



INTERA ENGINEERING LTD.
1 Raymond Street, Suite 200
Ottawa, ON K1R 1A2
Tel: (613) 232-2525
Fax: (613) 232-7149

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Friends of the Rural Communities and Environment (FORCE)
c/o Lawson Park Ltd.,
P.O. Box 15, R.R. #1
Freelton, Ontario L0R 1K0

Attention: Graham Flint, Chair, FORCE

Re: Review of Hydrogeological Work Plan, St. Marys Flamborough Quarry Site, City of Hamilton

Dear Mr. Flint,

Please accept this letter as INTERA Engineering Ltd. (INTERA) report on hydrogeologic review of the final hydrogeological work plan for the proposed St Marys Flamborough Quarry Site prepared by Gartner Lee Limited (GLL), dated March, 2008. The proposed Quarry is to be developed in the Amabel Formation dolostone to depths of about 36 to 40 m in Part of Lot 1, and Lots 2 and 3, Concession 11, geographic Township of East Flamborough, now the City of Hamilton.

This letter replaces my November 19, 2007 letter which reviewed the final draft hydrogeological work plan prepared by GLL dated August, 2007. This letter also revises parts of my November 19, 2007 letter by correctly referencing the pumping wells (i.e., TW-14, TW-15 and TW-16) proposed for the pilot test of the groundwater recirculation system (GRS).

The hydrogeological work plan, prepared by Gartner Lee Limited (GLL), describes the proposed sequence and recent results of activities undertaken to further characterize the Amabel Formation dolostone aquifer and to undertake the pilot scale testing of the groundwater recirculation system (GRS). The GRS is proposed to mitigate quarry-induced drawdowns in the bedrock aquifer and impacts to local surface water ecological features. The hydrogeological work plan was requested by the City of Hamilton.

The final hydrogeological work plan is follow-up to the *Final Draft – Hydrogeological Work Plan*, prepared by GLL in August, 2007, the *Revised Work Plan for the Evaluation of Groundwater Recirculation System* prepared by GLL in September 2006, the draft three-volume *Hydrogeological Level 2 Report* prepared by GLL in June, 2005 and the *Preliminary Hydrogeological Assessment Report*, prepared by GLL in August, 2004. The last two of these earlier reports were prepared for Lowndes Holdings Corporation, former site owners. I previously provided hydrogeological review comments on these four earlier reports in correspondence with you dated November 19, 2007, November 26, 2006, November 11, 2005 and March 28, 2005, respectively.

This report was prepared by Kenneth G. Raven, P.Eng., P.Geo., Principal and Senior Hydrogeologist of INTERA Engineering Ltd. This report reviews the primary documentation describing the proposed final hydrogeological work plan.

This letter is organized by the following four sections:

1. Primary Documents Reviewed
2. Hydrogeological Work Plan
3. Hydrogeologic Review and Concerns
4. Conclusions

1. PRIMARY DOCUMENTS REVIEWED

The following primary documents were the focus of this review:

- *Hydrogeological Work Plan, St Marys Flamborough Quarry Site*, Final Report with Supporting Documents on CD prepared by Gartner Lee Limited for St. Marys Cement CBM, March, 2008.
- *Hydrogeological Work Plan, St Marys Flamborough Quarry Site*, Final Draft Report prepared by Gartner Lee Limited for St. Marys Cement CBM, August, 2007.
- *Flamborough Quarry Project, Geophysical Logging and Testing Results for Monitoring and Test Wells*, Lotowater Technical Services Inc., Draft Report prepared for CBM St Marys Cement, July 24, 2007.
- *Flamborough Quarry Project, 2006/2007 Packer Testing and Depth Specific Water Quality Sampling Results for Monitoring and Test Wells*, Lotowater Technical Services Inc., Draft Report prepared for CBM St Marys Cement, July 31, 2007.
- *Drawdown Cone Prediction of the Proposed GRS Well Pumping*, Gartner Lee Limited Memorandum Reference # GLL60-699 to Ministry of the Environment from Helen Zhang, January 28, 2008.

2. HYDROGEOLOGICAL WORK PLAN

The hydrogeological work plan was prepared at the request of the City of Hamilton for submission to the Combined Aggregate Review Team (CART). The hydrogeological work plan was intended to assist the proponent, CART and others in "reaching a common understanding of the expectations of the required submission, and to establish a basis for the technical review of the submissions, once they have been received".

In short, the proposed hydrogeological work plan is intended to provide an integrated and comprehensive outline of the details of the hydrogeological work to be undertaken to assess the GRS pilot study and other hydrogeological site assessment work proposed or undertaken to support

hydrogeological characterization of the site.

The hydrogeological work plan report is a combination of a review/status report and a work plan for hydrogeological work completed and proposed for the Quarry site, with an appended set of generic or boiler plate field procedures, which may or may not be directly applicable to the proposed work. The work plan provides details on planned GRS testing and analysis activities, locations and types of monitoring to be performed, monitoring and procedures to address private well interference problems, adaptive management plans and contingency plans. Earlier versions of this plan were reviewed by Jagger Hims Limited on behalf of the City of Hamilton and the current version has benefited from those earlier reviews.

