TECHNICAL MEMORANDUM

DATE July 8, 2010 **PROJECT No.** 08-1132-116-0-M02

TO Ms. Peggy Van Mierlo-West, Director of Community Services
Municipality of Lambton Shores

CC Mr. John Byrne, CAO
Municipality of Lambton Shores

Mr. W.A. Boussey, P.Eng.
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FROM Mr. Philip R. Bedell, P.Eng. **EMAIL** phil_bedell@golder.com

REVIEW OF COMMENTS BY COMMUNITY GROUP ON GROUNDWATER AND SURFACE WATER TESTING RESULTS ZONE 3 SANITARY SEWAGE COLLECTION SYSTEM CLASS EA COMMUNITY OF GRAND BEND MUNICIPALITY OF LAMBTON SHORES, ONTARIO

Dear Ms. Van Mierlo-West:

Introduction

This technical memorandum provides our analyses of the comments provided by the Zone 3 Community Group, specifically the April 8, 2010 presentation by Dr. Carl Belke pertaining to the groundwater and surface water testing results for the above-noted study.

Background

The results of the groundwater and surface water monthly monitoring and sampling by Golder Associates Ltd. (Golder) for the period November 2008 to December 2009 has been provided in Golder Report No. 08-1132-116-0-R02 entitled "Summary Report on Groundwater Monitoring Wells, Community of Grand Bend, Municipality of Lambton Shores, Ontario", dated December 16, 2009. The program is being continued, as requested, on a quarterly basis.

Zone 3 Community Group Presentation

The presentation related to the hydrogeological issue consisted of a series of 15 powerpoint slides. The following are our comments on the presentation issues with which we do not agree:

Aquifer System

The overburden aquifer system is stated to be "from 3 to 7 metres below surface and 7 to 20 metres deep." Zone 3 is located on the Lakeshore dunes and the overburden aquifer is unconfined with the sand deposits

extending from ground surface to depths of as much as 20 metres. Groundwater levels are typically 3 to 7 metres below the ground surface.

Analytical Parameters

It was suggested during the presentation that only four (4) of the analytical parameters analysed for are significant for septic system effluent. This is not correct. In addition to E-coli, phosphate, ammonia and nitrate, dissolved organic carbon (DOC), total dissolved solids (TDS) and chloride are parameters which relate to the potential impacts of septic systems.

Phosphorus Concentrations

The water quality limit for phosphorus given in the presentation is unclear. However, as stated by the Provincial Water Quality Objectives (PWQO), "A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 µg/L or less. This should apply to all lakes naturally below this value". Based on data available from the United States Environmental Protection Agency, phosphorus concentrations in Lake Huron generally range between approximately 3 and 5 µg/L[1]. Therefore, phosphorus concentrations in Lake Huron should be maintained below the 10 µg/L limit.

In the presentation, the concentration of phosphorus in groundwater was given as an average value of all data from all monitoring wells over the period of record. Averaging of the analytical results without regard to location and groundwater gradients is not correct. Since the groundwater flow direction is towards Lake Huron, concentrations of septic system related contaminants are expected to increase along the groundwater flow direction. Concentrations of phosphorus in the downgradient well MW-9 were measured as high as 130 µg/L during the monitoring program. These results indicate that septic discharges in Zone 3 are providing a source of phosphorus to Lake Huron. Elevated concentrations of phosphorus have the potential to promote nuisance algal growth, thereby damaging the health of the nearshore aquatic environment.

Ammonia Concentrations

Ammonia was quantified in the presentation as an average concentration of less than 0.06 mg/L with a limit of 0.1 mg/L. Again, blanket averaging of results is incorrect.

Dissolved ammonia is present in two forms, the ionized (NH_4^+) and unionized form (NH_3). The relative amount of each form is dependant on the pH and temperature. The PWQO guideline for ammonia is based on the concentration of the unionized form. Based on the measured pH and temperature range of groundwater in Zone 3, the measured ammonia concentrations likely represent concentrations of unionized ammonia that are below the PWQO guidelines.

However, the presence of ammonia in groundwater is an indicator of septic system contamination. Under the typical pH and temperature conditions measured in groundwater within Zone 3, ammonia will be present primarily as the ionized (NH_4^+) form. As a positively charged ion, NH_4^+, will tend to sorb to negatively charged soil particles, which generally limits its mobility within groundwater aquifers. Further, within the highly oxic (high concentrations of dissolved oxygen) groundwater conditions measured within Zone 3, ammonia is rapidly converted to nitrate through the microbial process of nitrification.

[1] United States Environmental Protection Agency, Great Lakes Monitoring, Limnology Program, http://www.epa.gov/glnpo/monitoring/indicators/limnology/index.htm – Accessed June 17, 2010.

