A before-after dose-response (BADR) terrestrial biological monitoring framework for the oil sands

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A Before-After Dose-Response (BADR) Terrestrial Biological Monitoring Framework for the Oil Sands

List of contributing experts to this report and their and affiliations:

Erin Bayne [1]
Jacqueline Dennett [2]
Jenet Dooley [3]
Monica Kohler [3]
Jeff Ball [4]
Mark Bidwell [4]
Andrew Braid [5]
John Chetelat [6]
Eric Dillegeard [3]
Dan Farr [5]
Jason Fisher [7]
Maureen Freemark [6]
Ken Foster [8]
Christine Godwin [8]
Craig Hebert [6]
Dave Huggard [3]
Dianne McIssac [9]
Tara Narwani [3]
Scott Nielsen [2]
Bruce Pauli [6]
Sanjay Prasad [9]
David Roberts [5]
Simon Slater [5]
Samantha Song [4]
Stella Swanson [10]
Phil Thomas [6]
Judith Toms [4]
Colin Twitchell [3]
Shannon White [3]
Faye Wyatt [5]
Lukas Mundy [6]

[1] University of Alberta, Department of Biological Sciences
[2] University of Alberta, Department of Renewable Resources
[3] Alberta Biodiversity Monitoring Institute (ABMI)
[4] Canadian Wildlife Service (CWS)
[5] Alberta Environment and Parks (AEP)
[6] Environment and Climate Change Canada (ECCC)
[7] University of Victoria
[8] Owl Moon Environmental Inc.
[9] Wood Buffalo Environmental Association (WBEA)
[10] Swanson Environmental Strategies

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Comments, questions, or suggestions regarding the content of this document may be directed to:

Ministry of Environment and Parks, Resource Stewardship Division

Oil Sands Monitoring Program Office

10th Floor, 9888 Jasper Avenue NW, Edmonton, Alberta, T5J 5C6

Email: OSM-Info@gov.ab.ca

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Forward

Since February 2012, the governments of Alberta and Canada have worked in partnership to implement an environmental monitoring program for the oil sands region. In December 2017 both governments renewed their commitment to working together with Indigenous communities in the region by the signing the *Alberta-Canada Memorandum of Understanding (MOU) Respecting Environmental Monitoring in the Oil Sands Region*. The MOU establishes the foundation for an adaptive and inclusive approach to program implementation ensuring that the program is responsive to emerging priorities, information, knowledge, and input from key stakeholders and Indigenous peoples in the region.

The Oil Sands Monitoring Program is designed to enhance the understanding of the state of the environment and cumulate environmental effects as a result of oil sands development in the region though monitoring and publically reporting on the status and trends of air, water, land and biodiversity. Its vision is to integrate Indigenous knowledge and wisdom with western science to design, interpret, assess, report and govern the program.

Canada and Alberta have provided leadership to strengthen program delivery, and ensure that necessary monitoring and scientific activities meet program commitments and objectives. The oil sands industry provides funding support for the program under the Oil Sands Environmental Regulation (Alberta Regulation 226/2013). Key findings and results from the program inform regional resource management decisions and importantly, are considered as an objective source of scientific interpretation of credible environmental data.

A mandated cornerstone of the program is the public reporting of data, status and trends of environmental impacts caused by development of oil sands resources. The Oil Sands Monitoring Program *Technical Report Series* provides an objective, and timely, evaluation and interpretation of monitoring data and information collected across environmental media of the program. This includes reporting and evaluation of emission/release sources, fate, effects and transport of contaminants, landscape disturbance and responses across theme areas including atmospheric, aquatic, biotic, wetlands, and community based monitoring.

Preface

This document was developed by a collaborative team of Principal Investigators who lead the delivery of the Terrestrial Biological Monitoring (TBM) activities for the Oil Sands Monitoring Program (OSM), along with contributions from multiple individuals throughout OSM. BADR is the unifying sampling design under which TBM has evolved an integrated approach and represents the combined viewpoints of the authors. However, at the time of publication, this monitoring design has not been formally adopted by OSM Program governance as a directive for TBM under the OSM Program.

The Before-After-Dose-Response (BADR) design was developed to bring the TBM program into stronger alignment with OSM objectives. The description provided in this document was developed prior to the OSM Program's adoption of an environmental-effects-monitoring (EEM) or adaptive monitoring paradigm. While the authors see many points of alignment between the BADR design and an adaptive approach to monitoring, the details of this alignment are not included in this report. Efforts to demonstrate how BADR fulfills an EEM approach will be developed at a later time.

This work was funded under the Oil Sands Monitoring Program and is a contribution to the Program but does not necessarily reflect the position of the Program.

Executive Summary

Terrestrial Biological Monitoring and BADR

One of the theme areas monitored within the OSM program is terrestrial biodiversity, known programmatically as Terrestrial Biological Monitoring (TBM). Biodiversity refers to the diversity of wild species, habitats, and ecosystems. These biological resources provide incredible value, including cultural and spiritual, recreational, subsistence, and ecosystem services.

A Hierarchical Before-After Dose-Response (BADR) study design was developed to provide an integrated, efficient framework for the TBM program. The framework is used to address the following key questions in terrestrial ecosystems:

1. Have changes occurred?
2. To what degree are those changes attributable to oil sands activities?
3. What are the cumulative effects of oil sands stressors?

The BADR framework represents a major shift in how terrestrial ecosystems are monitored in the oil sands region and is directly aligned with addressing these three questions using indicator groups that are directly aligned with the conceptual model.

What is BADR?

BADR is a monitoring design that measures changes in selected indicator groups and attributes those changes to oil sands activities using two monitoring approaches:

1. **Before-After**: Monitoring at different phases of oil sands development (currently developed, not yet developed, and reference)
2. **Dose-Response**: Monitoring along a gradient of current oil sands disturbance (high to low)

The combination of these two approaches forms the BADR design. By repeatedly surveying monitoring locations within this design over time, we will gain information on how biological systems are changing as oil sands activity changes.

What BADR Measures

Change will be measured for a number of indicator groups, which fall into three categories: stressor, pathway, and response. Stressor indicators provide information on the state of oil sands stressors, pathway indicators inform the mechanisms by which those stressors impact ecosystems, and response indicators represent aspects of the environment that are susceptible to changes due to oil sands activity. Stressor, pathway, and response indicators have been selected for the priority linkages within the OSM conceptual model for each of the four indicator groups.

Table A. Terrestrial biological stressor indicators and their associated monitoring parameters that will be assessed within the BADR design.

Stressor indicators	
Indicator	**Parameter**
Landscape disturbance	Land use and land cover data Human footprint inventories
Natural disturbance	Disturbance indices: fire, disease, drought
Contaminants*	Air, water, sediment, and snowpack contaminants
Physical infrastructure	Off lease: above-ground pipelines, noise, light
Climate change	Projections and recent observations of climate change

Table B. Terrestrial biological pathway indicator groups and specific indicators that will be assessed within the BADR design.

Pathway indicators	
Indicator group	**Indicator**
Linking landscape disturbance with responses	Habitat loss, degradation, and recovery Behaviour related to reduced habitat connectivity Invasive species
Linking infrastructure with responses	Behaviour
Linking contaminants with responses *	Chemicals in lichen tissue Periphyton and aquatic macrophyte contaminants Mammal contaminant burdens in tissue, fur, feces Mammal health Contaminant levels in colonial waterbird eggs Wood frog tadpole tissue contaminants; water, aquatic invertebrates, and sediment contaminants
Linking climate change with effects on valued components	Increased frequency and severity of wildfire with deposition of contaminants Changes in habitat leading to changes in wildlife

* Contaminant sampling for mammals will be a collaborative effort between TBM and Community Based Monitoring Programs with Indigenous communities, hunters, and trappers. Contaminant stressor and pathway indicators will be collected in collaboration with the Air and Deposition, Water, and Wetlands Themes (details to be confirmed).

Table C. Terrestrial biological response indicators and their associated monitoring parameters that will be assessed within the BADR design.

Response indicators	
Indicators	**Parameter**
Vascular Plants, Mosses, Lichens	Height, cover, growth, species richness, community composition, density, structural complexity
Migratory Landbirds	Population growth rate (productivity, survival, recruitment), occupancy/density, habitat selection, functional group or guild abundance, species richness/diversity
Mammals	Occupancy, abundance, distribution, habitat selection, reproduction
Amphibians	Relative abundance

How BADR Works

BADR is used to decide where to put monitoring locations. This process occurs using a nested spatial hierarchy, which includes:

1. Dividing sampling across the oil sands region into large **Land-use Regions**: These Regions capture broad differences in oil sands activities and ecological context. Sampling across these regions ensures coverage for the full spectrum of oil sands stressors.
2. Focusing sampling effort into specific **Landscape Units**: Landscape units are based on watershed boundaries and are ranked according to oil sands footprint intensity. Landscape Units are selected to capture areas with low to high current oil sands footprint, and where oil sands stressors are expected to increase in the future.
3. Identifying specific locations to sample called Joint Environmental Monitoring - **JEM sites**: JEM sites are shared monitoring locations used by multiple agencies to centralize data collection. JEM sites are used to target specific oil sands disturbance types and intensities.
4. Placement of **local sampling protocols**: These are the specific locations where individual protocols will be implemented to collect data for different ecological indicators.

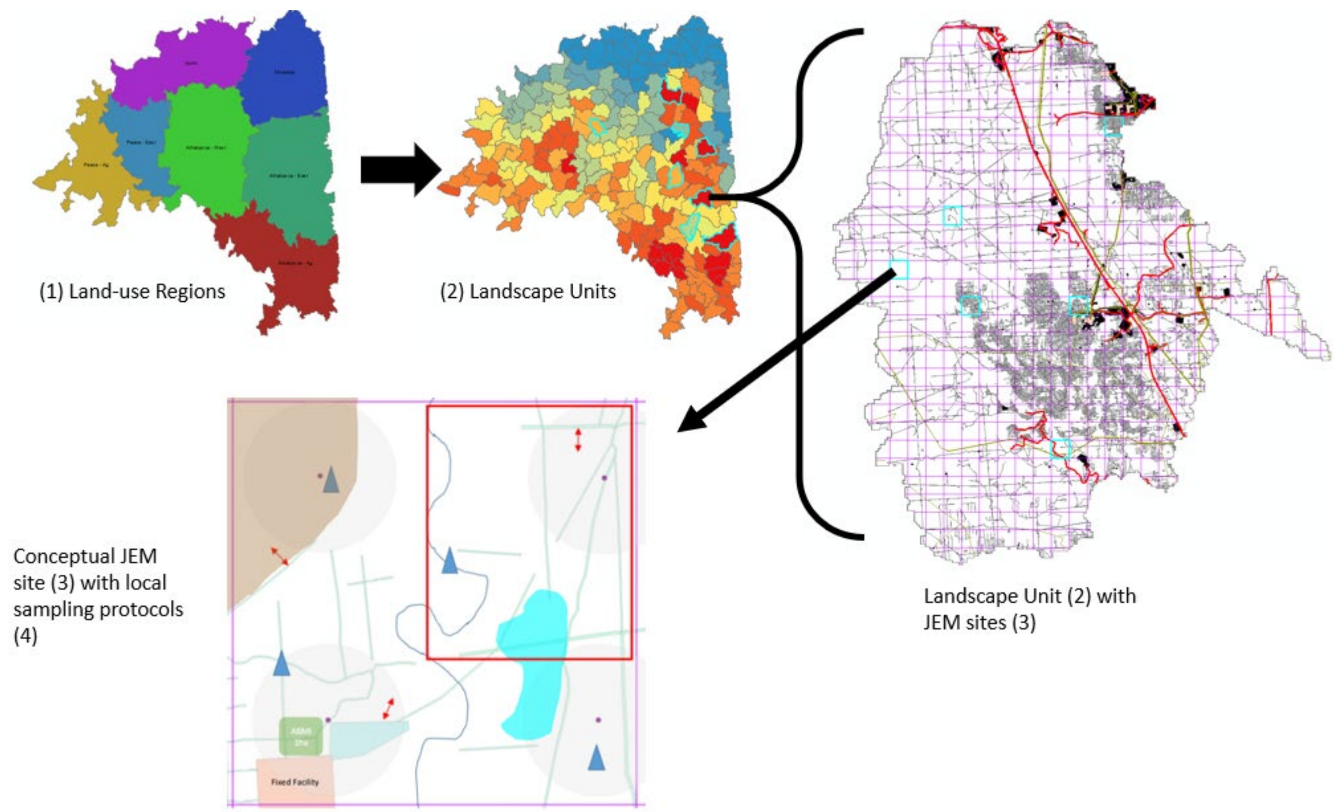

Figure A. Example of the nested hierarchical structure of BADR. There are four nested levels of spatial hierarchy in BADR: (1) land-use regions; (2) landscape units, depicted here with coloration reflecting oils sands footprint intensity and blue outlines reflecting a sampling scenario; (3) joint environmental monitoring (JEM) sites, depicted here as blue outlines within a single landscape unit; and (4) local sampling sites, depicted here as symbols representing individual program monitoring methods.

