# THE PETROLEUM AND ENVIRONMENTAL MANAGEMENT TOOL

## Risk-based Analysis and Cumulative Effects Scenarios for the Eastern Arctic



*Photo courtesy Narwhal-Whales*

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# EXECUTIVE SUMMARY

To help guide development in the Canadian Arctic, Indian and Northern Affairs Canada (INAC) developed the Petroleum and Environmental Management Tool (PEMT). The online tool[1] maps the sensitivities of a variety of a variety of Arctic features, ranging from whales to traditional harvesting, across the Arctic. The tool is intended to aid government, oil and gas companies, Aboriginal groups, resource managers and public stakeholders in better understanding the geographic distribution of areas which are sensitive for environmental and socio-economic reasons.

This document explores two approaches to estimate the relative risk associated with the environmental effects of development activities. It focuses on four Valued Components (VCs):

1. Bowhead whale
2. Toothed whale
3. Think-billed murre
4. Commercial fisheries.

Section 2 describes a simple approach for estimating the risk of Project effects. This approach could be adapted, and as appropriate, integrated into the PEMT.

Section 3 provides a simple model to estimate the risk of potential cumulative effects. The analyses focus on the offshore areas associated with the Eastern Arctic. It is important to note that the model developed here is not intended to be a full analysis of cumulative effects. Rather, it is intended to be a tool for exploring the potential effects of different development scenarios on different VCs.

The results described here suggest that the cumulative effects of development on VCs vary considerably. At one end of the spectrum, bowhead whales are sensitive to development, particularly underwater noise. Relative to routine shipping and drilling activities, seismic operations are expected to contribute the most to cumulative effects.

Seabirds such as thick-billed murre can be sensitive to disturbances to their breeding colonies, particularly if aircraft come in very close proximity (although this should generally be avoided as a result of routine flight rules). Compared with bowhead whales, they are much less sensitive to the routine effects of oil and gas development[2].

The commercial turbot fishery falls in between these two extremes. This is a deep water fishery often conducted in depths of 1,000 m or greater. The depth of the fishery in conjunction with the pelagic and migratory nature of turbot reduces the potential for effects on this species from routine oil and gas activities, as well as the potential for cumulative effects. The largest potential for cumulative effects on the commercial turbot fishery is from space conflicts between fishing vessels, and where there is both operating seismic and drill ships. Space conflicts occur when a fishing vessel is unable

[1] The PEMT is available at http://www.ainc-inac.gc.ca/nth/og/pemt/index-eng.asp

[2] Seabirds are very sensitive to oil spills, but accidents and malfunctions are beyond the scope of the assessment presented in this document.

to access a fishing location due to the presence of either an operating seismic vessel or locations of operating drill ships. The increase in any of the number of fishing vessels, seismic and drilling vessels or all three could potentially lead to increased cumulative effects on the fishery. Overall, the potential for cumulative effects based on the scenarios studies ranged from low to nil.

What are the implications for development in the Arctic? Would the development scenario described above put any of the VCs at risk? That question is easiest to answer when there are clear thresholds separating an acceptable environmental effect from one that is not. Thresholds may be ecological (e.g., habitat availability, the viability of a wildlife population), physical (e.g., concentration of contaminants), political (resource management objectives related to a given environmental effect) or social (e.g., acceptable perceived change). Unfortunately, clear thresholds are generally not yet available. For that reason, the analysis is limited to the relative risk of cumulative effects.

Despite the limitation, these approaches can be valuable. Both are easy to update as new information becomes available, making them easy to modify and improve. As information on relative importance of environmental effects on a VC (e.g., how probable they are, or how far from a source they extend), the sensitivity of different regions of the Arctic, or thresholds above which environmental effects become problematic becomes available it can easily be incorporated. The model can also be very easily modified to explore and compare the potential effects of different development scenarios. This iterative and exploratory approach could be used to generate discussion on the merits of different development options. It may also focus attention what information would best contribute to a better understanding of cumulative effects. Both should benefit resource management in the Arctic.

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# LIST OF ACRONYMS

DC .......... Disturbance Coefficient

DOE .......... Duration of Effect

DFO .......... Fisheries and Oceans Canada

INAC .......... Indian and Northern Affairs Canada

PEMT .......... Petroleum Environmental Management Tool

RMF .......... Risk Management Framework

VC .......... Valued Component

ZOI .......... Zone of Influence

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# 1 INTRODUCTION

To help guide development in the Canadian Arctic, Indian and Northern Affairs Canada (INAC) developed the Petroleum and Environmental Management Tool (PEMT). The online tool[3] maps the sensitivities of a variety of a variety of Arctic features, ranging from whales to traditional harvesting. The tool is intended to aid government, oil and gas companies, Aboriginal groups, resource managers and public stakeholders in better understanding the geographic distribution of areas which are sensitive for environmental and socio-economic reasons.

This document explores two options to build upon the PEMT.

1. The risk of project-related environmental effects. Section 2 of this report describes a simple method for characterizing the relative risk of project activities. It is based on two factors – the sensitivity of a given area and the relative strength of the interaction between a development activity and a given component of the Arctic environment (described below).
2. Cumulative effects scenarios. Section 3 develops a hypothetical development scenario for the eastern arctic and a simple model for estimating cumulative effects. It then provides an output of the relative cumulative effects for a variety of components of the eastern Arctic.

Both options are analyzed in terms of four Valued Components (VCs) of the Arctic:

1. Bowhead whale
2. Toothed whale
3. Thick-billed murre
4. Commercial fisheries.

The analyses focus on the offshore areas associated with the Eastern Arctic Study Area (which can be seen on a variety of the maps included in Section 5, including Map 5).

# 2 RISK-BASED ANALYSIS OF PROJECT EFFECTS

The PEMT currently identifies sensitive areas based on their importance to a VC. But not all activities affect all VCs equally. Expanding the PEMT to account for this variability could be useful. If successful, it would more accurately characterize the in the risk of environmental effects.

The first challenge is to develop a simple approach to characterize the risk of an environmental effect. One way to do this is based on the interaction of two factors:

*Risk of an environmental effect = sensitivity of an area x scale of a negative effect*

This approach builds on the risk management framework (RMF) developed by Fisheries and Oceans Canada (and captured in the 2006 *Practitioners Guide to the Risk Management Framework for DFO*

[3] The PEMT is available at http://www.ainc-inac.gc.ca/nth/og/pemt/index-eng.asp

*Habitat Management Staff*). The purpose of the RMF is threefold, to: (1) categorize risks to fish and fish habitat associated with proposed development activities; (2) communicate these risks; and (3) help identify appropriate management options to reduce risks to acceptable levels. While the DFO RMF was developed for freshwater environments, the underlying concepts are useful and could be adapted to a marine environment.

It is important to note that this is a different measure of risk than is sometimes used (risk = probability of an effect x consequence of that effect). We believe that the DFO approach has at least three related merits. First, geography matters. Some areas are more sensitive than others; explicitly incorporating the sensitivity of specific areas into the analysis can produce a better measure of environmental risk. A related benefit is that this information is readily available for the Arctic, as it forms the basis of the PEMT. Second, the approaches are not mutually exclusive. Assessing the probability and consequence of an effect can be integrated into this analysis, as described in Section 2.2.

An example can illustrate the utility of the RMF. Consider a scenario in which a helicopter flies low over an island and an area of open ocean. If the flight path takes the helicopter close to a colony of ivory gulls, the risk of potential effects is high as the gulls are endangered, the colony is a key (and therefore sensitive) resource and, under some circumstances, overflights may cause colonially nesting birds to abandon their nests. In a similar example where the helicopter passes over an area critical for feeding bowhead whales, the effect is negligible; it causes the same amount of sensory disturbance, but whales are generally not sensitive to it, and the effect on them is relatively inconsequential. The risk of important environmental effects therefore varies with the sensitivity on an area and likely response of the VC in question. In this example, the risk of an environmental effect associated with the helicopter is relatively high for migratory birds (although it could likely be reduced by rules separating the aircraft from the colony) and low for whales.

These are the types of distinctions that the RMF seeks to make. The overall risk of an environmental effect depends on the:

1. Nature of the activity (in this example, the helicopter overflight)
2. Associated environmental effects (e.g. noise which causes sensory disturbance for some wildlife species)
3. Interaction between the effects and the resource in question (e.g., Ivory gulls are much more likely to be affected than bowhead whales)
4. Sensitivity of the area (in this example, the area is important for both VCs).

The PEMT already contains information on (4), the sensitivity of all areas for a variety of VCs. To assess risk, information on must be added to characterize the degree (or scale) of a potential of a negative effect and a means to estimate risk. Both are described below.

## 2.1 Valued Components and Effects Pathways

This section provides a short summary of how activities associated with Arctic development can affect VCs such as bowhead whale, toothed whale, thick-billed murre, and commercial fisheries. These effects pathways link development activities with their associated environmental effects, the type of information referenced in 1 and 2 above.

### 2.1.1 Habitat Quality

Development activities can affect wildlife habitat through sensory disturbance (noise, ambient light, and the physical presence of equipment), habitat conversion (roads, camps, and pipelines), and the alteration of wildlife movement patterns. There may also be some beneficial effects such as fish habitat created by underwater structures associated with offshore drilling operations. Major effects pathways are briefly described below:

- **Sensory disturbance:** Navigation, pile driving, dredging, and seismic surveying all generate underwater noise. Change in ambient sound levels in the marine environment has the potential to directly affect fish, marine mammals and indirectly traditional use. Marine mammals use sound to communicate, forage and navigate underwater, and whales are known to be particularly sensitive to anthropogenic underwater noise (Richardson, *et al.* 1995). While the effects on whales are not fully understood, they may include masking of communication, increased stress, the abandonment of important habitat, and changes to reproductive and immune processes (Richardson, *et al.* 1995). Relatively little is known about the effect of seismic sound on fish. While polar bears are unlikely to be affected by seismic sound, they may interact with support vessels (e.g., picket vessels used for ice reconnaissance) and/or aircraft (e.g., helicopters used for crew transport), although they show little or no response to approaching marine vessels (Fay, *et al.* 1984 cited in Richardson, *et al.* 1995).

  Marine activities such as icebreaking, ship movements and aircraft overflights also could result in sensory disturbance to marine mammals and marine birds. Marine mammals may change movement patterns in response to icebreaking and ship movements. In relation to marine birds, some species such as eiders and loons concentrate in huge numbers in offshore polynyas during the spring migration and would be susceptible to disturbance by human activities.

  Sensory disturbance can also occur on land. For example, some congregatory birds may abandon their colonies if repeatedly disturbed by aircraft overflights. A majority of polar bear maternity dens are on land or in landfast ice, and they display a high site fidelity to these sites (i.e., they are found in the same areas year after year) (Van De Velde, *et al.* 2003). Anthropogenic change close to these areas has the potential to disturb these important sites.

  Under some circumstances, wildlife may habituate to sensory disturbance, which may then have less of an environmental effect over time. For example, pinnipeds (e.g., seals, walrus) that are consistently exposed to vessel traffic over a period of time will eventually display reduced startle response when vessels are in the area. Monitoring programs can help determine the extent to which wildlife are able to habituate to this and other disturbances. In the absence of this information, a conservative approach would assume that no habituation occurs.

- **Habitat conversion:** Habitat can be lost not only through sensory disturbance but also due to alteration of natural or semi-natural areas as a result of human use. This could include the footprints of a development on the seafloor (e.g., a drilling or production platform, installation of subsea pipelines), as well as icebreaking. In coastal areas, habitats may be converted to form the development footprint of a port facility or mine. In a marine environment, drilling muds or dredged materials discharged into a low energy environment may smother sessile organisms and their habitat in the adjacent sea floor, although effects disappear rapidly once drilling stops. Underwater structures associated with drilling platforms provide additional substrate for marine plants and invertebrates, increases the vertical availability of structural complexity (increased food source and protection habitat), and may result in a net gain in available fish habitat in the local area.
- **Movement:** Sensory disturbance or habitat conversion can also alter (temporarily or permanently) animal movement patterns. This can result in reduced access to foraging or hunting grounds and increased energy expenditure. For example, exposure to seismic may cause individual marine mammals to alter movement patterns, displace them from key feeding areas or increase travel distances (Richardson, *et al.* 1995). This also could affect traditional harvesting of these species.

### 2.1.2 Air Quality

Internal combustion engines, flaring, and other petroleum activities can produce carbon dioxide, nitrogen oxides, and sulfur oxides, ozone, and particulate matter. Although the various phases of oil and gas production have different levels and types of emissions, none of the changes in air quality is expected to have an important effect on any of the VCs selected.

### 2.1.3 Water Quality

Routine activities such as the discharge of effluent sewage, drainage, and produced water, as well as development of land based infrastructure such as roads and pipelines can result in changes in water quality. Produced water (generated with oil and gas during the production phase) may contain small amounts of oil and is highly saline. Sediments may become suspended during physical disturbance of the seabed (the physical footprint and sediment disturbance) and dredging. Increased turbidity can also result from mud and cuttings dumped overboard from drilling operations. These activities could potentially affect fish and fish habitat directly by increasing sedimentation, but additionally indirectly affect traditional use and potentially animals that prey on fish, as can oil spills. Many effects on water quality can be mitigated.

### 2.1.4 Change in Health – Injury

Several aspects of development can change the health of VCs in terms of physical injury. First, vessel traffic (associated with hydrocarbons development, shipping, fishing, or mining) can result in collisions with whales.

Serious (or lethal) vessel strikes to whales are infrequent at vessel speeds less than 14 knots and are rare at vessel speeds less than 10 knots (Laist, *et al.* 2001). Toothed whales and pinnipeds are rarely struck by vessels (Jensen and Silber 2003; Laist, *et al.* 2001). These marine mammals are fast swimming and agile, enabling them to avoid approaching vessels. Similarly, seals are highly maneuverable and can effectively modify their behavior (i.e., swim away, dive) to avoid being struck by slow-moving (<14 knots) vessels, such as those associated with seismic activity (Richardson, *et al.* 1995).

While the focus on the change in health is primarily injury, wild species could also affected through the update of contaminants such as mercury or polycyclic aromatic hydrocarbons (PAHs), which occur in oil deposits are byproducts of fuel burning.

## 2.2 Scales of Negative Effect

This section outlines two approaches to characterizing the scale of negative effects. It is important to note that the scale, as defined here, depends on the proposed activity, not where it occurs. In other words, all activities of a given type (e.g., helicopter overflights) will have the same “scale of negative effect.” Where an activity occurs will become important later, when information on scale and sensitivity is combined to assess risk.

### 2.2.1 Interactions Measured on a Three Level Scale

A relatively simple means to define the scale of a negative effect is described below Table 2-1. Each interaction between an activity, effect, and a VC is given a score of 0, 1, or 2.

**Table 2-1: Scale of Environmental Effects**

| Attributes | Scale Score |
|---|---|
| **Negligible interaction between an activity and a VC**. In other words, an activity is not likely to cause an environmental effect for a given VC that would result in an important change to the viability or sustainability of that VC. For example, underwater noise generated by a passing ship in open water would likely only result in a short-term disturbance of seals within tens of metres of a vessel, and this interaction would be scored as a zero. | 0 |
| **An interaction occurs but the effect is unlikely to be high consequence**. Based on past experience and professional judgment the interaction would (a) not result in a high consequence environmental effect, even without mitigation, or (b) the interaction would not be high consequence when codified practices or proven mitigation are used to avoid, reduce, and/or mitigate effects are applied. | 1 |

| Attributes | Scale Score |
|---|---|
| **An interaction is important and, under some circumstances, <u>may</u> result in a high consequence environmental effect**. The word "may" is key as without additional study it is not possible to say whether a given activity will or will not have a high consequence effect. Rather, there is a potentially strong interaction that merits additional attention, often in the context of an environmental assessment. For example, the underwater noise generated by seismic exploration has the potential to substantially affect marine mammals, although whether this actually occurs depends on a number of factors and requires additional study. | 2 |

Table 2-3 (below on Page 8) provides a summary of all the factors related to risk ratings. Since each activity, effect, and VC may interact differently, each requires a separate score on a scale of 0 to 2.

- The first column (anthropogenic activities) list the variety of activities expected to occur in the eastern arctic. The following three column list when these activities will occur (e.g., during routine vessel traffic, seismic operations, and exploration drilling).
- The effects of these activities on whales, marine birds, and commercial fisheries are illustrated next. In each case the types of effects are broken down into categories (such as habitat quality, water quality, and health).
- The risk of an environmental effect is characterized on scales of zero to two and zero to ten. The latter is described below.

Blank cells in the table represent a score of zero, meaning that there is no meaningful interaction between the activity, effect, and VC in question.

### 2.2.2 Interactions Measured on a Scale of Zero to Five

An alternative is to measure risk on a finer scale. One way to do this is to characterize it based on the interaction of two factors:

*Scale of an environmental effect = probability of an effect x consequence*

The probability of an effect is a conservative estimate, based on professional judgment, of the likelihood of an effect occurring on the VC should it be in the proximity of the activity in question. How far an effect propagates varies depending on the impact and the Valued Component in question. For example, in the case of whales for a ship strike to cause a mortality requires immediate proximity, which the effect of underwater noise can extend many kilometers. This is explored more in the discussion in Section 3 on cumulative effects. For the purposes here, suffice it to say that probability is the likelihood that an effect could occur if a given VC is in the zone of influence of that effect.

The consequence of an effect is characterized in Table 2-2. It is important to note that the scale is not linear. In other words, the scale jumps from zero, to one, then to five and to ten. The rationale is that the consequences of the effects become much more important moving down the scale and therefore are given higher numerical values. A regional change in a population has a much greater consequence than a local change in a population, which in turn is much more important than temporary change in behavior.

**Table 2-2: Consequence of an Effect**

| Scale | Descriptor |
|---|---|
| 0 | Negligible |
| 1 | Temporary change in behavior |
| 5 | Local change in population within area of direct of activity. |
| 10 | Detectable regional (study area) change in population |

Using this method, the risk scales for Arctic activities run from zero to five. It is important to note that using the values in Table 2-3; however, the maximum potential score is ten. This would result from an activity that is certain to cause a given effect (probability = 1) and that effect is likely to result in a regional change (scale = 10), given that 1 x 10 = 10. None of the interactions studied were judged to reach this theoretical maximum.

### 2.2.3 Which Measure is Better?

Both approaches have advantages and disadvantages, so answering that question depends on user preferences.

The three level scale (of zero, one, and two) has several advantages:

- It is simple. Users need only pick one of three categories for a given effect. No estimates of probability or multiplication are required.
- It is reasonably easy to understand. The challenge is separating those activities that have the potential to be high consequence (rating = 2) from the rest.
- There is less risk of “false precision,” or assigning values are beyond our ability to estimate with reasonable accuracy.

The second, finer scale as different advantages:

- It allows users to consider individually two factors which can drive the risk associated with an environmental effect: the probability of an effect and its consequence.
- It allows for finer distinctions. Where it is possible to accurately make these distinctions (such as different estimates of probability), then this allows for a more accurate analysis. But it does risk false precision where we do not have the ability to make estimates, particularly for the probability of an effect.

The overall patterns of risk illustrated in Table 2-3 are similar using both scales. This may be because the same authors developed both, but it does lend support for the idea that even when using two different yardsticks for the strength on an interaction between an activity and a VC, the overall patterns remain the same. The principle of parsimony suggests that in cases where there are two alternatives, the simplest one that provides a credible explanation may be preferred. This lends some support for using a three scale measure, at least initially, but both are viable options.

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**Table 2-3: PEMT Effects Pathways and Risk Ratings**

| Anthropogenic Activities | | | | Whales | | | | | | Scale of Effect | | | | Marine Birds | | | | | Scale of Effect | | | | Commercial Turbot Fishery | | | | | | Scale of Effect | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Occur During: | | | Habitat Quality | | Water Quality | | | Health | | Five Level | | | Habitat Quality | | Water Quality | | | | Five Level | | | Habitat Quality | | Water Quality | | | Human | | Five Level | | |
| | Routine Vessel Traffic | Exploration: Seismic | Exploration: Drilling | Communication Masking (underwater) | Change in Behavior (underwater) | Disturbances of Seabed | Discharge: Sea | Discharge: Runoff | Change in Health/Injury | Simple Three Level | Probability | Consequence | Scale | Change in Behavior | Terrestrial Habitat Conversion | Disturbances of Seabed | Discharge: Sea | Discharge: Runoff | Simple Three Level | Probability | Consequence | Scale | Change in Behavior | Displacement | Disturbances of Seabed | Discharge: Sea | Discharge: Runoff | Vessel Space Conflict & Reduced Fisheries | Simple Three Level | Probability | Consequence | Scale |
| | | | | | | | | | | | P | C | S | | | | | | | P | C | S | | | | | | | | P | C | S |
| **Vessel Traffic** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Transport/supply ships | * | * | * | * | * | | | | * | 1 | 0.90 | 1 | 0.9 | * | | | | | 1 | 0.20 | 1 | 0.2 | | | | | | * | 1 | 0.25 | 1 | 0.3 |
| Seismic ship and support vessel(s) | | * | * | * | * | | | | * | 1 | 0.90 | 1 | 0.9 | * | | | | | 1 | 0.20 | 1 | 0.2 | | | | | | * | 1 | 0.25 | 1 | 0.3 |
| Icebreaker | | * | * | * | * | | | | * | 1 | 0.50 | 1 | 0.5 | * | | | | | 1 | 0.20 | 1 | 0.2 | | | | | | * | 1 | 0.25 | 1 | 0.3 |
| **Exploration Activities** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Seismic acquisition (use of airguns) | | | | * | * | | | | | 2 | 1.00 | 5 | 5 | | | | | | | | | | * | * | | | | * | 1 | 0.80 | 5 | 4 |
| Drilling | | | * | * | * | | | | | 2 | 0.70 | 5 | 3.5 | | | | | | | | | | | | | | | * | 1 | 0.10 | 5 | 0.5 |
| **Aircraft Traffic** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fixed wing | | | | | | | | | | | 0.05 | 1 | 0.1 | * | | | | | 2 | 0.80 | 5 | 4 | | | | | | | | | | |
| Helicopter | | * | * | | | | | | | | 0.05 | 1 | 0.1 | * | | | | | 2 | 0.80 | 5 | 4 | | | | | | | | | | |
| **Shore-based Support Infrastructure** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Use of existing infrastructure | * | * | * | | | | | | | | 0.05 | 0 | 0 | * | | | | | | 0.10 | 1 | 0.1 | | | | | | | | | | |
| Development of new infrastructure | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ▪ Shoreline disturbance | | Varies | Varies | | | | | | | | 0.10 | 1 | 0.1 | | * | | | | 1 | 0.10 | 1 | 0.1 | | | | | | | | | | |
| ▪ Pile driving | | Varies | Varies | * | * | | | * | | 2 | 0.90 | 5 | 4.5 | | | | | | | | | | | | | | | | | | | |
| ▪ Construction activities | | Varies | | | | | | | | | 0.10 | 1 | 0.1 | * | | | | | | 0.10 | 1 | 0.1 | | | | | | | | | | |
| **Waste Water Treatment and Discharge** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ▪ Sewage | * | * | * | | | | * | | | | 0.01 | 1 | 0 | | | | * | | | 0.05 | 1 | 0.1 | | | | * | | | 1 | 0.01 | 1 | 0 |
| ▪ Grey water (shower, sinks, etc.) | * | * | * | | | | * | | | | 0.01 | 1 | 0 | | | | * | | | 0.05 | 1 | 0.1 | | | | * | | | 1 | 0.01 | 1 | 0 |
| ▪ Solid waste | * | * | * | | | | * | | | | 0.01 | 1 | 0 | | | | * | | | 0.05 | 1 | 0.1 | | | | * | | | 1 | 0.01 | 1 | 0 |
| ▪ Drilling wastes (drilling muds, well cuttings) | | | * | | | | | | | | 0.01 | 1 | 0 | | | | * | | | 0.05 | 1 | 0.1 | | | | * | | | 1 | 0.01 | 1 | 0 |

**KEY:**
* Interaction

**CONSEQUENCE:**
0 = Negligible
1 = Temporary change in behaviour
5 = Local change in population within area of direct of activity
10 = Detectable regional (study area) change in population

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## 2.3 Categorizing Risk

At this point, both the sensitivity of an area and the scale of an activity's negative effect have been defined. Sensitivity information can be drawn directly from the PEMT, and scale of an effect can be characterized using one of the two methods described above. It is now possible to assess the risk of an environmental effect.

