Initial Site Characterization and Development of Procedures for the Assessment of Groundwater Quality of Unsewered Subdivisions Built Directly on top of Fractured Paleozoic Sandstone, Eau Claire County, WI

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Introduction

Groundwater is the primary source for both public and private water supplies in much of the country. In the Midwest, the Paleozoic sandstone, bedrock-aquifers are an increasingly important source of drinking water (e.g. Madison, WI; Twin Cities metro; Eau Claire, WI) and recent studies in Wisconsin and Minnesota have shown that groundwater flow in the sandstones occurs primarily along fractures and bedding planes, which increases the potential for contamination of a well when compared to an isotropic porous media. This study examines groundwater flow and quality beneath a recently-developed unsewered subdivision built directly on top of the Cambrian sandstones (Mt Simon Fm., and Eau Claire Fm.) in the Eau Claire area. Subsurface geology was reconstructed using data collected from well construction records (depth of different geologic units) and outcrop investigations within and near the subdivision. The stratigraphy, combined with measurements of fracture spacing and orientation, is used to help understand groundwater flow. This study outlines the procedure for testing for specific human wastewater indicators (caffeine, artificial sweeteners, pharmaceuticals, and household disinfectants) using high-performance liquid chromatography paired with mass spec (HPLC-MS) to determine the impact of septic systems on local groundwater quality for subdivisions built on sandstone bedrock.

Septic System Function

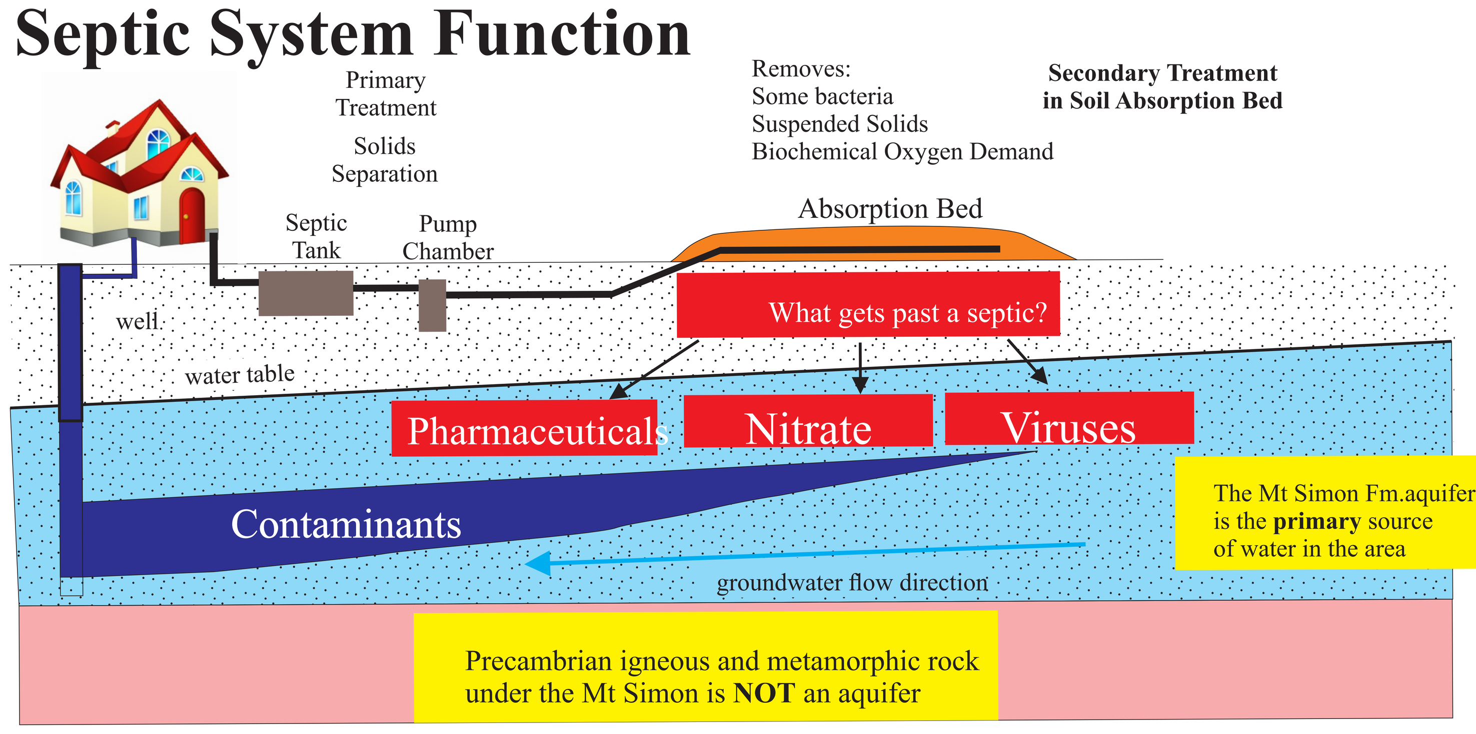

Fig 1. Summary diagram of a house with a private well for household consumption as well as a septic system with an absorption bed.
A mound septic is depicted in diagram.

