HEBRON PROJECT
ENVIRONMENTAL ASSESSMENT AMENDMENT

FINAL REPORT

Submitted by:

Hebron Project
ExxonMobil Canada Properties
Suite 701, Atlantic Place
215 Water Street
St. John's, Newfoundland and Labrador
Canada A1C 6C9

Prepared by:

Amec Foster Wheeler Environment & Infrastructure
A Division of Amec Foster Wheeler Americas Limited
133 Crosbie Road, PO Box 13216
St. John's, Newfoundland and Labrador
Canada A1B 4A5

Amec Fw TF1775223

June 2017

TABLE OF CONTENTS

Page No.

1.0 INTRODUCTION 4
1.1 Environmental Assessment Review and Approval 4
1.2 Purpose and Structure of the EA Amendment 6
2.0 PROJECT DESCRIPTION 7
2.1 Original Project Description 7
2.1.1 Offshore Project Area - Planned Activities (Including Well Drilling) 8
2.1.2 Planned Re-Injection of SBM-Associated (Cement) Drill Cuttings from the Platform 9
2.2 Proposed Amendment to the Project 11
2.3 General Overview of SBMs and SBM-Associated Drill Cuttings 13
2.3.1 Composition of Drilling Muds 14
2.3.2 Composition of SBMs Used Offshore Newfoundland 15
2.3.3 Composition of Shoe Track Cement 16
3.0 ENVIRONMENTAL SETTING 17
3.1 Air Quality 17
3.2 Fish and Fish Habitat 18
3.2.1 Benthic Macroinvertebrates 18
3.2.2 Corals and Sponges 22
3.2.3 Finfish 22
3.3 Commercial Fisheries 28
3.4 Marine Birds 36
3.5 Marine Mammals and Sea Turtles 37
3.6 Species at Risk 38
3.7 Sensitive or Special Areas 41
4.0 ENVIRONMENTAL EFFECTS ASSESSMENT 43
4.1 Air Quality 43
4.2 Fish and Fish Habitat (Including Species at Risk) 43
4.2.1 Potential Toxicity and Bioaccumulation 43
4.2.2 Potential Sedimentation and Burial 44
4.3 Commercial Fisheries 54
4.4 Marine Birds (Including Species at Risk) 54
4.5 Marine Mammals and Sea Turtles (Including Species at Risk) 55
4.6 Sensitive or Special Areas 56
5.0 SUMMARY AND CONCLUSION 57
6.0 REFERENCES 58

LIST OF TABLES

Page No.

Table 2-1 SBM-Associated Cuttings Release Summary (Per Typical Well) 13
Table 3-1 Corals Occurring on the Grand Banks 22
Table 3-2 DFO RV Surveys off Eastern Newfoundland (2017) 32
Table 3-3 Species at Risk or Otherwise of Special Conservation Concern (Current Designations) 39

LIST OF FIGURES

Page No.

Figure 1-1 Hebron Project Area 5
Figure 2-1 Generalized Schematic of the Hebron GBS and Associated Components 7
Figure 3-1 Striped Pink Shrimp Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012) 19
Figure 3-2 Northern Shrimp Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012) 20
Figure 3-3 Snow Crab Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012) 21
Figure 3-4 Coral Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012) 23
Figure 3-5 Sponge Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012) 24
Figure 3-6 Sand Lance Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012) 25
Figure 3-7 Sculpin Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012) 26
Figure 3-8 American Plaice Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012) 27
Figure 3-9 Commercial Fishing Locations, All Species (2010-2015) 29
Figure 3-10 Commercial Fishing Locations, Mobile Gear Types (2010-2015) 30
Figure 3-11 Commercial Fishing Locations, Fixed Gear Types (2010-2015) 31
Figure 3-12 NAFO Fisheries “Footprint” 33
Figure 3-13 Locations of Industry - DFO Post-Season Snow Crab Survey Stations 35
Figure 3-14 Identified Sensitive and Special Areas off Eastern Newfoundland 42
Figure 4-1 Cuttings Deposition Comparison. (L to R) i) CSR WBM, ii) SBM Cement Disaggregate and iii) SBM Cement Clumping 47
Figure 4-2 Cuttings Thickness Difference: CSR minus SBM Cement Disaggregate (Left) and Clumping (Right) Scenarios 48
Figure 4-3 Cuttings Deposition Footprint with Hebron EEM Sampling Station Grid 53

LIST OF APPENDICES

Appendix A Additional Mapping

Appendix B SBM Cement Drill Cuttings Modelling - Supplemental Technical Information

1.0 INTRODUCTION

The Hebron oil field is located offshore Newfoundland and Labrador, Canada in the Jeanne d'Arc Basin, approximately 350 kilometres southeast of St. John's in water depths of approximately 93 metres (mean sea level) (Figure 1-1). The oil field was first discovered in 1980, and is estimated to contain more than 700 million barrels of recoverable resources. The Hebron Project includes offshore surveys, engineering, procurement, fabrication, construction, installation, commissioning, development drilling, production, operations and maintenance and eventual decommissioning activities.

The Hebron field is being developed using a stand-alone concrete gravity based structure (GBS), which has been designed and constructed to store approximately 1.2 million barrels of crude oil. The GBS was constructed at Bull Arm, Newfoundland, with tow-out currently in progress and first oil being planned for later in 2017. Hebron is a major development project that is delivering significant benefits to Newfoundland and Labrador, including those related to its associated engineering, fabrication and construction activities, the employment and training of a diverse workforce, research and development opportunities, and significant royalty and tax revenues.

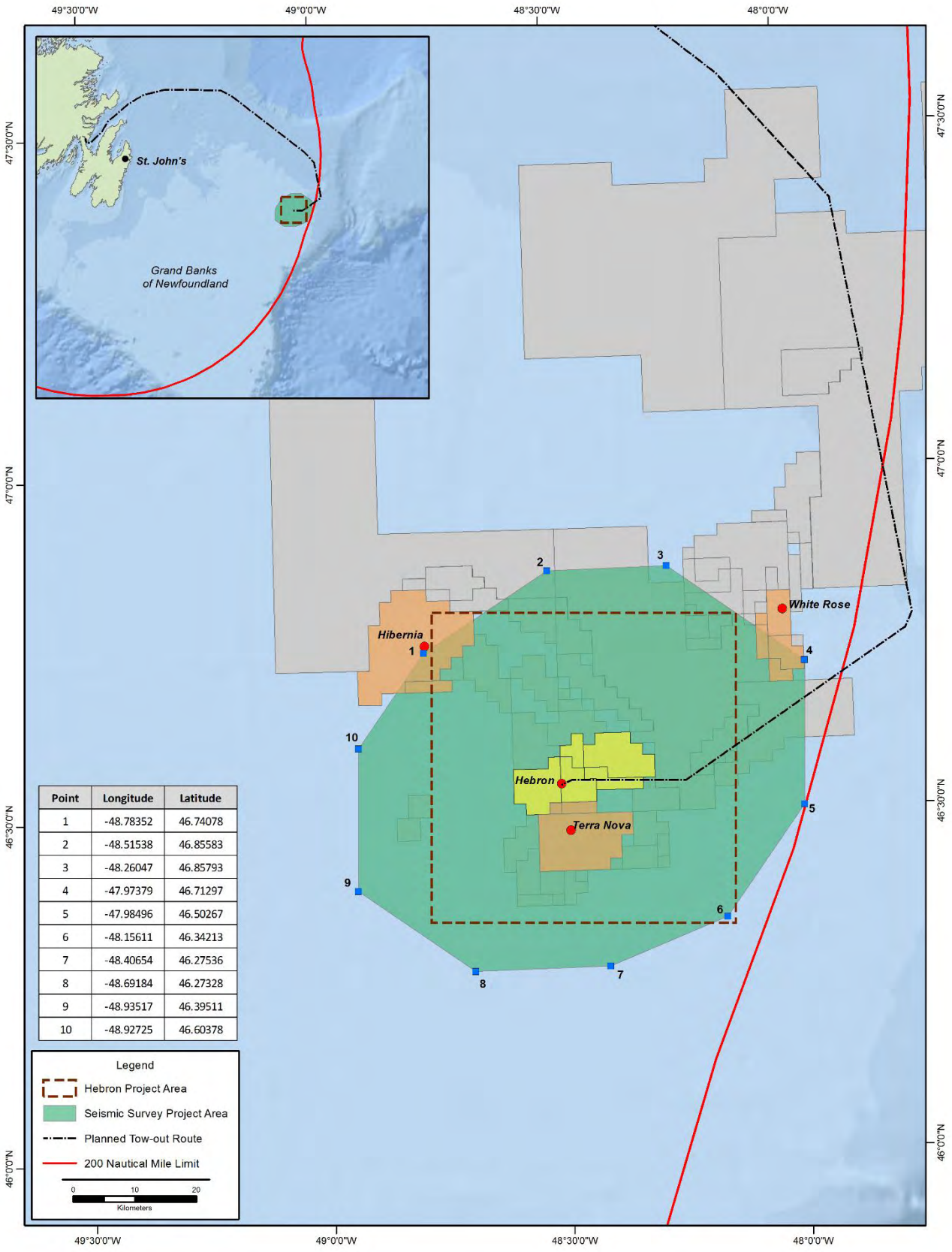
1.1 Environmental Assessment Review and Approval

The Hebron Project was subject to a detailed and comprehensive Environmental Assessment (EA) review, pursuant to the requirements of the *Canadian Environmental Assessment Act* (CEAA). That process commenced with ExxonMobil Canada Properties' (EMCP's) submission of a Project Description to the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) in March 2009, which was followed by determinations by relevant government departments and agencies regarding their respective regulatory interests in the Project, associated EA track decisions, and the eventual issuance of an EA Scoping Document by the C-NLOPB. EMCP subsequently prepared and submitted a Draft Comprehensive Study Report (CSR) for the Project in June 2010, which was subject to review and comment by relevant agencies and organizations, followed by subsequent requests for, and the submission and review of, additional information which continued to late 2011.

In December 2011 the federal Minister of the Environment issued his EA decision, which stated that "no additional information is necessary" and that "taking into account the mitigation measures described in the Comprehensive Study Report, the Project is not likely to cause significant adverse environmental effects". In June 2013 EMCP submitted an amendment to the Hebron Project CSR, which described proposed changes to a number of planned Project activities. This was also subject to review and the provision of additional information and clarification by EMCP, and was subsequently approved in June 2013.

Since EA approval for the Hebron Project was obtained, and in keeping with standard practice for offshore petroleum projects in this jurisdiction, EMCP has subsequently prepared and submitted annual EA Updates for the Project to the C-NLOPB. These updates provide an overview of planned Project activities for the upcoming year, update any applicable environmental baseline information for key environmental components that has become available since the CSR and previous EA Updates were produced, describe any public and stakeholder consultation activities that have occurred, and evaluate and confirm that the nature and scope of the planned activities are within the scope of those assessed and approved in the EA review, including the appropriateness and adequacy of the associated environmental effects predictions and mitigation measures.

Figure 1-1 Hebron Project Area



Point	Longitude	Latitude
1	-48.78352	46.74078
2	-48.51538	46.85583
3	-48.26047	46.85793
4	-47.97379	46.71297
5	-47.98496	46.50267
6	-48.15611	46.34213
7	-48.40654	46.27536
8	-48.69184	46.27328
9	-48.93517	46.39511
10	-48.92725	46.60378

1.2 Purpose and Structure of the EA Amendment

As is often the case with proposed projects and activities at the EA (pre-detailed engineering) stage of their planning and initial design, the Hebron Project has continued to evolve and become further defined since the initial EA documentation was prepared, submitted, reviewed and approved due to various factors and considerations.

This EA Amendment describes and assesses a proposed modification to the Project as compared to that which was originally assessed, approved and implemented pursuant to the EA review and approval process summarized above. In particular, this planned modification relates to the current requirement to dispose of a discreet portion of synthetic based drilling mud (SBM) associated drill cuttings from the Hebron Platform, including the planned treatment and at sea disposal of these materials. Discharge of treated SBM-associated cuttings is permitted under the *Offshore Waste Treatment Guidelines* (OWTG). A further discussion of the nature of and rationale for this proposed Project modification is provided in Chapter 2 of this document.

This EA Amendment provides a description and analysis of any implications of the proposed Project modification described above for the EA's predicted environmental effects, the mitigation measures that have been identified and proposed by EMCP for the Project, and thus for the overall findings and conclusions of the original CSR and associated EA approval.

Following this Introduction (*Chapter 1*), the remainder of this EA Amendment document is organized as follows:

Chapter 2: Project Description

- Provides a brief overview of the Project as originally proposed and assessed, and a description of the nature of and rationale for the proposed modification to it.

Chapter 3: Environmental Setting

- The identification, presentation and analysis of any new and relevant information on the existing (baseline) environment of the Project Area and its Offshore Study Area (as defined in the original CSR).
- This description is provided with particular reference to the Valued Environmental Components (VECs) that were considered in the CSR and subsequent EA Updates, focussing on those which are particularly relevant to the Project modification being assessed herein.

Chapter 4: Environmental Effects Assessment

- An analysis and discussion of any implications of the proposed Project modification referenced above for the original EA's environmental effects analysis, associated mitigation, residual effects significance determinations, and thus the overall findings and conclusions of the CSR.

Chapter 5: Summary and Conclusion

2.0 PROJECT DESCRIPTION

The following Chapter initially provides a brief overview of the Hebron Project as originally proposed and assessed, for general background and context. This is followed by a description of the nature of and rationale for the proposed modifications to the Project that are the focus of this EA Amendment.

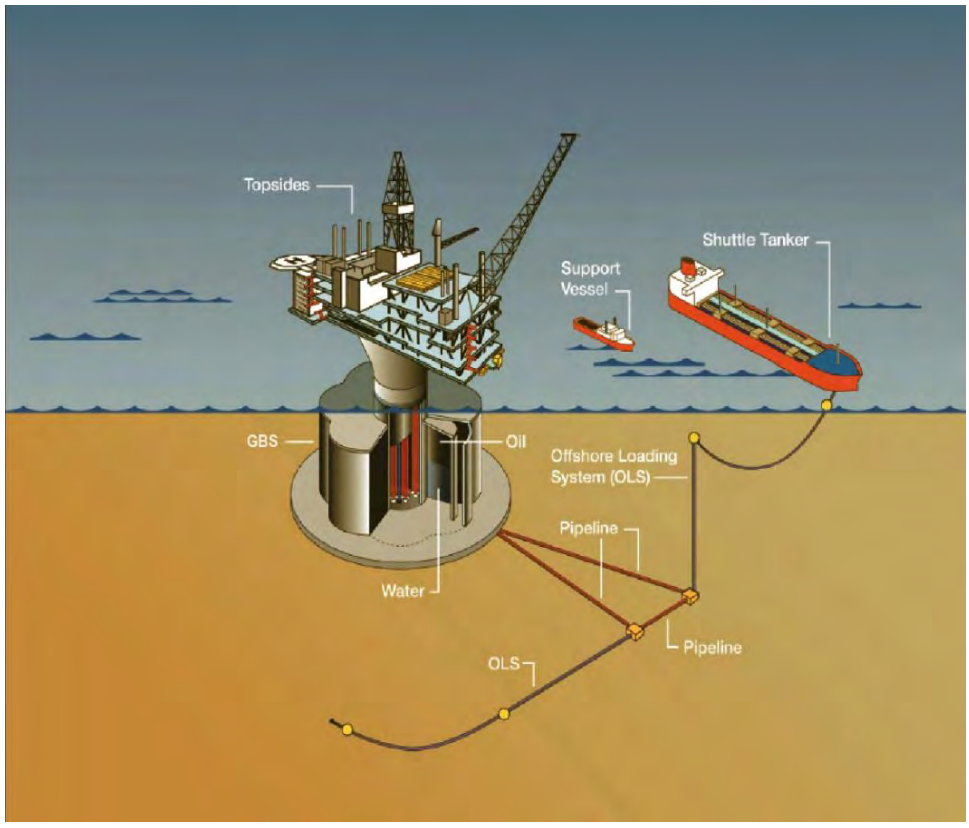
2.1 Original Project Description

The Hebron Project is an oil and gas production project located offshore Newfoundland and Labrador, approximately 350 km southeast of St. John's. EMCP, as Operator, is leading the development of the Project on behalf of the Hebron Project Proponents: ExxonMobil Canada Ltd.; Chevron Canada Limited; Petro-Canada Hebron Partnership through its managing partner Suncor Energy Inc. (Suncor); Statoil Canada Ltd.; and Nalcor Energy – Oil and Gas Inc.

The Hebron Platform will be situated approximately nine kilometers north of the Terra Nova Field, 32 km southeast of the Hibernia development and 46 km southwest of White Rose (see previous Figure 1-1). The Hebron Project will therefore be the fourth stand-alone development project on the Grand Banks and, considering the two tieback projects to the Hibernia and White Rose facilities, the sixth offshore petroleum project off Eastern Newfoundland. The Hebron Project will extend the life of the offshore oil and gas industry in Newfoundland and Labrador, and represents an important next step in the development of a sustainable offshore oil and gas industry in the province.

The Hebron field is being developed using a stand-alone concrete GBS, similar in concept to the existing Hibernia platform (Figure 2-1). The Hebron Project is currently under development, with GBS completion and tow-out in progress and first oil planned for later in 2017.

Figure 2-1 Generalized Schematic of the Hebron GBS and Associated Components



As described in the original CSR (see Chapter 2), the GBS for the Hebron Project is a reinforced concrete structure designed to withstand impacts from sea ice and icebergs and the meteorological and oceanographic conditions at the Hebron Field. It will accommodate up to 52 well slots with J-tubes inside the central shaft connected to the base of the GBS for potential future expansion. The GBS has been designed to store approximately 190,000 m^3 (1.2 million barrels) of crude oil in multiple separate storage compartments. The Offshore Loading System (OLS) consists of two main offshore pipelines running from the GBS to separate riser bases (pipe line end manifolds) with an interconnecting offshore pipeline connecting the two pipe line end manifolds. The notional offloading rate of the system is 8,000 m^3 / hour (50,300 barrels per hour). The Topsides hold the drilling support module, drilling equipment set, utilities and production module, flare boom and living quarters, including helideck and lifeboat stations.

The Hebron production facilities have the capacity to handle the predicted life-of-field production stream for 30 plus years. Based on the current initial development phase, the facility has been designed to accommodate an estimated production rate of 23,900 m^3 /day of oil.

2.1.1 Offshore Project Area - Planned Activities (Including Well Drilling)

As described in Section 1.5.2 (Project Components - Offshore Project Area) of the CSR, the scope of the Project for EA purposes included the following "Project activities within or affecting the marine environment in the offshore area…": (emphasis added)

a) Tow-out of platform to offshore site;
b) Offshore site and clearance surveys;
c) Installation of the platform at its offshore location (may include site preparation activities such as clearance dredging, seafloor levelling, underbase grouting, offshore solid ballasting, piles and mooring points, and placement of rock scour on the seafloor);
d) Platform commissioning;
e) Operation, production, maintenance, modifications, decommissioning of the platform petroleum production facility;
***f) Drilling operations (exploration and development drilling), from the GBS of up to 52 wells, including well testing, well completions and workovers and data logging**;*
g) Construction, installation, operation, maintenance of an offshore loading system (OLS) (may include dredging activities, pile driving, installation and insulation of riser and OLS (rock dumping, concrete mattress pads);
h) Supporting activities, including diving programs, and operation of support craft associated with the above activities, including but not limited to dredging vessels, shuttle tankers, shuttle tankers connecting / disconnecting to OLS, mobile offshore drilling units (MODUs), platform supply and standby vessels and helicopters; and
i) Associated surveys for all above activities, including: ROV surveys, diving programs, geotechnical programs, geophysical programs (e.g., 2D / 3D / 4D seismic, Vertical Seismic Profiles (VSPs), geohazard/wellsite surveys), geological programs, environmental surveys (including iceberg surveys).

2.1.2 Planned Re-Injection of SBM-Associated (Cement) Drill Cuttings from the Platform

With particular reference to item (f) above, the drilling process for planned wells from the GBS are described in detail in Section 2.6.4.1 of the CSR (Drilling Facilities), which stated that drilling facilities on-board the Hebron Platform would consist of the following systems (emphasis added):

- *Mechanical drilling systems, including drawworks and pipe handling*
- *Well-control system consisting of a blowout preventer (BOP) stack, complete with diverter assembly, hydraulic control system, kill and choke manifold, trip tank, atmospheric separator (de-gasser)*
- *Bulk material and storage system, including storage tanks and surge tanks for dry bulk materials*
- *Mud storage, mixing and high pressure system, including liquid storage tanks, mixing equipment, and mixing, transfer, pre-charge and high pressure mud pumps*
- *Mud return and reconditioning system, including shaker distribution box, shale shakers, degassers, centrifuges / dryers and associated tanks and pumps*
- *Onboard gravel pack equipment*
- *Cementing system, including a dual high-pressure pump unit, a batch mixing unit and a liquid additive system*
- *Driller's cabin containing drilling controls as well as monitoring capabilities for all drilling, pipe handling, mud handling and cement handling operations*
- ***Cuttings re-injection system for [non-aqueous fluid] NAF-based muds and cuttings. NAF based muds and cuttings will be re-injected into the subsurface via a re-injection well. There will be no NAF-based cuttings treatment on the platform. The cuttings re-injection system will be designed with dual redundancy; there will be a minimum of two wells for re-injection**. All water-based drill muds and cuttings will be discharged overboard, as per the OWTG (NEB et al 2010). There will be two shale chutes for water based cuttings discharge*

That section of the CSR also states that:

> *Water-based mud (WBM) cuttings are currently planned to be used on the first three hole sections of the Hebron wellbores.*
>
> *For the first hole section (conductor section), it is planned to return the WBM cuttings to the GBS shaft. Sediment strengths immediately below the GBS base slab are anticipated to be very weak and unable to sustain the additional hydrostatic load that would be introduced should the cuttings be returned to the Drilling Support Module (DSM) for re-injection. It is anticipated the DSM will be ±50 m above mean sea level. The returning fluid column would exert this equivalent hydrostatic head on the sediment in the conductor hole section. Based on operational experience at EMCP operations, it is anticipated this would result in significant fluid losses while drilling, subsequently creating a hole enlargement. This would pose potential risk to subsequent cementing operations of the conductor, overall well integrity and, potentially, stability of the soils beneath the base slab.*
>
> *Similarly, the second hole section (surface casing) is anticipated to encounter weak sands and sediments. It is currently planned to return these cuttings to the lower levels of the Platform, where they will be routed to the shale chutes for overboard discharge. Attempting to route the returns to the higher elevation of the cuttings re-injection system would introduce hydrostatic head that could also result in hole enlargement and risk to wellbore integrity.*

> *The third hole section (intermediate casing) will also be drilled with WBM systems. However, the geologic intervals to be penetrated typically return cuttings that tend to be tacky in texture and result in large masses, or clumps, of cuttings, that can best be defined as 'sticky'. These masses are not well suited to cuttings re-injection as they require large surface systems to dissolve the cuttings prior to routing to subsurface injection.*
>
> *Finally, at the current Project stage, analysis has been performed to identify candidate subsurface zones for cuttings re-injection. Modelling is currently planned to be completed to ensure containment can be maintained for the NAF-based mud drill cuttings and avoid out of zone fracture. Injection of large volumes of WBM cuttings potentially poses a risk for out-of-zone fracture and the subsequent loss of containment of NAF materials. Thus, the proposed plan of water-based discharge provides a balanced approach that minimizes overall risk of environmental damage.*
>
> *….The estimated cuttings volume per chute is approximately 4,453 m^3 from the 838 mm hole section will be deposited inside the GBS shaft. The growth of anaerobic bacteria and the resulting production of hydrogen sulphide could be potential health issues in addition to being corrosive to facilities. Anaerobic bacteria require very low or no oxygen in their environment in order to survive and grow. The GBS shaft for Hebron will be designed with a passive seawater circulation system using natural convection. Cold seawater will enter from the bottom of the shaft and warmer water will exit at the top of the shaft, with direct discharge to the ocean. The constant replenishment of fresh seawater (containing dissolved oxygen) will minimize the possibility for developing the anaerobic conditions suitable for growth of anaerobic bacteria, thereby minimizing the growth of anaerobic bacteria action in the GBS without requiring the addition of biocides. This circulation system design will account for drill cuttings that may be discharged at the shaft bottom…*
>
> *Cuttings from the 660 mm hole section will be returned to the surface and routed overboard via the shale chutes. Cuttings from the 432 mm hole section will be drilled with water-based drilling mud and will be discharged overboard.*

As noted above, the original Project concept involved the planned re-injection of drill cuttings produced during any well sections drilled from the Hebron Platform using NAF, also known as SBMs. This concept is referenced and described throughout the CSR, including in various sections of the environmental effects assessment (Chapters 6 to 12), some examples of which are provided through the following excerpts for general illustration:

> *Hebron plans to re-inject SBMs for drilling completed from the GBS and only release treated SBMs associated with drilling satellite wells from the MODU in potential future well developments.* (CSR Section 7.5.1.2)
>
> *SBM cuttings reinjection will be undertaken for Platform drilling as a means of waste reduction. However, this is not technically feasible for MODU drilling and SBM cuttings will be discharged overboard after treatment in accordance with the OWTG. These estimates are based on preliminary analyses which will be updated during FEED and detailed engineering phases. At least 1 cm thicknesses of cuttings accumulation are predicted to remain generally confined to within about 50 to 60 m of the base of the GBS. The cuttings near the GBS are almost exclusively the fast-settling pebbles and sand (a very small percentage of the fines will drift for a time and*

ultimately settle near the GBS), whereas at distances greater than about 50 to 200 m, the deposits will be exclusively fines (CSR Section 7.5.2.2).

2.2 Proposed Amendment to the Project

This EA Amendment proposes a modification to release some SBM-associated drill cuttings from the Hebron Platform to the marine environment, as opposed to complete reinjection of these cuttings as was described and assessed in the original CSR.

The drilling process for an offshore oil and gas well generally involves each well being drilled in sections by gradually reducing the size of the well bore. Drilling muds are fluids which lubricate and cool the drill bit and hole, circulate cuttings and carry them back to the surface, and help to maintain appropriate pressure in the well. The initial top hole drilling involves large diameter holes for the first part of the well followed by the installation of the conductor and surface casing. These initial sections of the well are often drilled using seawater or a WBM. The drilling muds and cuttings that are used in and result from these initial drilling activities are discharged directly overboard, as permitted under and in accordance with the OWTG.

When top-hole sections has been drilled to the depth where the rock formation strength is sufficient, steel casings are run and cemented in place to prevent the walls of the wellbore from caving in and to prevent the seepage of muds and other fluids. The wellhead is installed and the riser and blow-out preventer (BOP) are installed. The riser is a large diameter pipe that acts as a conduit connecting the platform to the wellhead, and the wellhead provides structural integrity and pressure integrity for drilling operations. A BOP is a system of high pressure valves that prevent fluids or hydrocarbons from escaping into the environment in the event of an emergency or equipment failure. Once the riser has been installed, the remaining sections of the well are drilled to predefined depths using WBM or SBM if the use of water-based fluids is technically impractical. At various intervals along the well, casing is cemented in place at set depths to reinforce the wellbore. Once the conductor hole is completed and when the riser is installed and in place, drill muds and cuttings can be returned to the surface and onto the drill rig for processing through the solids control equipment, and the cuttings are disposed of accordingly.

The drilling of each well from the Hebron Platform will therefore entail progressively advancing the well bore through to various, pre-defined depths involving progressively smaller hole sizes as drilling proceeds through the various depth intervals involved. Within several of the deeper sections of the wells, and in accordance with standard practice in the offshore oil and gas industry, it is planned that a "shoe track" will be installed in the well bore. The shoe track consists of a float collar, float joint(s) and a float shoe. The float joint is a full-sized length of casing run at the bottom of the casing string that is usually left full of cement on the inside to help ensure that good cement remains on the outside of the bottom of the casing. If cement were not left inside the casing in this manner, the risk of over displacing the cement (due to improper casing volume calculations, displacement mud volume measurements, or both) would be considerably higher, resulting in the absence of cement at the shoe of the casing where the cement is required for casing and well integrity. Hence, well design plans on a safety margin of cement left inside the casing to help ensure that the fluid left outside the casing is present and of good-quality. A float collar is placed at the top of the float joint and a float shoe placed at the bottom to prevent reverse flow of cement back into the casing after placement. Depending on the situation and requirements, there can be one, two or three joints of casing used for this purpose (Schlumberger 2017).

Once these shoe track sections are run in the wellbore, the drilling of subsequent sections of the well (using either SBMs of WBMs) will inevitably involve drilling through these shoe tracks and their associated cement material, which will in turn see cement being mixed into the SBM-associated drill cuttings (hereinafter also referred to as "SBM cement cuttings") that are returned to the Platform for processing.

Although, as described above, the CSR and current EA approval did not account for SBM-associated drill cuttings to be discharged from the Platform - as all such cuttings were originally planned to be re-injected via the cutting reinjection well (CRW, the first well drilled) - it has recently come to light that there is a risk to the Cuttings Re-Injection (CRI) system associated with the re-injection of cement-contaminated drill cuttings into that well, including the possibility of plugging up the CRI well. Learnings from Hibernia Project have illustrated the benefits of avoiding injection of cemented cuttings through the CRI well wherever possible. ExxonMobil's experience with CRI systems elsewhere also suggests that injecting "green" cement (i.e., cement not set up or hardened) or cement cuttings should be avoided, and key drilling contractors have established best practices to not inject green cement or cement cuttings in this manner. Specifically, re-injecting cement-contaminated cuttings has the potential to re-activate the cement, blocking the CRI well and rendering it inoperable. The maintenance and operations of the CRI well is critical to the operation of the Hebron Project, in being able to re-inject the majority of the SBM-associated cuttings from the Platform throughout the life of the Project.

