

Supplemental information for:

A review of control charts and exploring their utility for regional environmental monitoring programs

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Supplemental Tables

Table S1 Regression table for vanadium and arsenic Generalized Estimating Equations used to calculate response residuals used in Figure 2.

Variable	Model parameter	Estimate	Std.err	Wald	Pr(> W)
Vanadium	Intercept	0.272153	<0.001	<0.001	<0.001
	discharge	0.004928	<0.001	<0.001	<0.001
	AR1 correlation	0.453	<0.001	NA	NA
Arsenic	Intercept	0.321404	<0.001	<0.001	<0.001
	discharge	0.000841	<0.001	<0.001	<0.001
	AR1 correlation	0.257	<0.001	NA	NA

Table S2 Regression results for PM2.5 at 3 stations in the oil sands regions used to calculate response residuals for multivariate control charts in Figure 3; ‘AR1’ indicates the correlation coefficient between adjacent observations calculated using geeglm() function in the geepack R package; Lag1 variable is the lagged PM2.5 for previous week used as an input variable in the full regression models with no missing weeks.

Regression type	Site	Parameter	Coefficient	SE	p-value
Full	AMS01	Intercept	4.2536	0.5586	<0.001
		Lag1	0.4944	0.0364	<0.001
	AMS13	Intercept	4.0193	0.5883	<0.001
		Lag1	0.4366	0.0377	<0.001
	AMS15	Intercept	8.53	<0.001	<0.001
		AR1*	0.543*	<0.001	NA
Fire data removed	AMS01	Intercept	7.35	<0.001	<0.001
		AR1*	0.509	<0.001	NA
	AMS13	Intercept	6.01	<0.001	<0.001
		AR1*	0.511	<0.001	NA
	AMS15	Intercept	7.64	<0.001	<0.001
		AR1*	0.529	<0.001	NA