Septic systems only minimally treat private wastewater, principally lowering biological oxygen demand (BOD). Private septic systems do not remove most personal care products (PCP) nitrate or viruses. Shown above is a mound septic system, used when there are poor or limited soils. The drain field is elevated and a pump pushes the waste water into the drain field. Increasingly new housing subdivision are being built in areas with no soil and on top of fractured bedrock. Vertical and horizontal fracture dominated flow has been found to increase the speed at which contaminants a delivered to the groundwater system inlcuding viruses (Gelasch et al. 2012).

Site Reconnaissance

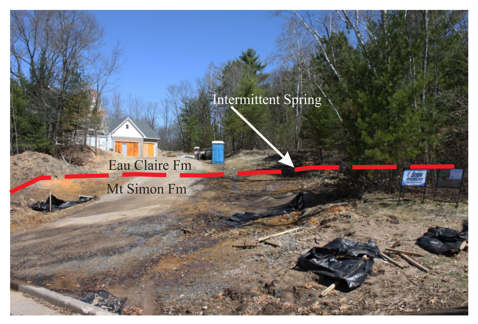

Fig 2. Home construction (Lot 15) built directly into bedrock at the Mt Simon and Eau Claire Fm. contact. An intermittent spring at the contact illustrates horizontal fracture flow in this hydrogeologic system.

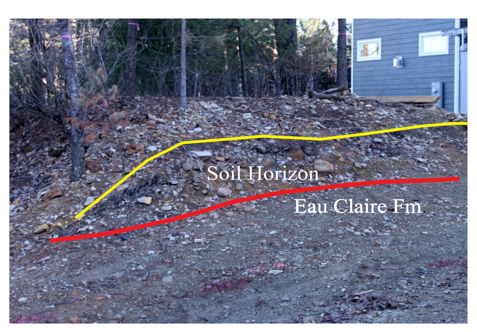

Fig 3. Thin soil horizon at lot 15. Soil depth varies from 10cm to 40cm.

Fig 4. Both the septic tank and absorption field on lot 15 were excavated directly into the bedrock Mt-Simon Fm. The absorption field is immediately downhill from the tank.

Fig 5. Newly constructed house on lot 20. Geologic cross section shows homes lower in elevation are constructed on glacial outwash (sand). Hillslope behind the house is sandstone bedrock (see X-section).

Fig 6. Typical Huntsinger Heights septic system absorption field. This newly constructed absorption field is located in the glacial outwash on the south side of lot 19 (Fig. 7)

