APPENDIX A

Guidelines for the Preparation of an Environmental Impact Statement

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

For the

West Flemish Pass Exploration Drilling Project

Chevron Canada Limited

December 20, 2018

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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 the 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

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

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

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.

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

The proponent is expected to engage with potentially affected Indigenous groups starting as early as possible in the project planning process in order to:

- Fulfil the statutory obligations of CEAA, 2012 to assess environmental effects of the proposed Project on Aboriginal peoples; and
- Assist the Agency fulfilling the Crown's constitutional obligations to consult with potentially impacted Indigenous groups on potential impacts to potential or established Aboriginal or Treaty rights.

The proponent is expected to work with potentially affected Indigenous groups to establish an engagement approach. The proponent will make reasonable efforts to integrate Indigenous knowledge into the assessment of environmental effects. For more information on requirements for the effects assessment, see Part 2, Section 7.1.8 and Section 7.3.7 of these guidelines. For more information on incorporating Indigenous knowledge, refer to Part 1, Section 4.2.2 of these guidelines.

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 October 23, 2018, Chevron Canada Limited, the proponent of the West Flemish Pass Exploration Drilling Project provided a project description to the Agency. Based on this project description, the Agency has determined that an EA is required under CEAA 2012 and will include the following project components and activities:

- the mobilization, operation and demobilization of Mobile Offshore Drilling Unit(s) designed for year-round operations for the drilling, testing and abandonment of up to eight wells in Exploration Licence 1138 operated by Chevron Canada Limited, including consideration of any proposed safety exclusion zones. Drilling may occur in various water depths under consideration, using Mobile Offshore Drilling Unit(s), and with multiple drilling units operating simultaneously, if applicable;
- vertical seismic profiling or any other in-water works (e.g. wellsite surveys) 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;
- well evaluation and testing; and
- the loading, refuelling and operation of marine support vessels (i.e. for re-supply and transfer of materials, fuel, and equipment; on-site safety during drilling operations; and transport between the supply base and the drilling unit(s) and helicopter support (i.e. for crew transport and delivery of light supplies and equipment) including transportation to the drilling unit(s).

Note: If the proponent acquires and becomes the operator of new or additional exploration licences issued by the Canada-Newfoundland and Labrador Offshore Petroleum Board and submits corresponding information to the Agency prior to the submission of the EIS, the Agency will consider whether activities on these additional licences may be incorporated into the scope of this EA.

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 7.3 (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:
    - health and socio-economic conditions,
    - physical and cultural heritage, or
    - 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 VCs.

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 should consult the Agency policy and guidance on topics to be addressed in the EIS, which is available on the Agency’s website, and liaise with the Agency during the planning and development of the EIS. The proponent should also consult relevant guidance from other federal departments and ensure that the most up to date version is being used.

The proponent is encouraged to engage with Indigenous groups on the planning and development of relevant sections of the EIS, including effects from changes to the environment and impacts to potential or established Aboriginal or Treaty rights as well as assessment of environmental effects as outlined in paragraph 5(1)(c) of CEAA 2012.

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 engage in a respectful dialogue with Indigenous groups about the collection and use of Indigenous knowledge and enter into agreements where necessary regarding the use of information during and after the EA. The proponent should collaborate with Indigenous groups to ensure, where possible, that the Indigenous knowledge is incorporated into the EIS in a way that appropriate for the Indigenous group. 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 on the topic. Should there be a lack of Indigenous knowledge, the proponent is still expected to seek information from other sources to complete the assessment of effects of changes to the environment on Aboriginal peoples or the assessment of impacts to rights. For more information on requirements for the effects assessment, see Part 2, Section 7.1.8 and 7.3.7 of these guidelines.

4.2.3. Existing information

In preparing the EIS, the proponent is encouraged to make use of existing information relevant to the project. When relying on existing information to meet requirements of the EIS Guidelines, the proponent will either include the information directly in the EIS or clearly direct the reader to where it may obtain the information (i.e. through cross-referencing). When relying on existing information, the proponent will also comment on how the data were applied to the 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.

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, 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 initial 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 Indigenous 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 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 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). The proponent will respond to the comments of Indigenous groups prior to submitting the EIS to ensure that the comments are adequately addressed. 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. Where there are discrepancies in the views of the proponent and Indigenous groups with respect to the outcomes of assessment(s), the EIS will document and provide a rationale for these discrepancies.

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; and
- 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 is preferred. The EIS may make reference to the 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 content 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 version 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 followings:

- 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 VC, 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 settings 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 land 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, ecologically and biologically sensitive areas, fishery closure areas, vulnerable marine ecosystems, marine refuge areas, and habitats of federally or provincially listed species at risk and other sensitive areas;
- description of local communities and Indigenous communities; and
- traditional territories and/or consultation areas, treaty lands, 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, land zoning, or community plans; 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[2] 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 assessment of alternative means in accordance with the Agency's Operational Policy Statement on this topic.

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);
- 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;

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

- 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 installing flare shields.

The *Offshore Waste Treatment Guidelines*[3] 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*[4] 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 shall conduct an environmental effects analysis at the same level of detail for each of the various options available (alternative means) within the EIS.

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[3] 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

[4] 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

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 of exploration licence 1138 with UTM coordinates;
- 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 Unit(s) and their operations (drilling, testing, suspension or abandonment) in locations and water depths under consideration;
- navigation activities (number and frequency of trips), size and types of vessels, anticipated vessel routes and anchorages, predicted percentage of increase in vessel traffic of similar size vessels resulting from the project, icebreaking activities (time of year, frequency, duration, expected start and end dates), and ballast water management
- helicopters, including routes, number and frequency of trips;
- vertical seismic profiling or any other in-water works (e.g. wellsite surveys) 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;
- well evaluation and testing;
- reagent requirements and uses (e.g. volumes, storage, types);
- petroleum products (e.g. source, volume, storage, types);
- 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 modelling;
- the management or disposal of wastes (e.g. type and constituents of waste, quantity, treatment and method of disposal) including:
  - ✓ drilling muds, drill solids;
  - ✓ deck drainage;
  - ✓ cooling water;
  - ✓ bilge and ballast 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 (including the contribution from any produced fluids that may be added to any flares), 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 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(s), including:
    - ✓ drilling at various water depths and in locations under consideration
    - ✓ well flow testing
    - ✓ waste management
    - ✓ water management

- vertical seismic profile surveys;

- flaring, including:
    - ✓ specifics on flare tip used, including type, manufacturer and/or model;
    - ✓ all flaring activities and estimation of flared volumes;
    - ✓ estimation of total greenhouse gas and criteria air contaminants emissions;
    - ✓ an estimate of the contribution of the flaring emissions at the local, provincial and federal scale;
    - ✓ justification for all estimated emissions and emission factors used; and
    - ✓ the estimation or derivation method, and a description of all assumptions and emission factors used;
- well evaluation and testing;
- 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

As noted in Part 1, Section 2.3 of these guidelines, the proponent is expected to engage with potentially affected Indigenous groups. 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:

- the project;
- 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 Aboriginal or Treaty rights, in respect of the Crown’s duty to consult, and where appropriate, accommodate Aboriginal peoples.

Aboriginal rights are defined 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. 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 time when Europeans effectively established political and legal control in the claimed area. Generally, these rights are fact and site specific. Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) Canada also define Aboriginal title as an Aboriginal right.

In order to allow the Indigenous groups to engage and provide views on the above, the proponent will provide the Indigenous groups with the following timely and relevant:

- opportunities to learn about the project including providing information about the proposed project (including but not limited to project design, location, potential effects, mitigation measures and follow-up and monitoring programs); and
- opportunities to provide input on the overall project; effects of changes to the environment on Aboriginal peoples pursuant to paragraph 5 (1)(c) of CEAA, 2012 and potential adverse impacts of the project on potential or established Aboriginal or Treaty rights.

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. 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);
- document the main issues and comments raised during the engagement activities by each group and the proponent’s responses (effort should be made to collating like issues together along VCs identified in the EIS);
- any future planned engagement activities;
- where and how Indigenous groups’ perspectives were integrated into and/or contributed to decisions regarding the project, design, operation, decommissioning, suspension abandonment, follow-up and monitoring and associated potential effects (paragraph 5(1)(c)) and the associated mitigation utilized to manage those effects. The effects and mitigation measures should be clearly linked to VCs in the EIS as well as to specific project components or activities; and
- how engagement activities by the proponent allowed groups to understand the project and evaluate its impacts on their communities, activities, potential or established Aboriginal or Treaty rights,. Where impacts are identified, provide a discussion of how those would be managed or mitigated (and provide this information for each Indigenous group separately).

To assist with the provision of records as requested above, the Agency recommends the proponent create a tracking table of key issues raised by each Indigenous group and responses provided by the

Proponent. Information provided related to potential adverse impacts on potential or established Aboriginal or Treaty rights rights will be considered by the Crown in meeting its common law duty to consult obligations.

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 interest in the EIS. These groups include:

Newfoundland and Labrador

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

Nova Scotia

- 11 Mi’kmaq First Nation groups represented by Kwilmu’kw Maw-klusuaqn Negotiation Office (KMKNO):
  - ✓ Acadia First Nation
  - ✓ Annapolis Valley First Nation
  - ✓ Bear River First Nation
  - ✓ Eskasoni First Nation
  - ✓ Glooscap First Nation
  - ✓ Membertou First Nation
  - ✓ Paqtnkek Mi’kmaw Nation
  - ✓ Pictou Landing First Nation
  - ✓ Potlotek First Nation
  - ✓ Wagmatcook First Nation
  - ✓ Waycobah First Nation
- Millbrook First Nation
- Sipekne’katik First Nation

New Brunswick

- eight Mi’gmaq First Nations groups represented by Mi’gmawe’l Tplu’taqnn Inc. (MTI)
  - ✓ Fort Folly First Nation
  - ✓ Eel Ground First Nation
  - ✓ Pabineau First Nation
  - ✓ Esgenoôpetitj First Nation
  - ✓ Buctouche First Nation
  - ✓ Indian Island First Nation
  - ✓ Eel River Bar First Nation
  - ✓ Metepnagiag Mi’kmaq First Nation
- Elsipogtog First Nation

- five Maliseet First Nation groups represented by Wolastoqey Nation in New Brunswick (WNNB)
  - ✓ Kingsclear First Nation
  - ✓ Madawaska Maliseet First Nation
  - ✓ Oromocto First Nation
  - ✓ Saint Mary’s First Nation
  - ✓ Tobique First Nation
- Woodstock First Nation
- Peskotomuhkati Nation at Skutik (Passamaquoddy)

Prince Edward Island

- Abegweit First Nation
- Lennox Island First Nation

Quebec

- three Mi’gmaq First Nation groups represented by Mi’gmawei Mawiomi Secretariat (MMS)
  - ✓ Micmas of Gesgapegiag
  - ✓ La Nation Micmac de Gespeg
  - ✓ Listuguj Mi’gmaq Government
- Les Innus de Ekuanitshit
- Innu First Nation of Nutashkuan

The groups referenced above may change as more is understood about the environmental effects 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 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 any Indigenous group, even those not listed above, the proponent shall provide that information to the Agency at the earliest opportunity.

With respect to the effects of changes to the environment on Aboriginal peoples, the assessment requirements are outlined in Part 2, Sections 7.1.8 and Part 2, 7.3.7 of these guidelines. With respect to the assessment requirements are outlined in Part 2, Section 6 of these guidelines.

6. IMPACTS TO POTENTIAL OR ESTABLISHED ABORIGINAL OR TREATY RIGHTS

With respect to potential adverse impacts of the project on potential or established Aboriginal or Treaty rights, the EIS will document for each group identified in Part 2, Section 5 of these guidelines (or in subsequent correspondence from the Agency):

- potential or established Aboriginal or Treaty rights[5], when this information is directly provided by a group to the proponent, the Agency or is available through public records, including but not limited to:
    - ✓ location of the right being practiced or exercised
    - ✓ context in which the right is practiced or exercised (including information about which groups of an Indigenous group practice the right (women, elders, youth), how the right was practiced historically),
    - ✓ how the Indigenous group's cultural traditions, laws and governance systems inform the manner in which they exercise their rights (the who, what, when, how, where and why)
    - ✓ the Indigenous group's perspectives on the importance of the land on which the Project is located and how it intersects with any land management uses and/or plans they may have,
    - ✓ how often the right is practiced or exercised and timing or seasonality 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 Aboriginal or Treaty rights, including those raised by Indigenous groups.
- measures identified to accommodate potential adverse impacts of the project on the potential or established Aboriginal or Treaty rights. These measures will clearly describe how the proponent intends to implement them, and may go beyond mitigation measures that are developed to address potential adverse environmental effects. Include perspectives and specific suggestions raised of potentially impacted Indigenous groups; as well as any views of Indigenous groups on the effectiveness of mitigation measures.
- potential adverse impacts on potential or established Aboriginal or Treaty rights that have not been fully mitigated or accommodated as part of the EA and associated engagement with Indigenous groups. Include perspective of potentially impacted Indigenous groups; and
- potential adverse impacts that may result from the residual and cumulative environmental effects. Include the perspectives of potentially impacted Indigenous groups.

This information and assessment will be informed from engagement with Indigenous groups described in Part 2, Section 5 of these guidelines. 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 Aboriginal or Treaty rights. However, there may be distinctions between the adverse impacts on potential or established Aboriginal or Treaty rights 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.

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[5] Refer to Crown-Indigenous Relations and Northern Affairs Canada or Indigenous Services Canada for more information.

7. EFFECTS ASSESSMENT

7.1. 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.

7.1.1. 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 area 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 (SOx), nitrogen oxides (NOx), volatile organic compounds (VOCs), hydrogen sulfide (H2S) and any other potentially toxic air pollutants;
- identify and quantify existing greenhouse gas emissions[6] by individual pollutant measured as kilotonnes of CO_2 equivalent per year in the project study areas;
- direct (e.g. emissions related to vessel traffic) and indirect sources of air emissions;
- current provincial/territorial/federal limits for greenhouse gas emission targets;
- current ambient noise levels in the project area. Information on typical sound sources, geographic extent and temporal variations will be included;
- existing ambient night-time light levels in the project area and at any other areas where project activities could have an effect on light levels. The EIS will describe night-time illumination levels during different weather conditions and seasons; and
- historical records of relevant meteorological information (e.g. total precipitation (rain and snow); mean, maximum and minimum temperatures; and typical wind speed and direction (freezing spray; lighting; 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

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[6] 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).

cyclone activity in the North Atlantic, NOAA's Climate Forecast System Reanalysis (CFSR), and the Canadian Lightning Detection Network.

7.1.2. Marine environment

- 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 marine transportation routes with consideration of predicted climate change effects;
- available bathymetric information (e.g. maximum and mean water depths) for the site and along marine transportation routes if applicable;
- ice climate in the regional study area, including ice formation and thickness, ridging, breakup and movement;
- ice conditions along the marine transportation 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 and along the marine transportation 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 such as DFO Research Vessel Surveys/Science Reports and other primary and secondary scientific literature 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.

7.1.3. 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 characterization of season variability; 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 and benthic environments likely to be affected by the project. 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.

7.1.4. Migratory birds and their habitat[7]

The EIS will describe migratory and non-migratory 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 Bird Protection 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.

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[7] 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.

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 Fisheries and Land Resources Wildlife Division, previous petroleum operations in the area and university or other research programs, if available.

7.1.5. Species at Risk

The EIS will describe federal species at risk and their habitat, including critical 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[8];
- any published studies that describe the regional importance, abundance and distribution of species at risk including recovery management plans, recovery strategies and action plans. The existing data must be supplemented by surveys, if required;
- residences, seasonal movements, movement corridors, habitat requirements, key habitat areas, identified 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; and
- identification of any potentially affected critical habitat as defined in the Species at Risk Act.

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.

7.1.6. Marine mammals

- *marine mammal species that may be present, the times of year they are present, the ranges of the species and their migration patterns; and*

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[8] Proponents are encouraged to consult COSEWIC's latest annual report for a listing of the designated wildlife species posted on their website

- *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.)*

Relevant datasets should be consulted, such as DFO marine mammal sightings database, DFO Research Vessel Surveys, Scientific Reports, and other primary and secondary scientific literature.

7.1.7. Marine turtles

- *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.)*

7.1.8. Indigenous peoples

The proponent shall gather and document baseline information in the EIS for each Indigenous group identified in Part 2, Section 5 of these guidelines (and any groups identified after these guidelines are finalized). The 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 3.2.3 of this document.
- 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, including consideration of the differences of experiences by sub-populations within an Indigenous group, as appropriate (for example, women, youth, elders, families) and cumulative effects.
- Be sufficient to provide a comprehensive understanding of the current state of each VC related to effects of changes to the environment on Aboriginal peoples. Each of the VCs for effects of changes to the environment on Aboriginal peoples is interrelated and therefore baseline information will often overlap.

The proponent should engage with Indigenous groups to understand where baseline information and the respective assessment fit appropriately. Note: VCs identified for biophysical assessment (such as fish and fish habitat) may contribute to assessment and conclusion of VCs related to effects of changes to the environment on Aboriginal peoples.

Health and Socio-Economic Conditions

Baseline information is required for health[9] and socio-economic conditions. For health this includes the state of physical, mental and social well-being. For socio-economic conditions, as well as the economic and social activities of an individual Indigenous group, the baseline will include contextual information regarding their practices. Specific aspects that will be considered include:

- general information about Indigenous populations and sub-populations;

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[9] The proponent should refer to Health Canada's guidance documents in order to include the appropriate baseline information relevant to human health.

- consumption of country foods (also known as traditional foods) including food that is trapped, fished, or hunted for subsistence or medicinal purposes, outside of the commercial food chain;
- which country foods are consumed by which groups, how frequently, and where these country foods are harvested;
- commercial activities (e.g. fishing, trapping, hunting, outfitting);
- any project components and a description of any activities (e.g. exclusion zones) that may affect commercial fisheries or other uses;
- human health, primarily with respect to potential contamination of food sources; and
- recreational uses.

Physical and Cultural Heritage

Baseline information for physical and cultural heritage (including any site, structure or thing of archaeological, paleontological, historical or architectural significance) will consider all elements of cultural and historical importance to Indigenous groups in the area and is not restricted to artifacts considered under provincial heritage legislative requirements.

Current Use of Lands and Resources for Traditional Purposes[10]

Baseline information for current use of lands and resources for traditional purposes will focus on the traditional activity (e.g. hunting, fishing) and include a characterization of all attributes of the activity that can be affected by environmental change. This includes understanding of the baseline conditions of the quality and quantity of resources (e.g. preferred species and perception of quality, cultural connections to species), access to resources (e.g. physical access, timing, seasonality, distance from community) and overall quality of the experience of the practice (e.g. noise, air quality, visual landscape and presence of others). Specific aspects that will be considered include, but are not limited to:

- location of traditional territory (including maps where available);
- location of reserves and communities;
- 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 and their habitats 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;
- cultural values associated with the area affected by the project and the traditional uses identified;

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[10] The proponent should refer to CEAA's guidance documents related to current use of lands and resources for traditional purposes in order to include the appropriate baseline information relevant to current use.

- other current uses identified by Indigenous groups.

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, including Indigenous knowledge, from groups 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. Information collected as part of Section 6 Aboriginal and Treaty rights can be used to inform the baseline information for the elements of 5(1)(c) listed above.

Should there be a lack of Indigenous knowledge; the proponent is still expected to seek information from other sources sufficient enough to allow for a complete the assessment of effects to be presented in the EIS. For more information on requirements for the effects assessment, see Part 2, Section 7.3.7 of these guidelines.

7.1.9. 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).

7.1.9.1. Special areas

The EIS will describe special areas (e.g. marine refuges, 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, ecological reserves, etc.) at the project site and within areas that could be affected by routine project operations or accidents and malfunctions, such as:

- Marine Protected Areas
- Ecologically and Biologically Significant Areas
- Fishery Closure Areas
- Vulnerable Marine Ecosystem
- Preliminary Representative Marine Areas

The EIS will describe the distances between the edge of the project area (i.e. drill sites and marine transportation routes) and special areas. It shall state the rationale for designating specific areas as “special” (i.e. the environmental features that define the special area).

7.1.9.2. Human environment

With respect to potential effects on the human environment, non-Indigenous people and the related VC 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[11] 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.

7.2. 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. As changes to various parts of the physical environment may be inter-related as part of an ecosystem, the EIS will explain and describe the connections between the changes described.

7.3. Predicted effects on valued components

Based on the predicted changes to the environment identified in Section 6.2, 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:

7.3.1. Fish and fish habitat

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[11] The proponent should refer to Health Canada's guidance documents in order to include the appropriate baseline information relevant to human health

- 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, fry-rearing areas, feeding). 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; and
  - ✓ 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;
  - ✓ any modifications in migration or local movements during and after project activities (e.g. vertical seismic profiling, drilling); and
  - ✓ any modifications and use of habitats by federally or provincially listed fish species at risk.
- a discussion of the effects of drilling waste disposal on fish health, marine benthos (fish habitat) 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 could be collected during and after drilling operations and how this would be used to verify effects predictions.

7.3.2. Marine plants

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

7.3.3. Marine mammals

- *effects on marine mammals, including but not limited to*:
  - ✓ mortality and other effects from vessel collisions or disturbance;

- ✓ 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, and behavioural disturbance);
- ✓ exposure to spilled contaminants (e.g. fuel, oils) and operational discharges (e.g. deck drainage, gray water, black water); and
- ✓ change in marine habitat quality from drill muds and cuttings and sedimentation.

7.3.4. Marine turtles

- *effects on marine turtles, including but not limited to*:
  - ✓ mortality and other effects from vessel collisions or disturbance;
  - ✓ 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, and behavioural disturbance);
  - ✓ exposure to spilled contaminants (e.g. fuel, oils) and operational discharges (e.g. deck drainage, grey water, black water); and
  - ✓ change in marine habitat quality from drill muds and cuttings and sedimentation.

7.3.5. Migratory birds

- direct and indirect adverse effects on migratory birds, including population level effects that could be caused by 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 activities, incineration in flares, disruption of normal activities);
  - ✓ exposure to spilled contaminants (e.g. fuel, oils) and operational discharges (e.g. deck drainage, grey 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(s) or support vessels;
  - ✓ physical harm or mortality from flaring on the drilling unit or other vessel-based activities;
  - ✓ 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.

7.3.6. Species at risk

- the potential adverse 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).

7.3.7. Indigenous peoples

With respect to Indigenous peoples, a description and analysis, for each Indigenous group, of how changes to the environment caused by the project will affect the health and socio-economic conditions, physical and cultural heritage including any structure, site or thing of historical, archaeological or paleontological importance, and current use of lands and resources for traditional purposes.

Health and Socio-Economic Conditions

Baseline information gathered as part of the assessment of effects described in 5(1)(c) of CEAA 2012, as well as general information about Indigenous populations and sub-populations could inform the assessment of human health.

- The assessment of impacts to human health will be based on effects of changes to the environment on Aboriginal peoples' human health, focusing on effects on health outcomes or risks in consideration of, but not limited to, potential changes in noise exposure, current and future availability of country foods (e.g. marine species), and water quality (recreational and cultural uses).
- When risks to human health due to changes in one or more of these components are predicted, the proponent is expected to complete a Human Health Risk Assessment (HHRA) examining all exposure pathways for pollutants of concern to adequately characterize potential risks to human health.
- 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.
- Consider effects to mental and social well-being of Indigenous peoples. Where adverse health effects are predicted, any incidental effects such as effects on current use of lands and resources for traditional purposes should also be assessed.
- Consider and document how effects of changes to the environment could be different for particular sub-populations within an Indigenous group (for example, women, youth, elders, specific families);
- This assessment of impacts to human health will assess effects of changes to the environment on Indigenous peoples' socio-economic conditions, including, but not limited to:

- ✓ the use of navigable waters (including any water used for Indigenous transport)
- ✓ commercial fishing, hunting, and trapping activities
- ✓ commercial outfitters
- ✓ recreational use
- ✓ food security[12]
- ✓ income inequity
- ✓ changes at the community level that affect socio-economic conditions for Indigenous peoples as result of increased population, economic activity, cost of living, among other factors
- ✓ non-commercial / trade economy

Physical and Cultural Heritage

- This assessment will assess effects of changes to the environment on Aboriginal peoples' 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
  - ✓ changes to sacred, ceremonial or culturally important places, objects, or things

Current Use of Lands and Resources for Traditional Purposes

- This assessment will characterize the effects (including cumulative effects) on the use or activity (e.g. hunting, fishing, trapping, and cultural practices) as a result of the underlying changes to the environment (i.e. how will the activity change if the project proceeds), using the approach described in the Agency's guide entitled Technical Guidance for Assessing the Current Use of Lands and Resources for Traditional Purposes under CEAA 2012. This assessment should consider changes caused by the Project through changes to the environment, can cause effects to the practice of a current use or activity through the following interactions with:
  - ✓ Resources used, such as changes to the quantity, quality, and availability of resources and habitat, as well as to the sufficiency of resources required to conduct an activity or practice, including perception of effects, avoidance, and consideration of the seasonal round;
  - ✓ any changes or alterations to access into the areas used for traditional purposes and commercial fishing, including implementation of exclusion zones;
  - ✓ 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; and
  - ✓ Experience by Indigenous peoples, including changes that affect the spiritual and cultural experiences of the activity or practice, as well as sense of place and wellbeing, and the applicability and transmission of Indigenous knowledge, laws, customs and traditions.

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[12] According to Health Canada and the Food and Agricultural Organisation "food security" is "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".

- Using the interactions listed in the above bullet, the proponent should also consider the following in their assessments:
  - ✓ the 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;
  - ✓ 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; and
  - ✓ an assessment of the potential to return affected areas to pre-project conditions to support traditional practices.
- Other effects of changes to the environment on groups should be reflected as necessary.

The proponent is expected to provide mitigation measures for effects of changes to the environment on Aboriginal peoples pursuant to section 5 (1)(c) of CEAA, 2012 (see Part 2, Section 7.4. of these guidelines).

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

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 authorization/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.

7.3.8.1. 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 vessel 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);
  - ✓ provide the estimation or derivation method, and disclose, describe, and justify assumptions and emission intensity factors used;
  - ✓ compare and assess the level of estimated emissions to the regional, provincial and federal emission targets; and
  - ✓ 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.

7.3.8.2. 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).

7.3.8.3. Special areas

- effects on special areas, including, but not limited to:
  - ✓ use of dispersants;
  - ✓ change to habitat quality (e.g. noise, light, water, sediment quality); and
  - ✓ change to the environmental features that define the special area (e.g. physical features, species assemblages, species abundance).

7.3.8.4. 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); and
- ✓ rural and urban settings that could be affected by routine activities and/or accidents and malfunctions.

7.4. 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 identify and describe mitigation measures to avoid, or lessen potential adverse effects on 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 also identify and describe mitigation measures to avoid or lessen adverse effects on listed COSEWIC species.

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.

The EIS will document specific suggestions raise by each Indigenous group for mitigating the effects of changes to the environment on Aboriginal peoples (section 5(1)(c) of CEAA 2012*).* For those mitigation measures intended to address effects of changes to the environment on Aboriginal peoples, the proponent must discuss the residual effects with the Indigenous groups identified in Part 2, Section 5 of these guidelines prior to submitting the EIS.

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.

7.5. 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 7.3 above. For those VCs related to effects of changes to the environment on Aboriginal peoples, the proponent must discuss the residual effects with the Indigenous groups identified in Part 2, Section 7 of these guidelines prior to submitting the EIS. 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 the Agency's guidance on determining whether a project is likely to cause significant adverse environmental effects.

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. For those predicted adverse effects that relate to effects of the changes to the environment on Aboriginal peoples, the proponent will consider the views of the Indigenous groups in the determination of the definitions of the significance criteria. 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[13]
- 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.

7.6. Other effects to consider

7.6.1. 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 adverse 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 and the effects of these scenarios.

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 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

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[13] 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.

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 in-situ burning). 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 Atlantic Canada.

Comparisons with similar settings would also be meaningful for deep water drilling where there is very low probability but very high consequences associated with landslides.

7.6.2. 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). These events will be considered in different probability patterns (e.g. 5-year flood vs. 100-year flood).

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

7.6.3. Cumulative effects assessment

The proponent will identify and assess the project's cumulative effects using the approach described in the Agency's guidance documents related to cumulative environmental effects.

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[14].

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

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[14] Definitions of these terms can be found in the Agency's technical guidance on cumulative environmental effects.

- identify and justify the spatial and temporal boundaries for the cumulative effects 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.
- 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. hunting, fishing, trapping).
- 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.

8. SUMMARY OF ENVIRONMENTAL EFFECTS ASSESSMENT

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

- potential environmental effects on VCs;
- 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).

9. 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;
- suggestions from Indigenous groups regarding the design of and involvement in follow-up and monitoring programs;
- incorporation of Indigenous knowledge, where available;
- 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.

9.1. 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 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.

9.2. 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 VCs and the measures and means planned to protect the environment;
- identification of regulatory instruments that include a monitoring program requirement for the VCs;
- 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

						Key Criteria for Determining Significance[15]							
Valued Component affected	Area of federal jurisdiction[16] (√)	Project Activity	Potential effects	Proposed mitigation	Residual effect	*Magnitude*	*Geographical Extent*	*Timing*	*Duration*	*Frequency*	*Reversibility*	Significance of residual adverse effect	Likelihood of 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													

---

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

[16] 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.

APPENDIX B

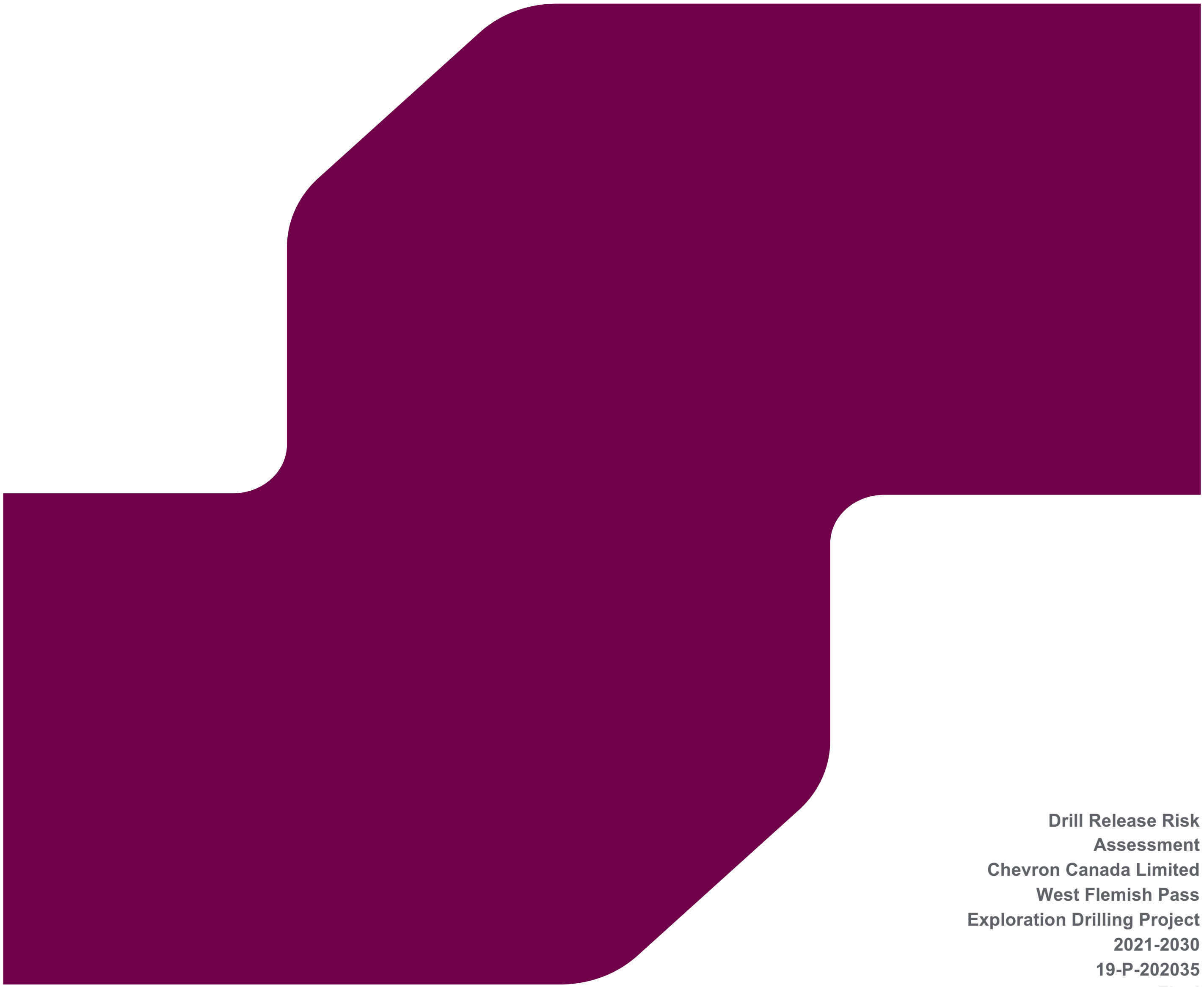
APPENDIX C

Drill Release Risk Assessment

CHEVRON CANADA LIMITED WEST FLEMISH PASS EXPLORATION DRILLING PROJECT 2021-2030

19-P-202035

Drill Release Risk Assessment



Drill Release Risk
Assessment
Chevron Canada Limited
West Flemish Pass
Exploration Drilling Project
2021-2030
19-P-202035
Final
August 14, 2019

www.rpsgroup.com

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
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Approval for issue

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EXECUTIVE SUMMARY

The operational release of drill cuttings and fluids were modelled to support an Environmental Impact Statement (EIS) for Chevron Canada Ltd., associated with the West Flemish Pass Exploration Drilling Project 2021-2030. The West Flemish Pass Project Area is located approximately 500 km northeast of St. John's, Newfoundland including portions of the northern Flemish Pass and northwestern Flemish Cap. Water depths at the two proposed drilling sites selected for modelling are 1,500 m for West Flemish 1 ("deep" site) and 500 m for West Flemish 2, ("shallow" site). Operational discharges from planned drilling sections were modelled as seafloor or surface releases, with release rate and location of the discharge in the water column depending on each drilling stage. Each of these simulations was performed for two different timeframes (summer-scheduled and early spring-alternative) to evaluate how ocean current variability in the region may affect the patterns of SBM dispersion.

Discharge simulations were completed using RPS' MUDMAP modelling system. The MUDMAP model is used to predict the transport of drilling solids released in the marine environment and the resulting seabed deposition. The model inputs include information regarding the discharge characteristics (release location, rate of discharge, etc.), the properties of the sediment (particle sizes, density), as well as environmental characteristics (bathymetry and ocean currents), to predict the dispersion and transport of solids through the water column. The model output consists of the predicted three-dimensional movement and shape of the discharge plume, the concentrations of insoluble discharge components in the water column, and the accumulation of discharged solids on the seabed. The model predicts the transport of solid particles from the time of discharge or release to initial settling on the seabed. MUDMAP does not account for resuspension and transport of previously discharged solids; therefore, it provides a conservative estimate of the potential seafloor depositions.

Bathymetry was characterized using databases provided by NOAA National Geophysical Data Center and GEBCO. Currents for the North Atlantic region were acquired from the three-dimensional HYCOM (HYbrid Coordinate Ocean Model) circulation model. For this study, daily current data were obtained, and trends were analyzed for the period of January 2006 through December 2012 for the North Atlantic region. As with any hydrodynamic model, there is the potential that local currents may deviate from predictions based upon grid resolution and small-scale variability in ocean circulation dynamics. However, the data used is sufficient for this type of modelling.