Supplemental Figures

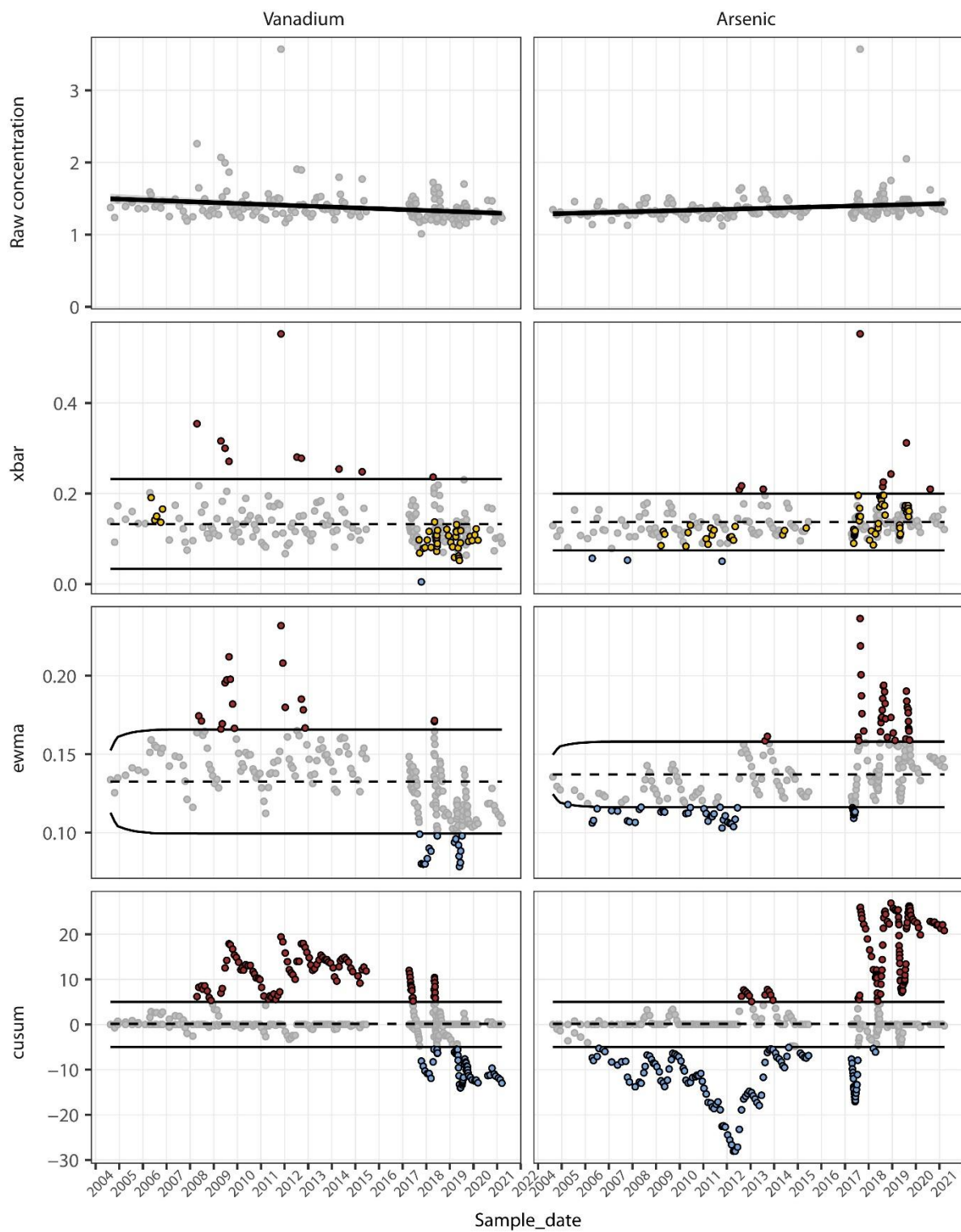


Figure S1 Control charts of raw concentrations of vanadium and arsenic at the lower Muskeg station, plus the raw concentrations plotted over time with a linear model.

