Environmental Monitoring in Alberta

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Science Co-Lead Oil Sands Monitoring (OSM) Program
Environmental Monitoring and Science Division (EMSD)
Alberta Environment and Parks

History of Environmental Monitoring in Alberta

2011

June

Release of Alberta Environmental Monitoring Panel Report

2012

June

Release of Alberta Environmental Monitoring Working Group Report

2013

September

The Environmental Monitoring Management Board presents advice on creation of arm's length environmental monitoring agency to Minister of Environment and Sustainable Resource Development

2014

April

Protecting Alberta's Environment legislation enacted

AEMERA created

2015

June

AEMERA fully funded and seconded staff offered full time employment

2016

April

Decision to re-integrate Environmental Monitoring & Science back into the Government of Alberta announced

2017

December

MOU between the Government of Alberta and Government of Canada renewed

2018

December

Operational Framework Agreement and new governance ……..

A(nother) New Beginning

- **An Act to Ensure Independent Environmental Monitoring was enacted on June 30, 2016.**
  - **Repealed the Protecting Alberta's Environment Act; and**
  - **Amended Section 15, Environmental Protection and Enhancement Act**
    - Minister has a legislated responsibility to report on the condition of the environment in Alberta;
    - Fulfilled by the Reporting of the Chief Scientist;
    - Position and role of the Chief Scientist established;
    - Two advisory panels established:
      - Science Advisory Panel and Indigenous Wisdom Advisory Panel
- **Environmental Monitoring and Science Division (EMSD) is created**

Scientific Integrity

Defined:

- Individual and Departmental transparency and rigour in the practice of monitoring and science, using internationally recognized, quality assured and quality-controlled standards and protocols.

Scientifically credible:

- Is accurate, repeatable, provable and, where appropriate, peer reviewed.

Independent advice:

- Input and feedback received from third party recognized experts that is unfettered by political or special interest influences.

EMSD: Who we are

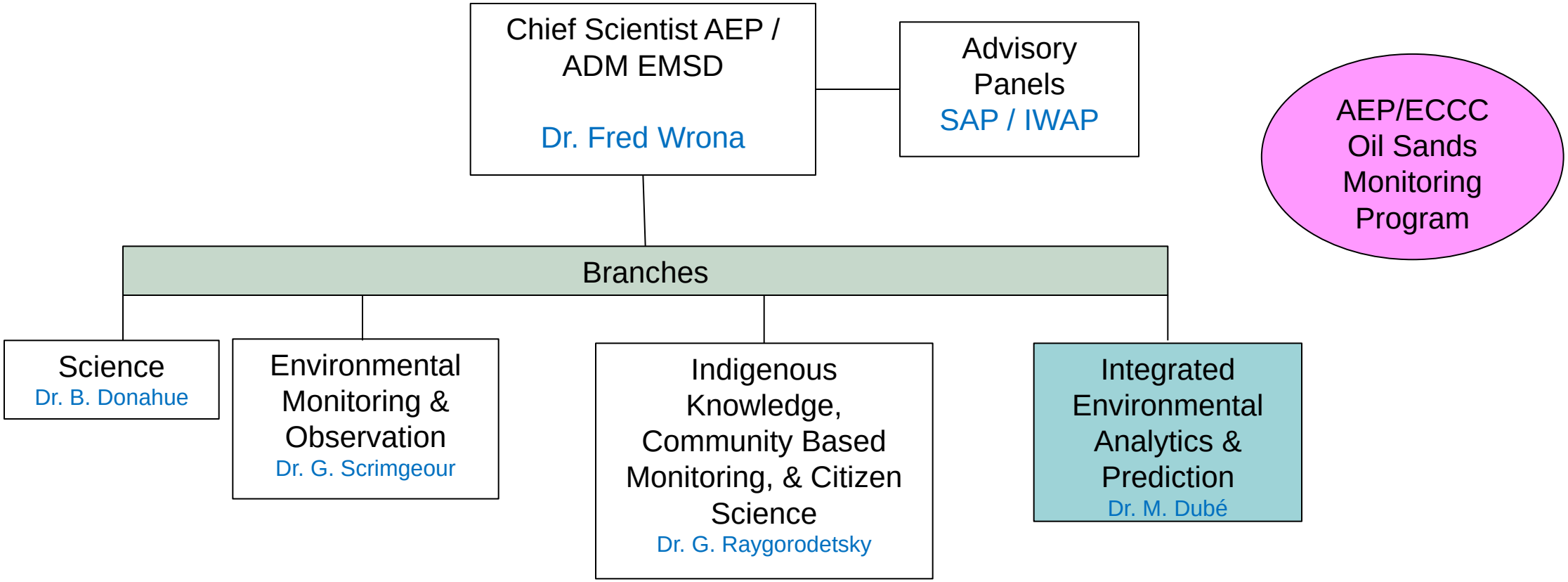
Chief Scientist & ADM

- **Dr. Fred Wrona, Chief Scientist & ADM, EMSD**

Roles and Responsibilities:

Chief Scientist	ADM
Plan, co-ordinate and conduct environmental monitoring	Day to day operation of division
Collect, store, manage, analyze, evaluate and assess environmental monitoring data and ensure information is scientifically credible	Work with DM and Executive Team to align monitoring and science programs with strategic direction and priorities of the Department
Make data and information available to the public	Ensure efficient and effective use of resources for monitoring and science programs
Consult with the Science Advisory Panel and Indigenous Wisdom Advisory Panel	Enable staff to do their best work collaboratively with other Divisions

Who we are


Chief Scientist AEP / ADM EMSD
Dr. Fred Wrona
Advisory Panels
SAP / IWAP
AEP/ECCC Oil Sands Monitoring Program
Branches
Science
Dr. B. Donahue
Environmental Monitoring & Observation
Dr. G. Scrimgeour
Indigenous Knowledge, Community Based Monitoring, & Citizen Science
Dr. G. Raygorodetsky
Integrated Environmental Analytics & Prediction
Dr. M. Dubé

Independent Advisory Panels

Science Advisory Panel (SAP)

Panel members: 6 internationally recognized scientists who provide scientific peer review and validation of science implementation. **Advice to the Chief Scientist and Minister.**

Indigenous Wisdom Advisory Panel (IWAP)

Panel members: 7 recognized and respected knowledge holders and experts in their fields who provide strategic advice and recommendations regarding meaningful incorporation of indigenous wisdom, and the inclusion of Indigenous peoples within the monitoring, evaluation and reporting system. **Advice to the Chief Scientist and Minister.**

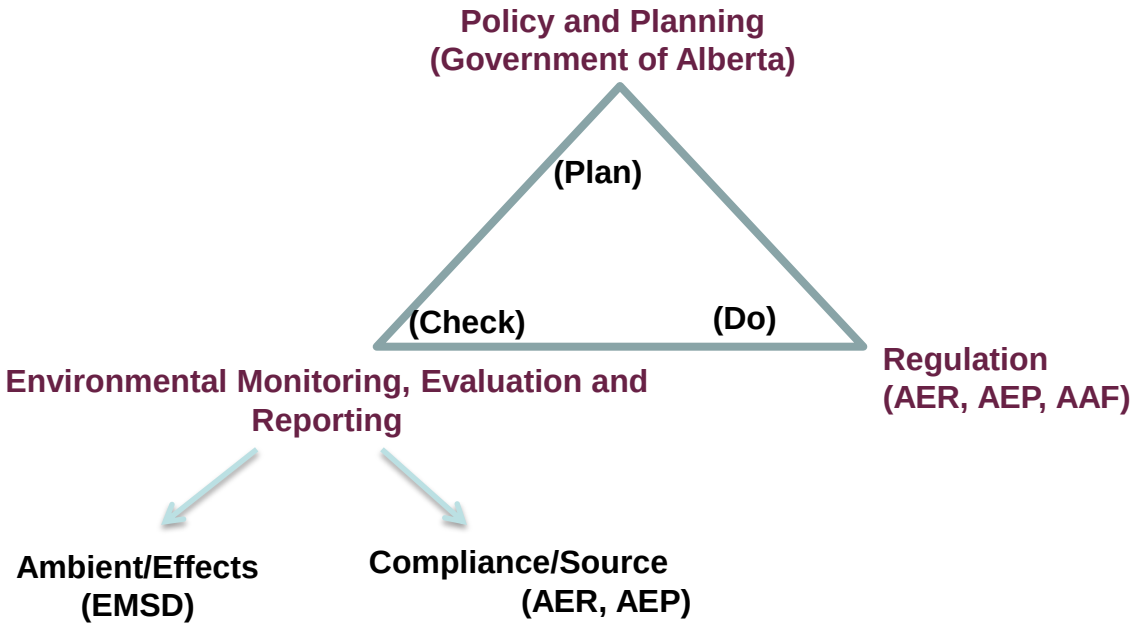
Integrated Environmental Analytics and Prediction Branch

- **Advance our understanding & prediction of the effects of environmental change on the structure and function of ecosystems and related ecosystem services at multiple scales**
- **Evaluate and assess impacts of single and multiple drivers, on populations, communities and ecosystems.**
- **Integrated analysis of water, air, biodiversity, and land data and results for cumulative effects assessment.**
- **Implement and manage open source data for accessible long-term and large-scale datasets that describe the state of the environment**

EMSD: What we do

Our role in IRMS

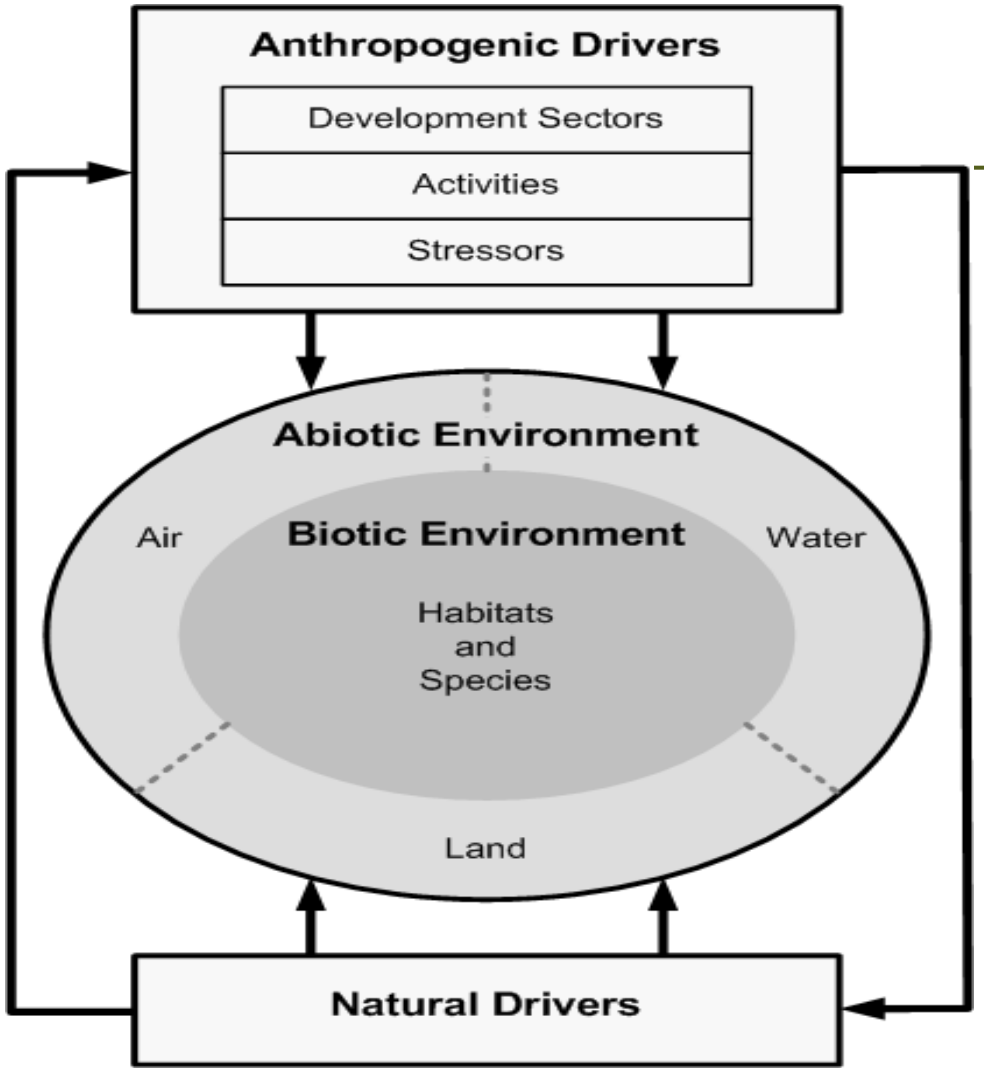
- **Provision of data to inform decision making**
  - **E.g. regional Environmental Management Framework reporting against thresholds & triggers under LARP and SSRP**



EMSD Responsibilities

- **Provincial Ambient Monitoring**
- **Ambient Environmental Monitoring of the Oil Sands**
- **Public Reporting**

Monitoring in Ecosystem Context



Stressors

- Release of substances
- Habitat loss, disturbance
- Water withdrawals
- Changing climate
- Others …

Impacts on Biotic Environment

- Changes in air, water, soil quality and water quantity
- Contaminants in biota
- Changes in distribution, and abundance of species & habitats
- Changes in ecological processes
- Potential for human exposure
- Others …

Monitoring enables understanding; supports management

EMSD: Provincial Programs

Core Business: Monitor, Evaluate and Report on Water, Air, Biodiversity

Water

- River and stream monitoring networks
- Lake monitoring network
- Groundwater monitoring network
- Provincial wetland monitoring network

