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Groundwater Protection Plan in Response to Release of Fracking Fluids in Shallow Sandstone

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Presentation Outline

- Fracking Incident

Groundwater Protection Plan:

- Objectives and Scope
- Desktop Review : Geology, Hydrogeology, and Geophysics
- Drilling and Testing Program: Scope, Challenges, and Results
- GW Chemistry: Indicator Parameter Selection for Fracking Fluids, Characterization and Trend Analysis
- Key Findings and Overview
- Questions and Answers

Fracking Incident – Depth and Released Fluids

Depth and Formation:

- Interval 136.2 mbg – 137.2 mbg (Sandstone)

Fracking Fluids:

- LPG (Propane) – 130 m³ (35,100 m³ in gas phase)
- Gel 912 L
- Activator 684 L
- Breaker 912 L

Fracking Incident – Initial Recovery

- 70% Propane Recovered (87.4 m³)
- Water recovered to extract gel, activator, and breaker
- No further recovery of water, apparently formation was dry

Fracking Incident - Fracking Chemicals (MSDS)

- Propane
- Petroleum distillates
- Magnesium oxide
- Ferric sulphate
- Isopropanolamine
- Ammonium citrate
- Sodium cumene sulfonate
- Mixed alkylphosphate ester
- Hexyl alcohol
- Amyl alcohol
- N-butanol and phosphoric acid

Groundwater Protection Plan - Objectives

- To determine the presence, extent, and potential migration of fracking fluids.
- To identify potential receptors and assess potential migration of chemicals of potential concern.
- To prepare a mitigation plan, if required, to manage risks to receptors.

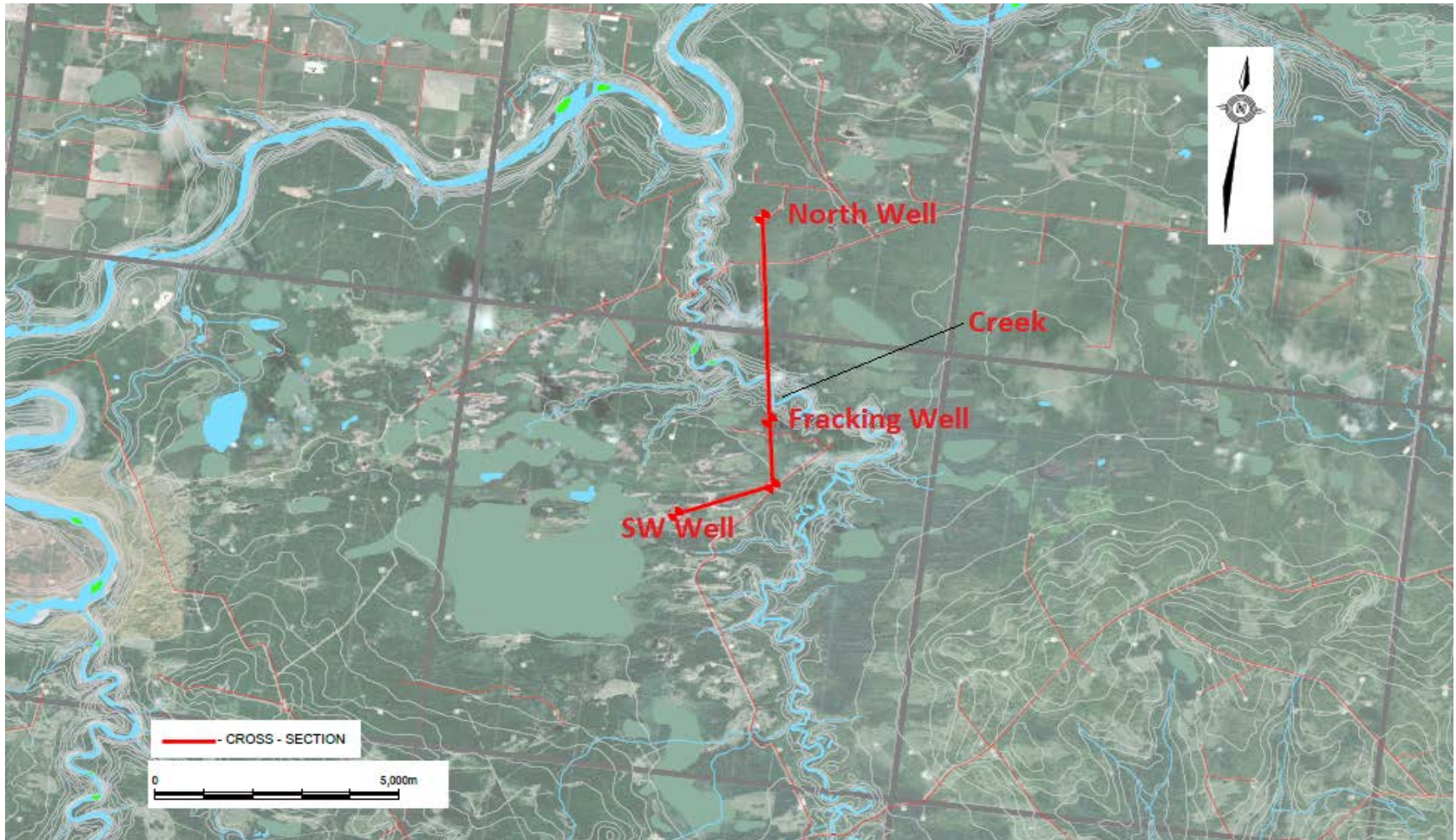
Groundwater Protection Plan - Work Scope Completed