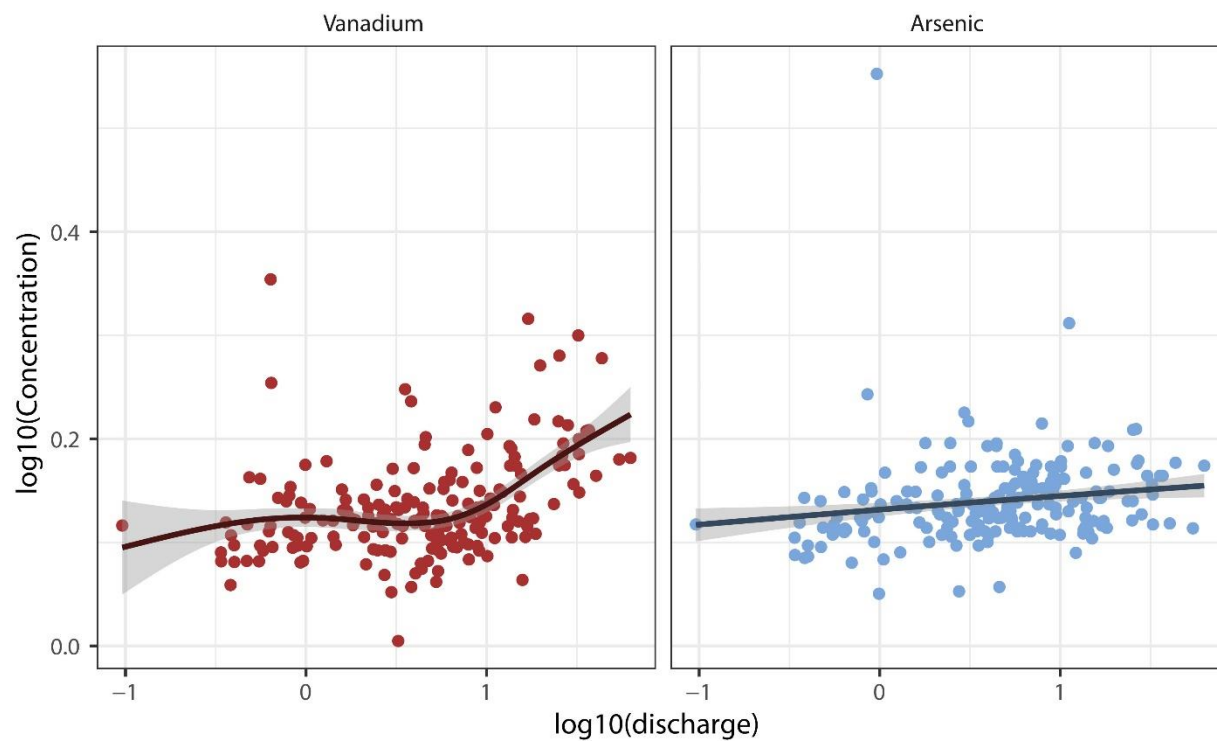


Figure S3 Relationships between the concentrations of vanadium and arsenic and discharge in the lower Muskeg River from 2004 to 2019; statistical relationship described with a Generalized Additive Model (with its 95% confidence interval).

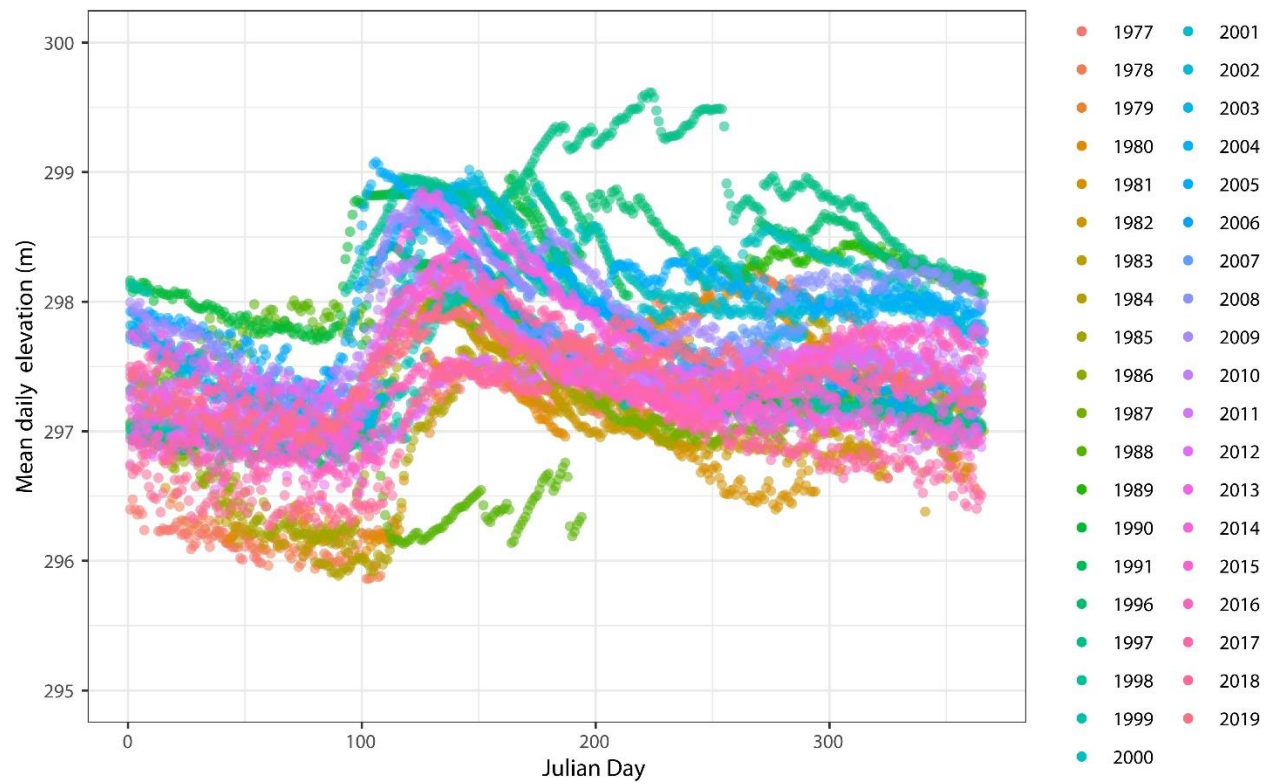


Figure S4 Mean daily elevation of groundwater at the sampling well 07DAG051 in the Muskeg drainage (57.237790845°N, -111.449408386°W).