In each modeled case, the deposition of muds and cuttings from operational discharges onto the seabed was controlled by the settling velocity of particles, the currents within the water column, and the depth of the water column. Modelled operational discharges from West Flemish 1 (1,500 m) and West Flemish 2 (500 m) were predicted to produce a spatially confined depositional areas of 1-2.5 km^2 above 0.1 mm, depending on the site and timeframe, with a maximum thickness of up to 5.3 mm. The difference in depth between both sites did not influence the seabed deposition patterns, because only the riserless sections (released at seabed) contributed to measurable thicknesses on the seafloor. Slow settling velocities associated with the fine silts/clays, which make up the dominant fraction of the cuttings drilled with SBM, allowed for greater dispersion before settling out.

Summer simulations (scheduled drilling) for both sites had weaker subsurface current regimes, which led to footprints extending radially from the discharge site at higher thicknesses. Depositional thicknesses above 0.1 mm were predicted to extend radially approximately 760-810 m during the summer due to low dispersion by weak subsurface currents. Maximum depositional thicknesses of 5.3 and 5.0 mm were predicted for West Flemish 1 and West Flemish 2, respectively, covering an area of approximately 1.1 km^2.

Spring simulations (alternative drilling) for both sites were subject to stronger seabed currents associated with the spring timeframe, and predicted depositional footprints were elongated, extending much further to the east from the sites. Depositional thicknesses above 0.1 mm were predicted to extend as much as 7.9 km for the deeper West Flemish 1 and upwards of 2.6 km for the shallow West Flemish 2. Because of this increased dispersion during spring the deeper West Flemish 1 was predicted to have a maximum thickness of 0.94 mm with a cumulative

area of 1.6 km^2 above 0.1 mm and the shallower West Flemish 2 was predicted to have a maximum thickness of 2.38 km^2 with a cumulative area of 1.6 km^2 above 0.1 mm.

The variations within predicted results between simulations were due to three main factors including: 1) settling velocity associated with different releases, 2) current patterns (i.e. velocity) and 3) release height relative to the seabed. The discharges modelled in this study may be considered representative of other potential discharges in the Project Area, as the depth of the sites (500 to 1500 m) are similar in depth to other potential sites within the Project Area. While this dispersion modelling targeted the most likely drilling windows for the Project (spring: April to May and summer: July to August), the predicted results are applicable outside of this temporal window.

Document Summary

This report includes an introduction describing the region, a description of the modelling approach, and the results of the study. The model results are summarized in figures and tables in the main body of this document, describing the potential for WBM and SBM contamination within the water column and on the seabed. This document is broken down into several sections. Section 1 includes an introduction to the modelling study and a description of project area. Section 2 includes the modelling approach using the MUDMAP model, scenarios, and a description of the model input data. Section 3 summarizes the seabed deposition and water column concentration model results. Section 4 provides conclusions and discussion points. Section 5 contains the references cited. Additional information may be found in supporting Appendix A, which provides a detailed description of the MUDMAP model, fates processes, and algorithms used.

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LIST OF ACRONYMS AND ABBREVIATIONS

Term	Definition
3D	Three-dimensional referring to x, y, and z directions (i.e. latitude, longitude, and depth)
EIS	Environmental Impact Statement
GEBCO	The General Bathymetric Chart of the Oceans operated by the International Hydrographic Organization (IHO) and Intergovernmental Oceanographic Commission (IOC) of UNESCO.
HYCOM	The U.S. Navy HYbrid Coordinate Ocean Model used for currents
MICOM	Miami Isopycnic-Coordinate Ocean Model
NCODA	U.S. Navy Coupled Ocean Data Assimilation
NOAA	U.S. National Oceanic and Atmospheric Administration
NRC	U.S. National Research Council
NRDA	The U.S. Natural Resource Damage Assessment
SBM	Synthetic based mud
SwRI	The Southwest Regional Institute

1 INTRODUCTION

RPS conducted drilling discharge modelling of operational releases of drill cuttings and water based mud (WBM), in support of an Environmental Impact Statement (EIS) for the Chevron Canada Ltd. West Flemish Pass Exploration Drilling Project 2021-2030. The West Flemish Pass Project Area is located approximately 500 km northeast of St. John's, Newfoundland including portions of the northern Flemish Pass and northwestern Flemish Cap. Water depth at the proposed drilling sites selected for modelling span 500-1,500 m. Major currents, including the Labrador Current and the Gulf Stream, influence the circulation and biological productivity in this region.

Simulations of operational releases of WBM and drill cuttings were completed using RPS' MUDMAP modelling system (Spaulding et al., 1994). MUDMAP predicts the transport of drilling solids released in the marine environment and the resulting seabed deposition. The model requires inputs describing: (i) the physical characteristics of the discharged effluent, (ii) the discharge timing and release location, and (iii) information describing the receiving waters (bathymetry, density structure, ocean currents). Model output includes estimates of environmental loadings to the seabed (deposition) from discharges associated with offshore drilling. A technical description of the MUDMAP model is included in Appendix A.

1.1 Project Area

Newfoundland is comprised of a series of islands off the east coast of Canada, and along with Labrador forms the easternmost Canadian province. The relatively shallow waters of the continental shelf extend eastward into the Northwest Atlantic Ocean, up to 500 km off the Newfoundland coast. The hypothetical modelled release location is within the West Flemish Pass Project Area, located approximately 500 km northeast of St. John's, Newfoundland (Table 1-1 and Figure 1-1). Water depth at the proposed drilling sites selected for modelling are 1,500 m for West Flemish 1 and 500 m for West Flemish 2. This captures both a "deep" and "shallow" site. This region sits atop substantial petroleum resources, with the Hibernia and White Rose fields approximately 300 km to the southwest. Bathymetry within the area ranges between approximately 400-2,500 within the surrounding tens of kilometers. However, regions within the broader model domain do exceed 4,500 m depths. Such regions include the Laurentian Basin, Bonnition Basin, and the abyssal plain east of the Flemish Cap. The model domain extends from 42°N to 57°N and 72°W to 28°W, encompassing Canadian, U.S., French, Greenland (Denmark), and International waters.

Table 1-1. Hypothetical release location within the Chevron West Flemish Pass Project Area.

Site Name	Latitude	Longitude	Water Depth (m)
West Flemish 1	48°13'20" N	47°11'00" W	1,500
West Flemish 2	48°01'00" N	47°18'23" W	500

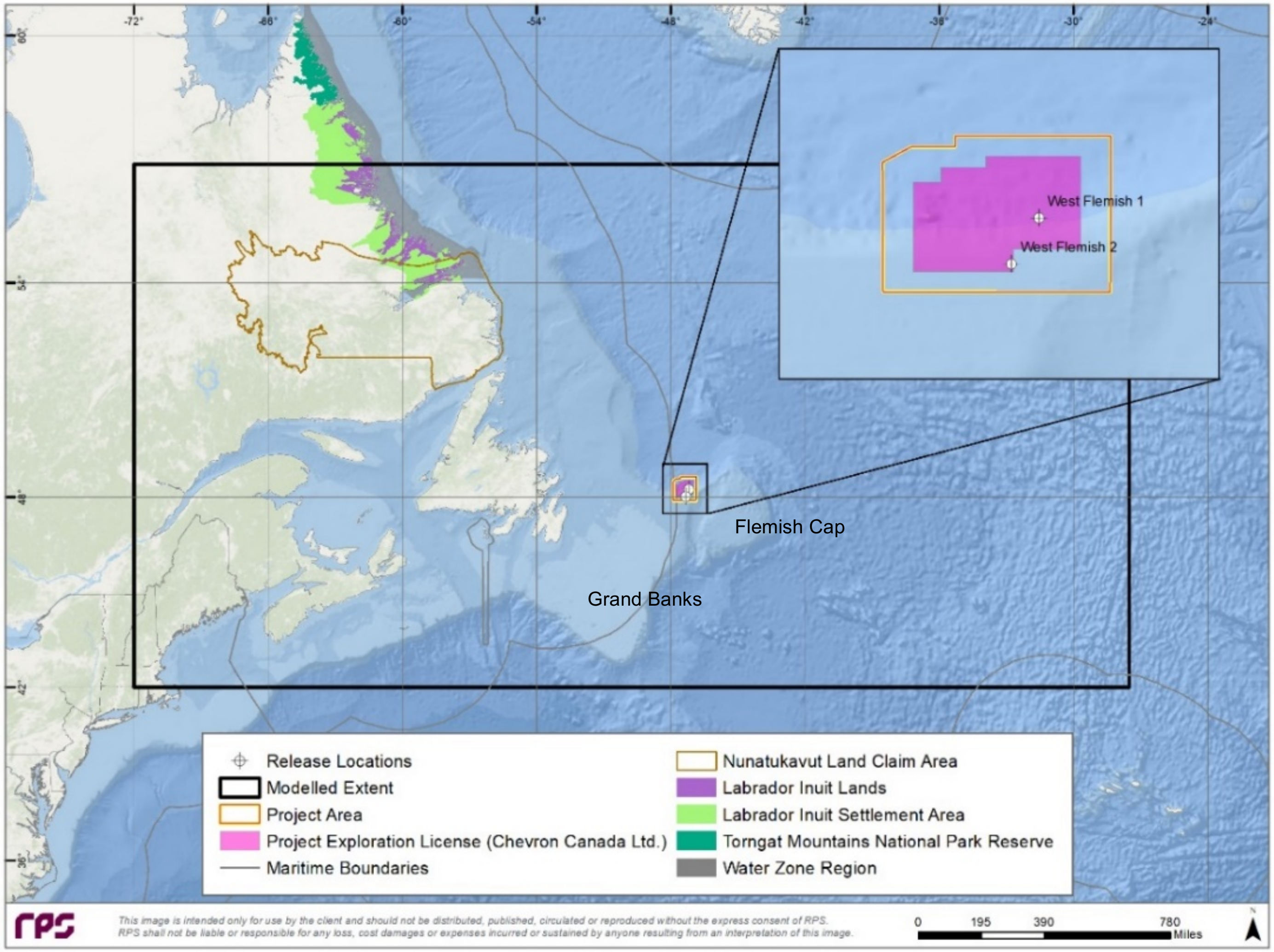


Figure 1-1. Project Area, including the two hypothetical release locations for deep West Flemish 1 and shallow West Flemish 2. The black bounding box represents the modelled extent used in the oil spill risk assessment, while the smaller orange box represents the Project Area. However, the model domain for the mud and cuttings model was focused on the surrounding few kilometers of the hypothetical release location.

1.2 Circulation and Currents

The Labrador Current dominates the large-scale ocean circulation in the Newfoundland region, originating in the Arctic Ocean and flowing south along the coasts of Labrador and then Newfoundland (Figure 1-2). This southerly current intensifies as waters funnel through the offshore branch, which follows the Flemish Pass between the Grand Banks and Flemish Cap. To a lesser extent, a portion of the Labrador Current flows through an inshore branch, which follows the Avalon Channel between Newfoundland and the Grand Banks. Over parts of the Grand Banks, currents can be generally weak and flow southward (Fuller and Myers, 2014). Maximum current speeds in the upper 200 m of the water column range from 0.3 – 2.0 m/s (C-NLOPB, 2014). The strong southerly current dominates the yearly average flow and winds may only account for approximately 10% of current variability in this region (Petrie and Isenor, 1985). South of the Flemish Pass, the Labrador Current mixes with the North Atlantic current. The boundary where these two currents converge produces extremely energetic and variable frontal systems and eddies on smaller scales, on the order of kilometers (Volkov, 2005). Due to these eddies, local transport may advect parcels of water in nearly any direction. Satellite and drifter studies of current dynamics demonstrate this complexity; however, drifting parcels generally move to the south and east (Han and Tang, 1999; Petrie and Anderson, 1983; Richardson, 1983) where they intersect with the North Atlantic current.

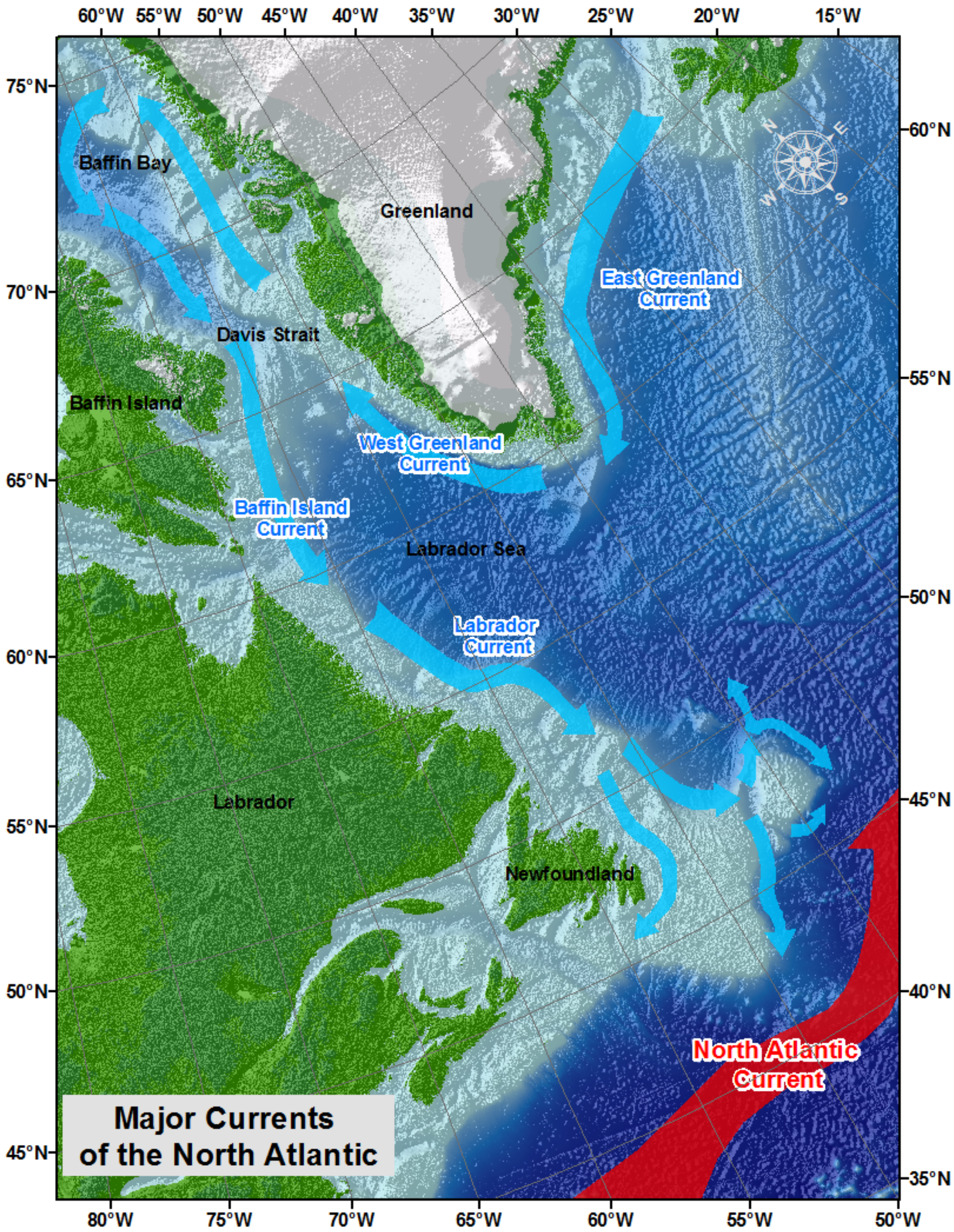


Figure 1-2. Large scale ocean currents in the Newfoundland region (USCG 2009).

Currents for the North Atlantic region were acquired from the HYCOM (HYbrid Coordinate Ocean Model) circulation model. HYCOM is a primitive-equation ocean general circulation model that evolved from the Miami Isopycnic-Coordinate Ocean Model (MICOM) (Halliwell, 2002; Halliwell et al., 1998, 2000; Bleck, 2002). The HYCOM global ocean system is a 3D dynamic model and uses Mercator projections between 78° S and 47° N and a bipolar patch for regions north of 47° N to avoid computational problems associated with the convergence of the meridians at the pole. The 1/12° equatorial resolution provides gridded ocean data with an average spacing of ~7-8 km between each point. Data is assimilated through the Navy Coupled Ocean Data Assimilation (NCODA) system (Cummings, 2005). The NCODA system employs a Multi-Variate Optimal Interpolation scheme, which uses model forecasts as a first guess and then refines estimates from available satellite and in-situ temperature and salinity data that are applied through the water column using a downward projection of surface information (Cooper and Haines, 1996). The HYCOM model is updated regularly, which may result in differences in predicted currents based upon the HYCOM model calculations, as opposed to environmental variability. A seven-year timespan was run using the latest HYCOM model in a process known as a re-analysis. Data for the period from 2006-2012 were acquired and is the most recent set of HYCOM re-analysis that uses a single HYCOM model. Bathymetry is derived from the U.S. Naval Research Laboratory BDB2 dataset. Surface forcing is derived from the Navy Operational Global Atmospheric Prediction System, which includes wind stress, wind speed, heat flux (using bulk formula), and precipitation. Surface forcing of HYCOM is derived from 1-hourly CFSR wind data with a horizontal resolution of 0.3125° and induced wind stress, wind speed, heat flux, and precipitation with bathymetry derived from the GEBCO dataset (HYCOM, 2016).

The HYCOM surface current pattern for the area of interest for the period of 2006-2012 (Figure 1-3) illustrates that the sites are very close to the location where Labrador Current divides into two branches near Flemish Cap. An analysis of the currents throughout the year was conducted to determine baseline conditions at each location, even though the anticipated drilling would occur during spring or summer. The monthly current roses of HYCOM at West Flemish 1 do not have any clear seasonality in terms of speed or directions (Figure 1-4). However, the current roses at West Flemish 2 illustrate that current direction is predominantly east-south eastward during October-April period, while for the rest of the year currents are primarily directed to the east (Figure 1-5). Monthly surface current speeds (cm/s) derived from the HYCOM model at both sites are moderate, with monthly average current speeds between 25-45 cm/s and 95th percentile current speeds between 50-85 cm/s (Figure 1-6). Maximum instantaneous current speeds are predicted during September at West Flemish 1 (164 cm/s – not depicted) and August in West Flemish 2 (158 cm/s – not depicted). Vertical current profiles and current roses for West Flemish 1 and West Flemish 2 are presented in Figure 1-7 and Figure 1-8, respectively, which compare the distribution of flow at various depths at drilling sites. In addition, horizontal current vector (cm/s) timeseries at five different depths for each location are used to portray variability in current speed and direction at different water levels (Figure 1-9 and Figure 1-10). Both the vertical profiles and the current vectors illustrate that the current speed decreases as the depth increases. Current directions at surface and mid-layer are predominantly east at West Flemish 1 and east-southeast at West Flemish 2. At the bottom layer, currents are predominantly heading towards the east at both drilling sites.

All figures display current data in the oceanographic convention, indicating the direction in which currents are flowing towards.

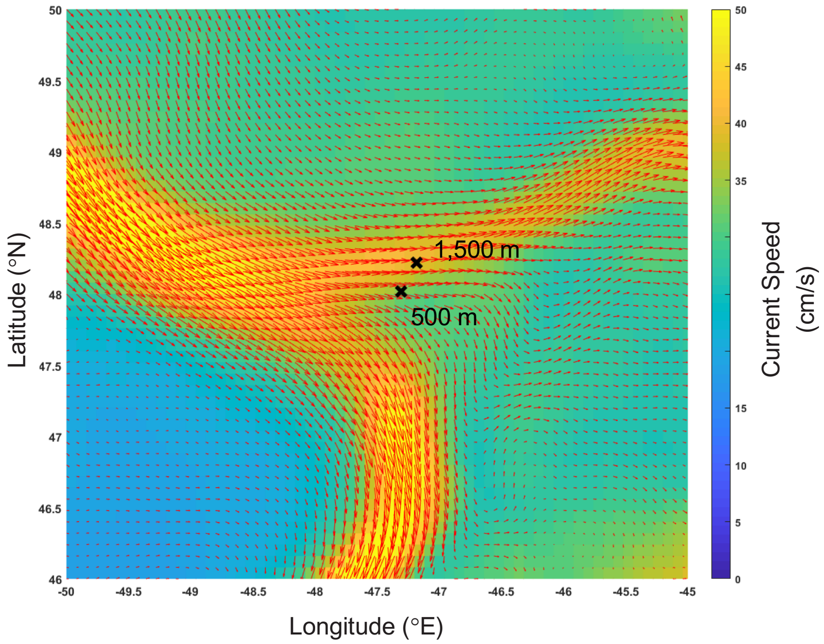


Figure 1-3. Averaged surface current speed (cm/s) in color, and direction presented as red vectors offshore Newfoundland from HYCOM (2006 – 2012). Black X's represent the representative drilling sites including the deep West Flemish 1 (north) and shallow West Flemish 2 (south).

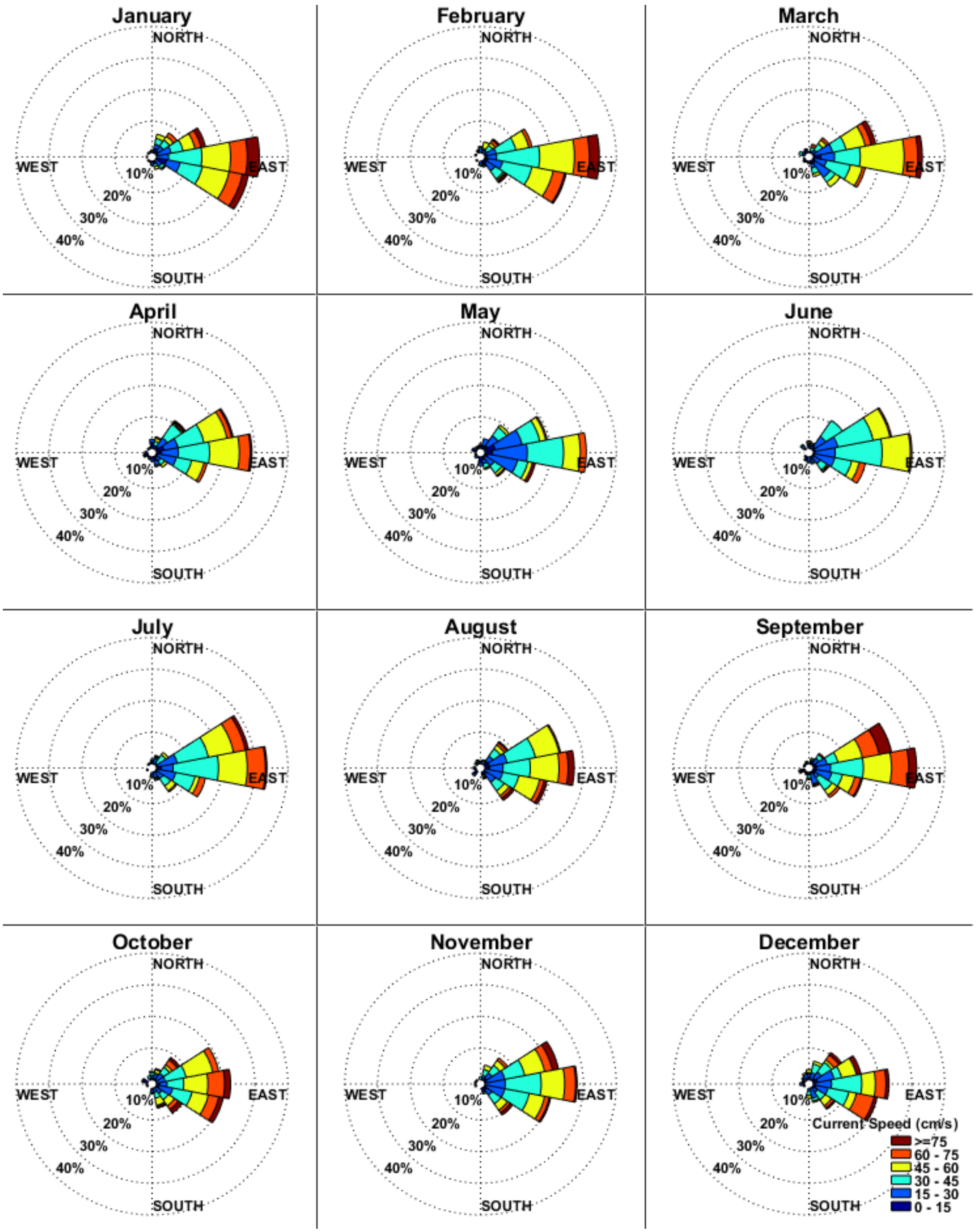


Figure 1-4. Current roses illustrating the distribution of HYCOM surface currents (speed and direction) by month at deep West Flemish 1 (model period from 2006-2012); using oceanographic convention (i.e., direction currents are flowing towards).

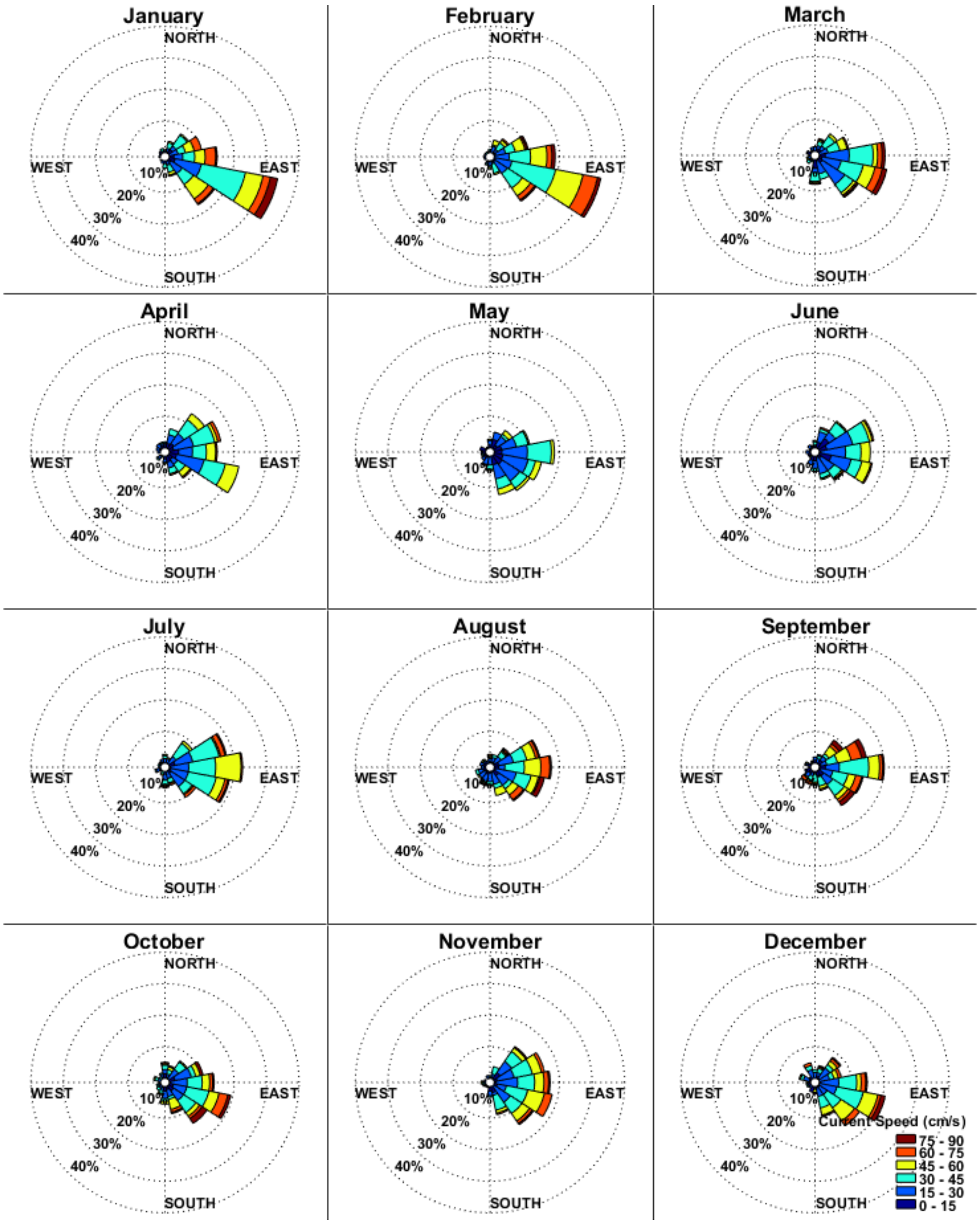
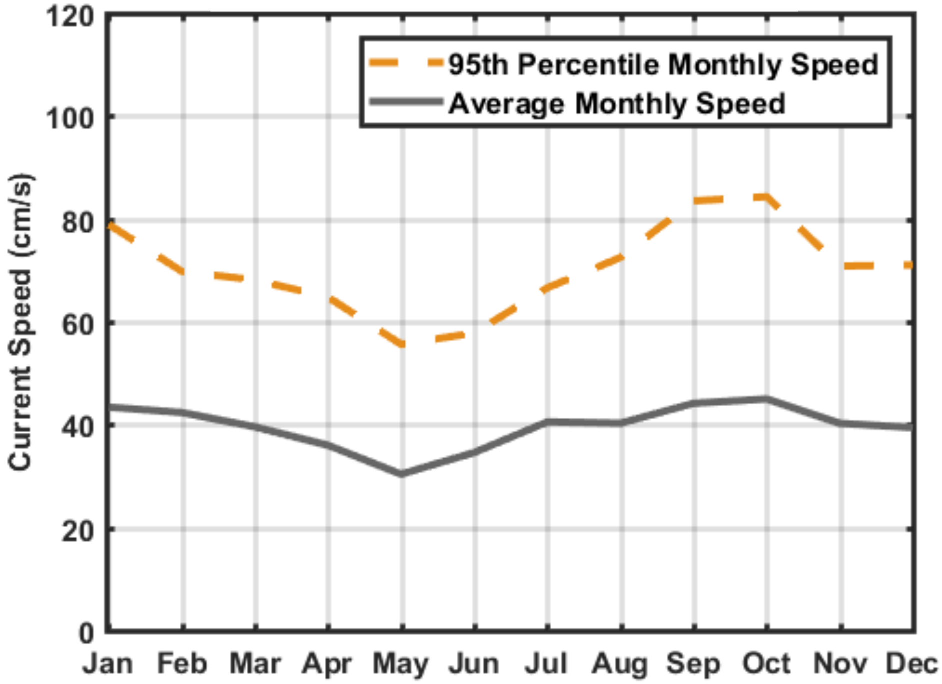


Figure 1-5. Current roses illustrating the distribution of HYCOM surface currents (speed and direction) by month at shallow West Flemish 2 (model period from 2006-2012); using oceanographic convention (i.e., direction currents are flowing towards).



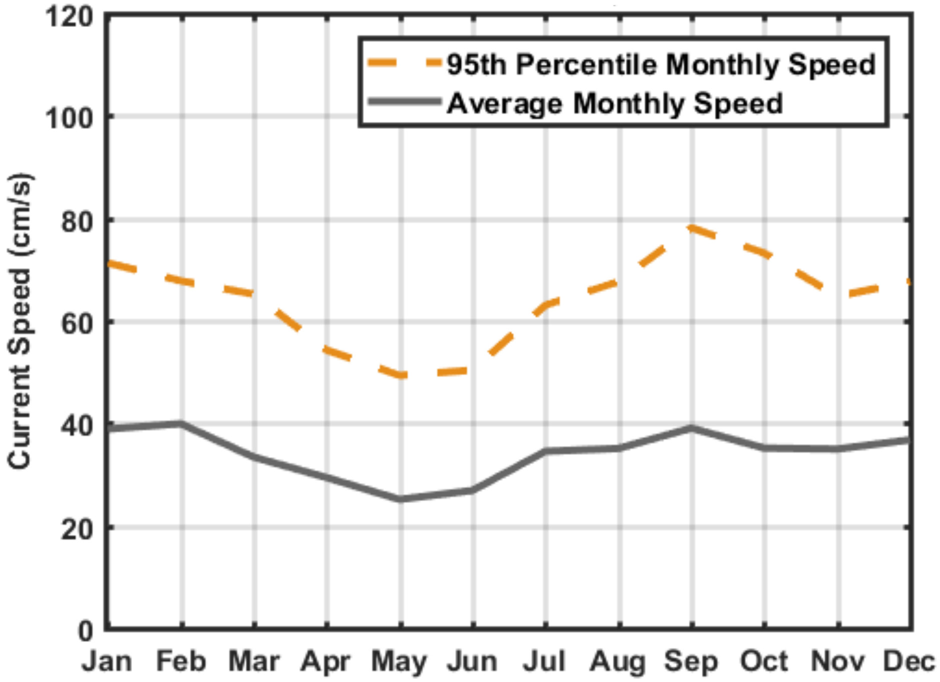


Figure 1-6. Monthly average (grey solid) and 95th percentile (orange dashed) HYCOM surface current speed (cm/s) statistics at deep West Flemish 1 (top) and shallow West Flemish 2 (bottom).

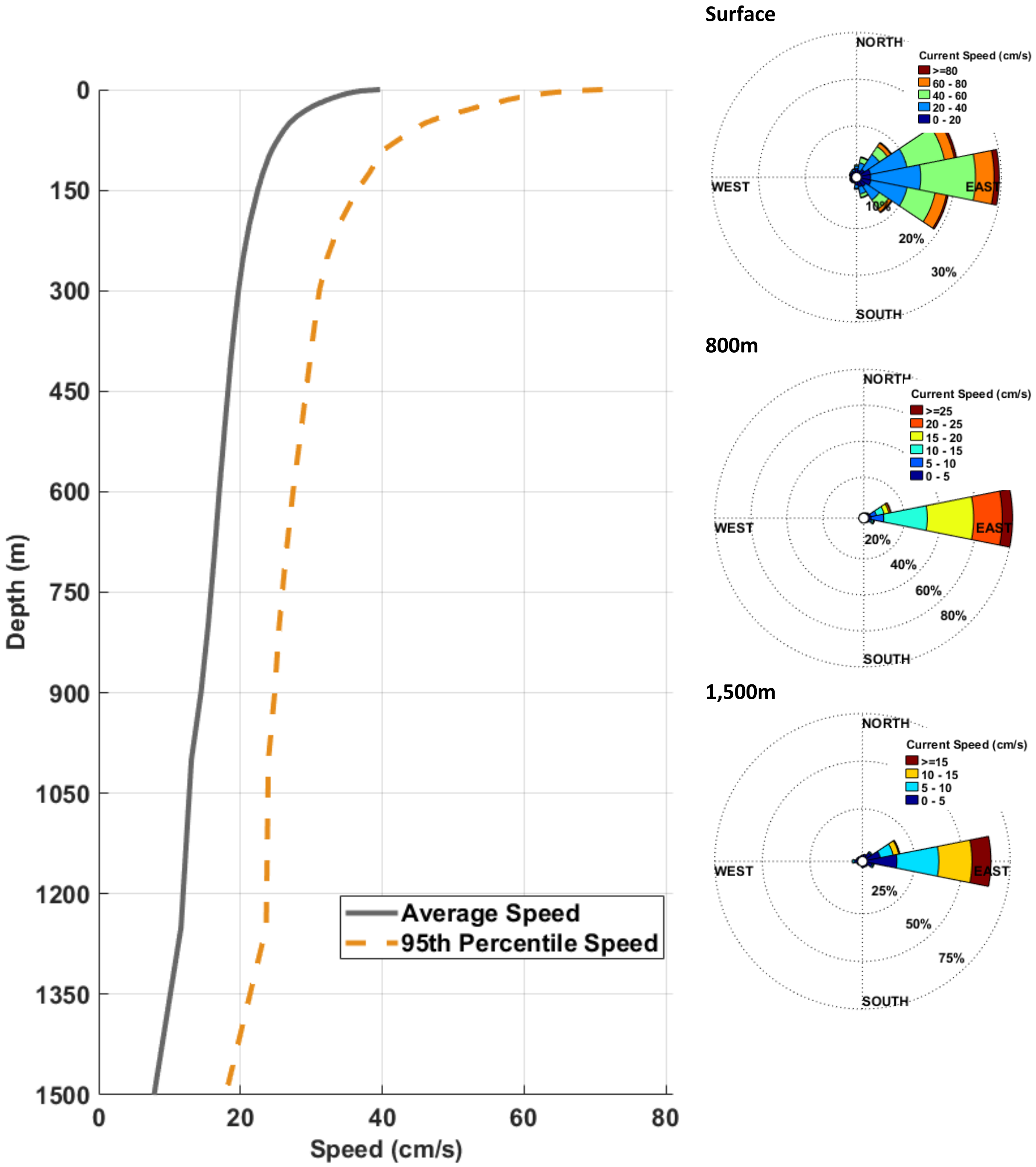


Figure 1-7. Vertical profiles of average and 95th percentile horizontal current speed (cm/s) by depth (m) (left) and current roses at multiple depths presented in oceanographic convention (i.e., direction currents are flowing towards) (right) at deep West Flemish 1; derived from HYCOM current model between 2006 and 2012.