BADR for Specific Questions

The monitoring of some organisms or habitats requires consideration of spatial scales outside the structure of BADR due to their life history (e.g., behaviour, space-use, home-range size). Currently, the following complementary, targeted programs operate alongside BADR:

- Rare Habitat Program: A set of sites targeted to rare habitats in order to gather sufficient data on rare species and how they are changing over time
- Aerial Ungulate Surveys: Standardized surveys to monitor critical survival and productivity information for ungulates, conducted at the Wildlife Management Unit scale
- Mortality Risk to Endangered Species: Whooping Crane monitoring project to assess risk of tailings ponds to this Endangered Species
- Contaminants: Samples will be collected from mammals, amphibians and colonial waterbirds to assess contaminant levels and provide information on food safety and security and the health status of harvested species.

Conclusion

The BADR design ensures that the three monitoring questions of terrestrial monitoring (Have changes occurred? To what degree are those changes attributable to oil sands activities? What are the cumulative effects of oil sands stressors?) are addressed in an effective, consistent, and credible manner. The design was developed to:

- Use an ecologically relevant landscape spatial unit – watersheds;
- Examine change along stressor gradients at various spatial scales;
- Include reference (low dose) sampling units;
- Include indicators at the individual, population, and community level;
- Incorporate areas of planned oil sands expansions; and,
- Produce results which can be used for model validation

The Hierarchical BADR design will contribute scientific information to help judge the efficacy of existing regulations and compliance with approvals as they apply to “beyond the fence line” responses to oil sands stressors at local, sub-regional and regional scales.

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Acronyms and Abbreviations

ARU	Automated Recording Unit
BADR	Before-After Dose-Response
CBM	Community-Based Monitoring
CFI	Cumulative Oil Sands Footprint Index
ECCC	Environment and Climate Change Canada
GIS	Geographic Information System
GOA	Government of Alberta
HUC	Hydrologic Unit Code
LU	Landscape Unit
JEM	Joint Ecological Monitoring
MAPS	Monitoring Avian Productivity and Survival
OSM	Oil Sands Monitoring Program
OSR	Oil Sands Region
PAD	Peace-Athabasca Delta
SAR	Species At Risk
TAC	Technical Advisory Committee
TBM	Terrestrial Biological Monitoring
VC	Valued Component
WMU	Wildlife Management Unit

Oil Sands Monitoring

The Oil Sands Monitoring Program (OSM) is an ongoing effort that “strives to monitor, evaluate, and report on environmental impacts of oil sands development in northern Alberta, assess the risks of any impacts, and improve the characterization of the state of environment in an open and transparent manner” (OSM, 2019).

Three core OSM outcomes drive program priorities and development, allowing for the evaluation of performance and progression through the adaptive monitoring and management cycles:

1. Assess accumulated environmental condition or state (have things changed?);
2. Determine relationships between oil sands-related stressors and effects (are the observed changes caused by the oil sands industry?); and
3. Assess cumulative effects (what are the combined effects of oil sands stressors across regions and over time?) (OSM, 2019).

Overarching OSM objectives, as stated in the multi-stakeholder governance process (GOA, 2017; Dubé et al., 2018), are as follows:

- **To Track Impacts from Oil Sands Development**: Monitoring will obtain data on baseline, current conditions to inform future state, identify and track any environmental impacts from oil sands development, including timely assessment of cumulative environmental effects;
- **To Conduct Comprehensive and Inclusive Monitoring**: Monitoring will be comprehensive, by seeking and integrating a multiple evidence-based approach, inclusive of Indigenous Knowledge and participation, to inform monitoring program decisions. This will include monitoring indicators relevant to Indigenous communities in the oil sands region (OSR) that respect Section 35 Rights and evaluation of environmental condition relative to tiers, triggers, limits, thresholds or other “limits of change” including, but not limited to, those defined under regional planning (i.e., Lower Athabasca Regional Plan);
- **To Inform Management and Regulatory Action:** Monitoring will provide data and information to decision-makers and other stakeholders to inform management and regulatory action including regulatory and policy assurance, adaptive management, and adaptive monitoring pertaining to individual and cumulative effects;
- **To Ensure Relevant Monitoring**: Monitoring will be relevant to the vision by seeking the best available Western Science and Indigenous Knowledge on environmental impacts of oil sands development from Indigenous communities, stakeholders, industry, non-government organizations, academia, and appropriate scientific and traditional knowledge experts, regardless of their affiliations to either level of Government, Indigenous communities, or industry;
- **To Implement Rigorous Monitoring**: Western Science and Indigenous Knowledge will be rigorous, ethical, methodologically sound, comprehensive, integrated, and transparent and meet the highest standards of scientific integrity as well as respectful integration and sharing of Indigenous Knowledge;
- **To be Cost-effective**: Monitoring will make use of the best cost-effective resources available and will focus on areas of greatest risk that consider community and stakeholder concerns and priorities, and the magnitude, frequency, type, and direction of environmental change occurring or with the potential to occur relative to “limits of change”;
- **To Inform Trans-Boundary Issues**: Monitoring will be of sufficient scope to consider the trans-boundary nature of the issue and, where appropriate, to collaborate with other territorial and provincial governments;
- **To Ensure Transparency**: Transparency will be ensured by timely public reporting through accessible, comparable, and quality-assured data and information, reports, and publications evaluating, interpreting and synthesizing the monitoring results of OSM. Communication and media materials will be made accessible and understandable to communities and;
- **To Incorporate Indigenous Monitoring, Endpoints, and Community-Based Monitoring**: Monitoring will include the identification and tracking of monitoring indicators of relevance to Indigenous communities. This will include monitoring indicators relevant to Indigenous communities in the OSR that respect potential impacts to Section 35 Rights and evaluation of environmental condition relative to “limits of change” including, but not limited to, those defined under regional planning (i.e., Lower Athabasca Regional Plan)

BADR: Technical Report

1. Terrestrial Biological Monitoring

1.1 Background

OSM monitors environmental impacts under multiple program theme areas: Air and Deposition, Surface Water, Groundwater, Terrestrial Biological, and Wetlands. These themes are distinct but related entities, each with their own workplan and Technical Advisory Committee. Integration among these theme areas will be achieved where appropriate, while being cognizant of the key differences in priorities and methodology that exist between them. The purpose of this document is to outline the vision and intent for the Terrestrial Biological Monitoring (TBM) program. This program aims to align TBM with the overarching priorities of OSM, while leveraging the value of monitoring data acquired to date. It represents a significant redesign in how biological monitoring is conducted in the oil sands region.

Alberta’s OSR is defined as the aggregate of 3 recognized administrative units that together represent 21% of the province’s land area (Figure 1):

- The Athabasca Oil Sands Region;
- The Cold Lake Oil Sands Region; and
- The Peace River Oil Sands Region.

The OSR is situated mainly within the Boreal Forest Natural Region with small areas of the Parkland, Foothills, and Canadian Shield Natural Regions. The boreal forest is characterized by a mosaic of upland forests composed of trembling aspen, white spruce, lodgepole pine, and jack pine, and lowland forests composed of black spruce and larch. These forests experience frequent natural disturbance like fire and insect outbreaks, which results in a mosaic of stands of different ages from young forests to forests more than 150 years old. The boreal-grassland transition zone, known as the aspen parkland, also covers large areas of the OSR, particularly in the Peace River and Cold Oil Sands Areas. Aspen parkland is a mixture of aspen and white spruce groves interspersed with prairie grasslands. Much of these grasslands have been converted to agricultural use.

Surface mining is the most recognizable form of bitumen extraction and only occurs in the Surface Mineable Area of the Athabasca region (Figure 1). In this form of bitumen extraction, heavy equipment is used to remove overburden and excavate oil sands deposits close to the earth’s surface. By comparison, *in-situ* extraction removes bitumen from deeper deposits by underground heating and thus separating the product from sand before pumping it to the surface. The vast majority of oil sands extraction is via *in-situ* operations, which occur in all three oil sands regions.

The facilities and stressors associated with these extraction activities are unique, as are the potential environmental impacts. Both are the focus of the OSM program and both can be addressed via the monitoring design presented here.

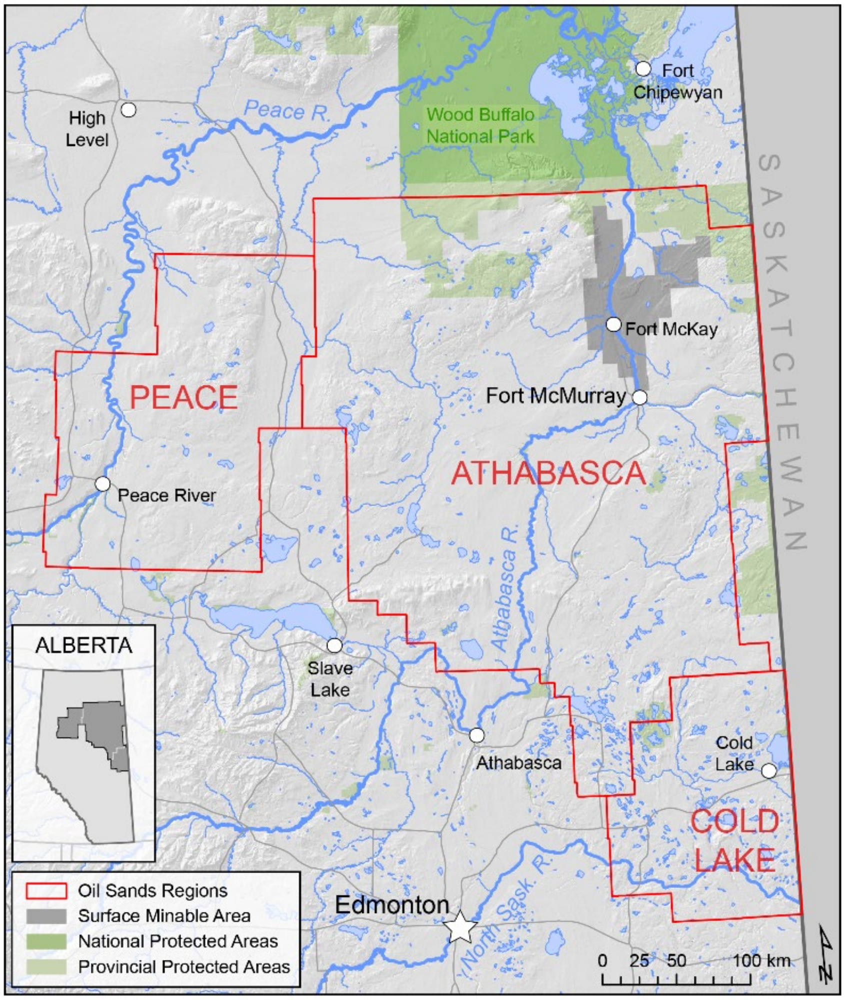

Figure 1. The Oil Sands Region (OSR) of northern Alberta comprises three areas: The Peace, Athabasca, and Cold Lake regions.

All OSM monitoring operates under a consistent framework provided by the OSM conceptual model which identifies environmental stressors, pathways, and resulting responses in the Oil Sands Region (OSR) and surrounding regions.

The OSM conceptual model also identifies Valued Components (VCs), which represent aspects of the environment that local communities and greater society value and which have potential to be affected by oil sands activity. Within Terrestrial Biological Monitoring (TBM), the priority VCs are Biodiversity, Healthy Ecosystems, and Traditional Resources and Cultural Practices. Figure 2 shows the OSM conceptual model with dashed boxes indicating TBM priority areas and the relationships, shown in bold, between them. This conceptual model forms the foundation of the TBM monitoring program design and the indicators selected for monitoring. An additional conceptual model specific to TBM has also been developed and provides greater resolution for model components that are relevant to terrestrial ecosystems (Appendix I, Figure A1).