- Desktop Review
- Drilling Program - Deep Well and Shallow Well
- Pumping Tests
- Groundwater Chemistry and Trend Analysis

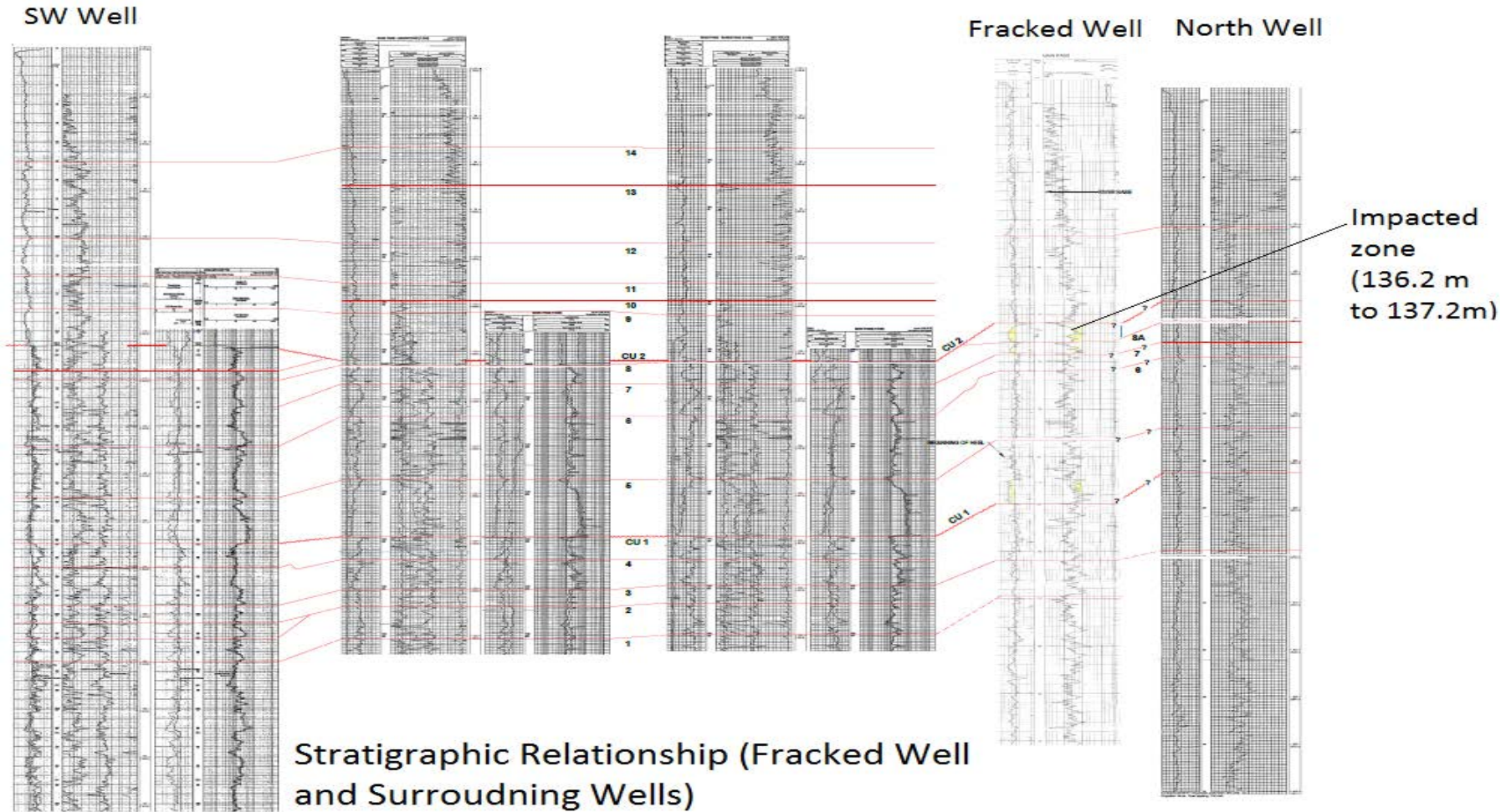
Desktop Review - Objective

- To analyze the stratigraphy of the well (fracked well), its stratigraphic relationships to surrounding wells, and the significance of the sand bodies encountered in the well for subsequent released fracking fluid movements.

