Practical Remediation Closure Solutions for Remote Sites in Northern British Columbia

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Recognition: Treaty 8 First Nations

Overview

- Description of the Dormancy and Shutdown Regulation
- Remote Problems
- Client Program
- Approach to Site Closure
- Groundwater Evaluation
- Summary
- Lessons Learned

Dormancy and Shutdown Regulation

- Legislated in 2019 and is the driver for restoration of wellsite's in British Columba.
- Well sites not active for 5 years or do not produce a minimum of 720 hours a year, are required to be abandoned, decommissioned, and restored.
- They have varying timelines on when restoration is required based on dormancy status.
- Liability Reduction Plan – producers submits a plan for approval from the regulator

Client Program

- Northern British Columbia – approximately 69 oil and gas sites in total
- Majority of the sites were approved in the 1960's
- The Sites required 69 Stage 1 and 2 Preliminary Site Investigation (PSIs)
- Major areas to investigate included pits, sumps, well centres, former infrastructure, pipeline risers and any other areas identified with potential environmental concern

Remote Problems

- Completing assessment and remediation work in remote locations has a variety of constraints including accessibility, equipment availability, short assessment seasons, and landfill distances
- Strict timelines from the regulator to complete the work (i.e. roughly 5 to 13 years)
- Some producers have high volumes of sites to be restored within the dormancy timeline