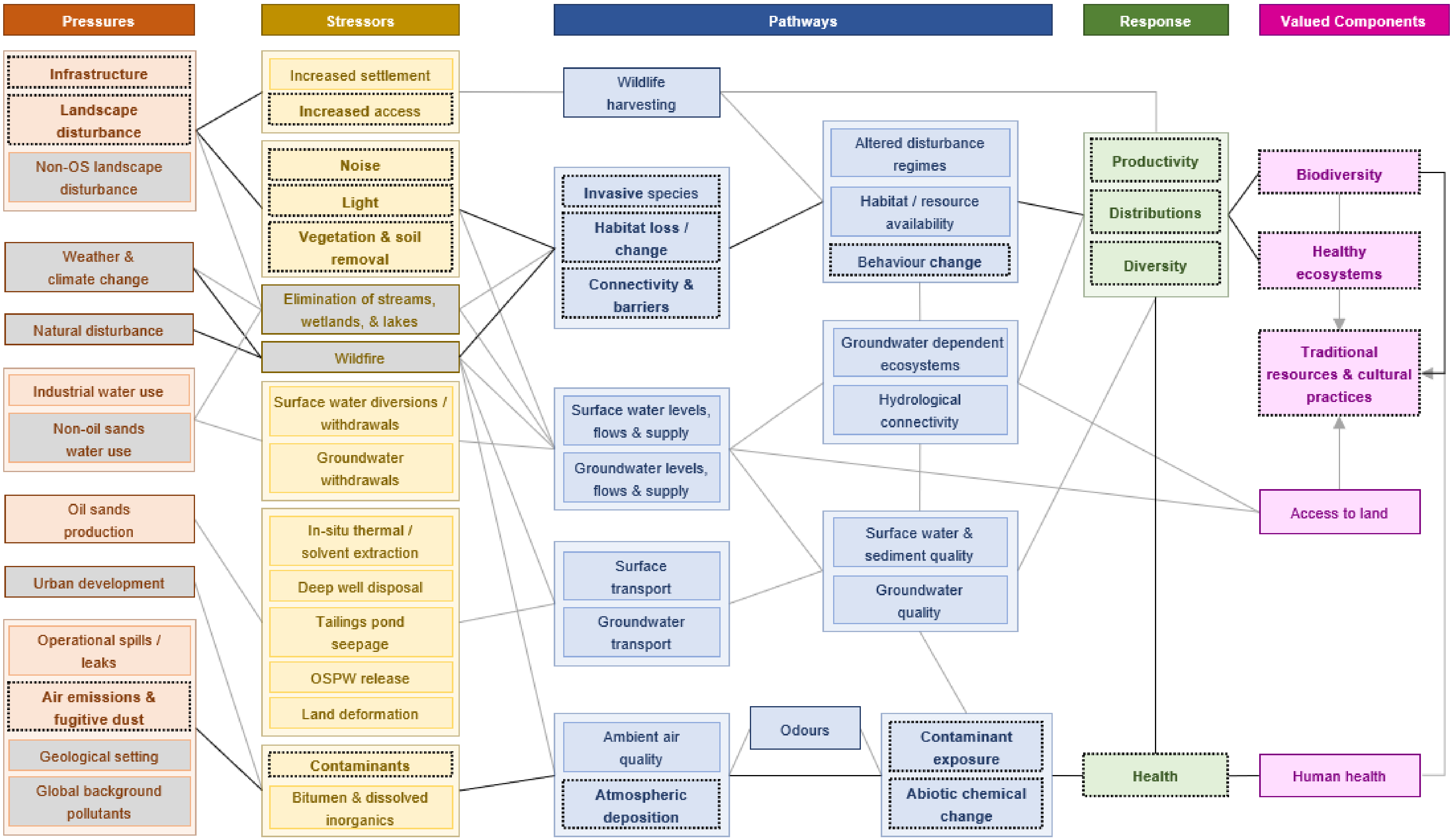

Figure 2. OSM conceptual model with black dotted borders indicating TBM priority areas and the relationships (bolded lines) between them.

1.2 Monitoring Questions and Design Framework

Terrestrial Biological monitoring in OSM will be conducted using a Hierarchical Before-After Dose-Response (BADR) design. BADR was developed by a collaborative team of subject matter experts with strong foundations in the fields of landscape ecology and ecotoxicology and is based on foundational, well-supported ecological monitoring approaches. The BADR design directly addresses OSM core outcomes and aligns with the OSM conceptual model. The BADR design was developed with consideration of the following OSM principles: cross-cutting integration amongst projects, themes and communities; contribution to State of the Environment Reporting; and monitoring that addresses mitigation, Indigenous issues, measuring change as accurately and precisely as possible, accounting for scale, transparency and efficiency.

The BADR design ensures the OSM Core Outcomes are addressed in an effective, consistent, cost-efficient, and credible manner.

The design was developed to:

- Use ecologically relevant landscape spatial units;
- Allow for examination of changes in response along stressor gradients at various spatial scales;
- Include control (or reference) sampling units;
- Include indicators at the individual, population, and community level;
- Incorporate areas of historical, current, and planned oil sands developments,
- Examine the cumulative effects of stressors across the landscape; and
- Produce results which can be used for model validation

Each term in the name “Hierarchical Before-After Dose-Response” is essential to understanding the monitoring design, how it integrates past efforts, and what can and cannot be monitored and measured under this program. Below, we describe the structure of BADR, beginning with selected monitoring indicators, then the Before-After and Dose-Response elements, and finally spatial nestedness. We further describe how BADR’s flexibility allows for the incorporation of Community Based Monitoring (CBM), rare habitat sampling, and endangered species work.

2. Hierarchical BADR Monitoring Design

2.1 Indicators

Indicators are grouped into three categories in alignment with the OSM conceptual model. Stressor indicators provide information on the state of oil sands stressors, pathway indicators inform the mechanisms by which those stressors impact ecosystems, and response indicators represent aspects of the environment that are susceptible to changes due to oil sands activity. Stressor, pathway, and response indicators have been selected for the priority linkages within the OSM conceptual model for each of the four indicator groups (Figure 2). These indicators can be adapted over time as we gain observations and capability to report on oil sands stressors, pathways, and biological responses.

The BADR framework is designed to efficiently collect data for many stressor, pathway, and response indicators, all of which provide appropriate data and tools to inform management action. The BADR design is not intended to immediately collect information on, or answer all questions about, all habitat combinations, types of energy stressors, levels of recovery, scales, and receptors. Rather, BADR provides a robust, adaptive monitoring approach that allows us to build increasingly refined analytical models for priority indicators and the relationships among them. These indicators may change over time and sampling will be adjusted to gain the data needed to improve model resolution where needed.

2.1.1 Stressor Indicators

The conceptual model describes identified stressors in the OSR (Figure 2). The current priority stressors are outlined in Table 1. These indicators will be measured through remotely-sensed models, where possible, combined with ground-truthing. Some contaminant datasets will be provided by the Air and Deposition, Surface Water and/or Wetland Themes, while some will be generated through ground-truthing in TBM. Geospatial datasets will be co-managed and created with the Geospatial Team.

Table 1. TBM stressor indicators, the parameters used to measure them, and details for those parameters.

Indicators	Parameters	Details
Landscape disturbance	Land use and land cover data Human footprint inventories	Interpretation of stereo imagery; remote sensing and earth observation Disturbance data from multiple agencies; satellite imagery
Natural disturbance	Disturbance indices: fire, disease, drought	
Contaminants	Air measures: emissions of SO2, NO2, base cations; Trace elements; PACs; Nitrogen; Phosphorus; Mercury; and VOCs Snow pack measures: Inorganic/organic contaminants Water: Nutrients, trace elements, mercury, PACs, naphthenic acids; Sediment: trace elements, PACs	Air measures: provided by Air and Deposition and Water Themes and through passive sampling ground-truthing in TBM Water: provided by Surface Water and/or Wetlands Theme and through passive sampling ground-truthing in TBM
Physical infrastructure	Off lease: above-ground pipelines, noise, light	
Climate change	Projections and recent observations of climate change	It is challenging to predict impacts in lowland habitat types as there is inherent uncertainty in response due to complex interactions and possible time lags in responses

Pathways are the mechanisms that could or have been shown to promote change in response indicators, which in turn represent the OSM-identified VCs of Biodiversity, Healthy Ecosystems, and Traditional Resources and Cultural Practices. Pathways can be extremely complex, interactive, and take careful unravelling to understand. The current priority pathway indicators are provided in Table 2.

Given the likely complexity of pathway indicators, several of the contaminant pathway indicators rely on the use of individuals of sentinel species, which were selected for their anticipated or demonstrated sensitivity to bioaccumulation given their trophic status and their value as a food resource or culturally important species. These individual organism-level responses are intended to provide an indication of contaminant exposure generally within biological communities.

Table 2. TBM pathway indicator groups, specific indicators that will be assessed under BADR, and associated details and parameters.

Indicator groups	Indicators	Details / Parameters
Linking landscape disturbance with responses	Habitat loss, degradation, and recovery Behaviour Invasive species	Note that this is addressed at multiple scales. Related to reduced habitat connectivity, including barriers and avoidance
Linking infrastructure with responses	Behaviour	
Linking contaminants with responses	Lichen tissue Periphyton PACs; Aquatic macrophytes, benthic invertebrates: metals, PACs Mammal contaminant burdens: PAC and trace metal concentrations in tissue, fur, feces. Mammal Health: endocrine responses, population genetics Bird contaminant burdens Amphibian contaminant burdens	Tissue chemical composition Samples collected under the BADR framework in collaboration with the Wetlands Theme (to be confirmed) Samples provided by Community Based Monitoring Programs, Indigenous communities, hunters and trappers Samples provided by Community Based Monitoring Programs, Indigenous communities, hunters and trappers. Contaminant levels in colonial waterbird eggs Wood frog tadpole tissue trace elements, PACs, naphthenic acids
Linking climate change with effects on valued components	Increased frequency and severity of wildfire with deposition of contaminants Changes in habitat leading to changes in wildlife	

2.1.2 Response Indicators

Four high-level indicator groups have been selected for monitoring under the BADR design. These groups are critical components of the OSM-identified VCs of biodiversity and healthy ecosystems: vegetation, migratory landbirds, mammals, and amphibians. These indicator groups were selected based on their ability to address OSM objectives, via a standard set of criteria including: social, cultural, and economic value, particularly to local communities in the OSR, and potential sensitivity to oil sands stressors. An indicator selection table presenting the scores for each criterion for each of the high-level indicator groups is included in Appendix I, Table A1Table A1. Details about selected response indicators and the parameters that will be used to measure them are provided in Table 3.

Broadly, TBM response indicators are focused primarily at the population and community ecological scales, excluding species-at-risk, for which individual organism responses are highly relevant. TBM takes a multi-taxa approach to response indicators, which reflects the significant efficiencies achieved by surveying with automated recording unit (ARU) and remote camera technologies.

Table 3. TBM response indicators for each of the four high level indicator groups.

High-level Indicator Groups	Indicators
Vascular Plants, Mosses, Lichens	Height, cover, growth, species richness, community composition, density, structural complexity
Migratory Landbirds	Adult survival, adult population, population growth rate, post-fledging productivity, occupancy/density, habitat selection, functional group or guild abundance, species richness/diversity
Mammals	Occupancy, abundance, distribution, habitat selection, reproduction
Amphibians	Occurrence, relative abundance

2.2 Before-After Aspects of the Design

Before-After refers to monitoring before and after oil sands development in order to measure ecological change as a result of oil sands activity. Before-After is captured in this program using two approaches: 1) repeated sampling of sites (measuring change over time), and 2) space for time inference (measuring change in disturbed areas relative to controls).

Specifically, for the former approach, repeat sampling will occur adaptively over time in order to achieve precision targets and meet the different needs of the four response indicator groups. The incorporation of historical monitoring locations during site selection will allow for immediate repeat sampling to occur to begin to monitor change over time. It is expected that oil sands activities will expand at some of these sites, allowing for direct measurement of change.

For the latter approach, environmental change due to oil sands activity can be inferred by sampling landscape units (see Section 2.5.2) that vary in disturbance and contaminant intensities. This reflects space-for-time substitution, which is a common, well-supported approach in ecology. Space for time will be applied by sampling from landscape units that comprise:

1. Current development: landscape units where oil sands development is already extensive and which are closer to air pollution sources. In the mid- to long-term, monitoring in these areas will provide information on how ecosystems respond to natural recovery, oil sands reclamation, restoration, and accumulated loadings of contaminants to soil and water.

2. Proposed future development: landscape units where oil sands exploration activities (e.g., seismic lines) have occurred prior to full development. In the mid- to long-term, these landscapes, if developed, can be used to validate our dose-response models by demonstrating how biodiversity changes over time as oil sands mines, wells, facilities, and roads transition these areas into landscape units with extensive development (thus changing from “before” treatments to “after” treatments).

3. Control: landscape units where oil sands activities are minimal and unlikely to occur in the future. This will allow us to separate the impacts of oil sands stressors from non-oil sands factors changing biodiversity (e.g., climate change, wildfire, extra-regional effects such as long-range atmospheric transport of contaminants or degradation of overwintering habitat for migratory birds).

As we monitor these locations over time, they will become repeated sampling locations, reflecting the former approach. This dual approach allows us to leverage existing monitoring locations while gathering information across the full gradient of disturbance and contaminants in the OSR. This will allow us to understand how ecological responses vary over time as a product of current disturbance levels.

