Remediation of Bromacil and Dicamba-Impacted Groundwater

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remediation technologies symposium

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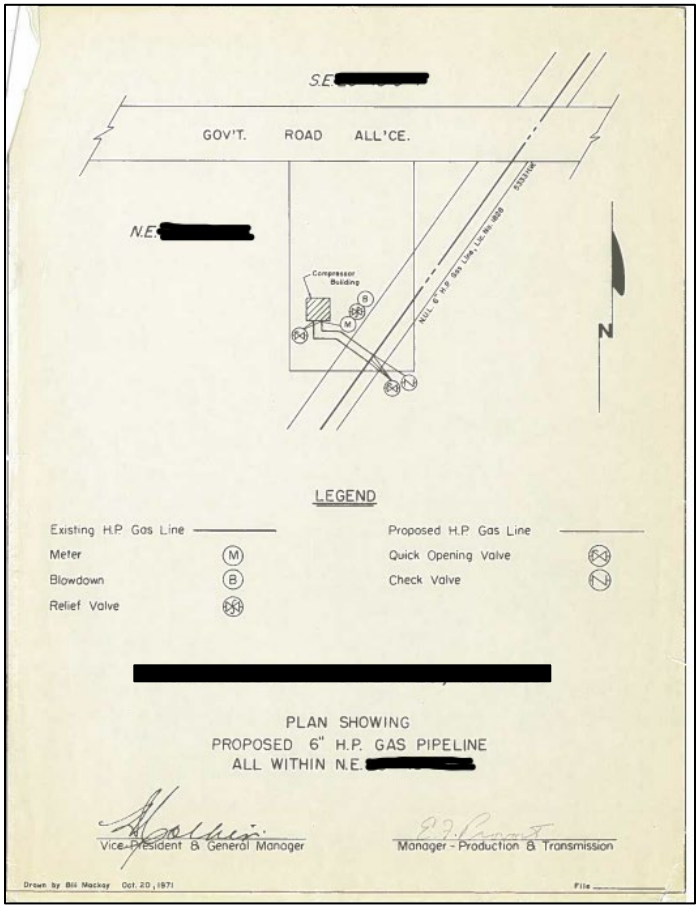
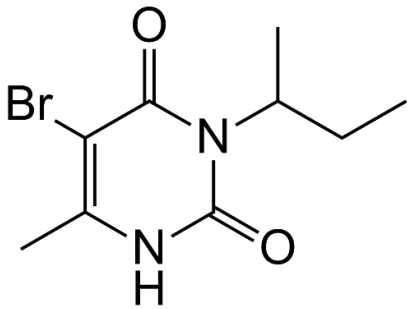
Outline

- Background on Bromacil and Dicamba
- Site History
- Guideline Criteria Selection
- Assessment History
- Remediation Options
- In-Situ Chemical Oxidation
- Groundwater Recovery and Treatment
- Results
- Lessons Learned
- Sustainability Features



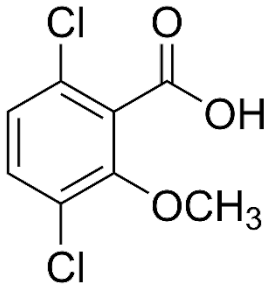
Background on Bromacil

- Bromacil was first registered in 1963 and its typical trade name was Hyvar®. Non-selective long term residual herbicide.
- Persistence – High (soil half-life between 14 and 1494 days)
- Mobility – High (Due to high half-life, low soil adsorption coefficient and high water solubility value)
- Degradation – primarily microbial, which is dependant on availability of microbial population
- Occurrence – most likely to reside in pore or groundwater, unless organic content in soil is high



Background on Dicamba

- Dicamba was first registered in 1964 and its typical trade name was Banvel®. Selective long term residual herbicide.
- Pesistence – Low (half-life of Dicamba in soil ranges from 4 to 555 days, with the average half-life of 25 days. Water = <7 days)
- Mobility – High (high solubility in water and low soil adsorption coefficient)
- Degradation - primarily microbial, which is dependant on availability of microbial population
- Occurrence - most likely to reside in pore or groundwater, unless organic content in soil is high or pH is between 4 and 6.



