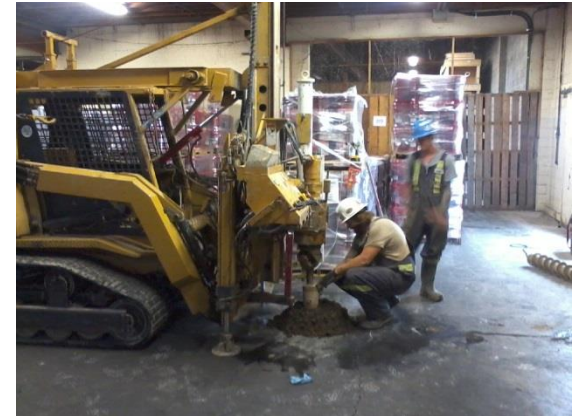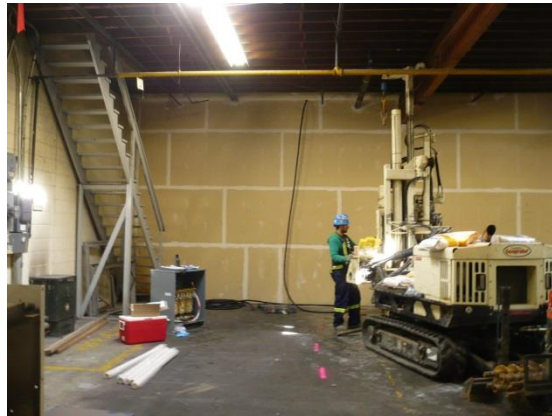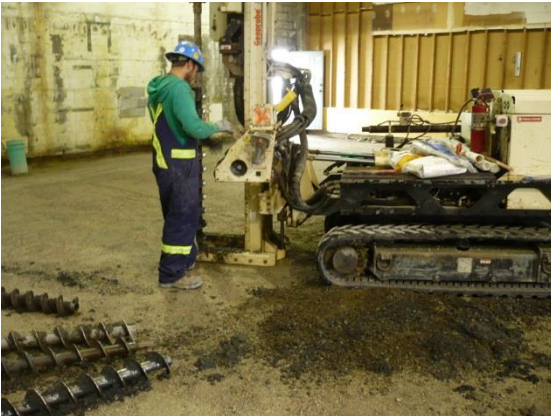# Determination of Local Background Concentrations in Groundwater at an Industrial Site

Dissolved Arsenic, Iron and Manganese

October 15, 2016

About the Presenter……

Tyler Joyce, C.Tech

Project Manager – Stantec Consulting

13 years experience in Contaminated Site Investigations.

•   British Columbia Institute of Technology, Environmental Engineering 2009 – 2010, Bachelor of Technology

•   British Columbia Institute of Technology, Chemical Sciences, 1999 – 2000, Certified Technician.

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Agenda

1. Site Background

2. BC Contaminated Site Regulations

3. Research and Literature Review

4. Field Data Supporting Protocol 9 Determination

5. Background Determination

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1. Site Background

History

- Light commercial multi-tenanted facility located in the lower mainland region of British Columbia

- Multiple areas of environmental concern to be investigated

- Potential for contamination in soil, groundwater and soil vapour to be present

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Site Investigation Locations

1. Site Background

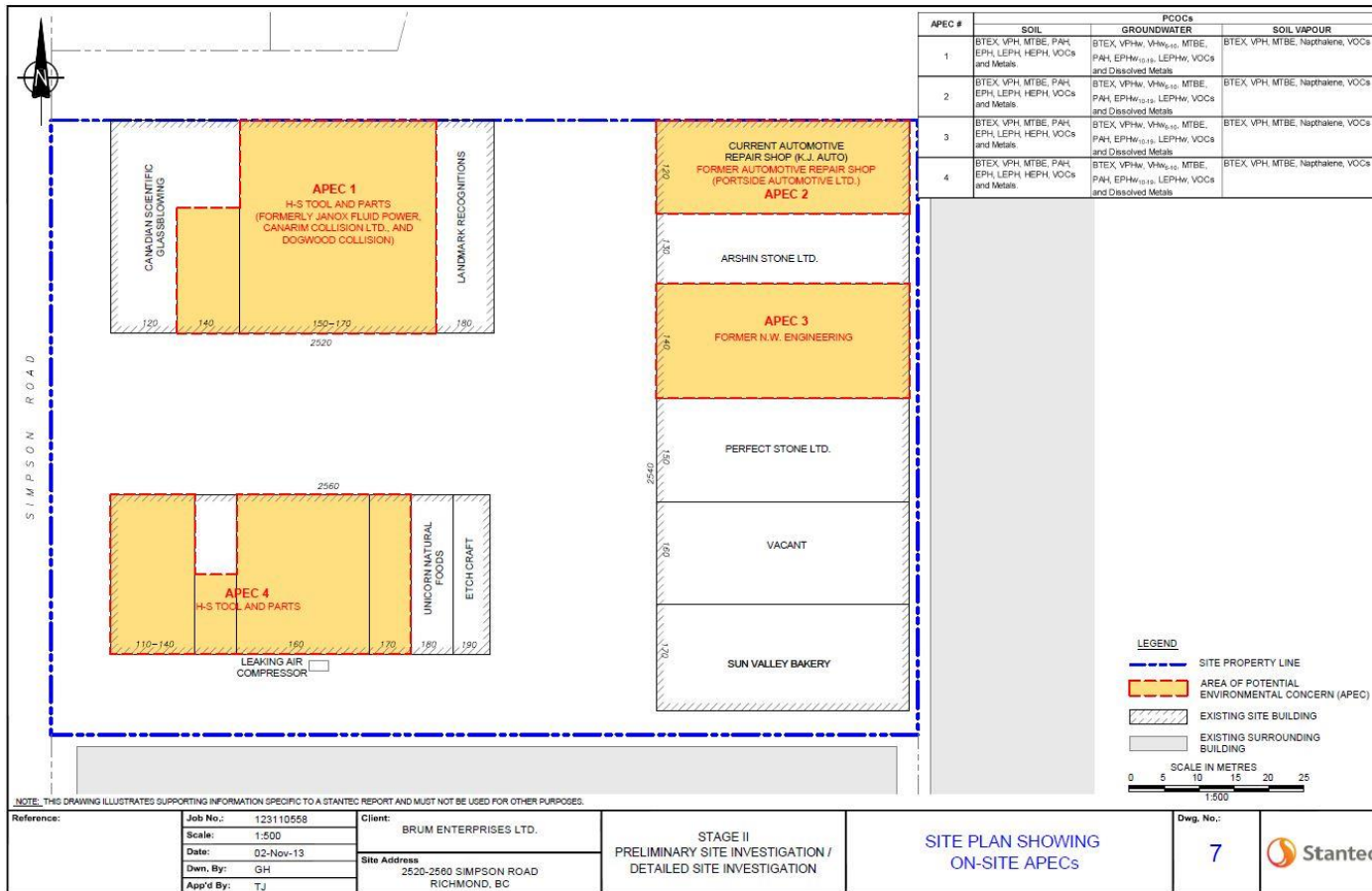**Environmental Investigations completed for the Site included:**

