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# An Integrated **Oil Sands** Environment Monitoring Plan



Canada 

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## EXECUTIVE SUMMARY

Industry and other observers expect significant expansion in oil sands operations over the medium to long-term. From today's production levels of just over 1.5 million barrels per day, production is projected to double to around 3 million barrels per day (MBPD) by 2020, and continue increasing thereafter, out to 2030 and beyond. The value of this production is estimated to be almost \$60 billion in 2012, and is expected to average \$86 billion per year from 2013 to 2020. Given the importance of the oil sands industry to the economies of Alberta and Canada it is essential that they proceed in an environmentally sustainable fashion. A world-class environmental monitoring program is key to realizing this goal. However, deficits in current environmental monitoring in the oil sands have been found that render current monitoring inadequate for providing the assurance that oil sands are being developed sustainably.

In December, 2010 a Federal Oil Sands Advisory Panel presented a report to the federal Environment Minister that reviewed current monitoring activities in the lower Athabasca River system, identified key shortcomings, and provided recommendations on what would constitute a world-class monitoring program for the oil sands region.

In response, Environment Canada coordinated federal, provincial, territorial and independent scientists in a two Phased process to develop a world class environmental monitoring Plan for the oil sands. The monitoring Plan is a series of technical documents that present what should be monitored, where, when and how. This Plan does not deal with implementation issues like funding or roles and responsibilities of existing organizations or institutions. The Plan was designed on the core principles recommended by the Advisory Panel of being: holistic and comprehensive; scientifically rigorous; adaptive and robust; inclusive and collaborative; and, transparent and accessible. The results of Phase 1, a conceptual framework for a world class monitoring Plan and detailed water quality monitoring scheme for the Lower Athabasca River - was released by the Minister in March 2011.

While Phase 1 focused on the issue of water quality, it was recognized that there was a need to expand to integrate air and biodiversity monitoring, as well as broader water quality monitoring and effects assessment. This holistic approach is designed to focus on specific areas where there are gaps in the scientific data and to adapt to changing needs as environmental data and understanding change over time.

A key philosophy in the monitoring Plan is that both the frequency of sampling and the geographic scope of coverage are linked to a series of decision triggers. This means that monitoring can be enhanced if important changes are detected at a given site, or alternatively, reduced where repeated sampling has shown no significant changes are occurring.

The Plan design shifts the paradigm from monitoring changes that have already occurred to an approach that will better assess current state, and predict future multiple stressor impacts and ultimately cumulative effects. All information will be available to the public.

The Plan retains sound components of existing monitoring efforts, changes elements that require change, increases the spatial and temporal coverage of monitoring locations, and broadens to include ecosystem components not previously monitored in a systematic way. Not only will this Plan have increased ability to detect change, but it will ensure a better understanding of natural variability and system responses to oil sands development activities.

**A key observation by expert reviewers of this Plan was that despite its technical competence, sound and timely implementation will dictate whether the Plan will succeed or fail in its goal of generating the data necessary to provide assurance that the oil sands are being developed sustainably.**

Priorities for implementation are presented in each of the Plan components that give specific monitoring details for water, air and biodiversity.



## CHAPTER 1. INTRODUCTION

*The design of the integrated water, air, terrestrial and aquatic biodiversity and Monitoring Plan for the lower Athabasca basin is based on the core principles of being: holistic and comprehensive; scientifically rigorous; adaptive and robust; inclusive and collaborative; and, transparent and accessible.*

*This Plan ensures that site selection, spatial and temporal sampling frequencies provide appropriate connectivity of relevant physical, chemical and ecological processes to assess impacts of oil sands development on local and regional water quality/quantity, air quality and aquatic and terrestrial biodiversity.*

*The Plan builds on the Phase 1 Water Quality Monitoring Plan, and by design, is adaptive to address both current and future emerging issues related to understanding the scale, duration and magnitude of the possible effects of oil sands development on the aquatic and terrestrial environments.*

*The foundation of the Plan is a solid and integrated regional monitoring strategy that will allow for assessment of any potential changes at local and regional scales and short-term to longer-term time periods. It will provide a basis for separating changes related to oil sands activities from natural influences such as natural bitumen seepages.*

*Relationships between any identified changes in this context will provide the basis for cumulative effects assessment. The embedded use of decision triggers, to increase or decrease monitoring effort as understanding of ecosystem status and trend evolves, will ensure effective use of resources to produce the data necessary to provide assurance the oil sands are being developed responsibly.*

Industry and other observers expect significant expansion in oil sands operations over the medium to long-term. From today's production levels of just over 1.5 million barrels per day, production is projected to double to around 3 million barrels per day (MBPD) by 2020, and continue increasing thereafter, out to 2030 and beyond. The value of this production is estimated to be almost \$60 billion in 2012, and is expected to average \$86 billion per year from 2013 to 2020. However, deficits in current environmental monitoring in the oil sands have been found that render current monitoring inadequate for providing the assurance that oil sands are being developed responsibly. A Federal Oil Sands Advisory Panel (Federal Oil Sands Advisory Panel Report, 2010,

<http://www.ec.gc.ca/pollution/default.asp?lang=En&n=E9ABC93B-1>) outlined the inadequacies and limitations of existing monitoring; key among them were a lack of integration and scientific oversight. In addition, the Panel report provided focused recommendations on a path forward for the design and implementation of a world-class environmental monitoring Plan. It was further recognized that given the scientific complexities in the oil sands region, it was necessary to use a phased approach to develop a Plan with media specific components for water, air and biodiversity. Ultimately however, it

was necessary to ensure all components were fully integrated into a single, holistic Plan founded on an ecosystem-based approach. Box 1 summarizes core scientific elements of a world-class monitoring Plan as identified by the Federal Oil Sands Advisory Panel.

In response, in December 2010, the Federal Minister of the Environment announced the first Phase of a process to develop a world class integrated oil sands Monitoring Plan. The result of the Phase 1 process, released in March 2011, was a conceptual monitoring framework and Water Quality Monitoring Plan for the Lower Athabasca mainstem and its tributaries. (<http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=1A877B42-60D7-4AED-9723-1A66B7A2ECE8>). The Phase 1 report was authored by independent academics and scientists from Alberta Environment and Environment Canada. Environment Canada played a coordinating role.

**Box 1: Principles that underpin an effective “world-class” monitoring program.**

- **Holistic and comprehensive:** a systemic approach that incorporates multiple essential components of the system as well as the relationships among the components, integrates multi-scale spatial measurements and recognizes the temporal dimension, from past to future.
- **Scientifically rigorous:** a science-based approach that uses robust indicators, consistent methodology and standardized reporting, including peer-review, that will result in independent, objective, complete, reliable, verifiable and replicable data.
- **Adaptive and robust:** an approach that can be evaluated and revised as new knowledge, needs and circumstances change and that ensures stable and sufficient funding.
- **Inclusive and collaborative:** an approach that engages concerned parties in the design and execution, including the prioritization of issues and setting of ecosystem goals.
- **Transparent and accessible:** an approach that produces publicly available information in forms (ranging from raw data to analyses) in a timely manner that will enable concerned parties to conduct their own analysis and draw their own conclusions and that will make the basis for judgment and conclusions explicit.

**The Integrated Oil Sands Environmental Monitoring Plan is comprised of the foundational monitoring framework, core monitoring concepts and water quality monitoring scheme developed during Phase 1, this document which provides additional context for scientific work and integration performed during Phase 2, and three media-specific components developed under Phase 2 which describe technical monitoring details for air, water and biodiversity.**

**Integrated Oil Sands Monitoring Plan documents:**

- 1. *The Lower Athabasca Water Quality Monitoring Plan – Phase 1 (released March 2011);***
- 2. *Integrated Oil Sands Environmental Monitoring Plan***
- 3. *Expanded Geographic Extent for Water Quality and Quantity, Aquatic Biodiversity and Effects, and Acid Sensitive Lakes Monitoring;***
- 4. *Air Quality Monitoring for the Oil Sands;***
- 5. *Terrestrial Biodiversity and Habitat Monitoring.***

Phase 1 of Monitoring Plan development dealt primarily with the physical (hydrological and climate) and chemical components of the Athabasca River mainstem and its tributary systems. It outlined a comprehensive sampling and analytical approach to quantify contaminant loadings, transport, and fate, from oil sands and other industrial and municipal sources into these systems to monitor water quality in the lower Athabasca. Phase 1 identified the necessary environmental components and processes to monitor surface water to enhance

spatial and temporal quantitative understanding of the key physical/chemical “stressors” affecting the system while improving knowledge of historical baseline conditions.

In addition, the document produced during Phase 1 provided the overall construct and framework for an integrated monitoring Plan for assessing cumulative effects across environmental media and temporal and spatial scales. It identified five critical elements to guide all phases of monitoring design and implementation:

1. Integrated Regional Monitoring;
2. Production of Core Results;
3. Triggers for Decision-Making;
4. Tools for Implementation;
5. Principles for Successful Implementation.

