5- YEAR LONG-TERM MONITORING OR OPERATIONAL ACTIVITY WORK PLAN

Changes to this Work Plan are only accepted via an Approved Addendum.

General Information		
Monitoring Category: *(From OSM long-term plan; choose from drop-down menu)*	Atmospheric Monitoring	
Strategic Monitoring Objective: *(From OSM long-term plan; choose from drop-down menu)*	Objective: Detect and report levels and trends of oil sands related chemical substances being deposited from the atmosphere	
Work Plan Unique Identifier:	*A-LTM-S-9-1718*	
Monitoring Activity Title:	Atmospheric Pollutant Deposition Monitoring – Lakes and Snowpack	
Geographic Location (*choose from drop-down menu, if Project Location is in more than one area choose from second drop-down***)**	Athabasca Oil Sands Region	Peace Athabasca Delta
Monitoring Site(s) Coordinates *(latitude and longitude)*	56.9997, -110.6657 to 57.0032, -112.4782 and 56.4624, -111.451 to 57.7799, -111.3619	
Monitoring Organization and Responsible Manager:	Environment and Climate Change Canada	**Jane Kirk**
Date Monitoring initiated:	**2011**	
Specific Monitoring Objective: *(State the monitoring objective addressed through this monitoring)*	Atmospheric contaminants deposition is impacting contaminant levels in major tributaries of the Athabasca River and this impact can be quantified by integrating catchment and sub-catchment scale snowpack contaminant loadings (from 2012-present) and tributary contaminant concentrations and loads measurements using Geographic Information System and hydrological modelling approaches. The impacts of the recent forest fires on algal and invertebrate community structure can be determined by re-coring a subset of lakes and comparing sediment core surface samples with previous results obtained from these same lakes.	

Deliverables (Annual): *What Data Reports will be produced and when?*	1. Quantification of the relative contribution of snowpack contaminants loadings to water quality in tributaries of the Athabasca OS region. 2. Improved estimates of atmospheric contaminant deposition to the Athabasca OS region, including more accurate deposition maps. 3. Deposition estimates provided to Air Quality Research Division as part of ongoing collaborations will improve atmospheric deposition models deposition fluxes and models. 4. Determination of the relative impacts of OS developments, climate change, and recent forest fires on PACs and metals deposition, lake primary productivity, and invertebrate and diatom community structure in lakes located within ~125 km of the major OS developments. 5. All raw data uploaded to the portal in a timely fashion. 6. Data published in the peer reviewed literature and presented at conferences. 7. Data shared with industry partners through the Canadian Oil Sands Innovation Alliance (COSIA) to design effective mitigation strategies if needed.

Monitoring Plan Summary: *Please summarize the monitoring including relevant information such as background, objectives, monitoring area, methods/monitoring design, assumptions, outcomes, and references. These should align with the information provided in Appendix 1: Annual Monitoring Schedule.*

Methods/Monitoring Design

1. We propose to quantify the impacts of atmospheric contaminant deposition on water quality of Athabasca River tributaries of the OS region by integrating catchment and sub-catchment scale snowpack contaminant loadings (2012-2014) and tributary contaminant concentrations and loads (2012-2014) measurements using Geographic Information System and hydrological modelling approaches. This work will be carried out in collaboration with AEP and a post-doctoral fellow. This is the first time that this type of work will be carried out and to-date, we have made progress on this project by developing a GIS-based approach to calculate catchment and sub-catchment scale snowpack contaminant loadings to each major tributary catchment.
2. We propose to quantify atmospheric contaminant deposition to the region within 125 km of the major OS developments, including both inorganic contaminants (Hg, MeHg, metals, nutrients etc) as well as PACs (52 routinely analysed PACs determined by GC-MS + novel PACs analysed by GCxGC-TOFMS). This will extend the current depositional dataset published by Kirk et al (2014) and Manzano et al (2016) permitting assessment of temporal trends. A long-term snowpack sampling study design will be finalized. In 2017-18, we will also design a future study plan to quantify contaminant deposition both in open areas and under the forest canopy so that in future years, open and under the forest canopy contaminant loads can be combined with forest coverage maps of the area to estimate contaminant depositional fluxes to the entire Athabasca OS region. This work is potentially important since measurements in other boreal regions of Canada have demonstrated that dry deposition of Hg and MeHg is 1.4-4 times higher under forest canopies than in the open because the forest is an efficient scavenger of aerosols and particulate matter from the atmosphere (Graydon et al., 2008, Mowat et al. 2012). The same is

likely the case for PACs although it has never been examined.