The proposed approach adapts DFO's Risk Assessment Matrix (Figure 2-1) for application in the PEMT. This matrix characterizes risk of an environmental effect based on the sensitivity of an area and the scale of a negative effect. In the DFO Matrix, risk falls into one of five categories:

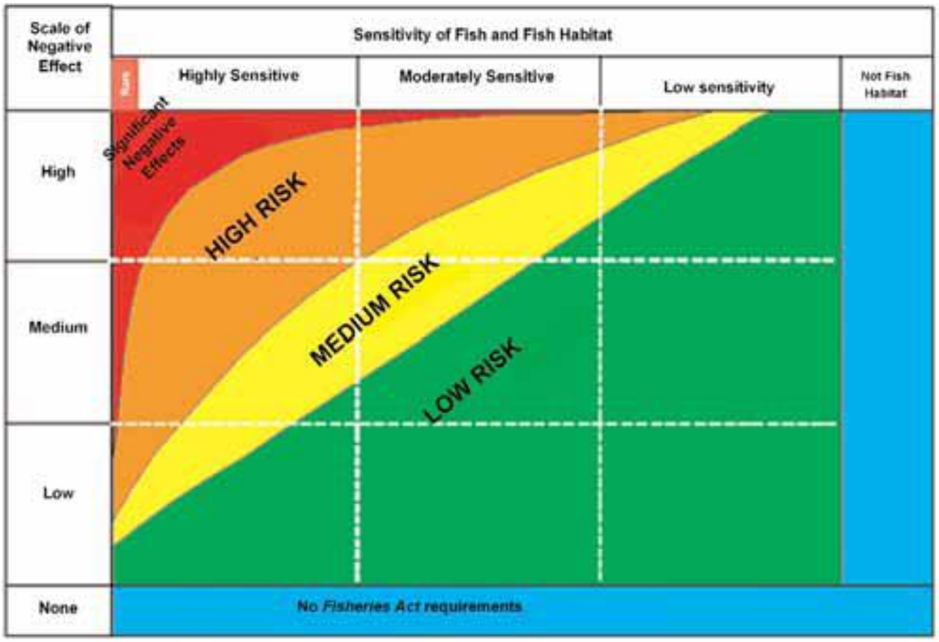
- **No Risk** (the blue area). There is no risk of an effect because either the scale of the negative effect is negligible; an area has no value/zero sensitivity for a VC, or both.
- **Low Risk** (the green area). An activity is not likely to result in an important residual effect if appropriate mitigation measures[4] are applied.
- **Medium Risk** (the yellow area). An activity may result in a small or temporary negative effect, even if appropriate mitigation measures are applied. Furthermore, the relationship between cause and effect is well understood, mitigation measures are known to be effective (i.e., uncertainty is low), and the residual effect is not expected to pose an important risk to the VC in question.
- **High Risk** (the orange area). An activity will result in a residual environmental effect that may affect the viability of the VC. This may be because the effect may persist over time, influence a broad area, or alter key or vulnerable resources, even with mitigation. These interactions that would typically form the focus of environmental assessments.
- **Very High Risk** (the red area). These activities have residual effects which are unacceptably large or important.

A Risk Assessment Matrix for the PEMT should be simpler than DFO's for several reasons. First, the PEMT can support decisions, but a more detailed environmental assessment would be needed to determine if a given effect is significant. The PEMT should not be expected to make this determination.

Second, given the complexity of interrelationships between a variety of stressors and VCs, the precise information needed to finely parse risk is likely not available. An example may make this clearer. Consider an activity which has a high scale of negative effects but occurs in an area of low sensitivity. This interaction would fall into the top right corner of the DFO matrix. The activity could be characterized as low, medium, or high risk depending on precisely where it fell within the high scale/low sensitivity box. In the Arctic, information needed to make such fine scale distinctions is not generally available.

[4] Appropriate mitigation measures may include standard industry practices, government guidelines, and identified best management practices.

**Figure 2-1: DFO's Risk Management Matrix**




**Source:** DFO 2006

To increase its practicality, it is recommended that the PEMT apply similar principles as DFO's risk management matrix, as they are useful and transferable. But the Risk Assessment Matrix itself should be simplified. One example of how this might be done is illustrated in Table 2-4. This is essentially a simplified version of the DFO Matrix. It is a lookup table whereby the PEMT could determine the risk of an environmental effect for any spot on a map. This risk score would be generated by multiplying the scores for sensitivity and scale and then characterized as high, moderate, low, or negligible. This information could be communicated to a PEMT user in text or graphically by displaying the scores on a map (with risk scores generated for each cell in the PEMT map).

**Table 2-4: Lookup Table for Characterizing the Risk[1] of an Environmental Effect**

| Scale of Negative Effect[3] | Sensitivity of an Area[2] | | | | |
|---|---|---|---|---|---|
| | **5 (High)** | **4 (Moderately High)** | **3 (Moderate)** | **2 (Moderately Low)** | **1 (Low)** |
| 2 (High) | 10 | 8 | 6 | 4 | 1 |
| 1 (Low) | 5 | 4 | 3 | 2 | 1 |
| 0 (Negligible) | 0 | 0 | 0 | 0 | 0 |

**NOTES:**

[1] Risk is characterized based on the produce of the sensitivity of an area x the scale of a negative effect:

- **High:** scores of 8 to 10 (red)
- **Moderate:** scores of 4 to 6 (orange)
- **Low:** scores of 1 – 3 (green)
- **Negligible:** score of zero (blue)

[2] Sensitivity information for a given VC is drawn directly from the existing PEMT

[3] In this example the Scale of Negative Effect is based on the simpler method described in Section 4.1.1. Using the more complex scale of 0 to 5 described in Section 4.2.2 would follow the same process but would require an expanded table.

The sensitivity numbers provided above are illustrative. Were the user to proceed with this approach, they would need to be tested using activities and areas to ensure and adjusted as needed.

### 2.3.1 Summary of Key Steps

This section reviews the key steps involved in this process.

1. A PEMT users would identify:
   a) A type of potential activity (from a list provided)
   b) The VC that they are interested in (from a list provided)
   c) Where the activity would occur (from a graphical interface). The user would have to identify a specific location as a single spot on a map, a line (for linear activities, such as ship travel), or a two dimensional area (assuming the activity would occur throughout that area).

2. PEMT[5] would then characterize the:
    a) **Sensitivity of the area identified by a user.** This would be done based on the VC, location identified by the user, and sensitivity scores already in the PEMT. Sensitivity would be characterized along a gradient of least sensitive (1) to most sensitive (5).
    b) **Scale of the negative effect.** This would be done based on the activity(ies) identified and one of the two methods described in Section 2.2. The scale of potential effects would be characterized along a gradient of no effect (0) to greatest potential effect (either 2 or 5, depending on whether of the two methods described above was used).
    c) **Risk of environmental effects.** This risk score would be generated by multiplying the scores for sensitivity and scale and then characterize the product as high, moderate, low, or negligible. This information could be communicated to a PEMT user either in text or graphically by displaying the scores on a map (with risk scores generated for each cell in the PEMT map).

This approach would only assess areas where an activity will occur (as defined by the user). It does not attempt to calculate how far out from that spot, in space or in time, effects may persist. It is also important to keep in mind that the focus of this approach is routine project-specific effects. Assessing the risk of accidents and malfunctions or cumulative effects requires different tools. Cumulative effects are discussed in Section 3.

[5] The pathways linking activities, environmental effects, and their interaction with VCs would already be built into the PEMT, allowing the following steps.

# 3 CUMULATIVE EFFECTS SCENARIOS

This section describes a process for exploring potential future cumulative effects in the eastern arctic. This analysis focuses on the routine key anthropogenic activities. Accidents and malfunctions, such as oil spills, are not part of this analysis.

## 3.1 Strategies for Addressing Uncertainty

Even in well studied areas, understanding the interactions that lead to cumulative environmental effects can be complex. This is more challenging for areas that are relatively less studied or for future scenarios. Both are true for the eastern Arctic.

Arctic research, even when it is done elsewhere, can illuminate the effects of oil and gas development. For example, recent research on bowhead whales is contributing to our understanding of how they respond to the underwater noise generated by vessel traffic and seismic arrays. However, we are only beginning to understand how these effects may act cumulatively.

In the face of uncertainty, a good approach can be to look at a range of potential effects. An example can help illustrate the point. We know that underwater noise generated by vessel traffic can mask communications and affect the behavior of bowhead whales. But over what distance would this effect be important for whales in the Eastern Arctic? While biologists do not have precise answers to these questions, research does point to potential ranges. So rather than making a single assumption – such as the effect of a passing ship on bowhead whale communication extends out 7 km from the source – the analysis presented here look at a range of values. At the high end is an estimate of the broadest (largest) effect that appears possible, based on current knowledge. At the low end is the smallest range over which whales may be affected. In this particular example, the range used in the cumulative effects analyses runs from a minimum of 0.5 km to a maximum of 10 km. For a complete list of all values used in the analysis, see Table C1 in Appendix C. As our understanding improves, these values can be easily updated.

This simple sensitivity analysis has several advantages. One is that while we do not know the precise distance or relative effects of different activities, we can describe ranges of distances within which effects from these activities may be of concern. These values might be expressed as a radius around a point activity or a buffer around linear activities or features or development polygons. If properly done, the true value will lie within these to extremes. This also makes it possible to model cumulative effects, repeating the same process for all activities in the eastern Arctic. This allows for an exploratory analysis. Its primary utility is to illustrate the potential effects associated with a given development scenario, a range of possible effects, and certain assumptions about the interaction between the two.

All parameters in the analysis can be easily modified. Thus, it is easy to explore potential cumulative effects if any of the parameters of the model are changed. These modifications are important as more information on the nature and cumulative effects of anthropogenic activities becomes available. Thus, the analysis is not intended to provide a precise description of cumulative effects, but to allow interested parties to explore the implications of differing assumptions and scenarios on the range of cumulative effects likely in the eastern Arctic.

## 3.2 Overview of the Model

Given the exploratory nature of the cumulative effects model, four valued components were used as examples in the analysis:

1. Bowhead whale
2. Toothed whale
3. Thick-billed murre
4. Commercial turbot fishery.

These valued components respond differently to oil and gas exploration. They therefore illustrate some of the range of potential cumulative effects both in terms of the nature of the response and the distance over which it occurs. For example, whales are sensitive to underwater noise, the effects of which can affect communication and behavior over a scale of tens of kilometers. Migratory birds, on the other hand, do not appear to be sensitive to underwater noise, although they can be affected by helicopter overflights if the flights occur too close to a breeding colony. By attempting to capture these varied responses, the analysis presented here attempts to illustrate the variety of potential cumulative effects, both in terms of their nature and spatial extent.

Since each of the four VCs is expected to respond differently to oil and gas development, each is analyzed separately. In other words, separate cumulative effects scenarios are developed for each of the four VCs.

Several inputs are used in the cumulative effect scenarios.

- The development scenario. This is a spatial model of the anthropogenic development that being modelled (see Section 3.3 for a full description). This is the only input which is the same for each VC.
- The environmental effects of anthropogenic activities are described in Section 3.4:
  - The zone of influence for the effect of an activity on a VC. This is the distance from the source that a given impact (e.g., underwater noise generated by seismic airguns) will affect a given VC (e.g., bowhead whales).
  - The scope or intensity of this effect (within the zone of influence). This is a measure of the strength of the interaction between the impact (e.g., airgun noise) and the effect for a given VC (e.g., How strongly will bowhead whales be affected?).
- The sensitivity of the area in which an effect occurs. This information is drawn directly from the sensitivity layers currently in the PEMT. See Section 3.5 for a full discussion.

While the development scenarios are described in detail in Section 3.3, a brief overview is provided here (in Table 3-1) to illustrate how the model works.

**Table 3-1: General Summary of Model Parameters**

| Activity/Disturbance | Geographic Representation in the Model |
|---|---|
| 2D Seismic Exploration | **Line.** These lines represent a typical seismic vessel's tracks within an area sampled during a single summer seasons (90 day period). |
| 3D Seismic Exploration | **Polygon.** Represented by a 25 km x 25 km square, this area represents a 3D seismic lease area. We assume that seismic vessels tracks are almost completely covering this area within a 90 day period. |
| Vessel Traffic (regular marine traffic moving along prescribed routes) | **Line.** Regular marine traffic moving along known routes (lines) to and from ports on Baffin Island. |
| Support Vessel Traffic (traffic related to oil and gas exploration activities) | **Polygon.** We assume that the support vessels stay close to the seismic vessels during a typical seismic operation. This is represented by a polygon buffering the seismic area. |
| Supply Vessel | **Line.** Supply vessels move to and from ports on Baffin Island to seismic ships or drill ships within the scenario polygons. |
| Helicopter traffic | **Line.** Helicopter traffic is represented by a straight line connecting ports on Baffin Island and seismic areas or drill ships. |
| Exploration Drilling Vessels | **Point.** Drilling vessels are represented as a point given that they are stationary during operations. |

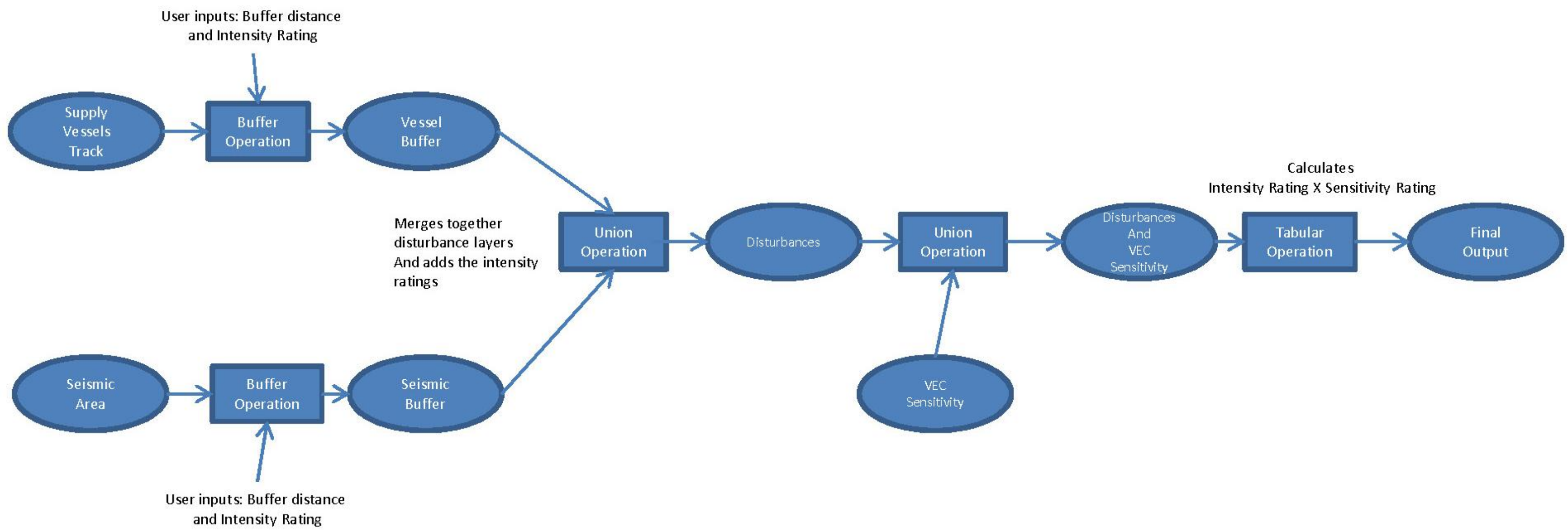
Each activity was given one or more VC-specific zone(s) of influence and effect scale(s) (intensity). For example, vessel traffic had two buffers, one for vessel strikes and one for communication masking, each having a particular intensity associated with the type of activity. The GIS model automates this process allowing the user to enter a buffer distance and intensity for each type of activity.

Where buffers overlap, the model adds their intensities, thus resulting in a higher cumulative disturbance for that area. But as described above, disturbance is only half the equation, as the sensitivity of an area for a given VC is also important. Thus, the disturbed areas (buffers) are overlaid with the previously developed VC sensitivity layers. When overlaying the anthropogenic disturbance buffers with the VC sensitivity layers, the GIS model multiplies the activity's intensity rating with the VC's sensitivity rating to give the final output rating.

The model makes it possible to automate the process of buffering, manipulating and combining spatial data into one resultant layer. Furthermore, it facilitates the analysis of different scenarios or disturbance ratings; simple lookup tables in the model allow easy changes to zones of influence or intensity ratings.

Figure 3-1 illustrates the processes involved in creating the model's final output. This simple model only has two disturbance layers, whereas those prepared in association with this report have several more. In this case, we use a minimum and maximum buffer distances to create best and worst case scenarios. A fuller description of the technical details associated with the model can be found in Appendices A (the architecture of the model) and B (the values used for the zones of influence and scales of negative effects).

## Figure 3-1: Simplified Model Diagram



## 3.3 Development Scenarios

Development scenarios were created using information from a number of sources, including oil and gas development currently occurring on the Greenland side of Baffin Bay. For example, the exploration drilling scenario is modeled after Cairn 2011. Seismic scenarios are based on various Canadian projects. All scenarios are built for a 90 day summer (ice off) season. A general summary of these activities is provided below, with additional details in Table B1, Appendix B.

Several important caveats bear mention.

First, these are development scenarios, not predictions of what development is likely to occur in the Arctic. While the intent is to make them realistic, they are illustrative and do not represent plans. They are merely chosen to illustrate certain situations and serve as a basis for evaluating associated effects. As described above, central premise of this approach is that the development scenarios should be adjusted as new information becomes available. The GIS-based cumulative effects model is built in a way to facilitate this, making it easy to explore the potential implications of changing the location or nature of development activities.

Second, there can be variation in the way development is carried out. For example, in terms of oil and gas exploration programs can vary depending on type of equipment, nature of survey, depth of drilling target, etc. The development scenarios are chosen to be broadly representative of what might occur. But as is true with all elements of the cumulative effects model, their predictive value will be improved when they are recalibrated based on new information and actual experience.

### 3.3.1 Oil and Gas Exploration

The oil and gas exploratory phase typically involves one or more kinds of seismic surveys to provide data about the subsurface geology, followed by exploration drilling to confirm the presence or absence of hydrocarbons.

**Seismic Activities**

Seismic energy waves propagate through ‘overburden’ rock to hydrocarbon reservoirs and are then reflected back to receivers where they register as a pressure pulse, providing an acoustic image of the subsurface. Seismic surveys can either be two dimensional (2D) or three dimensional (3D), the latter of which is more expensive but produces more extensive data.

Offshore seismic activities are conducted from a seismic survey vessel towing a submerged acoustic energy source array. The vessel will traverse along predetermined lines in the area while the arrays discharge at regular intervals. Offshore seismic is conducted during the open water season, which varies by location but may span from July through October (the cumulative effects model assumes a 90 day period). The *Statement of Canadian practice with respect to the mitigation of seismic sound in the marine environment* (DFO 2010) recommends minimum mitigation standards for seismic operations in Canadian waters including establishing safety zones of at least 500 m around the air source array, ramp-up procedures for starting up the airguns, shut-downs of the array if marine mammals are within the safety radius during operation, and use of a mitigation gun during periods of line change in low visibility.

The seismic vessel may come to shore for resupply. Depending on the duration of the particular survey, the seismic vessel may be supported by other vessels or aircraft to provide supplies, crew changes and ice management support. Of note, new methods for on-ice and below ice seismic surveys are being tested.

**Exploration Drilling**

Drilling is required to confirm the presence or absence of hydrocarbons once seismic surveys have identified targets of interest. Exploration drilling involves mobilizing the drilling rig to the site, positioning on site, drilling and testing the well(s), abandoning the wells, and demobilizing the drilling rig. A variety of structures might be used for drilling, including pier platforms, artificial islands, Mobile Offshore Drilling Units (MODUs), jack-up rigs, semi-submersible (i.e., anchored platforms), and drillships.

The model developed here assumes ship-based exploratory drilling. This requires support/supply vessels to transport equipment, supplies and personnel to the rig. Helicopter support is also often needed. In addition to offshore facilities, operations may require a base or support facilities onshore for equipment storage. Waste generated includes drill cuttings, drilling fluids and chemicals, cement, sewage, drainage, rig wash, assorted solid wastes and atmospheric emissions.

Offshore exploratory wells are drilled in a number of sections of decreasing diameter. Steel casing is then run down the well and cemented in place. Drill cutting and fluids are returned to the surface in the space between the drill string and steel casing, except for the initial spudding of the top section of the well when drill cuttings and aqueous muds are released directly to the surrounding seabed. Drilling fluid is recycled and used more than once prior to disposal.

If hydrocarbons are encountered, the potential production of the well is tested. In a well test hydrocarbons are allowed to flow up the well bore to the rig under controlled conditions so that samples can be taken for analyses and to determine the capability of the reservoir to deliver oil and/or gas. Well testing also usually involves flaring/burning of the reservoir oil and/or gas. Once testing is complete, mechanical packers and cement plugs are used to seal the well and the casing is cut below the seabed and removed.

### 3.3.2 Other Development Activities

Other important Arctic development activities include fishing, other shipping activities (including cruise ships), tourism, and the transport of mining products. These are in many ways similar, related to the movement of ships in the marine environment.

## 3.4 Environmental Effects of Activities

This section describes the environmental effects of development activities on the four VCs analyzed: bowhead whales, toothed whales, thick-billed murre, and the commercial turbot fishery. Appendix C lists all the values to characterize the effect of development activities on VCs. The interaction between each of the four VCs and each of the activities is characterized by:

- The zone of influence over which the effect occurs. Since the exact distance is unknown, a minimum and maximum potential value are included for each interaction.
- The scope of the effect, which is calculated as the product of the duration of the effect (the proportion of the summer season when it will occur), the probability of an effect, and the consequence of an effect.

Effects on VC's are summarized into four categories:

- **Change in habitat**—includes effects caused by sensory disturbance (due to communication masking, artificial lighting, visual disturbance), displacement from habitat due to physical loss (due to changes in food supply distribution and abundance, nesting or mating habitat, etc.) or alteration (i.e., icebreaking, acoustic disturbance, etc.)
- **Change in behaviour**—includes effects caused by sensory disturbance (i.e., altered movement or migration patterns, avoidance, etc.)
- **Change in health, injury, or mortality risk**—includes chronic health effects resulting from contaminated habitat or food sources, damage to sensory organs (i.e., TTS and PTS), altered energy expenditure, vessel strikes, and abandonment of young due to disturbance (i.e., birds abandoning nests due to disturbance).
- **Change in access to resources**—includes reduced commercial catches and displacement of commercial fishing vessels due to limitations on access to fishing areas, and loss of access to resources due to tainting or contamination concern.

### 3.4.1 Bowhead Whales

Activities associated with shipping and oil and gas development in the Eastern Arctic could result in changes in feeding, migration and the rearing of calves (i.e., nursing) under some circumstances. Potential changes in bowhead health may include increased risk of mortality or injury (due to vessel strikes, for example), permanent and temporary hearing loss, non-auditory physiological effects (e.g., stress), reductions in communication (i.e., masking) and reduced prey availability.

The operation of the seismic arrays and the associated generation of underwater sound could potentially result in changes in habitat use by bowhead whales and possibly affect bowhead whale health. Vessel operation and exploratory drilling will also generate underwater noise, which can influence the spatial distribution of bowhead whales.

#### 3.4.1.1 Vessel Traffic

Vessel traffic associated with the development scenario includes the seismic vessel, supply vessels, support vessels, and refuelling vessels. Increased vessel activity may potentially lead to vessel – whale strikes (change in health) and acoustic-related effects (change in behaviour, displacement from habitat, and communication masking) on bowhead whales.

Vessel strikes of slow moving whales, including bowheads, are more likely to occur when ships 80 m and longer are travelling at 14 knots or faster (Laist, *et al.* 2001). Vessels travelling at lower speeds (<14 knots) are less likely to cause direct mortality in large cetaceans and also tend to cause less behavioural disturbance (Laist, *et al.* 2001). It is assumed that vessels associated with development scenarios in the eastern Arctic will not exceed a maximum cruising speed of 14 knots when mobilizing to, and demobilizing from, the Program area. This minimizes the potential for direct mortality of bowhead whales as a result of vessel strikes. Seismic vessels operate at very low speeds (~4.5 knots), when acquiring seismic information, hence whale-vessel strikes are unlikely during this activity. It is also assumed that given the low intensity of vessel traffic and the area that could be transited by these vessels that the potential for whale strikes is low and that risk to the population is therefore minimal.