Regional monitoring must produce **three Core Results** on a consistent and ongoing basis:

- 1. Assessment of Accumulated Environmental Condition or State;**
- 2. Relationships between System Drivers and Environmental Response; and,**
- 3. Cumulative Effects Assessment.**

These elements are required for monitoring each environmental component (air, biodiversity and water) and through this consistency, integrated assessment can be achieved. In the absence of these Core Results, cumulative change cannot be detected, predicted, managed, or mitigated. The Plan recognizes that it is not necessary to monitor everything, everywhere, all the time. To ensure optimization of effort, a decision support system relying on decision “triggers” will be used that will allow both decreases and increases in monitoring effort. In this way monitoring effort will adapt continuously to changing conditions and/or changes in knowledge. If monitoring effort, location or methodology is changed, adequate inter-calibration will be required.

Phase 2 components of the Monitoring Plan build on and expand Phase 1 by providing further detailed monitoring designs for an expanded geographic coverage of relevant watersheds and downstream areas, as well as details on the air quality, aquatic and terrestrial ecosystem components to be monitored. The Phase 2 components also provide the rationale and multi-media sampling design to address the *relevance* of changes in the endpoints. The Plan identifies the most appropriate approaches to detect aquatic and terrestrial ecosystem impairment, changes in local and regional air quality, and identifies relevant biological and ecological indicators that will be used to monitor and assess local and regional impacts, including cumulative effects.

As outlined in the Phase 1 report, the development and validation of new integrated environmental modeling, decision support, and environmental predictions systems is a core component of the design that allows for improved assessment (**Core Result 1**) and projection of site-specific and regional impacts. The “cause-effect” relationships that will be developed through the implementation of the Plan (**Core Result 2**) will be used ultimately to predict

cumulative environmental impacts (**Core Result 3**) which will then be monitored. This Plan will be periodically reviewed by external experts to ensure it stays relevant and continues to improve and advance our fundamental scientific understanding of the actual and potential impacts of oil sands development on the environment, and to identify and address present and future stakeholder issues and concerns.

Phase 1 and Phase 2 Plan components were developed by teams of federal, provincial, territorial and independent scientists who were selected based on their previous involvement in oil sands monitoring review exercises and/or their specific scientific expertise. The scientists involved had expertise in: surface and groundwater quality and quantity; hydrology; climatology; environmental chemistry; paleo-limnology; air emissions and air quality; human health; atmospheric transport and deposition of contaminants; oil sands process related contaminant chemistry; aquatic and terrestrial ecology; amphibian, fish, vertebrate and invertebrate toxicology; aquatic and terrestrial monitoring plan design and implementation; cumulative effects assessment; and, statistical design. Many of the scientists that contributed to the Phase 1 process were also involved in the Phase 2 design process to help ensure appropriate system design integration and sampling network optimization.

A key philosophy in the monitoring Plan is that both the frequency of sampling and the geographic scope of coverage is linked to a series of decision triggers outlined for each respective environmental component (e.g., water, air, biota). For example, if a statistically significant change is detected at a site (i.e., changes are identified relative to historic or baseline site-specific range of variability), enhanced monitoring is conducted to validate the result. If after enhanced monitoring, there is a confirmed statistical change that signals a deterioration in water quality or ecological condition, the monitoring program is expanded to define both the extent and magnitude of the measured effect. Similarly, however, if no significant changes are consistently occurring at a location or set of locations after repeated sampling, the intensity and/or geographic scope of sampling can be reduced and assessed less frequently. In this manner, monitoring effort will be continually assessed and optimized, and guided by objective and peer-reviewed data interpretation.

Implementation priorities are presented in each of the air, water and biodiversity components.

## CHAPTER 2. CONTEXT OF THE INTEGRATED PLAN

*This integrated Plan recognizes linkages among atmospheric, aquatic and terrestrial ecosystem processes and media.*

*The requirement for standardized data collection protocols, analytical procedures, QA/QC protocols and reporting across media is fundamental to ensure compatibility, comparability and integration of results.*

*This integrated ecosystem-based Plan covers:*

- *The Lower Athabasca watershed, including the Athabasca River mainstem and its tributaries the Peace-Athabasca Delta, and Lake Athabasca. In addition, relevant segments of the Peace and Slave River systems (including the Slave River Delta), acid sensitive lakes in Alberta, Saskatchewan, and the Northwest Territories;*
- *Air quality and atmospheric deposition in northern Alberta, southern Northwest Territories, Saskatchewan and Manitoba;*
- *Strategic terrestrial habitats in Alberta and Saskatchewan.*

*Results generated will have application in the assessment of risks to aquatic, terrestrial and human health.*

Phase 2 components of the Plan will produce scientifically credible information to allow for:

- improved description of current and, where possible, baseline conditions and relevant air quality, aquatic and terrestrial ecosystem processes;
- assessment of changes in air emissions, air quality, aquatic and terrestrial ecosystem condition and trends;
- effects investigation and local and regional impact assessments;
- performance measurement and State of Environment (SOE) reporting;
- collection of data that could be used for evaluation of environmental and human health risk;
- support and feedback for modeling, management, and policy development;
- evolving stakeholder issues.

Implementation of the Plan will be founded on the principle of inclusion of Traditional Ecological Knowledge, and the training and involvement of members of local communities in the actual monitoring activities.

This Plan recognizes that in order to remain world-class, it must adapt to changing environmental, technological and social conditions. One way to ensure adaptation is to optimize monitoring effort using a triggering approach that will increase or decrease monitoring based on changes in knowledge about the monitored environment. In this way

monitoring can decrease where no longer needed and increase where necessary. Another technique to ensure adaptation is to continuously test new monitoring techniques and analytical approaches. To this end, appropriate levels of technique and analytical approach development will be performed under the Plan and be considered a critical element.

## **2.1 Development Context**

Phase 2 expands the geographic scope of water monitoring to include small streams in tributary catchments, the Peace-Athabasca Delta, Lake Athabasca, and relevant segments of the Slave and Peace Rivers systems (including the Slave River Delta). It provides for an improved scientific characterization of primary emissions, the atmospheric transformation products and the concentrations and deposition of pollutants in northern Alberta, Saskatchewan, Northwest Territories and Manitoba, and links to acid-sensitive lakes. It also includes monitoring of terrestrial habitats and targeted species populations in strategic areas in Alberta and Saskatchewan.

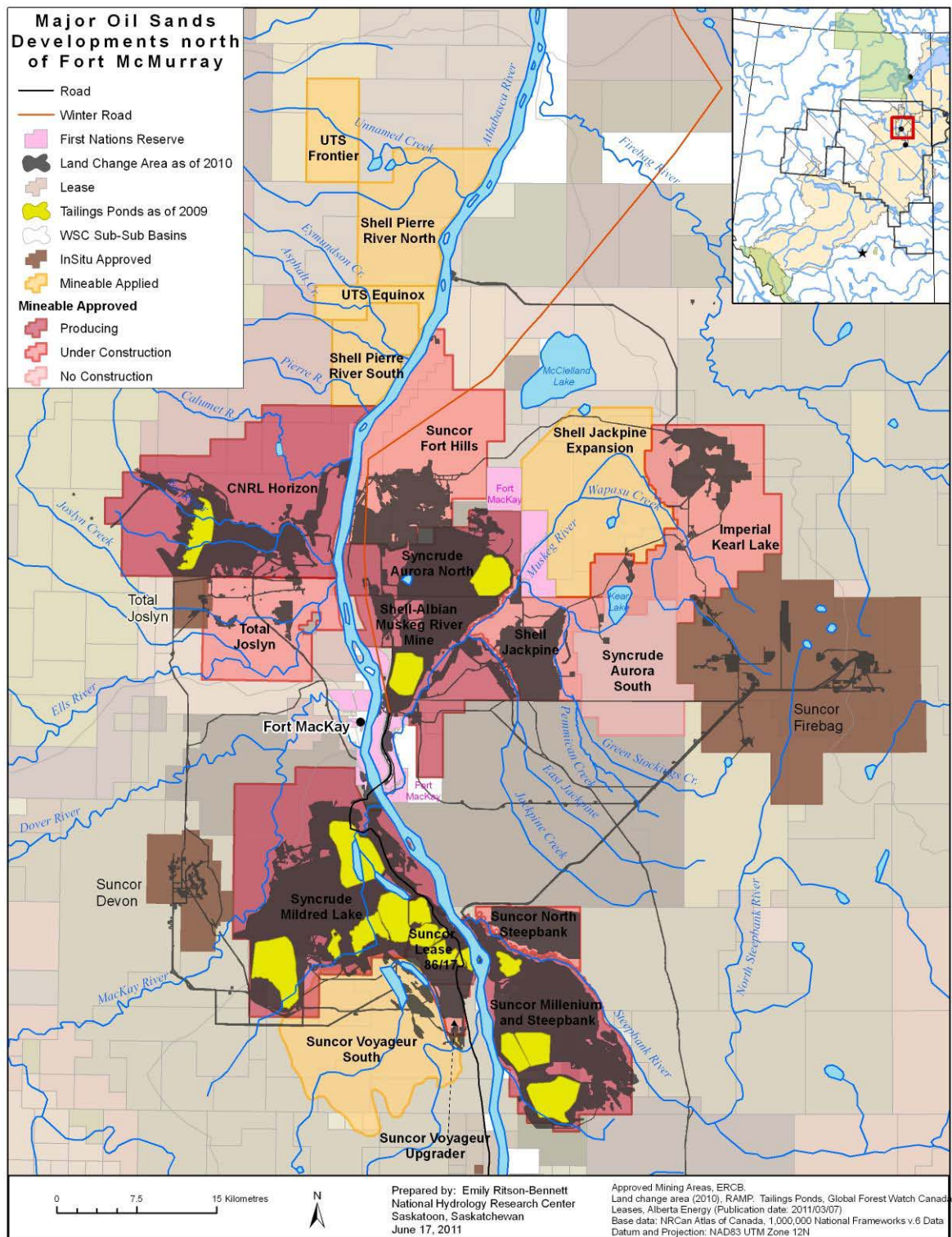
In addition, the Phase 2 design will deliver data of sufficient quantity and quality to detect or quantify the effects of oil sands development in a holistic and integrated manner. The integrated Plan has been developed by incorporating the sound components of existing monitoring initiatives, then presenting necessary additions or changes that will allow assessment of contaminant sources, transport, and their ultimate fate and effects on aquatic and terrestrial biota and relevant ecological processes, as well as the effects of habitat disturbance.