Biodiversity

- Provincial biodiversity monitoring networks

Air

- Urban and Ambient Air quality monitoring networks

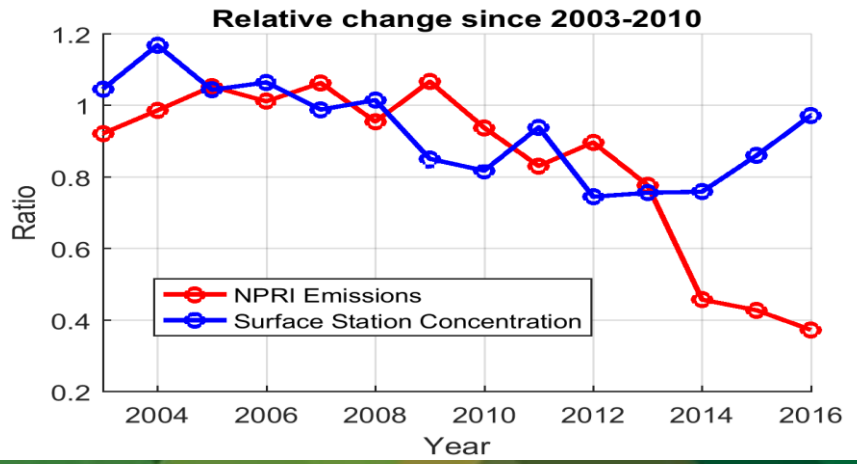
Air and Water Monitoring Networks

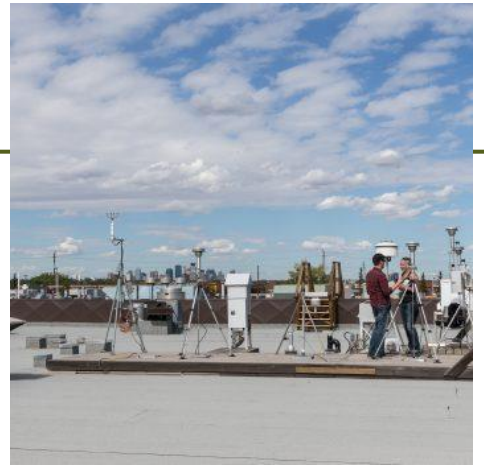
- Operate/or support a network of 20 long-term continuous air quality stations
  - Performance audit program
  - Mobile air monitoring program
- Operate near-real-time 36 hydrometerological stations
- Water quality of 40 lakes
- River monitoring of 37 mainstream and 65 tributary sites
- Groundwater monitoring of 200 wells
- Provide emergency response support

Air

Alberta Air Zones Reports

Fort McMurray Wild Fires

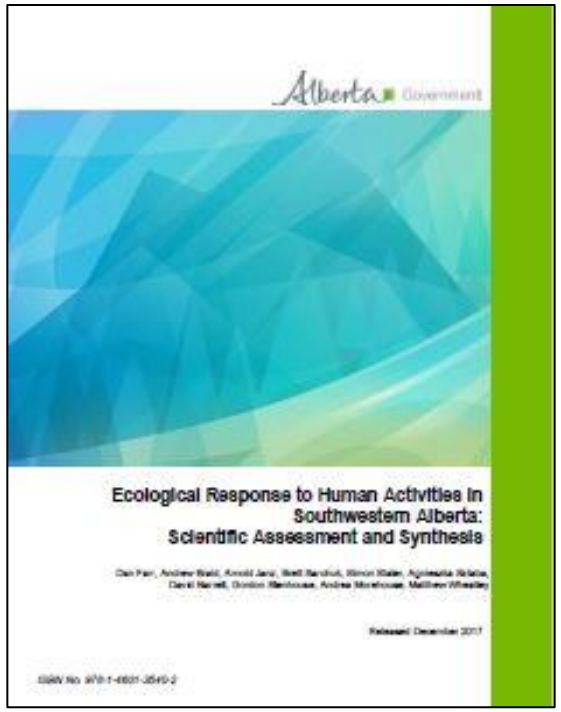




A Tale of Two Metrics

In Canada, provincial and federal governments use a variety of tools to monitor, regulate and maintain our air quality. The Air Quality Health Index (AQHI) and the Canadian Ambient Air Quality Standards (CAAQS) are two of the tools used to assess air quality in Alberta.

Biodiversity



Ecological Response to Human Activities in Southwestern Alberta: Scientific Assessment and Synthesis

D. Farr, A. Braid, A. Janz, B. Sarchuk, S. Slater, A. Sztaba, D. Barrett, G. Stenhouse, A. Morehouse, and M. Wheatley

This report summarizes the scientific evidence for ecological responses of soil, vegetation, hydrology, and wildlife to human activities in the Castle region of southwestern Alberta, based on over 150 peer-reviewed journal articles and technical reports.

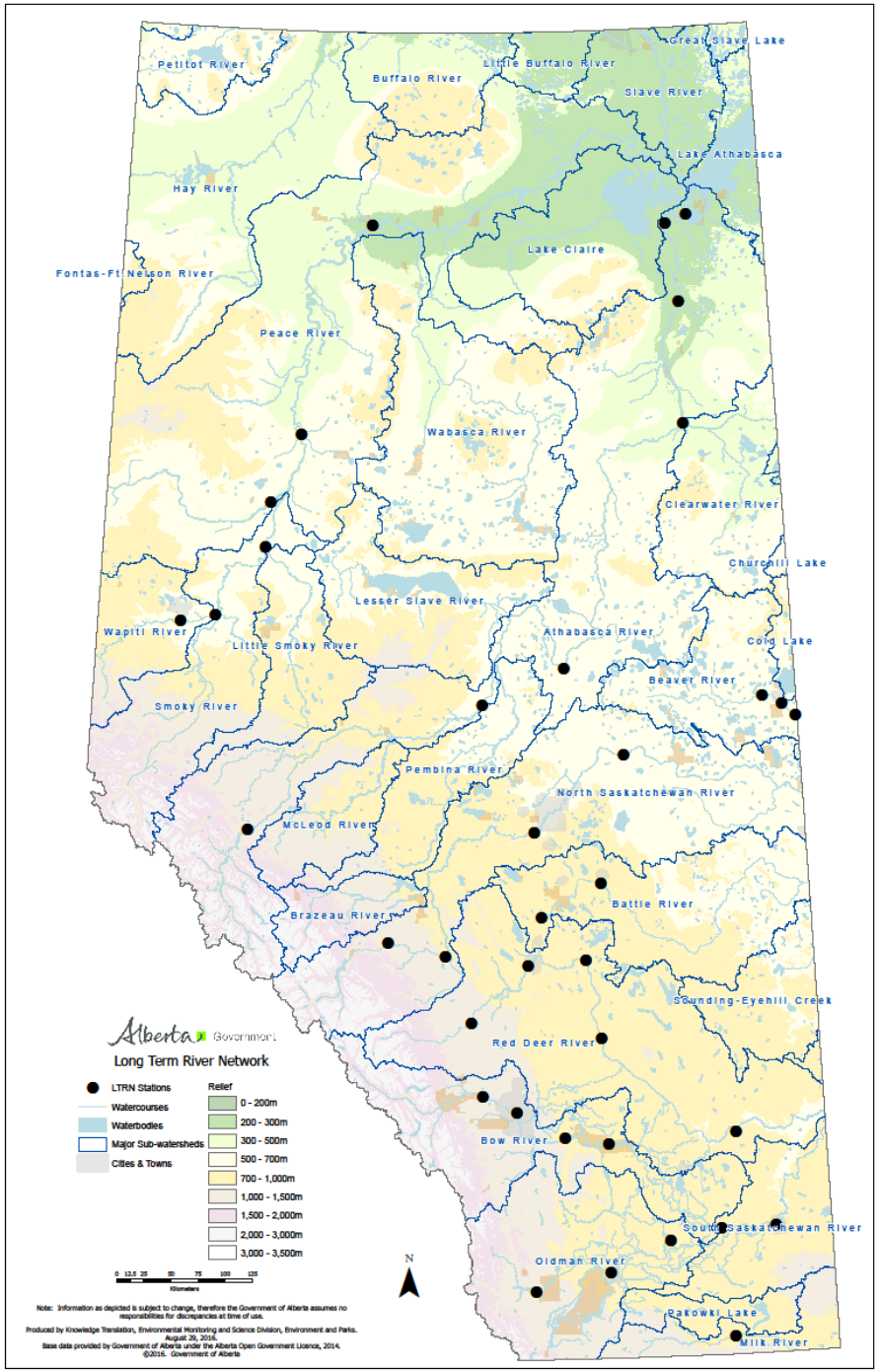
Water

Core Long-term River Network

- **Merged LTRN & MTRN into single LTRN program**
- **Creates efficiencies (e.g., validation, invoicing)**
- **Uniform sampling frequency**
- **Core suite of variables**

Tributary Monitoring Network

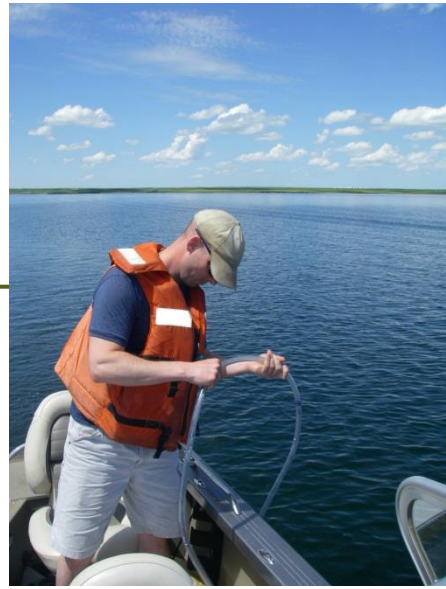
- A new program aimed at augmenting data generated from the LTRN (right)
- In response to the need to better understand the relative contribution of point versus non-point sources of a range of water quality parameters
- Based on comparison of similar landscape units (HRUs)



Long-term lake monitoring network

- Initiated in ≈ 1980, 5 lake basins representing gradient in trophic status: Wabamun, Ethel, Nakamun, Baptise north and south
- Ongoing (repeated) water quality monitoring - 7 sampling events + 1 winter sampling, 2 year rotation
- Most rigorous WQ sampling protocol (incl.: nutrients, ion chemistry, physical parameters, *discrete top and bottom samples for metal chemistry)
- Biological monitoring – chlorophyll; phytoplankton; zooplankton; microcystin
- Expansion of the Long-term Lake Network into Sentinel Lakes Program

Provincial Parks Lake Monitoring



- Established mid-1980's, 20 lakes within or adjacent to Provincial Parks
- Ongoing water quality monitoring - 5 lakes/year, 4 year rotation
- ALMS now contracted to collect samples with Prov Parks Staff

Regional Lake Monitoring Programs

- Document current conditions in lakes & res. of particular interest to communities
- Central Lakes monitor high demand recreational lakes in Alberta's central region
- Collect baseline data in North-Western Lakes (Upper Athabasca/Peace River)
- Sampled by AEP-EMSD Field Staff

ALMS Lakewatch Program

- Initiated - 1996; Volunteer-based lake water quality monitoring across Alberta
- Ongoing water quality monitoring in 20+ lakes/year
- Sampled by ALMS' Seasonal Field Staff; trained by AEP-EMSD Staff

Aquatic Invasives Monitoring

- Veliger sampling for dreissenid mussels incorporated into all lake & reservoir programs

Recreational Beach Monitoring (cyanotoxins)

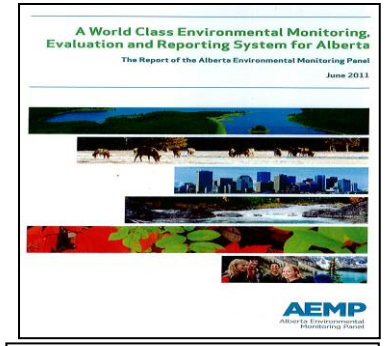
- Partnership with Alberta Health Services to monitor exposure risks at Alberta beaches

Oil Sands Monitoring Program

Origin of the Joint Canada-Alberta Oil Sands Monitoring Program

Oil Sands Advisory Panel Report (2010)

Royal Society of Canada Report (2010)



Alberta Environmental Monitoring Panel Report (2011)

Several expert reviews found <u>no consensus</u> on the degree of environmental impacts from oil sands development, despite extensive efforts. Attributed to:

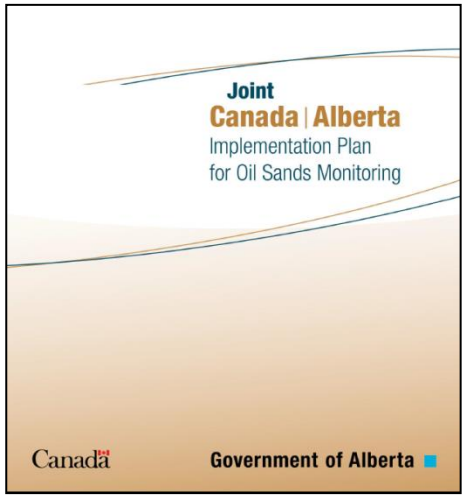
- **Inadequate monitoring design**
- **Uncoordinated monitoring by multiple, independent monitoring organizations**
- **Il-defined or undefined baselines to assess change**
- **Inadequate analytical capabilities**
- **A lack of scientific leadership**

Oil Sands ambient monitoring is conducted under a partnership between the Government of Alberta and the Government of Canada.

Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring (JOSM)

- Initiated in 2012 JOSM recognized and built on good work of others

- The Alberta Oil Sands Environmental Research Program (1975 to 1985)
- Northern River Basins Study (1992 to 1996)
- Northern Rivers Ecosystem Initiative (1998 to 2003)



Legislated Basis for Funding

- Alberta's *Environmental Protection and Enhancement Act* was amended in 2013 to enable collection of a fee from oil sands operators to support long-term ambient monitoring
- The *Oil Sands Environmental Monitoring Program Regulation*
- Current agreement generates $50M /yr
- Up for renewal in Jan 2019
- Funds administered by AEP to deliver annual monitoring programs approved by both federal and provincial government

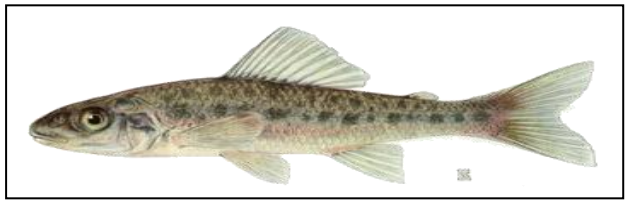
The “OSM Home”

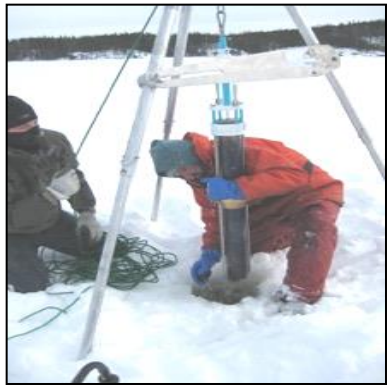
- Began with ECCC. Then became AEP + ECCC = Joint Oil Sands Monitoring Program in February 2012.
- Within Alberta Environment and Parks (AEP) the program was originally implemented on the Alberta side through ESRD = Environment Sustainable Resource Development (now AEP).
- Two years later (April 28, 2014), the OSM Program transitioned out to an “arms-length” agency called AEMERA (Alberta Environmental Monitoring, Evaluation and Reporting Agency)
- Two years later AEMERA was dissolved beginning in April of 2016 and the Alberta side of the OSM Program transitioned back to AEP June 30, 2016

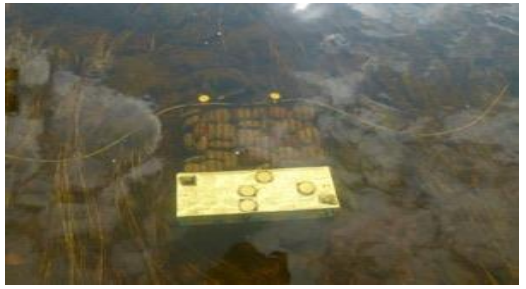
Questions Addressed by OSM Program

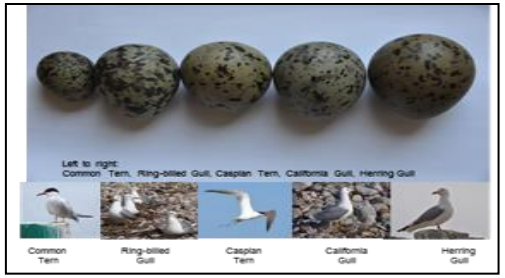
- What are the sources and types of substances being released?
- How are they distributed through air, water, and land?
- What are the spatial and temporal trends in these substances?
- How are these substances being transported and transformed?
- What happens to these substances in the environment?
- To what extent do these substances affect organisms and ecosystems?
- To what extent does habitat disturbance impact regional biodiversity?
- Are effects on biodiversity associated with different types of disturbance / environmental stressors?

Source → Fate → Effects



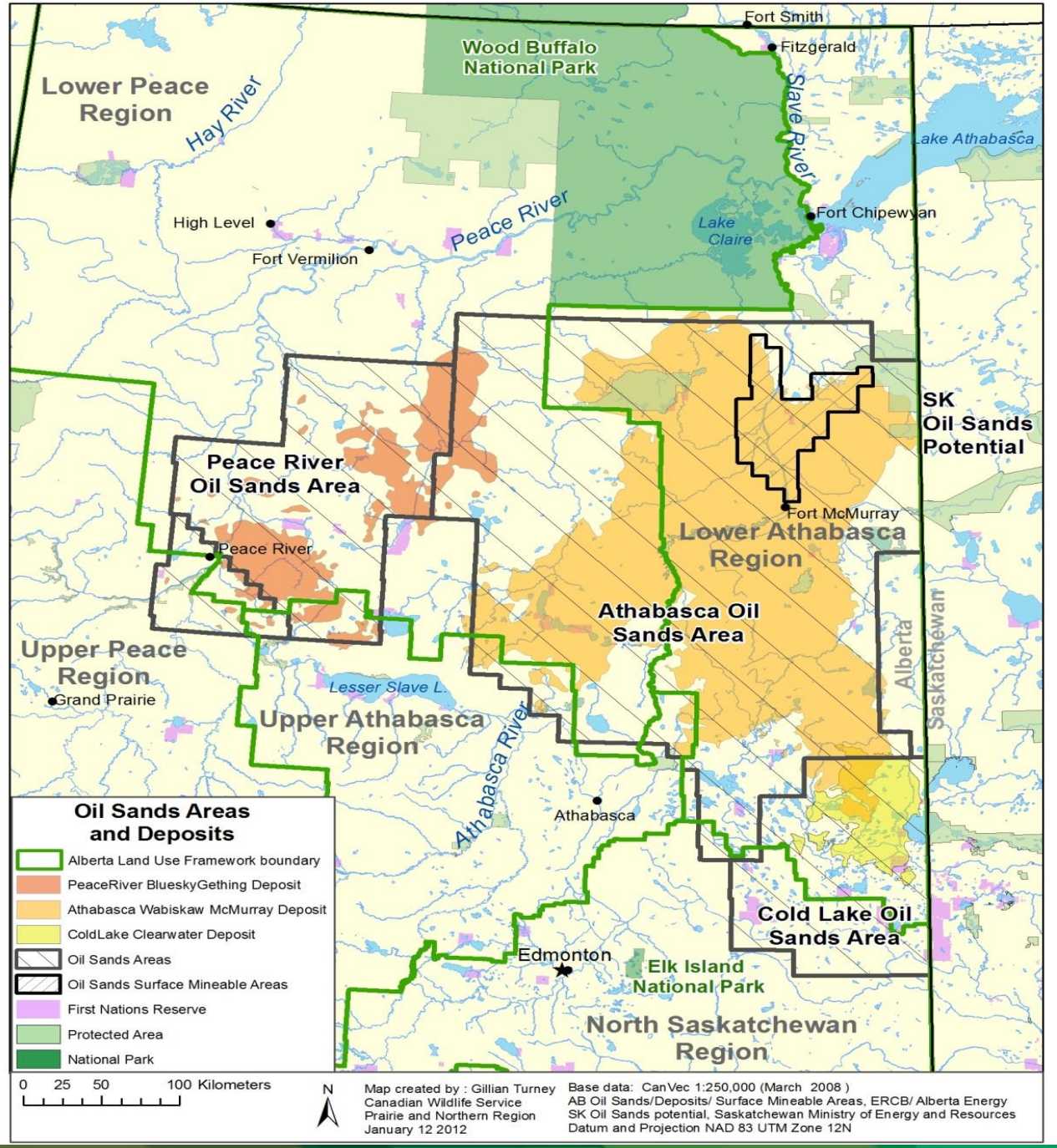


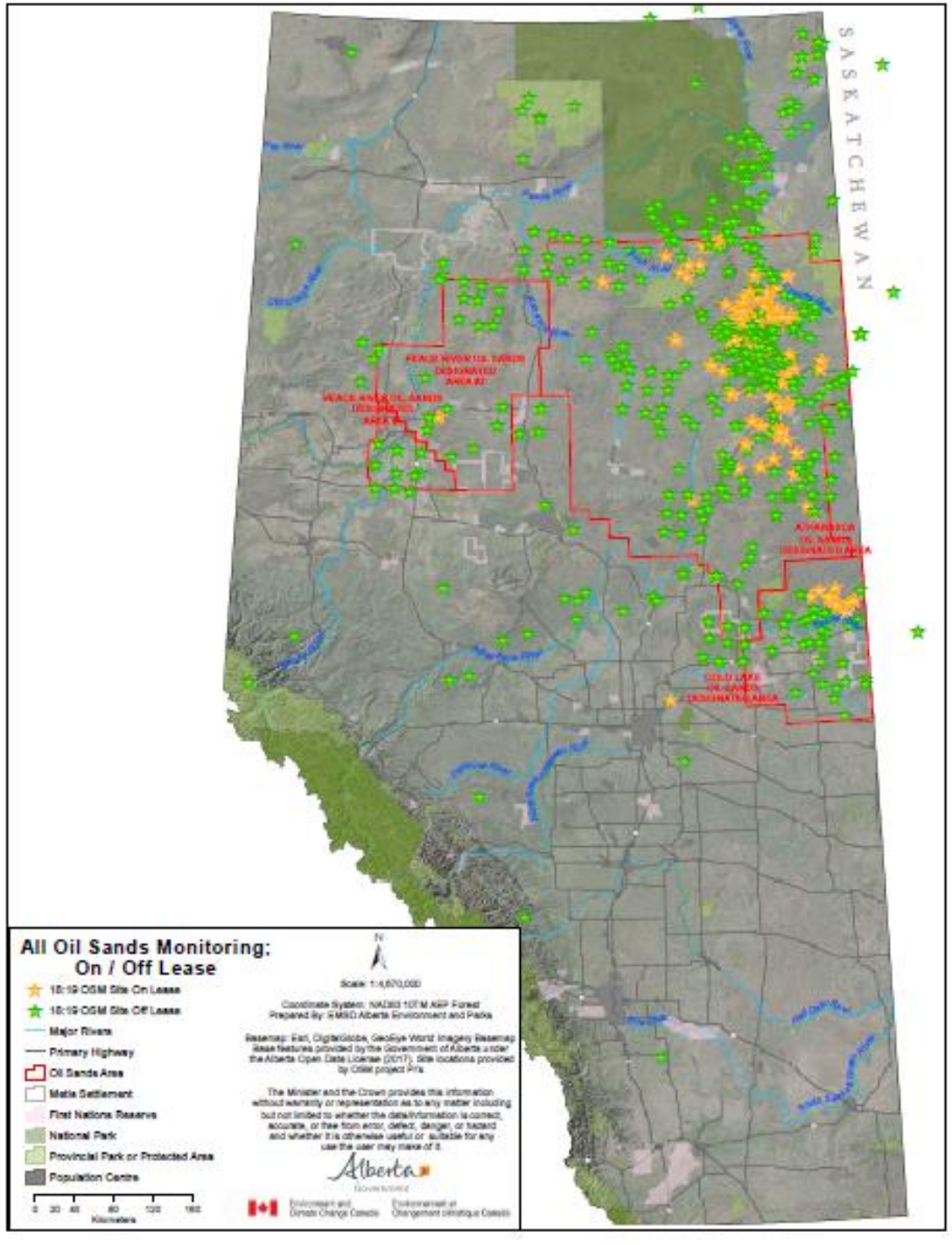


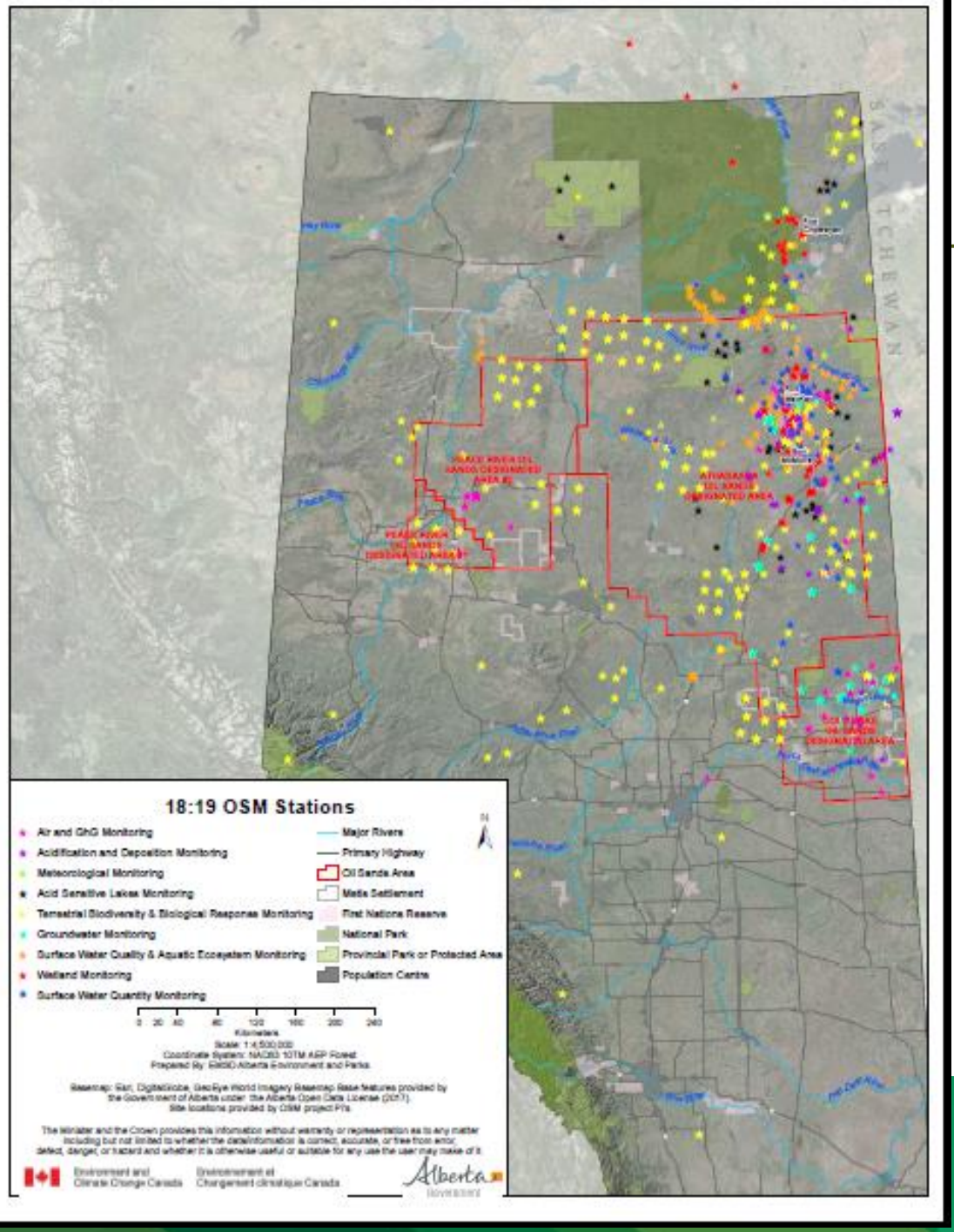


Geographic Scope

- Activities across spatial extent of 3 oil sands areas and Lower Athabasca Planning Region
- Stressors: individual effects of *in situ* and conventional oil sands activity and cumulative effects of multiple sectors