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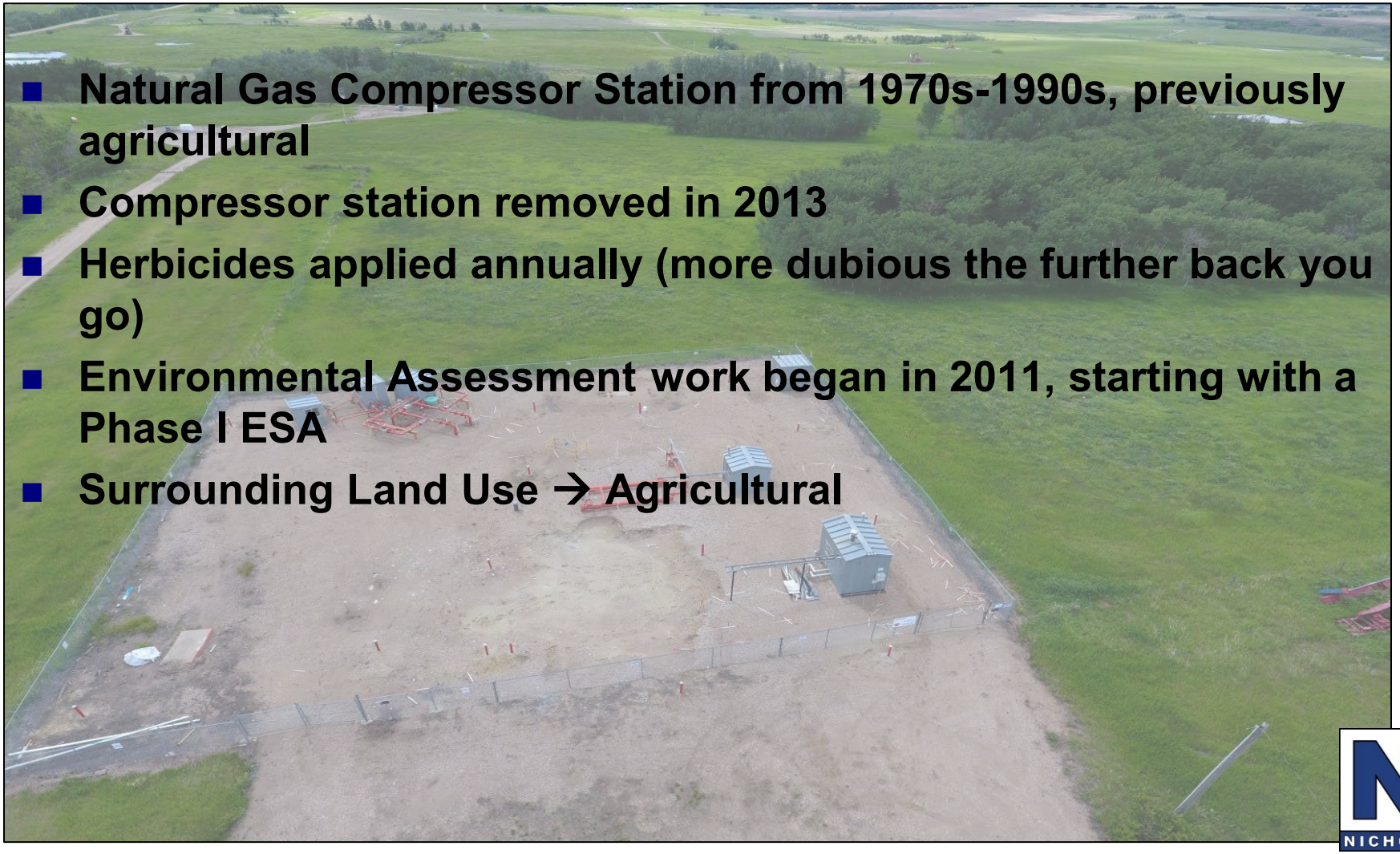
Site History



- Natural Gas Compressor Station from 1970s-1990s, previously agricultural
- Compressor station removed in 2013
- Herbicides applied annually (more dubious the further back you go)
- Environmental Assessment work began in 2011, starting with a Phase I ESA
- Surrounding Land Use → Agricultural

Guideline Criteria Selection

- End land use is Agricultural
- Coarse-grained soils
- Most sensitive receptor is irrigation (cannot exclude)

		Potable Water	Ecological Contact	Irrigation	Livestock Watering	Aquatic Life
Bromacil	SK	0.95	0.3	0.0002	1.1	0.005
	AB	0.95	0.3	0.0002	1.1	0.005
Dicamba	SK	0.12	--	0.0000006	0.12	0.01
	AB	0.009	--	0.000008	0.12	0.0061

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Assessment History

- Phase I ESA – 2011
- Phase II ESA – 2011
- Delineation Drilling and GW – 2012
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- Chemical Oxidation Program and GW Monitoring – 2014/2015
- Carbon Treatment Pilot Study – 2015
- Recovery Well Installation and Pumping Test – 2016
- Groundwater Monitoring Program – 2017
- Groundwater Monitoring Program -2017
- Groundwater Recovery and Treatment Program – 2019/2020

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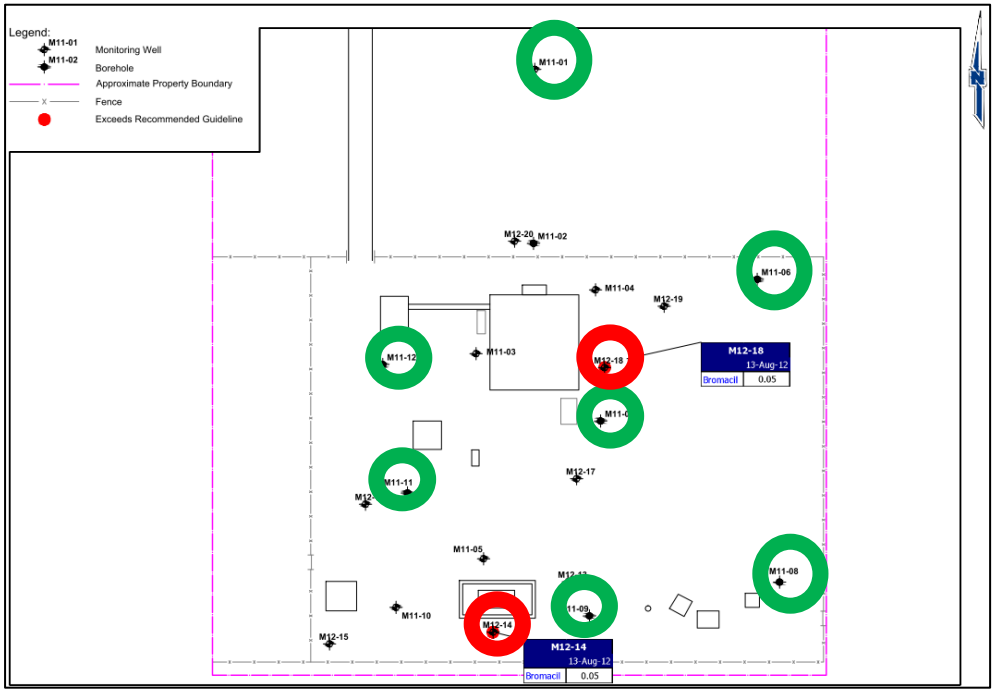
Phase I ESA (2011)