Supply and support vessels will generally accompany a seismic vessel during seismic acquisition and provide support to drilling platforms during the exploratory drilling phase of development and will, therefore, be traveling at low speeds during seismic and drilling operations. They are also used for refueling or resupplying the seismic vessel or drill ships and will be travelling along defined shipping routes to the nearest supply port. During transit, and operation within the development area, all vessels are expected to comply with a speed restriction of less than 14 knots to reduce the likelihood of direct mortality of a bowhead whale. Mitigation typically includes Marine Mammal Observers (MMOs) on the seismic vessel and support vessel to ensure potential interactions with bowheads are further minimized.

Underwater acoustic emissions from traveling vessels may result in changes in bowhead behaviour such as changes in surfacing, breathing and diving cycles (Richardson, *et al.* 1995). Studies have shown that bowhead whales will temporarily avoid transiting vessels up to 4 km away (Richardson and Fraker 1985). Conservative estimates of maximum and minimum zones of influence for the effects of underwater vessel noise were used in the model to demonstrate the variation and relative uncertainty associated with the effects of underwater noise on cetacean species. Vessel traffic associated with development activities is expected to occur for the duration of the operating season (open-water); therefore, the duration of effects was given a value of 1.00.

All vessels used for the Programs will comply with the *Arctic Waters Pollution Prevention Act*, conform to Regulation 4 of the Annex IV of MARPOL convention and ensure regular testing of effluent takes place to conform to regulatory requirements. No bilge water will be discharged and solid wastes will be either incinerated or disposed of on land after the Program. Therefore, no environmental effects associated with waste management from seismic ships, drill ships and support vessels are expected on bowhead whales; this is reflected in the very low probability of effects on bowhead whales due to pollution.

#### 3.4.1.2 Seismic acquisition

Several recent reviews are available on reactions to seismic sound by marine mammals (Gordon, *et al.* 2004; Miller, *et al.* 2005; Moulton and Miller 2005; Stone and Tasker 2006; Gailey 2007) (Abgrall, *et al.* 2008). Generally, baleen whales (the group to which bowhead whales belong) tend to avoid active airgun arrays, but the distance at which they react can be variable. They often show no overt reactions at distances greater than a few kilometres; however, when exposed to strong noise pulses at closer distances, they often react by deviating from their migratory course or interrupting their feeding and moving away. From a review of 201 seismic surveys conducted in United Kingdom waters between 1997 and 2000, baleen whales showed a statistically significant displacement of ~600m when comparing closest distance of approach of the whales with and without seismic array activity (Stone and Tasker 2006).

While seismic operations within the defined area will occur over the course of the open-water period (depending on ice and weather conditions), when bowhead whales are most likely to be present, effects to feeding whales from the passing array will be short-term in duration; and localized in nature Creation of underwater noise by the arrays will be continuous; however, given the transitory nature of the seismic activity relative to any specific geographic location within the survey area, effects relating to feeding on bowhead whale are likely to be infrequent.

#### 3.4.1.3 Drilling

Underwater noise from drilling rigs is attributed to two sources; the drilling process and the propellers keeping the drill ship/rig in position. Noise produced by the propellers will result in the same effects for bowhead whales as regular vessel traffic (see above), but the spatial extent of the acoustic disturbance will be limited to the area immediately surrounding the drilling activity. Bowhead whales have been observed to avoid drilling operations within a radius of up to 10 km in Alaska (Richardson, *et al.* 1990). This value was used as the maximum zone of influence for the effects of drilling noise on Bowheads in Appendix C; however, it is important to note that this reaction may not be exclusively attributed to drilling noise given the volume of vessel traffic associated with an active drilling rig. The greatest risk to bowhead whales from underwater noise produced by drilling rigs is displacement from critical habitat (e.g., feeding areas or migration routes) and communication masking. Since the drill rig is operating in a fixed geographical position for the duration of the open water season, the duration of effect and probability of these effects potentially occurring are rated relatively high[6]. Due to the nature of the noise generated from drilling activities, the risk of physical injury is low.

#### 3.4.1.4 Support Aircraft Operations

All support Aircraft Operations are expected to follow EISC Overflight Guidelines (Environmental Impact Steering Committee, 2004) when possible. Low flying aircraft (≤ 300 m altitudes) may initiate short-term changes in bowhead behaviour including: rapid dives, avoidance of aircraft, and dispersal (Richardson and Malme 1993; Patenaude, *et al.* 2002). To effectively mitigate potential effects of aircraft use on bowhead whales and other marine mammals, flying altitude restrictions will be implemented at >300 m except for takeoff and landing (Environmental Impact Steering Committee, 2004). Therefore, aircraft effects on bowhead whales are unlikely to occur. Given the confidence of

[6] Note that the sensitivity of the area (i.e., the likelihood that bowhead whales are feeding in the same location as the drill ship) ius not considered here. That information will comes from the sensitivity maps.

effective mitigation, the zone of influence for sensory disturbance to bowhead whales due to aircraft operations was conservatively estimated to be 0 km (min) to 0.5 km (max). Given the intermittent nature of support aircraft operations, the duration of effect and probability of effect were similarly low (Appendix C).

### 3.4.2 Toothed Whales

As with bowhead whales, toothed whales could potentially be affected by shipping or oil and gas development activities that result in changes in feeding, migration and the rearing of calves (i.e., nursing). Toothed whales (including beluga, narwhal, and killer whales) are susceptible to less risk of mortality and physical injury due to ship strikes because they are generally more agile and faster that the larger baleen whales. Possible primary effects of concern for toothed whales include permanent and temporary hearing loss, non-auditory physiological effects (e.g., stress), reductions in communication (i.e., masking) and reduced prey availability.

With the exception of some species specific differences in physiology, general effects from development activities are expected to be similar for all cetaceans. Values incorporated in the model are identical for bowhead whale and toothed whale (Appendix C). Variation in the outcome of the model results from differences in VC specific habitat sensitivity and is more thoroughly discussed in Section 3.6.

The following information applies specifically to toothed whales.

#### 3.4.2.1 Vessel Traffic

The likelihood of a highly mobile (e.g., fast swimming) animal, such as a beluga whale, being struck by vessels associated with oil and gas development activities is minimal. Studies on whale-vessel strikes suggest the larger baleen whales are more prone to strikes than their smaller, toothed counterparts (Laist, *et al.* 2001). As described above for bowhead whales, mitigation is expected to reduce the risk of vessel strikes.

#### 3.4.2.2 Seismic Acquisition

The dominant frequencies of beluga echolocation range between 20 – 60 and 100 – 130 kHz, while their hearing is most sensitive in the mid-frequency range, between 32 – 108 kHz (Richardson, *et al.* 1995; Klishin, *et al.* 2000). Most energy produced by airgun arrays is below 0.1 kHz, well below the frequencies of the calls and optimum hearing of belugas. As a result, while seismic noise is potentially audible, belugas may be rather insensitive to seismic sound pulses (Richardson, *et al.* 1995). However, recent studies measured substantial high frequency energy output from airguns, at levels clearly audible to most—if not all—cetacean species (Goold and Coates 2006).

It is important to note that both the likelihood and severity of biological effects on beluga whales that may result from seismic surveys are likely to vary with local environmental conditions (e.g., ice coverage, bottom topography, sea state), as well as the condition of the organisms themselves (e.g., breeding state, nutritional state). Additionally, the paucity of scientific information, particularly with respect to field experiments, makes it extremely difficult to evaluate effects of seismic sounds on this particular species.

#### 3.4.2.3 Drilling

Effects from drilling are expected to be similar to those described for bowhead whale (see above).

#### 3.4.2.4 Support Aircraft Operations

Aircraft flying at low altitude are known to disturb beluga whales (Richardson, *et al.* 1995). Patenaude, *et al.* (2002) documented short-term behavioural responses of belugas to a helicopter and twin otter fixed-wing aircraft, including short surfacing, long dives, sudden dives, diving under ice pans, abrupt changes in direction and temporary displacement. Some individuals react to aircraft flying at altitudes as high as 500 m, but reactions are more common at altitudes 150 – 200 m (Patenaude, *et al.* 2002). To mitigate these effects, flying restrictions are expected to require all Project-related aircraft to maintain a minimum altitude of 450 m.

### 3.4.3 Thick-billed Murre and other Migratory Birds

Davis Strait and associated coastal areas of Baffin Island, Devon Island, and Ellesmere Island provide important habitat for a number of seabirds, including Thick-billed murre, Black Guillemot, Northern Fulmar, and Ivory Gull. While all of these species are potentially relevant for modeling, Thick-billed murre may be the most appropriate species on which to focus, given that it has large coastal colonies, forages extensively offshore, and appears to be relatively sensitive to disturbance. Guillemot colonies are smaller, nests are better protected, and they forage closer to shore. Ivory Gulls generally nest far inland, and are unlikely to be exposed to underwater disturbances. Fulmars also have large coastal colonies, but in some parts of their range have habituated well to disturbances.

The discussion of anthropogenic effects on arctic seabirds focuses most frequently on oil spills, which are beyond the scope of the cumulative effects scenarios analyzed here. There is relatively little literature concerning routine effects of disturbance, and many reports focus on anecdotal observations, rather than systematic studies. However, by reviewing literature on the aforementioned species, as well as other common arctic seabirds such as Thick-billed murre, it is possible to characterize the issues that are likely to be of greatest concern. A generic guideline suggested by Chardine and Mendenhall (1998) is that disturbance at a nesting colony should be suspected and monitored if human activity is audible, is visible within 1 km, or if birds are observed to maintain a heightened level of alertness or other evidence of response to human activities. However, it should be noted that disturbance thresholds have generally not been experimentally tested, and therefore predictions are largely based on the relative intensity of stimuli within the context of behavioural responses that have been documented.

#### 3.4.3.1 Vessel Traffic

Disturbance to seabirds can be caused by vessels near shore. In particular, Thick-billed murres have been reported to abandon colonies in response to increased boat traffic (Barrett and Vader 1984). There is potential for vessels to temporarily displace feeding seabirds from preferred foraging areas, resulting in additional energy expenditure and possibly reduced foraging efficiency (Bryant, *et al.* 1999). Since many seabirds have high metabolic requirements, they can be sensitive to increased energetic demands or reduced rate of food availability and intake. Thick-billed murre is considered sensitive to changes in prey distribution and abundance (Gaston and Hipfner 2000). Black Guillemots forage closer to shore, and could be negatively affected by disturbance of prey communities in the nearshore zone (Butler and Buckley 2002). Considering the relative size of foraging areas in comparison to the locations that might be disturbed by vessel traffic, and the temporary nature of such disturbance, this effect is likely to be of low consequence, and the probability of occurrence is estimated at 0.2.

#### 3.4.3.2 Seismic acquisition

Underwater noise created by seismic acquisition is unlikely to be an important concern for seabirds. At close range, it may prompt a change in behaviour in the form of birds relocating to forage at a greater distance from the source of noise; however, this effect would already be captured in the disturbance effects noted above.

#### 3.4.3.3 Drilling

Noise-related effects are as noted above for seismic acquisition. Operation of drilling rigs within sight of breeding colonies may cause disturbance for some species, but there is likelihood of habituation to a relatively distant and constant stimulus. As with vessel traffic, stationary structures such as drilling rigs have the potential to displace seabirds from preferred foraging areas. Considering the small footprint of such structures and the potential for habituation, the probability of an effect is considered low and estimated at 0.2.

#### 3.4.3.4 Support Aircraft Operations

Overflights by helicopters and fixed-wing aircraft are consistently identified as the greatest stressor on seabirds at breeding colonies. Such disturbance can stimulate panic flights, leaving eggs or chicks vulnerable to predators or in the case of murres to the direct loss of eggs, since they incubate them on their feet (Chardine and Mendenhall 1998). The disturbance threshold for Thick-billed murres has been reported as up to 1 km for helicopters (Ainley, *et al.* 2002). Thick-billed murres are also known to temporarily abandon their nests in response to overflights, as well as other sensory disturbance such as gunshots, but threshold distances have not been estimated (Curry and Murphy 1995, Chardine and Mendenhall 1998). Northern Fulmars appear to be somewhat more tolerant, showing little reaction to aircraft as close as 100 m at some colonies, although tending to be more sensitive at remote locations (Hatch and Nettleship 1998). While Ivory Gulls have bred along an active airstrip in Greenland and on military bases in Russia, the abandonment of a nesting colony on Seymour Island and a decline in the Brodeur Peninsula population are attributed to a heavy volume of traffic from helicopters and other low-flying aircraft (Mallory, *et al.* 2008). Since the majority of research suggests that murres and other seabirds respond negatively to aircraft, but there are occasional exceptions, the probability of disturbance caused by aircraft is estimated to be 0.8.

#### 3.4.3.5 Human Activity

Disturbance can also be caused by human activity in the vicinity of breeding colonies. Human presence in nesting colonies can cause temporary desertion and failure, largely by facilitating attacks from opportunistic predators on abandoned nests (Birkhead and Nettleship 1980, Gaston and Donaldson 1994, Butler and Buckley 2002). However, there is also some evidence that colonial seabirds may become habituated to human activity over time (Fjeld, *et al.* 1988, Chardine and Mendenhall 1998). Northern Fulmars appear to habituate to various forms of disturbance (Hatch and Nettleship 1998). Ivory Gull also seems relatively tolerant of human presence, even visiting active camps (COSEWIC 2006, Mallory, *et al.* 2008). Given that terrestrial activities will not occur within colonies, the probability of any such disturbance affecting seabirds is low, and is estimated at 0.1.

### 3.4.4 Commercial Turbot Fishery

There are three main commercial fisheries in Nunavut. These are the turbot (Greenland halibut), shrimp and Arctic charr fisheries. The turbot fishery consists of an offshore fishery in Davis Strait and a winter fishery in Cumberland Sound. Since the analysis presented here focuses on the summer season, activities would not affect the winter turbot fishery. The shrimp fishery is also conducted offshore in Davis Strait. The Arctic charr fishery occurs in rivers and coastal areas along the east coast off Baffin Island. The coastal fishery is the portion of this fishery that could potentially experience cumulative effects based on the scenarios provided for this exercise. The offshore turbot fishery has been chosen for this exercise as it has the greatest potential for effects occurring and is also the largest fishery in Nunavut. Offshore turbot fisheries occur in deep water often at depths of 1,000 m or greater.

Industries which could potentially conflict with fishing activities and result in cumulative effects on the turbot fishery are shipping and oil and gas exploration activities. It is probable that shipping and fisheries will continue to increase over the next 10 years. Nunavut is also exploring opportunities to establish new fisheries which may also play a role in contributing to cumulative effects in the future.

It is important to note and caution that no studies have been conducted on the effects of oil and gas activities on turbot or turbot fisheries. It is also difficult to compare studies on other fisheries with that of the turbot fishery. Effects can vary by species, temperature, depth and potentially other factors. For example, most studies on the effects of seismic on fish or fisheries have been on fish which contain an air bladder which turbot do not. Seismic sound may affect fish with air bladders differently than those without.

Potential cumulative effects on the offshore turbot fishery may occur due to increased vessel traffic, seismic acquisition and drilling. Support aircraft operations would not contribute to any cumulative effects to the fishery.

#### 3.4.4.1 Vessel Traffic

Underwater noise from shipping is unlikely to contribute to effects on turbot or the fishery and therefore no zone of influence has been provided for ship noise nor the behavior of turbot.

#### 3.4.4.2 Seismic Acquisition

Boudreau, *et al.* (1999) identified a number of potential effects on fisheries from seismic activity such as:

- Decreased catch rates due to scaring (displacement) of fish
- Interference with fish spawning
- Space conflicts with existing fishing activities (and potential for damage to equipment such as nets)
- Mortalities in a number of species and a number of life stages (Boudreau, *et al.* 1999).

**Displacement and other Behavioural Changes**

Seismic activities can displace some fish species from an area where a fishery is occurring. Reductions in fish density have been recorded as high as 50% (NERI 2009). Displacement of fish for some fisheries can range up to 10 km or more (NERI 2009) and displacement is likely to be higher closer to the sound source. A zone of influence was selected between 1 to 10 km for displacement. The upper limit of 10 km is likely a conservative estimate as studies reporting displacement were conducted on species containing an air bladder and not on deep water flat fish such as turbot which have no air bladder. The absence of an air bladder in fish such as turbot as previously discussed can reduce the effects from sound as compared to species which have air bladders. While displacement of fish may also occur between 0 to 1 km, zero was not used as a fisheries vessel would be at least 1 km or more from a seismic vessel for safety purposes.

Fish may also react behaviourally to seismic sound beyond the 10 km range to distances greater than 30 km (NERI 2009). These reactions are generally less intense in nature as compared to being displaced from a wide area. These behavioural changes can include startle responses or changes in movement such as avoidance behavior by swimming short distances away from the sound, often doing so by swimming downwards. As previously discussed the deep water habitat of turbot and their lack of an air bladder, reduces the potential for effects as result 30 km is considered a conservative estimate. However effects although potentially low in probability cannot be fully discounted as no studies have been conducted on turbot and their response to seismic sound.

The potential for ecological effects on fish of a fishery are considered low however the ability to catch fish is dependent on the target species (DFO 2004) as species may respond to seismic sound differently. It is unlikely the effects of seismic would lead to long term changes in average catch rates or to the size of fish stocks in general (Gausland 2003).

**Interference with Fish Spawning**

There would be no interference with turbot spawning and seismic activity. Seismic activity would occur during the summer months while turbot spawn in winter.

**Space Conflicts**

Space conflicts, refers to the situation where a fisheries vessel must or will change its area for trawling due to the presence of a seismic vessel. Interaction between fishing vessels and seismic and other activities is inevitable in areas where activities are highly concentrated (Canada – Nova Scotia Offshore Petroleum Board 2003). However, in the Eastern Arctic, it is unlikely that areas of high concentrations of industrial activities will overlap areas of high fishing activity as is seen in the offshore areas of eastern Canada. Although the probability is low for special conflicts to occur the effect if a conflict occurred could result in reduced catches of turbot.

There is no data on the distances that fishing vessels use to avoid seismic vessels. The distance is determined by the ships captains; knowing the location of each other's vessel, the depth of water where an activity is occurring, weather, ice, and whether seismic or fishing gear is in the water. For the purpose of this assessment, it was assumed that active seismic and fishing vessels would maintain a minimum distance of 1 to 5 km from the seismic vessel.

**Mortalities**

Low densities of turbot eggs and larvae can be found in the upper 10 m of the water column and are widely dispersed. Due to the presence of some eggs and larvae in the upper water column there is the potential for small numbers of turbot eggs and larvae to incur mortality by seismic sound. As turbot grow from larvae to juvenile to adult they move downwards into deeper water. The older larger turbot, which are the target for commercial fisheries, are generally found at depths of 1,000 m or greater. At these depths, seismic sound would not cause mortality. Mortality of larvae and eggs would be localized and limited to small number of individuals. Effects on turbot populations would be negligible. No zone of influence is required related to turbot mortalities.

#### 3.4.4.3 Drilling

**Underwater Noise – Displacement**

Displacement is most likely to occur with fish which are territorial. Turbot are not territorial and are migratory in nature. There is still potential that displacement may occur locally. Any displacement effect would likely also be temporary in nature as fish generally react less to continual sounds as would occur from drilling activities. The probability of an affect would be low, within a short range (1 – 2 km) of the drill itself and the duration temporary. The consequence of the affect would also be expected to be low to nil. As the potential effect on turbot would not affect the fishery, no zone of influence is identified.

**Drilling Mud Disposal – Chronic Health Affects**

Dispersed muds, cuttings and associated hydrocarbons can cause localized sublethal effects for some bottom dwelling organisms (e.g., benthos) (Boudreau, *et al.* 1999), but generally would not affect pelagic fish. The zone of influence from drilling mud disposal is generally limited to less than a kilometer from the disposal site. As EEM studies sometimes extend to 5 km from a drill to ensure that monitoring extends beyond the zone of influence however, drilling mud is generally not detected after several hundreds of meters. As precautionary approach a conservative zone of influence used from 0 to 0.5 km. Effects would also likely decrease rapidly once drilling operations ceased (Boudreau, *et al.* 1999). Due to the migratory behaviour of turbot as well as their large spatial variability, it is unlikely any potential effects would be identified at a population level. Therefore the probability of chronic health effects from drilling mud disposal is low and the duration period would be short. No effects to the commercial fishery would be expected.

**Drilling Mud Disposal – Tainting**

There is little evidence to suggest concern over possible tainting of finfish resources due to drilling discharges (Boudreau, *et al.* 1999). The potential impacts of tainting can be expected to be less with isolated exploratory wells than with a production field and should not be an issue where water-based muds are used (Boudreau, *et al.* 1999).

**Space Conflicts**

For safety purposes, fishing vessels would require to stay a certain distance from a drilling rig or drill ship. Boudreau, *et al.* (1999) assumes a safety radius of 1 to 1.5 km around a drill ship. This safety radius may be larger under arctic conditions due to the potential of ice. The locations where drilling is occurring will have a direct effect on the probability of a conflict with fishing vessels. Due to the limited number of drill ships expected at any exploration area and number and depth where fishing vessels would be operating the probability of an effect is low, while duration would depend on the location of the drill ships.

## 3.5 Sensitivity of an Area

A summary of key information is provided below so that readers can understand the basis of the relevant sensitivity layers. A full description of the development of the sensitivity layers can be found in Nunami Stantec (2010).

To maintain a level of consistency in the application of the PEMT, the development of the sensitivity layers for each selected Valued Component (VC) in this study area was based on the methodology undertaken for the Canadian Beaufort Sea DST (Gartner Lee Limited 2008). As such, the decisions were made with a combination of various sources of relevant ecosystem (habitat use and availability) and socio-economic information. Each rating and its spatial distribution across the study area was dependent on data availability. While the general information on the selected VC is comprehensive, much of the habitat usage by VC is closely correlated with the seasonal patterns of sea ice. As a result, the spatial distribution of habitat usage may vary substantially on an annual basis and can be highly dependent upon environmental conditions. Taking this variability into consideration, sensitivity ratings were applied based on conservative interpretations of potential effects from projects among seasons.

### 3.5.1 Sensitivity Ranking Methodology

Sensitivity ranking considered ecological factors and habitats and the nature of potential effects on each of the VC. Factors considered in developing the rating system included sensitivity to development, susceptibility to habitat change for VC, life history and occurrence in the study area, and importance to local communities.

The process of rating the sensitivity layers for each VC was largely subjective and based on the unique characteristics of each component. However, to maintain some level of consistency in defining and assigning sensitivity rankings, a framework was developed based on the same guiding principles that were developed for the Beaufort Sea DST (Gartner Lee Limited 2008). Ranking systems considered habitat value and the susceptibility of those habitat values to development. The principles guiding this process were (Gartner Lee Limited 2008):

- Habitats that have specific value for a suite of VCs were incorporated and mapped.
- The ecological value of habitats that support the viability of the population of a VC were positively reflected in the sensitivity rating for an individual VC.
- The cultural value of areas to local and indigenous people was positively related to the sensitivity rating of a VSEC; particularly in regard to the ability of the area to support culturally significant activities, history, or education.
- In rating layers the precautionary principle was applied, in that in areas with lesser certainty of either the value of habitats or the implications of development were rated with higher sensitivity.

For each VC, habitat within the Eastern Arctic study area was assigned a sensitivity rating from 1 – 5, where the highest rating (5) identified areas that support a specific ecological function or process that is essential to the survival of the species or cultural resource.

- High Sensitivity – Rating 5
- Moderate-High Sensitivity – Rating 4
- Moderate Sensitivity – Rating 3
- Low-Moderate Sensitivity – Rating 2
- Low Sensitivity – Rating 1.

The lowest sensitivity ratings (1) include areas that are infrequently used and of relatively low value to the VC's and VSEC's viability. Moderately-Low, Moderate, and Moderately High ranking indicate intermediate levels of sensitivity. All ratings were defined and assigned based on the unique characteristics of each component and were determined on available literature, spatial data, expert opinion and professional judgment. For all VC's, areas that are provincially or federally protected are assigned a high sensitivity value. The following general guidelines were used to define sensitivity ratings for each of the valued components.

### 3.5.2 Seasonality

Some VCs display prominent seasonal use of particular habitat and potential effects from development may also be limited temporally by season, therefore seasonality was considered when ranking sensitivity. As sea ice coverage is the major limiting factor to shipping and marine based oil and gas activities in the study area. The analysis provided here is based on a 90 day summer (open-water) season which is generally expected to occur between early July and late October.