SASKATCHEWAN
All Oil Sands Monitoring:
On / Off Lease
18:19 OSM Site On Lease
18:19 OSM Site Off Lease
Major Rivers
Primary Highway
Oil Sands Area
Metis Settlement
First Nations Reserve
National Park
Provincial Park or Protected Area
Population Centre
Kilometers
Alberta


SASKATCHEWAN
18:19 OSM Stations
Air and GhG Monitoring
Acidification and Deposition Monitoring
Meteorological Monitoring
Acid Sensitive Lakes Monitoring
Terrestrial Biodiversity & Biological Response Monitoring
Groundwater Monitoring
Surface Water Quality & Aquatic Ecosystem Monitoring
Wetland Monitoring
Surface Water Quantity Monitoring
Major Rivers
Primary Highway
Oil Sands Area
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First Nations Reserve
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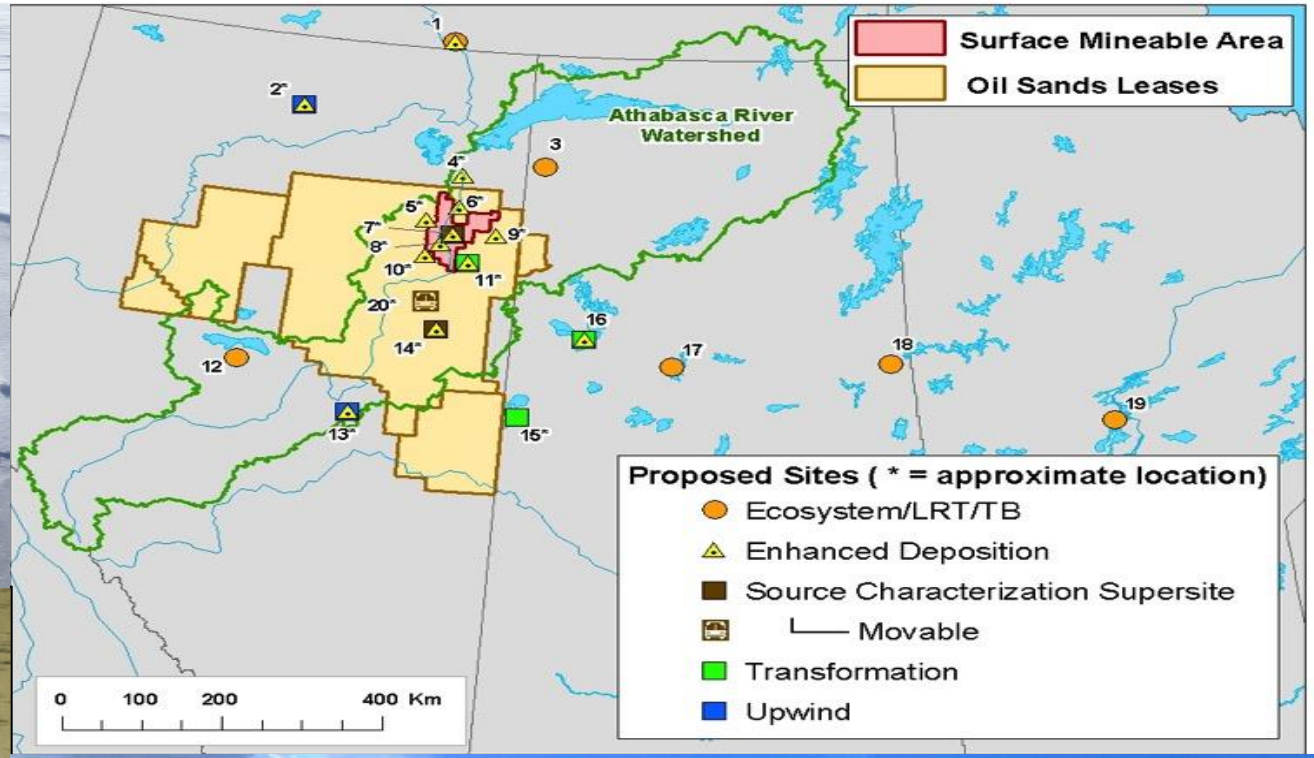
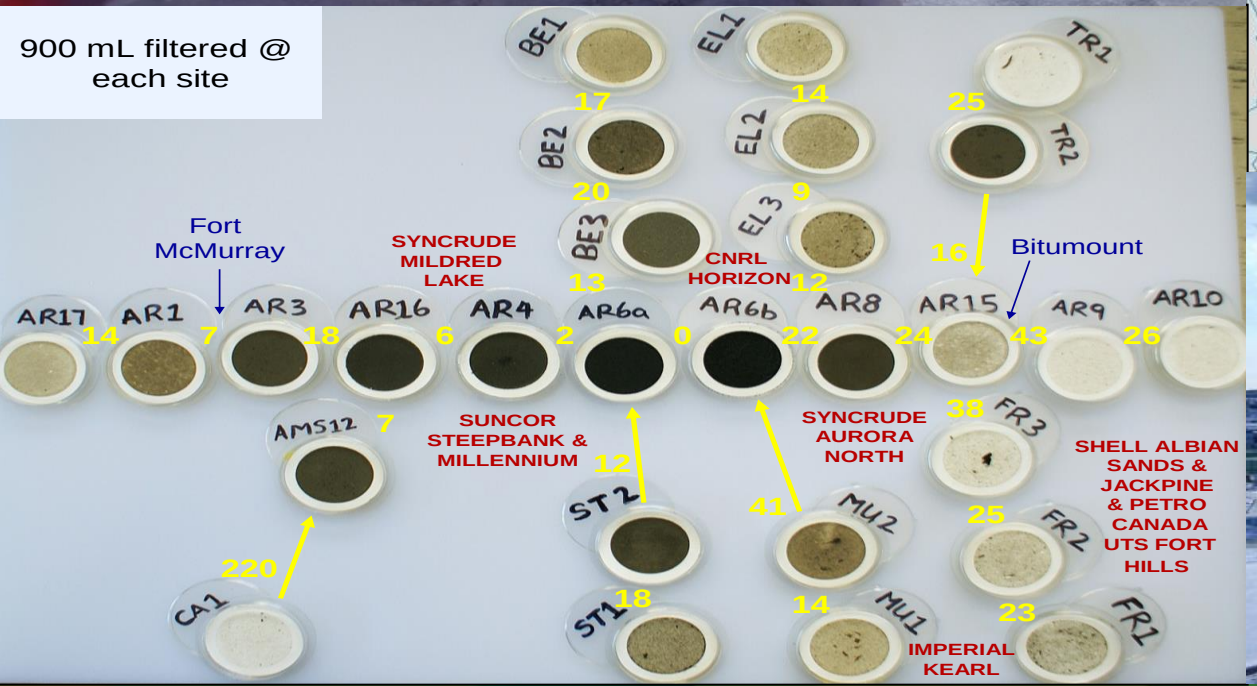
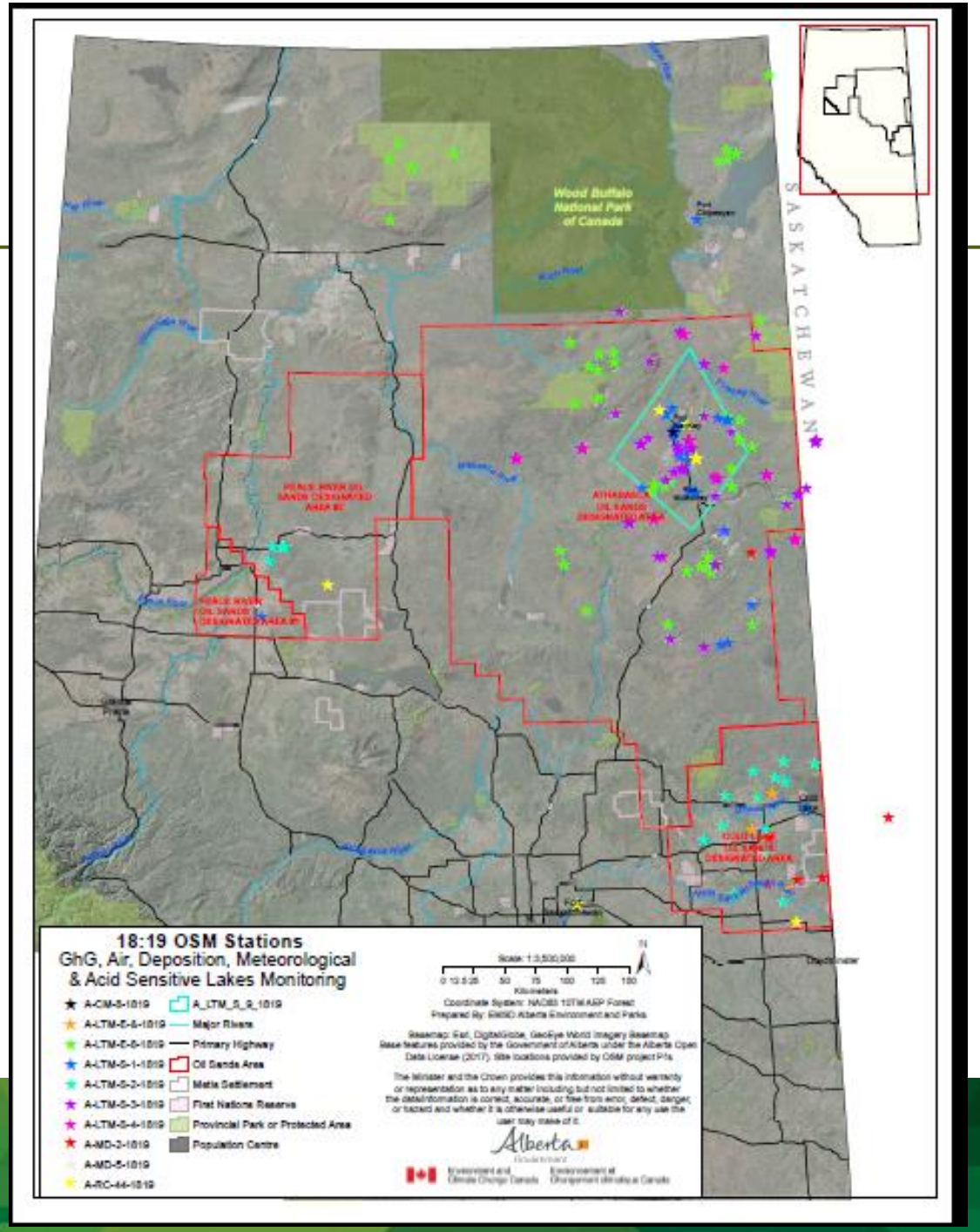
Air Quality