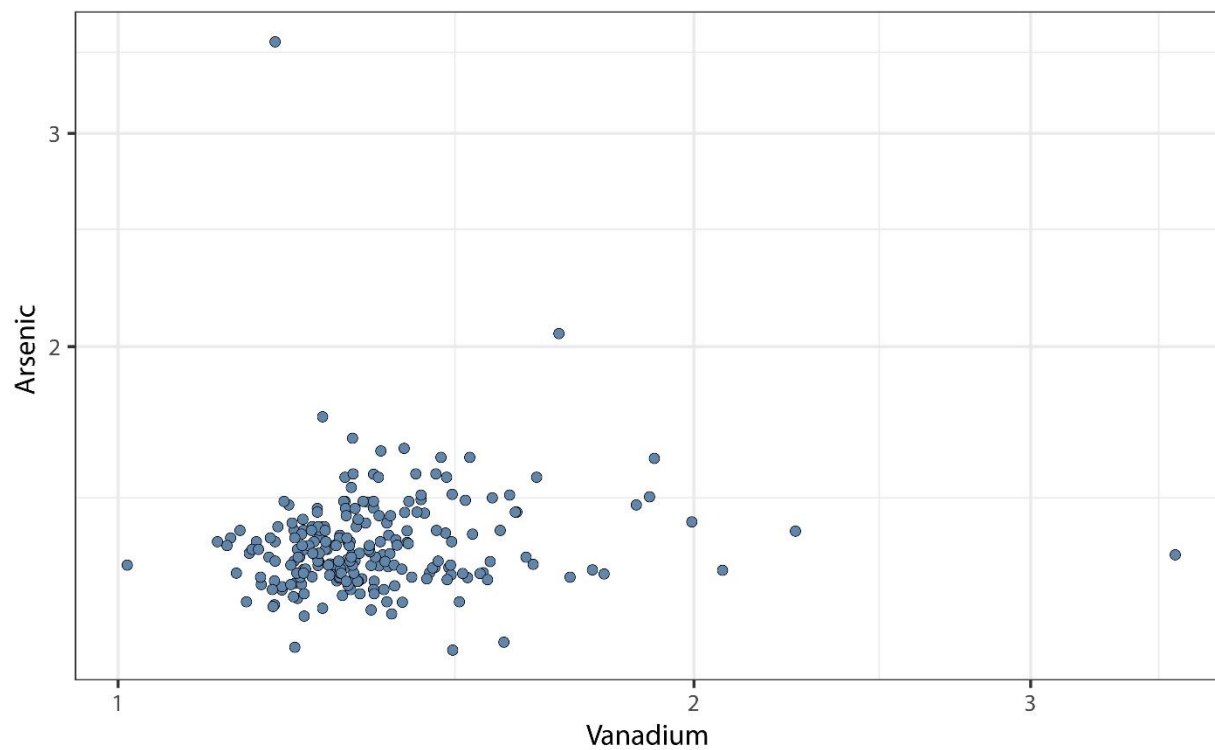


Figure S5 Relationship between the concentration of vanadium and arsenic (mg/L) at the lower Muskeg River site between 2004 and 2019.