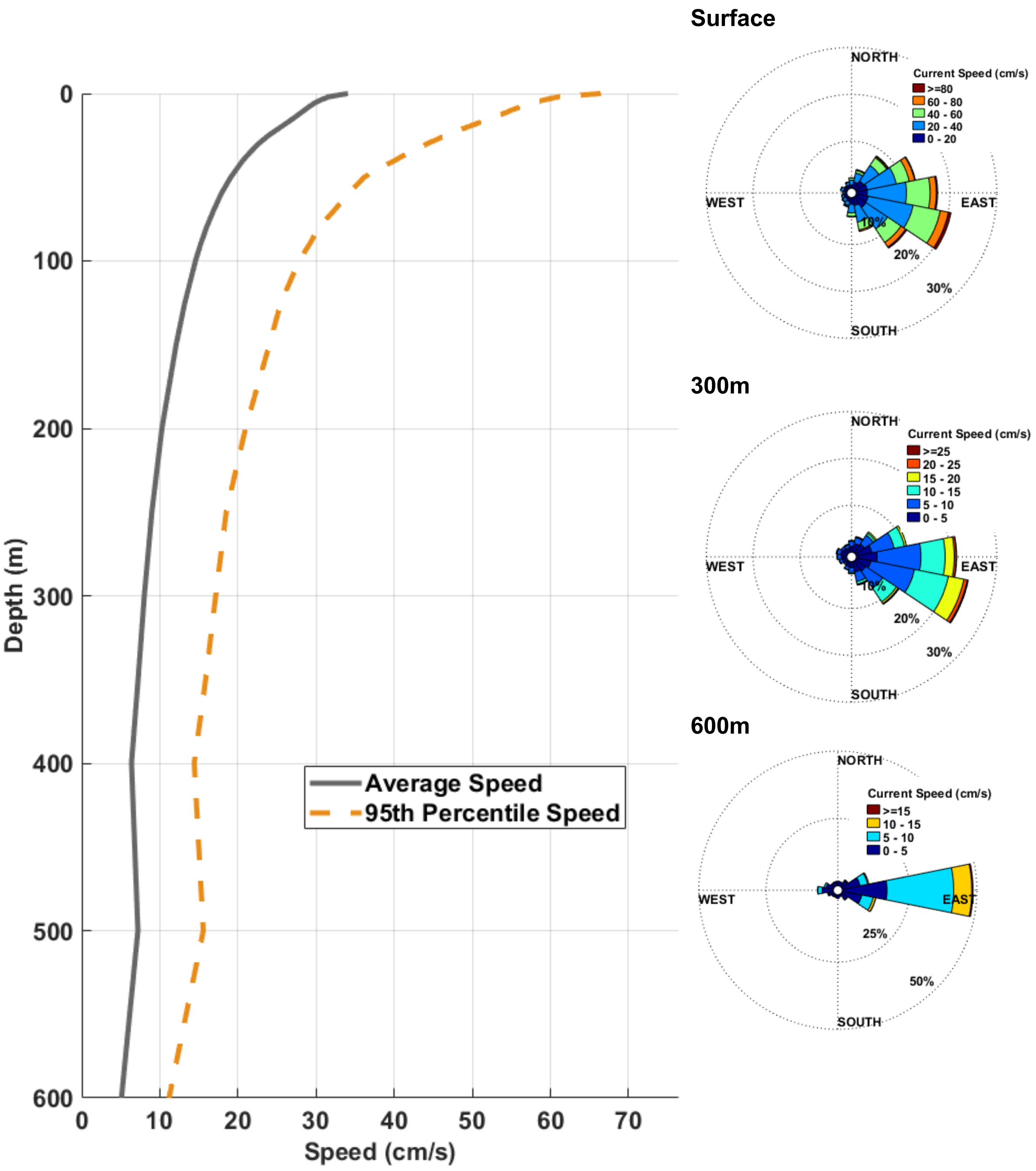


Figure 1-8. Vertical profiles of average and 95th percentile horizontal current speed (cm/s) by depth (m) (left) and current roses at multiple depths presented in oceanographic convention (i.e., direction currents are flowing towards) (right) at shallow West Flemish 2; derived from HYCOM current model between 2006 and 2012.

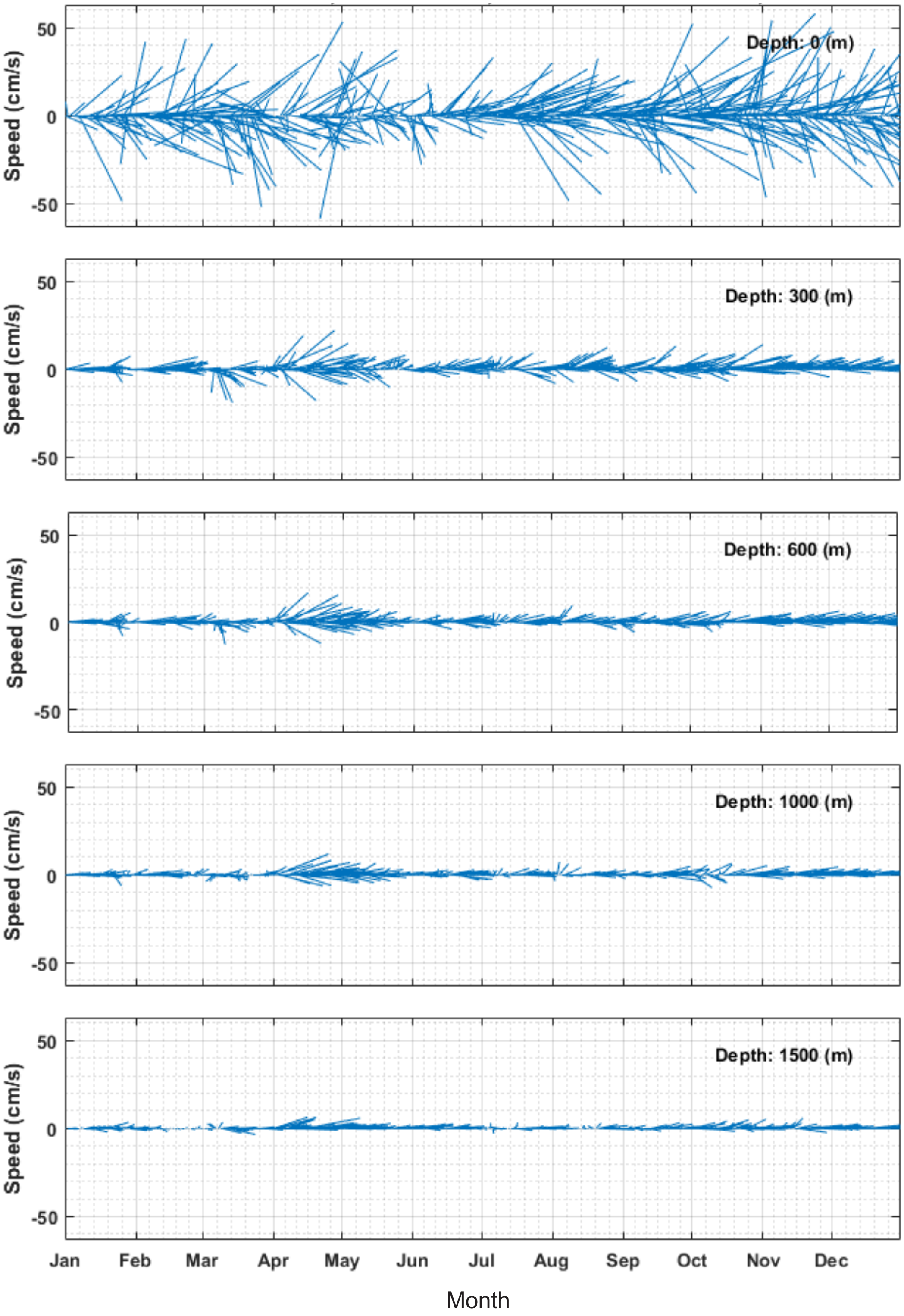


Figure 1-9. Timeseries of HYCOM current speeds (cm/s) with depth (m) at deep West Flemish 1. Note that the highlighted depths in this figure differ from those presented for shallow West Flemish 2 in Figure 1-10.

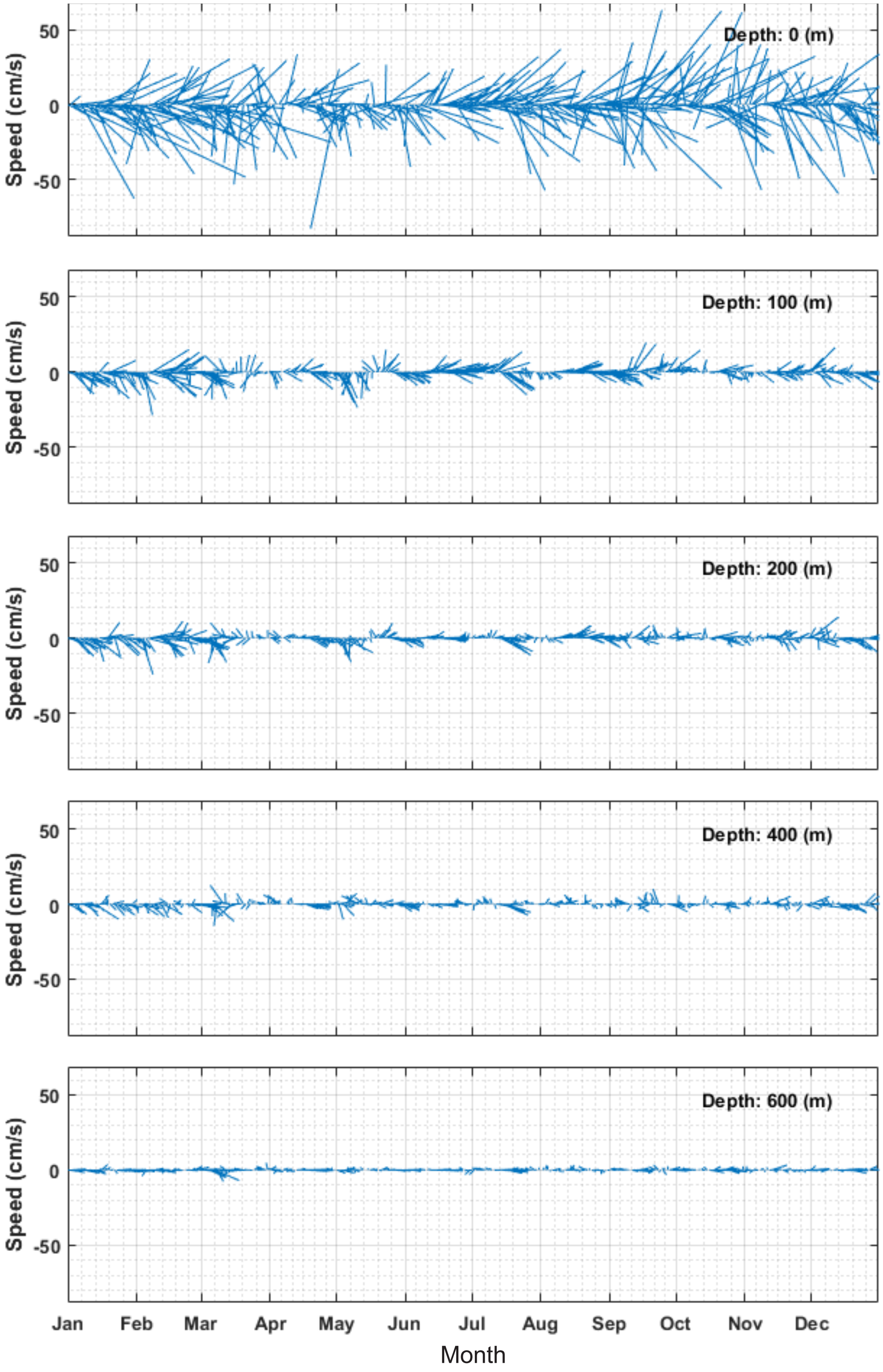


Figure 1-10. Timeseries of HYCOM current speeds (cm/s) with depth (m) at shallow West Flemish 2. Note that the highlighted depths in this figure differ from those presented for deep West Flemish 1 in Figure 1-9.

2 MODELLING APPROACH

2.1 Modelling Tool – MUDMAP Dispersion Model

Drilling discharge simulations were completed using RPS’ MUDMAP modelling system (Spaulding et al., 1994). MUDMAP is a numerical model developed by RPS to predict the near- and far-field transport, dispersion, and bottom deposition of drilling mud and cuttings. In MUDMAP, the equations governing conservation of mass, momentum, buoyancy, and solid particle flux are formulated using integral plume theory and then solved using a Runge Kutta numerical integration technique. The model includes three stages: convective descent/ascent, dynamic collapse, and far field dispersion. It allows the transport and dispersion of the release to be modelled through all stages of its movement. The initial dilution and vertical spreading of the release is predicted in the convective descent/ascent process. The far field process predicts the transport and dispersion of the release caused by the ambient current and turbulence fields. In the dynamic collapse process, the release impacts the surface or bottom, or becomes trapped by vertical density gradients in the water column.

MUDMAP is widely used to simulate settling and dispersion of drilling mud and cuttings for offshore environmental impact assessments and follows the same theoretical framework as several other common cuttings models (IOGP, 2016). The equations and solutions in MUDMAP are based on thirty years of research and the model is regularly updated as new scientific research is presented. The system has been applied for discharge operations in both coastal and offshore environments with excellent agreement among results compared with other industry accepted models such as the Offshore Operators Committee Mud and Produced Water Discharge Model (Spaulding et al., 1994). Examples of the model validation are provided in Burns et al. (1999), King and McAllister (1997, 1998), and Tetra Tech (2002). Limitations of the MUDMAP model are similar to those that exist for most other cuttings dispersion models (IOGP, 2016), including that it does not account for certain complex process such as aggregation (or degradation) of cuttings as they settle, flocculation, or post-depositional consolidation of cuttings over time. MUDMAP does not account for the resuspension and transport of previously discharged solids; therefore, it provides a conservative estimate of the potential seafloor depositions.

The MUDMAP model output consists of three-dimensional predictions of the movement and shape of the discharge plume, the concentrations of insoluble (i.e., cuttings and mud) discharge components in the water column, and the accumulation of discharged solids on the seabed. The model predicts the transport of solid particles from the time of discharge or release to initial settling on the seabed. With simplifying assumptions, concentrations of hydrocarbons or other pollutants adhered to cuttings can be derived from the seabed loading (Nedwed et al., 2004). The algorithms for the far field and passive diffusion stage are based on a particle based random walk model. More details about MUDMAP are included in Appendix A.

2.2 Mixing Parameters

For discharges near the sea surface, a horizontal dispersion (i.e., mixing) coefficient of 2.0 m^2/s was used to account for the turbulence of the sediment as it was transported from the release site. A vertical dispersion coefficient of 0.001 m^2/s was used to account for the influence of turbulence within the water column. These values were selected, based upon professional judgment and previous experience, to represent typical conditions of the deep marine environment.

2.3 Discharge Schedule

Representative drilling schedules were provided to RPS by Chevron Canada Ltd. to characterize discharges from five to six planned drilling sections at West Flemish 1 and West Flemish 2, respectively (Table 2-1 and

Table 2-2). The first two sections will be drilled using seawater and WBM at both sites. The remainder of the drilling sections will require the use of SBM at both sites. The discharge schedule provided by Chevron Canada Ltd. consists of a release of 610 m^3 of drill cuttings and 5,041 m^3 of drilling fluids at West Flemish 1 and 620 m^3 of drill cuttings and 5,045 m^3 of drilling fluids at West Flemish 2 over the duration of the anticipated drilling campaign. This captures approximately 2 months of work at each location with 66 days of active discharge.

During the initial phase of drilling (first 2 sections in Table 2-1 and

Table 2-2), all cuttings and WBM are expected to be released directly to the seabed (5 m above the wellhead on the seafloor). Subsequent sections will be drilled using SBM and cuttings will be returned to the platform and cleaned prior to discharge. The direct release of bulk SBM was not expected to occur as part of operational drilling, although for modelling, it was presumed that a fraction of the drilling fluid (approximately 6.9% by mass of the SBM cuttings) would remain adhered to cuttings drilled with SBM. The release of these combined surface returns (cuttings and adhered SBM) was simulated from a depth of 5 meters below the sea surface at a continuous discharge rate.

The schedule provided by Chevron Canada Ltd. indicated an expected spud date of Summer, 2021. Because the drilling schedule may be delayed, a modelling strategy was developed to compare the potential differences in seabed deposits during different offshore conditions for the scheduled and alternative drilling periods. Two (2) deterministic scenarios were performed at the theoretical well location using the MUDMAP dispersion model, each covering a period of approximately two months (spanning all active drilling stages and time necessary to allow for settling of fine particles):

1. Scenario 1 - scheduled drilling period (Summer; July-August)
2. Scenario 2 - alternative drilling period (Spring; April-May)

As described in Section 1.2, strong eastward-directed currents persist near the drilling site throughout the year. RPS performed a qualitative review of the HYCOM time series between 2006-2012, comparing current statistics (speeds and directions) from each year at multiple depths for each modelled timeframe. Current trends for the two model periods during 2012 were congruent with the overall 7-year trend and were thus deemed suitable as a representative modelling period.

Table 2-1. Proposed drilling program for deep West Flemish 1 (provided by Chevron Canada Ltd.). Each row defines drilling sections beginning with the sediment-water-interface (top) down to the reservoir (bottom).

Drilling Component	Diameter (inches)	Drilling period		Drilling Duration (days)	Discharge Duration (days)	Cuttings Discharge		Drilling Fluid (Mud) Discharge[1]		Drilling Fluid Type	Release Depth[2]
		Scheduled	Alternative Scheduled			vol (m^3)	rate (m^3/d)	vol (m^3)	rate (m^3/d)		
Conductor*	42”	Summer (July-August)	Spring (April-May)	1	1	89	89	1,049	1,049	WBM	Seafloor
Surface**	26”	Summer (July-August)	Spring (April-May)	1	1	137	137	3,977	3,977	WBM	Seafloor
Intermediate	17.5”	Summer (July-August)	Spring (April-May)	10	5	233	46.5	9.32	1.86	SBM	Surface
Production	12 ¼”	Summer (July-August)	Spring (April-May)	20	10	114	11.4	4.56	0.46	SBM	Surface
Reservoir	8 ½”	Summer (July-August)	Spring (April-May)	30	15	36.6	2.4	1.46	0.1	SBM	Surface
Total				**62**	**32**	**610**		**5,041**			

Table 2-2. Proposed drilling program for shallow West Flemish 2 (provided by Chevron Canada Ltd.). Each row defines drilling sections beginning with the sediment-water-interface (top) down to the reservoir (bottom).

Drilling Component	Diameter (inches)	Drilling period		Drilling Duration (days)	Discharge Duration (days)	Cuttings Discharge		Drilling Fluid (Mud) Discharge[1]		Drilling Fluid Type	Release Depth[2]
		Scheduled	Alternative Scheduled			vol (m^3)	rate (m^3/d)	vol (m^3)	rate (m^3/d)		
Conductor*	42”	Summer (July-August)	Spring (April-May)	1	1	89	89	1,049	1,049	WBM	Seafloor
Surface**	26”	Summer (July-August)	Spring (April-May)	1	1	137	137	3,977	3,977	WBM	Seafloor
Intermediate	26” (under-reamed)	Summer (July-August)	Spring (April-May)	3	2	137	68.5	5.48	2.74	SBM	Surface
Intermediate	16”	Summer (July-August)	Spring (April-May)	10	5	195	39	7.8	1.6	SBM	Surface
Production	12 ¼”	Summer (July-August)	Spring (April-May)	20	10	114	11.4	4.56	0.46	SBM	Surface
Reservoir	8 ½”	Summer (July-August)	Spring (April-May)	30	15	36.6	2.4	1.46	0.1	SBM	Surface
Total				**65**	**34**	**620**		**5,045**			

Notes: 1. Cuttings from sections drilled with SBM were modelled with an additional 6.9% by weight to account for base fluid that was assumed to be adhered to cuttings

2. Releases were simulated at 20 m above seabed and 5 m below the sea surface

* 4 hours drilling @ 4 m^3/min pump rate = 960 m^3 + hole displacement to pad mud 89 m^3

** 16 hours drilling @ 4 m^3/min pump rate = 3840 m^3 + hole displacement to pad mud 137 m^3

2.4 Discharge Solids Characteristics

To assess the fate of drilling discharges in the marine environment it is critical to characterize the components of the released materials. The composition of the drilling mud applied will depend on the characteristics of the formation being drilled. This composition is variable and determines the density and weight of the discharged fluid, its toxicity, and the settling velocities of the material released into the water column.

A description of the specific components of the drilling fluids to be used, including the percent solid material and concentration and type of weighting materials, was provided by Chevron Canada Ltd. with the discharge schedule. The discharge solids characteristics of the drilling by-products varies greatly by each drilling section (Table 2-3).

Table 2-3. Bulk density of drilling discharges used for modelling (densities provided by Chevron Canada Ltd.).

Discharged material	Bulk density (ppg)	Bulk density (kg/m^3)	Percent solid by weight	Average SG of solid fraction
WBM cuttings	21.7	2,600	100	2.6
WBM fluids	10.2	1,222	20	3.8
SBM cuttings	22.1	2,650	100	2.65

Particle size data, along with material density, are used to estimate settling velocities for MUDMAP simulations. The size distribution of discharged solids varies as a function of the geology, the type of drilling fluid, and the treatment of cuttings. Particle size distributions (PSD) used for operational drilling simulations are presented in Table 2-4, which are broken down into 6 size classes ranging from coarse sands to fine silt-clays. Additionally, section specific PSDs are presented, allowing for the simulation of discharges resulting from unique sections separately to more accurately characterize the seabed deposition.

Given the absence of local sample data, representative size distributions based on published values were used to characterize the cuttings and fluids released during the top-hole stages. A size distribution based on WBM was used to characterize the sea surface releases of fluids (

Table 2-5). The settling characteristics are based on experimental measurements of fall velocities in seawater of different discharges from the Gulf of Mexico. The study conducted by Southwest Research Institute (SwRI; 2003) includes fall velocity tests of 10 samples with different lithologies and solids control treatment methods. The specific sample used for modelling was collected from the cutting's dryer during drilling in the Mississippi Canyon lease area.

Samples from a laser diffraction analysis were provided by Weatherford Laboratories to estimate the PSDs of cuttings resulting from Statoil Canada Ltd. et. al Bay de Verde F-67 well (2014). Samples were taken at different depths corresponding to intermediate and reservoir sections. The conductor and surface sections were also assumed from the intermediate section

The extent to which discharged drilling fluids and cuttings accumulate on the seabed is largely controlled by the particle settling velocities, which are a function of size and density, and the prevailing currents in the water column, which will transport and disperse particles within the water column. The SwRI data has been used to compare the settling characteristics for each of the materials (i.e., cuttings and muds) used as model input. The data can be used to emphasize the different behaviours of discharged materials within the water column. Cuttings, which in general are relatively large and dense, are expected to sink rapidly and mostly accumulate in a thick near-field mound close to the wellhead. By contrast, drilling fluids will remain in suspension far longer and will disperse over greater distances, having a larger influence on the pattern of far field dispersion and thinner deposition on the seabed.

Table 2-4. Particle size distribution for operational modelling simulations.

	6 COARSE SAND	5 MEDIUM SAND	4 FINE SAND	3 V. FINE SAND	2 COARSE-MEDIUM SILT	1 FINE SILTS-CLAYS
Particle diameter (mm)	0.595	0.297	0.149	0.074	0.031	0.005
Cuttings Type, Well Section	**Measured Weight Percent Material**					
WBM, conductor and surface	0.1	0.1	0.5	3.9	28.0	67.4
Barite, conductor and surface	3.1	0.0	0.0	15.0	44.0	38.0
Average PSD for conductor and surface	1.1	0.1	0.3	7.5	33.2	57.9
SBM, intermediate (445 and 311 mm)	0.1	0.1	0.5	3.9	28.0	67.4
SBM, reservoir	1.5	0.9	2.5	5.9	19.0	70.2

Table 2-5. Water based mud settling velocities (Brandsma and Smith, 1999).

Size Class	Percent Volume	Settling Velocity	
		(cm/s)	(m/day)
1	7.01	2.74E-03	2.37
2	7.99	6.10E-03	5.27
3	5.00	1.48E-02	12.77
4	10.00	3.00E-02	25.94
5	13.26	4.36E-02	37.66
6	13.26	5.12E-02	44.24
7	19.24	6.40E-02	55.30
8	19.24	8.23E-02	71.10
9	4.00	4.27E-01	368.69
10	1.00	1.12E+00	969.12

2.5 Thresholds of Concern

2.5.1 Sedimentation Effects and Thresholds

Although sediment deposition is a natural process, the rate of sedimentation is variable, depending on the oceanographic characteristics within the area. Deep sea habitats, like those in the current study, are generally characterized by low-energy currents and slow sediment accumulation rates of approximately 1 – 100 mm per thousand years (Gage and Tyler, 1991; Glover and Smith, 2003). Benthic organisms associated with these environments are generally adapted to tolerate a range of conditions and sedimentation rates. Rapid increases in sedimentation associated with mud and cuttings discharges can have direct and indirect effects on benthic infauna communities in deep sea habitats. Direct effects can include smothering, toxicity exposure, and physical abrasion. Indirect effects include habitat alterations and changes to community assemblages (DOER, 2005). The severity of sedimentation effects on organisms depends on factors including burial depth, burial rate, burial time, species-specific tolerances, the grain size of the deposited sediments, and seasonal timing (Kjeilen-Eilertsen et al., 2004). For example, higher mortality can occur in the summer than in the winter (Smit et al. 2008). Higher mortality has been observed at higher temperatures in mesocosm and lab studies of burial for mussels and gastropods, possibly due to greater oxygen demand at higher temperatures (Chandrasekara and Frid, 1998; Hutchison et al. 2016). However, there is great variability as taxonomic groups react differently and have varying levels of tolerance to sedimentation. Sessile and attached organisms typically have the lowest tolerance and highest mortality rate during sedimentation events (DOER, 2005; Gates and Jones, 2012).

Observations from previous research conducted on sedimentation and recovery of benthic infauna in Newfoundland, Canada, was used to demonstrate an increased abundance and biomass in some polychaete species and declines in others in the area around the studied drill site. Reduced abundance was observed to extend approximately 1 - 2 km from the drill site for some species (Paine et al., 2014). This aligns with findings from an extensive literature review that documented biological effects (such as changes in benthic community structure) at distances of 200 – 2,000 m from platforms using water-based drilling fluids (Ellis et al., 2012). The range of effects from synthetic-based drilling fluids was found to be somewhat smaller, with detected biological effects from 50 – 1,000 m from the drill site (Ellis et al., 2012).

Specific sedimentation thresholds tested and reported by Smit et al. (2008) indicate that epibenthic, sessile, filter-feeding species cannot survive sediment burial depths over 10 mm. Meanwhile, infauna taxa that are adapted to habitat covered in sediment may escape from burial under 100 mm of sediment or more (Kjeilen-Eilertsen et al., 2004). In a mesocosm and field study, Trannum et al. (2011) observed that 24 mm of water-based drill cuttings lowered oxygen availability and reduced abundance for macrofauna in the sediment. Overall, Smit et al. (2008) estimated that mortality of 5% of benthic organisms (including mollusks, polychaetes, and crustaceans) would occur at burial depths of 6.3 mm (3.1 – 10.6 mm) and mortality of 50% would occur at burial depths of 54 mm (37 – 79 mm).

Benthic invertebrates are broadly considered to be unaffected by nontoxic sediment burial depths less than 6.5 mm, based on tolerances to burial, oxygen depletion, and change in sediment grain size (Wood, 2018; Kjeilen-Eilertsen et al., 2004; Smit et al., 2006; 2008). However, some more sensitive species are considered more susceptible to shallower burial depths (1.5 mm), and thus 1.5 mm is suggested as a more conservative predicted no effect threshold.

Studies on the recovery of benthic infauna communities post-sedimentation present varying results. The ability of a benthic community to recover after sediment deposition depends on larval settlement, the rate of bioturbation, and sediment mixing by currents (Smit et al., 2008; Trannum et al., 2011). Because many benthic species have drifting pelagic larvae, resettlement can occur within months post-disturbance. Trannum et al. (2011) observed reestablishment of species-rich communities within six months of sedimentation and noted that the most successful colonizers were species in the Spionidae family of polychaete worms. In studies from the North Sea, recolonization of cuttings piles from the edges of the pile occurs in 1-5 years (Kjeilen-Eilertsen et al., 2004). Areas with the thickest deposition will likely rely on larval transport and resettlement for recolonization, as survival of buried organisms is unlikely. In areas with lower levels of deposition, reestablishment by surviving organisms that burrow or sift through sediment to feed is possible, as they mix mud and cuttings with native sediments and slowly return habitats to pre-drilling conditions (Smit et al., 2008; Gates and Jones, 2012).

2.5.2 Turbidity and TSS Effects and Thresholds

Smit et al. (2006, 2008) described an increase in the concentration of total suspended solids (TSS) and water column turbidity due to the discharge of drilling cuttings and fluids, which could potentially affect pelagic organisms. Particulates in drilling muds come from bentonite clay and barite, which are toxicologically inert, but can be suspended in the water column. Suspended clay particles of less than 0.01 mm diameter settle very slowly and can potentially persist in the water column for weeks or months (Smit et al., 2008).

Increased turbidity decreases the light availability for phytoplankton in the water column (IOGP, 2016). Phytoplankton were negatively affected at concentrations of 10 mg/L bentonite clay or 1,000 mg/L barite, but these concentrations are unlikely to occur in a discharge plume greater than 25 m down-current (IOGP, 2016). In general, drilling fluid and cuttings solids rapidly disperse, dilute, and settle out of the water column, which reduces the risk of adverse effects on water column organisms because exposure to elevated turbidity or TSS is intermittent and brief (IOGP, 2016).

Benthic suspension feeders (e.g., mollusks) are sensitive to mud and cuttings discharges because they are sessile organisms that cannot escape discharge plumes, and fine suspended particles interfere with feeding and growth (DOER 2005; Smit et al. 2008). Filter-feeding zooplankton and algae were also more sensitive, likely due to greater exposure in the water column from drifting with the currents and therefore with portions of the discharge plume that encounter surface currents. Benthic crustaceans and siphon-feeding mollusks were relatively insensitive to suspended particulates, likely because they have evolved to inhabit the benthic boundary layer comprising mobile sediments and water that is naturally highly turbid (Smit et al. 2008). However, the quality of data available to evaluate TSS thresholds are poor, because there are few laboratory studies on bentonite or barite suspended clays.

Synthetic non-aqueous base fluids are not considered toxic to phytoplankton, zooplankton, and other water column marine organisms (IOGP, 2016). Certain chemicals within synthetic base fluids (primary emulsifier and fluid loss agent) elicited sublethal exposure responses in biomarkers of juvenile pink snapper fish, which suggests that chronic exposure from chemicals leaching out of cuttings piles may have some effect on fish over several days (Bakhtyar and Gagnon, 2012). However, a transient exposure to drilling fluids as they pass through the water column is unlikely to be toxic to mobile pelagic organisms.

3 MODEL RESULTS

The fate of mud and cuttings released from operational drilling activities at deep West Flemish 1 and shallow West Flemish 2 were assessed using deterministic scenarios corresponding to the drilling period and discharge volumes depicted in Table 2-1. One deterministic simulation was performed for operational discharges at each of the two sites during each of the two current regimes, totalling four simulations of operational discharges. MUDMAP was used to model the trajectory of cuttings and fluid particles from operational release simulations and to track the far field dispersion for several days after the release, accounting for the prolonged settling of very fine particles from the water column. Based off the depth at West Flemish 1 (1,500 m) and West Flemish 2 (500 m), and settling velocities of the finer sediments, several days were required to allow for all particles to reach the seabed.

3.1 Operational Discharges

3.1.1 Predicted Seabed Deposition

The output of each MUDMAP simulation is a predicted concentration grid that estimates the loading to the seabed, associated with each drill section. These grids were aggregated outside of the MUDMAP model to produce maps of cumulative deposition from all discharged sections. Figure 3-1 and Figure 3-2 depict the model-predicted deposition patterns from an aerial view. Table 3-1 and Figure 3-3 summarize the cumulative areal extent of seabed deposition for operational discharge simulations >0.01 mm. Deposition thicknesses were calculated based on mass accumulation on the seabed, sediment bulk density, and the assumption of no voids (i.e., zero porosity) (Table 3-2).

The summer modelling scenarios (July to August) had more tightly confined mud/cuttings pile up to 5.3 mm, when compared to the spring simulations (Figure 3-1 and Figure 3-2). Fine blankets of sediment are predicted to extend radially away from the wellhead during the summer conditions and are predicted to extend much further to the east during the spring timeframe. Because the spring scenario (April to May) had more extensive spreading to the east, subsequently thinner depositional thicknesses were predicted near the wellhead and further away. In both cases, deposition of muds and cuttings exceeding 1 mm was predicted to remain confined within 1 km from the drilling site (Figure 3-1 and Figure 3-2) and cover less than 2.545 km^2 (Table 3-1). Depositional thicknesses at or above the predicted no effect concentration threshold of 6.5 mm (Smit et al., 2008) were not predicted to occur in either deep or shallow scenarios. These low thicknesses can likely be attributed to the extremely long settling times for the finer silts/clays, which make up the majority of the cuttings. In addition, due to the relatively low settling velocities of cuttings drilled with SBM and the depth over which it needs to settle (500-1,500 m), no measurable thicknesses were reported above 0.1 mm for surface releases as they dispersed through the water column.

When comparing the different drilling periods, the predicted areal extent of deposition for the spring drilling period (April to May) was larger than the summer drilling period (July to August) for thicknesses less than 0.5 mm (Table 3-1). Stronger currents during the spring period were predicted to transport the cuttings and mud particles further from the discharge site allowing for more dispersion before settling. This resulted in a larger overall footprint, however the thicknesses over this larger area were predominantly less than then 0.5 mm. Due to the increased dispersion during spring, footprints for thicknesses greater than 0.5 mm were also decreased compared to those in the summer.