### 3.5.3 Bowhead Whales

Sensitivity rankings for eastern arctic bowhead whales were developed using two primary types of information: (1) known and likely range/distribution of this species (as determined from available literature sources [e.g., COSEWIC status reports] and professional experience in this region); and (2) ecological sensitivity described recently by Laidre, *et al.* (2008). Hence, application of the ecological sensitivity components included by Laidre, *et al.* (2008) may not always be consistent with known locations of bowhead habitat. It is important to note that the definition of winter (November – June) and summer (including July – October) heavily influences the sensitivity layers given the very large influence of ice in this region. To address and incorporate the extreme variability imposed by the dynamic ice regime, 30 year median ice charts, produced by the Canadian Ice Service, were used in applying the ecological sensitivities (as described by Laidre, *et al.* 2008, and others) and known ice distribution.

Lastly, a maximum sensitivity approach was used in differentiating between sensitive bowhead whale habitat types. In other words, if an area could be considered as having two different sensitivity rankings (for one or more months), only the highest sensitivity ranking was mapped.

Sensitivity ratings for the summer open water season are presented in Map 1.

**High Sensitivity (5)**

Isabella Bay, and the proposed Ninginuaik National Wildlife Area, is a well-known critical bowhead whale feeding habitat and hence designated as highly sensitive.

Highly sensitive habitat for bowhead whales also includes important summer feeding areas.

**Moderate-High Sensitivity (4)**

A moderate to high sensitivity rating was given to areas that provide valued seasonal habitat for bowhead whales. This includes shallow water (approximately 10 m to 100 m depth) and the continental shelf (approximately 100 m to 300 m depth) which provides habitat year round.

Much of the summer continental shelf and shallow-water habitat within the Eastern Arctic study area is classified as moderate to high bowhead whale habitat sensitivity. The Lancaster Sound region was designated as moderate to highly sensitive summer bowhead whale habitat for the increased number of animals in this region during July. Two types of moderate to highly sensitive bowhead habitat were identified within the Eastern Arctic study area during the open water season:

1. Those regions approximating the main shear-zone/lead off the coast of Baffin Island
2. Lancaster Sound and northern Baffin Bay. Large numbers of bowhead whales are known to use Lancaster Sound in June and evidence exists to suggest open-water regions next to pack-ice in northern Baffin Bay are used by numerous whales in late winter (June).

**Moderate Sensitivity (3)**

Moderately sensitive bowhead whale habitat includes areas of dense annual pack-ice and summer habitat where shear zones, leads, open water and open water adjacent to pack-ice are present.

In the summer (July primarily) the offshore region within the study area joining Baffin Bay and Davis Strait contains dense annual pack-ice, and hence this is the basis for the ranking of moderate sensitivity in this region.

**Low-Moderate Sensitivity (2)**

Areas that overlap with known bowhead whale habitat, or adjacent to known bowhead whale habitat were rated as low to moderately sensitive. This rating was also given to areas with loose annual pack-ice and shelf break habitat in the summer.

In the summer, bowhead whale habitat ranked with low to moderate sensitivity (4) was defined to represent the loose off-shore annual pack-ice in southern Baffin Bay and northern Davis Strait. This would be primarily for July and August given that ice is largely absent in this region (30 year median) in September and October.

**Low Sensitivity (1)**

Low sensitivity was given to areas where the bowhead whale is not known to be present, but potential habitat exists. This includes areas in the summer months such as shore-fast ice, deep ocean basins, estuaries, and lagoons.

In the summer, low sensitivity habitat in northern Baffin Bay was defined primarily on the basis of the deeper water and distance from pack-ice. Presence of offshore open-water in July in north-western Baffin Bay therefore was designated low sensitivity.

### 3.5.4 Toothed Whales

Sensitivity rankings for Eastern Arctic toothed whales were developed using two primary types of information: (1) known and likely range/distribution of this species (as determined from available literature sources [e.g., COSEWIC status reports] and professional experience in this region); and (2) ecological sensitivity described recently by Laidre, *et al.* (2008). Hence, application of the ecological sensitivity components included by Laidre, *et al.* (2008) may not always be consistent with known locations of toothed whale habitat. It is important to note that the definition of winter (November – June) and summer (July – October) heavily influences the sensitivity layers given the very large influence of ice in this region. To address and incorporate the extreme variability imposed by the dynamic ice regime, 30 year median ice charts, produced by the Canadian Ice Service, were used in applying the ecological sensitivities (as described by Laidre, *et al.* 2008, and others) and known ice distribution.

Lastly, a maximum sensitivity approach was used in differentiating between sensitive toothed whale habitat types. In other words, if an area could be considered as having two different sensitivity rankings (for one or more months), only the highest sensitivity ranking was mapped. Summer sensitivity ranking for toothed whale habitat in the eastern arctic study area is summarized in Map 2.

#### High Sensitivity (5)

Areas identified as highly sensitive for toothed whales includes areas designated as critical for any of the toothed whale species and a spatially limited area (<100 km) during the summer months that provides specific ecological functions essential to toothed whales.

With the exception of the protected areas in the region that overlap with the analysis, highly sensitive summer toothed whale habitat was not identified in the Eastern Arctic study area.

#### Moderate-High Sensitivity (4)

Areas with moderate to high sensitivity in the summer includes habitat with loose (beluga) or dense annual pack ice (narwhal), shallow continental shelf, estuaries, lagoons and fjords for belugas and shear-zone/leads, fjords, shelf-break, deep ocean basins for narwhals.

Summer toothed whale habitat of moderate to high sensitivity was determined primarily to reflect known ranges of beluga and narwhals (north eastern coast of Baffin Island, Lancaster Sound and Devon Island region), their preference for fjords (both beluga and narwhal), shallow continental shelf regions (belugas within their range) and areas of ‘shelf break’ (for narwhals).

#### Moderate Sensitivity (3)

Moderate sensitivity during the summer months was given to areas of open water, shelf-break, and the ice-edge (pack ice next to open water). This rating would also apply to areas that contain moderate to large numbers of toothed whales and shear zones and leads that are utilized by belugas.

Moderately sensitive toothed whale summer habitat was described primarily to capture the ice edge (pack ice next to open water) region of north western Baffin Bay. Moderate to large numbers of toothed whales may potentially occur in the Lancaster Sound region in July and hence this area has been also designated as moderately sensitive summer habitat.

#### Low-Moderate Sensitivity (2)

Loose annual ice or multiyear pack ice in summer and open-water habitat (>20 km from pack ice or land-fast ice or ice edge) in winter is considered low to moderately sensitive habitat for toothed whales.

Coastal summer toothed whale habitat in the south-western corner of the Eastern Arctic study area was identified as low to moderately sensitive habitat primarily on the reasonable likelihood of beluga whale presence in this region.

#### Low Sensitivity (1)

Low sensitivity habitat includes areas where no beluga or narwhal summer habitat is identified, summer offshore (>100 km), deep water (non-shelf break), and open-water habitat.

According to Laidre, *et al.* (2008) narwhal summer habitat is primarily coastal in nature. Similarly, beluga whales prefer coastal environs in the summer. Consequently, low sensitivity summer toothed whale habitat was identified for the majority of the offshore portion of the Eastern Arctic study area. A narrow band of low sensitivity coastal toothed whale habitat, extending south of Clyde River to

Cumberland Peninsula, was identified given that narwhal and belugas are not known to be common in this region.

### 3.5.5 Migratory Birds

Since limited information was available for Thick-billed murre, the ratings used for the environmental sensitivity are based more generally on information available for migratory birds. Habitat given a rating of high sensitivity includes areas globally important migratory birds because they meet any of the following criteria:

(a) Supports 1% of the North American population (following the IBA guidelines)

(b) Supports a very significant (i.e., 10%) portion of the Canadian population of a migratory bird species at any time during the year and/or an endangered species (e.g., breeding areas for the endangered Ivory Gull)

(c) Identified as being either globally or continentally significant Important Bird Area

(d) Legally protected (e.g., national or territorial park, marine protected area, migratory bird sanctuary, critical habitat for VC under the *Species at Risk Act*).

In the study area these areas include:

- NOW Polynya
- Eastern Jones Sound
- Eastern Lancaster Sound
- Cape Hay
- Cape Graham Moore
- Cape Searle (Qaqulluit) and Reid Bay (Minarets; Akpait)
- Cumberland Sound
- Frobisher Bay.

**Moderate-High Sensitivity (4)**

Moderate to high sensitivity was given to areas nationally important to migratory birds including:

- Areas that either support a significant (i.e., 1%) proportion of the national population at any time during the year or have been identified as nationally significant Important Bird Areas.
- Areas identified as key to the national persistence of a migratory bird species. Following (Mallory and Fontaine 2004), areas that support at least 1% of the national population are considered key habitat by the Canadian Wildlife Service and include marine areas within a 30 km radius of the major nesting colonies.
- Biological hotspots identified by Parks Canada, which includes areas of high productivity and numbers of seabirds.

In the study area, these areas include biological hotpots identified by CWS (outside of those areas listed as a 5 above).

**Moderate Sensitivity (3)**

Moderate sensitivity was given to areas that are regionally important to migratory birds because they support a high proportion of the regional population or have been identified as key to regional persistence.

In the study area, these areas include areas of moderate to high densities but less than 1% of the Canadian population, including:

- Coastal areas
- Offshore areas to the limit of summer pack ice
- Floodplains
- Upland areas
- Areas within the known range migratory birds whose populations are heavily dependent on the Canadian Arctic (the PEMT uses the summer range of Baird's Sandpiper).

**Low-Moderate Sensitivity (2)**

Low to moderate sensitivity was given to areas considered locally important to migratory birds. In the study area, these areas include areas with low to moderate densities. This includes areas which, while not permanently covered in ice, are outside the usual ranges of most migratory birds.

**Low Sensitivity (1)**

Low sensitivity was given to areas that have very limited or no use by migratory birds. In the study area, these areas include areas of permanent ice (the summer extent of pack ice).

### 3.5.6 Commercial Turbot Fishery

In developing a sensitivity layer for commercial turbot fishing, the sensitivity rating was dependent on the presence of commercial abundance of turbot and the frequency and amount of documented commercial fishing activity. Currently the commercial fishing season primarily coincides with the open water season which is likely when oil and gas activities would be expected to occur in the study area. Sensitivity ranking for commercial fishing in the eastern arctic study area is summarized in Map 3.

Determination of sensitivity for Commercial Fishing is based on the following.

**High Sensitivity (5)**

High sensitivity areas include those where commercially fished species are present in area, there is a commercial quota established, and there is active commercial fishing.

**Moderate-High Sensitivity (4)**

Moderate to high sensitivity applies to areas where commercially fished species are present and a commercial quota is established, but there is no current commercial fishing activity during open water season.

**Moderate Sensitivity (3)**

Moderate sensitivity was given to areas were commercially fished species are present in area and traditional subsistence fisheries are known to occur.

**Low-Moderate Sensitivity (2)**

Areas where limited information is available but suggests that commercial fish species and habitat may be present were given a low to moderate sensitivity rating.

**Low Sensitivity (1)**

Low sensitivity applies to areas where there is no documented information on presence of commercial fish species and no documented information about habitat for commercial fish species.

## 3.6 Results and Discussion

### 3.6.1 Bowhead Whale

As expected, the model predicts that areas where development activities will be of most concern occur where there is overlap between high risk activities (seismic operations) and bowhead habitat that is considered to be moderately to highly sensitive. Even under the 'maximum effect' model, routine vessel activity and aircraft operations are anticipated to result in very minimal effects, therefore cumulative effects are not expected. Drilling operations include a number of vessels operating in a spatially limited area, combined with underwater noise produced by drilling. This results in a higher risk of cumulative effects on bowhead whales. Under the 'minimum effect' model, effects are expected to limited to areas where seismic operations occur and are largely due to underwater noise produced by the seismic array. Relative to routine shipping and drilling activities, seismic operations are expected to contribute the most to cumulative effects.

In instances where cumulative effects are anticipated, mitigation programs may be effective in minimizing effects to marine mammal populations. The most effective strategy for avoiding effects on marine mammals is careful planning to avoid sensitive spatial and seasonal habitat. The PEMT provides an assessment of habitat sensitivity based on available information, recognizing that in the Canadian Arctic, knowledge on sensitive and biologically important habitat is at a coarse level. Additional surveys will assist proponents and government to more confidently plan and approve project implementation.

Standard mitigation measures regarding seismic testing are outlined in the Canadian Statement of Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (DFO 2010). These include the use of dedicated Marine Mammal Observers aboard related vessels, designation of a marine mammal exclusion zone around active seismic arrays (in which seismic operations are halted when a marine mammal enters the zone), soft-starts (ramp-ups, slowly increasing the intensity of the seismic array to allow marine mammals time to move out of an area) and use of Passive Acoustic Monitoring (although this can be costly and is not yet widely used). Vessel speed restrictions, use of common shipping routes, and minimum aircraft altitude restrictions are also common best practices with regard to minimizing the potential for mammal-vessel strikes and disturbance.

### 3.6.2 Toothed Whales

Although seismic activity is generally expected to have greater effects on toothed whales than drilling or shipping, results from the model illustrate that overall effects are minimized when the activity occurs outside of areas where habitat is considered moderately to highly sensitive. Because the 3D seismic activity occurs in low sensitivity habitat for toothed whales, the model predicts that effects are expected to be minimal. Portions of the 2D seismic survey area overlap with areas that have been identified as moderately to highly sensitive for toothed whales, therefore, cumulative effects in these areas are expected to be higher and proponents may need to consider additional mitigation strategies. Similarly, in areas where drilling (and associated vessel traffic) overlaps with sensitive toothed whale habitat, the risk of cumulative effects is expected to be higher relative to areas where the same activities occur in less sensitive habitat. Mitigation strategies for toothed whales are similar to those for bowheads and are described above.

### 3.6.3 Thick-billed Murre

The cumulative effects experienced by thick-billed murres are, based on the assumptions used in the scenarios, considerably less than those experienced by whales. In fact, even the ‘maximum effect’ model for murre was less than the ‘minimum effect’ model for the two whale species. This reflects the biology of thick-billed murre and its response to disturbance.

In the Northern, Central, and Southern Blocks, the potential for cumulative effects is very low. There is potential for some disturbance to offshore foraging areas, but distance from shore should preclude any other effects. In the North Central Block, cumulative effects are low - moderate. There is some disturbance to offshore foraging areas, and parts of the block may also be close enough to the coast for activities in that area to affect nesting colonies.

The maps of cumulative effects can highlight areas where additional mitigation may be helpful. Most strategies attempt to limit human disturbance to key areas for birds, particularly for species like thick-billed murre which congregate in large numbers and/or are “at risk.” Mitigation measures include (but are not limited to): (a) placing flight restrictions over bird colonies and using standard flight corridors; (b) adopting measures to reduce the volume, duration and frequency of noise-producing activities; (c) where possible, scheduling activities that may cause disturbance when most birds are absent (e.g., from October to April); (d) when possible, siting activities away from the most sensitive areas for birds; and (e) routing marine traffic to avoid concentrations of birds, especially molting or brood-rearing flocks, where practical.

### 3.6.4 Commercial Turbot Fishery

The offshore turbot fishery is a deep water fishery often conducted in depths of 1,000 m or greater. The depth of the fishery in conjunction with the pelagic and migratory nature of turbot reduces the potential for effects on this species from routine oil and gas activities, as well as the potential for cumulative effects. The largest potential for cumulative effect s on the commercial turbot fishery is from space conflicts between fishing vessels, and where there is both operating seismic and drill ships. Space conflicts occur when a fishing vessel is unable to access a fishing location due to the presence of either an operating seismic vessel or locations of operating drill ships. The increase in any of the number of fishing vessels, seismic and drilling vessels or all three could potentially lead to increased cumulative effects on the fishery.

The potential for cumulative effects for the four hypothetical lease areas range from low to nil.

The north block has an overall rating of nil for cumulative effects with the turbot fishery. The nil rating is due to the fact that offshore turbot fishing does not occur in the lease or adjacent areas. This rating could change is there were changes in areas where the turbot fishery currently occurs.

The remaining three blocks all have overall ratings of low potential for cumulative effects. Only a portion of these blocks have depths up to 1,000 m or more, reducing the potential for cumulative effects between other industries and commercial turbot fishing. The effects of underwater noise are minimal in terms of consequences or cumulative effects to turbot and likely the fishery. As mentioned above, the potential for cumulative effects is highest when there is conflict between active seismic and drilling vessels and fishing vessels resulting in potential reduced harvests by fishing vessels. There is likely to be little to no conflicts between other shipping activity and commercial turbot fishing. Although the potential for vessel space conflict is low, the consequence when it does occur could be at a moderate level for individual fishing vessels, resulting in reduced catches.

Mitigation measures for other effects on fish and fish habitat include: (a) ramp-up or soft start during seismic operations; (b) regular communication with hunting and trapping organizations and local harvesters on timing of seismic or other activities occurring nearshore to avoid peak migration periods; (c) timing of construction activities (e.g., pipelines) in the nearshore to avoid major spawning or migration periods, and (d) if marine structures are built, the selection of construction methods (e.g., use of a clamshell dredge vs. a cutter suction dredge) to minimize effects. Where possible, construction is preferable during the ice on period.

## 3.7 Conclusions

This report describes two approaches to integrating risk into analyses of environmental effects. The first is a simple approach to assess the risk of project effects. This could be adapted, and as appropriate, integrated into the PEMT.

The second is a relatively simple approach to explore the potential risk of cumulative environmental effects. It is important to note that the model developed here is not intended to be a full analysis of cumulative effects. Rather, it is intended to be an internal tool for exploring the potential effects of different development scenarios on different VCs.

The results described here suggest that the cumulative effects of development on VCs may vary considerably. At one end of the spectrum, bowhead whales are sensitive to development, particularly underwater noise generated by seismic exploration and vessel traffic. Seabirds such as thick-billed murre can be sensitive to disturbances to their breeding colonies, particularly if aircraft come in very close proximity (although this should generally be avoided as a result of routine flight rules). Compared with bowhead whales, thought they are much less sensitive to the routine effects of oil and gas development (seabirds are very sensitive to oil spills, but accidents and malfunctions are beyond the scope of the assessment presented in this document). By extension, thick-billed murre experience less cumulative effects, a result clearly visible in the map outputs. The commercial turbot fishery falls in between these two extremes.

What are the implications for development in the Arctic? Would the development scenario described above put any of the VCs (from whales to the turbot fishery) at risk?

That question is easiest to answer when there are clear thresholds separating an acceptable environmental effect from one that is not. Thresholds may be ecological (e.g., habitat availability, the viability of a wildlife population), physical (e.g., concentration of contaminants), political (resource management objectives related to a given environmental effect) or social (e.g., acceptable perceived change) (Hegmann, *et. al*. 2000). Unfortunately, clear thresholds are generally not yet available. For that reason, the analysis is limited to the relative risk of cumulative effects. In this regard, the greatest potential for cumulative effects is for whales.

Despite the limitation, we believe that these approaches can play a useful role. Both are easy to update as new information becomes available, making them easy to modify and improve. As information on relative importance of environmental effects on a VC (e.g., how probable they are, or how far from a source they extend), the sensitivity of different regions of the Arctic, or thresholds above which environmental effects become problematic becomes available it can easily be incorporated. The model can also be very easily modified to explore and compare the potential effects of different development scenarios. This iterative and exploratory approach could be used to generate discussion on the merits of different development options. It may also focus attention what information would best contribute to a better understanding of cumulative effects. Both should benefit resource management in the Arctic.

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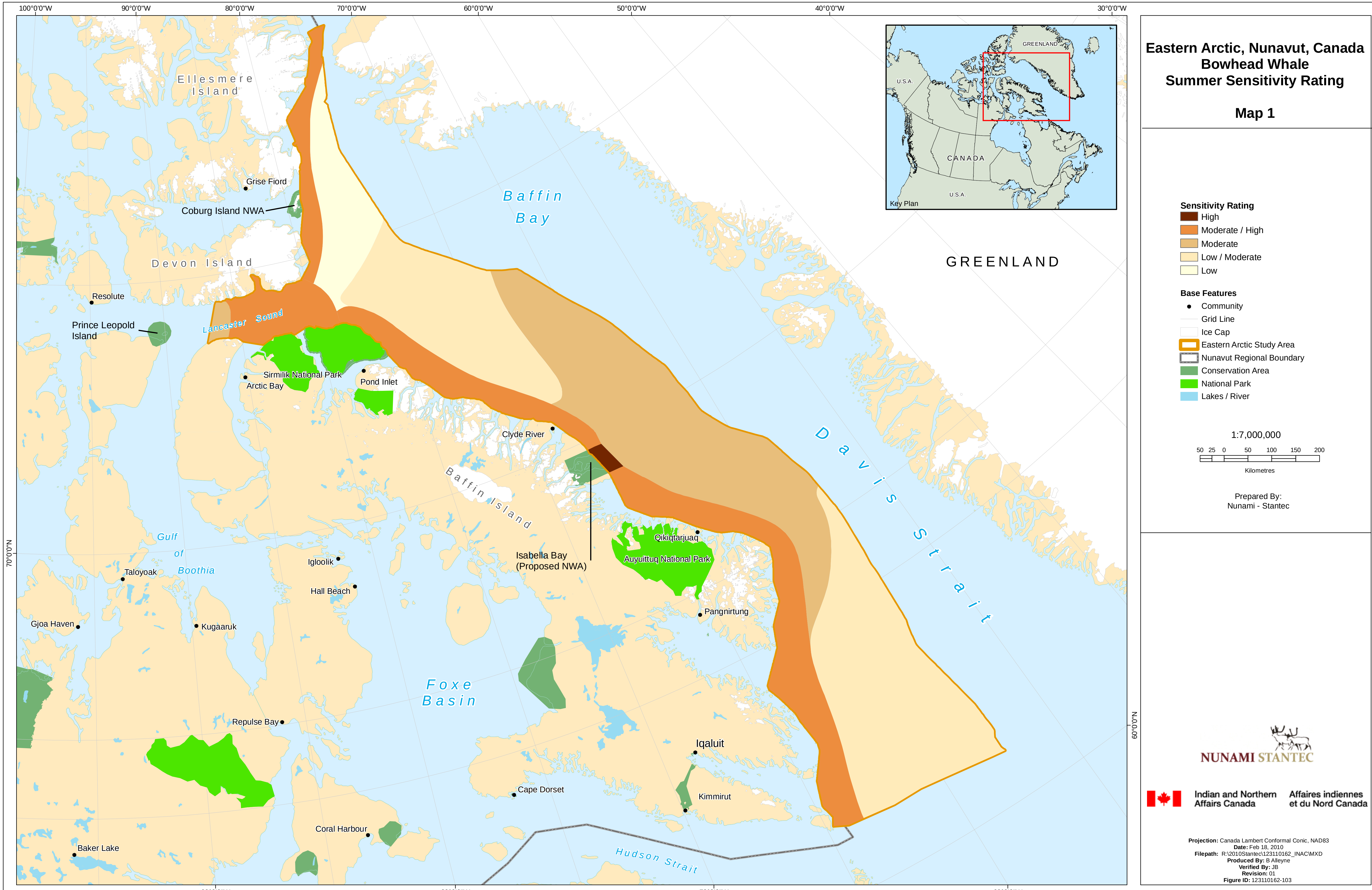
# 5 MAPS

Please see the following pages.