Desktop Review - Nearby Potential Receptors and Potential Impacts

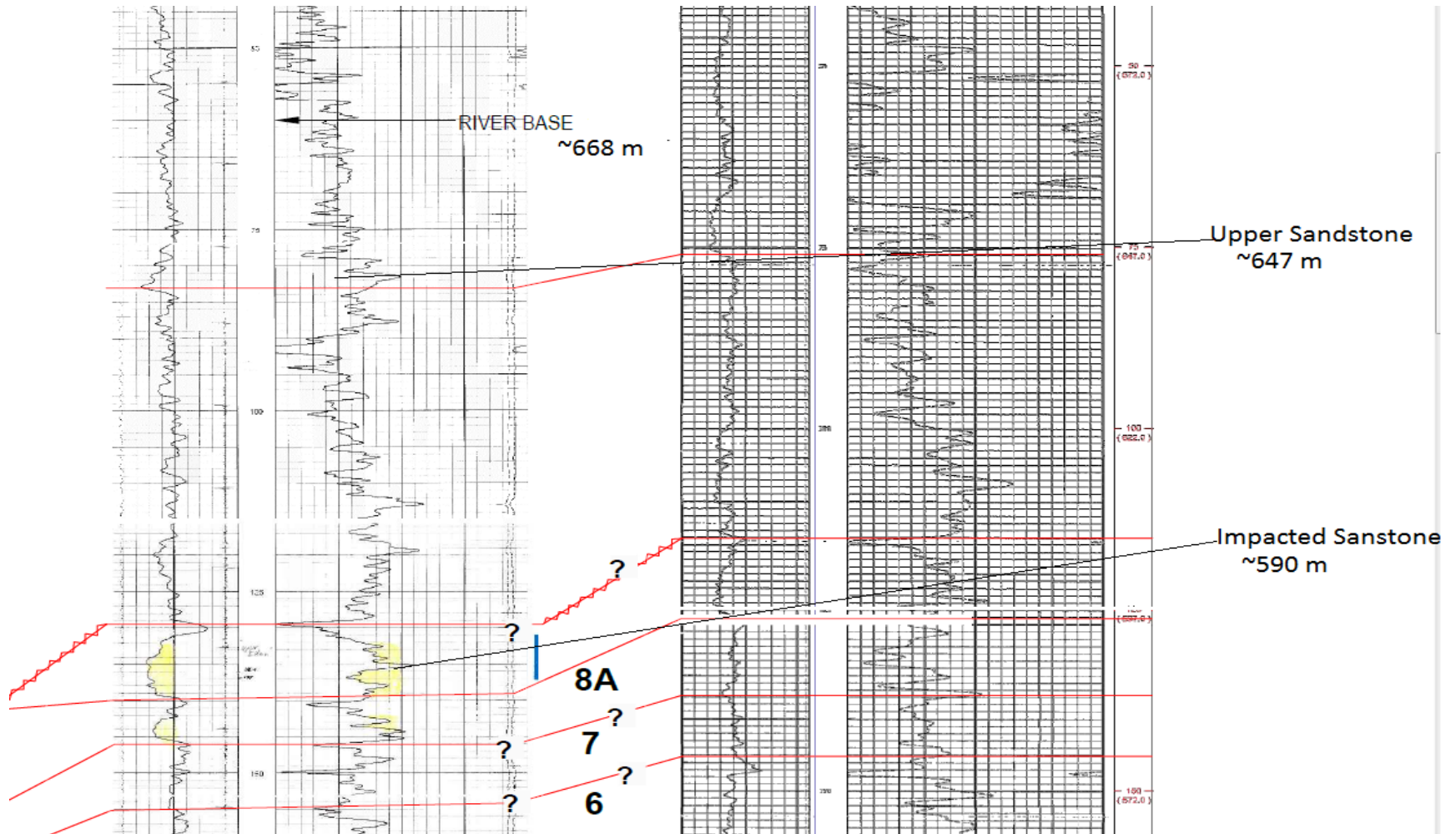


Desktop Review - Stratigraphic Cross-Section and Correlation



Stratigraphic Relationship (Fracked Well and Surrounding Wells)

Desktop Review - Stratigraphic Cross-Section and Correlation



Desktop Review – Results

The impacted sandstone;

- is isolated and tentatively to the north
- does not occur in any of the adjacent wells in south and southwest. It is missing by virtue of being eroded in the south and southwest
- very limited reservoir
- porous interval is interpreted to be only ~ 1.5 m in thickness.