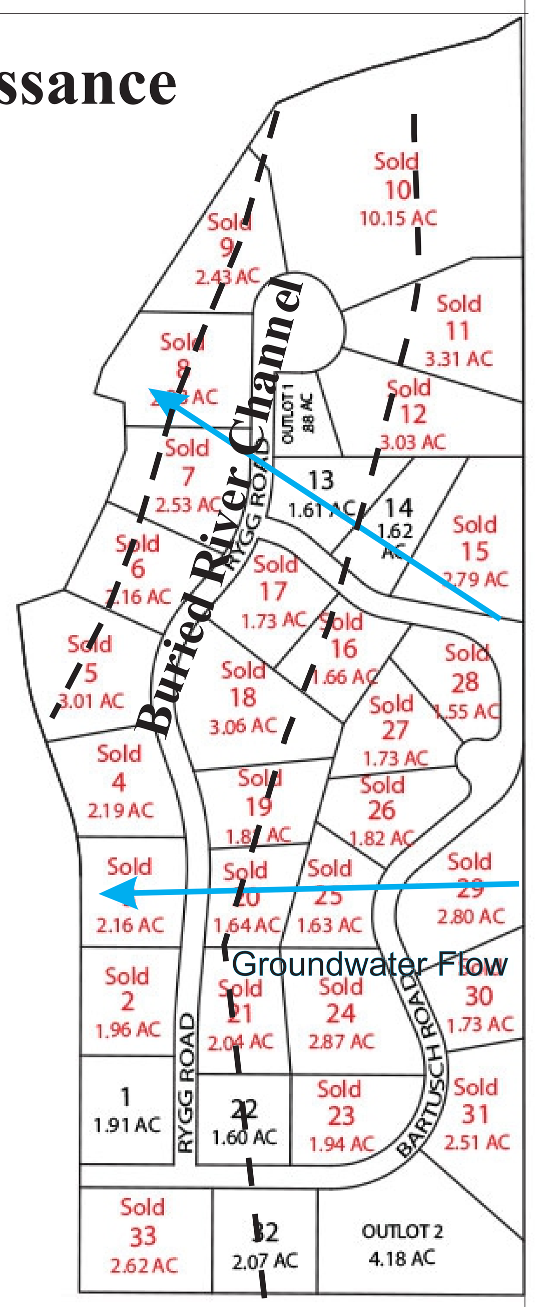

Fig 7. Huntsinger Heights map showing subdivision lot locations and sizes. Blue arrows show approximate regional groundwater flow directions. Local groundwater flow is likely to be influenced by fracture orientation.

Horizontal and Verticle Fractures

- Cambrian bedrock in eastern Minnesota and western Wisconsin has near vertical fractures oriented in a NW-SE orientation (Runkel et al, 2006).
- Distinct horizontal fractures, along bedding planes control groundwater flow.
- Ice sample collected from below Huntsinger Heights subdivision (Fig 9) where distinct ice flows formed during the winter (intermittent springs).

Fig 8. Vertical and Horizontal bedding plane fractures controlling water flow (springs) in the Mt. Simon Fm. at Dells Dam, Eau Claire. Photograph taken in March 2019 during initial snow melt.

Fig 9. Ice flows (springs) along Lowes Creek down gradient from Huntsinger Estates illustrating localized water flow along fractures.

Fracture Characterization

Fig 10. Outcrop measurements where fracture orientation were obtained along Wisconsin State Hwy 37 immediately below Huntsinger Heights subdivision.

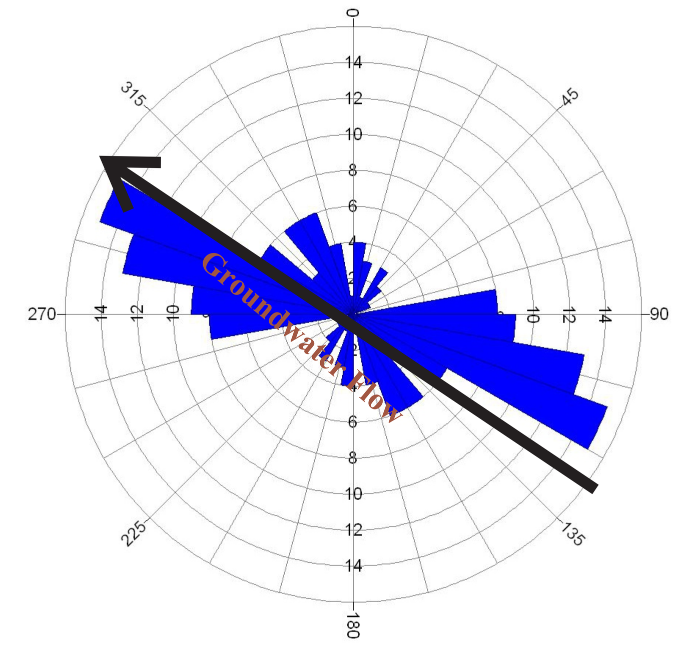

Fig 11. Rose Diagram based on fracture data obtained from outcrop. 86 fractures were measured that ranged in size from 10's of cm to a few mm. Fractures indicate strong NW-SE which, by chance, runs subparallel to groundwater flow.

- Measured fracture orientation (Figure 10, 11) on-site is consistent with regional fracture patterns observed in the Twin Cities area (Runkle et al, 2006). The orientation is dominated by fractures striking 120-300, complimented by a minor fracture pattern striking 145-325. Regional groundwater flow is fortuitously sub-parallel to the vertical fracture orientations. At Huntsinger Heights fracture orientation probably has little influence on groundwater flow direction.

Site Analysis: DNR Well Logs

- Static water levels were determined from well construction reports filed by well drillers.
- Water is flowing W-NW towards Lowes Creek and ultimately the Chippewa river. Ground water flow determined at Huntsinger Heights is consistent with a DNR derived regional groundwater flow map for Eau Claire County (Muldoon, 1992) but there is a very steep gradient across the subdivision.