Eastern Arctic, Nunavut, Canada
Bowhead Whale
Summer Sensitivity Rating
Map 1
Sensitivity Rating
High
Moderate / High
Moderate
Low / Moderate
Low
Base Features
Community
Grid Line
Ice Cap
Eastern Arctic Study Area
Nunavut Regional Boundary
Conservation Area
National Park
Lakes / River
1:7,000,000
50 25 0 50 100 150 200
Kilometres
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Affaires indiennes et du Nord Canada
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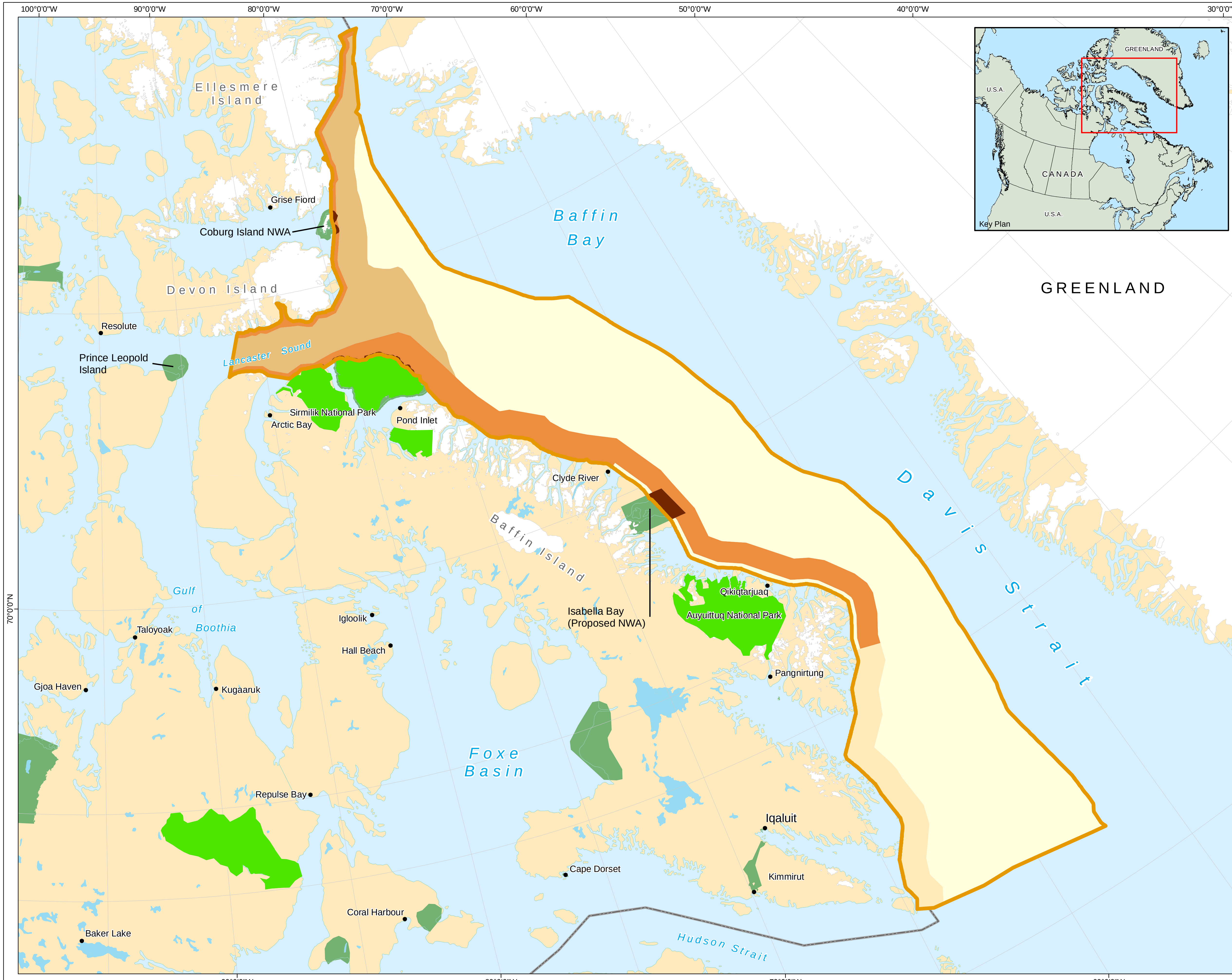
GREENLAND
U.S.A.
CANADA
U.S.A.
Key Plan
100°0'0"W
90°0'0"W
80°0'0"W
70°0'0"W
60°0'0"W
50°0'0"W
40°0'0"W
30°0'0"W
70°0'0"N
60°0'0"N
Ellesmere Island
Grise Fiord
Coburg Island NWA
Baffin Bay
GREENLAND
Devon Island
Resolute
Prince Leopold Island
Lancaster Sound
Sirmilik National Park
Arctic Bay
Pond Inlet
Clyde River
Davis Strait
Baffin Island
Isabella Bay (Proposed NWA)
Qikiqtarjuaq
Auyuittuq National Park
Pangnirtung
Gulf of Boothia
Taloyoak
Igloolik
Hall Beach
Gjoa Haven
Kugaaruk
Foxe Basin
Repulse Bay
Iqaluit
Cape Dorset
Kimmirut
Coral Harbour
Baker Lake
Hudson Strait




# Eastern Arctic, Nunavut, Canada
# Toothed Whale
# Summer Sensitivity Rating

## Map 2

**Sensitivity Rating**
- High
- Moderate / High
- Moderate
- Low / Moderate
- Low

**Base Features**
- Community
- Grid Line
- Ice Cap
- Eastern Arctic Study Area
- Nunavut Regional Boundary
- Conservation Area
- National Park
- Lakes / River

1:7,000,000

50 25 0 50 100 150 200

Kilometres

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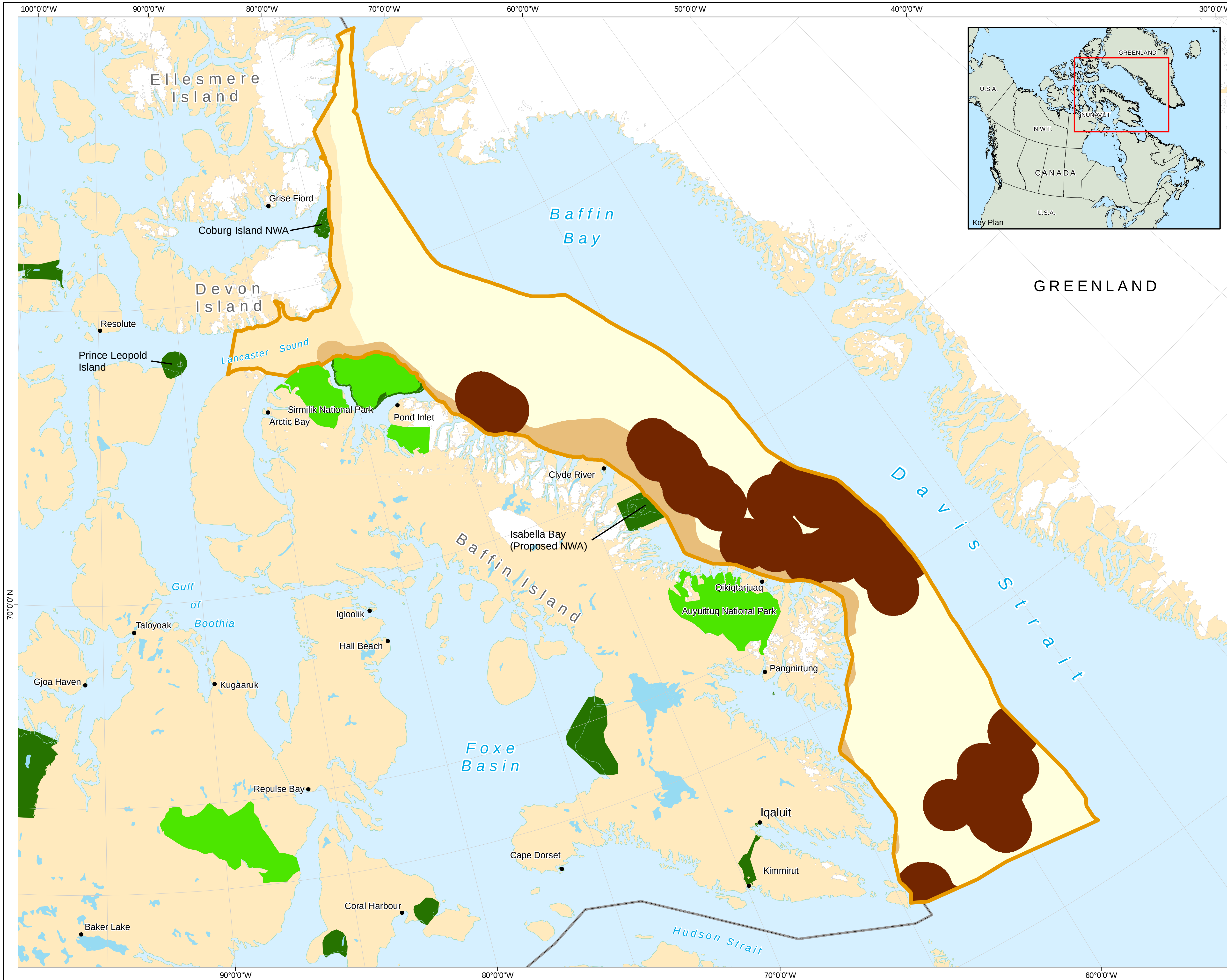


# Eastern Arctic, Nunavut, Canada Commercial Turobot Fishery - Summer Sensitivity Rating

## Map 3

**Sensitivity Rating**
- High
- Moderate / High
- Moderate
- Low / Moderate
- Low

**Base Features**
- Community
- Grid Line
- Eastern Arctic Study Area
- Ice Cap
- Nunavut Regional Boundary
- Conservation Area
- National Park
- Lakes / River

1:7,000,000

50 25 0 50 100 150 200

Kilometres

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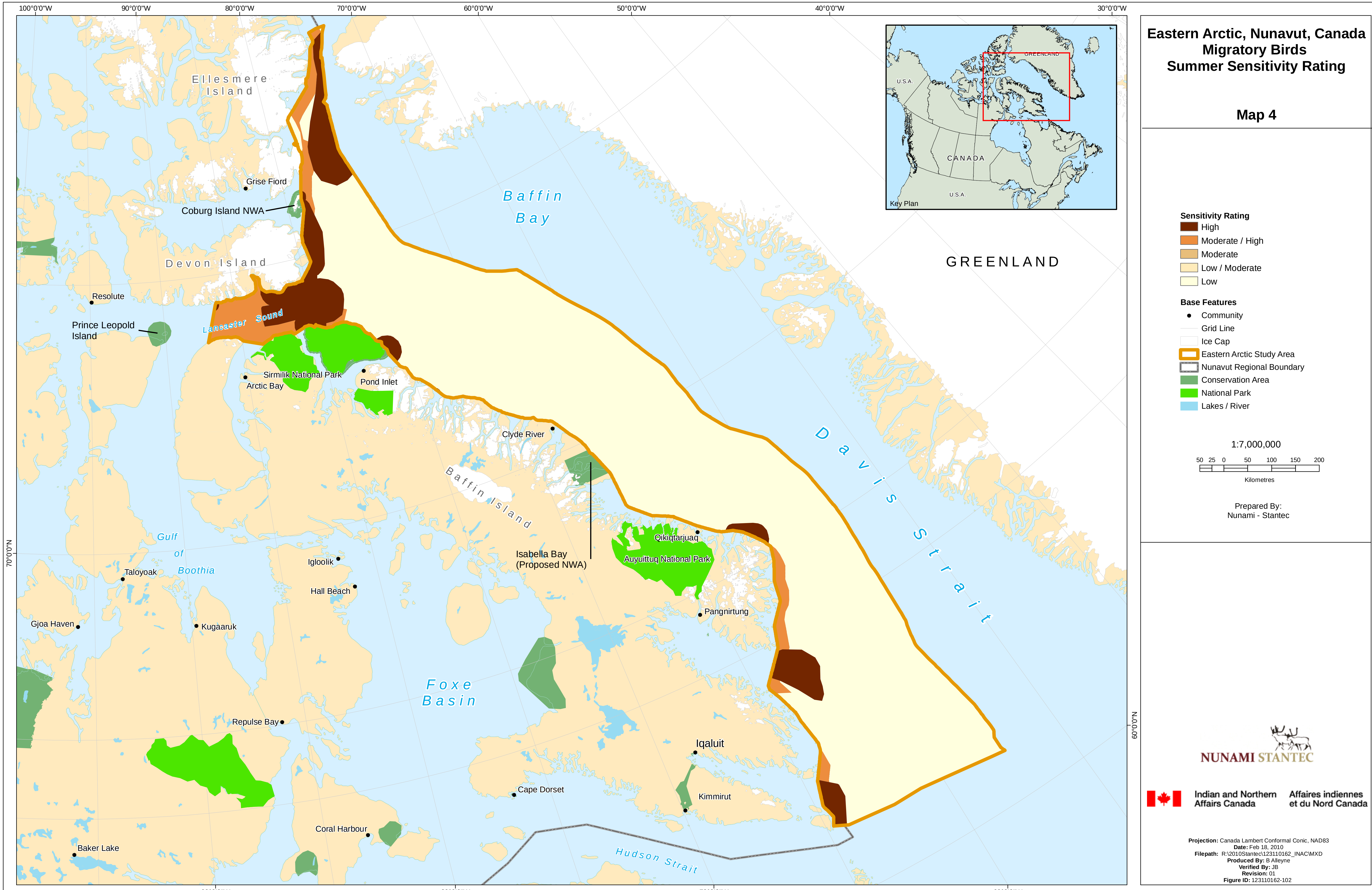

Eastern Arctic, Nunavut, Canada
Migratory Birds
Summer Sensitivity Rating
Map 4
Sensitivity Rating
High
Moderate / High
Moderate
Low / Moderate
Low
Base Features
Community
Grid Line
Ice Cap
Eastern Arctic Study Area
Nunavut Regional Boundary
Conservation Area
National Park
Lakes / River
1:7,000,000
50 25 0 50 100 150 200
Kilometres
Prepared By:
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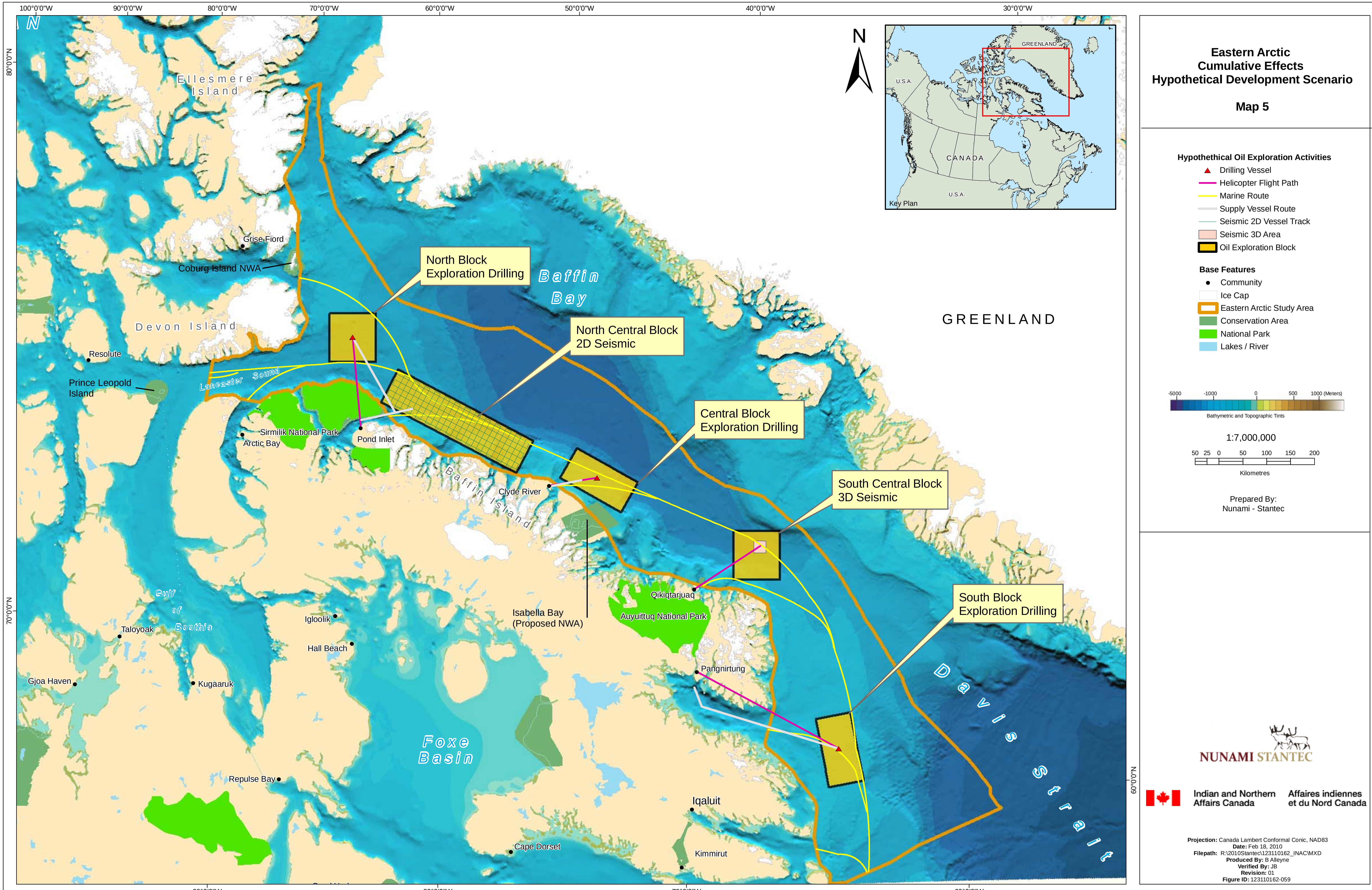
GREENLAND
U.S.A.
CANADA
U.S.A.
100°0'0"W
90°0'0"W
80°0'0"W
70°0'0"W
60°0'0"W
50°0'0"W
40°0'0"W
30°0'0"W
70°0'0"N
60°0'0"N
Ellesmere Island
Grise Fiord
Coburg Island NWA
Devon Island
Resolute
Prince Leopold Island
Lancaster Sound
Sirmilik National Park
Arctic Bay
Pond Inlet
Baffin Bay
GREENLAND
Clyde River
Baffin Island
Davis Strait
Isabella Bay (Proposed NWA)
Qikiqtarjuaq
Auyuittuq National Park
Pangnirtung
Gulf of Boothia
Taloyoak
Igloolik
Hall Beach
Gjoa Haven
Kugaaruk
Foxe Basin
Repulse Bay
Iqaluit
Cape Dorset
Kimmirut
Coral Harbour
Baker Lake
Hudson Strait


Eastern Arctic
Cumulative Effects
Hypothetical Development Scenario
Map 5
Hypothethical Oil Exploration Activities
Drilling Vessel
Helicopter Flight Path
Marine Route
Supply Vessel Route
Seismic 2D Vessel Track
Seismic 3D Area
Oil Exploration Block
Base Features
Community
Ice Cap
Eastern Arctic Study Area
Conservation Area
National Park
Lakes / River
-5000 -1000 0 500 1000 (Meters)
Bathymetric and Topographic Tints
1:7,000,000
50 25 0 50 100 150 200
Kilometres
Prepared By:
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Revision: 01
Figure ID: 123110162-059
North Block
Exploration Drilling
North Central Block
2D Seismic
Central Block
Exploration Drilling
South Central Block
3D Seismic
South Block
Exploration Drilling
Baffin Bay
GREENLAND
Davis Strait
Ellesmere Island
Devon Island
Baffin Island
Foxe Basin
Gulf of Boothia
Lancaster Sound
Grise Fiord
Coburg Island NWA
Resolute
Prince Leopold Island
Sirmilik National Park
Arctic Bay
Pond Inlet
Clyde River
Isabella Bay (Proposed NWA)
Qikiqtarjuaq
Auyuittuq National Park
Pangnirtung
Iqaluit
Kimmirut
Cape Dorset
Repulse Bay
Hall Beach
Igloolik
Taloyoak
Kugaaruk
Gjoa Haven
GREENLAND
U.S.A.
CANADA
U.S.A.
Key Plan
N
100°0'0"W
90°0'0"W
80°0'0"W
70°0'0"W
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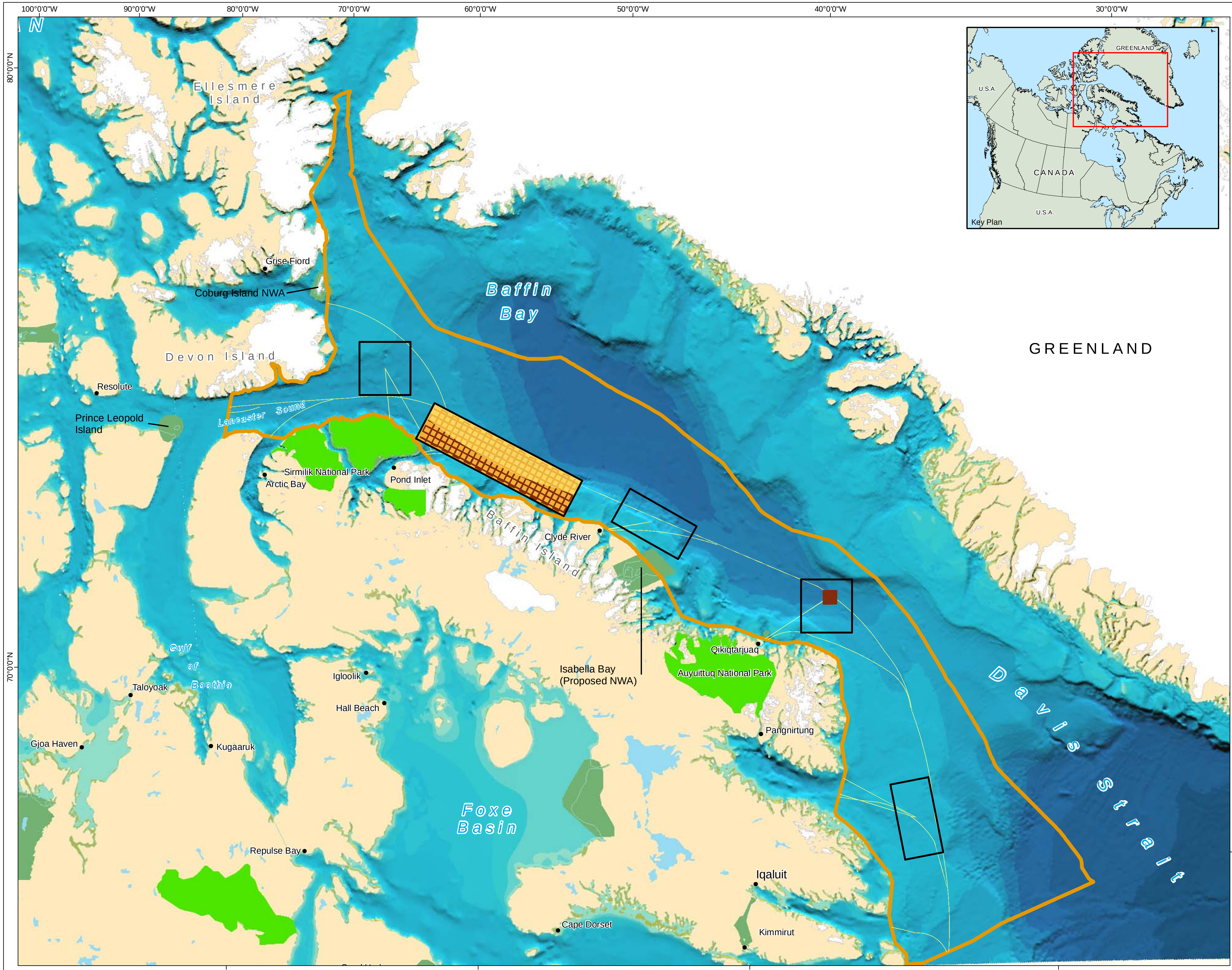
60°0'0"N




# Eastern Arctic PEMT Cumulative Effects Scenario Bowhead Summer Minimum Effect

## Map 6

**Cumulative Effects**

Minimum

Maximum

**Base Features**

- Community
- Scenario Polygons
- Ice Cap
- Eastern Arctic Study Area
- Conservation Area
- National Park
- Lakes / River

-5000 -1000 0 500 1000 (Meters)

