as well as high variability in abundance estimates from surveys, suggests that the early life history stages (pupping and juveniles) occur elsewhere.

The species has a very long gestation period (18 to 24 months), long sexual maturity (23 years), and low fecundity (average of six pups every two years), and as such is vulnerable to exploitation. There is also uncertainty about long-term trends in abundance, and particularly the abundance of mature females. The western Atlantic population is known to be broken into several well-defined 'groups', with concentrations in the southern Gulf of St. Lawrence, around Newfoundland, on the eastern and central Scotian Shelf, the Bay of Fundy and southwest Nova Scotia, as well as in Massachusetts and North Carolina. These groups undertake seasonal migrations and it is unclear how much mixing there is among groups.

1.4.19 Spotted Wolffish

The main range of the spotted wolffish is west of Greenland to the Grand Banks (COSWEIC 2012e, in BP 2016). The species is commonly found inhabiting the seafloor in water depths of 50 to 800 m. The species prefers a substrate of coarse sand and a sand and shell mix with rocks to provide shelter.

In the waters off Newfoundland, spotted wolffish are found in deep water, in a water temperature range of -1°C to 6°C, and it is believed that temperature is a limiting factor in their distribution. The spotted wolffish grows slower than other wolffish species. Females mature at seven years and spawning occurs in the summer to late fall/early winter. Approximately 50,000 large eggs are laid on the seafloor and are guarded by the male until they hatch (COSWEIC 2012e, in BP 2016).

1.4.20 Thorny Skate

The thorny skate can be found from Baffin Bay, Davis Strait, Labrador Shelf, Grand Banks, Gulf of St. Lawrence, Scotian Shelf, and Bay of Fundy to Georges Bank. Highest concentrations can be found on the Eastern Scotian Shelf and the Lower Bay of Fundy (COSEWIC 2012a, in BP 2016). The species is present in a range of water depths, but primarily from 18 to 1,200 m on substrates including sand, shell hash, gravel, pebbles, and soft muds. They are typically found in water temperatures of 0°C to 10°C.

Thorny skates are a slow-growing species reaching maturity at 11 years of age. Females lay 6 to 40 eggs per year. It is believed that peak spawning occurs in the fall and winter months. The most recent data available for suggests that there are approximately 79,137,000 thorny skates, including approximately 36,940,000 mature individuals, on the Grand Banks. These numbers are estimates of minimum trawlable abundance derived from DFO demersal trawl surveys in NAFO Divisions 3NLOPs and averaged for the period of 2007 to 2009 (COSEWIC 2012b).

1.4.21 White Shark

The white shark is rare in the northwest Atlantic (32 records in 132 years), as it is the northern edge of their range. Recorded sightings near the Project include the northeast Newfoundland shelf. They can range in water depth from the surface to 1,300 m, are highly mobile, and migrate

seasonally (COSEWIC 2006b, in BP 2016). Individuals in Atlantic Canada are likely seasonal migrants belonging to a widespread Northwest Atlantic population (LGL 2014, in BP 2016).

Females are ovoviviparous with a gestation period of 14 months, giving birth to an average of seven pups. It is believed that pupping takes place in the Mid-Atlantic bight (COSEWIC 2006b, in BP 2016). There have been no surveys in Canadian waters to determine the population size of the white shark. Information on the global population size is sparse, although most sources agree that the species is relatively rare (COSEWIC 2006b, in BP 2016).

1.4.22 White Hake

In general, white hake reside on the Grand Bank, with high concentrations on the southwest slope (Amec 2014). They are generally found near the bottom and are commonly captured over fine sediment substrates such as mud but have also been recorded on sand and gravel (COSEWIC 2013, in Amec 2014). They prefer water depths ranging from 200 to 1,000 m. Juvenile white hake feed on shrimp, polychaetes, and small crustaceans. Adults feed on herring, cod, haddock, other hake species, redfish, mackerel, and other species found in the area.

Males reach maturity at two to four years with females maturing at three to five years. Female white hake can produce several million eggs each during the spawning season (DFO 2013l, in BP 2016). Once released, the eggs are buoyant and float near the surface until they hatch. Larvae and juveniles are pelagic until they reach a size of 50 to 60 mm, which can take two to six months (DFO 2013l, in BP 2016). Spawning occurs from late spring to early summer (COSEWIC 2013, in BP 2016). The abundance of juvenile and mature individuals has been estimated (COSEWIC 2013, in BP 2016). In the 1970s the abundance of juveniles was estimated to be 12 million, which increased to 32 million in the 1980s and since then has declined to an average of 13 million in 2006-2011 (COSEWIC 2013, in BP 2016). The abundance of mature individuals was estimated to be 15 million in the 1970s, declining to 6 million in 1980 and rebounding to 30 million in the mid-1980s. Since then, the adult abundance has declined to an average of 8.3 million between 2006 and 2011 (COSEWIC 2013, in BP 2016).

1.4.23 Winter Skate

Winter skate are found from southern Newfoundland to Cape Hatteras, North Carolina and in the Gulf of St. Lawrence (Scott and Scott 1988; COSEWIC 2015). In Canadian waters, they occur primarily in the warmest available water, avoiding temperatures less than 2°C (COSEWIC 2015). The winter skate is a bottom-dwelling species, most common at depths less than 111 m but can occur at depths of up to 371 m (COSEWIC 2015). Winter skate prefer to prey on rock crab and squid; however, also prey on annelid worms, amphipods, shrimp, razor clams and eat whatever small fish that are readily available (Collette and Klein-MacPhee 2002 in COSEWIC 2015).

Females are through to deposit from 40 to 70 egg cases annual (Kelly and Handson 2013b, in COSEWIC 2015) and the eggs can take up to 22 months to develop (Simon and Frank 1998, in COSEWIC 2015). Winter skate outside the Gulf of St. Lawrence mature at 75 cm total length and

at 13 years with a generation time estimated to be 18 years (COSEWIC 2015). Based on available survey data for the Eastern Scotian Shelf over the last 2.4 generations, the abundance of mature individuals was estimates to have declined by 98% (COSEWIC 2015).

2.0 MARINE MAMMALS

2.1 Mysticetes

2.1.1 Humpback Whale

The humpback whale is listed as special concern under Schedule 3 of SARA and is not listed under COSEWIC. Humpback whales have a cosmopolitan distribution, but typically occur in coastal regions or over the continental shelf (Jefferson et al. 2008, in Husky Energy 2012a). There are an estimated 12,000 individuals in the central and western North Atlantic Ocean (IWC 2016). The results of the summer 2007 aerial survey conducted by DFO as part of the TNASS generated an abundance estimate of 2,080 humpback whales in Atlantic Canadian waters (estimate not corrected for availability and perception biases) (Lawson and Gosselin 2009). Humpback whales were the most commonly encountered cetaceans during the Newfoundland and Labrador portion of the survey, with 144 sighting events and a combined abundance estimate of 1,427 individuals (Lawson and Gosselin 2009).

Humpback whales undergo annual migrations from summer foraging grounds in high latitudes to tropical breeding grounds during the winter. Four distinct summer foraging concentration areas in the North Atlantic have been described, based on genetic and individual identification studies: the Gulf of Maine, eastern Canada, western Greenland, and the eastern North Atlantic (Stevick et al. 2006, in Husky Energy 2012a). Winter breeding occurs in the West Indies in three primary areas: the Virgin Bank, Puerto Rico, and the Dominican Republic (Katona and Beard 1990, in Husky Energy 2012a). Additionally, not all individuals migrate to the tropics each year, with some presumably remaining near their foraging grounds in mid- and high-latitudes during winter (Clapham et al. 1993, in Husky Energy 2012a). Photographic records indicate that several adult humpbacks remain in Newfoundland waters year-round, particularly off the north coast (Waring et al. 2016).

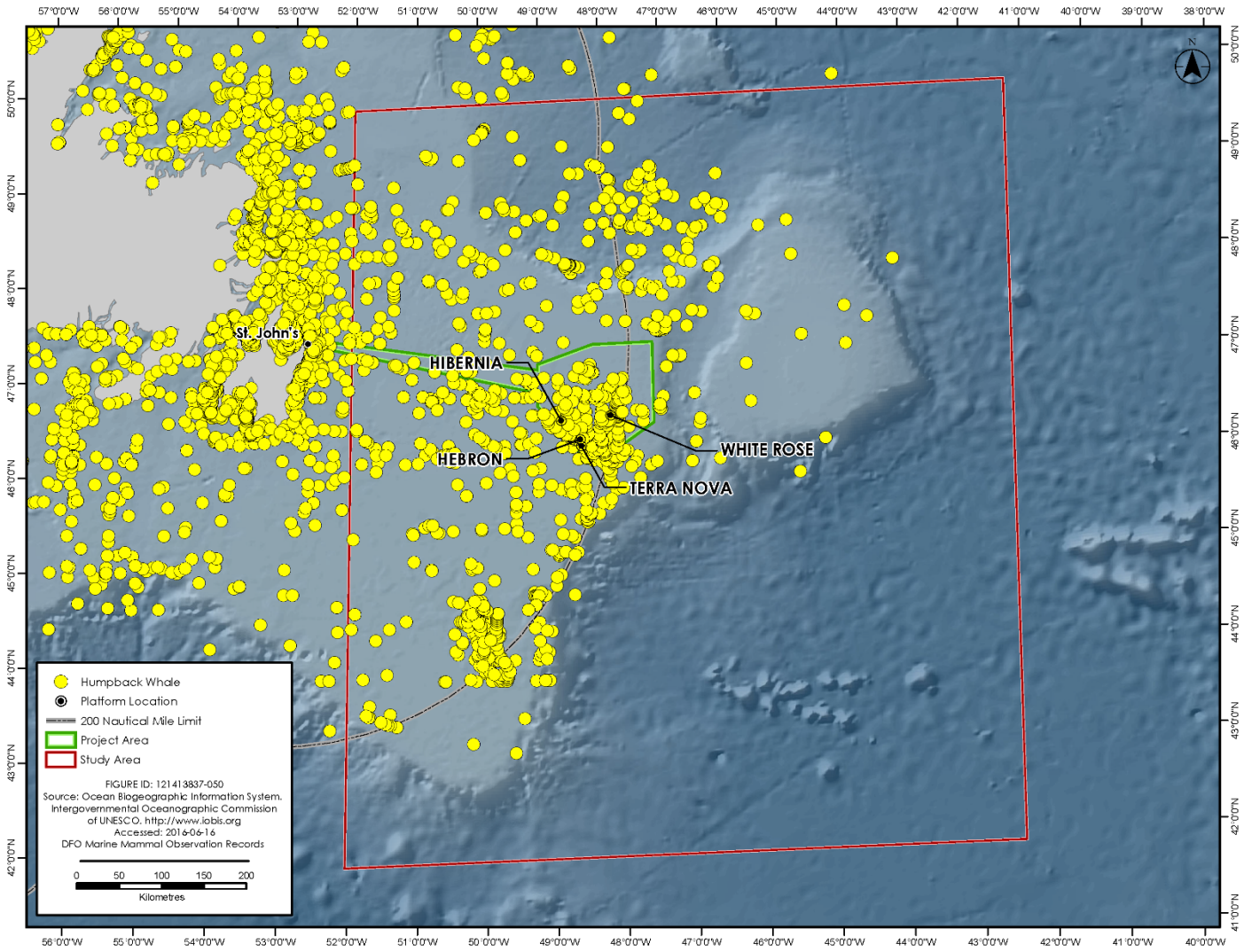
The humpback whale is common in Newfoundland waters, especially during summer. Humpback whales begin arriving in offshore areas by April and remain until October; they occur in inshore areas primarily from June to September. Some humpback whales likely stay in Newfoundland waters year-round. Humpback whales are common in the Study Area during early summer to fall, and a smaller number of animals may be present year-round. They are known to aggregate on the Southeast Shoal of the Grand Banks for summer foraging on capelin – their primary prey in Newfoundland waters (Whitehead and Glass 1985, in Husky Energy 2012a). Figure 2 represents visual observation data for humpback whales from 2004 to 2014, obtained from the OBIS dataset (Husum Marboe 2011; Hyrenbach et al. 2012; Kenney 2013; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).

2.1.2 Minke Whale

Minke whales can be found in every ocean around the world. Minke whales found in Canadian waters belong to the Canadian East stock inhabiting areas from the Gulf of Mexico in the south to the Davis Strait in the north (DFO 2011a, in BP 2016). Generally, minke whales are found along the continental shelf, feeding on plankton, krill, and small fish including capelin, cod, eels, herring, mackerel, salmon, sand lance and wolffish. minke whales are common in Canadian waters during the spring and summer. No observations of minke whales were noted from 2004 to 2014 in the study area (OBIS 2016).

The results of the summer 2007 aerial survey conducted by DFO as part of the TNASS generated an abundance estimate of 3,242 minke whales in Atlantic Canadian waters (estimate not corrected for availability and perception biases) (Lawson and Gosselin 2009). Fifty-three minke whales were encountered during the Newfoundland and Labrador portion of the survey, and the combined abundance estimate was 1,315 individuals (Lawson and Gosselin 2009).

Minke whales have a lifespan of approximately 50 years, and reach maturity at approximately six years of age for males, and seven years of age for females (DFO 2011a). It is believed that mating occurs during the winter in tropical and subtropical waters, followed by a gestation period of 10 to 11 months. Females give birth to a single calf.



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 2 Observation Data for Humpback Whales (2004 to 2014)

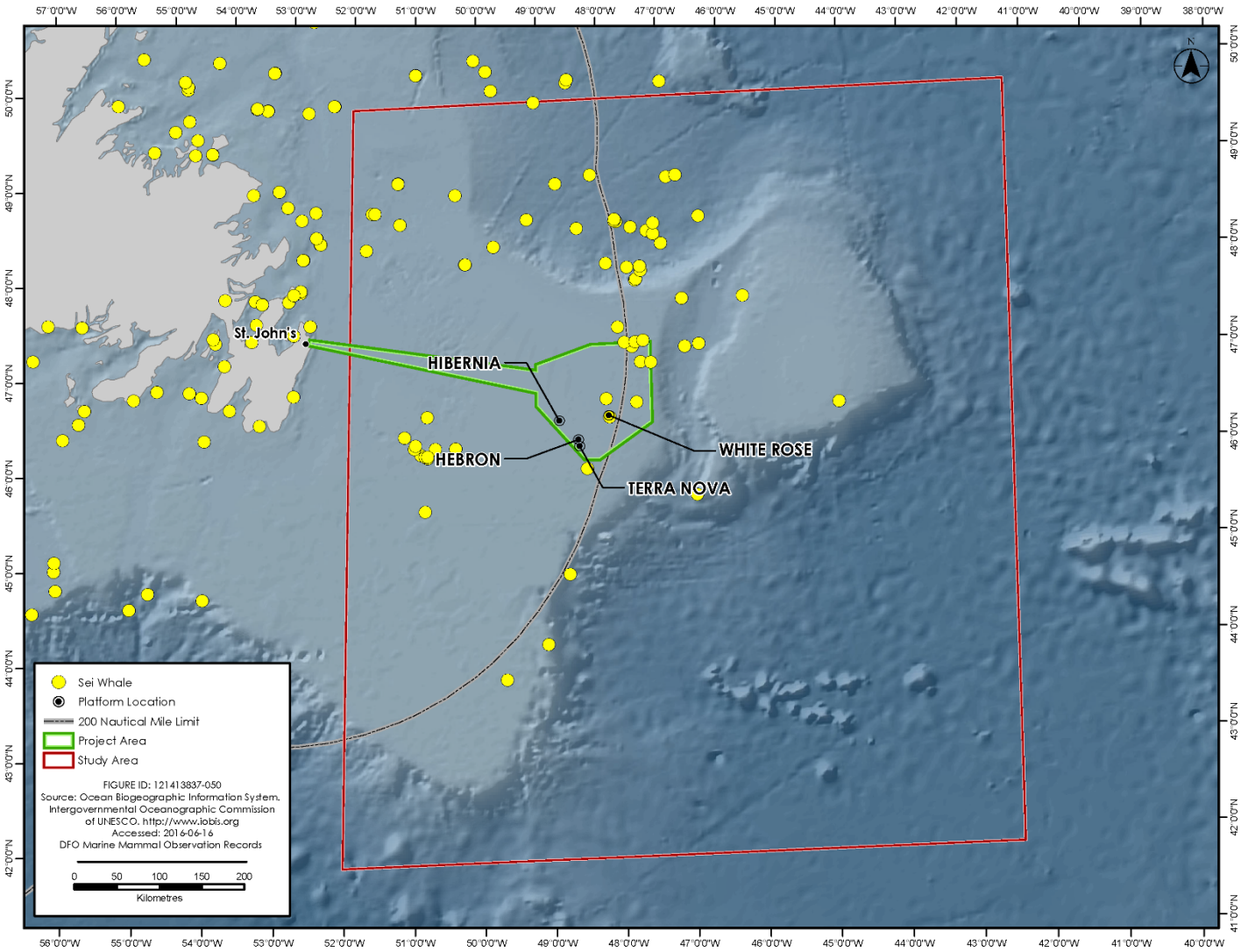
2.1.3 Sei Whale

In Atlantic Canadian waters sei whales can be found from Georges Bank in the south to Labrador in the north. There are two stocks of sei whales recognized in the Northwest Atlantic Ocean: a more well-known Nova Scotia stock, whose distribution extends from the northeastern US to the south of Newfoundland (Waring et al. 2016), and a Labrador Sea stock that extends northward from the southeastern coast of Newfoundland (NMFS 2011). The Nova Scotia stock was estimated in the summer of 2011 to contain 357 individuals, but this estimate is considered conservative (Waring et al. 2016). The putative Labrador Sea stock, proposed by Mitchell and Chapman in 1977, has remained relatively unexplored since commercial whaling for sei whales ceased in the late 1970s. No current population estimates are available for the Labrador Sea stock. It is unknown to what extent sei whales continue to use this region, and whether it is occupied by a unique stock or is used by animals from the Nova Scotia or Iceland-Denmark Strait stock (COSEWIC 2003). It is therefore unclear to which population animals occurring off eastern Newfoundland belong.

Sei whales reach maturity between 5 and 15 years of age, with a lifespan ranging from 50 to 70 years. Mating and calving occurs at lower latitudes during the winter months followed by a gestation period of 10 to 12 months (DFO 2011a, in BP 2016). Calves are weaned from their mothers at approximately six months of age.

Sei whales generally use pelagic habitats over deeper water of up to the 2,000 m depth, and tend to be found in areas with steep bathymetric relief like continental shelf breaks, seamounts, canyons, or basins near banks and ledges (Kenney and Winn 1987; Gregr and Trites 2001). Mitchell and Chapman (1977) hypothesized that sei whales in the Northwest Atlantic are migratory, moving from spring feeding areas on or near Georges Bank to the Scotian Shelf in June and July, eastward to Newfoundland and the Grand Banks in late summer, back to the Scotian Shelf in fall, and offshore and south during winter.

Available information suggests that sei whales are present near the Study Area during summer and fall months, but are likely uncommon in the Study Area. Figure 3 represents visual observation data for sei whales from 2004 to 2014; data were obtained from the OBIS dataset (Husum Marboe 2011; Hyrenbach et al. 2012; Harris 2015,) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 3 Observation Data for Sei Whales (2004 to 2014)

2.2 Odontocetes

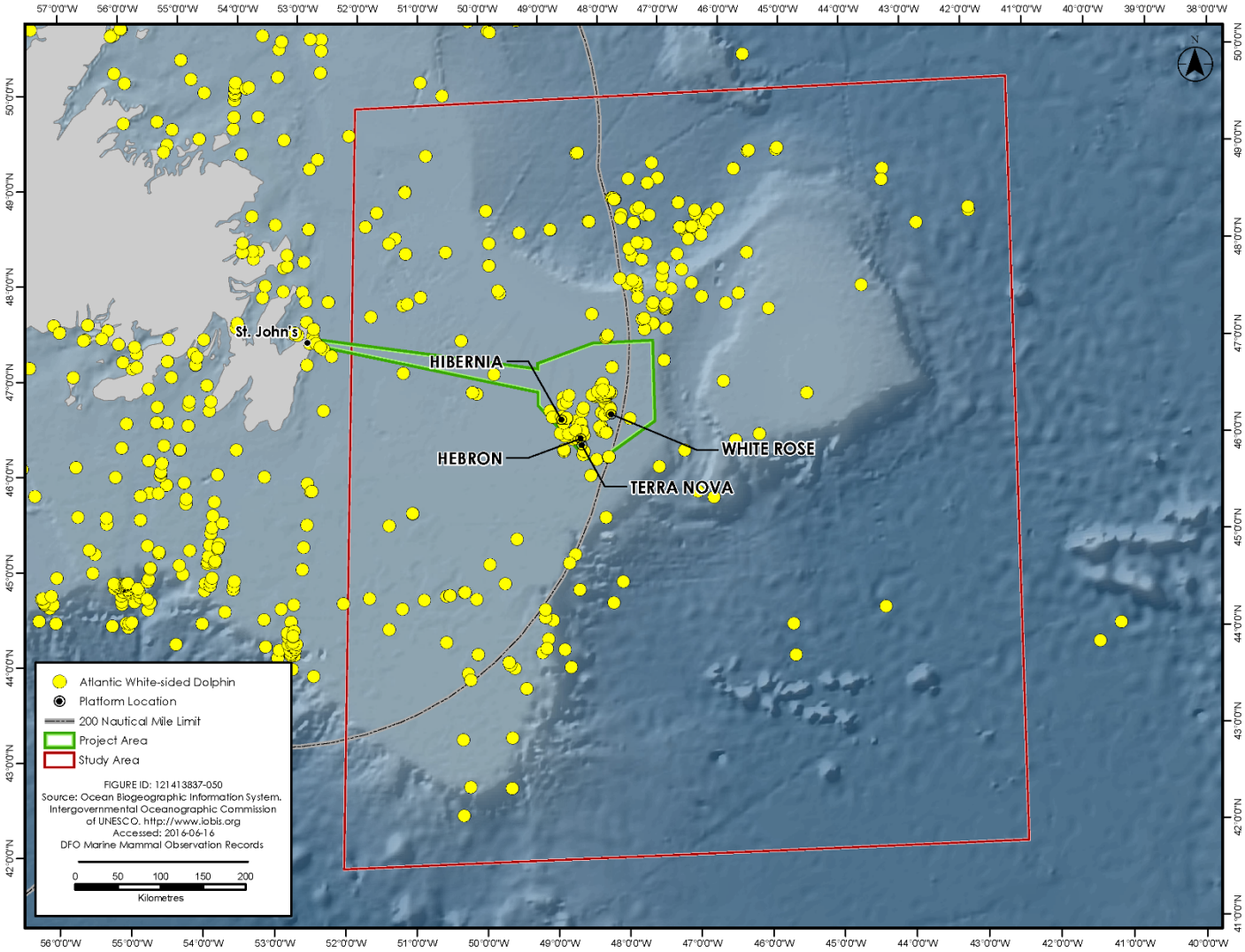
2.2.1 Atlantic White-sided Dolphin

Atlantic white-sided dolphins are distributed throughout the continental shelf and slope areas of the North Atlantic, and are primarily found in waters up to 100 m in depth between western Greenland to North Carolina (NOAA 2013n, in BP 2016). There are believed to be three stocks of this species: a Gulf of Maine stock, a Gulf of St. Lawrence stock, and a Labrador Sea stock. Based on the results of a survey conducted in 2011, there is an estimated 48,919 individuals in the Northwest Atlantic Ocean (Waring et al. 2016), but their abundance off eastern Newfoundland is unknown.

The results of the summer 2007 aerial survey conducted by DFO as part of the TNASS generated an abundance estimate of 5,796 white-sided dolphins in Atlantic Canadian waters (estimate not corrected for availability and perception biases) (Lawson and Gosselin 2009). The combined abundance estimate for white-sided dolphins in the Newfoundland and Labrador portion of the survey was 1,507 individuals (Lawson and Gosselin 2009).

Calving appears to occur from May to August, but peaks in June and July (Weinrich et al. 2001, in Husky Energy 2012a). Prey items range from cephalopods to pelagic or benthopelagic fishes like capelin, herring, hake, sand lance and cod (Selzer and Payne 1988; Weinrich et al. 2001, in Husky Energy 2012a). Primary habitat appears to coincide with the 100-m depth contour of the continental shelf, with sightings more common in areas with high sub-surface relief, and low sea surface temperatures and salinity (Selzer and Payne 1988, in Husky Energy 2012a).

Atlantic white-sided dolphins are regular inhabitants of eastern Newfoundland waters and have been observed to carry out seasonal distribution shifts. Generally, they move inshore and to the north in the summer, and offshore and south during the winter (NOAA 2014b, in BP 2016). The available data indicates that Atlantic white-sided dolphins are common in the Study Area, particularly from June to October. Figure 4 represents visual observation data for Atlantic white-sided dolphins from 2004 to 2014; data were obtained from the OBIS dataset (Hyrenbach et al. 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016: J. Lawson, DFO, pers. comm., 2016

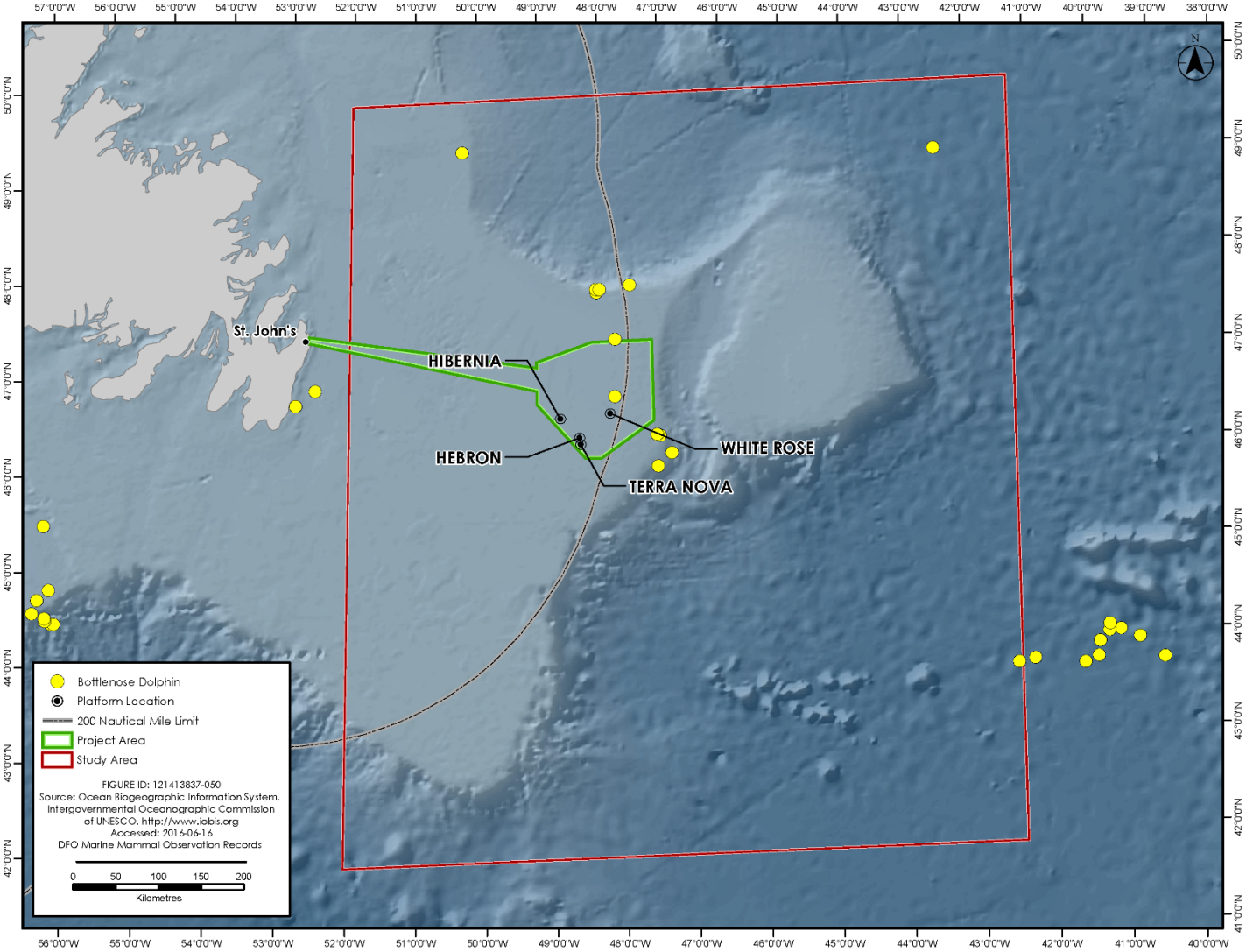
Figure 4 Observation Data for Atlantic White-sided Dolphins (2004 to 2014)

2.2.2 Bottlenose Dolphin

The bottlenose dolphin is one of the most well-known species of marine mammals, as it is the most common cetacean species in captivity (OBIS-SEAMAP 2014, in BP 2016). Bottlenose dolphins are found primarily in coastal and continental shelf waters of tropic and temperate regions, are considered generalists in terms of habitat, and have highly diverse and adaptable behavioural and social systems (OBIS-SEAMAP 2014, in BP 2016). They use high-frequency echolocation to locate and capture prey, which can include benthic invertebrates and fish in the nearshore, or pelagic squid and fish in the offshore (NOAA 2014d, in BP 2016). The main threats to this species include direct harvests and fisheries bycatch (OBIS-SEAMAP 2014, in BP 2016).

In the Northwest Atlantic, there are two morphologically and genetically distinct stocks, referred to as the coastal and offshore forms (Hoelzel et al. 1998, in Husky Energy 2012a). The offshore form tends to occur along the outer continental shelf and slope in the Northwest Atlantic Ocean, while the coastal form occurs from New York to Central Florida along the Atlantic coast (Waring et al. 2016). The population of the offshore form, potentially ranging into eastern Newfoundland waters, was estimated in 2011 to contain 77,532 individuals (Waring et al. 2016).

The distribution of bottlenose dolphins in higher latitudes appears to be seasonal, with a more northerly range during summer months (Shane et al. 1986). Bottlenose dolphins are considered at the northern limit of their range in eastern Newfoundland waters (Baird et al. 1993b, in Husky Energy 2012a). While it is possible that bottlenose dolphins will occur in the Study Area, particularly during summer, they are likely to be relatively rare. Figure 5 represents visual observation data for Atlantic bottlenose dolphins from 2004 to 2014; data were obtained from the OBIS dataset (Hyrenbach et al. 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

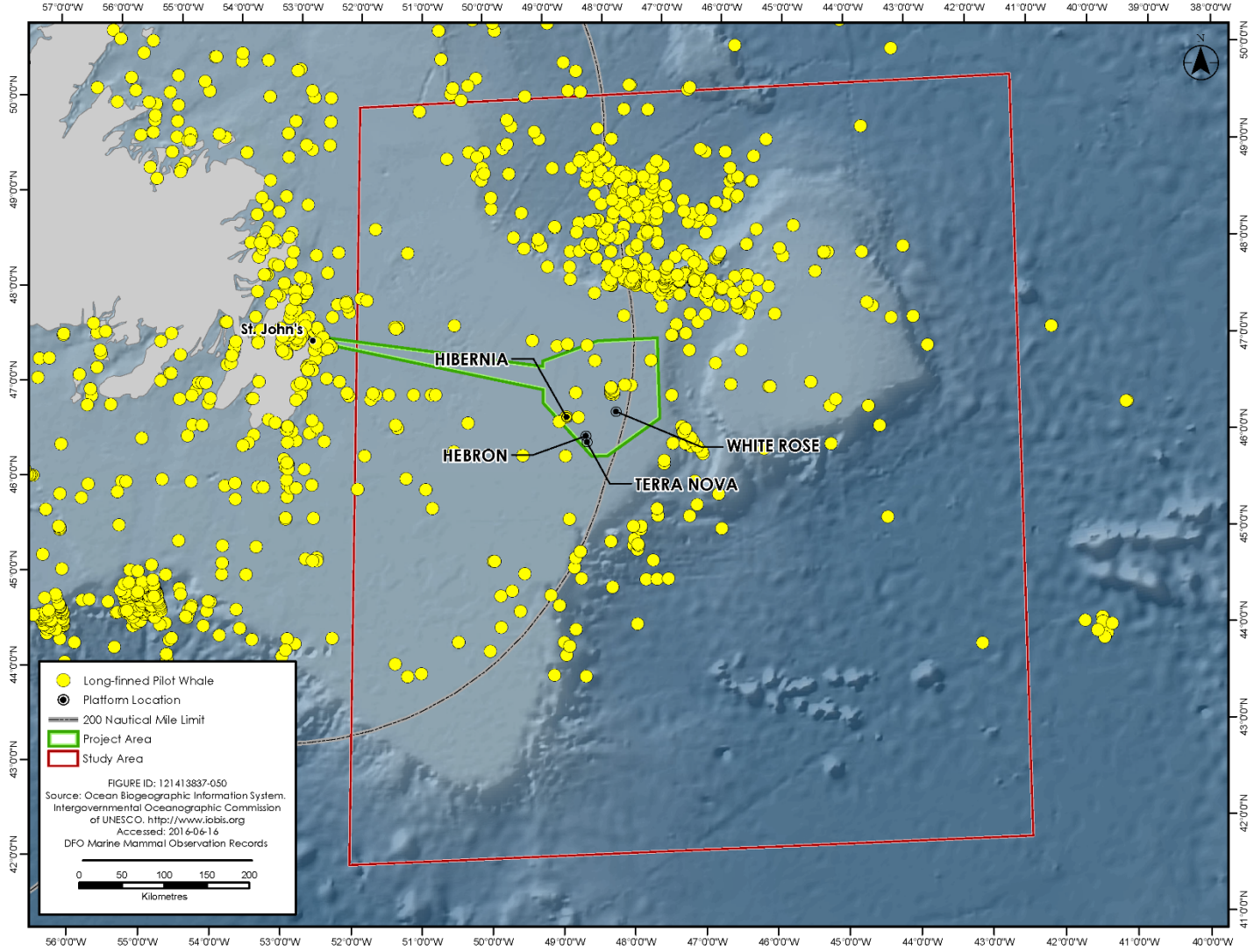
Figure 5 Observation Data for Bottlenose Dolphins (2004 to 2014)

2.2.3 Long-finned Pilot Whale

Long-finned pilot whales can be found from the waters off North Carolina to North Africa and north to Iceland, Greenland, and the Barents Sea (Waring et al. 2016). This species tends to inhabit areas of high relief and submerged banks, and is associated with the Gulf Stream and thermal fronts along the Continental Shelf (NOAA 2013n, in BP 2016). Based on the results of summer 2011 surveys covering waters from central Virginia to the lower Bay of Fundy, there are an estimated 5,636 individuals in the Northwest Atlantic; however, because these surveys did not include areas of the Scotian Shelf where the highest densities of pilot whales were observed in 2006, they are known to represent an underestimate the overall abundance of this stock (Waring et al. 2016). In 2004, the abundance of *Globicephala* spp. in the Northwest Atlantic Ocean was estimated to be 31,139 individuals, but that number may also include short-finned pilot whales (Waring et al. 2016). The results of the summer 2007 aerial survey conducted by DFO as part of the TNASS (refer to Section 4.2.5.1) generated an abundance estimate of 6,134 pilot whales in Atlantic Canadian waters (estimate not corrected for availability and perception biases) (Lawson and Gosselin 2009), but did not differentiate between short-finned and long-finned pilot whales.

Long-finned pilot whales in the North Atlantic mate and calve between April and September following a gestation period of 12 to 16 months (Reeves et al. 2002, NOAA 2014c, in BP 2016). The reproductive cycle for this species lasts between three and five years as females are not pregnant and lactating at the same time. The species feeds primarily on squid and mackerel.

Long-finned pilot whales are abundant year-round residents of Newfoundland waters (Nelson and Lien 1996, in Husky Energy 2012a). Long-finned pilot whales are expected to be common year-round in the Study Area, particularly during summer and fall. Figure 6 represents visual observation data for long-finned pilot whale from 2004 to 2014; data were obtained from the OBIS dataset (Husum Marboe 2011; Kenney 2012, Hyrenbach et al. 2012; Boisseau 2014; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 6 Observation Data for Long-finned Pilot Whale (2004 to 2014)

2.2.4 Risso's Dolphin

Risso's dolphins are widely distributed in tropical and warm temperate oceans (Jefferson et al. 2008, in Husky Energy 2012a). In the Northwest Atlantic, 18,250 individuals are estimated to occur from Florida to eastern Newfoundland (Waring et al. 2016). Eastern Canada appears to be at the northern limit of the Risso's dolphin's range, where an unknown number occur, but are considered rare (Baird and Stacey 1991, in Husky Energy 2012a).

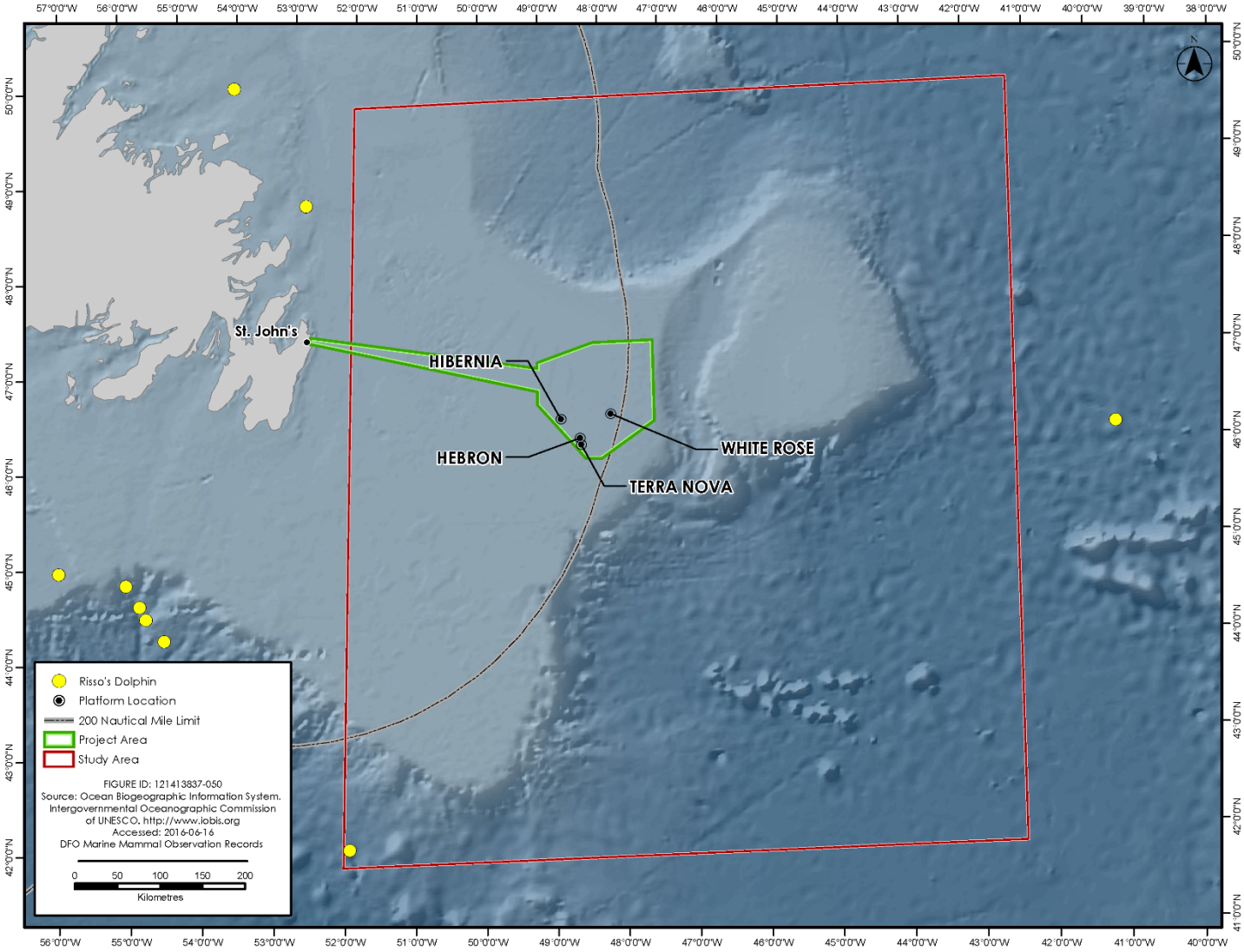
Risso's dolphin group sizes generally range from 10 to 100 animals, but groups of up to 4,000 individuals have been reported (Jefferson et al. 2008, in Husky Energy 2012a). They are often sighted in association with other cetacean species, and are thought to be deep divers. Squid are presumed to be their primary prey, but Risso's dolphin also consume crustaceans and other cephalopods (Jefferson et al. 2008, in Husky Energy 2012a). Risso's dolphin is primarily associated with steep portions of the continental slope that may concentrate cephalopod prey (Baumgartner 1997, in Husky Energy 2012a). Off the northeast US coast, they are distributed along the continental shelf edge during spring, summer, and autumn, but range into pelagic regions during winter (Waring et al. 2016).

Risso's dolphins are relatively abundant in warm temperate and tropical waters, but rarely range as far north as eastern Canada waters (Baird and Stacey 1991, in Husky Energy 2012a). While Risso's dolphin may occur in the Study Area, particularly deeper portions, its presence is likely to be rare. Figure 7 represents visual observation data for Risso's dolphins from 2004 to 2014; data were obtained from the OBIS dataset (Hyrenbach et al. 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).

2.2.5 Short-beaked Common Dolphin

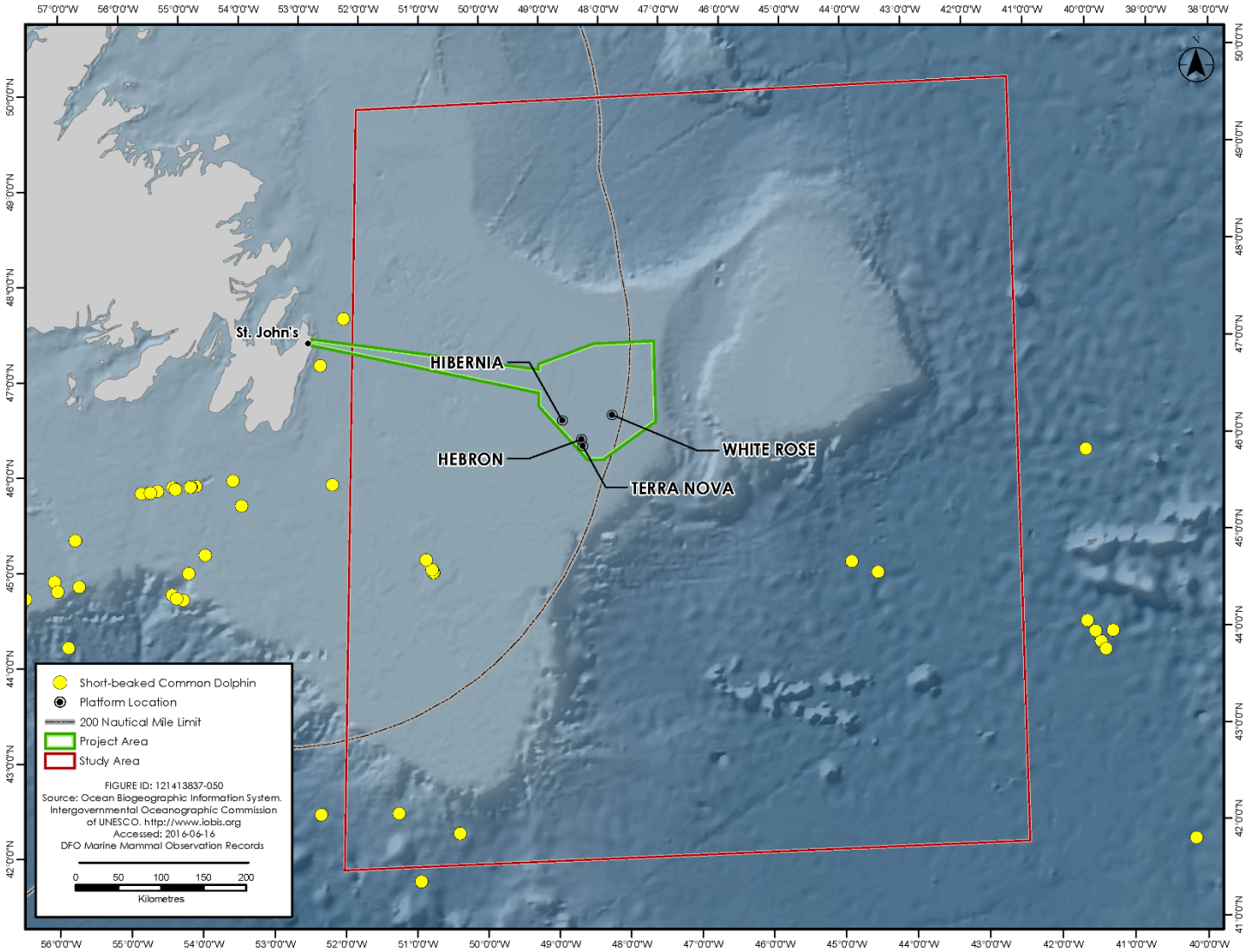
The short-beaked common dolphin is a widely distributed cetacean species, inhabiting tropical, sub-tropical, and temperate areas. In the Northwest Atlantic, the species can be found from Newfoundland to Florida (Reeves et al. 2002, in BP 2016). Gaskin (1992) indicated that common dolphins can be abundant off the coast of Nova Scotia and Newfoundland for a few months during the summer. Females remain in lower latitudes during calving and lactation periods in the late spring to early summer after a gestation period of 10 to 11 months (Reeves et al. 2002, in BP 2016). Short-beaked common dolphins feed primarily on schooling fish and squid. Whitehead and Glass (1985) reported seven sightings of common dolphins during surveys on the Southeast Shoal of the Grand Banks in June and July of 1982 and 1983, with group sizes ranging from 5 to 50 individuals.

During summer, it is likely that short-beaked common dolphins will occur in the Study Area. Figure 8 represents visual observation data for short-beaked common dolphin from 2004 to 2014; data were obtained from the OBIS dataset (Husum Marboe 2011; Kenney 2012, Hyrenbach et al. 2012; Boisseau 2014; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 7 Observation Data for Risso's Dolphin (2004 to 2014)



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 8 Observation Data for Short-beaked Common Dolphins (2004 to 2014)

2.2.6 Sperm Whale

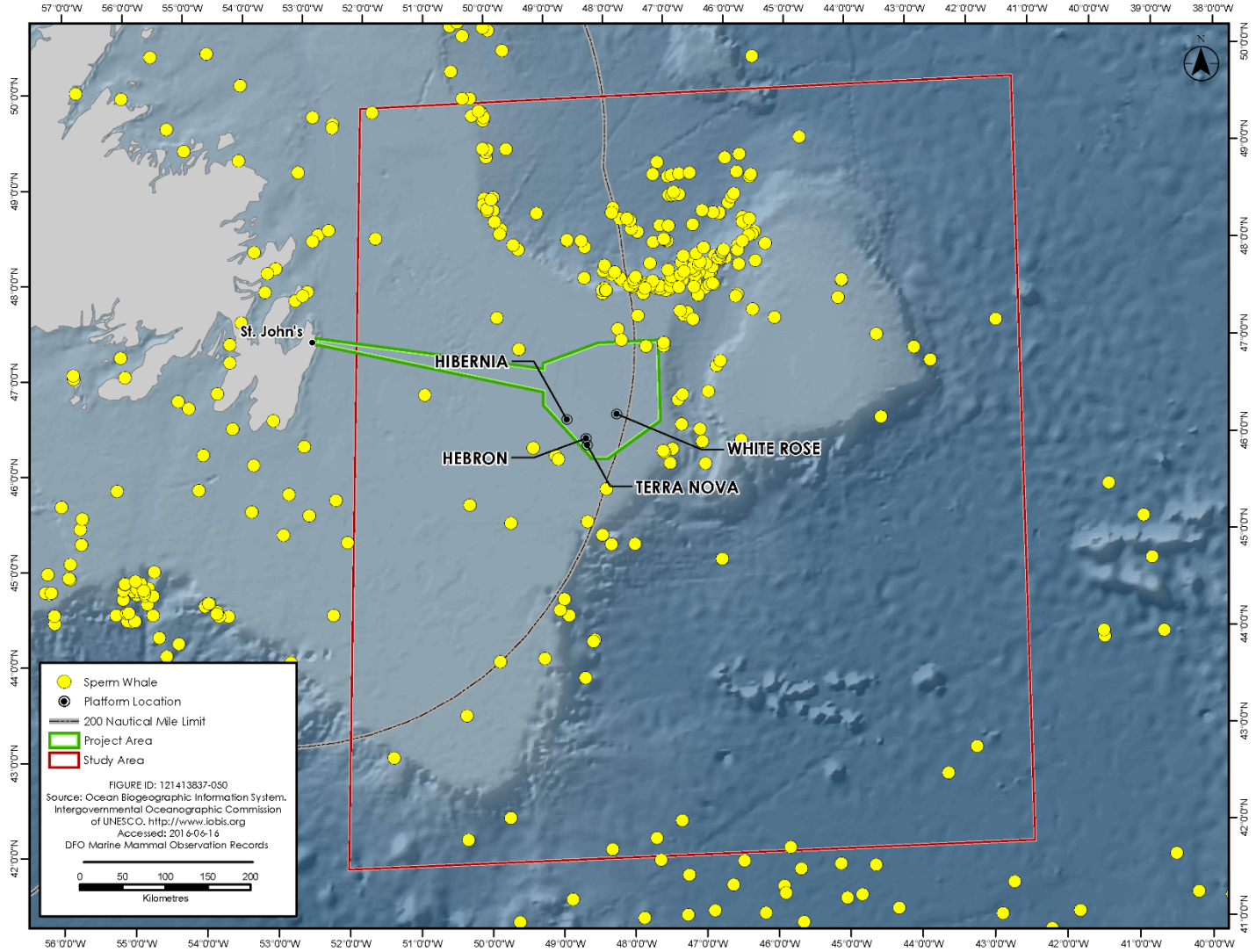
Sperm whales are the largest living toothed whales (approximately 18 m for an adult male (Reeves and Whitehead 1997, in Husky Energy 2012a)).

Sperm whales are widely distributed, occurring from the edge of polar pack ice to the equator, but are most common in tropical and temperate waters (Jefferson et al. 2008, in Husky Energy 2012a). Whitehead (2002) estimated a total of 13,190 sperm whales for the Iceland-Faroes area, the area to the northeast, and the east coast of North America combined, but Waring et al. (2016) estimated a total of only 2,288 sperm whales in the North Atlantic.

Sperm whale abundance and distribution in an area can vary in response to prey availability, particularly mesopelagic and benthic squid (Jaquet and Gendron 2002, Jaquet et al. 2003, in Husky Energy 201a). Sperm whales tend to occur in deep waters off the continental shelf, particularly in areas with high secondary productivity and steep slopes (Jaquet and Whitehead 1996). Distribution has also been linked to warm core rings of the Gulf Stream off the US continental shelf, with sightings occurring in water depths from 1,539 to 4,740 m (Griffin 1999, in Husky Energy 2012a). Sperm whales routinely dive to hundreds of metres, with maximum depths up to 3,000 m; foraging dives may last up to an hour and occur at depths below 1,000 m (Whitehead and Weilgart 2000, in Husky Energy 201a).

Males tend to range farther north than females, making sperm whales encountered in eastern Newfoundland more likely to be males. Adult females and juveniles form large aggregations in warm tropical and sub-tropical regions, but males typically occur singly or in small same-sex groups at higher latitudes (Whitehead et al. 1992, Whitehead and Weilgart 2000, Whitehead 2003, in Husky Energy 2012a). However, males can also sometimes form large aggregations of 20 to 30 individuals (Whitehead 2003), and mixed groups containing females and juveniles have occasionally been observed in higher latitudes (e.g., Whitehead and Weilgart 2000, in Husky Energy 2012a).

Sperm whales may periodically occur in the Study Area, but are relatively uncommon; they would most likely be found in deeper portions of the Study Area and during the summer months. It has been noted that sperm whales have been attracted to fishing operations on the Grand Banks and, therefore, may approach other vessels as well (DFO, pers. comm., in Husky Energy 2012a). Figure 9 represents visual observation data for sperm whale from 2004 to 2014, data were obtained from the OBIS dataset (Husum Marboe 2011; Kenney 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 9 Observation Data for Sperm Whale (2004 to 2014)

2.2.7 Striped Dolphin

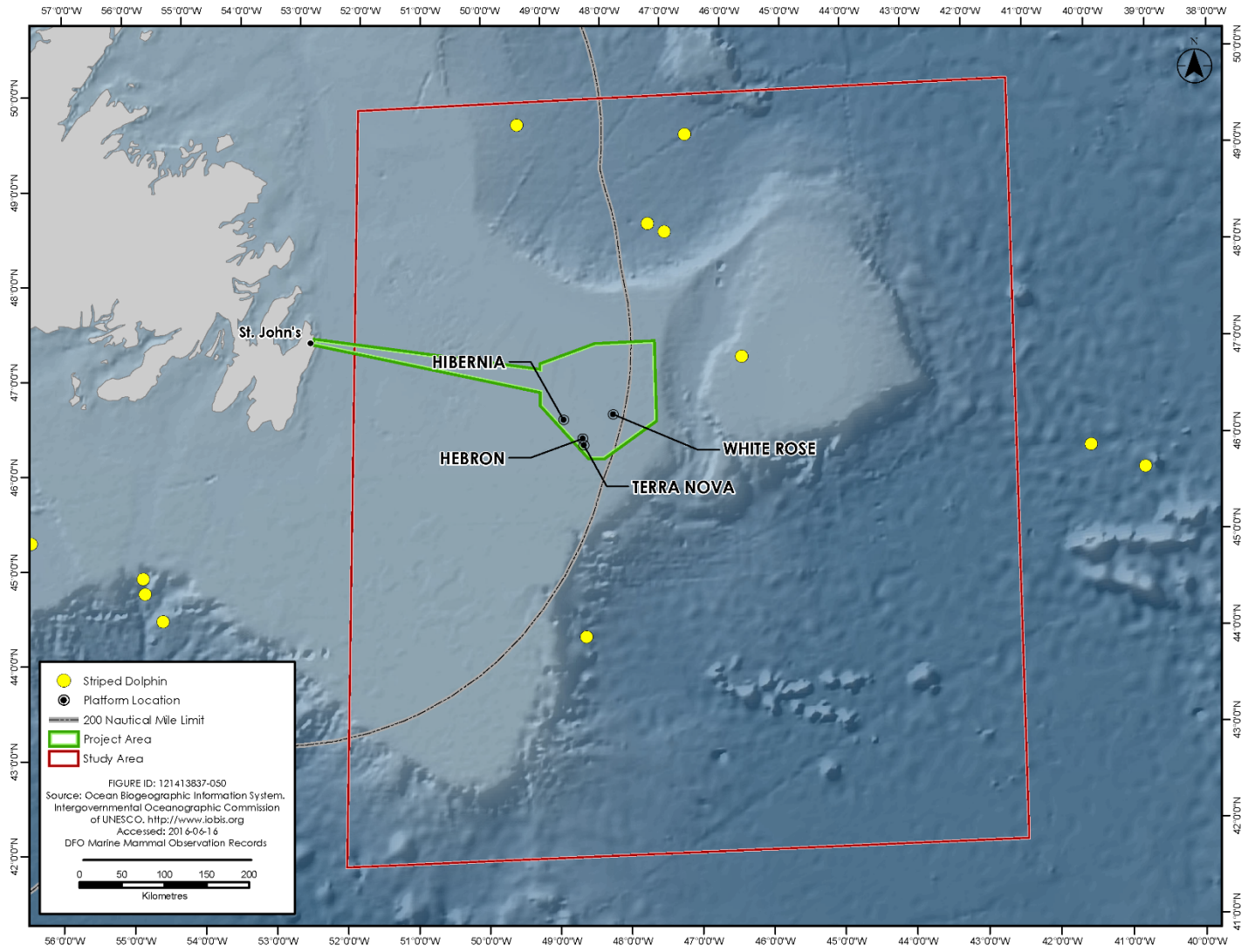
The striped dolphin can be found from Cape Hatteras to the southern margin of Georges Bank as well as offshore on the continental slope and the mid-Atlantic regions. In general, striped dolphins prefer continental slope waters offshore to the Gulf Stream (NOAA 2013n, in BP 2016). Offshore waters of the Grand Banks are at the northern limit of the striped dolphin's range. In 2011, the abundance of striped dolphins in the Northwest Atlantic Ocean was estimated to be 54,807 individuals (Waring et al. 2014, 2016).

Striped dolphins prey upon small schooling fish species such as herring, capelin, mackerel, and squid (Reeves et al. 2002, in BP 2016). Striped dolphins are born in the late summer or early fall after a gestation period of one year. Calving takes place in large schools of 30 or more individuals comprised of adults, calves and juveniles for a period lasting four years (Reeves et al. 2002, in BP 2016).

Available information suggests that the presence of striped dolphins is likely to be uncommon in the Study Area, but they could potentially occur there during summer and fall. Figure 10 represents visual observation data for striped dolphin from 2004 to 2014, data were obtained from the OBIS dataset (Husum Marboe 2011; Kenney 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).

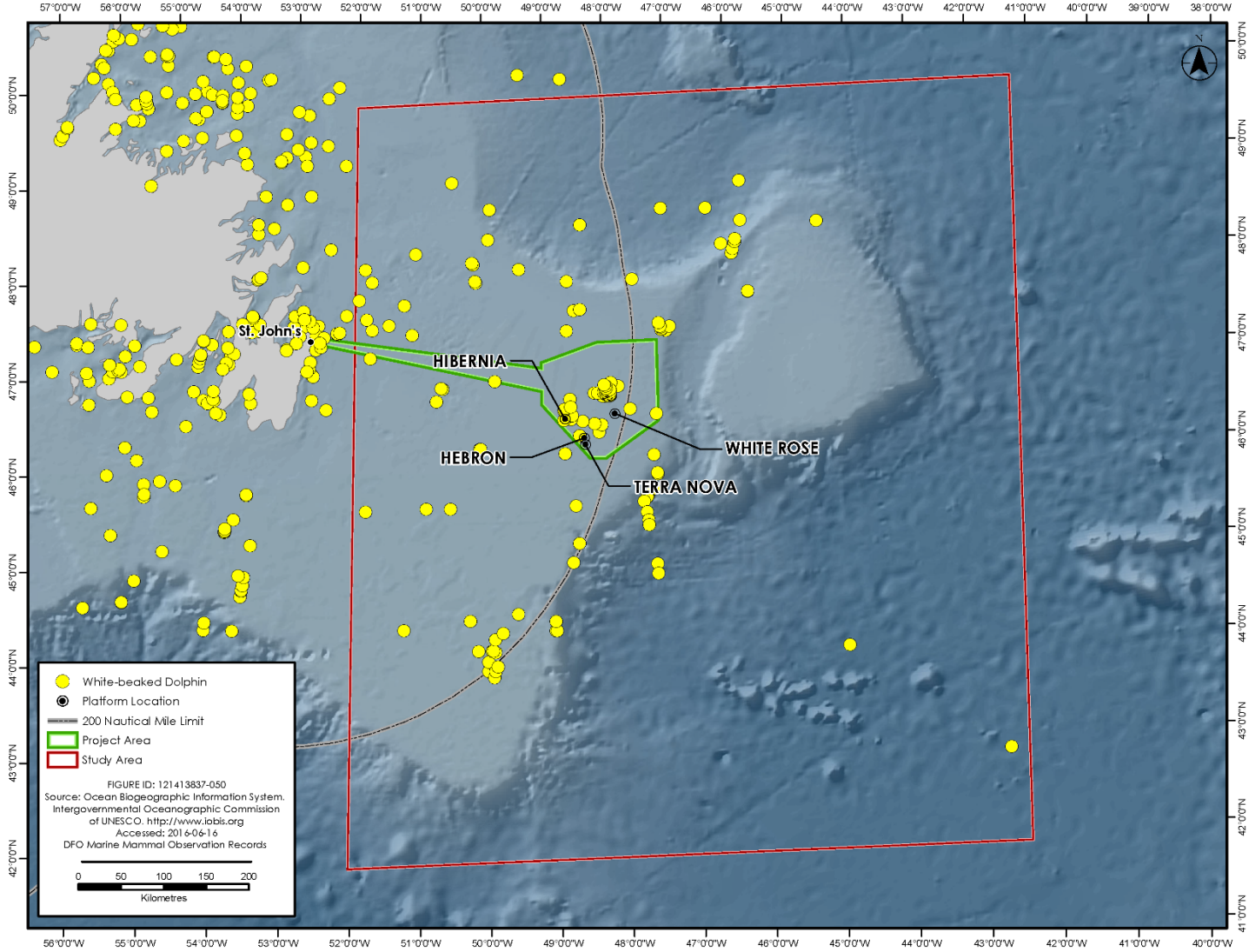
2.2.8 White-beaked Dolphin

The white-beaked dolphin is a year-round resident in waters from Cape Cod to Greenland. It is usually found in social groups of 5 to 30 individuals, and occasionally in groups as large as 1,500 (NOAA 2012b, in BP 2016). Little information is known about the reproductive cycle of the white-beaked dolphin. It is believed that this species calves from May to September after a gestation period of 11 to 12 months (NOAA 2012b, in BP 2016). White-beaked dolphins prey on small schooling fish species such as herring and capelin, squid, cod, haddock, octopus, as well as crustaceans (Reeves et al. 2002, in BP 2016). Figure 11 represents visual observation data for white-beaked dolphin from 2004 to 2014; data were obtained from the OBIS dataset (Husum Marboe 2011; Kenney 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 10 Observation Data for Striped Dolphin (2004 to 2014)



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 11 Observation Data for White-beaked Dolphin (2004 to 2014)

2.3 Phocids

2.3.1 Grey Seal

Grey seals are found throughout cold temperate to sub-Arctic waters of the North Atlantic, including areas of Nova Scotia, the Gulf of St. Lawrence and Newfoundland (Jefferson et al. 2008, in Husky Energy 2012a). The largest breeding colony in the North Atlantic is on Sable Island, south of Nova Scotia, and it is estimated to consist of well over 250,000 individuals (DFO 2011). At the end of the 2010 breeding season, the total population of grey seal herds on Sable Island, in coastal Nova Scotia, and in the Gulf of St. Lawrence was estimated to be 348,900 individuals, including pups (DFO 2011). No pupping colonies have been observed in Newfoundland (DFO 2011).