- Stage 1 Preliminary Site Investigation
- Stage 2 Preliminary Site Investigation
- Detailed Site Investigation
- Detailed Quantitative Human and Ecological Risk Assessment

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1. Site Background

Summary of Areas of Potential Environmental Concern

1. Site Background

Summary of Identified Groundwater Contamination
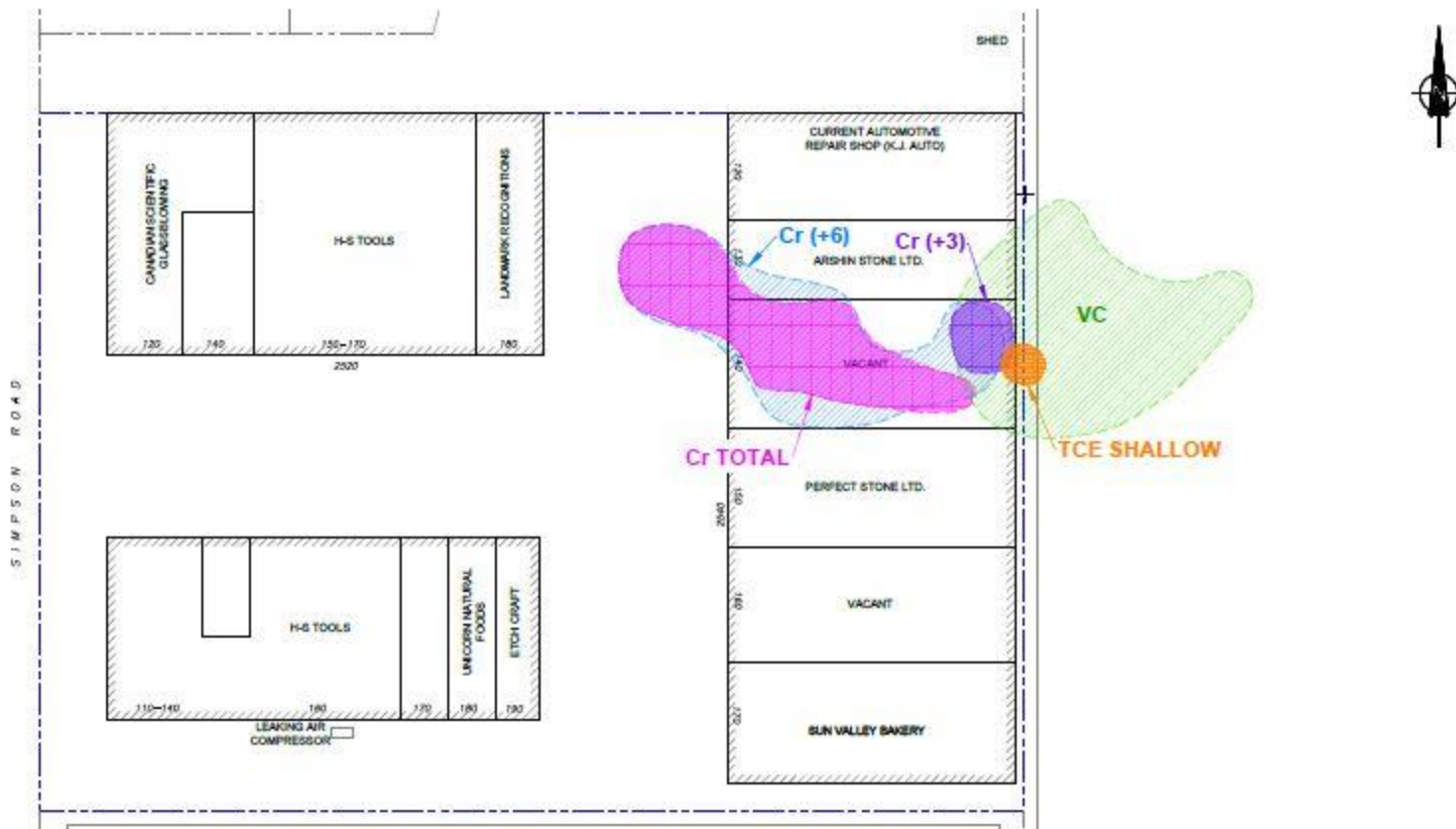
1. Site Background