2.3 Dose-Response Aspects of the Design

Dose is a measure of the intensity of one or more stressors (e.g., density of seismic lines, noise level, contaminant exposure). Response is the change in the behaviour or health of individuals, population, and/or community composition of receptors (i.e. species), as measured by an indicator or set of indicators. The dose-response aspect of the design is addressed at the landscape unit level (Section 2.5.2Landscape units) and the monitoring site level (Section 2.5.3). In the short term, current development landscape units, as described above, provide the high end of the dose-response gradient, proposed development landscape units provide the middle of the gradient, and the control landscape units provide the long-term low end of the gradient. In the longer term, monitoring locations will represent the entire range of the dose-response gradient. Doses will inevitably change with recovery and new disturbances at these locations, and thus the dose-response component will integrate with the before-after component.

The dose-response gradient will be addressed by locating half of the sampling in the current development landscape units (i.e., high dose) and the other half occurring in proposed future development and control units. The rationale for allocating greater effort to the high end of the stressor gradient is: 1) historical monitoring has been at the mid- to low- end of the dose-response gradient; and 2) high dose-response conditions are clustered in space within the OSR and thus require sampling where they exist in order to balance the design.

It is reasonable to ask why we can't simply focus our dose-response gradients in one part of the OSR. First, there are natural spatial gradients across the entire OSR (e.g., ecosystem productivity declines further north). Additionally, distance to agriculture, which predominates in the far west and south reaches of the OSR, has a strong influence on many species. Ecological responses vary according to these gradients upon which oil sands disturbances are imposed; the OSR is a complex, multi-stressor landscape. Second, the various types of oil sands development vary in disturbance extent, intensity of activity, and processing and extraction techniques. Comparing results among different development trajectories will provide insights into best practices that might be used in future development to mitigate any observed negative impacts. Thirdly, spatial coverage across land-use regions results in a more adaptable design that is able to incorporate changes in priorities, valued components, or scientific focus of the OSM program over time. These important factors are addressed by sampling across land-use regions (Section 2.5.1).

2.4 Design Hierarchy

The hierarchical structure of BADR addresses two scales: ecological and spatial. Ecological scale is addressed by collecting data for individual, population, and community-level indicators. Spatial scale is addressed by collecting data using a nested hierarchy of sampling units. There are four nested levels of spatial hierarchy, including: (1) at the highest spatial scale, land-use regions that vary in human disturbance types; each land-use region is further divided into (2) landscape units that vary in their level of cumulative disturbance stressors; which each contain a number of (3) Joint Ecological Monitoring Sites (JEMs), which are defined sampling areas that vary in the density of individual stressors; and within each JEM, there are (4) local sampling sites that vary in their distance to various oil sands stressors (Figure 3). This approach allows us to analyze data within different units of replication, from single points to landscapes, thus measuring responses at varying spatial scales.

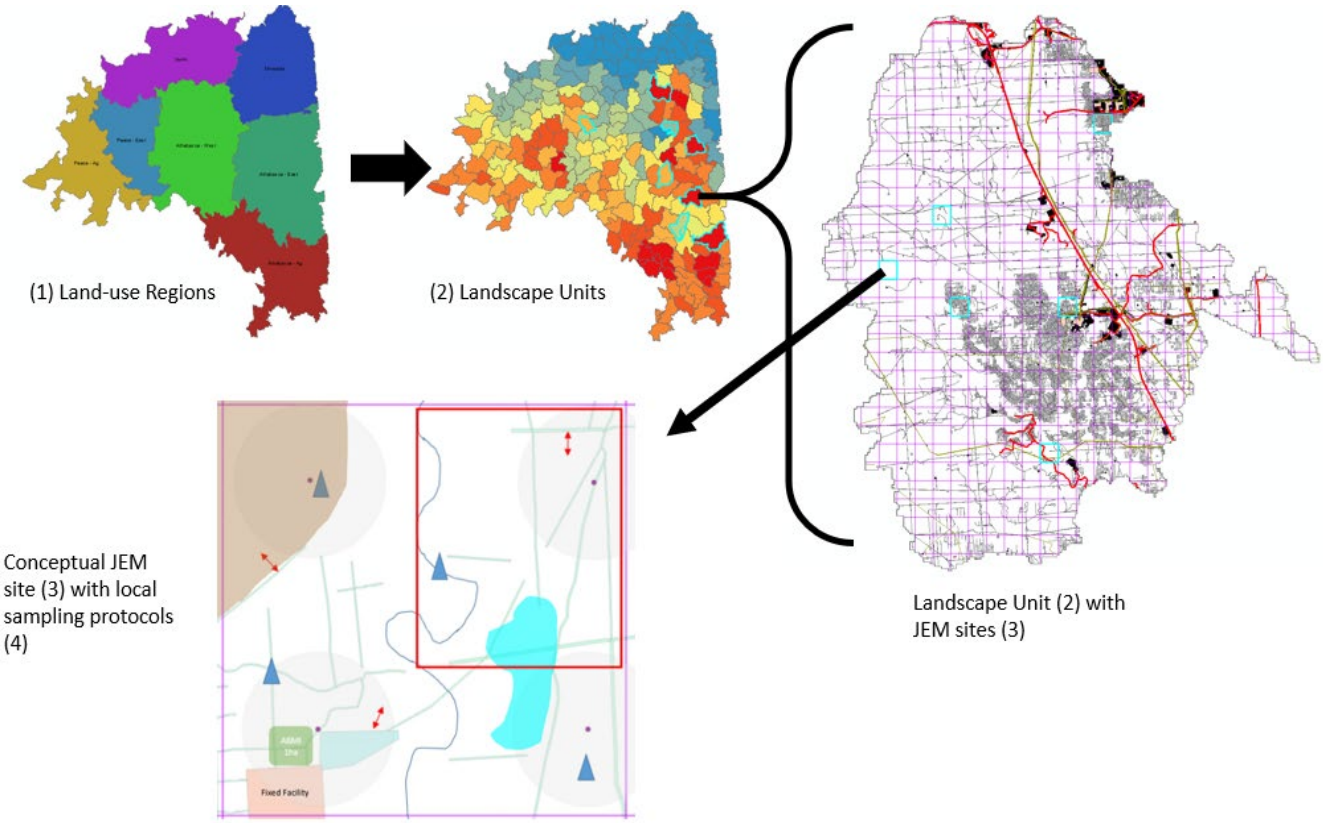

Figure 3. Nested hierarchical structure of BADR. There are four nested levels of spatial hierarchy in BADR: (1) land-use regions; (2) landscape units, depicted here with coloration reflecting oils sands footprint intensity and blue outlines reflecting a sampling scenario (See Figure 5); (3) JEM sites, depicted here in blue outlines within a single landscape unit; and (4) local sampling sites, depicted here as symbols representing individual program monitoring methods (See Figure 6).

2.5 Hierarchical Levels of the Design

2.5.1 Land-use regions

The OSR covers a massive area of land with different disturbance regimes, both from the oil sands activities themselves, and from other industries, occurring with differing intensities in different sub-regions. Examples of these differences in disturbance regimes include the highly centralized nature of oil sands mining activities relative to the dispersed nature of *in-situ* extraction activities. In addition, agricultural activities, which contain markedly different disturbance types, are present in certain parts of the OSR but not throughout. This variation in the distribution of different activities and their associated stressors requires consideration within the TBM design.

The seven land-use regions shown in Figure 4 are based on groupings of land-use types: the presence of private agricultural lands, whether oil sands mining occurs or could occur, the extent of energy development, and the intensity of *in-situ* development. These land-use regions, representing the largest spatial level of BADR, are used to capture variation in dominant land-use types and address natural, large-scale spatial patterns in the physical environment (e.g., climate, geology, topography) across the OSR. This will limit spatial confounding in the statistical models used to analyze the monitoring data. Within each land-use region, the placement of JEM sites and/or local sampling sites may be modified to accommodate these differences (e.g., distance-to sampling from a mine edge).

The land-use regions presented are the initial starting point for the program and focus on regions that currently contain oil sands developments and are thus subject to direct effects. Future adaptations of the design will evaluate opportunities to incorporate additional regions such as the Peace-Athabasca Delta (PAD).

Figure 4. Initial land-use regions used within the TBM program to implement the BADR design.

2.5.2 Landscape units

Based on hydrological features, the OSR can be subdivided into “hydrologic units”, or subwatersheds, defined according to a Hydrologic Unit Code (HUC) classification system (AEP, 2017). The HUC10 watershed category provides an appropriate spatial framework for ecological monitoring and site selection, and is therefore a foundational unit within the BADR design. The use of hydrological units also facilitates TBM integration with monitoring activities within the Wetlands and Surface Water Themes.

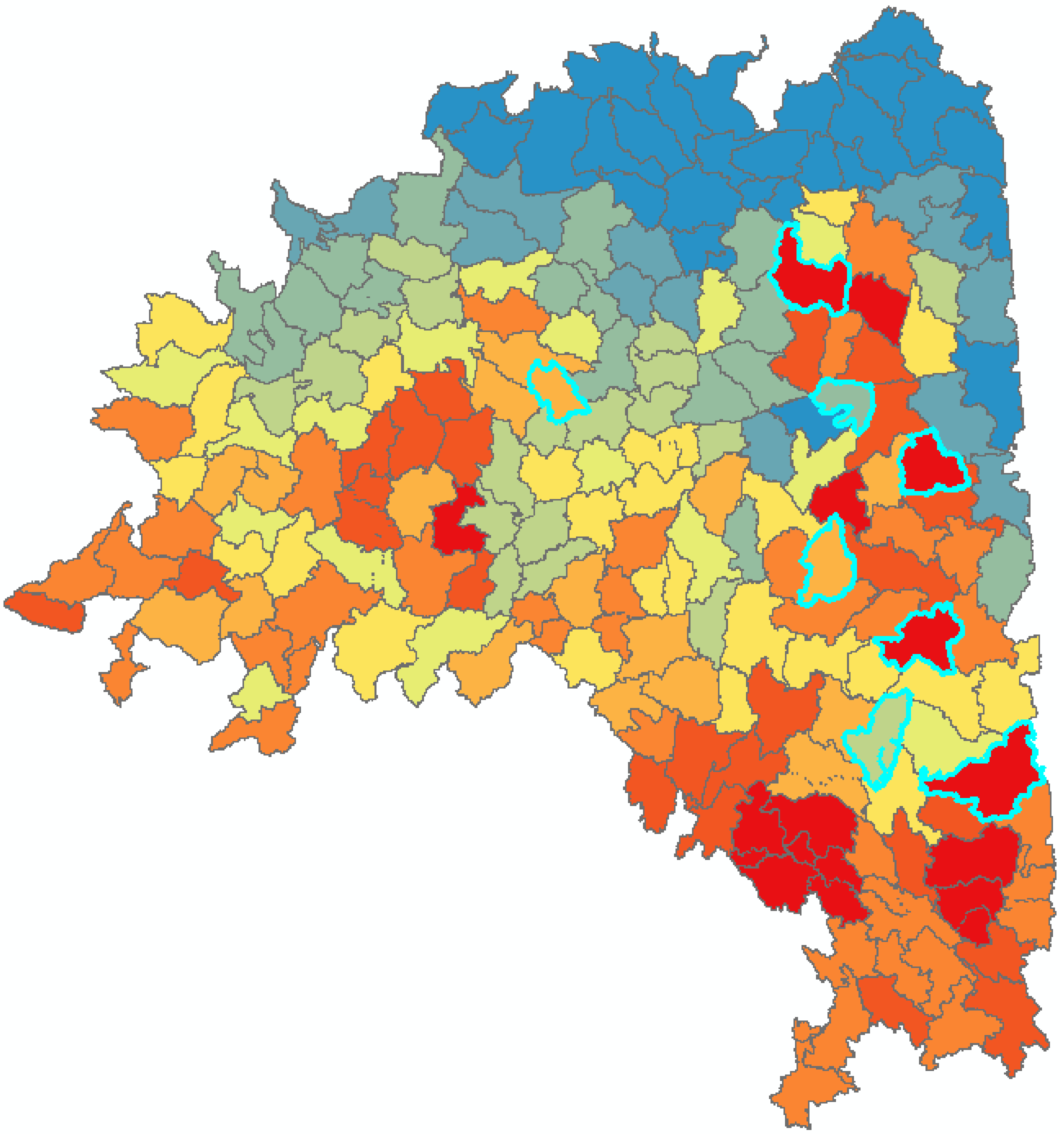

Figure 5. Landscape Units for the BADR program. The coloring represents the intensity of oil sands footprint based on the cumulative oil sands-related footprint index (CFI): red represents LUs with the highest level of cumulative footprint and blue represents the lowest. The areas outlined in bright blue represent the sampling scenario for the first round of monitoring under BADR. Additional landscape units will be added over time.

Each land-use region is divided into landscape units (LUs) of approximately 1000 km^2 (Figure 5), each representing an aggregation of 3-5 HUC10 watersheds. This size is suitable for monitoring the majority of TBM indicators. The clustering of HUC10s into landscape units was based on: minimizing internal (within-HUC10) variation in natural conditions, minimizing internal variation in industrial disturbance, the amount of existing OSM monitoring data, and the presence of ongoing and/or legacy monitoring locations from historical OSM monitoring efforts.