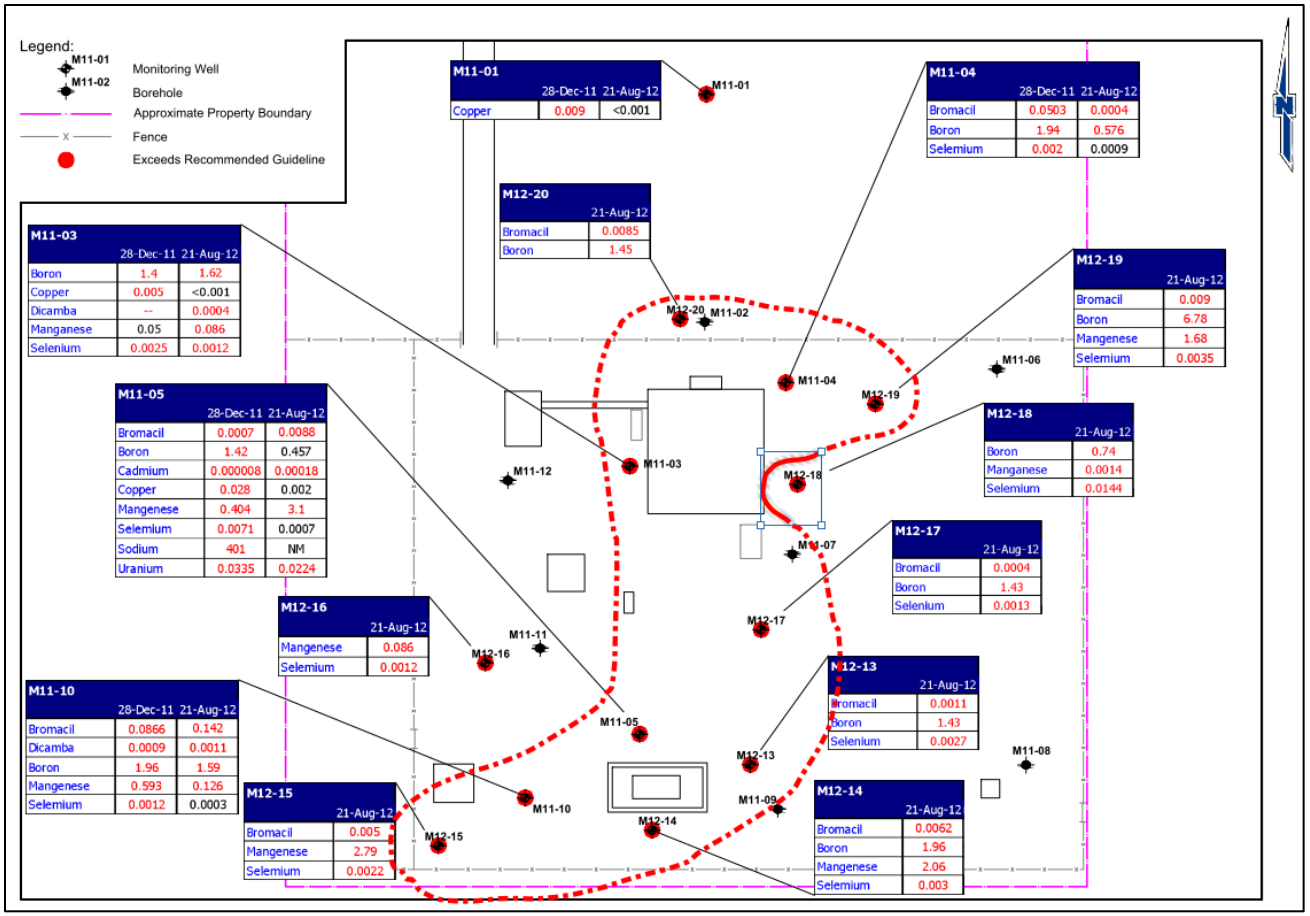
- APECs identified:
  - Condensate Tank
  - Compressor Building
  - Waste Storage (East side of Site)
  - Low areas across Site
  - Metering Building
- COPCs identified:
  - Petroleum hydrocarbons
  - Herbicides and sterilants
  - Metals (especially Mercury)

Phase II ESA/Delineation Soil Results (2011/2012)

- Phase II ESA (2011): submitted samples between surface and 1.5 mbg for herbicides and sterilants.
- All results < laboratory MDL
- MDL > guideline.
- Delineation (2012) results reported two bromacil exceedances at 0.30-0.45 mbg and at 3.1 mbg.
- Challenges with variable depths/locations of impacts on site, laboratory detection limits in 2011, cost of analysis and field detection capabilities.



Phase II ESA/Delineation and Groundwater Results (2011/2012)



Difficulty achieving delineation with two drilling events.

Bromacil impacts likely extended off-site to south and southwest.