900 mL filtered @ each site




Wood Buffalo National Park of Canada
SASKATCHEWAN
18:19 OSM Stations
GhG, Air, Deposition, Meteorological & Acid Sensitive Lakes Monitoring
A-CM-5-1019
A-LTM-5-5-1019
A-LTM-5-6-1019
A-LTM-5-1-1019
A-LTM-5-2-1019
A-LTM-5-3-1019
A-LTM-5-4-1019
A-MD-2-1019
A-MD-5-1019
A-RC-44-1019
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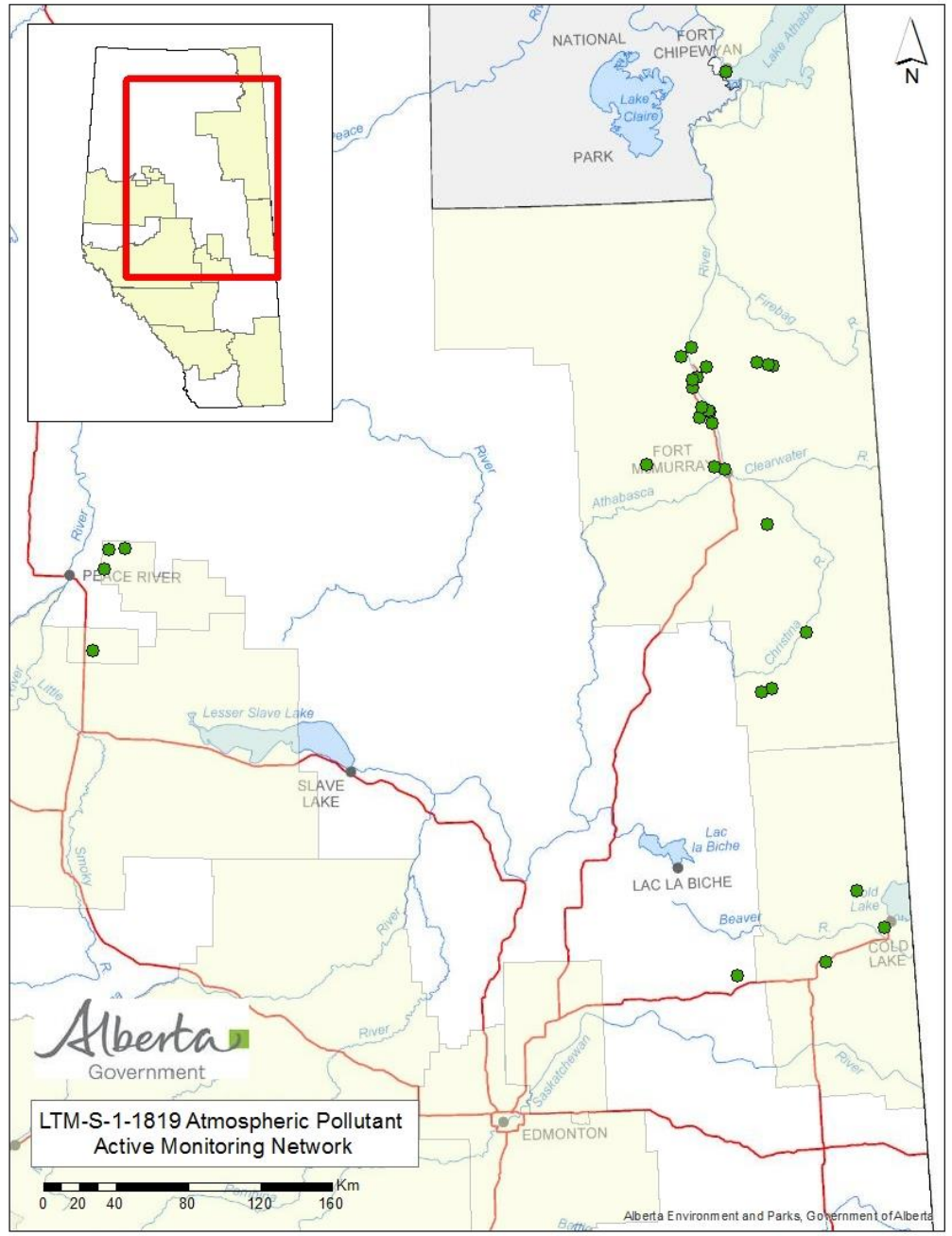
Major Rivers
Primary Highway
Oil Sands Area
Metis Settlement
First Nations Reserve
Provincial Park or Protected Area
Population Centre
Scale: 1:3,500,000
Kilometers
Coordinate System: NAD83 10TM AEP Forest
Prepared By: EMSD Alberta Environment and Parks
Alberta

Air Quality – What are we doing?

- **Monitoring air quality**
  - Measuring standard air quality health indicators (e.g., PM, O_3, NO_x, SO_x)
- **Evaluating sources of emissions**
  - Assessing and rationalizing various existing inventories of emissions
  - Characterizing sources of emissions which were previously unknown
- **Measuring deposition of substances to the landscape**
  - Measuring deposition of VOCs, PAHs, metals
  - Evaluating the chemical reactions that are transforming emitted material
  - Evaluating acidification of forests and lakes
- **Integrating results**
  - Constraining satellite measurements with ground-based measurements
  - Combing atmospheric models with meteorological models for prediction

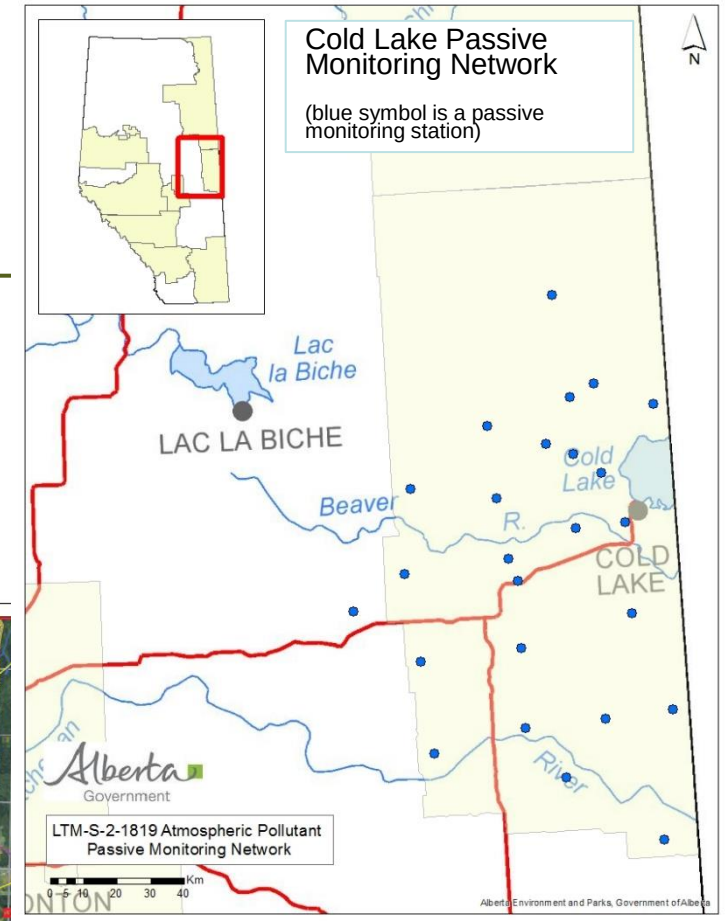
Continuous and Integrated Monitoring Stations

- The network includes:
  - 23 permanent and 5 portable monitoring stations in the **Athabasca oil sands** operated by WBEA since 1998
  - 3 permanent and 1 portable monitoring station in the **Cold Lake oil sands** operated by LICA since 2003
  - 4 permanent stations in the **Peace River oil sands** operated by PRAMP since 2016

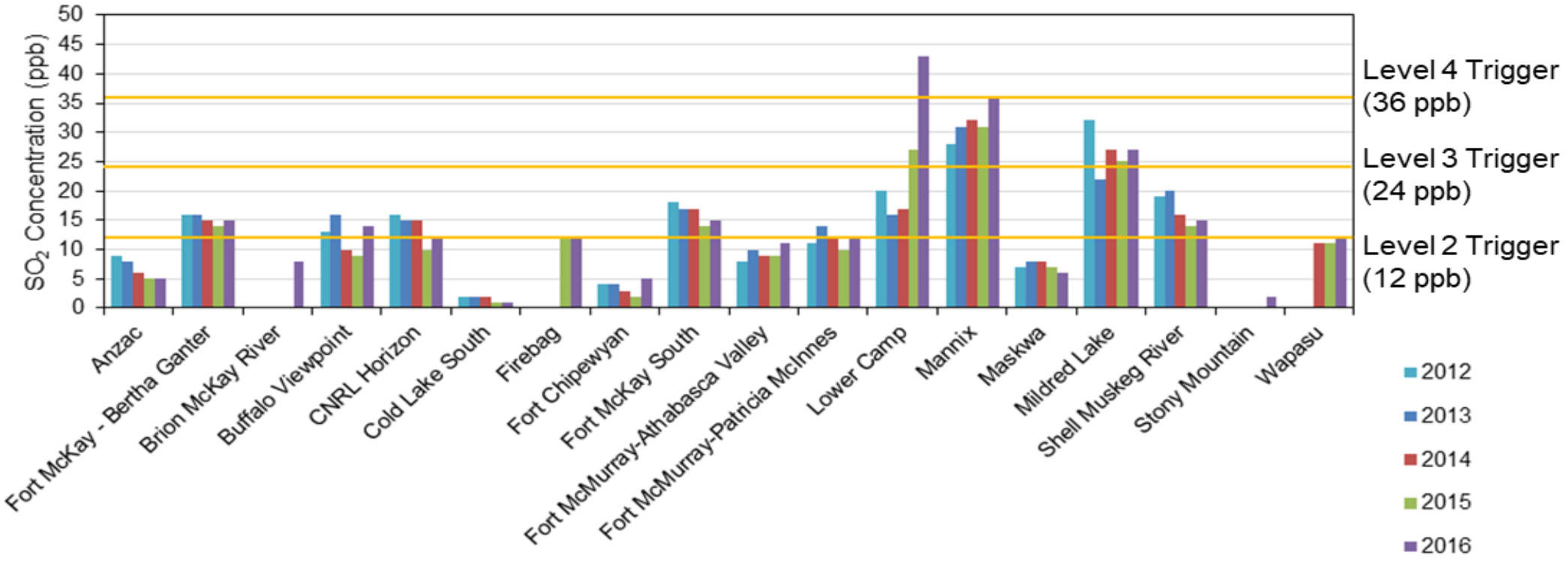


Passive Monitoring Stations

- The networks includes:
  - 27 monitoring stations in the Cold Lake oil sands operated by LICA
  - 13 monitoring stations in the Peace River oil sands currently operated by industry



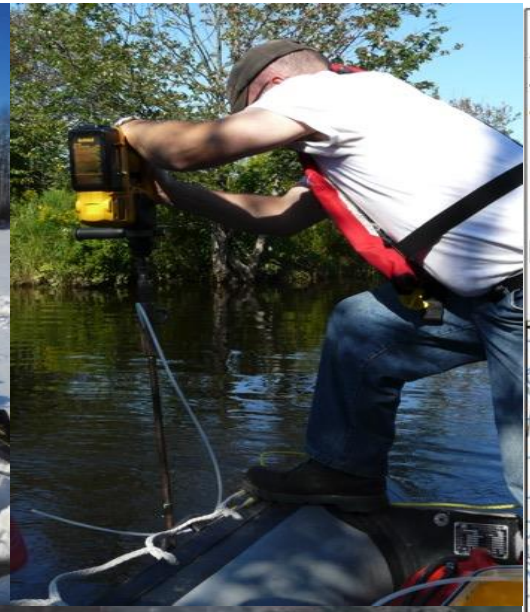
Results of Long-term Active Monitoring – Comparison with LARP Triggers