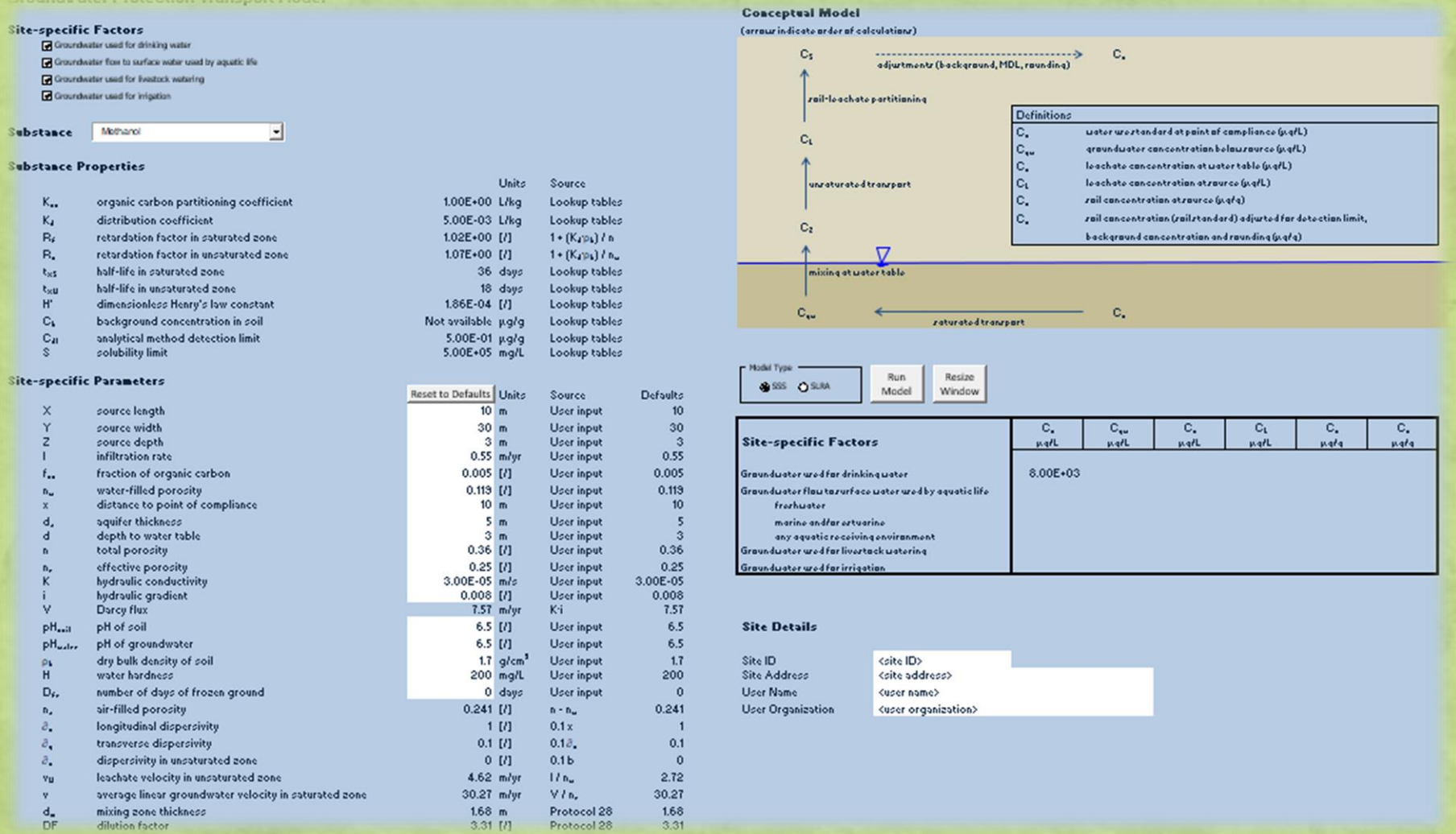
Assessment Strategy

- From the Stage 1 and 2 PSI, a total of 10 sites were determined to not have any exceedances or environmental concerns, and 4 were push ahead to be completed in 2025.
- An additional 10 sites required supplemental investigations to further investigate and delineate impacted areas
  - This included re-assessed areas that had assessment datasets over 10 years to confirm impact volumes.
- During the intrusive investigations, a total of 1,300 boreholes were drilled across the project area.
- Initial lab results determined 55 sites had parameters exceeding the BC Contaminated Sites Regulations (approx. 85% fail rate).
- Initial remediation volume calculated from the 55 sites would have been approximately 32,000 m^3

Approach to Site Closure

- The majority of exceedances were constrained by the drinking water pathway. Site specific guideline modification was proposed, utilizing the groundwater protection model
- A total of 24 sites were determined to be good candidates for modification due to their site-specific parameters. Groundwater wells were installed on 24 sites (85 wells in total)
- In BC, if soil exceedances are identified, groundwater is also required to be assessed – this can be done during the assessment or remediation stage. Wells were installed prior to remediation, to aid with site specific guidelines but could also be used for post remedial assessment

Groundwater Protection Model



Site-specific Factors

- Groundwater used for drinking water
- Groundwater flow to surface water used by aquatic life
- Groundwater used for livestock watering
- Groundwater used for irrigation

Substance Methanol

Substance Properties

		Units	Source
K_{oc}	organic carbon partitioning coefficient	1.00E+00 L/kg	Lookup tables
K_d	distribution coefficient	5.00E-03 L/kg	Lookup tables
R_f	retardation factor in saturated zone	1.02E+00 [/]	$1 + (K_d \rho_b) / n$
R_u	retardation factor in unsaturated zone	1.07E+00 [/]	$1 + (K_d \rho_b) / n_w$
$t_{1/2s}$	half-life in saturated zone	36 days	Lookup tables
$t_{1/2u}$	half-life in unsaturated zone	18 days	Lookup tables
H'	dimensionless Henry's law constant	1.86E-04 [/]	Lookup tables
C_b	background concentration in soil	Not available µg/g	Lookup tables
C_{sl}	analytical method detection limit	5.00E-01 µg/g	Lookup tables
S	solubility limit	5.00E+05 mg/L	Lookup tables

Site-specific Parameters

		Reset to Defaults	Units	Source	Defaults
X	source length	10	m	User input	10
Y	source width	30	m	User input	30
Z	source depth	3	m	User input	3
I	infiltration rate	0.55	m/yr	User input	0.55
f_{oc}	fraction of organic carbon	0.005	[/]	User input	0.005
n_w	water-filled porosity	0.119	[/]	User input	0.119
x	distance to point of compliance	10	m	User input	10
d_a	aquifer thickness	5	m	User input	5
d	depth to water table	3	m	User input	3
n	total porosity	0.36	[/]	User input	0.36
n_e	effective porosity	0.25	[/]	User input	0.25
K	hydraulic conductivity	3.00E-05	m/s	User input	3.00E-05
i	hydraulic gradient	0.008	[/]	User input	0.008
V	Darcy flux	7.57	m/yr	K·i	7.57
pH_{soil}	pH of soil	6.5	[/]	User input	6.5
pH_{gw}	pH of groundwater	6.5	[/]	User input	6.5
ρ_b	dry bulk density of soil	1.7	g/cm³	User input	1.7
H	water hardness	200	mg/L	User input	200
D_f	number of days of frozen ground	0	days	User input	0
n_a	air-filled porosity	0.241	[/]	$n - n_w$	0.241
∂_x	longitudinal dispersivity	1	[/]	0.1 x	1
∂_y	transverse dispersivity	0.1	[/]	$0.1 \partial_x$	0.1
∂_z	dispersivity in unsaturated zone	0	[/]	0.1 b	0
v_u	leachate velocity in unsaturated zone	4.62	m/yr	I / n_w	2.72
v	average linear groundwater velocity in saturated zone	30.27	m/yr	V / n_e	30.27
d_m	mixing zone thickness	1.68	m	Protocol 28	1.68
DF	dilution factor	3.31	[/]	Protocol 28	3.31