While the science and practice of monitoring has been fairly well established for some environmental components, key knowledge gaps exist. As a result the concept of continuous improvement is embedded in the Plan, ensuring the Plan is adaptive to new conditions, evolving technologies, societal issues or changes in knowledge. Additionally, integration of a monitoring design across components to produce core results under one framework for assessing cumulative effects is highly complex, rare in the world, and has not existed to date in the oil sands region. Key elements of this integrated design that do not exist in current monitoring systems is the co-location of sampling sites for water, biodiversity and air where appropriate, and archiving all data sets in common, accessible formats that are explicitly geo-referenced allowing data to be easily interpreted.

**Figure 1** summarizes the oil sands mining development and associated land-use changes as of June 2011 near Fort McMurray. The oil sands mining and sub-surface extraction developments (e.g., Steam Assisted Gravity Drainage – SAGD) have multiple potential environmental impacts on the air, water and land related to stack and particulate emissions (e.g., mine dust, coke stockpile, etc.), mine fleet and air emissions, water use (both surface and groundwater), production of waste streams including tailings ponds and associated contaminants, potential groundwater contamination, land disturbance and associated alterations in hydrological connectivity, and habitat loss and fragmentation. The media and ecosystem-specific components of the Phase 2 components recognize the links between the various potential



contaminant sources and their potential impacts on water, air quality and aquatic and terrestrial biodiversity.



**Figure 1.** Summary of the current oil sands developments (mining and *in-situ*) and associated land use changes in the Fort McMurray region, highlighting some of the challenges the integrated monitoring design addresses.

### CHAPTER 3. INTEGRATED MONITORING SAMPLING NETWORK DESIGN

*The integrated Plan addresses identified scientific and design shortcomings of previous monitoring programs.*

*The Plan builds on existing monitoring activities where appropriate, expands the range of core environmental parameters, and increases the spatial extent and temporal resolution that would be routinely monitored.*

*The Plan is designed to achieve a consistent regional approach in terms of sampling strategies, improved coordination of monitoring approaches and standardization and comparability of data.*

The Plan will provide the data necessary for an integrated cumulative effects assessment approach. Such an approach shifts the focus from assessing effects (both stressor-specific and cumulative) on a project-by-project basis, and instead provides a regional basis for addressing key questions of concern. This provides opportunities for cost-efficiencies, develops synergies by focusing questions, and reduces duplication of effort. The result is a framework that underpins the ecological assessment components required for Environmental Impact Assessment (EIA), focuses monitoring and research, provides regional baselines, provides the data to develop environmental thresholds for responses where required, and detects cumulative effects.

The Plan improves both the spatial and temporal resolution of the data being collected under existing monitoring efforts. This will enhance the ability to detect change in a timely fashion and predict effects, and adaptively manage for changing environmental conditions. Not only will this increase the statistical power to detect change, but also increase the fundamental understanding of the variability and responses in the system in relation to point and non-point sources of contaminants (including those brought to the region through long-range aerial transport), natural versus mined bitumen deposits, varying types of habitat disturbance, and cumulative effects.

Since biological endpoints can often be more sensitive and ecologically important than chemical endpoints, (e.g., Palmer et al. 2010), the design incorporates biological/ecological endpoints as key indicators of stress and impacts where possible. Continued efforts will be made to improve and quantify these end points to assess the degree of impact and whether acceptable environmental limits have been exceeded.



### 3.1 Expanded Monitoring Plan Components: Water, Air, Biodiversity

***The Integrated Oil Sands Environmental Monitoring Plan includes four integrated components:***

- (1) Water Quality Monitoring Plan (Phase 1 Athabasca River Mainstem and Tributaries);***
- (2) Expanded Geographical Extent for Water Quality and Quantity, Aquatic Biodiversity and Effects, and Acid Sensitive Lakes Monitoring;***
- (3) Air Quality Monitoring for the Oil Sands;***
- (4) Terrestrial Biodiversity and Habitat Monitoring.***

***The integration of these four components improves the capability to address hypothesis-driven questions related to current and projected area-specific and regional impacts of oil sands developments on environmental quality.***

The Integrated Oil Sands Environmental Monitoring Plan is structured around four core components:

1. Water Quality Monitoring (Phase 1 - Athabasca River Mainstem and Tributaries) (released March 2011 – Environment Canada and Alberta Environment);
2. Expanded Geographical Extent for Water Quality and Quantity, Aquatic Biodiversity and Effects, and Acid Sensitive Lakes Monitoring;
3. Air Quality Monitoring;
4. Terrestrial Biodiversity and Habitat Monitoring.

The integration of the four components improves the capability to address hypothesis-driven questions related to current and projected reach-specific and regional impacts of oil sands developments on the aquatic and terrestrial environments.

Understanding the fate, distribution, transport and effects of oil sands related contaminants requires each of the monitoring components to have purposeful integration and overlap in the geographical areas where monitoring is performed. This fact was incorporated in the spatial array of monitoring sites for each component. There is also recognition that both mineable oil sands and *in-situ* developments are occurring in the region, affecting fish and wildlife through both direct and indirect effects *via* habitat loss, landscape fragmentation and degradation, direct mortality, toxicology, and altered movements among ecosystems and habitats. The determination of local and regional environmental effects, and ultimately, cumulative effects at broader landscape scales necessitates that data from each of the components should be collected in a compatible and comparable manner (i.e., similar analytical approaches, detection limits, etc.) (see sections 8 and 9).

Sections 4-7 of this document describe and provide the rationale behind the proposed designs for each of the media- and ecosystem-specific monitoring components addressing *What, Why,*

*Where, When* and *How* monitoring will be performed. Each media specific component also describes how new designs are improvements over the existing monitoring, and which environmental variables and ecosystem processes are integrated across components, focusing on environmental parameters relevant to assessing oil sands development impacts related to contaminant releases and land disturbances.