Bathymetric and Topographic Tints

1:7,000,000

50 25 0 50 100 150 200

Kilometres

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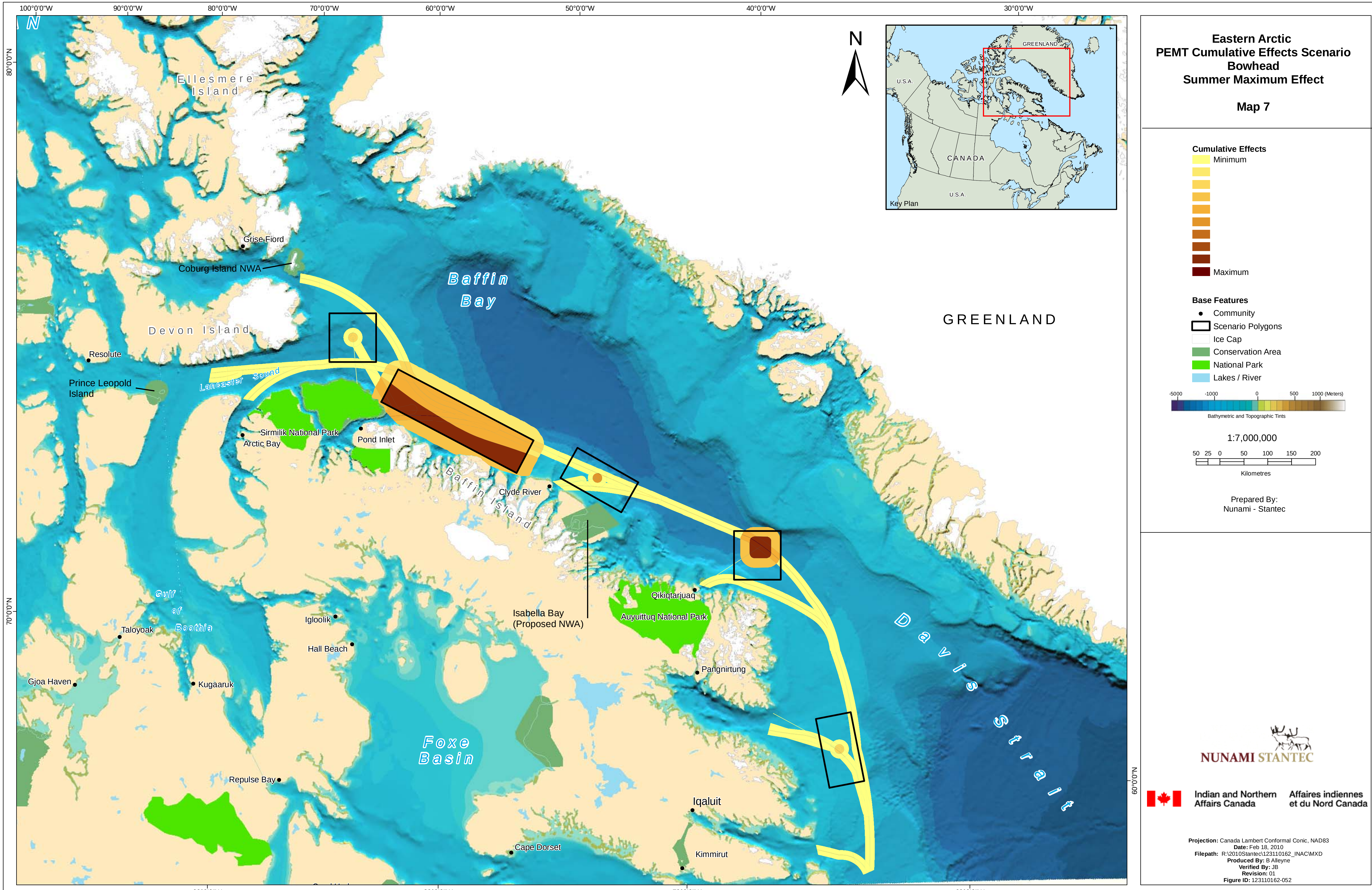

Eastern Arctic
PEMT Cumulative Effects Scenario
Bowhead
Summer Maximum Effect
Map 7
Cumulative Effects
Minimum
Maximum
Base Features
Community
Scenario Polygons
Ice Cap
Conservation Area
National Park
Lakes / River
-5000 -1000 0 500 1000 (Meters)
Bathymetric and Topographic Tints
1:7,000,000
50 25 0 50 100 150 200
Kilometres
Prepared By:
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GREENLAND
U.S.A.
CANADA
U.S.A.
N
Ellesmere Island
Grise Fiord
Coburg Island NWA
Baffin Bay
GREENLAND
Devon Island
Resolute
Prince Leopold Island
Lancaster Sound
Sirmilik National Park
Arctic Bay
Pond Inlet
Baffin Island
Clyde River
Isabella Bay (Proposed NWA)
Qikiqtarjuaq
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Davis Strait
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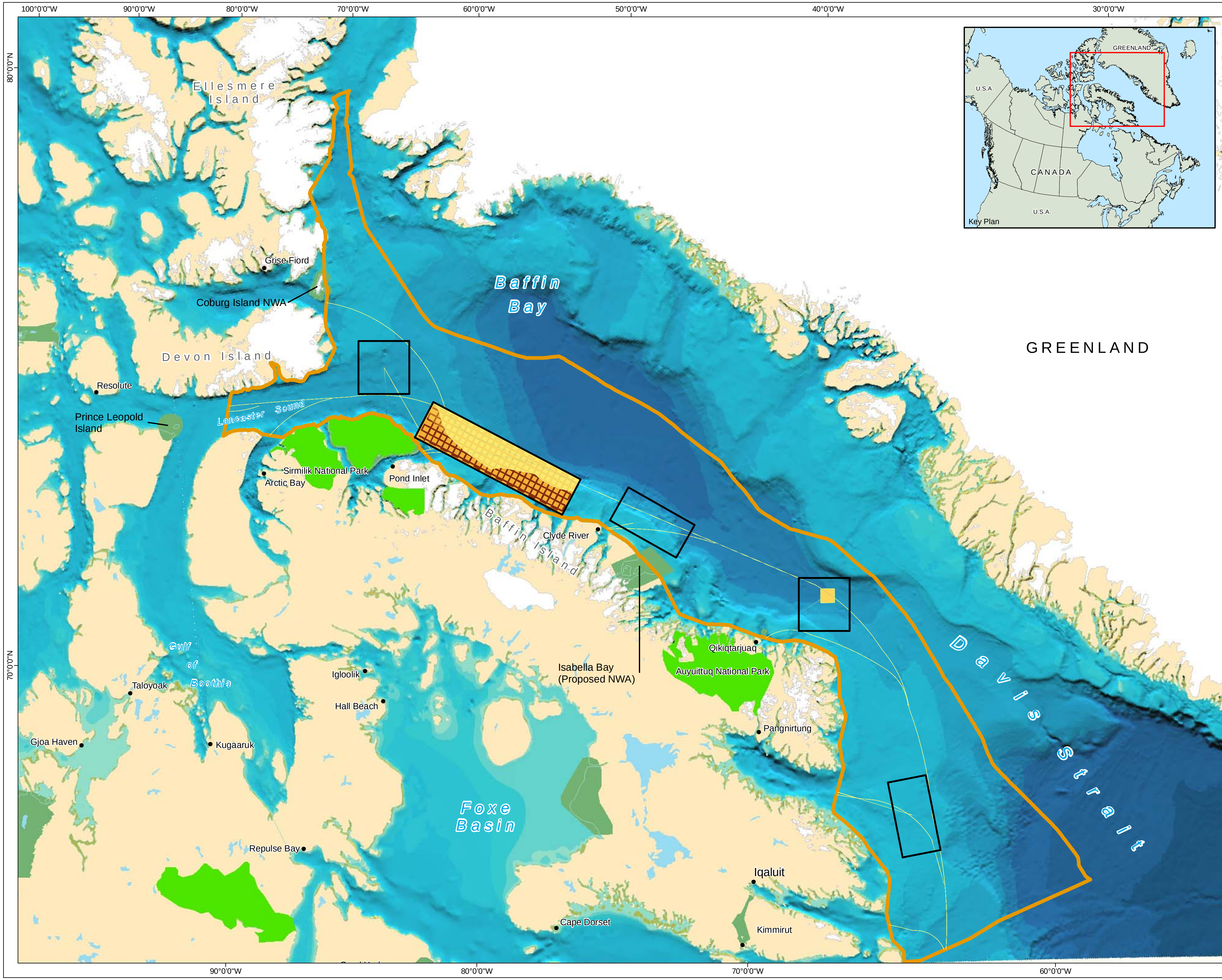
Hall Beach
Taloyoak
Gjoa Haven
Kugaaruk
Pangnirtung
Foxe Basin
Repulse Bay
Iqaluit
Cape Dorset
Kimmirut
100°0'0"W
90°0'0"W
80°0'0"W
70°0'0"W
60°0'0"W
50°0'0"W
40°0'0"W
30°0'0"W
80°0'0"N
70°0'0"N
60°0'0"N

## Eastern Arctic
## PEMT Cumulative Effects Scenario
## Toothed Whale
## Summer Minimum Effect

**Map 8**




**Cumulative Effects**

- Minimum
- Maximum

**Base Features**

- Community
- Scenario Polygons
- Ice Cap
- Eastern Arctic Study Area
- Conservation Area
- National Park
- Lakes / River

-5000 -1000 0 500 1000 (Meters)

Bathymetric and Topographic Tints

1:7,000,000

50 25 0 50 100 150 200

Kilometres

Prepared By:
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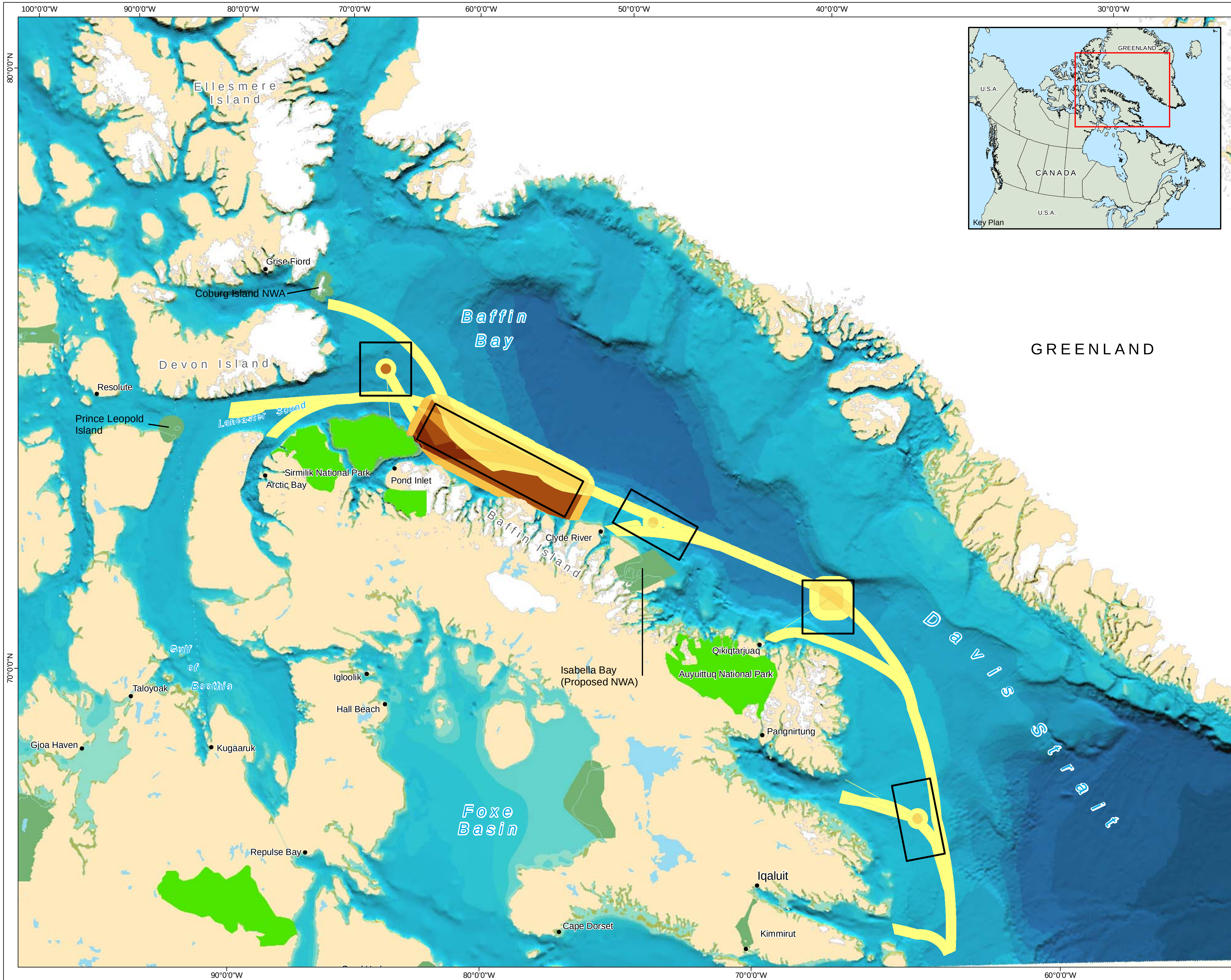


# Eastern Arctic
# PEMT Cumulative Effects Scenario
# Toothed Whale
# Summer Maximum Effect

## Map 9

**Cumulative Effects**

Minimum

Maximum

**Base Features**

- Community
- Scenario Polygons
- Ice Cap
- Conservation Area
- National Park
- Lakes / River

-5000 -1000 0 500 1000 (Meters)

Bathymetric and Topographic Tints

1:7,000,000

50 25 0 50 100 150 200

Kilometres

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**Date:** Feb 18, 2010
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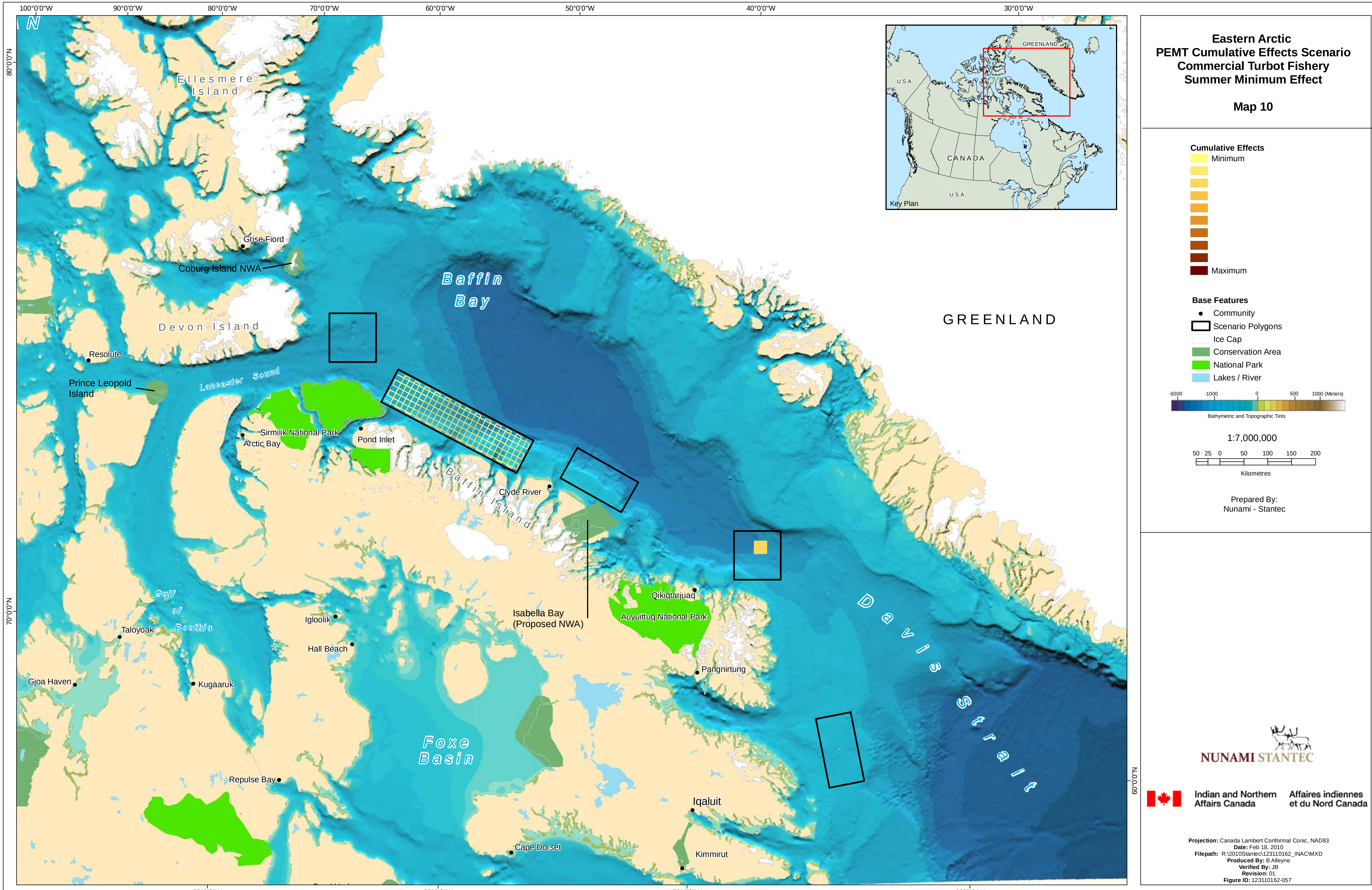
**Revision:** 01
**Figure ID:** 123110162-054



Eastern Arctic
PEMT Cumulative Effects Scenario
Commercial Turbot Fishery
Summer Minimum Effect
Map 10
Cumulative Effects
Minimum
Maximum
Base Features
Community
Scenario Polygons
Ice Cap
Conservation Area
National Park
Lakes / River
-5000
-1000
0
500
1000 (Meters)
Bathymetric and Topographic Tints
1:7,000,000
50 25 0 50 100 150 200
Kilometres
Prepared By:
Nunami - Stantec
NUNAMI STANTEC
Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada
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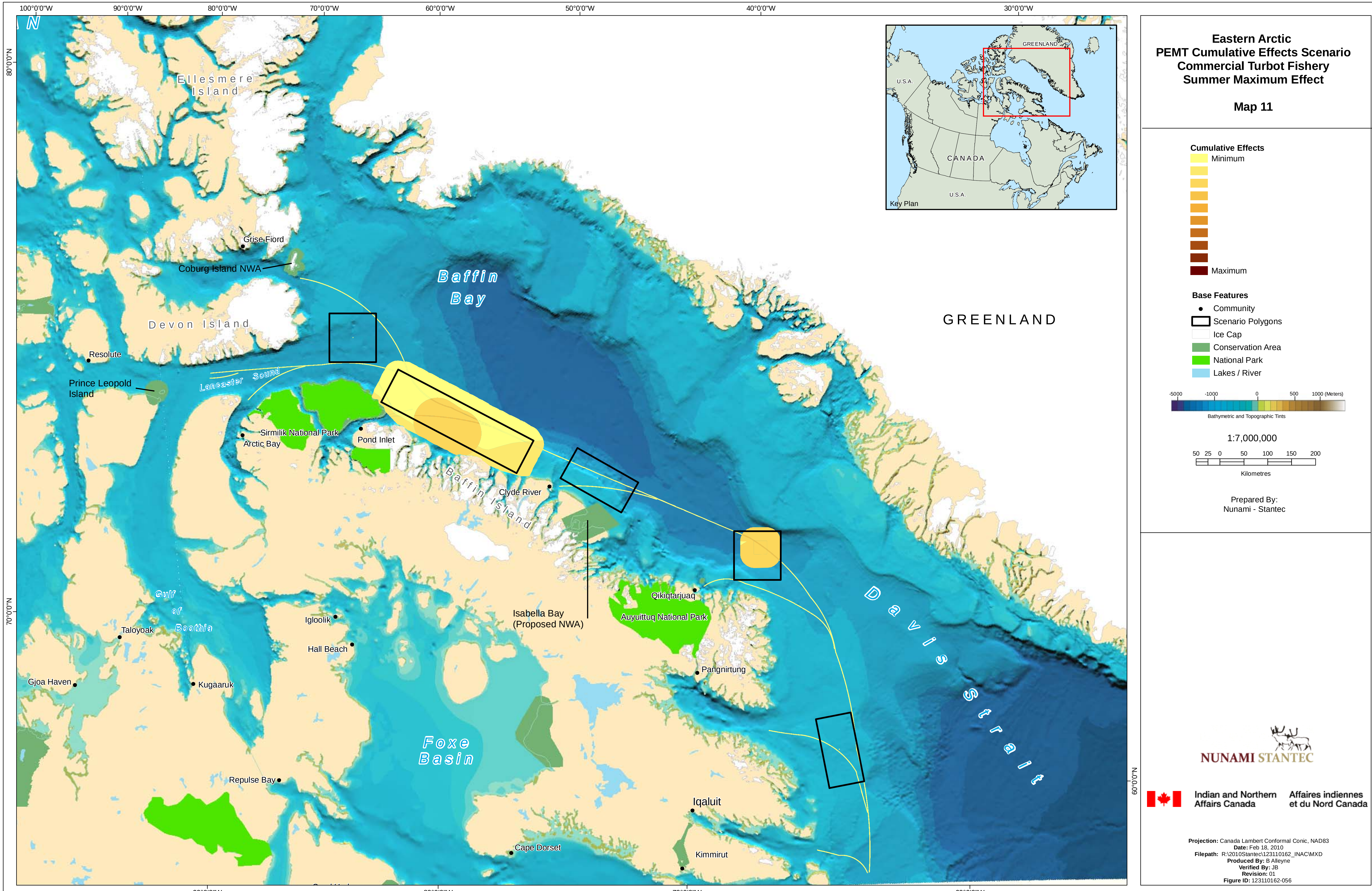
Date: Feb 18, 2010
Filepath: R:\2010Stantec\123110162_INAC\MXD
Produced By: B Alleyne
Verified By: JB
Revision: 01
Figure ID: 123110162-057
Key Plan
GREENLAND
U.S.A.
CANADA
U.S.A.
GREENLAND
Baffin Bay
Davis Strait
Foxe Basin
Gulf of Boothia
Lancaster Sound
Ellesmere Island
Devon Island
Baffin Island
Grise Fiord
Coburg Island NWA
Resolute
Prince Leopold Island
Sirmilik National Park
Arctic Bay
Pond Inlet
Clyde River
Isabella Bay (Proposed NWA)
Qikiqtarjuaq
Auyuittuq National Park
Pangnirtung
Igloolik
Hall Beach
Taloyoak
Gjoa Haven
Kugaaruk
Repulse Bay
Iqaluit
Cape Dorset
Kimmirut
100°0'0"W
90°0'0"W
80°0'0"W
70°0'0"W
60°0'0"W
50°0'0"W
40°0'0"W
30°0'0"W
80°0'0"N
70°0'0"N
60°0'0"N



Eastern Arctic
PEMT Cumulative Effects Scenario
Commercial Turbot Fishery
Summer Maximum Effect
Map 11
Cumulative Effects
Minimum
Maximum
Base Features
Community
Scenario Polygons
Ice Cap
Conservation Area
National Park
Lakes / River
-5000 -1000 0 500 1000 (Meters)
Bathymetric and Topographic Tints
1:7,000,000
50 25 0 50 100 150 200
Kilometres
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Figure ID: 123110162-056
Key Plan
GREENLAND
U.S.A.
CANADA
U.S.A.
GREENLAND
Ellesmere Island
Grise Fiord
Coburg Island NWA
Baffin Bay
Devon Island
Resolute
Prince Leopold Island
Lancaster Sound
Sirmilik National Park
Arctic Bay
Pond Inlet
Baffin Island
Clyde River
Isabella Bay (Proposed NWA)
Qikiqtarjuaq
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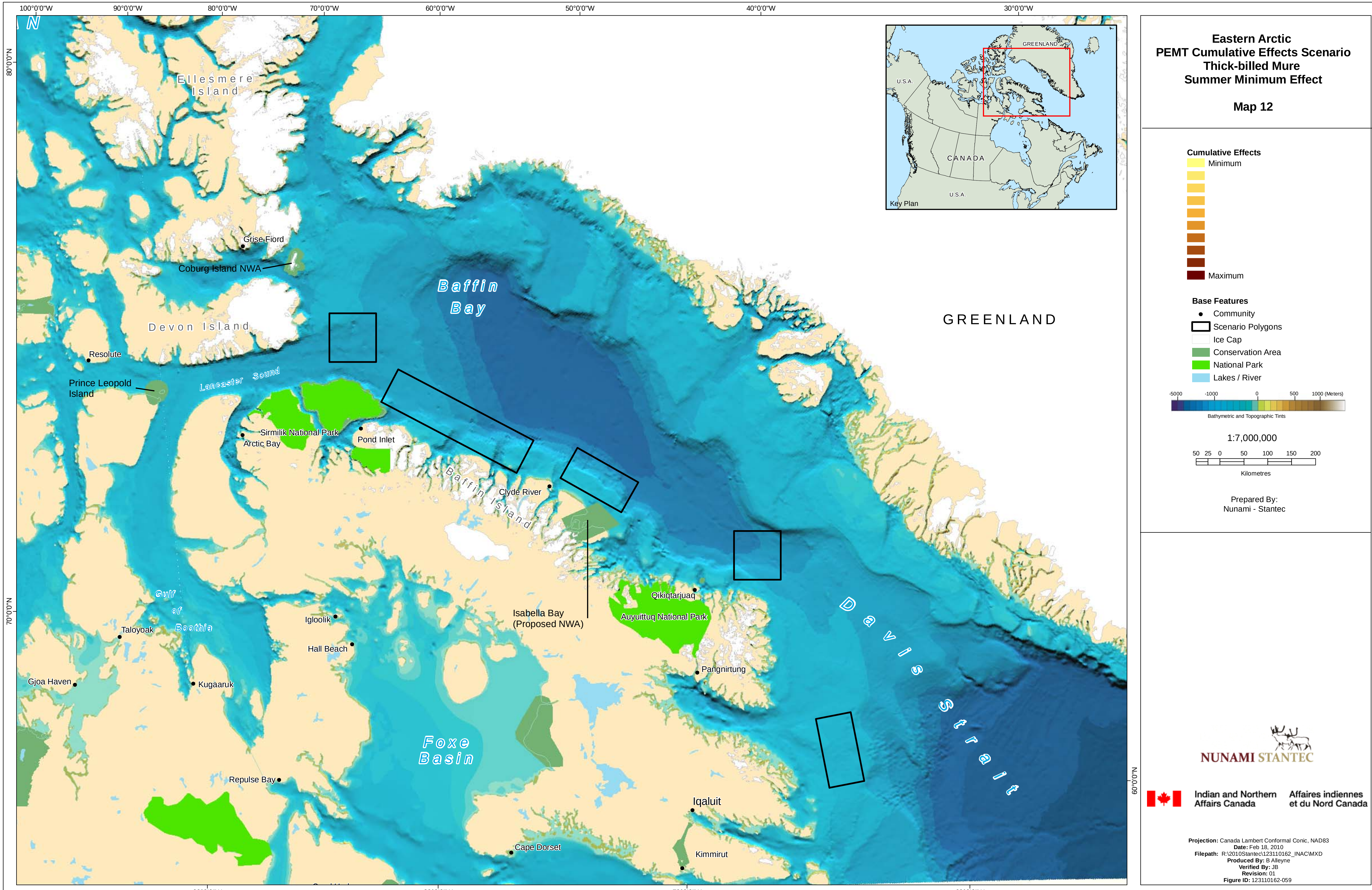
Davis Strait
Gulf of Boothia
Igloolik
Hall Beach
Taloyoak
Gjoa Haven
Kugaaruk
Pangnirtung
Foxe Basin
Repulse Bay
Iqaluit
Cape Dorset
Kimmirut
100°0'0"W
90°0'0"W
80°0'0"W
70°0'0"W
60°0'0"W
50°0'0"W
40°0'0"W
30°0'0"W
80°0'0"N
70°0'0"N
60°0'0"N