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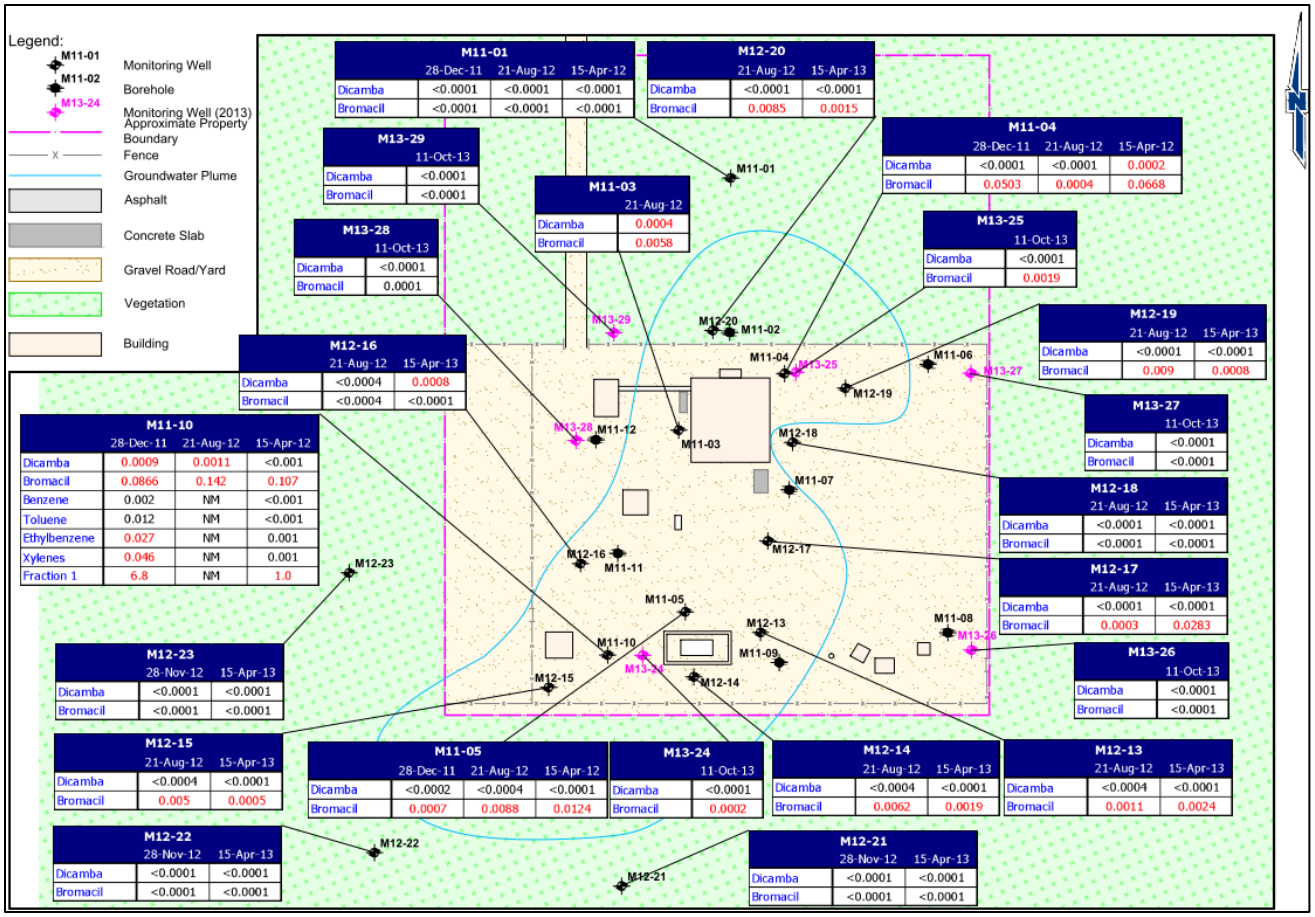
Delineation and Groundwater Results (2013)



Vertical and horizontal delineation achieved (plume defined).

Impacts do extend offsite to S/SW (flow direction).

Challenges with achieving low enough detection limit for Dicamba.

Site Decommissioned (2013-2017)

Remediation Options

Remediation Option	Outcome
Mechanical Excavation	Too deep and primarily in groundwater
Bioremediation	Effective for impacted surface soils primarily
Phytoremediation	Effective for impacted surface soils primarily
Low-Temperature Thermal Desorption and Incineration	Effective for impacted soils and groundwater, need to worry about capturing combustion emissions. Costly
In-Situ Chemical Oxidation	In-Situ treatment of organic-based sterilants in groundwater with an oxidizer
Groundwater Recovery	Recover water in-situ, treat through granular activated carbon, and reinject back into formaton

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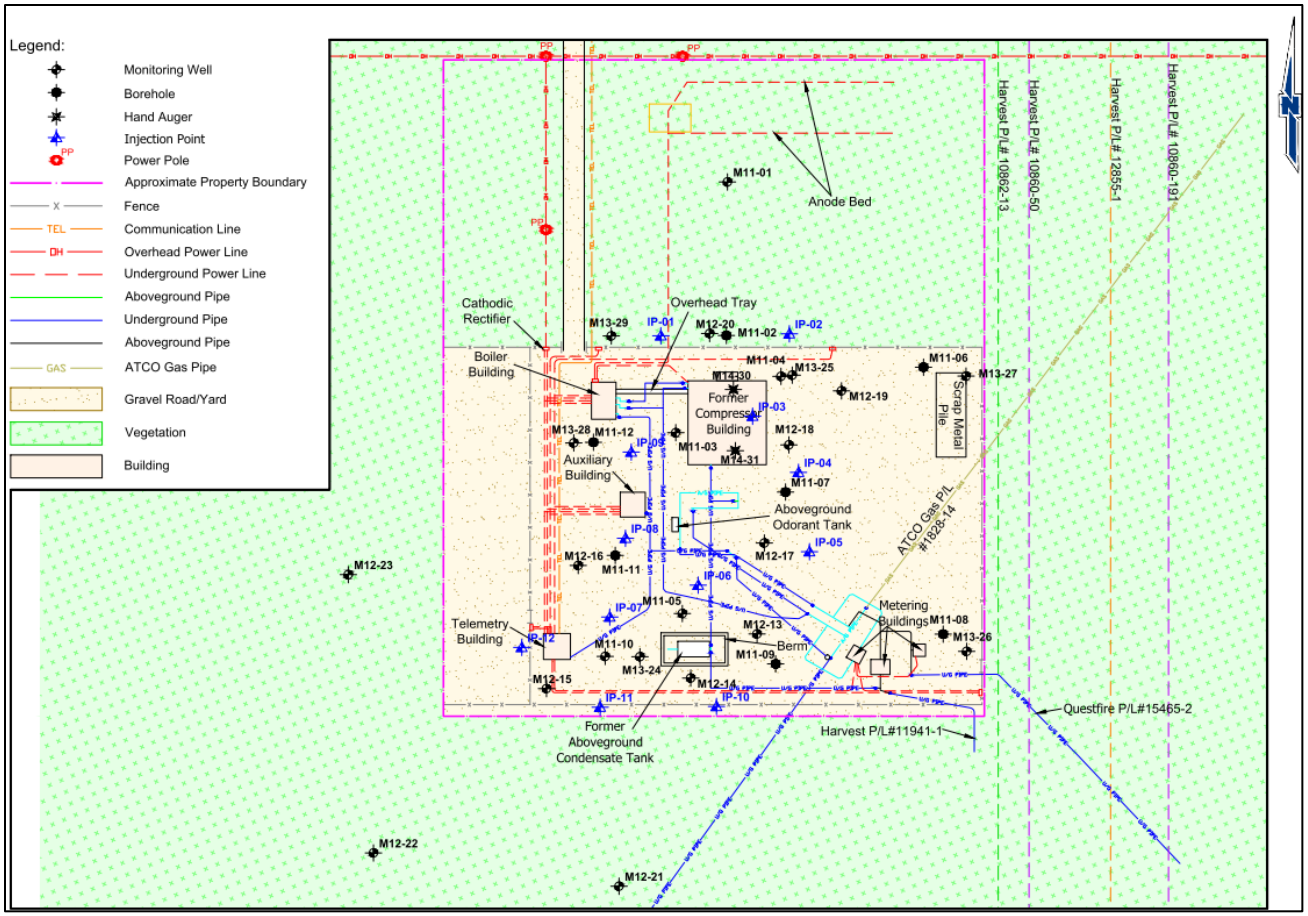
Chemical Oxidation and Groundwater Sampling Results (2014/2015)