Grey seals tend to be less tied to coastal and island rookeries than are harbour seals, but foraging still appears to be restricted to continental shelf regions (Austin et al. 2006, in Husky Energy 2012a). Grey seal prey species include herring, Atlantic cod, and sand lance (Lesage and Hammill 2001). Pupping occurs between September and March, with a peak in January in Canada (Lesage and Hammill 2001).

The number of grey seals to occur in the Study Area is unknown, but is likely small. Based on available information, it is expected that grey seal would be rare in the Study Area.

2.3.2 Harbour Seal

Harbour seals have a widespread distribution in the northern hemisphere, but are generally only found in coastal waters (Jefferson et al. 2008, in Husky Energy 2012a). In the Northwest Atlantic, harbour seals range from northern Florida to northern Baffin Island and along Greenland's southern coast (Bigg 1981, in Husky Energy 2012a). There were an estimated 75,834 individuals in the Northwest Atlantic Ocean in 2012 (Waring et al. 2016). Hammill and Stenson (2000) estimated a total of approximately 5,120 harbour seals in Newfoundland and Labrador in 1996, and further information suggests there may be at least 1,000 animals in coastal Newfoundland alone (Sjare et al. 2005a, COSEWIC 2007a, in Husky Energy 2012a).

Harbour seals are found in coastal areas, rarely more than 20 km from shore, and often enter bays, estuaries, and inlets where they sometimes also follow anadromous salmonids up coastal rivers (Baird 2001, in Husky Energy 2012a). They periodically haul out of the water at coastal sites, usually rocky outcroppings, and intertidal ledges. Primary prey species in Newfoundland waters include winter flounder, cod, and sculpins (Sjare et al. 2005a, in Husky Energy 2012a).

Females generally have one pup every year, with the pupping extending for one to two months with a two-week peak. The timing of pupping is variable and becomes progressively later at higher latitudes (i.e., approximately 1.7 days later per degree latitude) such that it ranges from late May in Maine to late June or early July on Southampton and Baffin Islands. Pups are weaned at approximately four weeks of age (COSEWIC 2007). Mating also tends to occur during pupping

season. Moulting occurs from mid-summer to early fall, and harbour seals haul out more frequently than at other times of the year.

Harbour seals are considered year-round residents of coastal Newfoundland (Sjare et al. 2005a, in Husky Energy 2012a). In comparison with other seal species in Newfoundland waters, spatial and temporal distribution and abundance is poorly known (Hammill and Stenson 2000, in Husky Energy 2012a). Harbour seals are unlikely to occur within he Study Area, based on their preference for coastal waters.

2.3.3 Harp Seal

The harp seal is found throughout the North Atlantic and Arctic Ocean, from the Gulf of St. Lawrence to Russia (Jefferson et al. 2008, in Husky Energy 2012a). Harp seals are the most abundant seal in the Northwest Atlantic, with an estimated population size of 8 million in 2008 (DFO 2011d, in Husky Energy 2012a). The majority of these seals aggregate off the east coast of Newfoundland and Labrador to pup and breed, with the remainder of the animals whelping in the Gulf of St. Lawrence (Lavigne and Kovacs 1988, in Husky Energy 2012a).

Harp seal diets off eastern Newfoundland and Labrador were estimated to primarily consist of capelin, Arctic cod, and sand lance, although Atlantic herring, Atlantic cod, redfish, and Greenland halibut were also substantial contributors to their diet (Hammill and Stenson 2000, in Husky Energy 2012a). During the summer, the Northwest Atlantic population of harp seals is found in the Canadian Arctic and Greenland before migrating south in the fall (DFO 2000, in Husky Energy 2012a). Dedicated at-sea surveys and data from satellite-tagged animals indicate that harp seals spend most of their time in offshore areas of southern Labrador and eastern Newfoundland during the winter (Stenson and Sjare 1997, Lacoste and Stenson 2000, in Husky Energy 2012a). Pups are born on the ice in late February or March, are nursed for approximately 12 days, then mate as adults and disperse (DFO 2000, in Husky Energy 2012a). Births typically begin in early March and peak around March 8 to 10 (Stenson et al. 2005, in Husky Energy 2012a). Older seals also aggregate to moult off northeastern Newfoundland and in the northern Gulf of St. Lawrence in April and May before migrating northward (DFO 2000, in Husky Energy 2012a).

The Jeanne d'Arc Basin and adjacent areas overlap with regions where harp seals have been observed during January and February (Lacoste and Stenson 2000, in Husky Energy 2012a). During years when pack ice extends into Jeanne d'Arc Basin, harp seals may use the region for spring pupping, mating and moulting.

Hooded Seal

Hooded seals occur in the North Atlantic and range from Nova Scotia to the high Arctic (Jefferson et al. 2008, in Husky Energy 2012a). However, it is common for hooded seals, particularly juveniles, to occur outside their normal range (Waring et al. 2007). The Northwest Atlantic stock of hooded seals whelps in three areas off Canada's east coast. The largest herd (i.e., the Front herd) breeds off the Newfoundland and Labrador northeast coast, the Gulf herd breeds in the Gulf of St. Lawrence, and a third herd breeds in the Davis Strait area of the Labrador Sea (Waring et al. 2007). Surveys of these pupping areas were carried out in 2005 and it was estimated that total pup production in the Northwest Atlantic was 116,900; 107,013 pups were born in the Front herd; 6,620 pups were born in the Gulf herd; and 3,346 pups were born in the Davis Strait herd (Waring et al. 2007). The total population of the Northwest Atlantic stock of hooded seals was estimated to be 592,100 in 2005 (Waring et al. 2007), and that number has not been updated in subsequent stock assessment reports (Waring et al. 2016).

Hooded seals seem to prefer deeper water and occur farther offshore than harp seals (Lavigne and Kovacs 1988, in Husky Energy 2012a). Birth takes place on the ice, and pups are weaned in approximately four days, after which they are abandoned by the female (Lavigne and Kovacs 1988, in Husky Energy 2012a). On average, pupping off northeast Newfoundland is completed by 28 March, but has ranged from March 18 to April 4; pups may spend several more weeks on the ice before entering the water and dispersing (Hammill and Stenson 2006b, in Husky Energy 2012a). Following whelping, hooded seals aggregate in the pack ice off eastern Greenland to moult during June-July before dispersing to the Greenland Sea or Davis Strait during the summer and fall (see Hammill and Stenson 2006a, in Husky Energy 2012a). Little is known about their winter distribution, but they have been observed feeding around the northern edge of the Grand Banks during winter (Stenson and Kavanagh 1994, in Husky Energy 2012a). Recent work suggests that hooded seals move along the continental shelf to Davis Strait and Baffin Bay after moulting in July, followed by southerly migrations into the Labrador Sea, before reaching breeding grounds in the spring (Andersen et al. 2009, in Husky Energy 2012a).

Recent studies of satellite-tagged hooded seals indicate that at least some individuals enter the Study Area in February, presumably to reach the Flemish Cap for winter foraging (Andersen et al. 2009, in Husky Energy 2012a). Hooded seals have also occurred in and near the Study Area during transit to moulting areas in May and June (Bajzak et al. 2009, in Husky Energy 2012a). Available information on their offshore distribution suggests that hooded seals may occasionally occur in the Study Area during winter and spring, particularly if seasonal pack ice extends into the Study Area.

2.4 Species at Risk

2.4.1 Mysticetes (Baleen Whales)

2.4.1.1 Blue Whale

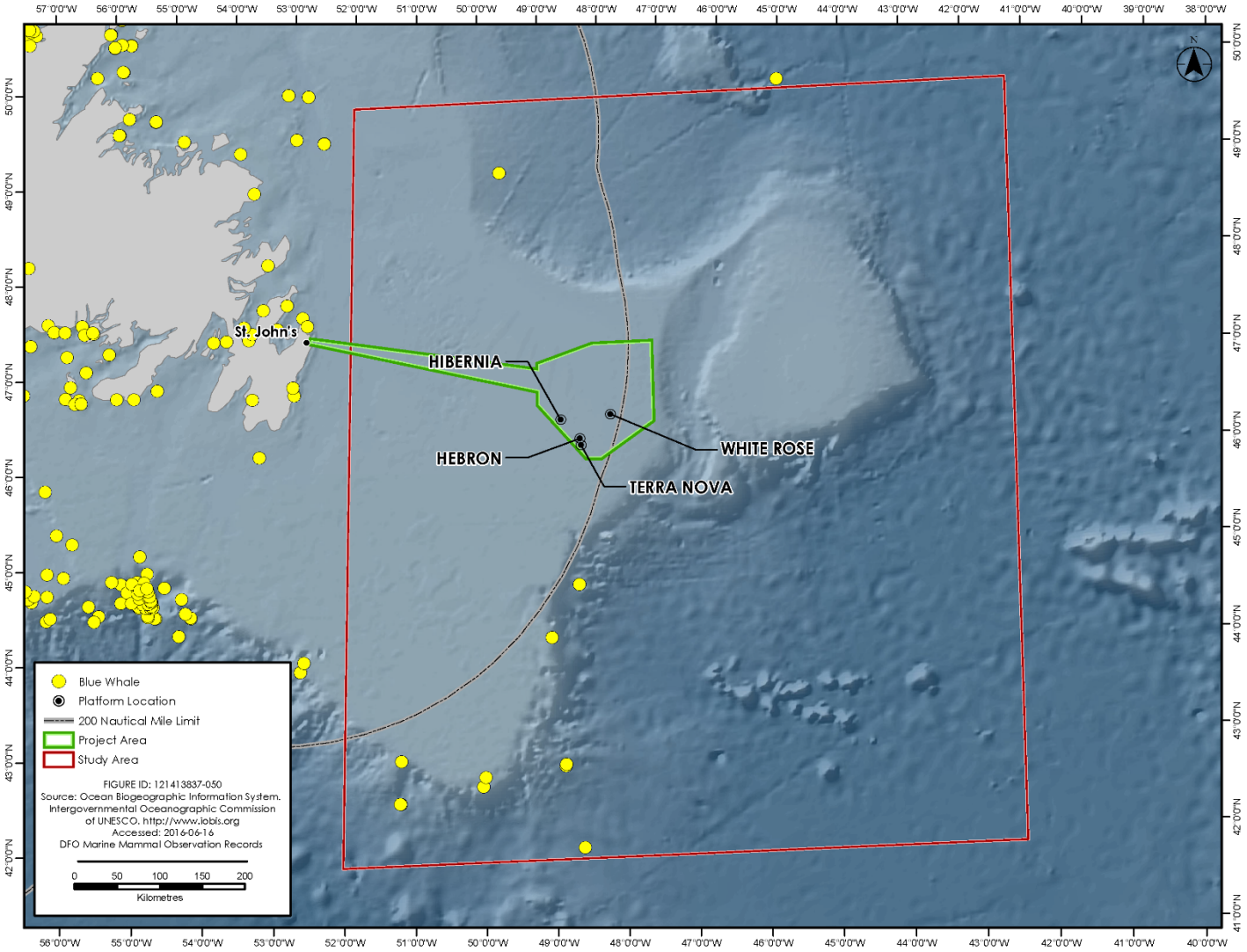
The blue whale is listed as endangered under both SARA (Schedule 1) and COSEWIC. The blue whale has a large range, with the Atlantic population observed mainly in the St. Lawrence Estuary and shallow coastal zones where mixing and upwelling produce high numbers of krill (Beauchamp et al. 2009; LGL 2014, in BP 2016). Blue whales feed in these cold upwelling zones in temperate and polar waters from spring to early winter. In Canadian waters, blue whales occur in the Gulf of St. Lawrence during the spring, summer, and fall (especially along the north shore of the Gulf from the St. Lawrence River estuary to the Strait of Belle Isle and off eastern Nova Scotia) and occur in the winter off southern Newfoundland. They also frequent the Davis Strait during the summer (Waring et al. 2016). No observations of blue whales were noted from 2004 to 2014 in the Study Area (OBIS 2016).

Little is known about the population size of blue whales except for within the Gulf of St. Lawrence area. A total of 440 individuals have been catalogued in the Gulf of St. Lawrence area (mainly in the St. Lawrence estuary and Gulf of St. Lawrence) from 1970 to the summer of 2009; this is a minimum population estimate for the western North Atlantic stock (Waring et al. 2016) and has not been updated in subsequent stock assessment reports (Waring et al. 2016).

Compared with other cetacean species, blue whales are uncommon in eastern Newfoundland waters. The blue whale has a low population density and can be found in small migrant herds, surfacing every 5 to 15 minutes for breath.

Blue whales mate and calve from late fall to mid-winter in the Northern Hemisphere (COSEWIC 2002b, in BP 2016). Male and female blue whales reach sexual maturity from 5 to 15 years. Females give birth to a single calf every two to three years after a gestation period of 10 to 11 months. The life expectancy of blue whales is believed to be approximately 70 to 80 years, possibly longer. Blue whales feed almost exclusively off krill in both coastal and offshore waters, especially in areas of upwelling where productivity is high (DFO 2011a, in BP 2016).

A Recovery Strategy has been published for the Northwest Atlantic population of blue whale (Beauchamp et al. 2009). The Strategy identifies nine threats to the blue whale population, including whaling, natural mortality, anthropogenic noise, food availability, contaminants, collisions with vessels, whale watching, accidental entanglement in fishing gear, epizootics and toxic algal blooms and toxic spills (Beauchamp et al. 2009). It concludes that the recovery of the Northwest Atlantic blue whale population is feasible and sets a target of increasing the current population to 1,000 mature individuals. Figure 12 represents visual observation data for blue whales from 2004 to 2014; data were obtained from the OBIS dataset (Husum Marboe 2011; Kenney 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

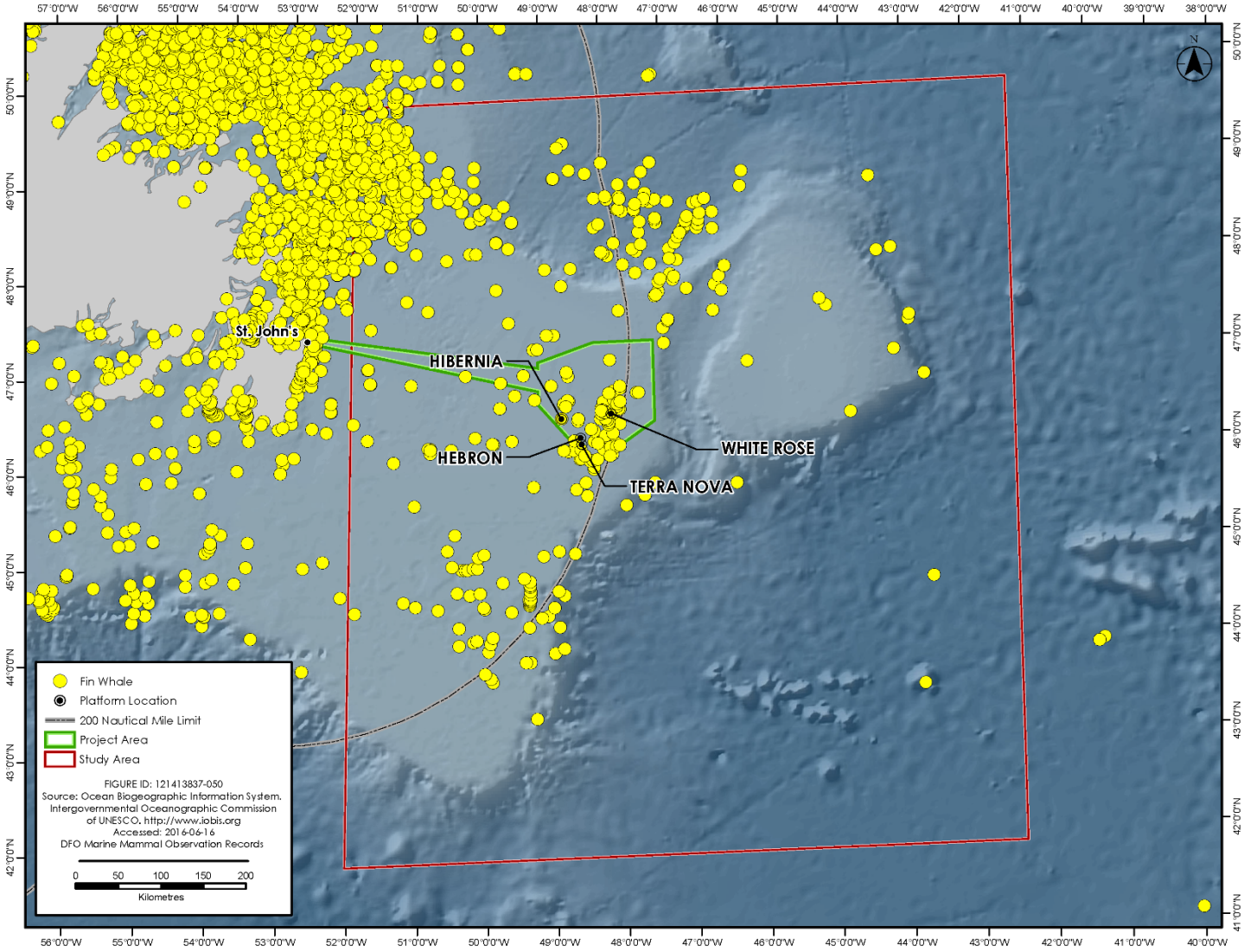
Figure 12 Observation Data for Blue Whales (2004 to 2014)

2.4.1.2 Fin Whale

The fin whale is listed as special concern under SARA Schedule 1 and under COSEWIC. Fin whales regularly occur in northeastern and eastern Newfoundland waters, particularly from early summer to late fall. Based on aerial surveys conducted from northern Labrador to the Scotian Shelf in July to August 2007, an estimated 1,967 fin whales occur in this region (LGL 2014, in BP 2016). The abundance estimate for the western North Atlantic stock is 3,522 individuals (LGL 2014, in BP 2016).

Fin whales reach sexual maturity at 5 to 15 years of age. There is little known information on where they spend their winter months or the location of calving and breeding areas (DFO 2011a, in BP 2016). It is believed that mating and calving occur in temperate waters at low latitudes during the winter months and is followed by a gestation period of 11 to 12 months. The calf will wean from its mother over six to seven months until reaching a winter feeding ground. Females give birth every two to three years. The fin whale is a filter feeder, feeding on small schooling fish such as herring and capelin, squid, and crustaceans including mysids and krill. Figure 13 represents visual observation data for fin whales from 2004 to 2014; data were obtained from the OBIS dataset (Husum Marboe 2011; Kenney 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).

A Recovery Strategy has been recently published for the fin whale, Atlantic population (DFO 2017). Whaling during the 20th century contributed to the reduction of the fin whale population; however, the species has not been hunted since 1971 in Canada (DFO 2017). Several factors are noted in the strategy as a threat to the population of Atlantic fin whale, including, concern related to noise, such as seismic exploration and navigation, food availability, toxic spills, ship strikes and whaling (DFO 2017).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

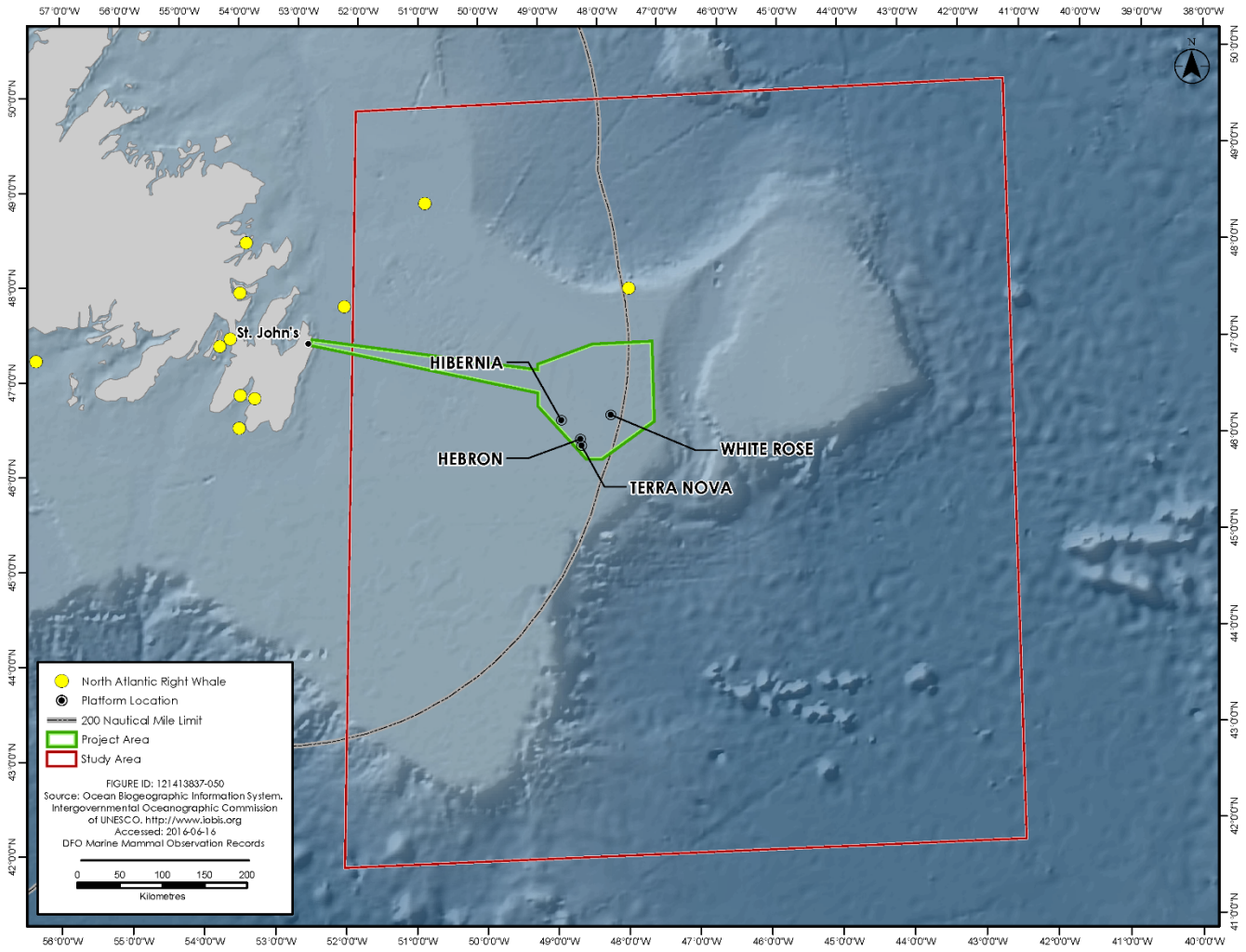
Figure 13 Observation Data for Fin Whales (2004 to 2014)

2.4.1.3 North Atlantic Right Whale

The North Atlantic right whale is listed as endangered under Schedule 1 of SARA and under COSEWIC. The North Atlantic right whale can be found from the coastal waters of the US to Newfoundland and the Gulf of St. Lawrence (DFO 2011a, in BP 2016). Adult females give birth in the coastal southern US, whereas males and non-calving females are rarely seen in this area, although their winter locations are largely unknown (DFO 2011a, in BP 2016). There are over-wintering aggregations that are known to reside in Cape Cod Bay and the central Gulf of Maine. A northern migration from the calving grounds occurs in the late winter and early spring with mother and calf pairs moving along the shore. During the spring, right whales can be seen feeding and socializing in the Great South Channel, Cape Cod Bay, and Massachusetts Bay. By July, right whales can be found in their critical habitats, including the Grand Manan Basin in the lower Bay of Fundy and the Roseway Basin on the Western Scotian Shelf. From October into the winter a southern migration can be observed with whales returning to the warmer waters of the southern US coast (DFO 2011a, in BP 2016). There have been rare sightings off southern Newfoundland (Sergeant 1966; Gaskin 1991, in Husky Energy 2012a).

Right whales migrate to Canadian waters to feed. Their main prey items include large and oil-rich copepods as well as other small zooplankton and barnacle larvae. The population of right whales in the northwest Atlantic is estimated to be approximately 522 (Pettis and Hamilton 2014, in BP 2016). Historically, some right whales may have moved through the Study Area during north-south migrations (Knowlton et al. 1992, in Husky Energy 2012a). Figure 14 represents visual observation data for North Atlantic right whales collected by Dr. Lawson.

There is a Recovery Strategy for the SARA-listed North Atlantic right whale (DFO 2014). As outlined in the strategy, threats to the North Atlantic right whale include strikes by vessels and entanglements in fixed fishing gear. Critical habitat has been identified for this species it is not located within the Study Area.



Data Source: J. Lawson, DFO, pers. comm., 2016

Figure 14 Observation Data for North Atlantic Right Whales (2004 to 2014

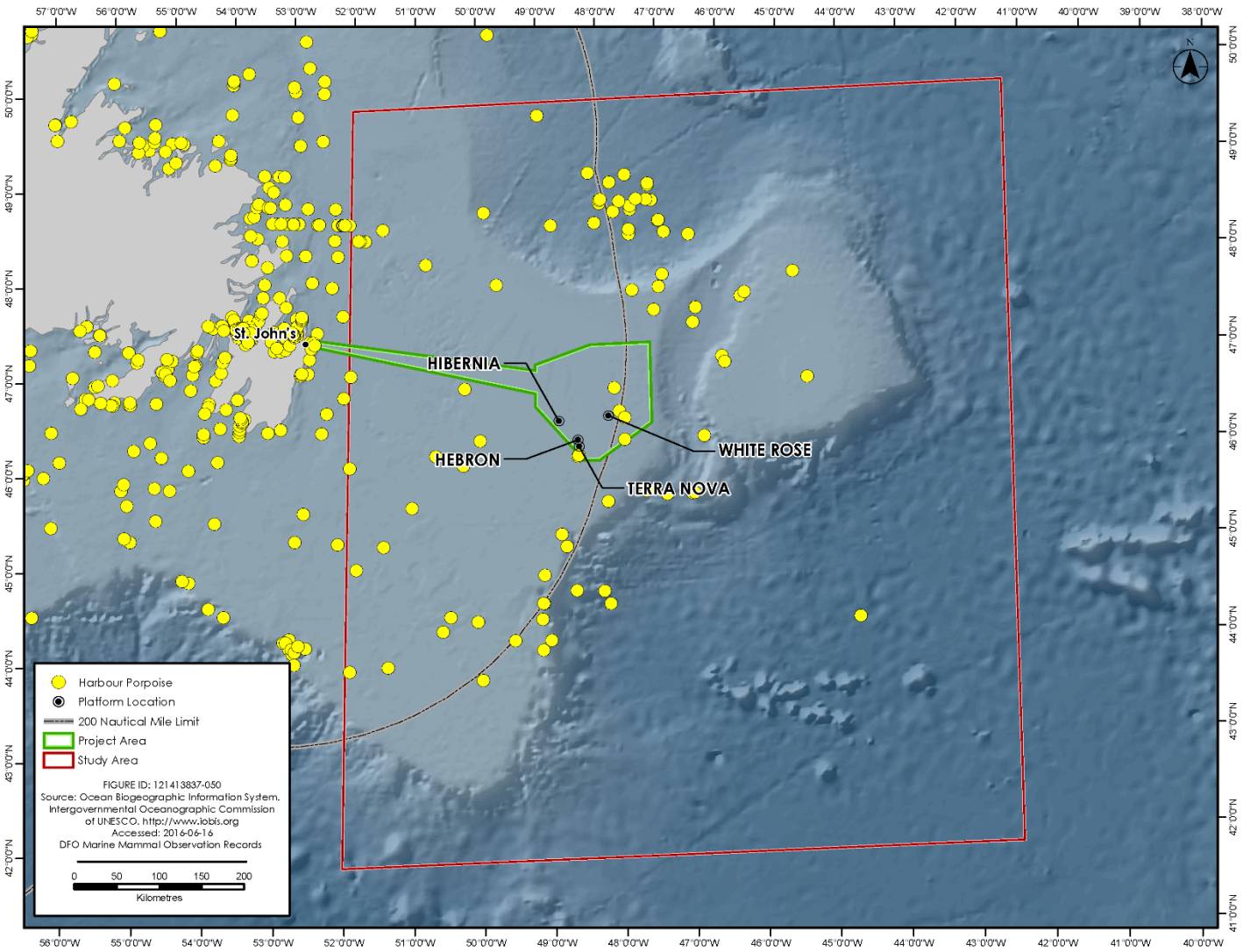
2.4.2 Odontocetes (Toothed Whales)

2.4.2.1 Harbour Porpoise

The harbour porpoise is listed as threatened under Schedule 2 of SARA and special concern under COSEWIC. Harbour porpoises can be found from the Bay of Fundy to Baffin Island in the Northwest Atlantic. At least three populations of harbour porpoises exist in the Northwest Atlantic, including the eastern Newfoundland and Labrador, Gulf of St. Lawrence and Gulf of Maine/Bay of Fundy populations (Palka et al. 1996; Wang et al. 1996, in Husky Energy 2012a). There are an unknown number of harbour porpoises in the Northwest Atlantic, as well as in the Newfoundland population, and there is little information regarding the movements and distribution of the Newfoundland and Labrador population of harbour porpoises (COSEWIC 2006a, in Husky Energy 2012a). Harbour porpoises occur in coastal shelf waters of Labrador and the eastern and southeastern Newfoundland coasts during spring and summer. They range up to Baffin Bay and deeper waters of the Labrador Sea during summer, but the offshore boundaries of their spring and summer distributions are unknown (Palka et al. 1996, in Husky Energy 2012a). The winter range for this population is undefined (Palka et al. 1996; COSEWIC 2006a, in Husky Energy 2012a).

Harbour porpoises are one of the smallest species of toothed whale (approximately 1.6 m for an average adult (COSEWIC 2006a, in Husky Energy 2012a)). Harbour porpoises tend to occur singly or in small groups of up to three animals, but occasionally form larger groups (COSEWIC 2006a, in Husky Energy 2012a). They consume small schooling fishes and appear to prefer areas with coastal fronts or topographically generated upwellings over the continental shelf, although there also appears to be an offshore component to their distribution (Westgate et al. 1998; Read 1999, in Husky Energy 2012a). Harbour porpoises appear to have an annual reproductive cycle; pregnant females were incidentally captured in commercial fishing operations during late summer and early autumn from the Gulf of Maine/Bay of Fundy population (Palka et al. 1996, in Husky Energy 2012a).

While harbour porpoises may occur in the Study Area throughout the year, they are likely uncommon relative to other cetacean species and generally are observed from spring to fall. Figure 15 represents visual observation data for harbor porpoise from 2004 to 2014; data were obtained from the OBIS dataset (Hyrenbach et al. 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

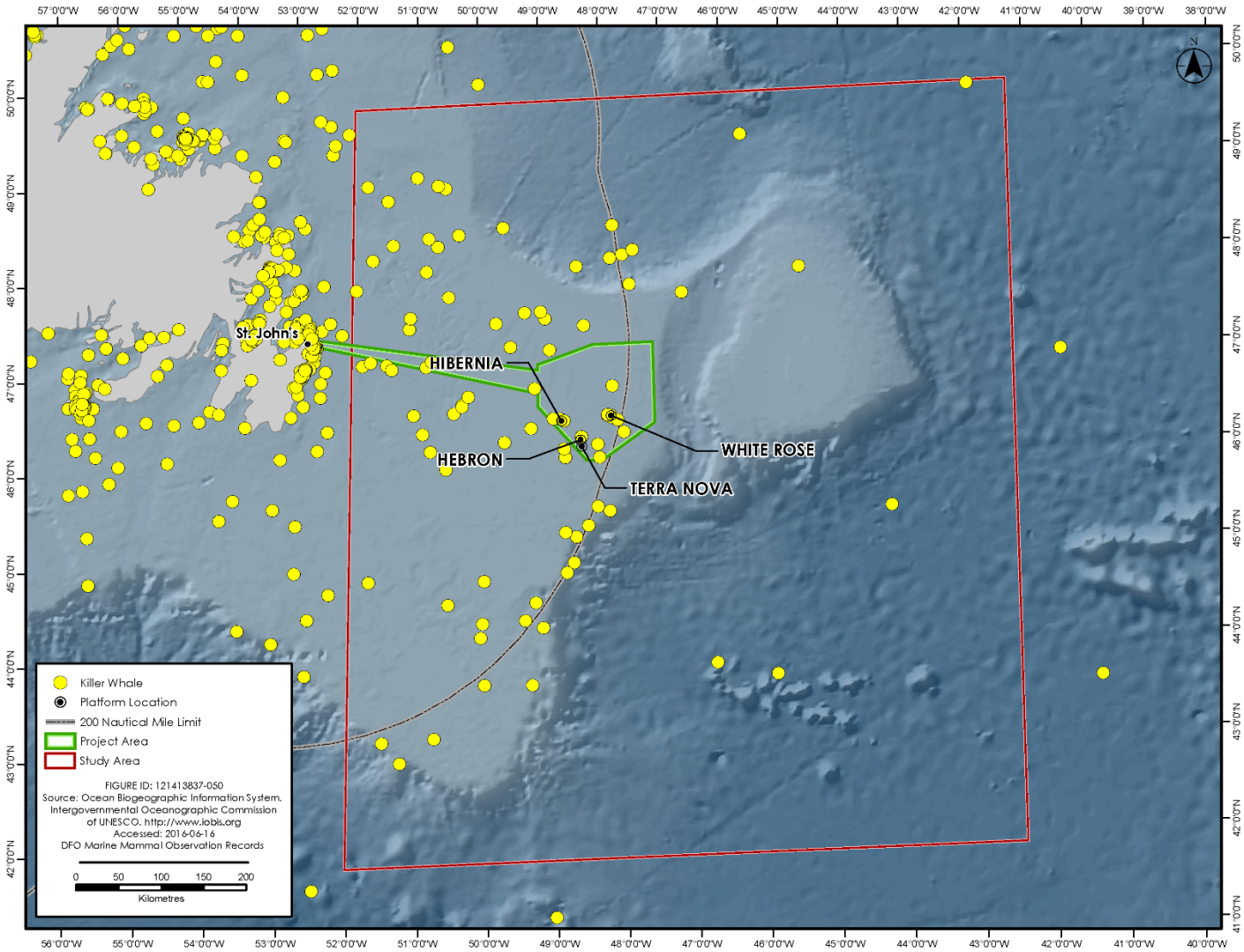
Figure 15 Observation Data for Harbour Porpoise (2004 to 2014)

2.4.2.2 Killer Whale

Killer whales in the Northwest Atlantic and eastern Canadian Arctic are listed as special concern under COSEWIC and are not listed under SARA. They can be found from Baffin and Hudson Bay to US coastal waters (COSEWIC 2008b, in BP 2016). Killer whales are characterized as relatively uncommon or rare and are now only occasionally sighted in the Gulf of St. Lawrence and the St. Lawrence estuary. Sighting events from 1785 to 2012 indicated this species was more common from June to September and sightings have been more frequent over the last ten years, potentially due to increased public awareness and increased boating, people, and cameras during these months (Warning et al. 2015, in BP 2016).

Male killer whales reach sexual maturity at about of 13 years of age, and females reach sexual maturity at about 14 (COSEWIC 2008b, in BP 2016). In the Northwest Atlantic, killer whales have been observed preying on harp seals, white-beaked dolphins, minke whales, beluga whales, humpback whales, auks, bluefin tuna, and herring.

Killer whales are considered year-round residents off eastern Newfoundland, although they occur in relatively low densities (Goff and Lien 1988; Lawson et al. 2007, in Husky Energy 2012a). Figure 16 represents visual observation data for killer whale from 2004 to 2014; data were obtained from the OBIS dataset (Husum Marboe 2011; Hyrenbach et al. 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

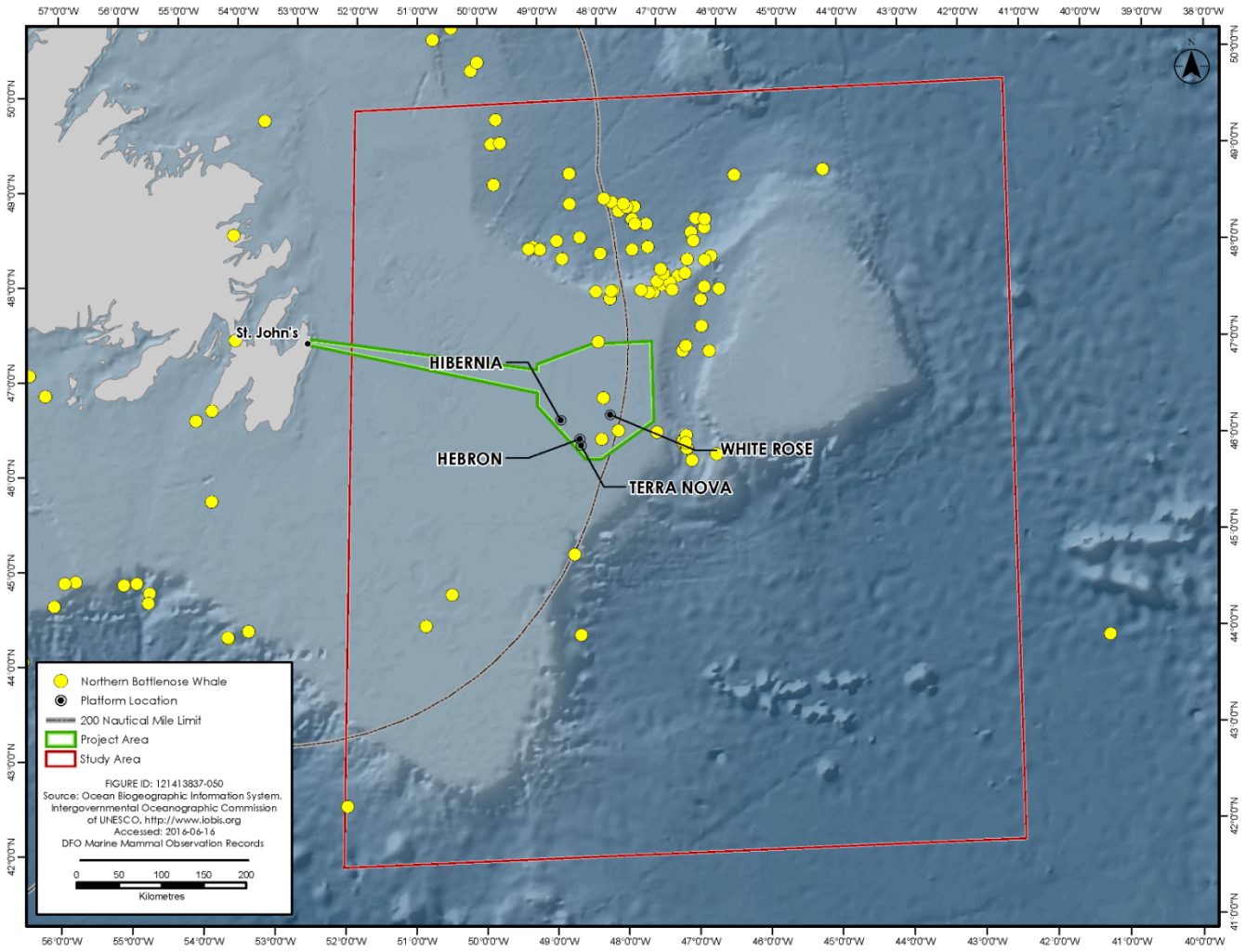
Figure 16 Observation Data for Killer Whale (2004 to 2014)

2.4.2.3 Northern Bottlenose Whale

Northern bottlenose whale occur only in the North Atlantic, predominantly in deep offshore areas, and have two (known) primary areas of concentration in the Northwest Atlantic: The Gully and adjacent canyons of the eastern Scotian Shelf; and Davis Strait, Baffin Bay, and Labrador Sea (Reeves et al. 1993, in Husky Energy 2012a). The abundance of northern bottlenose whales in the Northwest Atlantic is unknown (Waring et al. 2015, 2016), but there are an estimated approximately 163 individuals in the Scotian Shelf population (Whitehead and Wimmer 2005, in Husky Energy 2012a). The Scotian Shelf population is assessed as Endangered by COSEWIC and listed as Endangered on Schedule 1 of SARA, but the Davis Strait-Baffin Bay-Labrador Sea population has no status under SARA and is assessed as Special Concern by COSEWIC (COSEWIC 2011b).

It appears that the Scotian Shelf population has a relatively restricted distribution. This population spends most its time in The Gully (with a third of the population present there at any time), but nearby Shortland and Haldimand canyons are also extensively used; their home range is thought to be a few hundred kilometres or less (Wimmer and Whitehead 2004, in Husky Energy 2012a). On the Scotian Shelf, tagged northern bottlenose whales routinely dove to depths over 800 m and remained submerged for over an hour; the maximum recorded depth was 1,453 m (Hooker and Baird 1999b, in Husky Energy 2012a). Foraging appears to occur at depth, primarily for large and medium-bodied squid. Group sizes on the Scotian Shelf average around three individuals, and are rarely more than 10 individuals, with males forming long-term bonds while females do not seem to have preferred associates (Gowans et al. 2001, in Husky Energy 2012a).

For the purposes of this environmental assessment, it is assumed that northern bottlenose whales that occur in the Study Area would belong to the Davis Strait-Baffin Bay-Labrador Sea population. The available literature and data suggest that northern bottlenose whales likely occur at low densities, possibly year-round, in the deeper waters of the Study Area (COSEWIC 2011c, in Husky Energy 2012a). Figure 13 represents visual observation data for Northern bottlenose whales from 2004 to 2014; data were obtained from the OBIS dataset (Husum Marboe 2011; Hyrenbach et al. 2012; Harris 2015) and DFO (J. Lawson, DFO, pers. comm. 2016).



Data Source: OBIS 2016; J. Lawson, DFO, pers. comm., 2016

Figure 17 Observation Data for Northern Bottlenose Whales (2004 to 2014)

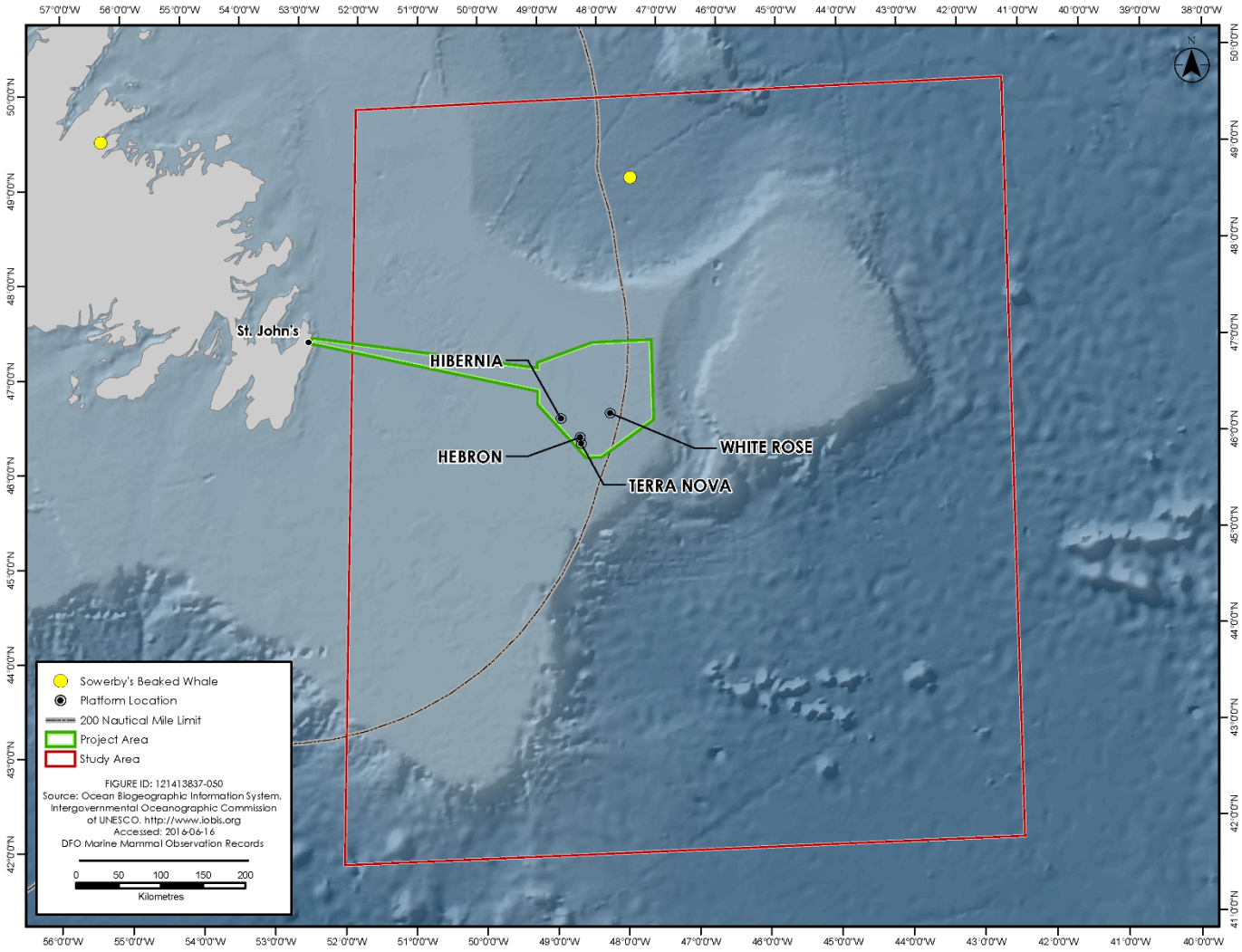
2.4.2.4 Sowerby's Beaked Whale

Sowerby's beaked whales are found only in the cold temperate waters of the North Atlantic, where just one record in the Northwest Atlantic occurs outside the area between Labrador and New England (MacLeod 2000; MacLeod et al. 2006, in Husky Energy 2012a). The number of Sowerby's beaked whales in eastern Newfoundland is unknown, and the best population estimate for the Northwest Atlantic (i.e., 7,092 individuals) combines sightings of all *Mesoplodon* spp. beaked whales (Waring et al. 2015). Sowerby's beaked whales are considered species of special concern by COSEWIC and are listed as special concern on Schedule 1 of SARA (COSEWIC 2006).

Little is known about beaked whales in general, and most information on Sowerby's beaked whales in Newfoundland is based on stranding records or a few opportunistic sightings (Lien and Barry 1990, in Husky Energy 2012a). Sowerby's beaked whales are also relatively difficult to detect at sea due to their short surface durations, apparent offshore distribution, and barely detectable blows (Hooker and Baird 1999a, in Husky Energy 2012a). They have most often been observed in deep waters and continental shelf edges or slopes (Kenney and Winn 1987, COSEWIC 2006f, in Husky Energy 2012a) and presumably make deep dives to forage on medium to large-bodied squid (COSEWIC 2006f, in Husky Energy 2012a).

Sowerby's beaked whales are expected to occur most frequently, although in relatively low numbers, in the deeper waters of the Study Area. Figure 18 represents visual observation data for Sowerby's beaked whales collected by Dr. Lawson.

There is a Recovery Strategy for the SARA-listed Sowerby's beaked whale (DFO 2016). Threats to the Sowerby's Beaked Whale include acute and chronic noise exposure, entanglement, vessel strikes, and contaminant exposure (DFO 2016). Critical habitat is not defined for species listed as special concern under SARA; however, the Sowerby's beaked whale likely benefits from the northern bottlenose whale critical habitat (in Nova Scotia) (DFO 2016).



Data Source: J. Lawson, DFO, pers. comm., 2016

Figure 18 Observation Data for Sowerby's Beaked Whales (2004 to 2014)

3.0 SEA TURTLES

3.1 Kemp's Ridley Turtle

Kemp's ridley turtle, the smallest of sea turtles, is distributed throughout the Gulf of Mexico and along the US eastern seaboard and occasionally in the waters of Nova Scotia and Newfoundland (NOAA 2013o, in BP 2016). Adult Kemp's ridleys can be found in depths of less than 50 m over sand or muddy substrates, feeding on crabs, fish, jellyfish, and mollusks.

Kemp's ridley sea turtles have a more restricted distribution than other sea turtles, primarily in the Gulf of Mexico (Spotila 2004, in Husky Energy 2012a). Some juveniles exhibit the widest range, sometimes feeding along the US east coast and rarely into the Canadian Atlantic (Spotila 2004, in Husky Energy 2012a). It is estimated that there are only approximately 5,000 nesting females worldwide (Spotila 2004, in Husky Energy 2012a), but it is unknown how many enter Canadian waters annually. Kemp's ridley turtles have not been considered by COSEWIC and have no status under SARA.

Nesting is focused within a small region of the central and southern Gulf of Mexico during May to late July, and only immature turtles seem to travel outside the Gulf of Mexico into more northerly waters (Morreale et al. 2007, in Husky Energy 2012a). Musick et al. (1994, in Husky Energy 2012a) suggested that juvenile Kemp's ridley sea turtles that travel north of Cape Hatteras, North Carolina, probably do so in April and return southward by November. In general, it appears the Kemp's ridley sea turtles prefer shallow water.

While adults rarely range beyond the Gulf of Mexico, juveniles have been sighted along the southeast coast of Newfoundland near St. Mary's Bay and along southern Nova Scotia (Ernst et al. 1994, in Husky Energy 2012a). The available information suggests that their presence in the Study Area is likely to be very uncommon and may only occur during summer or fall.

3.2 Leatherback Sea Turtle

The leatherback sea turtle is the largest and most widely distributed of all marine turtles. In the Northwest Atlantic, they can be found in both the shelf and offshore slope waters as well as in the Gulf of St. Lawrence (COSEWIC 2012f, in BP 2016). Data comprised of satellite tracking studies and sighting information indicate that the species is present in Atlantic Canadian waters from April to December with the highest densities from July to September. Generally, the species distribution shifts from the southwest to the northeast as the foraging period progresses (COSEWIC 2012f, in BP 2016). The species is commonly found in the shelf waters off Cape Breton Island, off the south coast of Newfoundland, the southern Gulf of St. Lawrence, as well as in offshore Scotian Slope waters including the Northeast Channel (LGL 2014). Distribution maps rely largely on opportunistic reporting and tracking of small numbers of individual leatherbacks. The primary determinant of movement and behaviour of leatherbacks is the spatial and temporal distribution of their primary

prey, gelatinous plankton generally known as jellyfish. In general jellyfish abundance is highest in coastal waters (James et al. 2006).

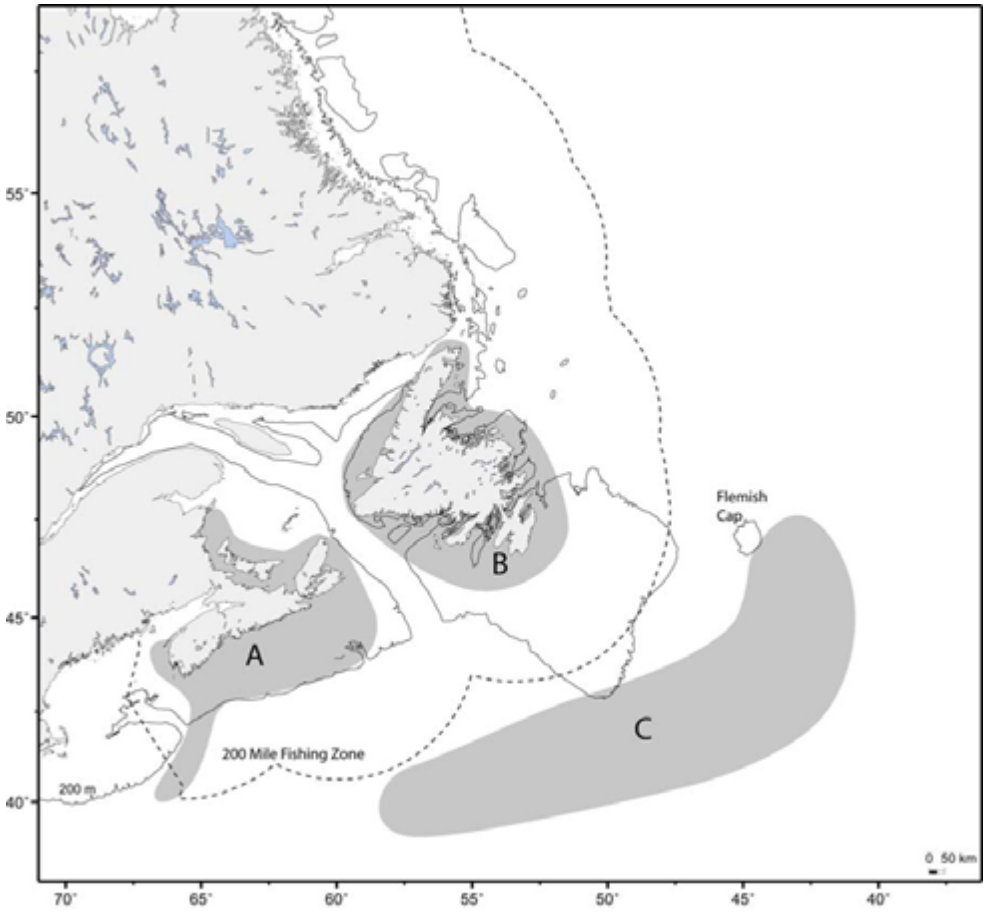
The Atlantic population of the leatherback turtle is cautiously considered stable containing approximately 15,000 females (Government of Canada 2016). The 2006 Recovery Strategy (ALTRT 2006) developed pursuant to SARA did not identify any critical habitat for the leatherback turtle in Atlantic Canada. An amended Recovery Strategy is currently being prepared in consideration of subsequent research by Dalhousie University and the Canadian Sea Turtle Network (CSTN, formerly the Nova Scotia Leatherback Turtle Working Group) that identified the following areas as important habitat for leatherback sea turtles (DFO 2013; DFO 2012a in DFO 2013):

- waters east and southeast of Georges Bank, along the southwestern Scotian Shelf near the southwest boundary of the Atlantic Canadian EEZ;
- the southeastern Gulf of St. Lawrence and waters off western and eastern Cape Breton Island, including Sydney Bight, the Cabot Strait, portions of the Magdalen Shallows and adjacent portions of the Laurentian Channel; and
- waters south and east of the Burin Peninsula, NL, including parts of Placentia Bay.

It is believed the leatherback sea turtle's distribution in Canadian waters is based primarily on maximizing foraging opportunities. During the summer and fall months, this species forages on gelatinous zooplankton (primarily jellyfish, of which they consume on average 330 kg/day) in the waters of the Scotian Shelf (Healslip et al. 2012). The species follows a predictable migratory cycle including annual return trips between southern feeding and breeding areas and northern foraging habitat (COSEWIC 2012f, in BP 2016). The leatherback sea turtle may swim more than 10,000 km between nesting locations in the tropics and foraging areas in the north. Leatherback sea turtles found in Atlantic Canada originate from nesting beaches in the wider Caribbean, South and Central America, and Florida. James et al. (2005) tagged 38 leatherback turtles from 1999 to 2003 with satellite tags and tracked their migration patterns. Figure 19 depicts the number of days that each turtle spends in a particular area.

There are five life-history stages in the leatherback sea turtle's life cycle: egg and hatching, post-hatchling, juvenile, sub-adult, and adult. The age of maturity is uncertain but is estimated to range from 7 to 29 years (COSEWIC 2012f, in BP 2016). Mating observations have been rare and occur in the southern latitudes of their nesting sites. Males will travel with nesting colonies in advance of the nesting season and remain until peak nesting has finished (COSEWIC 2012f, in BP 2016). Females generally nest on sandy, tropical beaches at two to four-year intervals. Both the time and duration of nesting varies with geographic location, lasting between three and six months in a nesting year (COSEWIC 2012f, in BP 2016). Over a single nesting season, females generally lay several clutches of approximately 80 eggs over a nesting season, typically at 8- to 12-day intervals. Nesting is generally nocturnal, with occasional daytime nesting (COSEWIC 2012f, in BP 2016).

Based on available information, leatherback sea turtles are uncommon in the Study Area and typically only occur there during late summer or early fall.



Source: Atlantic Leatherback Turtle Recovery Team, 2006

Figure 19 Occurrence of Leatherback Sea Turtles by visual observations in the Waters off Newfoundland

3.3 Loggerhead Sea Turtle

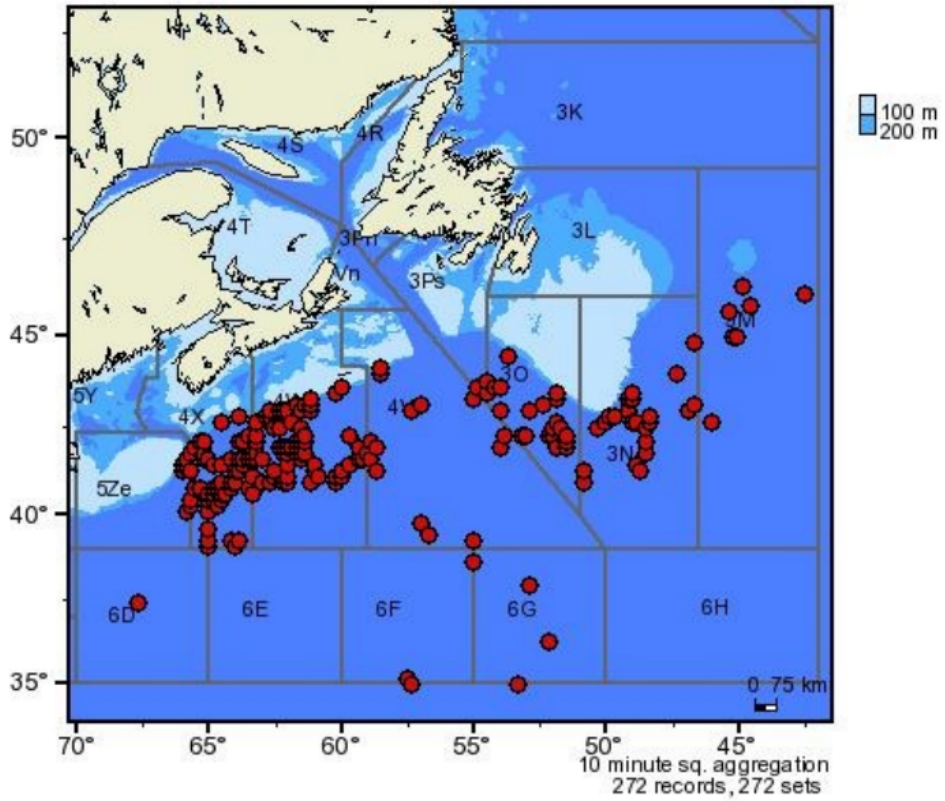
Loggerhead sea turtles migrate to Atlantic Canadian waters during the spring months and return south for the winter. They are known to breed as far north as Virginia with the largest breeding colony in North America in Florida (COSEWIC 2010e, in BP 2016). Recent findings have determined that not all loggerheads leave the area during the winter months. Telemetry data have shown that some sea turtles move east and northeast during the winter (COSEWIC 2010e, in BP 2016). Based on observations, loggerhead sea turtles are found mostly within the 20°C to 25°C water temperature contours with loggerheads absent when temperatures were below 15°C (Brazner and McMillan 2008, in Husky Energy 2012a). Generally, they are associated with the warm waters of the Gulf Stream in Atlantic Canada and are common off the Scotian Shelf, Georges Bank, and the Grand Banks from July through October (Brazner and McMillan 2008, in Husky Energy 2012a).

Loggerhead sea turtles generally make predictable migrations from southern breeding grounds in the Southern US, Caribbean, Gulf of Mexico, and South America to temperate foraging grounds

in the Northern Atlantic (COSEWIC 2010e, in BP 2016). Nesting occurs on beaches and occasionally estuarine shorelines at night with females returning to the site of their birth to nest. Females nest on a two- to three-year interval laying three to four clutches of 112 eggs on average with 14 days in between events. Eggs hatch in approximately 7 to 13 weeks (COSEWIC 2010e, in BP 2016).

Loggerheads may be seen in the open seas during migration and foraging. Hundreds of loggerheads have been caught off the southeast side of the Grand Banks in continental shelf slope waters by the pelagic longline fishery since 1992 (McAlpine et al. 2007, in Husky Energy 2012a; Brazner and McMillan 2008, in Husky Energy 2012a; COSEWIC 2010f, in Husky Energy 2012a). Most of these individuals were juveniles. These data are from only the observed portion of the fishery, which is approximately 10% of the longline sets. The number of individuals and locations in the fishery bycatch suggests that loggerhead is common in the far eastern portion of the Study Area during spring to fall.

Figure 20 depicts the location of loggerhead turtle captures recorded by at-sea observers on Canadian pelagic longline fishing trips between 1999 and 2008.



Source: COSEWIC 2010e
Each point represents a location where one or more loggerhead turtles were caught.