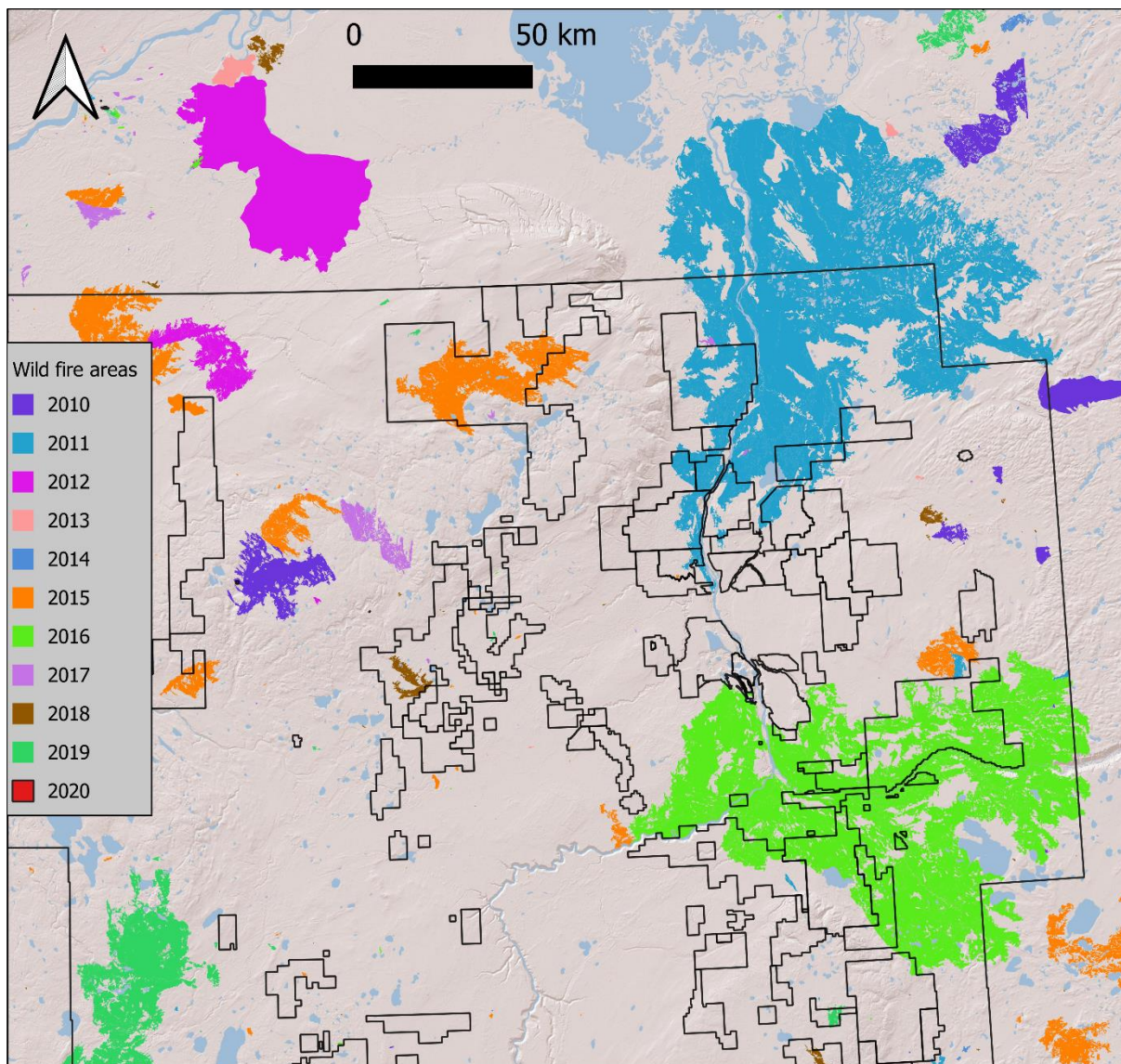


Figure S6 Areas of forest fires from 2010-2020 in northern Alberta showing the oil sands administrative area along with all project areas.