Chemical injection was recommended given historical success with other organic sterilants and favorable bench study.

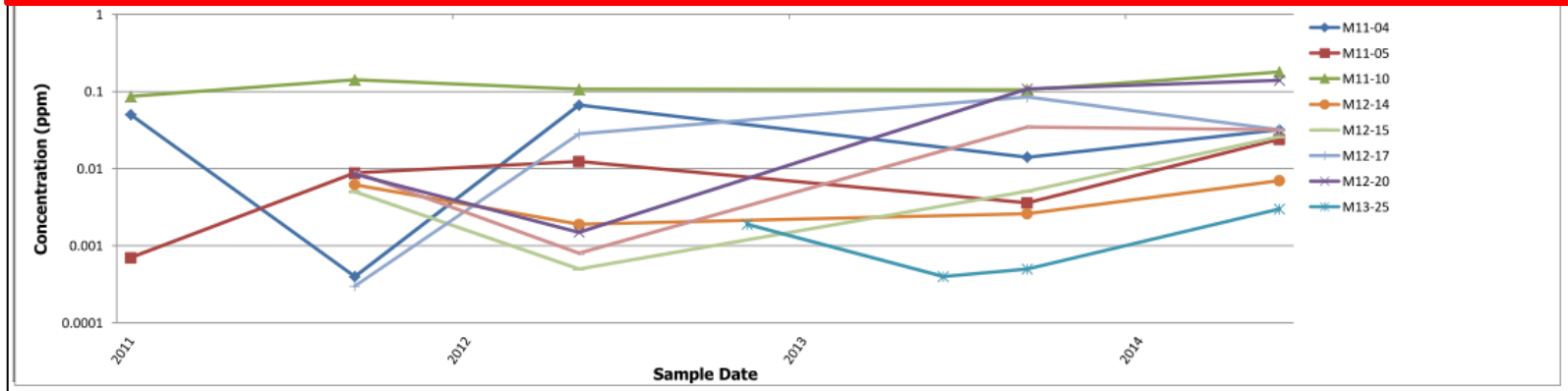
Sodium Persulphate injected at 12 pts over three events.

Above- and underground infrastructure limited amount and position of injection points.

Chemical Oxidation and Groundwater Sampling Results (2014/2015)

- First injection event occurred in May 2014
- Groundwater sampled August 2014 and May 2015
- (No trend change)

	Monitoring Well:	M11-04	M11-05	M11-10	M12-14	M12-15	M12-17	M12-19	M12-20	M13-25
Sampling Event	Sampling Date	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil
1	28-Dec-2011	0.0503	0.0007	0.0866						
2	21-Aug-2012	0.0004	0.0088	0.142	0.0062	0.005	0.0003	0.009	0.0085	
3	15-Apr-2013	0.0668	0.0124	0.107	0.0019	0.0005	0.0283	0.0008	0.0015	
4	11-Oct-2013									0.0019
5	21-May-2014									0.0004
6	12-Aug-2014	0.0141	0.0036	0.106	0.0026	0.0051	0.0852	0.0348	0.108	0.0005
7	11-May-2015	0.032	0.024	0.18	0.007	0.026	0.032	0.032	0.14	0.003
Mann-Kendall Statistic (S):		0	6	4	2	4	4	2	4	2
Confidence Factor		40.8%	88.3%	75.8%	62.5%	83.3%	83.3%	62.5%	83.3%	62.5%
Concentration Trend:		No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend



Linear trend analyses were performed based on the Mann-Kendall statistical method (Gilbert (1987), EPA (2009), and Connor et al. (2014)).
Values below the MDL were substituted with a value one-half of the historical low MDL.
Datasets with a high proportion of samples below MDL were defaulted to "No Trend."
(All concentrations in **mg/L = ppm**)

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Carbon Treatment Bench Study (2015)

- Extracted approximately 500-L of impacted water from the site and pushed through two drums containing granular activated carbon (GAC)

Bromacil

Pre-Treatment Concentration	Post-Treatment Concentration
0.025 ppm	<0.0001 ppm

- Move forward with a Groundwater Recovery and Treatment Design.
- Initial installation of a recovery well and completed a pump test.