Stage 2 PSI and Detailed Site Investigation Conceptual Site Model
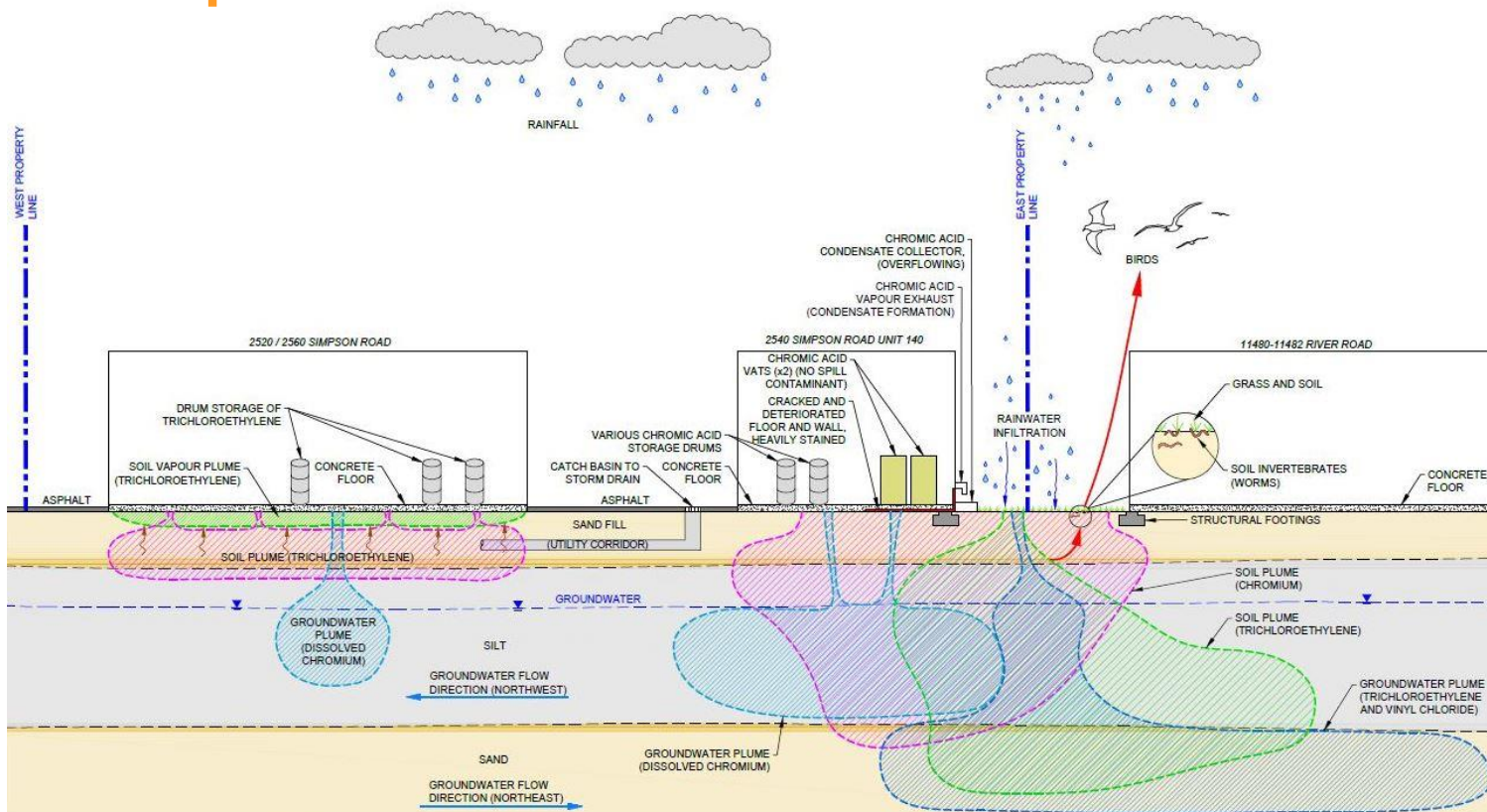
1. Site Background

- 🟢 GROUNDWATER SAMPLE CONCENTRATION IS LESS THAN THE APPLICABLE CSR STANDARDS FOR ALL PARAMETERS

- 🟠 GROUNDWATER SAMPLE CONCENTRATION IS GREATER THAN THE APPLICABLE CSR DRINKING WATER STANDARD FOR ONE OR MORE PARAMETERS SHOWN

NOTE: HIGHLIGHTING REFLECTS MOST RECENT GROUNDWATER SAMPLING EVENT

2. British Columbia Contaminated Site Regulations

- Documents are intended to provide stakeholders with support on navigating the CSR Regulations including:

  - Administrative, Technical and External Guidance documents

  - Protocols

  - Procedures
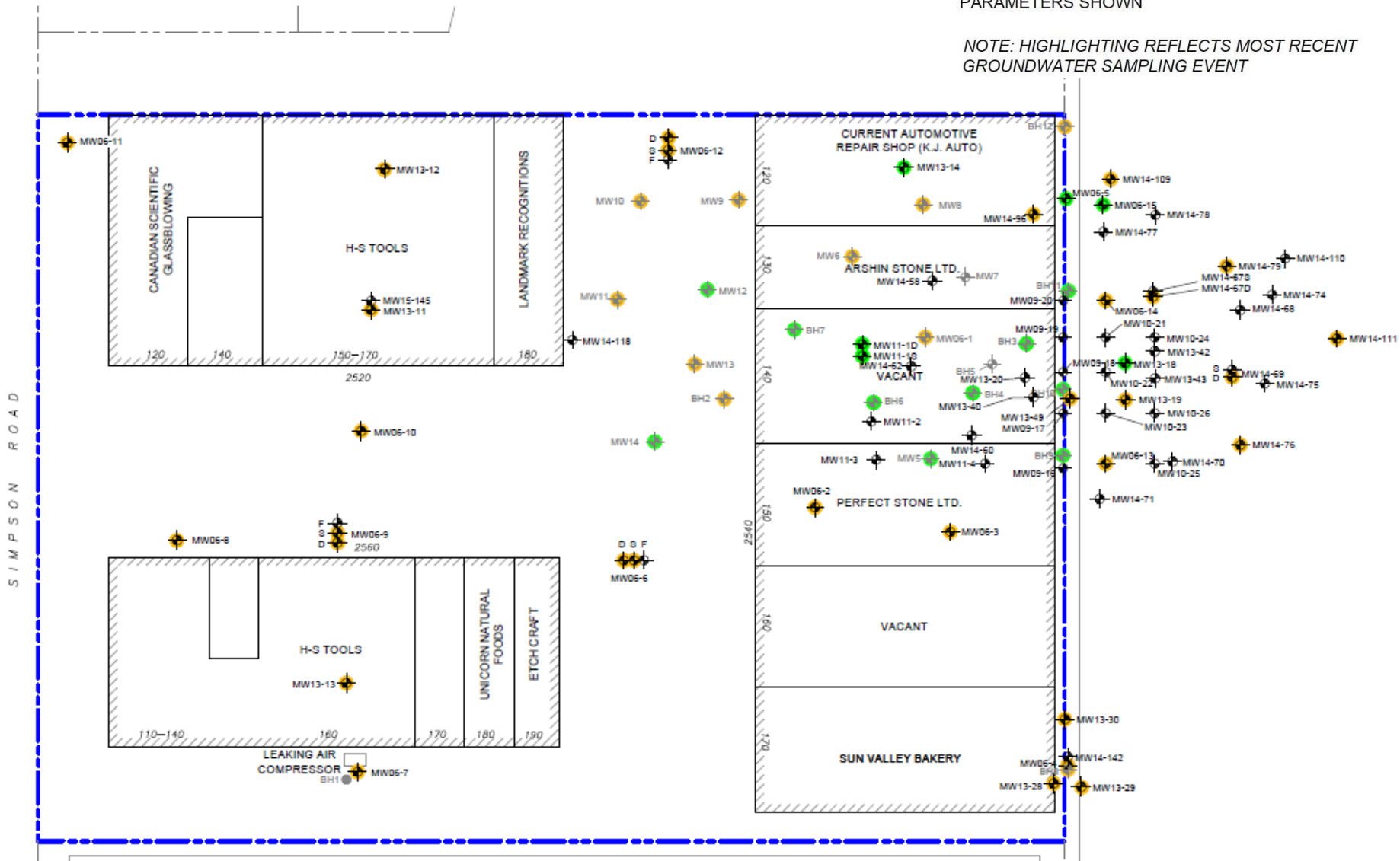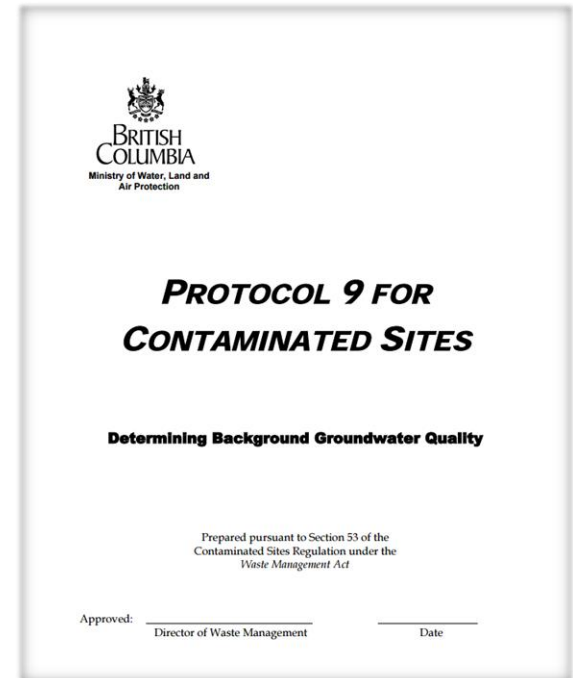

BRITISH COLUMBIA
Ministry of Water, Land and Air Protection

PROTOCOL 9 FOR CONTAMINATED SITES

Determining Background Groundwater Quality

Prepared pursuant to Section 53 of the
Contaminated Sites Regulation under the
Waste Management Act

Approved: _____   _____
Director of Waste Management   Date

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2. British Columbia Contaminated Site Regulations

- **Protocol 9: Determining Background Groundwater Quality**

  - Provides procedures to assist remediation at sites were local background concentration of substances are greater than the numerical standards.

  - Concentrations of a substance that occur naturally in a geographic area are considered representative of background conditions.

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2. British Columbia Contaminated Site Regulations

- **Protocol 9: Determining Background Groundwater Quality**
  - Minimum of 3 background wells are required
  - Background wells should be located in same geographical area and in the same groundwater flow system.
  - Background wells should not be located within the area of influence of contamination, they should be cross or up-gradient. On-Site wells can be used.
  - Background wells should be sampled at least twice to demonstrate temporal variability and to ensure a robust data set

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2. British Columbia Contaminated Site Regulations

- **Protocol 9: Determining Background Groundwater Quality cont'd**

  - Sampling strategy should account for season variability in groundwater conditions

  - Appropriate QA/QC measures should be taken to ensure data validation.

  - Where collective data fall within a single statistical population, the representative local background concentration is the 95th percentile concentration of the data set.

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3. Research & Literature Review

- Naturally occurring elevated Iron, Manganese and Arsenic in groundwater

- Geochemistry and its effect on metal concentrations in groundwater

- SABCS Conference of Contaminated Sites – 2012

- Core6 Environmental – Stephen Munzar

- UBC Hydrogeology – KIDD 2 Research Site, Richmond, BC – Roger Beckie

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3. Research Cont'd

Surficial Geology

- Deltaic sediments up to 300 m thick
- Made of three sets: deep marine clay, thick sands and silt and clays and silts at base intermittent with organic overbank silts and bog (peat)
- Delta contains high organic matter

3. Research Cont'd

Geochemistry

- Sources of Fe, Mn and As

- Dominant species in groundwater

- Aqueous mobility / Solubility Controls

Mechanism of Fe, Mn and As Release into Groundwater

- Natural release cause by reductive dissolution

- Fraser river contains abundant organic matter and Fe & Mn

3. Research Cont'd

Mechanism of Fe, Mn and As Release into Groundwater

- Arsenic bound/absorbed to Fe and Mn oxide coatings

- Organic matter consumes O_2 producing anaerobic conditions

- Fe/Mn oxide coatings dissolve releasing absorbed As.

- **Result**: groundwater with naturally elevated Fe, Mn and As.