As part of its recent and on-going planning and design activities for this component of the Project, EMCP has also identified and evaluated potential alternatives to the discharge of these SBM-associated drill cuttings from the Hebron Platform. This includes the potential use of WBMs for drilling these sections of the wells. Switching to WBM (vs. SBM) in these lower hole sections will, however, introduce a risk of wellbore stability issues associated with drilling through shale formations at high angles and is therefore not considered to be a technically feasible option. In addition, drilling the shoe tracks with WBM and then switching to SBM is likewise not recommended due to potential cross-contamination of fluids, which can destabilize the drilling fluid and create issues with cleaning the wellbore. Using SBM while drilling the shoe track also eliminates the risk associated with exposing new formation to WBM before drilling ahead with SBM, which can lead to wellbore stability issues.

EMCP is therefore proposing to release the SBM-associated drill cuttings that are produced and retrieved during drilling activity through the shoe tracks overboard (down the shale chute after the shale shakers).

Under the OWTG, other than residual base fluid retained on cuttings (as described below) no whole SBM is permitted to be discharged to the sea. Therefore, once onboard the drill rig, drill (rock) cuttings will be removed from the drilling muds in successive separation stages using solids control equipment. Some fluids will be reconditioned and reused, while any spent SBM will be re-injected or returned to shore for disposal. SBM-associated drill cuttings are permitted to be discharged at the drill site provided they are appropriately treated prior to discharge in accordance with proven and practicable best available technologies and practices.

As summarized below, overall the volume of the SBM-associated cuttings to be released per well is relatively low, since only the interval that contains cement cuttings as a portion of the total SBM-associated cuttings will be released, and the shakers will be adjusted to reduce any residual materials prior to discharge. The cement portion and additives will be comprised of chemicals and other materials that have already been screened through the Offshore Chemical Management System (OCMS) and allowed for release to sea.

Table 2-1 below provides an overview summary of the estimated drilling materials and discharges associated with a typical well drilled from the Hebron Platform.

Table 2-1 SBM-Associated Cuttings Release Summary (Per Typical Well)

Total SBM-associated cuttings (m^3)	140
Total non-SBM associated cuttings down shale chute (m^3)	260
Total SBM-associated cuttings released (m^3)	15
Percent of SBM-associated cuttings released (%)	10
Percent released to chute that is SBM-associated (%)	5
Note: These values are general and for illustrative purposes, and specific values for individual wells may vary.	

Through this EA Amendment, EMCP is therefore seeking regulatory approval to discharge SBM-associated cuttings overboard that are generated while drilling out the (340 mm and 244 mm casing) shoe tracks for all Hebron wells drilled from the Platform. It is anticipated that each such event will happen over a period of 8-12 hours.

A summary of these planned discharges is provided below:

- *Total Volume of SBM Cement Cuttings (per well):* Approximately 15 m^3 (10 m^3 & 5 m^3 for 340 mm and 244 mm casing, respectively);
- *Total Weight of Discharge (per well):* Approximately 6 MT
- *SBM Type*: Puredrill
- *Cuttings*: Ground set cement
- *Release Depth*: Shale Chute (69 m depth; same depth modelled for cuttings in CSR)

The sections that follow provide a further overview of SBMs and their composition and use, environmental implications and their discharge and treatment during offshore oil and gas drilling activities. This is followed by an assessment of the proposed change to the Project, including an evaluation of any implications of this change to the original CSR's environmental effects analysis and associated mitigation.

2.3 General Overview of SBMs and SBM-Associated Drill Cuttings

Drilling solids (cuttings) are the particles of crushed rock produced from the grinding action of the drill bit as it penetrates subsurface rocky formations (Neff et al 2000; Peralba et al 2010). The particle size, minerology and chemistry of drill cuttings depend on the geologic strata being penetrated (Neff et al 2000). Once formed, the drill cuttings are carried from the bottom of the well to the surface in a suspension of drilling fluid known as drilling muds (Peralba et al 2010). The fluids are pumped into the well bore primarily to cool and lubricate the drill bit, remove cuttings, maintain pressure (prevent blow-outs) and maintain the integrity of the hole to allow the installation of a casing (Neff et al 2000; Holdway 2002). Drill cuttings are typically regarded as toxicologically inert, however adhered drill fluids may be toxic depending on the type of drilling fluid being used (Neff et al 2000), with petroleum hydrocarbons and metals being the chemicals having the greatest potential toxicological concern (Neff 2008).

2.3.1 Composition of Drilling Muds

There are two general types of drilling muds used in the offshore: 1) WBMs and 2) non-aqueous fluids (NAFs), which include SBMs (Neff et al 2000). As described earlier, WBMs are generally used only for the top sections (conductor and surface sections) of the wells, whereas NAFs / SBMs are used for horizontal and deeper (intermediate and production) sections because of their better performance in various situations (CAPP 2001; DeBlois et al 2014a).

The primary constituents of WBMs are water, barium sulphate (also known as barite or $BaSO_4$) as a weighting agent, and bentonite clay as a viscosifier (Trefry et al 2013; DeBlois et al 2014a). Depending on the composition of the bedrock formation being drilled, various salts and organic gels may also be added (Trefry et al 2013; Thombare et al 2016). For example, sodium hydroxide (NaOH) and lime are included as a minor fraction (less than 10 percent of WBM) at the Terra Nova production field (DeBlois et al 2014a). The WBMs are primarily comprised of water and barite (which is relatively inert) (Neff 2008; Whiteway et al 2014).

The base fluid in Group III NAFs (which include SBMs) can be either highly processed mineral oils or synthetic hydrocarbons. The most common synthetic hydrocarbons are linear alpha olephins (LAO), internal olefins (IO), esters or parafins (COOGER and Lee 2009). Group III SBMs are characterized by a minimal polycyclic aromatic hydrocarbons (PAH) concentration (less than 0.001 percent) and low aromatic content (less than 0.5 percent) (OGP 2003). The advantages of using SBMs is they provide stability and effectiveness comparable to the oil-based drilling muds (OBMs), and their low toxicity (Neff et al 2000; COOGER & Lee 2009).

Due to the improved environmental performance of SBMs relative to OBMs they had been permitted for discharge to offshore waters until the regulatory decision by the Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) which allowed discharge of SBMs into the sea only in certain circumstances (Neff 2008). Consequently, during typical drilling operations a closed-loop recycling system recaptures used SBMs and drill cuttings when they come back to surface. The recycling systems use a series of screens, shale shakers and centrifuges to physically separate progressively smaller drill cuttings from the liquid fraction of SBMs and reduce waste of SBM fluid (OGP 2003; COOGER and Lee 2009). At each stage of mechanical separation, the liquid stream is diverted from the cuttings, reducing the volume of the oil on wet solids (OGP 2003). Oil on cuttings will be monitored and recorded while drilling shoe track and cement per standard procedures.

The regulatory performance target for SBM oil on wet solids prior to discharges defined in the OWTG is less than or equal to 6.9 g / 100 g. To further reduce exposure of the seabed to processed SBM-associated cuttings, the Hebron Project will be reinjecting the majority (approximately 90 percent) of SBM-associated cuttings into subsurface formations (as described in the Hebron Project CSR) during typical well drilling operations. Re-injection of SBM-associated cuttings has been in practice at the Hibernia Platform since 2002, and since then the Hibernia environmental effects monitoring (EEM) program has documented the return to near-baseline conditions for drilling analyte parameters in marine sediment (HMDC 2015).

Following this success, the Hebron Project will be re-injecting a majority of the SBM cuttings in sub-surface formations to help reduce any environmental effects on the seabed under normal drilling operations. However, as stated previously, the Hebron wells plan to drill the 340 mm and 244 mm shoe tracks with SBM that will generate cement cuttings that will return to the Platform, be processed on the shakers, and in turn, be discharged overboard.

2.3.2 Composition of SBMs Used Offshore Newfoundland

SBMs are generally regarded to have low toxicity (Scholten et al 2000; COOGER & Lee 2009). The base (organic) SBM fluid used by offshore operators in Atlantic Canada is Petro-Canada *Puredrill IA-35LV* (COOGER & Lee 2009; Li et al 2009; DeBlois et al 2014a); the base oil of which is composed of aliphatic hydrocarbons in the fuel range ($>C_{10}$–C_{21}) and contains no aromatic hydrocarbons (DeBlois et al 2014a). Moreover, Puredrill IA-35LV is rated as a Category E product (least hazardous) in the Offshore Chemical Notification Scheme (OCNS) (OWTG 2010; DeBlois et al 2014b).

Heavy Metals

Metals in drilling muds are primarily trace impurities in barite, bentonite clay and/or the drill cuttings from the subsurface formation being penetrated (Neff 2008). As a result, heavy metals can accumulate in SBMs as they are used (COOGER and Lee 2009). However, these metals are most commonly in an insoluble form and have low toxicity to plants and animals and limited environmental mobility (reviewed by Neff 2008). Futhermore, for these metals to become more bioavailable depends on their dissolution from inclusions of nearly insoluble barite; which is controlled in part by accessibility of the metals to the water phase at the solid-water interface as well as the solubility of the metals themselves in seawater (Neff 2008). The potential for this process to occur may be further limited, as SBM-associated cuttings tend to clump and settle rapidly to the bottom near the discharge location (Neff et al 2000; Neff 2008), thereby minimizing the potential for exposure to surrounding biota overall.

Toxicity of Puredrill IA-35LV SBM

For SBMs overall their acute (immediate/short-term) toxicity is reported to be unlikely although data on chronic toxicity is limited (as reviewed by Bakhtyar and Gagnon 2012; Gagnon and Bakhtyar 2013). However, a detailed risk assessment of PureDrill IA 35-LV was conducted using the PetroTox model which was developed to perform aquatic hazard assessments of petroleum substances based on the composition of their constituents. The model identifies ecologically relevant concentrations according to acute and chronic toxicity test data for constituents (Redman et al 2014a; 2014b; 2017; Redman and Parkerton 2015), below which biological effects would not be expected. The no-effects concentration obtained via PetroTox was 150 mg / kg, with a range of 115 to 190 mg / kg (Stantec 2013).

Laboratory examination of the toxicity of Puredrill IA-35LV SBM in particular has been assessed for both fresh and recycled drilling muds in sediments before and after biodegradation. The microcosms used for toxicity analysis were assessed after 0, 30 and 90 days incubation using standardized Microtox Solid Phase Test (EPS 1/RM/42 Environment Canada 2002), and amphipod (*Eohaustorius estuarius*) bioassays (EPS 1/RM/35 Environment Canada 1998) (COOGER & Lee 2009). None of the samples (control or Puredrill IA-35LV SBM on cuttings) were toxic according to the Microtox assay (COOGER & Lee 2009). In contrast, the amphipod assay showed all samples containing Puredrill IA-35LV SBM on cuttings to be toxic. However, this was suspected to be a consequence of the amphipods being confined in a test container undergoing high rates of rapid biodegradation of the original organic compounds into intermediate degradation analytes with greater bioavailability (COOGER & Lee 2009; Gagnon & Bakhtyar 2013).

Biodegradation and Mineralization of Puredrill IA-35LV SBM

The biodegradation and mineralization of SBMs with Puredrill IA-35LV as the active ingredient has been examined using laboratory microcosm studies (miniature-scale ecosystems maintained under

controlled conditions) (COOGER & Lee 2009; Li et al 2009). The aerobic biodegradation of fresh (unused) and recycled (used) SBMs provided by a North Atlantic offshore drilling operation was compared under two temperature regimes (5°C and 20°C). The rate of mineralization of Puredrill IA-35LV SBM in sediment was greater in the higher temperature treatment (20°C) compared to the lower one (5°C) as well as for sediment containing fresh (unused) SBM compared to used SBM. However, the rate of mineralization of the recycled SBMs was consistent between both temperature treatments (COOGER and Lee 2009). From these results it was inferred that the rate of degradation at seafloor temperatures on the Grand Banks (approximately 0°C) would likely be slower, however, bacteria adapted to cold temperatures may still carry out degradation of hydrocarbons (COOGER & Lee 2009).

2.3.3 Composition of Shoe Track Cement

The cement slurry is customized for the depth and composition of the subsurface formation in which it is pumped (Halliburton 2017). For the Hebron Project, a total of 33 bulk cement products and additives are used (sourced from Halliburton). All 33 compounds are Canadian Domestic Substances List (DSL) compliant, do not require a Chemicals Management Plan as assessed under the *Canadian Environmental Protection Act* and are approved for discharge. All cement additives will therefore have the necessary Offshore Chemical Notification Scheme (OCNS) rating and be allowed to be discharged under the OWTG.

Although the cementing components are all assessed as having a low environmental risk, in-situ they are pumped as a liquid slurry capable of setting in high-temperature and high pressure subsurface conditions. Drilling out the shoe tracks will re-suspend the polymerized compounds (as cuttings) in an SBM-based slurry and the behavior of these cement cuttings in SBMs when re-injected in subsurface formations is not known. Without being able to rule out the possibility of cement cuttings possibly obstructing the reinjection of SBM-associated cuttings even partially, the risk of causing a reinjection backflow cannot be overlooked. Therefore, as precaution, the SBM cement drill cuttings would be discharged overboard via the shale chute after screening. The total SBM cement cuttings estimated to be released (per typical well) is 15 m^3, or 5.7 percent of the total cuttings volumes (260 m^3) that will be discharged via the shale chute (see Section 2.2 above).

3.0 ENVIRONMENTAL SETTING

The Hebron Project CSR provided a detailed overview of the existing (baseline) environment within and around the proposed Project Area and associated EA Study Area (nearshore and offshore environments). This description focussed on relevant aspects of the existing physical, biological and socioeconomic environments in these areas, based on information available as of the time of CSR development and submission.

The sections that follow provide a brief, summary update of that description of the existing environmental setting for the offshore Project Area and Study Area, including the various VECs that were considered in the original CSR, namely:

1) Air Quality;
2) Fish and Fish Habitat;
3) Commercial Fisheries;
4) Marine Birds;
5) Marine Mammals and Sea Turtles;
6) Species at Risk; and
7) Sensitive or Special Areas.

This description has a particular focus on those environmental components which are considered to be particularly relevant to on-going environmental planning and management related to the Project, and especially, to the proposed modification to the Project that is being addressed through this EA Amendment. The brief overview that follows does not repeat all of the detailed environmental information and analysis provided in the original CSR and previous EA Updates, which should therefore also be referred to as required and relevant.

The descriptions that follow also draw from existing and available information sources, most notably the Eastern Newfoundland Strategic Environmental Assessment (SEA) (Amec 2014), which was prepared and released in August 2014 by the C-NLOPB. In keeping with the direction included in recent project-specific EA Scoping Documents issued by the C-NLOPB, they also do not repeat relevant information from the SEA but rather refer to that document as relevant.

3.1 Air Quality

As described in Section 6.2.2 of the CSR, given its offshore location, air quality within the Hebron Offshore Project and Study Areas is likely to be very good, with only occasional exposure to exhaust products from existing offshore oil production facilities (Hibernia, Terra Nova and White Rose), supply ships and other vessels in the area, as each platform would generally be downwind of another less than 15 percent of the time. This region also receives long-range contaminants from the industrial mid-west and northeastern seaboard of the United States. In describing the existing ambient air quality in the Offshore Study Area in the original CSR, site specific emissions data were presented from the National Pollutant Release Inventory (NPRI) and National greenhouse gas (GHG) reports, which are completed and submitted annually by each of the offshore oil and gas operators located near the proposed Hebron Project. This included 2008 NRPI data for criteria air contaminants for each of the existing offshore oil platforms, GHG data for each of these platforms and the provincial and national totals, and national GHG emissions by sector for the period 2004 to 2007.

Given that the proposed modification to the Project (planned SBM cement cuttings disposal) will not result in any increased or otherwise altered interactions with or effects on the atmospheric environment,

no additional or updated environmental baseline information is required or provided for the purposes of this EA Amendment.

3.2 Fish and Fish Habitat

Numerous species of marine fish and invertebrates and their habitats have been identified within or nearby the Hebron Project Area and its Offshore Study Area as defined in the original CSR. These species and habitat form the basis of the marine ecosystem, and support fisheries which have commercial, historical and recreational importance.

The overall presence, distribution and abundance of marine species and any important habitats in the Offshore Project and Study Areas are summarized in the original CSR and associated Updates, which include information on relevant life history characteristics. Updated information on the presence, life histories, and spatial and temporal distributions of marine species in the region is also provided in the Eastern Newfoundland SEA (Amec 2014, Section 4.2.1) Provided below is a summary of the most recent information available in respect to fish and fish habitat within and near the Hebron Project Area, with particular attention to benthic communities.

3.2.1 Benthic Macroinvertebrates

Benthic macroinvertebrates are a diverse group of marine biota that are made up of numerous taxa which live on, or in the top layer of the sea floor. Benthic macroinvertebrates play key roles in nutrient cycling and are a key prey item from many species (Barro Frojan et al 2012; Murillo et al 2016), including species with commercial, recreational and historic value. As indicated in the CSR, shrimp (*Pandalus borealis* and *Pandalus montagui*), sea urchins (*Strongylocentrotus droebachiensis*), and sand dollars (*Echinarachnius parma*) were the most abundant benthic invertebrates found in the Project Area. Soft shelled clams (*Mya arenaria*), snow crab (*Chinoecetes opilio*), toad crab (*Hyas araneus*), Icelandic scallop (*Chlamys islandica*), polychaetes, macoma clams (*Macoma balthica*) and seastars were also present. This coincides with available publications that indicate that the assemblage of benthic macroinvertebrates along the shelf habitat of the Grand Banks is typically dominated by echinoderms such as sand dollars, sea stars and sea urchins. Schneider et al (1987), for example, found brittlestars (*Ophiopholis sp*.), sand dollars and Icelandic scallop accounted for almost 75 percent of the total benthic macroinvertebrate abundance in photographic surveys of habitats at depths similar to the proposed Project Area (70-100 m).

Canadian RV surveys provide comprehensive trawl data for the Grand Banks and indicate that Northern shrimp, striped shrimp, and snow crab are key invertebrate taxa in regards to abundance and distribution (Amec 2014). More recent data from Canadian RV surveys (2008-2012, see the Figures that follow) indicate striped shrimp are found in relatively high abundance in the general region (although recent EEM baseline fish sampling have not found these in great abundance in the Project Area itself), while the highest concentrations of Northern shrimp were found to the northeast. Snow crab are also found within and around the Project Area. Detailed life histories and key spawning times for these and other species are presented in detail in the Eastern Newfoundland SEA (Amec 2014, Section 4.2.1).

Figure 3-1 Striped Pink Shrimp Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012)

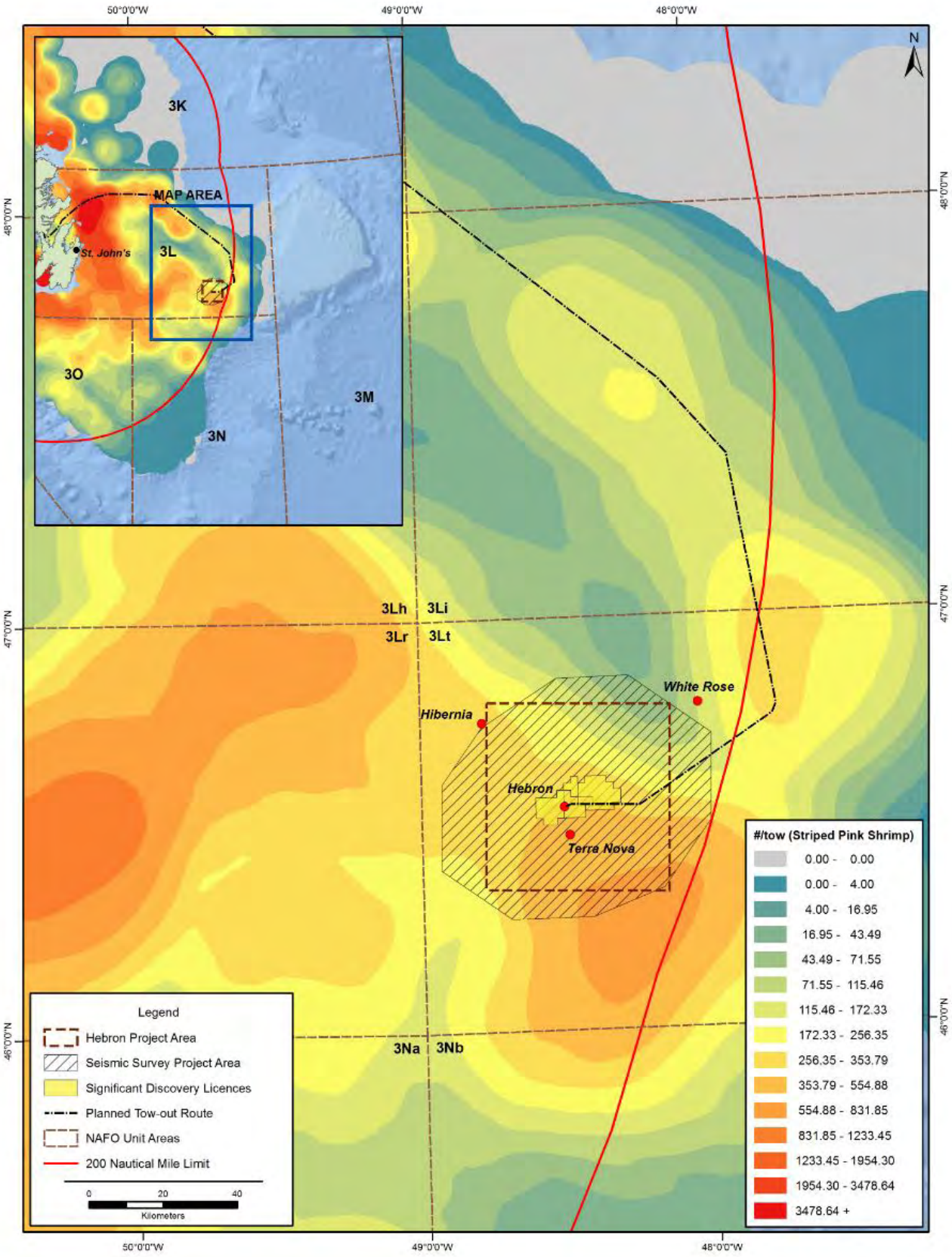


Figure 3-2 Northern Shrimp Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012)

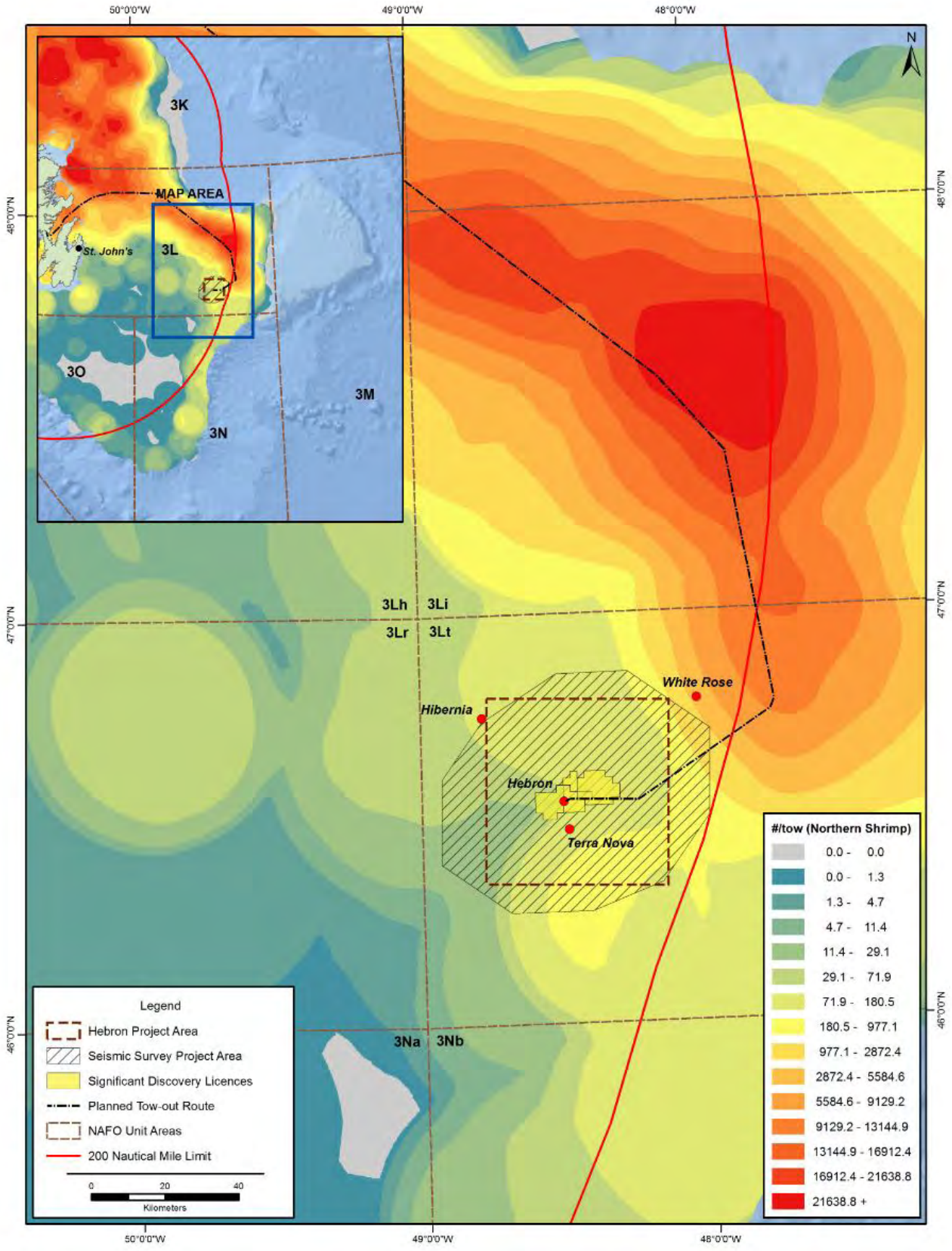
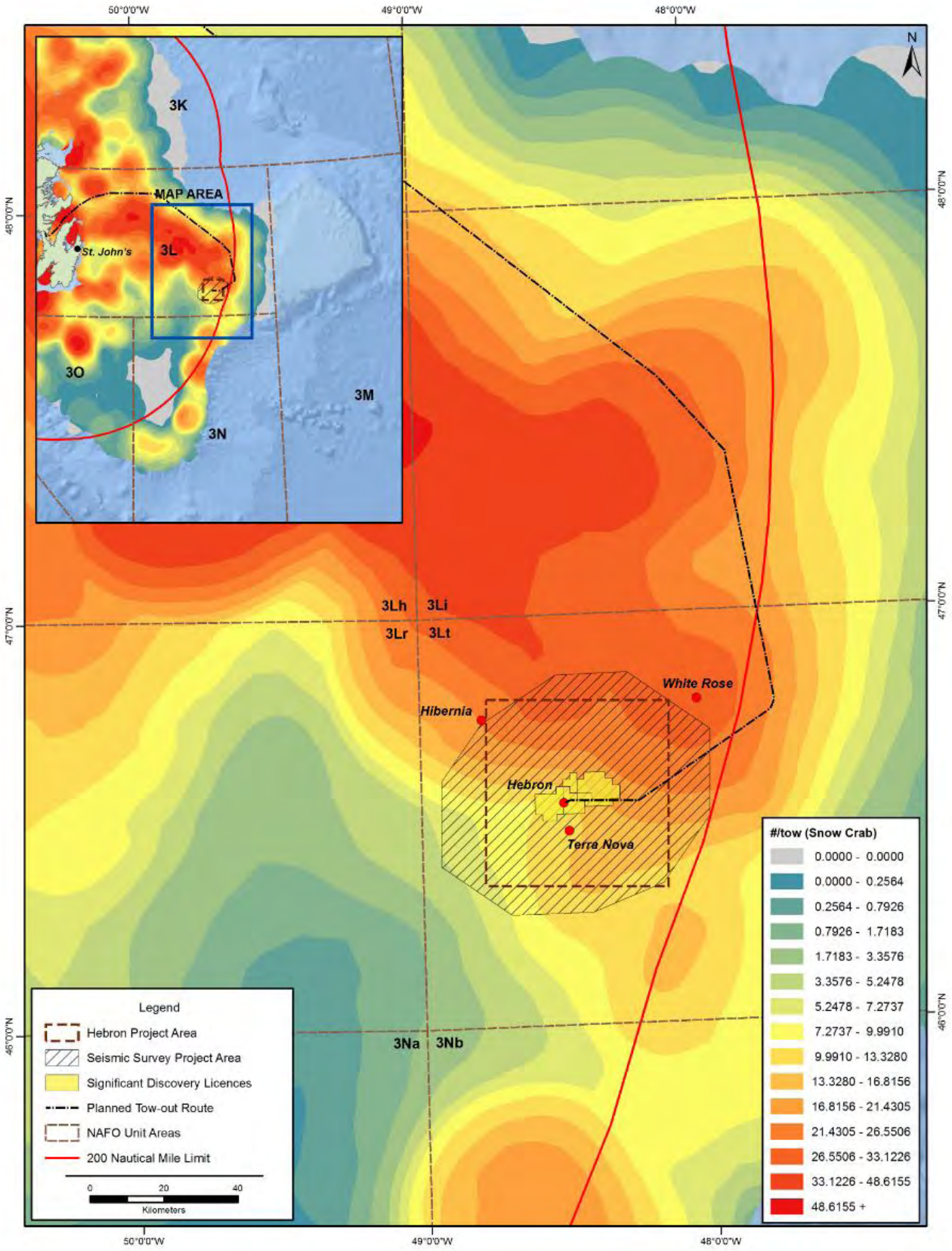


Figure 3-3 Snow Crab Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012)



3.2.2 Corals and Sponges

Corals and sponges are key organisms in creating habitat complexities and their presence is a key factor in the presence and abundance of other benthic invertebrates (DFO 2015). Generally, they are long lived organisms that provide refuges (Wareham 2009; Baker et al 2012), nursery areas (Beazley et al 2013; DFO 2015), and foraging areas (Baker et al 2012; DFO 2015) for fish and other macroinvertebrates. Corals and sponges are sessile in nature and therefore, they are particularly susceptible to bottom disturbances or deposition of materials on the seabed. Due to the sensitive nature of corals and sponges and their ecological importance, some areas that are known to be relatively rich with corals and sponges are identified as Ecologically or Biologically Significant Areas (EBSAs) or Vulnerable Marine Ecosystems (VME) and are closed to fishing activities (see Section 3.7 below).