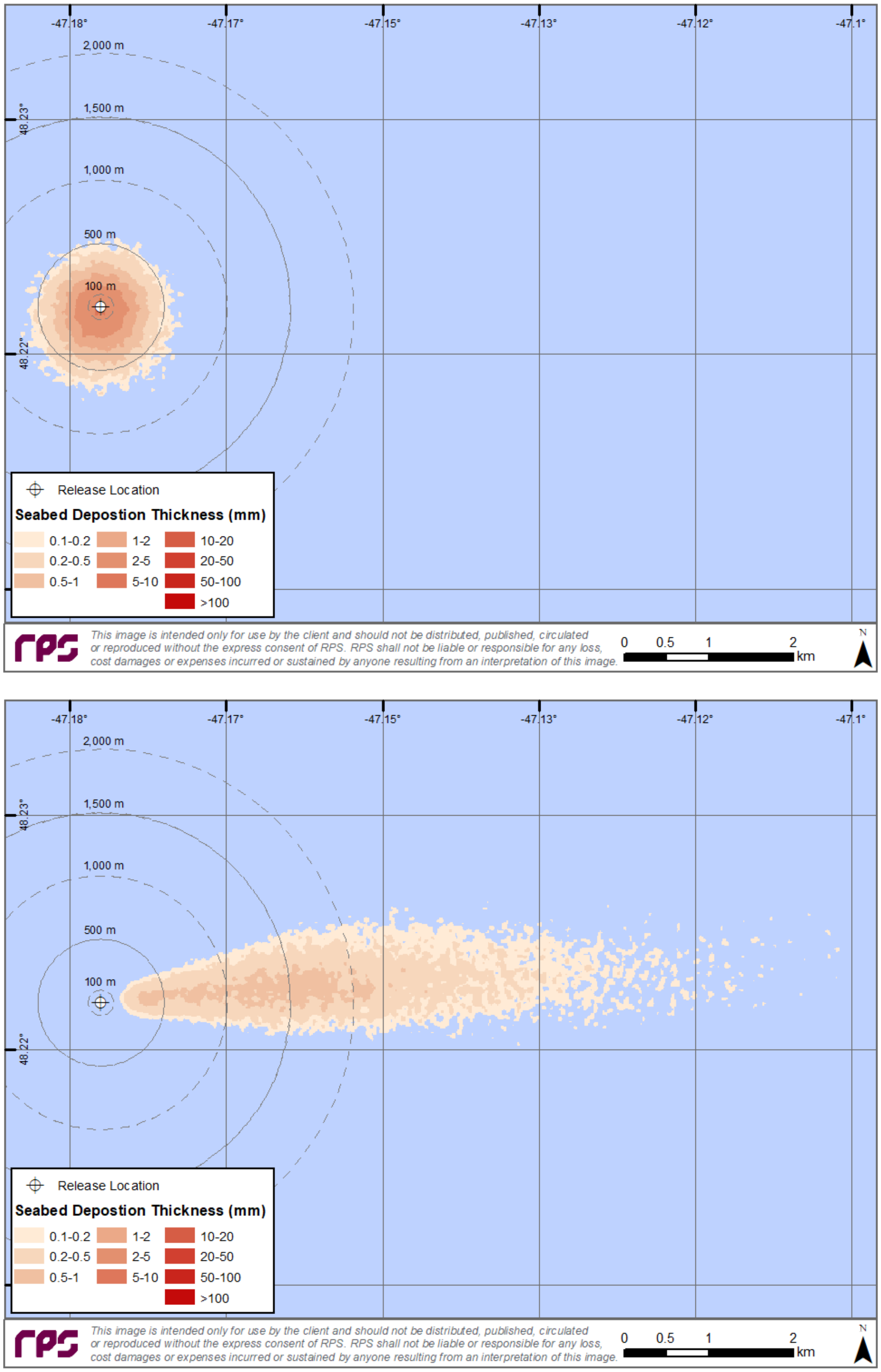


Figure 3-1. Predicted thickness of seabed deposition of discharged mud and cuttings resulting from all drilling sections during the scheduled summer (top) drilling period and during the alternative scheduled spring (bottom) drilling period at deep West Flemish 1.

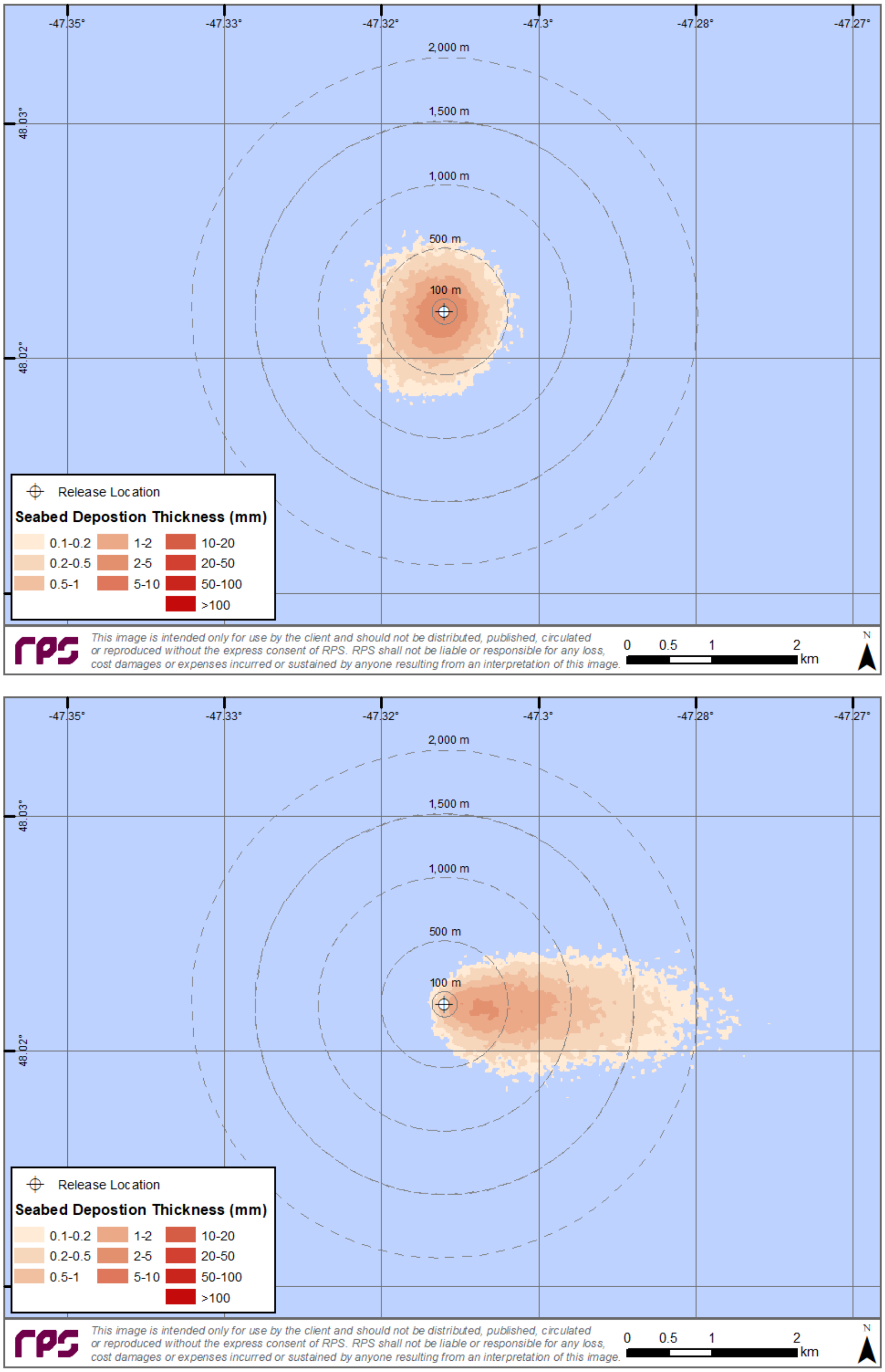


Figure 3-2. Predicted thickness of seabed deposition of discharged mud and cuttings resulting from all drilling sections during the scheduled summer (top) drilling period and during the alternative scheduled spring (bottom) drilling period at shallow West Flemish 2.

Table 3-1. Areal extent of predicted seabed deposition (by thickness interval) for operational discharge simulations in early spring and summer.

Deposition Thickness (mm)	Cumulative Area Exceeding (km²)			
	West Flemish 1 (deep)		West Flemish 2 (shallow)	
	Summer	Spring	Summer	Spring
>0.1	1.0506	2.5455	1.1611	1.6399
>0.2	0.7847	1.3702	0.8415	1.1056
>0.5	0.4648	0.2910	0.4752	0.5489
>1	0.2765	0.0000	0.2708	0.2572
>2	0.1356	0.0000	0.1206	0.0246
5-6.5	0.0044	0.0000	0.0001	0.0000
Maximum Thickness (mm)	**5.27**	**0.94**	**5.00**	**2.38**

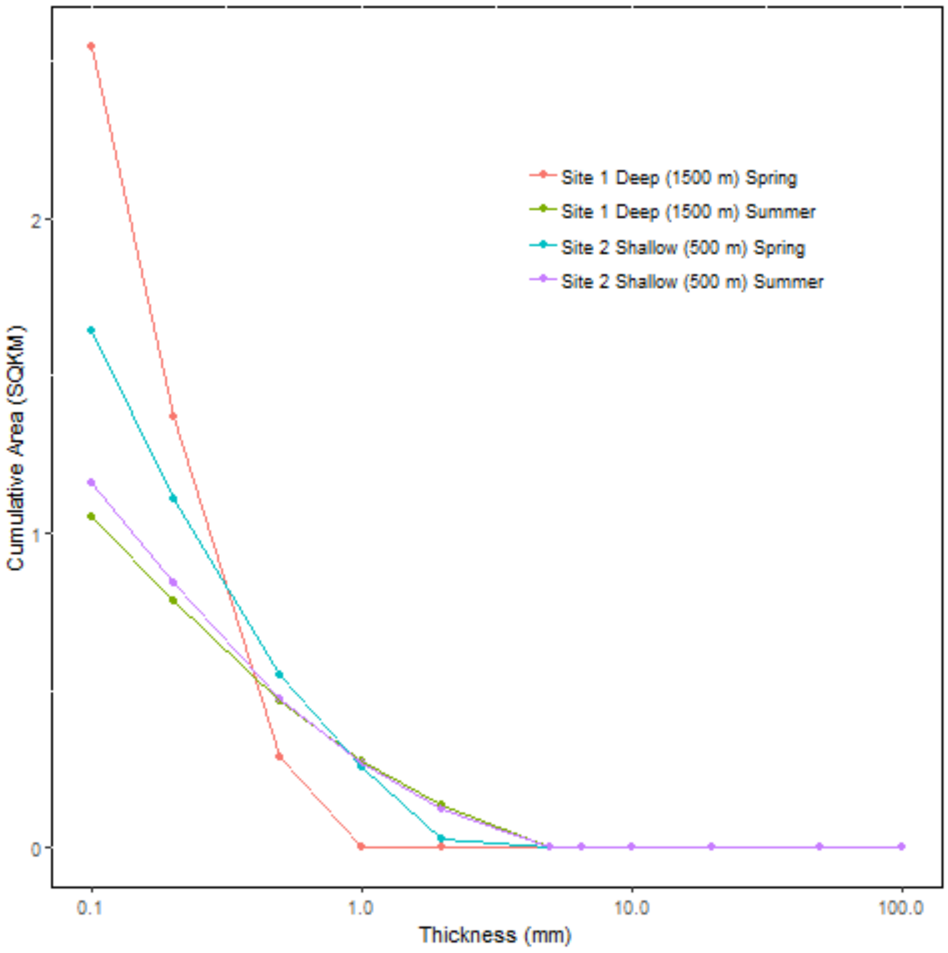


Figure 3-3 Cumulative areal extent of predicted seabed deposition for operational discharge simulations in Scheduled (Summer) and Alternative Scheduled (Spring) drilling periods.

Table 3-2. Maximum distance of thickness contours (distance from release site) predicted for operational discharge simulations.

Deposition Thickness (mm)	**Maximum extent from release site (km)**			
	West Flemish 1 (deep)		**West Flemish 2 (shallow)**	
	Cumulative Summer	Cumulative Spring	Cumulative Summer	Cumulative Spring
0.1-1	0.76	7.92	0.81	2.57
1-6.5	0.37	0	0.35	0.98

4 DISCUSSION AND CONCLUSIONS

In each modeled case, the deposition of muds and cuttings from operational discharges onto the seabed was controlled by the settling velocity of particles, the currents within the water column, and the depth of the water column. Modelled operational discharges from West Flemish 1 (1,500 m) and West Flemish 2 (500 m) were predicted to produce a spatially confined depositional areas of 1-2.5 km^2 above 0.1 mm, depending on the site and timeframe, with a maximum thickness of up to 5.3 mm. The difference in depth between both sites did not influence the seabed deposition patterns, because only the riserless sections (released at seabed) contributed to measurable thicknesses on the seafloor. Slow settling velocities associated with the fine silts/clays, which make up the dominant fraction of the cuttings drilled with SBM, allowed for greater dispersion before settling out.

Summer simulations for both sites had weaker subsurface current regimes, which led to footprints extending radially from the discharge site at higher thicknesses. Depositional thicknesses above 0.1 mm were predicted to extend radially approximately 760-810 m during the summer due to low dispersion by weak subsurface currents. Maximum depositional thicknesses of 5.3 and 5.0 mm were predicted for West Flemish 1 and West Flemish 2, respectively, covering an area of approximately 1.1 km^2.

Spring simulations for both sites were subject to stronger seabed currents associated with the spring timeframe, and predicted depositional footprints were elongated, extending much further to the east from the sites. Depositional thicknesses above 0.1 mm were predicted to extend upwards of 2.6 km for the shallow West Flemish 2 and as much as 7.9 km for the deeper West Flemish 1. Because of this increased dispersion, the maximum thickness was predicted to be 2.38 km^2 with a cumulative area of 1.6 km^2 above 0.1 mm for West Flemish 2 and 0.94 mm with a cumulative area of 1.6 km^2 above 0.1 mm for West Flemish 1.

The variations within predicted results between simulations were due to three main factors including: 1) settling velocity associated with different releases, 2) current patterns (i.e. velocity) and 3) release height relative to the seabed. The discharges modelled in this study may be considered representative of other potential discharges in the Project Area, as the depth of the sites (500 to 1500 m) are similar in depth to other potential sites within the Project Area. While this dispersion modelling targeted the most likely drilling windows for the Project (April to May and July to August), the predicted results are applicable outside of this temporal window.

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APPENDIX A: MUDMAP MODEL DESCRIPTION

MUDMAP is a personal computer-based model developed by RPS (ASA at the time of creation) to predict the near and far-field transport, dispersion, and bottom deposition of drill muds and cuttings and produced water (Spaulding et al; 1994). In MUDMAP, the equations governing conservation of mass, momentum, buoyancy, and solid particle flux are formulated using integral plume theory and then solved using a Runge Kutta numerical integration technique. The model includes three stages:

> Stage 1: **Convective decent/jet stage** – The first stage determines the initial dilution and spreading of the material in the immediate vicinity of the release location. This is calculated from the discharge velocity, momentum, entrainment and drag forces.
>
> Stage 2: **Dynamic collapse stage** – The second stage determines the spread and dilution of the released material as it either hits the sea surface or sea bottom or becomes trapped by a strong density gradient in the water column. Advection, density differences and density gradients drive the transport of the plume.
>
> Stage 3: **Dispersion stage –** In the final stage the model predicts the transport and dispersion of the discharged material by the local currents. Dispersion of the discharged material will be enhanced with increased current speeds and water depth and with greater variation in current direction over time and depth.

MUDMAP is based on the theoretical approach initially developed by Koh and Chang (1973) and refined and extended by Brandsma and Sauer (1983) and Khondaker (2000) for the convective descent/ascent and dynamic collapse stages. The far-field, passive diffusion stage is based on a particle based random walk model. This is the same random walk model used in RPS' OILMAP spill modelling system (ASA, 1999).

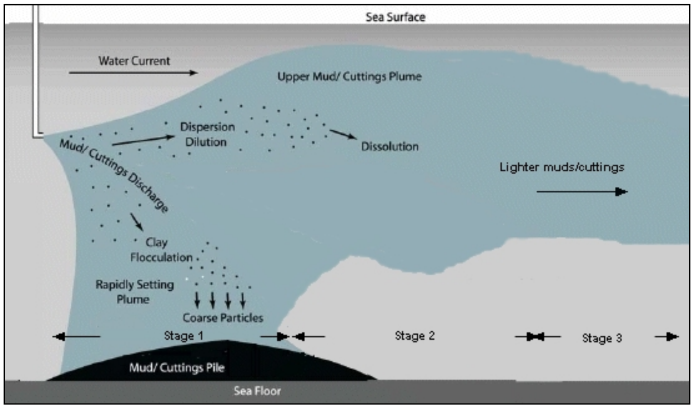

Figure A1. Conceptual diagram depicting the general behavior of cuttings and muds following discharge to the ocean and the three distinct discharge phases (after Neff 2005).

The model's output consists of calculations of the movement and shape of the discharge plume, the concentrations of soluble (i.e. oil in produced water) and insoluble (i.e. cuttings and muds) discharge components in the water column, and the accumulation of discharged solids on the seabed. The model predicts the initial fate of discharged solids, from the time of discharge to initial settling on the seabed As MUDMAP does not account for resuspension and transport of previously discharged solids, it provides a conservative estimate of the potential seafloor concentrations (Neff 2005).

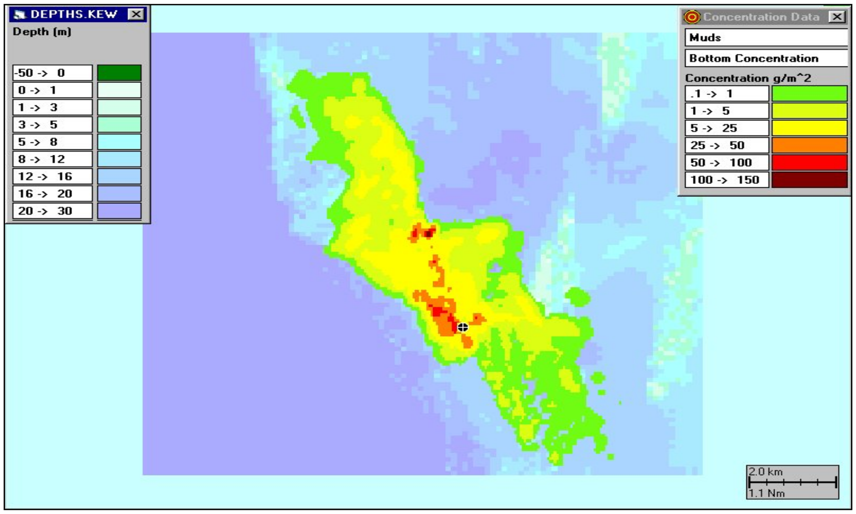

Figure A2 Example MUDMAP bottom concentration output for drilling fluid discharge.

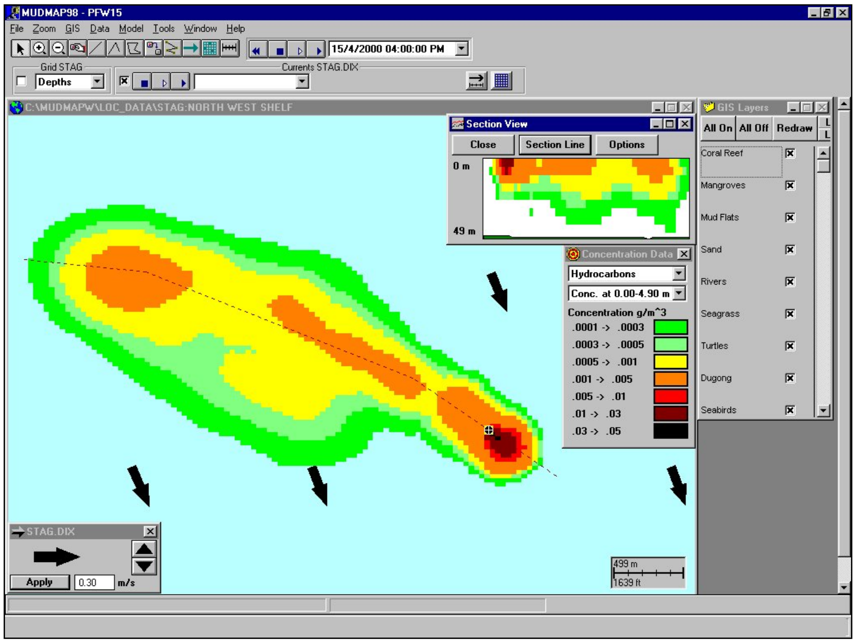

Figure A3. Example MUDMAP water column concentration output for drilling fluid discharge.

MUDMAP uses a color graphics-based user interface and provides an embedded geographic information system, environmental data management tools, and procedures to input data and to animate model output. The system can be readily applied to any location in the world. Application of MUDMAP to predict the transport and deposition of heavy and light drill fluids off Pt. Conception, California and the near-field plume dynamics of a laboratory experiment for a multi-component mud discharged into a uniform flowing, stratified water column are presented in Spaulding et al. (1994). King and McAllister (1997, 1998) present the application and extensive verification of the model for a produced water discharge on Australia's northwest shelf. GEMS (1998) applied the model to assess the dispersion and deposition of drilling cuttings released off the northwest coast of Australia.

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APPENDIX D

Acoustic Model

Underwater Sound Associated with Exploration Drilling Offshore Eastern Newfoundland

Chevron's West Flemish Pass Project

Submitted to:
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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

Contents

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1. Introduction

JASCO Applied Sciences (JASCO) undertook an acoustic propagation modelling study for Stantec Consulting Ltd. (Stantec) to predict underwater sound levels associated with an offshore exploration drilling program within license block EL-1138. (Figure 1). The EL-1138 block is located off Eastern Newfoundland in the Flemish Pass area.

The exploration program will require drilling and Vertical Seismic Profiling (VSP) to be performed. These activities will introduce acoustic noise into the water, which could potentially disturb marine mammals. At the time of this modelling study, the exact equipment had not been finalized. JASCO identified the specific equipment models that are commonly used for such activities.

The following operations and associated sound sources were modelled:

- Vertical Seismic Profiling: seismic airgun array
- Drilling: drilling platform/vessel (drillship) maintaining position with a dynamic positioning (DP) system.

The goal of the modelling study was to estimate the root-mean-square (rms) pressure level, referred to as sound pressure level (SPL), sound exposure level over a 24 h period (SEL_{24h}), and peak sound pressure level (PK) for the seismic source only.

The acoustic characteristics of the airgun array used for the seismic survey were modelled with JASCO's Airgun Array Source Model (Section 2.1), which accounts for individual airgun volumes and the array geometry. The source levels of the vessel were estimated based on the field measurements of a similar vessel.

The acoustic propagation modelling for the purpose of assessing SEL_{24h} field was conducted with JASCO's Marine Operations Noise Model (Section 2.2.1) for the ranges up to 50 km from a sound source in the frequency 10 to 25,000 Hz range for the seismic source and in the frequency 10 to 50,000 Hz range for the drillship. Sound propagation modelling for the purpose of calculating peak sound pressure level was conducted using a full waveform modelling approach up to 20 km from the acoustic source in the 9 to 891 Hz frequency band.

The acoustic field was modelled at one site within block EL-1138. The modelling was performed for the sound speed profile in the water column for May (Section 3.1). Schlumberger Dual Magnum 2400 in^3 airgun array was used as a proxy seismic source. *Seadrill West Sirius* semi-submersible platform was used as proxy for the drillship.

The SEL_{24h} and PK were assessed against the threshold levels for the onset of Permanent Threshold Shift (PTS) relevant to marine mammal groups using respective marine mammal auditory weighting functions (M-weighting functions) as per Southall et al. (2007) and National Marine Fisheries Service (NMFS 2018).

Section 2 details the methodology for predicting the source levels (Section 2.1) and modelling the sound propagation (Section 2.2). Section 3 describes the input parameters for the propagation modelling: the assumed environmental parameters (Section 3.1), receiver geometry (Section 3.2), and the specifications and derived source levels of the acoustic sources (Section 3.3). Section 4 presents results as sound field contour maps and tables of ranges to PTS-onset threshold levels. Appendix A explains the metrics used to represent underwater acoustic fields, and Appendix B presents the impact criteria considered.

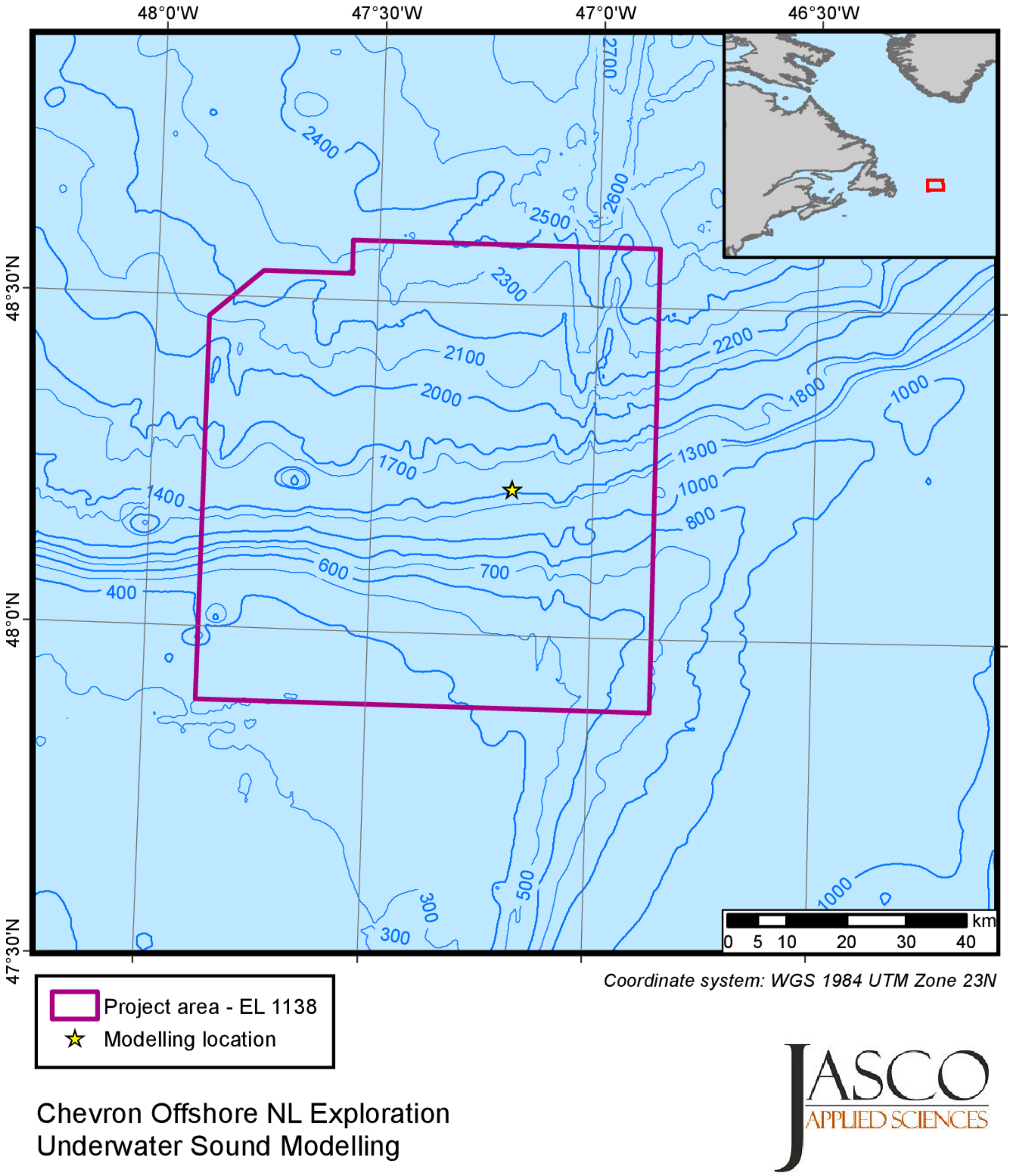


Figure 1. Project area overview. Blue contours indicate water depth in meters.

2. Methods

The underwater acoustic fields were predicted by first modelling the source level function and then modelling the pressure wave propagation around the source.

JASCO employed several acoustic source function models and acoustic wave propagation models. The models were selected based on the characteristics of the sound sources and the required output. The models incorporated parameters specific to the modelled source and the environment.

2.1. Acoustic Source Models

2.1.1. Seismic source

The energy source levels and directivity of the airgun array were predicted with JASCO's Airgun Array Source Model (AASM). This model is based on the physics of the oscillation and radiation of airgun bubbles as described by Ziolkowski (1970). The model solves the set of parallel differential equations that govern bubble oscillations. AASM also accounts for non-linear pressure interactions between airguns, port throttling, bubble damping, and Generated Injection (GI) airgun behavior, as discussed by Dragoset (1984), Laws et al. (1990), and Landro (1992). AASM includes four empirical parameters that are tuned so that the model output matches observed airgun behavior. The model parameters were fit to a large library of empirical airgun data using a "simulated annealing" global optimization algorithm (Černý 1985). These airgun data consist of measured signatures of Bolt 600/B airguns that range in volume from 5 to 185 in^3; the provided sampling rate of the time series was 50 kHz (Racca and Scrimger 1986).

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted deterministically. Therefore, the high-frequency module of AASM uses a stochastic simulation to predict the sound emissions of individual airguns above 800 Hz, using a multivariate statistical model. This model is based on a statistical analysis of a large library of high quality seismic source signature data obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo method to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of notional signatures for each airgun element based on:

- Array spatial layout
- Volume, tow depth, and operating pressure of each airgun
- Interactions between airguns in the array

Notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions between the air bubbles created by adjacent airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in the horizontal plane. This far-field[1] array signature is filtered into 1/3-octave passbands to compute the energy source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth). It can then be treated as a point source in the far-field.

---

[1] The far-field is the zone where, to an observer, sound originating from a spatially distributed source appears to radiate from a single point. The distance to the acoustic far field increases with frequency.

A seismic array consists of many sources and the point-source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{nf} < \frac{l^2}{4\lambda} \tag{1}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, an airgun array length of $l \approx 16$ m yields a near-field range of 85 m at 2 kHz and 17 m at 100 Hz. Beyond R_{nf}, it is assumed that an array radiates like a directional point source and is treated as such for propagation modeling.

The AASM accurately predicts the energy source level of each complete array as a point source for the purpose of acoustic propagation modeling in the far-field; however, predicted energy source levels for 0 to peak SPL and SEL metrics could be higher than the possible maximum levels during the array operation even within the array. AASM accounts for the effects of source depth on bubble interactions, the surface-reflected signal (i.e., surface ghost) is excluded from the far-field source signatures. The propagation models account for surface reflections, a property of the medium rather than the source.

The separations between individual elements of the array in the horizontal plain create directionality in overall acoustic emissions. Generally, this directivity is prominent mainly at frequencies in the mid-range of several tens to several hundreds of hertz; at lower frequencies, where acoustic wavelengths are much larger than the inter-airgun separation distances, directivity is small. At higher frequencies the pattern of lobes becomes too finely spaced to be resolved and the effective directivity is less.

The AASM model can predict the far-field airgun array signature in the frequency range from 10 to 25,000 Hz.

2.1.2. Vessel

Underwater sound that radiates from vessels is produced mainly by propeller and thruster cavitation, with a smaller fraction of sound produced by sound transmitted through the hull, such as by engines, gearing, and other mechanical systems. Sound levels tend to be the highest when thrusters are used to position the vessel and when the vessel is transiting at high speeds. A vessel's sound signature depends on the vessel's size, power output, propulsion system, and the design characteristics of the given system (e.g., blade shape and size). A vessel produces broadband acoustic energy with most of the energy emitted below a few kilohertz. Sound from onboard machinery, particularly sound below 200 Hz, dominates the sound spectrum before cavitation begins—normally around 8–12 knots on many commercial vessels (Spence et al. 2007). Under higher speeds and higher propulsion system loads, the acoustic output from the cavitation processes on the propeller blades dominates other sources of sound on the vessel (Leggat et al. 1981) in the broadband. However, with introduction of the criteria that rely on weighted spectrum it is important to account for the acoustic energy at higher frequencies.

Another common approach for defining the source levels for vessels is to use field measurements from a similar vessel of the same type (a "surrogate" vessel) while involved in a similar activity. The measured relative spectrum levels are taken unchanged, while the broadband level is adjusted to account for any difference in the total propulsion power between the surrogate vessel and the vessel of interest.

This modelling study applied a hybrid method of vessel source level estimation that involves calculation of the sound levels from the cavitating propeller and estimations based on the surrogate vessel approach. The resultant source level spectrum for the vessel that was used in this study was the maximum of the values provided by the two methods in each band.

2.1.2.1. Sound levels from cavitating propeller

The sound power from the propellers is proportional to the number of blades, the propeller diameter, and the propeller tip speed (Leggat et al. 1981).

Based on an analysis of acoustic data, Ross (1976) provided the following formula for the sound levels from a vessel's propeller, operating in calm, open ocean conditions:

$$L_{100} = 155 + 60\log_{10}(u/25) + 10\log_{10}(B/4)\,, \tag{2}$$

where L_{100} is the spectrum level at 100 Hz, u is the propeller tip speed (m/s), and B is the number of propeller blades. Equation 2 gives the total energy produced by the propeller cavitation at frequencies between 100 Hz and 10 kHz. This equation is valid for a propeller tip speed between 15 and 50 m/s. The spectrum is assumed to be flat below 100 Hz. Its level is assumed to fall off at a rate of −6 dB per octave above 100 Hz (Figure 2).

Another method of predicting the source level of a propeller was suggested by Brown (1977). For propellers operating in heavily loaded conditions, the formula for the sound spectrum level is:

$$\mathrm{SL}_B = 163 + 40\log_{10} D + 30\log_{10} N + 10\log_{10} B - 20\log_{10} f + 10\log_{10}(A_c/A_D)\,, \tag{3}$$

where D is the propeller diameter (m), N is the propeller revolution rate per second, B is the number of propeller blades, A_C is the area of the blades covered by cavitation, and A_D is the total propeller disc area. Similar to Ross's approach, the spectrum below 100 Hz is assumed to be flat. Tests with a naval propeller operating at off-design heavily loaded conditions showed that Equation 3 should be used with a value of $\mathrm{A_C}/\mathrm{A_D} = 1$ (Leggat et al. 1981).

If a vessel is equipped with multiple thrusters, the combined source level for a group of thrusters operating together can be estimated using the formula:

$$\mathrm{SL}_{\mathrm{total}} = 10\log_{10}\textstyle\sum_i 10^{\mathrm{SL}_i/10}\,, \tag{4}$$

where $\mathrm{SL}_{1,\ldots,N}$ are the source levels of individual thrusters. If a vessel is equipped with all the same type of thrusters (the source levels are equal), the combined source level can be estimated using the formula:

$$\mathrm{SL}_N = \mathrm{SL} + 10\log_{10} N\,, \tag{5}$$

where N is the total number of thrusters of the same type.

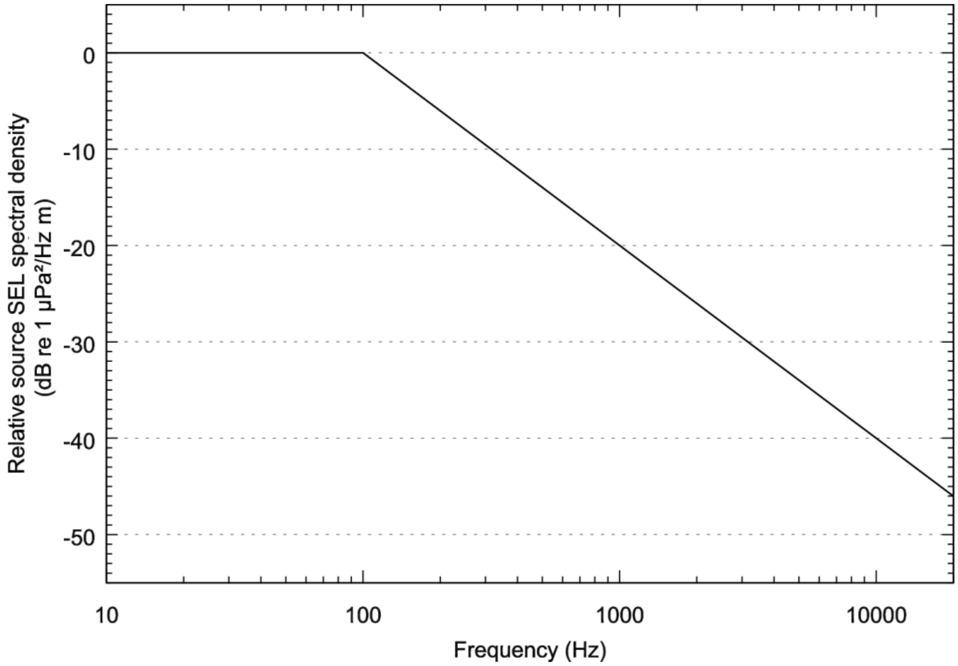


Figure 2. Estimated sound spectrum from a cavitating propeller (Leggat et al. 1981).

