Geological Observations Regarding the proposed Priory Rd. High-Density subdivision.

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Introduction: Figure 1. is a stratigraphic section that was developed to show the nomenclature of bedrock rocks units that occur in and near the proposed Priory Rd development in the Town of Washington, Eau Claire County, WI. This development requires approval of a rezoning request to allow development of relatively high-density rural housing subdivision with lots of approximately 1 acre. Presumably each house would have private wells supplying water and a private septic system for waste disposal. This extended outline covers the basic components of a summary report of the geology of the area and some recommendations for future development activities. These recommendations are based only on the geology. The following description is a scientific opinion and was developed to help guide sound planning for the Town of Washington and Eau Claire County, WI. This abbreviated summary is not a complete report on the geology of the area. **This report is not to be used for engineering site development.** A complete geological report would require considerably more work than time allowed.

1. **Regional Stratigraphy:**

Eau Claire's foundation is old (~ 2 billion years) Precambrian (PC) bedrock composed of igneous and metamorphic rocks eroded to a relatively flat surface. At the proposed Priory Rd development the elevation of this flat subsurface feature is at about 740 feet above mean sea level (msl), 230 - 300 feet below the present land surface. In a few local areas, the PC surface has been more deeply eroded by pre-glacial streams but that is not expected in the proposed development area due to the extensive siliciclastic sedimentary rock cover in this immediate area. Cambrian age (~535 million years ago) sedimentary rocks were deposited on this PC surface and exist today with a total thickness near the proposed development of almost 300 feet. The boundary between the Cambrian sedimentary rocks and the Precambrian is a zone of younger (younger than Cambrian) hydrothermal alteration consisting of unconsolidated clay which forms an impermeable layer between the PC and Cambrian sands (Hooper, 1998). The Cambrian sedimentary rocks are divided by geologist into three formations each with unique rock properties (lithology). The three units are the lower most Mt Simon Formation (Fm.), the middle Eau Claire Fm., and the Upper Wonewoc Fm. each named after the locality where the rock units were first described in Wisconsin. The same formation names are used across the upper- Midwest for these lithologic units whenever encountered in the subsurface. Any of the three formations could be potential aquifers in the area. Most private supply wells in the area surrounding the proposed development, draw their water primarily from the Mt Simon Fm.

A. Mt. Simon Formation: The Mt Simon Fm. is approximately 190 +/- 10 feet thick in the City of Eau Claire (At Mt Simon Park). The elevation at the top of the Mt. Simon is very predictable across Eau Claire implying a rather uniform thickness across the city. The thickness of the Mt. Simon in the area of proposed development is expected to be very similar. The Mt Simon Fm. is generally fairly clean quartz sand with moderate cementation. Where exposed in the city of Eau Claire, horizontal, sub-horizontal and vertical fractures are all commonly encountered.

B. Eau Claire Formation: The Eau Claire Fm. is less well exposed in Eau Claire but is always < 90 feet thick. The thickness along Priory Road is debatable but probably close to 60 feet thick. Determining an exact thickness would require more detailed study of existing well logs. The estimated thickness of Eau Claire Fm. is based on regional thickness of the Mt. Simon Fm. and the contact between the Eau Claire Fm. and the overlying Wonewoc Fm. which is exposed on the hill immediately to the SE of the proposed development. The contact between the Mt Simon Fm. and the Eau Claire Fm. is currently better exposed at locations such as Oakwood Hills, the North Crossing and US-53 bypass. Locally, in outcrop the Eau Claire Fm. has numerous fractures parallel to bedding typically on the order of 1-2 cm, and closely spaced (a few cm apart) vertical fractures. In southern WI, where the Eau Claire Fm. contains more shale, the Eau Claire Fm. sometimes serves as an aquiclude, limiting vertical groundwater flow.