A variety of coral species are found off Eastern Newfoundland in waters deeper than 200 m, with the slopes of continental shelfs and canyons being particularly favorable habitats (Edinger et al 2007; Campbell and Simms 2009; Guijarro et al 2016). Coral surveys of North Atlantic offshore areas have shown the highest biomass around the slope areas (600-900 m depths) of the Grand Banks and Flemish Pass (Murillo et al 2011), waters that are considerably deeper than those in the vicinity of the Hebron Project Area. Fewer species of coral inhabit the shallower waters present on the shelf, and those present are primarily soft corals, as was noted in the CSR. Coral species that may be found within or near the Hebron Project Area would therefore be limited to soft coral species (see Table 3-1 and Figure 3-4) based on the results of recent Canadian RV surveys and associated scientific publications (Wareham 2009; Murillo et al 2011; Baillon et al 2014; Murillo et al 2016).

Table 3-1 Corals Occurring on the Grand Banks

Order	Group	Species	Depth Range (m)	Reference
Alcyonacae	Soft Corals	*Duva florida*	56-1374	1,2,3,4,5
		Gersemia fruricosa	46-246	1,2,4
		Nephtheidae spp.	-	2,5
Sources: [1] Wareham (2009); [2] Murillo et al (2011), [3] Baillon et al (2014), [4] Murillo et al (2016), [5] Stantec (2011)				

In offshore areas, surveys showed the highest sponge biomass in the Flemish Pass, the Flemish Cap and the tail of the Grand Banks (Murillo et al 2012). Sponges have been found primarily in water depths ranging from 100-1,500 m, indicating that sponges may be located throughout shelf, slope and deep water habitats (Murillo et al 2012). However, sponges are not well distributed throughout the Grand Banks area itself (Figure 3-5).

3.2.3 Finfish

Finfish represent a numerically abundant and ecologically and morphologically diverse group that play a variety of trophic roles. They range from small planktivorous fish such as capelin to large predatory sharks with many of these species are also important ecologically, commercially and/or culturally.

The existing and available information does not indicate that the overall presence and distribution of finfish species has changed in and around the Project Area since the original CSR, in that key species remain the sand lance, mailed sculpin and American plaice. Recent Canadian RV surveys (2008-2012) indicate that sand lance are amongst the most abundant species within the area, while American plaice concentrations are higher in areas north of the Hebron Project Area (Figures 3-6 to 3-8).

Figure 3-4 Coral Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012)

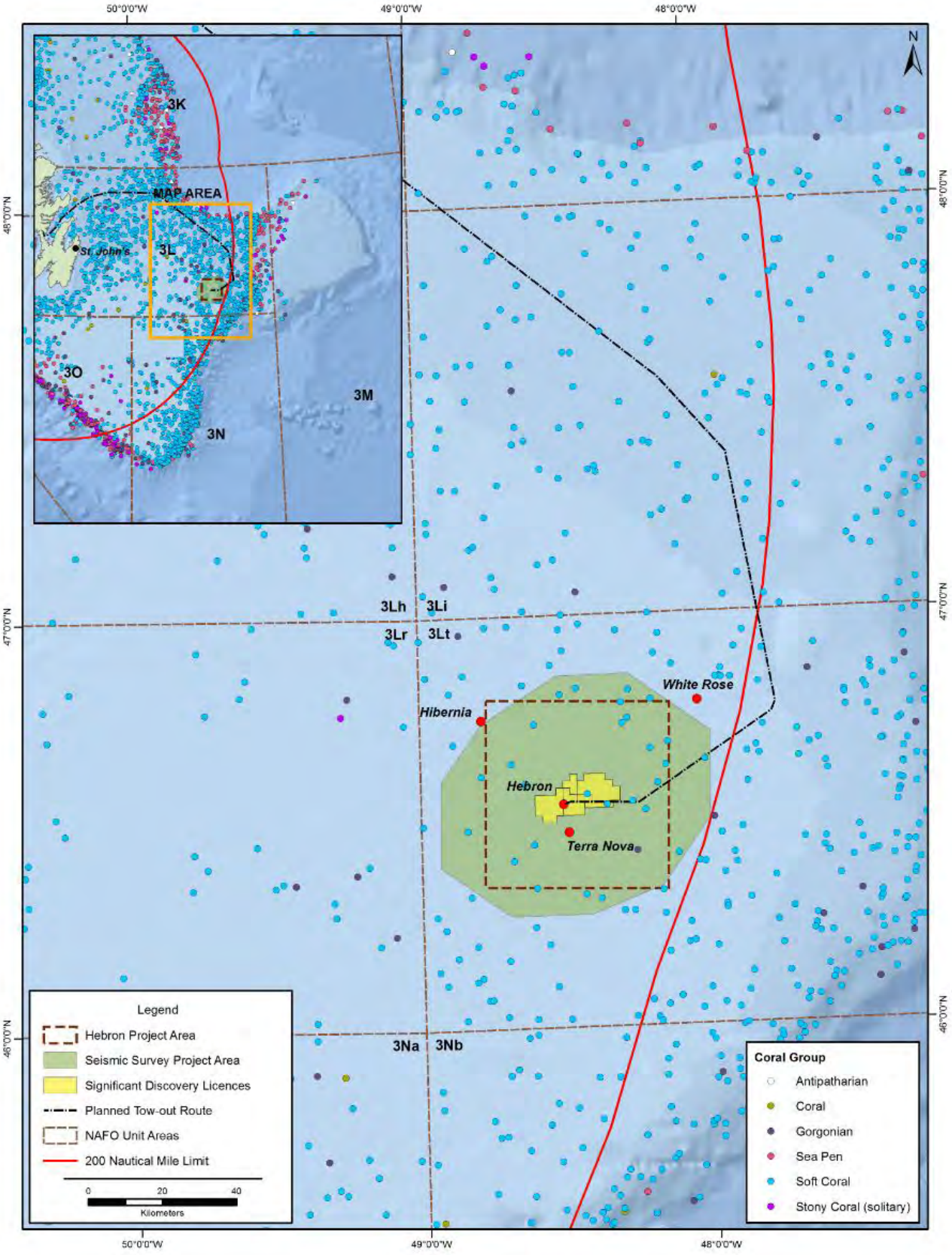


Figure 3-5 Sponge Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012)

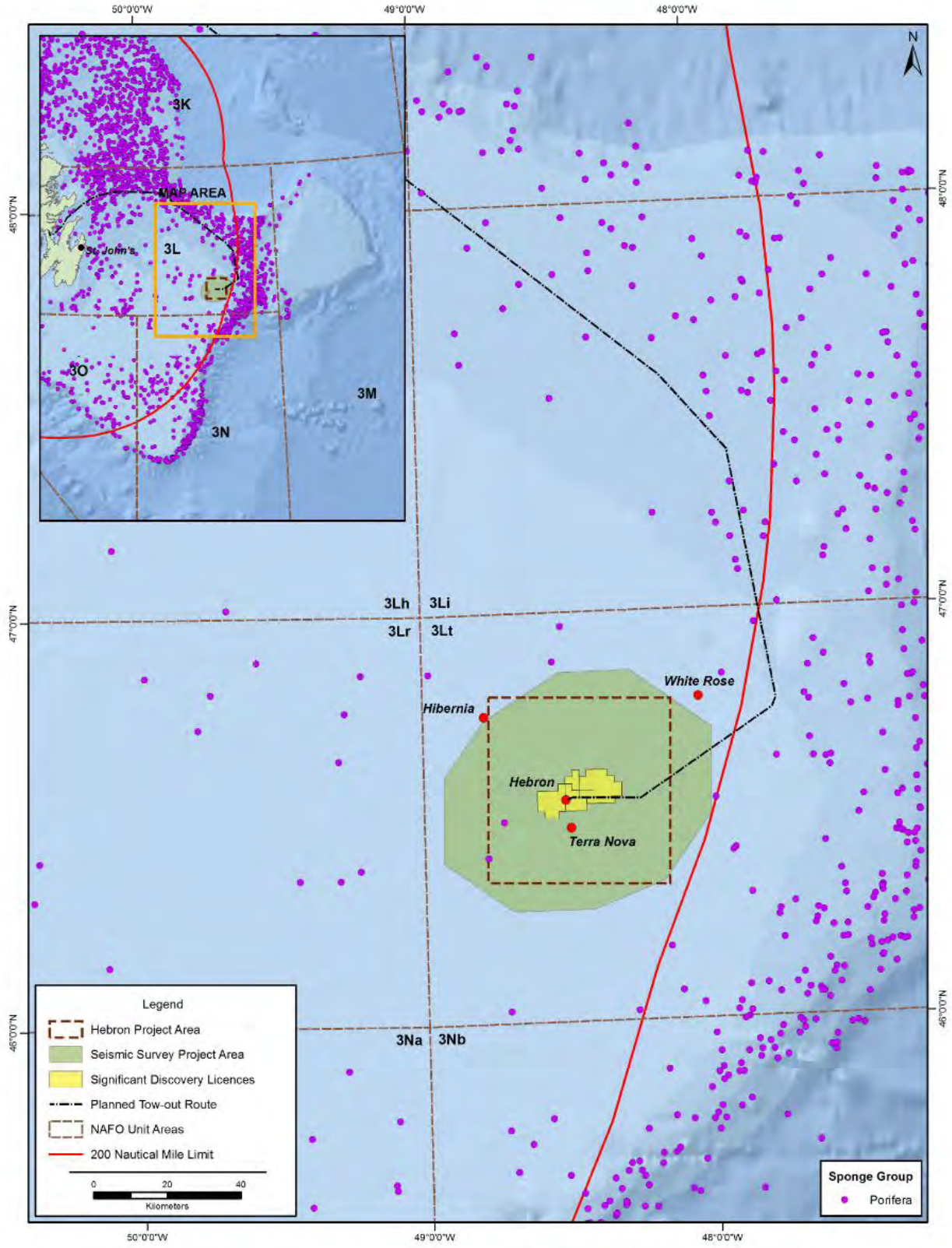


Figure 3-6 Sand Lance Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012)

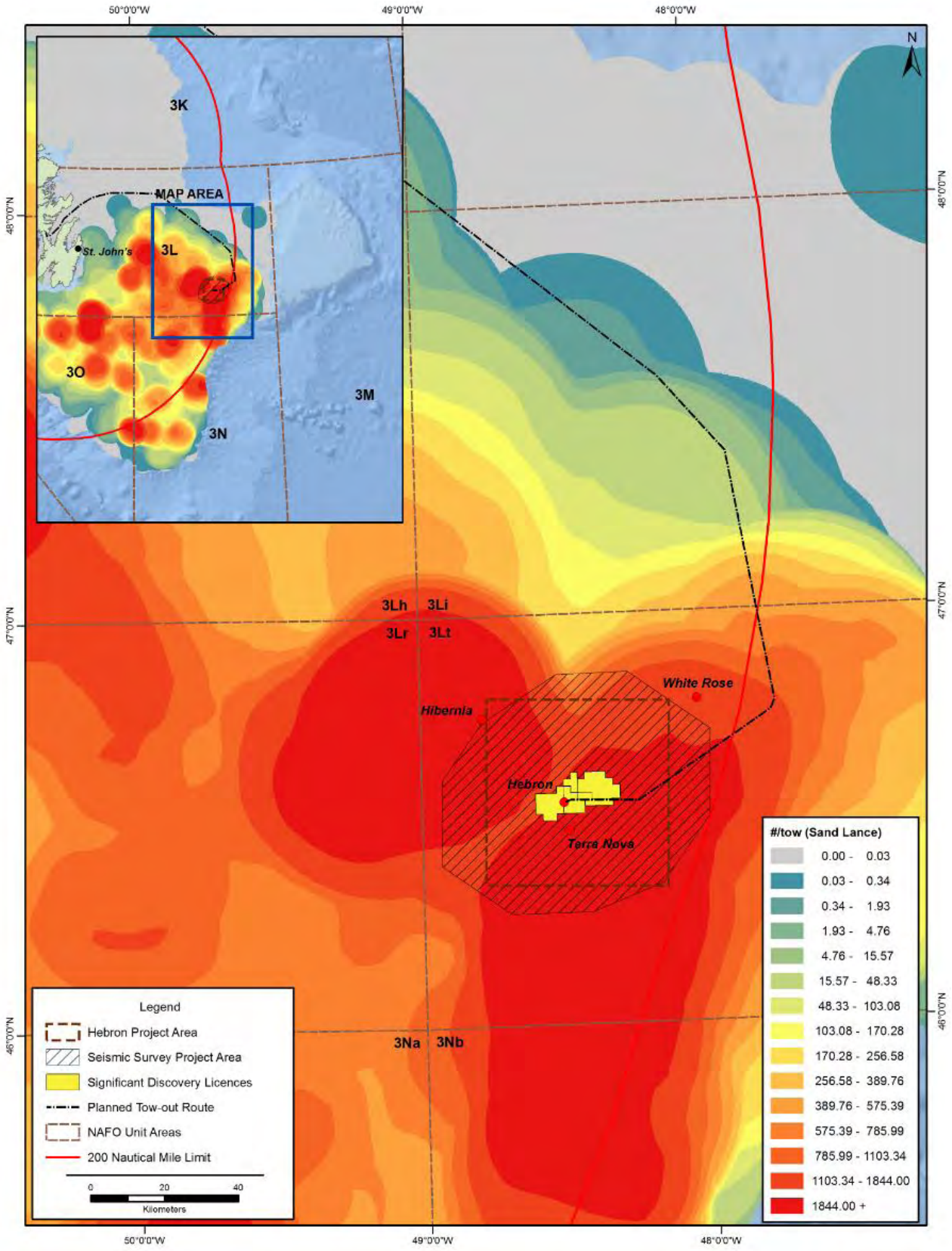


Figure 3-7 Sculpin Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012)

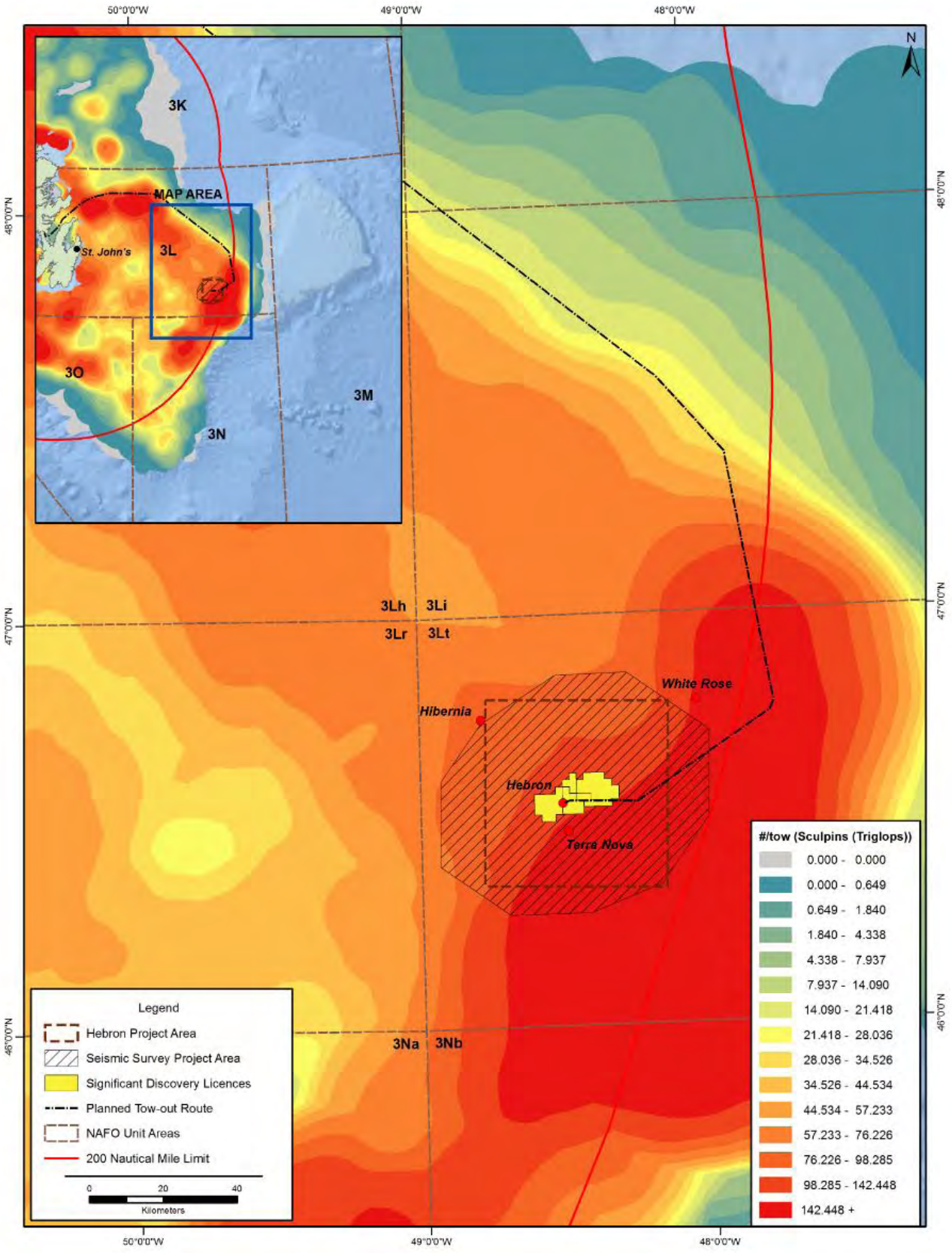
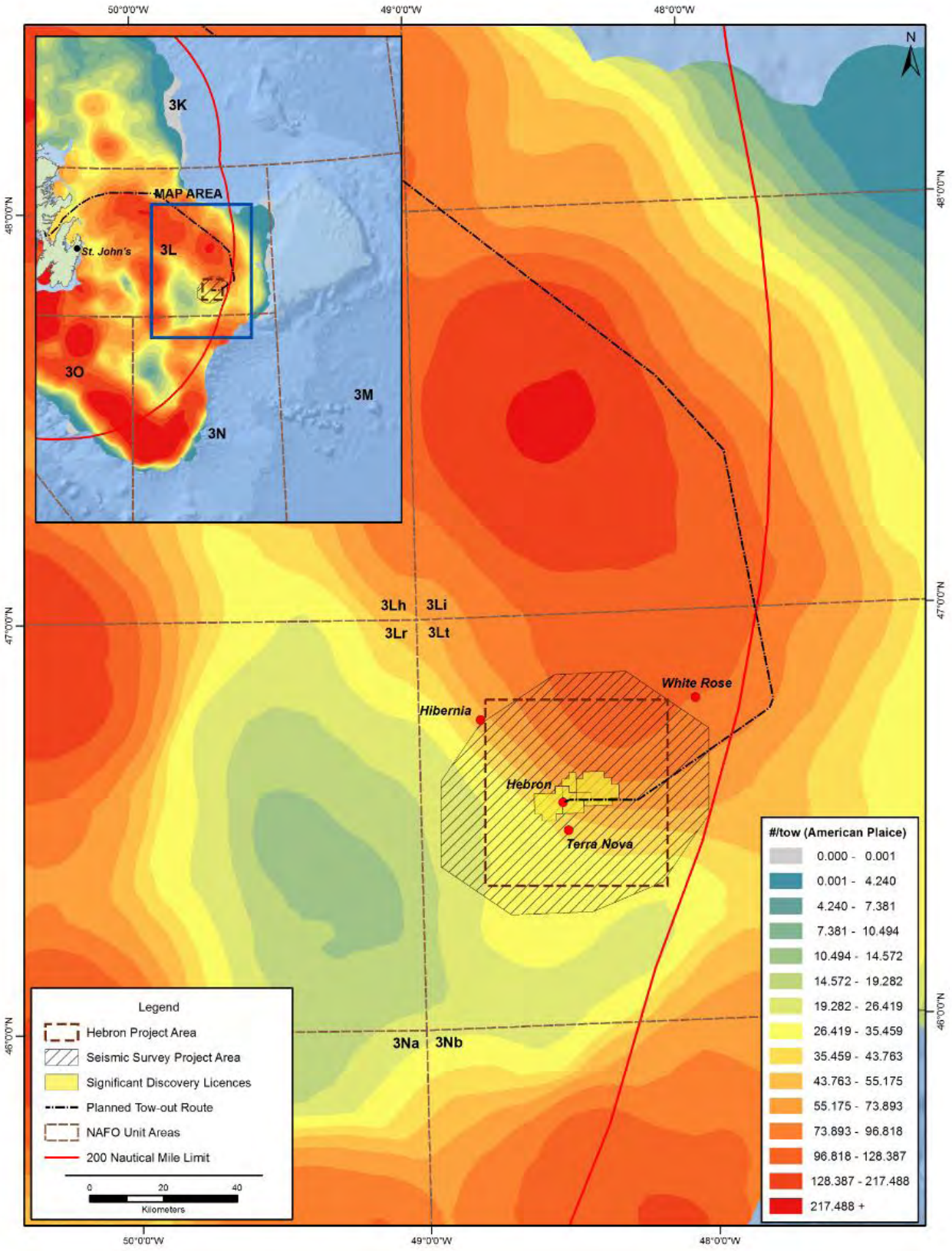


Figure 3-8 American Plaice Distributions in and Around the Project Area Based on Canadian RV Surveys (2008-2012)



3.3 Commercial Fisheries

Fisheries were a key area of focus of the EA review for the Project, and on-going Project planning and implementation have likewise placed a high degree of emphasis on addressing the potential for interactions between Project components and activities and commercial fishing activity within and near the Project Area. The Hebron Project CSR included a detailed description of commercial fisheries in the region based on existing data sources and other information that was available as of the time of EA preparation and submission (see, for example, CSR Section 8.3 and elsewhere). This included fisheries landings statistics and geospatial data up to 2008, with subsequent EA Updates providing fisheries information up to 2014. Commercial fisheries data are currently provided by Fisheries and Oceans Canada (DFO) Statistical Services in Ottawa, ON, including landing (weight and value) statistics and geospatial information on the location and timing of fishing activity. The DFO datasets record and report on domestic and foreign fish harvests that are landed in Canada.

The Hebron (offshore) Project Area is located entirely within NAFO Division 3L and its associated NAFO Unit Area 3Lt (Figure 3-9), portions of which are located both inside and beyond Canada's 200 nautical mile limit. The most recent fisheries data (up to 2015) available from DFO for this area indicates that approximately 1,981 tonnes of fish were landed in Canadian ports from this NAFO Unit Area in 2015, with an average of 2,067 tonnes being landed per year over the 2010-2015 period. Fish landings from NAFO Division 3Lt in 2015 (all fishing enterprises, for fish landed in Canadian ports) were valued at nearly $11 million, and had an average annual landed value of $9.3 million between 2010 and 2015. The available data indicate that the fishery in this area is currently dominated by snow crab, with other species fished including rough-head grenadier, grey sole / witch flounder, Atlantic halibut, Northern shrimp, turbot / Greenland halibut, and others. The main gear types include crab pots and bottom otter trawls. Fishing activity occurs year-round, but is concentrated primarily in the April-July period.

Fisheries mapping information is currently provided by DFO as an aggregated data set which gives a general indication of fishing areas (by species, gear types, fleet and other pre-determined categories and data classes) for individual grid "cells" that are approximately 6 x 4 nautical miles in size. The maps that follow provide an indication of the overall geographic distribution of commercial fishing activity within and adjacent to the Hebron Project Area for the years 2010 up to 2015 (the most recent year for which data are available) within the grid square system described above. This includes Figures that show all recorded commercial fishing activity (Figure 3-9), followed by gear types (fixed or mobile gear, Figures 3-10 and 3-11) and fishing areas for select, key species (see Appendix A) that were fished near the Project Area within that year. As illustrated, the Project Area itself occurs well outside the more intensive commercial fishing areas elsewhere on the Banks and along the shelf.

There are various regulatory jurisdictions that pertain to marine fish and fisheries within and around the Project Area and the various NAFO Divisions and Unit Areas that comprise the Eastern Newfoundland Offshore Area.

Figure 3-9 Commercial Fishing Locations, All Species (2010-2015)

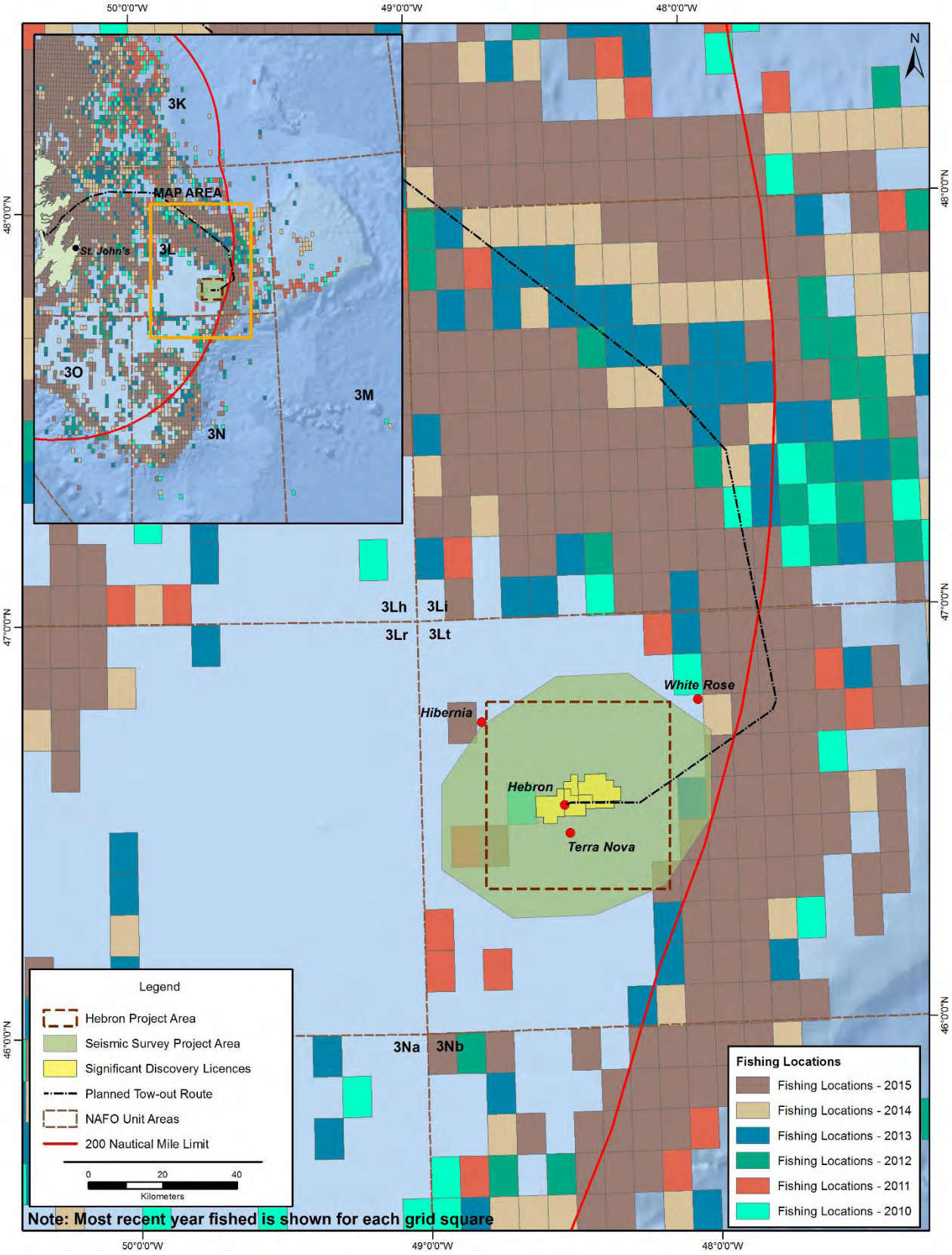


Figure 3-10 Commercial Fishing Locations, Mobile Gear Types (2010-2015)