Each landscape unit was scored using a cumulative oil-sands footprint index (CFI), which combines different oil sands-related footprints (i.e., disturbance types) into a single index number. The human footprint categories (i.e., landscape disturbance stressors) used to calculate the CFI were mines, industrial facilities (i.e. upgraders, compressor stations), wells, roads, pipelines, and seismic lines. Pollutants (currently including sulphur, nitrogen, and light) all showed a strong correlation (>0.7) with footprint at this spatial scale. Thus, CFI is considered to be a reasonable guide for incorporating contaminants. Not all landscape units will be sampled over time, rather, unit selection will be based on the type and magnitude of terrestrial disturbance expressed using the CFI. Ongoing, adaptive landscape unit selection will include collaboration with the Wetlands Theme and Geospatial team (which is part of Integrated Analytics for OSM), and, potentially, other themes, moving forward, as well as discussion with the TBM Technical Advisory Committee and OSM governance bodies including the Indigenous Community-Based Monitoring Advisory Committee, Science and Indigenous Knowledge Integration Committee, and Oversight Committee.

Although the majority of TBM programs integrate well at the landscape unit scale, several TBM monitoring programs require larger areas. These include large mammal population monitoring, whooping crane tracking and monitoring, elements of forest health monitoring related to atmospheric deposition, and monitoring of chemical contamination in colonial waterbirds and large mammals. These programs will center on the selected landscape units ensuring spatial overlap across monitoring activities.

2.5.3 Joint Environmental Monitoring sites

A JEM site is approximately a quarter-section in size (64 ha), and JEMs form the central physical location for implementation of data collection protocols in TBM. The majority of pathway and response indicators will be measured at the JEM site level and at higher levels, where necessary. Which indicators are monitored where, across and within JEMs, will depend on the appropriate scale, extent, and sample size required to detect change.

Within each selected landscape unit, at least six JEM sites will be selected to represent a range of disturbance types:

1. Control: a site with low energy sector disturbance;
2. Soft linear: a site with high density of seismic lines, pipelines, etc.;
3. Road: a site with high density of energy sector roads;
4. Low activity: a site with energy sector disturbance without light or noise impacts (e.g., exploration wellpads); and
5. High intensity: at least two sites with high intensity disturbances (varying combinations of high human activity, light, noise and atmospheric deposition).

JEM site selection will target the five different disturbance types with a habitat type criterion. Variation among habitat types will be controlled by limiting JEM sites within a landscape unit to one dominant habitat type. The disturbance regime in high intensity JEM sites will vary across landscape units depending on the dominant high intensity land-use type(s) in the landscape unit. For example, in a landscape unit dominated by *in-situ* development, high intensity JEM sites will be near active facilities or production wells, whereas a mineable landscape unit will have high intensity JEM sites adjacent to mine fence lines. Since not all disturbance types are available in all landscape units, a balancing of JEM sites across land-use regions will occur, such that the disturbance types will be balanced, ensuring coverage in the monitoring program and facilitating statistical analyses and modelling.

Within JEM sites, the types of data collected, spatial location, seasonality, and frequency will vary among the indicators, to make these parameters as ecologically relevant to the taxa of interest as possible (descriptions of the monitoring indicators are provided in Section 2.1). Sampling protocols for different indicators vary in the amount of effort and sampling intensity required and some will require visiting more JEM sites than others in a given year (e.g. acoustical recording units (ARUs) vs. vegetation sampling). Different indicators also require different sample sizes to report on oil sands stressors, pathways, and biological responses.

Monitoring under the BADR design will begin in 2021 with the goal of sampling in new landscape units each subsequent year to the extent required to cover the natural and oil sands related gradients across the OSR. The return interval to sites will vary across response indicators based on differences in the: 1) existing state of knowledge of dose-response relationships; 2) effort required to complete sampling, and 3) expected speed of response for different taxonomic groups. In addition, sampling effort will be guided by statistical analyses completed for each of the indicator groups. Precision analyses, and evaluation of statistical modelling approaches, applicable within the BADR design will be ongoing and these will inform decisions on landscape unit and JEM site selection, frequency of repeated sampling, and other methodological elements of each of the programs (individually and as integrated across the TBM). These analyses will be refined as more data are collected.

2.6 Monitoring Methods

Further details on monitoring methods are provided below and methodology describing sampling protocols will be further refined as BADR is implemented. A conceptual layout of integrated monitoring within a JEM site is shown in Figure 6, actual layouts will vary across landscape units and sites. Complementary monitoring protocols will be implemented outside JEM boundaries to supplement the sampling protocols for the high-level indicator groups and answer targeted questions. More details on complementary monitoring programs are provided in Section 2.7.

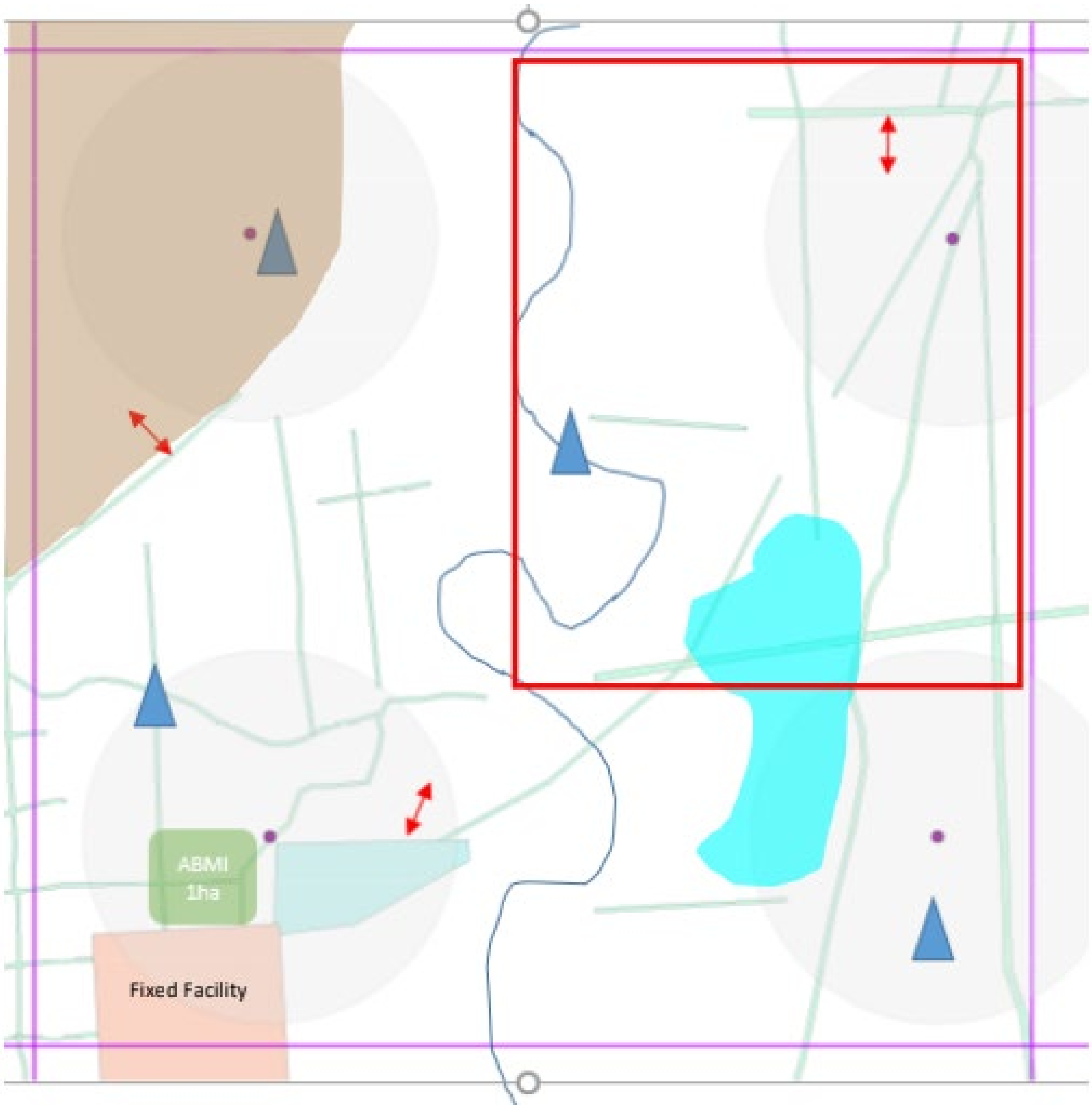

Figure 6. Conceptual layout of a 64-hectare JEM site (purple outline) with local sites for indicator monitoring methods. Grey circles represent ARU survey areas. Blue triangles represent remote camera locations. The green square represents a 1-hectare ABMI legacy site where vegetation monitoring will continue and red arrows represent vegetation transects. The red rectangle represents a MAPS sampling area. The tan polygon represents a legacy contaminant monitoring location.

2.6.1 Community Based Monitoring Programs

The BADR design is intentionally flexible enough to address a wide and potentially changing list of priority indicators. This lends itself well to the incorporation of CBM collaborations going forward to address issues around food safety and security and the maintenance of a traditional way of life for land users. Some priority indicators already identified by local communities (e.g., ungulate populations) are addressed here. The design is also flexible enough to integrate with CBM programs operating typically at local scales; there is no conceptual barrier to the integrated analysis of monitoring data collected within CBM programs. In fact, the hierarchical structure of the BADR design facilitates the integrated analysis of monitoring data collected at various spatial scales.

It is the goal of TBM to achieve meaningful integration with Indigenous communities through collaborative and/or participatory projects. We are committed to the production of lay language summaries and knowledge translation in collaboration with the Indigenous Community-Based Monitoring Advisory Committee and the OSM Program.

2.6.2 Contaminants

Although BADR uses the CFI, which reflects oil sands disturbance, as a primary tool for site selection, contaminants are a priority stressor for TBM and play a key role in the design. Since contaminant exposure within the landscape units is related to the intensity of the disturbance present in that unit, contaminant effects will be captured by selecting JEM sites with varying disturbance types and intensities. In addition, we will deploy both land-based and aquatic passive samplers at a subset of JEM and complementary monitoring sites. The resulting data will provide site-specific information on deposition to be used to assess ecological change caused by oil sands industrial activities in the context of cumulative effects. Passive sampler data will also be used to validate existing contaminant models developed by the Air and Deposition team. Contaminant levels in organism tissue will be monitored as a pathway indicator (Table 2). Further details on how the contaminants priority stressor will be monitored are provided below.

Opportunities to incorporate emission information and deposition maps for the oil sands region into site selection and data analysis will be explored and refined on an ongoing basis as integration with other Theme areas progresses. TBM will continue to work with the Air and Deposition, Surface Water, and Geospatial teams to develop maps for contaminants; these can be used for site selection and for the establishment of collaborative sampling protocols for the ground-truthing of air contaminants emissions and deposition models. The data resulting from these activities will be used to create more effective regression models for predicting ecosystem responses under the BADR design.

Besides potential effects on individual animal health, contaminant exposure may ultimately impact behavior, abundance, and community composition; the conceptual model (Figure 2) indicates that the pathway to responses at the population level can start with the exposure of individuals to contaminants. Thus, contaminant levels in organism tissue will be monitored as a pathway indicator (Table 2). Tissue will be collected from indicator species such as mammals (semi-aquatic furbearers), amphibians (wood frogs), and colonial waterbirds at JEM and complementary monitoring locations. Paired biotic and abiotic samples from their habitat and their aquatic food webs will also be collected. Measurements of contaminant burdens and assessments of health in harvested species will provide information on food safety and security and the health status of populations of harvested species. Samples will be provided through coordinated efforts by members of the TBM team, by community-based monitoring programs, Indigenous communities, hunters and trappers and local harvesters. ARUs and cameras will be co-located with tissue monitoring locations, where appropriate, in order to link density or abundance indicators and change over time to individual contaminant burdens.

2.6.3 Diversity and Distribution Monitoring

The TBM team employs technology that effectively monitors large areas for many indicator groups at once, which offers substantial efficiencies. The TBM team will align the continued use of these technologies and survey methods under the BADR design. Specifically, ARUs will be used to sample sound-producing organisms (e.g., migratory landbirds, amphibians, and mammals) at all JEM sites and cameras will sample mammals at all JEM sites.

Additional monitoring will target indicators not adequately captured with ARUs and cameras at a subset of JEMs. Specifically, the fourth indicator group, vascular and non-vascular plants, will be monitored at a subset of JEM sites, while maintaining the dose-response gradient. This reflects the scale of these organisms and the need for more labour-intensive, smaller-scale monitoring to capture their responses to stressors. Other indicators requiring similar labour-intensive, smaller-scale monitoring will be explicitly identified in the TBM program.