## CHAPTER 4. WATER QUALITY MONITORING (PHASE 1)

***Phase 1 (Environment Canada, 2011) outlines the design for a water quality/quantity and localized airshed monitoring plan for the main stem of the Athabasca River, and its major tributaries, between Fort McMurray to the boundary of Wood Buffalo National Park.***

***The primary goal of the plan was to present a comprehensive and integrated approach that quantifies and assesses the sources, transport, loadings, fate, and types of oil sands and other industrial and municipal contaminants into the Athabasca River system.***

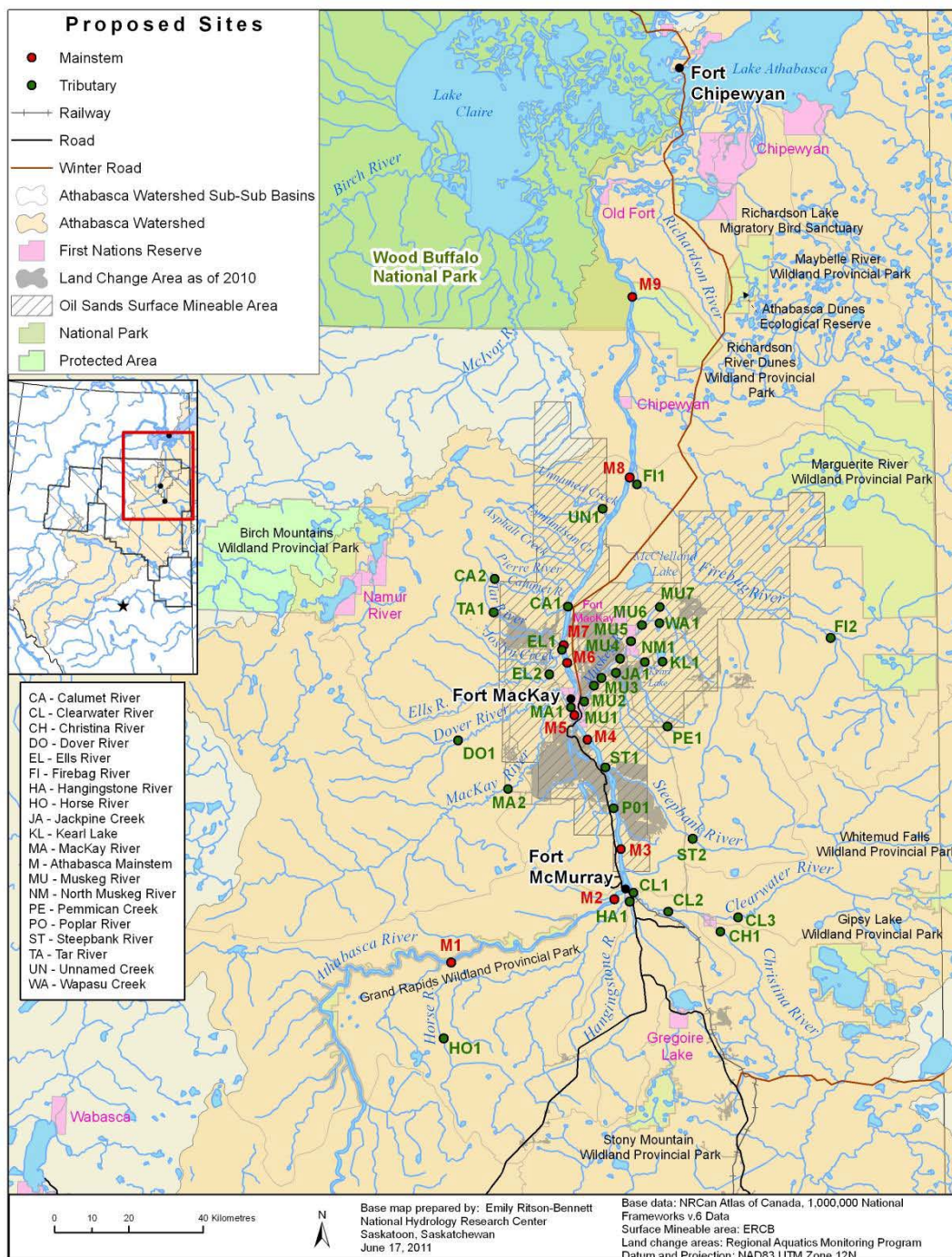
***Phase 1 is targeted at obtaining a better spatial and temporal quantitative understanding of the key physical/chemical “stressors” affecting the system and also improving knowledge on historical baseline conditions.***

The Phase 1 document (Environment Canada 2011) is the detailed design for monitoring water quality along the main stem of the Athabasca River, and its major tributaries, between Fort McMurray to the boundary of Wood Buffalo National Park. It is a technical plan about when, where, why and how to monitor surface water quality. It focuses on the physical and chemical components and stressors of the system. The primary goal of this technical plan is to present a comprehensive and integrated approach that quantifies and assesses the sources, transport, loadings, fate, and types of oil sands contaminants into the Athabasca River system. Phase 1 is targeted at obtaining a better spatial and temporal quantitative understanding of the key physical/chemical “stressors” affecting the system and also improving knowledge on historical baseline conditions.

Phase 1 was designed to address questions such as:

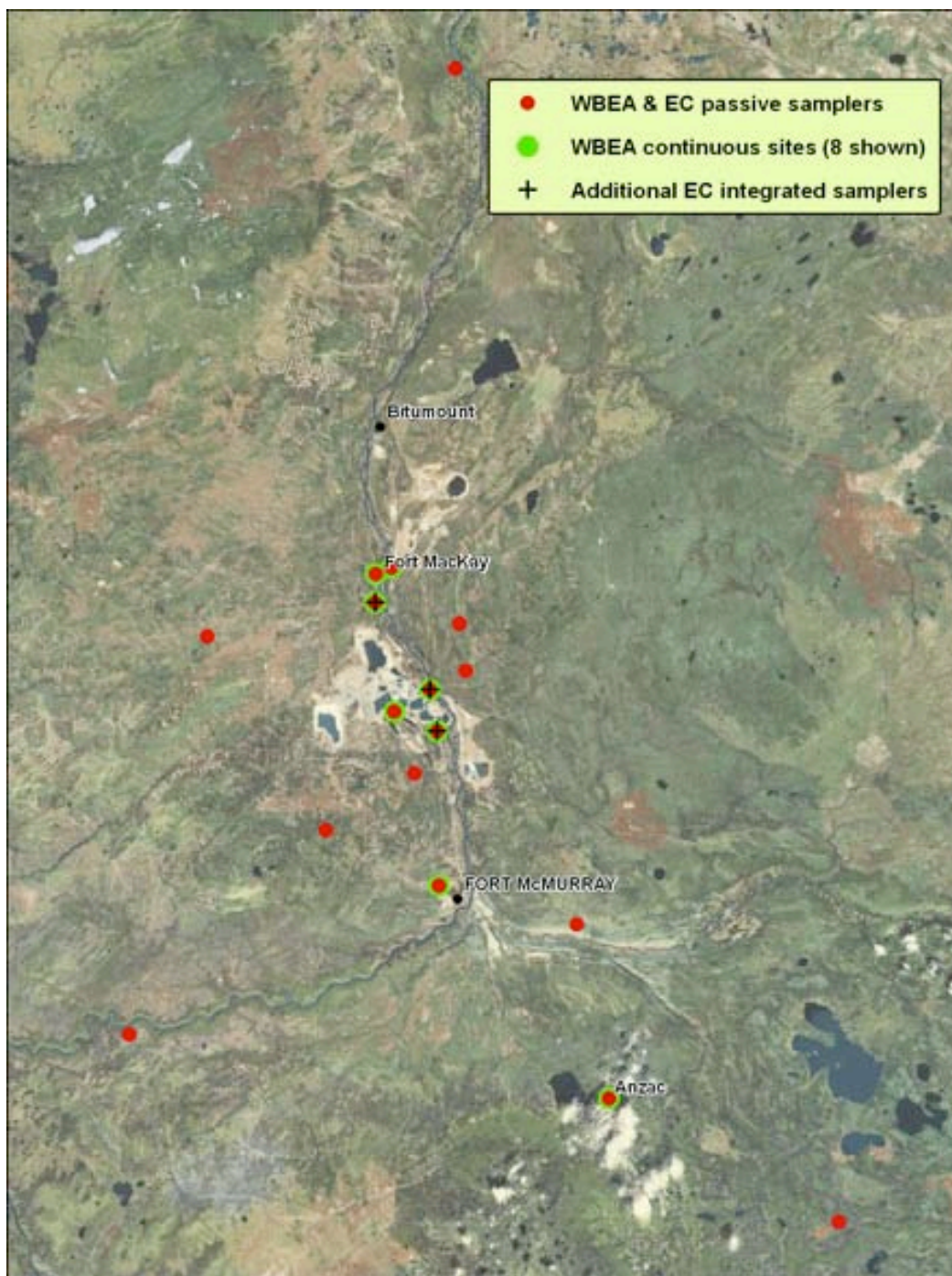
- What is the current state of the water quality of the Athabasca River basin?
- Which contaminants and levels are entering the Athabasca River directly or indirectly from oil sands operations?
- What is the distribution of contaminants in the aquatic ecosystem with particular reference to water and sediments?
- Can contaminant types and loads be attributed to specific sources?
- Are toxic substances such as mercury, naphthenic acids, PACs increasing or decreasing and what is their rate of change?
- Are the substances added to the rivers by natural and man-made discharges likely to cause deterioration of the water quality, and what is the relative importance of both inputs?
- What are the cumulative effects of land use alterations and man-made discharges on the water and aquatic environment?
- Is the data available to assess whether current contaminant loads or concentrations pose threats to human health or subsistence?

Key elements include taking measurements more frequently, in more places, to ensure sufficient data is available to track changes in water quality. **Figure 2** summarizes the water quality and quantity monitoring network sites designed under Phase 1, and **Figure 3** shows the location of the atmospheric deposition monitoring sites.



**Figure 2.** Phase 1 water quality/quantity monitoring sites on the Athabasca River mainstem and major tributaries. Red denotes mainstem sites, green denotes tributary sites (from Environment Canada, 2011).