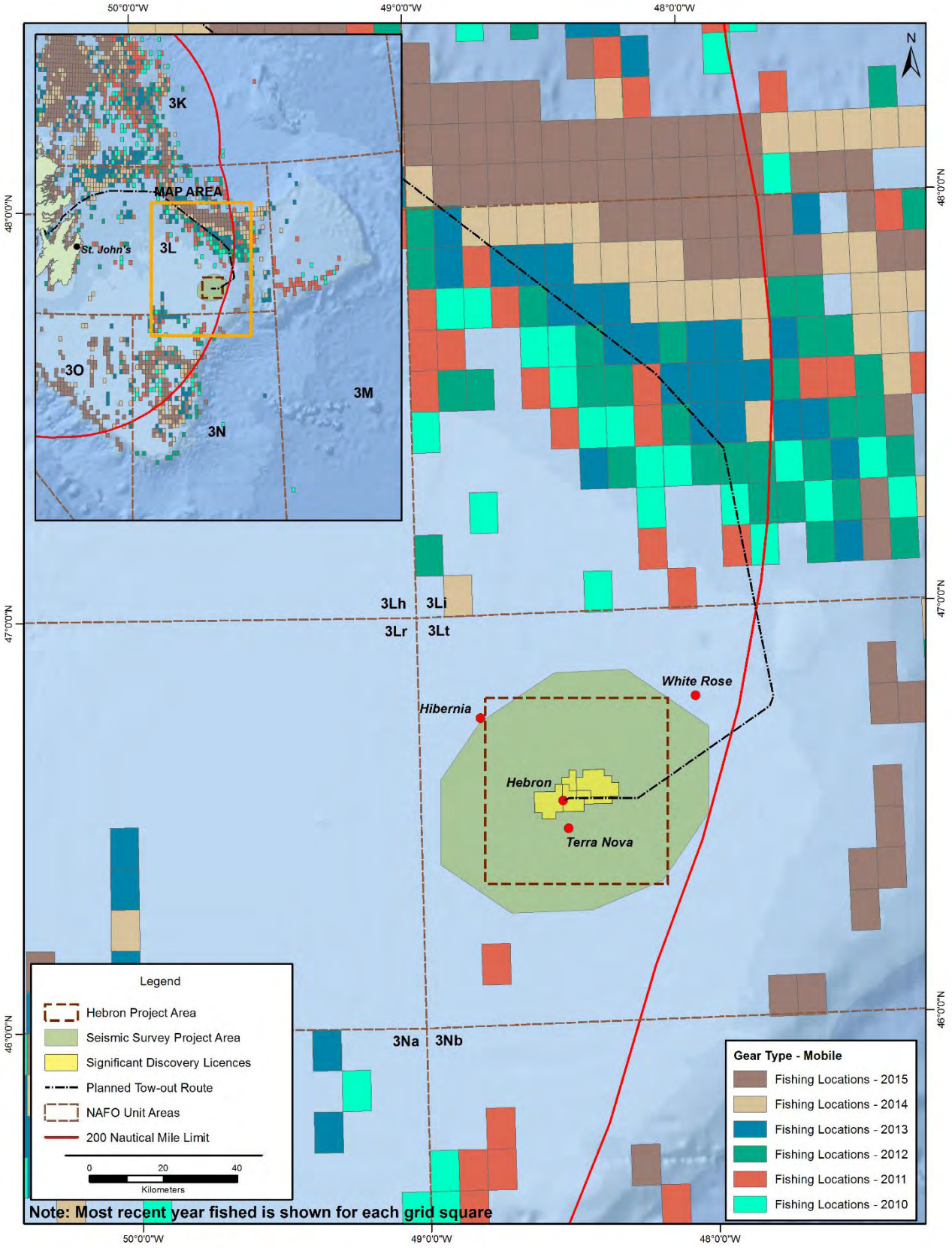
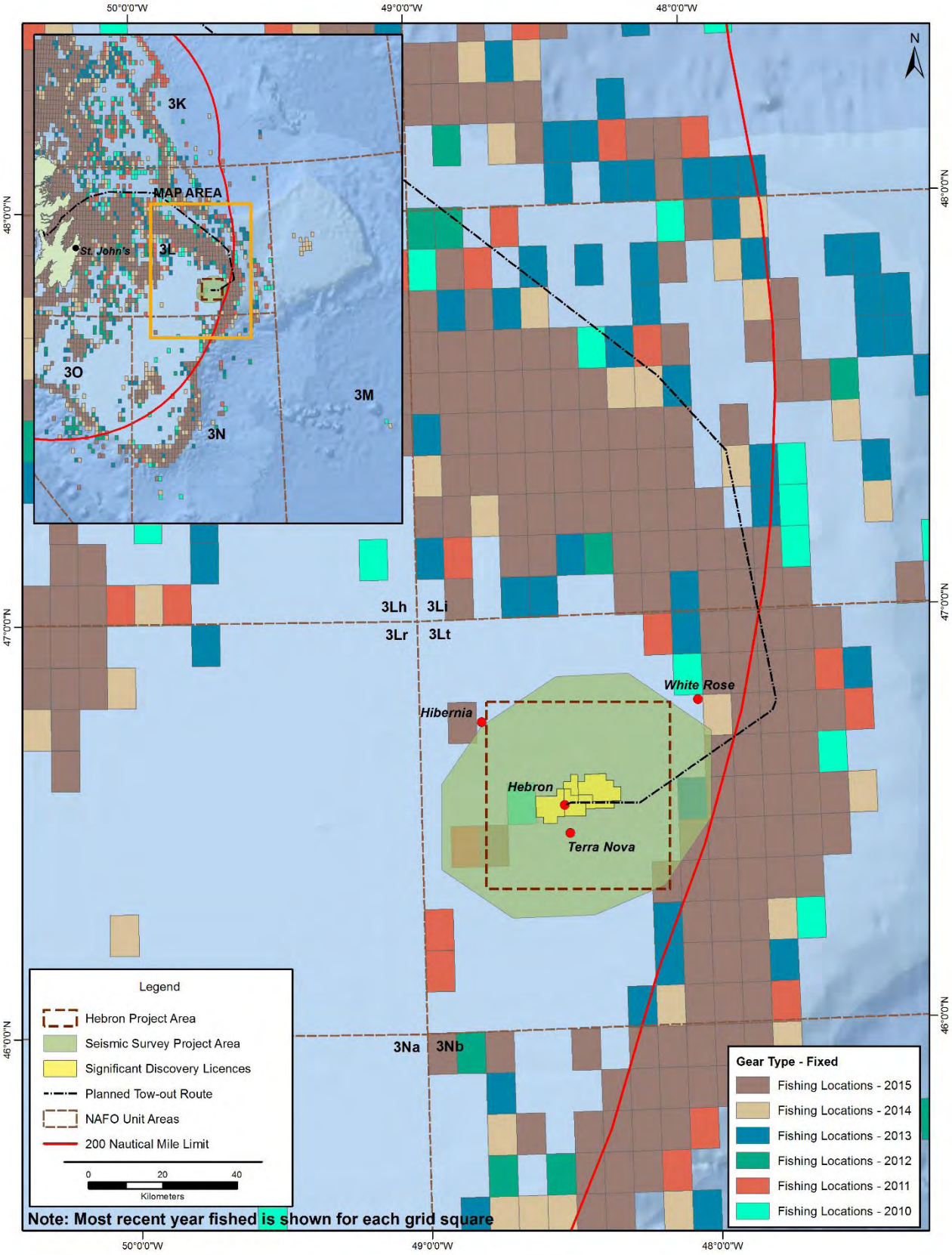


Figure 3-11 Commercial Fishing Locations, Fixed Gear Types (2010-2015)



While the Government of Canada has jurisdiction over fish stocks and fishing activities within the 200 nautical mile limit (EEZ) and for benthic invertebrates (such as crab) across the entire continental shelf, NAFO manages groundfish activities and other resources beyond that 200 mile limit. The NAFO Regulatory Area (NRA) is some 2,707,895 km^2 in size (or 41 percent of the total NAFO Convention Area) and comprises that part of the Northwest Atlantic high seas located adjacent to Canada's 200 mile EEZ (Amec 2014). Fishing activity in the NRA targets a range of species, including cod, redfish, Greenland halibut, shrimp, skates, and other finfish, and has an approximate landed value of $200 million annually across all members (NAFO 2014). As a result of the 2007 United Nations General Assembly (UNGA Res. 61/105, paragraph 83) request that Regional Fisheries Management Organizations regulate bottom fisheries, NAFO undertook an exercise to identify bottom fishing areas in the NRA, and in doing so, to identify and map NAFO's bottom fishing footprint in the area. The NAFO fisheries footprint is 120,048 km^2 in size, and its location and relationship to the Project Area is illustrated in Figure 3-12.

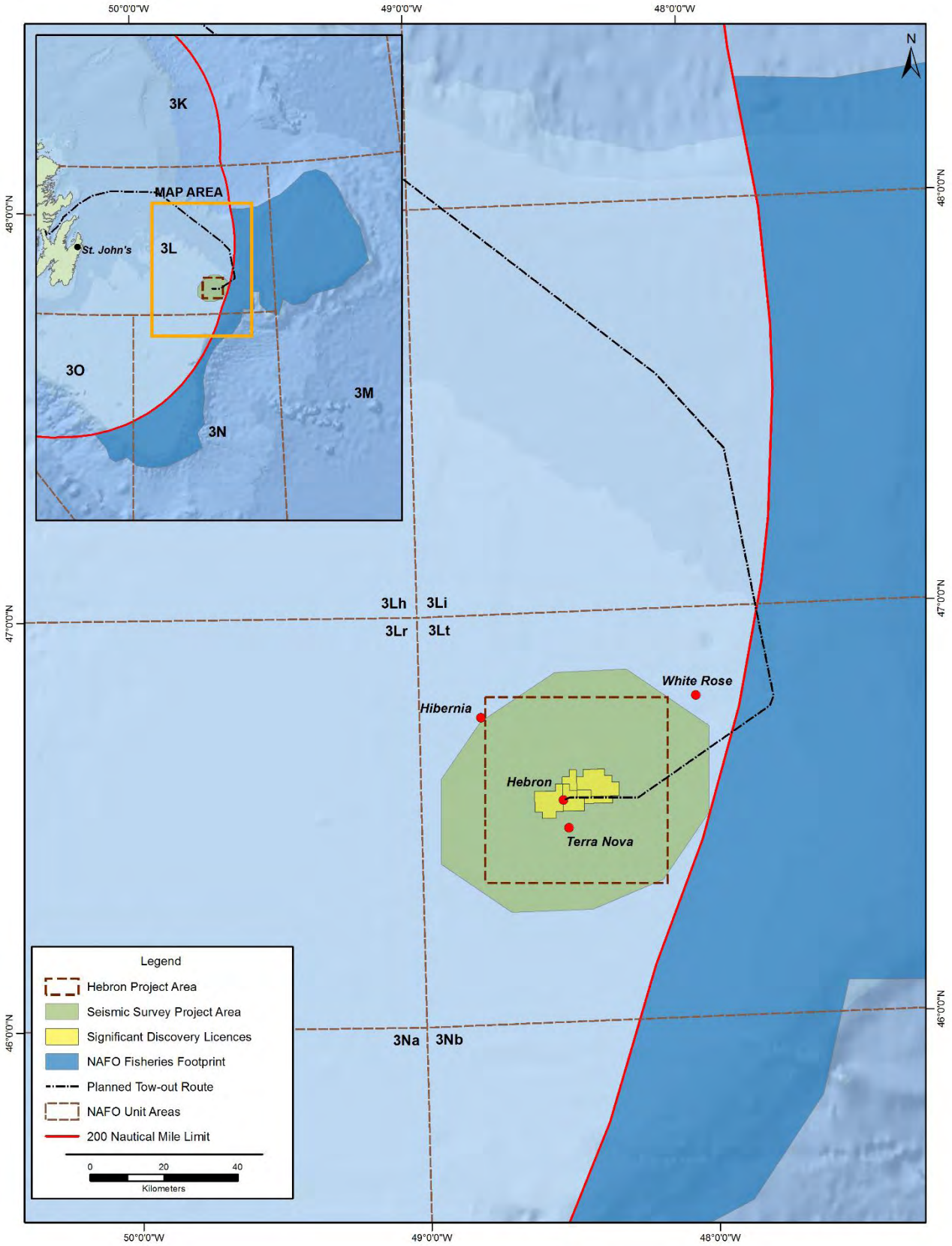
A number of fisheries survey programs by government and/or industry also occur in parts of the Eastern Newfoundland Offshore Area, including DFO Multispecies Research Vessel (RV) Trawl Surveys, which comprise annual (spring and fall) standardized bottom-trawl surveys to collect information for managing and monitoring fish resources in the Newfoundland and Labrador Region. Table 3-2 shows the (tentative) planned 2017 schedule for DFO's surveys as recently obtained from DFO representatives (D. Power, DFO – NL Region, personal communication). EMCP will obtain and verify 2017 survey plans with DFO as they are available, and will consider these and undertake associated consultations and communications with DFO in planning and undertaking its activities, as applicable.

Table 3-2 DFO RV Surveys off Eastern Newfoundland (2017)

Vessel	Activity	NAFO Division	Tentative Start Date	Tentative End Date
CCGS Needler	NL Spring Survey	3P	March 31	April 11
		3P	April 12	April 25
		3P+3O	April 26	May 9
		3O+3N	May 9	May 23
		3L+3N	May 24	June 10
	Shellfish Survey	2J+4R	August 31	September 12
	NL Fall Survey	3O	September 13	September 26
		3O+3N	September 26	October 10
		3N+3L	October 11	October 24
		3L	October 24	November 7
		3K+3L	November 8	November 21
			November 21	December 2
CCGS Teleost	NL Spring AZMP[1]	3L	April 4	April 25
	Capelin Survey	3KL	May 2	May 23
	NL Summer AZMP[1]		July 8	July 29
	NL Fall Survey	2H	October 5	October 10
		2H+2J	October 11	October 24
		2J+3K	October 24	November 7
		3K	November 8	November 21
		3K+3L Deep	November 21	December 5
			December 6	December 20

[1] Atlantic Zone Monitoring Program
Source: D Power, DFO-NL (2017**)**

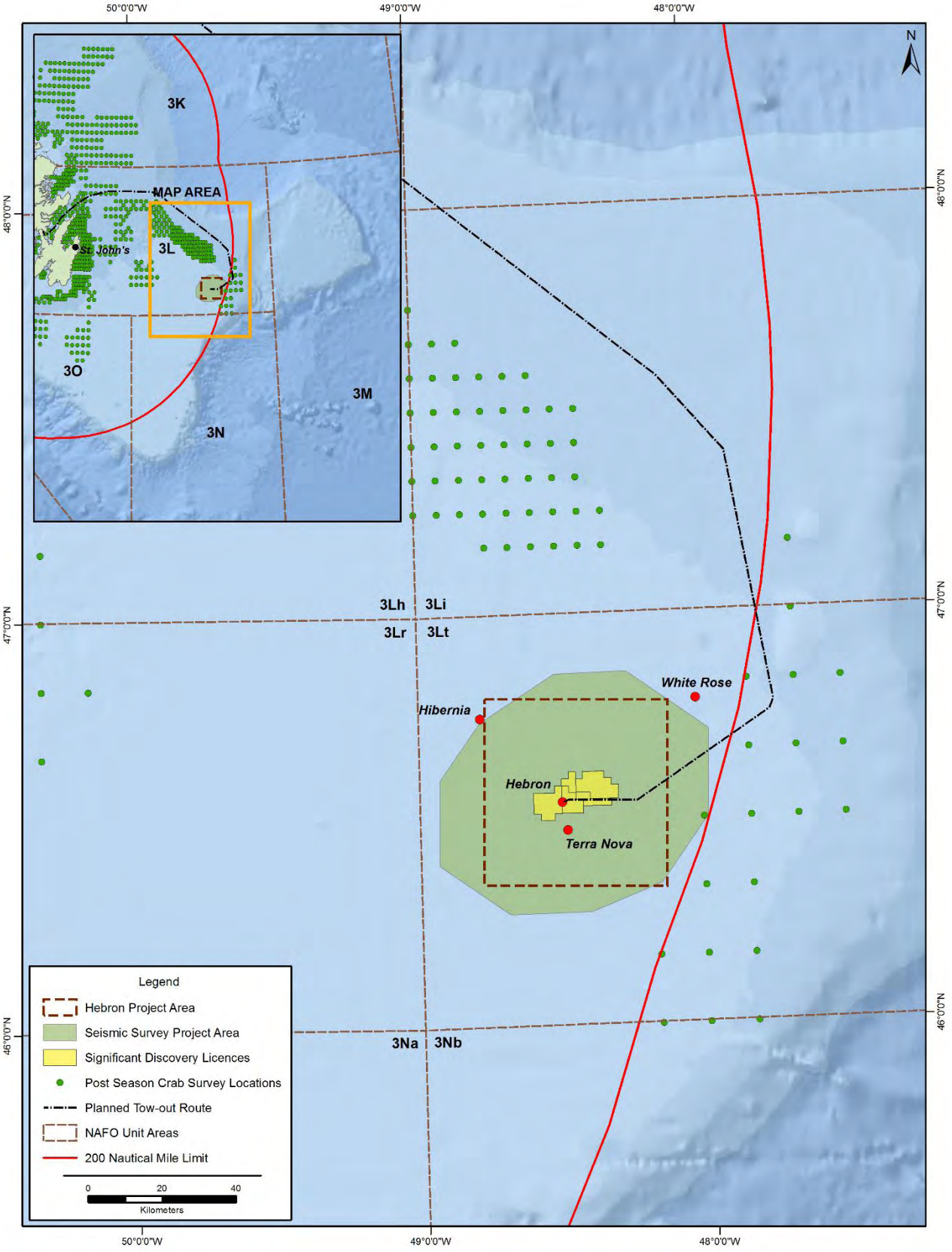
Figure 3-12 NAFO Fisheries "Footprint"



There is also an annual Industry - DFO Collaborative Post-season Trap Survey for snow crab in NAFO Divisions 2J3KLOPs4R, which is conducted using commercial and modified snow crab traps at established trap stations starting in late August or early September after the commercial snow crab season has ended (Figure 3-13). Recent discussions with DFO representatives indicate that the plans for the 2017 surveys are not yet available (D Mullowney, DFO – NL, personal communication). Although, as illustrated in Figure 3-13, the Project Area itself does not overlap directly with any of these established snow crab survey stations, EMCP will obtain and verify 2017 survey plans when they are available, and will again consider these in consultation with DFO in planning and undertaking its activities in 2017 and beyond.

Given its location far offshore, the Project Area does not contain or otherwise interact with other fisheries related activities off Eastern Newfoundland, including sealing areas, aquaculture operations, recreational fishing locations, or other human activities and components.

Figure 3-13 Locations of Industry - DFO Post-Season Snow Crab Survey Stations



3.4 Marine Birds

A variety of avifauna species occur within and around the Hebron Project Area and in adjacent marine and coastal regions, including seabirds and other marine-associated birds that inhabit the region at particular or extended periods for breeding, feeding, migration and other activities. A number of important habitats for birds have also been identified at locations along the coastline of Eastern Newfoundland, well outside of the Project Area.

As key components and indicators of ecosystem health, seabirds are often considered to be of high intrinsic ecological importance. Further, they are of socioeconomic importance in Newfoundland and Labrador both in terms of tourism and as a food source. Generally speaking, seabirds are long-lived species with low fecundity, delayed recruitment and relatively low rates of population growth. A diverse assemblage of seabirds can be found in the marine waters off Eastern Newfoundland at all times of year, including gannets, phalaropes, large gulls, kittiwakes, terns, alcids (auks), jaegers and skuas, fulmars, petrels and shearwaters (Amec 2014). The nutrient-rich Grand Banks and Flemish Cap regions off Eastern Newfoundland, for example, serve as a major feeding area for dozens of marine bird species throughout the year, particularly during the summer months. The eastern coast of Newfoundland is also home to several major colonies supporting tens of millions of seabirds, which travel long distances offshore from their nest sites to forage for themselves and their chicks. The region also contains several designated Important Bird Areas (IBAs) which provide important habitat for nationally and/or globally significant numbers of birds and/or for avian species at risk, and there are various other sites of provincial and regional significance to birds (Amec 2014). Although none of these areas or sites occurs within the Project Area itself, some of the bird species that make use of these designated habitats may spend some of their time in the Project Area

The original CSR summarized the distribution and abundance of marine-associated avifauna in the Offshore Project and Study Areas, and describes relevant life history characteristics and areas and times of particular significance to birds that are found within or in proximity to this region. The Eastern Newfoundland SEA (Amec 2014, Section 4.2.2) includes a detailed and updated overview of the presence, life histories, and spatial and temporal distributions of marine avifauna within and around the region. Other existing and available sources such as the current Eastern Canadian Seabirds at Sea (ECSAS) dataset (up to 2017), records from the Atlantic Canada Shorebird Survey (ACSS) and other available literature and datasets that provide additional information and insights on key species, times and locations.

As indicated in the original CSR, a number of marine avifauna have been observed to occur in the Offshore Project Area and Study Area at least seasonally, including large gulls, kittiwakes, dovekies, fulmars, storm-petrels, and others. A review of the most recent available information for the Study Area (including ECSAS data, the IBA database and other sources) indicates that the species presence and distribution has not changed appreciably since the original CSR. No areas of particularly important or sensitive habitat in the area have been identified. Many seabird groups such as cormorants and terns tend to have a more coastal distribution, and are therefore rarely observed this far offshore. Waterfowl occur in large numbers in marine habitats off Eastern Newfoundland, especially during the winter months, but they prefer open water in coastal areas and are thus not likely to frequent the northern and offshore portion of the Study Area (Amec 2014). The most commonly observed seabirds in and around the Project Area year-round are alcids, fulmars and gulls. Shearwaters and storm-petrels are common from spring to fall but less so in the winter months. Gannets, jaegers, skuas and phalaropes are occasionally observed, particularly in the summer and fall. Due to the great distance between this area

and the eastern coastline of the Island of Newfoundland, shorebirds and migrating landbirds are anticipated to be very infrequent visitors to the Project Area (primarily during fall migration). Important Bird Areas and breeding colonies are found in coastal areas and inland, far from the offshore environment that is found within the Project Area; therefore, nesting individuals are unlikely to forage in or around the Project Area with the exception of the Leach's Storm-petrel (*Oceanodroma leucorhoa*) which may make foraging trips of hundreds of kilometres from their breeding grounds (Pollet et al 2014).

3.5 Marine Mammals and Sea Turtles

The waters off Eastern Newfoundland support a diverse assemblage of marine fauna that includes some 20 marine mammals and several sea turtle species, many of which are considered to be at risk or otherwise of special conservation concern (see Section 3.6). The CSR and subsequent EA Updates have also summarized the distribution and abundance of marine mammals and sea turtles in and around the Project Area, and describe these species' relevant life history characteristics. The Eastern Newfoundland SEA (Amec 2014, Section 4.2.3) provides an updated summary of the distribution and abundance of marine mammals and sea turtles in the overall region.

The existing and available information indicates that marine mammal (cetacean) species that are known or considered likely to occur within the Eastern Newfoundland Offshore Area include a number of mysticetes (baleen whales), odontocetes (toothed whales and porpoises) and pinnipeds (seals), and several sea turtle species have also been observed. These differ considerably in their likelihood of presence and in the particular locations and habitat types that they utilize and the times at which they occur in or pass through the region. Key feeding grounds such as the Grand Banks are of particular importance to marine mammals and turtles, and several EBSAs have been identified due in part to their known importance to a number of marine mammal species (Templeman 2007, see Section 3.7 below). Given that a number of these species have been designated as species at risk under Canadian legislation or are otherwise considered to be of conservation concern, they are typically a key consideration in the EA review process for projects and activities off Eastern Newfoundland.

Again, there are a number of existing and available information sources that provide updated information on the characteristics, presence and spatial and temporal distribution of marine mammals and seabirds in and around the proposed Project Area since the original CSR. These are summarized in the Eastern Newfoundland SEA (Amec 2014, Section 4.2.3), and include, for example, the current DFO marine mammal sightings database, other available literature and available (published) marine mammal sightings data collected by operators working in the area. Data are also available from the Ocean Biogeographic Information System (OBIS), which incorporates sightings data from many different sources for a variety of marine taxa for the period between 1913 and 2012.

Although detailed species and site specific survey data are not available for the Project Area itself, and the available DFO sightings database includes limited coverage and observations in this immediate area (see Figures in Appendix A) it is likely that this general region is used by some marine mammals and/or sea turtles during parts of the year. Generally speaking, baleen whales are present in the region throughout the year and most abundant in the summer months; most species are migratory and absent from the region in winter, but common minke whale (*Balaenoptera acutorostrata*) and blue whale (*Balaenoptera musculus*) may occur in the area year-round. Most toothed whales are thought to be year-round residents of the area, with the exception of Risso's (*Grampus griseus*) and common bottlenose (*Tursiops truncatus*) dolphins (present only in the summer months) and beluga (*Delphinapterus leucas*, a rare winter visitor). Pinnipeds are most abundant in the winter, but grey

(*Halichoerus grypus*) and harbour (*Phoca vitulina*) seals may be present year-round. Sea turtles are most abundant in the area during the summer months and are absent between December and April.

3.6 Species at Risk

The Canadian *Species at Risk Act* (SARA) provides for the protection of species at the national level to prevent extinction and extirpation, facilitate the recovery of endangered and threatened species, and promote the management of other species to prevent them from becoming at risk in the future. Designations under the Act follow the recommendations and advice provided by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

There are currently a number of schedules associated with the *SARA*. Species that have formal protection are listed on Schedule 1, which includes the following potential designations:

- *Extirpated*: A species that no longer exists in the wild in Canada, but exists elsewhere;
- *Endangered*: A species that is facing imminent extirpation or extinction;
- *Threatened*: A species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction; and
- *Special Concern*: A species that may become threatened or endangered because of a combination of biological characteristics and identified threats.

Schedule 1 of *SARA* is the official federal list of species at risk in Canada. Once a species is listed, measures to protect and recover a listed species are established and implemented, including the development of a Recovery Strategy. Action Plans summarize the activities required to meet recovery strategy objectives and goals, and Management Plans set goals and objectives for maintaining sustainable population levels of one or more species that are particularly sensitive to environmental factors.

At the provincial level, the Newfoundland and Labrador *Endangered Species Act* (*NL ESA*) provides protection for indigenous species, sub-species and populations considered to be endangered, threatened, or vulnerable within the province. These potential designations under the legislation are defined as follows:

- *Endangered*: A species that is facing imminent extirpation or extinction;
- *Threatened*: A species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction; and
- *Vulnerable*: A species that has characteristics which make it particularly sensitive to human activities or natural events.

Designations are based on recommendations from COSEWIC and/or the provincial Species Status Advisory Committee (SSAC). Habitat that is important to the recovery and survival of endangered or threatened species can also be designated as critical habitat or recovery habitat, and protected under the *NL ESA*.

The following Table provides a listing of identified species at risk, as identified and considered in the original CSR and subsequent EA Updates, indicating their current designations under applicable legislation and by COSEWIC. As of November 2016, blue shark (*Prionace glauca*) is no longer designated by COSEWIC. There have been no other relevant designation changes within the past year (ie, since the 2016 EA Update for the Hebron Project).

Table 3-3 Species at Risk or Otherwise of Special Conservation Concern (Current Designations)

Family	Species		Federal		Provincial
	Common Name	**Scientific Name**	**SARA Status (Schedule 1)**	**COSEWIC Designation**	
MARINE FISH					
Anarhichadidae	Atlantic wolffish	*Anarhichas lupus*	Special Concern	Special Concern	
Anarhichadidae	Northern wolffish	*Anarhichas denticulatus*	Threatened	Threatened	
Anarhichadidae	Spotted wolffish	*Anarhichas minor*	Threatened	Threatened	
Anguillidae	American eel	*Anguilla rostrata*		Threatened	Vulnerable
Cetorhinidae	Basking shark	*Cetorhinus maximus*		Special Concern	
Gadidae	Atlantic cod (Newfoundland and Labrador population)	*Gadus morhua*		Endangered	
Gadidae	Cusk	*Brosme brosme*		Endangered	
Lamnidae	Porbeagle	*Lamna nasus*		Endangered	
Lamnidae	Shortfin mako	*Isurus oxyrinchus*		Threatened	
Lamnidae	White shark	*Carcharodon carcharias*	Endangered	Endangered	
Macrouridae	Roughhead grenadier	*Macrourus berglax*		Special Concern	
Macrouridae	Roundnose grenadier	*Coryphaenoides rupestris*		Endangered	
Phycidae	White hake (Atlantic and Northern Gulf of St. Lawrence population)	*Urophycis tenuis*		Threatened	
Pleuronectidae	American plaice (Newfoundland and Labrador population)	*Hippoglossoides platessoides*		Threatened	
Rajidae	Smooth skate (Funk Island Deep Population)	*Malacoraja senta*		Endangered	
Rajidae	Thorny skate	*Amblyraja radiata*		Special Concern	
Rajidae	Winter Skate (Eastern Scotain Shelf – Newfoundland)	*Leucoraja ocellata*		Endangered	
Salmonidae	Atlantic salmon (South Newfoundland	*Salmo salar*		Threatened (South Newfoundland	

Family	Species		Federal		Provincial
	Common Name	**Scientific Name**	**SARA Status (Schedule 1)**	**COSEWIC Designation**	
	Population; Outer Bay of Fundy population)			Population); Endangered (outer Bay of Fundy population)	
Scombridae	Atlantic bluefin tuna	*Thunnus thynnus*		Endangered	
Scorpaenidae	Acadian redfish (Atlantic population)	*Sebastes fasciatus*		Threatened	
Scorpaenidae	Deepwater redfish (Northern Population)	*Sebastes mentella*		Threatened	
Squalidae	Spiny dogfish	*Squalus acanthias*		Special Concern	
MARINE BIRDS					
Laridae	Ivory Gull	*Pagophila eburnea*	Endangered	Endangered	Endangered
Scolopacidae	Red-necked Phalarope	*Phalaropus lobatus*		Special Concern	
MARINE MAMMALS AND SEA TURTLES					
Balaenopteridae	Blue Whale - Atlantic Population	*Balaenoptera musculus*	Endangered	Endangered	
Balaenopteridae	Fin Whale - Atlantic Population	*Balaenoptera physalus*	Special Concern	Special Concern	
Balaenidae	North Atlantic Right Whale	*Eubalaena glacialis*	Endangered	Endangered	
Ziphiidae	Northern Bottlenose Whale - Davis Strait, Baffin Bay, Labrador Sea population; Scotian Shelf population	*Hyperoodon ampullatus*	Endangered (Scotian Shelf population)	Special Concern (Davis Strait, Baffin Bay, Labrador Sea population); Endangered (Scotian Shelf population)	
Ziphiidae	Sowerby's Beaked Whale	*Mesoplodon bidens*	Special Concern	Special Concern	
Delphinidae	Killer Whale (Northwest Atlantic / Eastern Arctic population)	*Orcinus orca*		Special Concern	
Phocoenidae	Harbour Porpoise (Northwest Atlantic population)	*Phocoena phocoena*		Special Concern	
Dermochelyidae	Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Endangered	
Cheloniidae	Loggerhead Sea Turtle	*Caretta caretta*		Endangered	

3.7 Sensitive or Special Areas

A number of marine and coastal areas within and off Eastern Newfoundland have been designated as protected under provincial, federal and/or other legislation and processes, or have been formally identified through relevant forums and processes as being otherwise special or sensitive due to their ecological, historical and/or socio-cultural characteristics and importance.