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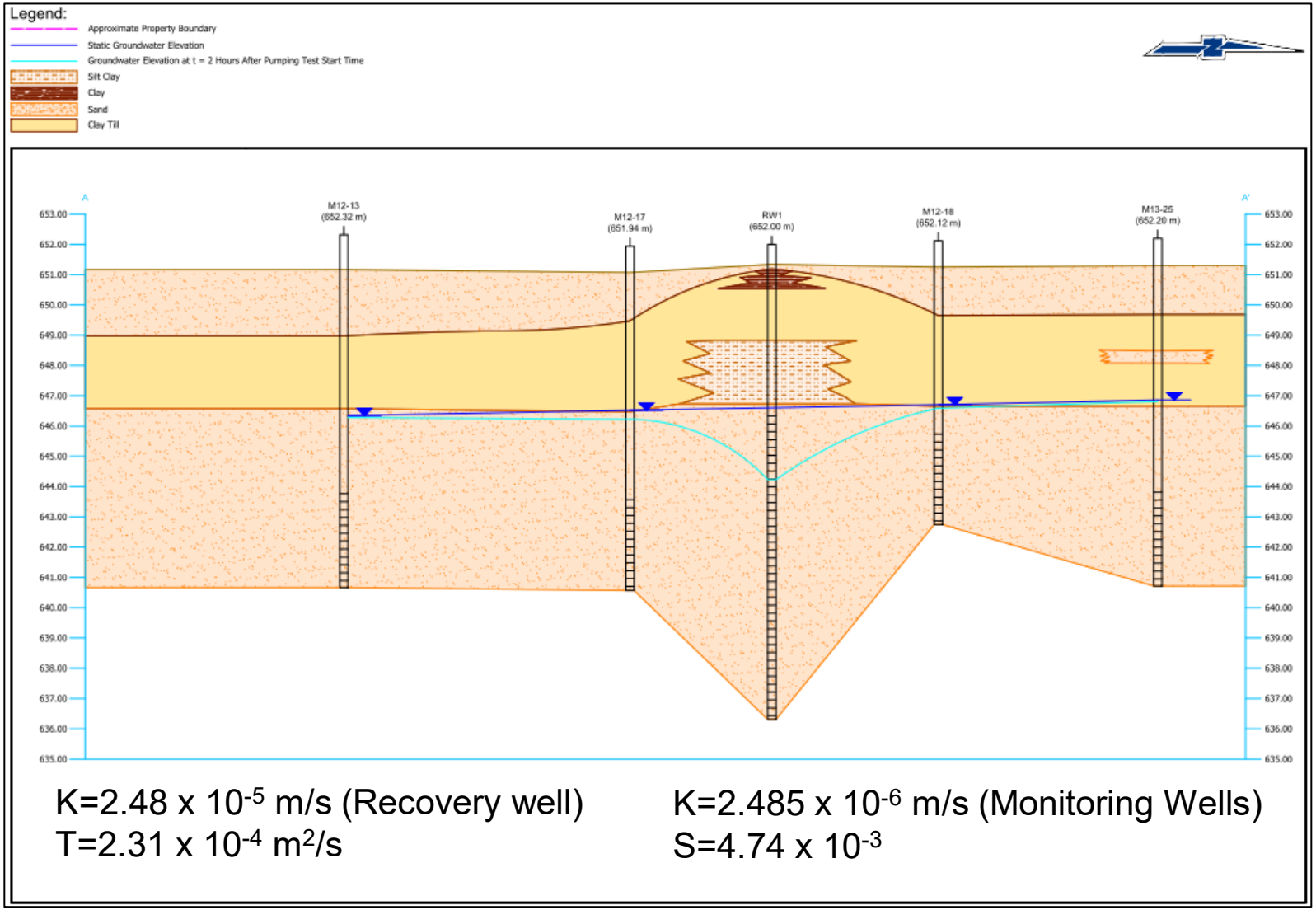
Recovery Well Installation and Pump Test (2016)

- Installed 254 mm diameter recovery well to 15 mbg
- Completed pump test following well development

Pump Test Results (2016)