Conceptual Model

(arrows indicate order of calculations)

Definitions

C_e	water use standard at point of compliance (µg/L)
C_{gw}	groundwater concentration below source (µg/L)
C_2	leachate concentration at water table (µg/L)
C_L	leachate concentration at source (µg/L)
C_s	soil concentration at source (µg/g)
C_s	soil concentration (soil standard) adjusted for detection limit, background concentration and rounding (µg/g)

Model Type: SSS / SLIRA — Run Model — Resize Window

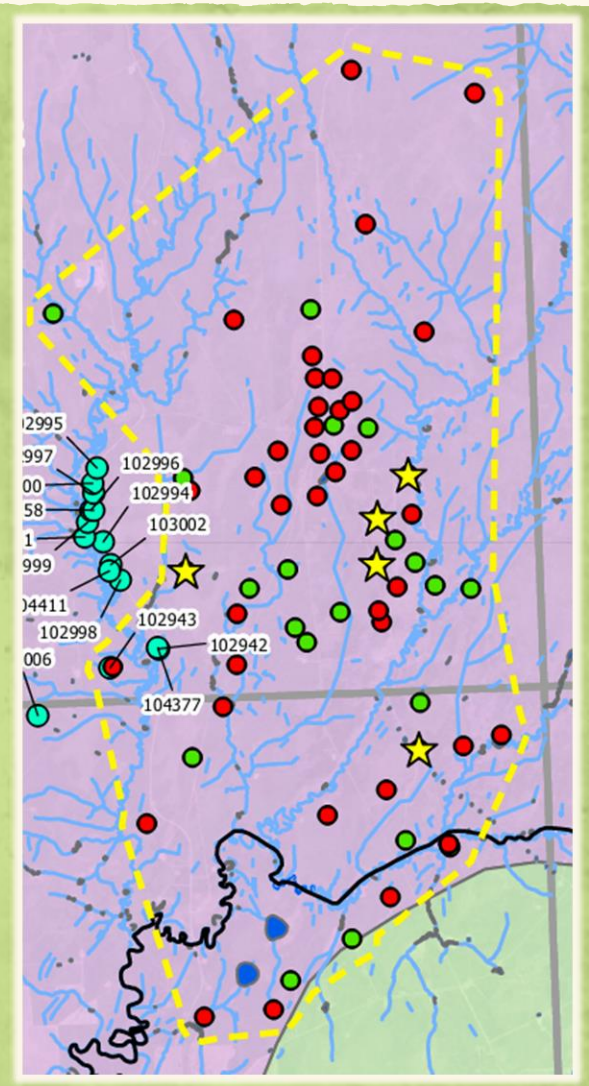
Site-specific Factors	C_e µg/L	C_{gw} µg/L	C_2 µg/L	C_L µg/L	C_s µg/g	C_s µg/g
Groundwater used for drinking water	6.00E+03					
Groundwater flow to surface water used by aquatic life						
freshwater						
marine and/or estuarine						
any aquatic receiving environment						
Groundwater used for livestock watering						
Groundwater used for irrigation						

Site Details

Site ID	<site ID>
Site Address	<site address>
User Name	<user name>
User Organization	<user organization>

Groundwater Evaluation

- Of the 24 sites, 11 sites (25 wells) were identified with water
- Only 11 wells had enough water column to perform hydrogeological assessments across 5 sites.
- The remaining 60 wells were dry, all drilled 3.0 m below the deepest known impact at the sites to a maximum depth of 10.5 m below grade.
- Lack of water in the wells were due to no water present within 3.0 m below contamination, shallow bedrock crops, and very slow recharge.



Regional Drinking Water Pathway Elimination

- Internal and external discussion resulting in proposing to develop a rationale and to seek approval from the regulator to eliminate the regional drinking water pathway for all sites
- There were no domestic use water users in the area to support this approach
- This was something new to us but were aware of this approach being used historically and being accepted with similar data gaps and rationale.

REJECTED

Justification

- BCER would not approve a blanket elimination of the drinking water pathway at a regional level and would only approve site specific removal
- We did not inquire further and suspect the decision was administrative in nature
- A small portion of the project area was within a mapped aquifer area with domestic water users
- Had the proposal been approved, 4 sites would have been removed from remediation requirements and impact volumes from 30 sites would have significantly been reduced

Next Approach

Additional ways landfill volumes were reduced included:

1. Utilizing BCER Protocol 4 – Establishing Local Background Concentrations in Soil

   Using Regional background metals guidelines for comparison and creating program background metals guidelines for comparison using statistical analysis outlined in the Protocol.