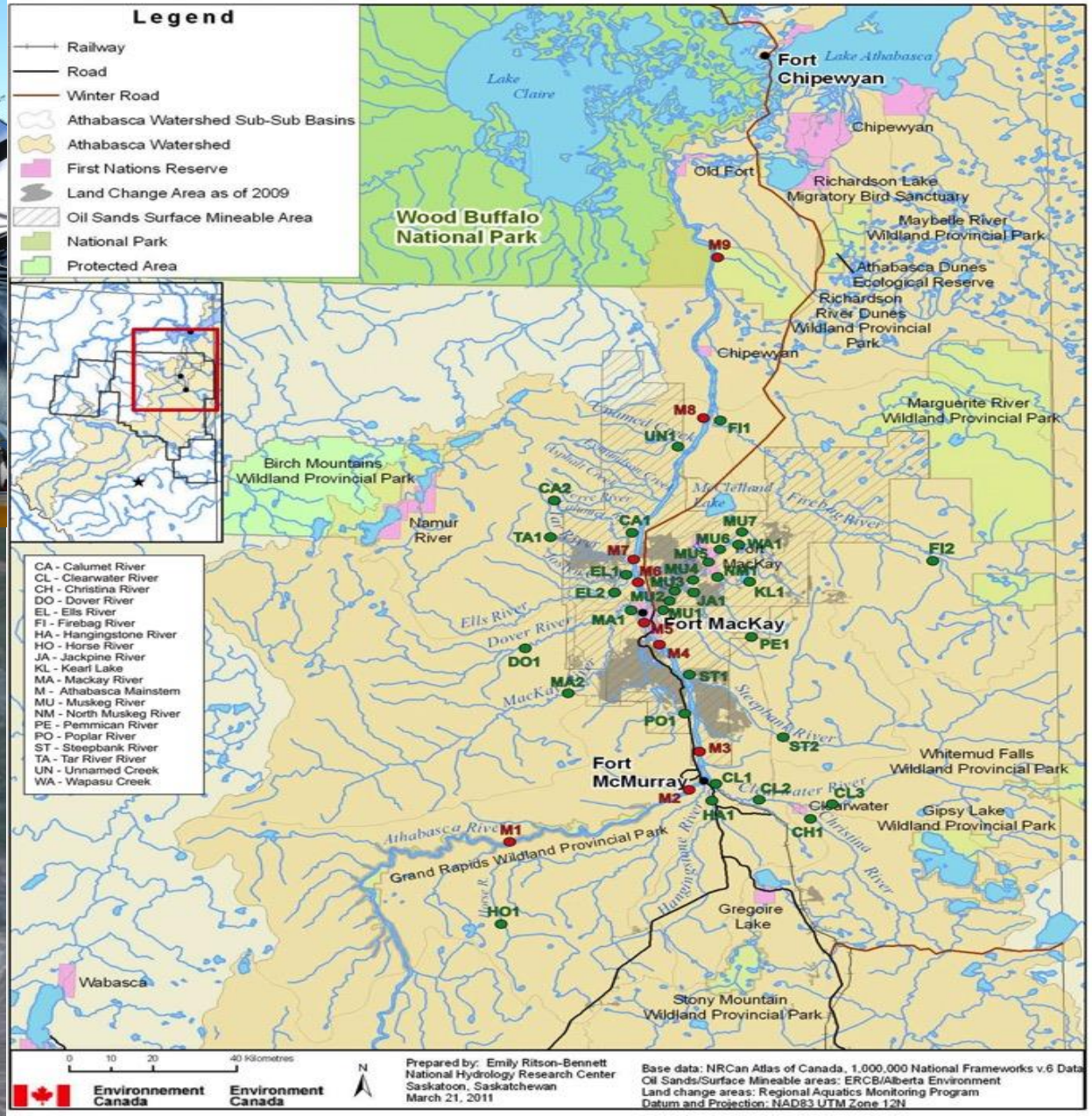


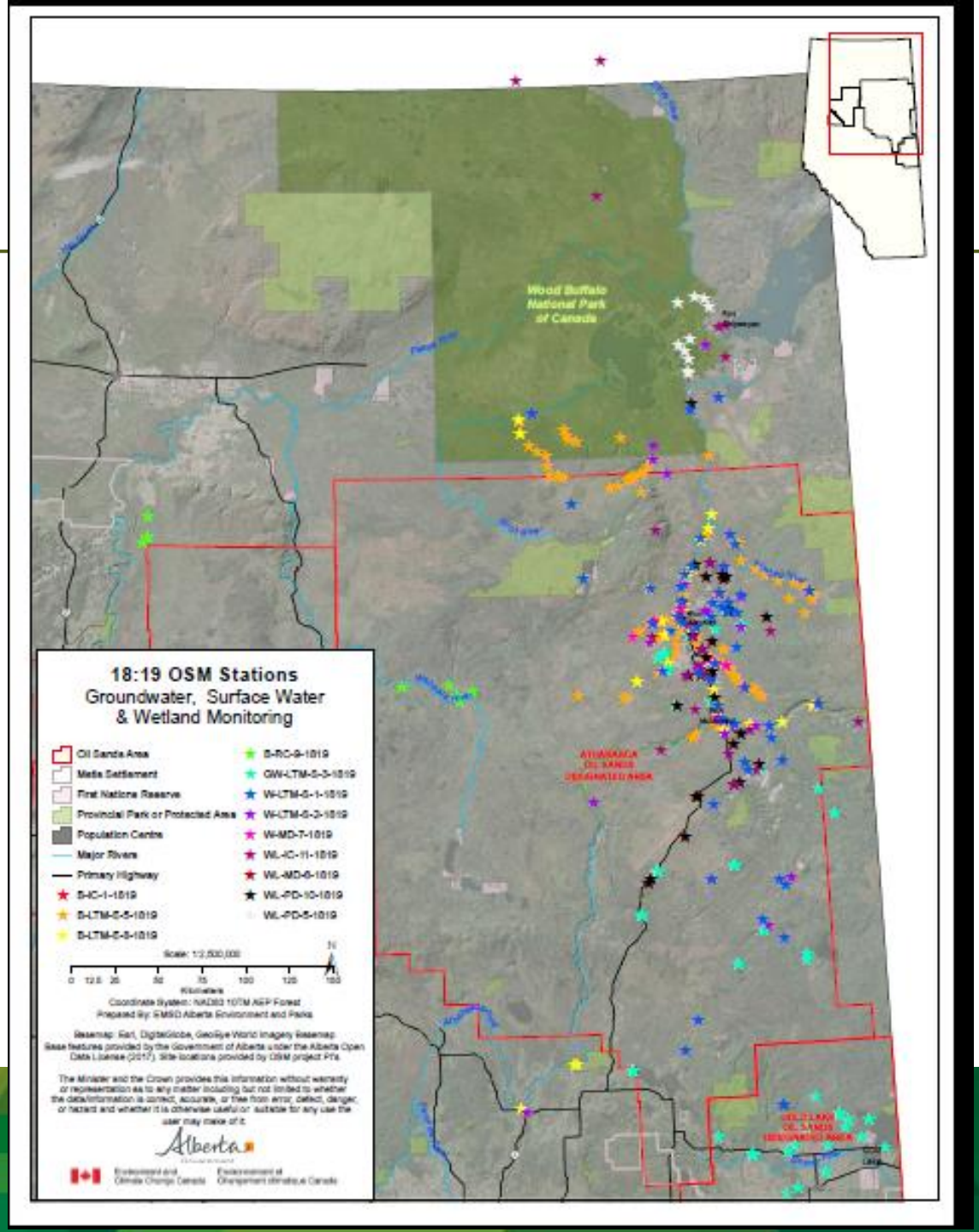
Air Quality - Findings

- A significant fraction of particulate matter can be generated post-emission.
- Measurements from aircraft show VOC and secondary organic aerosol formation is important. Ground-based measurements are monitoring for these and related pollutants – data are similar to other measurements throughout Alberta.
- Trends in NO_2 over 2005-2014 show an increase of 0–10% per decade,
- SO_2 trends over 2005-2014 are flat or declining over the surface mining area
- From 2010 to 2013, total gaseous mercury concentrations at sites near Fort McKay and Fort McMurray comparable to other Alberta locations

Water Quality/Quantity, Sediment Sampling



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S-HC-1-1819
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S-RC-9-1819
GW-LTM-S-3-1819
W-LTM-S-1-1819
W-LTM-S-2-1819
W-MD-7-1819
WL-IC-11-1819
WL-MD-6-1819
WL-PD-10-1819
WL-PD-5-1819
Scale: 1:3,500,000
Kilometers
Coordinate System: NAD83 10TM AEP Forest
Prepared By: EMSD Alberta Environment and Parks
Basemap: Esri, DigitalGlobe, GeoEye World Imagery Basemap
Base features provided by the Government of Alberta under the Alberta Open Data License (2017). Site locations provided by OSM project PIs.
The Minister and the Crown provides this information without warranty or representation as to any matter including but not limited to whether the data/information is correct, accurate, or free from error, defect, danger, or hazard and whether it is otherwise useful or suitable for any use the user may make of it.
Alberta
Environment and Climate Change Canada
Environnement et Changement climatique Canada

Alberta

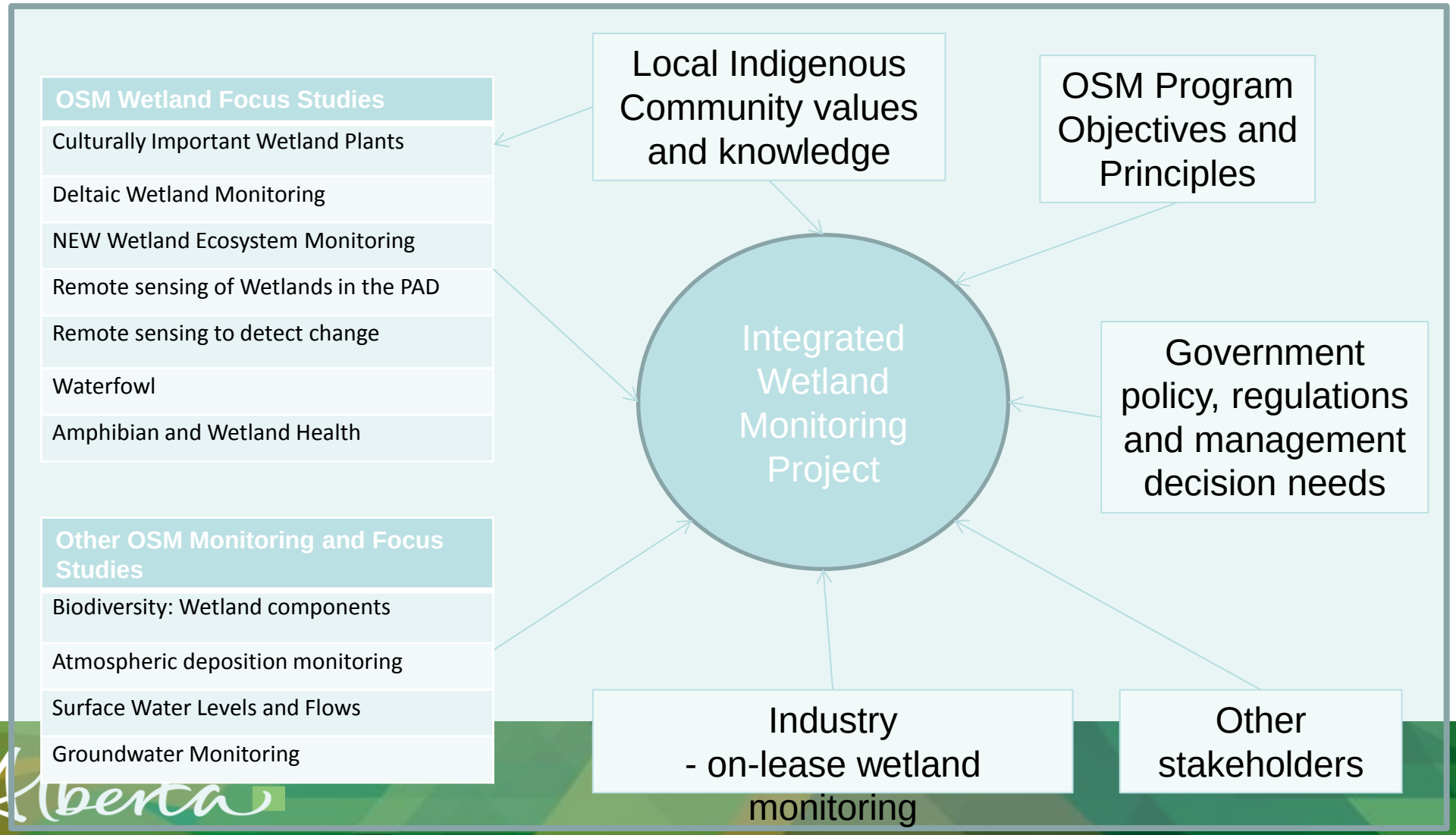
Water Quality – What are we doing?

- Measuring chemical substance concentrations in
  - Rivers, tributaries and lakes
  - River sediments
  - Shallow groundwater
- Measuring water flow and levels
  - In rivers and tributaries
- Measuring aquatic biological health
  - Benthic invertebrate diversity and community structure
  - Fish health indicators
  - Toxicology studies
- Integrating results
  - Modeling for sediment transport
  - Synthesis of existing water information

Water and Sediment Quality - Findings

- **Water quality in the lower Athabasca River, the Peace-Athabasca Delta, and tributaries is generally good with concentrations that are below applicable guidelines.**
  - **Annual spring run-off caused most of the guideline exceedances. These results are within the expected historical range.**
- **Sediment quality at all sites sampled is consistent with historical observations, with little difference compared to remote locations**
- **The shallow groundwater quality near to, or remote from, tailings ponds was not generally statistically different**
- **Evidence for 45 lakes/wetlands shows they are not currently acidifying**

OSM Wetland Monitoring Program Development



Develop Conceptual Framework to guide the development of Wetland LTM Program & Focus Studies

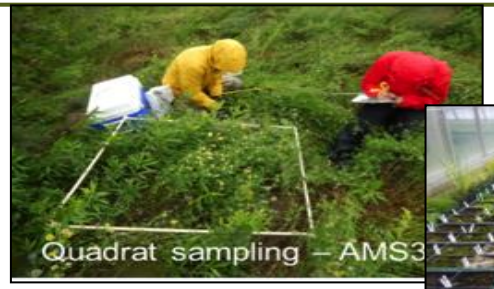
What to monitor?

- 3 Key Stressors
  - Atmospheric deposition (and sediments to downstream wetlands)
  - Land disturbance
  - Hydrologic alteration

- Key wetland responses
  - To assess wetland ecosystem condition and health and valued ecosystem components
  - *under development* - core variables, standardized methods

Wildlife Health Monitoring Context

Using a sentinel species approach with established study protocols



Data on Wildlife Contaminants and Toxicology

Terrestrial Biodiversity and Wildlife Health - What are we doing?

- Monitoring human footprint
  - Linear disturbances, clear cutting, mining, etc.
- Monitoring biodiversity
  - Core monitoring of insects, plants, animals birds
  - Ungulate monitoring
- Measuring substances in animal, bird and plant tissue
  - Nesting boxes near development, bird eggs
  - Hunter and trapper gathered carcasses
- Integrating results
  - Co-locating wildlife health sampling with air and water quality monitoring sites

Terrestrial Biodiversity and Wildlife Health - Findings

- Overall human footprint of energy development in the oil sands region (including Peace, Athabasca and Cold Lake deposit areas) averages approximately 2.2%. The human footprint for agriculture is approximately 8.5%.
- The biodiversity changes in the surface mineable area include:
  - Increased abundance in coyote, white-tailed deer, black-billed magpie and vesper sparrow
  - Decreased abundance in marten, fisher, black-throated green warbler and brown creeper.
- No differences in adult tree swallow health & reproductive performance in nests near and far from development sites
- Chemical substances are found in wildlife tissues, yet the concentrations are not likely posing a significant ecological risk