$K=2.48 \times 10^{-5}$ m/s (Recovery well)
$T=2.31 \times 10^{-4}$ m^2/s

$K=2.485 \times 10^{-6}$ m/s (Monitoring Wells)
$S=4.74 \times 10^{-3}$

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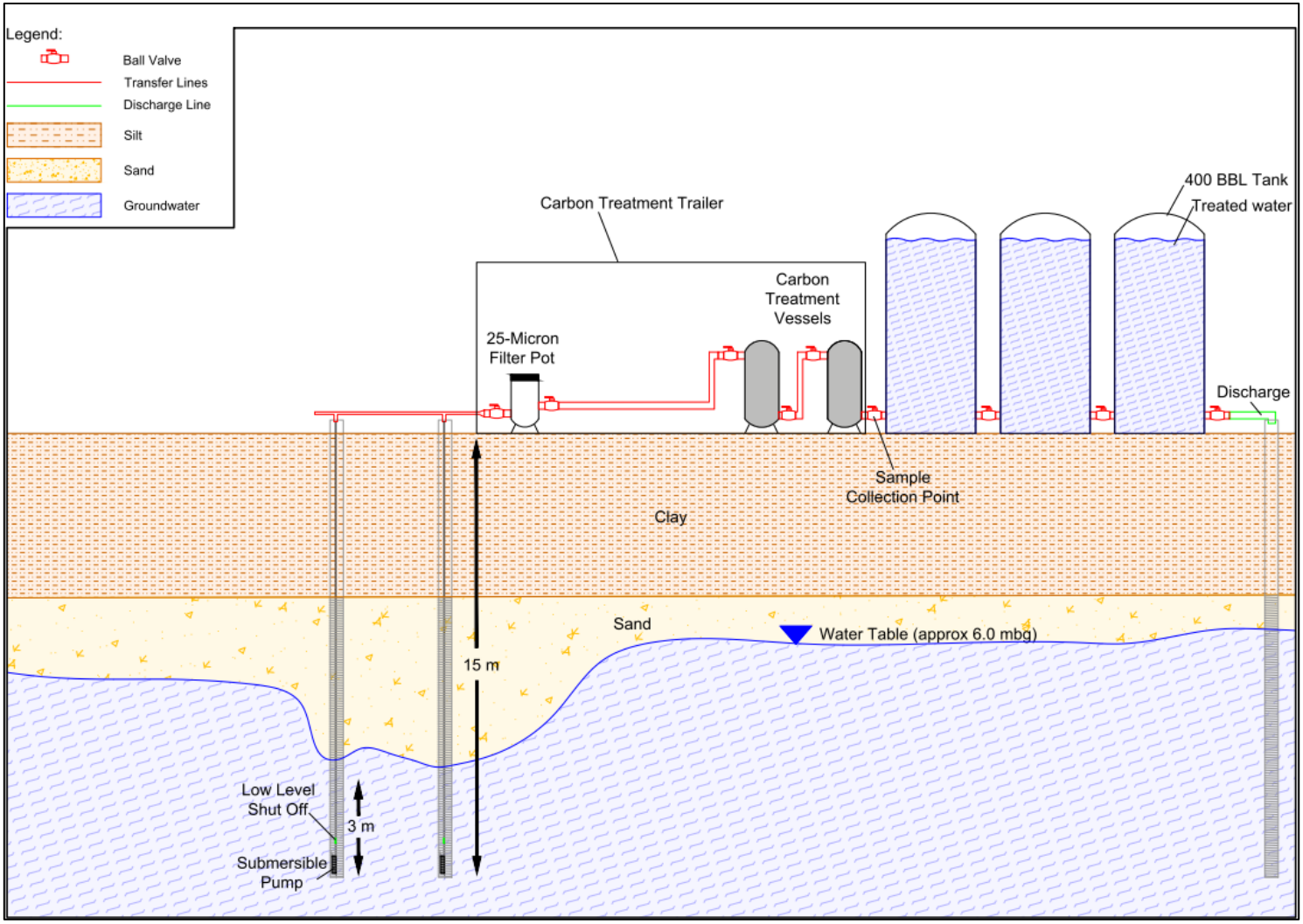
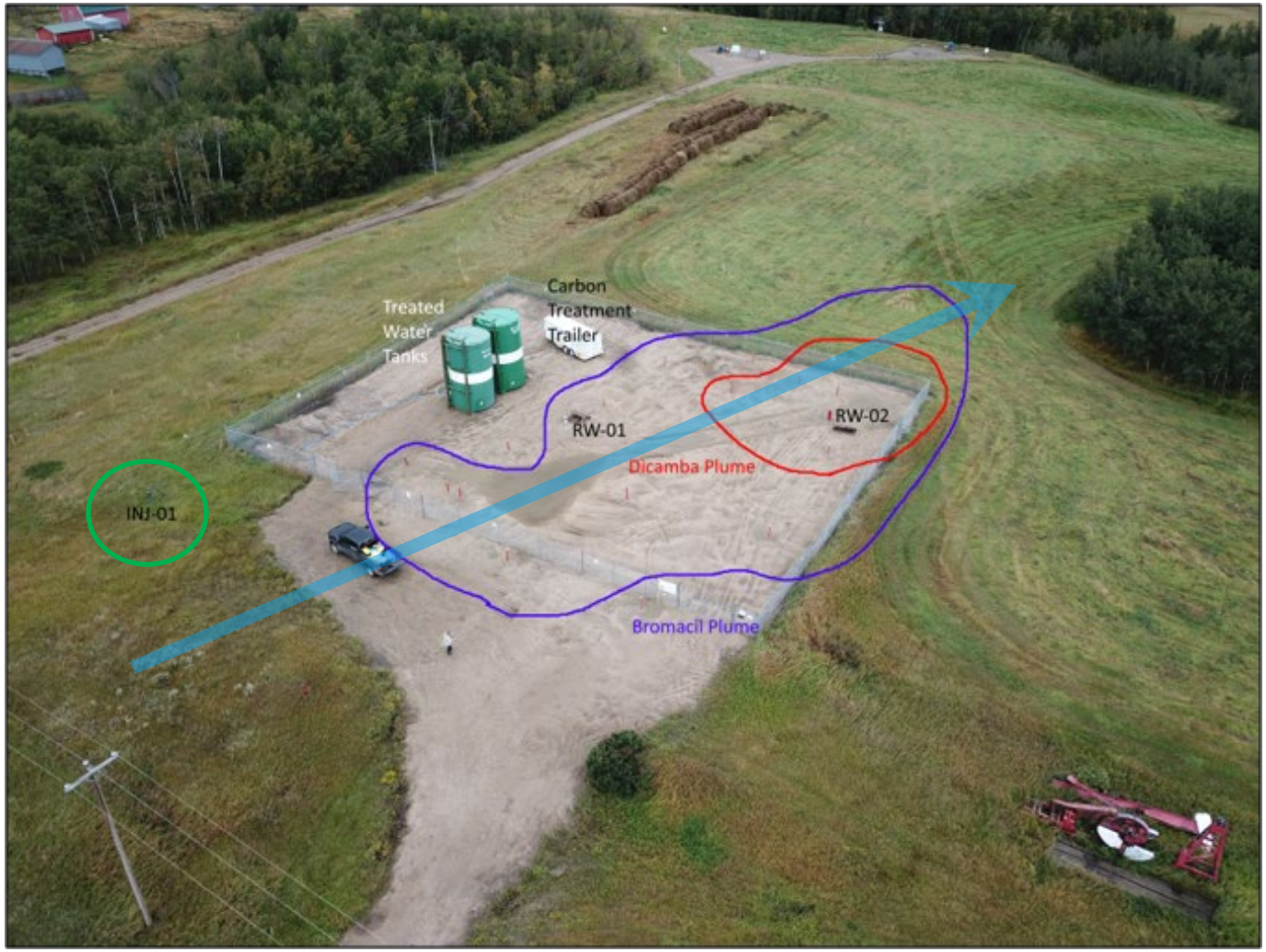
Pump Test Results (2016)

- System design driver…especially for pump selection and pumping rate.
- Results indicate there is lots of water and it flows into the well quickly.
- Not worried about over pumping the well, given treatment capacity of GAC system.