Figure 20 Location of Loggerhead Sea Turtle Captures Recorded by At-sea Observers on Canadian Pelagic Longline Fishing Trips, 1999 to 2008

4.0 MIGRATORY BIRDS

4.1 Seabirds

4.1.1 Northern Fulmar

Northern fulmars primarily nest in the Arctic but do breed along the coast of eastern Newfoundland and are present in offshore waters year-round (Figure 21). Although relatively common throughout the year, data indicate that they are particularly abundant in offshore waters of eastern Newfoundland in winter (Fifield et al. 2009). They are likely present in and around the Project Area at all times of the year but less common during the summer and fall. Data from Fifield et al. (2009) indicate that northern fulmars are more abundant on the Newfoundland and Labrador Shelves compared to waters in other areas of eastern Canada such as the Scotia Shelf. They are most abundant on the continental slope in the southern Orphan Basin, as well as the tail and nose of the Grand Banks in the spring, summer and fall months (Fifield et al. 2009, in Amec 2014). Along eastern Newfoundland, northern fulmars breed on Funk Island, Baccalieu Island, the Witless Bay Islands, Cape St. Mary's, and Ship Island (EC-CWS 2013, in Amec 2014).

4.1.2 Shearwaters

Shearwaters are common in the waters off eastern Newfoundland from spring to fall but spend the winter months in the southern hemisphere where they breed. PIROP and ECSAS data indicate that they are widely distributed throughout the Study Area during spring, summer, and fall months, being particularly abundant in waters associated with the continental shelf (Figure 22). Great shearwater (*Puffinus gravis*) account for most shearwater observations in the PIROP and ECSAS databases, although sooty shearwaters (*Puffinus griseus*) are also relatively abundant. Manx shearwater (*P. puffinus*) and Cory's shearwater (*Calonectris diomedea*), are also regular occurrences within waters off eastern Newfoundland. ECSAS and PIROP data indicate that other species of shearwater are occasionally observed within the Study Area, including Audubon's shearwater (*Puffinus lherminieri*) and wedge-tailed shearwater (*P. lherminieri*). Of the aforementioned species, only manx shearwater is known to breed near the Study Area, with a small colony on Middle Lawn Island (EC-CWS 2013, in Amec 2014) being one of the few known breeding sites for this species in North America.

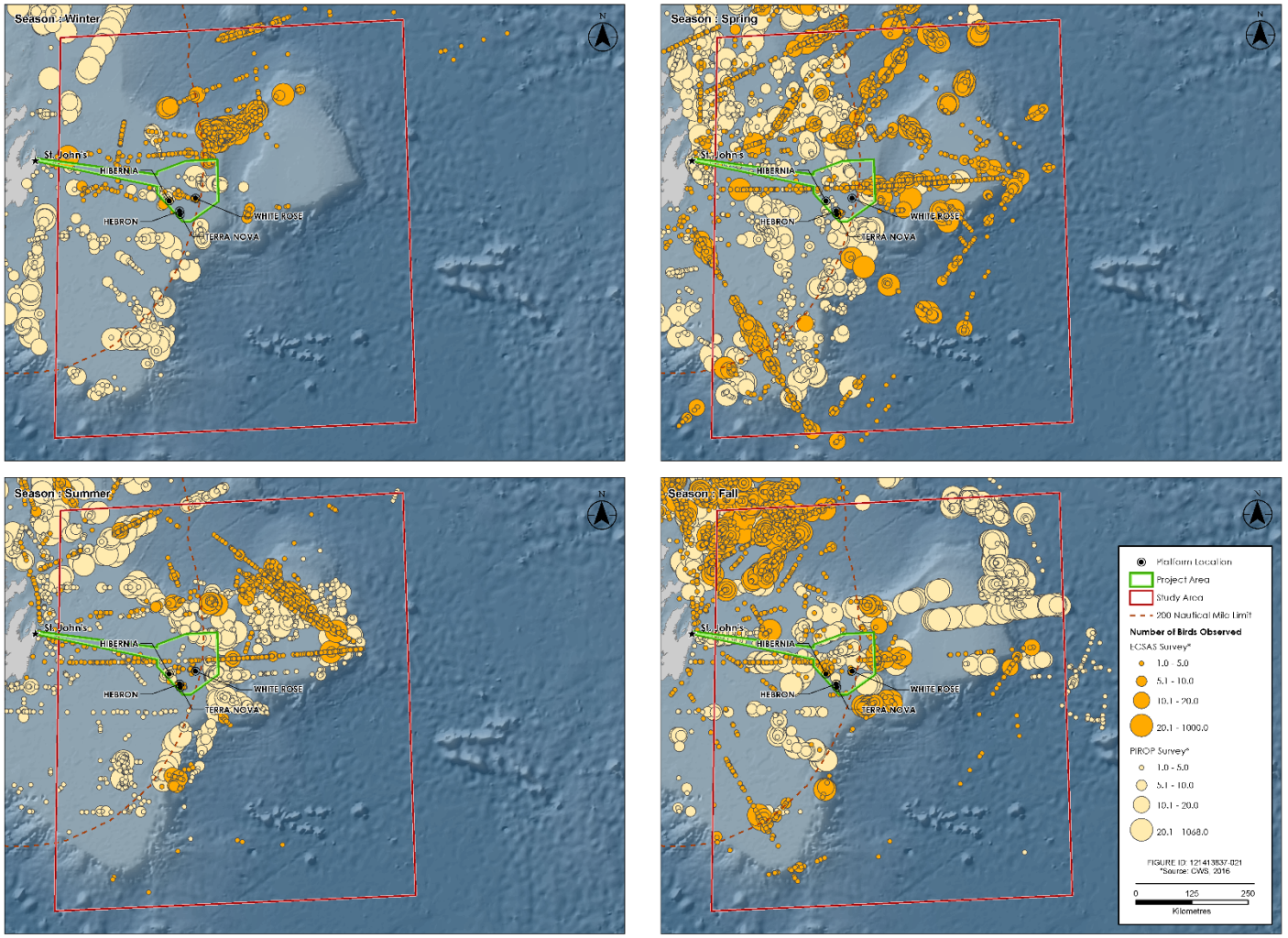


Figure 21 Distribution of Northern Fulmars in the Study Area, by Season

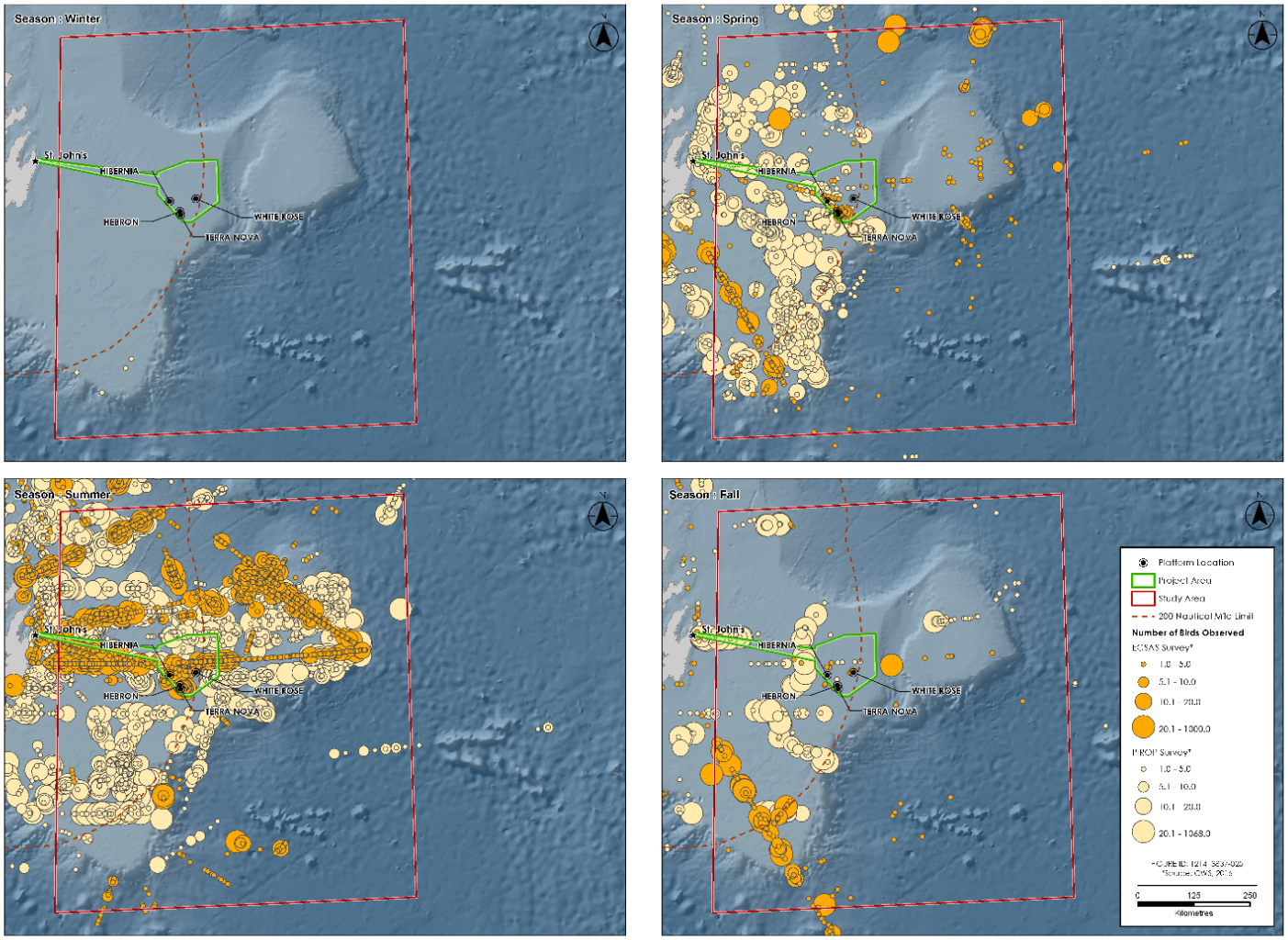


Figure 22 Distribution of Shearwaters in the Study Area, by Season

4.1.3 Storm-Petrels

Storm-petrels arrive in eastern Newfoundland waters in spring and stay until late fall, with very few records during the winter months. The majorities of ECSAS and PIROP storm-petrel records within the Study Area were from summer and spring months; and were concentrated in waters associated with the continental shelf (Figure 23). However, data from Fifield et al. (2009) suggest that peak densities on the Newfoundland and Labrador Shelves are reached in fall, after Leach's storm-petrels (*Oceanodroma leucorhoa*) emerge from their breeding colonies. The breeding range of the Leach's storm-petrel in the western North Atlantic is centered on Newfoundland and over five million pairs of Leach's storm-petrels breed on the eastern coast of Newfoundland (Amec 2014). Baccalieu Island and the Witless Bay Islands (EC-CWS 2013, in Amec 2014) support most of these birds, with the former being home to more than a third of the world's population of the species (Fifield et al. 2009). Leach's storm-petrel accounts for most ECSAS and PIROP observations within the Study Area during all seasons but Wilson's storm-petrel (*Oceanites oceanicus*) are also commonly observed during summer months.

4.1.4 Northern Gannet

Northern gannets are present in offshore waters of the Study Area in relatively low numbers during spring, summer and fall, and are largely absent in winter (Fifield et al. 2009). PIROP and ECSAS data obtained for the project indicate that majority of gannet records are from spring and summer and occur close to shore (Figure 24). Northern gannets breed in Eastern Newfoundland, with three large colonies situated in Funk Island, Baccalieu Island, and Cape St. Mary's (EC-CWS 2013; IBA 2013, in Amec 2014).

4.1.5 Jaegars

Jaegers do not breed in Atlantic Canada but are present in offshore waters of the region during their spring and fall migration to and from their Arctic nesting sites. Although rarely observed during this time they are widespread throughout the Study Area. PIROP and ECSAS records from the offshore waters of eastern Newfoundland indicate that pomarine jaegars (*Stercorarius pomarinus*) are most commonly observed followed by long-tailed jaegars (*S. longicaudus*) and parasitic jaegers (*S. parasiticus)*. Jaegers are also known to occur in the Study Area during summer months but are less frequently observed at this time (Figure 25).

4.1.6 Skuas

Skuas may be encountered in low abundance in waters off eastern Newfoundland throughout the year (Figure 26). The majority of records in the Study Area are from summer months and are of great skua (*Stercorarius skua*) but south polar skua (*S. maccormicki*) also occurs in waters off Newfoundland during migration. Great skua nest on islands in the northeast Atlantic but are known to overwinter in waters of the northwest Atlantic (Sibley 2000), and occur in waters off eastern Newfoundland during that time.

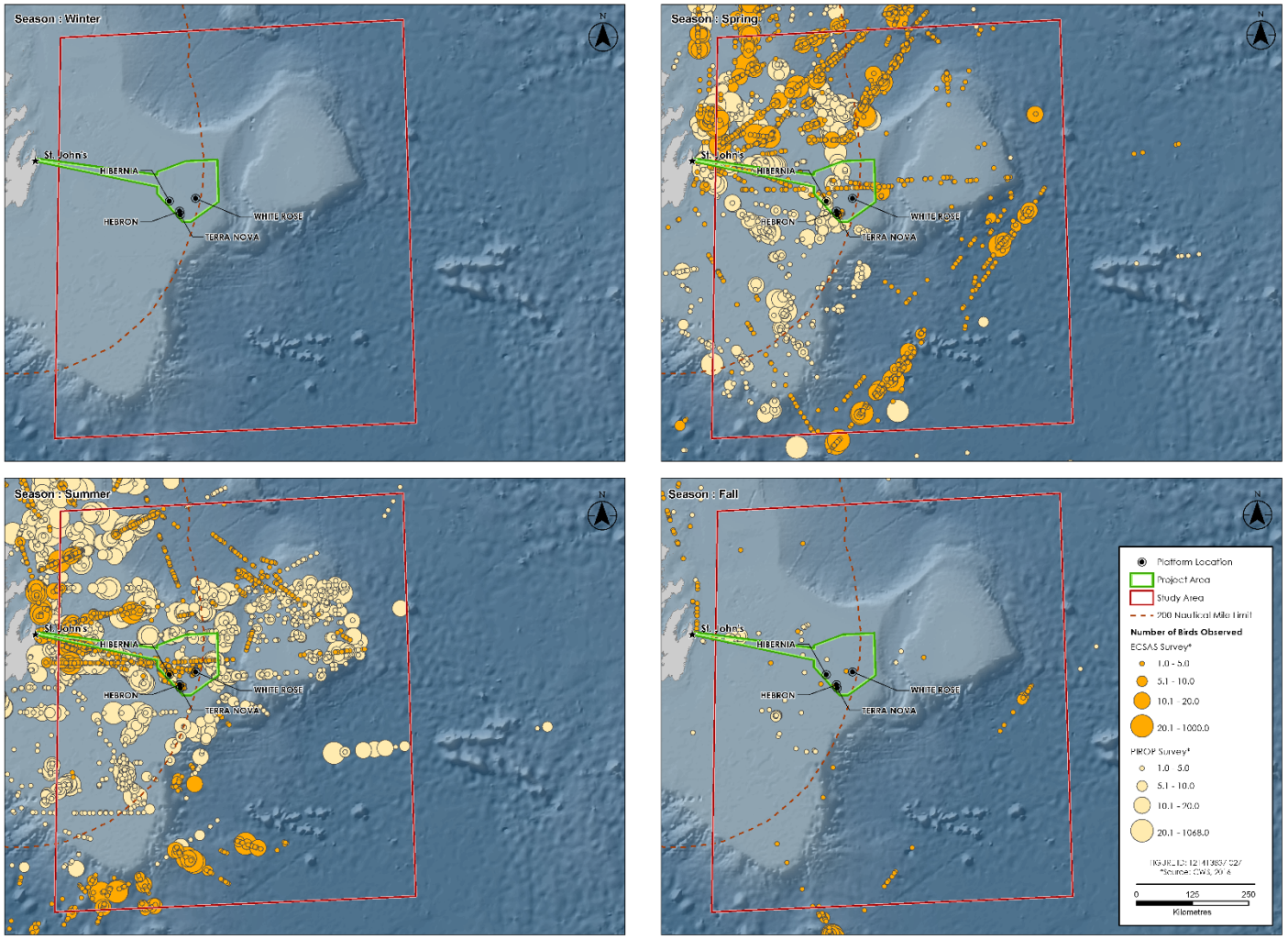


Figure 23 Distribution of Storm-Petrels in the Study Area, by Season

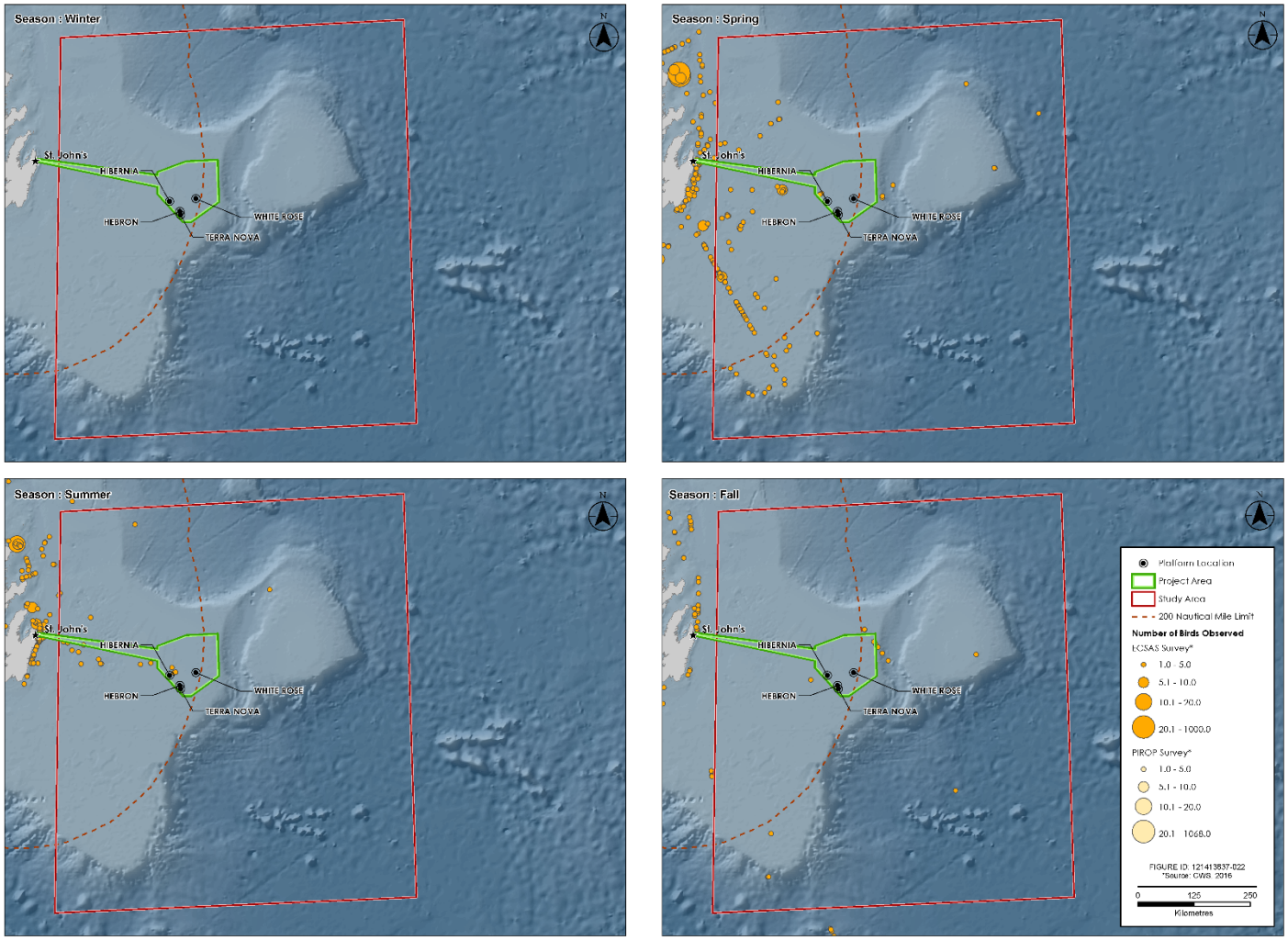


Figure 24 Distribution of Northern Gannets in the Study Area, by Season

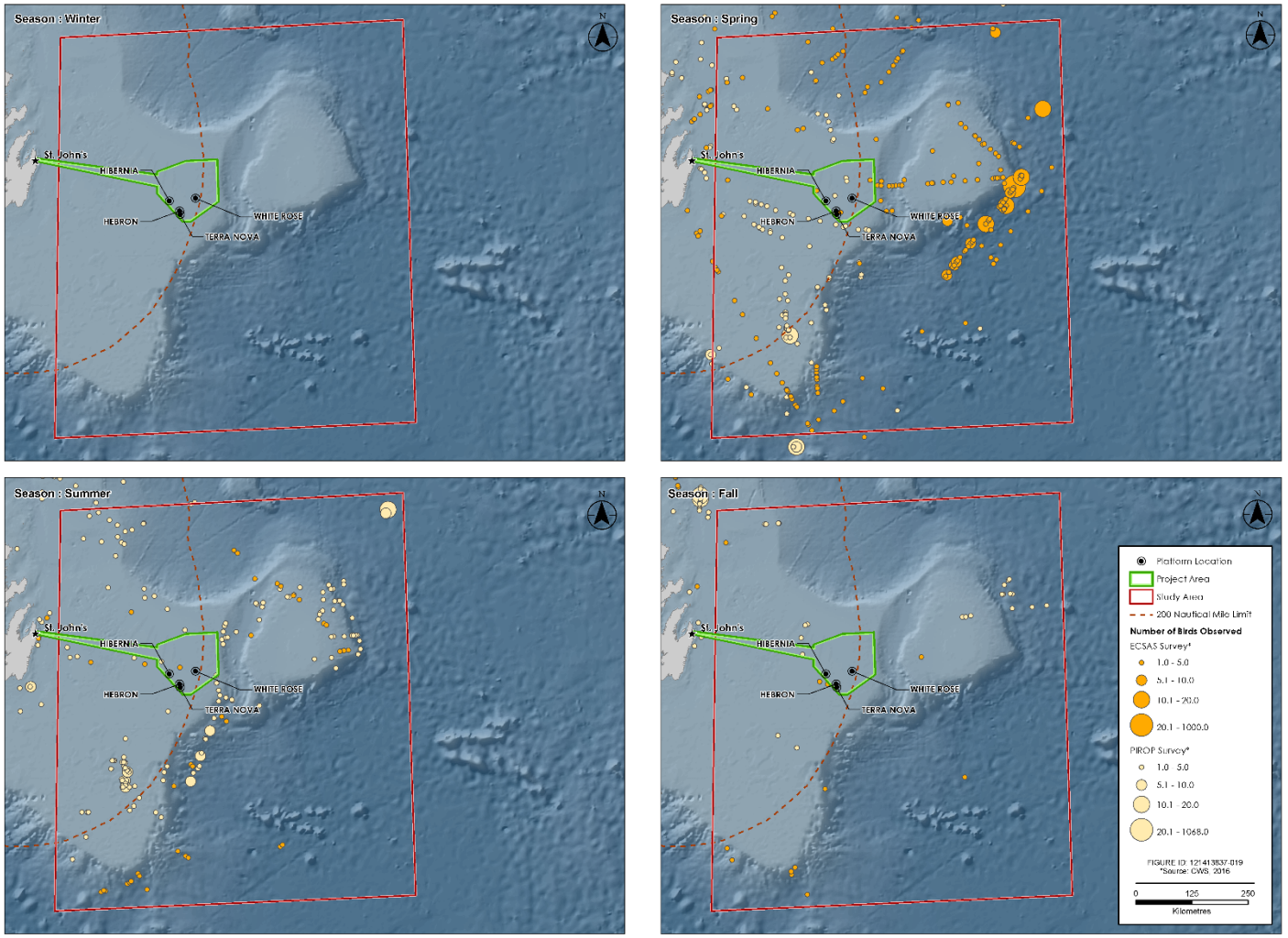


Figure 25 Distribution of Jaegars in the Study Area, by Season

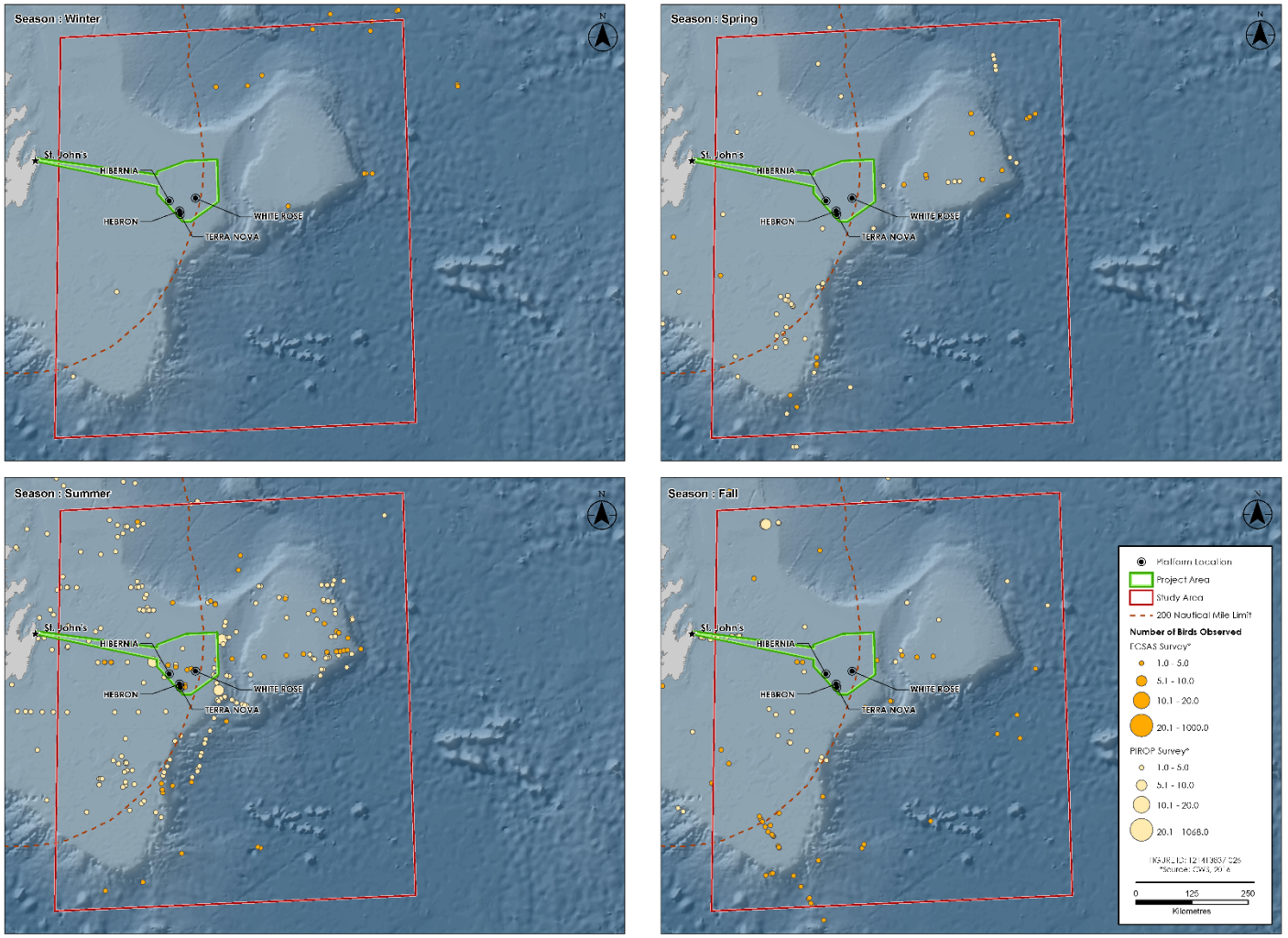


Figure 26 Distribution of Skuas in the Study Area, by Season

4.1.7 Black-legged Kittiwake

Black-legged kittiwakes are pelagic gulls that spend most their time in offshore waters except during the breeding season when they come ashore to nest. During spring and summer, black-legged kittiwakes tend to be more concentrated near their breeding colonies and most records for this species within the Study Area are during fall months when adults and juveniles have left their breeding grounds (Figure 27). High numbers overwinter in waters off eastern Newfoundland and ECSAS and PIROP data indicate that they are abundant species during that time. Black-legged kittiwakes are known to nest along eastern Newfoundland, with the largest colonies found in association with Baccalieu Island, Witless Bay, and Cape St. Mary's (EC-CWS 2013, in Amec 2014).

4.1.8 Dovekie

Dovekies (*Alle alle*) nest in the high Arctic and do not breed in Canada in significant numbers. They primarily occur in waters off eastern Newfoundland from the fall to spring (Figure 28). Although the majority of PIROP and ECSAS records are from spring and fall months, data from Fifield et al. (2009) indicate that they are at their highest numbers in the waters off eastern Newfoundland during winter, but that they are less abundant compared to other areas of eastern Canada (such as the Scotian Shelf and Gulf of Maine) during this season. Dovekies are also regularly encountered within the Study Area during fall months but are typically absent from the area in summer.

4.1.9 Murres

Murres are relatively abundant throughout the Study Area at all times of the year (Figure 29). Although the majority of ECSAS and PIROP records are from spring and winter and fall, data from Fifield et al. (2009) indicate that they are most abundant during spring and winter montths. ECSAS and PIROP data obtained for the Project indicate that both thick-billed murre (*Uria lomvia*) and common murre (*U. aalge*) are commonly encountered, with most birds identified to species being thick-billed murre in the fall and winter, and common murre in the summer. The greatest concentrations of murres during summer months occur in coastal waters near their breeding grounds; with large colonies located in association with Funk Island, South Cabot Island, Witless Bay, and Cape St. Mary's (EC-CWS, in Amec 2014). Coastal areas also support concentrations of murres during winter, as well as more offshore waters of the Grand Banks (Fifield et al. 2009).

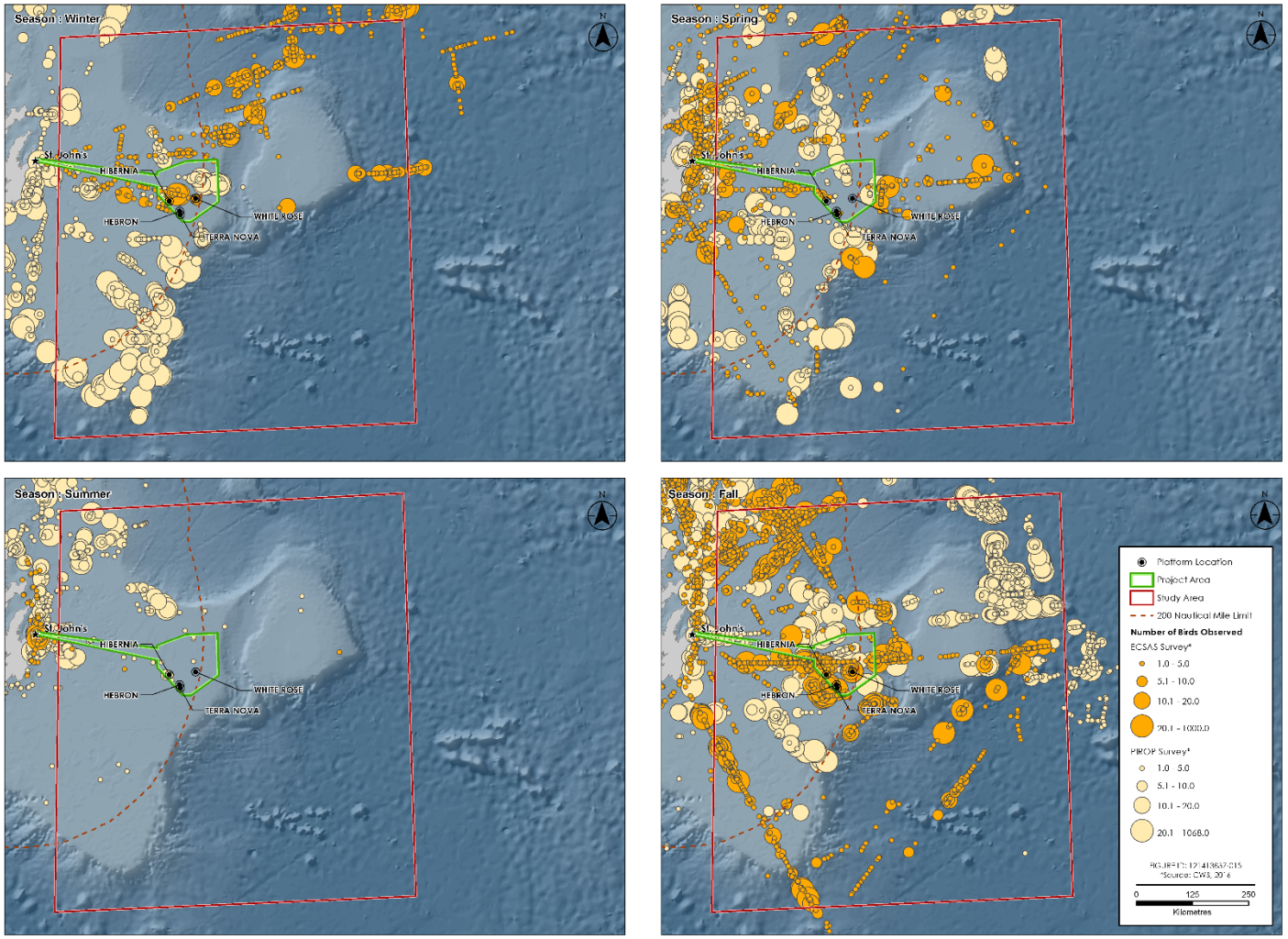


Figure 27 Distribution of Black-legged Kittiwakes in the Study Area, by Season

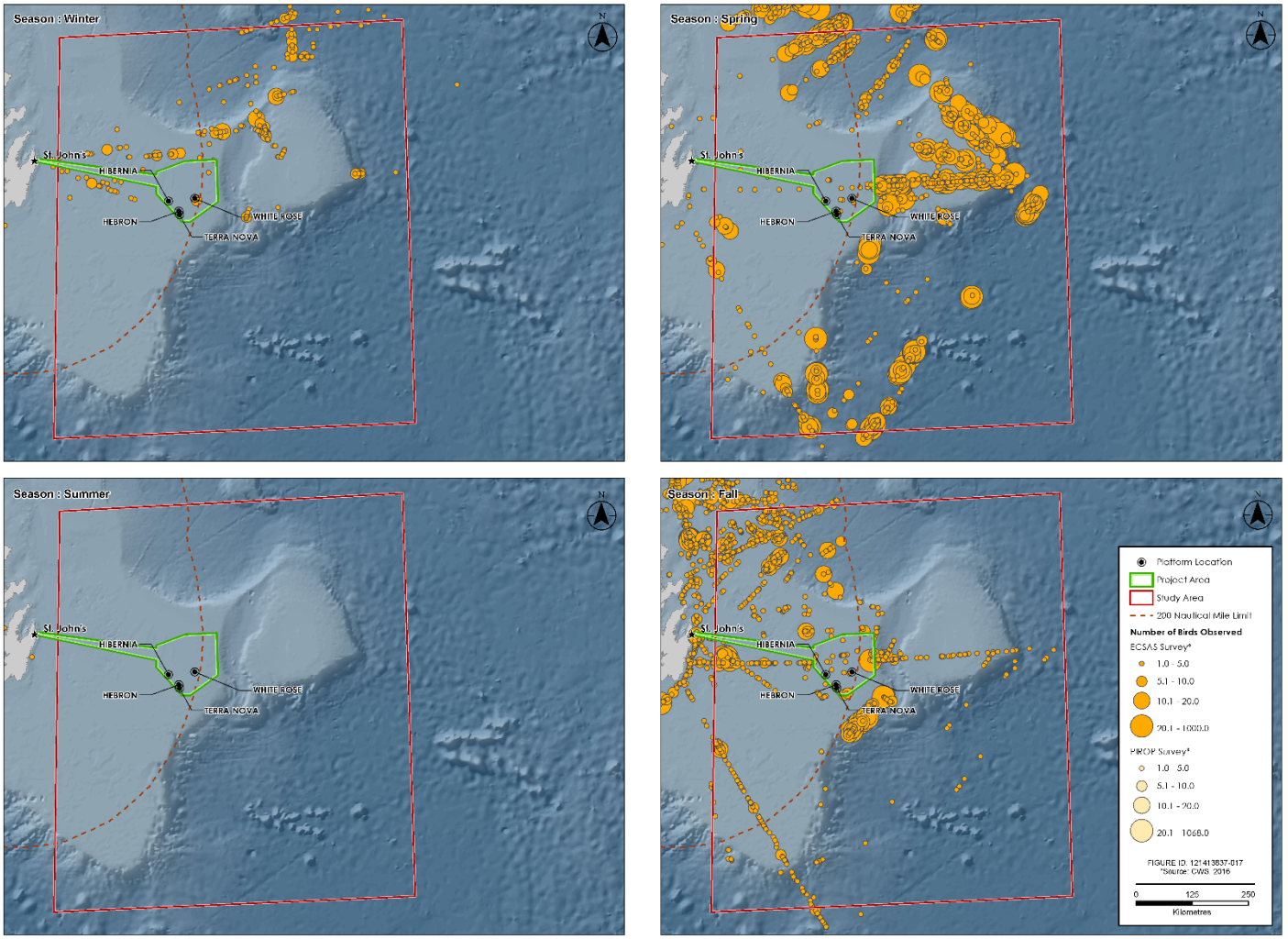


Figure 28 Distribution of Dovekie in the Study Area, by Season

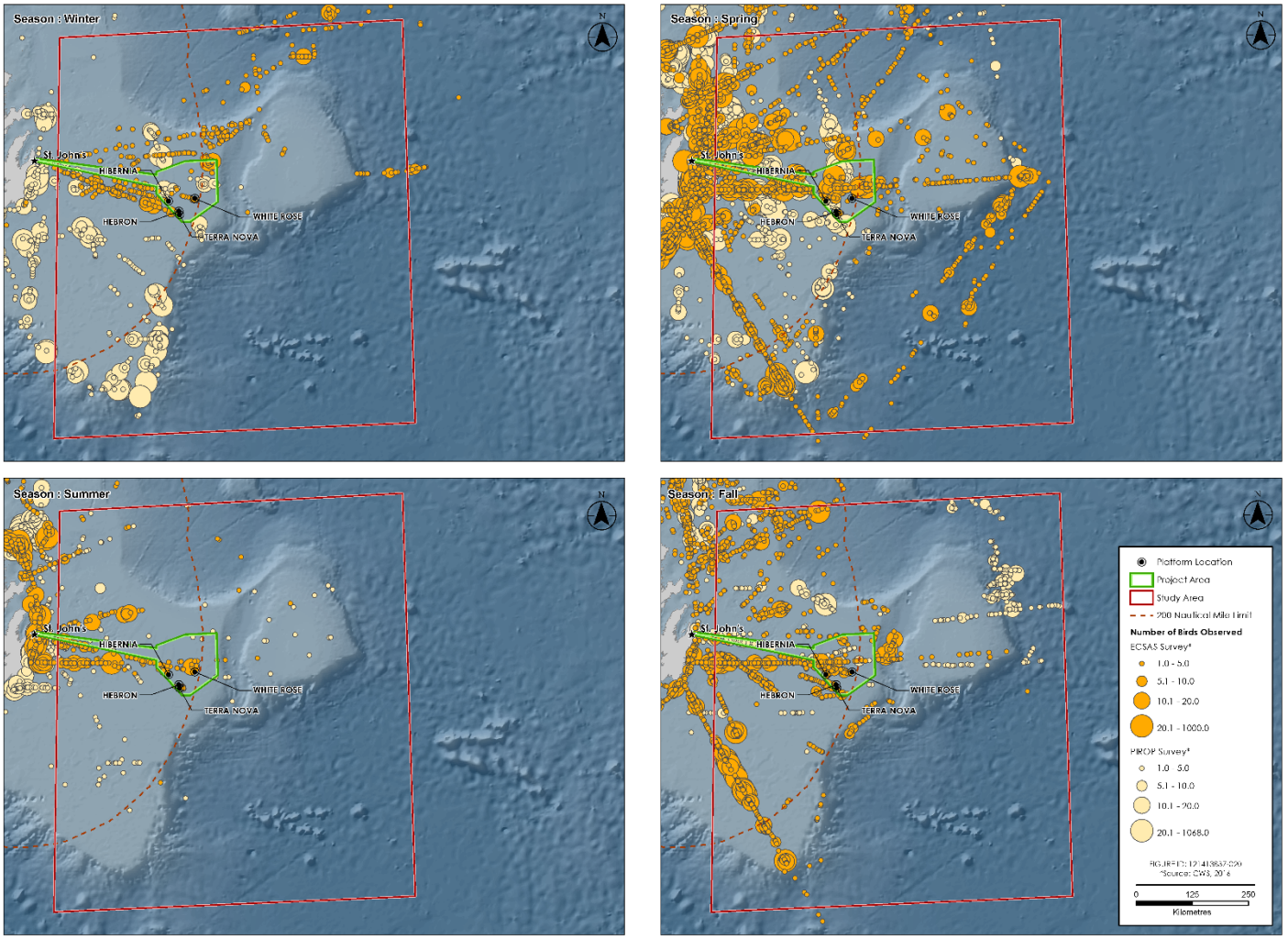


Figure 29 Distribution of Murres in the Study Area, by Season

4.1.10 Other Alcids

Other alcids include razorbill (*Alca torda*), Atlantic puffin (*Fratercula arctica*), black guillemot (*Cepphus grille*), and unidentified auks. This group is present in the waters off eastern Newfoundland at all times of the year (Figure 30). The majority of PIROP and ECSAS records obtained for this group are from the spring, summer, and fall but data from Fifield et al. (2009) indicate that other alcids are most abundant in waters of the Newfoundland and Labrador Shelves during winter and spring. Although this group occurs throughout the waters off eastern Newfoundland, the highest concentrations during spring and summer are located in proximity to the coastline near breeding colonies (Figure 30). The majority of ECSAS and PIROP records for this group are of Atlantic puffin, with records of razorbills and black guillemots being relatively uncommon and associated with coastal waters. Breeding activities for these species occur in spring and summer and colonies are located on cliffs and islands, where the young are provisioned until fledged. All three species are known to breed along coastal Newfoundland, but particularly large colonies of Atlantic puffin are present in association with Baccalieu Island and Witless Bay. Atlantic puffins typically fledge in August (Nettleship 1972), at which time they can fly, are independent of parents (Harris and Birkhead 1985), and disperse out to sea far from the colonies. In contrast, razorbills fledge earlier in the summer and although flightless at the time, they maintain a coastal affinity and are accompanied by one parent (typically the male) that cares for the chick for several weeks (Harris and Birkhead 1985). In addition to some species having flightless young, auks are flightless during a molting period, which may last more than a month, and occurs at sea during late winter for Atlantic puffins (Harris 1984) and in early fall for razorbills (Bédard 1985; Freethy 1987). Black guillemots are largely restricted to coastal areas and are not expected to regularly occur in the offshore Project Area.

4.1.11 Cormorants

Cormorants are typically restricted to coastal environments and are only infrequently observed in offshore waters (Figure 31). Double-crested cormorants (*Phalacrocorax auritus*) have a wide breeding distribution in Newfoundland but the breeding range of great cormorants (*P. carbo*) is restricted to the south and southwest coast of the Island (Cairns et al. 1989, in Amec 2014). In southeastern Newfoundland, both great and double-crested cormorants are reported to nest at Cape St. Mary's (IBA 2013, in Amec 2014). Cormorants are not expected to regularly occur in or adjacent to the Project Area because of its distance from the coastline.

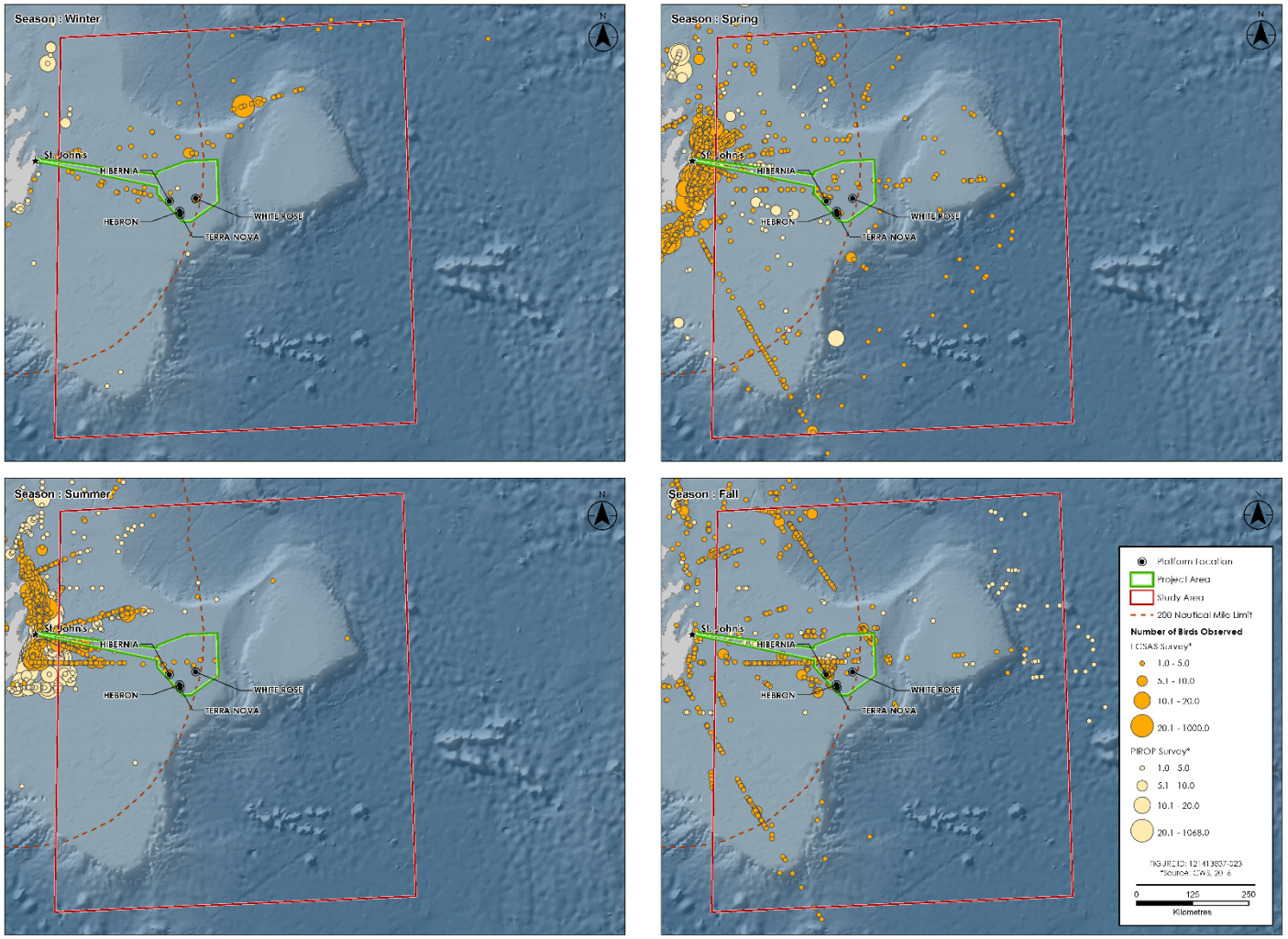


Figure 30 Distribution of Other Alcids in the Study Area, by Season

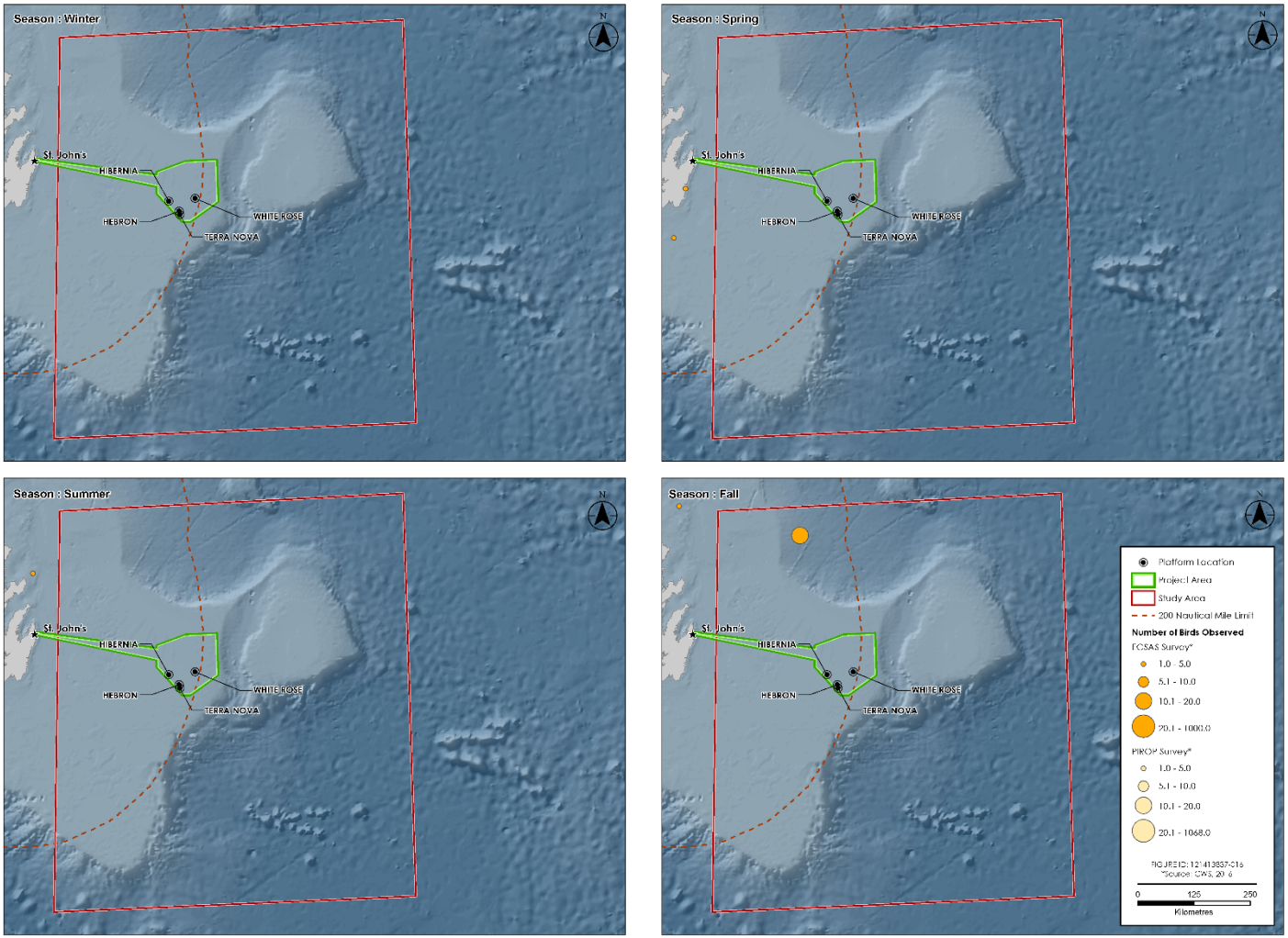


Figure 31 Distribution of Cormorants in the Study Area, by Season

4.1.12 Gulls

As a guild, gulls are among the most abundant marine birds in waters off eastern Newfoundland, and data indicate that they are present throughout the region during all seasons (Figure 32). Large and small gulls are included in this group, except for black-legged kittiwakes that have been described separately. Gulls are expected to occur in the Project Area during all seasons but seasonal patterns vary depending on the species. The most abundant species recorded in the Study Area during ECSAS and PIROP surveys were herring gull (*Larus argentatus*) and great black-backed gull (*L. marinus*), both of which breed in colonies along much of the coast of eastern Newfoundland. Although relatively common in offshore waters of eastern Newfoundland year-round, data from Fifield et al. (2009) suggest that they are most common during spring and winter. During summer months they tend to be more common closer to shore near their breeding colonies, but they are more widespread outside the breeding season and are abundant in areas that support high fishing activities such as the Nose and Tail of the Grand Banks (Fifield et al. 2009, in Amec 2014). Two colonies of ring-billed gulls (*L. delawarensis*) are also known along the coast of eastern Newfoundland, but this species is not regularly observed in offshore waters. According to PIROP and ECSAS data, glaucous gulls (*L. hyperboreus*) and lesser numbers of Iceland gulls (*L. glaucoides*) are also relatively abundant in the Study Area, except during summer months when they are associated with more northerly breeding grounds. Other species, such as ivory gull (*Pagophila eburnea*) and Sabine's gull (*Xema sabini*), are high Arctic breeders that are occasionally found in offshore waters of the Study Area. Other gull species recorded in the Study Area during ECSAS and PIROP surveys include lesser black-backed gull (*Larus fuscus*), laughing gull (*Leucophaeus atricilla*), and black-headed gull (*Larus ridibundus*).

4.1.13 Terns

Most terns arrive in eastern Newfoundland during May from their more southern wintering grounds and are most frequently encountered in proximity to coastal features near their breeding colonies (Figure 33). Although not common in offshore waters, ECSAS and PIROP data indicate that they are have been observed in the Study Area during spring and summer, with the greatest concentrations observed during spring. Common tern (*Sterna hirundo*) was the most abundant species of tern encountered within the Study Area during PIROP and ECSAS surveys, with Arctic terns (*S. paradisaea*) recorded in lesser numbers. Several colonies of common and Arctic terns are present along the coast of eastern Newfoundland, and caspian terns also reportedly breed in the area (Warkentin and Newton 2009, in Amec 2014).

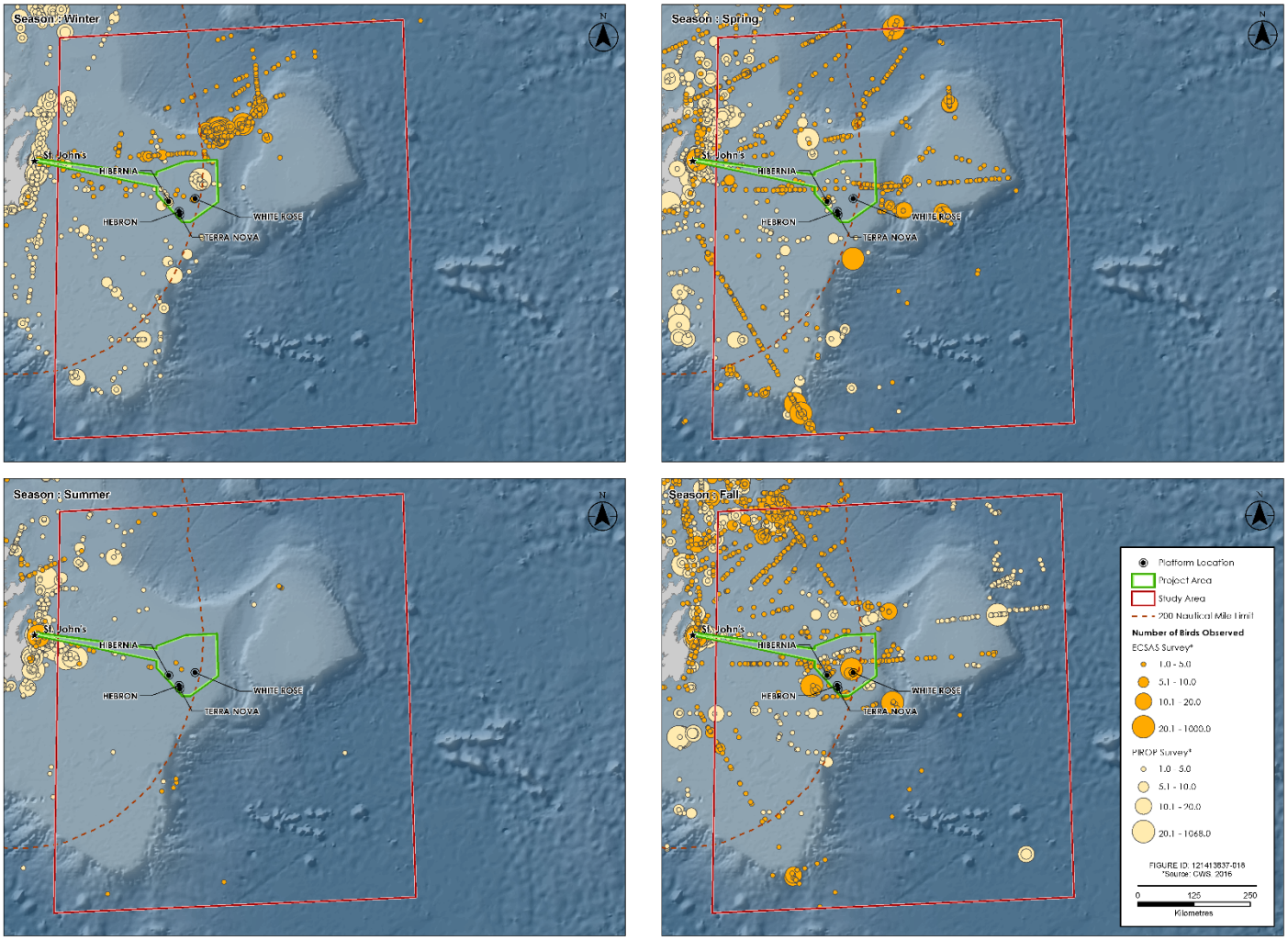


Figure 32 Distribution of Gulls in the Study Area, by Season

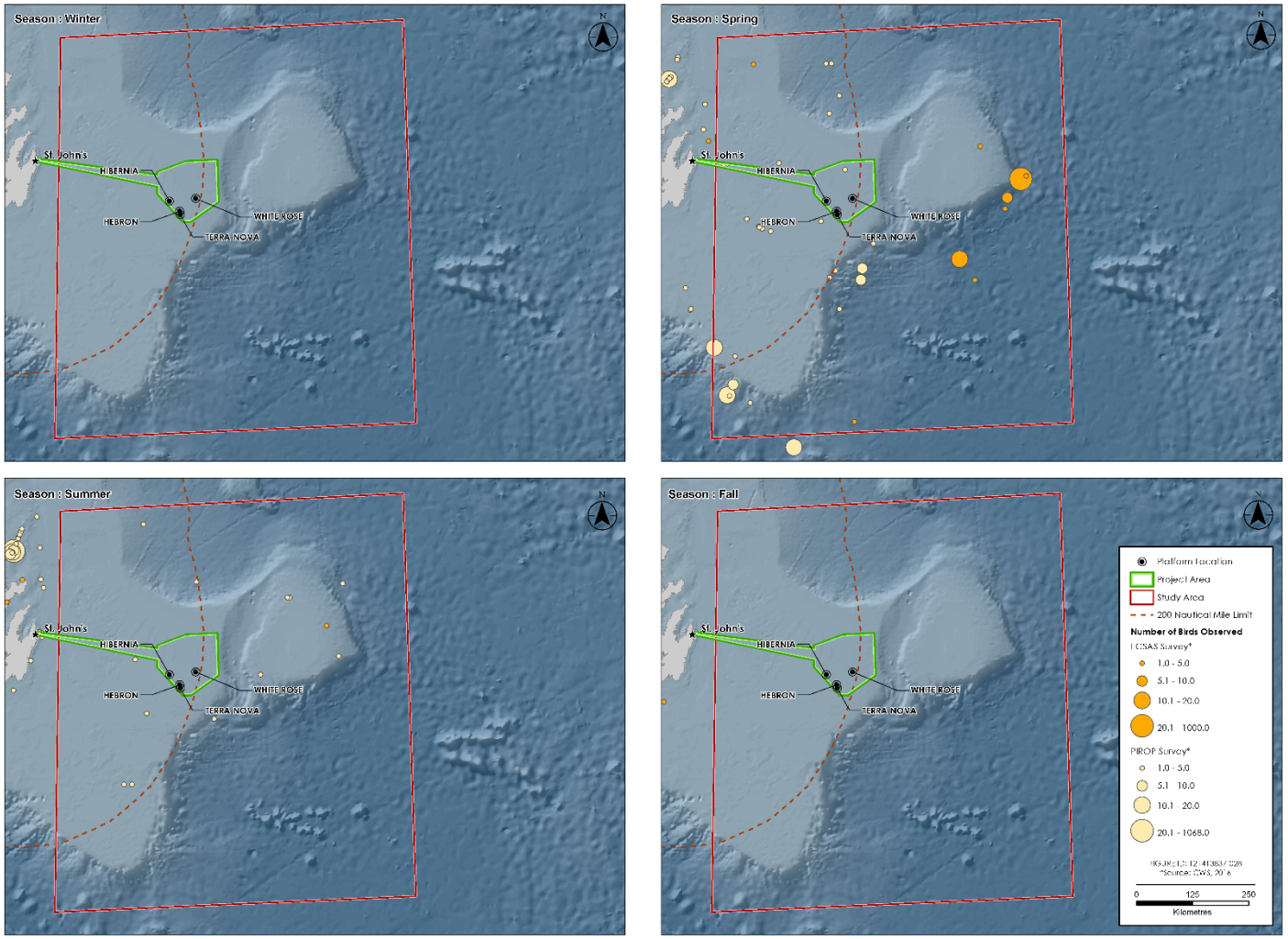


Figure 33 Distribution Terns in the Study Area, by Season

4.2 Waterfowl

A variety of waterfowl, loons, and grebes are present in the waters of eastern Newfoundland throughout the year but they are likely to be infrequent visitors to the Project Area. Sea ducks (particularly scoters, common eider (*Somateria mollissima*), and long-tailed duck (*Clangula hyemalis*) are the most abundant waterfowl recorded in the Study Area during PIROP and ECSAS surveys, with most records being from the fall (Figure 34). Waterfowl generally nest near fresh water, except for eiders which nest on coastal islands where fresh water is available and raise their broods in coastal waters. Outside of the breeding season, seaducks are typically found in coastal waters, over reefs and banks where benthic prey is accessible. They often occur in large flocks ("rafts") in coastal waters from autumn to spring (Lock et al. 1994). The waters associated with the Witless Bay Islands are particularly important for sea ducks during fall and large wintering congregations of up to 25,000 eiders can be seen between the Cape Freels coastline and nearby Wadham Islands (Amec 2014). Other major wintering areas for common eider and other sea ducks include Grates Point, Cape St. Francis, Mistaken Point, Cape St. Mary's, and Placentia Bay (Amec 2014).