Given its location approximately 330 km offshore, the Hebron Project will not occur within, or otherwise interact directly with, any of the existing provincial or federal Parks, Ecological Reserves, Wildlife Reserves, Marine Protected Areas, Migratory Birds Sanctuaries, IBAs or other locations that have been designated as protected on or around the coast of the Island of Newfoundland (Amec 2014). The Project Area likewise does not overlap with any of the identified EBSAs, Preliminary Representative Marine Areas (RMAs), Vulnerable Marine Ecosystems (VMEs) or NAFO Fishery Closure Areas (FCAs) in the offshore environment of Eastern Newfoundland (Figure 3-14).

As illustrated in Figure 3-14, the Project Area is located within the Grand Banks Marine Region, which is one of 29 Marine Regions identified to encompass all of Canada's coastlines. Parks Canada has stated its long-term goal of establishing at least one national marine conservation area within each Marine Region (Parks Canada 2017).

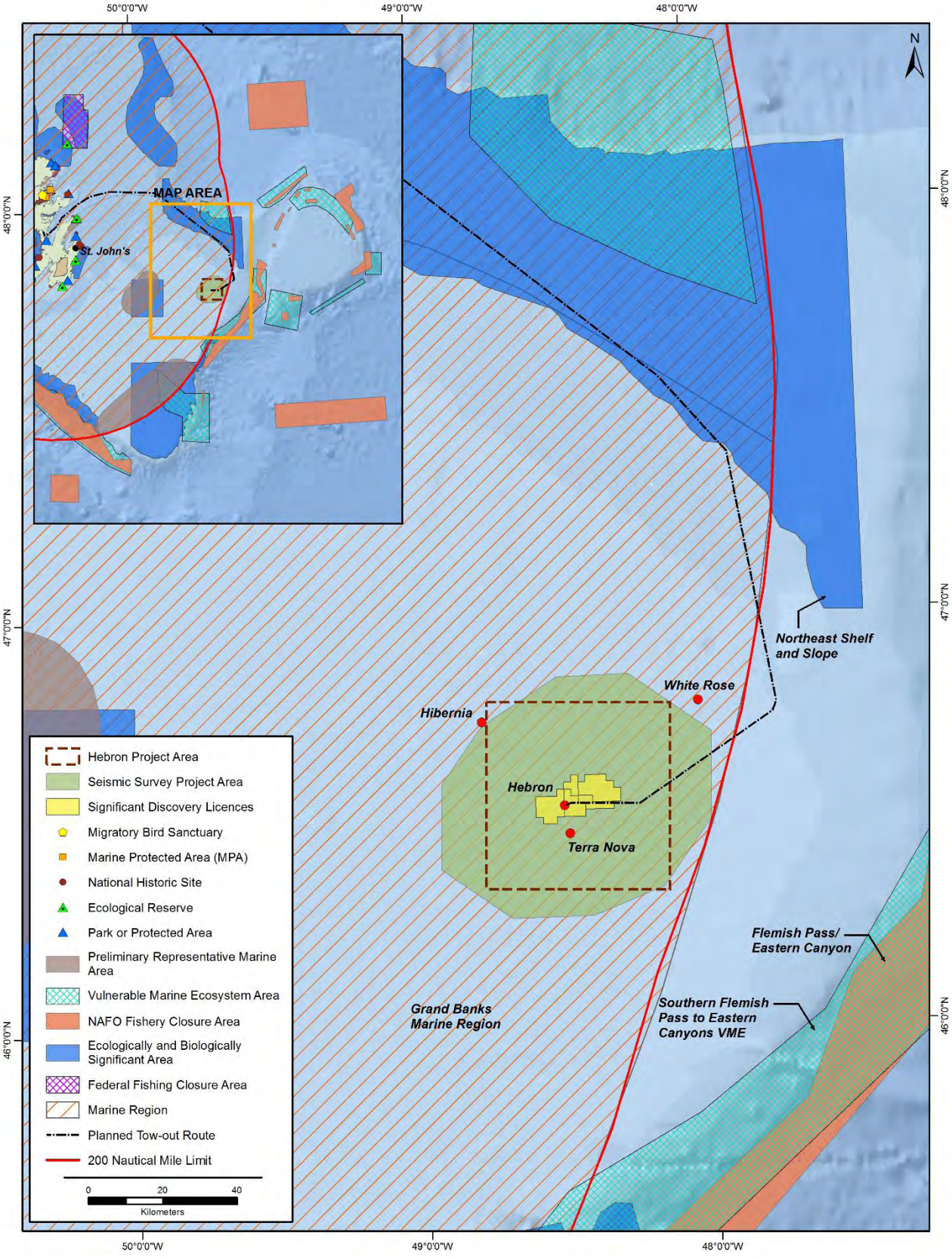
Several types of special areas are located within 100 km of the planned location of the Hebron Platform, as follows (Figure 3-14):

- The Northeast Shelf and Slope EBSA is approximately 90 km from the proposed Hebron Platform location. EBSAs are designated under the *Oceans Act* by DFO for their ecological criteria of fitness, aggregations, uniqueness, naturalness and resilience (Templeman 2007; DFO 2013).

- The Southern Flemish Pass to Eastern Canyons VME, which has been identified by the NAFO Scientific Council Working Group on Ecosystem Approach to Fisheries Management (WG-EAFM) based on the vulnerability of the habitat and constituent species to bottom contact fishing, is located some 88 km from the planned Hebron Platform location (FAO 2016).

- The Flemish Pass / Eastern Canyon FCA, which has been identified by NAFO and legislated by DFO through the *Fisheries Act* to protect VME areas from bottom contact fishing activities, is located approximately 90 km from the site (NAFO 2017).

Figure 3-14 Identified Sensitive and Special Areas off Eastern Newfoundland



4.0 ENVIRONMENTAL EFFECTS ASSESSMENT

The following sections provide an analysis and discussion of any implications of the proposed Project modification (see Chapter 2) for the original EA's environmental effects analysis, associated mitigation, residual effects significance determinations, and thus the overall findings and conclusions of the CSR.

4.1 Air Quality

The proposed modification to the Project (partial SBM-associated cuttings disposal from the Platform) will not result in any increased or otherwise different interactions with, or potential effects on, the atmospheric environment as compared to those which were assessed and described in the original CSR.

4.2 Fish and Fish Habitat (Including Species at Risk)

The planned release of drilling waste materials, including cuttings and residual fluids, represents one of the main potential interactions with marine fish and fish habitat during offshore drilling programs. The primary issues related to this activity have not changed with respect to those considered and assessed in the CSR and include sediment deposition and seabed disturbance (smothering habitat, creation of piles, and extent of deposition); chemical toxicity; and potential bioaccumulation (uptake of contaminants by fish and the presence or perception of taint).

The original CSR for the Hebron Project states that (Section 7.4.2.2, Operations / Maintenance):

> *The primary offshore Project activities / components during operations and maintenance that could potentially interact directly or indirectly with marine fish and fish habitat include (but are not limited to):*
>
> - *Drill cuttings and muds discharges (water-based mud (WBM) from the Hebron Platform, WBM and synthetic-based mud (SBM) from mobile offshore drilling unit (MODU)-drilling associated with potential expansion opportunities) (potential siltation of the water column and mortality and/or change in habitat quality of marine species by smothering)*

The CSR also states that (Section 7.5.2, Operations and Maintenance):

> *SBM cutting reinjection will be undertaken for Platform drilling as a means of waste reduction. SBM cutting reinjection is not technically feasible for MODU drilling and SBM cuttings will be discharged overboard after treatment in accordance with the OWTG.*

The analysis that follows assesses and evaluates the potential environmental effects of the proposed Project modification that would see SBM cement cuttings being discharged at sea from the Hebron Platform during drilling through concrete shoe tracks associated with each of the 52 drill locations. The characteristics of the SBMs as well as the associated drill cuttings have been described earlier in Section 2.3.

4.2.1 Potential Toxicity and Bioaccumulation

An overview discussion of the potential toxicity and bioaccumulation considerations associated with SBMs and their use and disposal in the marine environment, both in general and in the context of the

particular drilling fluids planned for use here, was provided earlier in Section 2.3. Specifically, according to the PetroTox aquatic hazard assessment model no biological effects are expected.

Acute toxicity testing of SBMs in general suggests they are non-toxic (Gagnon & Bakhtyar 2013), although there are no data available assessing the effects of PuredrillTM SBM itself on fish (Petro Canada 2015). The effects of chronic exposure of SBMs on fish have been somewhat less studied, however. Although a negative biomarker response (increase in condition factor, liver somatic index and biliary metabolite accumulation) in fish have been observed in a laboratory study, this has been seen in response to a four week exposure period in semi-static laboratory environmental conditions that were likely unrealistic compared to conditions fish would encounter in nature (Gagnon & Bakhtyar 2013).

In contrast, based on a 10 year field study of fish health and body burden analysis around the Terra Nova production field, with the exception of hydrocarbons resembling SBM fluid being noted once in an American plaice (*Hippoglossoides platessoides*) liver sample collected near drill centres in 2000, there has been no evidence of project-related metals or hydrocarbon contamination in plaice liver or fillet samples (DeBlois et al 2014a). Furthermore, there has been no evidence of taint for either plaice fillet or Iceland scallop (*Chlamys islandica*) adductor muscle in baseline or EEM years (DeBlois et al 2014a). Moreover, a parallel study on fish bioindicators demonstrated that fish health at Terra Nova was similar to that at a distant Reference Area (Mathieu et al 2011; DeBlois et al 2014a). Collectively, there were few to no detectable biological effects on either plaice or scallop resulting from Terra Nova activities (Deblois et al 2014a).

Therefore, although pelagic fish species are potentially located within the area of planned SBM cement cuttings deposition from the Hebron Platform, it is not anticipated that the quantity and duration of release (see Section 2.2) combined with the low toxicity of the material will have any adverse effects on fish and fish habitat, and specifically, will not alter the effects predictions made in the original CSR (Section 7.5.6).

4.2.2 Potential Sedimentation and Burial

The main potential effects of SBMs are associated with the disposal of drill wastes on the seabed, leading to the possible alteration of marine habitats and creation of anoxic environments through local eutrophication from degradation of SBM organic components (Schaanning et al 2008; Ellis et al 2012). Previous studies and monitoring programs have shown that the nature and magnitude of these effects on benthic invertebrates and their habitats are linked to the thickness and extent of the associated cuttings pile that may accumulate on the seabed following discharge (Smit et al 2006; Schaanning et al 2008) and that the response of the benthic community to drill cuttings discharges can be dependent on the types of SBM drilling fluid used (Holdway 2002; Netto et al 2008). SBM-associated cuttings have been shown to stay closer to the discharge source and do not disperse as widely as WBMs and their associated cuttings (CAPP 2001). SBM-associated cuttings do not tend to disperse like WBM-associated cuttings unless the fluid retention values are below five percent (Getliff et al 1997; CAPP 2001).

SBM Cement Drill Cuttings Deposition Analysis

To provide additional, Project-specific information and analysis related to the nature and extent of the planned SBM cement drill cuttings disposition resulting from the Project modification, the previous drill cuttings dispersion modelling carried out for the CSR (Amec 2010) was revisited and additional modelling completed for an additional scenario that covers the now proposed SBM cement cuttings

disposal. This additional modelling effort used the same overall approach and methods as those used in the original modelling of drill cuttings for the CSR (Amec 2010). Further information on this modelling exercise is provided as Appendix B.

The results of this modelling are presented below and utilized herein to assess potential effects on benthic habitats and biota, particularly the overall habitat alternations that may be associated with the cuttings footprint (including its location, extent, and thickness).

The following points describe the modelling effort and its associated inputs and analysis[1]:

- A total of 52 production wells are simulated to be drilled sequentially with a duration of 90 days per well.
  - The first production well[2] is assumed to start 1 Aug 2017, the second on 2 Nov 2017, and so on up to a final well (well 52) commencing 6 Aug 2031.
  - A random offset of from 0 to 20 days is inserted after each well completion date simply to provide some added seasonal variance with the ocean currents input to the model.

- A total of 15 m^3 (an upper limit) of SBM cement cuttings are released via shale chute at elevation 20 m above the seabed (94 m depth assumed for Hebron).
  - 10 m^3 from the 340 mm shoe track hole section, released on day 24 (of 90)
  - 5 m^3 from the 244 mm shoe track hole section, released on day 37

- The cuttings thicknesses are calculated and reported for a model grid size of 32 m

For the purposes of the model, it is also assumed that cuttings from drilling of the cement shoe tracks will be processed sequentially through the shale shaker solids control systems onboard the GBS. It assumed that these processed cuttings will be comprised of mostly fines (approximately 81 percent) with the remainder pebbles (11 percent), coarse and medium sand (eight percent).

The hydrophobic nature of SBM-associated cuttings results in their forming clumps that settle rapidly to the bottom and which tend not to mix with bottom sediments (Neff et al 2000). A recent review paper by the International Association of Oil & Gas Producers (IOGP 2016), similarly notes that SBM-associated cuttings containing more than about five percent SBM tend to clump since the cuttings are oil wet. A large degree of clumping is therefore considered likely, including some clumping on the shale shakers. These clumps will tend to settle rapidly given their larger size, although it is not expected that all the material will clump so that disaggregate larger pebbles and smaller fines will be included in the cuttings mixture. Since there is some uncertainty as to the extent of clumping that will take place and the exact behaviour of these cement cuttings on release to the sea, two deposition modelling scenarios were completed in order to estimate a range of cement shoe track cuttings fates.

The first ("disaggregate") scenario considered the cuttings composition as above with particles entering the sea in a relatively disaggregated manner (i.e., the material has minimal clumping). Due to the large percentage of fines, 73 percent of the entire (52 well) shoe track cuttings (2,000 t) initially settle outside 500 m and within about six kilometers of the GBS. Of the remaining 27 percent that is modelled to settle inside 500 m, 14 percent settle at the GBS base. The majority of the cuttings footprints have thicknesses

[1] These values are general and representative, but specific values for individual wells may vary.
[2] The first well to be drilled will be a CRI well. This well has no associated SBM-associated cuttings discharge so is not considered here.

of 0.5 mm or less, with a few patches of one mm within about 600 m of the GBS. Outside 500 m, cuttings thicknesses are thin, averaging 0.1 mm or less with a maximum thickness of 0.8 mm at a distance of 520 m from the GBS. Eight model grid cells within about 50 m of the GBS report thicknesses greater than two mm. The largest is 143 mm at the GBS (origin) with an average thickness over these eight cells of 25 mm.

A second scenario simulated the clumping nature of the SBM cement cuttings by assuming a majority (78 percent) of the material to behave as coarse and medium sand size (the remainder 11 percent pebbles, 11 percent fines). These sand clumps will settle to the seabed within about two to five minutes and (assuming average near-bottom currents on the order of 15 cm/s) travel about 20 to 50 m horizontally. Within this second modelled scenario, 30 percent of the material settles at the base of the GBS with another 59 percent settling within 100 m. Cuttings thicknesses are about 320 mm at the GBS, as thick as about 100 mm at 30 to 50 m away, and average about 20 mm out to 100 m. Outside of 100 m, thicknesses are less than 0.1 mm. Since some fines are still assumed as part of the cuttings composition, light dustings are still predicted to about six km and will be highly dispersed.

The extent of these footprints is in keeping with the original modelling report (Amec 2010) which notes "… *thicknesses up to 1 mm as far as about 5.5 km to the southwest and 6 km to the northeast. Northern, western, and southeastern extents are generally limited to about 2 to 4 km.*"

The modelled cuttings footprints about the GBS for the original CSR and for the two new SBM cement cuttings scenarios are presented, in eight km and one km views, in Figure 4-1. The footprints show the initial deposition and can be considered predictions of the range of the amount of material deposited and proximity to the GBS. The extent of SBM cement cuttings are generally within the original CSR footprint. This makes sense given the same cuttings release location and ambient ocean currents used in the model.

The SBM cement cuttings discharge represents about five percent of the total WBM-associated cuttings to be discharged. To assess the change introduced by the SBM cement cuttings, Figure 4-2 presents the difference in cuttings deposition thickness between the original CSR model run and the two SBM cement cuttings scenarios. Cuttings thickness differences that are greater than zero indicate locations where the CSR predictions are thicker. Conversely a negative thickness indicates a greater presence of SBM cement cuttings. These figures show that the majority of these cuttings settle within the original footprint and the only places modelled SBM cement cuttings contribute more than the original CSR WBM-associated cuttings (and those areas are few, mostly 2 to 4 km or farther away from the GBS), the thicknesses are less than 0.1 mm (lightest grey). The bottom two panels in the figure confirm the original modelled CSR WBM-associated cuttings are at least one mm, and generally at least 10 mm, thicker than the SBM cement cuttings contributions within one km of the GBS.

Figure 4-1 Cuttings Deposition Comparison. (L to R) i) CSR WBM, ii) SBM Cement Disaggregate and iii) SBM Cement Clumping

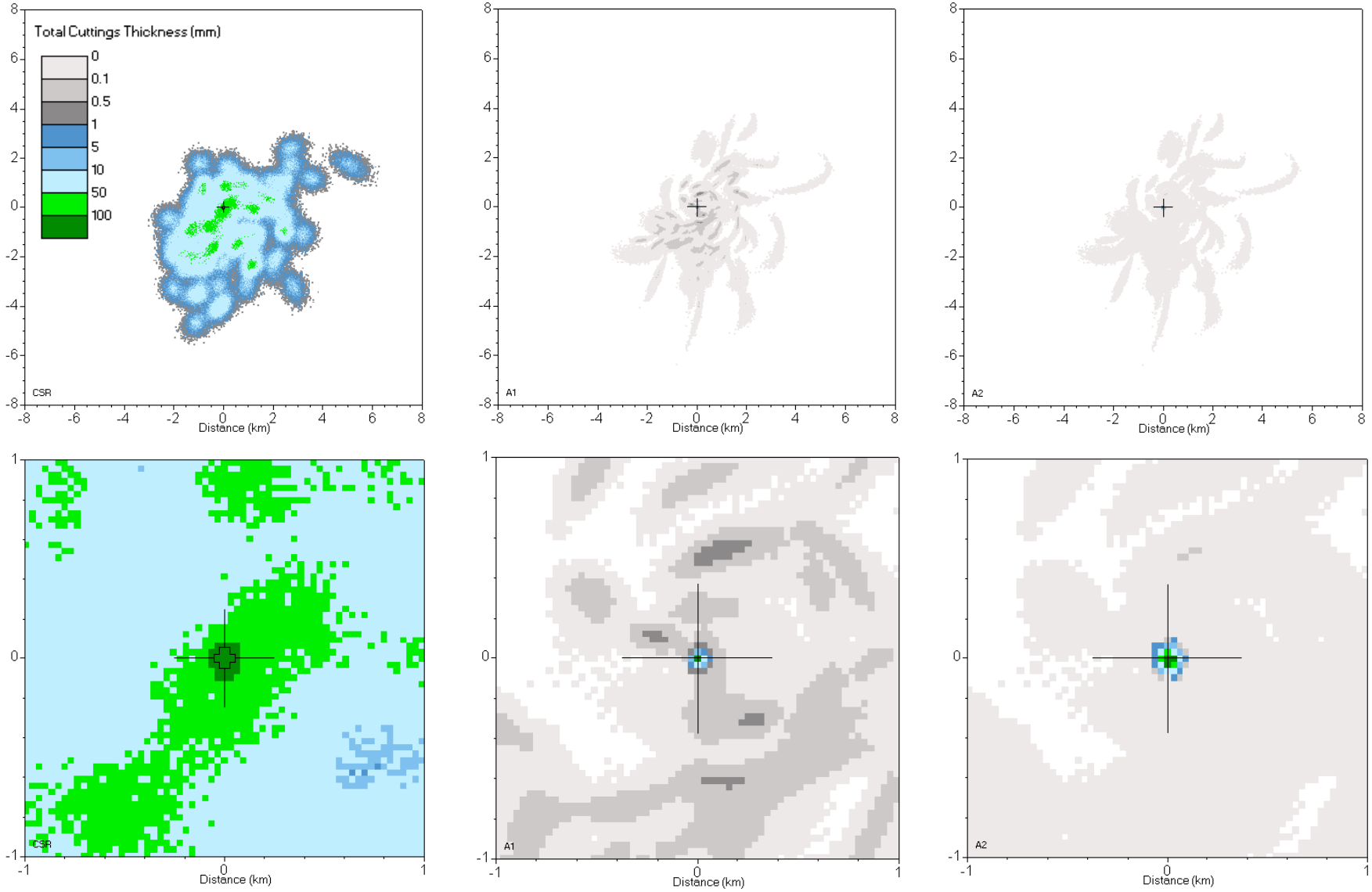
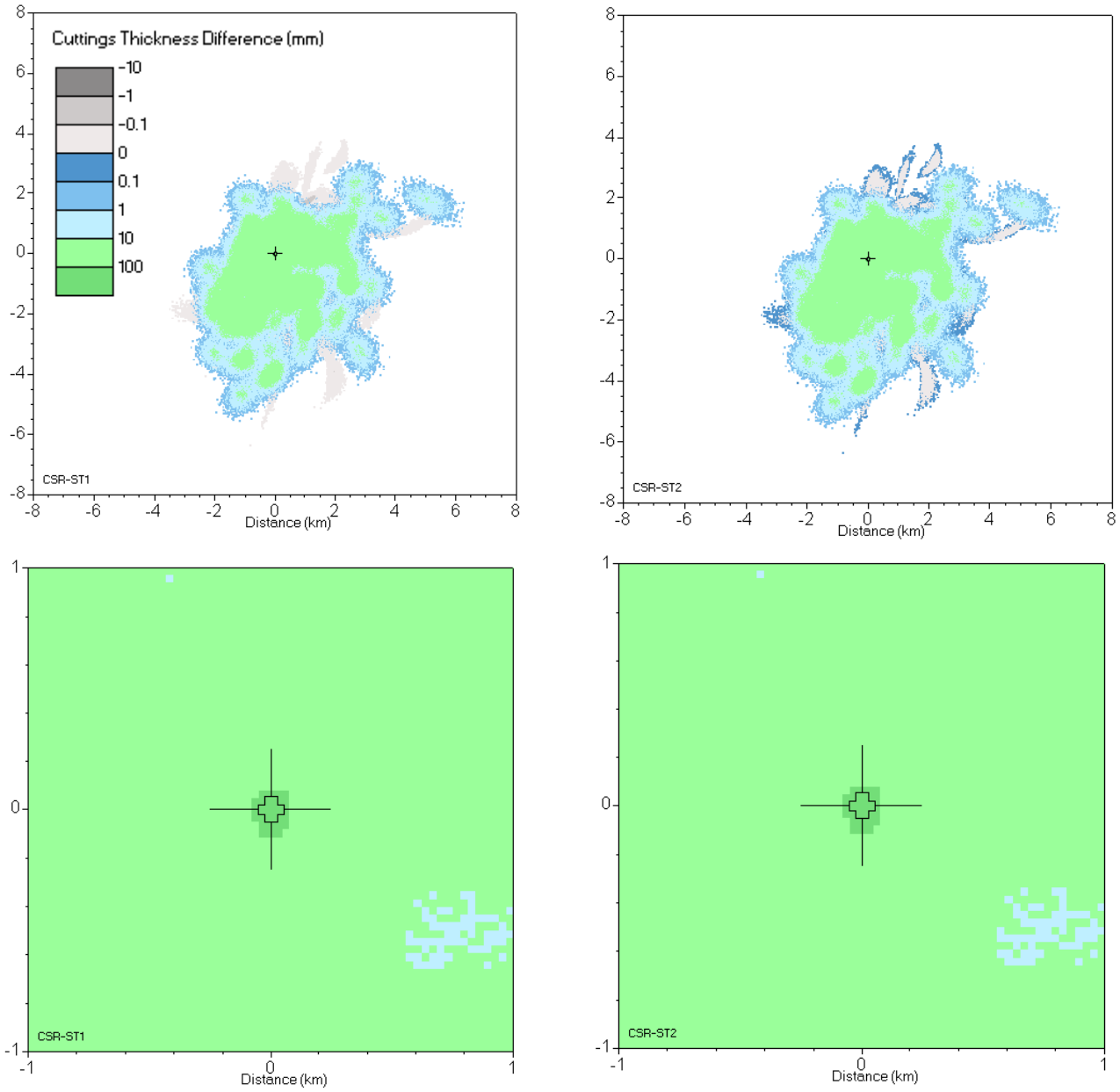


Figure 4-2 Cuttings Thickness Difference: CSR minus SBM Cement Disaggregate (Left) and Clumping (Right) Scenarios



Potential Biological Effects

The potential biological effects of ocean discharge of drill cuttings and any associated drilling fluids are again primarily relevant to the benthic environment (IOGP 2016), including toxicity, bioaccumulation, sedimentation and burial. As stated, the nature and degree of potential effect are dependent on the frequency and quantity of deposition and composition of discharged material.

The upper limit of the discharge volume of these SBM cement cuttings expected to be released per typical well is 15 m^3, in addition to 260 m^3 of WBM-associated cuttings. This is projected to occur for up to five wells per year out to 2031. Both the SBM cement cuttings and the WBM-associated cuttings will be released from the platform via the shale chute.

The high clumping scenario discussed in the preceding section is considered the more likely scenario. Cuttings deposition is estimated to be mainly localized to the GBS with potential burial effects out to 100 m. Average burial depths of 6.5 mm are considered to be the predicted no effect threshold (PNET) for non-toxic sedimentation based on benthic invertebrate species tolerances to burial, oxygen depletion and change in sediment grain size (Kjeilen-Eilertsen et al 2004; Smit et al 2006). However, as some species may be more susceptible to shallower burial depths, an average PNET burial depth of 1.5 mm is suggested to be a more conservative approach to assessing drilling discharges (Kjeilen-Eilertsen et al 2004; Smit et al 2006; Larsson et al 2013).

As illustrated through the modelling described above, the deposition of the SBM cement cuttings is likely to be within the previously predicted and assessed footprint of WBM-associated cuttings. Assuming high clumping scenarios, accumulated SBM-associated and WBM-associated cuttings piles thickness at the base of the GBS would cumulatively be less than 2.5 m, and be predominantly be comprised of WBM-associated cuttings discharged during the life of the Project. Although highly localized (less than 10 m from GBS), this is already well beyond the PNET. However, the addition of the SBM cement cuttings does not appreciably contribute to the potential burial effects of the deposited WBM-associated cuttings. Similarly, drill muds and cuttings depths are estimated to be less than one metre at distances within 50 m of the GBS and less than 10 cm at distances less than 100 m from the GBS. Beyond 100 m from the Hebron Platform, deposited sediment thicknesses are estimated to be below PNET at 0.1 mm for released SBM cement cuttings. At this range, the majority of remaining discharged material for SBM- and WBM-associated discharges will be comprised of highly dispersed fine material that will not appreciably accumulate and is not likely have any effects on fish and fish habitat.

Eventual recovery from the biological effects of drill cuttings piles (through recolonization) can vary considerably based on such factors as disturbance size, frequency, distance and density of source colonizer and local environmental conditions (Gates and Jones 2012; Jones et al 2012). As per the above results, the addition of the SBM cement drill cuttings will not alter the biological effects of, nor the eventual recovery of, the cuttings pile as compared to the analysis provided in the original CSR.

In summary, therefore, the majority of discharged SBM cement cuttings will settle within the original WBM-associated cuttings footprint identified and assessed in the CSR and have comparatively much lower levels of sediment deposition. Furthermore, in disaggregate and clumping scenarios, SBM cement cuttings accumulation (between 0.05-50 cm thickness) are limited to within 600 m of the Platform. The small areas where SBM cement cuttings settle outside the WBM-associated cuttings footprint will have negligible levels of SBM cement cuttings accumulation (less than 0.1 mm thickness).

The proposed modification to the Project (SBM cement cuttings disposal from the Platform) will therefore not result in any increased or otherwise different effects on Fish and Fish Habitat as compared to those which were assessed and described in the original CSR. The proposed Project modification therefore does not change the results of the original environmental effects assessment for this VEC, and the Project is still not likely to result in significant adverse environmental effects on Fish and Fish Habitat.

The Table excerpts below update (in red text) the relevant sections of the environmental interactions and effects summary tables included in the original CSR for the Fish and Fish Habitat VEC[3].

Table 7-9 Potential Project-related Interactions: Fish and Fish Habitat

Project Activities, Physical Works Discharges and Emissions	Potential Environmental Effects			
	Habitat Quantity	Habitat Quality	Habitat Use	Fish Mortality
Offshore Operations and Maintenance				
WBM- and SBM-associated Cuttings		x		x

Table 7-12 Environmental Effects Assessment: Operations and Maintenance

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
WBM- and SBM-associated Cuttings	• Change in Habitat Quality • Potential Mortality	• Re-use of drill mud • Discharge of only a portion of SBM-associated (cement) cuttings from Platform, reinjection of most SBM-associated cuttings • Chemical screening / management	1	2	5/2	R	2

[3] Please note that these updated CSR Tables are provided for this VEC only, for illustration, and given that the nature of the proposed Project modification is such that it and its potential effects are only relevant to Fish and Fish Habitat, as assessed and described in the other VEC sections that follow.