2.1.2.2. *Estimating source levels using the "surrogate" vessel approach*

The second common approach for defining the source levels for vessels is to use field measurements completed on a similar vessel of the same type ("surrogate" vessel) involved in a similar activity. The measured spectrum is taken unchanged while the broadband source level is adjusted to account for any difference in the total propulsion power between the reference vessel and the vessel of interest. The adjusted broadband source level is calculated as:

$$SL = SL_{ref} + 10\log_{10}\left({}^{P}/_{P_{ref}}\right), \tag{6}$$

where SL_{ref} is the broadband source level of the surrogate vessel, and P and P_{ref} are the total propulsion power of the vessel of interest and the surrogate vessel, respectively. The relative source level spectrum of the surrogate vessel is left unchanged.

2.2. Sound Propagation Modelling

The sound field around a source can be estimated using two approaches: modelling in bands (usually in decidecade bands) and full waveform modelling. In the decidecade band modelling approach, the sound propagation modelling is performed only for the central frequencies of each band. Only 35 individual frequency modelling runs are required for covering the frequency range from 10 Hz to 25 kHz. For the full waveform approach, the propagation modelling has to be performed for individual frequencies with a constant step across the entire modelled frequency range.

The modelling in bands approach is suitable for efficiently modelling a wide frequency range of the SPL field from continuous sound sources and SEL field from both continuous and impulsive sources.

The full waveform approach, which is much more computationally intensive, outputs a synthetic pressure time domain series that allows direct calculation of metrics such as SPL and PK level for impulsive sources.

2.2.1. Energy propagation loss modelling using the decidecade band approach

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analyzing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into decidecade bands, which are approximately one-third of an octave (base 2) wide and often referred as 1/3-octave-bands. Each octave represents a doubling in sound frequency. The centre frequency of the ith band, $f_c(i)$, is defined as:

$$f_{\mathrm{c}}(i) = 10^{\frac{i}{10}} \tag{7}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith band are defined as:

$$f_{\mathrm{lo},i} = 10^{\frac{-1}{20}} f_{\mathrm{c}}(i) \quad \text{and} \quad f_{\mathrm{hi},i} = 10^{\frac{1}{20}} f_{\mathrm{c}}(i) \tag{8}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure 3).

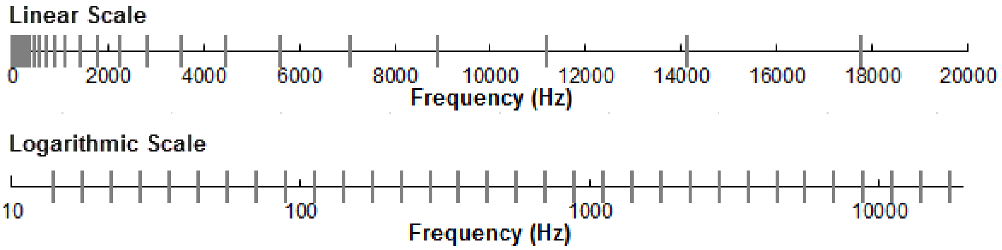


Figure 3. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

2.2.1.1. Propagation loss modelling

The propagation of sound through the environment can be modeled by predicting the acoustic propagation loss—a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which propagation loss occurs. Propagation loss also happens when the sound is absorbed and scattered by the seawater, and absorbed scattered, and reflected at the water surface and within the seabed. Propagation loss depends on the acoustic properties of the ocean and seabed; its value changes with frequency.

If the acoustic energy source level ($L_{\mathrm{S},E}$), expressed in dB re 1 µPa²m²s, and energy propagation loss ($N_{\mathrm{PL},E}$), in units of dB, at a given frequency are known, then the received level ($L_{E,p}$) at a receiver location can be calculated in dB re 1 µPa²s by:

$$L_{E,p}(r) = L_{\mathrm{S},E} - N_{\mathrm{PL},E}(r)\,, \tag{9}$$

where r is the range of the receiver from the source.

JASCO's MONM predicts underwater sound propagation (i.e., propagation loss) at frequencies from 10 to 25,000 Hz. MONM employs two underlaying subroutines: MONM-RAM is used for propagating acoustic waves at low frequencies (up to 2000 Hz) and MONM-BELLHOP is used for high frequencies (above 2000 Hz).

MONM-RAM computes acoustic propagation via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for an elastic seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM-RAM accounts for the additional reflection loss at the seabed due to partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM-RAM incorporates the following site-specific environmental properties: a modeled area bathymetric grid, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

MONM-BELLHOP employs Gaussian beam acoustic ray-trace model (Porter and Liu 1994). This version of MONM accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). The former type of sound attenuation is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results. MONM-BELLHOP incorporates the following site-specific environmental properties: a modeled area bathymetric grid, underwater sound speed as a function of depth, average temperature and salinity in the water column for calculating the sound attenuation due to energy absorption, and geoacoustic properties of the surficial sediments.

The accuracy of MONM's predictions have been validated against experimental data from several sound source verification programs conducted by JASCO (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).

The propagation loss values calculated for each individual band are subject to range averaging that replaces frequency averaging (Harrison and Harrison 1995, Siderius and Porter 2006). The range averaging technique allows us to increase the accuracy with which propagation loss function calculated for single frequency matches the band average propagation loss calculated using 1 Hz step frequency propagation loss functions.

2.2.1.2. *Summing over decidecade bands*

In case the source emits acoustic energy that spans across multiple frequency bands, the composite broadband received SEL can be computed by summing the received decidecade band levels (provided in dB units):

$$L_E = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right). \tag{10}$$

If frequency weighed SEL is required ($L_{E,\mathrm{MW}}$) for the impact assessment with criteria thresholds (Appendix B), it can be obtained by adding the relative levels (MW) to the equation:

$$L_{E,\mathrm{MW}} = 10 \cdot \log_{10} \sum_{i=1}^{N} 10^{(L_E,i+\mathrm{MW}_i)/10}\ . \tag{11}$$

2.2.2. Full waveform modelling

For impulsive sounds, time-domain representations of the pressure waves generated in the water are required for calculating SPL and PK. The synthetic pressure waveforms can be computed using Full Waveform Rangedependent Acoustic Model (FWRAM), which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM-RAM (Section 2.2.1.1). FWRAM computes synthetic pressure waveforms (Figure 4) for virtual receivers placed at various ranges from the source and through the water column. The computations occur for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM-RAM (bathymetry, water sound speed profile, and seabed geoacoustic profile). FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to further increase accuracy of the sound propagation modeling from a spatially distributed source (MacGillivray and Chapman 2012).The FWRAM modelling method requires propagation modelling to be performed at frequencies with constant step across the entire frequency range of interest. The frequency step (Δf) is defined by the necessary length of the time series (t):

$$\Delta f = {}^{1}/_{t}\,. \tag{12}$$

Therefore, to produce a 2 second long time series, the modelling frequency step needs to be 0.5 Hz, and for 0.5 second long time series–2 Hz step.

Full waveform modelling is substantially more computationaly extensive compared to the propagation loss in bands modelling approach. It is performed within a narower frequency band with practical top limit at 2000 Hz and fewer modelling profiles. Because most acoustic energy emmited by a seismic source is below 500 Hz and SPL and PK is calculated on an unweighted field, the exclusion of higher frequencies does not affect the accuracy of the levels in these metrics.

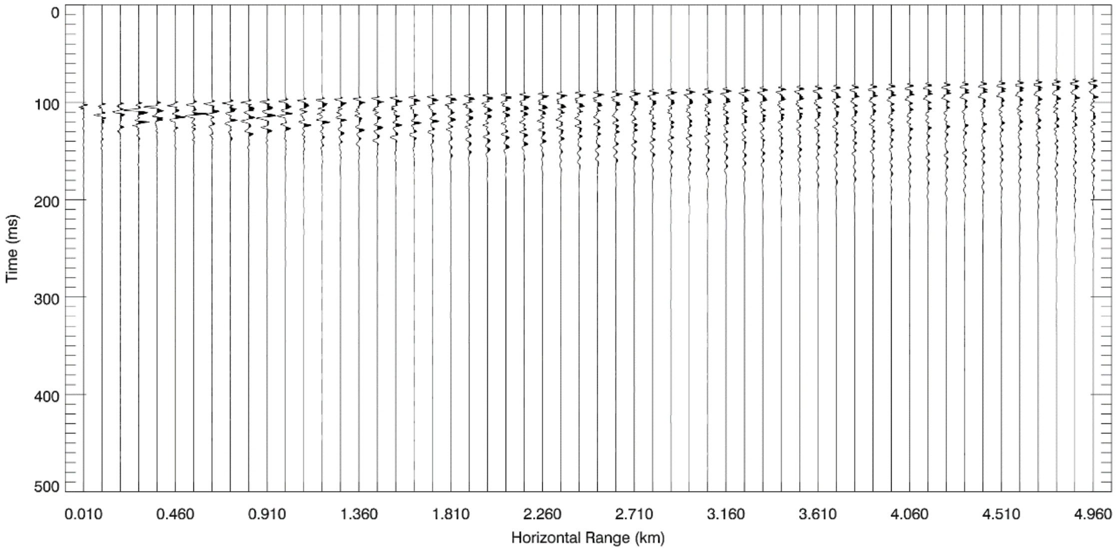


Figure 4. Example of synthetic pressure waveforms computed by FWRAM.

2.2.3. *N*×2-D volume approximation and maximum-over-depth sampling

The sound propagation models employed for this project are limited to two-dimensional (2-D) acoustic propagation. The calculations of the acoustic fields in three dimensions is achieved by propagating the acoustic field within 2-D vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as *N*×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding $N = 360°/\Delta\theta$ number of planes (Figure 5).

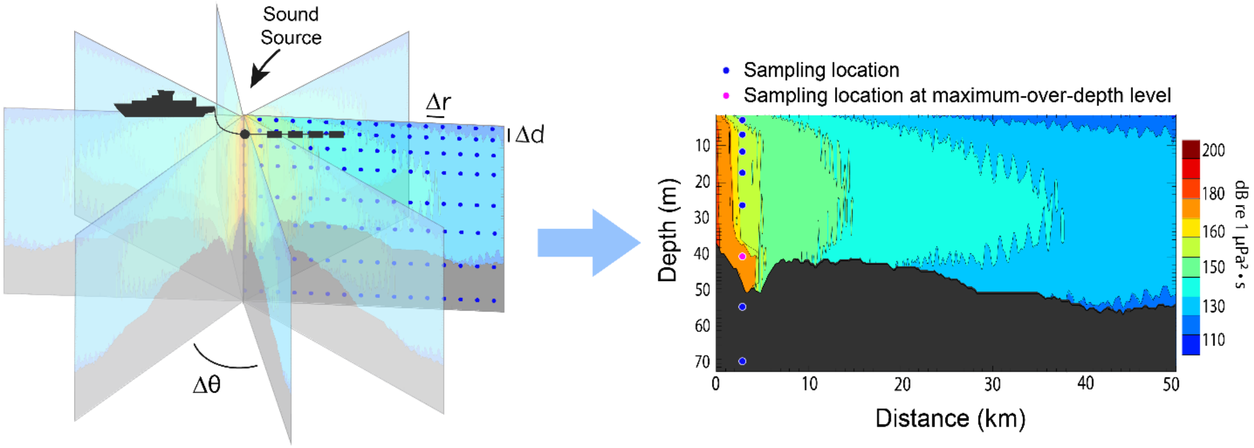


Figure 5. The *N*×2-D and maximum-over-depth modelling approach.

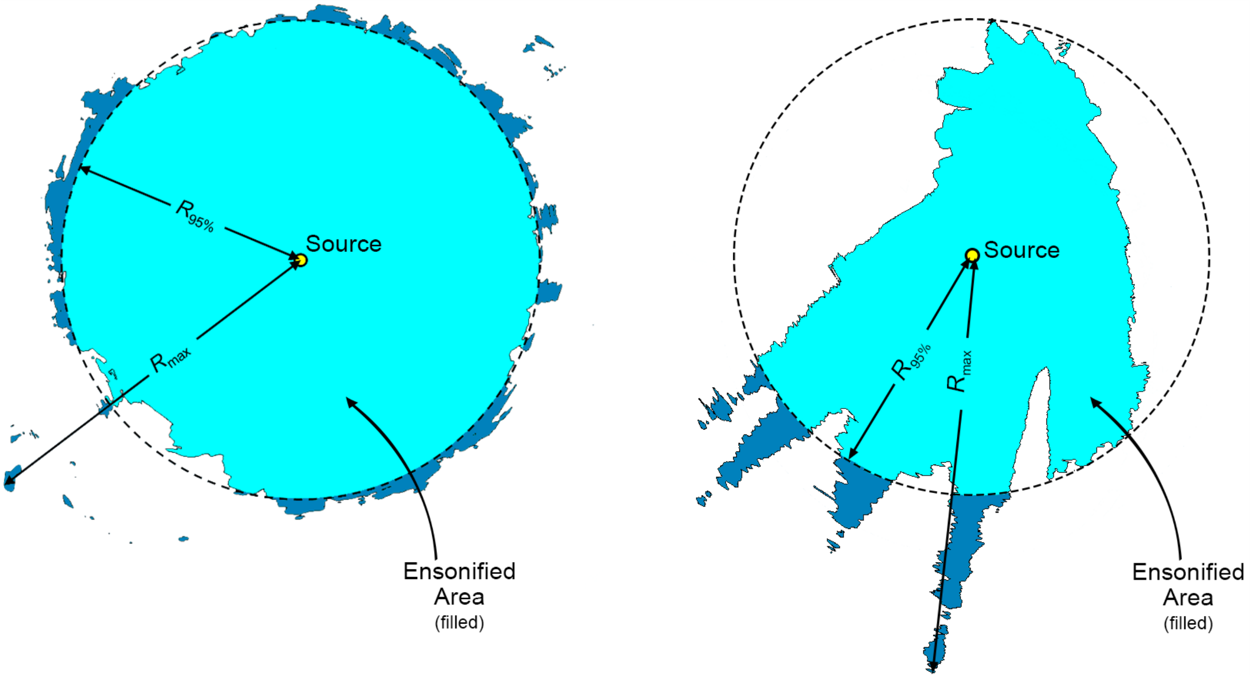
The received sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size (Δ*r* in Figure 5). At each sampling range along the surface, the sound field is sampled at various depths (Δ*d* in Figure 5), with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received acoustic levels at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received level. These maximum-over-depth acoustic levels are further used to calculate the ranges to specific thresholds and create acoustic field maps.

2.2.1. Calculating isopleth contours and ranges to threshold levels from acoustic fields

The output from received level modelling after reducing the vertical dimension using maximum-over-depth rule is a series of data points along radials originating at the source, i.e., in polar coordinates system. The data are interpolated onto a Cartesian grid. The isopleth contours and ranges to specific thresholds are both calculated from the acoustic field grids.

For the threshold level ranges, two distances relative to the source are reported: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after 5% of the farthest points were excluded (see examples in Figure 6).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure 6(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure 6(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.



(a) (b)

Figure 6. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two contrasting scenarios. (a) a largely radially symmetric sound level contour with small protrusions, for which $R_{95\%}$ best represents the ensonified area; and (b) a strongly asymmetric sound level contour with long protrusions, for which R_{max} best represents the ensonified areas in some directions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the ensonified areas beyond $R_{95\%}$ that determine R_{max}.

3. Model Parameters

3.1. Environmental Parameters

The water depths within the Project Area range from 400 to 2000 m. The acoustic propagation modelling was performed at a site near the proposed well (Figure 1). The site coordinates are provided in Table 1.

Table 1. Modelling site parameters.

Site	Geographic coordinates	UTM coordinates (Zone 23 North)	Water depth at source (m)
1	48°13'20" N 47°11'00" W	338000E 5343000N	1440

3.1.1. Bathymetry

Water depths throughout the modelled area were obtained from digital bathymetry grid SRTM15+ (Smith and Sandwell 1997, Becker et al. 2009). The bathymetry grid has a resolution of 15 arc-seconds (~330 × 460 m at the studied latitude). The data were extracted for a 600 × 400 km area and re-gridded onto a Universal Transverse Mercator (UTM) Zone 23 coordinate projection with a regular grid spacing of 200 × 200 m.

3.1.2. Geoacoustics

The geoacoustic properties of surficial layers depend on the sediment type. As the porosity decreases, the compressional sound speed, sediment bulk density, and compressional attenuation increase. MONM assumes a single geoacoustic profile of the sea bottom for the entire modelling area.

MONM used the following geoacoustic properties of the sediments:

- Bulk density (g/cm^3),
- Compressional-wave (or P-wave) speed (m/s),
- P-wave attenuation in decibels per wavelength (dB/λ),
- Shear-wave (or S-wave) speed (m/s), and
- S-wave attenuation in decibels per wavelength (dB/λ).

The geoacoustic parameters were calculated using a sediment grain-shearing model (Buckingham 2005), which computes the acoustic properties of the sediments from porosity and grain-size measurements. The grain size and the porosity variation with depth were estimated based on the expected bottom sediment type (silt). Table 2 presents the full set of geoacoustic parameters used for the acoustic propagation modelling.

Table 2. Geoacoustic properties of the sub-bottom sediments as a function of depth. Within the depth range, each parameter varies linearly within the stated range. The compressional wave is the primary wave. The shear wave is the secondary wave.

Depth below seafloor (m)	Material	Density (g/cm³)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–5	Silt mixed with sand and clay	1.5–1.7	1525–1585	0.25–0.40	200	3.65
5–50		1.7–2.0	1585–1775	0.40–0.75		
50–500		2.0–2.1	1775–2100	0.75–1.4		
> 500		2.1	2100	1.4		

3.1.3. Sound speed profile

The sound speed profiles for the modelled site was derived from temperature and salinity profiles from the U.S. Naval Oceanographic Office’s *Generalized Digital Environmental Model V 3.0* (Teague et al. 1990, NAVO 2003, Carnes 2009). GDEM provides a climatology data of temperature and salinity for the world’s oceans as a latitude-longitude grid with 0.25° spatial resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy’s Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed-depth points to a maximum depth of 6,800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to the equations of Coppens (1981).

Typical sound speed profiles for May to September were calculated based on the data extracted from GDEM database for the location at 48°13'20" N 47°11'00" W (Figure 7, left). The sound speed profile for May was selected for modelling (Figure 7, right), as it represents the most favourable conditions for sound propagation and therefore will provide the most precautionary results.

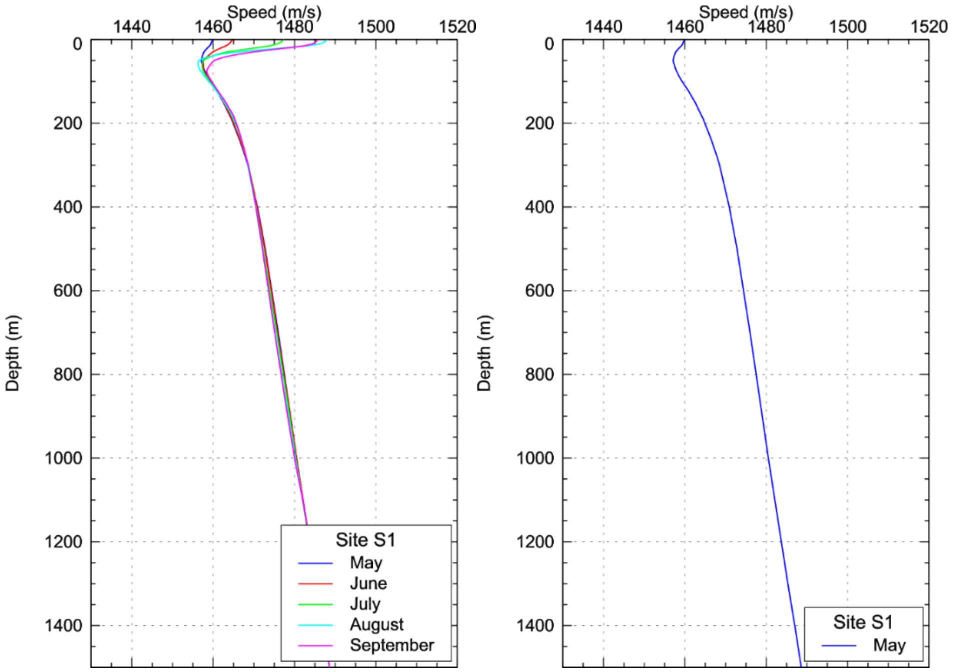


Figure 7. Mean monthly sound speed profiles near the modelled site for (left) May to September and (right) May, the month selected for modelling. The profiles were derived from data obtained from *GDEM V 3.0* (Teague et al. 1990, Carnes 2009).

3.2. Geometry and Modelled Volumes

The modelling geometry for each source was selected individually based on the parameters of the source and the required output (Table 3). At each surface sampling location, the sound field was sampled at the bottom and following depths:

- 2 m,
- Every 5 m from 5 to 25 m,
- Every 25 m from 50 to 100 m,
- Every 50 m from 150 to 500 m,
- Every 100 m from 600 to 1000 m, and
- Every 200 m from 1200 to 2400 m.

Table 3. Modelling geometry for the individual sources.

Source	**Metric**	**N-profiles (azimuthal step)**	**Horizontal resolution (m)**	**Maximum distance (km)**
Airgun array	SEL	72 (5°)	20	50
Airgun array	SPL and peak SPL	36 (10°)	10	20
Vessels	SEL and SPL	72 (5°)	20	50

3.3. Acoustic Source Parameters and Modelled Source Levels

3.3.1. Seismic source: Schlumberger Dual Magnum 2400 in^3

The Schlumberger Dual Magnum 2400 in^3 airgun array that was modelled as the seismic source for this project is routinely used for VSP surveys. The Schlumberger airgun array consists of four triangular clusters with in-line separations of 2 m. Two clusters are assembled from three 250 in^3 source elements with 0.9 m separation between each element. The two other clusters have three 150 in^3 source elements with 0.6 m separation between each element. The airguns are activated simultaneously at 2000 psi air pressure. The airgun array was modelled at a tow depth of 4.5 m (the centre of the clusters). Figure 8 presents the airgun distribution in the horizontal (*x*-*y*) plane.

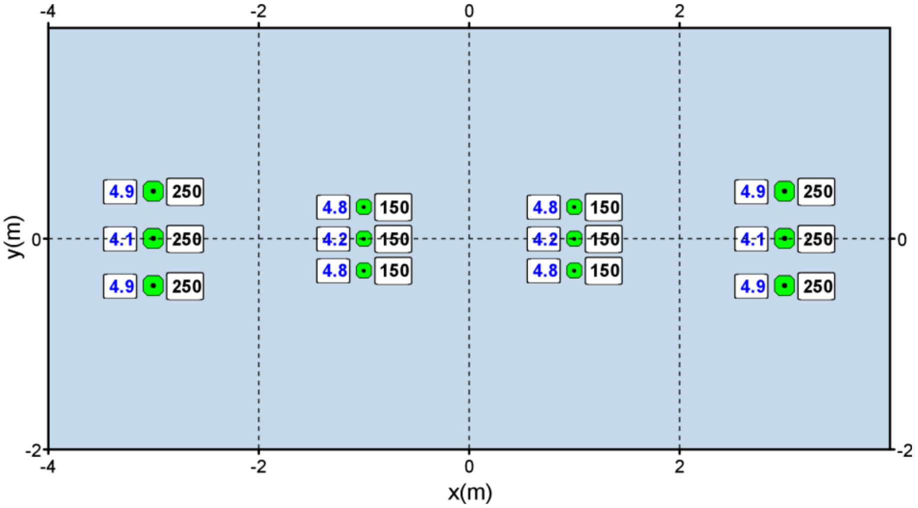
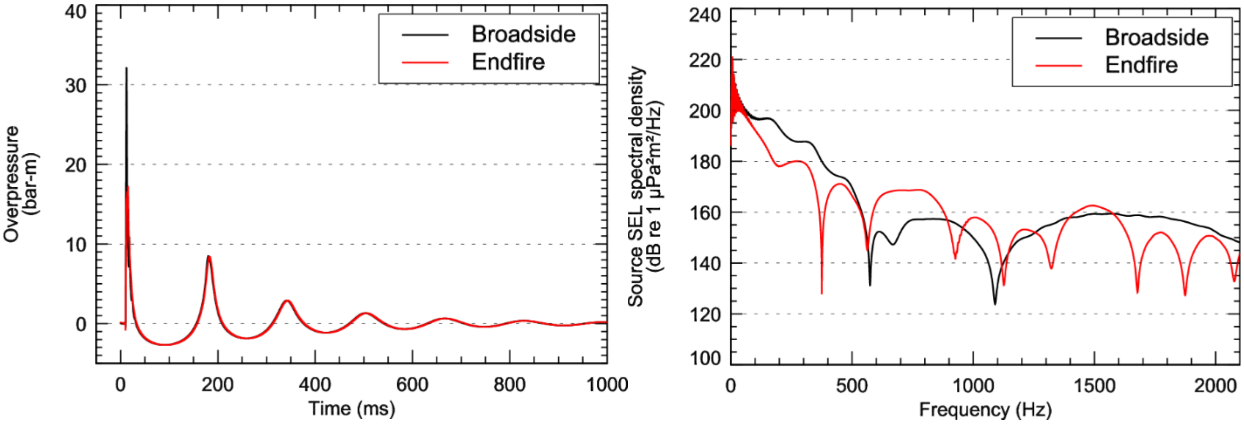


Figure 8. Layout of the modelled airgun array (2400 in^3 total firing volume, 4.5 m depth). Relative symbol sizes and black numbers indicate airgun firing volume in cubic inches. The blue numbers indicate the depth of the source element below to the sea surface. The front of the array is at positive X-axis.

The pressure signatures of the individual airguns and the composite decidecade band source levels of the array, as functions of azimuthal angle (in the horizontal plane), were modelled with AASM (see Section 2.1.1).

Figure 9 and Table 4 show the horizontal overpressure signatures and corresponding power spectrum levels for the 2400 in^3 airgun source array, stationary at a 4.5 m depth (to the vertical centre of the source element clusters), for the broadside (perpendicular to the tow direction) and endfire (parallel to the tow direction) directions. The signatures (Figure 9a) consist of a strong primary peak, related to the initial firing of the airguns, followed by a series of pulses associated with the bubble oscillations. Most energy is produced at frequencies below 600 Hz (Figure 9b). Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the array and reflect the volumes and relative locations of the airguns.

Horizontal decidecade band source levels are shown as a function of band centre frequency and azimuth (Figure 10). Directivity in the sound field was most noticeable at mid-frequencies from 100 to 400 Hz. Broadside and endfire decidecade band unweighted source levels and M-weighted source levels for Southall et al. (2007) and NMFS (2018) M-weighting functions are presented in Figures 11 and 12, respectively. The maximum band source level after mid- and high-frequency cetacean M-weighting were applied occurs at 8000 Hz and decreases more than 15 dB below maximum at 25,000 Hz. This indicates that the selection of the modelling frequency range up to 25,000 is correct.



(a) (b)

Figure 9. Predicted (a) overpressure signature and (b) power spectrum in the broadside and endfire (horizontal) directions for the 2400 in^3 array.

Table 4. Horizontal source level specifications for the airgun source array (2400 in^3) at 4.5 m depth, computed with AASM in the broadside and endfire directions (unweighted).

Direction	**Zero-to-peak SPL (dB re 1 µPa m)**	**SEL (dB re 1 µPa²m²s)**			
		10–25,000 Hz	10–500 Hz	500–5,000 Hz	5,000–25,000 Hz
Broadside	248.2	224.7	224.7	192.5	171.6
Endfire	245.6	224.1	224.1	195.0	172.2

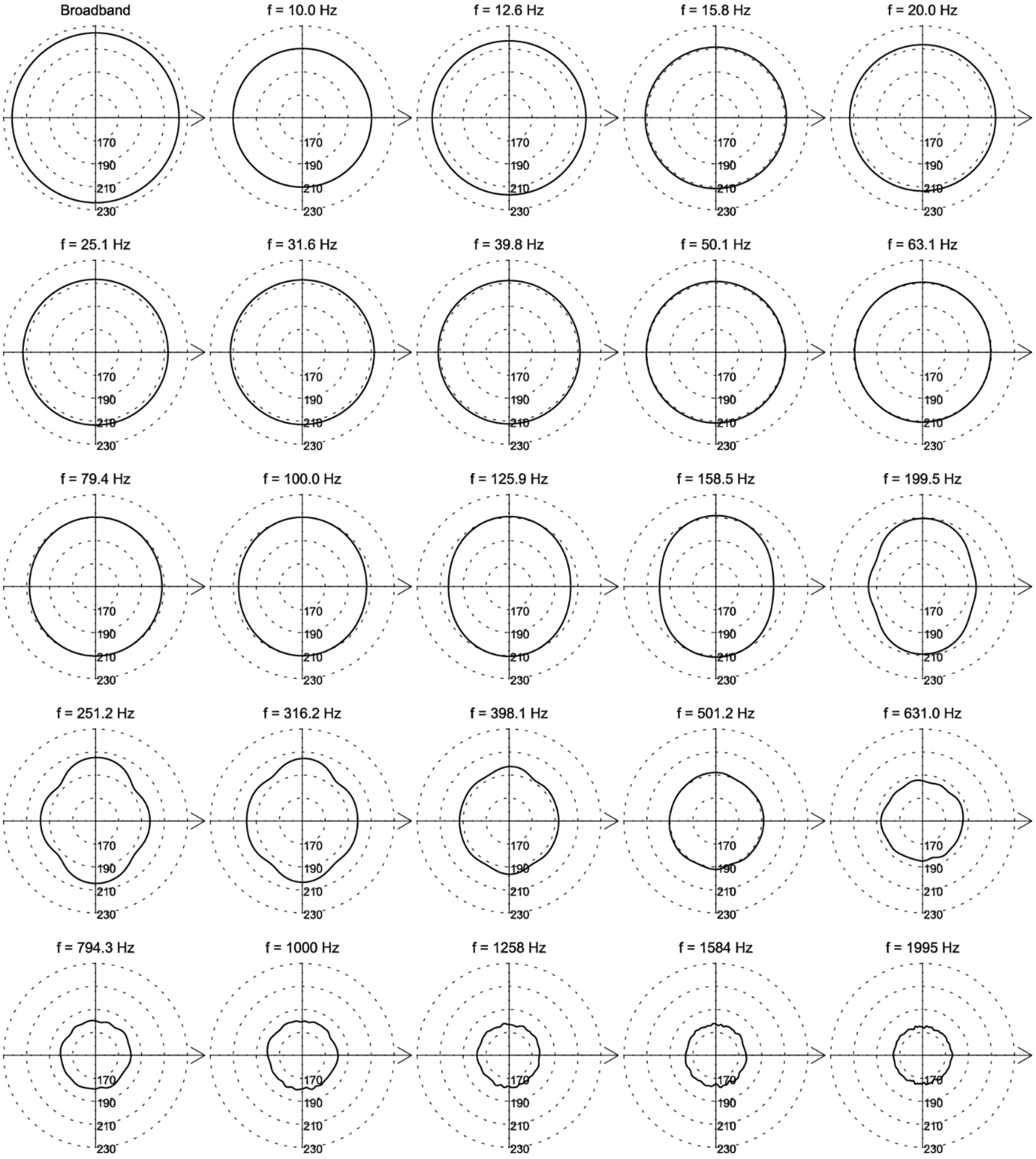


Figure 10. Directionality of the predicted horizontal source levels for the 2400 in^3 array. Source levels (in dB re 1 µPa^{2}m²s) are shown as a function of azimuth for the centre frequencies of the decidecade bands modelled; frequencies are indicated above each plot. The front of the array is to the right.

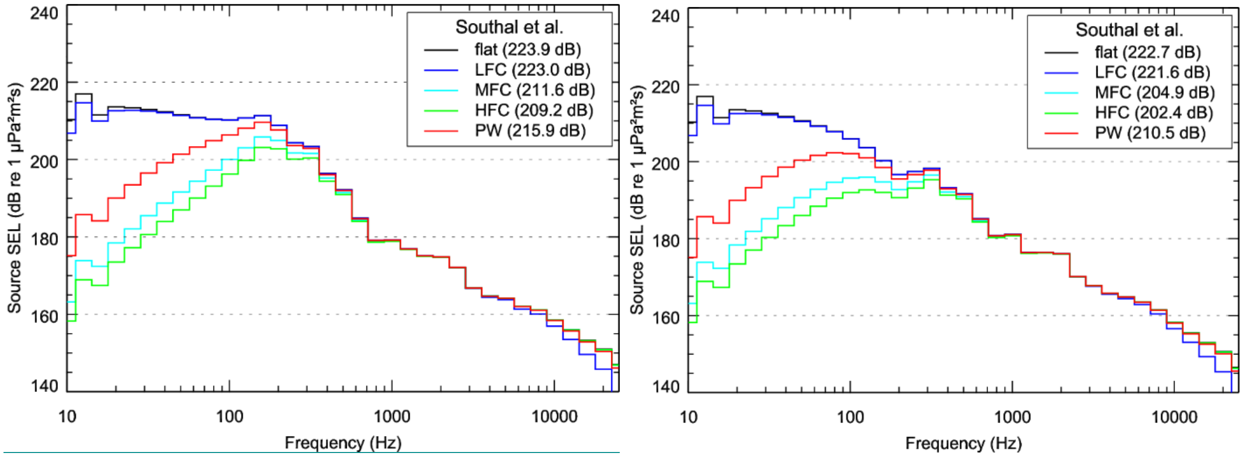


Figure 11. (Left) Broadside and (right) endfire decidecade band unweighted (flat) source levels in the horizontal plane for the 2400 in³ seismic array and M-weighted source levels using Southall et al. (2007) weighting functions for five marine mammal groups (see Appendix B.2.1.1). The bracketed values show broadband source levels after M-weighting was applied. LFC = Low-frequency cetaceans. MFC = Mid-frequency cetaceans. HFC = High-frequency cetaceans. PW = Pinnipeds in water.