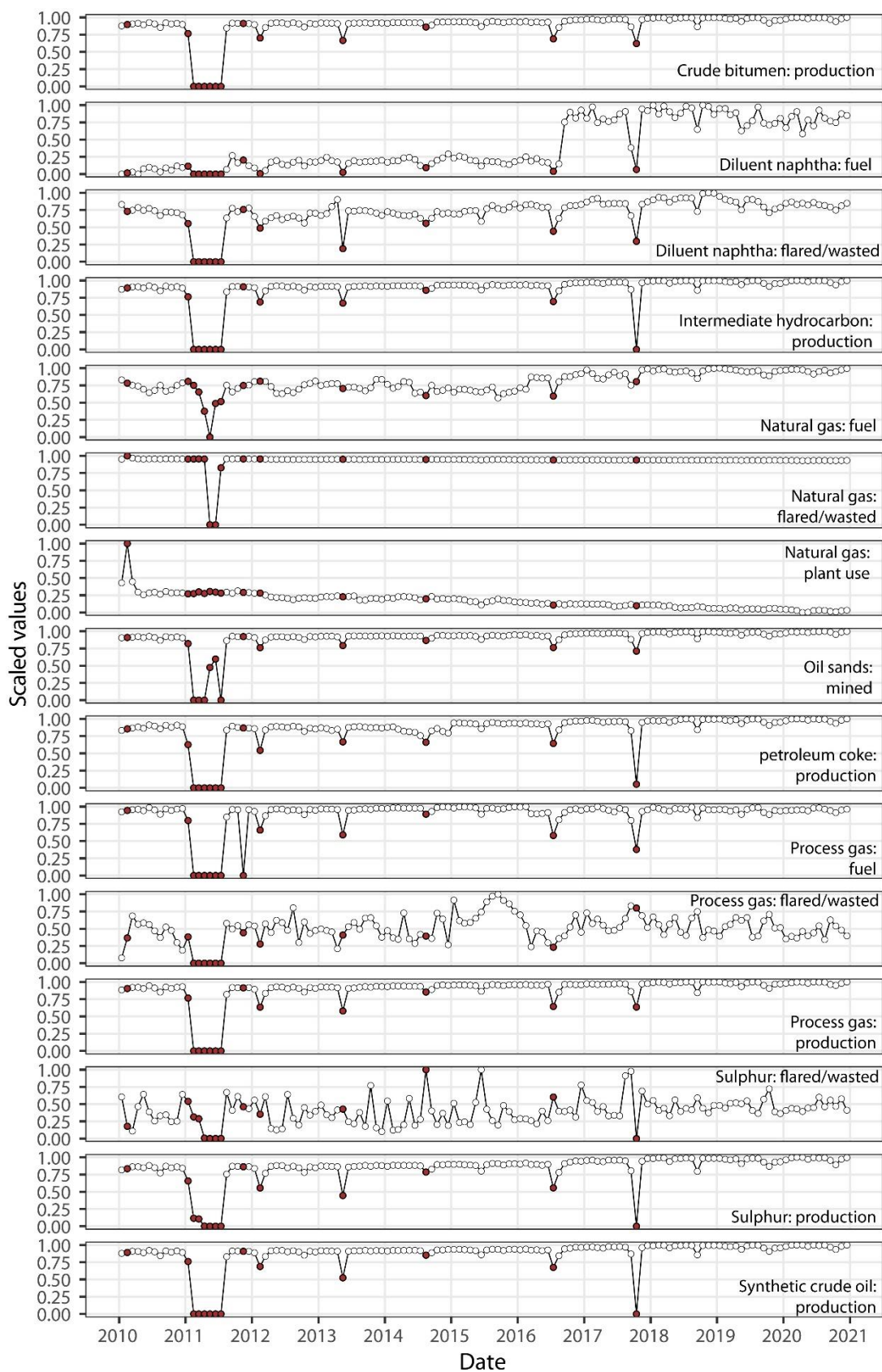


Figure S7 Scaled (0 to 1) performance and production mean daily values (per month) for the Horizon mine; red symbols show out-of-control measurements using all variables and the full T^2 chart (see Figure 4 in main text).