2.6.4 Productivity of Populations

Within the conceptual framework, productivity, diversity, and distributions are TBM priority responses. Diversity and distributions are assessed using the technologies and surveys described above (e.g., remote cameras and vegetation inventories), which leverage and build upon existing datasets. There are two primary sources of productivity and survival data that exist within OSM that will be integrated into BADR, which are focused on birds and mammals, and one newly proposed protocol that builds on existing legacy data in the region for vascular plants. Mammal productivity will be addressed through a complementary monitoring program detailed in Section 2.7.2.

Monitoring Avian Productivity and Survival (MAPS)

ARUs are appropriate for assessing behaviour, density, and community composition of landbirds, however, they do not allow us to partition variation in population growth rates into the base components (productivity, recruitment, and survival). Bird mist-netting provides these data and is key to understanding why changes in bird populations are occurring. Understanding the causes of population change requires estimation of vital rates (i.e., productivity, survival and recruitment) relative to stressors, with consideration of stressors that occur outside the breeding grounds. A plan to transition from the current distribution of

MAPS stations to one that aligns with the BADR design is being prepared. This plan will balance the needs for data continuity that is required for vital rate estimation with the requirements for monitoring land disturbances targeted under the BADR design.

Vegetation Productivity and Quality

Vascular plant productivity may decline in areas with available, yet degraded, habitat, resulting in populations that are less productive or of lower quality to land users than those in unaffected areas. As part of the monitoring used to assess plant community responses, we will select a set of focal species and assess their productivity at a subset of sites. For these species, we will measure plant size and seed production at the end of the growing season on disturbances, edges, and in control areas. Focal species will be those that are known to be edge-sensitive, meaning responding positively or negatively to edges associated with energy stressors, and those of wildlife and cultural value, including fruiting shrubs. This approach will provide greater sensitivity and direct measures of pathways to achieve greater confidence in the mechanisms of decline or recovery among vascular plants on, adjacent to, and away from disturbances.

2.6.5 Amphibians

Although amphibians are monitored at all locations with ARUs, they are more likely to be heard vocalizing near open water wetlands. Thus, we will place ARUs and collect amphibian contaminant indicators at open-water sites in or adjacent to a subset of JEM sites to assess occupancy for vocalizing amphibians. The selection of monitoring sites will be made following the BADR design, in collaboration with the Wetlands Theme, and legacy sites will be prioritized. Information on occupancy and distribution across the landscape provided by ARUs will be integrated with the contaminants and landscape disturbance indicators being collected to provide information on amphibian population health in the region.

2.7 Complementary Monitoring Programs

The monitoring of some organisms or habitats requires consideration of spatial scales outside the structure of BADR due to their life history (e.g., behaviour, space-use, home-range size). Therefore, monitoring of colonial waterbirds, rare habitats, ungulates, and whooping crane, which are integral to the TBM program, are currently considered as complementary monitoring programs; they will be integrated into BADR by spatial alignment or through design aspects (e.g., dose-response) where possible.

2.7.1 Rare Habitats

Rare habitats are inherently infrequent on the landscape and are not evenly distributed in space. Thus, landscape units cannot be relied upon to capture variation in these habitats as it relates to a dose-response gradient. For example, graminoid fen habitat is quite rare in the entire OSR. Thus, to sample enough graminoid fen to achieve sufficient detection of rare species that occur in it requires sites outside of the landscape unit scheme. The current focus of the rare habitat program is graminoid fens and old-growth upland forests (>100 years of age). Existing old growth and graminoid fen programs will be adapted to integrate with the monitoring conducted at JEM sites and create appropriate dose-response gradients for these habitats. A rare species working group will be developed that identifies additional concerns. To the extent appropriate, rare habitat monitoring will be incorporated into the BADR design; this will be determined once the working group has defined the objectives of the program.

2.7.2 Aerial Ungulate Surveys

Mammalian productivity is an important metric to assess if consequences are arising from factors other than habitat loss, i.e., habitat is available but degraded. For example, cow:calf ratios were a key metric used for caribou to identify drivers of caribou declines. There is currently no cost-effective way to obtain productivity information for all mammals. Thus, to gather ungulate productivity, population size, distribution, and trend information, TBM will collaborate with AEP to include aerial ungulate surveys. Specifically, we will establish flight lines to estimate ungulate densities and cow:calf ratios within landscape units selected by BADR. The surveys will be conducted across larger areas defined as Wildlife Management Units (WMUs), which include the landscape units selected. These surveys will also provide information on deer/moose observations which will inform habitat selection models and also be used to validate our density estimates for moose and deer based on cameras.

2.7.3 Mortality Risk to Endangered Species from Oil Sands Infrastructure

There are considerable risks of direct mortality from infrastructure (e.g., tailings ponds, power lines, towers, and other structures) for many species in the oil sands region, including whooping cranes (SAR; Endangered) which migrate through the oil sands region (OSR) twice annually in spring and fall. These risks have not yet been quantified, so this data gap is being addressed by ECCC and partners using satellite transmitters to track whooping cranes during migration through the OSR, define migratory pathways, and estimate risk from oil sands-related infrastructure and other alterations to migratory habitat. Under TBM, a working group will be established to examine the risk from contaminants to whooping cranes that land in the oil sands region. These projects are focused on identifying risk. If risk is identified, then a program will be required to actively monitor the species and develop mitigation strategies.

3. Implementation of BADR

The landscape units selected for sampling in 2021 (Figure 5) and targeted JEM disturbance types will capture the dose-response gradient for the three selected land-use regions and control for their natural variation. Additional landscape units will be added to the program through 2022 and beyond to capture the full dose-response gradient and natural variability for the entire OSR. Over time, we anticipate an increase in the number of landscape units and JEM sites sampled annually as roles and responsibilities become better integrated and cost-efficiencies are identified. Our intent is to minimize cost and environmental disturbance through integrated planning.

The ABMI developed an example site selection procedure following the guidance of the BADR design and 2021 sampling plan as described above. The procedure concentrated on the selection of JEM sites based on the JEM disturbance types described in Section 2.5.3, as identified with geographical human footprint data sets. Legacy sites were prioritized and the blocking of sites by habitat was included. A detailed write up of the procedure is included in Appendix II and forms the current basis for ongoing site selection and methodological refinement.

3.1 Monitoring Cycle

Biological monitoring is a time-sensitive undertaking because it is dictated by seasonal fluctuations in species presence and activity on the landscape. Site selection, staff recruitment, acquisition of regulatory permits for handling and tagging of wildlife, logistical integration, and mobilization of field programs all require substantial lead time and are ideally undertaken from January to March each year. Timely reception of feedback from the OSM governance structure allows for meaningful discussion and incorporation into annual monitoring, therefore facilitating adaptive monitoring, and will result in a robust TBM program. To support timely scope and budget authorizations by OSM, the TBM work plan will ideally be submitted by October 31 annually.

Within the framework of the nested hierarchical design, we will sample taxa at scales and return intervals that are appropriate to their life history traits. Thus, sampling all taxa across the dose-response gradient in the entirety of the OSR will take time. We will examine the statistical power of more repeat sampling versus more spatial replication to determine the appropriate number of sites to sample annually for each taxon. For most taxa, TBM will sample new landscape units for 3 years (2021, 2022, 2023) and then return to these units (i.e. 2024, 2025, 2026). A subset of JEM sites will be sampled annually to improve change estimation, estimate repeatability, and potentially identify early warning signals, or where appropriate for the indicator. Annual resampling at JEM sites will be along the dose-response gradient.

3.2 Data Management and Reporting

All TBM team members and existing programs have a strong record of public data-sharing and reporting. TBM will comply with program requirements on sharing data, namely all data will be “open by default”. Datasets for TBM programs are located in digital databases that are publicly accessible. Data will also be made available through the OSM data platform currently in development by Service Alberta. TBM team members are working with Service Alberta to create an application program interface (API) to call the data stored in individual TBM systems to the OSM data system rather than rely on manual transfers.

Table 4. Details on data management and reporting for individual TBM projects and data types.

Data	Management and reporting
All TBM camera and ARU data (birds, amphibians, and mammals)	Managed in the Wildtrax system, a data storage, data sharing, and data processing platform.
MAPS data	Reported annually to the Canadian Wildlife Service and to Alberta Environment and Parks as required under the bird banding permits issued by these agencies. The master database is held by the Institute for Bird Populations.
WBEA Forest Health Program	Public database in development. Data is currently available by request (info@wbea.org).
Vegetation data	Managed and made publicly available through the Applied Conservation Ecology Laboratory and the ABMI's Data and Analytics Portal
ECCC Wildlife Contaminants data	Publicly available through the Government of Canada Oil Sands Portal.
AEP Aerial Ungulate Survey data	Managed and publicly available by the Alberta Environment and Parks - Fish and Wildlife Information Management System (FWMIS)

Knowledge produced from the TBM program will directly contribute to OSM State of Environment (SoE) Reporting. Results generated will be compiled, analysed and reported according to an integrated TBM Theme-level reporting process. TBM members are working with OSM so that the TBM Theme-level reporting process is integrated with OSM SoE Reporting. The TBM Theme is committed to the production of lay language summaries and knowledge translation in collaboration with the ICBMAC and OSM.

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Appendix I

Table A1. TBM indicator selection table as submitted in the original 2020 workplan. Note that soil mites were evaluated and were not selected as an Indicator Group based on the evaluation.

Criterion	Vascular plants	Soil mites & soil measures	Mosses & lichens	Furbearers	Large mammals	Landbirds	Amphibians
High social, cultural and/or economic value	4	3	4	4	4	4	3
Reflect several values	4	2	3	4	4	4	3
Already known to have changed from baseline	4	3	4	4	4	4	4
Sensitive to several stressors, including interactions among multiple stressors	3	3	4	4	4	4	4
Sufficient knowledge to allow selection of measurement indicators	4	4	4	3	3	4	3
Assessment will inform a range of decision-making (regulatory, Indigenous, industry)	4	3	2	4	4	4	3
Can be readily integrated with Indigenous Knowledge	4	2	4	4	2	2	2

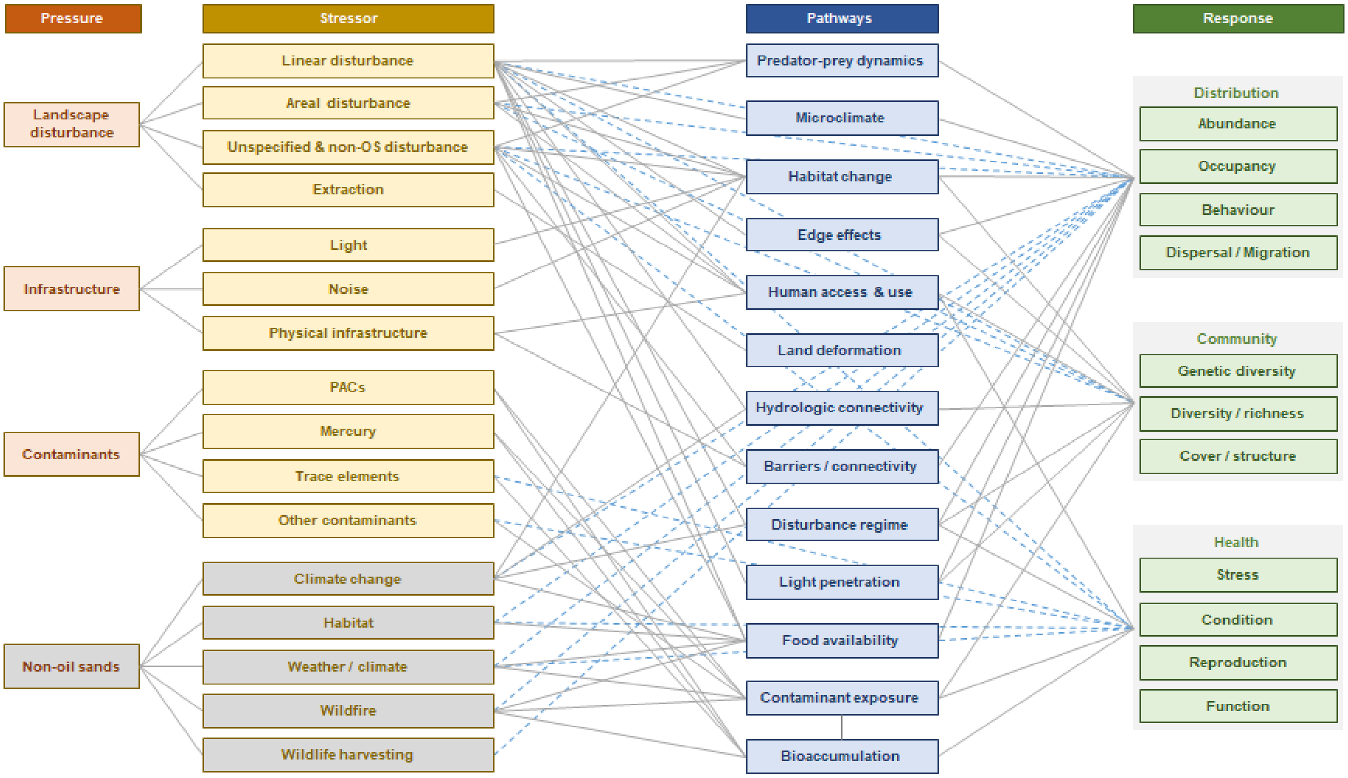

Figure A1. Terrestrial biological conceptual model for the oil sands region, showing pressures, stressors, pathways, and responses.