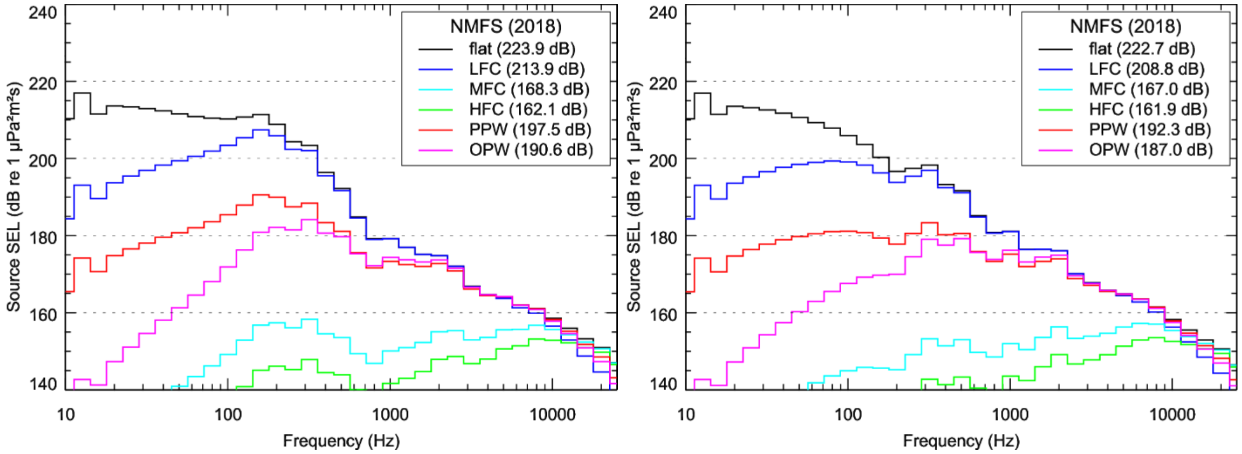


Figure 12. (Left) Broadside and (right) endfire decidecade band unweighted (flat) source levels in the horizontal plane for the 2400 in³ seismic array and M-weighted source levels using NMFS (2018) weighting functions for five marine mammal groups (see Appendix B.2.2.1). The values in brackets following the abbreviated group show broadband source levels after M-weighting was applied. LFC = Low-frequency cetaceans. MFC = Mid-frequency cetaceans. HFC = High-frequency cetaceans. PPW = Phocid pinnipeds in water. OPW = Otariid pinnipeds in water.

3.3.2. Vessel: Semi-Submersible Platform

The estimates of the semi-submersible platform acoustic source levels and sound spectrum were based on the *Seadrill West Sirius* (Figure 13). *Seadrill West Sirius* is reportedly equipped with eight Rolls-Royce UUC 355 thrusters. The thruster has a fixed-pitch propeller. The parameters for the UUC 355 thruster are:

- 3.5 m propeller diameter,
- 177 rpm nominal propeller speed, and
- 3800 kW maximum continuous power input.

The vertical position of the thrusters is 18 m below the sea surface (draft of the rig during drilling operations). For modelling the source levels, all eight thrusters (combined maximum power 30,400 kW) were assumed to operate at 50% of maximum power.

Figure 13. *Seadrill West Sirius* semi-submersible platform.

As described in Section 2.1.2, a hybrid approach for defining the source levels for the drilling platform was used. The source level spectrum calculated for a cavitating propeller was combined with the source levels defined using a surrogate vessel by taking maximum value in each of the decade bands.

The source levels and the sound spectrum (Figure 14) for a cavitating thrusters were estimated based on the thruster specifications (diameter, and rpm) according to the method described in Section 2.1.2.1. Table 5 lists the broadband source levels for a single UUC355 thruster operating at 100%, as well as eight thrusters at 100 and 50%.

Table 5. Estimated broadband levels for cavitating thrusters used on the *Seadrill West Sirius*.

Source	Power output (% of nominal)	SPL (dB re 1 µPa m)
UUC355	100	187.7
8 × UUC355	100	196.7
8 × UUC355	50	193.7

The source level spectrum based on surrogate vessel (Figure 14) was derived from the field measurements of *Fu Lai* vessel by adjusting for the difference of the propulsion power using Equation 6 assuming 50% power output of the dynamic positioning system (DP) thrusters.

The resultant source levels for the drillship that was used for estimating sound field in this modelling project are shown on Figure 14. The source level spectrum accounts for the noise generated by cavitating propeller (which dominates in the lower frequency band below 500 Hz), as well as machinery noise (which dominates at higher frequencies from 3 to 10 kHz)

For the purpose of acoustic propagation modelling, all eight thrusters were assumed to be located at the same spot, i.e., represented by a point source.

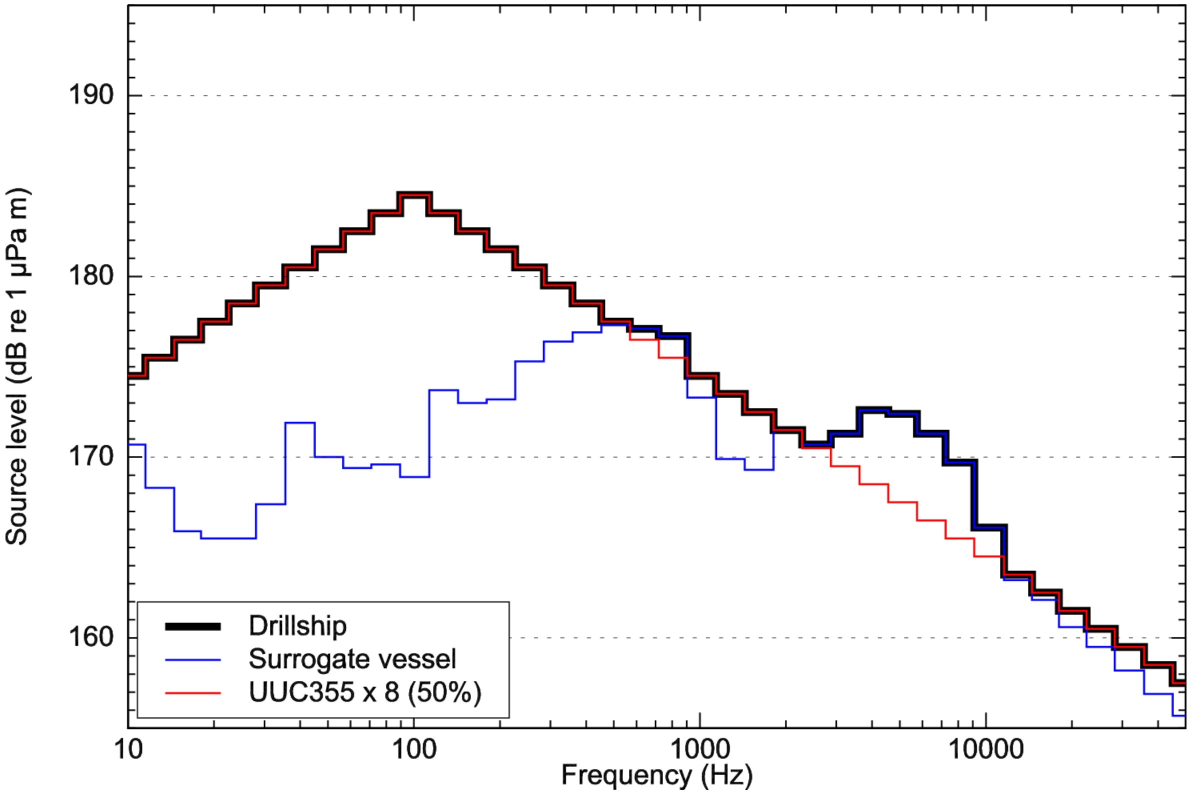


Figure 14. Source level spectrum assumed for the drillship. The spectrum for eight UUC355 thrusters operating at 50% capacity and the surrogate vessel are also shown.

4. Acoustic Field Modelling Results

Three types of acoustic field metrics were modelled for each source: rms SPL, cumulative SEL, and peak SPL. The modelled fields were assessed against the criteria thresholds defined in Southall et al. (2007) and NMFS (2018).

Maps of the horizontal acoustic field footprints were plotted, and the ranges to specific thresholds were calculated based on a 2-D Cartesian grid representing horizontal distribution of the acoustic field around a source (see Section 2.2.1). The vertical dimension was reduced using the maximum-over-depth rule (see Section 2.2.3).

4.1. Seismic Survey Source

The 2400 in^3 airgun array was modelled at single site. The modelling was performed using the sound speed profile representing typical propagation conditions for May.

The seismic source will be deployed from or near the drilling platform and was assumed to be stationary for the duration of the survey. For the purpose of calculating SEL$_{24h}$, it was assumed that the maximum number of seismic pulses delivered within a 24 hr period is 2040.

4.1.1. SPL and PK

The SPL and peak sound pressure level (PK) for the seismic source were estimated based on the full waveform modelling (see Section 2.2.2). The modelling was performed along 36 transects (10° regular angular steps) up to a 20 km range from the source for the frequencies from 9 to 891 Hz. The SPL and PK were calculated directly from the synthetic pressure waveforms.

The ranges to the specific thresholds for SPL are presented in Table 6. The injury thresholds (190 dB for pinnipeds and 180 dB for cetaceans) as well as the behavior response threshold for an impulsive sound source (160 dB) based on NMFS (2018) criteria (see Section B.1) are bolded. The ranges to the criteria-defined PTS-onset thresholds for the PK are presented in Table 7. Examples of the vertical distribution of the SPL field are provided on Figure 15. A contour map of the maximum-over-depth SPL field around the source is provided in Figure 16.

Table 6. VSP 2400 in^3 airgun array: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal ranges from the source to modelled maximum-over-depth sound pressure level (SPL) thresholds. The injury threshold for pinnipeds and cetaceous (190 dB and 180 dB, respectively) and behaviour response threshold for impulsive source (160 dB) are bolded (NMFS 2018).

SPL (dB re 1 µPa)	R_{max}	$R_{95\%}$
210	<20	<20
200	40	40
190	**140**	**130**
180	**450**	**410**
170	1640	1370
160	**6180**	**4770**
150	19800	17400
140	>20000*	n/c**

* Extends beyond modelling boundary
** n/c = not computed because R_{max} was not defined

Table 7. VSP 2400 in³ airgun array: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal ranges from the source to modelled PTS-onset thresholds defined for the PK field based on Southall et al. (2007) and NMFS (2018).

Marine mammal group	Threshold (dB re 1 µPa)	R_{max}	$R_{95\%}$
Southall et al. (2007)			
Low-frequency cetaceans	230	—	—
Mid-frequency cetaceans	230	—	—
High-frequency cetaceans	230	—	—
Pinnipeds (underwater)	218	<20	<20
NMFS (2018)			
Low-frequency cetaceans	219	20	20
Mid-frequency cetaceans	230	—	—
High-frequency cetaceans	202	200	190
Phocid pinnipeds (underwater)	218	30	30
Otariid pinnipeds (underwater)	232	—	—

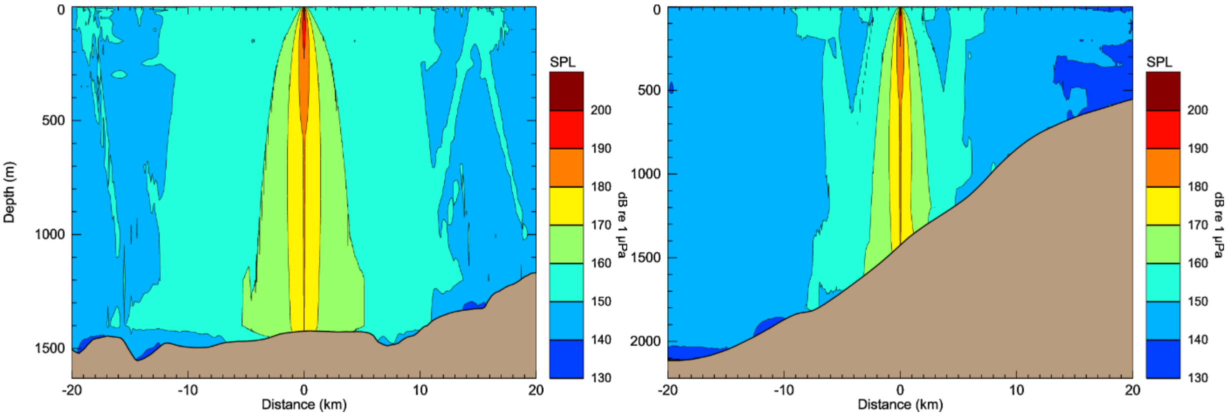


Figure 15. VSP 2400 in³ airgun array: Modelled vertical distribution of the sound pressure level (SPL) field for 90° (left) and 180°(right) modelled profiles.

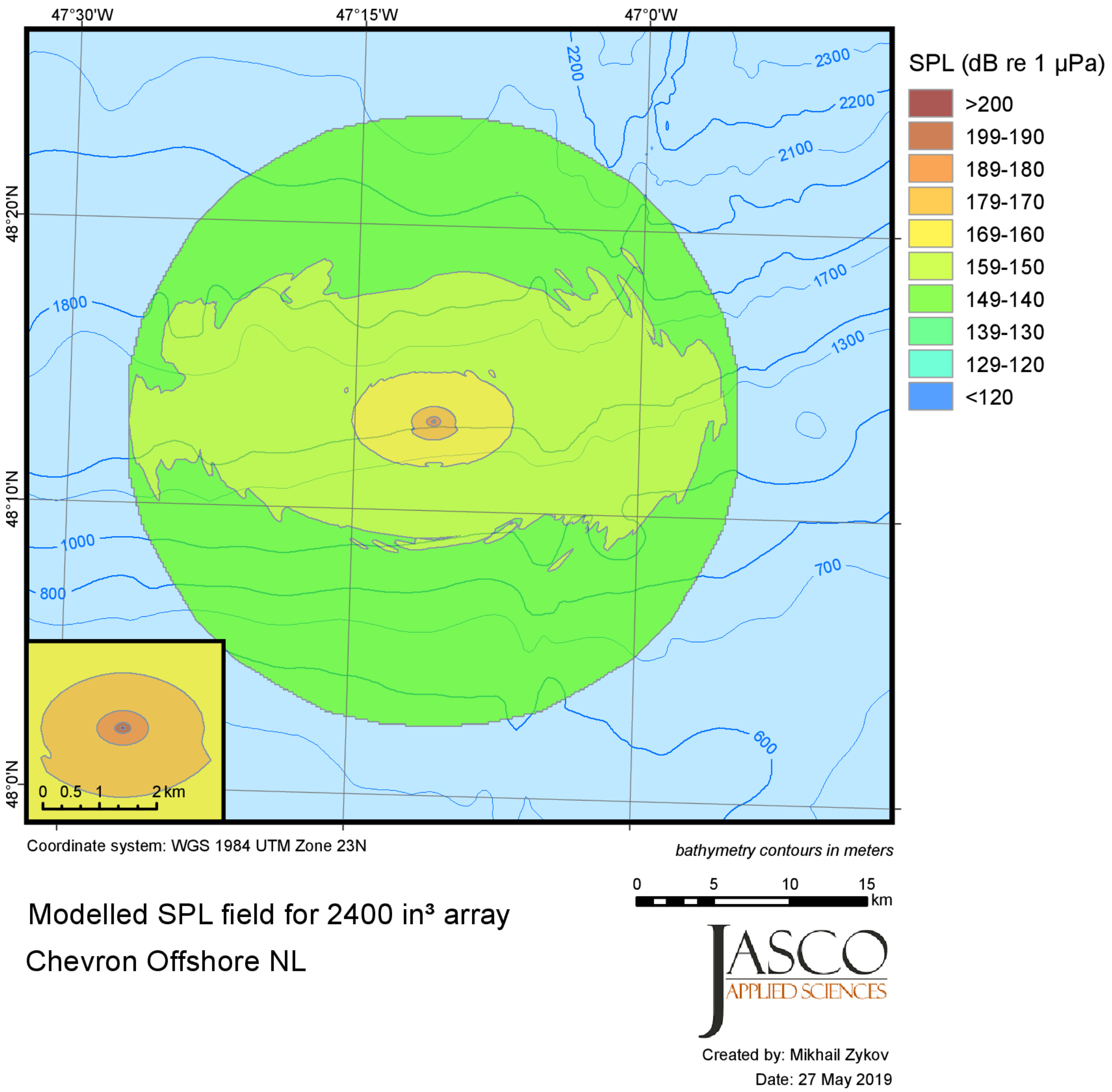


Figure 16. VSP 2400 in³ airgun array: Modelled maximum-over-depth sound pressure level (SPL) field.

4.1.2. SEL

The per-pulse SEL field modelling was performed along 72 transects (5° regular angular step) up to a 50 km range from the source utilizing energy propagation loss in the decidecade band approach (Section 2.2.1). Bands with central frequencies from 10 to 25,000 Hz were considered. The ranges to specific thresholds based on unweighted per-pulse SEL field are provided in Table 8 and the threshold contour map in Figure 17.

The SEL_{24h} for the VSP source was calculated based on the per-pulse SEL with the assumption that the VSP source will be delivering a maximum of 2040 pulses in a given 24 hr period. According to Equation A-4, the 2040 pulses result in an increase in exposure by 33.1 dB over a single pulse exposure.

The SEL_{24h} field was assessed against impulsive source criteria for each marine mammal group defined in Southall et al. (2007) and NMFS (2018) after application of specific M-weighting functions. The PTS-onset threshold ranges based on M-weighted SEL_{24h} field are provided in Table 9 and the PTS-onset threshold contour map in Figure 18.

Table 8. VSP 2400 in³ airgun array: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances from the source to modelled unweighted per-pulse maximum-over-depth sound exposure level (SEL) thresholds.

$SEL_{per\text{-}pulse}$ (dB re 1 µPa²s)	R_{max}	$R_{95\%}$
200	20	<20
190	40	40
180	130	120
170	440	390
160	1410	1250
150	6460	5680
140	34700	27200
130	>50000*	n/c**

* Extends beyond modelling boundary

** n/c = not computed because R_{max} was not defined

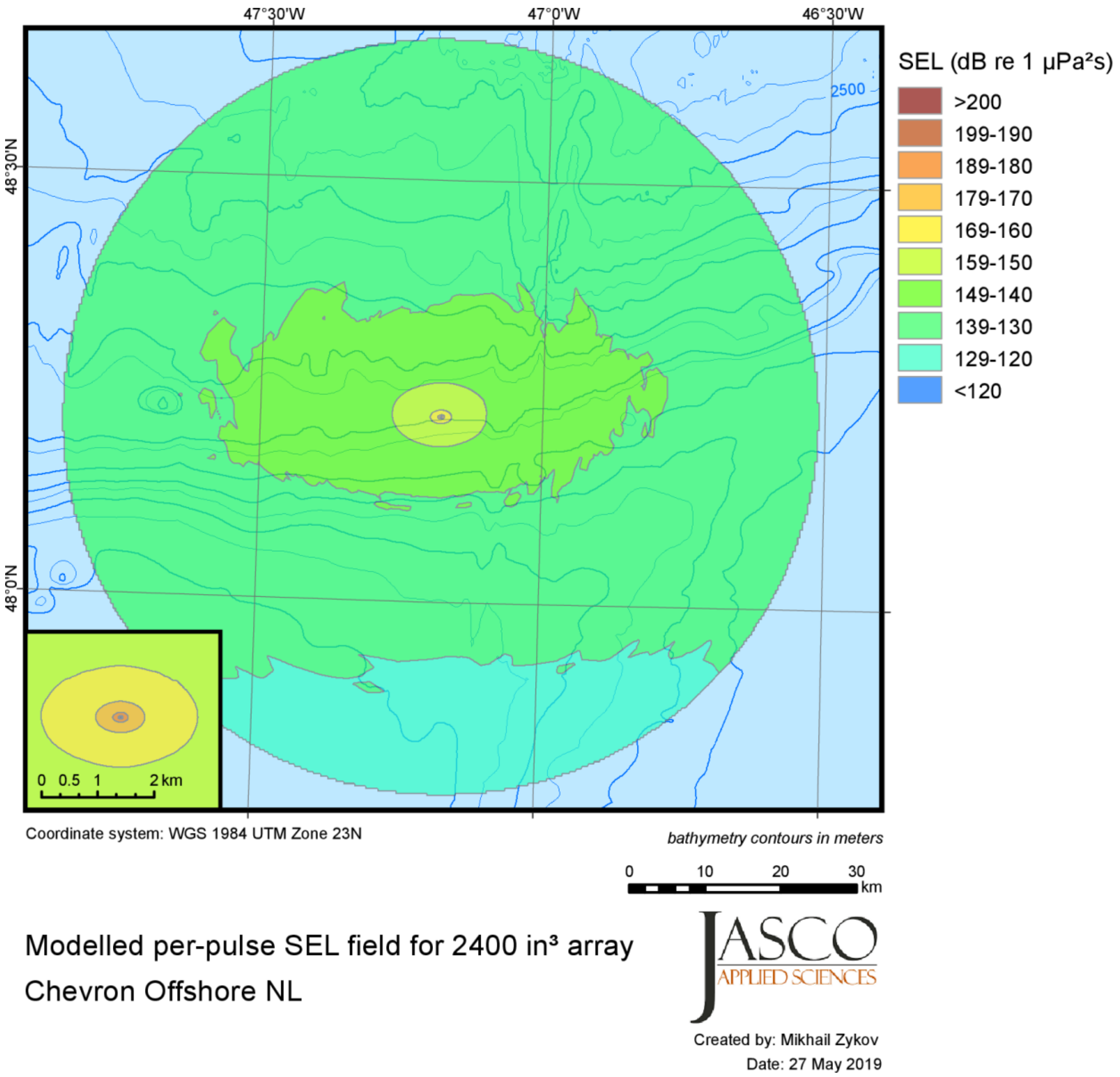


Figure 17. VSP 2400 in³ airgun array: Modelled sound exposure level (SEL) field.

Table 9. VSP 2400 in^3 airgun array: Maximum ($R_{\max}$, m) and 95% ($R_{95\%}$, m) horizontal distances from the source to PTS-onset thresholds (Southall et al. 2007, NMFS 2018) based on the 24 hr M-weighted sound exposure level (SEL) field.

Marine mammal group	**PTS-onset**		
	SEL (dB re 1 µPa^2·s)	$R_{\max}$	$R_{95\%}$
Southall et al. (2007)			
Low-frequency cetaceans	198	780	700
Mid-frequency cetaceans	198	360	320
High-frequency cetaceans	198	280	240
Phocid pinnipeds (underwater)	186	2220	1970
NMFS (2018)			
Low-frequency cetaceans	183	4520	4160
Mid-frequency cetaceans	185	<20	<20
High-frequency cetaceans	155	130	120
Phocid pinnipeds (underwater)	185	300	270
Otariid pinnipeds (underwater)	203	<20	<20

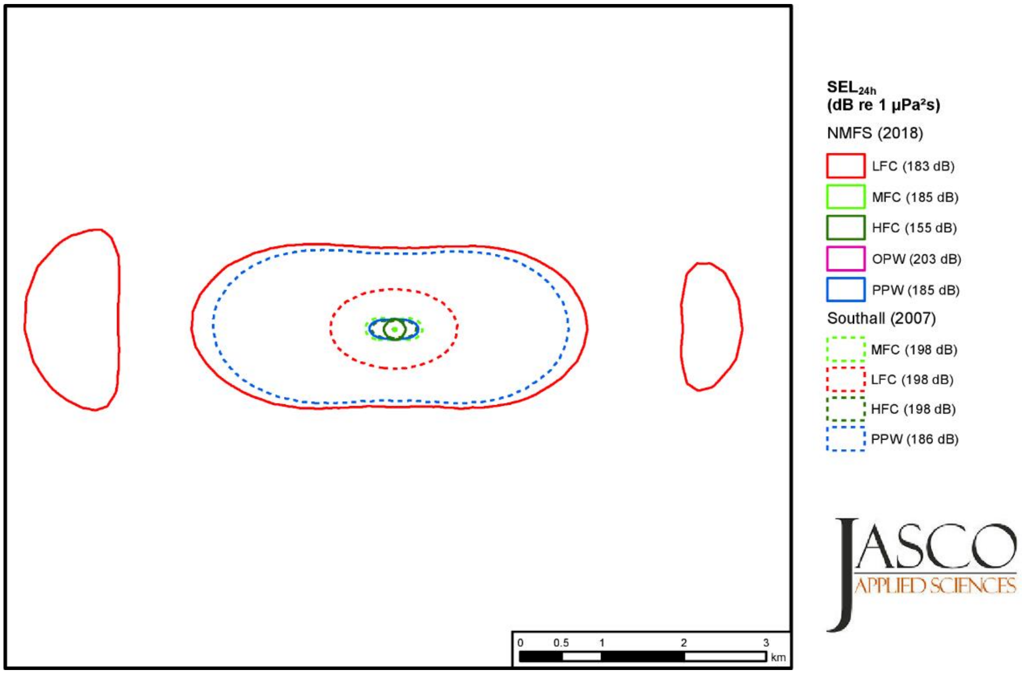


Figure 18. VSP 2400 in^3 airgun array: PTS-onset threshold contours (Southall et al. 2007, NMFS 2018) based on the 24 hr M-weighted sound exposure level (SEL) field.

4.2. Semi-submersible platform

Vessels are non-impulsive, or continuous, noise sources. For continuous sources, SPL and per-second SEL are equivalent because the integration time for the purpose of the SPL calculations (Equation A-2) is taken as constant and equal to 1 second.

The acoustic field around drilling platform was modelled at a single site for the typical propagation condition for May. The per-second SEL field modelling was performed along 72 transects (5° regular angular step) up to a 50 km range from the source utilizing propagation loss in the decidecade band approach (Section 2.2.1). Bands with central frequencies from 10 to 50,000 Hz were considered.

4.2.1. SPL

The distances to the sound level thresholds from 170 to 110 dB re 1 µPa SPL with 10 dB step are presented in Table 10. The behavior response threshold for a continuous sound source (120 dB) based on NMFS (2018) criteria (see Section B.1) is bolded.

The contour maps of the estimated acoustic fields in SPL are presented on Figure 19.

Table 10. Semi-submersible platform: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to modelled maximum-over-depth sound pressure level (SPL) thresholds. The behaviour response threshold for continuous source (120 dB) is bolded (NMFS 2018).

SPL (dB re 1 µPa)	R_{max}	$R_{95\%}$
170	<20	<20
160	70	70
150	230	220
140	730	700
130	5470	5410
120	**31700**	**26600**
110	>50000*	n/c**

* Extends beyond modelling boundary

** n/c = not computed because R_{max} was not defined

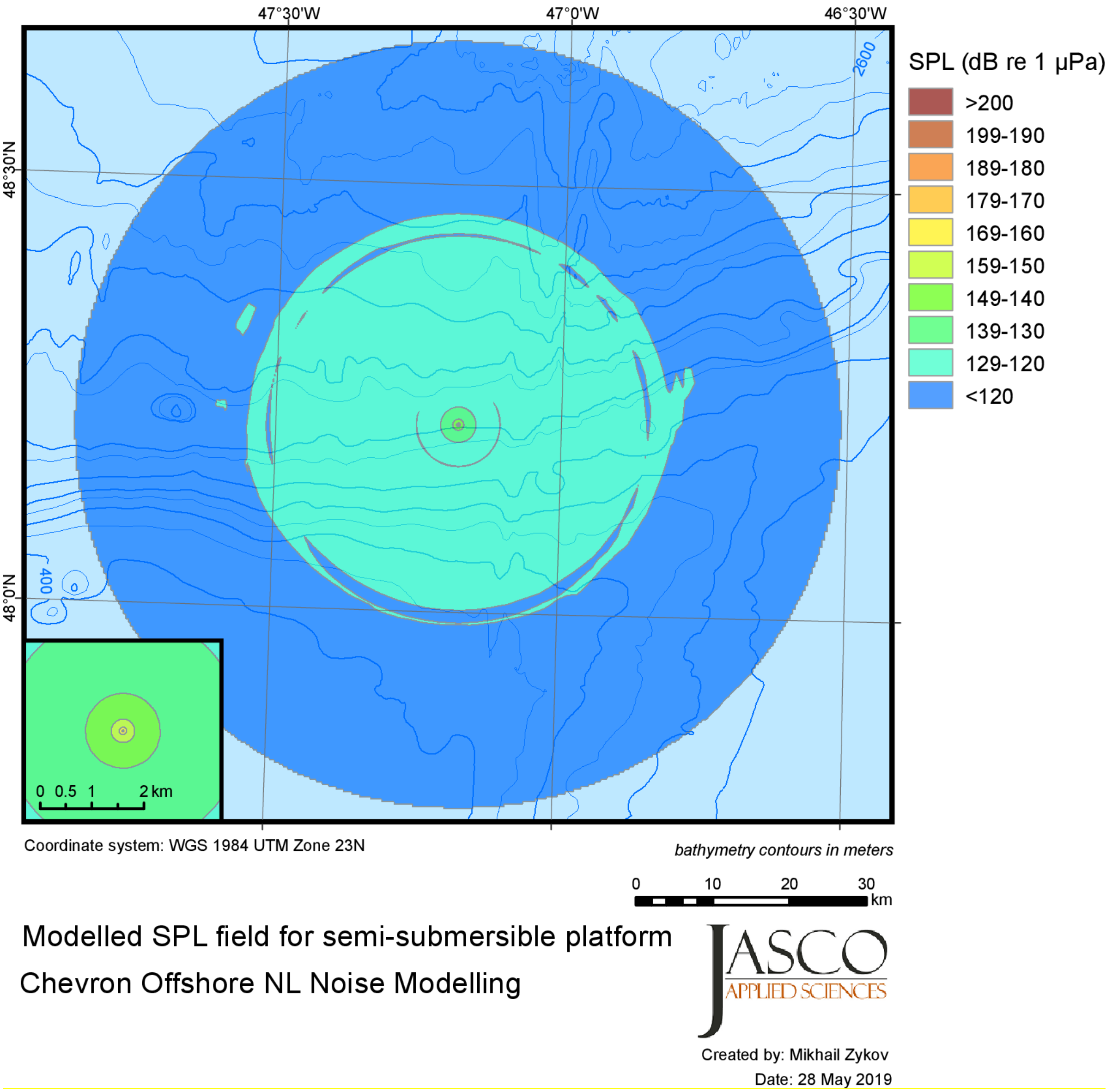


Figure 19. Semi-submersible platform: Modelled maximum-over-depth sound pressure level (SPL) field

4.2.2. SEL

For the purpose of the 24 hr SEL calculations, it was assumed that the vessel are stationary and the source levels do not change with time. The SEL_{24h} was estimated from per-second SEL by adding 49.3 dB (Equation A-4) to account for the number of seconds in 24 hour period (86,400 seconds).

The SEL_{24h} field was assessed against non-impulsive source criteria for each marine mammal group defined in Southall et al. (2007) and NMFS (2018) after application of specific M-weighting functions. The PTS-onset threshold ranges based on M-weighted SEL_{24h} field are provided in Table 11 and the PTS-onset threshold contour map in Figure 20.

Table 11. Semi-submersible platform: Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances from the source to PTS-onset thresholds (Southall et al. 2007, NMFS 2018) based on the 24 hr M-weighted sound exposure level (SEL) field.

Marine mammal group	**PTS-onset**		
	SEL (dB re 1 µPa²s)	R_{max}	$R_{95\%}$
Southall et al. (2007)			
Low-frequency cetaceans	215	<40	<40
Mid-frequency cetaceans	215	<40	<40
High-frequency cetaceans	215	<40	<40
Phocid pinnipeds (underwater)	203	110	100
NMFS (2018)			
Low-frequency cetaceans	199	140	140
Mid-frequency cetaceans	198	<40	<40
High-frequency cetaceans	173	250	250
Phocid pinnipeds (underwater)	201	40	40
Otariid pinnipeds (underwater)	219	<40	<40

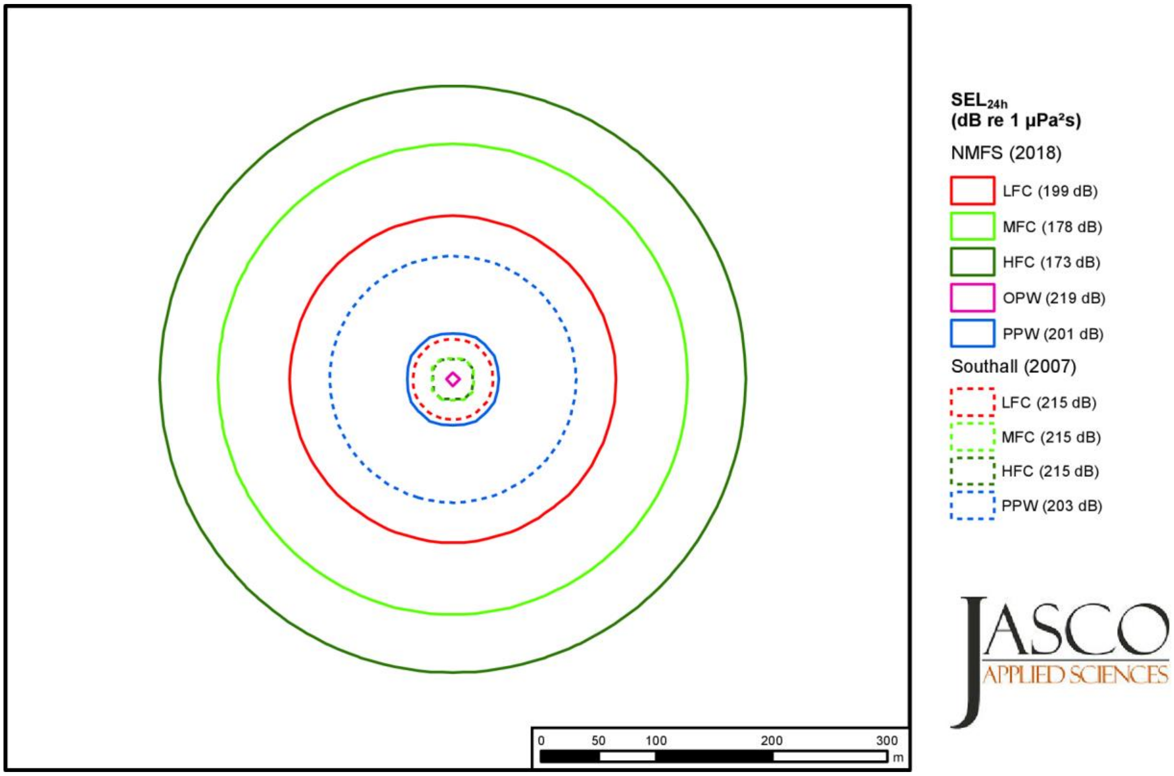


Figure 20. Semi-submersible platform: PTS-onset threshold contours (Southall et al. 2007, NMFS 2018) based on the 24 hr M-weighted sound exposure level (SEL) field.

5. Conclusion

The acoustic field modelling was performed for two types of sources: a seismic source (impulsive) and a vessel (non-impulsive). The propagation conditions were tested for a single month (May) featuring the sound speed profile in the water column with the most favourable propagation conditions within the May to September period.

The propagation of the sound along different azimuths depends on the directivity of the source and the topography of the ocean bottom. The source levels of the 2400 in^3 seismic array in the 100–400 Hz frequency band were higher in the broadside lobe (Figure 10). The source was virtually omnidirectional at frequencies below 100 Hz and above 400 Hz. As a result, the ranges to specific acoustic thresholds were longer for the endfire and broadside directions. The topography defines the spread of the acoustic energy in the vertical dimension. As the water depth increases, the acoustic wave has more space to refract upward without hitting the bottom and losing energy at the bottom interface, as such the transmission loss decreases compared to the profile with constant water depth. For the propagation profiles with decreasing water depth, two effects take place. The decreasing water depth concentrates the acoustic energy within narrower waveguide, which increases the sound levels. Conversely, the acoustic wave interacts with the bottom more often, losing a greater fraction of its energy in the sediment. The latter effect prevails, and propagation profiles with decreasing water depths, such as towards the continental shelf, have higher propagation loss decreases compared to profiles with constant water depths.

The acoustic fields modelled in this study were tested against various impact criteria defined in terms of a single event, per-pulse in case of impulsive sources and per-second for non-impulsive sources, and continuous source operation for a specific time period.

When applying impact criteria based on the SPL signal metric (NMFS 2018) to the sound field from the seismic source (impulsive source type), the ranges from the source to the injury thresholds were 140 m and 450 m for pinnipeds (190 dB) and cetaceans (180 dB), respectively, and 6180 m to the behavior response (160 dB) for all mammals (Table 6). The injury thresholds ranges from the vessel (continuous source type) were estimated to be less than 20 m. The range to the behaviour response threshold from the vessel (120 dB) was 31,700 m. The significantly larger behaviour response range for the vessel compared to the seismic source is due to applicable threshold level: the vessel is a continuous source and 120 dB threshold is applied, while seismic source is an impulsive source, for which 160 dB behaviour response threshold is used (see Section B.1).