4.3 Shorebirds

4.3.1 Phalaropes

Although taxonomically aligned with shorebirds such as sandpipers and plovers, the phalaropes that occur in the region are pelagic outside of the breeding season. The red phalarope (*Phalaropus fulicarius*) and red-necked phalarope (*P. lobatus*) are occasionally encountered in the waters off eastern Newfoundland and are surface plankton feeders that generally concentrate in areas where prey items are most readily available, such as along ocean fronts and around upwelling areas. Phalaropes use the offshore waters of eastern Newfoundland during migration between their arctic nesting grounds and more southerly wintering areas. PIROP and ECSAS data indicate that phalaropes have been recorded in the Study Area during spring, summer, and fall and although uncommonly encountered, may be found throughout the area (Figure 35). The majority of phalaropes identified to species within the Study Area are red phalaropes, but small numbers of red-necked phalarope have also been recorded during fall.

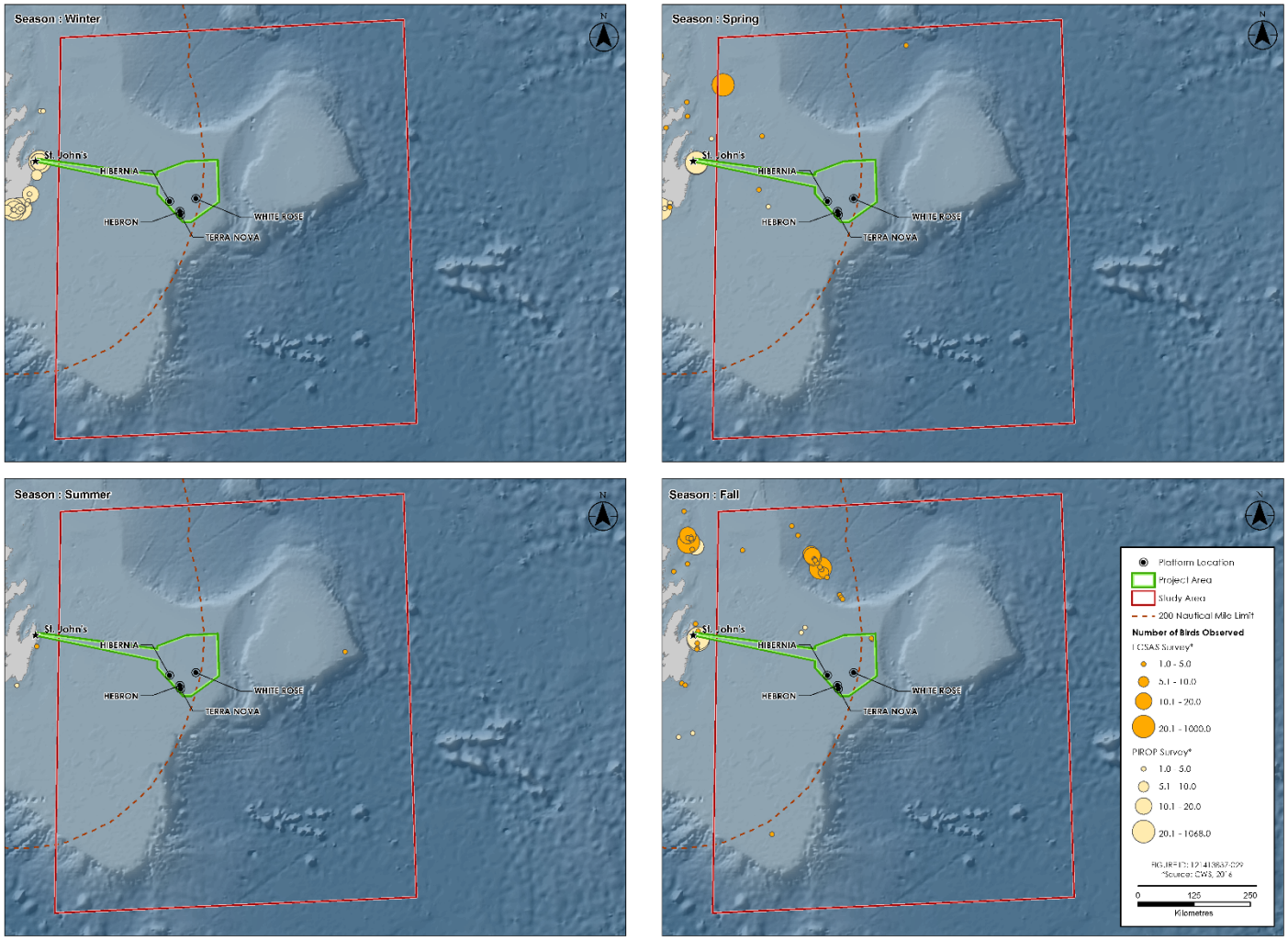


Figure 34 Distribution of Waterfowl in the Study Area, by Season

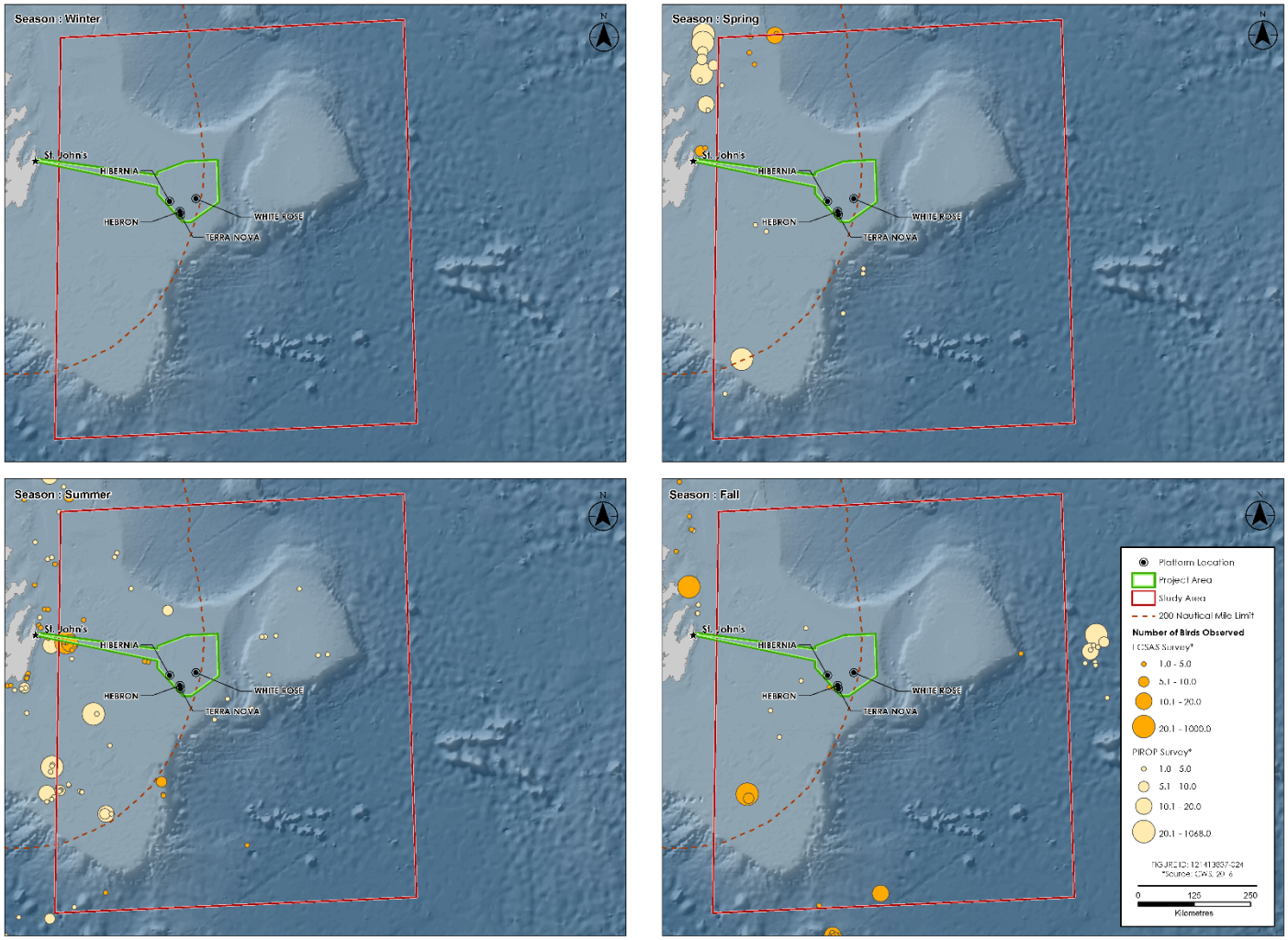


Figure 35 Distribution of Phalaropes in the Study Area, by Season

4.4 Species at Risk

4.4.1 Ivory Gull

Ivory gulls nest on flat terrain or on sheer cliffs in the high-Arctic from May to early June and outside their breeding season they live near the edges of pack ice in the North Atlantic Ocean, particularly in the north Gulf, Davis Strait, the Labrador Sea, and the Strait of Belle Isle (COSEWIC 2006). They are known to occur within offshore waters of eastern Newfoundland and PIROP and ECSAS data obtained for the Project include several records of this species within the Study Area. In particular, three observations (i.e., of one, two, and nine individuals) were made in April during a 1978 PIROP survey.

Until recently, the Canadian Arctic was considered to support 20% to 30% of the entire global breeding population of ivory gull and to contain colonies of global importance. However, aerial surveys conducted during 2002 to 2005 suggest that the Canadian breeding population has declined and is now comprised of 500 to 600 individuals, representing an approximate 80% decline over the last 18 years (COSEWIC 2006). Approximately 35,000 individuals were observed among the pack ice of the Labrador Sea in 1978 (Orr and Parsons 1982), representing the bulk of the world population. However, a 2004 survey conducted off the coast of Newfoundland and Labrador showed a decrease in ivory gull numbers, with sightings of 0.69 individuals sighted per 10 minutes observed in 1978 compared to 0.02 individuals sighted per 10 minutes in 2004 (COSEWIC 2006). Confirmed threats to ivory gulls (in Canada and/or globally) include illegal shooting of adults for food, climate change that is altering ice conditions in the circumpolar Arctic, oiling at sea, and escalating diamond exploration and drilling activities at key breeding locations (COSEWIC 2006).

As outlined in the management plan for ivory gull (Stenhouse 2004), the recovery goal was to return the breeding population to historic levels of approximately 1,000 breeding pairs and the breeding range to historic areas to at least four regional breeding areas by 2014. The recovery objectives are to prevent further loss to the population, understand the life history and potential threats to ivory gull, protect known habitat, and to reach out to the public and cooperate internationally in recovery efforts (Stenhouse 2004). Although there have been advances in increased awareness and understanding of the ivory gull since the last status assessment (COSEWIC 2006), breeding populations appear to be remaining at low levels within Canada (Government of Canada 2012).

4.4.2 Red-necked Phalarope

The red-necked phalarope is a member of the shorebird family but they are functionally much more like seabirds. Phalaropes are generally pelagic outside of the breeding season and spend up to nine months of the year at sea (Rubega et al. 2000). This species breeds in the low Arctic or Subarctic regions of Canada and Alaska, where they build nests near freshwater lakes, ponds, or marshes. In the fall, red-necked phalaropes depart from their breeding grounds and migrate southward to their tropical wintering grounds off the coast of South America (Rubega et al. 2000). Red-necked phalaropes forage mostly while swimming and feed on insects, crustaceans, and

molluscs. They are known for their unusual behaviour of spinning in circles on shallow water, likely to stir it up and bring food to the surface (Elphick et al. 2001).

The red-necked phalarope is designated as a species of *special concern* by COSEWIC; which reflects declines in its population during the past 40 years at an important staging area in Atlantic Canada. Threats to this species include habitat degradation associated with climate change and exposure to oil and other pollutants during winter and migration when it gathers in large abundances in areas where pollutants are concentrated by currents (COSEWIC 2014).

Red-necked phalaropes are most likely to occur in the Study Area during the spring or fall migration periods, and to be most abundant in the fall when staging for migration. Data obtained for the Project include red-necked phalarope records within the Study Area. In particular, two sightings (i.e., of one and four individuals) were made during an ECSAS survey in October 2007, both of which were within the Project Area. In addition, multiple records of unidentified phalaropes occur within the Study Area during spring, summer, and fall.

5.0 ADDITIONAL REFERENCES CITED EXCLUSIVELY IN THIS APPENDIX

Note: These references are exclusive to this appendix. Other references cited in the main report, as well as this appendix, as provided in Chapter 12 of the main report.

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APPENDIX E

Husky Oil Spill Response Plan Table of Contents

Husky Energy

Procedure

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APPENDIX F

White Rose Extension Project Environmental Assessment SBM Accidental Release and Dispersion Modelling (Amec 2012)

Husky Energy

White Rose Extension Project

SBM Accidental Release and Dispersion Modelling

June 2012

Husky Energy SUNCOR ENERGY nalcor energy

Environmental Impact Assessment

White Rose Extension Project

SBM Accidental Release and Dispersion Modelling

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Executive Summary

The development of the White Rose Extension Project (WREP) will involve the use of synthetic-based muds (SBMs), due to their unique performance characteristics, as well as their low toxicity and relatively low environmental effects compared to oil-based muds (OBMs).

As part of the environmental assessment process, a review was conducted of the latest scientific literature and industry spill databases from Atlantic Canada and the United States Outer Continental Shelf (US OCS) to determine the most probable modes of accidental SBM release. Four potential release spill scenarios were selected as being most representative for the WREP:

- Surface tank discharge
- Riser flex joint failure (two scenarios, for two fall velocities)
- BOP disconnect

Subsequently, a numerical dispersion modelling study was conducted to predict the potential seasonal footprints of SBM spills on the seafloor for each of the four scenarios. The numerical model used a full-year time series derived from ADCP current measurements at White Rose from 2008 to the end of 2010, with approximately 13,000 model realizations being simulated in each seasonal scenario per release mode. The total spill footprint area, length and distance from release site, as well as projected initial SBM layer thickness on the seafloor, were estimated for each simulated event, and seasonal median, maximum and average values were derived.

The maximum predicted distances from the release site are those for the winter surface dispersion scenario, where the maximum concentrations of the footprint are found at up to 1,061 m from the release site. For the other dispersion scenarios, the spill footprints remain within a maximum distance of 201 m or less. These maximum distances are expected to occur if a spill occurs during periods when the current magnitudes are at the seasonal maximum.

The footprint areas, and the associated footprint lengths, are expected to be influenced by the period over which the SBM is released and the fall velocities, as well as the variability of the currents over the release and settling periods. The largest footprint areas were found for the first riser flex joint scenario, which had the lowest fall velocity and the longest release period of 3 h. The single largest spill area in this scenario was observed in the winter season, and represented an area spanning approximately 579 m long by 40 m wide. The majority of the spill footprints were 1,800 m^2 or smaller, corresponding to spill areas measuring 30 m by 60 m. The smallest footprints (30 m by 30 m) were predicted for the BOP disconnect scenarios, which exhibited a combination of low height above sea bottom, relatively quick release time (1 h) and high fall velocities.

The interpretation of the predicted footprint areas and thicknesses should take into account that these are only preliminary dimensions of the projected landing area for the SBM droplets, and the estimated SBM layer thickness if the full spill volume landing in each model cell were to be equally distributed within that cell. The subsequent fate and

the footprint are likely to evolve in a less predictable fashion, as the negatively buoyant SBM droplets are expected to coalesce into streams or pools, and flow under the influence of gravity and the local bathymetric features. As there is a tradeoff between the area covered by the spill and the thickness of the spill, it can be expected that an area of the seafloor that is relatively flat and with few roughness features is likely to result in a thinner and widely distributed SBM layer, while a localized depression in the seafloor could retain the received SBM as a thicker layer within a smaller area.

While the weathering properties for the SBM considered in the present study are not precisely known, it is expected that the biodegradation of the SBM on the seafloor would take place over periods on the order of several weeks. This timescale far exceeds the duration of the spill and settling of SBM to the floor; therefore, the SBM is considered to be stable during the entire duration of the physical dispersion of the droplets in all modelled scenarios.

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1.0 INTRODUCTION

1.1 Project Background

An option for the development of the White Rose Extension Project (WREP) includes the operation of a semi-submersible drilling rig to perform the drilling, completions and well interventions for up to 64 wells within up to four glory holes. It is anticipated that the drilling operations for the intermediate and main well hole sections will necessitate the use of synthetic-based mud (SBM). The use of SBMs in offshore drilling operations is regulated in accordance with the Offshore Waste Treatment Guidelines (OWTG) (NEB et al. 2010), which dictate the following:

> Where there is technical justification (e.g., requirements for enhanced lubricity or for gas hydrate mitigation), operators may use synthetic based mud (SBM) or enhanced mineral oil based mud (EMOBM) in the drilling of wells and well sections. Other than the residual base fluid retained on cuttings as described in the operator's EPP, no whole SBM or EMOBM base fluid, or any whole mud containing these constituents as a base fluid, should be discharged to the sea (NEB et al. 2010).

For this (subsea drill centre) development option the drill cuttings recovered from operations involving the use of SBM will be treated and, for each well, approximately 500 t of cuttings with approximately 26 m^3 of SBM on cuttings will be released[1] from the drilling rig in accordance with the OWTG. The OWTG specify the performance target for the retained SBM on cuttings that may be discharged to the environment as follows:

> The 48-hour mass weighted average of retained "synthetic-on-cuttings" or "enhanced mineral oil-on-cuttings" discharged to sea should not exceed 6.9 g/100 g oil on wet solids (NEB et al. 2010).

SBMs are defined as drilling muds in which the continuous phase consists of a synthetic base fluid, while the dispersed phase consists of brine and other additives. SBMs have been developed as a more environmentally friendly alternative to oil-based muds (OBMs), as the synthetic fluids that comprise the continuous phase exhibit low toxicity to aquatic life and are more biodegradable in marine sediments than OBMs. SBMs exhibit several performance advantages over the more commonly used WBMs; therefore, they are commonly used for challenging wells in deep water, or wells with highly deviated wellbores. They serve several essential functions during the drilling process: transport of cuttings to the surface; cooling, cleaning and lubrication of the drill bit; maintaining a pressure balance between the geological formation and the borehole; reduction of friction in the borehole; sealing of permeable formations; and maintaining stability of the borehole walls (Burke and Veil 1995).

[1] Under the wellhead platform (WHP) development option (the alternative to the subsea drill centre option), for both intermediate and main well sections, all SBM will be treated and reinjected or stored/ transferred to the next well.

1.2 Objectives

As part of the environmental assessment process, the requirement for an assessment of the zone of influence of potential accidental SBM spills has been identified. The following sections present the results of a modelling study undertaken by AMEC, aimed at characterizing the dispersion and zone of influence of potential accidental releases of SBM for the WREP. The objectives were to:

- assess the potential modes of accidental releases of SBM to the marine environment

- model the most likely scenarios of SBM dispersion and deposition in the marine environment, based on possible combinations of potential accidental release modes and seasonal environmental conditions.

It is noted that these studies are preliminary and the information will be updated as design progresses through FEED and detailed engineering.

2.0 MODES OF ACCIDENTAL SYNTHETIC-BASED MUD RELEASES

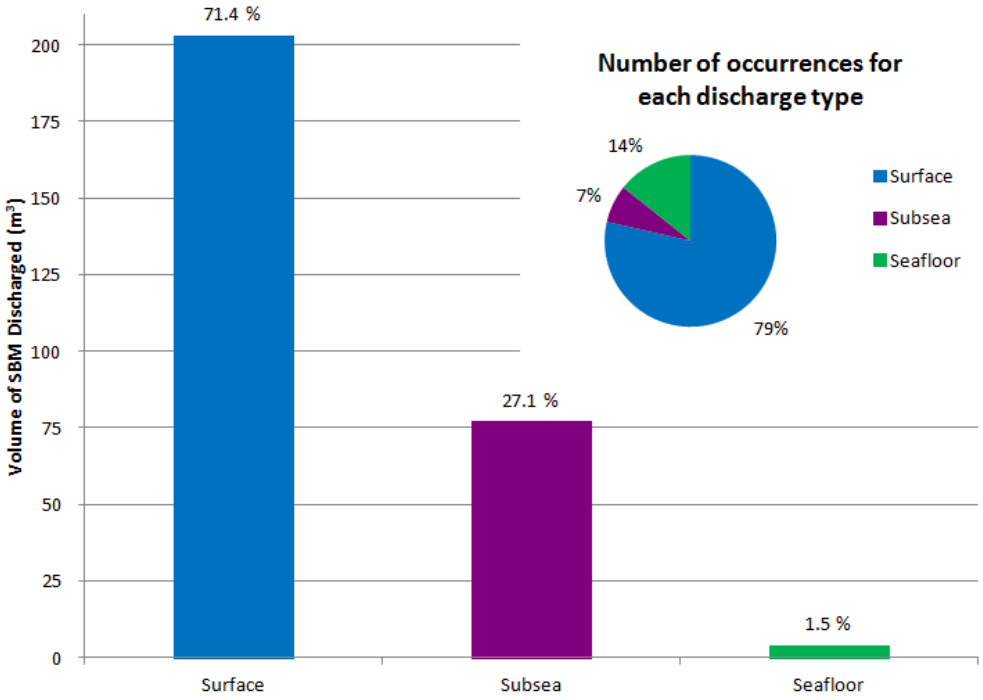
2.1 Historical Events in Industry Databases

SBMs have been adopted for use in offshore drilling operations for nearly two decades. In order to characterize the most likely modes of accidental SBM releases, industry reports and spill statistics databases were investigated, and the frequency of occurrence, specific amounts and locations of the spills were analyzed. The main sources of relevant information comprised of the publicly-available databases of oil spill events resulting from oil and gas operations in Atlantic Canada, maintained by the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB 2012) and the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB 2012). Additionally, the study considered the comprehensive database of substantial spills (greater than 50 bbl, or 7.95 m^3) resulting from oil and gas activities in the United States Outer Continental Shelf (US OCS), compiled by the United States Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly the Minerals Management Service (BOEMRE 2012).

The oil spill incident database for the Newfoundland and Labrador offshore area covers the period from 1997 to 2011, and contains a listing of the reported spill amounts, the operators and rigs involved, as well as the locations on the rig system where the reported spill likely originated. For the period of record to the end of 2011, accidental spills of SBMs and synthetic-based fluids constituted approximately 18 percent of all recorded spill events greater than 1 L by frequency of occurrence; however, they accounted for approximately 61 percent of the spilled volume. There were 43 spill events greater than 1 L, amounting to a total of approximately 286 m^3 of spilled volume over the entire period of data coverage. The spill events were categorized into surface spills, subsea spills and seafloor spills, based on the likely location where the spill originated. The frequency of occurrence and volumes of the three main categories of spills for the Newfoundland and Labrador offshore area are presented in Figure 2-1.

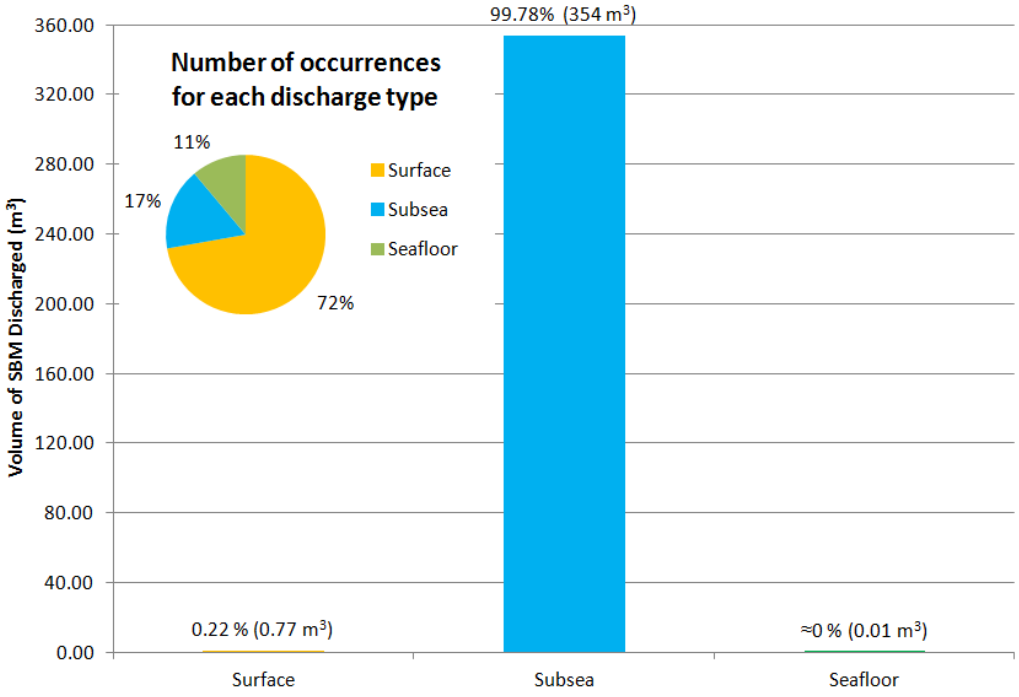
The data show that synthetic based fluid spills occurred most often at the sea surface (79 percent of the time), contributing over 71 percent of the total spilled volume. These spills are associated with leaks from mud pits, tanks, shale shakers, slip joints, hoses and other components of the mud circulation system found near the sea surface. Subsea spills, occurring under the surface and anywhere along the marine riser, kill lines, choke lines, boost lines and blowout preventer (BOP) control lines, occurred approximately 10 times less frequently, but still contributed over 27 percent of the volume. Spills near the seafloor contributed the least in terms of spilled volume, as they seem to have mostly consisted in minor events.

Similar statistics were derived from data from the Nova Scotia offshore area, as well as the US OCS, as shown in Figure 2-2 and Figure 2-3, respectively. There were a total of 18 spill events in the Nova Scotia offshore area, all except one being below 1 m^3 in volume. The most substantial event recorded was the 2004 spill of 354 m^3 of SBM, caused by a failure in the riser flex joint during abandonment of the Crimson F-81 exploration well by Marathon Canada Petroleum ULC.



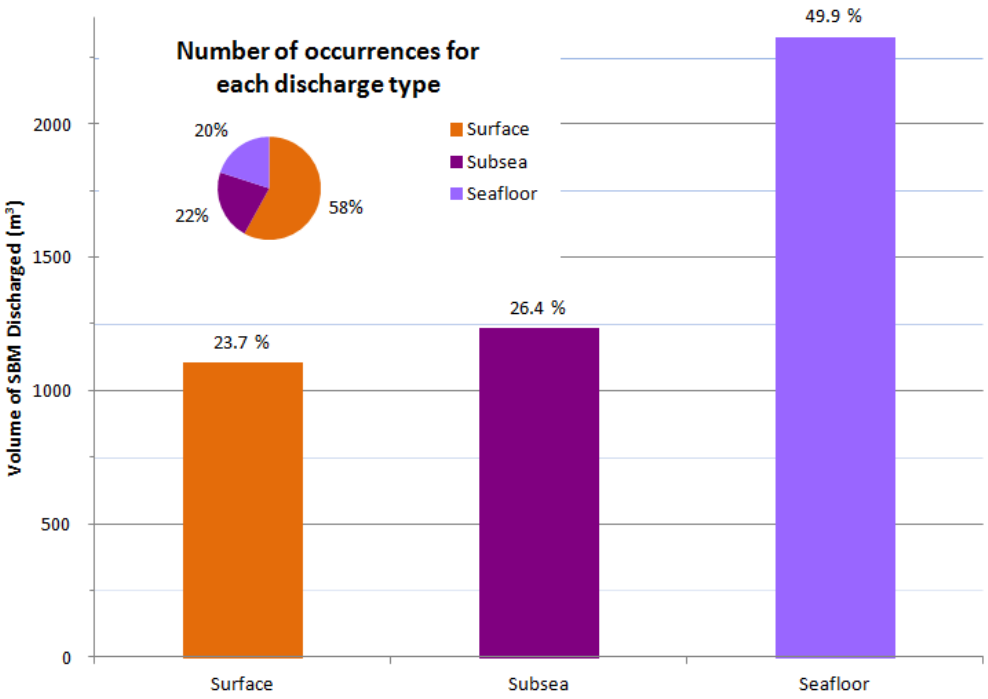
Source: data from C-NLOPB 2012

Figure 2-1 Synthetic-based Fluids Spill Statistics for the Newfoundland and Labrador Offshore Area, 1997 to 2011



Source: data from CNSOPB 2012

Figure 2-2 Synthetic-based Fluids Spill Statistics for the Nova Scotia Offshore Area, 1997 to 2011



Source: data from BOEMRE 2012

Figure 2-3 Synthetic-based Fluids Spill Statistics (greater than 7.95 m^3) for the United States Outer Continental Shelf, 1999 to 2010

The data from the BOEMRE show that for the US OCS surface spills are also the most frequent mode of SBM release; however, the seafloor spills contribute a disproportionately higher percentage of the volume compared to the Atlantic Canadian datasets. The discrepancy between the datasets can be attributed to the fact that the BOEMRE data include a larger number of drilling operations, with multiple incidents of BOP disconnection events due to severe weather and other emergencies in the US Gulf of Mexico. An additional factor in the spilled volumes at the seafloor is the fact that the drilling operations in the US Gulf of Mexico are in deeper water (e.g., 2000 m), necessitating the use of up to 20 times larger amounts of SBMs compared to operations on the Grand Banks of Newfoundland and Labrador. This fact is reflected in the total spill volume for the 50 events included in Figure 2-3, which is an order of magnitude larger than the total spill volumes in Atlantic Canada. The shallower water depths on the Grand Banks (on the order of 100 m) dictate that the capacity of the marine riser, as well as the associated mud transport system components of a typical drilling rig, are proportionately lower, and therefore, the overall potential effect of accidental spills is expected to be lower compared to that in deeper waters.

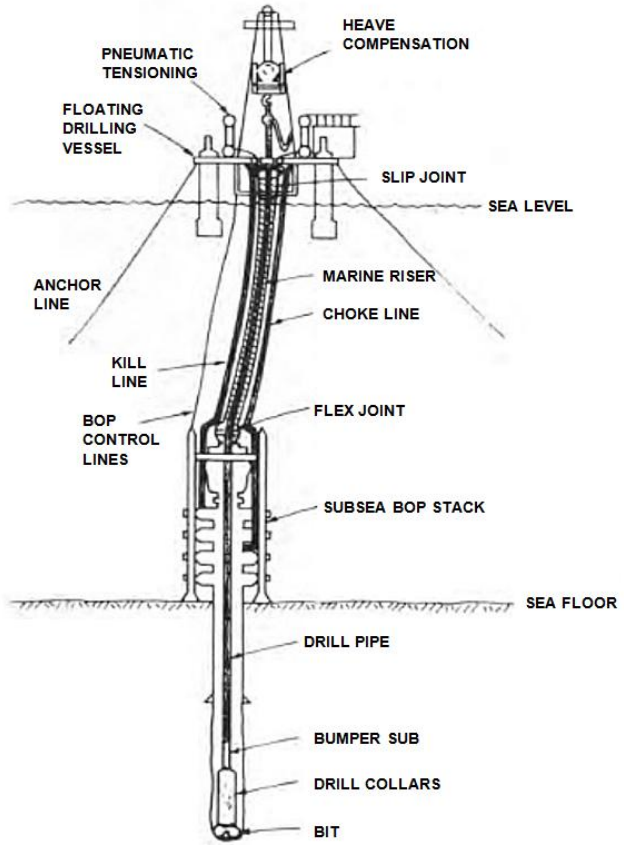
2.2 Potential Synthetic-based Mud Accidental Release Scenarios for the White Rose Extension Project

In order to capture the full range of possible accidental spill scenarios within a reasonable scope, it was necessary to consider the possible release modes based on past events, while taking into account the characteristics and capacities of the drilling rig likely to be used for WREP development. A conservative approach, assuming worst

case scenarios for each potential mode of release, dictated that the full amount of SBM potentially affected by the mode of release should be considered.

A surface accidental release scenario is potentially the most likely based on historical data. The most severe hypothetical scenario that can be anticipated for the WREP involves the inadvertent discharge of the entire volume of a mud tank, resulting in 60 m^3 of SBM being discharged through a 25 cm (10 inch) (internal diameter) pipe a few metres below the sea surface. The discharge would be expected to happen over a short period of time, over the course of several minutes to several tens of minutes.

Another potential location of an accidental release would be a subsea release in the lower half of the water column or near the seafloor. This type of release is associated with leaks at the riser joints, leaks and ruptures of the choke, kill and boost lines, or emergency disconnection of the riser and mud transportation lines. The components of a typical offshore drilling rig are illustrated in Figure 2-4. The most severe accidental release considered might occur at or near the riser flex joint, where the marine riser and other mud transport system components connect to the subsea BOP stack. The flex joint is a crucial component that provides flexibility for the riser to operate in a wide range of current conditions, while maintaining the pressure integrity of the mud circulation system.



Source: Bourgoyne et al. 1986

Figure 2-4 Main Components on a Typical Offshore Drilling Rig

The most substantial example of such a release in Atlantic Canada is the previously mentioned event at the Crimson F-81 well in 2004. A latent manufacturing defect in the seal ring of the flex joint was identified as the root cause of the substantial SBM spill. Since the Crimson F-81 well was in approximately 2,000 m depth, a total of 466 m^3 of SBMs were used in the marine riser, choke, kill and booster lines. The emergency response actions of the crew in that case allowed for 25 percent of the volume to be recovered. This included amounts from the choke and kill lines, the wellbore and the drill pipe, as well as the marine riser. In this case, SBM was released in the form of relatively fast and narrow jets pouring out through two ports in the riser wall over the course of three hours, ultimately forming streams and pools on the seafloor around the wellhead (CNSOPB 2005). This event illustrates one possible sequence of events following a subsea spill scenario.

Another potential severe scenario that could result in a different kind of subsurface release of most or all of the SBM contents, from the marine riser and associated transport lines, would be an emergency disconnection of the riser, which might prevent the crew from taking the necessary actions to displace the transport lines to seawater and therefore minimize spill amounts. In such an event, it would be expected that the SBM would be released within a shorter period of time (on the order of an hour or less), and through large orifices, resulting in a wider but slower jet of SBM being released. The rate of release and the size of the orifices are expected to contribute substantially to the subsequent behaviour and dispersal of the SBM in the environment. While it is difficult to predict the exact mode of failure of mechanical components and their behaviour during rare extreme weather events, the two subsea scenarios described here are expected to capture the range of possible conditions under which SBMs might be released under extreme conditions.

The drilling system planned for WREP development is expected to have a riser capacity of 29 m^3, and the associated mud transport lines would have a combined capacity of 20 m^3, for a total of 49 m^3. In a worst case scenario, either of the two modes of potential subsea release of SBM could result in the loss of all 49 m^3 of SBM at a height of approximately 20 m above the seafloor, or at approximately 100 m water depth. Therefore, even though these events are classified as subsea releases, they capture scenarios categorized under both the “subsea”, as well as the “seafloor” spill category in the historical industry databases. The modes of release and the associated details selected for the modelling study are summarized in Table 2-1.

Table 2-1 Modes of Release Selected for Synthetic-based Mud Dispersion Modelling

Mode of Release	Location of Release	Rig Components Contributing to SBM volume	Total Volume (m^3)	Period of Release (hours)	SBM Flow Type
Surface	120 m above seafloor	Mud tank	60	0.5	Wide, low-speed jet
Subsea (flex joint failure)	20 m above seafloor	Marine riser; choke, kill, booster, surface lines; mud gas separator	49	3	Narrow, high-speed jet
Subsea (BOP disconnect)	20 m above seafloor	Marine riser; choke, kill, booster, surface lines; mud gas separator	49	1	Wide, low-speed jet

3.0 SYNTHETIC-BASED MUD SPILL DISPERSION MODELLING

The faithful representation of the dispersion of SBM spills in the marine environment requires knowledge of the properties and behaviour of the SBM fluid in the immediate vicinity of the release site under different release scenarios, as well as the subsequent behaviour under the influence of the ambient ocean currents. A literature review of the current state of scientific knowledge of the behaviour of SBM in the marine environment, as well as reports of observations of actual SBM spill events, revealed that SBMs exhibit a unique behaviour in the marine environment due to the fact that they are immiscible in water (i.e., cannot be mixed with), and are negatively buoyant. Unlike water-based fluids, they tend to form distinct jets and droplets that fall relatively rapidly through the water column, and they are prone to form visible and clearly-defined streams and pools at the seafloor, where their dispersion is in large part driven by gravity in conjunction with the local seafloor features. The approaches for modelling the dispersion of WBMs and other water-based fluids are therefore not applicable to SBMs.

The scientific literature treating SBM spills is, in most cases, focused on the effects of SBMs at the seafloor, their persistence and biodegradability, as well as the biological effects on a number of marine species. To date, there have been no systematic field observations of SBM dispersion in the marine environment that could be used to quantify their dispersion properties in a real world scenario. The modelling study conducted by AMEC relies on data from an experimental study of SBM fall velocities under several release scenarios, which was commissioned by the BOEMRE and conducted by the Southwest Research Institute (SwRI) (2007). The following subsections briefly describe the findings of the experimental study, and the methods AMEC used to implement them in an SBM dispersion model. Furthermore, the ocean current inputs, limitations and assumptions behind the modelling study are described, and results are presented for all release modes.

3.1 Synthetic-based Mud Properties and Behaviour

The drilling operations during WREP development will use SBM that represents an emulsion in which the continuous phase is comprised of Puredrill IA-35LV, a non-toxic and readily biodegradable synthetic fluid produced by Petro-Canada. The synthetic fluid will comprise 65 percent of the SBM volume, with other additives (barite, viscosifiers, emulsifiers, lime, fluid loss control agents and water) accounting for the rest. The overall density of the SBM will be 1,350 kg/m^3.

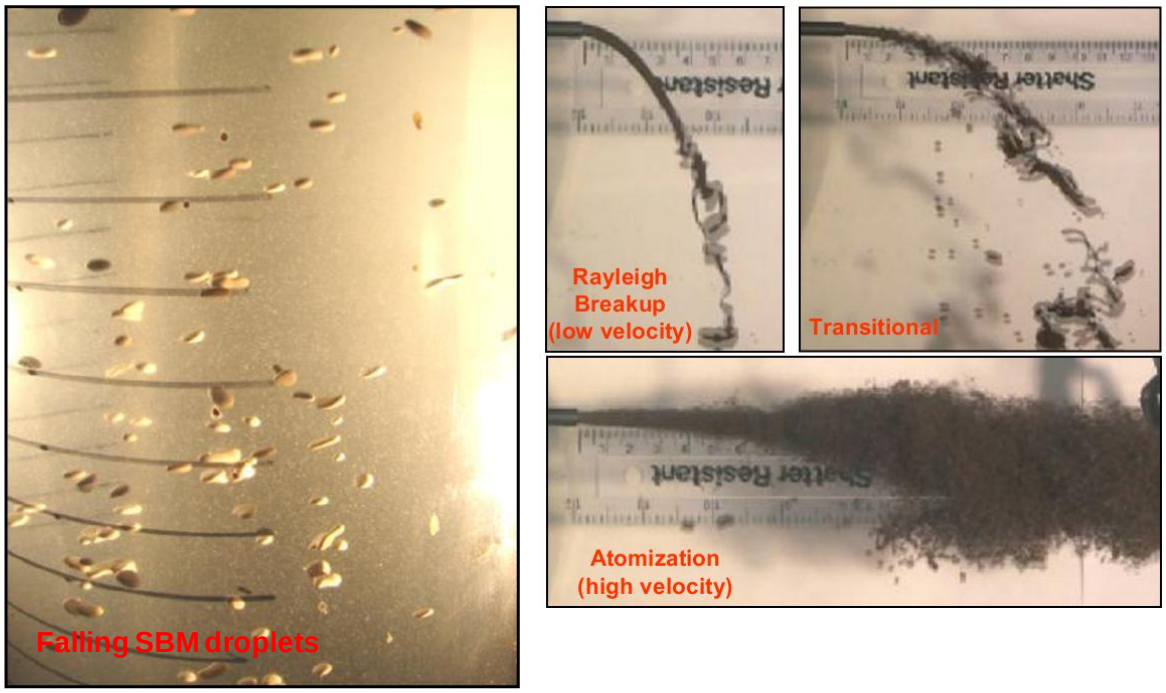
Since SBMs are immiscible in water, once released, they would form droplets of various sizes that are then subject to dispersal by the ocean currents. Some key aspects of the SBM behaviour that determine how it would spread in the marine environment are the breakup of the fluid into droplets of varying sizes and the stability of the SBM emulsion under different release and environmental conditions, as well as the terminal fall velocity of the droplets. For immiscible fluids, there exists a maximum stable droplet size at terminal fall velocity, which is governed by the balance between the interfacial tension holding the drop together, and the deforming force imparted by the buoyant flow (Grace et al. 1978). If the droplets formed in a spill event are larger than the maximum stable size, they will break up as they fall through the water column until they reach a stable size at the final fall velocity. The deforming shear forces are expected to be much larger for higher jet speeds, when it is likely that the SBM would be broken into droplets that are smaller than the stable droplet size.

Clift et al. (1978) have shown that droplets fall faster as they grow bigger in diameter, up to a certain threshold size beyond which increasing the droplet size does not increase the fall velocity. This was explained by the fact that drops retain their spherical shape only until a certain threshold in size, beyond which the deforming forces act on the drops to make them flatter and resistant to further increases in fall velocity.

The behaviour of immiscible fluids becomes more complex when they are discharged as jet of varying speed. Kitamura and Takahashi (1986) showed that there are three main flow regimes that a jet undergoes, depending on the fluid properties and the relative speed of the jet and the receiving fluid. At low jet velocities, large drops form from a laminar jet of fluid in which Rayleigh instabilities grow until they pinch off the jet into individual drops – a flow regime named Rayleigh breakup, or laminar breakup. This flow regime results in a relatively uniform distribution of droplet sizes. In contrast, higher speed jets break up into a spray of fine drops that have a wide size distribution – a flow regime called the spray or atomization breakup. Instead of Rayleigh instabilities, the dominant breakup forces in the atomization regime are exerted by the fluid momentum in conjunction with the viscous forces. At intermediate jet speeds, there exists a transitional flow regime in which both the Rayleigh instabilities and the fluid momentum impart a substantial influence on the breakup process.

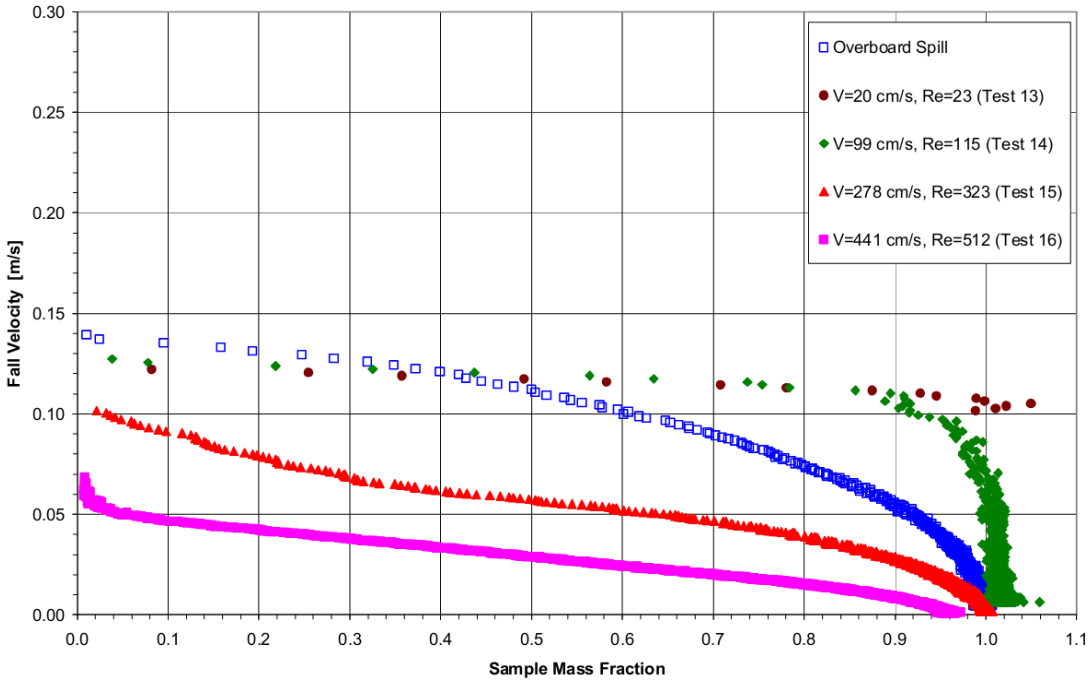
The SwRI (2007) conducted an experimental study of fall velocities for five different batches of SBM, labelled from A through E, exhibiting a range of densities used by industry in offshore drilling in the Gulf of Mexico. Out of these, the mud sample D exhibited the most similar density (1,402 kg/m^3) to the SBM planned for use in the WREP. They designed their experiment in such a way as to capture the most frequent spill modes, which they determined partly by conducting an industry survey, and partly by analysis of spill modes in the Gulf of Mexico from BOEMRE database statistics similar to those presented in Section 2.0. Furthermore, their experimental setup allowed them to simulate overboard spills of SBM (dropped above the sea surface), as well as to capture the different flow regimes (Rayleigh to atomization) for low- and high-speed jets (Figure 3-1) for each of the SBM samples, and to measure the fall velocity distributions for each of the spill scenarios.

The SwRI (2007) experimental study focused on producing fall velocity distributions instead of the more difficult to measure droplet size distributions, due to the fact that the fall velocity of the resulting SBM droplets is the controlling factor that determines the time period in which they would settle and reach the seafloor. The settling period also represents the time during which they would be subject to horizontal dispersal by the ambient ocean currents. Therefore, the expected terminal fall velocities under each release scenario will be a primary factor in their fate and footprint on the sea bottom. The fall velocity distributions for mud D, presented in Figure 3-2, were used as the basis for the SBM dispersion model.



Source: SwRI 2007

Figure 3-1 Falling Synthetic-based Mud Droplets (left panel) and Jet Breakup Regimes (three right panels)



Source: SwRI 2007

Figure 3-2 Fall Velocity Distributions for Synthetic-based Mud Droplets under Different Flow Regimes

The experimental scenario with the lowest jet speed (V=20 cm/s) for mud D corresponded to a laminar (not turbulent) breakup regime and as such, is considered representative of the SBM release scenarios involving large orifices or pipes, and the lowest expected jet speeds (e.g., surface release of mud tank contents through pipe; subsea release via BOP disconnect). The highest tested SBM jet speed (V=441 cm/s) was found to produce an atomization regime and as such, is representative of subsea releases through small cracks or orifices in the riser or mud transport system. It is notable that the two extreme jet regimes produced very different distributions of fall velocities – while the droplets produced by the low-speed jet exhibited very uniform fall velocities (centred around 11 cm/s), the highest-speed jet produced droplets with a variety of fall velocities, ranging from nearly 0 to 7 cm/s. In order to incorporate this aspect of the fall velocity distribution for the high speed jet, the two border values of 1 and 5 cm/s were selected as representative model inputs for this mode of release, accounting for approximately 95 percent of the points in the distribution.

3.2 Ambient Ocean Current Conditions

The ocean currents at White Rose are characterized by high variability, most of which is associated with the ocean's response to various atmospheric disturbances, ranging from atmospheric pressure systems, wind forcing during storms, to the influence of tropical cyclones tracking in the area. In contrast, the highly-predictable tidal current components play a relatively minor role, and explain approximately 20 percent of the annual current variability in the area (Oceans Ltd. 2011). In order to capture the full range of ocean current variability, including components driven by factors that are difficult to predict, it was deemed appropriate to adapt a subset of the currents measured throughout the full water column at White Rose over the past several years.

The Acoustic Doppler Current Profiler (ADCP) datasets for the three-year period from 2008 through 2010 (S. Russell, pers. comm.) were analyzed by AMEC for completeness of coverage in each season. The 2010 dataset was found to be the most complete, with only three gaps: 8 h, 3 days, and one spanning from mid-November to the end of year. To fill the gaps, and yield a representative one year time series, current data from the 2008 dataset from the representative periods were substituted satisfactorily.

It was found that the raw data contained a high-frequency (at periods less than 1 h) variability, particularly pronounced in the upper half of the water column. This current variability could not be linked to any plausible physical process, therefore it is likely attributable to measurement errors related to unfavourable sampling conditions. The factors affecting the quality of near surface data included surface reflection of the acoustic beam, high mixing rates, turbulence and water mass quality (S. Russell, pers. comm.).

In order to eliminate this unexplained variability, as well as to produce a uniform sampling interval for use in the SBM dispersion model, the raw time series were resampled at a uniform sampling rate of 10 minutes; they were then low-pass filtered by using a 30-point Finite Impulse Response filter to eliminate signals with a period smaller than two hours; finally, the filtered signal was resampled at the original 10 minute interval. Three ADCP depth bins, at depths of 28 m, 60 m and 112 m, were selected to represent the conditions at the surface, mid-depth and near the bottom. The seasonal statistics for the processed current for the three depth layers are presented in Table 3-1.

Table 3-1 Seasonal Current Statistics for the Processed Currents Used as Model Inputs

Season	Depth	Max Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction To (^{o} True N)
Winter (Jan-Mar)	Near surface	62	15	4	180
	Mid-depth	62	14	3	178
	Near bottom	40	13	4	165
Spring (Apr-Jun)	Near surface	43	12	2	173
	Mid-depth	26	10	0	175
	Near bottom	31	10	2	170
Summer (Jul-Sep)	Near surface	65	12	1	187
	Mid-depth	51	10	1	183
	Near bottom	31	8	1	174
Fall (Oct-Dec)	Near surface	61	20	4	175
	Mid-depth	47	15	2	179
	Near bottom	40	12	5	163
Source: ADCP data from Oceans Ltd. 2011.					

3.3 Synthetic-based Mud Model Setup

A modelling effort aimed at capturing the fate of accidental SBM spills would need to incorporate in a meaningful way the timing, location and amounts of each potential spill event, as well as the ocean current variability over the duration of the spill event. Moreover, since the timing of the spill cannot be predicted, it should be assumed that the spill can take place at any time during the year. Therefore, the SBM dispersion model runs should take into account the full ocean current time series available. In this context, the modelling approach was based on the consideration of the specific parameters and assumptions for each of the scenarios, which were derived from the details of each of the three selected release modes described in Section 2.2.

The scenario details are listed in Table 3-2 as they apply to the SBM dispersion model. Two main SBM flow regimes are considered in the modeled scenarios, the wide, low-speed jet that produces relatively uniform fall velocity distributions (approximately 11 cm/s), and a narrow, high-speed jet that produces droplets with a wider range of fall velocities (mostly within 1 to 5 cm/s). In order to capture the wide range of fall velocities expected for the subsea release mode resulting in a high-speed jet flow (e.g., a flex joint failure), this scenario was modelled separately at the two ends of the fall velocity range (plotted with pink markers in Figure 3-2). The four release scenarios were modelled for each of the four seasons, resulting in a total of 16 scenarios.

The settling times shown in Table 3-2 are a function of the fall velocity, as well as the location of the release above the seafloor. It is expected that the SBM droplets would reach the seafloor within a period from 3 to 30 minutes. Therefore, each collection of droplets released simultaneously would be subjected to a relatively narrow range of

ocean currents, as the currents are not expected to change substantially within 30 minutes. The implication of this is that the droplets from spills with shorter durations of release are expected to fall within a relatively narrower area at the seafloor compared to longer-duration spills, all other factors being equal. In contrast, if the SBM is released over a longer period of time (e.g., 3 h in the flex joint failure scenarios), the droplets released toward the end of the spill event are likely to experience different current conditions compared to those at the beginning of the spill.

Table 3-2 Synthetic-based Mud Model Input Parameters for Each Release Scenario

Release Scenario	Total Volume (m^3)	Duration of Release (hours)	SBM Flow Type	Fall Velocity (cm/s)	Location of Release	Settling Time (seconds)
Surface Tank Discharge	60	0.5	Wide, low-speed jet	11	120 m above seafloor	1,091
Flex Joint Failure I	49	3	Narrow, high-speed jet	1	20 m above seafloor	2,000
Flex Joint Failure II	49	3	Narrow, high-speed jet	5	20 m above seafloor	400
BOP Disconnect	49	1	Wide, low-speed jet	11	20 m above seafloor	182

The modelling procedure included splitting the full spill volume into discrete collections of droplets over the duration of the release. Since the input current series had a time resolution of 10 minutes, the currents were linearly interpolated so that each collection of packages experienced the most up-to-date set of current conditions. To calculate the horizontal trajectory of the droplets, it was necessary to compute the time they would spend in each of the three depth layers. Based on an analysis of the ADCP data, the surface layer was defined as extending from 0 to 30 m depth (25 percent of the water column), while the bottom layer was taken from the seafloor to 12 m above the seafloor (10 percent of the water column). The mid-depth currents were applied to the middle 65 percent of the water column. The destination at the seafloor for each collection of droplets experiencing a set of current conditions [(u_s, v_s),(u_m, v_m),(u_b, v_b)] is computed according to the following equations:

$$x = x_0 + u_s \times t_s + u_m \times t_m + u_b \times t_b$$

$$y = y_0 + v_s \times t_s + v_m \times t_m + v_b \times t_b$$

where the subscripts *s, m, b* stand for *surface, mid-depth* and *bottom*, respectively. The time spent in each of the three layers is defined in terms of the initial height above the seafloor, $H_{release}$, and the settling velocity, $w_{settling}$, as follows:

$$t_s = \frac{H_{release}}{w_{settling}} \times 0.25;$$

$$t_m = \frac{H_{release}}{w_{settling}} \times 0.65;$$

$$t_b = \frac{H_{release}}{w_{settling}} \times 0.10 \ .$$

for the surface release, and in the following manner for the subsea release scenarios:

$$t_s = \frac{H_{release}}{w_{settling}} \times 0 \ ;$$

$$t_m = \frac{H_{release}}{w_{settling}} \times 0.40;$$

$$t_b = \frac{H_{release}}{w_{settling}} \times 0.60 \ .$$

Each set of east and north destination components (*x, y*) were fit within a horizontal grid with a 30 m resolution, and the amount of SBM within each grid cell was counted for the full duration of the spill event. Any model grid cell that received any amount of SBM was included within the spill area. The thickness of the initial SBM layer on the seafloor was computed on the assumption that the SBM was equally distributed across the area of each cell. In order to capture the full range of seasonal conditions, approximately 13,000 independent spill events were simulated for each of the four seasons. The distance from the release site, as well as the size of the footprint of each spill event, was recorded separately, and the most probable and extreme seasonal statistics were derived for each modelled scenario. The presentation and discussion of these results are the subject of the next section.

3.4 Synthetic-based Mud Dispersion Model Results

The outcomes of the modelled scenarios reveal several ways in which the mode of release and the ocean current conditions influence the spill footprint. The results for the modelled scenarios are presented in Table 3-3. These include the maximum and median seasonal values for the area of the predicted spill footprints, as well as the maximum and average values of the thickness of SBM within the projected spill area. In addition to the size of the spill area, it was important to characterize the location of the spill relative to the position of the release. This distance was calculated in each model realization as the location of the model cell that received the highest fraction of the spilled SBM volume. In the majority of the realizations, the spill footprints exhibited an elongated shape, which was measured and recorded as the length of the footprint, and it represents the longest horizontal dimension of the area in which the SBM droplets land.

The distance from the release site at which most of the SBM droplets will land appears to be largely dependent not only on the height of release above the sea bottom and the droplet fall velocity, but also on the seasonal currents. Overall, there was no strong tendency for the spills to land in a particular direction from the spill site in any given season. The maximum predicted distances from the release site are those for the winter surface dispersion scenario and the first riser flex joint scenario (high-speed jet, low fall velocity), where the maximum concentrations of the footprint were found at 1,061 and

1,008 m from the release site, respectively. For the other dispersion scenarios, the spill footprints remain within a maximum distance of 201 m (second riser flex joint scenario, high fall velocity), and 108 m (BOP disconnect scenario). These maximum distances are expected to occur during periods when the current magnitudes are at the seasonal maximum. However, this does not necessarily imply that the spill footprint is larger than normal, only that the footprints are shifted horizontally with respect to the release location.

Table 3-3 Synthetic-based Mud Dispersion Modelling Results for All Scenarios

SBM Dispersion Scenario		Distance from Release Site (m)		Footprint Length (m)		Footprint Area (m^2)		SBM Layer Thickness (cm)	
		max	med	max	med	max	med	max	mean
Surface Tank Rel.	Winter	1,061	201	101	47	4,500	1,800	6.7	4.4
	Spring	458	162	81	47	3,600	1,800	6.7	4.5
	Summer	677	134	106	47	4,500	1,800	6.7	4.4
	Fall	834	212	133	51	5,400	1,800	6.7	4.1
Riser Flex Joint I	Winter	1,008	192	579	161	23,400	6,300	5.4	0.9
	Spring	443	175	465	164	18,900	6,300	5.4	0.9
	Summer	836	150	839	166	34,200	6,300	5.4	0.9
	Fall	757	234	826	206	32,400	8,100	5.4	0.7
Riser Flex Joint II	Winter	201	42	140	56	5,400	1,800	5.4	2.9
	Spring	108	30	117	57	5,400	1,800	5.4	2.8
	Summer	190	30	192	57	9,000	1,800	5.4	2.8
	Fall	175	60	189	65	8,100	2,700	5.4	2.4
BOP Disc.	Winter	108	30	46	34	2,700	900	5.4	4.9
	Spring	67	30	44	34	3,600	900	5.4	4.9
	Summer	108	30	53	34	3,600	900	5.4	4.8
	Fall	85	30	55	35	3,600	900	5.4	4.8

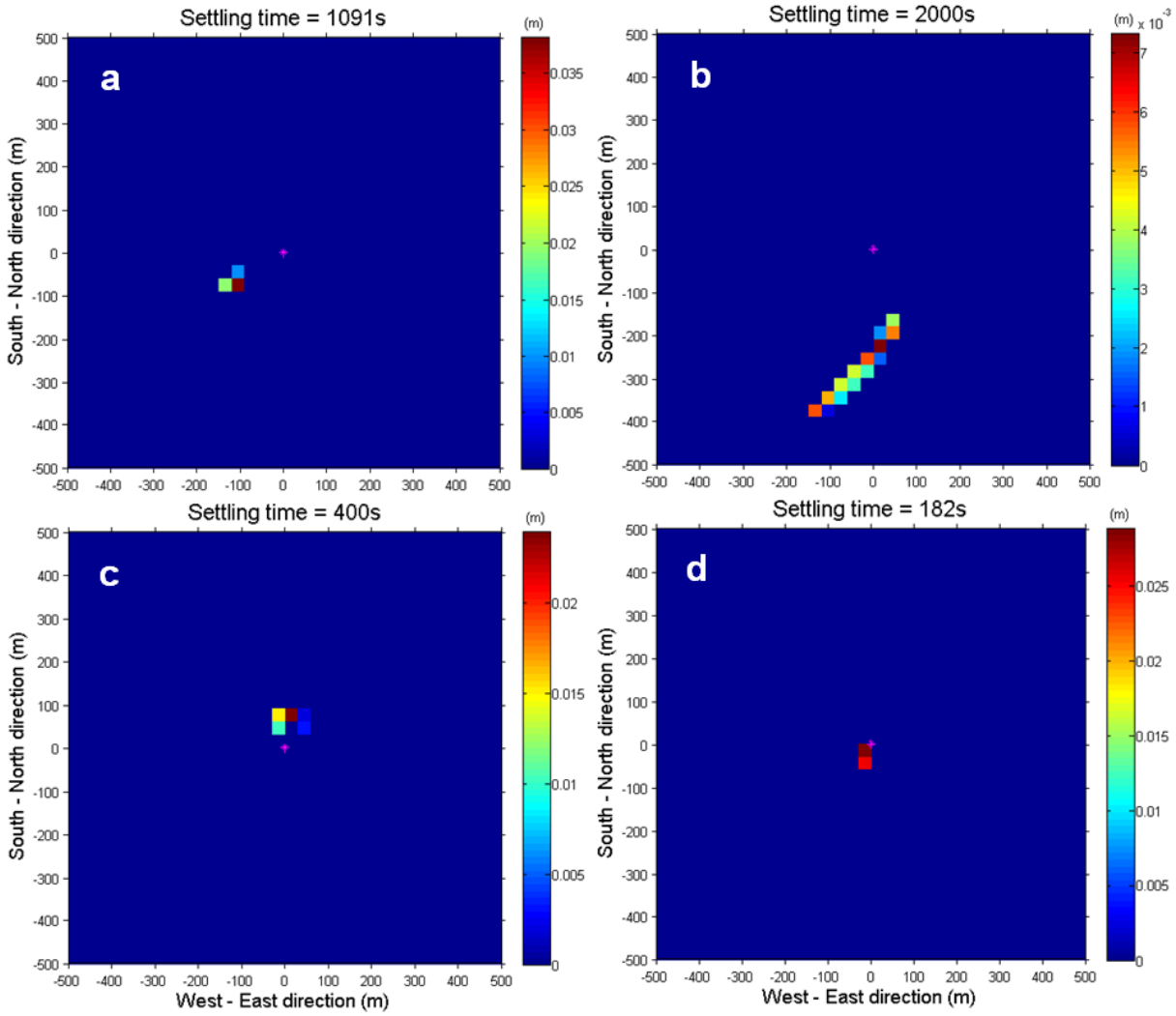
The footprint areas, and the associated footprint lengths, are expected to be associated with the period over which the SBM is released, the fall velocities, as well as the variability of the currents over that period and the settling period.