C. Wonewoc Formation: The top part of the Eau Claire Fm. has a transitional boundary with Wonewoc Fm. in N. Wisconsin and Minnesota (There is an erosional unconformity in the Wonewoc about 15 feet above base; Runkel et al., 1998, Havholm et al., 1998). The Wonewoc Fm. lower boundary for this outline report was made at the last significant clay/shale layers in this study area. Therefore, I have included all of the significant clay and shale layers as part of the Eau Claire Fm. in this report. Changing the formation boundary by a few feet would have no impact on my conclusions regarding the overall suitability of the proposed development.

A very brief lithologic description of each of these sedimentary units is given in figure 1 which also shows their relative thickness, approximate vertical position, and grain sizes present within the different units. The transitional nature of the contacts is not really visible at the vertical scale used in figure 1.

2. Extenuating Circumstances: The current topographic hills in the immediate vicinity of the proposed project represent erosion resistant bedrock knobs. The erosional resistance is a result of fracture controlled **excessive cementation** of the Wonewoc Fm. by potassic diagenetic fluids flowing along the Cambrian and Precambrian Contact. Excessive cementation locally results in the Wonewoc Fm. being altered to an impermeable orthoquartzite which behaves as a crystalline rock in the hydrologic system (a quartz arenite (sandstone) that behaves as though it is a metamorphic quartzite). The Wonewoc Fm. is only exposed on the highest hills in this area. The Wonewoc Fm., where present, forms the flat bench at the tops of the hills in and adjacent to the proposed Priory Rd. development. The well cemented part of the Wonewoc Fm. is an extremely hard unit that greatly complicates construction in the local area and significantly increases construction expenses on the top of the hills south and west of the Priory. The presence of the Wonewoc Fm. on the hilltops has greatly complicated the installation of underground utilities in the local area.

3. Groundwater Flow Considerations:

A. In the upper Mississippi Valley water flow in the upper ~90 feet of the rocks units exposed in the proposed development occurs primarily along fractures in the sedimentary rocks (Runkel et al., 2006) resulting in high transmission speed for contaminants. Similar results were found in other Cambrian units with similar lithology in central Wisconsin (Swanson et al., 2006) Contaminants that would be expected to be problematical would include: nitrate, viruses (Gellasch et al., 2014), bacteria and pharmaceuticals from septic systems or leaking sewers (Gellasch et al., 2013,) as well as any other contaminants (incl. fertilizers and herbicides) applied to the land surface or disposed of in private septic systems.

B. Of the three Cambrian sedimentary units, the thickest unit, the Mt. Simon Fm. has the fewest fractures, but fractures are still a dominant flow path if intersected by a well. A recent study of fractures in the Mt Simon Fm. (Gellasch et al., 2013), demonstrates that even if the well intersects a small number of fractures that the fractures can account for most of the flow in the well. In one borehole in the city of Madison, **five (5) fractures in the Cambrian rocks accounted for more than 80% of the total flow of groundwater into the borehole** (Gellasch et al., 2013). Leaking **urban sewer pipes in the city of Madison, WI have locally contaminated the Mt Simon Fm. aquifer even though the Mt. Simon Fm. aquifer is over 200 feet below the present land surface** in Madison, WI. In Madison, the Mt. Simon Aquifer is also over 200 feet below the leaking sewer pipes and it **was predicted during engineering studies that the Mt. Simon Fm. aquifer would be protected from contamination by the overlying Eau Claire Fm.** The Eau Claire Fm. which contains significantly more shale in southern WI than in city of Eau Claire, was expected to locally serve as an aquiclude (impermeable layer). **There is conclusive evidence that the Eau Claire Fm. did not function as an effective aquiclude because of incipient fractures** (Gellasch, 2013). **Similar fracture dominated flow has been observed in all of the other Cambrian siliciclastic bedrock units that occur in the upper- Midwest** (Swanson 2006; and Runkel, 2006).

C. Recent research has also demonstrated that the travel time between the leaking sewer in Madison, WI and the Mt Simon aquifer is less than two years and is associated with rapid subsurface water along discrete fractures in the overlying bedrock. In Madison, the Mt. Simon Fm. is overlain by the Wonewoc Fm., the Eau Claire Fm., and an additional 60 feet of younger rocks and 30 feet of unconsolidated glacial sediments which should behave as a porous media, filtering contaminants from the surface (Gellasch et al., 2013).