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3. Research Cont'd

Mechanism of Fe, Mn and As Release into Groundwater

RESULT = High Dissolved Fe, Mn and As in groundwater
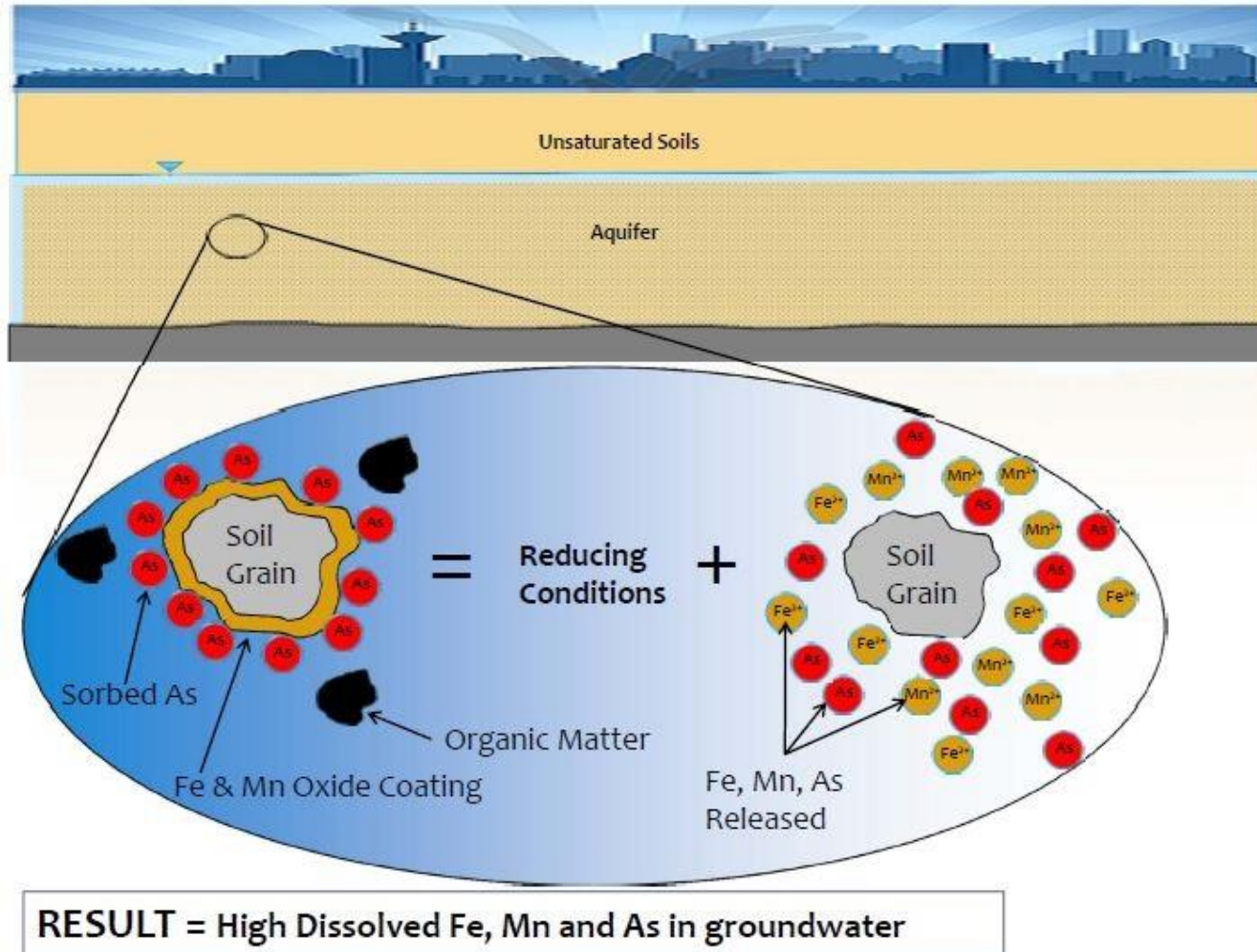
3. Field Data

Soil Stratigraphy

- Presence of organic material in soils (FOC ranged from 3 – 8% g/g)

- Greater amount present in the silt than in the sand layer

- Geology encountered included Fraser River Delta sands overlain by silt with trace amounts of organics

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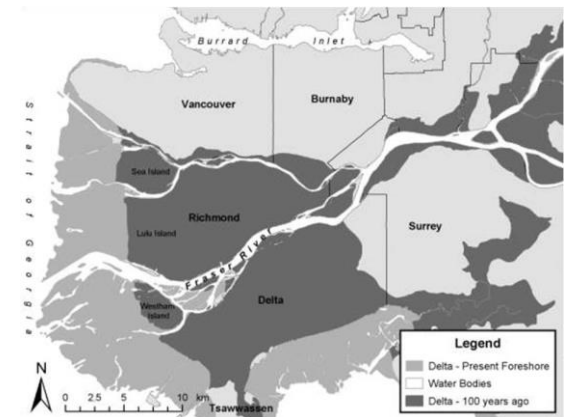
4. Field Data

Hydrogeology

- Tidally influenced groundwater system
- Two distinct hydro geologic zones
- Completed a complex hydrogeology monitoring program
- Groundwater flow direction determined to be northwest in silt
- Groundwater flow direction determined to be northeast in sand