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context

KEY

Magnitude:
1 = Low: <10 percent of the or habitat in the will be affected
2 = Medium: 11 to 25 percent of the population or habitat in the will be affected
3 = High: >25 percent of the population or habitat in the will be affected

Geographic Extent:
1 = <1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = >10,000 km^2

Duration:
1 = < 1 month
2 = 1-12 months.
3 = 13-36 months
4 = 37-72 months
5 = >72 months

Frequency:
1 = <11 events/year population
2 = 11-50 events/year Study Area
3 = 51-100 events/year
4 = 101-200 events/year
5 = >200 events/year Study Area
6 = continuous

Reversibility: Study Area
R = Reversible
I = Irreversible

Ecological / Socio-economic Context:
1 = Area is relatively pristine or not adversely affected by human activity
2 = Evidence of adverse environmental effects

A Where there is more than one potential environmental effect, the evaluation criteria rating is assigned to the environmental effect with the greatest potential for harm

Table 7-16 Residual Environmental Effects Summary: Fish and Fish Habitat

Phase	Residual Adverse Environmental Effect Rating[A]	Level of Confidence	Probability of Occurrence (Likelihood)
Operation and Maintenance	NS	3	N/A
Cumulative Environmental Effects	NS	2	N/A

KEY

Residual Environmental Effects Rating:
S = Significant Adverse Environmental Effect
NS = Not Significant Adverse Environmental Effect

Level of Confidence in the Effect Rating:
1 = Low level of Confidence
2 = Medium Level of Confidence
3 = High level of Confidence

Probability of Occurrence of Significant Environmental Effect:
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

A As determined in consideration of established residual environmental effects rating criteria.
B Includes all Bull Arm activities, engineering, construction, removal of the bund wall, tow-out and installation of the Hebron Platform at the offshore site.
C Includes decommissioning and abandonment of the GBS and offshore site.
D Effect is not predicted to be significant, therefore the probability of occurrence rating is not required under CEAA

The fate of environmental discharges associated with operations at the Hebron production field will be monitored and evaluated through the Hebron Environmental Effects Monitoring (EEM) Plan (ECMP 2016). The EEM plan is designed to detect any changes in the receiving marine environment that may be associated with offshore drilling and other activities at the Hebron Program. This includes a comprehensive analytical suite of chemical, toxicity and biological assays for sediment, water and biota that has been curated over more than two decades of offshore EEM programs on the Grand Banks and are common to other production fields on the Grand Banks such as the Hibernia Platform, the Hibernia Southern Extension excavated drill centre, and the Terra Nova production field (DeBlois et al 2014b; HMDC 2015).

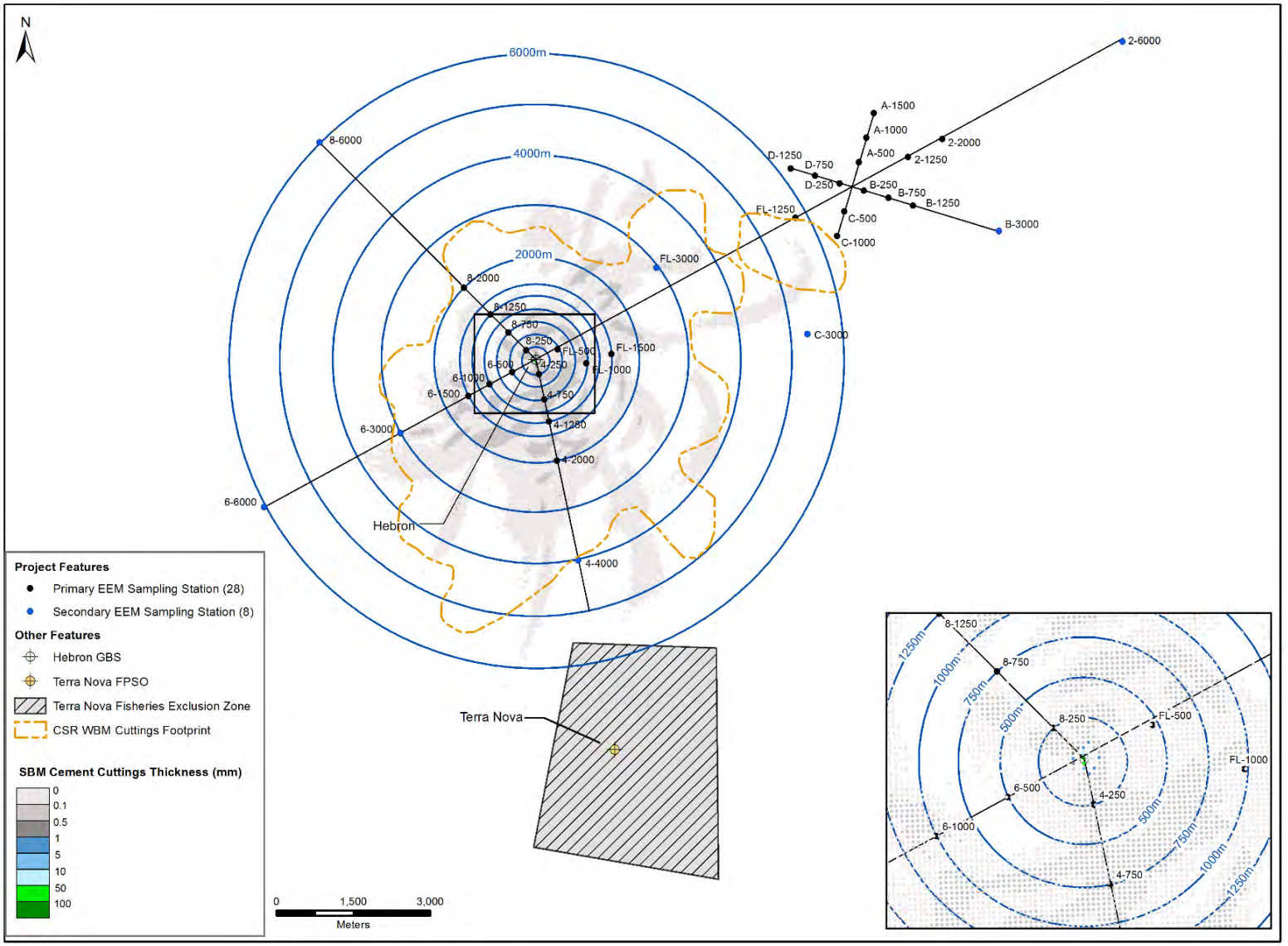
As illustrated in Figure 4-3, the EEM grid continues to effectively cover the predicted extent of cuttings deposition near the GBS. Benthic sediment samples will be collected from 28 primary stations within two km of the GBS (near-field) and eight secondary stations between two and six km from the Platform. Additional sediment samples are collected from two reference areas to the north and northeast of the Hebron field and concentrations of detected analytes are compared between each area, as well as comparing concentrations at various distances from the GBS.

The testing parameters for detecting chemical analytes are standardized and include analytical suites for the detection of hydrocarbons, PAHs, alkylated-PAHs, metals including weak-acid extractable barium, and carbon among others (EMCP 2016). Among these, the analytes associated with the detection of SBMs are $>C_{10}–C_{21}$ (fuel range) hydrocarbons and barium (Whiteway et al 2014), which are most likely to identify any potential SBM accumulation around the GBS. In addition, amphipod survival toxicity tests will be performed on all samples collected within 500 m of the GBS as well as for any stations with total petroleum hydrocarbon values in exceedance of the PetroTox calculated threshold. Water sampling will also be conducted around the GBS and at reference areas to measure the concentrations of suspended analytes (ECMP 2016).

In addition, the Hebron EEM Plan includes a biological survey to compare the abundance and condition of a commercial flatfish species, American plaice (*Hippoglossoides platessoides*), around the Hebron field as well as at a distant reference area. Fish tissue samples will also be analyzed for concentrations of metals, PAHs, and alkylated-PAHs in liver and tissue as well as bioassays including EROD, tissue histology and blood analysis. Taste testing is also performed on fillet samples.

Overall, if any changes occur beyond the predictions of the CSR the objective of the EEM program is to detect them and inform adaptive management procedures as required and relevant.

Figure 4-3 Cuttings Deposition Footprint with Hebron EEM Sampling Station Grid



4.3 Commercial Fisheries

The presence and operation of the Hebron Platform has the potential to interact with commercial fisheries in a number of ways, including through direct interference by making parts of the Project Area unavailable for fishing activities (through the associated safety zone), as well as potentially damaging fishing gear, vessels and equipment in the unlikely event of a direct interaction. The presence and operation of the Project may also lead to changes in the abundance, location and/or quality of marine resources due to the associated underwater noise, emissions, drill cuttings, etc, which may in turn affect their availability and use by commercial fishing enterprises. Any Project-related biophysical effects to fish or other marine resources could therefore result in a subsequent change in the nature, quality and/or value of one or more of the marine activities that utilize or depend upon them.

Potential effects on commercial fishing as a result of direct interference or potential gear damage due to the presence and conduct of Project activities in the offshore marine environment were fully assessed in the original CSR, and the potential for, and nature and degree of, these potential interactions will not increase or otherwise change as a result of the proposed modifications (partial SBM-associated cuttings release from the Platform) that are being assessed here.

As assessed and described in some detail in the preceding section (Fish and Fish Habitat), the proposed discharge of SBM-associated cuttings is not expected to result in different (and certainly, not significant) adverse effects upon marine fish or their habitats. Although these cuttings discharges have the potential to interact with marine biota, as discussed above, SBM toxicity is not a primary concern associated with drill cuttings discharge. Any disturbance to fish or their habitats due to cuttings deposition on the seabed will be localized and reversible, and well within the immediate vicinity of the Project itself, in an area that will not be subject to commercial fishing activity due to the presence of the surrounding safety zone referenced above.

It is therefore unlikely that marine resources will be affected in a manner and to a degree that would then translate into effects on the overall availability or quality of any marine resource, and thus, on the overall nature, intensity or value of commercial fishing activity in this region. The proposed modification to the Project (SBM cement cuttings disposal from the Platform) therefore does not change the results of the original environmental effects assessment for this VEC, and the Project is still not likely to result in significant adverse environmental effects on Commercial Fisheries.

As described above, the Hebron EEM Plan includes a commercial fish survey that will assess the abundance and condition of a commercial flatfish species, American plaice (*Hippoglossoides platessoides*), along with assessing the concentrations of metals, PAHs, and alkylated-PAHs in liver and tissue as well as bioassays including liver enzyme assays, tissue histology and blood analysis consistent, which are similar to the design of biological sampling program of the Terra Nova production field (DeBlois et al 2014).

4.4 Marine Birds (Including Species at Risk)

There are no anticipated direct interactions between marine birds and the currently planned discharge of SBM cement cuttings from the Hebron Platform. Most of the avifauna species present in the region feed at or near the water's surface, and are therefore unlikely to interact with any such release of SBM cement cuttings. Discharging these SBM-associated drill cuttings at depth further mitigates the potential for marine and migratory birds to come into contact with any residual chemical components of SBM

retained on the discharged cuttings. Thick-billed Murres (*Uria lomvia*), the deepest-diving seabirds found in the Project Area, may forage to depths of 50 - 70 m, although they may reach a maximum depth of 200 m (Gaston and Hipfner 2000). With appropriate screening and selection of chemicals (including use of non-toxic drilling fluids), and the above described treatment and disposal of drill muds and cuttings, effects on birds (either directly, or through effects on the availability or quality of their food sources) will not occur.

The proposed modification to the Project (SBM cement cuttings disposal from the Platform) therefore does not change the results of the original environmental effects assessment for this VEC, and the Project is still not likely to result in significant adverse environmental effects on Marine Birds.

4.5 Marine Mammals and Sea Turtles (Including Species at Risk)

The primary potential environmental interactions between marine mammals and sea turtles and offshore drilling and associated marine discharges relate to possible changes in health (contaminants). Adverse effects of marine discharges on the health of marine fish may have secondary effects on the quality of marine mammal and sea turtle prey. With the implementation of mitigation measures (as identified and committed to in the CSR) the planned discharge of some SBM-associated drill cuttings from the Hebron Platform are not expected to result in a change in health conditions for marine mammals and sea turtles.

Although treated marine discharges can result in a localized and temporary reductions in water and sediment quality, muds and cuttings are unlikely to introduce heavy metals in concentrations that are harmful to marine mammals (Neff et al 1980, cited in Hinwood et al 1994). These discharges are therefore expected to have little or no environmental effect on marine mammals and sea turtles, including consideration of potential effects on prey species (see Section 4.3). None of the marine mammals that regularly occur in or near the Project Area are known to feed on benthos in the area. The likely avoidance of the area immediately surrounding the Platform by some species due to Project related noise and other disturbances will likely further reduce the potential for direct or indirect interactions between drill cuttings discharges and the various species that comprise this VEC.

As described in Section 3.5, a review of recent data indicates that the offshore Project Area is not known or likely to be used by species that were not considered and addressed in the original CSR, nor have any new areas of particularly important or sensitive habitats been identified that overlap with the Project Area. The modified Project activities considered in this EA Amendment are therefore not expected to increase the potential for, or degree of, environmental interactions and effects. This includes no new (not previously considered) interactions, and no closer proximity of planned Project activities to identified important areas and times for these species off Eastern Newfoundland.

The proposed modification to the Project (SBM cement cuttings disposal from the Platform) therefore does not change the results of the original environmental effects assessment for this VEC, and the Project is still not likely to result in significant adverse environmental effects on Marine Mammals and Sea Turtles.

4.6 Sensitive or Special Areas

Environmental interactions between offshore oil and gas activities and identified sensitive and special areas may be both direct and indirect in nature and cause. The conduct of such activities directly within or near such areas may, for example, have adverse implications for these locations and their important and defining ecological and socio-cultural characteristics. These interactions may occur through the possible presence of oil and gas production equipment, personnel and activities in the area, as well as the associated routine emissions and resulting disturbances that may occur in nearby environments. Biophysical effects resulting from oil and gas or other human activities within the region may also "spread" to adjacent protected and otherwise important and sensitive areas by affecting the marine fish, birds, mammals or other environmental components that move to and through the area. Any resulting decrease in the real or perceived integrity of these areas in the short or long term may also affect their ecological and/or societal importance and value.

A description (and mapping) of marine areas off Eastern Newfoundland that have been designated as protected or identified as otherwise special or sensitive was provided in Section 3.7. The existing and available information indicates that the Project Area is located 50 km or more from any of these areas, and they will therefore not be subject to direct overlap or interaction with the Project in general, nor the currently planned discharge of SBM cement cuttings from the Platform in particular. The very small and localized environmental zone of influence of these cuttings discharges will mean that their effects will not extend to or otherwise affect these areas, and the implementation of the various environmental protection measures and procedures outlined in the CSR and in this EA Amendment including those designed to avoid or reduce Project-related discharges and/or disturbances and their associated environmental changes and resulting effects, will also serve to help address any direct or indirect potential environmental effects that may have implications for overlapping or adjacent Special Areas. The Project will therefore not adversely affect the ecological features, processes and integrity of any marine or coastal locations that are designated as special or sensitive areas, nor their human use and societal value.

The proposed modification to the Project (SBM cement cuttings disposal from the Platform) therefore does not change the results of the original environmental effects assessment for this VEC, and the Project is still not likely to result in significant adverse environmental effects on Sensitive or Special Areas.

5.0 SUMMARY AND CONCLUSION

The Hebron Project was subject to a detailed and comprehensive EA review pursuant to the requirements of the *Canadian Environmental Assessment Act* (CEAA) and is currently under development, with first oil planned for later in 2017.

This EA Amendment describes and assesses a proposed modification to the Project as compared to that which was assessed, approved and implemented pursuant to the original EA review and approval process. This planned modification relates to the current requirement to dispose of a discreet portion of SBM-associated drill cuttings from the Hebron Platform into the marine environment, as opposed to complete reinjection of these cuttings as was described and assessed in the original CSR. Specifically, EMCP is seeking regulatory approval to discharge SBM cement cuttings that are generated while drilling out the (340 mm and 244 mm well depth) shoe tracks for all Hebron wells drilled from the Platform.

The primary environmental considerations related to this activity include sediment deposition and seabed disturbance (smothering habitat through cuttings deposition), as well as chemical toxicity and potential bioaccumulation issues (uptake of contaminants by marine biota). Although various marine species are or may be located within the area of planned SBM cement cuttings deposition from the Hebron Platform, it is not anticipated that this will have adverse effects due to the limited quantity and duration of these planned releases, the non-toxic nature of the materials involved, and the low potential for interaction.

The main potential effects of SBMs are associated with the disposal of drill wastes on the seabed, leading to the possible alteration of marine habitats and creation of anoxic environments. Previous studies and monitoring programs have shown that the nature and magnitude of these effects on benthic invertebrates and their habitats are linked to the thickness and extent of the associated cuttings pile that may accumulate on the seabed following discharge. To provide additional, Project-specific information and analysis related to the nature and extent of the planned SBM cement cuttings disposition resulting from the Project modification, the previous (WBM-associated cuttings only) drill cuttings dispersion modelling carried out for the CSR was revisited based on this Project amendment. The results of this modelling indicate that the majority of discharged SBM cement cuttings will settle within the original WBM-associated cuttings footprint identified and assessed in the CSR and have comparatively much lower levels of sediment deposition. Furthermore, in disaggregate and clumping scenarios, SBM cement cuttings accumulation (between 0.05-50 cm thickness) are limited to within 600 m of the Platform. The small areas where SBM cement cuttings settle outside the WBM-associated cuttings footprint will have negligible levels of SBM-associated cuttings accumulation (less than 0.1 mm thickness).

The proposed Project modifications described and assessed herein do not result in any changes in the original environmental effects predictions, required mitigation or effects significance evaluations for any component of the environment. The amended Project is therefore not likely to result in significant adverse environmental effects.

6.0 REFERENCES

Amec Environment and Infrastructure (2010). Drill Cuttings Deposition, Produced Water, and Storage Displacement Water Dispersion Modelling for the Hebron Project. Prepared for Stantec Consulting Ltd., St. John's, Prepared by Amec Earth & Environmental, St. John's. September 2010.

Amec Environment and Infrastructure (2014). Eastern Newfoundland Strategic Environmental Assessment. Prepared for Canada-Newfoundland and Labrador Offshore Petroleum Board

Baillon, S., Hamel, J.-F., and A. Mercier (2014). Diversity, distribution and nature of faunal associations with deep-sea pennatulacean corals in the Northwest Atlantic. PloS one, 9(11): e111519.

Baker, K.D., Haedrich, R.L., Snelgrove, P.V.R., Wareham, V.E., Edinger, E.N. and K.D. Gilkison (2012). Small-scale patterns of deep-sea fish distributions and assemblages of the Grand Banks, Newfoundland continental slope. Deep Sea Research Part I: Oceanographic Research Papers. 65:171-188.

Bakhtyar, S. and M.M. Gagnon (2012). Toxicity assessment of individual ingredients of synthetic-based drilling muds (SBMs). Environmental Monitoring and Assessment, 184(9), 5311–5325. https://doi.org/10.1007/s10661-011-2342-x

Barrio Froján, C.R., MacIsaac, K.G., McMillan, A.K., del Mar Sacau Cuadrado, M., Large, P.A., Kenny, A.J., Kenchington, E. and E. de Cárdenas González (2012). An evaluation of benthic community structure in and around the Sackville Spur closed area (Northwest Atlantic) in relation to the protection of vulnerable marine ecosystems. ICES Journal of Marine Science: Journal du Conseil, 69(2): 213-222.

Beazley, L.I., Kenchington, E.L., Murillo, F.J. and M. del Mar Sacau (2013). Deep-sea sponge grounds enhance diversity and abundance of epibenthic megafauna in the Northwest Atlantic. ICES Journal of Marine Science: Journal du Conseil, 70(7): 1471-1490.

Campbell, J.S. and J.M. Simms (2009). Status Report on Coral and Sponge Conservation in Canada. St. John's, NL: Fisheries and Oceans Canada.

CAPP (Canadian Association of Petroleum Producers). (2001). Offshore Drilling Waste Management Review. Technical Report 2001–0007. CAPP, St. John's, NL. 289 pp.

COOGER (Centre for Offshore Oil, Gas and Energy Research) and K. Lee (2009). Environmental Persistence of Drilling Mud and Fluid Discharges and Potential Impacts. Environmental Studies Research Funds Report No. 176, NE22-4/176(December), 1–35.

DeBlois, E. M., Paine, M. D., Kilgour, B. W., Tracy, E., Crowley, R. D., Williams, U. P. and G.G. Janes (2014a). Alterations in bottom sediment physical and chemical characteristics at the Terra Nova offshore oil development over ten years of drilling on the grand banks of Newfoundland, Canada. Deep-Sea Research Part II: Topical Studies in Oceanography, 110(March 2016), 13–25. https://doi.org/10.1016/j.dsr2.2014.10.013

DeBlois, E.M., Tracy, E., Janes, G.G., Crowley, R.D., Wells, T.A., Williams, U.P., Paine, M.D., Mathieu, A. and B.W. Kilgour (2014b). Environmental effects monitoring at the Terra Nova offshore oil development (Newfoundland, Canada): Program design and overview. Deep Sea Research Part II: Topical Studies in Oceanography, 110, 4–12. https://doi.org/10.1016/j.dsr2.2014.10.012

DFO (Fisheries and Oceans Canada) (2013). Identification of Additional Ecologically and Biologically Significant Areas (EBSAs) within the Newfoundland and Labrador Shelves Bioregion. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/048.

DFO (Fisheries and Oceans Canada). (2015). Coral and sponge conservation strategy for Eastern Canada 2015.

EMCP (ExxonMobil Canada Properties). (2016). Hebron Offshore Environmental Effects Monitoring (EEM) Plan. EMCP Document CAHE-EC-OOREF-01-006-5010-000. 68 pp.

Edinger, E. N., Wareham, V. E. and R.L. Haedrich (2007). Patterns of groundfish diversity and abundance in relation to deep-sea coral distributions in Newfoundland and Labrador waters. Bulletin of Marine Science, 81(3): 101-122.

Ellis, J.I., Fraser, G. and J. Russell (2012). Discharged drilling waste from oil and gas platforms and its effects on benthic communities. Marine Ecology Progress Series, 456: 285-302.

Environment Canada (1998). Reference methods for determining acute lethality of sediment to marine or estuarine amphipods. Report EPS 1/RM/35. Environment Canada, Ottawa, Ontario.

Environment Canada (2002). Biological test Method: Reference Method for Determining the Toxicity of Sediment Using Luminescent Bacteria in a Solid-Phase Test. Report EPS 1/RM/42. Environment Canada, Ottawa, Ontario.

FAO (Food and Agriculture Organization of the United Nations) (2016). Vulnerable Marine Ecosystems Database. Retrieved November 28, 2016 from http://www.fao.org/in-action/vulnerable-marine-ecosystems/vme-database/en/.

Gagnon, M.M. and S. Bakhtyar (2013). Induction of Fish Biomarkers by Synthetic-Based Drilling Muds. PLoS ONE, 8(7). https://doi.org/10.1371/journal.pone.0069489

Gaston, A.J. and J.M. Hipfner. (2000). Thick-billed Murre (Uria lomvia), The Birds of North America (P. G. Rodewald, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America: https://birdsna.org/Species-Account/bna/species/thbmur

Gates, A.R. and D.O. Jones (2012). Recovery of benthic megafauna from anthropogenic disturbance at a hydrocarbon drilling well (380 m depth in the Norwegian Sea). PloS one, 7(10): e44114.

Getliff, J., Roach, A., Toyo, J. and J. Carpenter (1997). An overview of the environmental benefits of LAO based drilling fluids for offshore drilling. Report from Schlumberger Dowell.

Guijarro, J., Beazley, L., Lirette, C., Kenchington, E., Wareham, V., Gilkinson, K., Koen-Alonso, M. and F.J. Murillo (2016). Species distribution modelling of corals and sponges from research vessel survey data in the Newfoundland and Labrador region for use in the identification of significant benthic areas. Canadian technical Report for Fisheries and Aquatic Sciences. 3171: vi + 126p.

Halliburton (2017). Materials, Chemicals and Additives. Available from: http://www.halliburton.com/en-US/ps/cementing/materials-chemicals-and-additives.page?node-id=hfqelabf.

Hinwood, J.B., A.E. Potts, L.R. Dennis, J.M. Carey, H. Houridis, R.J. Bell, J.R. Thomson, P. Boudreau and A.M. Ayling (1994). Drilling activities. Pp. 123-207. In: J.M. Swan, J.M. Neff and P.C. Young (eds.). Environmental Implications of Offshore Oil and Gas Development in Australia -

the Findings of an Independent Scientific Review, Australian Petroleum Exploration Society, Sydney, Australia. xiv + 696 pp.

HMDC. (2015). Hibernia Management and Development Corporation. Hibernia Produciton Phase Environmental Effects Monitoring Program - Year Nine (2014) Volume I - Interpretation.

Holdway, D. A. (2002). The acute and chronic effects of wastes associated with offshore oil and gas production on temperate and tropical marine ecological processes. Marine Pollution Bulletin, 44(3), 185–203. https://doi.org/10.1016/S0025-326X(01)00197-7

Jones, D.O., Wigham, B.D., Hudson, I.R. and B.J. Bett (2007). Anthropogenic disturbance of deep-sea megabenthic assemblages: a study with remotely operated vehicles in the Faroe-Shetland Channel, NE Atlantic. Marine Biology, 151(5): 1731-1741.

Kjeilen-Eilertsen, G., Trannum, H., Jar, R., Smit, M., Neff, J. and G Durell (2004). Literature report on burial: derivation of PNEC as component in the MEMW model tool. Report AM, 24.

Larsson, A.I., van Oevelen, D., Purser, A. and L. Thomsen (2013). Tolerance to long-term exposure of suspended benthic sediments and drill cuttings in the cold-water coral Lophelia pertusa. Marine pollution bulletin, 70(1): 176-188.

Li, Z., Robinson, B., Ma, X., Cobanli, S. and K. Lee (2009). Biodegradation of Synthetic Drilling Mud in Marine Sediments. Proceedings of the 10th International In Situ and On-Site Bioremediation Symposium, (January).

Mathieu, A., Hanlon, J., Myers, M., Melvin, W., French, B., DeBlois, E.M., King, T., Lee, K., Williams, U.P., Wight, F.M. and G. Janes (2011). Studies on Fish Health Around the Terra Nova Oil Development Site on the Grand Banks Before and After Discharge of Produced Water. In Produced Water (pp. 375-399). Springer New York.

Mullowney, D (2017). Aquatic Science Biologist, Fisheries and Oceans Canada. Personal communication. February 10, 2017

Murillo, F. J., Muñoz, P. D., Altuna, A. and A. Serrano (2011). Distribution of deep-water corals of the Flemish Cap, Flemish Pass, and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): interaction with fishing activities. ICES Journal of Marine Science: Journal du Conseil, 68(2): 319-332.

Murillo, F. J., Muñoz, P. D., Cristobo, J., Ríos, P., González, C., Kenchington, E. and A. Serrano (2012). Deep-sea sponge grounds of the Flemish Cap, Flemish Pass and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): distribution and species composition. Marine Biology Research, 8(9): 842-854.

Murillo, F.J., Serrano, A., Kenchington, E. and J. Mora (2016). Epibenthic assemblages of the Tail of the Grand Bank and Flemish Cap (northwest Atlantic) in relation to environmental parameters and trawling intensity. Deep Sea Research Part I: Oceanographic Research Papers. 109: 99-122.

NAFO (Northwest Atlantic Fisheries Organization) (2017). Statlant 21A Database. https://www.nafo.int/Data/Catch-Statistics. Accessed 19 January 2017.

Neff, J.M. (2008). Estimation of bioavailability of metals from drilling mud barite. Integrated Environmental Assessment and Management, 4(2), 184–193. https://doi.org/10.1897/IEAM_2007-037

Neff, J. M., McKelvie, S. and Ayers, R.C.J. (2000). Environmental Impacts of Synthetic Based Drilling Fluids. U.S. Department of the Interior Minerals Management Service, 141.

Netto, S.A., Gallucci, F. and G. Fonseca (2009). Deep-sea meiofauna response to synthetic-based drilling mud discharge off SE Brazil. Deep Sea Research Part II: Topical Studies in Oceanography, 56(1): 41-49.

OGP (International Association of Oil and Gas Producers) (2003). Environmental aspects of the use and disposal of non aqueous drilling fluids associated with offshore oil & gas operations. Report No. 342. 105.

OGP (International Association of Oil and Gas Producers) (2016). Environmental fates and effects of ocean discharge of drill cuttings and associated drilling fluids from offshore oil and gas operations. International Association of Oil & Gas Producers. Report 543. March 2016.

Parks Canada (2017). Canada's National Marine Conservation Areas System Plan. http://www.pc.gc.ca.

Petro Canada 2015. Material Safety Data Sheet PuredrillTM/MC IA-35LV Version 3.0. Available online: http://www.online.petro-canada.ca/datasheets/en_CA/iaf35lv.pdf

Peralba, M.D.C.R., Pozebon, D., Dos Santos, J.H.Z., Maia, S.M., Pizzolato, T.M., Cioccari, G. and S. Barrionuevo (2010). Metal and hydrocarbon behavior in sediments from Brazilian shallow waters drilling activities using nonaqueous drilling fluids (NAFs). Environmental Monitoring and Assessment, 167(1–4), 33–47. https://doi.org/10.1007/s10661-010-1516-2

Pollet, I.L., Ronconi, R.A., Jonsen, I., Leonard, M.L., Taylor, P.D. and Shutler, D. (2014). Foraging movements of Leach's storm-petrels Oceanodroma leucorhoa during incubation. J. Avian Biol. 45(4): 305-314.

Redman, A. D. and T.F. Parkerton (2015). Guidance for improving comparability and relevance of oil toxicity tests. Marine Pollution Bulletin, 98(1–2), 156–170. https://doi.org/10.1016/j.marpolbul.2015.06.053

Redman, A. D., Parkerton, T. F., Comber, M. H., Paumen, M. L., Eadsforth, C. V., Dmytrasz, B., King D, Warren CS, den Haan K, and N. Djemel (2014). PETRORISK: A risk assessment framework for petroleum substances. Integrated Environmental Assessment and Management, 10(3), 437–448. https://doi.org/10.1002/ieam.1536

Redman, A. D., Parkerton, T. F., Leon Paumen, M., Butler, J. D., Letinski, D. J. and K den Haan (2017). A re-evaluation of PETROTOX for predicting acute and chronic toxicity of petroleum substances. Environmental Toxicology and Chemistry, 9999(9999), 1–8. https://doi.org/10.1002/etc.3744

Redman, A. D., Parkerton, T. F., Letinski, D. J., Manning, R. G., Adams, J. E. and P.V. Hodson (2014). Evaluating toxicity of heavy fuel oil fractions using complementary modeling and biomimetic extraction methods. Environmental Toxicology and Chemistry, 33(9), 2094–2104. https://doi.org/10.1002/etc.2659

Schaanning, M.T., Trannum, H.C., Øxnevad, S., Carroll, J. and T. Bakke (2008). Effects of drill cuttings on biogeochemical fluxes and macrobenthos of marine sediments. Journal of Experimental Marine Biology and Ecology, 361(1): 49-57.