Appendix II - Proposed Site Selection Procedure for Integrated Terrestrial Biological Monitoring-Oil Sands Monitoring for Discussion

Background: In the spring of 2020, ABMI Science Centre and Geospatial Centre staff undertook an example site selection exercise in support of further development of the BADR design. This exercise identified overall considerations in design to inform: 1) An assessment of legacy monitoring sites from across the suite of historical TBM monitoring to identify where legacy monitoring could be leveraged for BADR, and 2) Identification of new, additional JEM sites to fill in the BADR design. The process involved a number of decisions regarding the interpretation of BADR and its definitions which require review and discussion. The objective of this document is to provide details on the decision pathway and steps that were implemented to support this site selection exercise. The document is shared as an example to stimulate continued development and refinement of the BADR design by the OSM TBM Technical Advisory Committee (TAC).

Overview of Terrestrial Biological Monitoring (TBM) monitoring design

There are three nested levels in the proposed Oil Sands Monitoring (OSM) monitoring design:

1. **Landscape units (LUs).** These are aggregations of several adjacent HUC10 watersheds. Each LU has one of three treatments: 1) Current *in-situ* development or oil sands mine, 2) Proposed future *in-situ* development or mine, 3) Low disturbance reference site. Only oil sands footprint is considered when assigning these units to treatment types, so the reference LUs may contain extensive forestry or other footprint types. Eight LUs and four back-up LUs ("BUs") were chosen for 2020 OSM monitoring during TBM OSM workplan development (prior to the COVID-19 pandemic). Site selection was focused on these preselected LUs.

2. **Joint ecosystem monitoring sites (JEMs)**. JEMs are areas of approximately 64 ha, representing different treatments within each type of LU. We interpret the treatments included in the Integrated TBM Work plan as:

   For currently developed LUs:

   i. Edge of large *in-situ* processing plant or active mine,
   ii. High-activity footprint associated with *in-situ* development (SAGD well sites, pipelines, and associated infrastructure),

Roads used by the oil sands industry,

   iii. Low-activity areal developments (e.g., exploration well sites and associated access),
   iv. Dense linear features (particularly 3D seismic grids),
   v. Reference areas away from oil sands footprint.

   Note: Treatments i) and ii) represent two distinct types of high-activity footprint included in the workplan. Treatment ii) will not occur in LUs with surface mines and could be replaced by a second site adjacent to the active mine in that situation. Some treatments may not be available in currently developed LUs. In particular, treatments iv) and v) are produced during exploration, and may be covered by the *in-situ* development or mine when these are fully built out.

   For proposed future development LUs:

   Treatments i) and ii) are replaced by the edge of proposed future processing plants or mines, and the area of proposed future *in-situ* developments (or two locations near the mine edge for LUs with proposed mines). The other treatments are the same, with the exploration-related treatments iv) and v) possibly most extensive immediately prior to development.

   For low disturbance (reference) LUs:

The main JEM treatment is vi), the reference. However, there are also likely to be roads and other (non-oil sands) footprint types that may provide comparisons to the oil sands roads, low-activity footprint, and dense linear features treatments. Alternatively, more reference sites could be established to account for the variety of other footprint types (e.g., forestry) and natural habitat types in these LUs.

3. **Local monitoring plots.** Within each JEM unit, projects for each Indicator Group will establish local plots (or cameras/ARU groupings) or sampling locations according to project-specific needs, usually including a focus on particular oil sands footprint types.

With this hierarchical design, the local plots provide direct information on particular footprint types, while also acting as subsamples to represent the JEM unit. The JEM units provide comparisons of the JEM treatments, and also act as subsamples to represent the overall LU. The replicated LUs allow comparisons of the LU treatments. The same hierarchical structure holds if the design is treated as a nested regression – JEMs providing larger scale covariates for local plots, and LUs providing a larger-scale context for JEMs and local plots.

Subregions are an even larger fourth level of hierarchy in which LUs are nested. Subregions act as a blocking factor, meant to ensure that monitored LUs are spread geographically, rather than as a very large-scale treatment.

What is a JEM site?

Given the large variation in sampling among the Indicator Groups (sub-workplans) within the TBM program, our idea was to define a central point for each JEM site, rather than a fixed area. Individual projects can establish plots as needed within the approximately 450 m that defines a 64-ha circle around that point. Those plots could include particular footprint types, transects across edges, or a fixed array of sample sites, depending on the indicator and sub-workplan goals. For instance, a JEM central point in the high-activity *in-situ* treatment may be 150 m from the nearest high-activity well site. Studies can put plots on the well site, or at a different distance from the edge of the well site or the connecting pipelines, etc.

Co-ordinated monitoring at the JEM sites, rather than independent sub-workplan sampling, will ensure that projects are able to report on comparable JEM treatments at the 64-ha scale. It will also allow synergies and efficiencies between projects (e.g., sharing data on environmental covariates, or basic field logistics). It will be up to sub-workplan projects to ensure that their local-scale plots are representative enough of the JEM site to be able to make inferences at the JEM level, or to use conditions in the JEM site as a larger-scale covariate for plot-level analyses.

Locations of LUs

During workplan development, eight Landscape Units (LU) were chosen for 2020 sampling by Erin Bayne (University of Alberta) in consultation with the OSM and the TBM team, including the TBM TAC. An additional four back-up LUs (labeled as "BU") were also chosen. We used these LUs and BUs for this site selection procedure.

Steps to choosing JEM sites

We used the following steps to identify candidate JEM sites within each of the 2020 selected LUs (including BUs). Each step is described in more detail below.

1. Delineate JEM treatment strata in each LU based on GIS layers of human footprint types associated with the oil sands industry.

2. Decide on a main target vegetation type ("blocking habitat") for each LU.

3. Summarize which JEM treatments and broad vegetation types exist within the LUs and select legacy sites if they represent a JEM treatment in the targeted vegetation type.

4. For JEM treatments not represented by legacy sites in a LU, choose a set of random points within the treatment and blocking vegetation type.

We understand that the TBM will select sites from those prioritized choices, considering factors such as other human disturbance types and practical issues like access and proximity to other sites.

Step 1. Delineate JEM treatment strata.

Why this is important

A "JEM treatment stratum" is the footprint in each LU that has that JEM-level treatment or which is under the influence of that land use. For example, it is the area that is within the buffer of a large processing plant or mine for treatment (i), or is within an area of dense linear footprint for treatment (v).

Delineating strata for each JEM treatment has three important purposes. First, it forces us to define the treatment rigorously enough that we can use GIS layers to map it. This ensures that treatments are clear to both researchers and stakeholders and ensures consistency in how treatments are defined among current and future LUs.

Second, being able to map the treatments means that we know what part of each LU area the treatment results apply to. That means that we can use the JEM results as a stratified sample of the LU, and, we can, therefore, make LU-level estimates to compare LU treatments, even if local sampling is not representative of the LU (because it targets high-priority oil sands footprint types that may not be common in the landscape). This stratification allows conclusions to be drawn using this complex hierarchical design, without requiring massive sample sizes, as would be expected with independent sub-workplan sampling or post-hoc approaches.

Last, the area of each treatment is also needed to infer the overall regional effect of oil sands activities, and how that changes over time. For instance, treatment i) (edge of large *in-situ* processing plant or active mine) may reduce some particular species by 50%, but if that treatment only covers 1% of the region, it only causes a 0.5% drop in that species regionally.

Procedure

We defined each treatment in GIS, using ABMI sector layers and the ABMI province-wide human footprint layer (2018). These treatments are in order of precedence, so treatments higher on the list supersede treatments lower on the list where treatments overlap. GIS scripts are available on request.

A. <u>Edge of large plants and mines</u>

Large *in-situ* processing plants included only area in the BITUMEN_INSITU sector layer, with the footprint types: CAMP-INDUSTRIAL, FACILITY-OTHER, MISC-OIL-GAS-FACILITY, FACILITY-UNKNOWN, OIL-GAS-PLANT, RIS-CAMP-INDUSTRIAL, RIS-FACILITY-OPERATIONS, RIS-FACILITY-UNKNOWN, and RIS-PLANT. We assessed these areas visually from satellite images and eliminated any small polygons or areas with limited industrial facilities. We also checked available GIS layers for light and noise levels, but found they did not reliably identify processing plants.

Mines included only area in the BITUMEN_MINING_SURFACE sector layer, with footprint types: FACILITY-OTHER, MINES-OILSANDS, RIS-DRAINAGE, GRVL-SAND-PIT, RIS-MINES-OILSANDS, RIS-OVERBURDEN-DUMP, RIS-OILSANDS-RMS, RIS-RECLAIMED-CERTIFIED, RIS-RECLAIMED-PERMANENT, RIS-RECLAIMED-TEMP, RIS-RECLAIM-READY, RIS-SOIL-REPLACED,RIS-SOIL-SALVAGED, RIS-TAILING-POND, RIS-WASTE, RIS-WINDROW, and TAILING-POND[1].

We buffered these plants or mines by 400 m. Recall that local monitoring plots can be within the approximate 450 m-radius JEM area, so even if a JEM central point is 200 m from a mine edge, sampling can occur immediately adjacent to the mine if that is part of a particular project. The 400 m buffer for this highest-precedence treatment ensures that no other treatment is within 400 m of large plants or active mines. The area of the processing plant or the mine itself are not included in this stratum, because we assume that monitoring plots will not be allowed in those areas.

B. <u>High-activity *in-situ* sites</u>

We used 400 m buffers around well sites with moderate or high activity levels in the oil sands sector area. This includes all wells except abandoned wells with no production reported or wells with last production reported before 2013 (demarcation reflects the available GIS layers). The 400 m buffer was used because many *in-situ* developments have well sites <800 m apart, so this buffer encompasses the entire *in-situ* development. GIS smoothing and sliver removal were used to make this treatment stratum a more continuous area. The resulting stratum closely conformed to the areas of the *in-situ* developments that are obvious on satellite imagery. With the typical layout of *in-situ*

[1] This can include non-active parts of mines. We included these to establish the buffer around mines, but located actual JEM sites near areas of active mining.

developments, a JEM site anywhere in that area will encompass well sites, connecting pipelines and associated roads and powerlines.

C. Roads

ABMI, in conjunction with oil sands companies, has identified roads associated with the oil sands sector. We excluded highways, urban roads, and winter-only roads. We then buffered the oil sands roads by 200 m (each side). The central point of the JEM site was placed right on the road, to maximize the area near the road. Local monitoring plots can, of course, be at any distance from the road. A main reason for the 200 m buffer was to exclude JEM sites for lower-precedence treatments from being close to roads.

D. Low-activity areal footprint

The main low-activity areal (non-linear) footprint associated with the oil sands industry is arrays of exploratory well sites. We identified these as no-activity or low-activity well sites in the area of oil sands activity, which are primarily exploration wells in the oil sands area. Inspection of aerial images showed that these well sites usually lack any structures and often have some tree regeneration. We buffered these by 400 m and smoothed and removed slivers as in the high-activity treatment.

E. Dense linear features

This treatment was identified using the LOW-IMPACT-SEISMIC layer in the oil sands sector. This layer corresponded closely to the 3D seismic grids used for oil sands exploration. Because this treatment is of lower precedence, it does not occur anywhere that exploration wells were conducted in those areas (treatment 4), or where *in-situ* developments or mines have been built (treatments 1 and 2).

F. Low disturbance reference

Everything not included as a treatment above forms the reference treatment stratum. In practice, our choice of JEM sites avoided concentrations of non-oil sands disturbance. However, in the low-disturbance LUs, where we provide several reference JEMs, we did include some areas with substantial forestry footprint (and others with low forestry footprint), because forestry can occupy large areas in those LUs. Additionally, substantial area around high-activity *in-situ* developments has been harvested, as has some area in other treatments, so it is appropriate to have some forestry area in comparison reference areas.

In the LUs with proposed future *in-situ* or mine developments, we do not yet know where those proposed developments are located. Therefore, we do not have JEM sites representing those treatments. The other oil sands and reference treatments were identified the same ways as above for those proposed future development LUs.