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4. Field Data
Hydrogeology

Groundwater Contour – Shallow Silt Aquifer

4. Field Data

Hydrogeology
Groundwater Contour – Deep Sand Aquifer
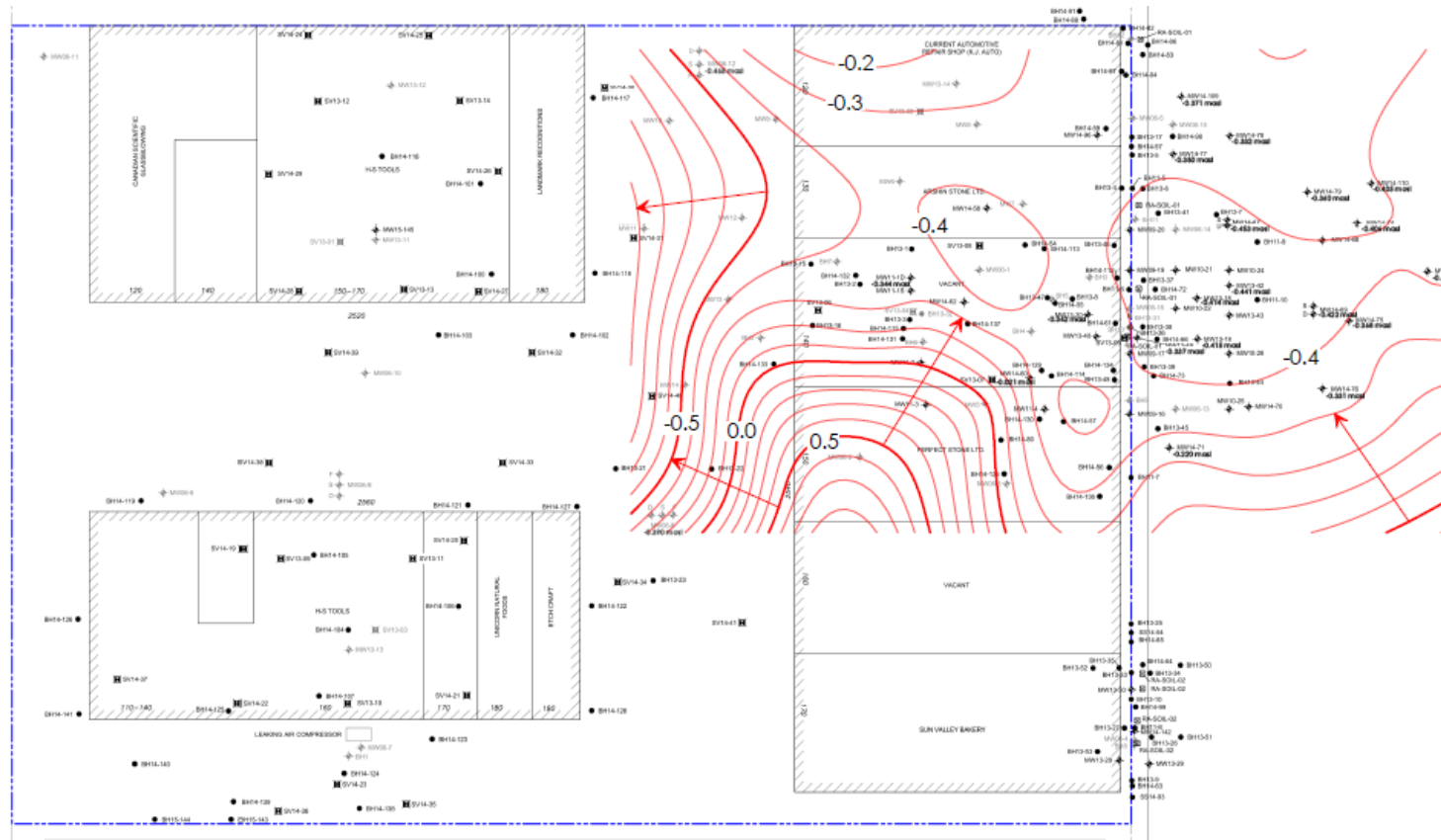
4. Field Data

- **Geochemistry**
  - Groundwater monitoring data showed reducing conditions

Field Parameters	Maximum	Minimum	Average
ORP (mV)	5.0	0.1	0.8
DO (mg/L)	6.0	-158.9	-54.9

Notes: ORP – Oxidation Reduction Potential
DO – Dissolved Oxygen

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4. Field Data

Groundwater Analytical Results

- Concentration of Iron, Manganese and Arsenic determined to exceed the CSR standards in multiple monitoring wells over multiple events

Parameter	CSR Standard (µg/L)	Maximum Concentration (µg/L)
Iron	6500	71100
Manganese	550	4180
Arsenic	10	19

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4. Field Data

- **Lines of Evidence**
  - High concentrations of Fe, Mn and As at the Site
  - No activities known to introduce these parameters into the environment
  - Field data (geology, hydrogeology and geochemistry) to support available research to indicate that this is background
  - **Hypothesis**: Evidence suggests that Fe, Mn and As is likely background

5. Background Determination

- **Selection of Background Wells**
- **Statistical Analysis of Data Sets**
  - Compilation of data Sets (Site vs. Background)
  - Outlier evaluation
  - Statistical Assessment including Population Evaluation
  - Determination of 95th Percentile of Background data
  - Comparison of Site data to 95th Percentile

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5. Background Determination

- **Site Wells versus Background Wells**
- **How did we select Background Wells?**
  - On-Site Wells were used to determine background concentrations
  - Absence of PCOCs in soil and groundwater analytical results
  - Up Gradient or Cross Gradient of identified AECs
  - Silt versus Sand stratigraphy

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5. Background Determination

- **Statistical Assessment using Pro UCL Software to determine the following:**

  - **Outlier evaluation –** if outliers are encountered these were removed from the raw data set.

  - **Population Evaluation –** Determine if sample results belong to the same population

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5. Background Determination

- **Statistical Assessment using Pro UCL Software to determine the following:**

  - **Background Determination –** Determine 95th Percentile of background data set that contained temporal assessment data

  - **Background Comparison** – Compare background concentration to Site data set to determine if contamination is present

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5. Background Determination

- **Background Monitoring Wells – Silt Layer**

MW ID	Iron	Manganese	Arsenic
MW9	X	X	X
MW10	X	X	X
MW11	X	X	X
MW14		X	X
MW06-2	X	X	X
MW06-3	X	X	X
MW06-7	X	X	X
MW06-8	X	X	X
MW06-9S	X	X	X
MW06-11	X	X	X
MW06-12S	X	X	X
MW13-14	X	X	X

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5. Background Determination

- **Background Monitoring Wells – Sand Layer**

MW ID	Iron	Manganese
MW06-6D	X	X
MW06-9D	X	X
MW06-12D	X	X
MW14-76	X	X
MW14-96	X	X
MW14-109	X	X
MW14-111	X	X

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5. Background Determination

- **Selected Background Monitoring Wells**

5. Background Determination

- **Temporal Assessment – Silt Layer**

MW ID	Iron	Manganese	Arsenic
MW9			X
MW10			X
MW11			X
MW14			X
MW06-7	X	X	X
MW06-8	X	X	X
MW06-11	X	X	x