Schlumberger Oilfield Services (2017). Oilfield Glossary - "Shoe Track". http://www.glossary.oilfield.slb.com/Terms/s/shoe_track.aspx

Schneider, D.C., Gagnon, J.M. and K.D. Gilkinson (1987). Patchiness of epibenthic megafauna on the outer Grand Banks of Newfoundland. Marine ecology progress series. Oldendorf, 39(1): 1-13.

Scholten, M.C.T., Karman, C.C., and Huwer, S. (2000). Ecotoxicological risk assessment related to chemicals and pollutants in off-shore oil production. Toxicology Letters 112, 283-288.

Smit, M.G.D., Holthaus, K.I.E., Tamis, J.E., Jak, R.G., Kjeilen-Eilertsen, G., Trannum, H. and C.C Karman (2006). Threshold levels and risk functions for non-toxic sediment stressors: Burial, grain size change and hypoxia—Summary report. ERMS report, 9.

Stantec Consulting Ltd. (2011). Hebron Project: Comprehensive Study Report. Report prepared for ExxonMobil Canada Properties, St. John's, NL.

Stantec Consulting Ltd. (2013). Development of a Marine Sediment Quality Guideline for Puredrill IA-35. Prepared for Hibernia Management and Development Company Limited, St. John's, NL. ii + 15 pp.

Templeman, N.D. (2007). Placentia Bay-Grand Banks Large Ocean Management Area Ecologically and Biologically Significant Areas. DFO Canadian Science Advisory Secretariat Research Document 2007/052.

Thombare, N., Jha, U., Mishra, S. and M.Z Siddiqui (2016). Guar gum as a promising starting material for diverse applications: A review. International Journal of Biological Macromolecules, 88, 361–372. https://doi.org/10.1016/j.ijbiomac.2016.04.001

Trefry, J. H., Dunton, K. H., Trocine, R. P., Schonberg, S. V., McTigue, N. D., Hersh, E. S. and T.J. McDonald (2013). Chemical and biological assessment of two offshore drilling sites in the Alaskan Arctic. Marine Environmental Research, 86 (April 2016), 35–45. https://doi.org/10.1016/j.marenvres.2013.02.008

Van Der Oost, R., Beyer, J. and N.P.E. Vermeulen (2003). Fish bioaccumulation and biomarkers in environmental risk assessment: a review. Environmental Toxicology and Pharmacology, 13, 57–149. Retrieved from www.elsevier.com/locate/etap

Wareham, V.E. (2009). Updates on deep-sea coral distributions in the Newfoundland and Labrador and Arctic Regions, Northwest Atlantic. The ecology of deep-sea corals of Newfoundland and Labrador waters: biogeography, life history, biogeochemistry, and relation to fishes. Canadian Technical Report on Fisheries and Aquatic Sciences, 2830: 4-22.

Whiteway, S. A., Paine, M. D., Wells, T. A., DeBlois, E. M., Kilgour, B. W., Tracy, E., Crowley, R.D., Williams, U.P. and G.G. Janes (2014). Toxicity assessment in marine sediment for the Terra Nova environmental effects monitoring program (1997–2010). Deep Sea Research Part II: Topical Studies in Oceanography, 110, 26–37. https://doi.org/10.1016/j.dsr2.2014.10.014

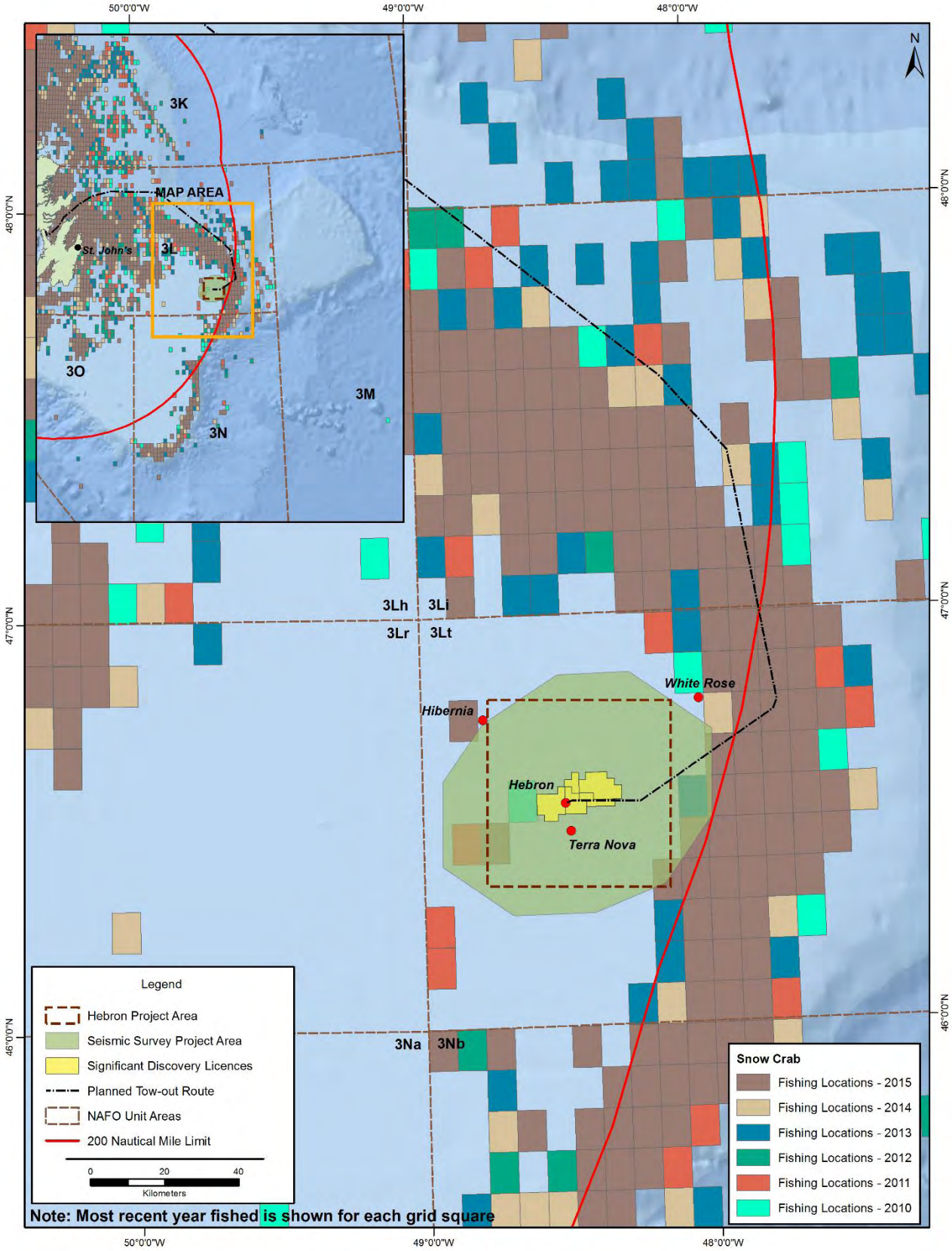
.

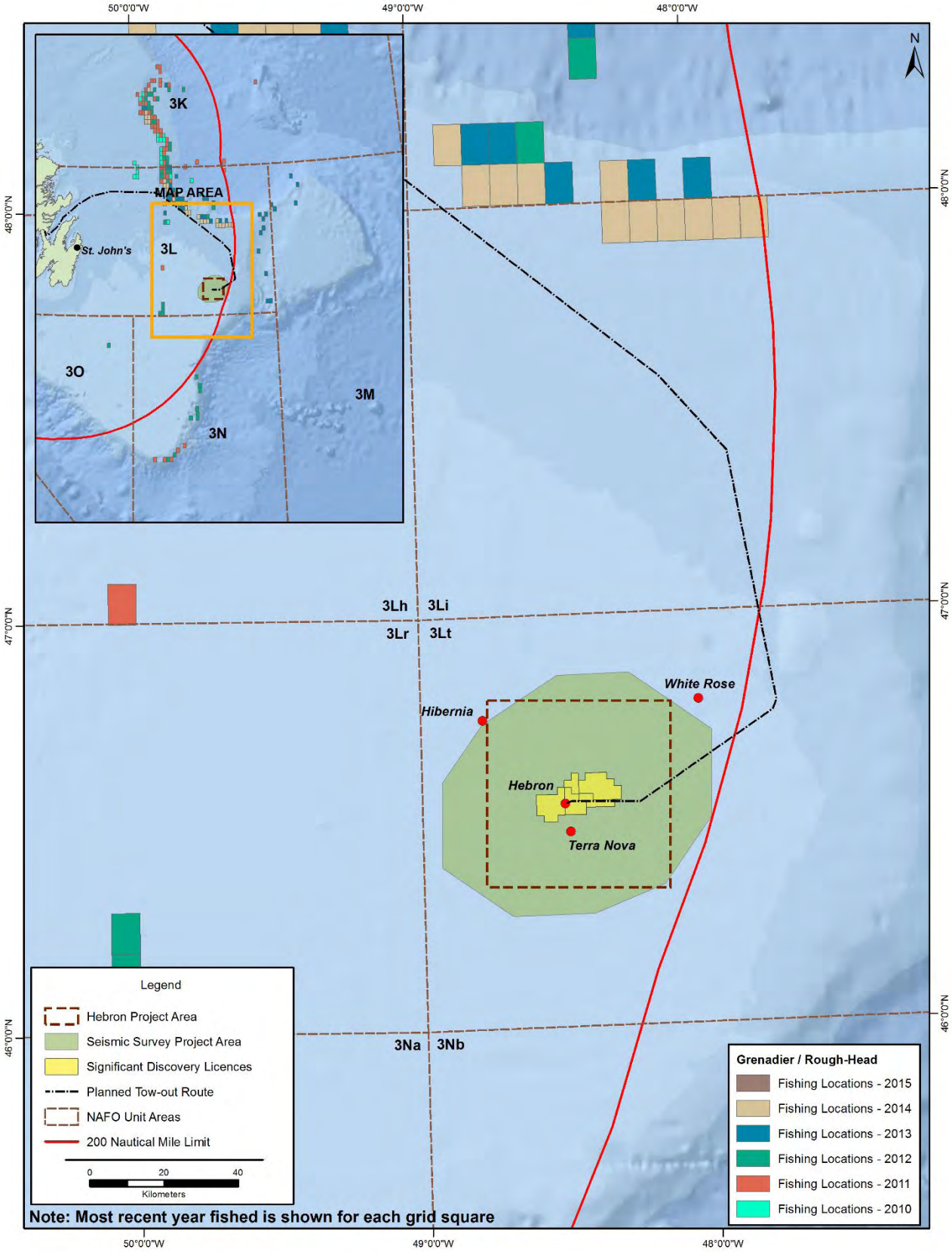
.

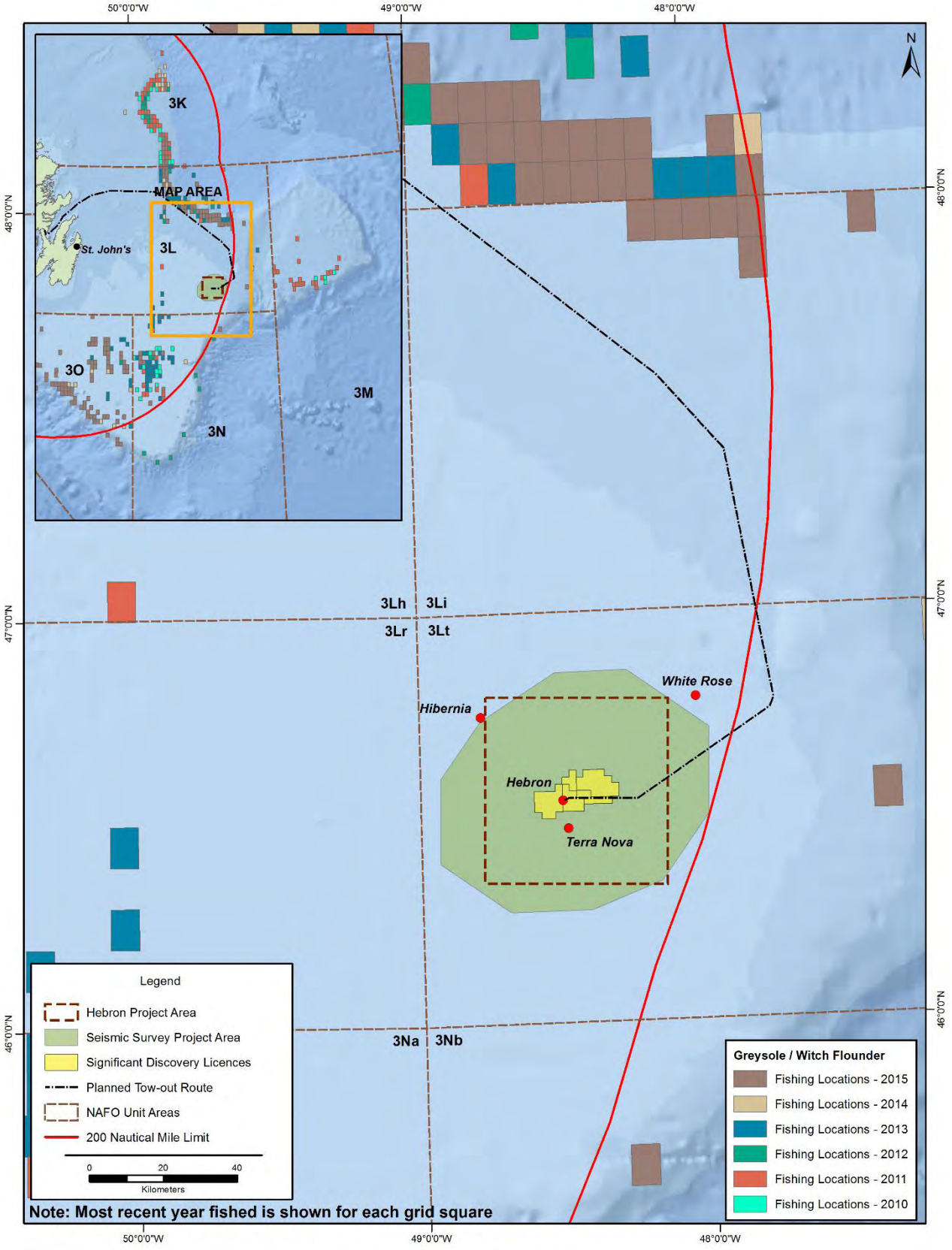
APPENDIX A

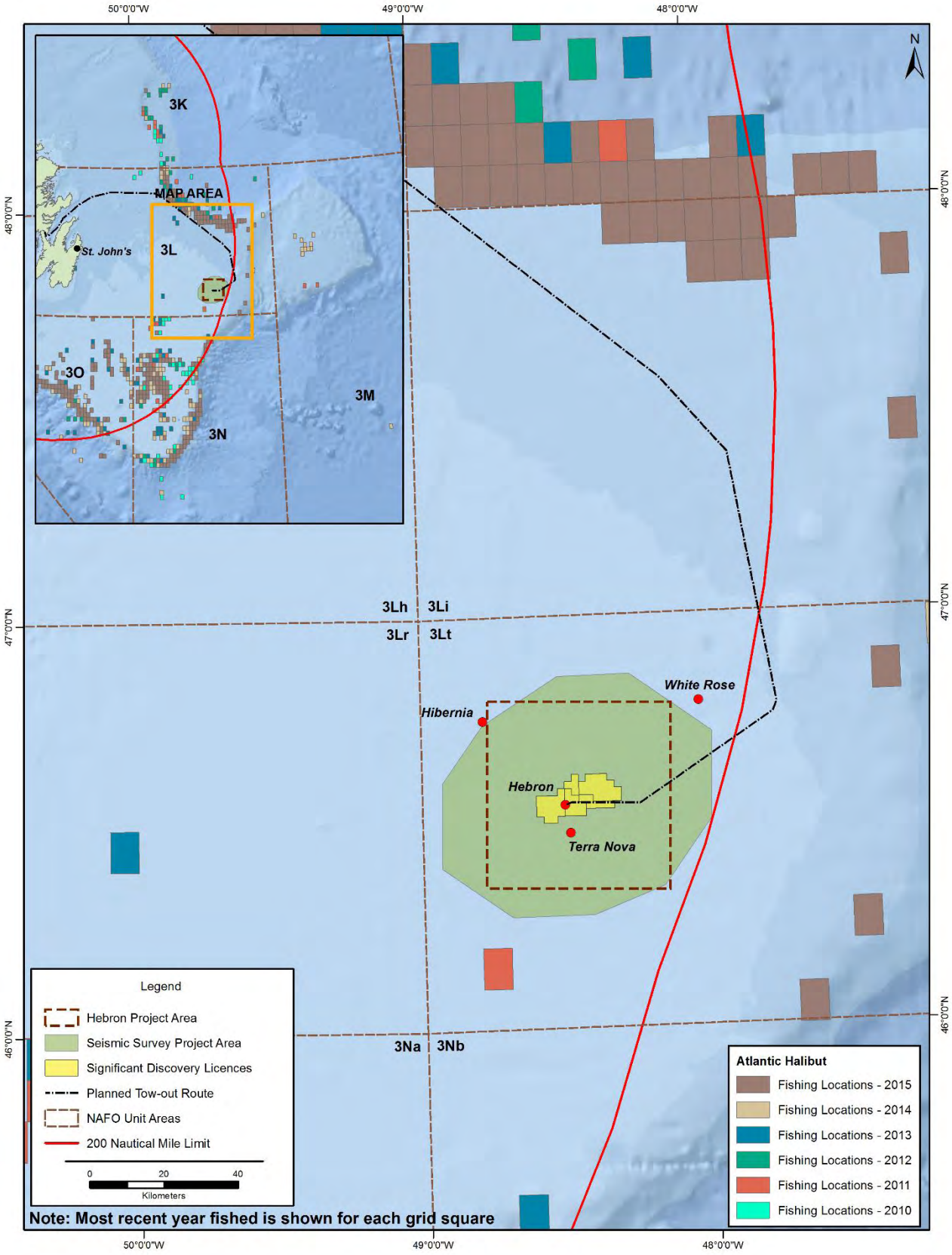
Additional Mapping

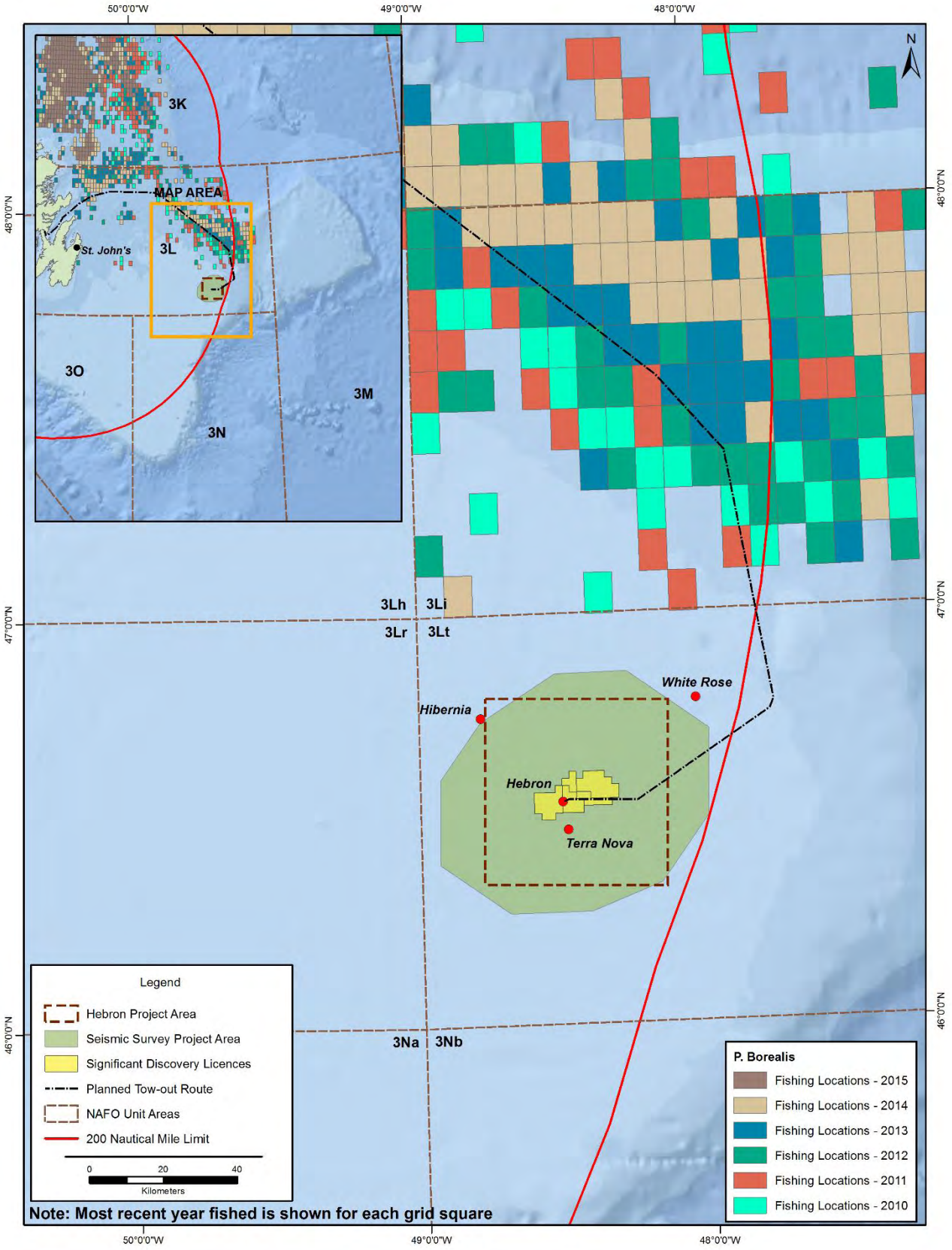
Fisheries (By Key Species) and Marine Mammals and Sea Turtles

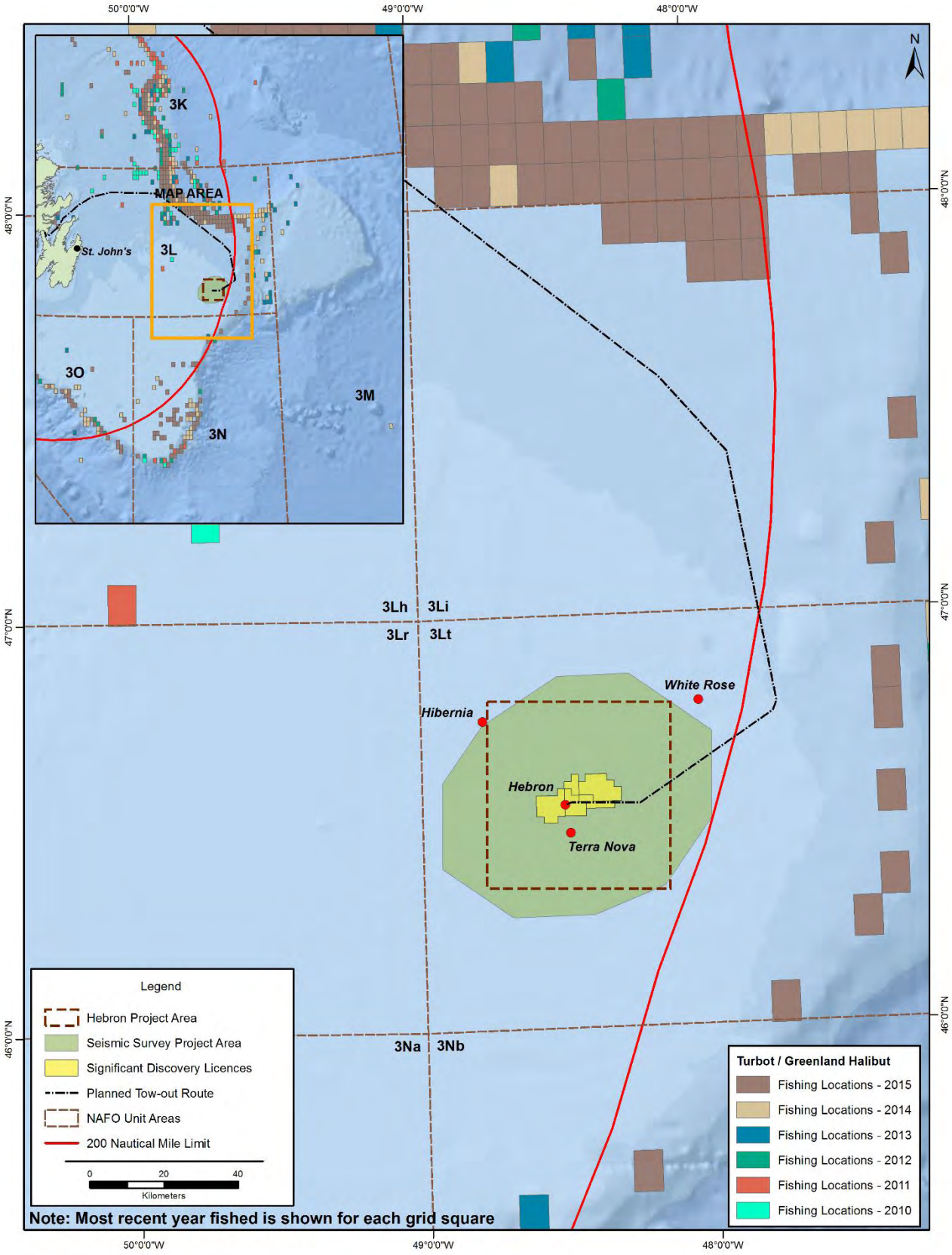

50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
3K
MAP AREA
St. John's
3L
3O
3M
3N
3Lh
3Li
3Lr
3Lt
White Rose
Hibernia
Hebron
Terra Nova
3Na
3Nb
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
NAFO Unit Areas
200 Nautical Mile Limit
0
20
40
Kilometers
Snow Crab
Fishing Locations - 2015
Fishing Locations - 2014
Fishing Locations - 2013
Fishing Locations - 2012
Fishing Locations - 2011
Fishing Locations - 2010
Note: Most recent year fished is shown for each grid square

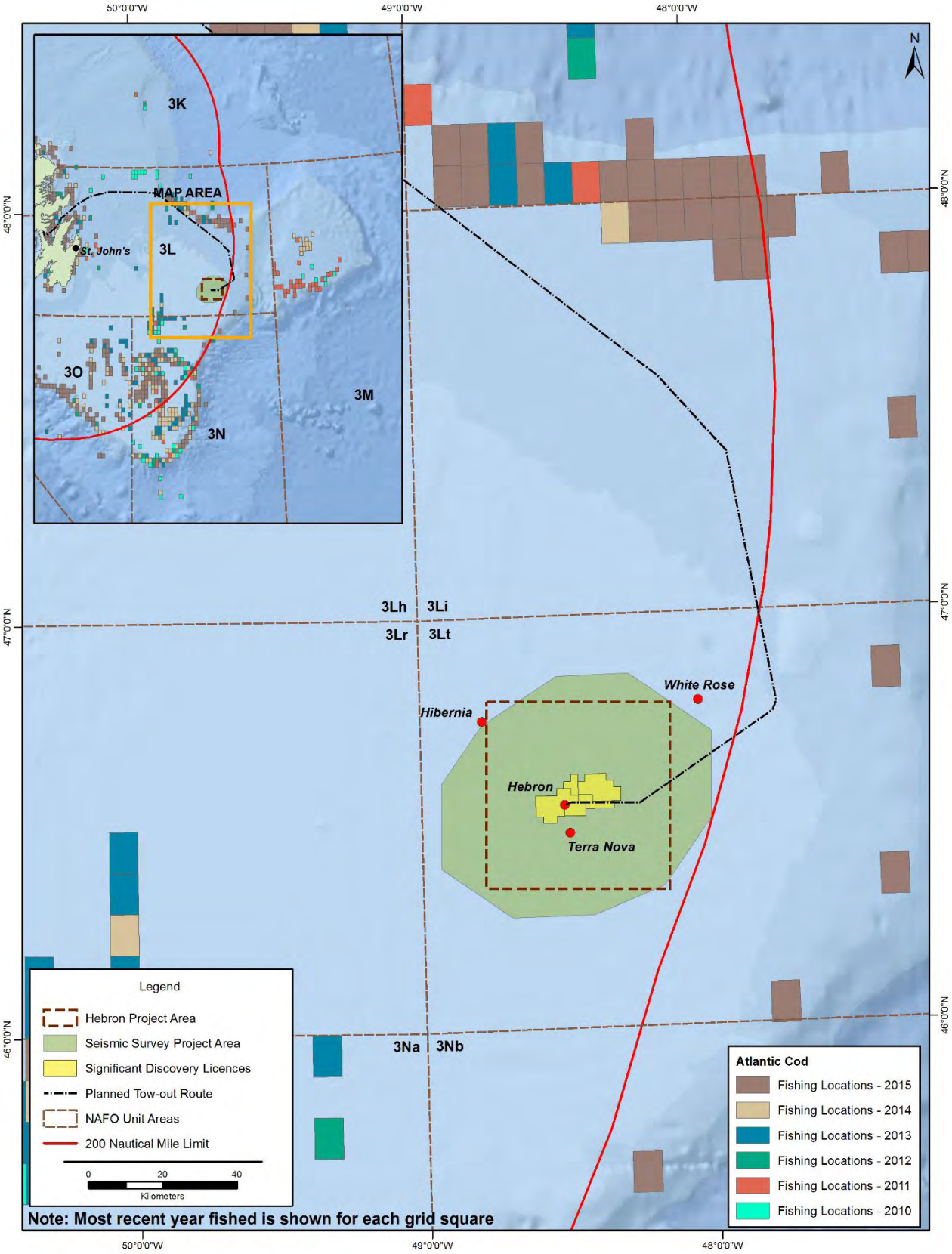

50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
3K
MAP AREA
St. John's
3L
3O
3M
3N
3Lh
3Li
3Lr
3Lt
White Rose
Hibernia
Hebron
Terra Nova
3Na
3Nb
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
NAFO Unit Areas
200 Nautical Mile Limit
0
20
40
Kilometers
Grenadier / Rough-Head
Fishing Locations - 2015
Fishing Locations - 2014
Fishing Locations - 2013
Fishing Locations - 2012
Fishing Locations - 2011
Fishing Locations - 2010
Note: Most recent year fished is shown for each grid square