In the LUs with low oil sands footprint, we have so far only identified reference JEM units. The possibility of sampling near roads or non-oil sands footprint (e.g., conventional well sites or linear features) in those LUs needs to be discussed by the TBM team.

Step 2. Target (“blocking”) vegetation type

Why this is important

With limited numbers of samples possible in this complex study design, it is important to reduce sources of variability unrelated to treatments whenever possible. A prime source of variability for most species is variation among habitat types. Without large numbers of samples, JEM treatment effects are likely to be either hidden by habitat variation, and/or confounded with it. Therefore, we tried to choose JEM sites in the same habitat types in the LUs. Using one blocking vegetation type per LU, rather than just trying to balance the JEM treatments and blocking types across several LUs, simplified logistics (e.g., for studies that just want to focus in a particular habitat type), and reduces complexity when species show spatial gradients. The TBM team could consider options for “trading” JEM sites in different habitat types in pairs of LUs (see legacy sites, below).

We used slightly more refined habitats than the original workplan idea of upland versus lowland, because there are some major distinctions within those types that affect almost all Indicator Groups. Within upland, deciduous and conifer forests have different communities, and upland grass or shrub areas are distinct from either forest type. Within forests, some species show strong age gradients, particularly between the early-seral stages (e.g., recent burns) and mid-seral or later stages. Within lowlands, there are strong species and environmental differences between treed areas and shrubby or open wetlands. We did not want, for example, a reference site in a young pine stand being compared to a high-activity site in an old deciduous stand.

Procedure

We first summarized the habitat types in each LU. Habitat types are broad stand types (deciduous, mixedwood, upland conifer, lowland treed) by age classes, or upland or lowland open types. We grouped age classes and habitat types as necessary to find a broad group that was dominant in each landscape unit, which we chose as the blocking type for that LU. We tried to make sure there were equal numbers of high- and low-disturbance LU's with each blocking habitat type. Broad habitat types with enough area that they included each treatment type in a LU were restricted to deciduous+mixedwood stands 40+ years old, treed lowlands 20+ years old, and for two LUs recently burned stands. Other types like upland conifers, or shrubby wetlands are patchier in these LUs and do not occur in all treatments when they are in a LU.

Step 3. Legacy sites

We assessed existing OSM and other relevant monitoring sites (legacy sites) in the current LU to see if they fit in one of the JEM treatment types and were in the blocking habitat type. Vegetation and footprint composition were assessed for a 451 m radius around the site centre (=64 ha). Legacy sites were selected as candidate JEM sites if they were mostly in one JEM treatment type and were dominated by the blocking habitat type for the LU, and did not have high levels of other human footprint types or very different habitat types.

In low disturbance LUs, where we were looking for four reference JEM sites, we included randomly selected legacy sites that were generally in the right habitat type, even if they had fairly high levels of forestry footprint or a mix of other habitat types. We ensured that the other reference JEM sites in those LUs had low forestry and high blocking habitat type levels.

Legacy sites were divided into two types, primary and secondary. Primary legacy sites included the main sites of any of the long-term monitoring programs in the area: ABMI, WBEA, Owl Moon, and Wildlife Contaminants sites were a priority. Secondary legacy sites were additional ABMI off-grid sites or Erin Bayne Big Grid sites. ABMI off-grid sites were originally targeted to represent particular treatments or vegetation types, and so are non-representative of the region, and were not originally intended for remeasurement. Erin Bayne Big Grid sites (and equivalent off-grid ABMI sites that are sometimes called focal sites, off-grid sites, or other big grid sites) are part of large grids in a few areas that have had single sessions of recordings for a single taxon, either birds via ARUs or mammals via cameras. There were often many secondary legacy sites in a JEM treatment type in a LU because they come from dense grids. Therefore, we summarized the proportion of the JEM treatment strata, habitat, and human footprint types in a 451 m radius (64 ha) of each site, and ranked the sites by how much of the target stratum and target habitat types they contained.

Step 4. Completing the design with randomly located JEM sites

For JEM treatments that did not have a legacy site in a LU, we generated 10 random points in the intersection of the treatment type and the blocking habitat layer. We summarized JEM stratum composition, habitat, and human footprint types in a 451 m radius (64 ha) around each random point. Suitability of the 10 random points in each LU was scored based on the proportion of the target treatment stratum and the target veg type in the 64-ha area. Additional value was given to random sites in the disturbed treatments if they had higher amounts of the target footprint type (e.g., linear features in the dense linear treatment).

The maps of JEM treatments in each LU show primary and secondary legacy sites, and suitable randomly-located sites when there were no legacy sites in a particular JEM treatment in a LU.

Step 5. Selecting sites when there are multiple choices (pending)

Priority was given to the primary legacy sites – if there was a primary legacy site in a treatment type and suitable habitat, it was selected as the suggested JEM site. In the absence of an appropriate primary legacy site, priority was given to secondary legacy sites. If there were multiple secondary legacy sites in a treatment (which is often the case, given that they come from dense grids), they were assessed in order of their suitability rank. The TBM team can find the best one that meets practical criteria of being accessible and near other sites.

If there are no legacy sites for a treatment type in a LU, we recommend that the TBM team proceed through the list of random points in order of their suitability, assessing whether the point appears to be in an accessible place, if it is in reasonable proximity to other sites, and is free of other important constraints (e.g., Cold Lake Air Weapons Range).

Terrestrial Biological Monitoring: Program Timeline

Introduction

The efficient execution of the Oil Sands Monitoring - Terrestrial Biological Monitoring program depends on timely submission and authorization of TBM’s annual scope and budget. Biological monitoring is a time sensitive undertaking because it is dictated by seasonal fluctuations in species presence and activity on the landscape. Successful monitoring efforts therefore depend on timely OSM decisions that allow sufficient time for monitoring site selection, recruitment of staff, acquisition of regulatory permits, procurement of equipment and supplies, logistical integration, and mobilization of field programs. The purpose of this document is to highlight the annual monitoring timeline for the TBM program

TBM Timeline and Decision Dates

Annual monitoring activity requirements and restrictions vary among TBM programs. To allow all TBM programs to operate effectively given their differences in timelines, the TBM workplan must be submitted by October 31st each year, which allows for timely delivery of OSM scoping and budget authorization decisions. The TBM critical path and milestone schedule is presented in Table 5 and includes details on the timing of individual programs.

January to March are typically focused on recruitment and onboarding of field staff, regulatory authorization applications for some programs, equipment procurement, access permissions, and integrated logistical planning. Camera and ARU deployment begins in early January to take advantage of frozen ground conditions for efficient collection of data. Related access negotiations typically involve industry and Indigenous community representatives and work will be communicated as tentative, based on OSM workplan approval. October to March are typically focused on integration and collaborative analyses of data for incorporation into annual reports. Thus, there is an unavoidable overlap between data analyses and reporting activities at the end of one fiscal year occurring concurrently with field planning and preparatory activities required for the next.

Table 5. Terrestrial Biological Monitoring critical path & milestones (in bold italics).

Timing	Critical path activities & milestones
PLANNING & PREPARATION	
October 31	• ***Annual workplan submission***
October to December	• Data entry, QA/QC, analyses, and interpretation for completed field program (current fiscal) • Land access permissions for upcoming field season (next fiscal) • Indigenous community engagement (ongoing)
November	• OSM feedback and information requests on annual workplan
January to March	• ***Timely OSM approvals of TBM programs*** • TBM annual report preparation • Data analysis, release, and reporting (ongoing) • TBM logistics and planning meetings • Field staff recruiting & onboarding • Equipment and supplies procurement • Applications for regulatory permits • Land access permissions • Indigenous community engagement (ongoing) • Field logistics planning
DATA COLLECTION & REPORTING	
April to March	**Field Programs:** • Vegetation: June 15 - July 31 • Amphibians (ARUs): January 1 - March 31 [1] • Mammals (Cameras): January 1 - March 31 [1] • Birds (ARUs): January 1 - March 31 [1] • Birds (MAPS): May 10 - August 8 • Rare Habitats: April 15 - June 30 • Forest Health Monitoring: July – September [2] • Amphibians (Contaminants): May 1 - September 30 • Mammals (Contaminants): April 1 - March 31 • Colonial Waterbirds (Contaminants): May 1 - September 30 • Whooping Cranes: May 15 - August 15 • Aerial Ungulate Surveys: December 1-March 31
August to March	• Data entry, QA/QC, analyses, and interpretation
March 31	• ***Workplan deliverables & annual report submission***

Notes: (1) ARU and cameras are deployed in Jan of previous fiscal year for logistical efficiencies from frozen ground conditions; (2) FHM soil, vegetation, and community composition sampling occur in Jul-Sep on a 3 or 6-year interval.

Regulatory Authorizations

Authorizations from various regulatory agencies are required to conduct activities that may or do result in disturbance to wildlife, wildlife handling, sampling involving wildlife, and activities in parks and/or restricted areas. Authorizations may be specific to an activity, individual, organization, or program, and require sufficient lead time to identify staff to be named in the authorization(s) and for permitting agency review. TBM programs that require regulatory authorizations are listed below. This list is not exhaustive, and additional authorizations may be required for activities in specific locations, the use of specific equipment, and/or during sensitive periods for wildlife:

Colonial waterbirds:

- Canadian Wildlife Service (ECCC)
- Alberta Environment and Parks
- Parks Canada Agency
- Government of the Northwest Territories, Environment and Natural Resources

Monitoring Avian Productivity and Survival (MAPS):

- Canadian Wildlife Service (ECCC)
- Alberta Environment and Parks
- Alberta Historical Resources

Whooping crane:

- Canadian Wildlife Service (ECCC)

Amphibians:

- Alberta Environment and Parks
- Parks Canada Agency
- Restricted Activity Permit

Mammals:

- Canadian Wildlife Service (ECCC)
- Alberta Environment and Parks

Workshops and Meetings

The annual TBM workplan includes a meeting and workshop schedule. Some of these events are TBM-specific, while others relate to OSM cross-theme events. Those directly related to the TBM field programs are listed in Table 6, with the timing adjusted from the original 2020 workplan to reflect the urgency of decisions and holding meetings and workshops remotely under COVID-19 requirements. These are important events supporting efficient site selection, logistical coordination, data sharing, and development of integrated analytical models.

OSM cross-theme events are scheduled and coordinated by the OSM Program Office and are therefore, not included in Table 6. Nevertheless, TBM members understand that they will be included in cross-theme events as appropriate, and additional TBM Technical Advisory Committee (TAC) meetings may be required to prepare for these broader OSM events.

Table 6. TBM Workshop and Meeting Schedule.

Timing	Event
September	• Annually: Joint TBM Principal Investigator/TAC meeting
October & November	• 2021-2023: Site selection workshop (initial set of landscape units & Joint Environmental Monitoring sites) • Annually: BADR design and terrestrial monitoring methods review workshop • Annually: TBM Workplan workshop • Annually: Joint TBM Principal Investigator/TAC meeting
January	• 2021: Rare species/habitat workshop • Annually: Joint TBM Principal Investigator/TAC meeting • Annually: TBM Principal Investigator meeting for identification of opportunities for improvement
February	• Annually: logistics planning meeting • Annually: Joint TBM Principal Investigator/TAC meeting
March	• TBM symposium: data and information presentation, dialogue among symposium participants

Note: Workshops and meetings will be convened in person, by conference call or through web-based systems as required in response to COVID-19.

Transition to BADR

Transitioning existing and integrating new TBM monitoring programs into the cohesive BADR design requires data evaluation, logistical planning, and multi-party collaboration. Effective transition requires that TBM participants have the time necessary to evaluate data, explore synergies, and reach consensus decisions. Transition discussions, planning and implementation is expected to require two to three months and has commenced as of September 2020.

Risks

Failure to authorize scope and budget for TBM programs, aligned with the timing and budget requirement specific to each of the programs, creates program risks including:

- Loss of data integration and reduction in the analytical power associated with the BADR design;
- Delayed or fractured selection of landscape units and/or monitoring sites compromising the BADR design;
- Reduction in cost and logistical efficiencies;
- Improper planning related to land access permissions, safety, Indigenous engagement, and staff work planning due to insufficient lead time;
- Loss of database continuity;
- Cancellation of TBM programs; and
- Substantially diminished capacity to mount programs that can answer the core OSM outcomes.

The TBM team is working to mitigate the negative outcomes of these risks, and trusts that the discussion of the timeline in this document supports OSM's timely budget and scope authorization processes.

Conclusion

We trust that this summary of the timeline and necessity of timely scope and budget authorizations is supportive of the OSM's objectives of a robust, cost-effective and credible monitoring program. TBM participants have and continue to invest in the development of the BADR design, the development of and transition of individual monitoring programs into the BADR framework, and efforts to achieve statistical/analytical and logistical integration. This effort will result in a cost-effective, holistic program that delivers on the key questions and needs of the OSM program. We anticipate that the BADR design will evolve as information is gained and new questions are revealed.