Eastern Arctic
PEMT Cumulative Effects Scenario
Thick-billed Mure
Summer Minimum Effect
Map 12
GREENLAND
U.S.A.
CANADA
U.S.A.
Key Plan
Cumulative Effects
Minimum
Maximum
Base Features
Community
Scenario Polygons
Ice Cap
Conservation Area
National Park
Lakes / River
-5000
-1000
0
500
1000 (Meters)
Bathymetric and Topographic Tints
1:7,000,000
50 25 0 50 100 150 200
Kilometres
Prepared By:
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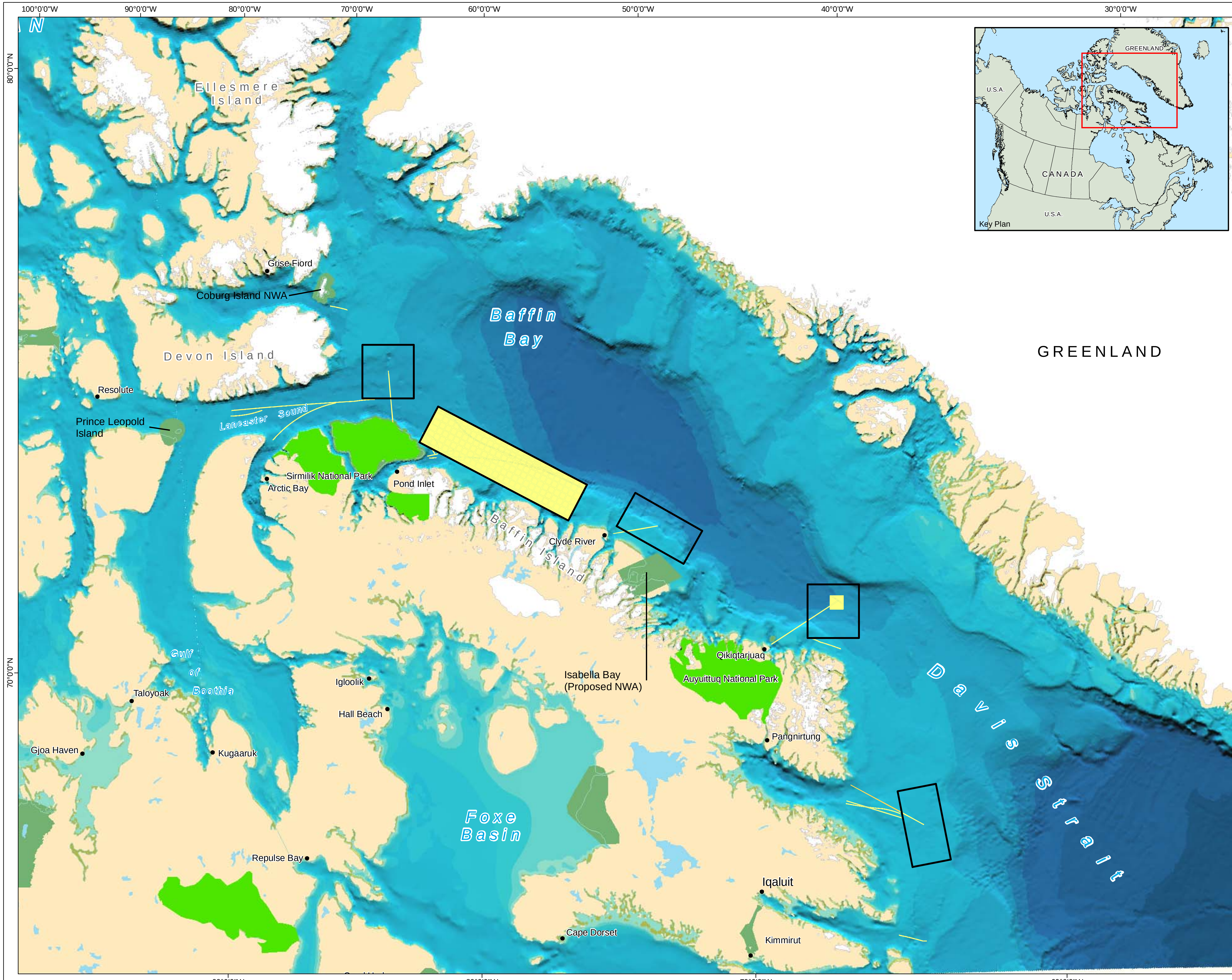
Projection: Canada Lambert Conformal Conic, NAD83
Date: Feb 18, 2010
Filepath: R:\2010Stantec\123110162_INAC\MXD
Produced By: B Alleyne
Verified By: JB
Revision: 01
Figure ID: 123110162-059
100°0'0"W
90°0'0"W
80°0'0"W
70°0'0"W
60°0'0"W
50°0'0"W
40°0'0"W
30°0'0"W
80°0'0"N
70°0'0"N
60°0'0"N
Ellesmere Island
Grise Fiord
Coburg Island NWA
Devon Island
Resolute
Prince Leopold Island
Lancaster Sound
Baffin Bay
Sirmilik National Park
Arctic Bay
Pond Inlet
Baffin Island
Clyde River
Isabella Bay (Proposed NWA)
Qikiqtarjuaq
Auyuittuq National Park
Pangnirtung
Davis Strait
Gulf of Boothia
Taloyoak
Igloolik
Hall Beach
Gjoa Haven
Kugaaruk
Foxe Basin
Repulse Bay
Iqaluit
Cape Dorset
Kimmirut

# Eastern Arctic
# PEMT Cumulative Effects Scenario
# Thick-billed Murre
# Summer Maximum Effect

**Map 13**




**Cumulative Effects**
- Minimum
- Maximum

**Base Features**
- Community
- Scenario Polygons
- Ice Cap
- Conservation Area
- National Park
- Lakes / River

-5000 -1000 0 500 1000 (Meters)

Bathymetric and Topographic Tints

1:7,000,000

50 25 0 50 100 150 200

Kilometres

Prepared By:
Nunami - Stantec

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**Revision:** 01
**Figure ID:** 123110162-058

# APPENDIX A

## Geomatics Aspects of the Cumulative Effects Model

The oil and gas exploration scenario model was developed in ArcGIS 9.3.1 using the Model Builder Tool. The model is a vector based analysis which contains 65 operations which are illustrated in Figure A1. The tool uses a series of buffers, unions and tabular calculations to generate a final output which shows cumulative effects of different hypothetical environmental disturbances. In the figure, disturbance inputs are illustrated as blue ovals, spatial operations are orange rectangles, and outputs are green ovals. The Scenario Tool can be added into any Map Document (MXD), and is designed to run off the local (C) drive. However, it can be manipulated to run of a server for multi-user access.

The model is based on four sources of information, as described in the body of this report.

1. Environmental sensitivity. The sensitivity of an area for a given Valued Component (VC, such as bowhead whale or commercial turbot fishery). This information is drawn from the sensitivity layers contained in the PEMT.
2. The disturbance layer developed for the model.
3. Effects parameters. An estimate of the residual effect of the anthropogenic disturbances (in 2 above) on a given VC. This is characterized by two values, the:
    a) Zone of influence of an effect (in kilometres) and
    b) Scope of an effect (measured on a scale of zero to ten).
4. A full list of these values is provided in Appendix C.

The model is broken down into seven parts (two for each VC, one for minimum estimated effect and one for the maximum effect), which are have the same structure but use different default values (see Figure A1).

The model can be easily modified in a number of ways.

1. **Sensitivity layers.** Any of the sensitivity layers can be edited (e.g., change the shape of the bowhead summer sensitivity areas) by simply swapping the file for another with the same name.
2. **Disturbance layer.** Any of the disturbance layers can be edited (e.g., Change the shape or location of vessel tracks) or swapped for another file with the same name. To do this the GIS user would create a new disturbance layer and save it into the model's geodatabase, replacing the old layer.
3. **Effects parameters.** By double-clicking on the tool in ArcGIS, the parameters window appears allowing the user to enter new parameter values or use the default values. All buffer values are entered in meters and must be whole numbers (i.e., decimal fractions are not permitted). Values for the intensity ratings can be any number. The model does not accept buffer distances of zero. However, if the user wishes to make a disturbance nil, zeros are accepted in the 'rating' value field, thus nullifying the disturbance from the model.

These options for modification allow the model to be easily adjusted to fit many different scenarios.

All base data is contained with an accompanying file geodatabase (.gdb) in a feature dataset called 'Base Data'. The geodatabase should be stored in the root of the C drive, in order for the tool to run.

The model's output files and intermediate files are also stored in the geodatabase. The final resultant file will have the suffix "_final". The final output file can be symbolized in many ways, for this report we used a color scale with ten equal intervals.

By right-clicking on the model tool and selecting 'Help', one can see an explanation for each of the parameters and operations in the model.

The key steps to run the model are:

**Step 1:** Open the Scenario_Model.mxd file in ArcGIS. Or you may open any ArcGIS map document and add the model tool to the toolbox.

**Step 2:** Open the red toolbox and click on the INAC_Scenario_Tool. Seven models should appear underneath it.

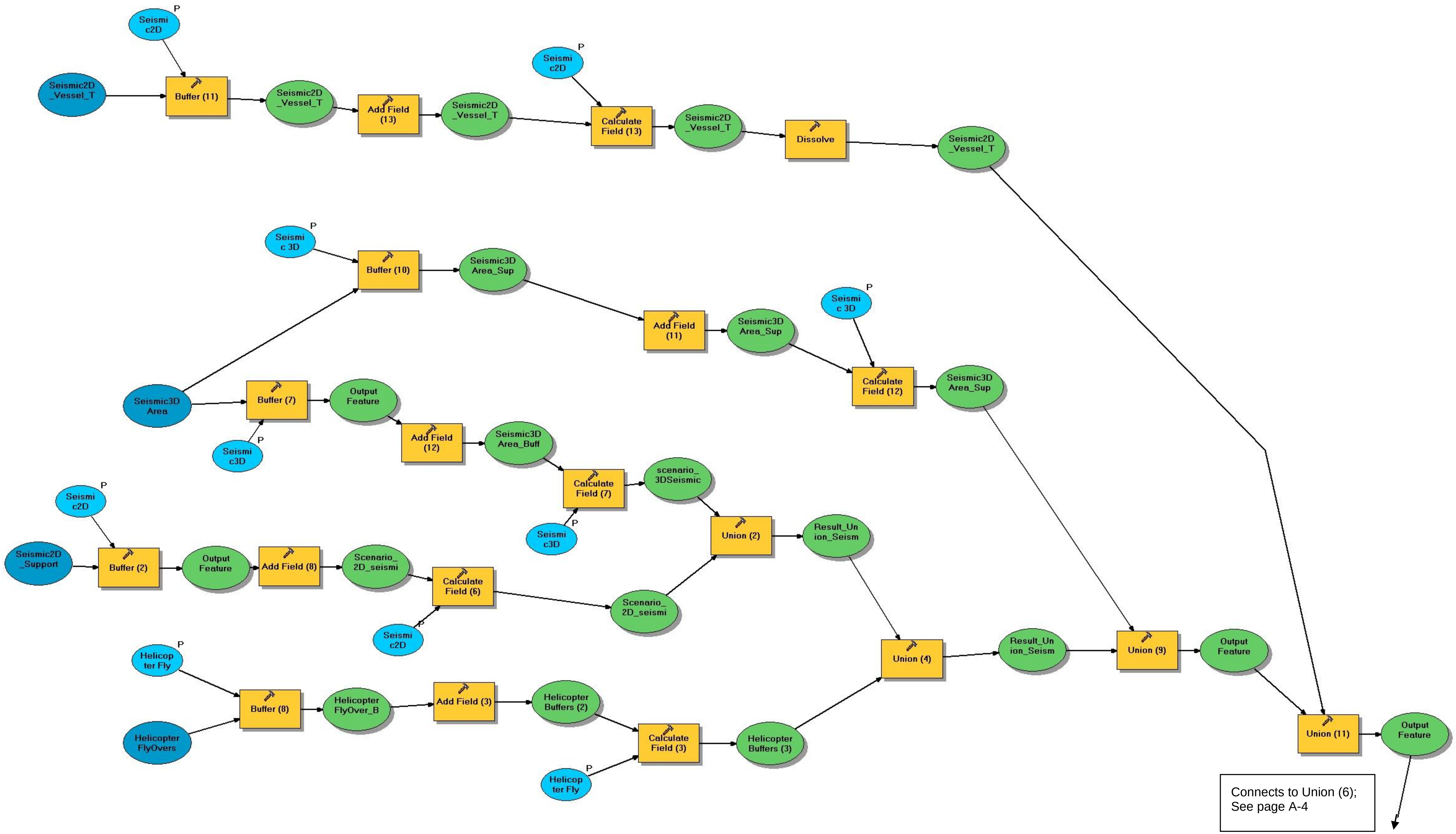
**Step 3:** Double-click on one of the models depending on which VC you are interested in. A parameters window will appear.

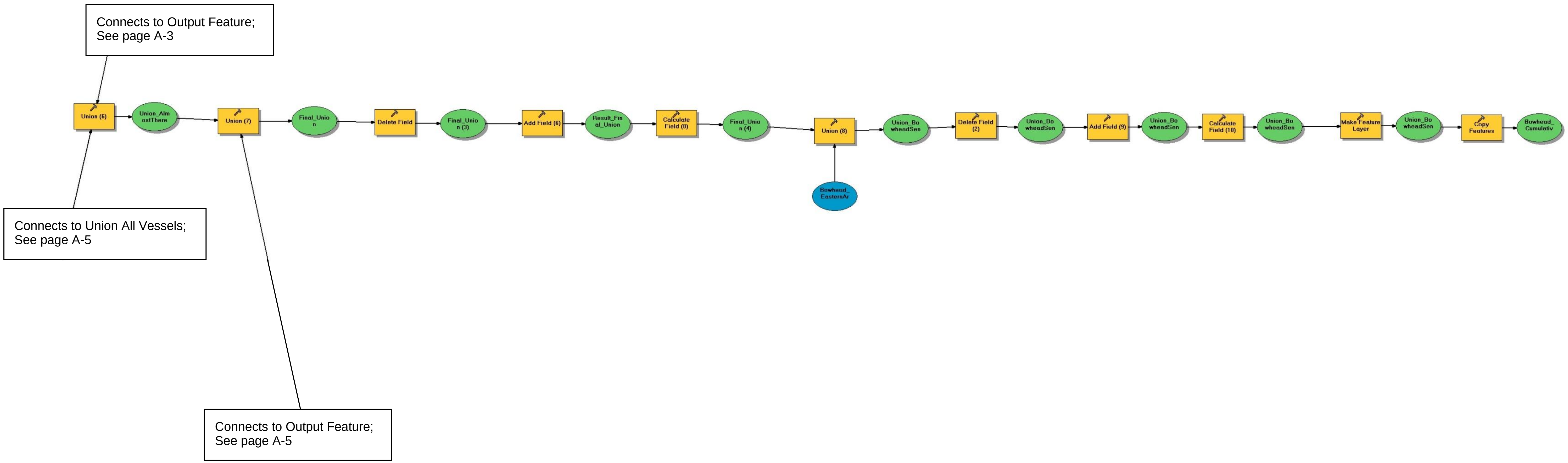
**Step 4:** Click OK to run the model with the default parameters or enter new parameters (remember whole numbers in metres for buffer distances).

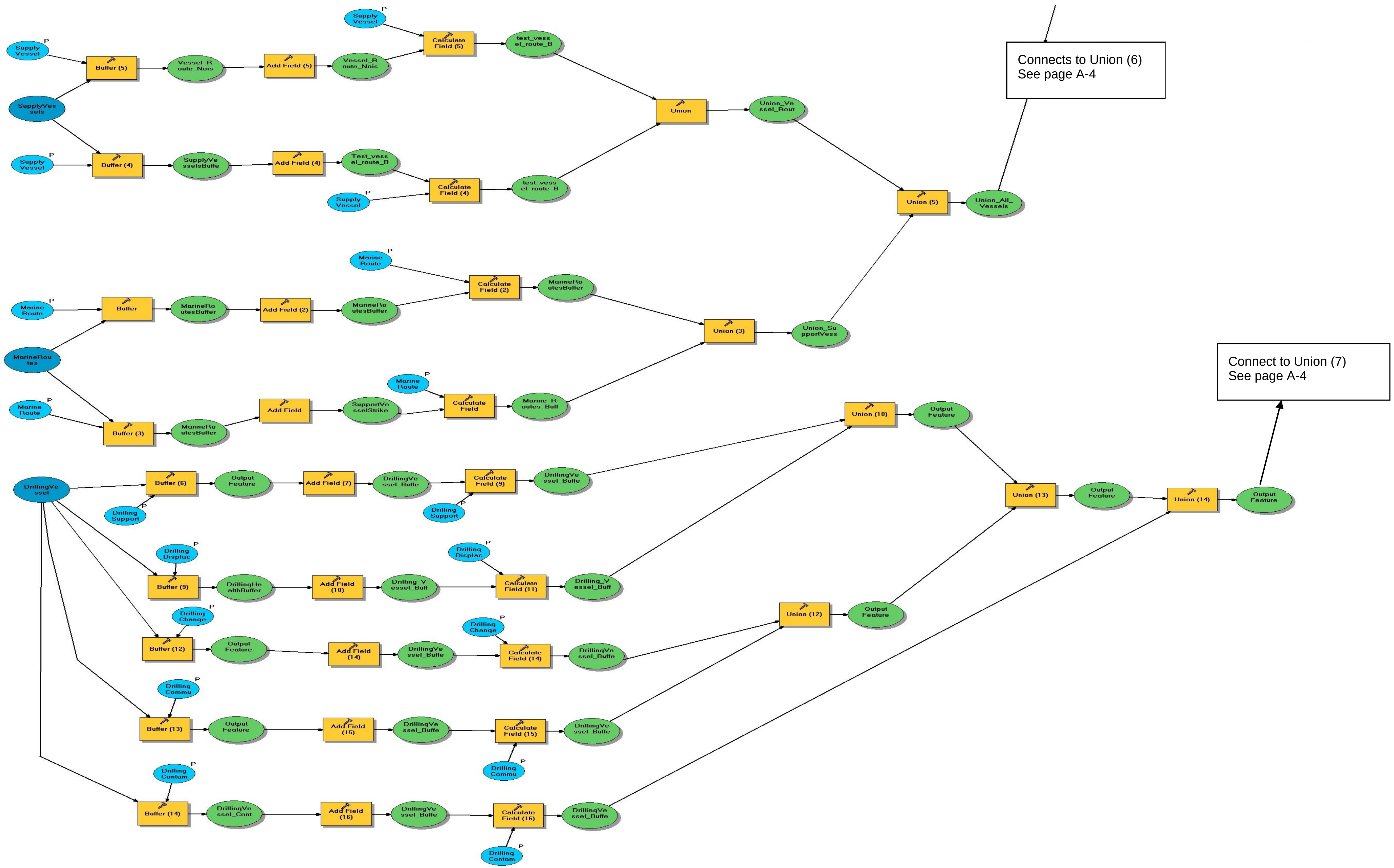
**Step 5:** Open ArcCatalog. Browse to the C drive where the Scenario geodatabase is stored. There will be a feature in the geodatabase with the suffix "_final". This is the model's output. Drag it to a map document to symbolize.

**Step 6:** Right-click on the model output you just dragged in. Select properties > Symbology Tab > Quantities > Graduated color. In the Value drop down select Rating_Adj2. In the color ramp drop down, select the color scheme. In the Classification box click, classify > method > Equal Interval. Select 10 Classes. Click OK, now you can view your model output.