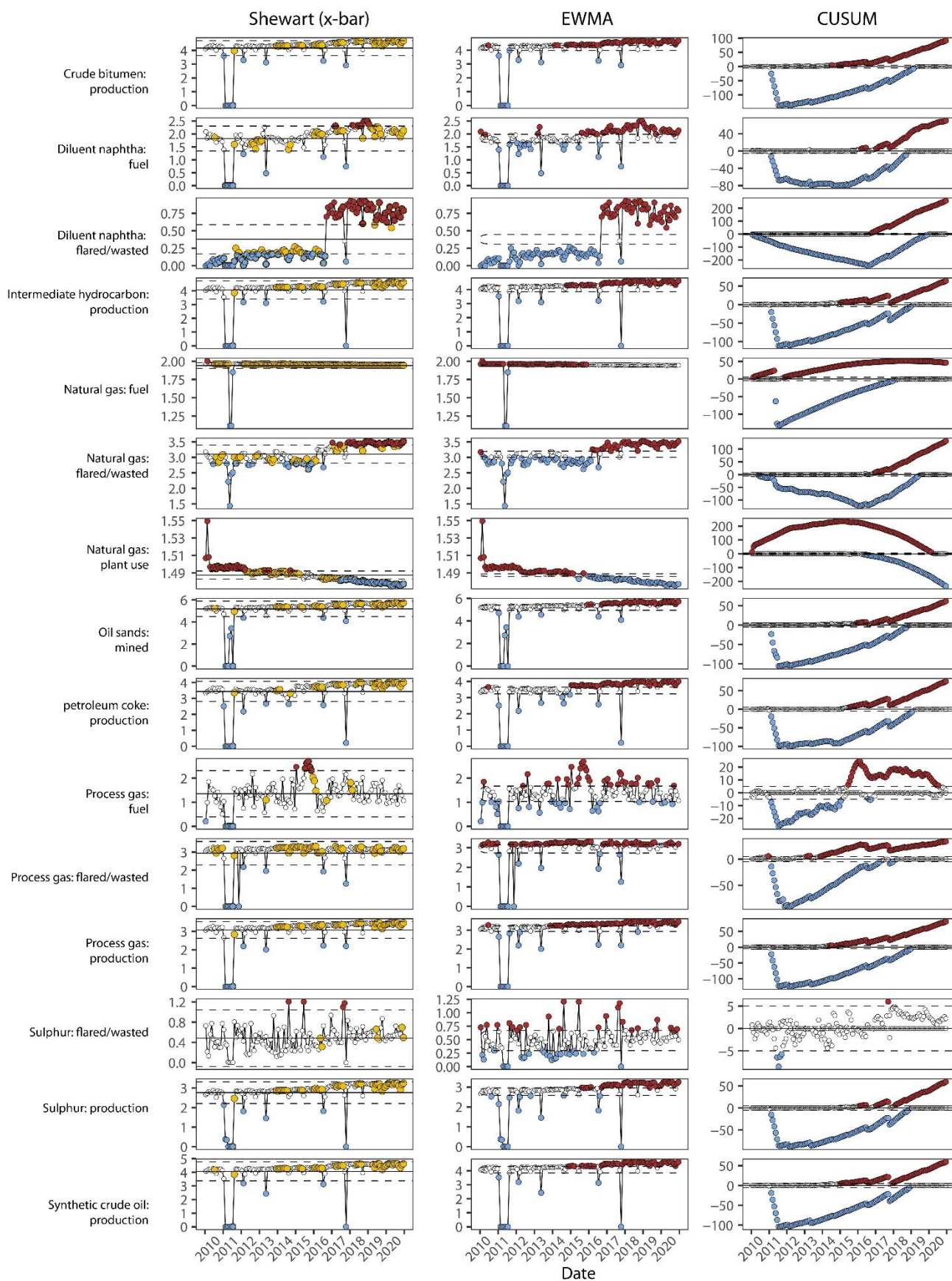


Figure S8 Univariate control charts (x-bar, EWMA, CUSUM) for industrial production and performance measurements for the Horizon Mine from January 2010 to December 2020; red symbols indicate exceedances of upper control limits (UCL); blue symbols indicate exceedances of lower control limits (LCL); yellow symbols indicate runs of >6 serial observations above or below the mean in the x-bar chart.