As such, the presence of ammonia in groundwater samples from Zone 3 suggests that much higher concentrations are likely present elsewhere in the aquifer. For these reasons, the presence of ammonia in groundwater samples collected from Zone 3 indicates contamination from septic systems.

Nitrate Concentrations

The criterion for nitrate of 10 mg/L given during the presentation was based on the Ontario Drinking Water Standards (ODWS) and does not apply since the groundwater discharge is to surface waters. The Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Aquatic Life provides a limit of 2.9 mg/L for the protection of aquatic life forms in surface water. This limit is related to the direct toxicity to aquatic organisms and does not account for eutrophication effects.

Based on data available from the United States Environmental Protection Agency, the concentration of nitrate in Lake Huron has historically ranged from approximately 0.3 to 0.35 mg/L[2]. The nitrate concentration provided in the presentation was an average value of all data from all monitoring wells over the period of record. This is grossly misleading as it ignores the effects of groundwater flow and varying site conditions and therefore does not capture the effect of the septic systems. Concentrations of nitrate in the downgradient well MW-9 have been measured as high as 6.5 mg/L. This is a clear indication that septic systems in Zone 3 are contributing nitrate to Lake Huron.

It was stated in the presentation that the data does not indicate an increasing trend of nitrate concentration over time. However, the averaging technique used to plot nitrate concentrations against time is inappropriate, as discussed above, and masks the true variations. Some wells, such as 5, 8 and 9, indicated increasing nitrate concentrations over the study period. Further, the period of study, while giving some indication of seasonal variations, is far too short to define long-term trends. Short term (month to month or year to year) variations in groundwater quality are to be anticipated in response to variations in precipitation on similar time scales.

Summary Questions

The summary questions listed in the presentation and the correct responses are:

1. Q: Is the groundwater being impacted by Zone 3 septic systems?

   A: There is very clear evidence that the groundwater is being adversely impacted by septic systems.

2. Q: Are the levels of NO_3 of concern?

   A: The concentrations of nitrates in the groundwater discharging to the surface water in Lake Huron exceed the CCME criterion established for the protection of aquatic life. As detailed below, the groundwater discharge from Zone 3 to Lake Huron represents an annual load of approximately 19,000 kilograms of nitrate (as nitrogen) and 400 kilograms of phosphorus from Zone 3 to Lake Huron.

3. Q: Are the levels of NO_3 increasing?

   A: In some areas, concentrations are increasing. Overall averaging is very misleading. The duration of the groundwater monitoring program is far too short to identify any long term trends in groundwater quality.

[2] United States Environmental Protection Agency, Great Lakes Monitoring, Limnology Program, http://www.epa.gov/glnpo/monitoring/indicators/limnology/index.htm – Accessed June 17, 2010.

4. Q: If the status quo is maintained, will there be an increase in groundwater NO_3?

   A: As detailed below, nitrate concentrations in the groundwater will increase as build out of lots continues, population increases and septic system discharges continue to increase. Even without an increase in population, increased discharges of nitrate and phosphate to Lake Huron may be expected as the soil loses the ability to treat septic effluent with time.

Chloride concentrations are not addressed in the presentation. The measured concentrations in Zone 3 are typically 16 times higher than in the Pinery well. This is a clear indicator of septic system impacts.

Additional Comments

Nitrate and Phosphorus Loads to Lake Huron

As stated in our summary report dated December 16, 2009, the water level measurements indicate that the primary groundwater flow direction is towards Lake Huron with localized groundwater discharge to Parkhill Creek and the Old Ausable River Channel, especially during the spring months when groundwater levels are high.

The hydraulic conductivity (K) of the granular material encountered in Zone 3 can be estimated from the grain size distribution for representative samples collected during the borehole drilling and monitoring well installation using the Hazen approximation:

$$K = Cd_{10}^2$$ (in Freeze and Cherry, 1979)[3]

where:

C = empirical constant (for K in centimeters per second (cm/s) and d in millimeters (mm), C is equal to 1.0); and

d_{10} = effective grain size at which 10 per cent by weight of the soil particles are finer.

Based on the above relationship, the hydraulic conductivity of the saturated sand and sand and gravel aquifer within Zone 3 was estimated to range between approximately 1×10^{-4} to 4×10^{-4} metres per second (m/s). It should be noted that estimates of hydraulic conductivity obtained using the Hazen method are based on discrete samples and do not account for aquifer heterogeneity. As such, the bulk hydraulic conductivity of the aquifer may be much greater than these estimates and the flow rates discussed below likely represent lower range estimates.

Based on the average groundwater and surface water levels measured over the period of study, the average horizontal hydraulic gradient between Zone 3 and Lake Huron was approximately 0.005.

