

Appendix A

1 Supplemental Methods

1.1 Covariates

Covariates were included to increase the sensitivity of the analysis to potential sources of uncaptured variation. For example, seasonality affects water quality in many surface waterbodies, including the Athabasca River [1]. However, industrial activity can also influence flow in tributaries and consequently, discharge measured at some study locations may include some of the industrial signal we are interested in revealing if present. Among the sites examined here flow data was also not available for all locations for all years. Furthermore, flows are summarized as mean daily flows, and are not instantaneous (like the water quality measurements) and are based on regularly updated rating curves. To account for seasonality and accommodate the known limitations of discharge data, but to also limit the elimination of an industrial signal in the OSR, we used the mean flow in the Athabasca River per Julian Day calculated using data from 1959-2018. We used the same process to calculate mean daily flows for both the Peace and Slave River locations. The mean daily flow mis-specifies the effect of actual flow, but also highlights potentially unusual observations which are the basis of adaptive monitoring programs [2]. Mean daily precipitation on 3 days prior to collecting samples for water quality measurements from the Mildred Lake meteorological station [3] were also obtained and included to account for potential influences associated with rain events.

Other covariates were also included in the analysis here. In records of specific conductivity, records indicate either ‘lab’, ‘field’, or was not reported. Where both lab and field conductivity were included in the records, field conductivity was used. We included the type of conductivity as a covariate and was dummy coded. Where less than 3 measurements were reported for either lab or field, these measurements were folded into the unknown category. Dummy codes were either 0 or 1 and additional variables were created if more than 2 categories were present for a given covariate, such as technique. If only one type of conductivity measurement was done at a site, this factor was not included as a covariate in the analysis of site-specific data.

The use of multiple collection types (other than discrete grabs) was also done at the Athabasca River locations. The other data collection types included isokinetic transect composite-, equal volume transect-, and vertically integrated-samples during the OSM/JOSM collections between 2011 and 2019 [4]. The various sampling methods also followed different designs. These collection techniques, and consequently, the study designs were included as dummy-coded covariates in the analyses.

In contrast to type of conductivity measurement and collection technique, the source program and the original site could not be used as covariates. Despite their potential relevance, these factors varied systematically over time (e.g., OSM samples were collected after 2015) and their inclusion could remove relevant signals.

References

1. Arciszewski, T.J.; Hazewinkel, R.R.; Munkittrick, K.R.; Kilgour, B.W. Developing and Applying Control Charts to Detect Changes in Water Chemistry Parameters Measured in the Athabasca River near the Oil Sands: A Tool for Surveillance Monitoring. *Environmental Toxicology and Chemistry* **2018**, *37*, 2296–2311, doi:10.1002/etc.4168.
2. Arciszewski, T.J.; Munkittrick, K.R.; Scrimgeour, G.J.; Dubé, M.G.; Wrona, F.J.; Hazewinkel, R.R. Using Adaptive Processes and Adverse Outcome Pathways to Develop Meaningful, Robust, and Actionable Environmental Monitoring Programs. *Integrated Environmental Assessment and Management* **2017**, *13*, 877–891, doi:10.1002/ieam.1938.
3. Arciszewski, T.J.; Ussery, E.J.; McMaster, M.E. Incorporating Industrial and Climatic Covariates into Analyses of Fish Health Indicators Measured in a Stream in Canada’s Oil Sands Region. *Environments* **2022**, *9*, 73, doi:10.3390/environments9060073.
4. Glozier, N.E.; Pippy, K.; Levesque, L.; Ritcey, A.; Armstrong, B.; Tobin, O.; Cooke, C.A.; Conly, M.; Dirk, L.; Epp, C.; et al. *Surface Water Quality of the Athabasca, Peace and Slave Rivers and Riverine Waterbodies within the Peace-Athabasca Delta.*; Oil Sands Monitoring Program Technical Report Series No. 1.4, 2018; ISBN 9781460140284.