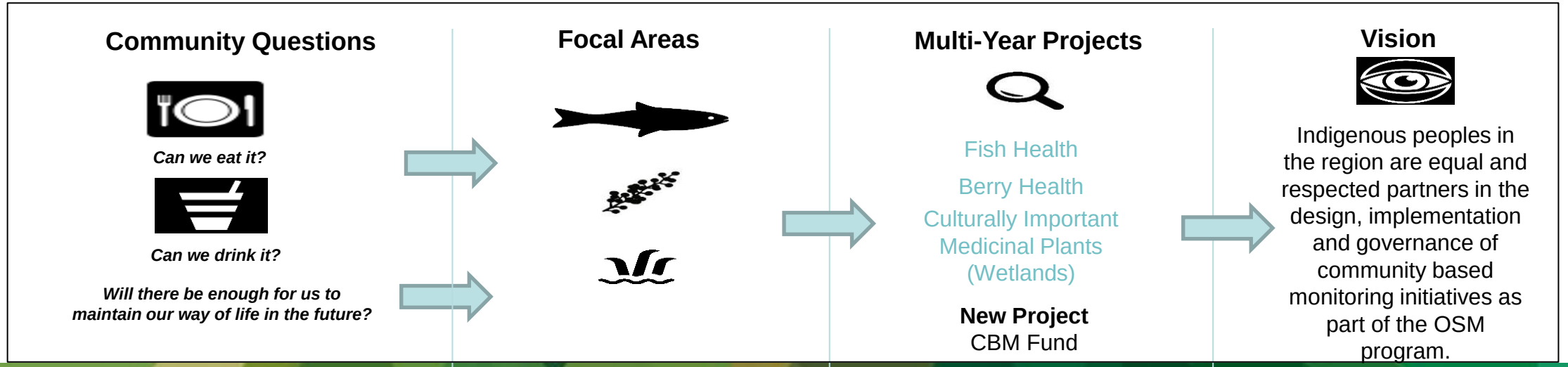
Aquatic Biodiversity/Health

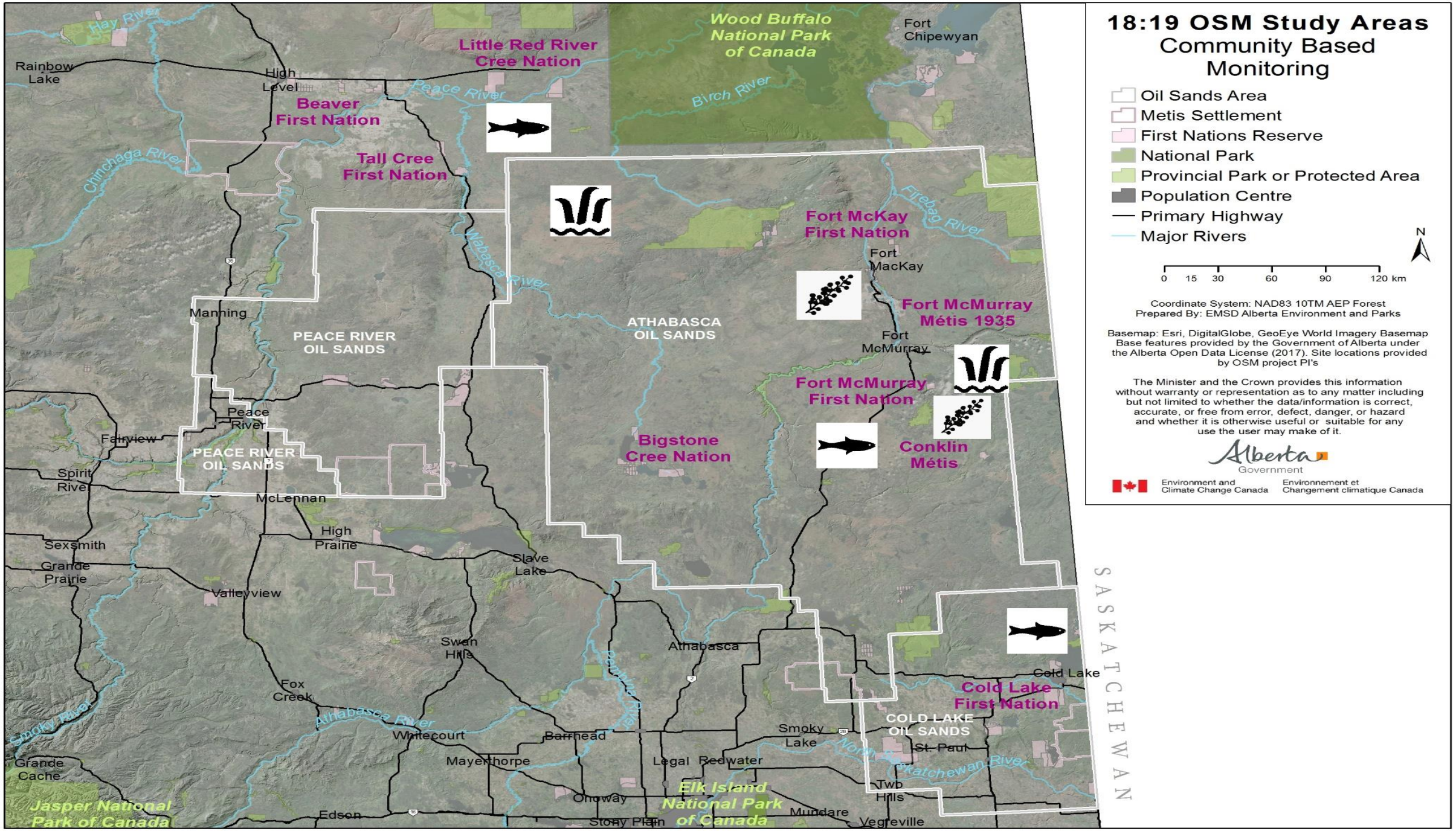
Aquatic Biodiversity

- **Benthic macroinvertebrates (insects, crusteaceans, molluscs and worms) were diverse and reflected the complex and diverse habitats in the area.**
  - **Increases in pollution-tolerant species may be an early warning of environmental stress (e.g. nutrient enrichment)**
- **Caged mussels and freshwater shrimp placed in tributary rivers showed no changes in growth or survival**
- **Fish health was comparable to historical**
  - **Chemical substance levels & physical abnormalities are similar to historic levels.**
  - **Mercury levels in Lake Whitefish was higher compared with 2011 and below the Health Canada guideline for subsistence fishers; levels in Walleye were higher in 2014 compared with previous years and consumption advice is in place for fish larger than 300 mm.**

Indigenous Peoples' Engagement in OSM

- **Increasing as OSM evolves … key projects include:**
  - **Contaminant monitoring of aquatic species (fish, muskrat)**
  - **Real-time Water Quality Monitoring in Lake Athabasca**
  - **Atmospheric monitoring at Oski-Otin site**
  - **TEK Berry Health study**
  - **Environmental Monitoring Technician training program**



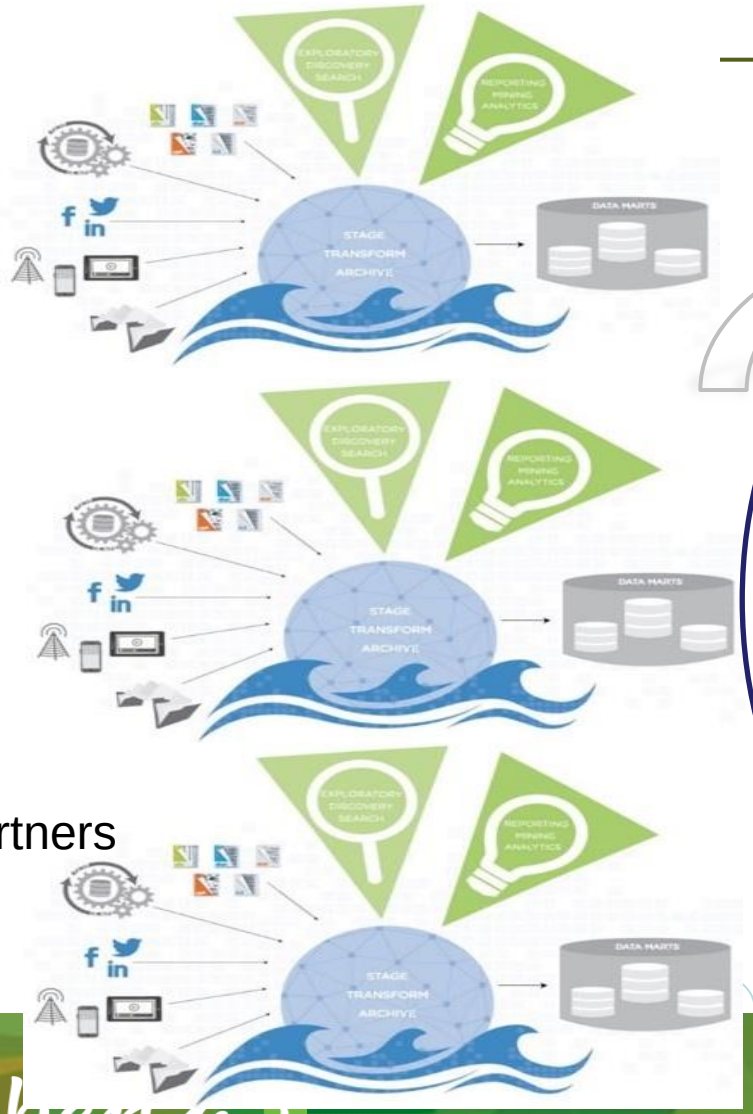

18:19 OSM Study Areas
Community Based Monitoring
Oil Sands Area
Metis Settlement
First Nations Reserve
National Park
Provincial Park or Protected Area
Population Centre
Primary Highway
Major Rivers
N
0 15 30 60 90 120 km
Coordinate System: NAD83 10TM AEP Forest
Prepared By: EMSD Alberta Environment and Parks
Basemap: Esri, DigitalGlobe, GeoEye World Imagery Basemap
Base features provided by the Government of Alberta under the Alberta Open Data License (2017). Site locations provided by OSM project PI's
The Minister and the Crown provides this information without warranty or representation as to any matter including but not limited to whether the data/information is correct, accurate, or free from error, defect, danger, or hazard and whether it is otherwise useful or suitable for any use the user may make of it.
Alberta Government
Environment and Climate Change Canada
Environnement et Changement climatique Canada
Little Red River Cree Nation
Beaver First Nation
Tall Cree First Nation
Fort McKay First Nation
Fort McMurray Métis 1935
Fort McMurray First Nation
Bigstone Cree Nation
Conklin Métis
Cold Lake First Nation
Wood Buffalo National Park of Canada
Elk Island National Park of Canada
Jasper National Park of Canada
PEACE RIVER OIL SANDS
ATHABASCA OIL SANDS
COLD LAKE OIL SANDS
Hay River
Rainbow Lake
High Level
Peace River
Chinchaga River
Birch River
Fort Chipewyan
Firebag River
Nabasca River
Manning
Fort MacKay
Fort McMurray
Peace River
Fairview
Spirit River
McLennan
High Prairie
Sexsmith
Grande Prairie
Valleyview
Slave Lake
Swan Hills
Athabasca
Cold Lake
Fox Creek
Athabasca River
Whitecourt
Barrhead
Smoky River
Smoky Lake
St. Paul
North Saskatchewan River
Mayerthorpe
Legal
Redwater
Grande Cache
Onoway
Twb Hills
Edson
Stony Plain
Mundare
Vegreville
SASKATCHEWAN

Data Management, Accessibility and Decision Support

EMSD

ECCC

Other Partners (ABMI, WBEA etc.)



Data needs to be harmonized in order to provide a consolidated data view.

Data and Information - Single point of <u>Access</u>

Data and Information <u>Consumers</u>

OSM Looking Forward (2017-18 and Beyond)

Oil Sands Monitoring MOU

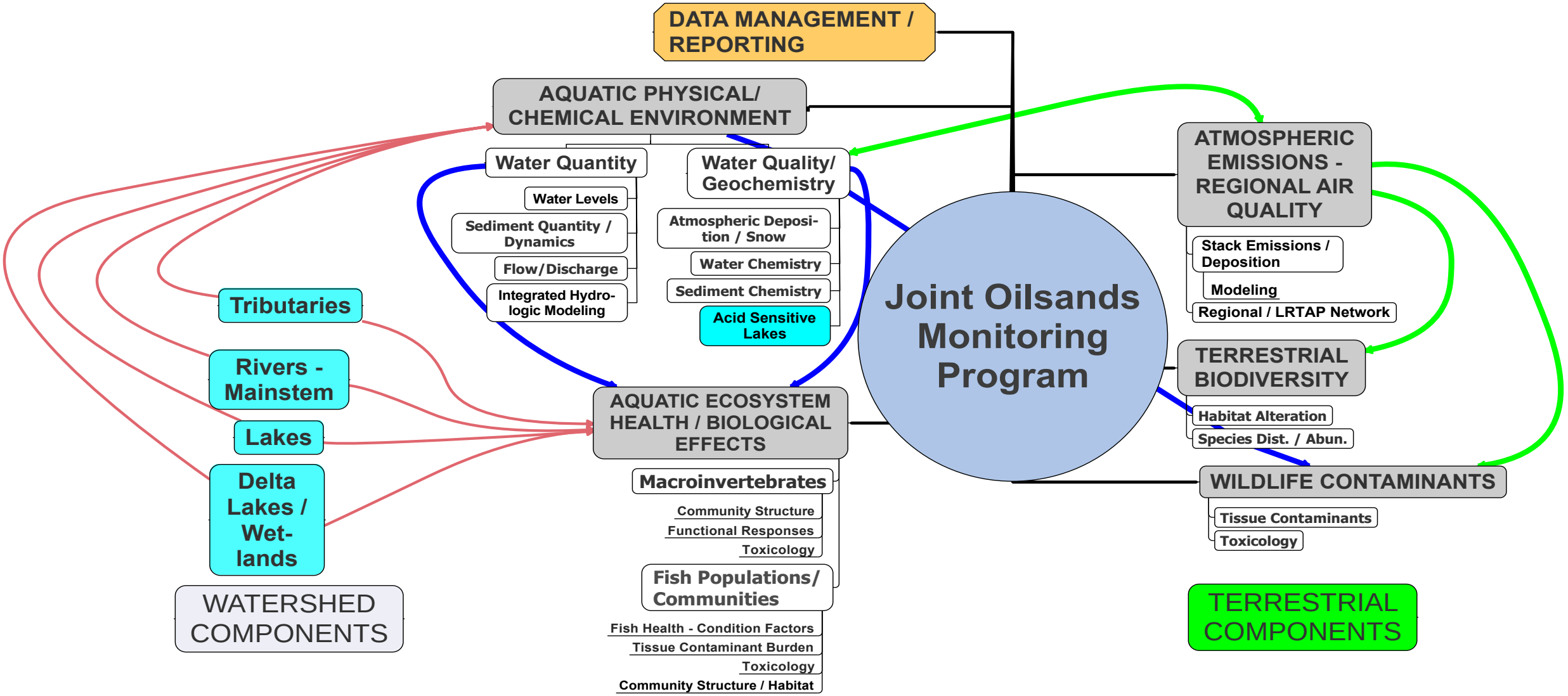
- **MOU between the Governments of Alberta & Canada signed Dec. 21, 2017**
- **Renews joint commitment to monitor environment in the oil sands region**

  - Whereas the treaty and aboriginal rights of Indigenous people are recognized and affirmed in section 35 of the *Constitution Act*, 1982.