**Figure 3.** Map showing the proposed locations for an expanded sampling network. Red dots are Wood Buffalo Environmental Association (WBEA) and Environment Canada (2010) passive air samplers. Green dots are WBEA sampling sites, + signs are proposed additional powered hi-volume air and precipitation monitoring (from Environment Canada, 2011).

## CHAPTER 5. EXPANDED AQUATIC ECOSYSTEM MONITORING

*Building on the outcomes of the Phase 1 Plan development process, the Expanded Aquatic Ecosystem Monitoring for water quality, quantity, aquatic biodiversity and ecological effects under Phase 2 includes:*

- *Expanding the geographic coverage of water and habitat monitoring activities to include: the Athabasca River mainstem and its tributaries (including streams); the Peace-Athabasca Delta; Lake Athabasca and the Slave River culminating in the Slave River Delta on the southern shores of Great Slave Lake,*
- *Incorporating ecological and biological indicators and endpoints to assess potential impacts of oil sands development on ecosystem health and integrity, and,*
- *Assessing potential impacts of air emissions from oil sands operations on acid sensitive lakes in northeastern Alberta, northwestern Saskatchewan and southern portions of the Northwest Territories.*

This monitoring component ensures that site selection, and spatial and temporal sampling frequencies provide appropriate inter-connectivity of relevant physical, chemical and ecological processes to assess (i) sources, fate and transport of oil sands-related contaminants, and (ii) potential impacts of oil sands development at site-specific and regional scales. In addition, time-integrative sampling (e.g., use of passive samplers) and sample archiving (e.g., fish tissue samples, sediment) will be performed. Archival samples will serve as important reference/baselines samples for comparison against future change if necessary.

### 5.1 Expanded Geographic Scope

This component expands the geographic scope of monitoring beyond the Athabasca mainstem and its tributaries, as outlined in Phase 1, to include key downstream receiving aquatic ecosystems and habitats. The sampling design includes portions of the Athabasca Oil Sands region that have headwater areas that drain directly into the Peace Athabasca Delta (e.g., Birch River) and to the Peace River west of the Wood Buffalo National Park (including the Mikkawa and Wabasca rivers), and Lake Athabasca. Sampling sites also incorporate relevant segments of the Peace and Slave River systems, including the Slave River Delta.

Key science questions that have guided the development of the expanded water plan include, for example:

- What is the historical and current state of water quality in regions of the Lower Athabasca basin, now including key downstream receiving environments?
- What are the levels and fate (transport, transformation, deposition) of oil sands contaminants in downstream deltaic and lake environments?
- What are the biological and ecological impacts of oil sands contaminants and operations on ecosystem health?

- What is the quality of fish habitat, and are any changes related to oil sands development?

With the expansion of the geographic area, it is recognized that an increase in hydrologic and ecological complexity must be considered. This added complexity requires careful consideration of the questions that need to be answered as well as the type and approach to monitoring in the expanded geographic area. At a broad regional scale, the expansion of the geographic scope takes into account the primary vectors of transport (air and water) and key environments for the deposition (fate) and potential bioaccumulation of oil sands related contaminants. Given the expanded geography, the sampling program must now deal with increasing complex chemical-physical environments (e.g., deltas), including their biota.

Water quality and quantity parameters identified in Phase 1 will be sampled similarly at the identified geographical locations in Phase 2; however, new habitat-specific protocols are also identified. A series of core sites have been identified to broaden the regional assessment of contaminant fate, distribution and transport. In addition, these sites will further quantify baseline/reference conditions, and be used to assess exceedances in water quality/quantity guidelines and thresholds further downstream.

## **5.2 Aquatic Ecosystem Biodiversity and Effects**

The objectives of the integrated aquatic ecosystem biodiversity and effects component of the Plan is to use key freshwater species and communities, and associated ecological and biological endpoints to assess whether oil sands developments are affecting ecosystem integrity and health. There are two main elements to this component; (i) fish populations, and (ii) invertebrates and other biota. Monitoring of fish and benthic invertebrates will be prioritized in Plan implementation as one of the most likely sensitive endpoints to oil sands development effects.

### **5.2.1 Fish**

The objectives of the fish component are to provide the necessary data to address key questions related to both environmental health of fish populations, and fish health issues relevant to use and consumption. Considerations of lessons learned from current and past regional and national fish monitoring programs have guided the development of the component (e.g. Environmental Effects Monitoring Program – <http://www.ec.gc.ca/eseem/>).

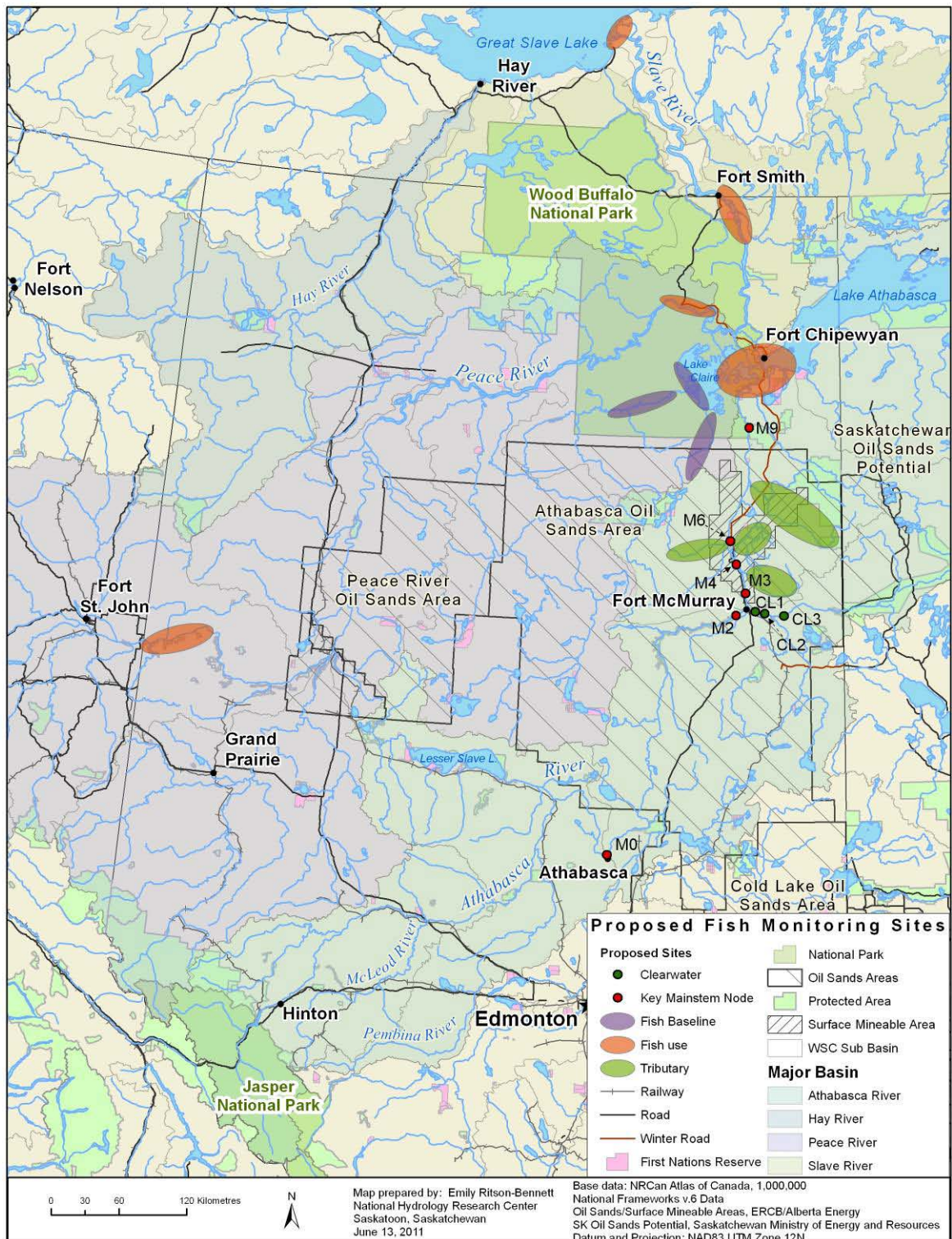
Key science questions that have guided the development of the fish component of the plan include, for example:

- What is the historical and current state of fish population health in the Lower Athabasca mainstem, tributaries, and key downstream environments?

- What are the levels of toxic substances such as mercury, naphthenic acids, and other contaminants in fish tissues, and are the levels increasing or decreasing?
- What are the cumulative effects of oil sands development on fish and fish habitat?