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5. Background Determination

- **Temporal Assessment – Sand Layer**

MW ID	Iron	Manganese
MW06-6D	X	X
MW06-9D	X	X
MW06-12D	X	X

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5. Background Determination

- **Example Calculation for Manganese**
  - Data Set for Mn

Silt Layer
Background Data
617
793
484
835
878
2790
560
2100
1060
2450
1160
4180
856
1450
1440

Silt Layer	
Site Data	
255	387
209	87
236	469
79	444
122	1530
224	426
238	166
236	765
13	1530
56	463
996	2730
187	1780
226	636
850	308
159	

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5. Background Determination

- **Example Calculation for Manganese**
  - Data Set for Mn

Sand Layer
Background Data
723
399
972
421
381
178
746
2740
532
2740

Sand Layer
Site Data
201
789
624
171
765
532
828

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5. Background Determination

- **Example Calculation for Manganese**
  - Outlier Test Result
    - Silt Layer – no outliers were found
    - Sand Layer – no outliers were found

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5. Background Determination

- **Example Calculation for Manganese**
  - Population Assessment Result
    - **Background Data Set Silt** – Pro UCL confirmed that the population of background in the silt layer was normally distributed
    - **Background Data Set Sand** – Pro UCL confirmed that the population of background in the sand layer was normally distributed

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5. Background Determination

Descriptive Statistics Results for Mn

Item	N	Min	Max	Mean	SD	Skewness	CV
SILT LAYER							
Mn-Bkgd	26	2790	1104	705.6	226	1.005	0.639
Mn-Site	13	1530	353.3	368.8	13	2.124	1.055
SAND LAYER							
Mn – Bkgd	10	178	2740	983.2	952.7	1.543	0.969
Mn - Site	8	171	828	527.3	268.9	-0.304	0.510

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5. Background Determination

- **Manganese – 95th Percentile Background Data - Silt Layer**

Location	MW06-7		95th Percentile	MW06-8		95th Percentile	MW06-11		95th Percentile	95th Percentile Based on the 95 Percentile of Background Concentrations
Date	14-Jun-06	8-Oct-14		14-Jun-06	8-Oct-14		14-Jun-06	8-Oct-14		
Mn	2790	560	2679	2100	1060	2048	4180	856	4013.8	**3880**

5. Background Determination

- **Manganese – 95th Percentile Background Data - Sand Layer**

Location	MW06-6D		95th Percentile	MW06-9D		95th Percentile	MW06-12D		95th Perc.	95th Percentile Based on the 95 Percentile of Background Concentrations
Date	14-Jun-06	28-Oct-15		14-Jun-06	28-Oct-15		14-Jun-06	8-Oct-14		
Mn	723	399	706.8	972	421	944.5	381	178	370.9	**921**

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5. Summary

Parameter	CSR Standard (μg/L)	Background Concentration (μg/L)
Iron – Silt Layer	6500	64858
Iron – Sand Layer		47130
Manganese – Silt Layer	550	3880
Manganese – Sand Layer		921
Arsenic – Silt Layer	10	18