  - Whereas the Parties are committed to the engagement of relevant Indigenous Communities in the oil sands region in the integrated monitoring, evaluation and reporting system for the environmental impacts of oil sands development including the appropriate use of the best available Indigenous knowledge.

  - “The Parties, in cooperation with Indigenous communities, will develop a comprehensive ongoing agreement (the “Operational Framework Agreement”) that articulates the respective roles and responsibilities for the System of the Parties, relevant Indigenous Communities and various stakeholders.”

Integration and Integrated Reporting



Synthesis Report for the Water Component, Canada-Alberta Joint Oil Sands Monitorina: Key F Recor

1.1 Report Series

Cana

Atmospheric Deposition to the Athabasca Oil Sands Region Using Snowpack Measu Dated

1.2 Report Series

Canad

Surface Water Quality of Lower Athabasca River Tributaries

1.3 Report Series

Canada Alberta

Assessments of Groundwater Influence on Selected River Systems in the Oil Sands Region of Alberta

1.5 Report Series

Canada

Regional Hydro-Climatic and Sediment Modelling

1.6 Report Series

Ca

Assessing Ecosystem Health in Benthic Macroinvertebrate Assemblages of the Athabasca River Main Stem, Tributaries and Peace-Athabasca Delta

1.7 Report Series

Canada Alberta

Aquatic Ecosystem Health Assessment of the Athabasca River Mainstem and Tributaries Using Fish Health and Fish and Invertebrate Toxicological Testing

1.8 Report Series

Canada Alberta

Alberta

DRAFT – 5 June 2018

Fact Sheet - OSM peer-reviewed publications 2012-2017

Summary (Air, Biodiversity and Water)

Purpose	To compile and summarize a comprehensive list of peer-reviewd research completed under the Alberta-Canada Oil Sands Monitoring Program during the 2013-2018 period						
	Air	*Water*	*Bio*	*Total*			
Total papers referenced	75	46	50	171			

PAC deposition and monitoring		Environmental Change		
Yassine et al. 2017	Method: NAs		No	
Galarneau et al. 2014	Tailing Pond Emissions: Early estimate		No	
Small et al. 2015	Tailing Pond Emissions: Review		No	
Harner et al. 2013	Passive: Method development			Base
Schuster et al. 2015	Passive: Spatial trends	Yes		
Jariyasopit et al. 2016	Passive: Spatial & in vitro assays	Yes		
Zhang et al. 2015a	Continuous: Wet deposition industry		No	
Zhang et al. 2015b	Continuous: Dry deposition estimates			Base
Hsu et al. 2015	Continuous: Ambient community		No	
Studabaker et al. 2012	Lichens: Spatial trends	Yes		
Studabaker et al. 2017	Lichens: Method development			Base
Graney et al. 2017	Lichens: Spp-specific relationships	Yes*		
Wnorowski, 2017	Oxidized PAC transformation (2)			Base
Wnorowski & Charland, 2017				Base
Manzano et al. 2016a	Method: heterocyclics (N- & S-PAHs)			Base
Cho et al. 2014	Snowpack (2)	Yes		
Manzano et al. 2016b		Yes		
Manzano et al. 2017	Heterocyclics: snow, cores & passive	Yes		
	Total papers: 18	7	5	6

**Also reported trace elements, Pb ratios & incorporated Landis et al. (2017) PM dataset*

Table 2. Number of studies that reported an environmental change for each of the monitoring or research themes identified in the air component review.

Monitoring / Research Theme	Study count	Environmental Change		
		Yes	No	Baseline
PAC deposition & monitoring	18	7	5	6
Nitrogen & sulfur deposition & modelling	12	9	2	1
Trace element deposition & source attribution	10	4	4	2
Emissions monitoring	10		3	7
WBEA monitoring reviews	10	2	8	
Satellite monitoring	7	3	1	3
Mercury deposition & monitoring	5	2	2	1
Forest fires	2	2*		
Reclamation	1		1	
Total	*75*	*29*	*26*	*20*

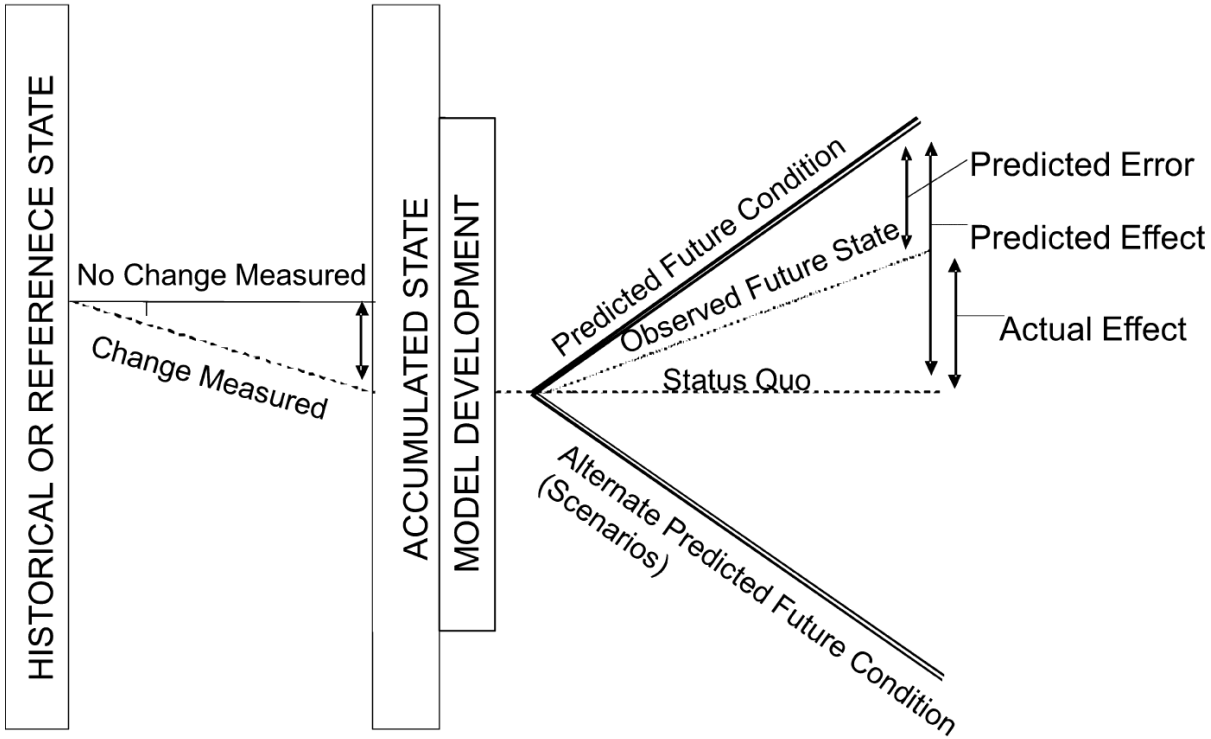
** Environmental change related to fire not OS activities*

Table 3 Number of studies reviewed broken down by organisms and whether environmental change, attributable to industrial activity, was measured

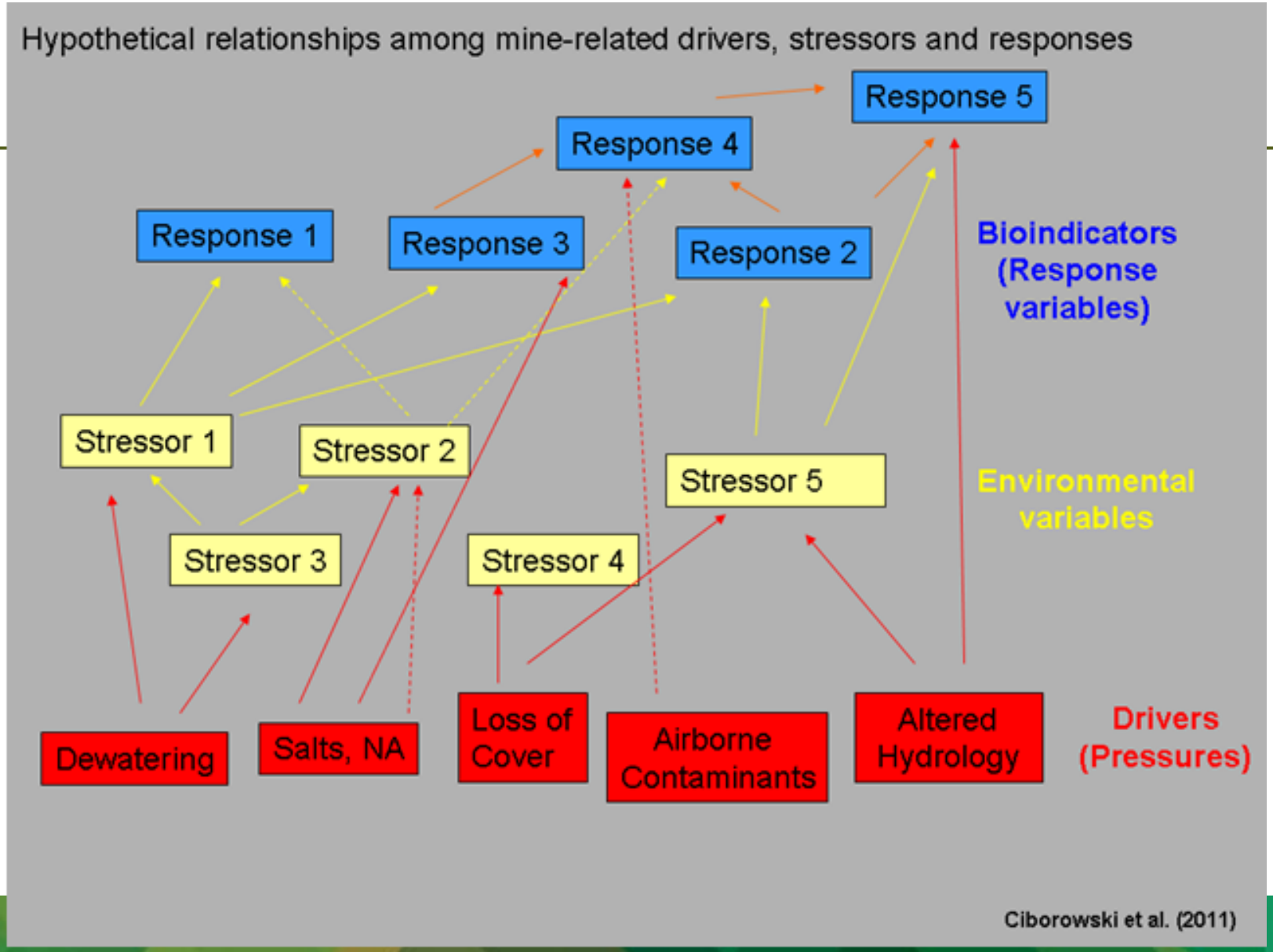
Organism type	Study count	Region			Environmental Change		
		Athabasca River and Tributaries	*Boreal Forest*	*Other*	*Yes*	*No*	*N/A or Baseline*
Fish	17	8	0	9	5	0	12
Bird	14	0	7	7	5	1	8
Aquatic Invertebrate	5	2	0	3	1	0	4
Terrestrial Organism	6	0	4	2	2	1	3
Vegetation	6	0	5	1	1	0	5
Microbial organism	1	1	0	0	0	0	1
Mollusk	1	1	0	0	1	0	0
Total	50	12	16	22	15	2	33

Cumulative effects assessment

- Is there a change?
- Relative to what?
- Are we concerned about it?
- What is causing the change?
- What are we going to do about it?

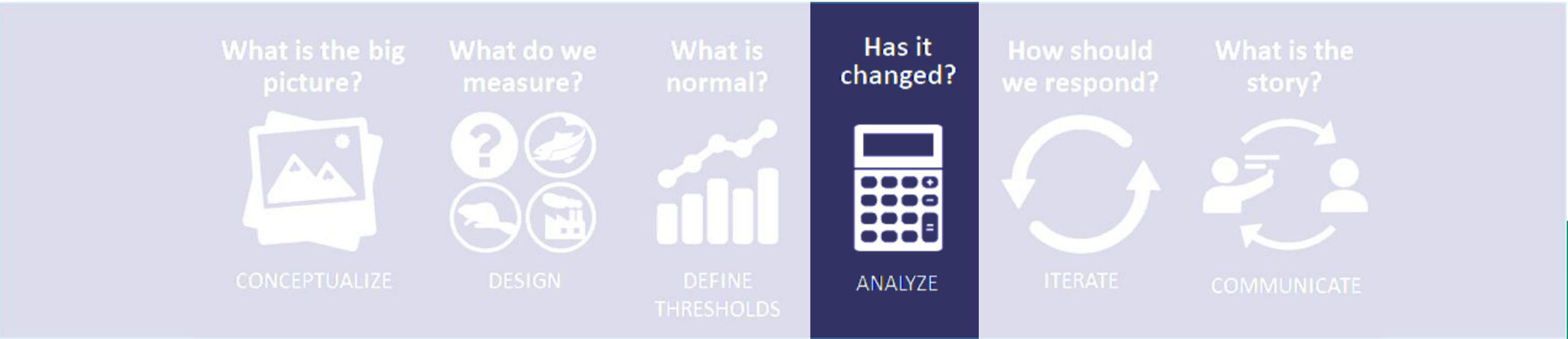


Adverse Outcome Pathways



Benchmarks

- A change in a indicator relative to a benchmark determines when or if a change matters and may trigger a response from the cumulative effects management system



Thank You