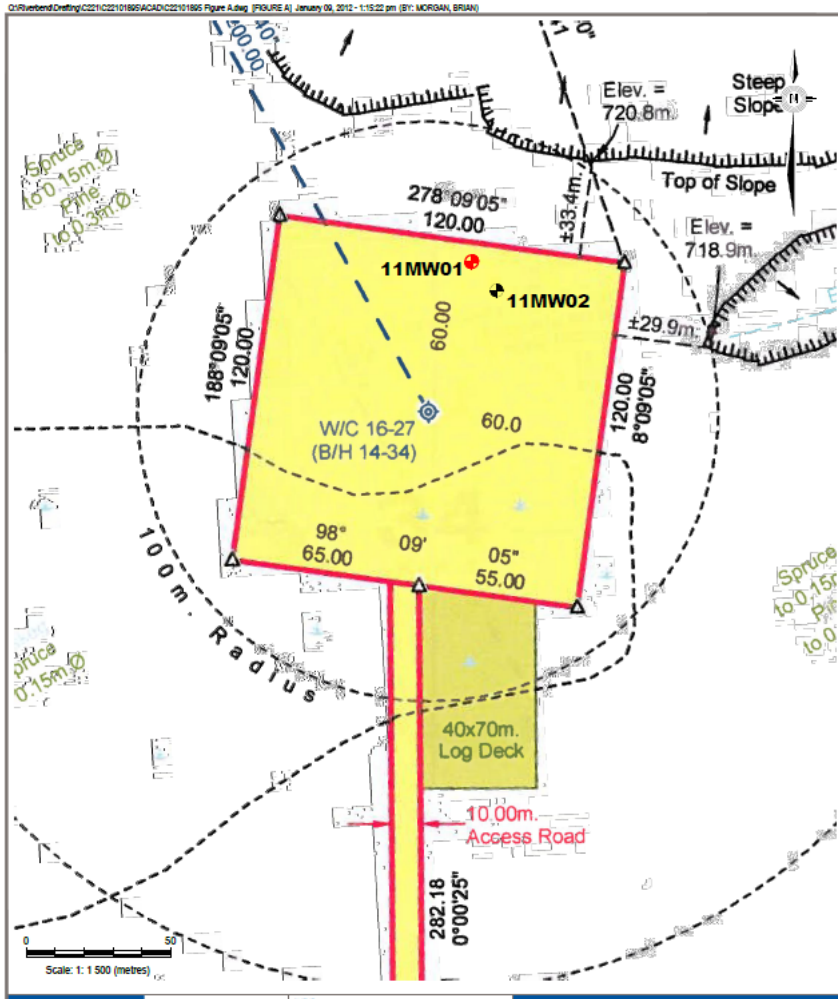
Desktop Review – Results (Continued)

- River bed is approximately 78 m above the impacted sandstone
- The impacted sandstone does not crop out in river valley.
- No vertical connection exists between the impacted sandstone and sandstone above it (approximately 80 mbg)
- Nearest water well: 4 km north of the site and 18 m below ground.
- The impacted sandstone does not appear to be present in the water well.