The largest footprint areas were found for the first riser flex joint scenario, which had the lowest fall velocity and the longest release period of 3 h. The single largest spill area in this scenario was observed in the winter season, and represented an area spanning approximately 579 m long by 40 m wide. Since the SBM was dispersed over a large area, the average layer thicknesses were much lower for this dispersion scenario compared to the other three.

The majority of the spill footprints were 1800 m^2 or smaller, corresponding to spill areas measuring 30 m by 60 m. The smallest footprints (30 m by 30 m) were predicted for the

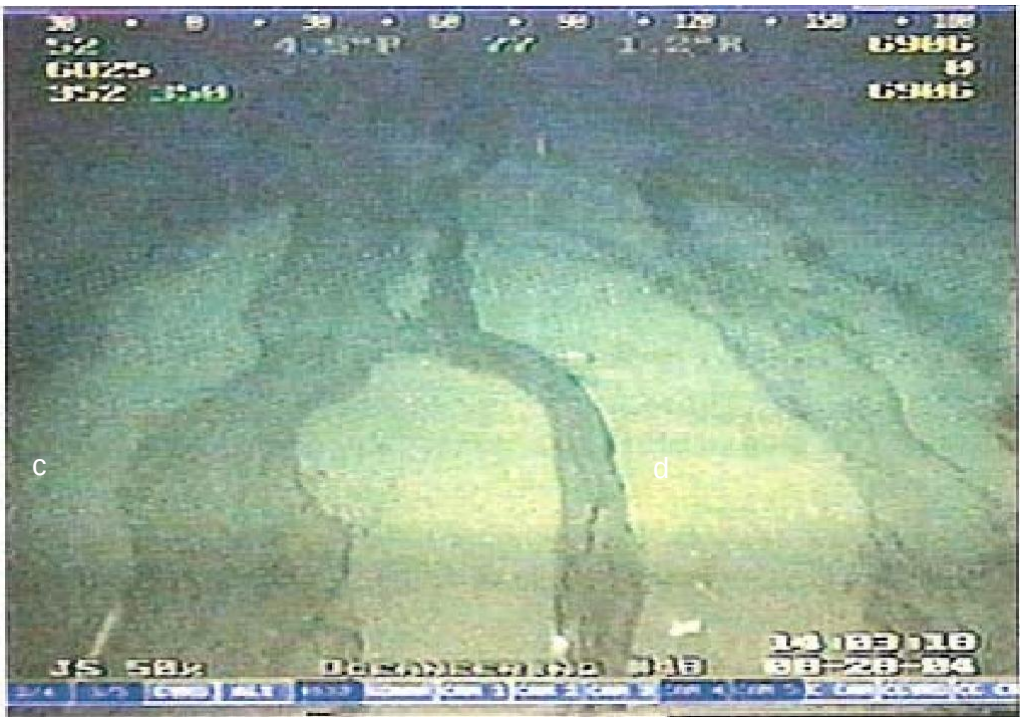
BOP disconnect scenarios, which exhibited a combination of low height above sea bottom, relatively quick release time (1 h), and high fall velocities.

Typical realizations of the spill footprints for the four selected modes of release are shown for the winter season in Figure 3-3. In the context of these descriptions of the footprint areas and thicknesses, it should be noted that these are only preliminary dimensions of the projected landing area for the SBM droplets, and the estimated SBM layer thickness if the full spill volume landing in each model cell were to be equally distributed within that cell. The subsequent fate and the footprint are likely to evolve in a less predictable fashion, as the negatively buoyant SBM droplets are expected to coalesce into streams or pools, and flow under the influence of gravity and the local bathymetric features, as evidenced by the photographic images of the seafloor taken following the Marathon SBM spill event offshore Nova Scotia in 2004 (Figure 3-4).



Note: a) surface low-speed jet release; b) subsea high-speed jet – low fall velocity; c) subsea high-speed jet – high fall velocity; d) subsea low-speed jet (BOP disconnect)

Figure 3-3 Example Realizations for the Four Modelled Release Scenarios in Winter



Source: Marathon Oil Corporation for CNSOPB (2005)

Figure 3-4 Synthetic-based Mud (dark ribbons) on the Sloping Seafloor as Seen on Remotely Operated Vehicle Video Footage at the Marathon Oil Spill Site, Offshore Nova Scotia

3.5 Synthetic-based Mud Dispersion Model Sensitivity Tests

Two alternative sets of model scenario parameters were derived for sensitivity testing of the model outcomes, based on the observed relationships between the physical parameters and the model outcomes in the main model runs. The first one involved increased fall velocities (by 1 cm/s for all scenarios), while the second one involved release periods with twice the length of the original model runs. The results, shown in Figure 3-3 and Figure 3-4 reveal further the influence of these parameters on the model outcomes, as well as the cases in which they make the largest difference to the outcomes.

An increase in the fall velocities by 1 cm/s (Figure 3-3) resulted in smaller footprint areas and lengths in all scenarios, but the difference was most pronounced for the first flex joint failure scenario, in which the original fall velocity was 1 cm/s. In this instance, doubling the fall velocity cut the footprint areas in half, and similarly reduced the footprint distances from the site of release. This resulted in an increase in the average SBM layer thicknesses, as more of the material was distributed within a smaller area on the seafloor. The other scenarios showed similar effects, but to a lesser degree, as a fall velocity change of 1 cm/s represented a smaller percentage of the original fall velocity for those scenarios.

Table 3-4 Sensitivity Testing for all Fall Velocities Increased by 1 cm/s: Synthetic-based Mud Dispersion Modelling Results for All Scenarios

SBM Dispersion Scenario		Distance from Release Site (m)		Footprint Length (m)		Footprint Area (m^2)		SBM Layer Thickness (cm)	
		max	med	max	med	max	med	max	mean
Surface Tank Rel.	Winter	969	182	95	46	4,500	1,800	6.7	4.5
	Spring	417	150	77	45	3,600	1,800	6.7	4.7
	Summer	626	124	100	46	4,500	1,800	6.7	4.6
	Fall	774	192	124	49	4,500	1,800	6.7	4.2
Riser Flex Joint I	Winter	510	95	304	95	11,700	3,600	5.4	1.6
	Spring	234	90	247	97	9,900	3,600	5.4	1.6
	Summer	437	67	435	98	17,100	3,600	5.4	1.5
	Fall	391	120	428	118	17,100	4,500	5.4	1.3
Riser Flex Joint II	Winter	175	42	121	52	5,400	1,800	5.4	3.1
	Spring	95	30	102	52	5,400	1,800	5.4	3.1
	Summer	162	30	165	53	7,200	1,800	5.4	3.1
	Fall	150	42	163	59	7,200	1,800	5.4	2.6
BOP Disc.	Winter	95	30	45	34	3,600	900	5.4	5
	Spring	67	30	42	34	2,700	900	5.4	5
	Summer	95	30	52	34	2,700	900	5.4	4.9
	Fall	85	30	53	35	2,700	900	5.4	4.8

The second sensitivity test (Table 3-5) showed that doubling the time period over which the SBM is discharged increases the average and maximum footprint areas by approximately a factor of two, while the distances of the footprints from the site of release were changed to a much lesser degree. These tests illustrate the fact that all other factors being equal, lengthening the period of release presents the opportunity for the overall volume of SBM to be exposed to ocean currents that might change drastically and therefore, substantially change the expected trajectory of SBM droplets at the end of the release, compared to that at the beginning of the spill event. However, the tradeoff is that the larger footprint will result in a lower average SBM layer thickness at the seafloor, compared to the case where a smaller area receives a larger portion of the SBM.

Table 3-5 Sensitivity Testing for all Release Periods Increased by a Factor of Two: Synthetic-based Mud Dispersion Modelling Results for All Scenarios

SBM Dispersion Scenario		Distance from Release Site (m)		Footprint Length (m)		Footprint Area (m^2)		SBM Layer Thickness (cm)	
		max	med	max	med	max	med	max	mean
Surface Tank Rel.	Winter	1,060	201	207	73	8,100	2,700	6.7	2.7
	Spring	458	162	157	71	6,300	2,700	6.7	2.9
	Summer	677	134	219	72	9,000	2,700	6.7	2.8
	Fall	824	212	284	81	11,700	2,700	6.7	2.5
Riser Flex Joint I	Winter	969	192	919	237	42,300	11,700	5.0	0.5
	Spring	433	175	637	247	36,900	11,700	5.1	0.5
	Summer	836	150	1,406	249	65,700	12,600	4.3	0.5
	Fall	750	234	1,128	308	54,900	16,200	3.6	0.4
Riser Flex Joint II	Winter	190	42	208	71	9,900	2,700	5.4	1.9
	Spring	108	30	151	73	9,000	2,700	5.4	1.8
	Summer	190	30	305	74	15,300	2,700	5.4	1.8
	Fall	175	60	250	86	11,700	3,600	5.4	1.5
BOP Disc.	Winter	108	30	46	34	2,700	900	5.4	4.9
	Spring	67	30	44	34	3,600	900	5.4	4.9
	Summer	108	30	53	34	3,600	900	5.4	4.8
	Fall	85	30	55	35	3,600	900	5.4	4.8

4.0 SUMMARY

It is anticipated that certain stages of the drilling operations in the development of the WREP will involve the use of SBMs, due to their unique performance characteristics, as well as their low toxicity and relatively low environmental effects compared to OBMs.

As part of the environmental assessment process, to characterize possible accidental SBM releases, a review was conducted of the latest scientific literature and industry spill databases from Atlantic Canada and the US OCS to determine the most probable modes of accidental release. Four potential release spill scenarios were selected as being most representative for the WREP:

- Surface tank discharge
- Riser flex joint failure (two scenarios, for two fall velocities)
- BOP disconnect

Subsequently, a numerical dispersion modelling study was conducted to predict the potential seasonal footprints of SBM spills on the seafloor for each of the four scenarios.

The comparison of regional and local spill statistics from 1997 to 2011 (published by the C-NLOPB, CNSOPB and the BOEMRE) showed that the modes of accidental discharges of SBMs are similar between regions, with surface spills being the most frequent, while subsea spills due to leaks or failures in the mud circulation system or emergency events are less frequent, but tend to result in bigger amounts of spilled volumes. However, it is notable that drilling operations offshore Newfoundland and Labrador have generally resulted in smaller spill amounts compared to other jurisdictions, which could be at least partly explained by the fact that drilling operations on the Grand Banks are conducted on the continental shelf in relatively low water depths (on the order of 100 m), compared to the developments offshore Nova Scotia and in the Gulf of Mexico (on the order of 2,000 m). The lower water depths generally imply that lower amounts of drilling mud are required for the drilling operations, as the total length of components in the mud circulation system are shorter and of smaller overall capacity.

The SBM planned for use during drilling operations in the WREP will be based on the synthetic drilling fluid Puredrill IA-35LV (65 percent by volume), and will exhibit a total density of 1,350 kg/m^3. The SBM is therefore negatively buoyant and immiscible in water, and is expected to form droplets of varying sizes that will fall toward the seafloor upon being discharged in the marine environment. The fall velocities of droplets resulting from the most frequent modes of accidental SBM spills have been measured in an experimental laboratory study commissioned by the BOEMRE, and conducted by the SwRI (2007). These experimental results formed the basis for the numerical SBM dispersion model developed by AMEC, in which four different release scenarios were represented during each season, resulting in a total of 16 spill model scenarios.

The numerical model used a full-year time series derived from ADCP current measurements at White Rose from 2008 to the end of 2010, with approximately 13,000 model realizations being simulated in each seasonal scenario per release mode. The total spill footprint area, length and distance from release site, as well as projected initial

SBM layer thickness on the seafloor, were estimated for each simulated event, and seasonal median, maximum and average values were derived.

The distance from the release site at which most of the SBM droplets will land appears to be largely dependent not only on the height of release above the sea bottom and the droplet fall velocity, but also on the variability of the seasonal currents. Overall, there was no strong tendency for the spills to land in a particular direction from the spill site in any given season.

The maximum predicted distances from the release site are those for the winter surface dispersion scenario and the first riser flex joint scenario (high-speed jet, low fall velocity), where the maximum concentrations of the footprint are found at 1,061 and 1,008 m from the release site, respectively. For the other dispersion scenarios, the spill footprints remain within a maximum distance of 201 m (second riser flex joint scenario, high fall velocity), and 108 m (BOP disconnect scenario). These maximum distances are expected to occur if a spill occurs during periods when the current magnitudes are at the seasonal maximum. However, this does not necessarily imply that the spill footprint would be larger than normal, only that the footprint would be shifted horizontally with respect to the release location.

The footprint areas, and the associated footprint lengths, are expected to be associated with the period over which the SBM is released and the fall velocities, as well as the variability of the currents over the release and settling periods. The largest footprint areas were found for the first riser flex joint scenario, which had the lowest fall velocity and the longest release period of 3 h. The single largest spill area in this scenario was observed in the winter season, and represented an area spanning approximately 579 m long by 40 m wide. Since the SBM was dispersed over a large area, the average layer thicknesses were much lower for this dispersion scenario compared to the other three.

The majority of the spill footprints were 1,800 m^2 or smaller, corresponding to spill areas measuring 30 m by 60 m. The smallest footprints (30 m by 30 m) were predicted for the BOP disconnect scenarios, which exhibited a combination of low height above sea bottom, relatively quick release time (1 h) and high fall velocities.

The interpretation of the predicted footprint areas and thicknesses should take into account that these are only preliminary dimensions of the projected landing area for the SBM droplets, and the estimated SBM layer thickness if the full spill volume landing in each model cell were to be equally distributed within that cell. The subsequent fate and the footprint are likely to evolve in a less predictable fashion, as the negatively buoyant SBM droplets are expected to coalesce into streams or pools, and flow under the influence of gravity and the local bathymetric features. As there is a tradeoff between the area covered by the spill and the thickness of the spill, it can be expected that an area of the seafloor that is relatively flat and with few roughness features is likely to result in a thinner and widely distributed SBM layer, while a localized depression in the seafloor could retain the received SBM as a thicker layer within a smaller area. While the weathering properties for the SBM considered in the present study are not precisely known, it is expected that the biodegradation of the SBM on the seafloor would take place over periods on the order of several weeks. This timescale far exceeds the duration of the spill and settling of SBM to the floor; therefore, the SBM is considered to be stable during the entire duration of the physical dispersion of the droplets in all modelled scenarios.

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6.0 ACRONYMS

Term	Description
ADCP	Acoustic Doppler Current Profiler
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
h	hour
kg/m^3	kilograms per cubic metre
m/s	metres per second
OWTG	Offshore Waste Treatment Guidelines
OBM	Oil-based mud (a type of drilling mud)
OCS	Outer Continental Shelf (ref. to United States)
s	seconds
SBM	synthetic-based mud (a type of drilling mud)
SwRI	Southwest Research Institute
WBM	water-based mud (a type of drilling mud)
WREP	White Rose Extension Project

7.0 GLOSSARY

Word	Definition
ADCP	An instrument designed to measure water flow by making use of the acoustic Doppler effect
Bathymetry	The measurement of depths of water in oceans, seas and lakes; also the information derived from such measurements
Drilling Mud	A special mixture of clay, water and chemical additives pumped down the wellbore through the drill pipe and drill bit to cool the rapidly rotating bit, lubricate the drill pipe as it turns in the wellbore, and carry rock cuttings to the surface; may have a **water base** or a **synthetic oil base** fluid
Fall Velocity	The vertical speed at which particles or negatively buoyant droplets fall through the water column
Roughness features	Seafloor irregularities, including ripples, dunes, channels, localized elevations and depressions
Rayleigh instability	The flow perturbation responsible for the tendency of streams and droplets to break up into smaller droplets under laminar flow in a stagnant fluid
Oil-based Mud (OBM)	A **drilling mud** in which the continuous phase consists of diesel or mineral oils that are refined from crude oil
Synthetic-based Mud (SBM)	A **drilling mud** in which the continuous phase is a synthetic fluid
Water-based Mud (WBM)	A **drilling mud** in which the continuous phase is water
Water Column	The vertical dimension of a body of water (i.e., the water between a reference point or area on the surface and one located directly below it on the bottom)

Note: Bolded **words within a definition are themselves defined**

APPENDIX G

Nearshore Oil Spill Trajectory Report (Oceans Ltd. 2017)

Offshore Supply Vessels
Season Oil Spill Trajectory Study
for the Husky Exploration Drilling Project

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March 2017

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1.0 Introduction

Seasonal oil spill trajectories were modelled using the Applied Science Associates (ASA) OILMAP oil Spill Trajectory model for the position 47°31'41" N; 52°26'16" W located approximately 10 nautical miles at a bearing of 103° from the St. John`s Harbour Approaches. The spill assumes a worst case scenario spill of 5,000 cubic metres of Marine Diesel Fuel.

2.0 Data Sources

2.1 Oil Properties

Oil Properties were obtained from the ASA OILMAP database.

The OILMAP database does not contain the Flashpoint temperature for Marine Diesel Fuel Oil and at the time of the model run, data from Environment Canada`s Environmental Science and Technology Centre was unavailable. Therefore, a minimum flashpoint temperature of 52°C was used for the analysis. This value was obtained from Tesoro Corporations Materials Safety Data sheet for Marine Gas Oil (Safety Data Sheets | Tesoro, 2017).

Table 2.1Marine Diesel Fuel Properties

Oil Name	Marine Diesel Fuel
Density (gm/cm^3)	0.869
Viscosity (cP)	1.150
Interfacial Tension (dyne/cm)	20.000
Maximum Water Content (%)	0.000
Minimum Thickness (mm)	0.100
Flash Point	52.000
Initial Boiling Point (K)	453.770
Gradient of Curve	241.320
Evaporation Constant A	15.990
Evaporation Constant B	16.250

2.2 Sea Surface Temperature

Seasonal sea surface temperatures for the analysis were obtained from the National Oceanic and Atmospheric Administration (NOAA) Optimum Interpolation Sea Surface Temperature (OISST) data set (Banzon, Smith, Chin, Liu, & Hankins, 2016). This data set contains an analysis of global sea surface temperature at a 0.25° resolution and is produced by combining observations from multiple sources, including satellites, ships and buoys. Bias adjustments of satellite and ship observations are made (referenced to buoys) to compensate for platform differences and sensor biases. The climatological means were

computed over the period of 1971 – 2000. Sea surface temperature climate statistics were computed for the position 46.625°N; 52.375°W.

2.3 Surface Currents

Season surface currents were obtained from the Bedford Institute of Oceanography's Canadian East Coast Ocean Model (CECOM) coupled ice-ocean model (Wu, Tang, & Hannah, 2012). CECOM is based on the Princeton Ocean Model and a multi category sea-ice model. The model grid has a horizontal resolution of 0.1° x 0.1° in a rotated spherical coordinate system. Statistics were generated from an eleven year hindcast climatological data set consisting of four separate periods, 1987 – 1989; 1994-1996; 2002-2004 and 2007-2008. These periods were chosen based on the availability of current meter data which were used to calibrate and validate the model. Due to limitations of the Oilmap model, a subset of the current model on a 0.5° x 0.5° grid was used for this analysis.

2.4 Wind Speed and Direction

Wind speed and direction climate statistics for the area were extracted from the MSC50 North Atlantic wind and wave climatology data base (Swail, et al., 2006) compiled by Oceanweather Inc under contract to Environment Canada. The MSC50 data base consists of continuous wind and wave hindcast data in 1-hour time steps from January 1954 to December 2015, on a 0.1° latitude by 0.1° longitude grid. Winds from the MSC50 data set are 1-hour averages of the effective neutral wind at a height of 10 m (Harris, 2007). Eight grid points were chosen to represent conditions over the entire area. These grid points are provided in Table 2.2 below. Hourly wind speeds for the 15th to the 24th of the month were averaged over the entire data set for each season resulting in a 10-day record of 1-hour wind speeds.

Table 2.2Wind File Locations

Grid Point	Latitude	Longitude
11580	47.0N	51.5W
11590	47.0N	50.5W
12553	47.5N	52.5W
12563	47.5N	51.5W
12573	47.5N	50.5W
13366	48.0N	52.5W
13376	48.0N	51.5W
13391	48.0N	50.0W

3.0 Results

Resultant trajectory plots along with their associated weathering plots of volume, viscosity, thickness, total area, total volume - Oil and Water and Flashpoint are presented in Figure 3.1 through Figure 3.28 below. Oil spill trajectories were run for a total of 240 hours (10-days) for each season. Oil spills during the Autumn and Winter dissipated near the 120 hour (5-day) mark, while spills during the Spring and Summer took nearly twice as long to dissipate. The minimum mass for the model to track was set to 5.0% of the total spill amount.

Arrows on each trajectory plot represent the direction and magnitude of the wind speed at each of the eight wind file locations used in the analysis.

The oil fates mass balance graph depicts the mass of oil on the water surface, in the atmosphere, in the water column and on the shoreline. The amounts skimmed and dispersed into the water column can also be depicted.

3.1 Winter

The winter trajectory has the oil tracking towards the east-southeast with a final location projected to be centred approximately 96.6 nm bearing 114° from the original spill location. The complete track may be seen in Figure 3.1 below. Information on the weathering and fates for the Winter oil spill are presented in Table 3.1 below. Mass balance graphs of the weathering and fates are presented in Figure 3.2 through Figure 3.7.

Table 3.1 12-Hourly Oil Spill Weathering and Fates Information for Winter

Time (hours)	Surface (m^3)	Water Column (m^3)	Ashore (m^3)	Evaporated (m^3)	Radius (m)	Viscosity (cP)	Thickness (m)
0	0.0	0.0	0.0	0.0	333333.4	19.3	0.01500
12	2026.0	2104.4	0.0	931.0	929859.8	23.2	0.00215
24	1223.4	2630.0	0.0	1208.0	1043231.0	24.5	0.00116
36	863.2	2831.7	0.0	1366.4	1109641.0	25.3	0.00077
48	452.5	3122.5	0.0	1486.3	892935.6	25.9	0.00045
60	259.8	3221.9	0.0	1579.7	501905.9	26.4	0.00033
72	178.1	3232.5	0.0	1650.8	284021.8	26.8	0.00029
84	117.2	3244.1	0.0	1700.1	49607.5	27.1	0.00033
96	83.2	3245.0	0.0	1733.2	27290.6	27.4	0.00033
108	82.5	3223.0	0.0	1755.9	6977.3	27.7	0.00039
120	39.4	3248.6	0.0	1773.4	0.0	0.0	0.00000

3.1.1 Trajectory

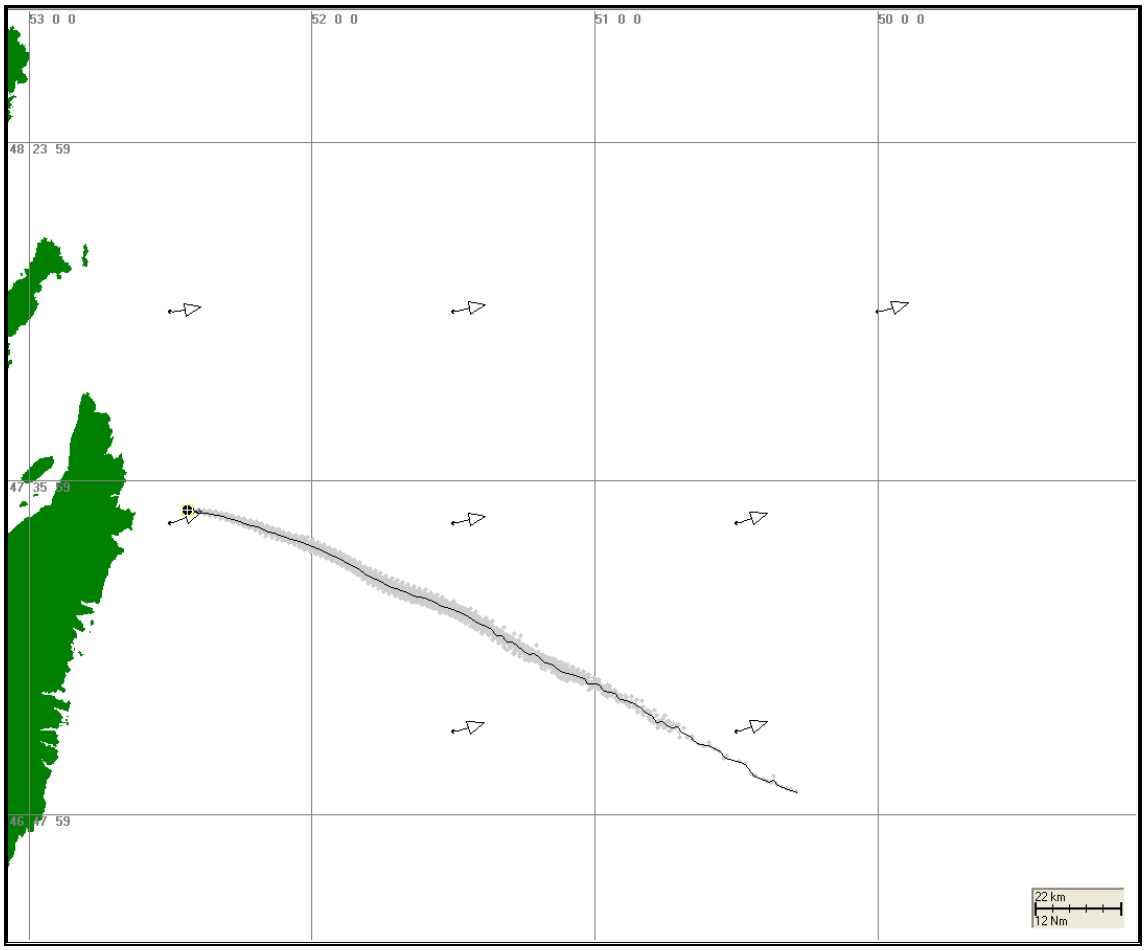


Figure 3.1 Winter Oil Spill Trajectory

3.1.2 Fates

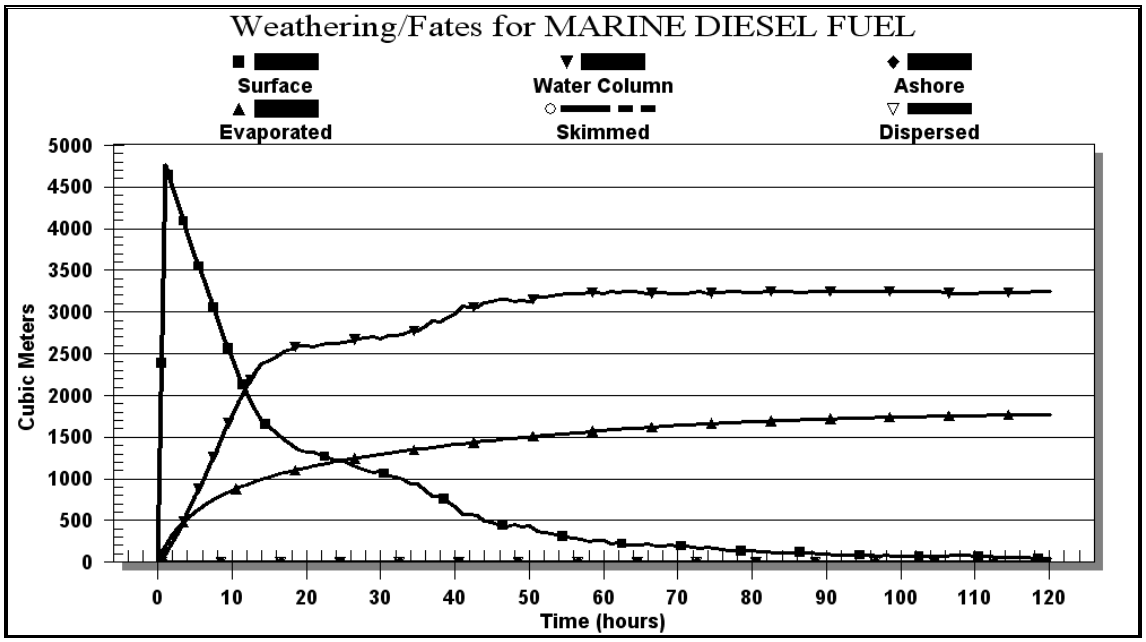


Figure 3.2 Weathering Mass Balance Graph for Winter

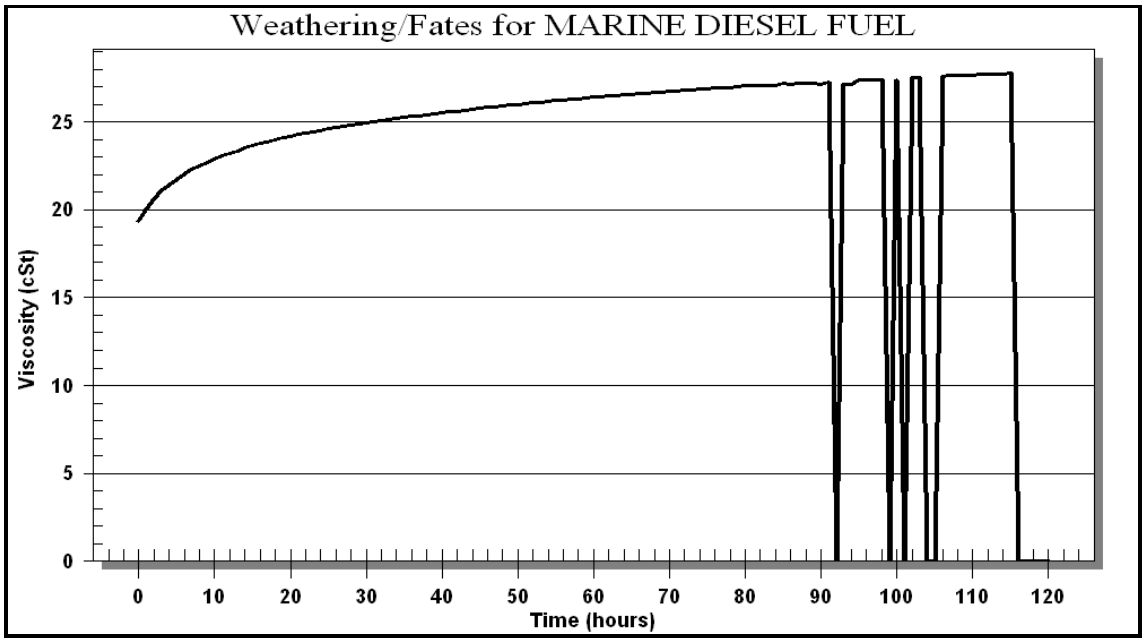


Figure 3.3 Viscosity Mass Balance Graph for Winter

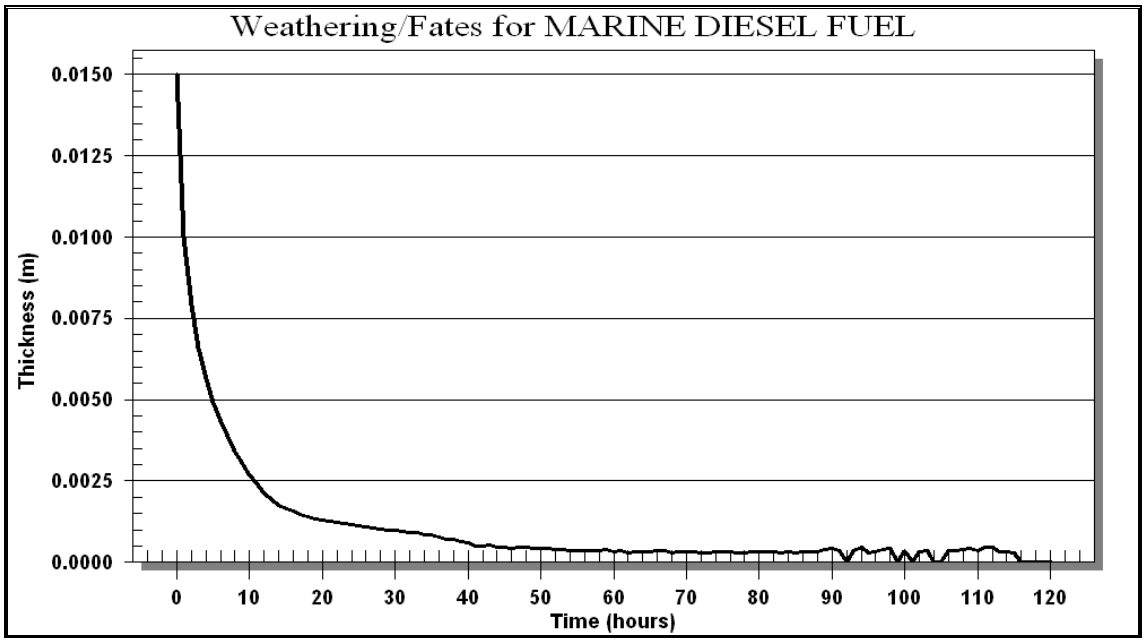


Figure 3.4 Thickness Mass Balance Graph for Winter

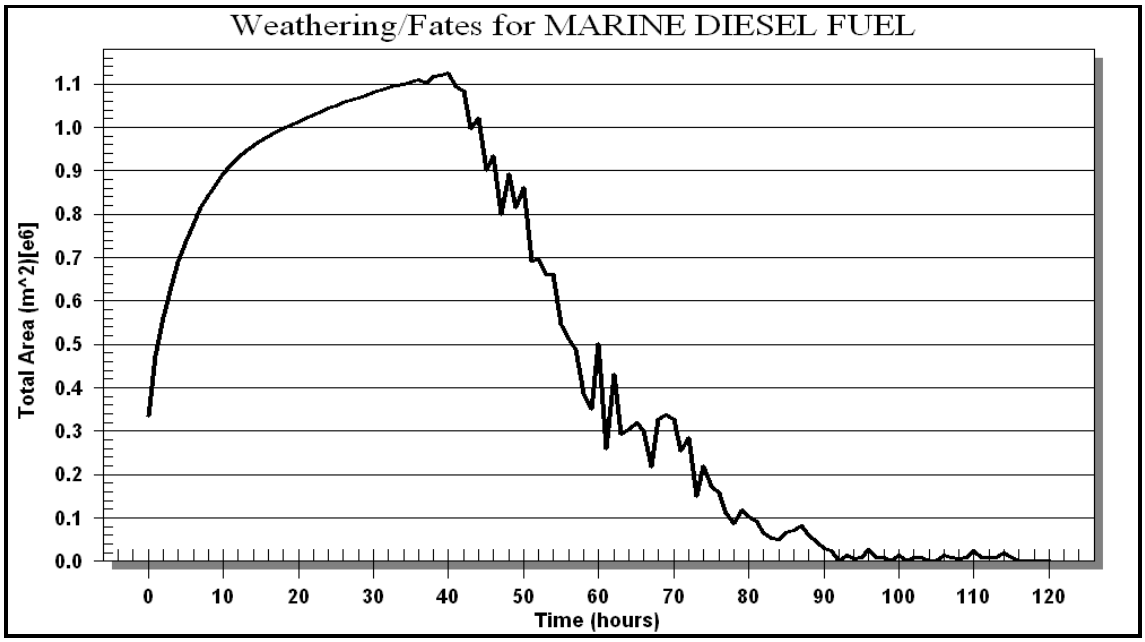


Figure 3.5 Surface Area Mass Balance Graph for Winter

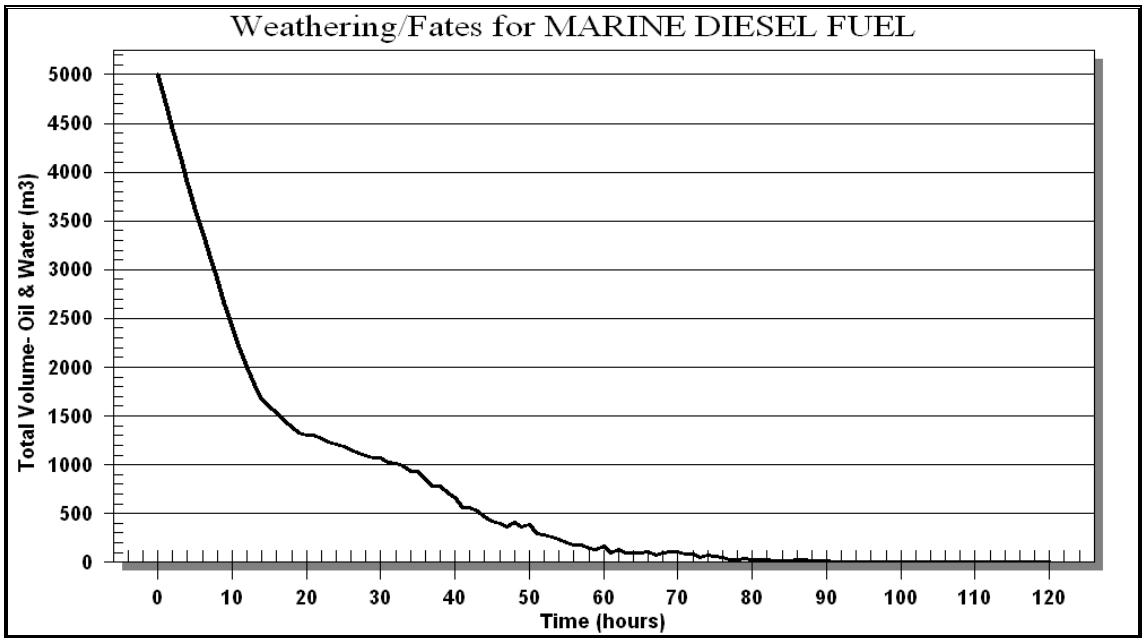


Figure 3.6 Total Volume Graph for Winter

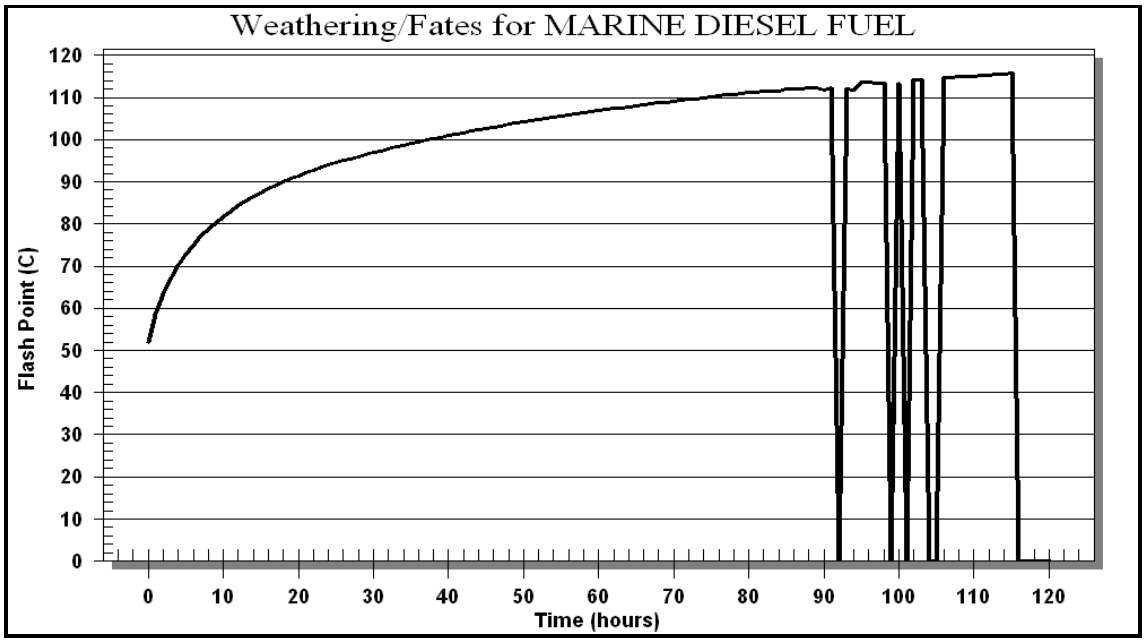


Figure 3.7 Flashpoint Graph for Winter

3.2 Spring

The spring trajectory has the oil tracking towards the east with a final location projected to be centred approximately 97.8 nm bearing 083° from the original spill location. The complete track may be seen in Figure 3.8 below. Information on the weathering and fates for the Spring oil spill are presented in Table 3.2 below. Mass balance graphs of the weathering and fates are presented in Figure 3.9 through Figure 3.14.

Table 3.2 12-Hourly Oil Spill Weathering and Fates Information for Spring

Time (hours)	Surface (m^3)	Water Column (m^3)	Ashore (m^3)	Evaporated (m^3)	Radius (m)	Viscosity (cP)	Thickness (m)
0	0.0	0.0	0.0	0.0	333333.4	13.7	0.015
12	3847.4	286.5	0.0	915.5	1040214	16.4	0.00366
24	3269.1	559.5	0.0	1220.8	1335882	17.4	0.00242
36	3020.4	627.0	0.0	1402.1	1539798	18	0.00194
48	2838.0	682.4	0.0	1529.0	1705062	18.5	0.00165
60	2402.7	1014.7	0.0	1632.0	1838436	18.9	0.00129
72	2168.1	1165.3	0.0	1716.1	1938520	19.2	0.00111
84	1869.4	1393.1	0.0	1787.0	2019770	19.5	0.00092
96	1514.5	1686.1	0.0	1848.9	2083897	19.7	0.00072
108	1114.0	2031.2	0.0	1904.3	2128677	19.9	0.00052
120	671.1	2424.9	0.0	1953.4	2152963	20.1	0.00031
132	532.6	2520.9	0.0	1995.9	2168019	20.3	0.00024
144	443.2	2572.3	0.0	2033.9	2180000	20.4	0.0002
156	358.1	2622.5	0.0	2068.9	2096224	20.6	0.00017
168	276.4	2676.2	0.0	2096.9	1065351	20.7	0.00019
180	267.6	2663.3	0.0	2118.5	888635.4	20.8	0.00019
192	193.4	2717.9	0.0	2138.2	197897.6	20.9	0.00017
204	130.3	2763.1	0.0	2156.2	44216.3	21	0.00021
216	94.2	2786.5	0.0	2168.7	0	0	0
228	94.6	2776.3	0.0	2178.6	0	0	0
240	76.8	2785.6	0.0	2187.1	0	0	0

3.2.1 Trajectory

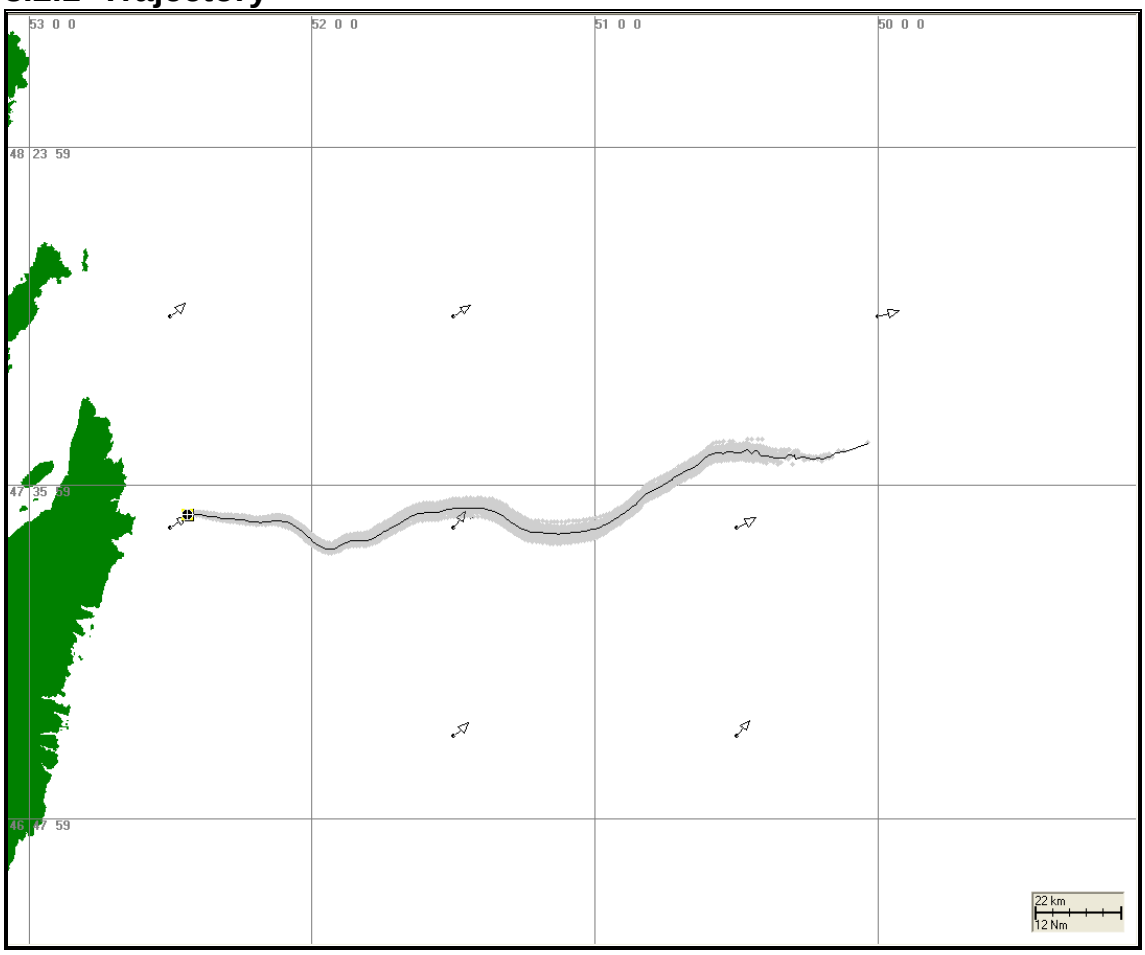


Figure 3.8 Spring Oil Spill Trajectory

3.2.2 Fates

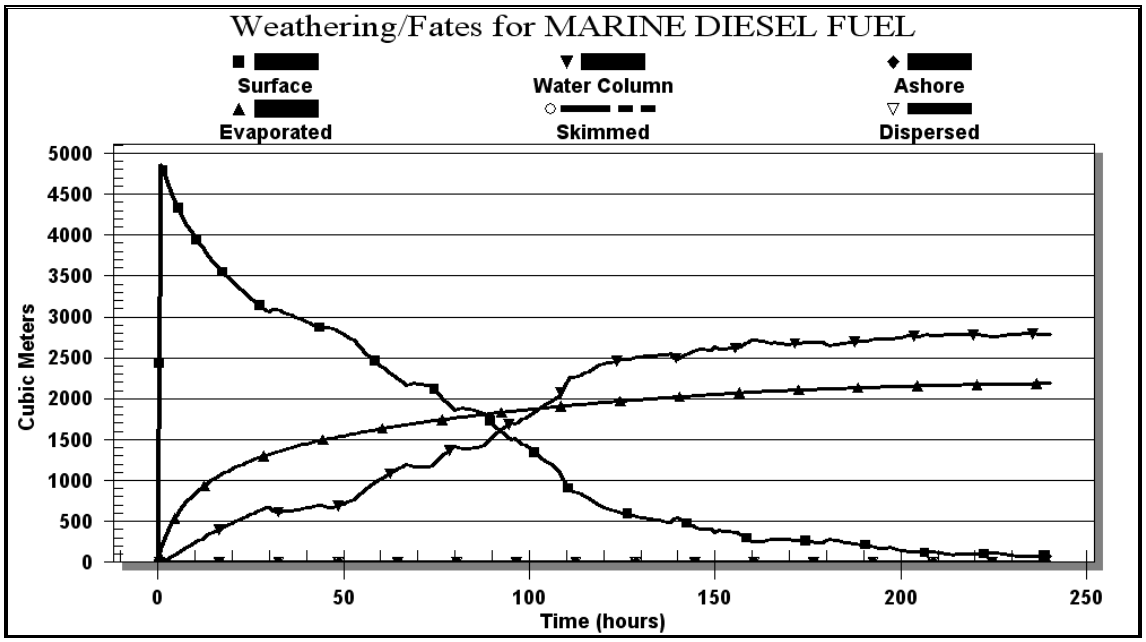


Figure 3.9 Weathering results for Spring

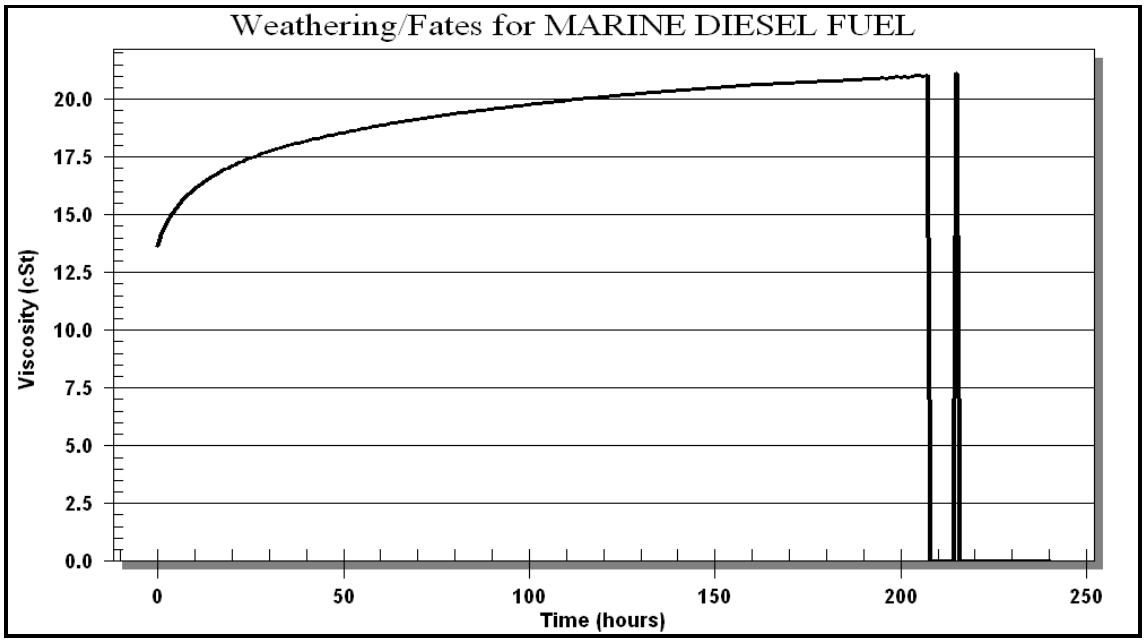


Figure 3.10 Viscosity Mass Balance Graph for Spring

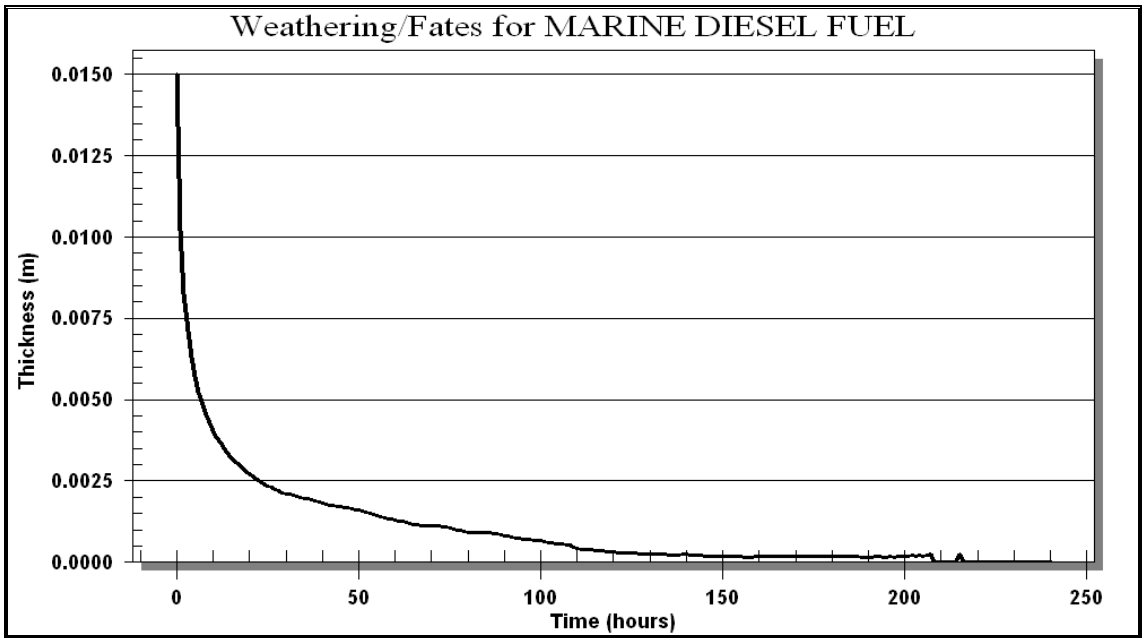


Figure 3.11 Thickness Mass Balance Graph for Spring

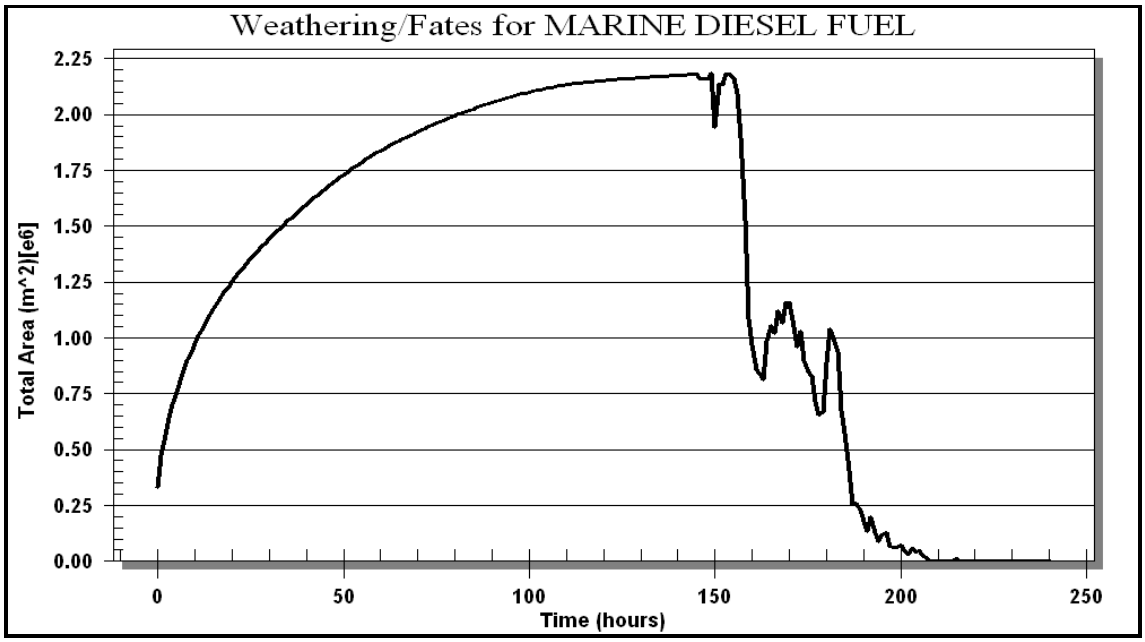


Figure 3.12 Surface Area Mass Balance Graph for Spring

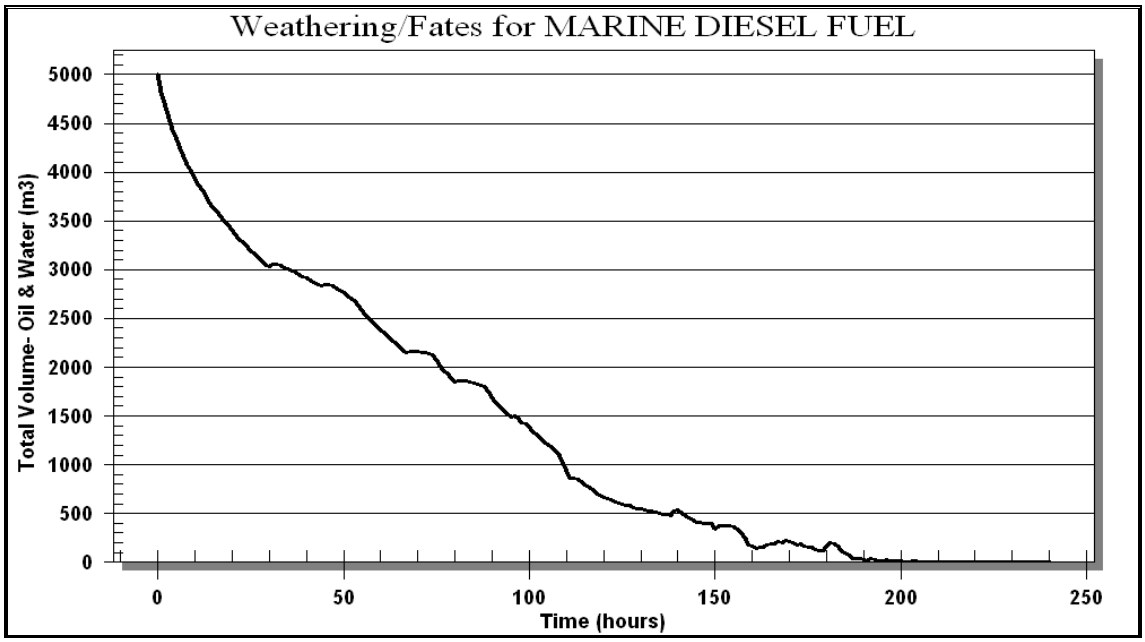


Figure 3.13 Total Volume Graph for Spring

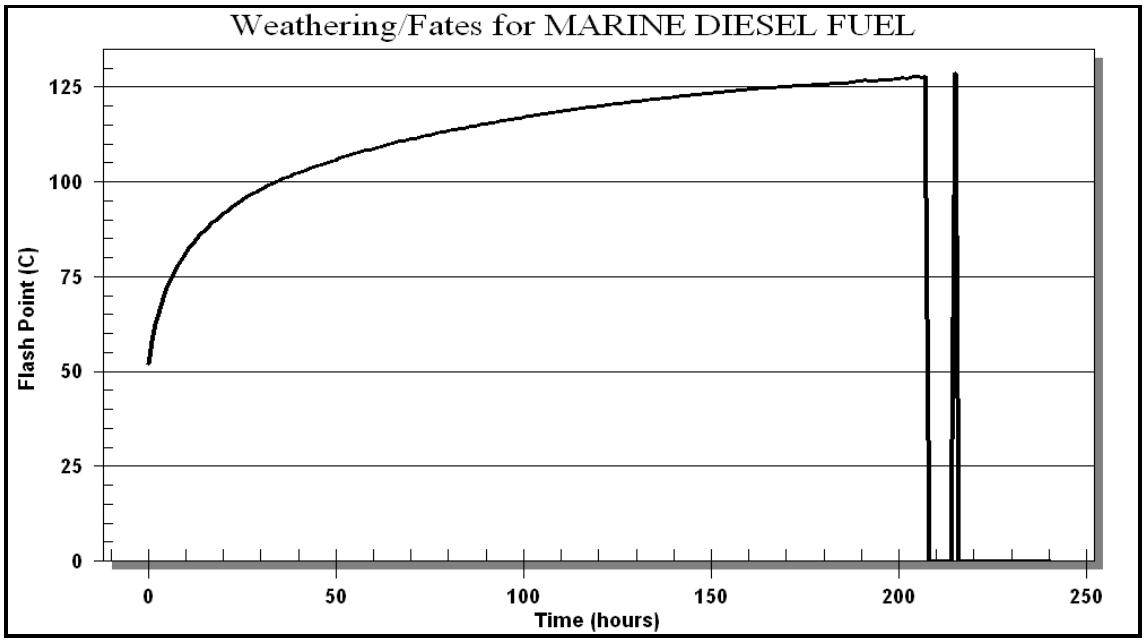


Figure 3.14 Flashpoint Graph for Spring

3.3 Summer

The summer trajectory has the oil tracking towards the east with a final location projected to be centred approximately 113.0 nm bearing 079° from the original spill location. The complete track may be seen in Figure 3.15 below. Information on the weathering and fates for the Summer oil spill are presented in Table 3.3 below. Mass balance graphs of the weathering and fates are presented in Figure 3.16 through Figure 3.21.