3. We propose to continue to utilize novel paleolimnoligcal analyses including characterization of cladoceran/zooplankton, chironomid and diatom fossil remains, climate proxies, such as visual near infrared reflectance spectroscopy (VNIRS) chlorophyll a, and contaminant analyses of dated lake sediment cores collected from waterbodies located within ~125 km of the major OS developments to determine the relative impacts of OS developments, climate change, and recent forest fires on PACs and metals deposition, lake primary productivity, and invertebrate and diatom community structure. To assess the impacts of the recent forest fires specifically, we propose to re-core 5 of the ~28 lakes in 2018 we have examined previously and compare sediment core surface samples with previous results obtained from these same lakes. This will extend our previous work based on the analysis of dated sediment cores (Kurek et al. 2014; Summers et al 2016).

Assumptions

1. Constraints on snow sampling. The focus on snow deposition assumes that it captures winter deposition of metals and PACs and that the sampling design is sufficiently robust to allow areal deposition estimates to be made by kriging. The snow sampling is constrained by lack of access to private land near the upgrader and mining facilities. Also extreme variations in annual snowfall eg very limited snow in March 2010, could impact the sampling although this was not the case for 2011 to 2016.
2. Ability to put analytical contracts in place in a timely fashion.
3. Ability to hire term employees and co-op students in a timely fashion.

References

Graydon, J., St. Louis, V. L., Hintelmann, H., Lindberg, S., Sandilands, K., Rudd, J., Kelly, C., Tate, M., Krabbenhoft, D., Lehnherr, I. 2009. Investigation of Uptake and Retention of Atmospheric Hg(II) by Boreal Forest Plants Using Stable Hg Isotopes. Environmental Science & Technology 43, 4960–4966.

Kirk, J.L., Muir, D.C.G., Gleason, A., Wang, X., Lawson, G., Frank, R.A., Lehnherr, I., Wrona, F., 2014. Atmospheric deposition of mercury and methylmercury to landscapes and waterbodies of the athabasca oil sands region. Environmental Science & Technology 48, 7374-7383.

Kurek, J., Kirk, J.L., Muir, D.C.G., Wang, X., Evans, M.S., Smol, J.P., 2013. Legacy of a half century of Athabasca oil sands development recorded by lake ecosystems. Proceedings of the National Academy of Sciences of the United States of America 110, 1761-1766.

Manzano, C.A., Muir, D., Kirk, J., Teixeira, C., Siu, M., Wang, X., Charland, J.-P., Schindler, D., Kelly, E., 2016. Temporal variation in the deposition of polycyclic aromatic compounds in snow in the Athabasca Oil Sands area of Alberta. Environmental Monitoring and Assessment 188, 1-12.

Mowat, L., St. Louis, V. L., Graydon, J., Lehnherr, I. 2011. Influence of Forest Canopies on the Deposition of Methylmercury to Boreal Ecosystem Watersheds. Environmental Science & Technology 45, 5178–5185

Summers, J.C., Kurek, J., Kirk, J.L., Muir, D.C.G., Wang, X., Wiklund, J.A., Cooke, C.A., Evans, M.S., Smol, J.P., 2016. Recent warming, rather than industrial emissions of bioavailable nutrients, is the dominant driver of lake primary production shifts across the Athabasca Oil Sands Region. PLoS ONE 11.

Data Management

If this work generates data please summarize your project-level data management plan.

Deliverables	Timeframe
Data Collection Period: *Field work*	Start : Click here to enter a date. End
Data Analysis Period: *Laboratory analysis and QA/QC of data*	Start : 2017-04-01 End: 2018-07-31
Data Release Date: *Metadata and data consistent, complete and meet basic standard format for publication in Open Data; on or linked to JOSM portal*	2018-10-31

Reporting and Publications

Provide information on the anticipated reports / publications. (Insert additional rows if needed)

Expected Subject/Titles of Publications or Reports	Short Description of Publication or Report	Expected Year of Publication
Spatial and temporal patterns in trace element deposition in the Athabasca oil sands region (Alberta, Canada). In review.	Summarizes deposition based on results from dated sediment cores from over 20 lakes	2017
Spatial and temporal patterns in deposition of polycyclic aromatic compounds inferred from dated sediment cores in the Athabasca oil sands region (Alberta, Canada). In prep.	Summarizes deposition based on results from dated sediment cores from 28 lakes	2017