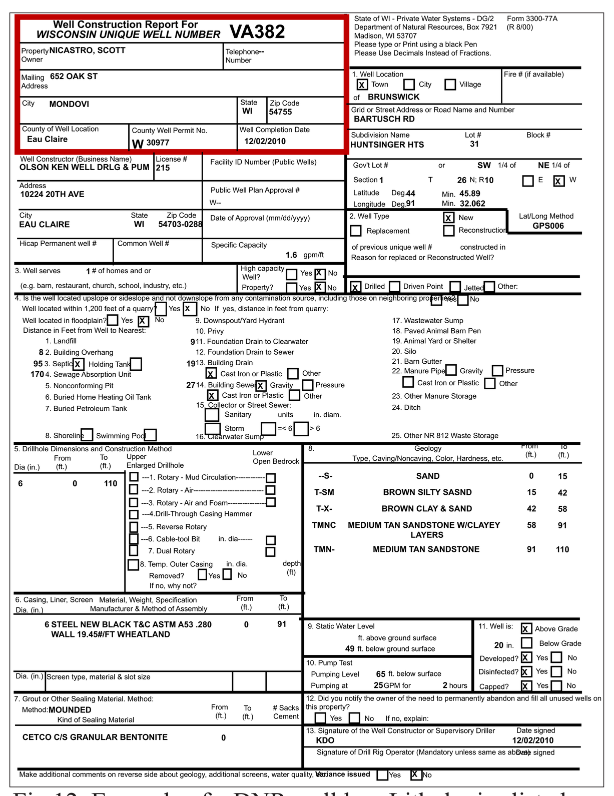

Fig 12. Example of a DNR well log. Lithologies listed were interpreted between well logs to obtained continuous units.