The fish monitoring component design will develop enhanced baseline data for future site-specific comparisons and to improve the ability to examine cumulative effects. Over time, site-specific information will be used to develop an understanding of the key drivers or ecological responses to allow the development of a cumulative effects approach, and contribute to the development of better predictive capabilities for oil sands environmental impact predictions. Examples of biological/ecological attributes to be measured include assessments of overall fish health (e.g., assessment of age, growth, liver size, gonad size), fish distributions, tissue contamination, and abnormalities within the mainstem Athabasca, its tributaries, and downstream habitats (e.g. Lake Athabasca; Peace, Athabasca and Slave Deltas). Fish sampling sites will be linked directly to invertebrate sampling locations and to water quality and quantity sites as outlined in Phase 1 and the expanded plan. **Figure 4** summarizes fish population sampling sites in the Lower Athabasca region.





**Figure 4.** Fish population sampling sites in the Lower Athabasca region.

### 5.2.2 Invertebrates and Other Biota

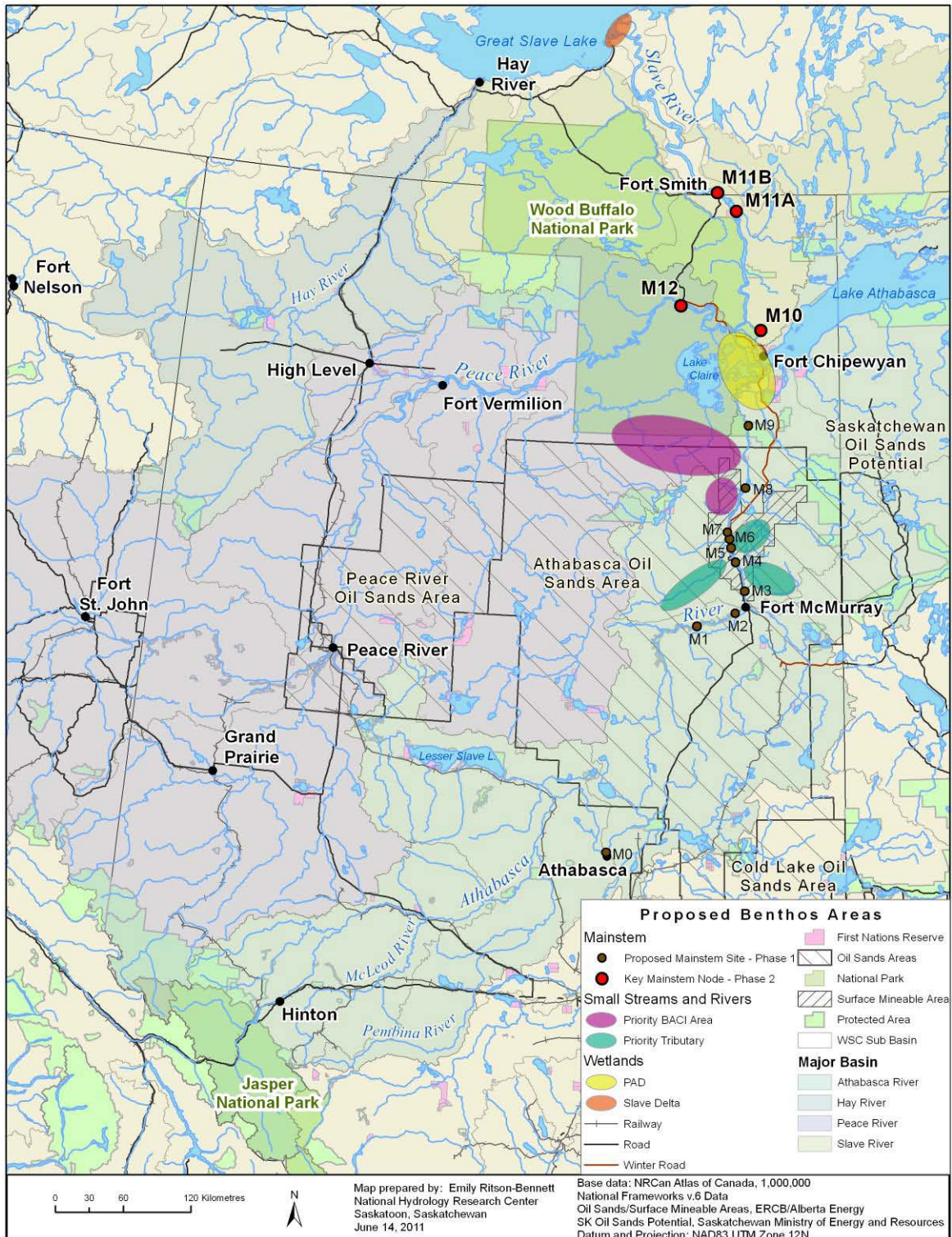
Aquatic invertebrate and other biological monitoring will be conducted to assess change in benthic and pelagic biotic communities in relation to reference condition(s), and to assess ecological effects of cumulative stressors related to oil sands development. Used together with the chemical and physical monitoring components, invertebrate monitoring will integrate “effect” measurements associated with causal factors. Examples of effects endpoints include changes in community structure, tissue contaminant levels, changes in functional groups and trait patterns. The proposed area of study will include sites on the main stem of the Athabasca, Peace and Slave rivers, sites in small rivers and streams in the Lower Athabasca River basin including some in the Lake Claire-Birch River and Christina River watersheds. In addition, a sampling plan is outlined for deltaic wetland habitats in downstream areas of the basin.

Key science questions that have guided the development of the invertebrate component of the plan include, for example:

- What is the historical and current state of invertebrate community structure and function in the Lower Athabasca mainstem, tributaries, and key downstream environments?
- What are the levels of toxic substances such as mercury, naphthenic acids, and other contaminants in invertebrate tissues, and are the levels increasing or decreasing?
- What are the impacts of oil sands developments on invertebrate and other biota (e.g., algae) food-web complexity and stability?
- What are the cumulative effects of oil sands development on invertebrate habitat?

This component has been designed specifically to address the short comings of existing programs identified in recent expert reviews (e.g., Federal Oil Sands Advisory Panel 2010, Dillon et al. 2011). It uses internationally-established sampling and enumeration methods, and diagnostic indicators, while recognizing the benefits of previous monitoring for background information. The design for site selection and frequency of sampling utilizes both BACI (Before-After-Control-Impact) for reach-specific assessments and a broader multivariate Reference Condition Approach (RCA) for regional synoptic analyses. This component focuses on using benthic and pelagic invertebrate and algal communities given their ecological importance for fish habitat quality and contaminant transfer and potential bio-magnification through aquatic food-webs. **Figure 5** summarizes the integrated invertebrate and fish sampling locations in the broad geographic area of interest.





**Figure 5.** Summary of monitoring sites for integrated aquatic biodiversity and effects monitoring.

### 5.3 Acid Sensitive Lakes

Atmospheric emissions of acidifying pollutants (most importantly SO<sub>x</sub>, but also NO<sub>x</sub>) from oil sands industry in Alberta have been increasing, resulting in increased regional acidic deposition. The coincidence of elevated or increasing deposition levels and acid sensitive receptors is prescriptive for an acid deposition “region of concern” where monitoring should occur to determine whether atmospheric deposition of acidifying pollutants is producing discernable impacts on the geochemistry and health of aquatic ecosystems, and whether the pollutants are of oil sands origin.

The acid sensitive lakes component is designed to address the shortcomings identified by various recent reviews (e.g., Federal Oil Sands Advisory Panel, 2010), and is based upon >30 years of information obtained through similar statistically-based lake monitoring on acid-sensitive lakes in eastern Canada, the USA and Europe. The objectives of the monitoring plan are to:

- Establish a monitoring network of representative lake ecosystems in acid sensitive regions of Saskatchewan, Alberta and the Northwest Territories that are (potentially) influenced by SO<sub>x</sub> and NO<sub>x</sub> emissions from oil sands industry;
- Establish baseline conditions;
- Present a sampling design with sufficient statistical power to detect chemical and biological changes from baseline conditions; and
- Identify a sub-set of monitoring sites for intensive investigation to determine the cause of observed changes.

The geographical monitoring extent of the acid-sensitive lake component is linked to the Air Quality Component and is defined by present occurrences of aquatic critical load exceedances (in northwestern Saskatchewan and northeastern Alberta) and geologically sensitive terrain where no critical load information exists (Northwest Territories).

The acid sensitive lake component incorporates a hierarchy of integrated monitoring levels:

1. Statistically-based (stratified-random) regional surveys of hundreds of lakes to establish current regional acidification status (already available for 715 lakes in Saskatchewan, but will have to be conducted in Alberta and the Northwest Territories);
2. Monitoring 40-60 lakes, mostly selected from the regional survey above, to detect changes in acidification status over time (sampled seasonally/annually).  
Paleolimnological analyses of lake sediments will define historical conditions and how they differ from the present. The sampling design takes advantage of historical data records. These data will be used to define regional baseline conditions where appropriate, and quantify critical loads for acidity and water quality exceedances (e.g. major ions and DOC). Some biological sampling (i.e., zooplankton) will be conducted to establish baseline characterization; however, additional sampling will be ‘triggered-in’ where deemed necessary as results dictate; and

3. Intensive monitoring of 2-3 lakes for assessment of causal changes in geochemistry via a mass-balance approach, to identify the cause of any change detected in 2 above.