Technical / Professional Roles and Responsibilities

Identify members of the monitoring team/organization, their roles and responsibilities. Identify monitoring organization leads if different from overall monitoring activity lead. (Insert additional rows if needed)

Role	Responsibilities
Project Lead (Environment and Climate Change Canada)	- Project coordinator and principal investigator on metals and methyl mercury in snow and mercury in sediments
Project Lead (Alberta Environment and Parks)	- Project coordinator and principal investigator on metals in sediments
Project Lead (Environment and Climate Change Canada)	- Project coordinator and principal investigator on PACs in snow, water, air, and sediments
Post-doctoral fellow (Environment and Climate Change Canada)	- Interpretation and write up of metals data in snow - Source attribution studies to identify relative importance of pet coke/fugitive dusts etc. to contaminants loads (using metal isotope ratios, carbon particle analysis)
Collaborator (Air Science and Technology Directorate – ECCC)	- Air Science and Technology Directorate/Air Quality Research Division program on deposition and effects; PACs in passive and active air samplers
Collaborator (Alberta Environment and Parks)/University of Alberta	- Determine the potential impact of wintertime snowpack mercury loads on tributary river water mercury concentrations using Geographical Information Systems and hydrological modelling
Collaborators (Air Science and Technology Directorate - ECCC)	- Air Science and Technology Directorate/Air Quality Research Division program on deposition and effects; Heavy metals in air particulates at 3 Wood Buffalo Environmental Association sites
Collaborators (Queen's University and Mount Allison University)	- Analysis and data interpretation of cladoceran, chironomid and diatom fossil remains, chlorophyll a, and black carbon in dated lake sediment cores
Collaborators (Fort Chipewyan)	- Provide input into future snow sampling design including sites of concern in the Peace Athabasca Delta
Technical Support (Environment and Climate Change Canada)	- Water chemistry and metals sample analysis coordination
Technical Support (Environment and Climate Change Canada)	- Processing of water chemistry and metals in snow samples - Extraction of PACs in snow
Technical Support	- Analysis of trace methyl mercury in snow and total mercury analysis in lake

(Environment and Climate Change Canada)	sediments - QA/QC and data uploads to the portal
Technical Support (Environment and Climate Change Canada)	- Analysis of trace total mercury in snow
Technical Support (Environment and Climate Change Canada)	- Analysis of PACs in snow
Technical Support (Environment and Climate Change Canada)	- Extraction of snow (separate filtered particles and dissolved phases) - GC-MS analysis of selected PACs and reference materials
Technical Support (Environment and Climate Change Canada)	- Dating of sediment cores

Deliverables (Year 1) If your Focus Study is longer than 1 year then complete **Appendix C** for multi-year deliverables breakdown

Deliverable(s) (please provide enough information to support status reporting)
Q1 – April to June
Publication on "Spatial and temporal patterns in trace element deposition in the Athabasca oil sands region (Alberta, Canada)" which summarizes deposition based on results from dated sediment cores from over 20 lakes.
Publication on "Sources of methylmercury to snowpacks of the Alberta Oil Sands Region: A study of in situ methylation and particulates" which summarizes 2015 results of methylation experiments and particulate measurements in snowpacks.
Q2 – July to September
Lab analyses of March 2017 snowpack samples for mercury, methylmercury, multi-elements, and water chemistry.
Lab analyses of March 2017 lake sediment cores for Pb-210 dating.
Q3 – October to December
SETAC North America presentation on "Spatial and temporal patterns in deposition of metals and polycyclic aromatic compounds inferred from dated sediment cores in the Athabasca oil sands region (Alberta, Canada)."
SETAC North America presentation on "Impact of winter-time atmospheric metals deposition on water concentrations in major tributaries of the Athabasca River."
Laboratory analyses of paleo-limnological data including carbon particles, biological communities (cladoceran and diatoms),

and chlorophyll to assess sources and environmental change in the region using dated lake sediment cores.
Q4 – January to March
Lab analyses of March 2017 snowpack samples for PACs.
Lab analyses of March 2017 sediment core samples for mercury and PACs.
Data analyses of paleo-limnological data including carbon particles, biological communities (cladoceran and diatoms), and chlorophyll to assess sources and environmental change in the region using dated lake sediment cores.