D. In the area of the proposed development west of Priory Rd., the Mt Simon Fm. water wells that could potentially yield higher water flows rates would be more susceptible to contamination because high-flows likely result from intersecting bedrock fractures or other secondary porosity.

E. By “luck”, some wells screened only in the Mt. Simon might represent local flow systems that are actually dominated by behavior as porous media (more capacity for filtering bacteria and with slower flow-rates). Low well flow-rates in some nearby residential homes probably represent more of a porous flow component. It is probable that these lower flow conditions

would correlate with a higher probability that viruses could become inactive over time. Low flow rates are not likely to have any long-term impact on predicted nitrate and bacteria levels in private wells.

F. Regional groundwater flow is north-northwest toward the Chippewa River and Lowes Creek. Local groundwater flow especially along transient and/or perched aquifers is probably strongly dominated by fracture orientations and bedding plane secondary porosity.

4. Implications of Proposed High Density Residential Subdivision:

A. Housing densities of 1 dwelling per 5 acres (current zoning) will likely result in minor well contamination by bacteria, viruses, pharmaceuticals, and nitrate both within and adjacent to the subdivision. Contamination will disperse with increasing distances from the proposed development. Housing densities higher than 1 dwelling per 5 acres will exacerbate the problem especially within, and immediately adjacent to, the proposed development. Developing this land is a bad idea that gets worse with an increasing density of housing. An impact on GW quality from the proposed high density development is not in question.

B. The extent of the contamination to be expected from a high-density housing development is difficult to quantify without additional data that does not currently exist. However, it is my professional judgement based on research in western Wisconsin on nitrate contamination that a high-density housing development is likely to lead to GW contamination exceeding Wisconsin Drinking Water Standards for nitrates (Tinker, 1991), and the same result would be expected for coliform bacteria especially in fractured bedrock. In addition, residents should be just as concerned about un-regulated contaminants that may show up in private wells.

C. The proposed development has the potential to be an **Excellent research project for geology students if the developers move ahead with the subdivision as planned** (1 acre lots)– The Wisconsin Geological and Natural History Survey is increasingly interested in fractured clastic aquifers because of the implications for ground-water contamination and its public health implications. Recent research results suggest that there would be a high probability that the proposed development would result in contaminated bedrock water supply wells both within the proposed subdivision and in nearby private water supply wells adjacent to the subdivision. **The most significant impact is to be expected at existing private wells along the western, northern and north-eastern side of the proposed development; an area of existing homes on de-facto 5+ acre lots.**

5. Complicating factors (factors that could influence the outcomes)

A. Lithologic formation boundaries may or may not represent hydrogeologic units. There can be considerable variation even within a single geological formation. No actual subsurface data is available for the proposed development.

B. Presence of fractures are poorly constrained and hard to determine without direct subsurface examination in either borings or excavations. Fracture size and density will greatly influence both local and potentially even regional groundwater flow. Recent evidence suggest modeling groundwater flow using a porous media model will not accurately account for the movement of

groundwater at this location. Any groundwater flow velocities modeled on porous media flow will underestimate flow velocities because of the high transmissivity (flow-rate) along zones of secondary porosity (fractures or bedding planes). This means contaminants are likely to flow much faster between residential septic systems and wells in this area of shallow fractured sedimentary bedrock.

C. Due to elevation differences in the proposed area, hydrogeologic conditions are likely to vary across the proposed development. The northern and western side of proposed subdivision are more prone to contamination due to bedrock at or very near the surface (Within 24"). One would also expect greater impacts on neighbors to the north and west of the subdivision. The north and west directions are also down gradient from the rest of the development which only exacerbates the potential for significant contamination.