This monitoring hierarchy will provide crucial information needed to accurately estimate resource-level acidification status, detect change, identify the causes of change, and predict future conditions. This component recognizes that a lake cannot be divorced from its terrestrial catchment, and that the entire lake ecosystem must be considered when specifying monitoring components. The component focuses on lakes located downwind of most of the oil sands atmospheric emissions, and is linked to the air quality and atmospheric deposition component plan outlined in Section 6 below.

## CHAPTER 6. AIR QUALITY MONITORING

***Emissions of air pollutants to the atmosphere are a significant by-product of the oil sands industry. An effective air quality monitoring program is needed to understand and quantify the emissions from the oil sands operations, to quantify their impacts on local and regional air quality, provide data to allow assessment of ecosystem and human health, and to link across environmental media to relate emissions to acute and cumulative, long-term effects. Air quality monitoring is integral to the management of air pollutant emissions.***

Environmental management of the oil sands is a complex issue that requires a complex air monitoring approach. The air emissions and air quality component is based on state-of-the-science measurement, data management and data analysis techniques that are at the leading edge of science and air pollution management.

This component is focused on the monitoring needs required to understand the temporal and spatial trends in air pollutant emissions, their chemical transformation in the atmosphere, long-range transport and subsequent deposition to the local and regional environment. It is comprehensive in that it includes monitoring at the point of emission through to monitoring systems that will provide the data that will enable the evaluation of potential ecosystem and human health impacts. The geographic scope includes the immediate oil sands region, as well as upwind and downwind areas in Alberta, the Northwest Territories, Saskatchewan and Manitoba. This geographic scope reflects the transboundary nature of air pollution, and the predicted geographical extent of potential human and ecosystem health impacts.

Key science questions that have guided the development of this component include:

- What is being emitted into the air from the oil sands operations, how much and from what sources?
- What is the atmospheric fate (transport, transformation, deposition) of oil sands emissions?
- What are the impacts of oil sands operations on ecosystem and human health?
- What additional impacts on ecosystem health and human exposure are predicted as a result of anticipated future changes in oil sands development?

Increased monitoring of air pollutant emissions from the oil sands region is recommended, including enhanced monitoring of industrial stacks, mobile sources and area sources (including tailings ponds and mine faces). Improved quantification and characterization of emissions will provide a science-based emission inventory with increased spatial and temporal resolution, including more chemical species, leading to improved understanding of air emissions and their impact on local and regional air quality.

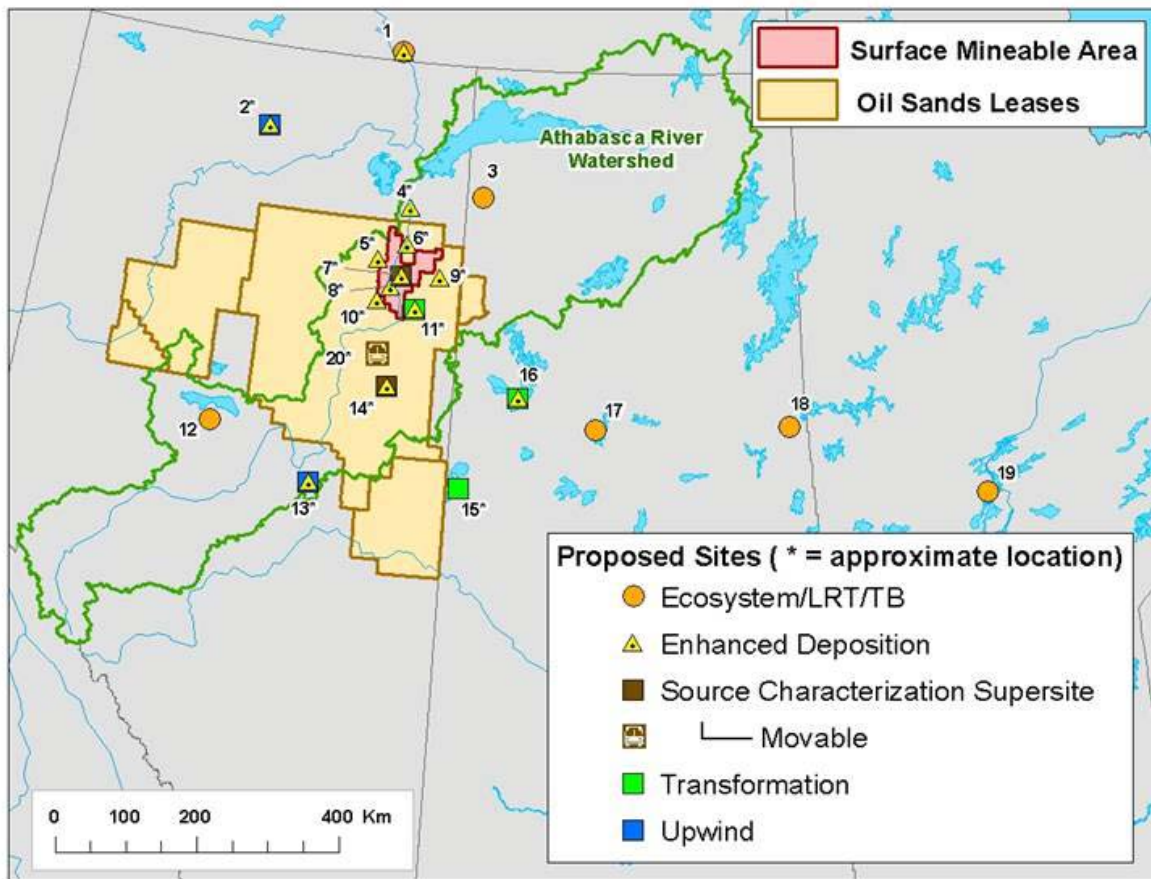
To understand how air pollutant emissions are transformed and transported in the atmosphere and to provide data to assess the resulting impact on human and ecosystem health, a multi-component ambient monitoring system is presented. Fourteen new ambient monitoring stations are recommended, in addition to the six new atmospheric deposition sites included in the Phase 1 component, as a complement to existing monitoring sites, to monitor the impact of the oil sands locally and regionally, and to evaluate the transboundary movement of air pollutants (**Figure 6**). The new sites include two stations in locations primarily upwind of oil sands activities to monitor air quality that is not influenced by the oil sands region, and two 'source characterization' sites in close proximity to oil sands operations. Six of the monitoring sites will also measure the downwind deposition of air pollutants, which is critical to evaluating potential impacts on sensitive ecosystems.

In addition to traditional monitoring techniques, this component's approach uses air quality models and satellite-based information to integrate the information gathered from the ambient and emissions monitoring work. This step is critical to interpolate between monitoring sites to areas of the region that will not be sampled through conventional *in-situ* monitoring, and will give insight into the transport and fate of air pollutants from the oil sands. Information from air quality models can be linked to ecosystem models to provide additional insight into the potential ecosystem and human health impacts from the oil sands.

The assessment of impacts of atmospheric emissions/deposition to aquatic and forest ecosystem health can be integrated using a critical loads approach. The Water Quality Phase 1 component incorporates a mass-balance approach for assessing critical load impacts on aquatic ecosystems. The Air Quality component includes monitoring efforts to assess critical loads to forests and soils in and around the oil sands area. Both activities rely upon atmospheric deposition fluxes quantified by the Air Quality monitoring component. This integrative approach allows for the generation of ground-truthed maps of terrestrial/forest critical loads and exceedances. This will allow for an evaluation of forest resources at risk in northern Alberta, northern Saskatchewan and the Northwest Territories. Moreover, this information will be integrated with the aquatic critical loads/exceedance assessment, thereby further integrating atmospheric, aquatic and terrestrial monitoring activities.

The Air Quality component reflects a science-based approach that is broader than the individual responsibilities of government, industry and multi-sector organizations engaged in air quality monitoring in Alberta, and complements existing air quality monitoring in Alberta. It will provide support for the Air Quality Management System (AQMS) requirements for airshed monitoring and reporting.





**Figure 6.** Ground-level air monitoring sites in Alberta, Saskatchewan, Manitoba and the Northwest Territories. Sites 4, 5, 6, 8, 9, 10 have been identified in the Phase 1 water quality plan. Installation of sites 12, 17, 18 and 19 has been initiated through the Environment Canada Canadian Air and Precipitation Monitoring Network (CAPMoN).