Recovery and Treatment Design (2016)



Recovery and Treatment Design (2016)



Results (Bromacil - 2019)

- Recovered and treated ~230,000 L of impacted groundwater between May and September of 2019
- Groundwater sampling in November 2019
- Trend Analysis shows:

	Monitoring Well:	M11-04	M11-05	M11-10	M12-13	M12-14	M12-15	M12-17	M12-19	M12-20	M13-25
Sampling Event	Sampling Date	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil
1	28-Dec-2011	0.0503	0.0007	0.0866							
2	21-Aug-2012	0.0004	0.0088	0.142	0.0011	0.0062	0.005	0.0003	0.009	0.0085	
3	15-Apr-2013	0.0668	0.0124	0.107	0.0024	0.0019	0.0005	0.0283	0.0008	0.0015	
4	11-Oct-2013										0.0019
5	21-May-2014										0.0004
6	12-Aug-2014	0.0141	0.0036	0.106		0.0026	0.0051	0.0852	0.0348	0.108	0.0005
7	11-May-2015	0.032	0.024	0.18	0.002	0.007	0.026	0.032	0.032	0.14	0.003
8	6-Oct-2016	0.028						0.091			
9	5-Jun-2017	0.028	0.02	0.16	0.057	0.027	0.0094	0.17	0.016	0.079	0.0059
10	7-Nov-2019	0.075	0.0143	0.0707	0.0118	0.0455	0.00176	0.116	0.0133	0.00046	0.0059
Mann-Kendall Statistic (S):		5	11	1	6	11	3	17	1	-1	10
Confidence Factor		76.5%	97.2%	50.0%	88.3%	97.2%	64.0%	>99.9%	50.0%	50.0%	95.2%
Concentration Trend:		No Trend	Increasing	No Trend	No Trend	Increasing	No Trend	Increasing	No Trend	No Trend	Increasing

- Even though increasing trends are appearing in some monitoring wells, this is good news as there was no trending in 2015.
- Indicative of plume movement/contaminant mobilization.
- Increase opportunity for recovery and treatment of contaminants.

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Results (Bromacil - 2020)

- Recovered and treated ~160,000 L of impacted groundwater between June and September of 2020
- Groundwater sampling in September 2020
- Trend Analysis shows:

	Monitoring Well:	M11-03	M11-04	M11-05	M11-10	M12-13	M12-14	M12-15	M12-17	M12-19	M12-20	M13-25	M13-28
Sampling Event	Sampling Date	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil	Bromacil
1	28-Dec-2011		0.0503	0.0007	0.0866								
2	21-Aug-2012	0.0058	0.0004	0.0088	0.142	0.0011	0.0062	0.005	0.0003	0.009	0.0085		
3	15-Apr-2013		0.0668	0.0124	0.107	0.0024	0.0019	0.0005	0.0283	0.0008	0.0015		
4	11-Oct-2013											0.0019	0.0001
5	21-May-2014											0.0004	
6	12-Aug-2014	0.0723	0.0141	0.0036	0.106		0.0026	0.0051	0.0852	0.0348	0.108	0.0005	0.0018
7	11-May-2015	0.13	0.032	0.024	0.18	0.002	0.007	0.026	0.032	0.032	0.14	0.003	0.009
8	6-Oct-2016		0.028						0.091				
9	5-Jun-2017	0.14	0.028	0.02	0.16	0.057	0.027	0.0094	0.17	0.016	0.079	0.0059	0.0096
10	7-Nov-2019	0.0311	0.075	0.0143	0.0707	0.0118	0.0455	0.00176	0.116	0.0133	0.00046	0.0059	0.0216
11	20-Sep-2020	0.0627	0.0229	0.0139	0.0736	0.0165	0.0194	0.006	0.126	0.0082	0.0498	0.0123	0.0087
Mann-Kendall Statistic (S):		3	1	12	-4	9	13	5	22	-3	-1	16	9
Confidence Factor (CF):		67.5%	50.0%	98.2%	69.0%	97.5%	99.2%	76.5%	>99.9%	64.0%	50.0%	>99.9%	97.5%
Concentration Trend:		**No Trend**	**No Trend**	**Increasing**	**No Trend**	**Increasing**	**Increasing**	**No Trend**	**Increasing**	**No Trend**	**No Trend**	**Increasing**	**Increasing**

- Continued plume movement/contaminant mobilization.
- Some additional wells now have enough data sets for trending.
- Increase opportunity for recovery and treatment of contaminants.

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Results (Dicamba - 2020)

- Recovered and treated ~160,000 L of impacted groundwater between June and September of 2020
- Groundwater sampling in September 2020
- Trend Analysis shows:

	Monitoring Well:	M11-05	M11-10	M12-14	M12-15	M12-16
Sampling Event	Sampling Date	Dicamba	Dicamba	Dicamba	Dicamba	Dicamba
1	28-Dec-2011		0.0009			
2	21-Aug-2012		0.0011			
3	15-Apr-2013					0.0008
4	12-Aug-2014	0.000019	0.0011	0.000031	0.000013	0.00076
5	11-May-2015	0.000021	0.0003	0.000021	0.000021	0.000015
6	5-Jun-2017	0.000065	0.0015	0.00038		
7	7-Nov-2019	0.0000274	0.00188		0.000059	0.0000298
8	16-Sep-2020		0.00196	0.000163	0.000236	0.0000075
Mann-Kendall Statistic (S):		4	14	2	6	-8
Confidence Factor (CF):		83.3%	>99.9%	62.5%	95.8%	95.8%
Concentration Trend:		**No Trend**	**Increasing**	**No Trend**	**Increasing**	**Decreasing**

- Enough data sets in 2020 to complete trend analyses.

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Lessons Learned

- Extended turnaround time between groundwater recovery, sampling the treated water and discharging tanks/reinjecting treated water (turnaround time approximately 4 months)
- Some simple design changes could eliminate this extended turnaround time such as:
  - Double storage capacity on site (two being filled and two being discharged at the same time)
  - Additional solar panels to increase flow rate, decrease recovery time.
  - Potentially discharge treated water into highway ROW with regulatory approval.
  - Remote telemetry for real time monitoring and overall system optimization.

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Sustainability Features

Treated groundwater re-injected on-site providing savings on transportation and disposal transportation cost.

Keeps water within the same hydrological system and creates preferred hydraulic gradient, moving the plume to recovery wells.

Solar-powered pumping system provides low cost, renewable energy source.

Questions??


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SURVIVOR


Time traveler: What year is it?
Me: 2020
Time traveler:


@classicdadmoves
Zoom meetings with coworkers: Day 1
Zoom meetings with coworkers: Day 18


Lets see who's
really behind COVID-19


zoom
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