Table 3.3 12-Hourly Oil Spill Weathering and Fates Information for Summer

Time (hours)	Surface (m^3)	Water Column (m^3)	Ashore (m^3)	Evaporated (m^3)	Radius (m)	Viscosity (cP)	Thickness (m)
0	0.0	0.0	0.0	0.0	333333.4	4.1	0.015
12	3361.4	357.7	0.0	1286.6	992922	5.3	0.00338
24	2927.3	483.3	0.0	1595.2	1258608	5.6	0.00232
36	2536.3	685.9	0.0	1783.7	1443591	5.8	0.00176
48	2330.3	759.0	0.0	1916.5	1582764	6	0.00147
60	2160.3	827.1	0.0	2018.4	1699684	6.1	0.00127
72	1874.5	1027.6	0.0	2103.7	1797185	6.2	0.00104
84	1488.5	1338.3	0.0	2179.0	1868174	6.3	0.0008
96	998.4	1762.3	0.0	2245.1	1915517	6.4	0.00052
108	660.7	2042.5	0.0	2302.5	1940956	6.5	0.00034
120	685.8	1969.8	0.0	2350.2	1959725	6.5	0.00035
132	525.7	2087.7	0.0	2392.5	1978321	6.6	0.00027
144	354.3	2220.5	0.0	2431.0	1988967	6.6	0.00018
156	290.9	2249.6	0.0	2465.4	1936568	6.7	0.00015
168	253.7	2255.4	0.0	2496.7	960254.4	6.7	0.00015
180	298.4	2185.6	0.0	2521.8	1413380	6.8	0.00019
192	265.8	2194.6	0.0	2545.5	800145.4	6.8	0.0002
204	176.7	2260.2	0.0	2568.9	0	0	0
216	140.5	2277.2	0.0	2588.1	0	0	0
228	125.7	2275.9	0.0	2604.2	0	0	0
240	198.6	2188.8	0.0	2618.4	0	0	0

3.3.1 Trajectory

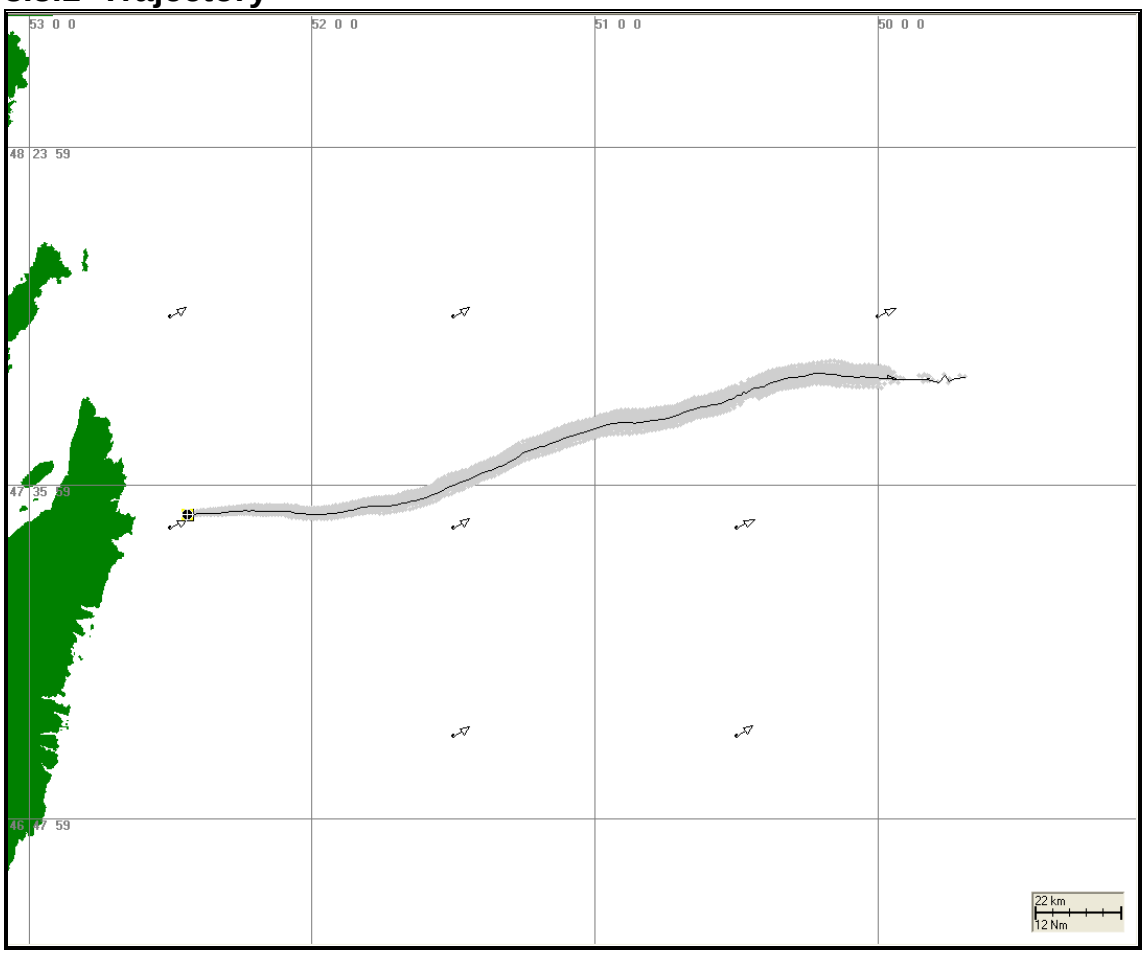


Figure 3.15 Summer Oil Spill Trajectory

3.3.2 Fates

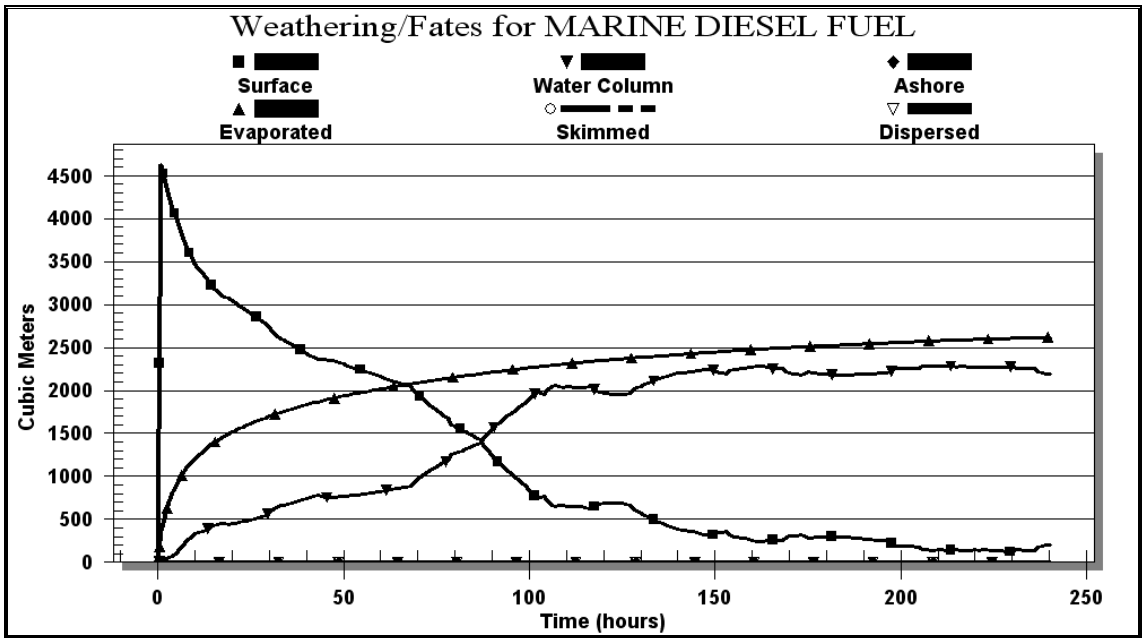


Figure 3.16 Weathering results for Summer

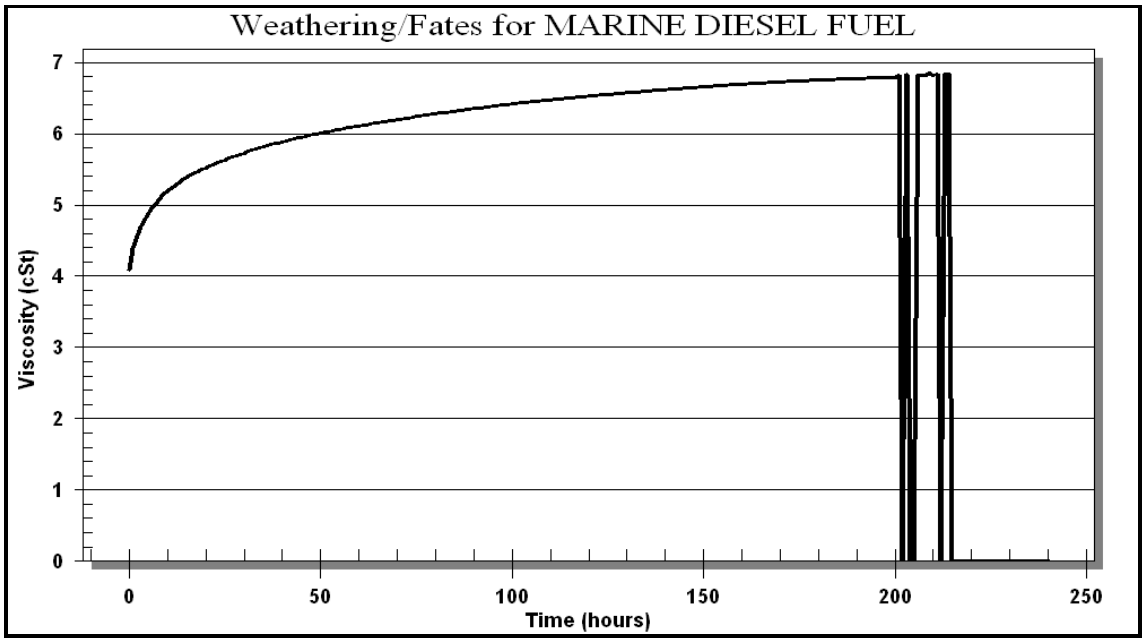


Figure 3.17 Viscosity Mass Balance Graph for Summer

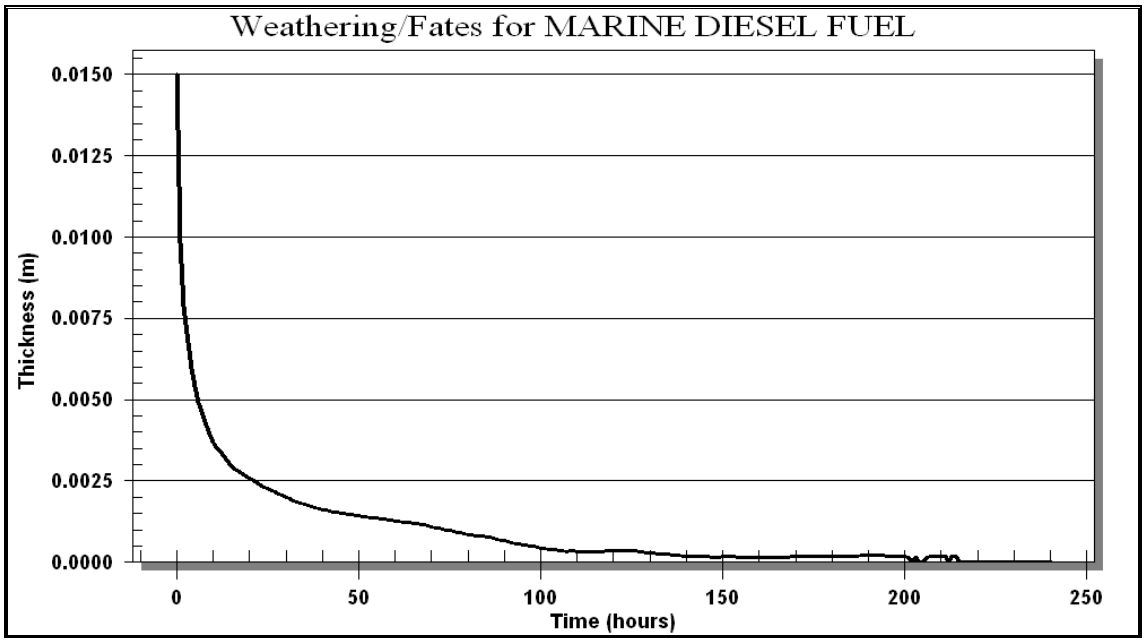


Figure 3.18 Thickness Mass Balance Graph for Summer

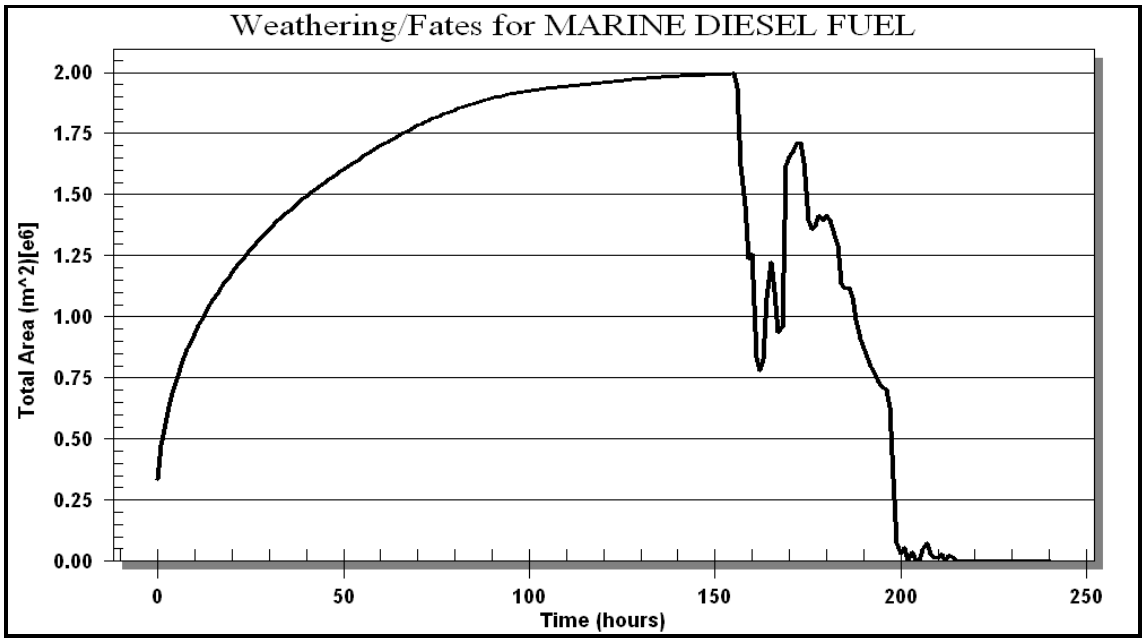


Figure 3.19 Surface Area Mass Balance Graph for Summer

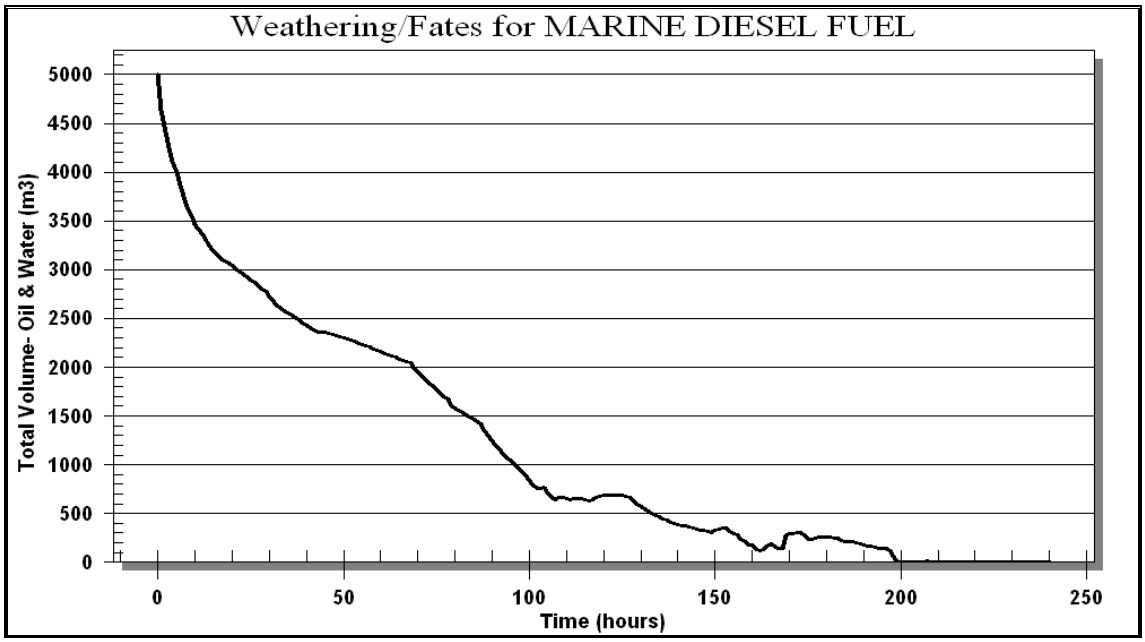


Figure 3.20 Total Volume Graph for Summer

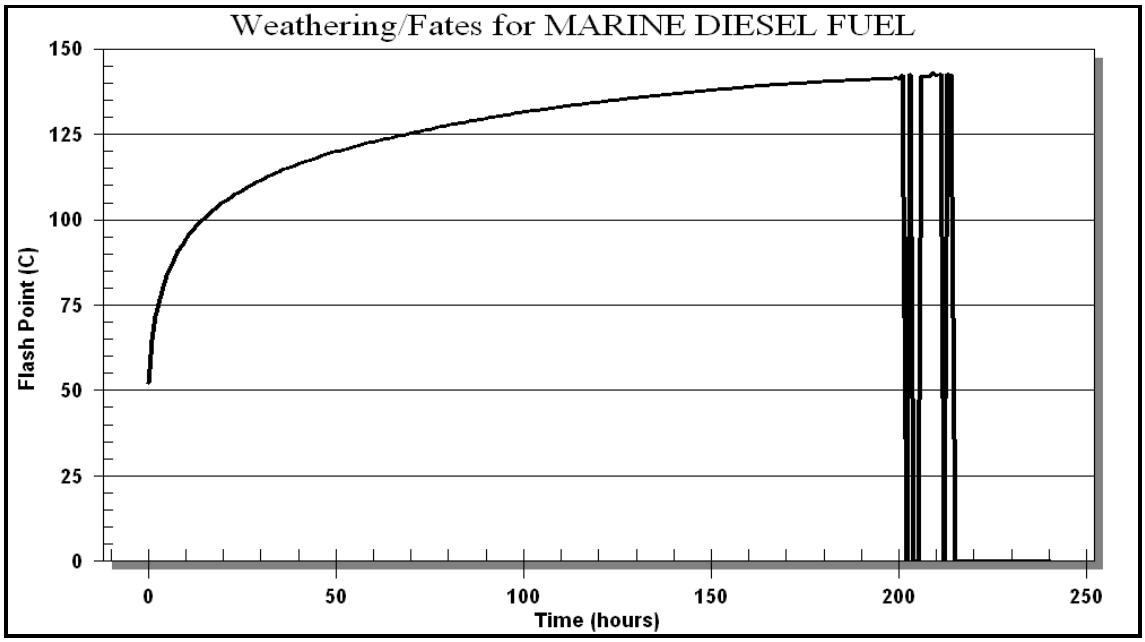


Figure 3.21 Flashpoint Graph for Summer

3.4 Autumn

The autumn trajectory has the oil tracking towards the east with a final location projected to be centred approximately 83.0 nm bearing 104° from the original spill location. The complete track may be seen in Figure 3.22 below. Information on the weathering and fates for the Autumn oil spill are presented in Table 3.4 below. Mass balance graphs of the weathering and fates are presented in Figure 3.23 through Figure 3.28.

Table 3.412-Hourly Oil Spill Weathering and Fates Information for Autumn

Time (hours)	Surface (m^3)	Water Column (m^3)	Ashore (m^3)	Evaporated (m^3)	Radius (m)	Viscosity (cP)	Thickness (m)
0	0.0	0.0	0.0	0.0	333333.4	9.7	0.015
12	2794.5	1151.8	0.0	1091.2	964181.8	12.1	0.00288
24	1484.9	2163.5	0.0	1389.1	1140930	12.8	0.00129
36	759.9	2708.1	0.0	1569.5	1198650	13.3	0.00063
48	613.9	2731.9	0.0	1691.8	1193734	13.6	0.0005
60	414.0	2839.2	0.0	1784.4	1005320	13.9	0.00037
72	365.2	2812.7	0.0	1859.7	827473.1	14.1	0.00036
84	309.8	2807.6	0.0	1920.2	734239.7	14.3	0.00032
96	229.5	2835.8	0.0	1972.2	459919.1	14.4	0.0003
108	139.5	2883.5	0.0	2014.6	32161.6	14.5	0.00032
120	112.2	2877.2	0.0	2048.1	36285.9	14.6	0.0004

3.4.1 Trajectory

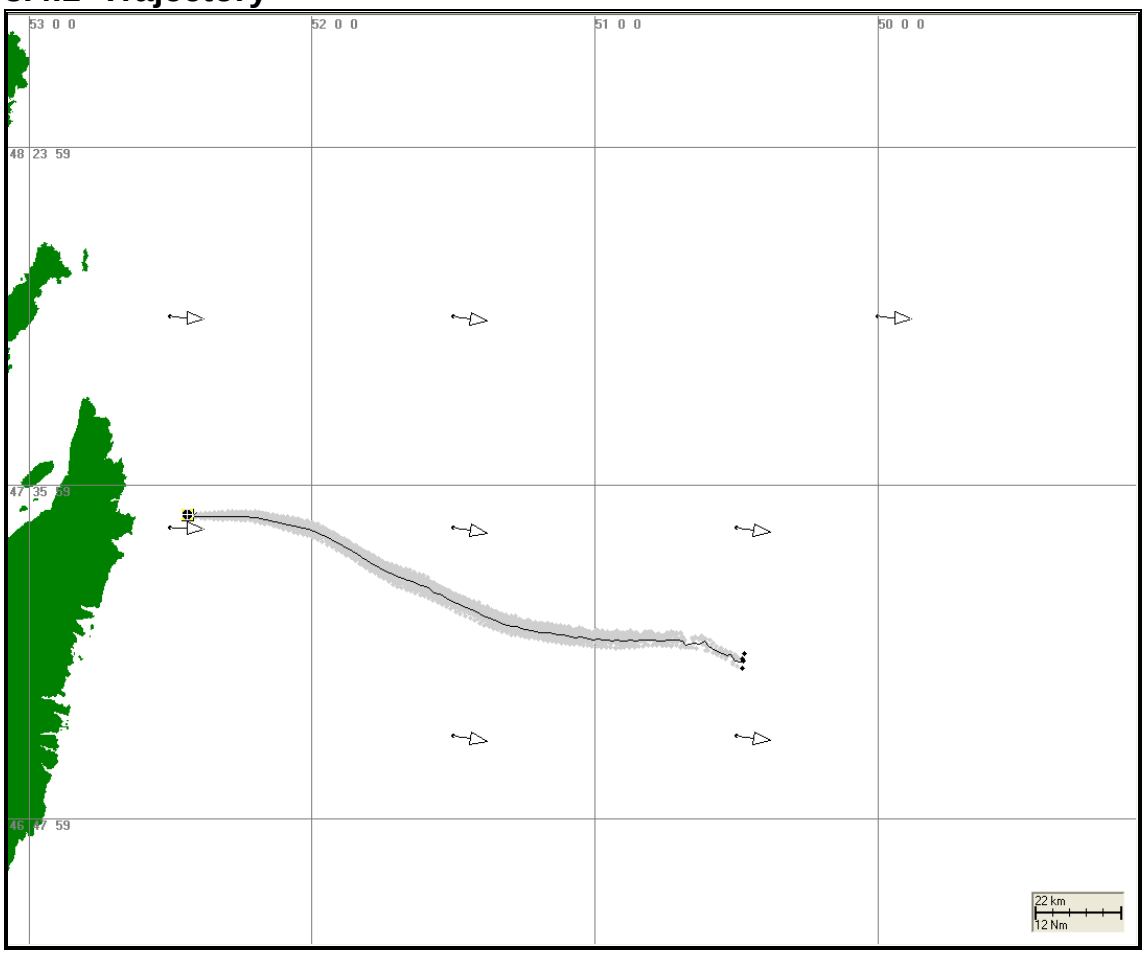


Figure 3.22 Autumn Oil Spill Trajectory

3.4.2 Fates

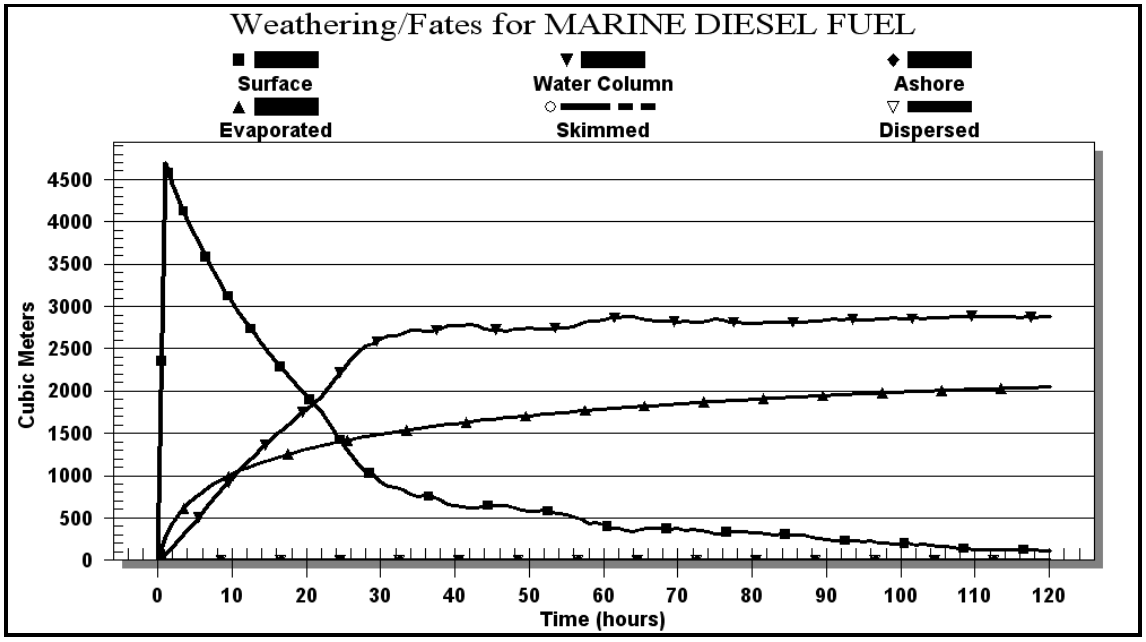


Figure 3.23 Weathering results for Autumn

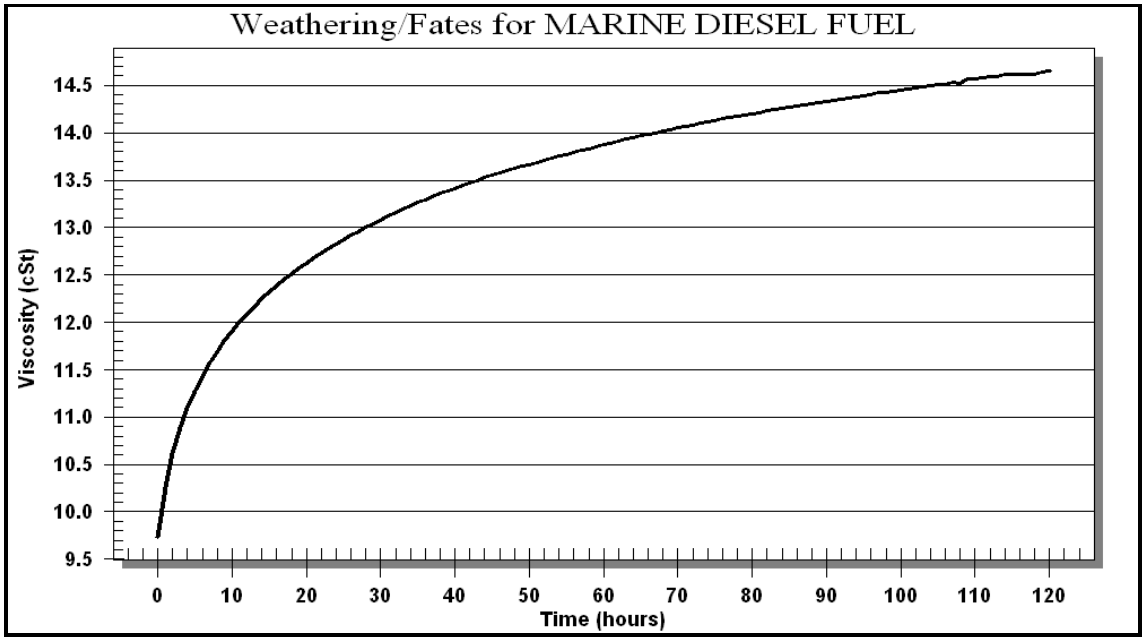


Figure 3.24 Viscosity Mass Balance Graph for Autumn

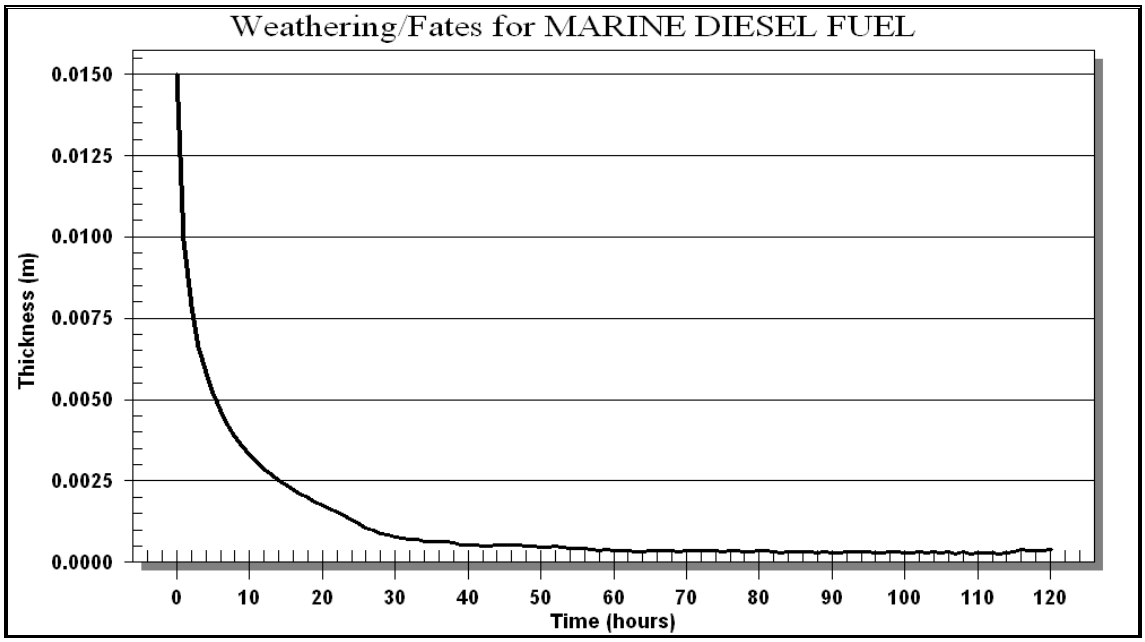


Figure 3.25 Thickness Mass Balance Graph for Autumn

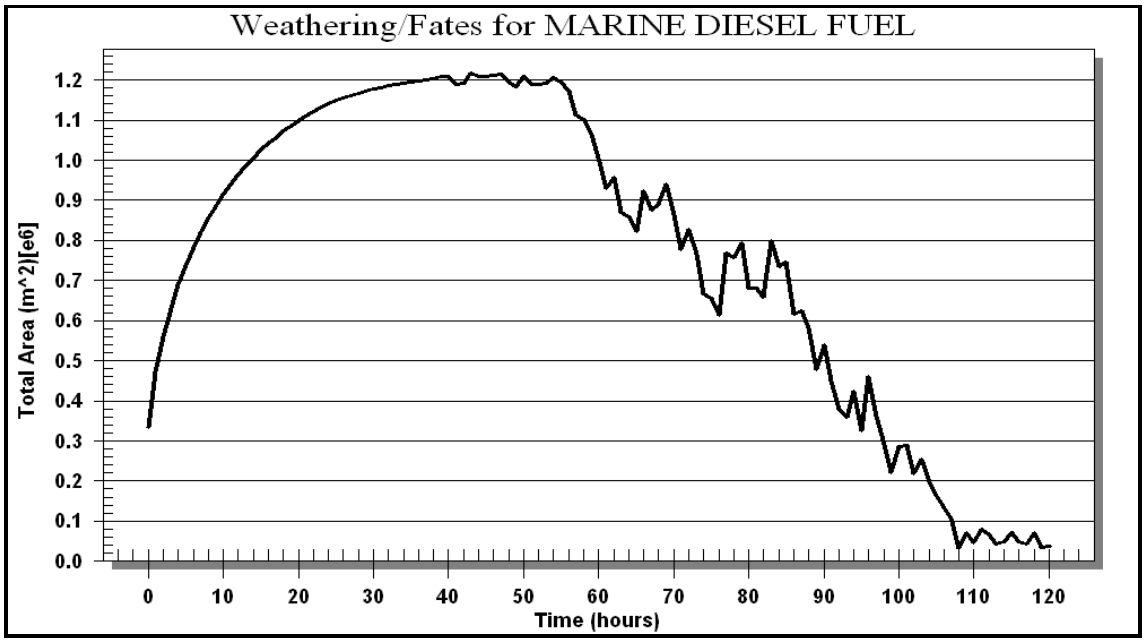


Figure 3.26 Surface Area Mass Balance Graph for Autumn

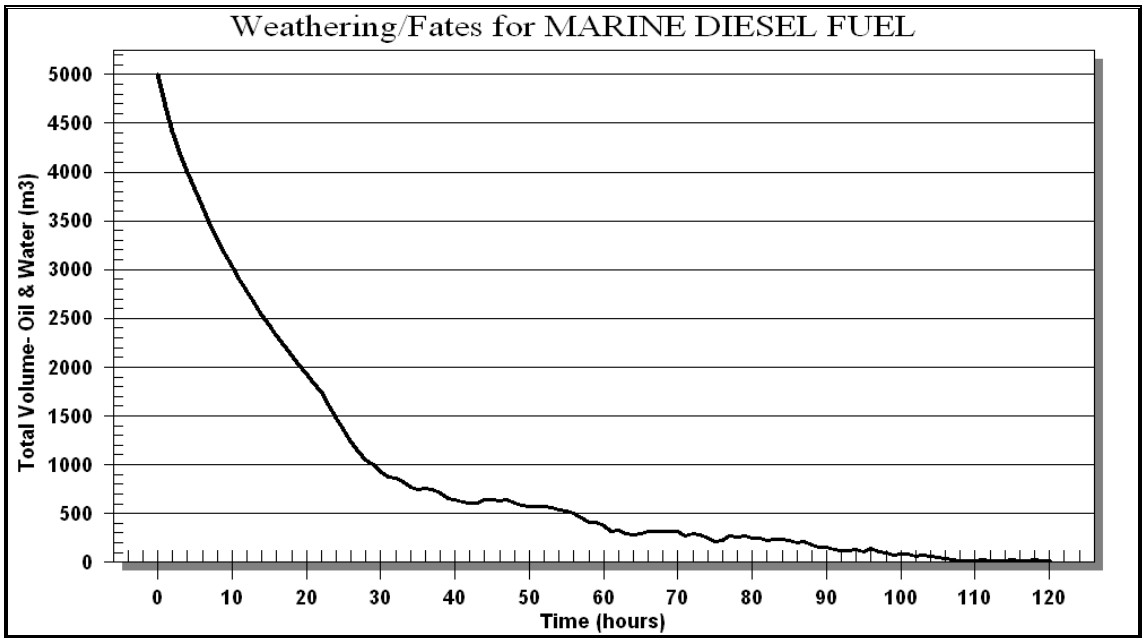


Figure 3.27 Total Volume Graph for Autumn

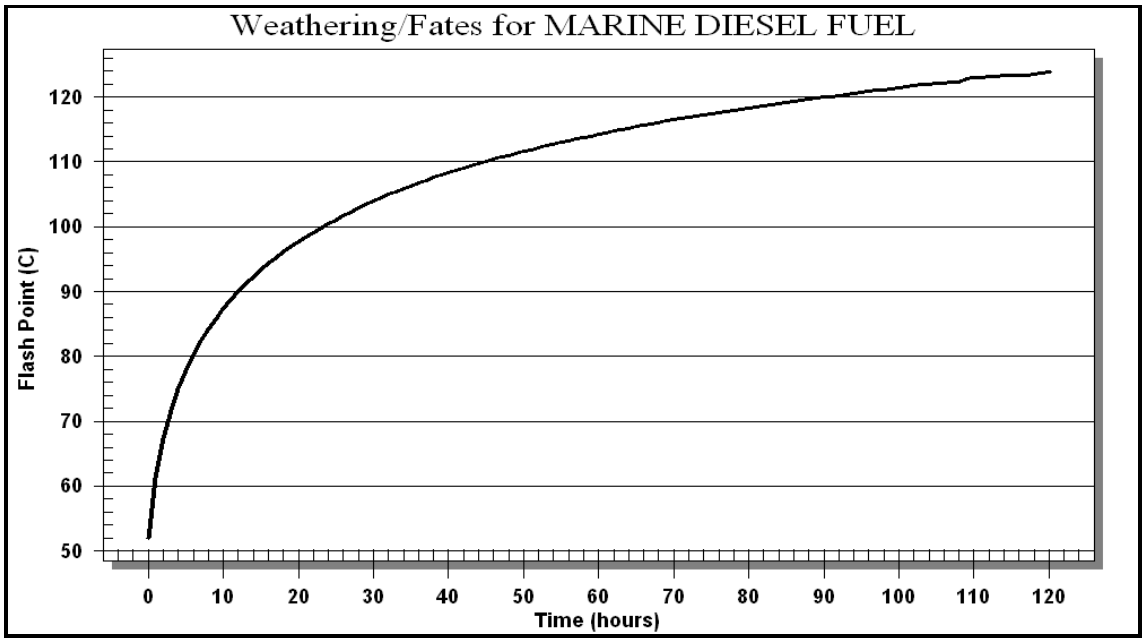


Figure 3.28 Flashpoint Graph for Autumn

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APPENDIX H

White Rose Extension Project Environmental Assessment Oil Spill Modelling Report (SL Ross 2012)

Husky Energy

White Rose Extension Project

Oil Spill Fate and Behaviour Modelling

April 2012

Husky Energy SUNCOR ENERGY nalcor energy

Oil Spill Fate and Behaviour Modelling

in Support of Husky Energy White Rose Extension EA

Prepared by SL Ross Environmental Research

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Executive Summary

This document presents the results of oil spill fate and trajectory modeling and is a prepared as a support document for the White Rose Extension Project Environmental Assessment. No attempt is made to present detailed modeling results in this executive summary. Instead the basic approach to the modeling and a brief discussion of some of the key modeling inputs are provided.

Fate and trajectory modeling were completed for two distinct study areas. One was the near-shore region in Placentia Bay in the vicinity of the proposed graving dock and top-sides mating sites. The near shore modeling evaluates batch diesel spills in the months of March through July, as this is the period that marine project activities in this area will be conducted. The basic fate and trajectory of diesel spills under average seasonal conditions is presented to provide the user with typical slick characteristics and trajectories over time. Long term wind data (MSC50 data) is then used to model the trajectory of slicks released on a daily basis over a 57 year period to assess the likely trajectory of spills in this area. Water current mapping provided by the Fisheries and Oceans Canada (DFO) was used in the modeling. Slick 'time to shore' assessments and trajectory probabilities have been processed from these historical trajectories. Oil will come to shore within a few hours to a few days, depending on the wind conditions, from spills in this area and will most often impact the western and north western shores of the Avalon Peninsula within Placentia Bay. The extent of the diesel spills will be confined to Placentia Bay environs.

The second study area encompasses the broader offshore region surrounding the White Rose Field. Batch spills of diesel fuel and subsea and surface blowouts of crude oil were modelled in the offshore study area. The basic fates of oil from these spill types have been modelled under average environmental conditions to provide users with typical slick characteristics and trajectories over time for the different spill types. For the blowout scenarios, slick characteristics are provided for both the maximum oil and gas flows possible at the start of a release and the lower flows that would be likely 120 days into a release. Historical spill trajectories are modelled in the offshore region using the 57 year MSC50 data set and DFO's east coast water current data. The modeling results show that shoreline contacts from these releases are very unlikely. Slick trajectory probability contours are provided on a monthly basis to identify the zones of most likely oil movement in the offshore.

1.0 Introduction

The objective of this modelling is to assess the behaviour and trajectory of oil spills that might occur during the activities being proposed by Husky Energy in the White Rose Extension Project (WREP). The spills of concern are:

1. sub-sea and surface platform blowouts of crude oil from the offshore location,

2. small platform or vessel based batch spills of marine fuel oil at the offshore production site, and

3. marine fuel oil spills in the vicinity of the Argentia graving dock and the deep-water mating sites in Placentia Bay.

Refer to Figures 1-1 and 1-2 for locations of the White Rose field and the nearshore work sites.

The approach is to select a number of hypothetical oil spills that cover the main concerns and to describe their behaviour and trajectory. These spill scenarios, involving various spill types and sizes, serve subsequently as the basis for impact assessment and countermeasures analyses.

The spill modelling data inputs and results for the near-shore project activities are presented first, followed by the offshore site results.

Two different types of modelling are completed for each site. The first looks at the behavior of spills if seasonal (summer and winter) average air and water temperatures and wind speeds are assumed. The characteristics of the spills over time (slick width, oil thickness, oil viscosity, time to loss of surface oil, and dispersed oil concentration) are presented assuming these average environmental conditions prevail over the life of each spill. These characteristics provide a general picture of the behavior of a single patch of oil released from the spill site for each of the spill scenarios being considered. This information is useful in assessing potential spill countermeasures operations and their likely effectiveness over time and potential zones of impact from a hypothetical spill during typical weather conditions.

The second modelling effort looks at where the oil is likely to travel given long-term historical wind records. Thousands of spill trajectories are initiated from the spill sites and their fate and behavior are determined using 57 years of 6 hourly wind data. The results of the trajectories are then used to identify zones of high and low probability of surface oiling. The results of this modelling are useful in identifying the extents of possible impact zones from hypothetical spills from the operation.



Figure 1-1 Location of White Rose Field

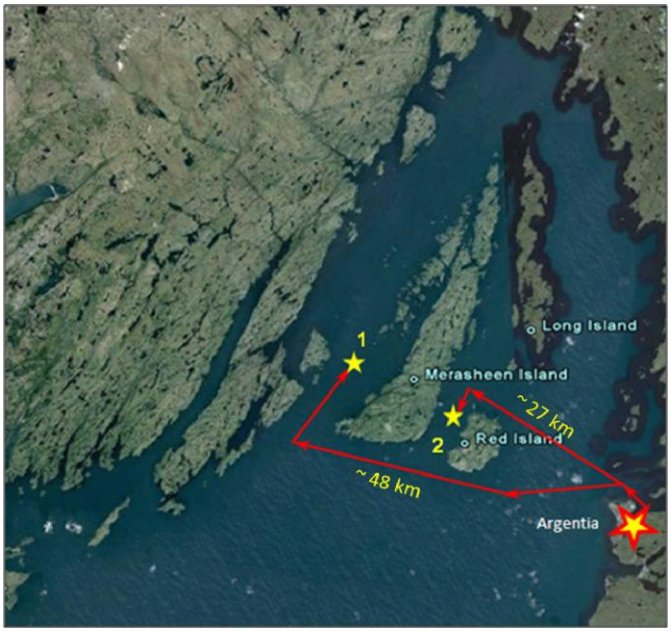


Figure 1-2 Graving Dock and Potential Deep-Water Mating Sites

2.0 Fate and Behaviour of Hydrocarbon Spills in the Near-Shore Study Area

2.1 Spill Scenarios of Interest

The only potential sources of marine spills from the WREP near-shore operations are batch spills of fuel oil as a result of ship accidents or groundings during the tow-out activities from the graving dock to the deep-water mating site and the support vessel activities during the top-sides installation (pers. com. D. Pinsent, Husky Energy). Batch spills are considered instantaneous events and are modeled by considering the surface spreading, evaporation, dispersion, emulsification and drift of a single patch or slick of oil.

2.2 Spill Modelling Inputs

The oil property data, spill volumes, air and water temperatures, winds and water currents used in the near shore spill behavior and trajectory model are described in the following sections.

2.2.1 Oil Properties

The tugs and supply vessels that will be used in the near shore operations will be fueled by marine gas oil (MGO) which is similar in makeup and spill behavior to diesel fuel. Oil property data for diesel oil from Environment Canada's online oil property database (www.etc-cte.gc.ca/databases/spills/oil_prop_e.html) have been used to develop the modelling inputs, shown in Table 2-1. These data have been used in SL Ross's oil spill model (SLROSM) to predict oil evaporation, emulsification, dispersion and property change.

2.2.2 Discharge Volumes and Flow Rates

Instantaneous batch spills of 100 m^3 and 350 m^3 barrels have been modeled for diesel. The two spill sizes have been chosen as representative of a reasonably large spill and the maximum possible spill size based on the fuel tank capacity of the vessels that will be operating in the near shore.

Table 2-1 Oil Property Parameters Used in SLROSM Fuel Oil Spill Modelling

Oil Property	Diesel Fuel
Initial Density (kg/m3)	827.0
Standard Density Temperature (°C)	288.0
Density Constant 1	200.0
Density Constant 2	0.733
Initial Viscosity (cP)	5.0
Standard Viscosity Temperature (°C)	313.0
Viscosity Constant 1	8.755
Viscosity Constant 2	1607.0
Oil Water Interfacial Tension (dynes/cm)	37.0
Water Interfacial Tension Constant	0.0
Oil Air Interfacial Tension (dynes/cm)	22
Air Interfacial Tension Constant	0.0
Initial Pour Point (°C)	243.0
Pour Point Constant	0.139
ASTM Distillation Constant A (slope)	285.0
ASTM Distillation Constant B (intercept)	473.0
Emulsification Delay	99999999999
Fv Theta A	6.3
Fv Theta B	10.3

2.2.3 Water Currents

Surface water current fields developed by the Ocean Sciences Division, Maritimes Region (Atlas of Ocean Currents in Eastern Canadian Waters, Wu and Tang et.al. 2011) and by the Biological and Physical Oceanography Section, Northwest Atlantic Fisheries Centre (Han 2012), both of Fisheries and Oceans Canada (DFO), were used in the spill trajectory modelling. The east coast Atlas data were supplemented by the higher resolution surface water current field provided by the Northwest Atlantic Fisheries Centre for the Placentia Bay modelling. Seasonal mean surface water velocities were provided by DFO and these were converted to a map format used by the SL Ross oil spill model (SLROSM). Surface water current maps for spring (April to June), summer (July to September), and winter (January to March) seasons were used in the modelling. Coarse representations of the summer vector fields for the near shore study areas are provided in Figure 2-1. These water currents were combined with 3% of the average winds to determine the surface water currents influencing the initial formation and movement of the oil slicks.

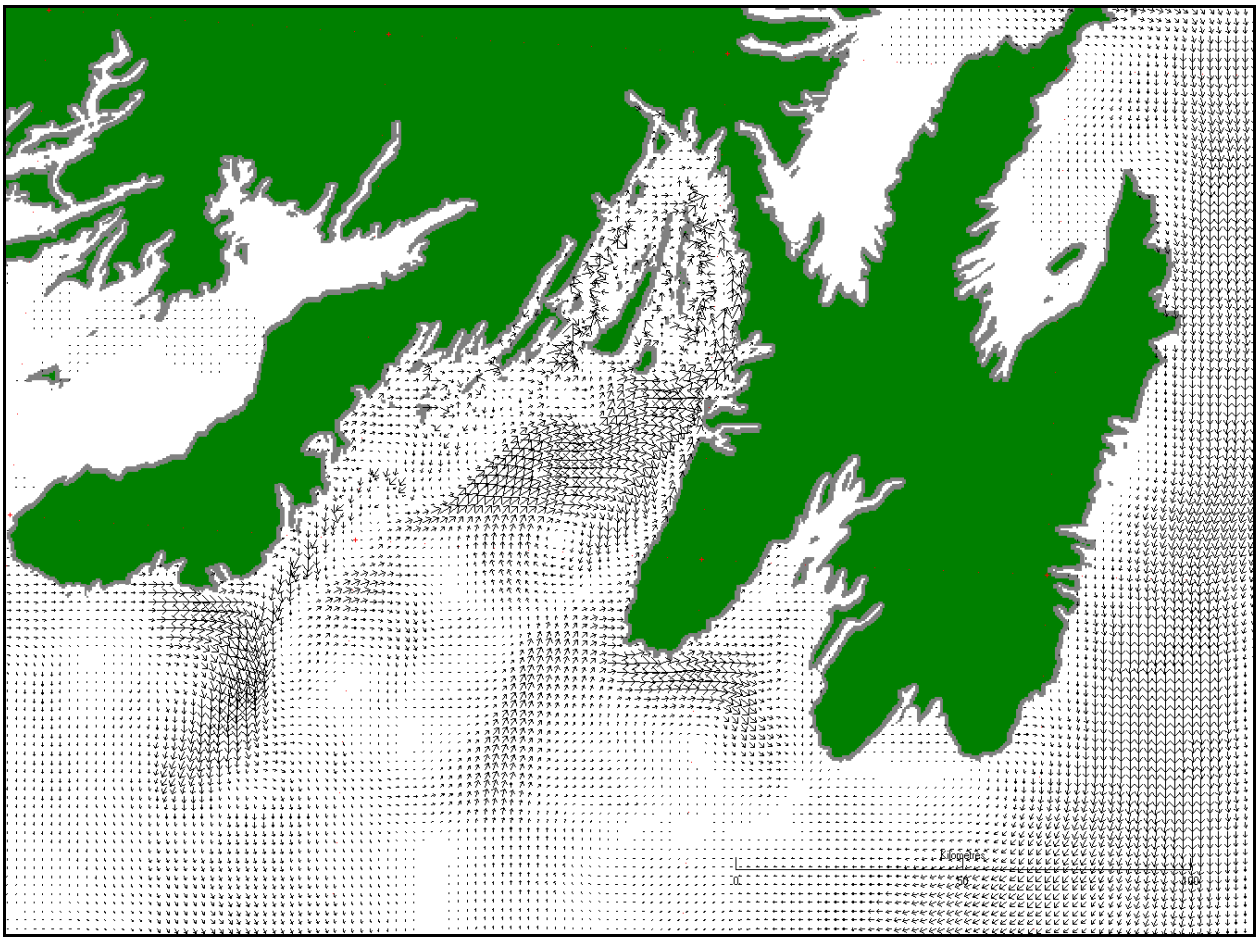


Figure 2-1 Near Shore Summer Surface Water Current Vectors

2.2.4 Air and Water Temperatures

The monthly average air and water temperatures used in the Placentia Bay historical near shore oil fate trajectory modelling are shown in Table 2-2. Summer and winter average air temperatures of 13.5°C and -0.9°C, respectively, were used in the seasonal oil fate modelling. Summer and winter average water temperatures of 14°C and 2.0°C, respectively, were used in the seasonal oil fate modelling.

Table 2-2 White Rose Placentia Bay: Average Monthly Air and Water Temperatures

Medium	Average Temperatures (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air	-0.6	-1.6	-0.4	1.7	4.3	8.0	12.5	14.8	13.2	9.2	5.4	2.2
Water	2	2	2	2	2	14	14	14	14	14	8	8

(source: AMEC 2012. ICOADS air temperatures, BIO Hydrographic Database water temperatures)

2.2.5 Winds

The MSC50 Wind data (Swail et. al.2006) were used in the detailed spill trajectory modelling reported in section 2.4. The data set has wind and wave data for the years 1954 to 2010. Six-hourly wind speed and direction data were extracted from the full MSC 50 data set at grid points with 0.5 degree spacing over the entire study area and at 0.1 degree spacing within Placentia Bay. The Placentia Bay seasonal spill behaviour modelling uses summer and winter average wind speeds of 6.2 m/s and 10.0 m/s, respectively. These were derived from the monthly wind data presented in Table 2-3.

Table 2-3 White Rose Placentia Bay: Average Monthly Wind Speeds and Predominate Directions

Parameter	Average Wind Speeds and Predominate Direction											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Speed (m/s)	10.6	10.0	9.3	8.0	6.3	5.7	5.4	6.0	7.2	8.6	9.4	10.4
Direction	W	W	W	W	SW	SW	SW	SW	WSW	W	W	W

(source: AMEC 2012. Average of Data from 3 MSC50 Grid Points)

2.3 Oil Spill Fate Modelling Results

2.3.1 Spill Behaviour: Average Environmental Conditions

Two diesel fuel spill scenarios have been considered in Placentia Bay with spill volumes of 100 cubic metres (reasonable large spill) and 350 cubic metres (maximum volume of fuel on board). Table 2-4 shows the fate of the “batch” spills for the winter and summer seasons. The winter and summer scenarios were modeled using the average seasonal air and water temperatures provided in section 2.2.4 and the average winter and summer wind speeds shown in section 2.2.5. The following discussions assume that the spilled oil persists on the ocean surface and does not contact shore prior to loss of the surface slick. Spills within Placentia Bay could reach shore prior to complete evaporation and dispersion under certain wind and water current conditions. Section 2.4 looks at the issue of time to shore and shoreline contact locations in detail.

There are not any large differences in the behavior of the spills in the two seasons from the perspective of spill countermeasures and impacts. Since the near shore on-water WREP operations are scheduled to be completed in the late spring or summer months the most relevant fate information to consider are the summer values. The winter data are provided in Table 2-4 to show the range of possible spill behavior based on seasonal differences. The summer discharges lose about 37% of the diesel to evaporation while the winter scenario lose only about 25% by evaporation; the higher summer evaporation is due to a combination of the warmer summer temperatures and the longer slick survival times due to the less energetic summer conditions. The following data are discussed only for the summer season for the two spill sizes and assumes that the oil does not reach shore. The diesel fuel from the 100 and 350 m^3 batch spill scenarios will disperse or evaporate from the surface within about 52 and 67 hours, respectively and the surface slicks will travel distances of about 43 to 53 km (again, if they do not reach shore). The peak diesel concentration in the upper 30 m is estimated to be 0.7 and 1.1 ppm for the 100 and 350 m^3 releases, respectively. Within 52 hours the naturally dispersed oil clouds in the water column from the 100 m^3 spills will grow to a width of

about 5 km and diffuse to 0.1 ppm oil concentration (assuming a conservative 30 m mixing depth). The concentration of 0.1 ppm of total petroleum hydrocarbon is the exposure concentration below which no significant biological effects are expected. The 0.1 ppm threshold is based results of many lab toxicity studies reviewed over many years (French-McCay, 2004). The dispersed oil clouds from the 350 m^3 spills will diffuse to 0.1 ppm within 90 hours and reach a diameter of 9.5 km. The dispersed oil clouds from the 100 m^3 spills will travel 43 km prior to reaching 0.1 ppm; the oil clouds from the 350 m^3 spills will travel 63 km, assuming average water currents and wind.

Table 2-4 Placentia Bay Batch Diesel Spill Characteristics: Average Environmental Conditions

Spill Volume m^3 (bbl)	Season	Initial Slick Width (m)	Slick Survival Time (hr)	Max. Slick Width (m)	Total Evap. %	Max Oil Viscosity (cP)	Dist. to Loss of Slick (km)	Peak Disp. Oil Conc. (ppm)	Time to Peak Conc. (hr)	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (m)	Distance to 0.1 ppm (km)
100 (630)	Winter	80	29	250	25	1311	36	1.9	6	54	5,200	43
100	Summer	80	52	269	37	2975	43	0.7	6	52	5,050	43
350 (2200)	Winter	150	39	410	25	1360	47	2.9	6	96	10,200	58
350	Summer	150	67	440	37	3080	53	1.1	6	90	9,500	63

2.3.2 Spill Trajectories Placentia Bay: Average Conditions

Spill trajectories have been run from three locations in Placentia Bay using average summer wind speeds and prevailing water currents. The three locations selected were the mid-point between the graving dock and Red Island and the two proposed deep-water mating sites. The modelling results are shown in Figure 2-2. These basic trajectories illustrate the general movement of spills from hypothetical spill sites in the near shore operation. These slicks move to the NE due to the prevailing SW summer winds and local water currents and took 19.5, 22.7 and 67 hours to reach shore.

Section 2.4 provides more details on possible spill movements and shore contact timing and locations based on a detailed assessment using 57 year of historical winds.

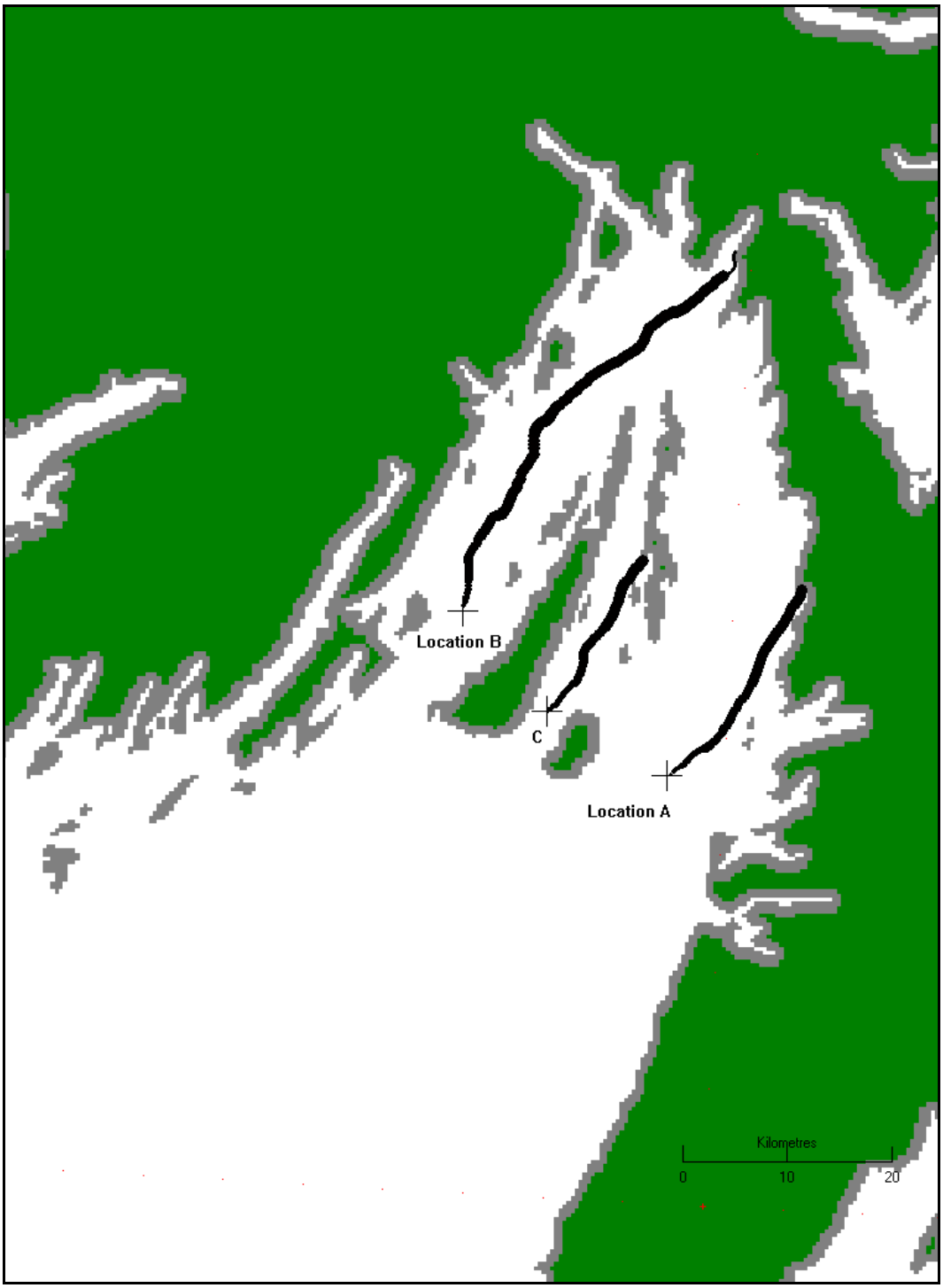


Figure 2-2 Average Conditions Trajectory Modelling: 350 m3 Batch Diesel Spills

2.4 Historical Spill Trajectory Assessment

A total of 8721 trajectories from batch diesel spills were run in this analysis from locations A and B shown in Figure 2-2. These trajectories used the 57 years of wind data available from the MSC50 dataset as described in Section 2.2.5. Trajectories were completed in the months of March, April, May, June and July as these are the months when marine-based activities likely will be occurring in the near shore. For months with 30 days a total of 1710 individual slick trajectories were followed, one released every day starting at the beginning of the first day in each the month. For months with 31 days a total of 1767 trajectories were modelled. The shoreline contact statistics on a monthly basis from these hypothetical spills are provided in Table 2-5 for Location A and Table 2-6 for Location B. A high percentage of slicks reach shore due to the close proximity of the spill sites to land and the prevailing W or SW winds. The minimum time to shore values ranged from 2 to 5 hours. The minimum and maximum survival times for slicks that did not reach shore but instead evaporated and dispersed offshore are shown in the last two columns of Tables 2-5 and 2-6. The minimum survival times were on the order of 0.5 to 1 day and the maximum survival times between 4.5 to 8 days.