D. This outline does not even attempt to address whether or not suitable sites for the placement of the private septic systems required for the proposed development plan could be located within each individual lot in the proposed development. Even if septic systems could be permitted within each lot, the project developer should also consider the locations within the proposed lots where they could possibly place a water supply well without being in very close proximity to either the septic system on the same lot or the proximity of the well to the septic systems on neighboring properties.

6. Recommendation:

Most of the proposed subdivision is planned on a land surface where there will be no appreciable cleansing of wastewater by passage through a porous media. The shallow fractured bedrock within just inches of the current land surface means that wastewater, fertilizers and herbicides will quickly enter the bedrock where fracture dominated flow will control its eventual contamination of the Mt Simon Fm. aquifer.

For this site, the housing density should be kept as low as possible to protect both existing private water supply wells bordering the proposed development, and also the future inhabitants of the proposed development. It would also help if most of the developed area was kept in a natural state so that land application of fertilizer and herbicides is minimized. Neighboring developments located on the same bedrock units and drawing water from the Mt. Simon Fm. average 5+ acres per residence. Most of these adjacent subdivisions also have kept natural vegetation in place. These lower density less intensely developed parcels have been at least moderately successful at keeping regulated contaminants below state drinking water standards. Based on past experience, a lot size that equals or exceeds five acres per residence would seem to be a reasonable standard for development on this type of fractured bedrock. Given the geology of the local area, development with an engineered housing density higher than one residence per five acre parcel is very likely to have a significant negative impact on the quality of water both within the development and for property owners adjacent to the proposed development.

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Priory Road Stratigraphic Section

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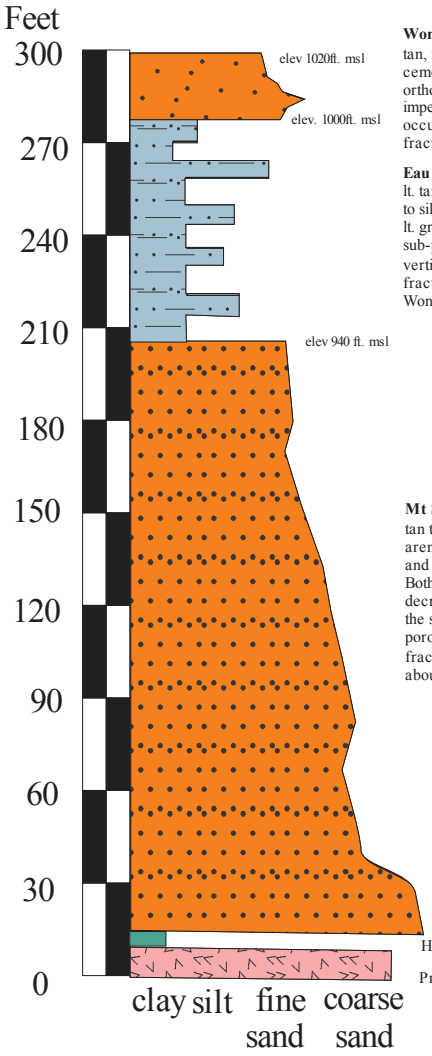

Wonewoc Fm: Medium to thick bedded, tan, fine to medium grained, very-well cemented, quartz arenite to quartz orthoquartzite. Orthoquartzite layers are impermeable and dominant water flow occurs along moderately spaced vertical fractures and along beds with less cement.

Eau Claire Fm: Thin bedded, lt. tan to lt. green, fine-grained sandstone to siltstone with thin (1-2mm) lt. green clay lenses. Alternating sub-parallel beds with closely spaced vertical fractures. Primary water flow via fractures. Gradational contact with overlying Wonewoc Fm.

Mt Simon Fm. Moderately cemented, tan to lt. orange, cross stratified quartz arenite (sandstone) pebbly near the base and fining upwards in the section to med. sand. Both grain size and bedding thickness decrease upwards. Moderately fractured in the subsurface with water flow both as a porous media and along widely spaced fractures. Thickness in city of Eau Claire about 190'.

Hydrothermal alteration (clay) aquiclude

Precambrian Basement