Groundwater Map

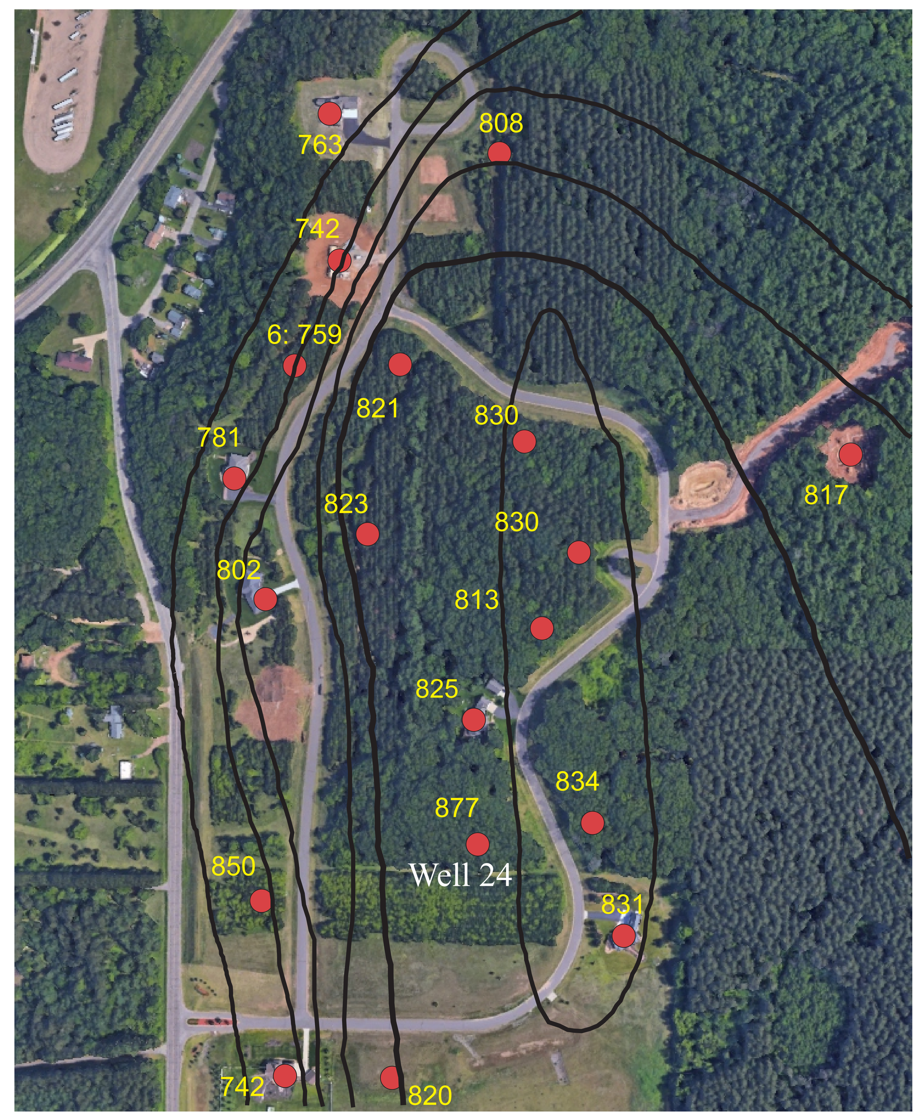

Fig 13. Groundwater Water table contour map shows flow directions to the West-Northwest and illustrates a very steep gradient across the subdivision. Well 24 seems to terminate in a perched aquifer as illustrated in the cross section (figure 14). **Contour interval is 10 ft.**