Drilling

- Locations
- Safety Issues/Challenges
- Well Construction

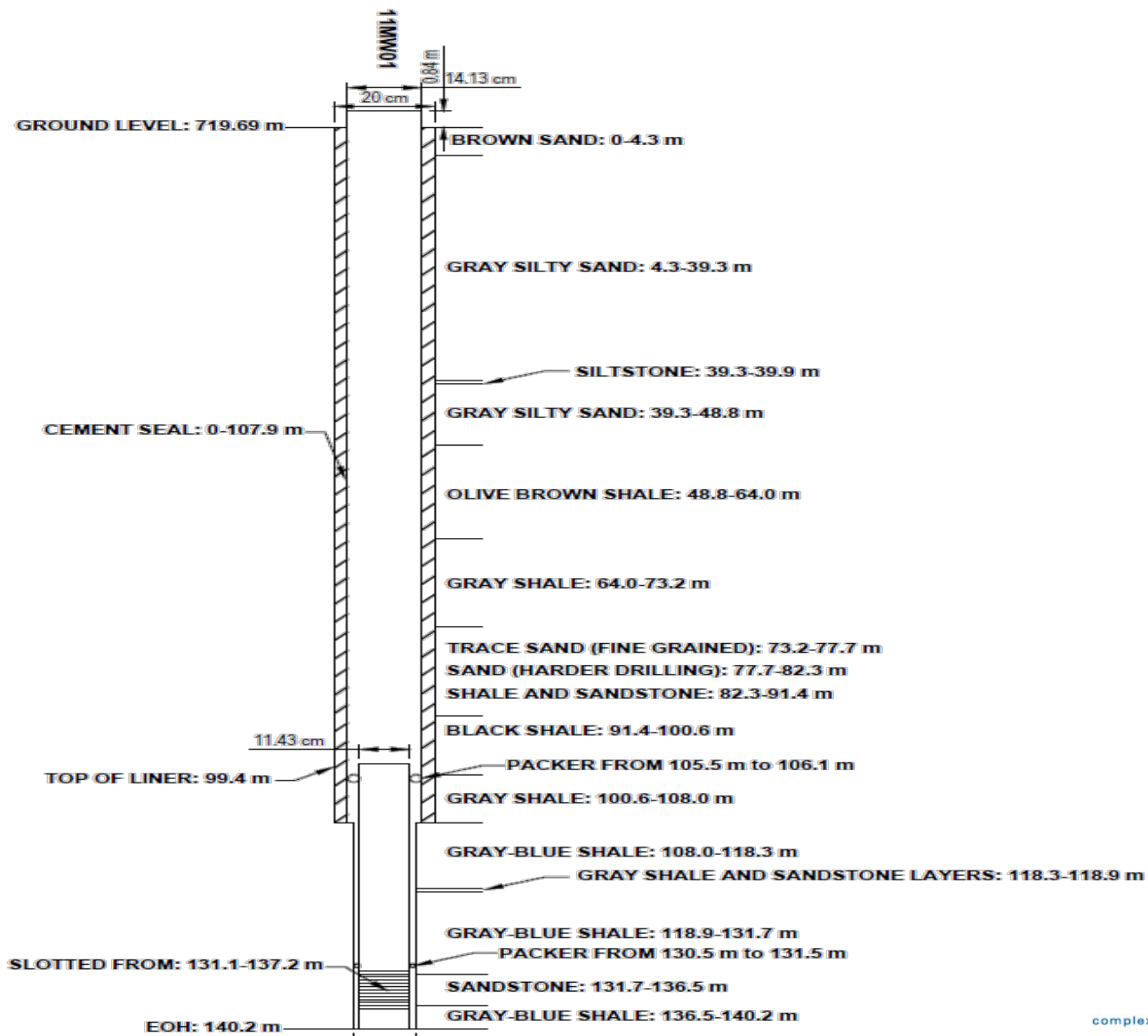
Drilling: Locations



Drilling: Safety Issues and Challenges

- Propane in formation – could be explosive in gaseous form
- Cold weather conditions – absolutely no ignition source (torch etc.) to thaw equipment
 - Needed to build certain pressure during drilling to keep propane in liquid form (mud rotary, no air)
 - Drill and seal casing to top of formation (precaution to prevent blow out of casing)
 - Screen installation within impacted zone (used smaller diameter screen with packers)

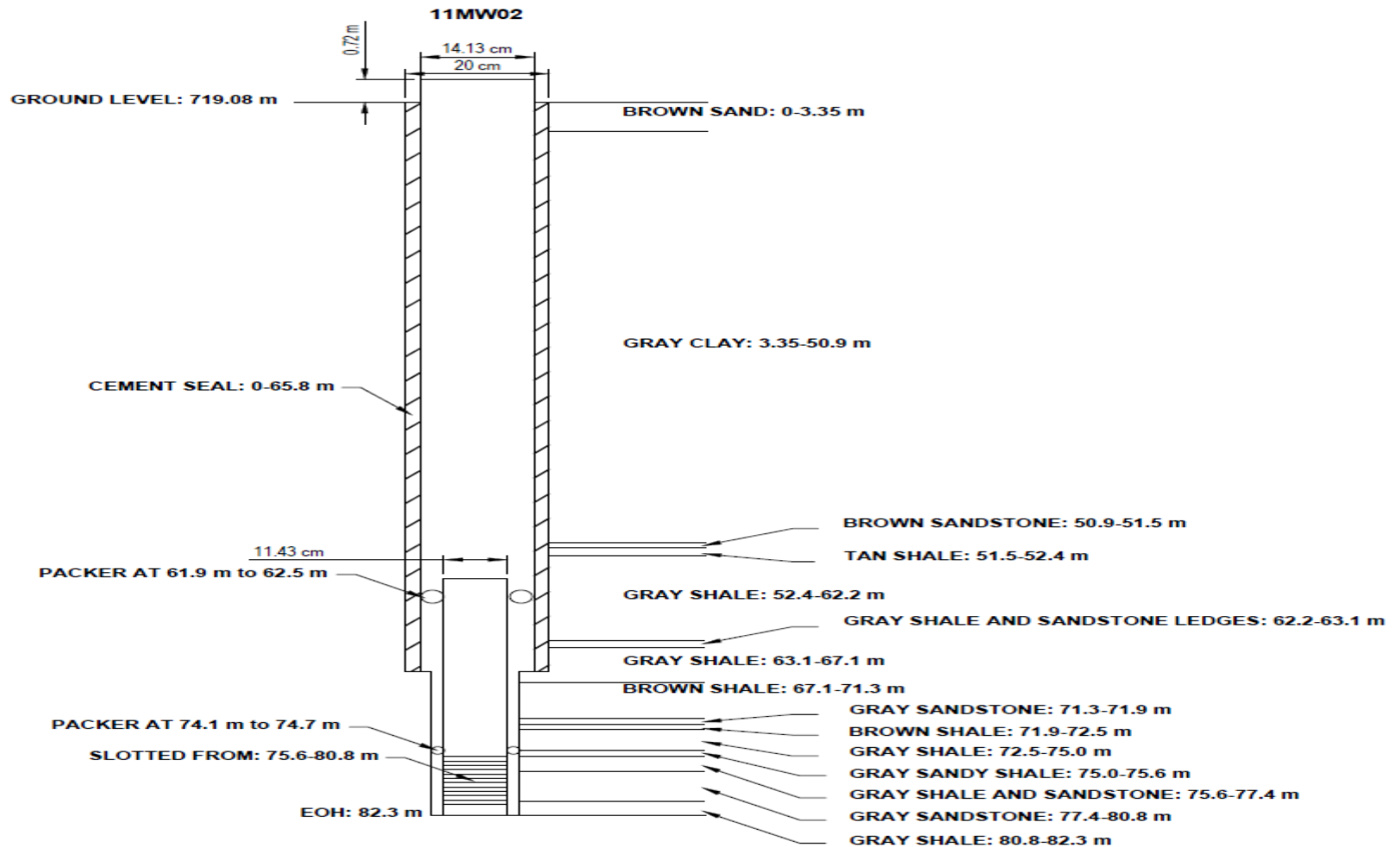
Drilling: Well Construction (11MW01)