Detailed Financial Breakdown – Year 1 of 3 (2017-2020)

Also complete **Appendix B** for the multi-year financial breakdown

Budget requirements – List areas that require budget expenditures: (ADD OR DELETE BUDGET CATEGORIES AS REQUIRED)	**OS Funding**	**External Funding (*outside JOSM*)**
O&M - Operations and Maintenance:		
Helicopter Costs	**$**	**$**
Data Management	**$**	**$**
Publication costs (translation + open access)	**$500**	
TMU related analyses (multi-element suite and water chemistry at NLET; PAC analysis by PYLET)	**$40,000**	
Internal Lab Analysis (mercury and methyl Hg analyses in Kirk lab; core dating by Muir/Yang)	**$35,000**	**$**
Consumable Materials & Supplies (for filtering & extraction of snow for PACs)	**$17,612**	**$**
Sub-Total	**$93,112**	**$**
O&M - Travel		
Field Work	**$**	**$**
International Conference on Mercury as a Global Pollutant	**$3,000**	**$**
Training	**$**	
Sub-Total	**$3,000**	**$**
O&M - External Contracts :		
Goods and Services Contract (*describe contractor*)	**$20,000**	**$**

Budget requirements – List areas that require budget expenditures: (ADD OR DELETE BUDGET CATEGORIES AS REQUIRED)	**OS Funding**	**External Funding (*outside JOSM*)**
Geographical Information Systems support contract (Strategic Natural Resource Consultants Inc.)		
External Lab Analysis Contract to specialized paleolimnology laboratory	**$40,000**	**$**
Sub-Total	**$60,000**	**$**
Salaries:		
Principal Investigator	**$**	**$21,586**
Technical / Professional Assistants	**$200,000**	**$23,022**
Field Staff (overtime)	**$**	**$**
Visiting Fellow (O&M)	**$55,200**	**$**
Students (O&M)	**$24,000**	**$**
Sub-Total	**$279,200**	**$**
2017-2018 GRAND TOTAL* (BEFORE OTHER RELATED COSTS)	**$435,312**	**$44,608**

Appendix 1 – Annual Monitoring Schedule

(Please provide detailed information on the specifics of your monitoring schedule including – **locations, schedule, methods**, **SOPs, QA/QC data release**, **references**)

Sampling Locations/Sites	**Sampling Schedule** (*timing/frequency)*	**Compounds to be Analyzed**	**SOPs to be Consulted** (*hyperlinks accepted*)	**QA/QC Complete & Date Data to be Released**
Not applicable in the design phase.				

Appendix 2 – Detailed Multi-Year Financial Breakdown:

if changes are to be made then an Addendum must be Complete and Approved.

(Complete the following detailed financial breakdown; add or delete categories as required)

Budget requirements	Year 1 (2018-2019) APPROVED		Year 2 (2019-2020) NOT APPROVED		Year 3 (2020-2021) NOT APPROVED	
	Cash	In-kind	Cash	In-kind	Cash	In-kind
1) Salaries and benefits						
a) Investigators		$21,586		$21,586		$21,586
b) Technical/professional assistants	$200,000	$23,022	$132,938	$23,022	$132,938	$23,022
c) Field Staff			$5000		$5000	
d) Post-docs (O&M)	$55,200		$55,200		$55,200	
e) Co-op students (O&M)	$24,000		$24,000		$24,000	
2) Operations and maintenance						
a) Facilities						
b) Equipment						
c) Lab analysis (TMU related analyses (multielement suite and water chemistry at NLET; PAC analysis by PYLET + Internal Lab Analysis (mercury and methyl Hg analyses in Kirk lab; core dating by Muir/Yang)	$75,000				$220,000	
d) Data management			$3,000		$3,000	
e) Field work (Helicopter)			$100,000		$75,000	

3) Consumable Materials and supplies						
a) Field supplies			$30,000		$18,000	
b) Laboratory Supplies	$17,612					
4) Travel						
a) Conferences and meetings	$3,000		$3000		$3000	
b) Field work			$32,000		$20,000	
c) Project-related travel			$2000		$2000	
5) Dissemination & Engagement						
a) Publications/Reports	$500		$500		$500	
b) Translation (if required)			$1000		$1000	
c) Communications						
d) Stakeholder Engagement						
e) Indigenous Peoples Engagement						
6) External Contracts						
a) Geographical Information Systems support contract (Strategic Natural Resource Consultants Inc.)	$20,000		$20,000		$22,000	
b) Contract to specialized paleolimnology laboratory	$40,000		$20,000		$55,050	
Grand Total * (Before other related costs)	$435,312	$44,608	$428,638	$44,608	$636,688	$44,608