Table 2-5 Slick Shoreline Contact and Slick Life at Sea for 350 m3 Batch Diesel Spills From Location A

Month	Number of Slicks Tracked	# of Slicks Tracked Reaching Shore	Minimum Time to Shore (hr)	Maximum Time to Shore (hr)	Minimum Slick Life at Sea (hr)	Maximum Slick Life at Sea (hr)
March	1767	1548	4	94	12	130
April	1710	1476	4	122	16	132
May	1767	1530	4	126	22	184
June	1710	1554	4	143	16	165
July	1767	1532	5	131	17	194

Table 2-6 Slick Shoreline Contact and Slick Life at Sea for 350 m3 Batch Diesel Spills From Location B

Month	Number of Slicks Tracked	# of Slicks Tracked Reaching Shore	Minimum Time to Shore (hr)	Maximum Time to Shore (hr)	Minimum Slick Life at Sea (hr)	Maximum Slick Life at Sea (hr)
March	1767	1636	2	111	13	106
April	1710	1611	2	137	16	104
May	1767	1657	3	159	21	165
June	1710	1551	3	159	20	152
July	1767	974	4	145	17	195

The time-to-shore data for all five months has been combined and plotted in Figures 2-3 and 2-4 for locations A and B, respectively. During the near-shore operations period between March and July over 55% of the time slicks will reach shore within less than 24

hours and over 75% of the time they will reach shore within 48 hours. This is based on the 57 years of MSC50 wind data used to drive the trajectories.

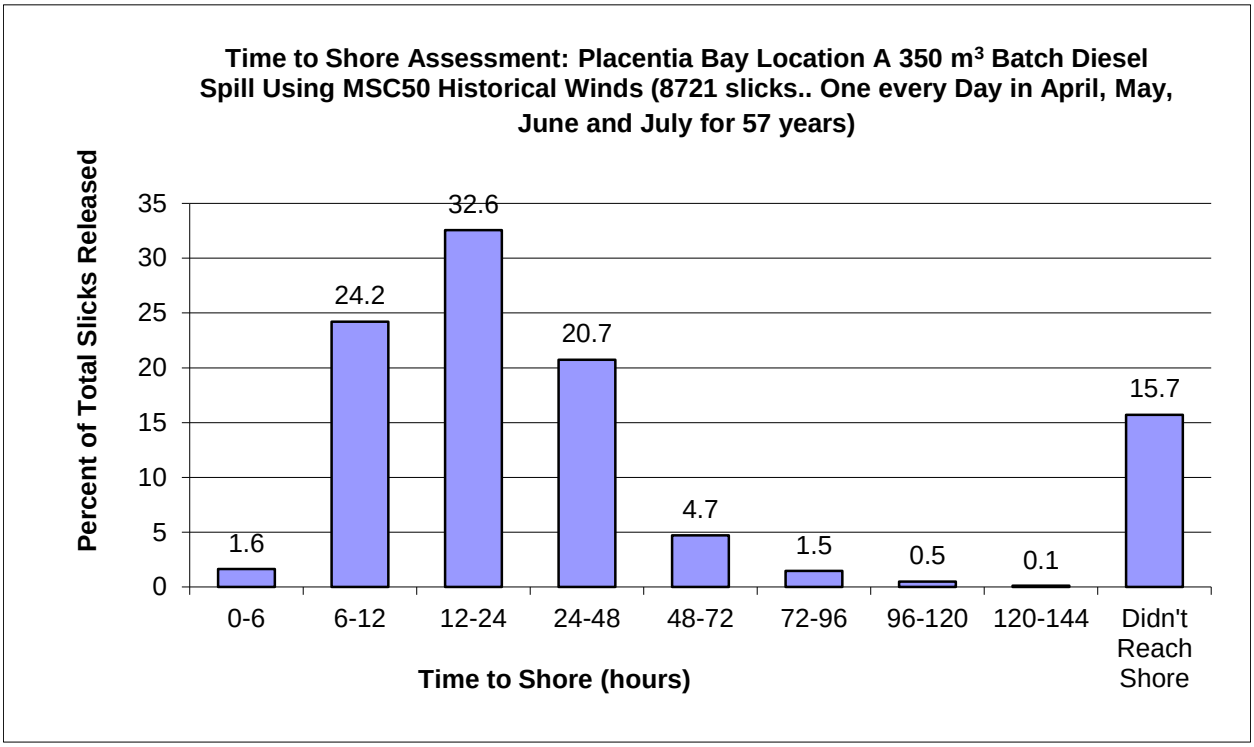


Figure 2-3 Time to Shore Statistics Placentia Bay Location A

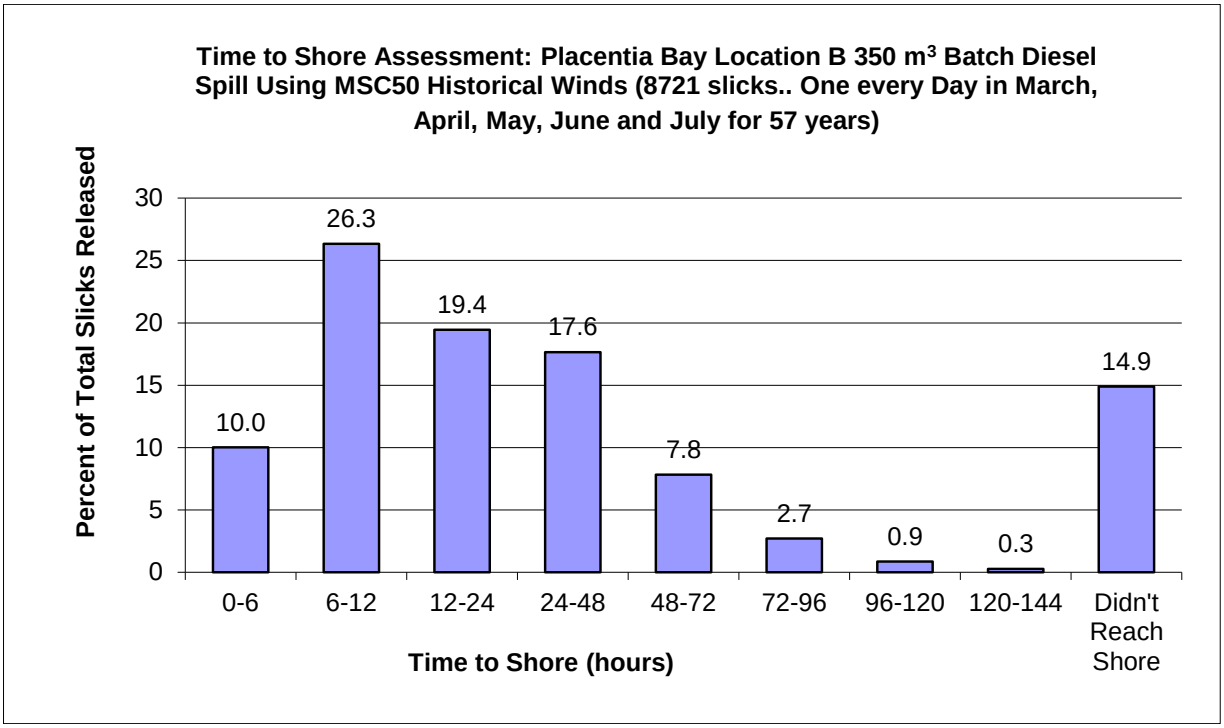


Figure 2-4 Time to Shore Statistics Placentia Bay Location B

The trajectory data has been further processed, on a monthly basis, to identify the probability of a slick reaching specific areas. The slick movements for all spills released in a given month of the year, for the 57 years of data, have been processed to identify the percent of the spills released in the month that enter each grid area in a 1 km x 1 km grid placed over the study area. Figures 2-5 through 2-9 show the spill movement probabilities on a month by month basis for releases from Location A, as identified in Figure 2-2. The total sweep area of each slick has been used in this assessment. The zones on these figures represent areas where 1 to 5% of the slicks released over the 57 years of trajectory processing will pass (light green), 5 to 10% (yellow), 10 to 25% (brown), 25 to 50% (red), and 50 to 100% (black). These figures provide insight into the most likely path of oil and which shore zones are most likely to be oiled based on the 57 years of available wind data. These figures **do not** show areas covered by oil at a point in time but rather identify the probability that oil from a release on any given day will pass through the zone. For releases from location A, the figures show that the oil will generally move to the east and is more likely to contact shore along the western shore of the Avalon Peninsula in Placentia Bay. The likelihood of oil reaching the Burin Peninsula from spills at Location A is small.



Figure 2-5 Batch Spill Trajectory Probabilities for Location A Release: March

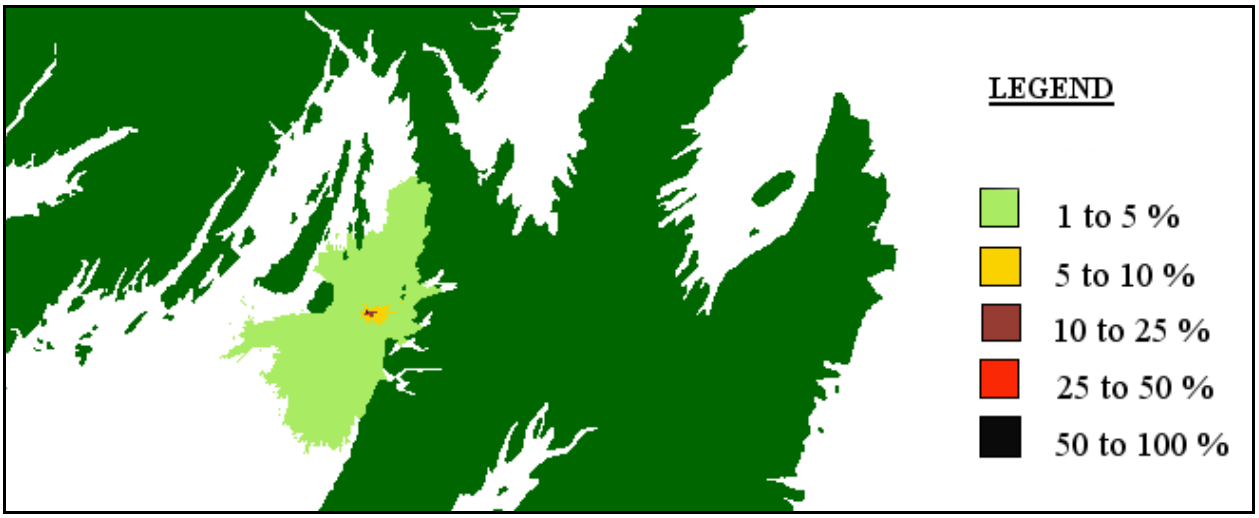


Figure 2-6 Batch Spill Trajectory Probabilities for Location A Release: April

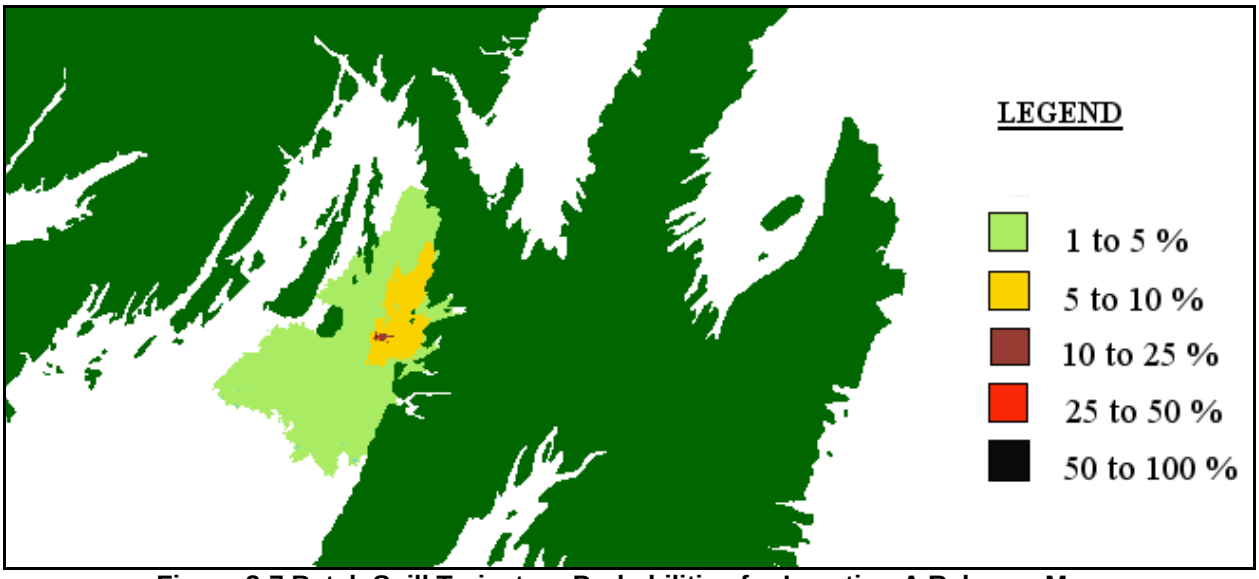


Figure 2-7 Batch Spill Trajectory Probabilities for Location A Release: May



Figure 2-8 Batch Spill Trajectory Probabilities for Location A Release: June

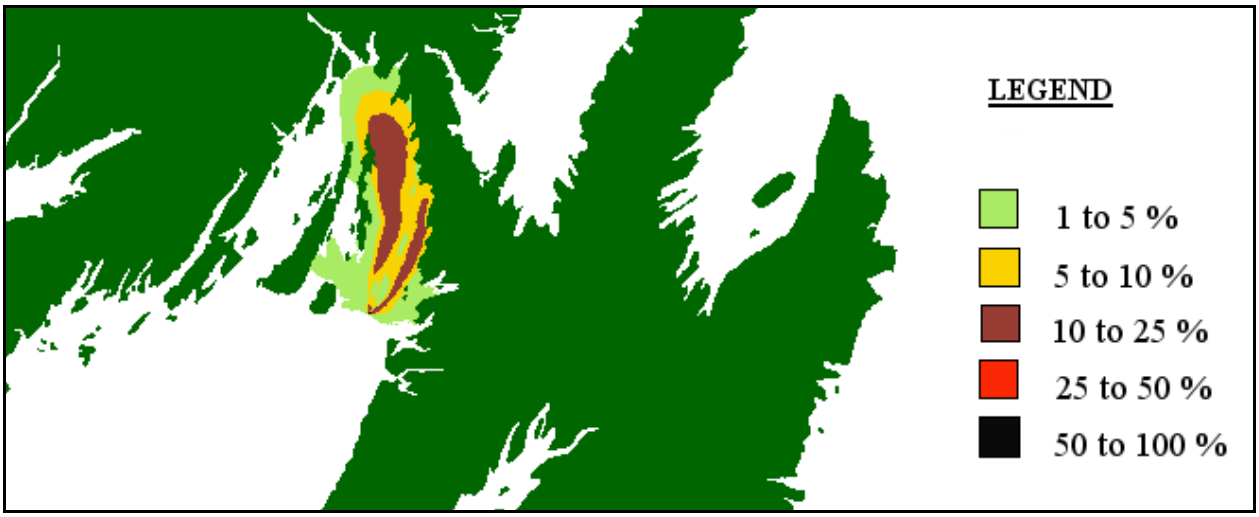


Figure 2-9 Batch Spill Trajectory Probabilities for Location A Release: July

Figures 2-10 through 2-14 show the spill movement probabilities on a month by month basis for releases from Location B, as identified in Figure 2-2. Spills from this location will tend to contact shore areas in the upper reaches of Placentia Bay and the eastern shores of the Burin Peninsula. In May, June and July there is a stronger tendency for the oil to move consistently to the north-east.



Figure 2-10 Batch Spill Trajectory Probabilities for Location B Release: March



Figure 2-11 Batch Spill Trajectory Probabilities for Location B Release: April



Figure 2-12 Batch Spill Trajectory Probabilities for Location B Release: May

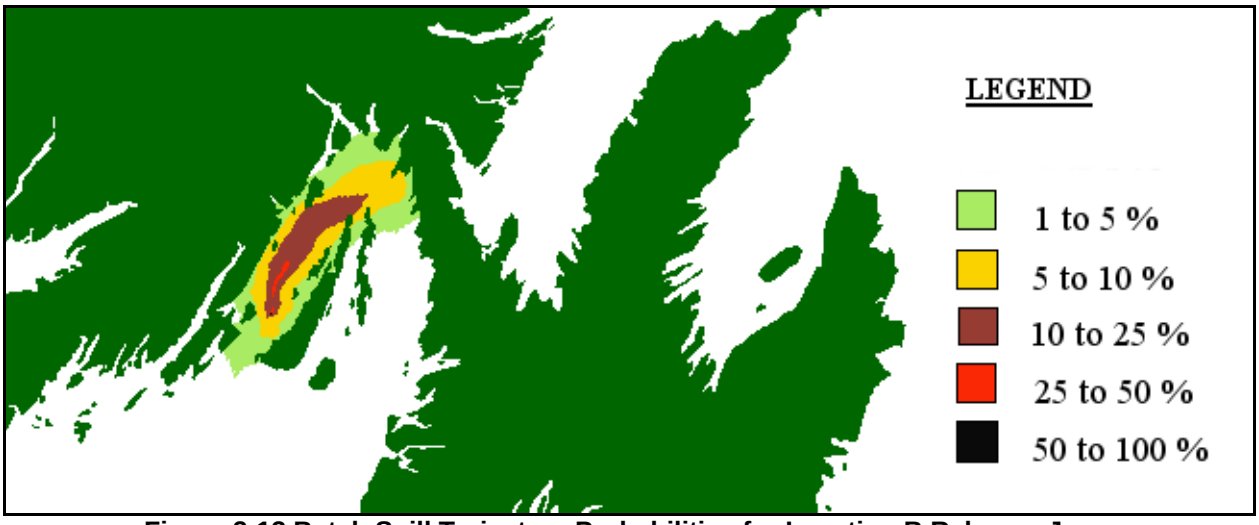


Figure 2-13 Batch Spill Trajectory Probabilities for Location B Release: June



Figure 2-14 Batch Spill Trajectory Probabilities for Location B Release: July

3.0 Fate and Behaviour of Hydrocarbon Spills in the Offshore

3.1 General Oil Spill Behaviour of Spill Scenarios of Interest

The following sections describe the general behaviour of oil associated with the key spill scenario types that may occur during the offshore activities of the WREP: small fuel oil batch spills from vessels or the platform, and subsea and above surface crude oil blowouts from the offshore drilling activities.

3.1.1 Small Batch Spills

Small batch spills of diesel fuel from hose ruptures during transfer operations from a supply vessel or from platform storage facilities are a possibility during drilling operations. Ship collisions could conceivably result in larger batch spills of fuel oil up to a maximum volume of the size of the vessels fuel tanks. Batch spills are considered instantaneous events and are modeled by considering the surface spreading, evaporation, dispersion, emulsification and drift of a single patch or slick of oil.

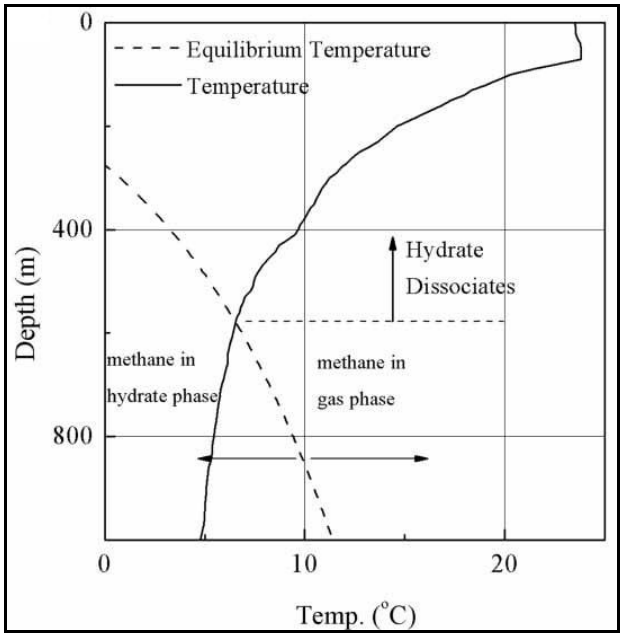
3.1.2 Subsea Blowouts

Well blowouts generally involve crude oil (or gas condensate) and natural gas. The volume ratio of the oil and gas is a function of the characteristics of the fluids and the producing reservoir. The natural gas, being a compressible fluid under pressure at reservoir conditions, provides the driving force for an uncontrolled blowout. As the well products flow upwards, the gas expands, finally exiting at the well head at very high velocities. At this point oil often makes up only a small fraction of the total volumetric flow.

Subsea blowouts can be classified as shallow- or deep- water blowouts based on the behavior of the gas once it exits and comes in contact with water. Deep water blowouts are those where the gas exiting from the subsea release point quickly combines with water to form a solid ice-like substance known as hydrates that form under high pressure and cold temperatures. The gas volume may also be depleted through dissolution into the water. With the loss of gas through either or both of these processes, the driving buoyancy of a rising gas bubble plume may be completely lost, which will result in the oil droplets rising slowly under gravity forces alone. The movement of the oil droplets is affected by cross currents during their rise. This will result in the separation of the oil droplets based on their drop size. The large diameter oil drops will surface first and smaller drops will be carried further down current prior to reaching the surface. Oceanic diffusion processes will result in additional separation of the oil drops due to their varying residence times in the water column. The 2010 BP Macondo blowout in the Gulf of Mexico was a deep-water subsea blowout.

In 5°C waters deeper than about 600 to 700 m complete conversion of the gas to solid hydrates is likely whereas in 5°C waters less than about 500 m deep little hydrate formation is likely. The phase diagram for methane presented in Figure 3-1 provides guidance in the likely formation of hydrates as a function of water depth (pressure) and temperature. The formation of hydrates is also dependent on the actual composition of the gas and impurities in the gas and water so there is some uncertainty in the prediction of hydrate formation in water depths between 400 to 800 m. Because the water depth at

the proposed drilling site is only about 120 m deep and the water temperature is 5°C or more, a subsea blowout at this site would behave as a shallow-water event in this situation and conversion of gas to hydrate will not occur.



Source: from Yapa et al 2010

Figure 3-1 Methane Phase Diagram

In a shallow water blowout most or all of the gas does not convert to hydrates and a gas bubble plume develops that powers the movement of oil and gas and entrained water quickly to the water surface. Oil and gas released from a shallow subsea blowout pass through three zones of interest as they move to the sea surface (Figure 3-2). The high velocity at the well head exit generates the jet zone dominated by the initial momentum of the gas. This highly turbulent zone is responsible for the fragmentation of the oil into droplets ranging from 0.5 to 2.0 mm in diameter (Dickins and Buist 1981). Because water is also entrained in this zone, there is a rapid loss of momentum a few metres from the discharge location. In the buoyant plume zone, momentum is no longer significant relative to buoyancy, which then becomes the driving force for the remainder of the plume. In this region, the gas continues to expand due to reduced hydrostatic pressures. As the gas rises, oil and water in its vicinity are entrained in the flow and carried to the surface.

Although the terminal velocity of a gas bubble in stationary water is only about 0.25 m/sec, velocities in the center of blowout plumes can reach 5 to 10 m/sec due to the pumping effect of the rising gas in the bulk liquid. That is, the water surrounding the upward moving gas is entrained and given an upward velocity, which is then increased as more gas moves through at a relative velocity of 0.25 m/sec. When the plume becomes fully developed, a considerable quantity of water containing oil droplets is pumped to the surface.

In the surface interaction zone, the upward flow of water turns and moves in a horizontal layer away from the center of the plume. The influence of the surface water current causes this radial flow to turn and form a parabolic surface influence as seen in Figure 3-2. This surface influence carries the oil down-current and spreads it over the surface up to the point where this flow no longer affects the surface water motion (between 1 to 1.5 slick widths down-current). At this point the oil moves with the prevailing currents and spreads as any batch spill of oil would. The gas exits from the center of the plume and causes a surface disturbance or “boil zone” identified by the arrows in the top view of Figure 2-2. At the surface, the oil is spread into an area much faster than conventional oil slick diffusion or spreading rates.

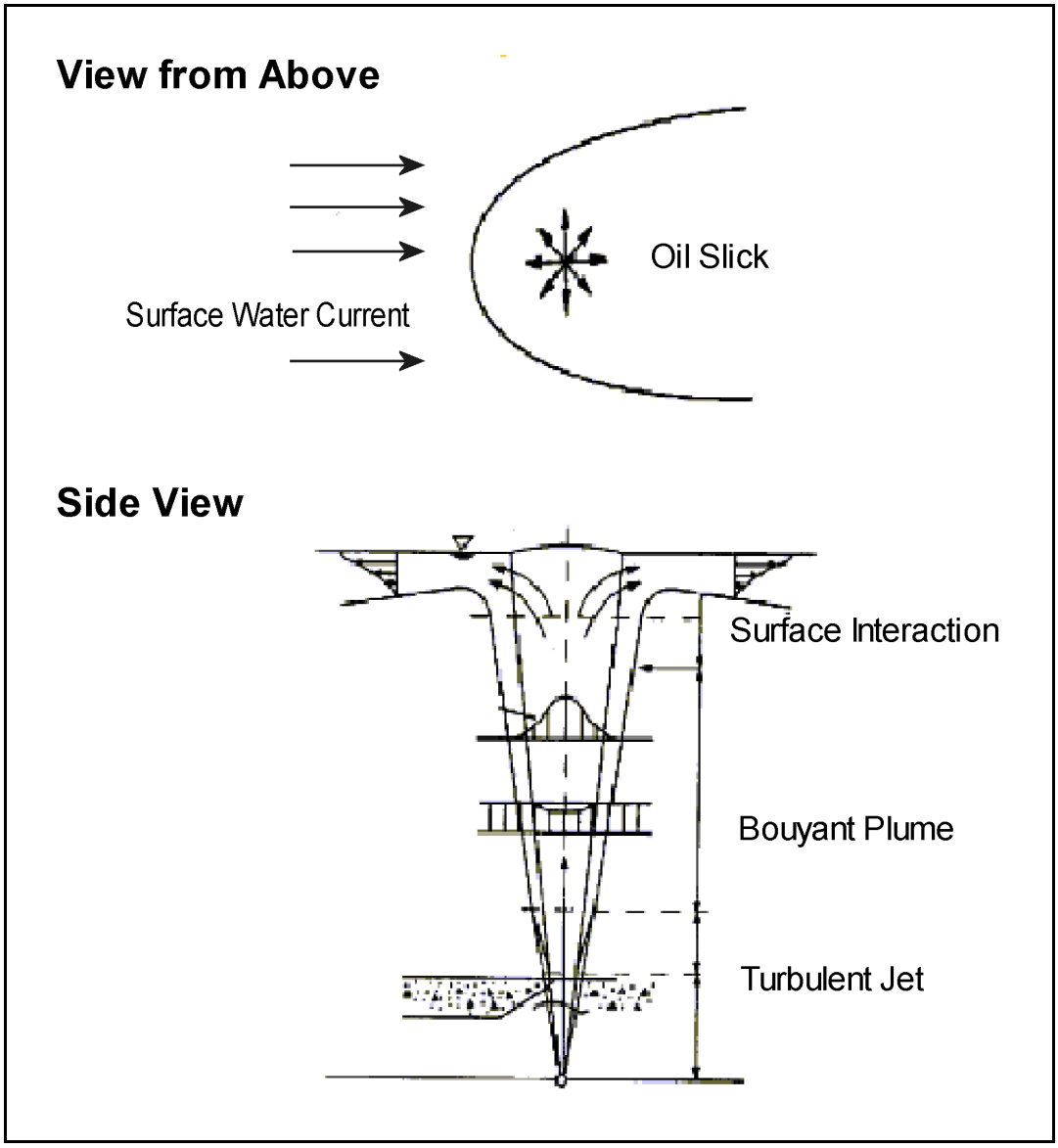


Figure 3-2 Subsea Blowout Schematic

The equations of motion and supporting parameters developed by Fannelop and Sjoen (1980) have been used to model the behaviour of subsea gas and oil releases. These

equations and their numerical solution form the basis for the subsea modelling component of the SL Ross Oil Spill Model (SLROSM) used in this report to estimate the oil slick characteristics from shallow subsea blowouts.

3.1.3 Above-Surface Blowouts

Oil released during a blowout from an offshore platform above the water's surface will behave differently than that from a subsurface discharge. The gas and oil will exit at a high velocity from the well-head and will be fragmented into a cloud of fine droplets. The height that this cloud rises above the release point will vary depending on the gas velocity and the prevailing wind velocity. Atmospheric dispersion processes and the settling velocity of the oil particles determine the fate of the oil and gas at this point.

Figure 3-3 illustrates a simple Gaussian model of this behaviour that can be used to predict the concentrations of oil and gas downwind from the release point. Atmospheric dispersion is controlled in part by atmospheric turbulence that is influenced by solar radiation, wind speeds and temperatures.

On clear, sunny days, with light winds, solar radiation will create highly turbulent conditions. Overcast conditions regardless of the winds will result in a neutral atmospheric stability. Low winds will tend to make mixing more prominent whereas high winds tend to reduce the vertical and lateral mixing conditions. The shape of the concentration profile of the plume will vary depending on the atmospheric stability. In very stable conditions the spread both vertically and laterally will be less than in very turbulent conditions.

The atmospheric plume representation shown in Figure 3-3 can also be used to illustrate the behaviour of oil droplets with the following two modifications. The plume centerline is sloped down to account for the oil droplets' fall velocities. The oil will "rain" down, with the larger droplets falling closer to the release point. As oil drops fall, they will also be spread by atmospheric turbulence. A portion of the falling oil evaporates and the remainder eventually lands on the water and is carried down current. As water passes through the area of falling oil it will be "painted" by the falling oil and an accumulation of oil over the width of the fallout zone will occur. Changing wind and water current directions will affect the ultimate distribution of the oil on the water surface in the fallout zone. If the gas and oil is blowing through the derrick or some other obstruction, some of the oil droplets may agglomerate on the obstruction(s) and flow down onto the rig floor and eventually to the water surface. This portion of the oil will then behave more like a continuous surface release of oil.

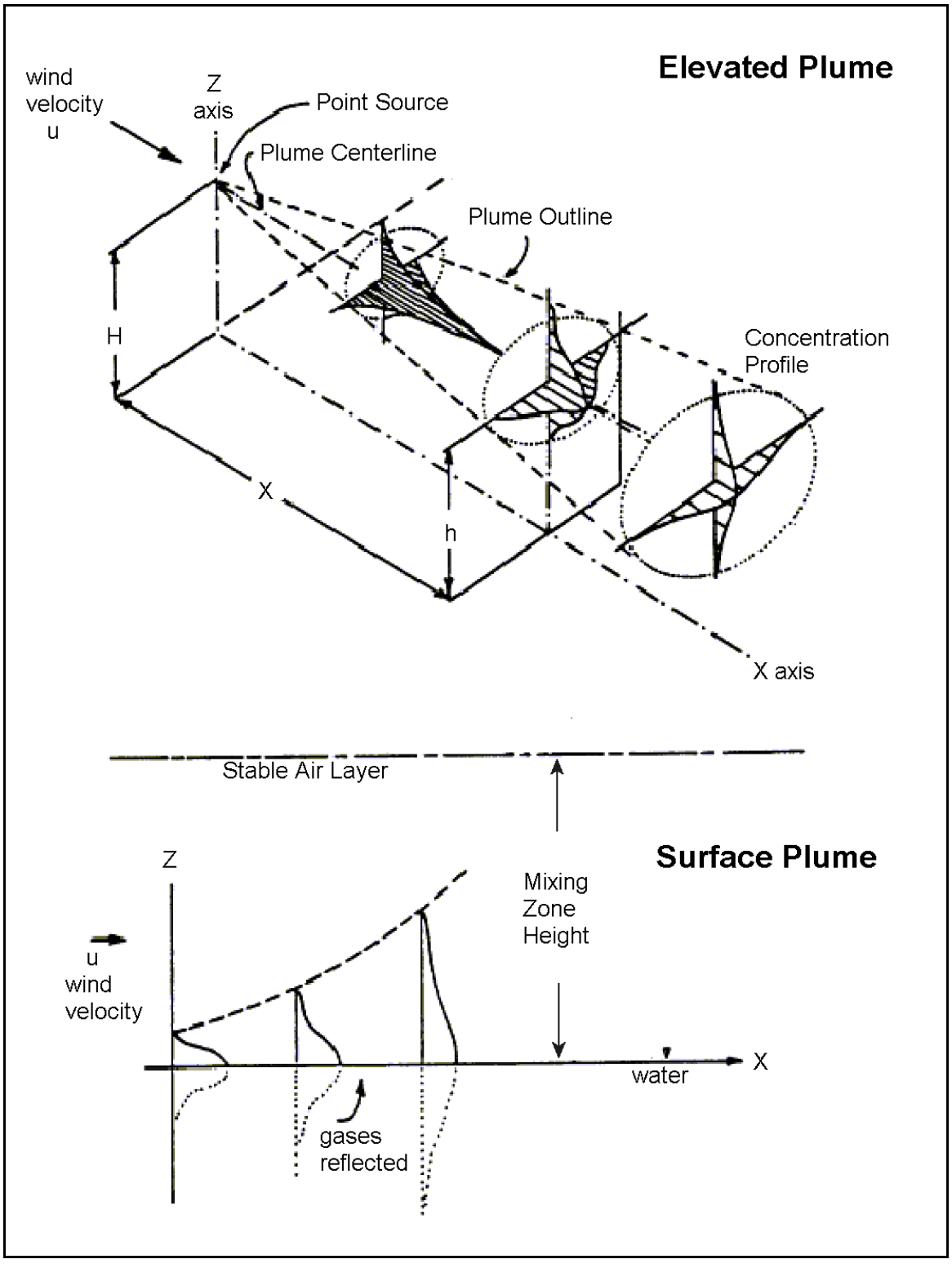


Figure 3-3 Plume Behaviour Schematic

3.2 Spill Modelling Inputs

The oil property data, spill flow rates and volumes, air and water temperatures, winds and water currents used in the spill behavior and trajectory model are described in the following sections.

3.2.1 Oil Properties

Husky Energy have indicated that the crude oil presently being produced from the existing White Rose operation will be representative of the crude likely to be encountered in the extension project. A November 2011 sample of White Rose crude oil was provided to SL Ross for weathering and physical property analysis to gather the information necessary to complete oil fate and behaviour modelling using the SL Ross oil spill model, SLROSM. Summaries of the measured fresh and weathered oil property data for the recent sample of White Rose crude oil are provided in Table 3-1.

Similar oil property data for diesel oil was taken from Environment Canada's online oil property database (www.etc-cte.gc.ca/databases/spills/oil_prop_e.html) for use in the diesel spill scenario modelling.

Table 3-2 shows the oil property modelling parameters derived from the fresh and weathered properties for the two oils that were used in the SLROSM.

Table 3-1 White Rose Crude Oil (Nov. 2011) Fresh and Weathered Properties

Spill-related properties	White Rose	API°=	31.53	
Evaporation (Volume %)	**0**		**4.70**	**14.12**
Density (g/cm^3)				
15 °C	0.869		0.877	0.887
30 °C	0.853		0.862	0.872
Dynamic Viscosity (mPa.s)	at approx 30 s^{-1} for 0° and 115 s^{-1} for 15°			
0 °C	928		1,461	2,146
15 °C	39		66	134
Kinematic Viscosity (mm^2/s)				
0 °C	1,068		1,666	2,419
15 °C	45		76	154
Interfacial Tension (dyne/cm)				
Oil/ Air	27.6		27.4	29.5
Oil/ Seawater	19.3		20.4	21.6
Pour Point (°C)				
	3		6	15
Flash Point (°C)				
	1		9	6
(gelled oil samples flashed as soon as stirrer activated)				
Emulsion Formation-Tendency and Stability @			0 °C	
Tendency	Likely		Likely	Unlikely
Stability	Stable		Stable	Gelled
Water Content	63%		61%	0%
Emulsion Formation-Tendency and Stability @			16.3 °C	
Tendency	Unlikely		Likely	Likely
Stability	Unstable		Entrained	Entrained
Water Content	0%		39%	47%
ASTM Modified Distillation				
			Liquid	Vapour
	Evaporation		Temperature	Temperature
	(% volume)		(°C)	(°C)
	IBP		143.2	39.2
	5		180	64.3
	10		212	73.6
	15		245	86
	20		277	129.4
	25		304	148.9
	30		333	164.1
	40		377	172.1
	0		396	169

Table 3-2 Oil Property Parameters Used in SLROSM Spill Modelling

Oil Property	White Rose Crude	Diesel Fuel
Initial Density (kg/m3)	867.9	827.0
Standard Density Temperature (°C)	288.7	288.0
Density Constant 1	128.5	200.0
Density Constant 2	1.010	0.733
Initial Viscosity (cP)	38.7	5.0
Standard Viscosity Temperature (°C)	288.16	313.0
Viscosity Constant 1	7.14	8.755
Viscosity Constant 2	15833.7	1607.0
Oil Water Interfacial Tension (dynes/cm)	19.4	37.0
Water Interfacial Tension Constant	0.836	0.0
Oil Air Interfacial Tension (dynes/cm)	27.2	22
Air Interfacial Tension Constant	0.543	0.0
Initial Pour Point (°C)	275.72	243.0
Pour Point Constant	0.314	0.139
ASTM Distillation Constant A (slope)	609.98	285.0
ASTM Distillation Constant B (intercept)	425.4	473.0
Emulsification Delay	30000	99999999999
Fv Theta A	6.7	6.3
Fv Theta B	13.0	10.3

3.2.2 Discharge Volumes and Flow Rates

Instantaneous batch spills of 1.6 m^3 (10 barrels), 16 m^3 (100 barrels), 100 m^3 (630 barrels) and 350 m^3 (2200 barrels) have been modeled for marine diesel. The two smallest spill sizes were chosen as they are representative of small and medium sized platform spills based on historical records. The larger spill sizes were chosen to illustrate the behavior of large diesel spill sizes. The modelling of the continuous releases of gas and oil from well blowouts has been completed using the gas and oil flow rates shown in Table 3-3. The blowout flow rates identified in Table 3-3 were determined by Husky Energy engineers based on the best available reservoir information.

Table 3-3 Spill Flow Rates and Volumes Used in Modelling

Spill Type	Source	Flow	Gas-to-Oil Flow Ratio m^3/m^3
Crude Oil Well Blowout (Max Flow at Start of Blow)	Subsea	6,435 m^3/day (40,476 BOPD)	138
	Platform	6,435 m^3/day (40,476 BOPD)	138
Crude Oil Well Blowout (Flow after 120 Days)	Subsea	3,963 m^3/day (24,927 BOPD)	275
	Platform	3,963 m^3/day (24,927 BOPD)	275
Batch Oil Spills	Transfer	1.6 m^3 (100 bbl)	na
	Transfer	0.16 m^3 (10 bbl)	na
	Vessel Accident	100 m3 (630 bbl)	na
	Vessel Accident	350 m3 (2200 bbl)	na

3.2.3 Water Currents

Surface water current fields developed by the Ocean Sciences Division, Maritimes Region of Fisheries and Oceans Canada (Wu and Tang et.al. 2011) were used in the spill trajectory modelling in the offshore study area. Seasonal mean surface water velocities were provided by Fisheries and Oceans Canada and these were converted to a map format used by the SL Ross Oil Spill model (SLROSM). Surface water current maps for Spring (April to June), Summer (July to September), Fall (October to December) and Winter (January to March) seasons were used in the modelling. Coarse representations of the Summer and Winter vector fields for the offshore study area are provided in Figures 3-4 and 3-5, respectively. These water currents were combined with 3% of the average winds to determine the surface water currents influencing the initial formation and movement of the oil slicks.

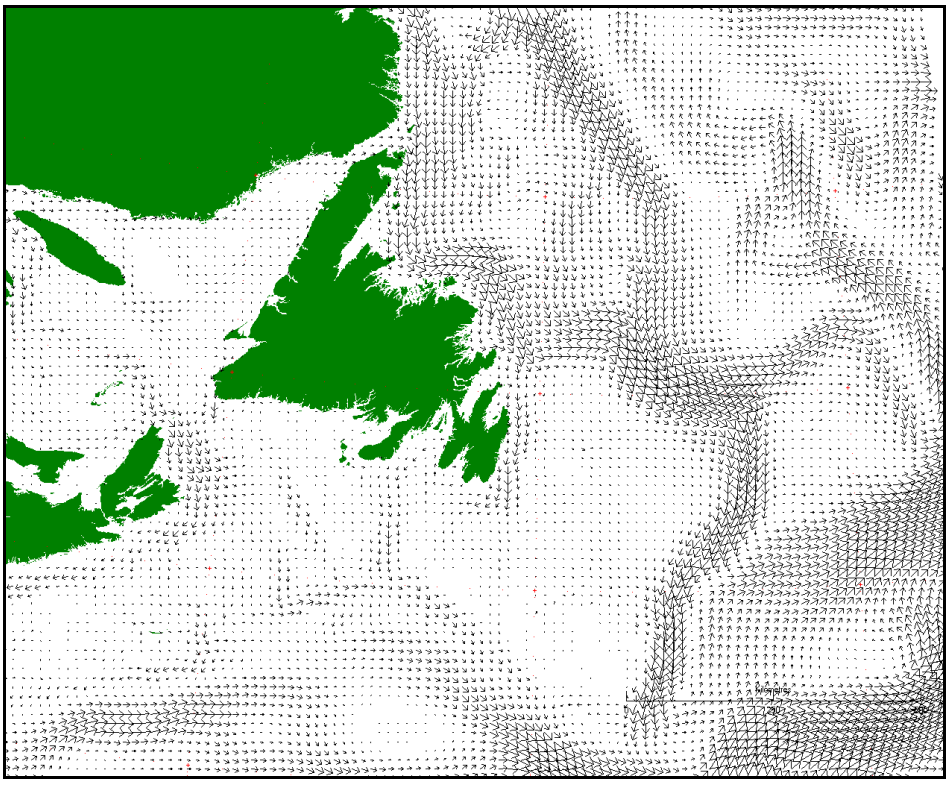


Figure 3-4 Offshore Summer Surface Water Current Vectors



Figure 3-5 Offshore Winter Surface Water Current Vectors

3.2.4 Air and Water Temperatures

The monthly average air and water temperatures used in the fate modelling for the detailed fate and trajectory modelling for the offshore are shown in Table 3-4. Summer and winter average air temperatures of 12.9°C and 0.1°C, respectively, were used in the seasonal oil fate modeling. Summer and winter average water temperatures of 12.3°C and 0.5°C were used in the seasonal oil fate modelling.

Table 3-4 White Rose Extension Site: Average Monthly Air and Water Temperatures

	Average Temperatures (°C)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Air	0.1	-0.4	0.3	1.9	4.1	7.1	11.9	14.3	12.6	8.8	5.1	2.1
Water	1.0	0.3	0.3	1.0	3.0	5.9	10.5	13.7	12.7	9.1	5.5	2.7

(source: Oceans Ltd 2012. ICOADS air and surface water temperatures)

3.2.5 Winds

The MSC50 Wind data set (Swail et. al.2006) was used in the detailed spill trajectory modelling completed in this study. The data set has wind and wave data for 57 years from 1954 to 2010. Six-hourly wind speed and direction data were extracted from the full MSC 50 data set at grid points with 0.5 degree spacing over the study area. The seasonal spill behaviour modelling used summer and winter average wind speeds of 6.7 m/s (SW) and 10.6 m/s (W), respectively. Table 3-5 shows the average monthly wind speeds on a monthly basis near the offshore site.

Table 3-5 White Rose Extension Site: Average Monthly Wind Speeds and Predominate Directions

	Average Wind Speeds and Predominate Direction											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Speed (m/s)	11.1	10.9	9.8	8.3	7.0	6.5	6.1	6.4	7.5	8.8	9.5	10.7
Direction	W	W	W	W	SW	SW	SW	SW	WSW	W	W	W

(source: Oceans Ltd 2012 MSC50 Grid Point 11034)

3.3 Oil Spill Fate Modelling Results

3.3.1 Diesel Batch Spill Fate Modelling

Four diesel fuel spill scenarios have been considered with spill volumes of 1.6, 16, 100 and 350 cubic metres. Table 3-6 shows the fate of the "batch" spills for the winter and summer seasons for the different spill volumes. The winter and summer scenarios were modeled using the average seasonal air and water temperatures and wind speeds provided in sections 3.2.4 and 3.2.5.

The summer discharges lose 36 to 38% of the diesel to evaporation while the winter scenarios lose about 25 to 27% by evaporation; this is due to a combination of the warmer summer temperatures and the more energetic winter conditions that disperse the oil more quickly thus reducing the opportunity for evaporation. The slicks in the winter are lost from the surface more quickly (13 to 37 hours in winter versus 25 to 62 hours in summer, depending on initial volume spilled) due to the higher winds and thus more energetic wave action. Surface oil will persist for 16 to 49 km from the source in the winter versus 22 to 62 km in the summer; the shorter distance in winter again due to the more rapid natural dispersion. The faster dispersion in the winter months results in higher peak in-water oil concentrations (0.6 to 3 ppm in winter versus 0.24 to 1.2 ppm in summer). The naturally dispersed oil in the water column is assumed to mix to a conservative depth of 30 metres. The clouds of dispersed oil from the winter spills will grow to widths of o 0.3 to 10.2 km at the point where the oil has diffused to below 0.1 ppm oil concentration. The winter dispersed oil clouds will sweep distances of 10 to 130 km prior to diffusing to a 0.1 ppm in-water oil concentration. The size of the summer spill clouds will be somewhat smaller (0.3 to 9.7 km) and they will sweep smaller distances (5 to 102 km). The in-water concentration of 0.1 ppm of total petroleum hydrocarbon is the exposure concentration below which no significant biological effects are expected (French-McCay 2004).

The maximum viscosity that the surface oil will reach in these batch spills is about 1700 cP in the winter and 3700 cP in the summer. The higher summer viscosity is due to the higher evaporation that results in a greater increase in viscosity than that caused by the colder winter water temperatures. These predicted maximum viscosities are significantly lower than viscosities that would hamper traditional containment and recovery countermeasures operations. Chemical dispersants also should remain effective on these diesel spills over the lifespan of the surface slicks.

Table 3-6 Batch Diesel Spill Characteristics

Spill Volume m^3 (bbl)	Season	Initial Slick Width (m)	Slick Survival Time (hr)	Max. Slick Width (m)	Total Evap. %	Max Oil Viscosity (cP)	Dist. to Loss of Slick (km)	Peak Disp. Oil Conc. (ppm)	Time to Peak Conc. (hr)	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (m)	Distance to 0.1 ppm (km)
1.6 (10)	Winter	10	13	50	26	1350	16	0.6	2	8	315	10
1.6	Summer	10	25	54	38	3700	22	0.24	2	4	275	5
16 (100)	Winter	32	19	120	27	1340	24	1.13	2	26	2,210	30
16	Summer	32	35	130	36	3070	31	0.5	2	18	1,490	17
100 (630)	Winter	80	28	247	25	1660	36	2.0	4	58	5,630	65
100	Summer	80	48	264	36	3075	45	0.8	4	54	5,210	55
350 (2200)	Winter	150	37	402	26	1320	49	3.0	6	98	10,400	130

350	Summer	150	62	430	36	2890	62	1.2	6	92	9,720	102

3.3.2 Offshore Diesel Spill Trajectories: Seasonal Average Environmental Conditions

Spill trajectories have been run from the White Rose platform location using average summer and winter wind speeds and prevailing water currents for the four diesel fuel spill volumes. The summer and winter trajectory results are shown in Figure 3-6 and 3-7, respectively. These basic trajectories illustrate the general movement of batch fuel oil spills from hypothetical spill at the offshore site. The locations where the surface oil slicks have completely evaporated and dispersed are marked on the figures as are the locations where the dispersed oil cloud concentrations drop to below 0.1 ppm concentration. For the smaller spills the plume concentrations are below this level prior to loss of the surface oil.

Section 3.4 provides more details on possible spill movements based on a detailed assessment using 57 year of historical winds.

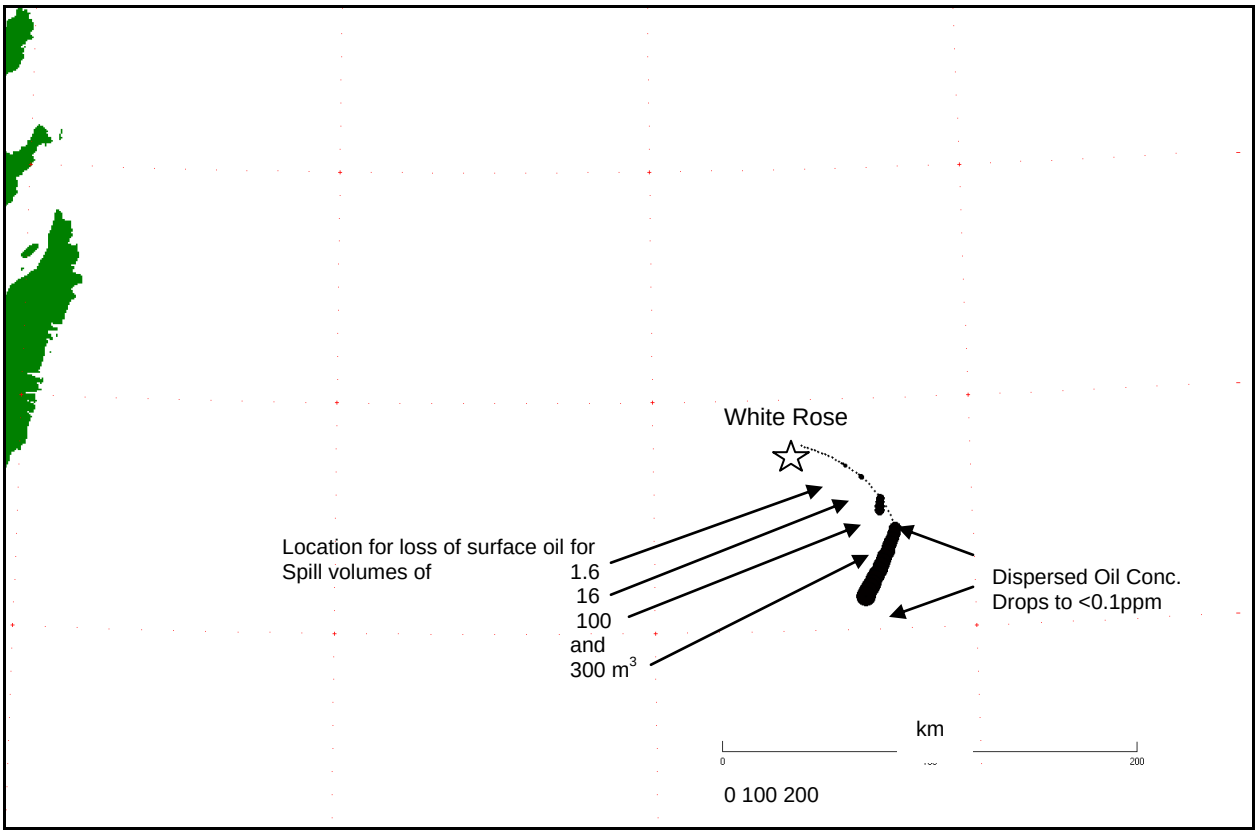


Figure 3-6 Offshore Summer Diesel Spill Trajectories: Average Environmental Conditions

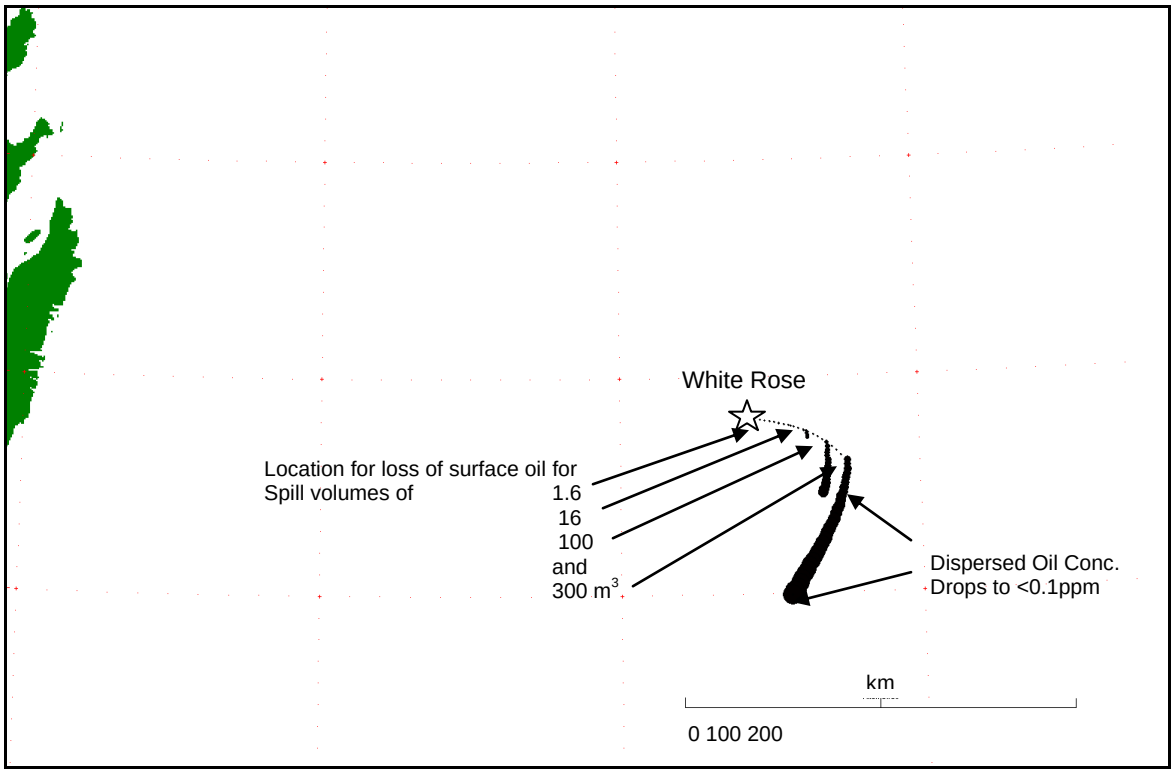


Figure 3-7 Offshore Winter Diesel Spill Trajectories: Average Environmental Conditions

3.3.3 Subsea Crude Oil Blowout Fate and Behaviour Modelling

The fate of crude oil from winter and summer subsea blowout scenarios has been modeled using the methods outlined in Section 3.1.2 and the results are summarized below. Oil properties of White Rose crude oil sampled and analyzed in the fall of 2011 have been used in this modelling.

Oil flow rates of 6,435 m^3/day and 3,963 m^3/day with gas-to-oil ratios (GOR) of 138 m^3/m^3 and 275 m^3/m^3 were used in the modelling. These flows represent the maximum oil flow rate estimated from the reservoir and the reduced flow expected after a 120 day release period (Husky Energy 2012). At the beginning of a blowout the oil fate will most closely match the results provided for the higher flow rate. By the end of a 120 day release the results presented for the lower flow rates will be more representative.

In this scenario the fluids are assumed to erupt from the seabed with the formation of small oil droplets in the turbulent jet region of the discharge. The oil drops are then quickly carried to the surface with entrained water and gas. The average winter and summer seasonal temperatures and wind speeds presented in sections 3.2.4 and 3.2.5 are used in this modelling.

At the surface, the oil drops spread to form a slick in the summer since the ambient temperature is above the fresh oil's initial pour point, however, in the winter the oil is assumed to remain in the form of small drops of about 1 mm in diameter because the ambient water temperature is well below the oil's pour point. Because the oil drops are

essentially semi-solid spheres it is assumed that they will not mix and coalesce into a traditional oil slick. The small drops have a larger surface area than a traditional slick and this allows for a more rapid evaporation and further increase in the oil's pour point and viscosity. If high concentrations of these droplets were to form offshore during a sunny day with calm conditions then solar radiation could warm the oil to the point where the drops might coalesce and form a more traditional oil slick. The entrained water flow from the blowout creates a hyperbolic-shaped oil distribution at the surface that extends several hundred metres up-current of the gas boil zone (located at the focus of the hyperbole, see Figure 3-2) and that is between about 1.7 to 2.8 kilometres wide down-current of the gas boil depending on the season (see initial slick width in Table 3-7).

The oil slicks are predicted to be very persistent due to the formation of water-in-oil emulsions in the summer and because the water is colder than the oil's pour point in the winter. As such the oil does not naturally disperse and will remain on the surface for an extended period of time.

After about 1 day of exposure on the water surface the oil will have lost between 18 to 21% of its volume to evaporation. The maximum amount expected to be removed through evaporation over the life of the surface oil is 31 to 36%.

The initial oil viscosity at the summer temperature is 65 cP, in winter it would be 712 cP. Under average summer conditions, evaporation and emulsification raises the viscosity of the oil to 10,000 cP after 9.7 to 15 hours (depending on the spill flow rate). The viscosity of the oil is predicted to increase to a maximum of between 39,350 to 45,600 cP by the end of the slick's life. In the winter the water temperature is more than 15 °C lower than the oil's pour point so the oil will remain in the form of drops, will not coalesce to for a slick and will not form water-in-oil emulsions. The maximum viscosity of the drops is estimated to be about 7,500 cP.

Natural dispersion will be minimal in all of the subsea blowout scenarios either due to emulsion formation or the high oil pour point and cold water. In-water oil concentrations from these spills will remain below 0.001ppm.

Table 3-7 Subsea Crude Oil Blowout Spill Characteristics

Spill Flow Rate m^3/day (bopd)	Season	Initial Slick Width (m)	Initial Slick Thick (mm)	Slick Survival Time (days)	% Evap after 1day	Total Evap. %	Peak Disp. Oil Conc. (ppm)	Time to 0.1 ppm Disp. Oil Conc. (hr)	Initial oil Viscosity (cP)	Time to Oil Viscosity of 10,000cP (hrs)	Maximum Oil Viscosity cP
6,435 (40,476)	winter	1670	1.0[2]	>30	18	31	<0.001	na[1]	712	na[1]	7,400[1]
6,435 (40,476)	summer	2600	0.18	>30	19	36	<0.001	na	65	15	39,350
3,963 (24,927)	winter	1790	1.0[2]	>30	18	33	<0.001	na	712	na[1]	7,400[1]
3,963 (24,927)	summer	2760	0.1	>30	21	33	<0.001	na	65	9.7	45,600

[1]Water temperature more than 15 °C lower than oil pour point – no natural dispersion and no emulsification assumed

[2] Oil remains as 'solid' drops with a 1 mm diameter due to high pour point and low water temperature in winter

3.3.4 Sample Subsea Blowout Spill Trajectories

Two random dates have been selected to provide sample trajectories of oil from a 120 day subsea blowout in the summer and winter months. The 6-hourly MSC50 wind data described in section 2.2.5 for September 2009 and February 2009 have been used to drive the trajectories. The spatially and temporally variable winds of the MSC50 data set are used here instead of seasonal average values to illustrate how the time-varying winds will affect the motion of slicklets that are released over the 120 day discharge period. Slicklets were released at the beginning of each day, starting on the first day of the month, over the 120 day releases. The position of each slicklet is plotted on the final graph after every 6 hours of movement. Average summer and winter air temperatures have been used in the modeling. The summer and winter model results are shown in Figues 3-8 and 3-9, respectively. These plots DO NOT represent the area of the ocean covered by oil at any given time but merely identify the area that would be influenced by the oil over the release period. The dots in the figures represent the positions of 28 or 31 slicks of oil reported every 6 hours. Each parcel was released at the start of each day in the month and then tracked for 120 days or until the average surface oil coverage dropped to below 1 g/25m^2. This level of contamination of highly weathered crude is considered innocuous to wildlife (French-McCay 2004).

The plots identify possible “zones of influence” of oil from a 120-day blowout at the drilling site for summer and winter conditions. Section 3.4 looks in more depth at the possible movement of slicks using long-term historical wind data.