Drilling: Well Construction (11MW01)

- Sandstone Interval = 131.7 m to 136.5 m.
- Screen Interval = 131.7 m to 137.2 m.
- 27 slots on a 20 ft. (6.09 m) screen.
- Each slot size equals to 1/8 inch x 12 inches.
- Open area of approximately 40.5 square inches.
- The well screen transmitting capacity at maximum entrance velocity of 0.03 m/sec = approximately 783.8 cm³/sec (10.3 Imperial gallon per minute [igpm]).

Drilling: Well Construction (11MW02)



Pumping Test

- Safety Issues Considered
- Logistics: Storage and Disposal
- Pumping Rates
- Pumping Test Results



Pumping Test: Safety Issues Considered

- Propane in Formation: cavitation, properly maintained pump, hydraulic pressure, and cavitation indicators (reduced flow rates, pump noise, etc.).
- Propane at Surface: potential expansion of propane, threshold values (20% lower explosive limit), ventilation, detection of odours, gas, and flow monitoring.

Pumping Test: Logistics (Storage and Disposal)

- On-site Storage:
 - One 400 bbl storage tank
 - Five to six 400 bbl storage tanks, steamers, and trucks for off-site disposal (on standby).
- Off-site Disposal (options, depending upon volume and chemistry):
 - Injection well.
 - Nearby waste-water treatment system.
 - Another fracking well nearby.



Pumping Test: Pumping Rates

- Planned step tests at 5 igpm, 10 igpm, 15 igpm, and 20 igpm. Each step for 30 minutes.
- No suction at 5 igpm >>> Increased to 10 igpm.
 - Quick drop in water levels from 10.2 mbg to pump intake at 128.7 mbg.
 - Pumped approx. 325 imperial gallons.
 - Well casing storage ~ 345 ig, based on an inner radius of the casing of 0.065 m and a water column of 118.5 m (pump intake at 128.7 mbg – initial “static” water at 10.2 mbg).

Pumping Test: Pumping Rates (Continued)