Background Metals Statistical Summary

	pH	Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Soluble Barium[3] (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)[4]	Chromium (Cr) - Total	Cobalt (Co)	Copper (Cu)[4]	Iron (Fe)	Lead (Pb)[4]	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)[4]	Selenium (Se)	Silver (Ag)	Thallium (Tl)	Tin (Sn)	Uranium (U)	Vanadium (V)	Zinc (Zn)[4]
Average	4.96	11363	1	15	288	57	0.8	6	0.6	25	11	30	26496	13	165	0.5	2	30	1.1	0.5	0.5	1	2	46	105
Maximum Value	9.45	22000	4	39	926	57	2.4	14	6.8	50	36	67	64900	31	1180	0.5	11	156	4.3	0.6	0.5	4	5	115	319
95th Percentile	6.95	16345	1	22	450	57	1.3	11	1.0	37	19	42	35850	20	426	0.5	3	55	1.5	0.5	0.5	1	3	72	160

Substance	Region 1 Vancouver Island	Region 2 Lower Mainland	Metro Vancouver[7]	Region 3/8 Thompson/Nicola/ Okanagan	Region 4 Kootenay[8]	Region 5 Cariboo	Region 6 Skeena	Region 7 Omineca/ Peace
aluminium	55 000	35 000	35 000	30 000	25 000	25 000	40 000	40 000
antimony	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
arsenic	(4)	8.5	8.5	15	(4)	10	10	10
barium	250	150	90	200	350	250	300	300
beryllium	0.7	0.7	0.7	0.5	0.8	0.3	0.6	1
boron	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
cadmium	0.95	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)
chromium[5]	65	55	50	70	35	100	40	50
cobalt	30	15	15	20	15	20	15	25
copper	100	75	150	75	35	60	50	70
iron	70 000	30 000	30 000	30 000	30 000	30 000	30 000	40 000
lead	40	200	300	15	120	15	20	25
manganese	5 000	900	1 000	1 000	2 000	850	1 500	1 500
mercury[6]	0.15	0.3	0.35	0.075	0.085	0.09	0.15	0.09
molybdenum	(1)	4	6	2	(1)	(1)	3	3
nickel	50	75	40	85	50	200	40	60
selenium	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
silver	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
strontium	100	60	55	250	150	250	100	70
sulfur	1 000	2 000	3 000	550	950	800	2 500	450
tin	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
vanadium	200	80	75	85	40	75	85	95
zinc	150	100	90	100	200	85	150	150

Next Approach

2. Analyzing parameters that would aid with site specific standards during the Stage 2 Phase (i.e. foc with organics, etc.)
3. Resampled 8 sites with analytes that exceeded for volatiles or were anomalous which removed 6 sites from requiring remedial work.
    1. This included metals, polycyclic aromatic hydrocarbons (PAHs) or petroleum hydrocarbon (PHC) parameters.
    2. Re-analyzed mineral and organic soils separately.
4. Completed additional groundwater monitoring and hydrogeological assessments, removed an additional 3 sites.
5. Using professional justification, an additional 8 sites were removed.

- In total an additional 17 sites were removed from remediation obligations. Leaving the total number of sites to 38.

Summary

- A total of approx. 32,000 m^3 for landfill is now reduced to 19,500 m^3 additional analyses, desktop review and professional justifications.
- Utilizing Protocol 3 – Blending, Mixing or Diluting as a Remediation Approach. Soils were excavated and aerated to aid in natural degradation of organic impacts. Stockpiled soil was sampled after a predetermined amount of time and any impacts still in excess were transported offsite for disposal.
- The total volume transported to landfill was approximately 11,500 m^3 (640 truck loads).

Summary

- Overall, approximately 19,500 m^3 was diverted from landfill (i.e. 1,085 truckloads)
- Essentially 64,500 L of fuel not required or roughly 175 tons CO_2
- Over 90% of the sites were able to meet BC regulatory requirements and were restored within 2 years. The remaining sites are still in progress.

Lessons Learned and Recommendations

- Know and use the regulations and the guidance material to aid with justifications
- Engage with the regulator at various stages throughout a program
- Fully analyze site details and minimize site visits
- Reassessing anomalies and treating residuals
- Look at the full closure plan for a site to integrate remediation and reclamation plans

Lessons Learned and Recommendations

- Discussion with BCER on averaging borehole analytes for Drilling Waste Disposal Areas
- Biodegradation for residual organic concentrations with amendments
- Discussion with regulator for dormancy timelines
- Start Winter Area Based Closure Projects Mid/Late November as instead of the fiscal year

Thank you!

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