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Mn in Silt Before & After

5. Background Determination
Mn in Sand Before & After

Iron in Silt – Before and After
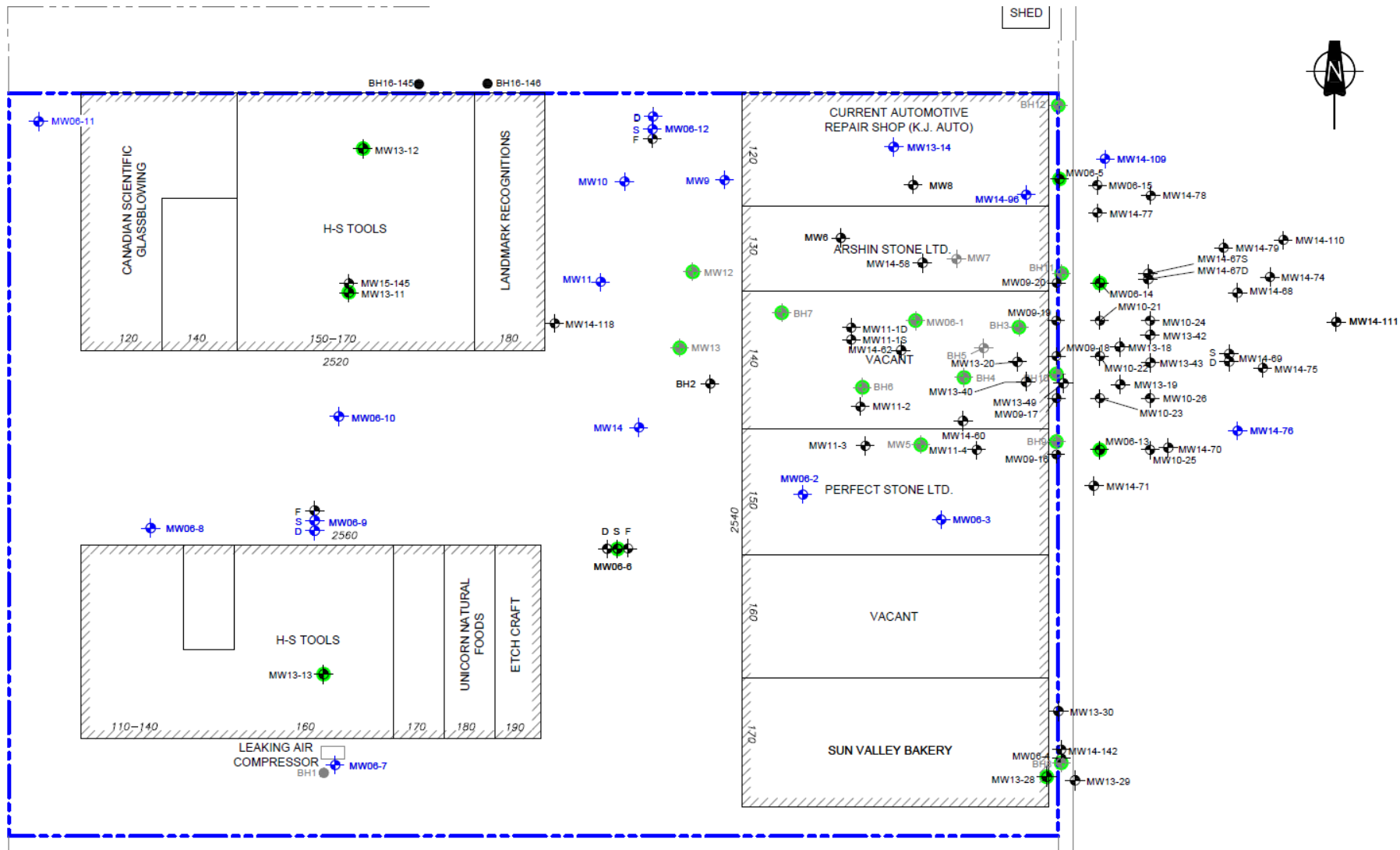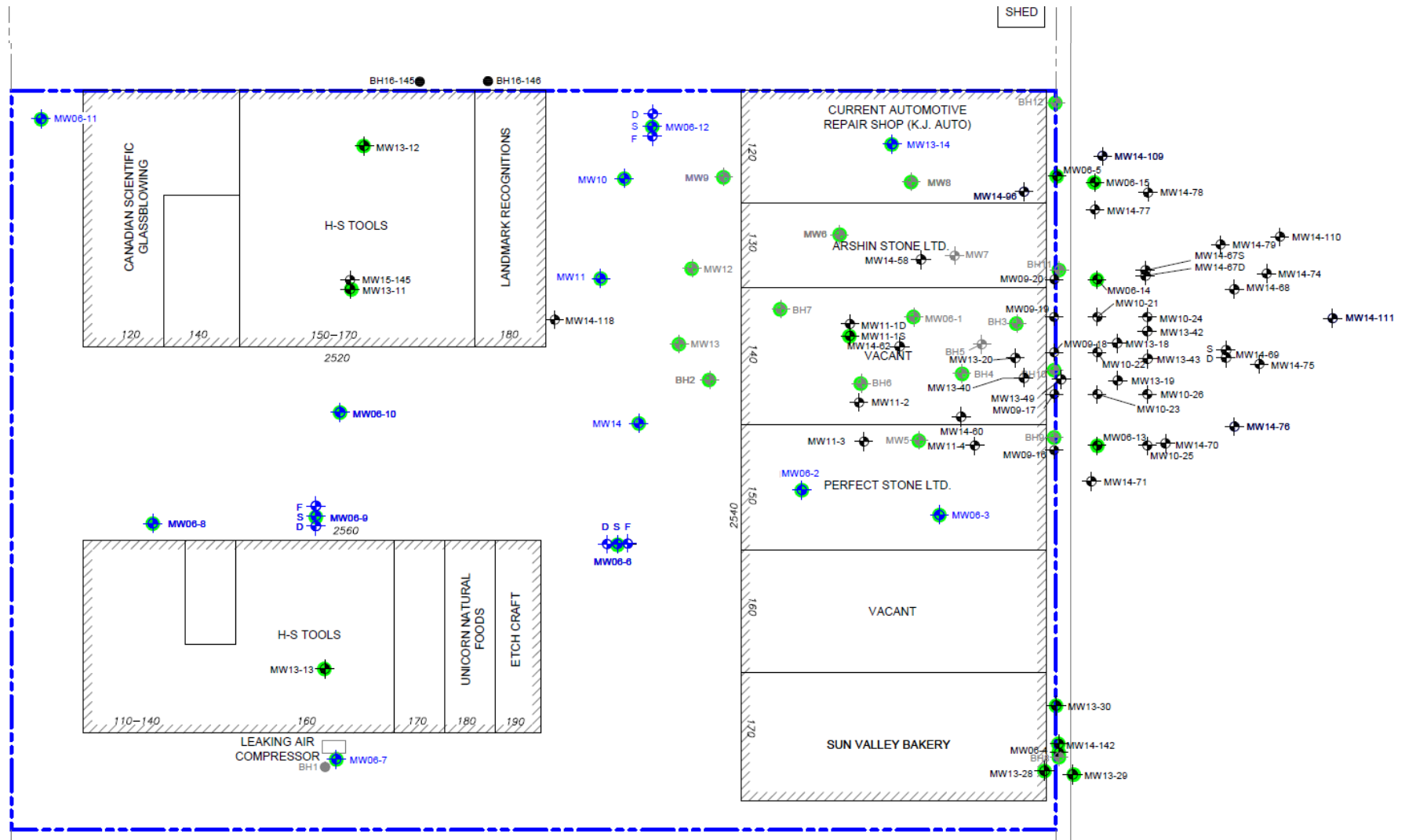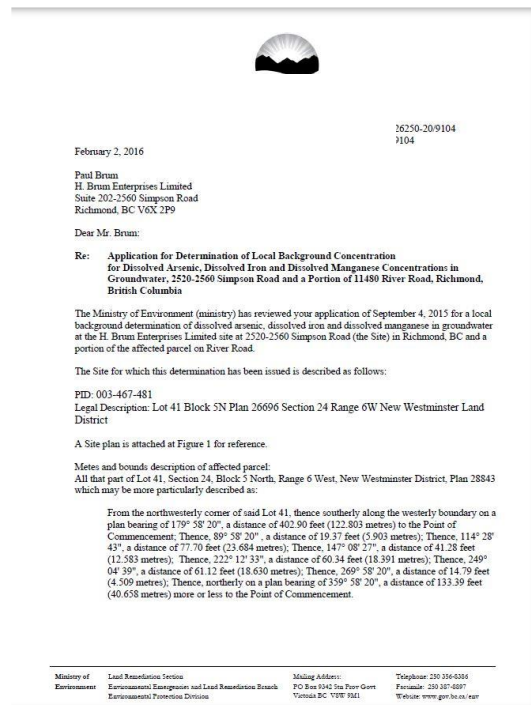
Iron in Sand – Before and After

Arsenic in Silt – Comparison to Background

6. Conclusion

- BC MOE Issued Background Determination for Iron, Manganese and Arsenic for the Site on February 9, 2016

Questions?

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