**Figure A1: Graphic Representation of Cumulative Effects Model**




Connects to Output Feature; See page A-3
Union (6)
Union_AlmostThere
Union (7)
Final_Union
Delete Field
Final_Union (3)
Add Field (6)
Result_Final_Union
Calculate Field (8)
Final_Union (4)
Union (8)
Bowhead_EasternAr
Union_BowheadSen
Delete Field (2)
Union_BowheadSen
Add Field (9)
Union_BowheadSen
Calculate Field (10)
Union_BowheadSen
Make Feature Layer
Union_BowheadSen
Copy Features
Bowhead_Cumulativ
Connects to Union All Vessels; See page A-5
Connects to Output Feature; See page A-5


Supply Vessel
SupplyVessels
Buffer (5)
Vessel_Route_Nois
Add Field (5)
Calculate Field (5)
test_vessel_route_B
Buffer (4)
SupplyVesselsBuffe
Add Field (4)
Test_vessel_route_B
Calculate Field (4)
Union
Union_Vessel_Rout
Union (5)
Union_All_Vessels
Connects to Union (6)
See page A-4
Marine Route
MarineRoutes
Buffer
MarineRoutesBuffer
Add Field (2)
Calculate Field (2)
Union (3)
Union_SupportVess
Buffer (3)
Add Field
SupportVesselStrike
Calculate Field
Marine_Routes_Buff
Connect to Union (7)
See page A-4
DrillingVessel
Buffer (6)
Output Feature
Add Field (7)
DrillingVessel_Buffe
Calculate Field (9)
Drilling Support
Union (10)
Union (13)
Union (14)
Drilling Displac
Buffer (9)
DrillingHealthBuffer
Add Field (10)
Drilling_Vessel_Buff
Calculate Field (11)
Drilling Change
Buffer (12)
Add Field (14)
Calculate Field (14)
Union (12)
Drilling Commu
Buffer (13)
Add Field (15)
Calculate Field (15)
Drilling Contam
Buffer (14)
DrillingVessel_Cont
Add Field (16)
Calculate Field (16)

# APPENDIX B

## Development Scenario

**Table B1: Summary of the Development Scenario**

<table>
<tr><th rowspan="2">Elements</th><th rowspan="2"></th><th rowspan="2">Number/Rate</th><th colspan="2">Movement</th><th rowspan="2">Description/Rationale</th></tr>
<tr><th>To</th><th>From</th></tr>
<tr><td rowspan="16">3D Seismic Exploration</td><td colspan="5">Seismic Vessel</td></tr>
<tr><td>Exploration</td><td>1 vessel;<br>10 weeks</td><td></td><td></td><td>3,000 km$^2$ of seismic shot</td></tr>
<tr><td>Refueling</td><td>Twice</td><td>Shallow areas (30 – 40 m) near closest community</td><td>Lease</td><td>Return trip</td></tr>
<tr><td colspan="5">Ice-breaking Support Vessel</td></tr>
<tr><td>Support to seismic</td><td>1 vessel;<br>10 weeks</td><td>Seismic</td><td></td><td>Within 2 nautical miles of the seismic ship (approximately 4 km)</td></tr>
<tr><td>Refueling</td><td>Twice</td><td></td><td></td><td>Supply ships will transport supplies, muds, etc. but not fuel.</td></tr>
<tr><td colspan="5">Supply Vessels</td></tr>
<tr><td>Early season supply</td><td>1 trip/season</td><td>Towns listed below</td><td>Newfoundland</td><td></td></tr>
<tr><td>Local resupply</td><td>1 round trip every 3 weeks</td><td>Seismic Vessel</td><td>Nearest community</td><td>Vessels to ferry supplies from nearest community to seismic ship. Travel path:<br>▪ North: to/from Pond Inlet<br>▪ North Central: Pond Inlet or Clyde River<br>▪ Central: to/from Clyde River (currently little developed but we assume that will change by the time exploration occurs)<br>▪ South: to/from Qik or Pang.</td></tr>
<tr><td colspan="5">Helicopter Support</td></tr>
<tr><td>Ice reconnaissance</td><td>1h/day</td><td>Within 5 – 10 NM of seismic vessel</td><td></td><td></td></tr>
<tr><td>Crew change</td><td>No crew change during summer season</td><td></td><td></td><td></td></tr>
<tr><td>Marine mammal surveys</td><td>Daily @ altitude >450 m</td><td>Lease area and control areas outside the lease area</td><td>Nearest community</td><td>Three to four weeks, flying 6 hours a day.</td></tr>
</table>

| Elements | | Number/Rate | Movement | | Description/Rationale |
|---|---|---|---|---|---|
| | | | To | From | |
| 2D Seismic | **Seismic Vessel** | | | | |
| | Exploration | 1 vessel;<br>10 weeks | Shooting 20,000 $km^2$ of seismic | | |
| | Refueling | Three times | Nearest community | Seismic area | |
| | **Ice-breaking Support Vessel** | | | | |
| | Support to seismic | 1 vessel;<br>10 weeks | | | Generally within 2 nautical miles of the seismic ship, so we will assume in the same area as seismic. |
| | Refueling | Three times | | | Supply ships do not bring fuel, just supplies, muds, etc. |
| | Supply vessels | Same as 3D | | | Same as 3D |
| | Helicopter support | Same as 3D | | | Same as 3D |
| Exploration Drilling | Drilling vessels | 2 | | | One drill ship for same season relief well. Under current regulations, at depths >40 we both ships would need to be drilling to allow a same season relief. The two vessel model is drawing from the Cairn program – where three wells were drilled and each rig provided the support to drill a relief well. |
| | Ice management vessels | 6 | | | |
| | Emergency response and rescue vessels | 2 | | | |
| | Supply vessels | 2 vessels making one trip/week | Drill ships | Nearest community | Assume that fuel will be ferried to the site (unlike seismic) and that drill ships will not move.<br>Travel path:<br>▪ North to Pond Inlet<br>▪ Central Clyde River<br>▪ South Qik or Pang. |
| | Support vessels | 1 | | | Generally within 2 nautical miles of the drill ships, so we will assume in the same area. |

| Elements | | Number/Rate | Movement | | Description/Rationale |
|---|---|---|---|---|---|
| | | | To | From | |
| | Wareship | 1 | | | Like a floating warehouse. Generally within 2 nautical miles of the drill ships, so we will assume in the same area. |
| | Helicopter support | 3 | Vessels in lease | | Three helicopters dedicated to operations<br>Crew change every 3 weeks; flight to nearest community:<br>▪ North to Pond Inlet<br>▪ Central Clyde River<br>▪ South Qik or Pang.<br>Ice reconnaissance: daily flight for 1 hour<br>Between ship helicopter support: 1 hours/day |
| Shipping (commercial and coast guard) | Vessel traffic | 30/mo | Lancaster Sound | | Assumes an increase in shipping in this future scenario. Shipping lanes will reflect the current marine transport routes that we have developed for the PEMT. Shipping includes supply barges to communities, transport to mining operations, +5 cruise ships but not inter-oceanic shipping through the northwest passage. |
| Commercial fishing | Vessel traffic | 10/mo | Lease | Nearest port | North: limited commercial fishing (fishing based out of Pond Inlet is outside lease area)<br>**Central:** moderate commercial fishing based in Pang:<br>**South:** moderate commercial based in Iqaluit |
| Other low flying aircraft (ecotourism, etc.) | | 5 trips/week | | | The model assumes commercial flights are generally above 3,000 m and do not need to be considered. |

# APPENDIX C

## Zones of Influence and the Scope of an Effect

**Table C1: Zones of Influence and the Scope of an Effect on Four Valued Components – Bowhead Whales**

| Activity | Impact | Effect | Bowhead Whales | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Seismic** | | | | | | | | | |
| Vessel traffic – seismic refueling and supply | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 0.004 | 1.00 | 1 | **0.004** |
| | Acoustic disturbance | Change in behavior/displacement | 180 dB | 0.5 | 10 | 0.004 | 0.70 | 5 | **0.015** |
| | Vessel strikes | Change in health/injury/mortality risk | | 0.025 | 0.025 | 0.004 | 0.02 | 5 | **0.000** |
| | Space conflict | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Vessel traffic – Seismic vessel and support vessel | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 1.000 | 1.00 | 1 | **1.000** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 10 | 1.000 | 0.70 | 5 | **3.500** |
| | Vessel strikes | Change in health/injury/mortality risk | | 0.025 | 0.025 | 1.000 | 0.02 | 5 | **0.100** |
| | Space conflict | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Seismic acquisition – 3D | Acoustic disturbance | Change in habitat | 180 dB | 1.5 | 30 | 0.750 | 1.00 | 1 | **0.750** |
| | Acoustic disturbance | Change in behavior | 180 dB | 1.5 | 30 | 0.750 | 0.90 | 5 | **3.375** |
| | Acoustic disturbance | Change in health/injury/mortality risk – larvae only | | 1.5 | 3 | 0.750 | 0.50 | 5 | **1.875** |
| | Space conflict | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Seismic acquisition – 2D | Acoustic disturbance | Change in habitat | 180 dB | 1.5 | 30 | 0.750 | 1.00 | 1 | **0.750** |
| | Acoustic disturbance | Change in behavior | 180 dB | 1.5 | 30 | 0.750 | 0.90 | 5 | **3.375** |
| | Acoustic disturbance | Change in health/injury/mortality risk – larvae only | | 1.5 | 3 | 0.750 | 0.50 | 5 | **1.875** |
| | Space conflict | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |

| Activity | Impact | Effect | Bowhead Whales | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Exploration Drilling** | | | | | | | | | |
| Vessel traffic – Drilling refueling and supply | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 0.016 | 1.00 | 1 | **0.016** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 10 | 0.016 | 0.70 | 5 | **0.057** |
| | Vessel strikes | Change in health/injury/mortality risk – larvae only | N/A | 0.025 | 0.025 | 0.016 | 0.02 | 5 | **0.002** |
| | Exclusion of fishing activities | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Vessel traffic – Drilling | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 1.000 | 1.00 | 1 | **1.000** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 10 | 1.000 | 0.70 | 5 | **3.500** |
| | Vessel strikes | Change in health/injury/mortality risk – larvae only | N/A | 0.025 | 0.025 | 1.000 | 0.02 | 5 | **0.100** |
| | Exclusion of fishing activities | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Drilling | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 20 | 0.750 | 1.00 | 1 | **0.750** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 20 | 0.750 | 1.00 | 1 | **0.750** |
| | Contaminants – disposal drilling muds etc. | Change in health/injury/mortality risk | 180 dB | 0.25 | 0.5 | 0.750 | 0.01 | 5 | **0.038** |
| | Tainting, exclusion of fishing activities | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Overflights | Acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior | <300m | 0 | 0.5 | 0.02 | 0.05 | 1 | **0.001** |
| | Acoustic disturbance | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Operation of structures | Visual and acoustic disturbance | Change in habitat | N/A | 0 | 0.5 | 1.000 | 0.00 | 0 | **0.000** |
| | | Change in health/injury/mortality risk | N/A | 0 | 0 | 0.000 | 0.00 | 0 | **0.000** |
| | | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |

| Activity | Impact | Effect | Bowhead Whales | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Other Activities** | | | | | | | | | |
| Non-exploration Vessel traffic - Shipping | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 0.000 | 1.00 | 1 | **0.000** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 10 | 0.000 | 0.70 | 5 | **0.002** |
| | Vessel strikes/ underwater noise | Change in health/injury/mortality risk | N/A | 0.025 | 0.025 | 0.000 | 0.02 | 5 | **0.000** |
| | | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Waste water treatment and discharge from routine ship operations | Pollution | Change in habitat | N/A | 0 | 0 | 0.800 | 0.01 | 0 | **0.000** |
| | | Change in behavior | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |

**NOTES AND KEY**
Exploration, ice off scenario
It is assumed that industry standard mitigation measures are applied
Any "not applicable" categories scored a "0"

**COMPONENTS OF THE SCOPE OF AN EFFECT**
Duration of Effect—estimated proportion of the season the effect lasts

**Consequence of Effect:**
0 = Negligible
1 = Temporary and local adverse effect unlikely to be of high consequence
5 = Potential adverse effect that is regional (study area) or seasonal
10 = Regional long-term change

**Table C2: Zones of Influence and the Scope of an Effect on Four Valued Components – Toothed Whales**

| Activity | Impact | Effect | Toothed Whales (Narwhale) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Seismic** | | | | | | | | | |
| Vessel traffic – seismic refuelling and supply | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 0.004 | 1.00 | 1 | **0.004** |
| | Acoustic disturbance | Change in behavior/displacement | 180 dB | 0.5 | 10 | 0.004 | 0.70 | 5 | **0.015** |
| | Vessel strikes | Change in health/injury/mortality risk | N/A | 0.025 | 0.025 | 0.004 | 0.02 | 5 | **0.000** |
| | Space conflict | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Vessel traffic – Seismic vessel and support vessel | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 1.000 | 1.00 | 1 | **1.000** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 10 | 1.000 | 0.70 | 5 | **3.500** |
| | Vessel strikes | Change in health/injury/mortality risk | N/A | 0.025 | 0.025 | 1.000 | 0.02 | 5 | **0.100** |
| | Space conflict | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Seismic acquisition – 3D | Acoustic disturbance | Change in habitat | 180 dB | 1.5 | 30 | 0.75 | 1.00 | 1 | **0.750** |
| | Acoustic disturbance | Change in behavior | 180 dB | 1.5 | 30 | 0.75 | 0.90 | 5 | **3.375** |
| | Acoustic disturbance | Change in health/injury/mortality risk – larvae only | N/A | 1.5 | 3 | 0.75 | 0.50 | 5 | **1.875** |
| | Space conflict | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Seismic acquisition – 2D | Acoustic disturbance | Change in habitat | 180 dB | 1.5 | 30 | 0.75 | 1.00 | 1 | **0.750** |
| | Acoustic disturbance | Change in behavior | 180 dB | 1.5 | 30 | 0.75 | 0.90 | 5 | **3.375** |
| | Acoustic disturbance | Change in health/injury/mortality risk – larvae only | N/A | 1.5 | 3 | 0.75 | 0.50 | 5 | **1.875** |
| | Space conflict | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |

| Activity | Impact | Effect | Toothed Whales (Narwhale) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Exploration Drilling** | | | | | | | | | |
| Vessel traffic – Drilling refueling and supply | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 0.016 | 1.00 | 1 | **0.016** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 10 | 0.016 | 0.70 | 5 | **0.057** |
| | Vessel strikes | Change in health/injury/mortality risk – larvae only | N/A | 0.025 | 0.025 | 0.016 | 0.02 | 5 | **0.002** |
| | Exclusion of fishing activities | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Vessel traffic – Drilling | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 1.000 | 1.00 | 1 | **1.000** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 10 | 1.000 | 0.70 | 5 | **3.500** |
| | Vessel strikes | Change in health/injury/mortality risk – larvae only | | 0.025 | 0.025 | 1.000 | 0.02 | 5 | **0.100** |
| | Exclusion of fishing activities | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Drilling | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 20 | 0.75 | 1.00 | 1 | **0.750** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 20 | 0.75 | 1.00 | 1 | **0.750** |
| | Contaminants – disposal drilling muds etc. | Change in health/injury/mortality risk | 180 dB | 0.25 | 0.5 | 0.75 | 0.01 | 5 | **0.038** |
| | Tainting, exclusion of fishing activities | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Overflights | Acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior | <300 m | 0 | 0.5 | 0.02 | 0.05 | 1 | **0.001** |
| | Acoustic disturbance | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Operation of structures | Visual and acoustic disturbance | Change in habitat | N/A | 0 | 0.5 | 1.00 | 0.00 | 0 | **0.000** |
| | | Change in health/injury/mortality risk | N/A | 0 | 0 | 0.00 | 0.00 | 0 | **0.000** |
| | | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |

| Activity | Impact | Effect | Toothed Whales (Narwhale) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Other Activities** | | | | | | | | | |
| Non-exploration Vessel traffic – Shipping | Acoustic disturbance | Change in habitat | 180 dB | 0.5 | 10 | 0.000 | 1.00 | 1 | **0.000** |
| | Acoustic disturbance | Change in behavior | 180 dB | 0.5 | 10 | 0.000 | 0.70 | 5 | **0.002** |
| | Vessel strikes/ underwater noise | Change in health/injury/mortality risk | N/A | 0.025 | 0.025 | 0.000 | 0.02 | 5 | **0.000** |
| | | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Waste water treatment and discharge from routine ship operations | Pollution | Change in habitat | N/A | 0 | 0 | 0.80 | 0.01 | 0 | **0.000** |
| | | Change in behavior | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |

**NOTES AND KEY**

Exploration, ice off scenario

It is assumed that industry standard mitigation measures are applied

Any "not applicable" categories scored a "0"

**COMPONENTS OF THE SCOPE OF AN EFFECT**

Duration of Effect—estimated proportion of the season the effect lasts

**Consequence of Effect:**

0 = Negligible
1 = Temporary and local adverse effect unlikely to be of high consequence
5 = Potential adverse effect that is regional (study area) or seasonal
10 = Regional long-term change

**Table C3: Zones of Influence and the Scope of an Effect on Four Valued Components – Commercial Turbot Fisheries**

| Activity | Impact | Effect | Commercial Turbot Fisheries | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) | | Scope of Effect | | | |
| | | | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Seismic** | | | | | | | | |
| Vessel traffic – seismic refueling and supply | Acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior/displacement | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Vessel strikes | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Space conflict | Change in access to resources | 1 | 5 | 0.250 | 0.10 | 1 | **0.025** |
| Vessel traffic – Seismic vessel and support vessel | Acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Vessel strikes | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Space conflict | Change in access to resources | 1 | 5 | 0.250 | 0.10 | 1 | **0.025** |
| Seismic acquisition – 3D | Acoustic disturbance | Change in habitat | 1 | 10 | 1.00 | 0.02 | 5 | **0.100** |
| | Acoustic disturbance | Change in behavior | 1 | 30 | 1.00 | 0.50 | 1 | **0.500** |
| | Acoustic disturbance | Change in health/injury/mortality risk – larvae only | 0 | 0.01 | 1.00 | 0.25 | 1 | **0.250** |
| | Space conflict | Change in access to resources | 1 | 5 | 0.25 | 0.25 | 5 | **0.313** |
| Seismic acquisition – 2D | Acoustic disturbance | Change in habitat | 1 | 10 | 0.25 | 0.01 | 1 | **0.003** |
| | Acoustic disturbance | Change in behavior | 1 | 30 | 1.00 | 0.25 | 1 | **0.250** |
| | Acoustic disturbance | Change in health/injury/mortality risk – larvae only | 0 | 0.5 | 1.00 | 0.10 | 1 | **0.100** |
| | Space conflict | Change in access to resources | 1 | 5 | 0.25 | 0.10 | 1 | **0.025** |

| Activity | Impact | Effect | Commercial Turbot Fisheries | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) | | Scope of Effect | | | |
| | | | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Exploration Drilling** | | | | | | | | |
| Vessel traffic – Drilling refueling and supply | Acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Vessel strikes | Change in health/injury/mortality risk – larvae only | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Exclusion of fishing activities | Change in access to resources | 0 | 1 | 0.10 | 0.10 | 1 | **0.010** |
| Vessel traffic – Drilling | Acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Vessel strikes | Change in health/injury/mortality risk – larvae only | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Exclusion of fishing activities | Change in access to resources | 0 | 1 | 0.10 | 0.10 | 1 | **0.010** |
| Drilling | Acoustic disturbance | Change in habitat | 0 | 1 | 0.75 | 0.20 | 1 | **0.150** |
| | Acoustic disturbance | Change in behavior | 0 | 2 | 0.75 | 0.20 | 1 | **0.150** |
| | Contaminants – disposal drilling muds etc. | Change in health/injury/mortality risk | | | 0.00 | 0.00 | 0 | **0.000** |
| | Tainting, exclusion of fishing activities | Change in access to resources | 0 | 5 | 1.00 | 0.01 | 1 | **0.010** |
| Overflights | Acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Operation of structures | Visual and acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in access to resources | 1 | 3 | 0.10 | 0.05 | 1 | **0.005** |

| Activity | Impact | Effect | Commercial Turbot Fisheries | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) | | Scope of Effect | | | |
| | | | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Other Activities** | | | | | | | | |
| Non-exploration Vessel traffic - Shipping | Acoustic disturbance | Change in habitat | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Vessel strikes/underwater noise | Change in health/injury/mortality risk | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in access to resources | 1 | 5 | 0.050 | 0.05 | 1 | **0.003** |
| Waste water treatment and discharge from routine ship operations | Pollution | Change in habitat | 1 | 2 | 1.00 | 0.01 | 1 | **0.010** |
| | | Change in behavior | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in health/injury/mortality risk | 1 | 2 | 1.00 | 0.01 | 1 | **0.010** |
| | | Change in access to resources | N/A | N/A | N/A | N/A | N/A | **N/A** |

**NOTES AND KEY**

Exploration, ice off scenario

It is assumed that industry standard mitigation measures are applied

Any "not applicable" categories scored a "0"

**COMPONENTS OF THE SCOPE OF AN EFFECT**

Duration of Effect—estimated proportion of the season the effect lasts

**Consequence of Effect:**

0 = Negligible
1 = Temporary and local adverse effect unlikely to be of high consequence
5 = Potential adverse effect that is regional (study area) or seasonal
10 = Regional long-term change

**Table C4: Zones of Influence and the Scope of an Effect on Four Valued Components – Common Murre**

| Activity | Impact | Effect | Common Murre | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Seismic** | | | | | | | | | |
| Vessel traffic – seismic refueling and supply | Acoustic disturbance | Change in habitat | Unlikely | 0 | 0.1 | 0.004 | 0.00 | 0 | **0.000** |
| | Acoustic disturbance | Change in behavior/displacement | Not documented | 0 | 1 | 0.004 | 0.20 | 1 | **0.001** |
| | Vessel strikes | Change in health/injury/mortality risk | unlikely | 0 | 0.05 | 0.004 | 0.00 | 0 | **0.000** |
| | Space conflict | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Vessel traffic – Seismic vessel and support vessel | Acoustic disturbance | Change in habitat | Unlikely | 0 | 0.1 | 1.000 | 0.01 | 0 | **0.000** |
| | Acoustic disturbance | Change in behavior | Not documented | 0 | 1 | 1.000 | 0.20 | 1 | **0.200** |
| | Vessel strikes | Change in health/injury/mortality risk | Unlikely | 0 | 0.05 | 1.000 | 0.01 | 0 | **0.000** |
| | Space conflict | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Seismic acquisition – 3D | Acoustic disturbance | Change in habitat | Not documented | 0 | 0 | 0.75 | 0.00 | 0 | **0.000** |
| | Acoustic disturbance | Change in behavior | Not documented | 0 | 1 | 0.75 | 0.01 | 1 | **0.008** |
| | Acoustic disturbance | Change in health/injury/mortality risk – larvae only | | 0 | 0 | 0.75 | 0.00 | 0 | **0.000** |
| | Space conflict | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Seismic acquisition – 2D | Acoustic disturbance | Change in habitat | Not documented | 0 | 0.1 | 0.75 | 0.00 | 0 | **0.000** |
| | Acoustic disturbance | Change in behavior | Not documented | 0 | 1 | 0.75 | 0.01 | 1 | **0.008** |
| | Acoustic disturbance | Change in health/injury/mortality risk – larvae only | | 0 | 0 | 0.75 | 0.00 | 0 | **0.000** |
| | Space conflict | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |

| Activity | Impact | Effect | Common Murre | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| **Exploration Drilling** | | | | | | | | | |
| Vessel traffic – Drilling refueling and supply | Acoustic disturbance | Change in habitat | Unlikely | 0 | 0.1 | 0.016 | 0.00 | 0 | **0.000** |
| | Acoustic disturbance | Change in behavior | Not documented | 0 | 1 | 0.016 | 0.20 | 1 | **0.003** |
| | Vessel strikes | Change in health/injury/mortality risk – larvae only | Unlikely | 0 | 0.05 | 0.016 | 0.00 | 0 | **0.000** |
| | Exclusion of fishing activities | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Vessel traffic – Drilling | Acoustic disturbance | Change in habitat | Unlikely | 0 | 0.1 | 1.000 | 0.00 | 0 | **0.000** |
| | Acoustic disturbance | Change in behavior | Not documented | 0 | 1 | 1.000 | 0.20 | 1 | **0.200** |
| | Vessel strikes | Change in health/injury/mortality risk – larvae only | Unlikely | 0 | 0.05 | 1.000 | 0.00 | 0 | **0.000** |
| | Exclusion of fishing activities | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Drilling | Acoustic disturbance | Change in habitat | Unlikely | 0 | 0.1 | 0.75 | 0.00 | 0 | **0.000** |
| | Acoustic disturbance | Change in behavior | | | | | | | |
| | Contaminants – disposal drilling muds etc. | Change in health/injury/mortality risk | Unlikely | 0 | 2 | 0.01 | 0.01 | 5 | **0.001** |
| | Tainting, exclusion of fishing activities | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Overflights | Acoustic disturbance | Change in habitat | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in behavior | Captured below | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | Acoustic disturbance | Change in health/injury/mortality risk | Up to 1 | 0.2 | 1 | 0.05 | 0.05 | 5 | **0.013** |

| Activity | Impact | Effect | Common Murre | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Zone of Influence (km) of Effect | | | Scope of Effect | | | |
| | | | Literature Values | Minimum (10%) | Max (90%) | Duration of Effect (Proportion of Season) | Probability of an Effect | Consequence of Effect | Total |
| Operation of structures | Visual and acoustic disturbance | Change in habitat | Up to 1 | 0.2 | 1 | 1.00 | 0.20 | 1 | **0.200** |
| | | Change in health/injury/mortality risk | Unlikely | 0 | 0 | 0.00 | 0.01 | 5 | **0.000** |
| | | Change in access to resources | N/A | N/A | N/A | N/A | N/A | N/A | **N/A** |
| **Other Activities** | | | | | | | | | |
| Non-exploration Vessel traffic – Shipping | Acoustic disturbance | Change in habitat | Unlikely | 0 | 0.1 | 0.000 | 0.00 | 0 | **0.000** |
| | Acoustic disturbance | Change in behavior | Not documented | 0 | 1 | 0.000 | 0.20 | 1 | **0.000** |
| | Vessel strikes/ underwater noise | Change in health/injury/mortality risk | Unlikely | 0 | 0.05 | 0.000 | 0.00 | 0 | **0.000** |
| | | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| Waste water treatment and discharge from routine ship operations | Pollution | Change in habitat | | 0.1 | 1 | 0.80 | 0.05 | 1 | **0.040** |
| | | Change in behavior | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in health/injury/mortality risk | | N/A | N/A | N/A | N/A | N/A | **N/A** |
| | | Change in access to resources | | N/A | N/A | N/A | N/A | N/A | **N/A** |

**NOTES AND KEY**

Exploration, ice off scenario

It is assumed that industry standard mitigation measures are applied

Any "not applicable" categories scored a "0"

**COMPONENTS OF THE SCOPE OF AN EFFECT**

Duration of Effect—estimated proportion of the season the effect lasts

**Consequence of Effect:**

0 = Negligible
1 = Temporary and local adverse effect unlikely to be of high consequence
5 = Potential adverse effect that is regional (study area) or seasonal
10 = Regional long-term change