Using these values, and assuming a porosity of 0.3 for the sand aquifer, the average linear groundwater velocity is estimated to be as much as 210 metres per year towards Lake Huron. Assuming an approximately 10 metre thick mixed zone within the groundwater aquifer, this flow represents a discharge of approximately 3.5 billion litres per year (3.5×10^6 m^3 per year) of groundwater from Zone 3 to Lake Huron.

[3] Freeze, R. Allan, Cherry, John A. (1979) Groundwater. Prentice-Hall Inc.

Based on the average concentrations measured at the downgradient well MW-9, this discharge represents an annual load of approximately 19,000 kilograms of nitrate (as nitrogen) and 400 kilograms of phosphorus from Zone 3 to Lake Huron.

Denitrification

It has been suggested that denitrification would be able to remove nitrate from the groundwater in Zone 3 before it is discharged to the environment. However, research has shown that denitrification is unable to remove nitrate from septic system effluent in sand aquifers with a high dissolved oxygen concentration[4].

The microbial process of denitrification is the step-wise reduction of nitrate through to nitrite, nitric oxides and finally to molecular nitrogen. Heterotrophic bacteria are responsible for much of the denitrification activity in soils; however, these bacterial species are facultative aerobes and only denitrify when oxygen becomes depleted. Denitrifying microbes utilize nitrate to oxidize organic material to gain energy for growth and function. Thus, two conditions are needed for denitrification to occur: a lack of dissolved oxygen and a source of organic material. Based on groundwater monitoring data, the concentrations of dissolved oxygen in groundwater in Zone 3 were generally high, while the concentrations of dissolved organic carbon (DOC) were generally very low. Furthermore, the concentration of dissolved oxygen measured in Lake Huron was always high and the organic content of beach sand is very low. Therefore, due to the high dissolved oxygen concentrations and lack of organic material, it is highly unlikely that denitrification is removing a significant amount of nitrate in the near shore environment where contaminated groundwater from Zone 3 is discharging to the lake.

Simplified Numerical Modelling

Simplified numerical modelling of the portion of Zone 3 between the Old Ausable River channel and Lake Huron was undertaken to compare the effects of theoretical/regulatory septic system loadings on the groundwater together with the effects of variations in various parameters such as:

- annual precipitation;
- build out of underdeveloped lots;
- increases in population;
- seasonal versus permanent residence occupation;
- lot size; and
- de-nitrification by proprietary septic systems.

In general, the modelling suggest that nitrate conditions in the groundwater would be higher than the measured values; however, the pattern of increasing concentrations towards the lake is consistent. The potential effects of the parameters noted above were found to be:

- Annual Precipitation - A decrease of 10 per cent would increase nitrate concentrations by about 10 per cent.
- Build Out of All Undeveloped Lots - An increase in nitrate concentrations of 15 per cent would be expected.

[4] Robertson, W.D., Cherry, J.A., and Sudicky, E.A, 1991, Ground-water Contamination from Two Small Septic Systems on Sand Aquifers, *Groundwater*, 29(1).

- Increases in Residential Population - Current values are based on two people per residence. An increase in nitrate concentrations proportional to any increase in population would be expected.
- Seasonal Versus Permanent Occupancy - Full permanent occupancy would increase nitrate levels by approximately 25 per cent.
- Lot Size - if any lots were subdivided, additional nitrate loadings would occur.

Furthermore, the available research indicates that, with continued application of septic effluent, the ability of soil to treat the effluent may decrease over time[5,6]. This would lead to a long term increase in nitrate and phosphorus discharges to Lake Huron, even without an increase in population.

Conclusions

Based on the results of the monitoring program, it is clear that septic systems in Zone 3 are contributing nitrate and phosphate loads to Lake Huron. The Lake Huron Centre for Coastal Conservation, in association with Environment Canada, has consistently identified private septic systems as a major source of bacterial and nutrient contamination to the southeastern shore of Lake Huron and have cited much research indicating that septic systems in sandy soils contribute significant amounts of nitrate and phosphorus to the nearshore environment[7]. The input of these nutrients may contribute to the growth of nuisance algae and to a general decline in the water quality and health of the nearshore lake environment.

Closure

We trust that this technical memorandum is sufficient for your immediate requirements. If further detail is required at this time, please contact our office.

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[5] Viraraghavan, T., and Warnock, R.G., 1976, Groundwater Pollution from a Septic Field, in *Water, Air, and Soil Pollution,* 5, pp 281-287.

[6] Harman, J., Robertson, W.D., Cherry, J.A., and Zanini, L., 1996, Impacts on a Sand Aquifer from an Old Septic System: Nitrate and Phosphate. *Groundwater,* 34(6), pp 1105-1114

[7] The Lake Huron Centre for Coastal Conservation, 2004, Nearshore Water Quality, A Preliminary Report on Historical Nearshore Water Quality Information for Southeastern Lake Huron, Sauble Beach to Sarnia.