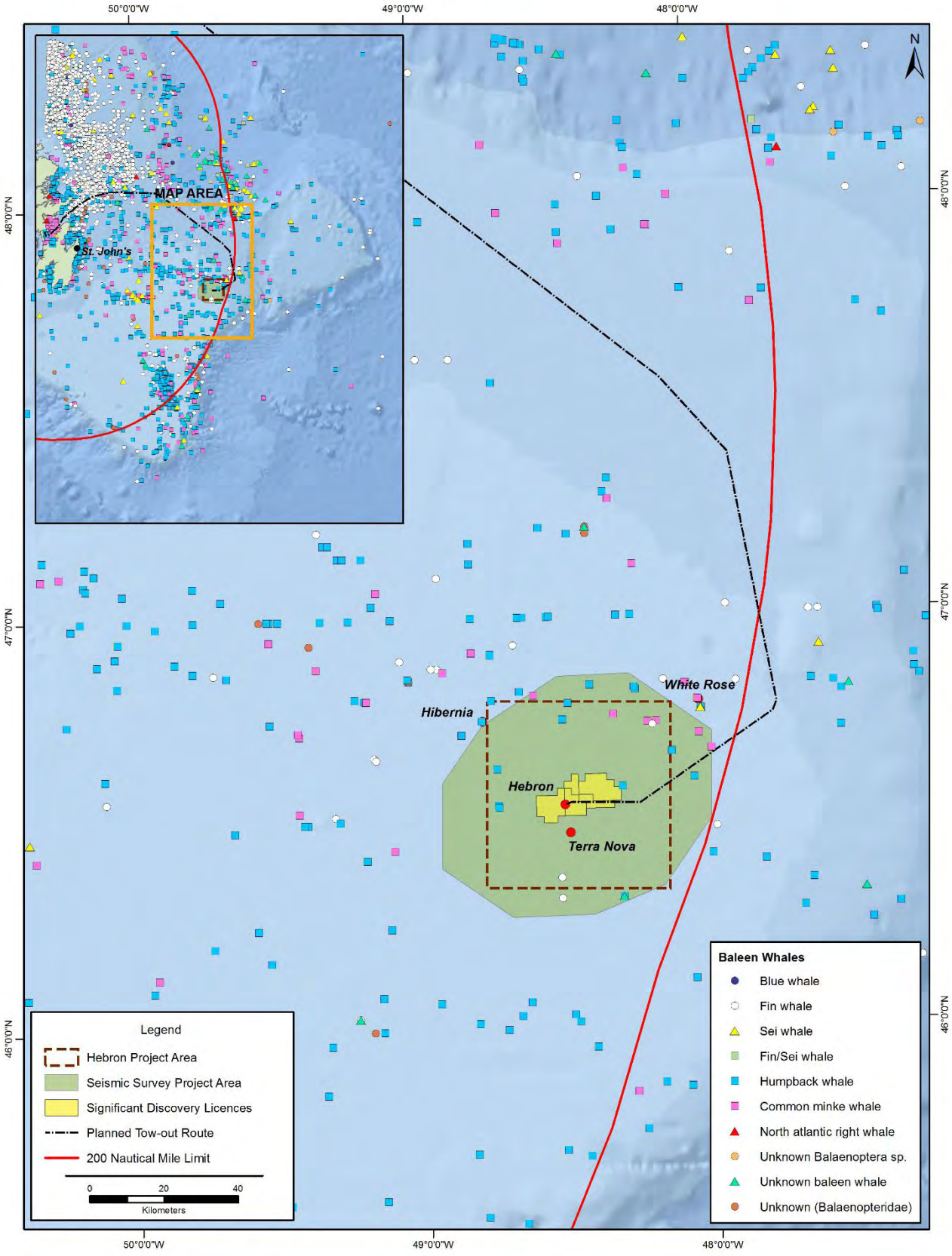

50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
3K
MAP AREA
St. John's
3L
3O
3M
3N
3Lh
3Li
3Lr
3Lt
White Rose
Hibernia
Hebron
Terra Nova
3Na
3Nb
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
NAFO Unit Areas
200 Nautical Mile Limit
0
20
40
Kilometers
Greysole / Witch Flounder
Fishing Locations - 2015
Fishing Locations - 2014
Fishing Locations - 2013
Fishing Locations - 2012
Fishing Locations - 2011
Fishing Locations - 2010
Note: Most recent year fished is shown for each grid square

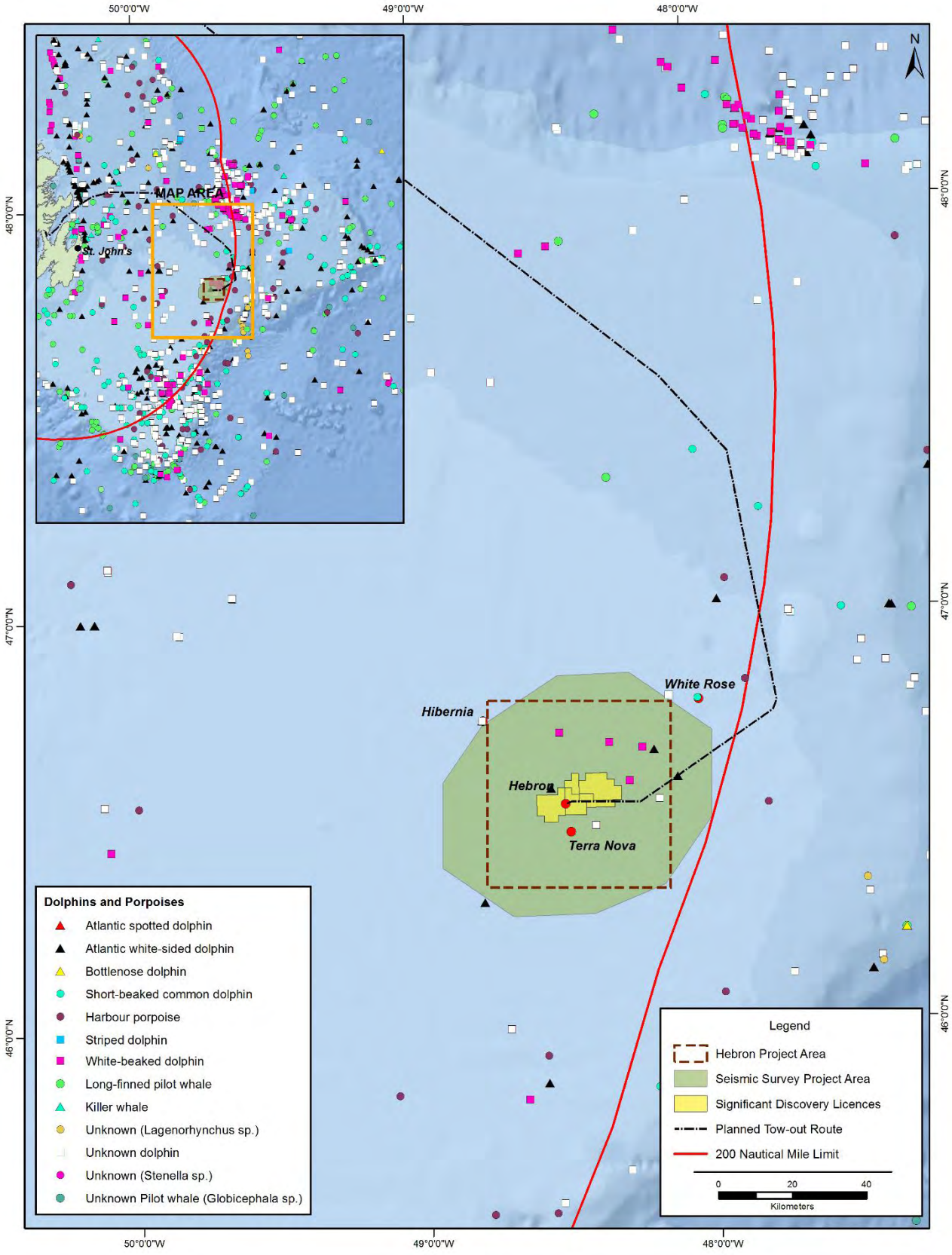

50°0'0"W
49°0'0"W
48°0'0"W
N
48°0'0"N
47°0'0"N
46°0'0"N
3K
MAP AREA
St. John's
3L
3O
3M
3N
3Lh
3Li
3Lr
3Lt
White Rose
Hibernia
Hebron
Terra Nova
3Na
3Nb
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
NAFO Unit Areas
200 Nautical Mile Limit
0
20
40
Kilometers
Atlantic Halibut
Fishing Locations - 2015
Fishing Locations - 2014
Fishing Locations - 2013
Fishing Locations - 2012
Fishing Locations - 2011
Fishing Locations - 2010
Note: Most recent year fished is shown for each grid square

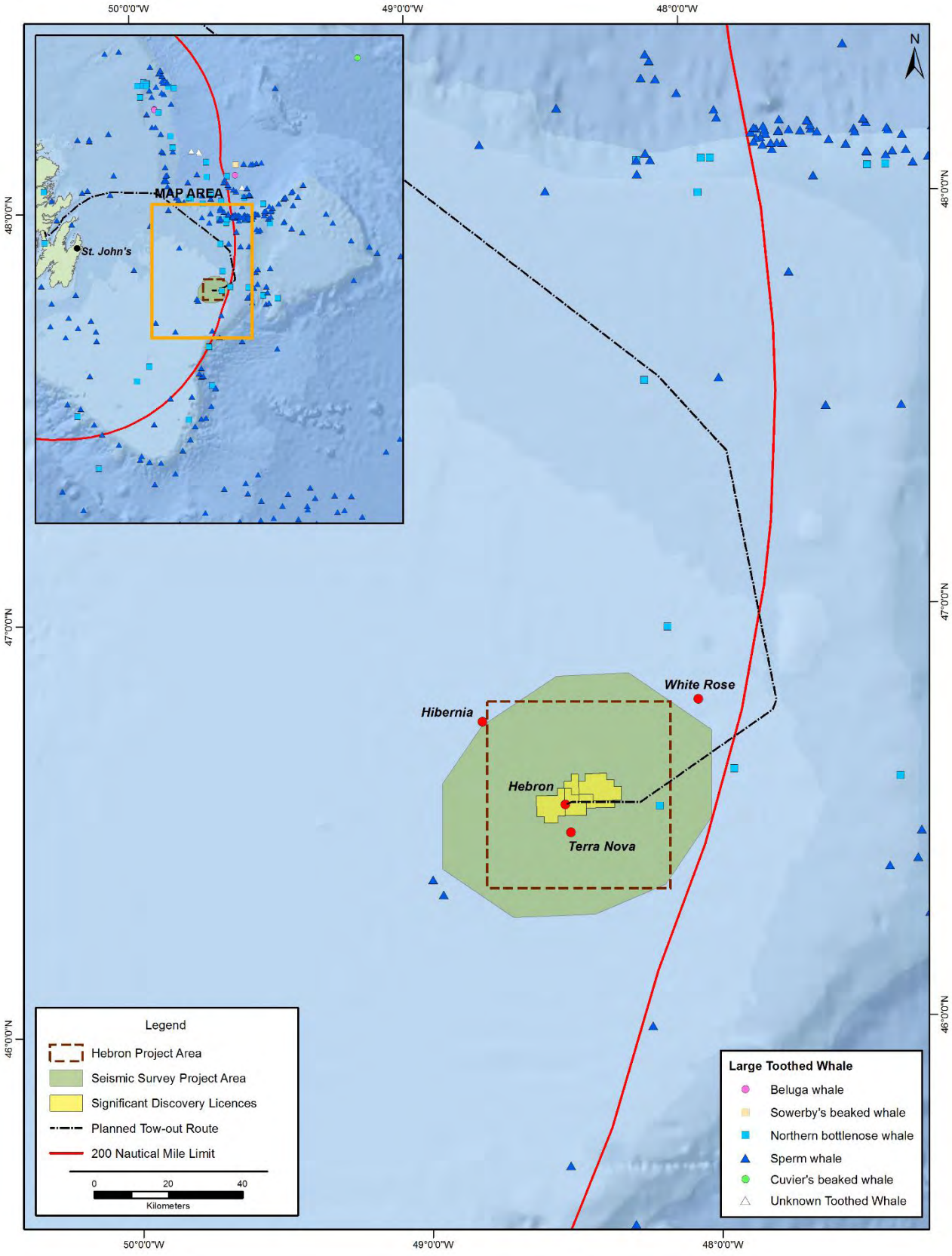

50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
3K
MAP AREA
St. John's
3L
3O
3M
3N
3Lh
3Li
3Lr
3Lt
White Rose
Hibernia
Hebron
Terra Nova
3Na
3Nb
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
NAFO Unit Areas
200 Nautical Mile Limit
0
20
40
Kilometers
P. Borealis
Fishing Locations - 2015
Fishing Locations - 2014
Fishing Locations - 2013
Fishing Locations - 2012
Fishing Locations - 2011
Fishing Locations - 2010
Note: Most recent year fished is shown for each grid square

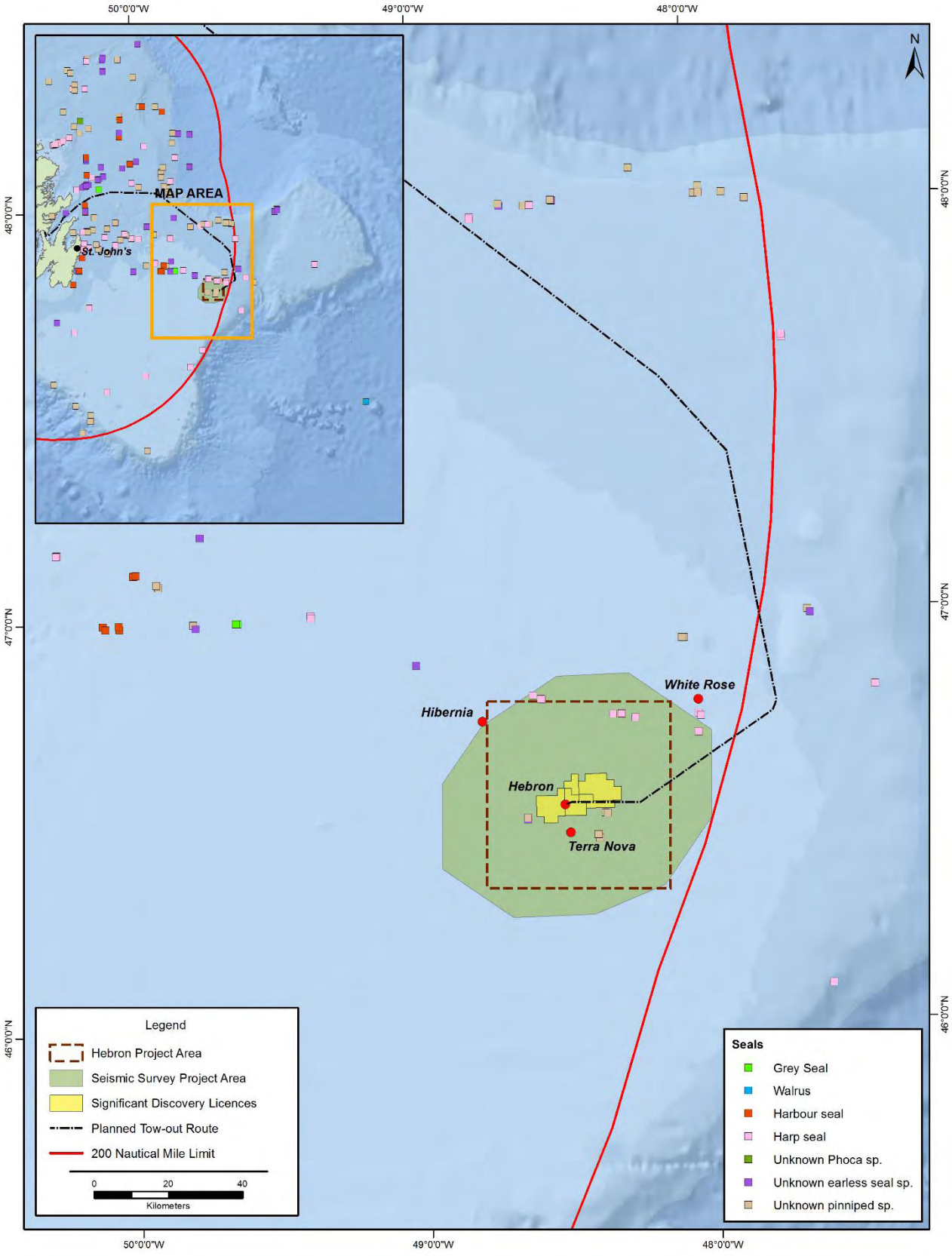

50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
3K
MAP AREA
St. John's
3L
3O
3M
3N
3Lh
3Li
3Lr
3Lt
White Rose
Hibernia
Hebron
Terra Nova
3Na
3Nb
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
NAFO Unit Areas
200 Nautical Mile Limit
0
20
40
Kilometers
Turbot / Greenland Halibut
Fishing Locations - 2015
Fishing Locations - 2014
Fishing Locations - 2013
Fishing Locations - 2012
Fishing Locations - 2011
Fishing Locations - 2010
Note: Most recent year fished is shown for each grid square

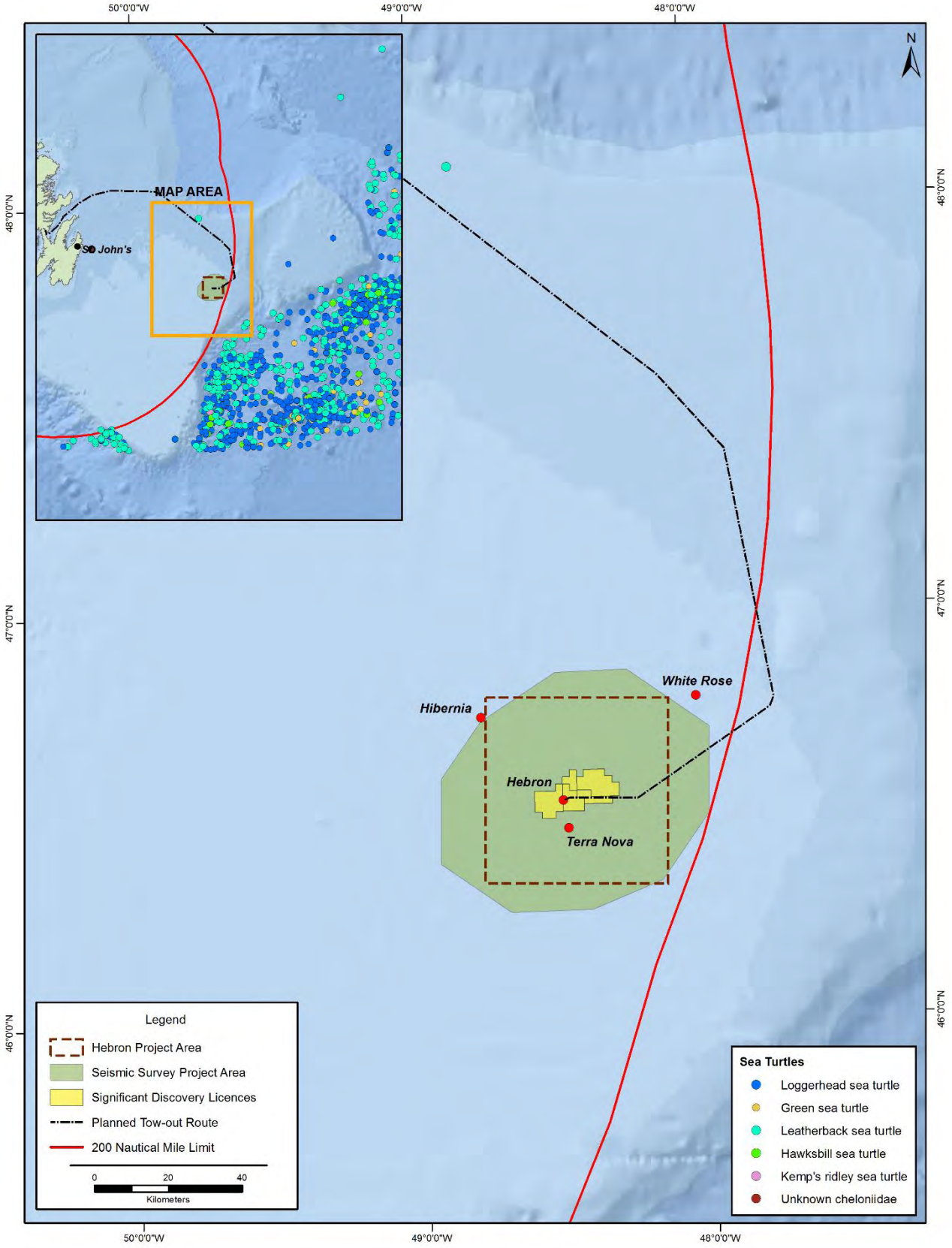

50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
3K
MAP AREA
St. John's
3L
3O
3M
3N
3Lh
3Li
3Lr
3Lt
White Rose
Hibernia
Hebron
Terra Nova
3Na
3Nb
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
NAFO Unit Areas
200 Nautical Mile Limit
0
20
40
Kilometers
Atlantic Cod
Fishing Locations - 2015
Fishing Locations - 2014
Fishing Locations - 2013
Fishing Locations - 2012
Fishing Locations - 2011
Fishing Locations - 2010
Note: Most recent year fished is shown for each grid square


50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
MAP AREA
St. John's
Hibernia
White Rose
Hebron
Terra Nova
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
200 Nautical Mile Limit
0 20 40
Kilometers
Baleen Whales
Blue whale
Fin whale
Sei whale
Fin/Sei whale
Humpback whale
Common minke whale
North atlantic right whale
Unknown Balaenoptera sp.
Unknown baleen whale
Unknown (Balaenopteridae)


50°0'0"W
49°0'0"W
48°0'0"W
N
48°0'0"N
47°0'0"N
46°0'0"N
MAP AREA
St. John's
Hibernia
White Rose
Hebron
Terra Nova
Dolphins and Porpoises
Atlantic spotted dolphin
Atlantic white-sided dolphin
Bottlenose dolphin
Short-beaked common dolphin
Harbour porpoise
Striped dolphin
White-beaked dolphin
Long-finned pilot whale
Killer whale
Unknown (Lagenorhynchus sp.)
Unknown dolphin
Unknown (Stenella sp.)
Unknown Pilot whale (Globicephala sp.)
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
200 Nautical Mile Limit
0 20 40
Kilometers


50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
MAP AREA
St. John's
Hibernia
White Rose
Hebron
Terra Nova
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
200 Nautical Mile Limit
0 20 40
Kilometers
Large Toothed Whale
Beluga whale
Sowerby's beaked whale
Northern bottlenose whale
Sperm whale
Cuvier's beaked whale
Unknown Toothed Whale


50°0'0"W
49°0'0"W
48°0'0"W
48°0'0"N
47°0'0"N
46°0'0"N
N
MAP AREA
St. John's
Hibernia
White Rose
Hebron
Terra Nova
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
200 Nautical Mile Limit
0 20 40
Kilometers
Seals
Grey Seal
Walrus
Harbour seal
Harp seal
Unknown Phoca sp.
Unknown earless seal sp.
Unknown pinniped sp.


50°0'0"W
49°0'0"W
48°0'0"W
N
48°0'0"N
47°0'0"N
46°0'0"N
MAP AREA
St. John's
Hibernia
White Rose
Hebron
Terra Nova
Legend
Hebron Project Area
Seismic Survey Project Area
Significant Discovery Licences
Planned Tow-out Route
200 Nautical Mile Limit
0 20 40
Kilometers
Sea Turtles
Loggerhead sea turtle
Green sea turtle
Leatherback sea turtle
Hawksbill sea turtle
Kemp's ridley sea turtle
Unknown cheloniidae

APPENDIX B

SBM Cement Drill Cuttings Modelling: Supplemental Technical Information

Appendix B
SBM Cement Drill Cuttings Modelling Supplemental Technical Information

EA Amendment Model Runs 2017	
Method and Assumptions The model employed was the same as that used for the 2010 CSR modelling study. There were several differences noted below, which include model grid size, well sequence – the timing of wells, and drill cuttings volumes and composition newly specified for the SBM cement drill cuttings.	
Drill Cuttings Dispersion Model – Overview and Assumptions	The analysis of drill cuttings discharges is accomplished using a numerical computer model developed by Amec Foster Wheeler to determine cuttings depositions at the time of drilling operations. The Advection Dispersion Model (ADM) software is written in Visual Fortran. In the model, a transport computation is employed to simulate the advection of the dispersed drill cuttings materials in three dimensions through the water column, following release into the sea, until the particles come to rest on the sea bottom. For the purposes of predicting their physical deposition on the seabed, the cuttings are considered as a composition of particle types or sizes; typically larger cuttings pieces, pebbles, coarse sand, medium sand and fines. These particle sizes are assumed to be generally representative of the materials likely to be encountered in the area and generated using WBM or SBM – see Cuttings Particle Size Composition below. At any given time, a particle is assumed to be subject to independent displacing forces due to the ocean current and to a fall velocity that is constant for a given particle type. A term to model turbulent diffusion is added to the displacements. Over the time step of the available ocean current data, the displacements are calculated and added to yield a new particle position. Vector additions are computed over each successive time step until the simulation terminates with deposition on the sea bottom (which may be some time after well drilling has terminated). A model grid is selected to encompass the drilling area and possible domain for the deposition of the cuttings. The model tracks the fate and deposition of the particles. In addition to each particle's path, the weight of material is tracked. This is the primary particle attribute. After completion of a model run, when all particles have settled, or have reached the model grid boundaries (in which case, they are taken to have drifted outside the domain and are tabulated as 'lost'), each particle is binned in one of the model grid cells and the total weight, density and thickness are calculated for each grid cell. The grid employed in the model to track the spatial extent of the deposition was a Cartesian grid centred on the Hebron location and extending out a finite distance both in X (or East) and Y (or North) directions. The grid consists of a 2000x2000 array of grid cells each of size 32 m was selected. This covers the Hebron location $\pm$ 32 km. A uniform depth of 94 m is assumed for the model grids.
Inputs	
Well Sequence	A generic well with discharge solely of the SBM cement cuttings was assumed. The design basis of 52 production wells was selected and it was assumed that each well required 90 days to drill and they would be drilled sequentially.

<table>
<tr><td></td><td>The first production well (the first well to be drilled will be a CRI well which will have no associated SBM-associated cuttings discharge so is not considered here) was assumed to start 1 Aug 2017, the second on 2 Nov 2017, and so on up to a final well (well 52) commencing 6 Aug 2031. A random offset of from 0 to 20 days was inserted after each well completion date simply to provide some added seasonal variance with the ocean currents input to the model.</td></tr>
<tr><td>Drill Cuttings Volumes and Discharge Location</td><td>The generic well modelled consists of a total of 15 m^3 (assumed to be an upper limit, of the SBM cement cuttings, released via shale chute at elevation 20 m above the seabed with 94 m depth assumed for Hebron). This includes 10 m^3 from the 340 mm shoe track hole section - released on day 24 (of the 90 day well duration), and 5 m^3 from the 244 mm shoe track hole section, released on day 37, with each shoe track estimated to be about 35 m length. The duration of these discharges estimated to be 0.5 d each was modelled at a 1 day duration each as a simplifying assumption.</td></tr>
<tr><td>Cuttings Particle Size Composition</td><td>Two cuttings particle compositions were modelled.

1. A SBM Cement Disaggregate scenario considered the cuttings composition with particles entering the sea in a relatively disaggregated manner – this is based on the same composition used in the 2010 modelling report with the update that an average of the original model base case and a ‘less fines’ sensitivity scenario was deemed to be representative:

Measured Weight Percent Material

<table>
<tr><th></th><th>Pebble</th><th>Coarse Sand</th><th>Medium Sand</th><th>Fines</th><th>total</th></tr>
<tr><td>Base</td><td>7</td><td>4</td><td>1</td><td>88</td><td>100</td></tr>
<tr><td>Less Fines</td><td>14</td><td>8</td><td>2</td><td>76</td><td>100</td></tr>
<tr><td>SBM cement cuttings</td><td>10.5</td><td>6</td><td>1.5</td><td>82</td><td>100</td></tr>
<tr><td>Assumed Values=></td><td>11</td><td>6</td><td>2</td><td>81</td><td>100</td></tr>
</table>

2. A SBM Cement Clumping scenario assumed a majority of the material would behave as coarse and medium sand size:

<table>
<tr><th></th><th>Pebble</th><th>Coarse Sand</th><th>Medium Sand</th><th>Fines</th><th>total</th></tr>
<tr><td>SBM Cement Clumping</td><td>11</td><td>39</td><td>39</td><td>11</td><td>100</td></tr>
</table>

The model assumed the same particle size and settling velocities as the original 2010 modelling report:

<table>
<tr><th></th><th>Pebble</th><th>Coarse Sand</th><th>Medium Sand</th><th>Fines</th></tr>
<tr><td>particle diameter (mm)</td><td>7</td><td>1</td><td>0.25</td><td>0.1</td></tr>
<tr><td>particle fall velocity (m/s)</td><td>0.3510</td><td>0.1330</td><td>0.0660</td><td>0.0012</td></tr>
</table>
</td></tr>
<tr><td>Ocean Currents</td><td>The Hibernia five-year time-series of currents (near-surface, mid-depth, near-bottom) was employed, the same as used for the 2010 CSR Modelling.</td></tr>
</table>