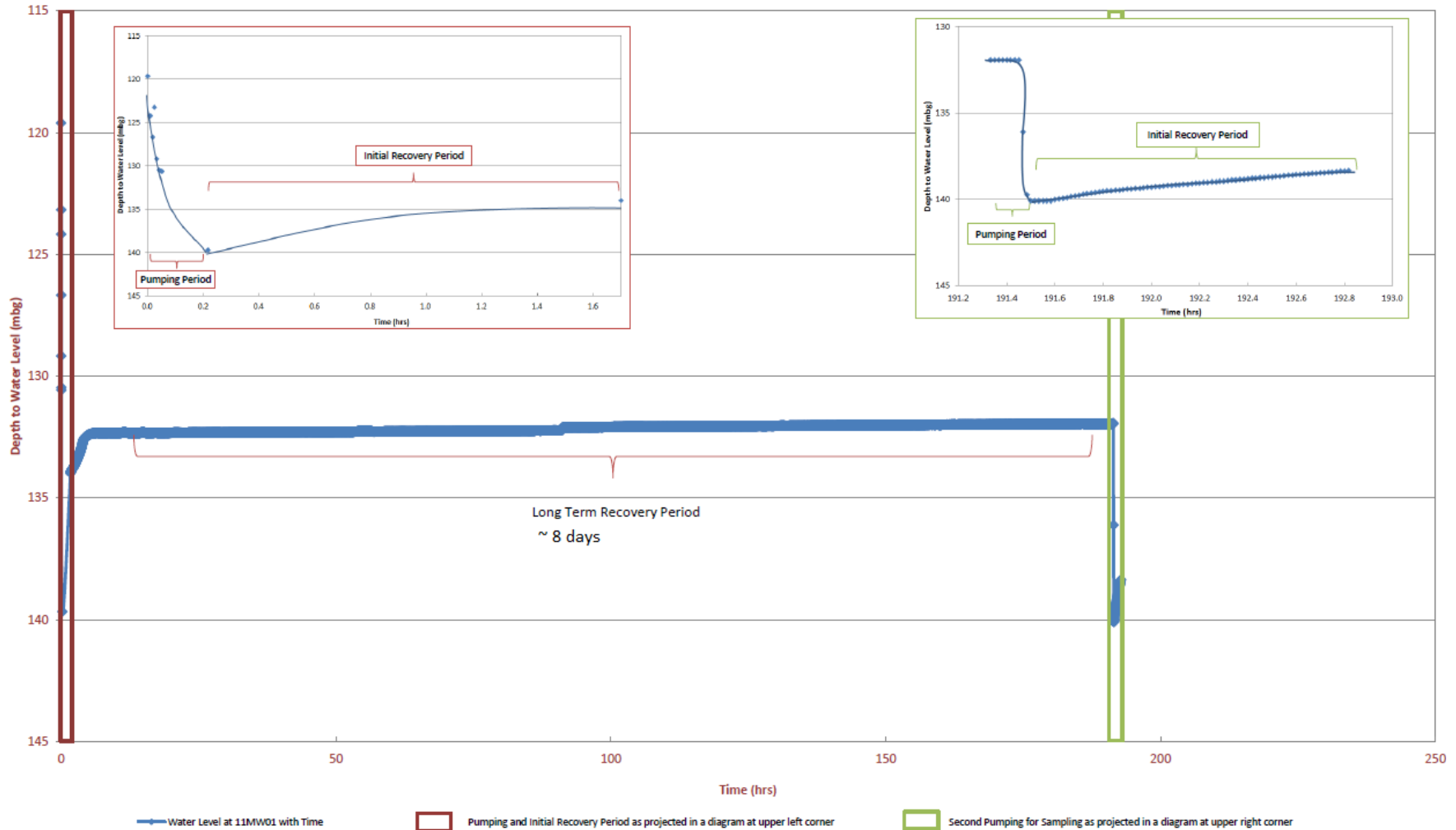
- Changed pump (lower capacity); place pump close to well bottom (~ 138 mbg), left water level to recover for ~ 48 hours.
- Pumped at 1.25 igpm.
 - Water levels prior to pumping at 128.3 mbg
 - Water level dropped to pump intake (~ 138 mbg) in 8 minutes.
 - Recovery data >>> no valid data: backflow of water from the flow line into the well casing.
- No water level changes were measured at the shallow monitoring well (11MW02) during the pumping tests.

Pumping Test: Results

- At 10 igpm (45.5 L/min):
 - Removed well casing storage water and, not from the adjacent formation.
 - No recovery observed.
- At 1.25 igpm (5.7 L/min):
 - Drawdown data analysis: Hydraulic Conductivity (K) = 5.2×10^{-7} m/sec, Transmissivity = 2.9×10^{-6} m²/sec, and Sustainable Yield (Q) = 3.4×10^{-6} m³/sec (0.2 L/min).
 - Estimated K and Q are less than the values defined by Alberta Environment for a domestic use aquifer (DUA) (K = 1×10^{-6} m/sec or greater and Q = 0.76 L/min).

Additional Pumping and Recovery Monitoring

Time vs Depth to Water Level (11MW01)