*Total Salary Costs for ECCC ($200,000) in 2017-18 with other related costs is $275,040. Total O&M for ECCC ($235,312) in 2017-18 with other related costs is $270,960. **The Grand Total for ECCC ($435,312) with other related costs is $546,000.**

Appendix 3 – Staffing Plan

(Complete the following detailed staffing plan; add or delete categories as required)

	Year 1 – Budget Allocation		Year 2 – Budget Allocation		Year 3 – Budget Allocation		Year 4 – Budget Allocation		Year 5 – Budget Allocation	
Responsible Role	OSM Funding	External Funding	OSM Funding	External Funding	OSM Funding	External Funding	OSM Funding	External Funding	OSM Funding	External Funding
Science Expertise	$55,200		$132,938		$132,938					
Technical/Field Staff	$200,000		$60,200		$60,200					
Administrative and Program Coordination	$24,000		$24,000		$24,000					
Grand Total (*inserted into Appendix 2*)	**$279,200**	**$**	**$217,138**	**$**	**$217,138**	**$**		**$**		**$**

Appendix 4 - Approvals

Project Submitted by:		
Name:		
Organization:	Signature:	Date:

Project Approved by:	
Dr. Monique Dubé (AEP)	**Dr. Kevin Cash (ECCC)**
Signature 	Signature 
Date	Date

APPENDIX 5 –Years 2 and 3 Deliverables (Complete the following detailed breakdown. Provide a summary of tangible quarterly deliverables. Identify major project areas (deliverables) and results that can be identified as a tangible goal.)

Year 2 (2018-2019)
Deliverable(s) (please provide enough information to support status reporting)
The following deliverables are based on projected activities at the present time (Dec 2016). ECCC will provide updated deliverables and budget estimates for as work continues in the next fiscal years. Changes will be made depending on the previous years' progress and new science questions that arise.
Q1 – April to June
Publication on "Spatial and temporal patterns in mercury and trace element deposition in the Athabasca oil sands region (Alberta, Canada)" which summarizes deposition based on results from 2008-2017 snowpack measurements (led by post doc Yamini Gopalapillai).
Q2 – July to September
Update of PACs, water chemistry, and multielement snowpack and sediment core data to the portal.
Deposition maps and calculation of loadings using ArcGIS kriging approaches
Presentation at internal meeting on progress to date via WebEx
Q3 – October to December
SETAC North America presentation on "Spatial and temporal patterns in deposition of mercury and trace element deposition inferred from 2008-2017 snowpack measurements in the Athabasca oil sands region (Alberta, Canada)."
Data analyses of paleo-limnological data including carbon particles, biological communities (cladoceran and diatoms), and chlorophyll to assess sources and environmental change in the region using dated lake sediment cores.
Q4 – January to March
March 2019 field season: gridwork pattern on the landscape so that deposition maps can be created.
Total Annual Budget

Year 3 (2019-2020)
Deliverable(s) (please provide enough information to support status reporting)
The following deliverables are based on projected activities at the present time (Dec 2016). ECCC will provide updated deliverables and budget estimates for as work continues in the next fiscal years. Changes will be made depending on the previous years' progress and new science questions that arise.
Q1 – April to June
Publication on "Impact of snowpack melt on mercury concentrations in major tributaries of the Athabasca Oil Sands region (led by post doc Yamini Gopalapillai).
Processing of 2019 snowpack samples including melting, filtering, etc.
Q2 – July to September
Lab analyses of March 2019 snowpack samples for mercury, methylmercury, multielements, and water chemistry.
Lab analyses of March 2019 lake sediment cores for Pb-210 dating.
2019 deposition maps using ArcGIS kriging approaches + publication and presentation maps
Q3 – October to December
SETAC North America presentation on "Impact of snowpack melt on mercury concentrations in major tributaries of the Athabasca Oil Sands region."
Laboratory analyses of paleo-limnological data including carbon particles, biological communities (cladoceran and diatoms), and chlorophyll to assess sources and environmental change in the region using dated lake sediment cores.
Presentation at internal meeting on progress to date
Q4 – January to March
Lab analyses of March 2019 snowpack samples for PACs.
Lab analyses of March 2019 sediment core samples for mercury and PACs.
Field work to collect snowpack and lake sediment core (n=5 lakes) in the Athabasca Oil Sands region.
Data analyses of paleo-limnological data including carbon particles, biological communities (cladoceran and diatoms), and chlorophyll to assess sources and environmental change in the region using dated lake sediment cores.
Total Annual Budget