Geologic Cross Section

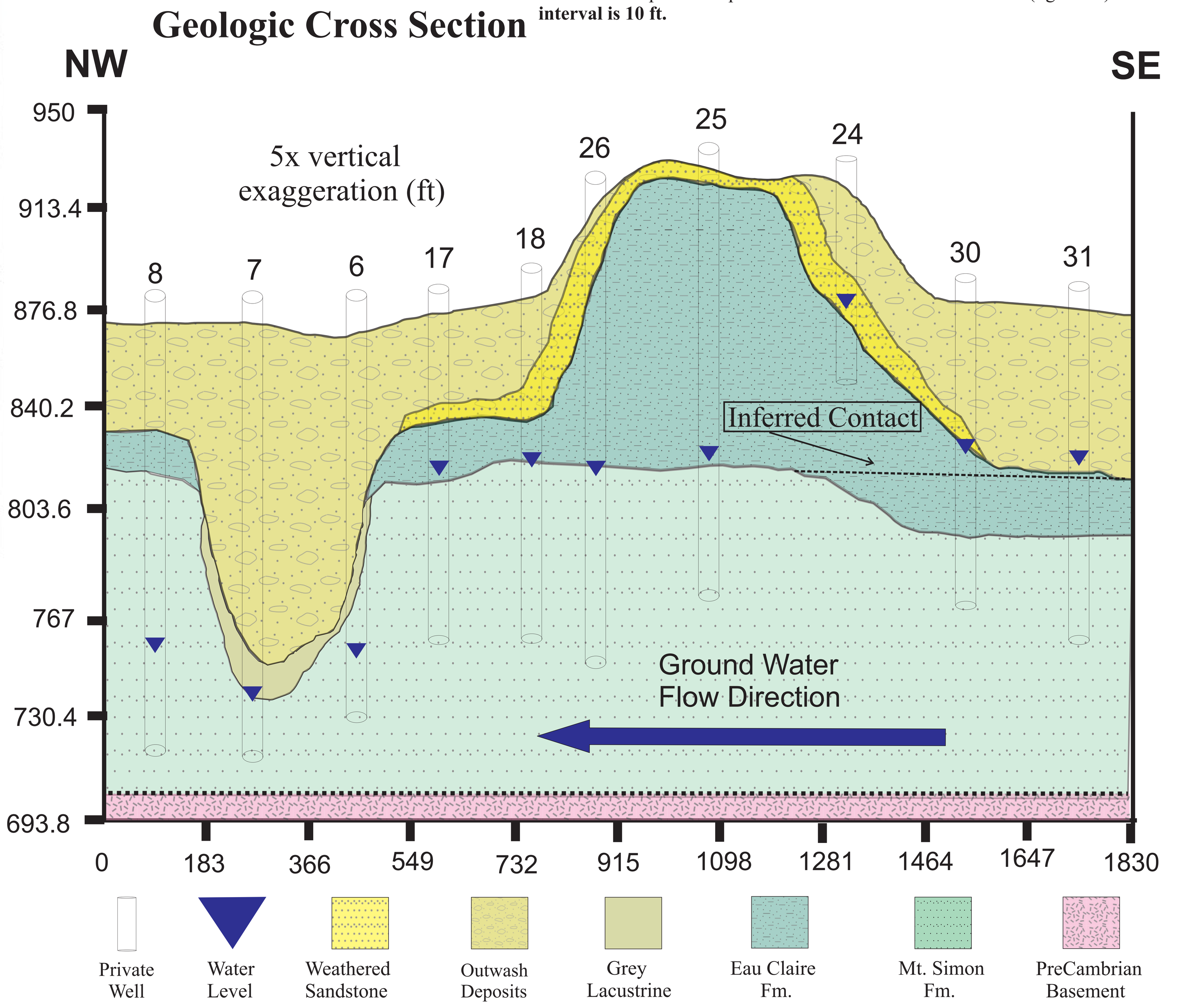

Fig 14. Cross section of Huntsinger Heights from NW to SE. NW shows a deeply incised glacial outwash river channel while the central portion contains a steep knoll of Cambrian sandstone. Lower elevations are covered by ~30 ft of glacial outwash. Inferred contact (dashed line) in the Southeast is the expected contact between Mt Simon Fm. and Eau Claire Fm. The bold line in the East is the contact inferred from well construction reports.

PCP of Interest

Personal care products (PCP) of interest were primarily selected based on their frequency of use and their stability in wastewater treatment plants (successfully treated or not), persistance, and the detection limit were also taken into account (Fram & Belitz 2011, Subedi & Kurunthachalam, 2014). Highlighted contaminants were used to determine HPLC conditions.

Chemical Name	Use	Frequency of use	Fate in WW treatment	Persistance t 1/2	Expected conc in wastewater	Detection limit HPLC (ng/L)	EPA Group
Acesulfame *	ASW	common	not removed	3000 hours in sediment	356 g/day/100K	1	3
Acetaminophen	NSAID	mod common				6.7	1
Aspartame	ASW	common	removed		254 g/day/100K		
Caffeine	stimulant	necessary				3.6	1
Carbamazpine	Anti epileptic	uncommon				0.4	1
Ciprofloxacin	antibiotic	mod. Common					
Erythromycin	antibiotic	mod common				0.1	1
Fluoxetine	antidepressant	mod common					
Gemfibrozil	lipid control	mod common				0.2	3
Ibuprofen	NSAID	mod common				1	3
Naproxen	NSAID	mod common				1	3
Saccharin	ASW	uncommon	removed		907 g/day/100k		
Salicylic Acid	Aspirin	common					
Sucralose*	ASW	common			2390 g/day/100K		
sulfamethoxazole	antibiotic	less common					
Theobromine	chocolate	mod comon					
Triclosan	Anti-Bac	Common	effectively treated			23	3
Trimethoprim	antibiotic	less common					
Wafarin	anti-coagulant	uncommon				0.2	3
* = used together							

Fig 15. Potential contaminants of interest highlighted in blue and other possible PCP contaminants.

Procedure: SPE HPLC-MS

EPA Method 1694
Procedure Flow Chart

1. 1000 ml tap water sample from first faucet after the water supply well or spring

2. Adjust pH= 2.0 (+/- .05) with HCl + add 500mg Na_4EDTA

3. 1L Water passed through HLB 20 Solid Phase Extraction Cartridge

4a. Load 10ml wash distilled H_2O Dry (5 min) and Elute with 12ml Methanol

4b. Elute again with 6ml mixture of Acetone and Methanol (1:1 ratio). Mix steps 4&5.

5. N_2 dessication to nearly dry at 50C in water bath

6. Reconstitute in 3ml Methanol and bring to 4ml total volume with 0.1% formic acid buffer

- Procedure outlined in Fig. 16 outline the SPE pretreatment of water samples to be ran through HPLC-MS.
- HPLC-MS is currently non-functional so no water samples have been run.
- Samples greater than 1000 ml will be obtained due to the fact that trace contaminants will be compared to major ion chemistry to gain a larger picture of water quality and compare different quality tests.

Figure 16. Procedure for SPE pretreatment, derived from EPA methods for SPE HPLC-MS

Discussion and Future Work:

1. Detailed geologic study shows area is more geologically complex than appeared from preliminary site investigation. Presence of so much glacial outwash was not expected based on examination of surface outcrops!
2. Fix HPLC/MS vacuum system and prepare PCP standards!
3. Collect water samples from wells and springs in Huntsinger (starting spring 2019)
4. Study water using ultra-trace PCP analysis HPLC-MS and major element and minor element chemistry (HR-ICPMS)
5. Examine impact of seasonal variation on water quality (one sample every quarter for a year)
6. Extend study are into other subdivisions with higher housing density and different subsurface geology especially areas with less outwash and more bedrock.
7. Examine subdivisions with more new housing down-gradient (more houses in alignment with groundwater flow direction).

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