The ranges to the injury thresholds defined in terms of peak SPL were substantial (200 m; Table 7) only for high-frequency cetaceans based on NMFS (2018) criteria. The ranges to the injury thresholds for all other marine mammal groups were less than 40 m as the acoustic thresholds levels for those were at least 17 dB higher.

It should be noted that both SPL and peak SPL signal metrics are calculated based on the unweighted broadband signal, i.e., the hearing frequency band of specific marine mammals is not taken into account, and M-weighting functions are not applied in this case.

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Appendix A. Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow the American National Standard Institute and International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017, ANSI R2013), but these standards are not always consistent.

The zero-to-peak sound pressure, or peak sound pressure (PK or $L_{p,\mathrm{pk}}$; dB re 1 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,\mathrm{pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0}\ \mathrm{dB} \tag{A-1}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The sound pressure level (SPL or L_p; dB re 1 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_\mathrm{p} = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt\Big/p_0^2\right)\mathrm{dB} \tag{A-2}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function. For short acoustic events, such as sonar pulses and marine mammal vocalizations, it is important to choose an appropriate time window that matches the duration of the signal. For in-air studies, when evaluating the perceived loudness of sounds with rapid amplitude variations in time, the time weighting function $g(t)$ is often set to a decaying exponential function that emphasizes more recent pressure signals. This function mimics the leaky integration nature of mammalian hearing. For example, human-based fast time-weighted SPL ($L_{p,\mathrm{fast}}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $g(t)$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,\mathrm{boxcar\ 125ms}}$. Another approach, historically used to evaluate SPL of impulsive signals underwater, defines $g(t)$ as a boxcar function with edges set to the times corresponding to 5% and 95% of the cumulative square pressure function encompassing the duration of an impulsive acoustic event. This calculation is applied individually to each impulse signal, and the results have been referred to as 90% SPL ($L_{p,90\%}$).

The sound exposure level (SEL or L_E; dB re 1 µPa^{2}s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_\mathrm{E} = 10\log_{10}\left(\int_T p^2(t)\,dt\Big/T_0 p_0^2\right)\mathrm{dB} \tag{A-3}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{\mathrm{E,N}} = 10\log_{10}\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \tag{A-4}$$

If applied, the frequency weighting of an acoustic event should be specified, as in the case of M-weighted SEL (e.g., $L_{E,\mathrm{LFC,24h}}$; see Appendix B.2) or auditory-weighted SPL ($L_{p,\mathrm{ht}}$). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

Appendix B. Marine Mammal Impact Criteria

It has been long recognized that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggest that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance based on SPL (Appendix B.1) and SEL and peak sound pressure levels (Appendix B.2). The following sections summarize the development of the current thresholds relevant to this study; this remains an active research topic, however.

B.1. Sound Pressure Level (SPL)

The National Marine Fisheries Service (NMFS) SPL criteria for injury to marine mammals from acoustic exposure were set according to recommendations for cautionary estimates of sound levels leading to onset of permanent hearing threshold shift (PTS). These criteria prescribed injury thresholds of 190 dB re 1 µPa SPL for pinnipeds and 180 dB re 1 µPa SPL for cetaceans, for all types of sound sources except tactical sonar and explosives (NMFS 2018). These injury thresholds are applied to individual noise pulses or instantaneous sound levels and do not consider the overall duration of the noise or its acoustic frequency distribution. Criteria that do not account for exposure duration or noise spectra are generally insufficient on their own for assessing hearing injury.

The NMFS currently uses SPL thresholds for behavioural response of 160 dB re 1 µPa for impulsive sounds and 120 dB re 1 µPa for non-impulsive sounds for all marine mammal species (NMFS 2018), based on observations of mysticetes (Malme et al. 1983, Malme et al. 1984, Richardson et al. 1986, Richardson et al. 1990). As of 2016, NMFS applies these disturbance thresholds as a default, but makes exceptions on a species-specific and sub-population specific basis where warranted.

B.2. Sound Exposure Level (SEL) and Peak Sound Pressure Level (PK)

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. It was noted, that the potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal’s sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24 h refers to the accumulation period for calculating SEL. In order to account for specific sensitivity of different marine mammal groups a set of weighting functions were introduced to be applied during calculation of the SEL (Southall et al. 2007). Subsequent studies resulted in reconsideration of how the weighting functions are defined and the values for the threshold levels (NMFS 2018).

SEL_{24h} is frequency weighted according to one of four Southall et al. (2007) or five (NMFS 2018) marine mammal species hearing groups. Low-, mid- and high-frequency cetaceans (LFC, MFC, and HFC respectively) are groups identified in both publications, whereas Southall et al. (2007) considers pinnipeds as a single group and NMFS (2018) splits the pinnipeds into two subgroups: phocids, earless or true seals, and otariids, eared seals. The onset threshold levels for Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) differ by group and are applied to M-weighted SEL.

B.2.1. Southall et al. (2007) criteria

B.2.1.1. Marine mammal auditory weighting functions

Auditory weighting functions for marine mammals—called M-weighting functions—were proposed by Southall et al. (2007). These M-weighting functions are applied in a similar way as A-weighting for noise level assessments for humans. Functions were defined for five hearing groups of marine mammals:

- Low-frequency (LF) cetaceans—mysticetes (baleen whales)
- Mid-frequency (MF) cetaceans—some odontocetes (toothed whales)
- High-frequency (HF) cetaceans—odontocetes specialized for using high-frequencies
- Pinnipeds in water (Pw)—seals, sea lions, and walrus
- Pinnipeds in air (not addressed here)

The M-weighting functions have unity gain (0 dB) through the passband and their high and low frequency roll-offs are approximately –12 dB per octave. The amplitude response in the frequency domain of each M-weighting function is defined by:

$$G(f) = -20\log_{10}\left[\left(1+\frac{a^2}{f^2}\right)\left(1+\frac{f^2}{b^2}\right)\right] \tag{B-1}$$

where *G*(f) is the weighting function amplitude (in dB) at the frequency *f* (in Hz), and *a* and *b* are the estimated lower and upper hearing limits, respectively, which control the roll-off and passband of the weighting function. The parameters *a* and *b* are defined uniquely for each functional hearing group (Table B-1).

The auditory weighting functions recommended by Southall et al. (2007) are shown in Figure B-1.

Table B-1. Parameters to be used in Equation B-1 to obtain the auditory weighting functions recommended by Southall et al. (2007).

Functional hearing group	*a* (Hz)	*b* (Hz)
Low-frequency cetaceans	7	22,000
Mid-frequency cetaceans	150	160,000
High-frequency cetaceans	200	180,000
Pinnipeds in water	75	75,000

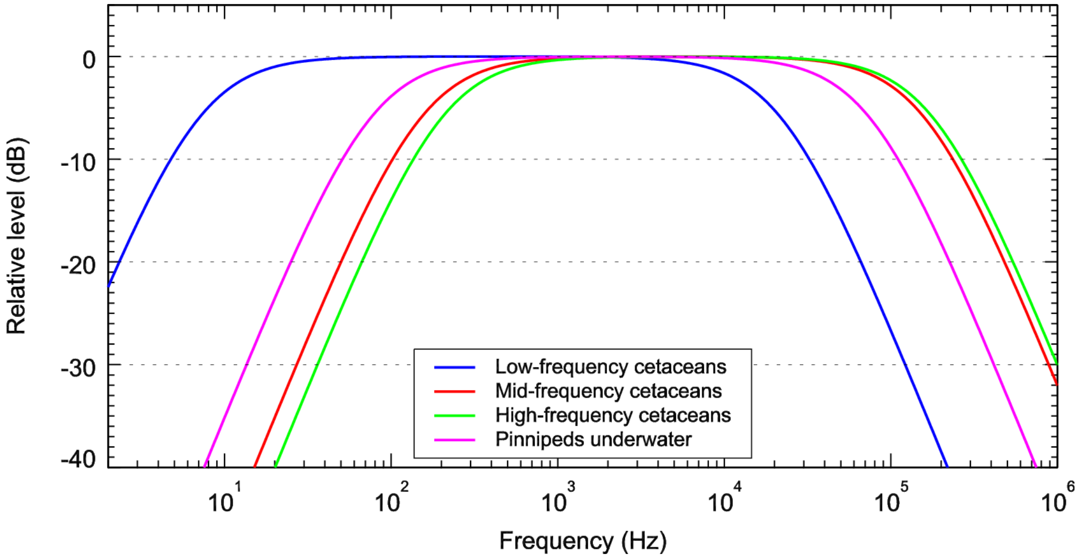

Figure B-1. Auditory weighting functions for functional marine mammal hearing groups as recommended by Southall et al. (2007).

B.2.1.2. Impact thresholds

Southall et al. (2007) introduced dual injury criteria consisting of both zero-to-peak (peak) sound pressure level ($L_{p,\mathrm{pk}}$) thresholds, expressed in dB re 1 µPa, and SEL thresholds, expressed in dB re 1 µPa^{2}s (Table B-2). A PTS-onset (injury) is assumed to occur if a received sound exposure exceeds $L_{p,\mathrm{pk}}$ criterion, the SEL criterion, or both. The $L_{p,\mathrm{pk}}$ is not frequency weighted whereas the SEL is frequency-weighted ($\mathrm{SEL_w}$) using an M-weighting function related to the specific marine mammal functional hearing group.

Table B-2. Peak sound pressure level ($L_{p,\mathrm{pk}}$; dB re 1 µPa) and auditory-weighted cumulative sound exposure level ($\mathrm{SEL_w}$; dB re 1 µPa^{2}s) dual acoustic thresholds for permanent threshold shift (PTS) from impulsive and non-impulsive sounds proposed by Southall et al. (2007).

Functional hearing group	Impulsive sound		Non-impulsive sound	
	$L_{p,\mathrm{pk}}$	$\mathrm{SEL_w}$	$L_{p,\mathrm{pk}}$	$\mathrm{SEL_w}$
Low-frequency cetaceans	230	198	230	215
Mid- frequency cetaceans	230	198	230	215
High-frequency cetaceans	230	198	230	215
Pinnipeds in water	218	186	218	203

The PTS-onset thresholds based on the $L_{p,\mathrm{pk}}$ metric were estimated by adding 6 dB to the known or assumed $L_{p,\mathrm{pk}}$ that elicit TTS-onset. The PTS-onset thresholds based on the SEL metric were estimated by adding 15 dB (for impulsive sounds) and 20 dB (for non-impulsive sounds) to the known or assumed cumulative SEL of elicit TTS-onset.

Southall et al. (2007) criteria consider not only the factor of individual pulses impact but also a temporal factor, i.e., the history of the exposure to the sound over a specific period of time. For impulsive sound, the shape of the pulse is not considered any more, only the maximum amplitude and the energy of the acoustic wave.

B.2.2. NMFS (2018) criteria

B.2.2.1. Marine mammal auditory weighting functions

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The auditory weighting functions for marine mammals are applied in a similar way as A-weighting for noise level assessments for humans. The new frequency-weighting functions are expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^{2}\right]^{a}\left[1+(f/f_{hi})^{2}\right]^{b}}\right)\right], \qquad \text{(B-2)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively), phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA’s technical guidance that assesses noise impacts on marine mammals (NMFS 2016), which was updated two years later after extensive consultations within the scientific community (NMFS 2018). The updates did not affect the content related to either the definitions of M-weighting functions or the threshold values. Table B-3 lists the parameters for the M-weighting functions for each hearing group; Figure B-2 shows the resulting frequency-weighting curves.

Table B-3. Parameters to be used in Equation B-2 to obtain the auditory weighting functions recommended by NMFS (2018).

Functional hearing group	a	b	f_{lo} (Hz)	f_{hi} (Hz)	K (dB)
Low-frequency cetaceans	1.0	2	200	19,000	0.13
Mid-frequency cetaceans	1.6	2	8,800	110,000	1.20
High-frequency cetaceans	1.8	2	12,000	140,000	1.36
Phocid pinnipeds in water	1.0	2	1,900	30,000	0.75
Otariid pinnipeds in water	2.0	2	940	25,000	0.64

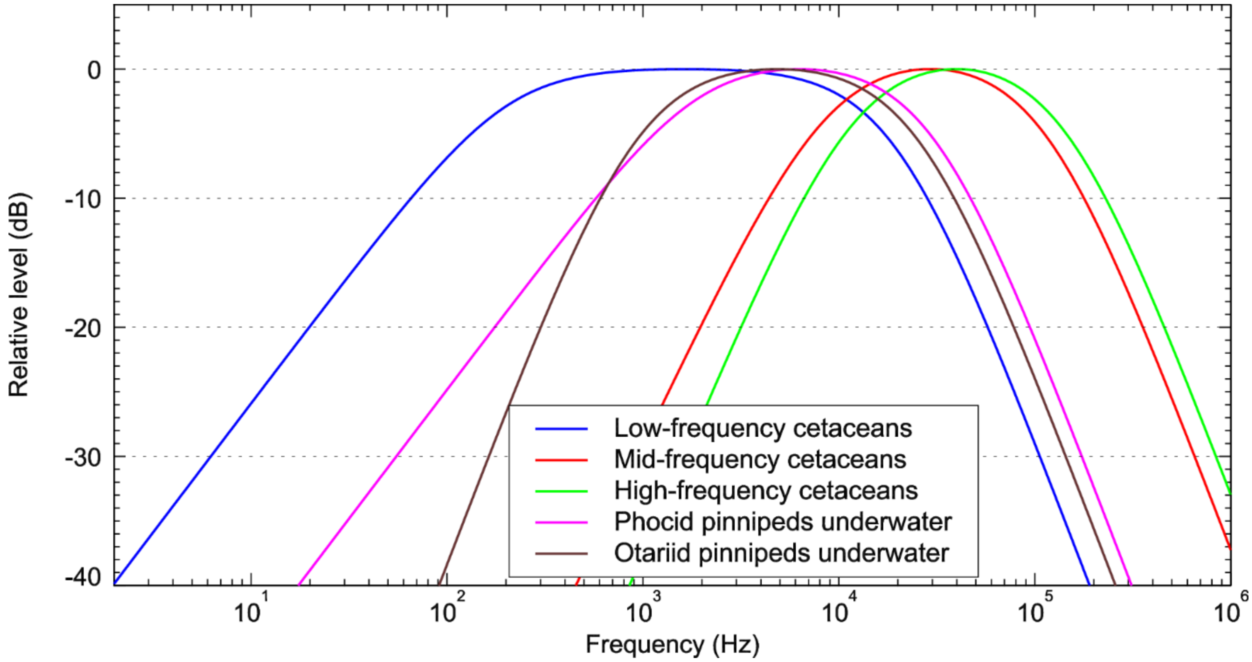

Figure B-2. Auditory weighting functions for the functional marine mammal hearing groups as recommended by NMFS (2018).

B.2.2.2. Impact thresholds

Table B-4 lists the PTS-onset threshold levels for each hearing group (NMFS 2018). The threshold levels are defined separately for impulsive sources (e.g., seismic airgun arrays, echosounders) and non-impulsive sources (e.g., vessels). The SEL thresholds are applicable to weighted acoustic fields, while the $L_{p,\mathrm{pk}}$ fields are tested against the thresholds without applying the weighting functions.

Table B-4. Onset levels for permanent threshold shift (PTS) for marine mammal groups defined by NMFS (2018).

Functional hearing group	**Non-impulsive**	**Impulsive**	
	SEL$_w$ (dB re 1 µPa²s)	**SEL$_w$ (dB re 1 µPa²s)**	**$L_{p,\mathrm{pk}}$ (dB re 1 µPa)**
	PTS-onset	PTS-onset	PTS-onset
Low-frequency cetaceans	199	183	219
Mid-frequency cetaceans	198	185	230
High-frequency cetaceans	173	155	202
Phocid pinnipeds underwater	201	185	218
Otariid pinnipeds in water	219	203	232

APPENDIX E

Chapter 5, Additional Data

West Flemish Pass
Exploration Drilling Program

Chapter 5 – Appendix E

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Draft Report

JULY 19, 2019

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LIST OF TABLES

LIST OF FIGURES

This appendix to Chapter 5 provides additional data to support information on ocean currents, extreme events, seawater properties, and marine icing provided in Chapter 5.

1.0 OCEAN CURRENTS

Progressive vector diagrams for moorings 1 to 6 at different depth levels are presented in Figures 1-1 to 1-6. The plots have speed in cm/s, direction referenced to true north, and time in GMT.

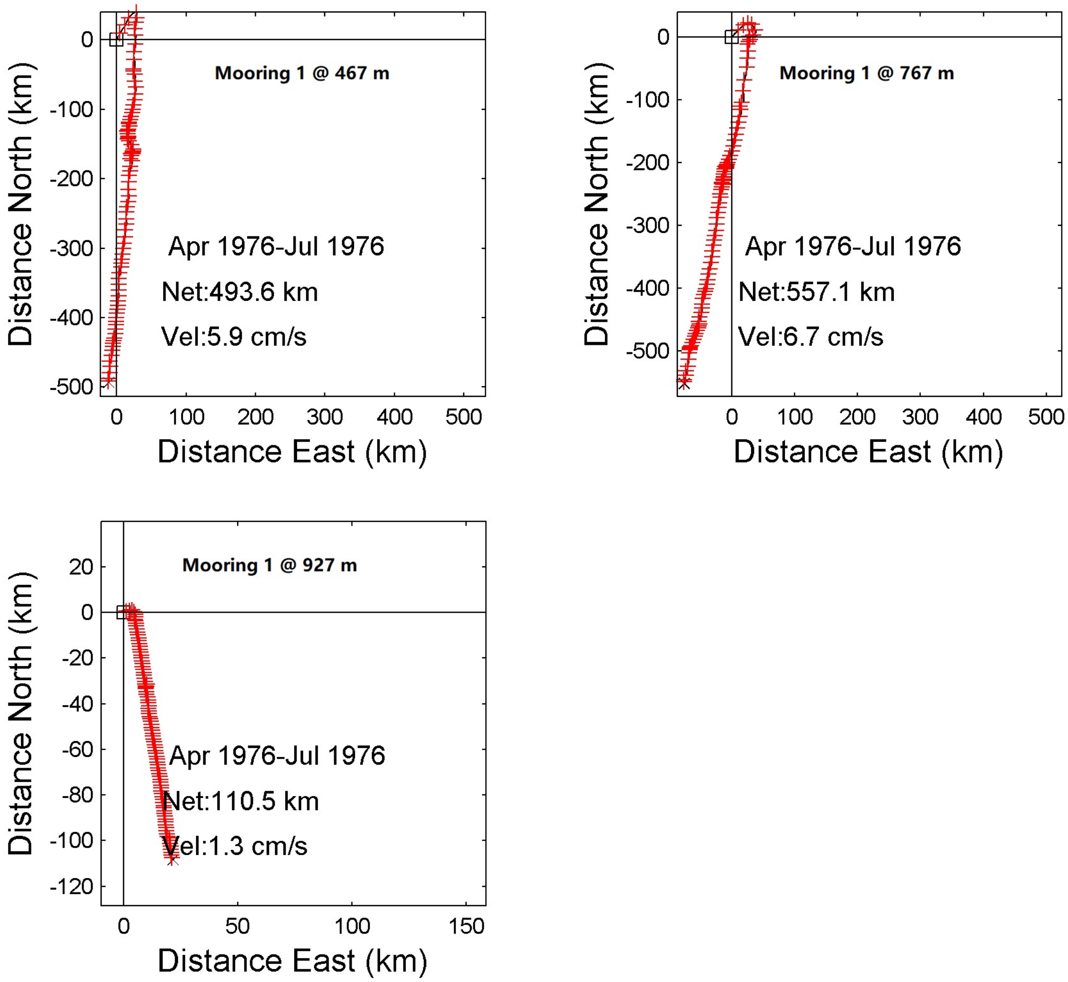

Figure 1-1 Progressive Vector Diagrams for current at West Flemish Pass Mooring 1

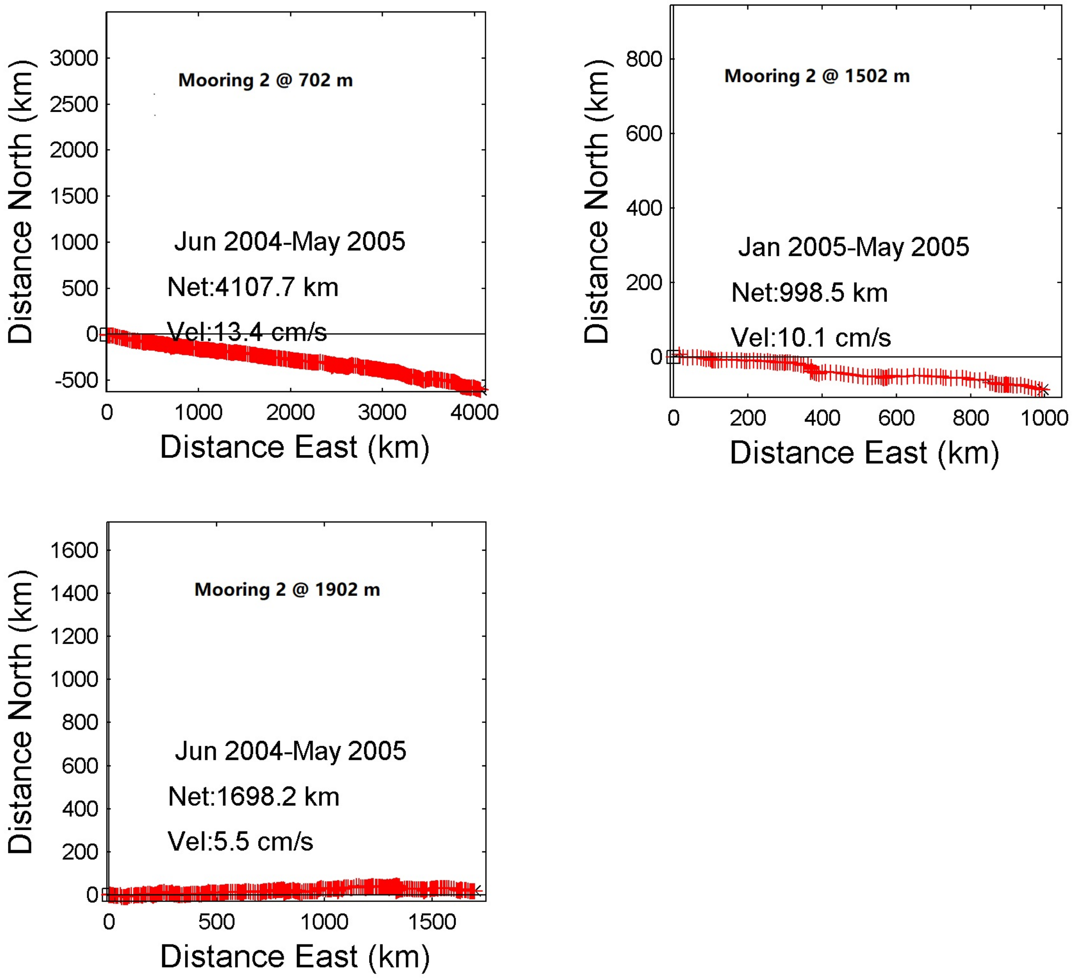

Figure 1-2 **Progressive Vector Diagrams for current at West Flemish Pass Mooring 2**

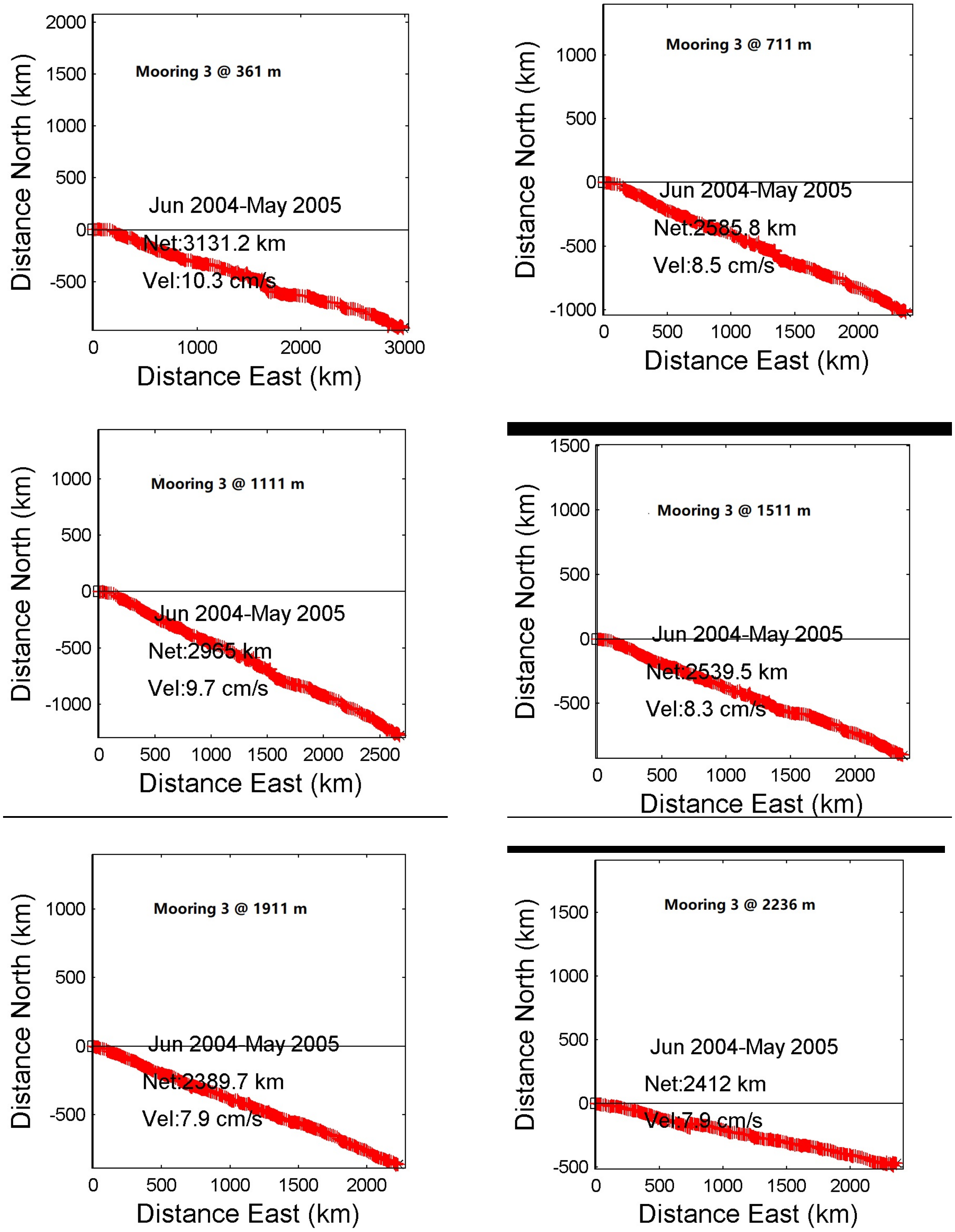

Figure 1-3 Progressive Vector Diagrams for current at West Flemish Pass Mooring 3

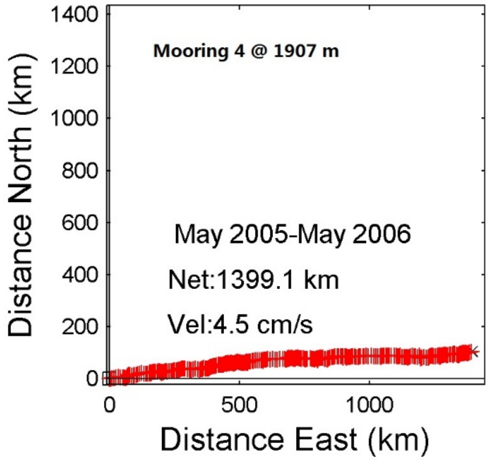

Figure 1-4 Progressive Vector Diagrams for current at West Flemish Pass Mooring 4

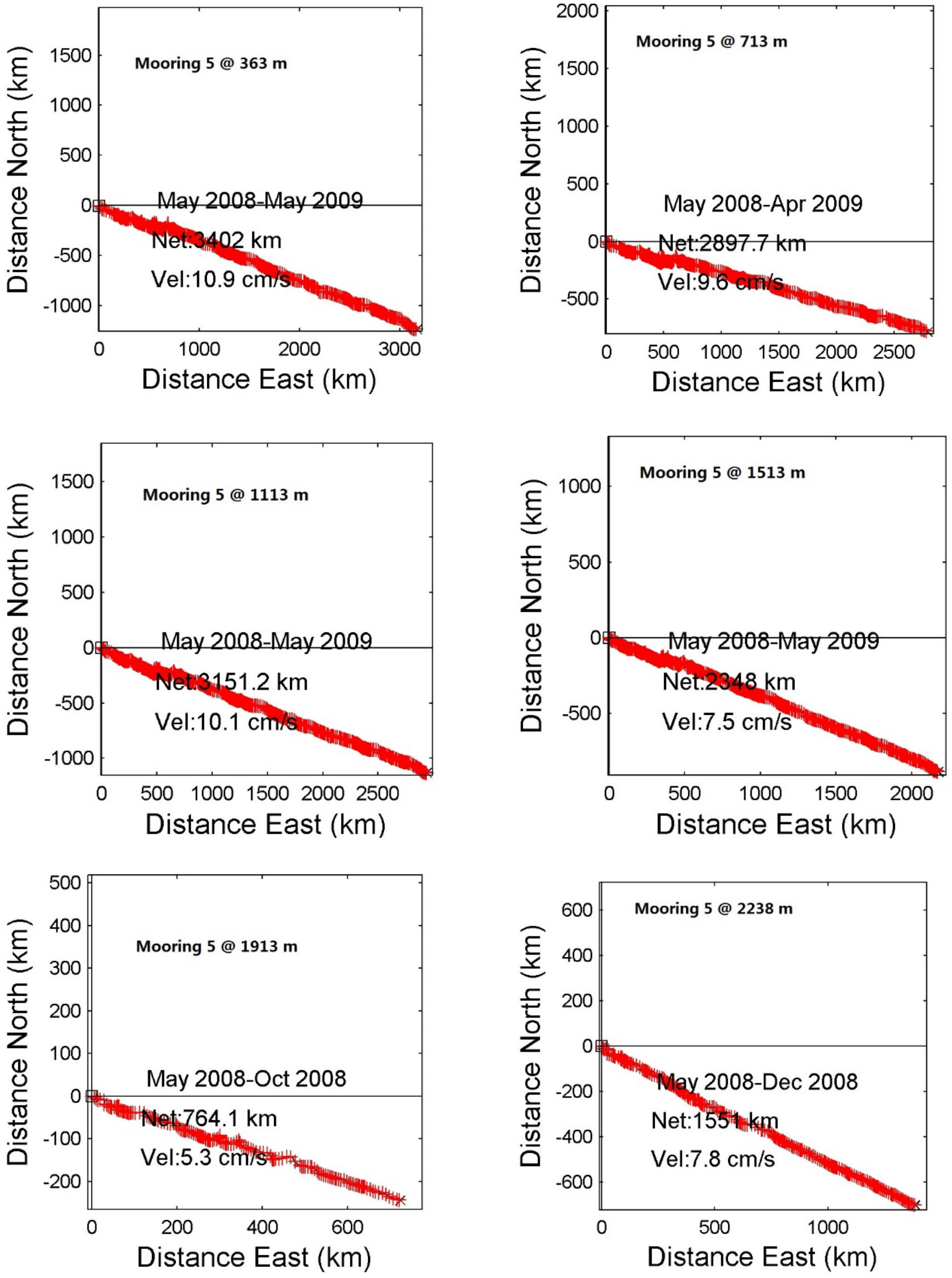

Figure 1-5 Progressive Vector Diagrams for current at West Flemish Pass Mooring 5

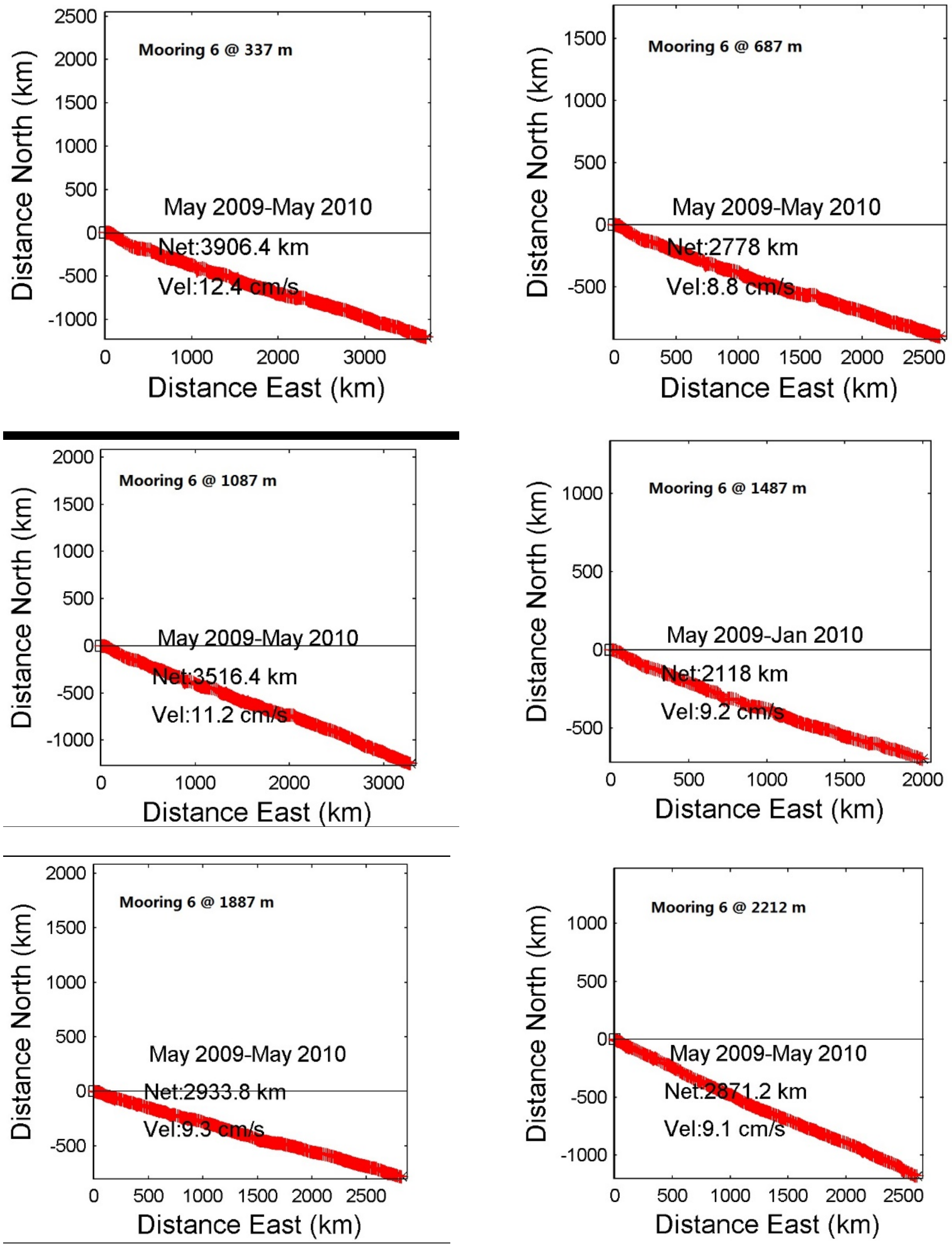

Figure 1-6 Progressive Vector Diagrams for current at West Flemish Pass Mooring 6

Statistics of currents at West Flemish Pass moorings 1 to 6 are provided in Tables 1.1 to 1.6.