## CHAPTER 7. TERRESTRIAL BIODIVERSITY AND HABITAT

Although development of the oil sands will impact terrestrial biodiversity in a variety of ways, the most consequential impacts are anticipated to result from two main industrial activities: the release of contaminants to the environment; and the loss and degradation of wildlife habitat. As a result, the terrestrial biodiversity monitoring component is structured around two important elements:

1. Monitoring the impacts of oil sands-related contaminants on selected wildlife indicators, including birds, mammals, amphibians and plants, with a view to identifying broader implications for biodiversity in the region; and
2. Monitoring the impact of habitat disturbance by oil sands activities on wildlife, in conjunction with monitoring the success of mitigation efforts.

The primary objective of the wildlife contaminants component is to monitor the levels and effects of oil sands-related contaminants, and their influence on the health of individual wildlife and wildlife populations, at varying distances from oil sands operations. This component will produce data on an annual basis on a variety of oil sands-related contaminants of concern (including PAHs, mercury, arsenic) measured in wildlife tissues (birds, mammals, amphibians and plants) at various locations. The proposed sampling schemes will permit the determination of contaminant levels and trends (used to track the effectiveness of management actions). In addition, contaminant concentrations in tissues will be compared to published threshold levels for contaminant effects to identify wildlife populations that may be at risk of health impairment (e.g. lower productivity, increased susceptibility to disease) in the oil sands region. Where toxicity standards and thresholds do not exist, the toxicity information generated can be used to assess effects.

To monitor wildlife contamination and contaminant trends and effects, there are five inter-related monitoring components:

- Monitoring the effects of oil sands activities on breeding waterbird populations, diet, and egg contaminants downstream from the oil sands on the Athabasca River and Lake Athabasca;
- Monitoring the impacts of contaminants associated with oil sands processing on the health and development of amphibian (wood frog) indicator species;
- Monitoring the effects of oil sands contaminants on avian health using non-lethal measures of stress and physiology;
- Toxicological assessments of hunter/tapper-harvested wildlife (waterfowl and mammals), and dead and moribund birds in oil sands impacted areas and lower reaches of the Athabasca River; and

- The use of native plants to monitor the condition of oil sands-associated wetlands.

The habitat disturbance element of this monitoring component focuses on identifying the impact of habitat disturbance (caused by development of the oil sands) on terrestrial biodiversity over time, and assessing the success of mitigation efforts. This requires population monitoring for status and trends, and effects assessment (cause-effect monitoring) to identify causal mechanisms of wildlife responses. While it is clear that surface mines result in a virtual complete loss of biodiversity on those sites until reclamation, there are other important though less obvious impacts from *in situ* operations that affects a much broader area.

Given the large potential scope of such monitoring, a staged approach must be pursued. This component initially focuses on the development of a conceptual model of ecosystem function and a clearer understanding of how the development of oil sands interacts with ecosystem components. This in turn will inform the identification and prioritization of a refined set of questions that the monitoring plan will address, and subsequently, the parameters, design, protocols and analyses necessary to answer those questions.

In terms of scope, the first stage primarily involves the monitoring of key vertebrate wildlife and wildlife habitats, where there is more current knowledge and where there is high societal interest. Selection of target species for monitoring will reflect a range of considerations including:

- Species that rely on the oil sands regions for breeding habitat;
- Species that have known population declines, are found in a relatively small geographic range, or are strongly dependent upon vulnerable and difficult-to-replace habitats;
- Selection of a suite of species that show a range of response (positive or negative) to gradients of stressors/activities; and
- Species that have cultural, traditional, nutritional, economic, aesthetic or other value beyond their inherent value.

The geographic scale of this component is not on individual oil sands operations, but is bounded by habitat disturbance from oil sands activities at the scale of bitumen deposits across Alberta and Saskatchewan. Within this geographic area, monitoring will focus on overall status and trends combined with cause-effect studies of the cumulative and individual impacts to habitat from linear disturbance, such as seismic lines, pipelines and roads, and polygonal disturbance such as well-pads, compressor stations, and mine sites. Some monitoring outside of the bitumen deposits will be needed for ecological context.

Beyond clearing of habitat, there is disturbance to habitat through factors such as noise generated by machinery and vehicles, through altered water regimes arising from disturbance to hydrological systems, and through invasive species, either introduced species or through landscape conversion that creates habitat for species that would not typically occupy contiguous boreal forest.

Articulation of the potential pathways of the effects of oil sands and subsequent mitigation on wildlife is crucial to the design. The overall design for long-term collection of monitoring data will be robust enough to allow reporting on the changes in wildlife through time, but also provide complementary information on the relationship of wildlife to these disturbance gradients. The design of this monitoring component will take existing monitoring activities into account and will benefit from interaction with organizations and agencies where appropriate.

## CHAPTER 8. QA/QC: FIELD, LABORATORY AND DATA CONTINUUM

*Open, transparent, field and laboratory protocols, Standard Operating Procedures, analytical standards, data evaluation analyses and evaluation techniques, and reporting and access requirements, are either presented in each of the component documents, or where they do not exist, will be developed.*

To ensure scientific rigour and to maintain consistent high quality data, each component will have media-specific sampling, handling and processing QA/QC requirements that will be followed and audited as part of the overall QA/QC management system. State-of-the-art QA/QC protocols will be used and standardized within and among each monitoring component to allow appropriate data comparability and integration (e.g., Environment Canada 2011). As outlined in the Phase 1 report, a robust QA/QC program will:

- be designed to assure comparability among participating laboratories in the analysis of a broad range of analytes and to take action when lab results are out of line with consensus or reference values;
- evaluate lab performance annually for a core list of contaminants following ISO guidelines;
- be designed to demonstrate that high quality is maintained over the lifetime of the program;
- include appropriate handling procedures regarding sampling, data reporting, and archiving of data/samples/extracts;
- encompass inter-lab comparison of all media of interest;
- involve a QA audit program that will be run by an independent accredited laboratory;
- ensure field and laboratory personnel are appropriately trained in standardized operating procedures;
- evaluate and incorporate, where appropriate, new and emerging state-of-the-art technologies and analytical methods; and
- support focused studies for sampling or analytical method development when required.

## **CHAPTER 9. DATA MANAGEMENT AND DECISION SUPPORT**

This Plan is founded on the principles and recommendations in the Federal Oil Sands Advisory Panel's Report (2010) that emphasized the need for a data management framework where information can be uploaded, organized and accessed in a standardized coordinated manner such that it is transparent and freely accessible, in a timely manner. It should enable concerned parties to retrieve data, conduct their own analyses and draw their own conclusions, and that will make the basis for judgment and conclusions explicit.

A first step to in achieving efficiency in data archiving and access will be the implementation of a data management system that makes all raw data collected through the integrated oil sands monitoring program, value-added data/information, scientific interpretation of the data, and communication products easily and freely available. Based on expert consultations, an appropriate web-based portal will be established through which all information can be accessed. Initially, the portal will summarize what is being measured, where, when, why, how and by whom, along with the standard operating procedures (SOPs) and QA/QC protocols used for data collection and data archiving. Subsequently, where appropriate and required, further databases containing raw and value-added data, and real-time data where possible, will be linked or incorporated.

It is recognized that development and implementation of an integrated database management system (i.e., loading and organizing data in an easily retrievable manner) is only the starting point for what is necessary for a world-class monitoring program. More importantly, integrated assessment tools need to be developed and implemented to produce key results such as:

- Core Results on accumulated states (trends and exceedances including those relative to baseline/reference states);
- Relationships, and ultimately predictive models, for cumulative effects assessments; and
- Timely data interpretation to address designated tiers and triggers, where applicable, and/or threshold exceedances that informs/adjusts the monitoring program design and related sampling implementation (in time and in space).

Ideally, integrated assessment tools will be core automated features of the data management and related decision support system.

## CHAPTER 10. SUMMARY

The outlined integrated oil sands monitoring program framework and proposed sampling design meets the key principles that were identified by the Federal Oil Sands Advisory Panel for the design and implementation of a “world-class” monitoring program. Although the Monitoring Plan was designed in two phases, the final integrated design fully captures geographic and media-specific sampling complexities involved.

An ecosystem-based approach was used that incorporated multiple essential components of the system (e.g., hydrology, surface and groundwater quality and quantity, climatology, sediment dynamics and quality, local and regional air quality and atmospheric deposition, aquatic and terrestrial biological indicators and endpoints) as well as the relationships among the components. Sampling sites were chosen to integrate multi-scale, spatial measurements (e.g., linkages between tributary, mainstem, deltaic and lake system; impacted vs. baseline in the watershed context; emissions, local, transformation and transboundary transport scales for air quality) recognizing the importance of addressing the spatial and temporal variability, and improving the ability to define “baseline” or historical environmental conditions.

The best available science-based approach was used to select the chemical, hydrological, atmospheric, biological and ecological variables to be measured, methodologies for field sampling and laboratory analyses, and field and laboratory quality assurance and quality control. Standardized reporting, including peer-reviewed and plain language publications, will also be core outcomes of Plan implementation.

## CHAPTER 11. REFERENCES

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