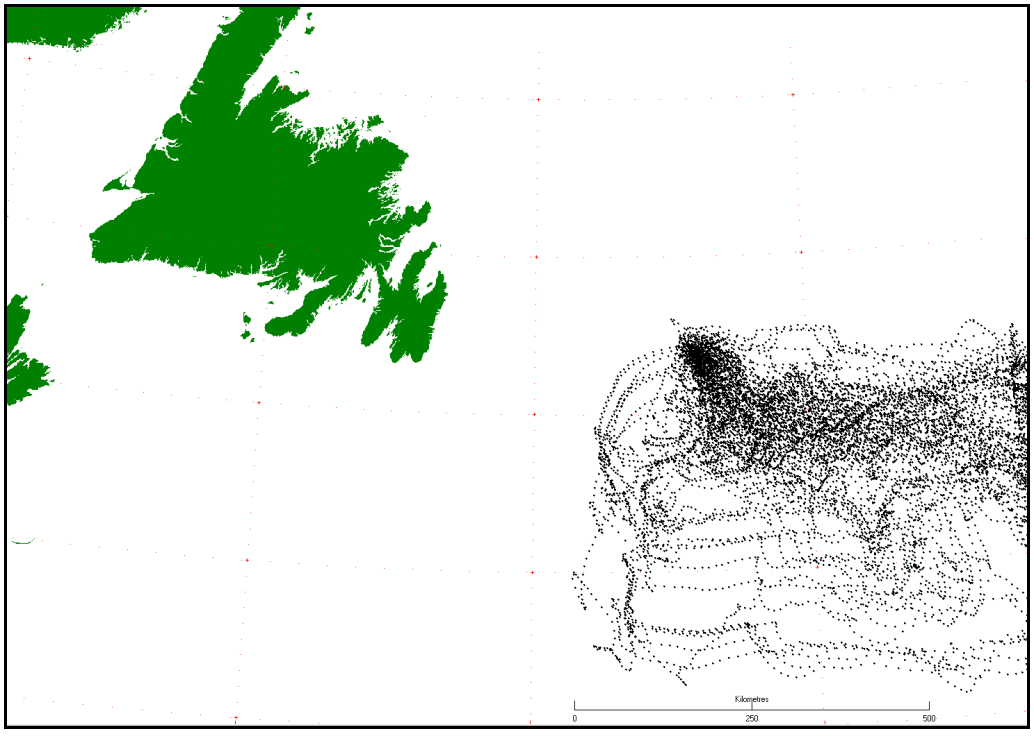


Figure 3-8 Trajectory Envelope for a 120 day Summer Subsea Blowout: started September 1, 2009

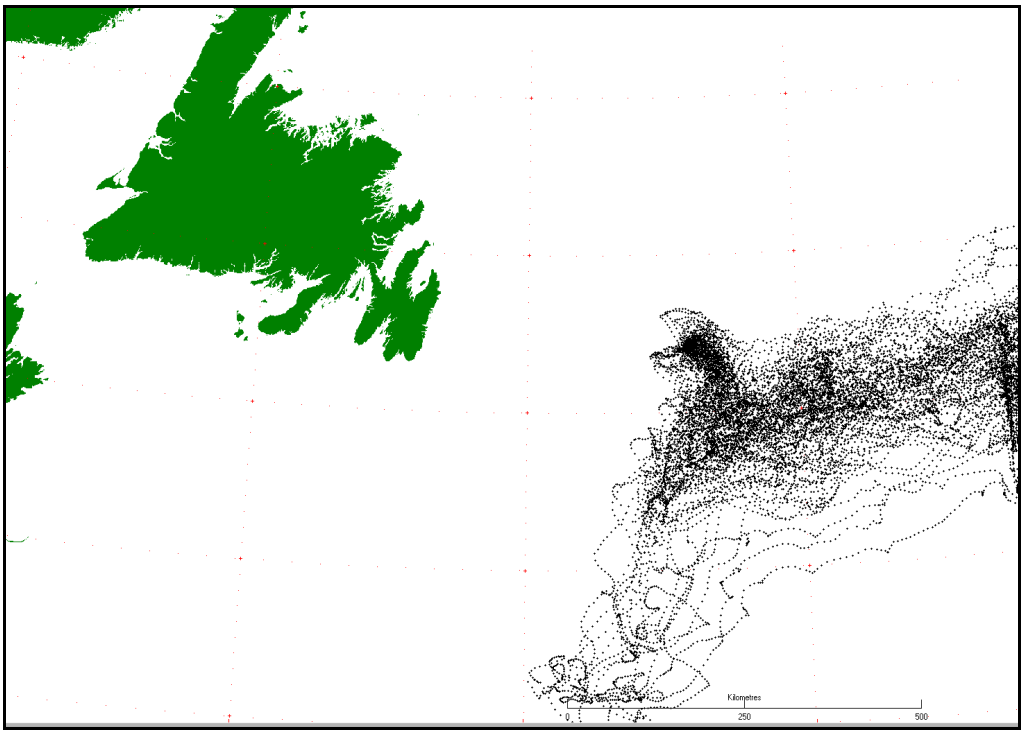


Figure 3-9 Trajectory Envelope for a 120 day Winter Subsea Blowout: started February 1, 2009

The zones of influence of the winter trajectories tend to smaller due to more persistent winds from the west. In the summer months the wind direction is more variable and this tends to move the slicklets over a wider area during a long term release.

3.3.5 Surface Crude Oil Blowout Fate and Behaviour Modelling

In this scenario, a blowout occurs on the on-site rig 43 m above the water surface resulting in a discharge of oil and gas into the air. Oil flow rates of 6,435 m^3/day and 3,963 m^3/day with gas-to-oil ratios (GOR) of 138 m^3/m^3 and 275 m^3/m^3 were used in the modelling. These flows represent the maximum oil flow rate estimated from the reservoir at the start of the release and the reduced flow expected after a 120 day release period (Husky Energy 2012). The platform and rig are not damaged and they remain in position throughout the blowout period. The gas exits 43 m above the water surface at high velocity and shatters the oil into small diameter droplets. These droplets are shot upward by the jet of gas, impact on the derrick and agglomerate to a size of about 0.75 mm. This median drop size has been selected for all surface blowout modelling based on model calibration results using data from the Ekofisk blowout. These droplets rain down on the surface of the water down-wind of the rig. Most of the droplets fall onto the water surface within a few hundred metres of the rig in a swath about 150 metres wide and re-coalesce to form a slick a 1 to 3.5 mm thick. A ‘traditional’ oil slick is assumed to form in both summer and winter in this above water blowout scenario. A Gaussian model of atmospheric plume behaviour (as illustrated in Figure 3-3) has been used to predict the concentrations of oil downwind from the release point of a surface blowout, following the method described by Turner (1970). Winter and summer seasonal temperatures and wind speeds have been used in the modelling of the fate of this oil. Minor differences in

the initial slick characteristics and change in oil property over time will exist depending on the season (due to temperature and wind speed differences). The results of the fate modelling are summarized in Table 3-8 and described below.

The slick at source will be between 116 and 160 metres wide and 1.0 to 3.4 mm thick. The oil making up the slick will have lost between 4 and 7 percent (depending on the season) of its volume through evaporation of the oil droplets in the air. The oil droplets will re-coalesce to form a slick on the water surface and this oil will immediately begin to emulsify. The initial oil will have a viscosity of 110 cP in the summer scenario and 960 cP in the winter.

After about 1 day of exposure on the water surface, the slicks will have lost between 10 to 13% of their volume to evaporation; this increases to a maximum of about 27% over the life of the surface oil slicks.

Evaporation and emulsification raises the viscosity of the slicks to 10,000 cP within 1 hour in the winter and between 136 and 190 hours in the summer, depending on the spill flow rate. The viscosity will increase to maximums of about 21,000 cP in the summer and 195,000 cP in the winter; the higher winter viscosities are due to the colder conditions.

Under both average summer and winter conditions the model predicts that the surface slicks will persist for periods greater than 30 days with very little natural dispersion. As the oil drifts from the site, wave action will break the slicks up into viscous particles of oil that move away from each other under the influence of oceanic turbulence. The makeup of this oil will depend on the harshness of the environment over this period. It is likely that after a several weeks of exposure to the energetic conditions of the North Atlantic Ocean the oil will be broken into small tar-balls spread over a large area, with the oil particles separated by large expanses of water.

Table 3-8 Above Sea Crude Oil Blowout Spill Characteristics

Spill Flow Rate m^3/day (bopd)	Season	Initial Slick Width (m)	Initial Slick Thick (mm)	Slick Survival Time (days)	% Evap in Air	% Evap after 1day	Total Evap. %	Peak Disp. Oil Conc. (ppm)	Time to 0.1 ppm Disp. Oil Conc. (hr)	Initial oil Viscosity (cP)	Time to Oil Viscosity of 10,000cP (hrs)	Maximum Oil Viscosity cP
6,435 (40,476)	winter	150	1.7	>30	4	10	22	<0.001 ppm	na	950	1	170,000
6,435 (40,476)	summer	116	3.4	>30	7	12	27	<0.001 ppm	na	108	190	20,000
3,963 (24,927)	winter	160	1.0	>30	4	12	24	<0.001 ppm	na	960	1	195,000
3,963 (24,927)	summer	126	1.9	>30	7.4	13	26	<0.001 ppm	na	110	136	21,000

3.3.6 Typical Surface Blowout Spill Trajectories

The trajectories for the surface blowout scenarios will be identical to those from the subsea discharges because the oil from both types of spills will be very persistent. The starting slicklet sizes and oil thicknesses will be different but the paths that the slicklets

take will not vary. The trajectories provided in section 3.3.4 are thus indicative of typical trajectories for the surface blowouts as well.

3.4 Historical Spill Trajectory Assessment

3.4.1 Introduction

As noted in the previous sections, spills of White Rose crude oil will tend to be very persistent and surface slick survival times of many weeks is likely. The modelling in this section looks at which surface areas on the Grand Banks are more likely to be swept by surface oil and the likelihood of crude oil slicks released from the drilling block reaching Newfoundland shorelines. Because the oil is very persistent the mode in which it is released (subsea or surface blowout or batch spill) is not a critical factor in determining the long term trajectory of spills. We have chosen to represent long term releases from the production site as discrete batches of oil released at six-hour intervals. Each batch of oil contains the full quantity of oil that would have been released during the six hour period by a blowout flowing at the maximum discharge rate. This ensures that all of the oil spilled is accounted for and provides a reasonable separation between batches (6 hours) for the assessment of variations in trajectory as a result of variations in wind speed and direction.

A total of 83,220 trajectories were run in this analysis from a spill release site of 46.800728 N, 48.063392 W. These trajectories used the 57 years of wind data available from the MSC50 dataset described in section 2.2.5. For months with 30 days a total of 6840 individual slick trajectories were followed, one released every 6 hours starting at the beginning of the first day in the month. For months with 31 days a total of 7068 trajectories were modelled and 6384 spills were modelled for February.

3.4.2 Shoreline Contact

Shoreline contact statistics on a monthly basis from these hypothetical spills is provided in Table 3-9. A small number of slicks came to shore only in the months of March (9 slicks), October (29 slicks) and November (1 slick). This amounts to only 0.04% of the 83,220 oil slicks tracked that reached shore as seen in Figure 3-10. The slicks arrived at shore between 45 and 92 days after release.

Table 3-9 Slick Shoreline Contact from White Rose Offshore Releases

Month	Number of Slicks Tracked	# of Slick's Centres Reaching Shore	% of Slick's Centres Reaching Shore	Minimum Time to Shore		Maximum Time to Shore	
				Hours	Days	Hours	Days
January	7,068	0	0	-	-	-	-
February	6,384	0	0	-	-	-	-
March	7,068	9	0.13	1638	68	2220	92.5
April	6,840	0	0	-	-	-	-
May	7,068	0	0	-	-	-	-
June	6,840	0	0	-	-	-	-
July	7,068	0	0	-	-	-	-
August	7,068	0	0	-	-	-	-
September	6,840	0	0	-	-	-	-
October	7,068	26	0.37	1080	45	1746	73

November	6,840	1	0.01	1410	59	1410	59
December	7,068	0	0	-	-	-	-

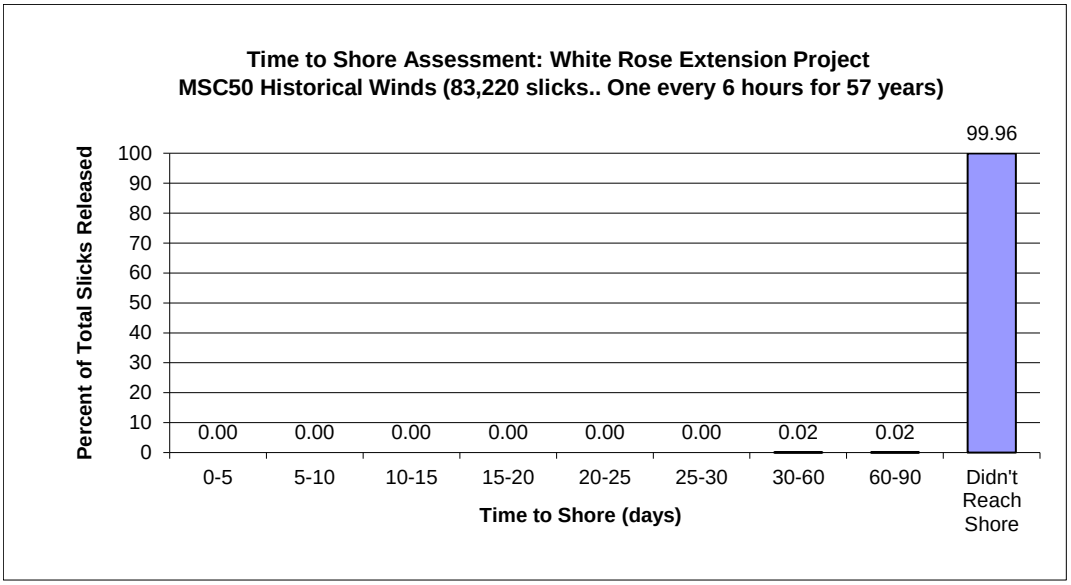


Figure 3-10 Slick Survival Time Statistics for WREP: All Months and Years

3.4.3 Spill Trajectory Probabilities

The data has been further processed, on a monthly basis, to identify the probability of a slick reaching specific areas in the offshore. The slick movements for all spills released in a given month of the year, for the 57 years of data, have been processed to identify the percent of the spills released in the month that enter each cell in a 1 km x 1 km grid placed over the study area. The results are shown in Figures 3-11 through 3-22. The total sweep area of the slicks (as defined using an oceanic diffusion model, Okubo 1971) has been used in this assessment. The contours on the following graphs represent the boundaries where 0 to 1% of the slicks will pass 1 to 5%, 5 to 10%, 10 to 25%, 25 to 50%, and 50 to 100%. These graphs provide insight into the most likely path of oil over when spilled in a given month based on the 57 years of available wind data.

Trajectories have been run for 120 days or until the oil evaporates and disperses from the surface or the average oil concentration on the surface has dropped below 1 gram per 25 square metres This level of contamination of highly weathered crude is considered innocuous to wildlife (French-McCay 2004).

It cannot be stressed enough that our confidence in accurately modelling the fate of crude oil on the open ocean past a few weeks is not high. Very little data has ever been collected on the long-term fate of different oil types in the offshore (past even one-week of exposure). A study completed for the US Minerals Management Service reviewed the worldwide data on the persistence of crude oil spills on open water (SL Ross et al, 2003). The study found that the persistence of large spills (> 1000 barrels) was predicted best with the following equation:

$$PD= 0.0001S-1.32T+33.1$$

Where: PD= spill persistence in days
S= spill size in barrels
T = Water temperature in degrees Celsius

If the single day's release of oil is considered as a unique slick with a volume of 40,500 barrels then its long term persistence would be about 34 days in the winter and about 20 days in the summer. These estimated surface slick persistence values (based on the equation above) are somewhat shorter than those predicted in the detailed spill modeling prepared for this report and are presented only to provide additional insight into the possible survival time of surface slicks based on historical records.

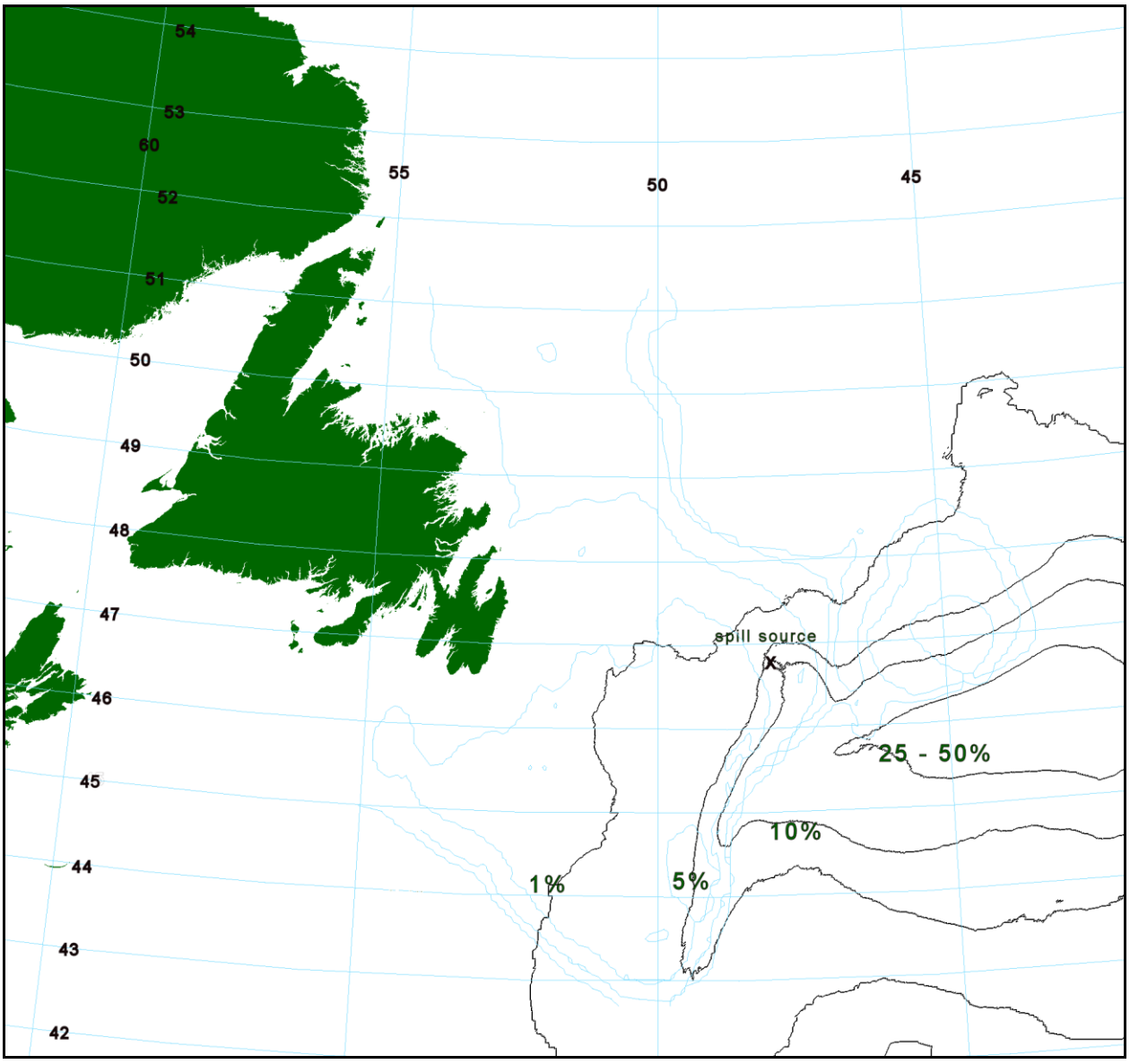


Figure 3-11 Spill Trajectory Probabilities for Releases from White Rose: January

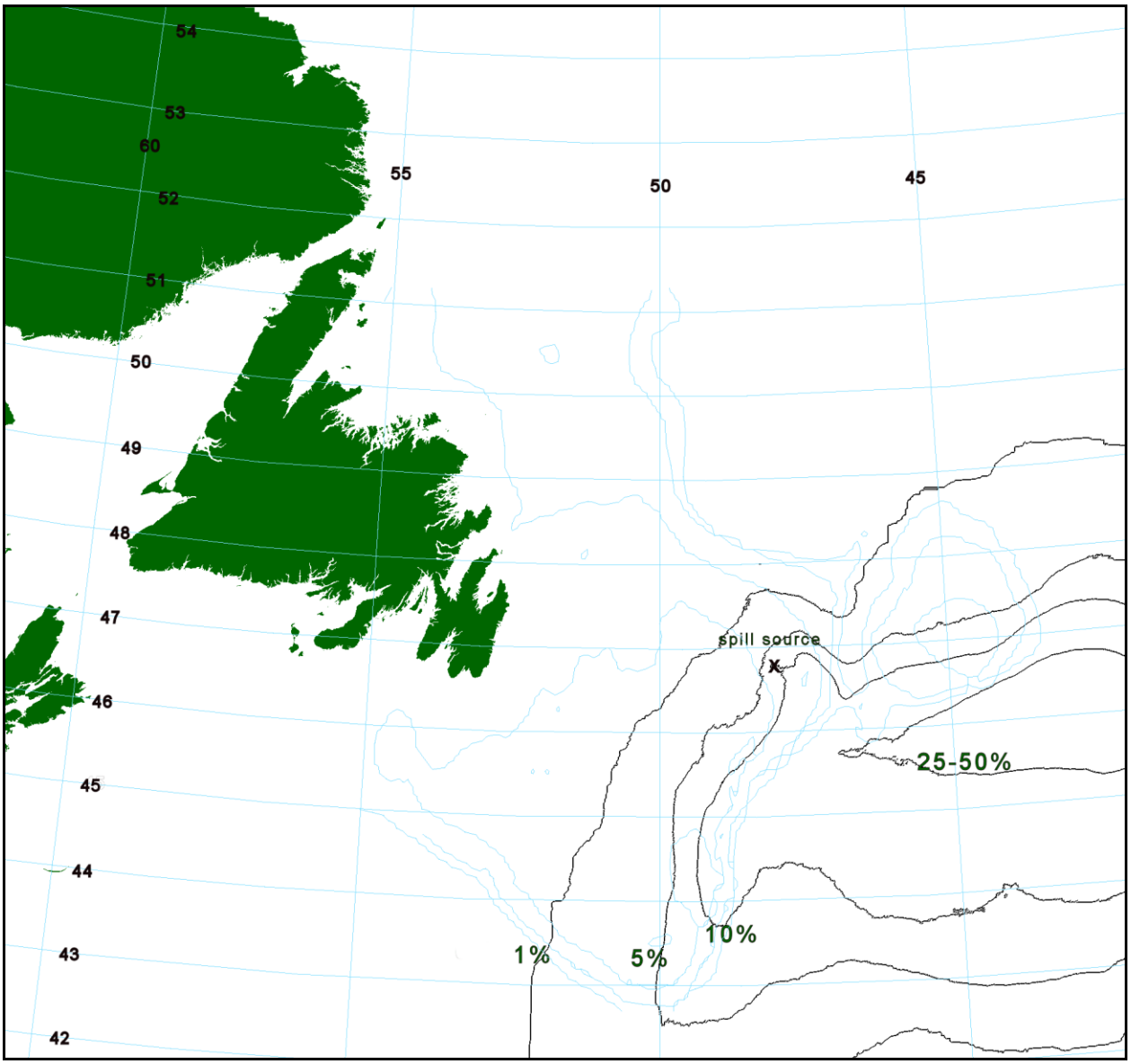


Figure 3-12 Spill Trajectory Probabilities for Releases from White Rose: February

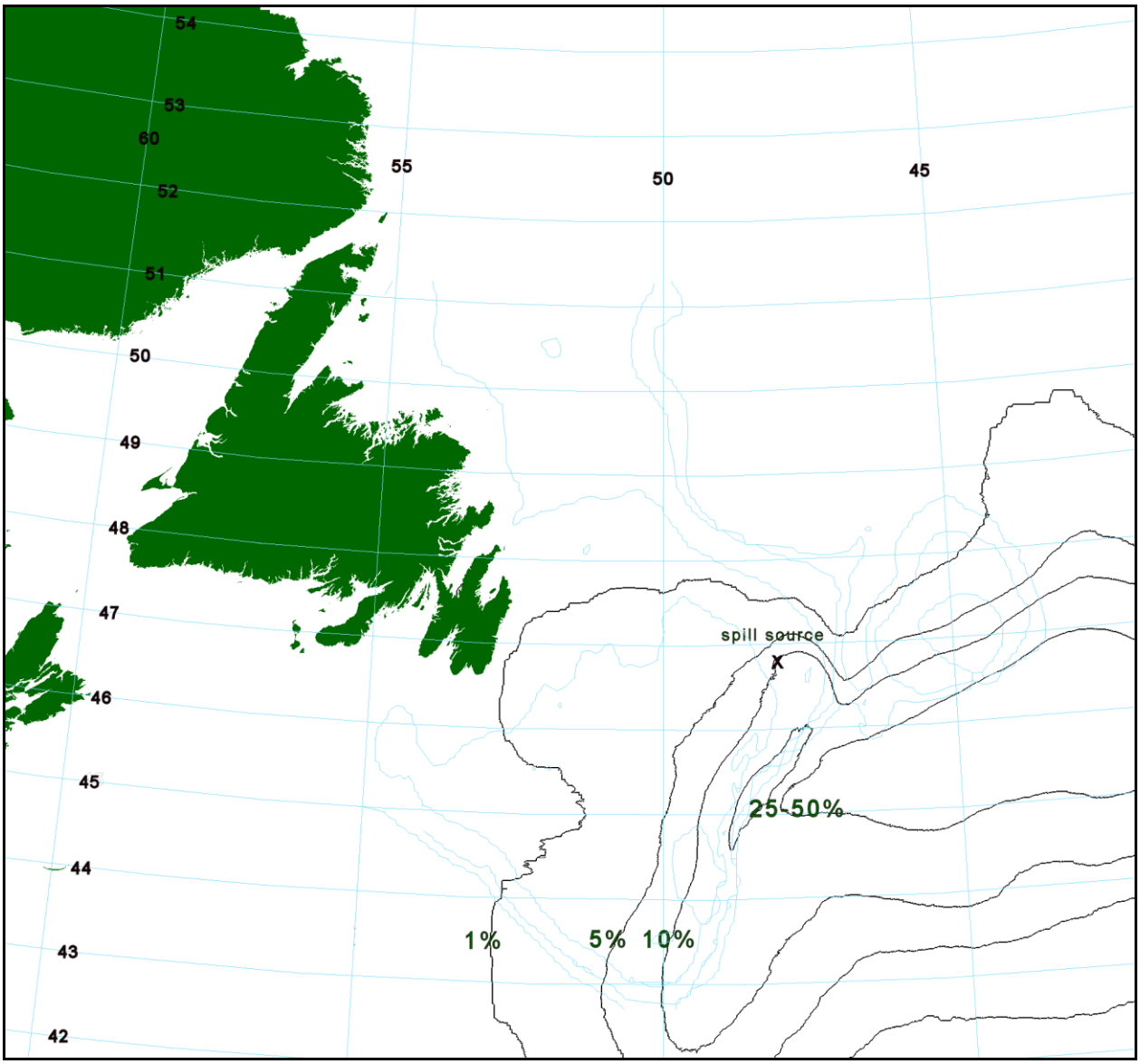


Figure 3-13 Spill Trajectory Probabilities for Releases from White Rose: March

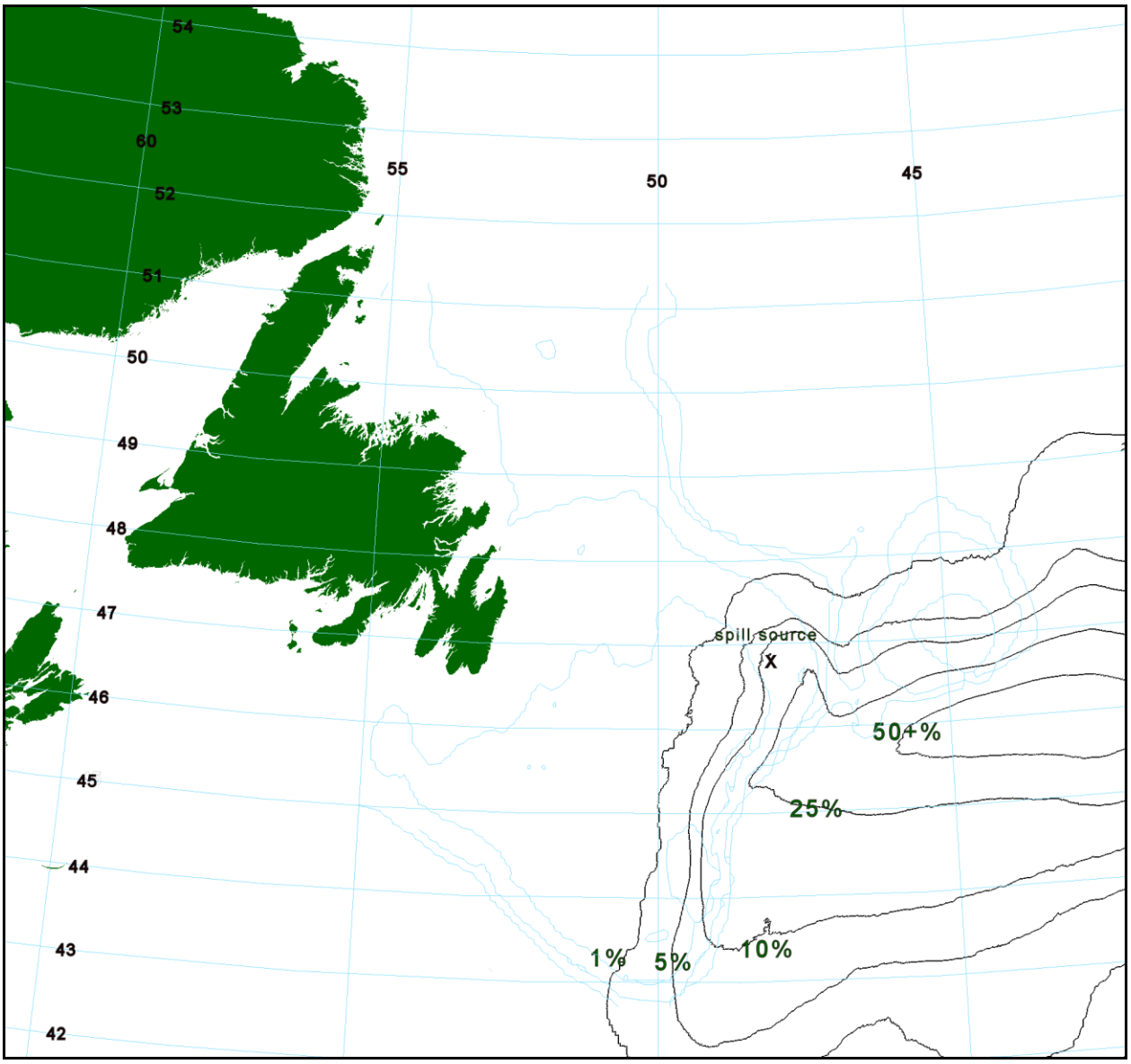


Figure 3-14 Spill Trajectory Probabilities for Releases from White Rose: April

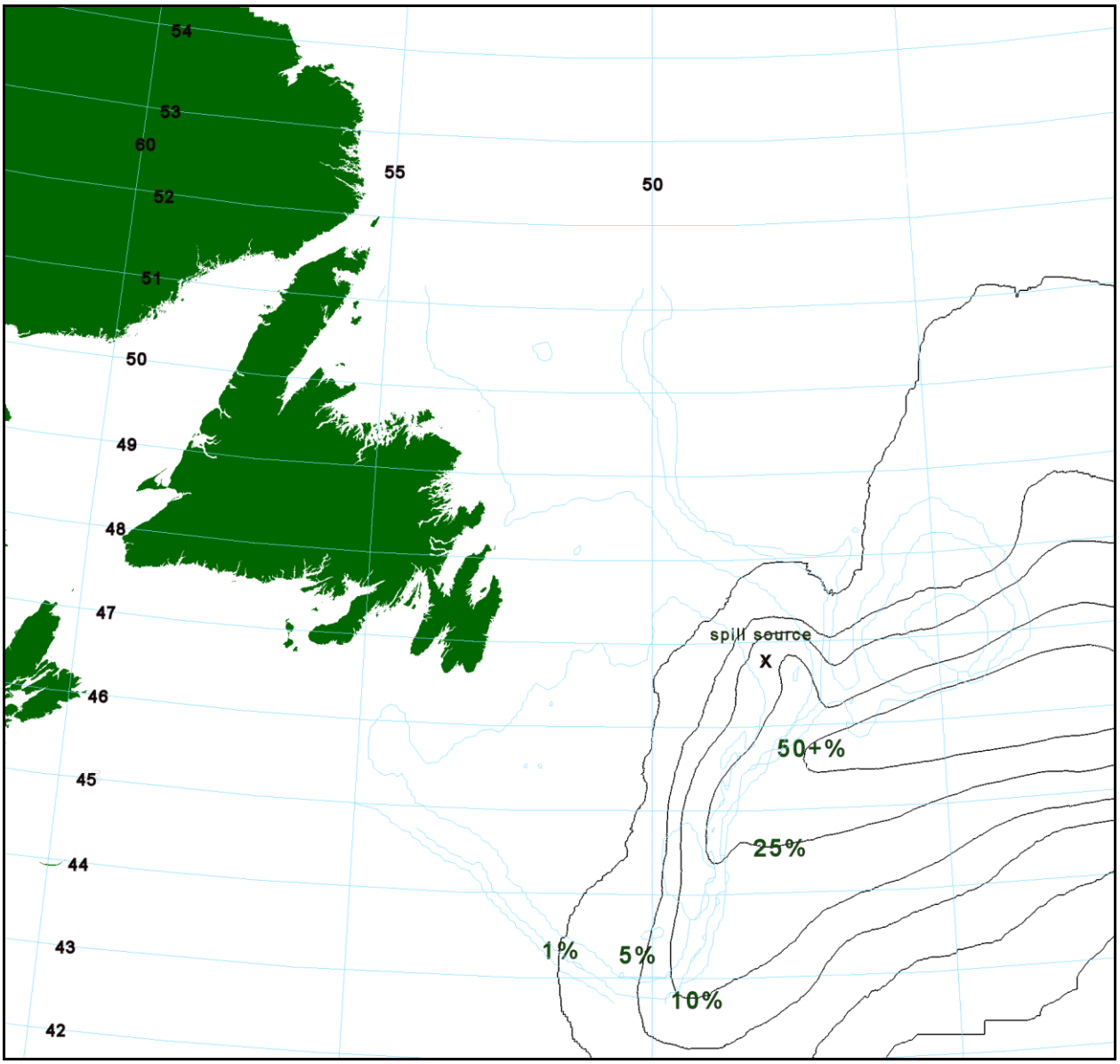


Figure 3-15 Spill Trajectory Probabilities for Releases from White Rose: May

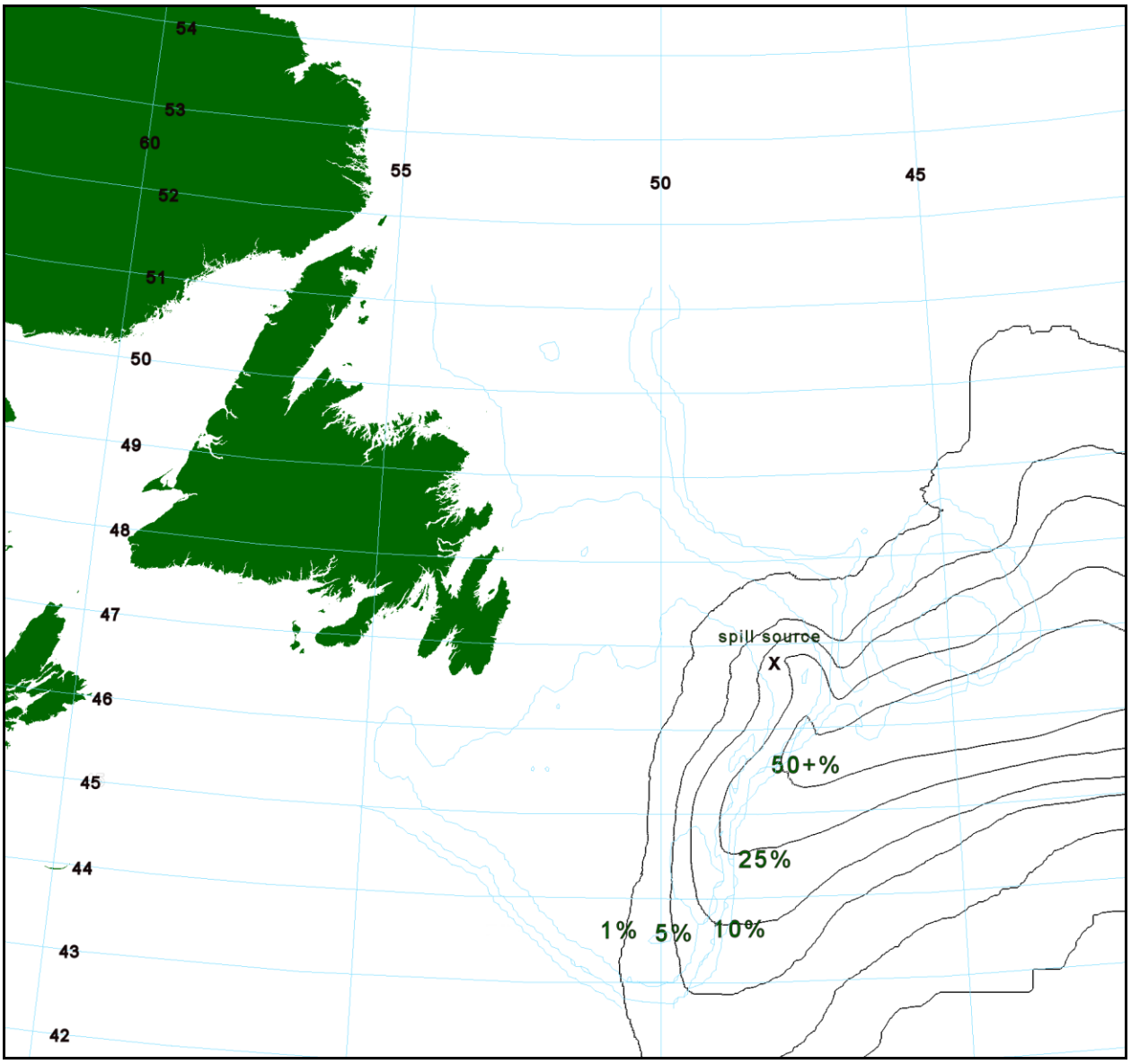


Figure 3-16 Spill Trajectory Probabilities for Releases from White Rose: June

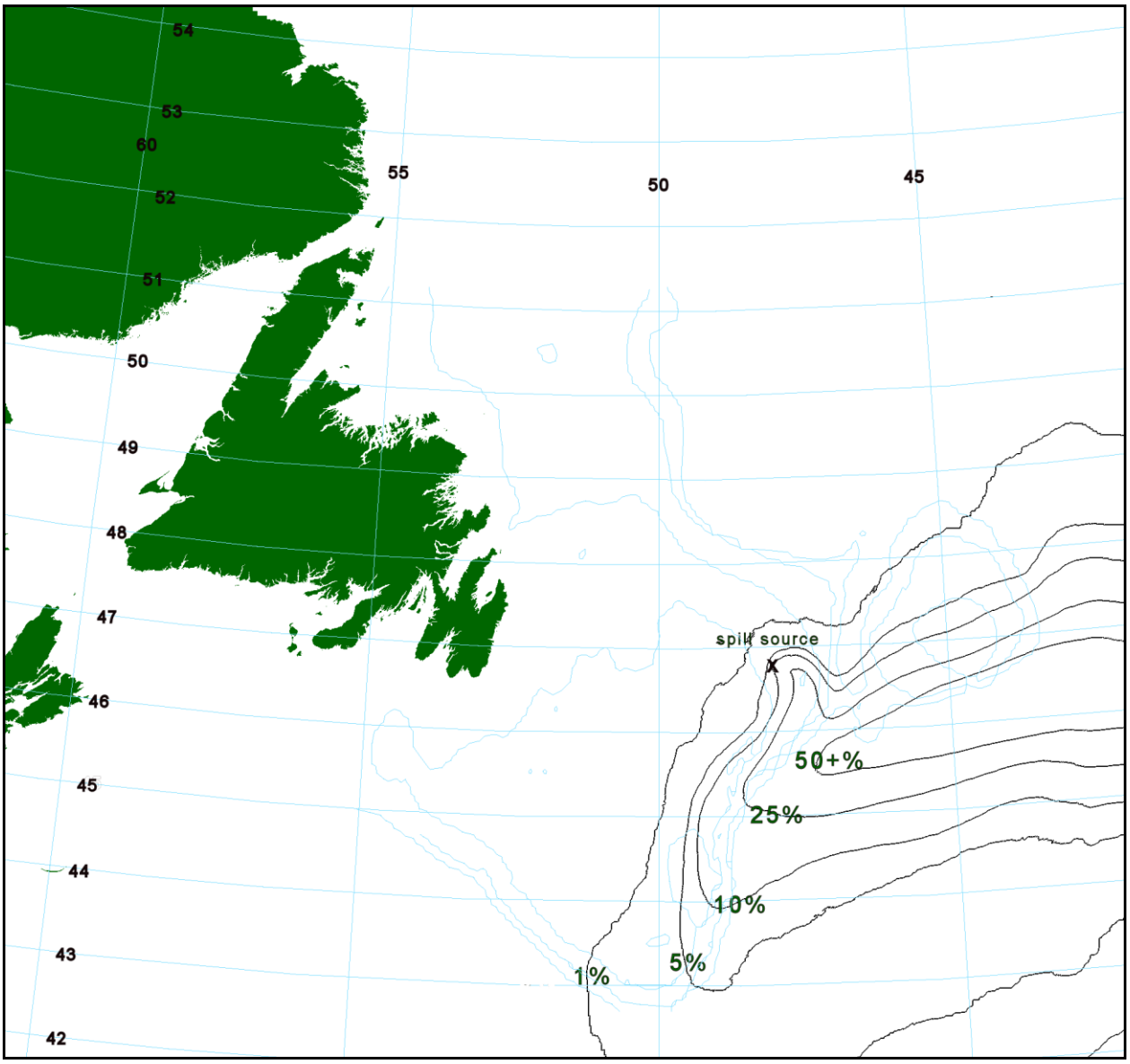


Figure 3-17 Spill Trajectory Probabilities for Releases from White Rose: July

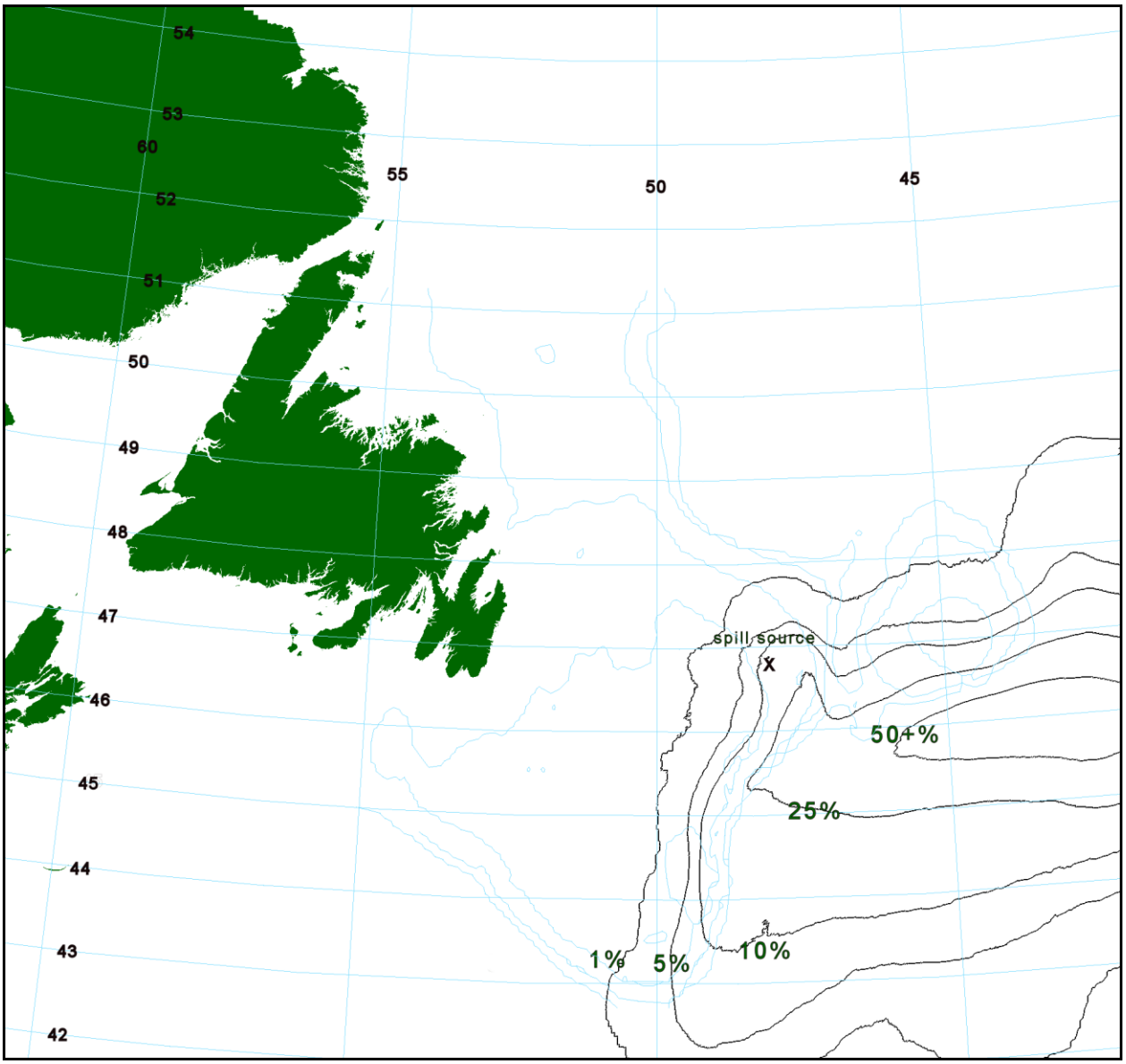


Figure 3-18 Spill Trajectory Probabilities for Releases from White Rose: August

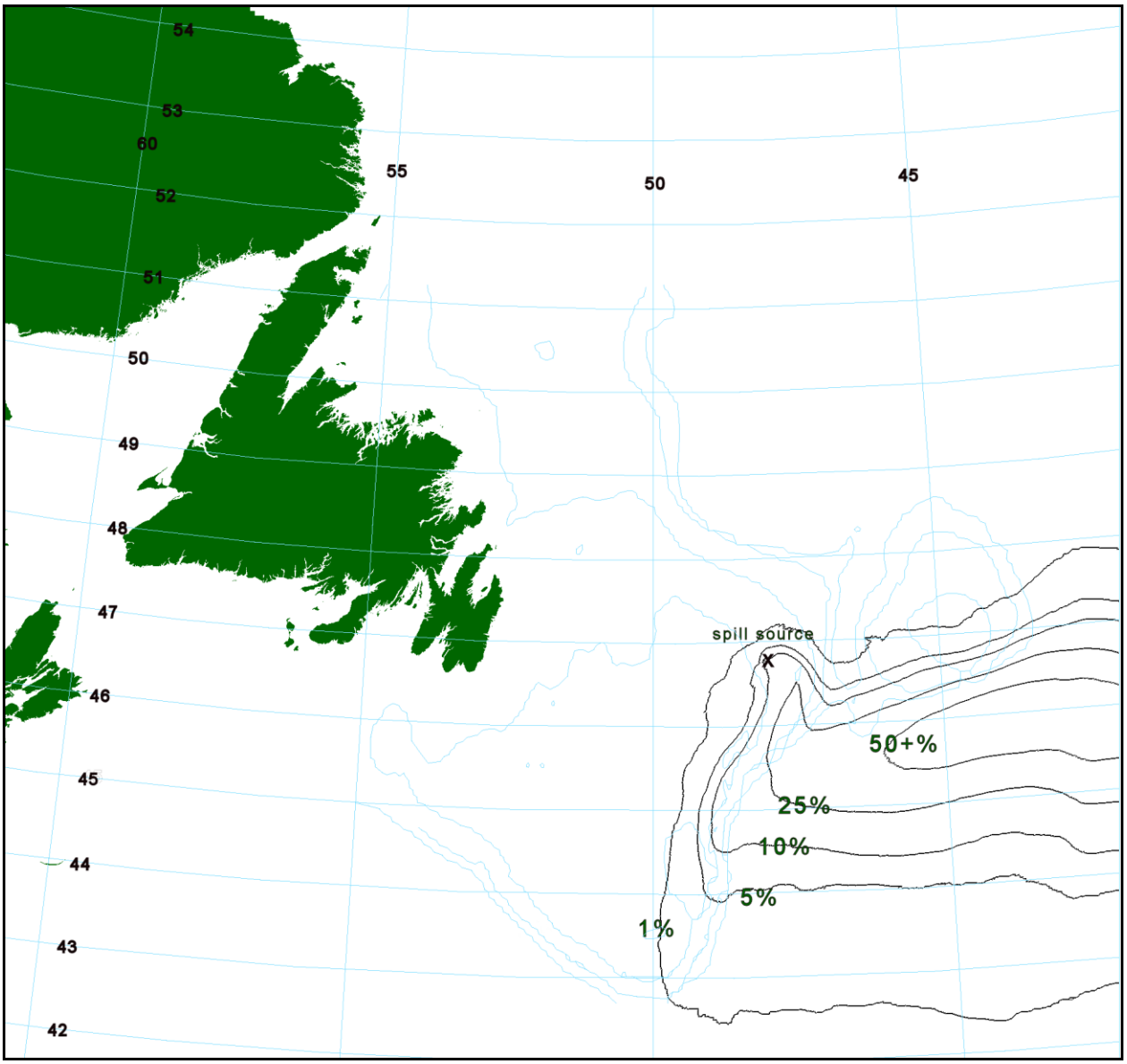


Figure 3-19 Spill Trajectory Probabilities for Releases from White Rose: September

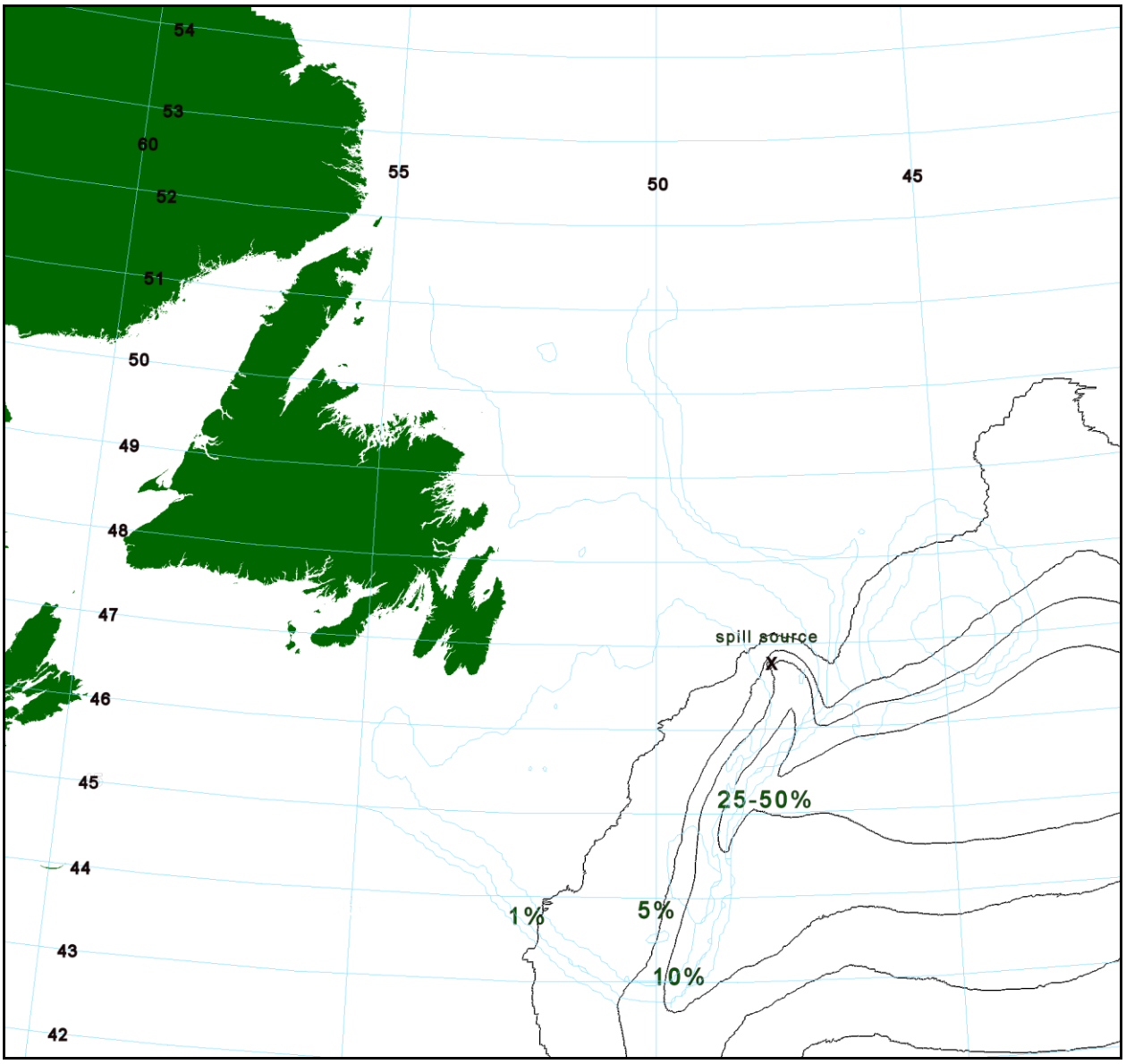


Figure 3-20 Spill Trajectory Probabilities for Releases from White Rose: October

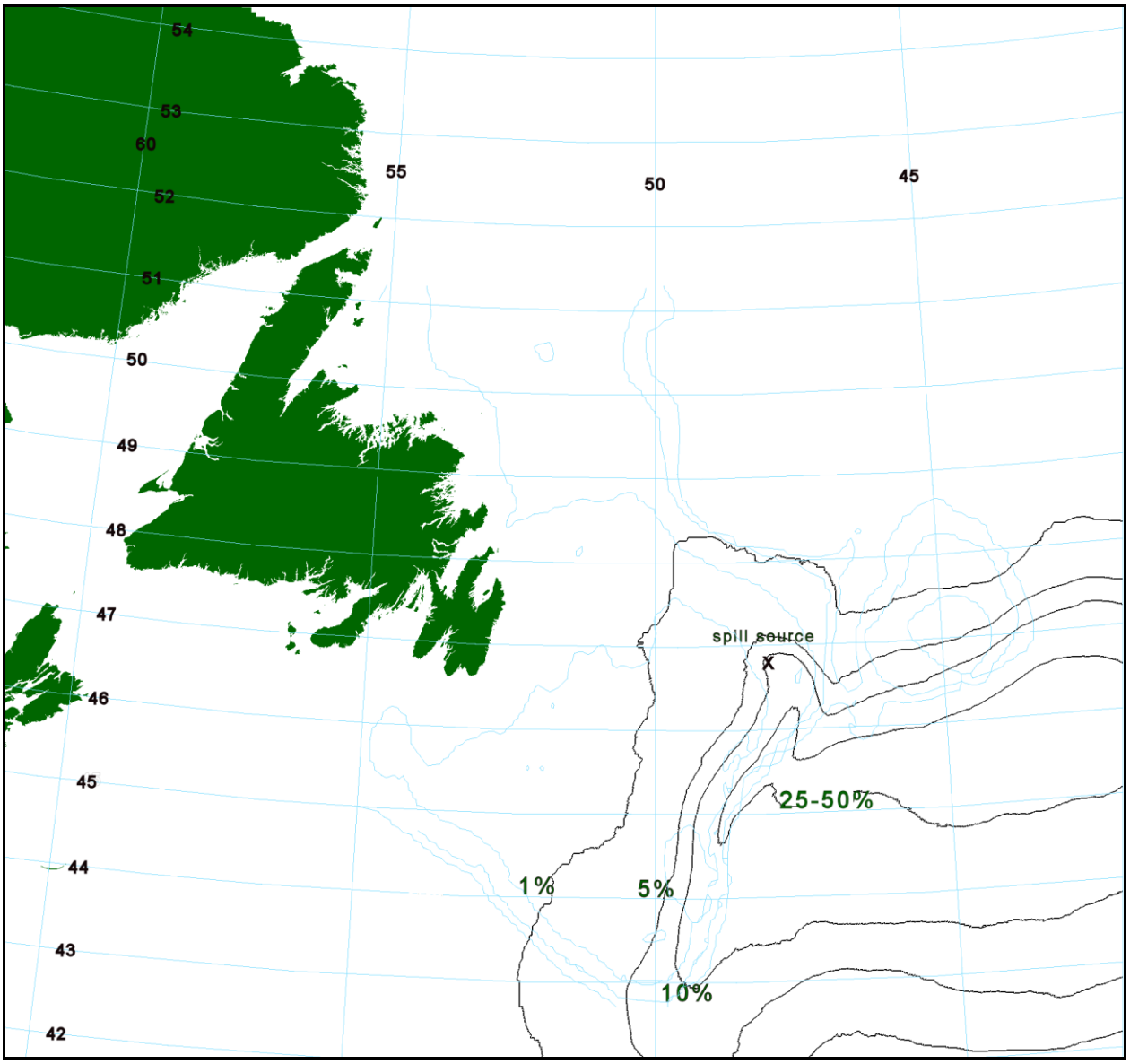


Figure 3-21 Spill Trajectory Probabilities for Releases from White Rose: November

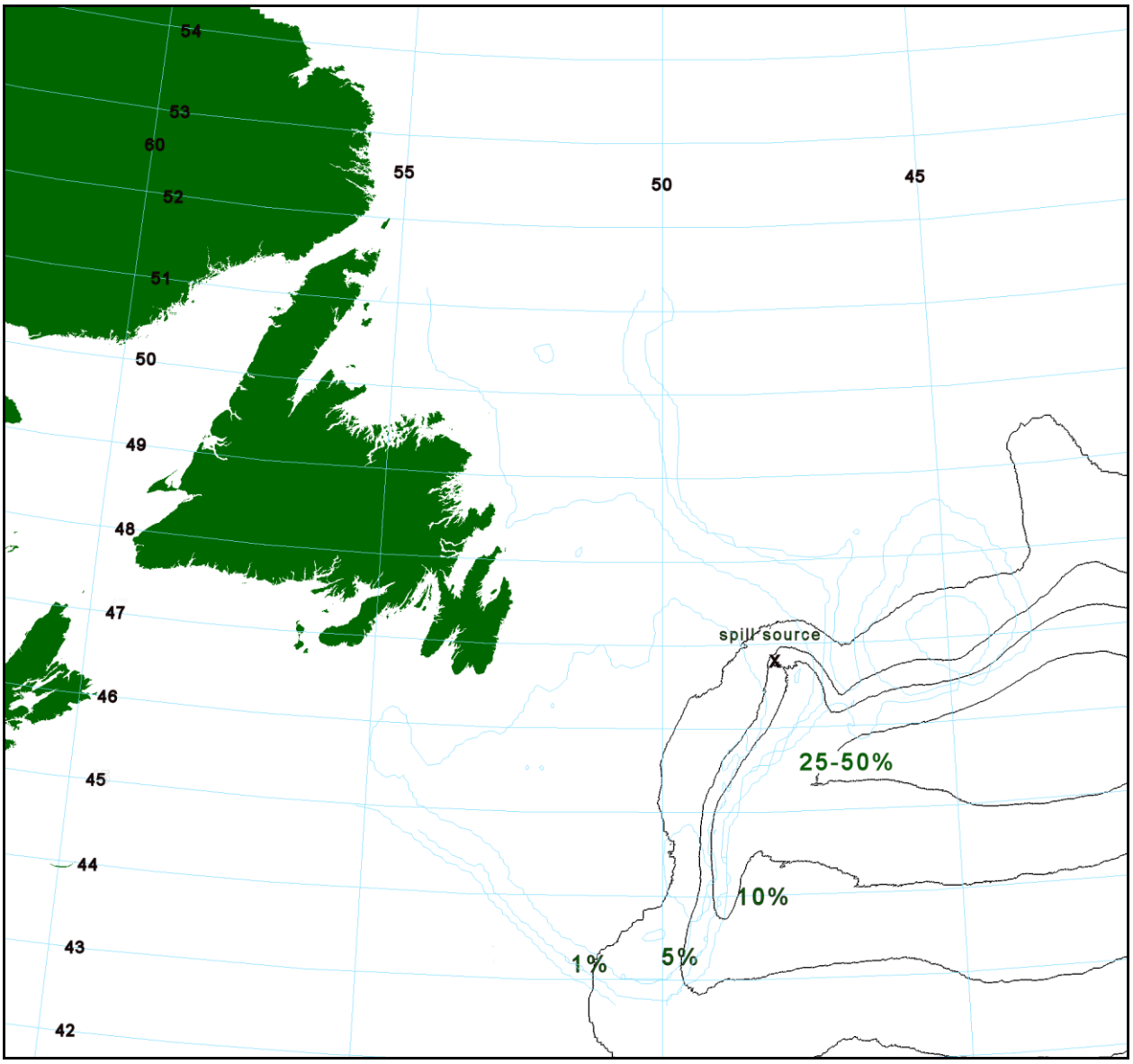


Figure 3-22 Spill Trajectory Probabilities for Releases from White Rose: December

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5.0 Acronyms

Term	Description
ADW	Approval to Drill a Well
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
bcf	billion cubic feet
Bbl/d	barrels per day
CDC	Central Drill Centre
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CSA	Canadian Standards Association
DA	Development Application
DGPS	Differential Global Positioning System
DNV	Det Norske Veritas
DST	drill stem test
EEM	environmental effects monitoring
FEED	Front End Engineering Design
Fm	formation
FPSO	Floating Production, Storage and Offloading Facility
FVF	formation volume factor
GOR	gas oil ratio
GR	gamma ray
ISO	International Standards Organization
kPa	kilopascals
LWD	logging while drilling
Ma	million years
md	millidarcies
MDT	modular dynamic formation tester
MMbbls	million barrels
mmscf/d	million standard cubic feet per day
MODU	Mobile Offshore Drilling Unit
m/s	metres per second
mTVDss	metres true vertical depth subsea
NADC	North Amethyst Drill Centre
NDC	Northern Drill Centre
N:G	net to gross ratio
NPV	net present value

Term	Description
OGIP	original gas in place
OOIP	original oil in place
OWC	Oil / water contact
PVT	pressure, volume, temperature
Psi	pounds per square inch
ROV	remotely operated vehicle
Rs	solution gas-oil ratio
Rw	resistivity of water
RVP	Reid vapour pressure
s	seconds
SWRX	South White Rose Extension Tie-back
Sw	water saturation
TVD	true vertical depth
WREP	White Rose Extension Project
WWRX	West White Rose Extension
XTree	Christmas (xmas) tree