Table 1.1 Statistics of Current at Mooring 1 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
467	1976 Apr	1833	27.2	10.7	3.4	153
	1976 May	2976	17.7	5.8	4.4	183
	1976 Jun	2880	19.8	9.2	8.8	185
	1976 Jul	1598	14.9	7.3	6.9	186
	Overall	9287	27.2	8.1	5.9	181
767	1976 Apr	1834	37.3	12.2	7.1	173
	1976 May	2976	18.1	6.1	4.9	194
	1976 Jun	2880	21.4	8.9	8.6	190
	1976 Jul	1597	19.4	6.7	6.4	194
	Overall	9287	37.3	8.3	6.7	188
927	1976 Apr	1831	1.5	1.5	1.2	157
	1976 May	2976	3	1.5	1.3	172
	1976 Jun	2880	1.7	1.5	1.5	171
	1976 Jul	1601	1.5	1.5	1.4	169
	Overall	9288	3	1.5	1.3	169

Table 1.2 Statistics of Current at Mooring 2 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
702	2004 Jun	658	45.0	18.1	17.6	102
	2004 Jul	744	24.1	10.5	9.5	96
	2004 Aug	744	24.6	11.7	10.4	97
	2004 Sep	720	25.2	15.1	14.7	97
	2004 Oct	744	26.1	15.7	15.4	97
	2004 Nov	720	25.2	15.1	14.8	97
	2004 Dec	744	38.3	15.1	12.9	99
	2005 Jan	744	32.2	14.4	12.8	93
	2005 Feb	672	31.6	14.1	13.3	98
	2005 Mar	744	29.0	12.4	11.7	104
	2005 Apr	720	31.9	17.0	16.1	98
	2005 May	546	24.9	13.6	12.6	106
	Overall	8500	45.0	14.4	13.4	98

Table 1.2 Statistics of Current at Mooring 2 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
1502	2005 Jan	66	30.7	17.1	14.3	93
	2005 Feb	672	24.3	10.9	10.1	93
	2005 Mar	744	22.6	10.2	8.7	99
	2005 Apr	720	25.5	12.9	12.1	92
	2005 May	546	28.4	9.9	8.9	98
	Overall	2748	30.7	11.2	10.1	95
1902	2004 Jun	658	22.6	8.0	5.5	89
	2004 Jul	744	21.2	7.2	5.1	86
	2004 Aug	744	20.0	7.3	5.1	91
	2004 Sep	720	17.1	7.0	5.5	87
	2004 Oct	744	20.0	7.9	6.6	89
	2004 Nov	720	17.7	6.9	4.1	90
	2004 Dec	744	27.3	8.0	5.5	86
	2005 Jan	744	25.5	10.0	7.4	88
	2005 Feb	672	24.9	6.8	5.3	90
	2005 Mar	744	22.6	7.6	4.6	94
	2005 Apr	720	21.2	7.5	6.1	89
	2005 May	546	22.0	7.6	6.0	96
	Overall	8500	27.3	7.7	5.6	89

Table 1.3 Statistics of Current at Mooring 3 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
361	2004 Jun	635	40.6	13.9	12.8	101
	2004 Jul	744	23.8	11.8	11.1	112
	2004 Aug	744	19.4	9.7	9.1	108
	2004 Sep	720	32.2	10.4	9.4	108
	2004 Oct	744	29.9	13.4	12.6	106
	2004 Nov	720	25.2	9.5	6.7	106
	2004 Dec	744	32.2	13.1	8.8	127
	2005 Jan	744	34.2	14.3	13.0	96
	2005 Feb	672	27.8	8.4	6.6	107
	2005 Mar	744	47.9	16.9	15.8	106
	2005 Apr	720	27.8	10.4	9.6	110

Table 1.3 Statistics of Current at Mooring 3 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
	2005 May	520	28.4	13.7	8.3	114
	Overall	8451	47.9	12.1	10.3	108
711	2004 Jun	634	41.4	11.2	10.6	110
	2004 Jul	744	21.7	9.5	9.1	117
	2004 Aug	744	18.8	8.7	8.3	111
	2004 Sep	720	28.7	8.6	7.9	113
	2004 Oct	744	27.6	11.2	10.7	113
	2004 Nov	720	25.8	8.6	5.8	109
	2004 Dec	744	18.2	9.3	6.8	125
	2005 Jan	744	29.3	10.3	9.5	104
	2005 Feb	672	18.8	6.3	5.4	113
	2005 Mar	744	46.3	14.0	13.2	114
	2005 Apr	720	23.8	8.3	7.8	116
	2005 May	521	20.2	9.4	6.8	116
	Overall	8451	46.3	9.6	8.5	113
1111	2004 Jun	635	36.8	12.1	11.4	109
	2004 Jul	744	22.9	10.9	10.3	120
	2004 Aug	744	18.2	10.3	10.0	114
	2004 Sep	720	26.7	9.9	9.2	116
	2004 Oct	744	28.7	12.7	12.1	116
	2004 Nov	720	34.2	10.7	6.9	115
	2004 Dec	744	19.7	10.5	8.2	125
	2005 Jan	744	27.3	11.6	10.9	106
	2005 Feb	672	21.2	8.1	6.8	116
	2005 Mar	744	36.3	15.0	14.0	115
	2005 Apr	720	21.7	9.8	9.3	121
	2005 May	520	21.4	9.2	7.6	119
	Overall	8451	36.8	11.0	9.8	116
1511	2004 Jun	635	26.7	9.7	9.2	105
	2004 Jul	744	21.4	8.3	7.9	116
	2004 Aug	744	15.9	9.1	8.7	109
	2004 Sep	720	22.3	8.7	8.0	112
	2004 Oct	744	22.0	10.8	10.3	113
	2004 Nov	720	28.4	9.2	6.6	109
	2004 Dec	744	17.7	8.8	7.2	116

Table 1.3 Statistics of Current at Mooring 3 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
	2005 Jan	744	24.6	10.3	8.7	99
	2005 Feb	672	19.1	7.2	6.3	112
	2005 Mar	744	27.0	12.4	11.6	111
	2005 Apr	720	20.3	9.7	9.3	116
	2005 May	520	19.7	7.3	5.9	113
	Overall	8451	28.4	9.4	8.4	111
1911	2004 Jun	635	24.6	9.8	9.1	108
	2004 Jul	744	22.9	8.4	7.7	115
	2004 Aug	744	16.2	8.2	7.5	109
	2004 Sep	720	20.6	9.2	7.8	113
	2004 Oct	744	21.7	10.6	10.0	112
	2004 Nov	720	21.2	8.3	6.9	107
	2004 Dec	744	19.1	8.3	6.7	113
	2005 Jan	744	23.2	8.5	6.9	106
	2005 Feb	672	19.7	7.9	6.8	110
	2005 Mar	744	31.3	11.6	10.7	115
	2005 Apr	720	24.6	10.1	9.5	114
	2005 May	520	20.6	7.0	3.8	108
	Overall	8451	31.3	9.0	7.9	111
2236	2004 Jun	635	27.5	9.9	8.4	98
	2004 Jul	744	24.6	9.1	7.9	104
	2004 Aug	744	20.9	7.6	6.6	107
	2004 Sep	720	22.6	11.6	9.2	98
	2004 Oct	744	24.9	10.5	9.9	104
	2004 Nov	720	24.6	9.3	8.0	100
	2004 Dec	744	24.6	8.1	6.5	98
	2005 Jan	744	29.0	7.7	5.5	104
	2005 Feb	672	25.2	8.5	7.7	99
	2005 Mar	744	29.3	11.5	10.2	102
	2005 Apr	720	27.8	11.0	10.4	105
	2005 May	520	25.8	9.5	4.4	83
	Overall	8451	29.3	9.5	7.9	101

Table 1.4 Statistics of Current at Mooring 4 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed(cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
1902	2005 May	195	17.9	9.4	8.6	85
	2005 Jun	720	19.1	6.7	4.5	79
	2005 Jul	744	14.4	5.8	4.1	84
	2005 Aug	744	19.9	6.1	4.2	86
	2005 Sep	720	15.0	6.0	4.5	83
	2005 Oct	744	15.5	5.8	3.3	81
	2005 Nov	720	24.1	7.0	5.0	87
	2005 Dec	744	21.7	6.2	3.2	90
	2006 Jan	744	20.2	7.2	4.4	88
	2006 Feb	672	24.1	8.0	6.3	89
	2006 Mar	744	20.8	7.6	5.9	90
	2006 Apr	720	17.0	6.1	3.9	89
	2006 May	394	16.4	5.6	3.9	76
	Overall	8605	24.1	6.6	4.5	86

Table 1.5 Statistics of Current at Mooring 5 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
363	2008 May	481	42.1	16.0	14.6	119
	2008 Jun	720	30.7	9.4	7.7	105
	2008 Jul	744	17.1	7.5	5.4	114
	2008 Aug	744	39.7	14.4	3.3	94
	2008 Sep	720	54.9	13.8	9.6	102
	2008 Oct	744	32.2	13.9	13.4	113
	2008 Nov	720	18.2	9.4	8.9	113
	2008 Dec	744	29.6	13.8	13.1	112
	2009 Jan	744	34.8	16.6	15.9	111
	2009 Feb	672	41.2	16.8	15.6	111
	2009 Mar	744	42.9	14.2	12.8	112
	2009 Apr	720	31.0	13.5	12.5	115
	2009 May	180	28.7	13.2	11.0	113
	Overall	8677	54.9	13.2	10.9	111
713	2008 May	480	35.5	12.7	11.8	116
	2008 Jun	720	30.5	8.3	7.1	101

Table 1.5 Statistics of Current at Mooring 5 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
	2008 Jul	744	16.4	6.5	4.8	117
	2008 Aug	744	39.6	12.8	3.2	88
	2008 Sep	720	45.2	12.1	8.7	96
	2008 Oct	744	26.4	12.1	11.6	107
	2008 Nov	720	18.8	7.9	7.4	106
	2008 Dec	744	26.4	12.0	11.3	105
	2009 Jan	744	34.6	14.9	14.2	106
	2009 Feb	672	34.6	14.6	13.9	104
	2009 Mar	744	48.1	12.3	11.4	107
	2009 Apr	624	26.4	12.6	11.6	107
	Overall	8400	48.1	11.5	9.6	106
1113	2008 May	480	27.0	11.5	10.7	121
	2008 Jun	720	24.9	8.5	7.5	109
	2008 Jul	744	15.3	7.1	5.7	119
	2008 Aug	744	26.4	12.4	4.9	99
	2008 Sep	720	28.7	12.2	9.7	103
	2008 Oct	744	29.6	12.7	12.2	113
	2008 Nov	720	18.0	8.7	8.1	112
	2008 Dec	744	28.4	12.4	11.9	110
	2009 Jan	744	34.2	15.2	14.5	111
	2009 Feb	672	36.6	15.3	14.2	109
	2009 Mar	744	31.3	12.9	11.7	112
	2009 Apr	720	22.9	12.0	11.2	112
	2009 May	181	19.7	9.9	8.6	119
	Overall	8677	36.6	11.7	10.1	111
1513	2008 May	481	18.5	7.0	6.2	121
	2008 Jun	720	15.5	6.1	5.4	109
	2008 Jul	744	11.7	5.1	4.4	116
	2008 Aug	744	16.7	8.4	4.8	102
	2008 Sep	720	23.8	8.8	7.4	106
	2008 Oct	744	20.5	8.7	8.4	114
	2008 Nov	720	12.9	6.5	6.2	111
	2008 Dec	744	22.0	9.2	8.8	112
	2009 Jan	744	28.5	11.5	11.0	113
	2009 Feb	672	23.8	10.8	10.2	111

Table 1.5 Statistics of Current at Mooring 5 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
	2009 Mar	744	29.3	9.9	9.0	114
	2009 Apr	720	22.0	9.3	8.8	114
	2009 May	180	15.0	6.9	5.7	118
	Overall	8677	29.3	8.5	7.5	112
1913	2008 May	480	15.8	5.9	3.9	114
	2008 Jun	720	19.1	5.7	4.7	107
	2008 Jul	744	12.0	4.6	4.0	113
	2008 Aug	744	15.5	7.2	5.7	106
	2008 Sep	720	24.3	7.7	6.8	107
	2008 Oct	570	18.2	7.4	6.9	110
	Overall	3978	24.3	6.4	5.3	109
2263	2008 May	480	39.9	9.3	6.0	122
	2008 Jun	720	26.7	8.4	6.8	116
	2008 Jul	744	19.1	7.2	6.3	124
	2008 Aug	744	25.8	10.4	9.2	116
	2008 Sep	720	31.1	10.3	9.3	114
	2008 Oct	744	22.0	9.0	8.2	117
	2008 Nov	720	18.2	8.4	7.9	116
	2008 Dec	675	20.2	8.8	7.9	115
	Overall	5547	39.9	9.0	7.8	117

Table 1.6 Statistics of Current at Mooring 6 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
337	2009 May	552	29.0	14.8	14.1	116
	2009 Jun	720	27.3	15.2	14.4	108
	2009 Jul	744	22.6	13.3	13.0	109
	2009 Aug	744	27.3	14.5	12.7	110
	2009 Sep	720	27.0	11.6	11.1	104
	2009 Oct	744	20.6	10.3	8.1	113
	2009 Nov	720	24.3	10.7	9.4	107
	2009 Dec	744	30.7	14.6	13.8	101
	2010 Jan	744	24.1	12.8	12.2	107
	2010 Feb	672	26.4	14.9	14.7	107

Table 1.6 Statistics of Current at Mooring 6 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
	2010 Mar	744	25.2	13.7	13.2	108
	2010 Apr	720	23.2	13.8	13.4	109
	2010 May	154	19.4	13.5	13.1	103
	Overall	8722	30.7	13.3	12.4	108
687	2009 May	552	22.7	10.4	10.0	117
	2009 Jun	720	20.4	10.3	9.8	110
	2009 Jul	744	16.8	9.3	9.0	111
	2009 Aug	744	22.4	10.4	9.4	111
	2009 Sep	720	23.3	8.5	8.1	106
	2009 Oct	744	18.0	7.1	5.8	114
	2009 Nov	720	16.2	7.4	6.6	108
	2009 Dec	744	24.2	10.3	9.9	101
	2010 Jan	744	19.5	9.2	9.0	110
	2010 Feb	672	21.5	10.6	10.4	107
	2010 Mar	744	19.5	9.4	9.2	108
	2010 Apr	720	16.2	9.7	9.5	108
	2010 May	154	14.4	10.0	9.9	104
	Overall	8722	24.2	9.4	8.9	109
1087	2009 May	553	26.7	13.1	12.6	114
	2009 Jun	720	23.8	13.3	12.8	110
	2009 Jul	744	20.3	11.6	11.3	112
	2009 Aug	744	26.7	13.4	12.1	112
	2009 Sep	720	27.5	11.2	10.6	105
	2009 Oct	744	17.4	9.3	8.0	115
	2009 Nov	720	20.3	10.3	8.9	109
	2009 Dec	744	27.0	13.1	12.3	104
	2010 Jan	744	24.3	12.2	11.7	112
	2010 Feb	672	25.2	13.7	13.5	111
	2010 Mar	744	23.5	12.1	11.6	114
	2010 Apr	720	20.3	12.0	11.7	113
	2010 May	153	17.4	13.6	13.5	108
	Overall	8722	27.5	12.1	11.4	111
1487	2009 May	553	19.8	10.5	10.0	115
	2009 Jun	720	21.0	9.6	9.2	111
	2009 Jul	744	18.6	9.5	8.9	112

Table 1.6 Statistics of Current at Mooring 6 at West Flemish Pass

Depth (m)	Month	No. of Records	Maximum Speed (cm/s)	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction of Mean Velocity (T)
	2009 Aug	744	23.9	11.6	10.5	111
	2009 Sep	720	24.2	9.4	8.9	105
	2009 Oct	744	17.4	8.0	7.0	111
	2009 Nov	720	21.0	9.0	8.2	108
	2009 Dec	744	22.1	10.3	9.5	104
	2010 Jan	736	22.4	11.1	10.6	108
	Overall	6425	24.2	9.9	9.2	109
1887	2009 May	552	16.8	9.3	8.7	108
	2009 Jun	720	20.3	9.7	8.4	106
	2009 Jul	744	20.9	9.8	9.0	106
	2009 Aug	744	23.5	10.6	9.8	106
	2009 Sep	720	21.2	9.1	8.3	102
	2009 Oct	744	16.8	8.8	7.9	109
	2009 Nov	720	23.5	11.2	10.0	108
	2009 Dec	744	22.6	10.6	8.6	100
	2010 Jan	744	19.7	11.3	10.8	105
	2010 Feb	672	21.4	12.1	11.7	105
	2010 Mar	744	18.2	9.5	9.2	105
	2010 Apr	720	21.7	9.7	9.0	107
	2010 May	154	20.6	13.1	12.9	105
	Overall	8722	23.5	10.2	9.3	105
2212	2009 May	552	22.3	9.0	6.1	120
	2009 Jun	720	25.2	10.7	8.7	114
	2009 Jul	744	27.0	10.4	9.2	115
	2009 Aug	744	27.6	13.0	11.4	117
	2009 Sep	720	23.8	9.6	8.5	113
	2009 Oct	744	23.8	10.4	8.8	117
	2009 Nov	720	22.9	10.4	9.3	112
	2009 Dec	744	25.2	9.6	8.4	111
	2010 Jan	744	22.9	10.9	9.9	112
	2010 Feb	672	23.8	11.8	11.2	114
	2010 Mar	744	21.7	9.4	8.1	112
	2010 Apr	720	26.1	11.2	8.6	117
	2010 May	154	21.4	14.1	13.8	113
	Overall	8722	27.6	10.6	9.1	114

2.0 EXTREME EVENTS

2.1 Gumbel Extreme Value Analysis of Winds

The extreme value estimates for wind are calculated using Oceanweather's Osmosis software program for the return periods of 1-year, 10-year, 25-year and 100-year. The analysis used hourly wind values for the reference height of 10 m above sea level. The calculated extreme values are then converted to values corresponding to 10-minute and 1-minute wind speeds using a constant ration of 1.06 and 1.22, respectively (US Geological Survey 1979).

2.2 Gumbel Extreme Value Analysis of Waves

The maximum individual wave heights are calculated within Oceanweather's Osmosis software by evaluating the Borgman integral (Borgman 1973), which is derived from Raleigh distribution. The variant of this equation used in the software has the following form (Forristall 1978):

$$Pr\{H > h\} = exp\left[-1.08311\left(\frac{h^2}{8M_0}\right)^{1.063}\right], T = \frac{M_0}{M_1},$$

where h is the significant wave height, T is the wave period, and M0 and M1 are the first and second spectral moments of the total spectrum. The associated peak periods are calculated by plotting the peak periods of the chosen storm peak values versus the corresponding significant wave heights. This plot is fitted to a power function *y* = *axb* and the resulting equation is used to calculate the peak periods associated with the extreme values of significant wave height.

2.3 Environmental Contours of Waves

In order to examine the period ranges of storm events, an environmental contour plot is produced showing the probability of the joint occurrence of significant wave heights and the spectral peak periods using the methodology of Winterstein et al. (1993). The wave heights are fitted to a Weibull distribution and the peak periods to a lognormal distribution. The wave data is divided into bins of 1 m for significant wave heights and 1 second for peak periods. Since the lower wave values have too much of an impact on the wave extremes, the wave heights below 2 m are modeled separately in a Weibull distribution. The two Weibull curves are combined near 2 m, the point where both functions have the same probability.

Three-parameter Weibull distributions are used with a scaling parameter α, shape parameter β, and location parameter γ. The three parameters are solved using at least square method, the maximum log likelihood and the method of moments. The following equations is minimized to get the coefficients:

$$LS(\alpha,\beta,\gamma) := \sum_{i=0}^{13}\left[ln\left(ln\,(1-FP_i)\right) - \beta\cdot ln\left(\frac{h_i-\gamma}{\alpha}\right)\right]^2,$$

where hi is the endpoint of the height bin (0.5, 1.5, ...) and FPi is the cumulative probability of the height bin. Using a minimizing function, the three parameters α, β and γ are calculated.

A lognormal distribution is fitted to the spectral peak periods in each wave height bin. The coefficient of the lognormal distribution is then calculated. Using the coefficients and the two distribution functions, the joint wave height and period combinations are calculated for the various return periods.

The contour plots depicting these values for return periods of 1-year, 10-year, 25-year, 50-year and 100-year using hourly and 6-hourly datasets, respectively, are presented in Figure 2-1 and Figure 2-2. The extreme wave heights for all return periods are higher using the Weibull distribution when compared to the Gumbel distribution.

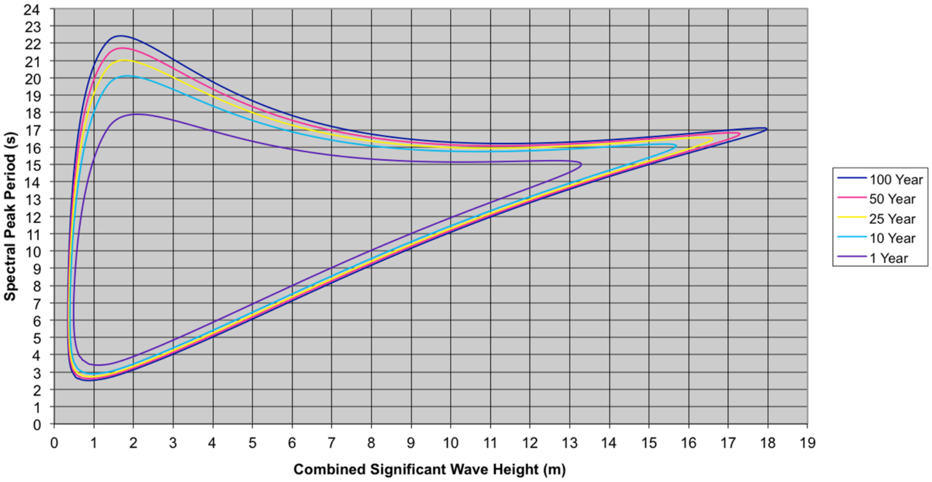

Figure 2-1 Environmental Contour Plot of 1, 10, 25, 50 and 100-year Return Periods for Grid Point 13741 Located at 48.2°N and 47.3°W (1954 to 2015) Using an Hourly Data Set

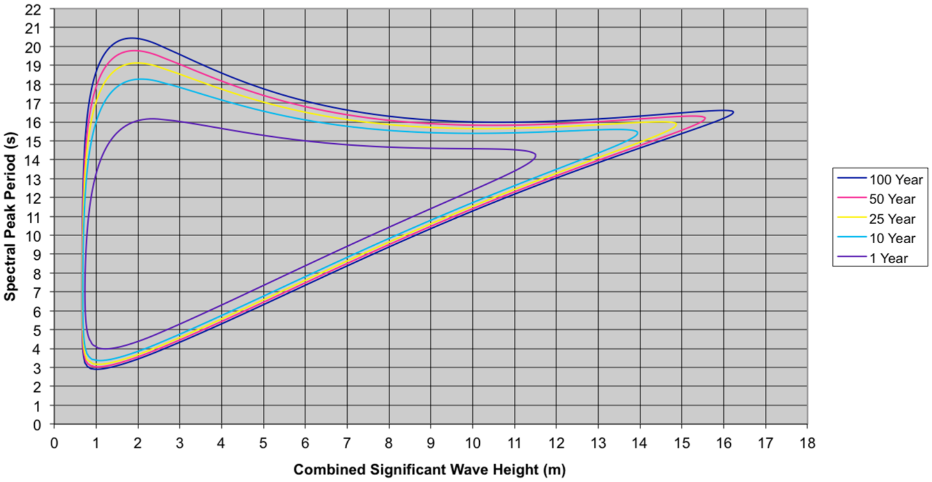

Figure 2-2 Environmental Contour Plot of 1, 10, 25, 50 and 100-year Return Periods for Grid Point 13741 Located at 48.2°N and 47.3°W (1954 to 2015) Using a 6-hourly Data Set

3.0 SEAWATER PROPERTIES

Summarized statistics of sea water temperature and salinity at depths of 0 m, 50 m, 100 m, 200 m, 300 to 900 m, and 1,000 to 3,000 m at West Flemish Pass are provided in Tables 3.1 to 3.6.

Table 3.1 Monthly Temperature and Salinity Statistics at 0 m Water in West Flemish Pass from Historical CTD Data

Month	Surface Temperature (0 m)			Surface Salinity (0 m)		
	Mean (°C)	Max (°C)	Min (°C)	Mean (psu)	Max (psu)	Min (psu)
Jan	1.79	2.75	-0.60	34.07	34.43	33.19
Mar	-0.78	0.21	-1.37	33.52	33.75	33.23
Apr	-0.15	3.73	-1.55	33.04	34.66	31.41
May	2.48	5.69	-0.06	33.53	34.79	32.57
Jun	4.19	8.59	-0.24	33.00	34.24	31.37
Jul	10.80	13.41	2.80	32.58	33.66	31.30
Aug	10.60	12.60	3.14	32.80	33.81	32.35
Oct	6.88	9.36	2.86	33.94	34.18	33.18
Nov	5.06	7.79	1.09	33.84	34.51	32.55
Dec	3.45	5.82	0.81	33.92	34.31	33.06
Overall	4.72	13.41	-1.55	33.44	34.79	31.30

Table 3.2 Monthly Temperature and Salinity Statistics at 50 m Water in West Flemish Pass from Historical CTD Data

Month	Temperature (50 m)			Salinity (50 m)		
	Mean (°C)	Max (°C)	Min (°C)	Mean (psu)	Max (psu)	Min (psu)
Jan	1.70	3.12	-0.20	34.15	34.54	33.48
Mar	-1.11	0.54	-1.50	33.49	33.89	33.23
Apr	0.25	3.43	-1.34	33.62	34.68	32.89
May	1.65	5.27	-1.22	33.98	34.75	33.02
Jun	0.69	5.71	-1.65	33.70	34.55	32.71
Jul	2.60	5.00	-1.53	34.21	34.80	33.31
Aug	1.20	3.02	-1.11	33.99	34.46	33.40
Oct	5.10	9.22	1.86	34.17	34.76	33.69
Nov	4.34	7.64	0.92	34.04	35.29	33.29
Dec	3.36	5.78	0.74	34.08	34.64	33.23
Overall	2.65	9.22	-1.65	33.95	35.29	32.71

Table 3.3 Monthly Temperature and Salinity Statistics at 100 m Water in West Flemish Pass from Historical CTD Data

Month	Temperature (100 m)			Salinity (100 m)		
	Mean (°C)	Max (°C)	Min (°C)	Mean (psu)	Max (psu)	Min (psu)
Jan	2.43	3.44	0.01	34.32	34.52	33.73
Mar	0.71	2.06	-0.83	34.13	34.49	33.76
Apr	1.36	3.41	-1.03	34.08	34.68	33.30
May	2.22	3.97	-0.62	34.38	34.75	33.54
Jun	1.30	4.41	-1.65	34.06	34.76	33.12
Jul	3.76	4.72	-0.95	34.62	34.86	33.58
Aug	1.90	3.24	-0.57	34.30	34.61	33.75
Oct	3.76	5.11	1.86	34.61	34.81	33.70
Nov	3.33	5.96	0.22	34.43	34.81	33.64
Dec	3.63	5.10	-0.03	34.41	34.85	33.29
Overall	2.67	5.96	-1.65	34.34	34.86	33.12

Table 3.4 Monthly Temperature and Salinity Statistics at 200 m Water in West Flemish Pass from Historical CTD Data

Month	Temperature (200 m)			Salinity (200 m)		
	Mean (°C)	Max (°C)	Min (°C)	Mean (psu)	Max (psu)	Min (psu)
Jan	3.72	4.42	2.35	34.67	34.81	34.36
Mar	2.31	3.09	1.59	34.55	34.74	34.38
Apr	2.44	4.00	0.63	34.55	34.75	33.39
May	3.01	3.80	1.66	34.65	34.81	34.35
Jun	2.83	4.61	0.04	34.56	34.92	33.86
Jul	4.38	4.85	1.25	34.82	34.88	34.30
Aug	3.09	3.24	2.81	34.66	34.73	34.56
Oct	3.92	4.22	2.19	34.82	34.88	34.24
Nov	3.87	4.93	1.22	34.75	34.87	34.23
Dec	4.14	4.53	0.87	34.81	34.89	34.11
Overall	3.57	4.93	0.04	34.70	34.92	33.39

Table 3.5 Monthly Temperature and Salinity Statistics at 300 - 900 m Water in West Flemish Pass from Historical CTD Data

Month	Temperature (300 to 900 m)			Salinity (300 to 900 m)		
	Mean (°C)	Max (°C)	Min (°C)	Mean (psu)	Max (psu)	Min (psu)
Jan	3.91	4.36	3.05	34.84	34.89	34.57
Mar	3.41	4.16	2.87	34.83	34.89	34.66
Apr	3.21	3.71	2.63	34.80	34.90	34.37
May	3.80	4.05	2.93	34.85	34.89	34.66
Jun	3.50	4.02	1.46	34.83	35.01	34.21
Jul	3.81	4.70	2.53	34.85	34.89	34.60
Aug	3.27	3.52	3.18	34.77	34.87	34.72
Oct	3.71	4.05	3.38	34.87	34.96	34.73
Nov	3.93	4.75	1.65	34.84	34.92	34.32
Dec	3.90	4.59	1.79	34.85	34.98	34.33
Overall	3.76	4.75	1.46	34.85	35.01	34.21

Table 3.6 Monthly Temperature and Salinity Statistics at 1000 -3000 m Water in West Flemish Pass from Historical CTD Data

Month	Temperature (1000 to 3000 m)			Salinity (1000 to 3000 m)		
	Mean (°C)	Max (°C)	Min (°C)	Mean (psu)	Max (psu)	Min (psu)
Jan	3.35	3.51	3.05	34.90	34.94	34.86
Mar	3.20	3.22	3.16	34.87	34.87	34.86
Apr	3.23	3.45	2.67	34.92	34.93	34.90
May	3.57	3.69	2.26	34.88	34.91	34.87
Jun	3.44	3.44	3.44	34.89	34.89	34.89
Jul	3.55	3.57	3.51	34.86	34.87	34.85
Oct	3.52	3.85	3.35	34.89	34.95	34.85
Nov	3.39	3.61	2.98	34.87	34.93	34.83
Dec	3.22	3.35	3.07	34.84	34.86	34.83
Overall	3.46	3.85	2.26	34.88	34.95	34.83

4.0 MARINE ICING

A review of the spray icing hazard is provided by Minsk (1977). The frequency of potential icing conditions and its severity are estimated from the algorithm proposed by Overland et al. (1986) and subsequently updated by Overland (1990). These algorithms are based primarily on reports from vessels that are 20 to 75 m in length. Here is the algorithm presented by Overland (1990):

$$PPR = \frac{V_a(T_f - T_a)}{1 + 0.3(T_w - T_f)}$$

where PPR is the icing predictor (m°Cs-1), V_a wind speed (ms-1), T_f is freezing point of seawater (usually -1.7°C or -1.8°C), T_a is air temperature (°C) and T_w is sea temperature.

The algorithm generates an icing predictor based on air temperature, wind speed, and sea temperature. The predictor is empirically related to observed icing rates of fishing vessels in the Gulf of Alaska. This method will provide conservative estimates of icing severity in the study region as winter sea surface temperature are colder and wave conditions are lower in the study area compared to the Gulf of Alaska, where the algorithm is calibrated (Makkonen et al. 1991). Potential icing rates are computed using wind speed, air temperature, and sea surface temperature from the ICOADS data set from 1984 to 2015 (Table 4.1; Figure 4-1).

Table 4.1 Frequency OF Occurrence of Potential Spray Icing Conditions

Month	None (0 cm/hr)	Light (0.7 cm/hr)	Moderate (0.7-2.0 cm/hr)	Heavy (2.0-4.0 cm/hr)	Extreme (>4.0 cm/hr)
January	68.5	21.5	6.0	2.5	1.6
February	69.4	23.1	4.8	1.2	1.5
March	78.8	14.8	4.6	1.0	0.8
April	96.5	2.9	0.6	0.0	0.0
May	99.9	0.1	0.0	0.0	0.0
June	100.0	0.0	0.0	0.0	0.0
July	100.0	0.0	0.0	0.0	0.0
August	100.0	0.0	0.0	0.0	0.0
September	100.0	0.0	0.0	0.0	0.0
October	100.0	0.0	0.0	0.0	0.0
November	99.4	0.6	0.0	0.0	0.0
December	94.7	4.8	0.5	0.0	0.0
Winter	75.2	18.0	4.2	1.4	1.2
Spring	92.7	5.2	1.5	0.3	0.2
Summer	100.0	0.0	0.0	0.0	0.0
Autumn	99.8	0.2	0.0	0.0	0.0
Annual	92.3	5.6	1.4	0.4	0.3

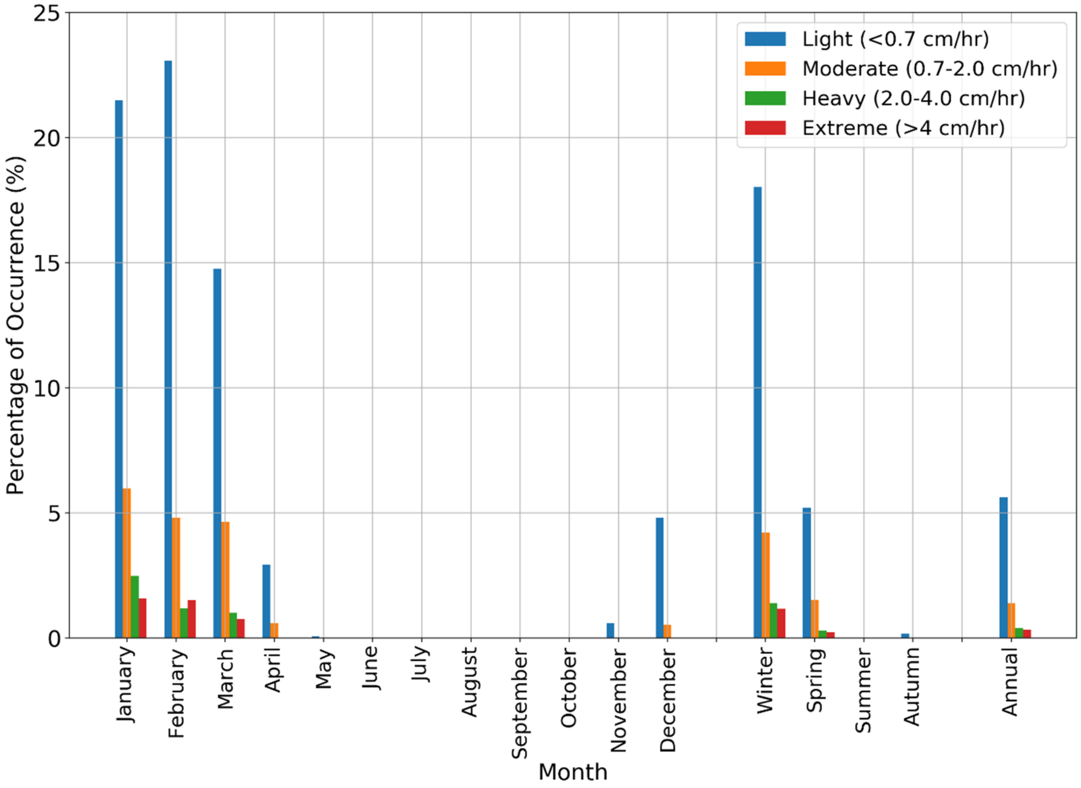

Figure 4-1 **Frequency of Occurrence of Potential Icing Conditions**