Groundwater Chemistry

- Analytical Suite
- Groundwater Sampling - Characterization
- Trend Analysis

Groundwater Chemistry: Analytical Suite

Table 1: Proposed Analytical Suite

Product	Key Ingredient	Co mp.	Test Options	Comment/Target
LPG	Propane	~98 %	Various low molecular weight gases.	Difficult to collect a representative sample for lab analyses; suggest field screening with RKI Eagle portable gas detector.
BRKLP-10	Petroleum distillates	~0.8 %	Hydrocarbons.	Benzene, toluene, ethylbenzene, and xylenes (BTEX)/F1-F4.
BRKLP-10	Magnesium oxide		Magnesium.	Routine water chemistry.
ACTIVATOR XL-46D	Ferric sulphate	~0.6 %	Sulphate, iron.	Run routine water chemistry and ICP metals.
ACTIVATOR XL-46D	Isopropanol amine		Organic amine.	Target with Total Kjeldahl Nitrogen (TKN) and dissolved organic carbon (DOC).
ACTIVATOR XL-46D	Ammonium citrate		Organic ammonium salt.	Target with ammonium and DOC.
ACTIVATOR XL-46D	Sodium cumene Sulfonate		Organic sodium salt.	Target with routine water chemistry and DOC.
GELLP-10	Mixed alkyl phosphate ester	~0.8 %	Phospho-organic compounds.	Target with total phosphate and DOC.
GELLP-10	Hexyl alcohol		Alcohol, no commercial target analyses available.	DOC.
GELLP-10	Amyl alcohol		Alcohol, no commercial target analyses available.	DOC.
GELLP-10	n-butanol		Target analyses available.	n-butanol.
GELLP-10	Phosphoric acid		pH effect, phosphate ion.	Target with routine water chemistry.
Overall chemistry and redox condition	Miscellaneous		Assess (changes in) chemistry, inferred redox condition and possible effects of breakdown and interaction with aquifer materials (pH, hardness, alkalinity, and metal dissolution).	Routine water chemistry and dissolved metals.

Groundwater Sampling - Characterization

- 11MW02 (Shallow Well): GW sample collected after drilling (December 7, 2011).
- 11MW01 (Deep Well): Sample 1 near the end of pumping test at 10 igpm (February 13, 2012).
- 11MW01 (Deep Well): Sample 2 near the end of pumping test at 1.25 igpm (February 15, 2012).

Groundwater Chemistry: Analytical Results

Parameter	11MW01-01 (deep, sample 1)	11MW01 -02 (deep, sample 2)	11MW02 -03 (shallow)	AEW Tier 1 Guideline (mg/L) – All Land Uses/Fine Soils
pH	<u>8.93</u>	<u>8.52</u>	<u>9.68</u>	6.5 – 8.5
Sodium	<u>363</u>	<u>373</u>	<u>230</u>	200
Total Dissolved Solids	<u>889</u>	<u>971</u>	<u>620</u>	500
Chloride	14.5	74	14	230/100 (Agricult.)
TKN	0.88	21.5	0.85	NA (Not Available)
DOC	11.2	15.6	8.2	NA
phosphorus	0.06	8.0	0.24	50
Ammonium - N	0.29	2.56	0.18	NA
Benzene	0.005	<u>0.009</u>	<0.001	0.005
Toluene	<u>0.076</u>	<u>0.509</u>	<0.001	0.024
Ethylbenzene	0.002	<u>0.003</u>	<0.001	0.0024
Xylene	0.013	0.018	<0.001	0.3
F1-BTEX	<0.2	<0.2	<0.2	2.2
F2	Non detect	<u>8.7</u>	<0.1	1.1
F3 (C16 – C36)	0.3	23.4	<0.1	NA
F3 (C36+)	0.4	9.9	<0.1	NA
Isopropanolamine	<0.002	0.004	Not Analyzed	NA
Acetone	0.43	0.77	Not Analyzed	NA

Groundwater Chemistry: Analytical Results

- Shallow well: No indication of fracking fluid chemicals.
- Deep well:
 - indicator parameter concentrations indicated presence of fracking fluids in both samples. Overall consistent with fracking fluid chemical information from MSDS.
 - Hydrocarbons, sodium, and total dissolved solids exceeded Alberta Tier 1 guidelines.
 - Volatile organic compounds (VOC) present in both samples (e.g. acetone)
 - Isopropanolamine (IPA) was not detected in Sample 1, and 0.004 mg/L in Sample 2.
 - Overall Sample 2 had higher concentrations of indicator parameters, VOCs, and IPA, compared to Sample 1.

Groundwater Chemistry Trend Analysis (Winter 2012 to Fall 2013)

- COPCs are still present
- Several COPCs present are biodegrading (e.g., BTEX, PHC fractions F1 to F4) – significant decrease between Fall 2012 and Fall 2013 (>50%).
- IPA was non-detect in later samples and is not interpreted as a concern.
- DOC and chlorides increased.
- Gross indicator parameters i.e., TKN, ammonia and phosphorus were less than average of the initial results
- Suggest further periodic sampling to monitor natural biodegradation process and chemistry trends.
- Decide on further action after more data collected.

Key Findings and Overview

- Deep sandstone is impacted by fracking chemicals. However COPCs are naturally degrading with time.
- Deep sandstone has low hydraulic conductivity and is not considered to be an aquifer.
- Migration of chemicals beyond the fracking zone is unlikely.
- No vertical connection exists between shallow and deep sandstone.
- No potential impacts to nearby receptors i.e., nearby creek and water well(s) and creek are anticipated.



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Thank you!
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