The final hydrogeological work plan dated March 2008 is an update of the final draft hydrogeological work plan prepared in August 2007. The final hydrogeological work plan includes several revisions and clarifications put in place to address the City of Hamilton Public Health Services letter of October 26, 2007 to MOE.

The final hydrogeological work plan includes specific additional information on:

- the toxicology and testing procedures of the proposed water tracing dyes (Supporting Documents 45 and 46);
- borehole geophysics and flow profiling for new well MWB28 (Supporting Documents 49 and 50);
- summary minutes of trigger setting meetings (Supporting Documents 37 and 38);
- groundwater modeling memo on predicted GRS pilot test drawdowns (Supporting Document 35);
- procedure for resolution of private well interference complaints (Supporting Document 36); and
- groundwater triggers (Table 6) and surface water triggers (Appendix C) and set of related response actions for the proposed pilot scale GRS testing.

3. HYDROGEOLOGIC REVIEW AND CONCERNS

Based on my review of the primary documents outlined in Section 1 and in consideration of previous reports prepared for this site as listed in my earlier review letters, I offer the following comments and identify the following hydrogeologic issues and concerns for the proposed final hydrogeological work plan.

1. There is new hydrogeological data in this report (notably the Lotowater borehole geophysical/dynamic flow logging and packer testing) that confirm for me the great difficulties that will be encountered in doing the GRS pilot test and in attempting to implement a full scale GRS for the quarry. For example, the dynamic flow logging and the packer testing show that there are very permeable horizons (production zones) within the bedrock that are separated by intervening low permeability thicknesses of bedrock. Such production zones are shown to sporadically exist at depths of 5-15 m, 20-25 m and 30–35 m depth in different wells across the site. The presence of these low permeability intervening zones will clearly compromise the functioning of the GRS in both pilot and full scale applications.

2. The depth occurrence of the permeable bedrock horizons or production zones is clearly not predictable and will likely create operational problems with the pilot scale GRS. For example, several of the wells tested (e.g., TW-13) and those intended to simulate full Quarry drawdown (i.e., TW-14, TW-15) show much different depth distribution and magnitude of these permeable production zones. The bottom of TW-14 is permeable (transmissivity, $T = 84 \text{ m}^2/\text{day}$), but only the top of TW-13 is permeable ($T=1350 \text{ m}^2/\text{day}$), while the bottom of TW-15 is permeable, but less than that than for TW-14. The magnitude range and depth distribution of these bedrock permeabilities mean that it will be difficult to achieve the 30 m drawdown in the GRS pumping wells. That is, while pumping from TW-14 may achieve the targeted drawdown in the 30-35 m deep production zone, pumping from wells with properties like those in TW-13 will not create any significant drawdown in this deeper zone. Such are the inescapable difficulties of undertaking pumping tests and trying to implement a GRS in the fractured and highly heterogeneous permeability rocks of the Amabel Formation.
3. The occurrence of the very high transmissivity in the shallow zone of TW-13 with little to no transmissivity in the deeper zones of TW-13 is the scenario I outlined in point 10 of my November 26, 2006 letter to you, that can contribute to escape of injected water during the GRS. If these same TW-13 conditions exist in some of the trench injection wells while conditions similar to those of TW-14 occur in the pumping wells, re-injected water has the potential to escape.
4. The proposed pilot scale GRS test has the proper objective of creating drawdown in the vicinity of the pumping wells equal to the proposed base of the Quarry (about 40 m depth or elevation of 250 mASL) in order to correctly simulate Quarry-induced drawdown. How will such drawdowns be confirmed when one is pumping very large quantities of water (e.g., 300-500 l/gpm or more) from the individual GRS pumping wells, and such pumping will most likely create significant head losses at the wells due to non-linear turbulent flow conditions and positive skin effects in the wells. It would not be uncommon for drawdowns of 40 m being measured in the pumping wells to yield drawdowns in the formation of only half of that amount or 20 m, due to these non-linear turbulent head losses and skin effects. Such pumping conditions would not meet the drawdown objective of the pilot scale GRS pumping tests. There needs to be a clear outline as to how the proposed drawdowns will be confirmed for the bedrock in the vicinity of the pumping wells under such high pumping rates
5. The issue of discharge of groundwater that exceeds PWQO remains a concern to me, notwithstanding the recalculation of surface water impact using deep groundwater and the cited Stantec arguments given on why exceedence of PWQO for zinc should not be a problem. The water quality testing conducted by Lotowater shows that some wells and intervals will produce water that exceeds PWQO for zinc. For example, the proposed main pumping well for the GRS pumping test (TW-14) will yield zinc concentrations that exceed PWQO. It should be noted that the reported zinc concentrations (0.034 and 0.038 mg/L) are only for dissolved zinc concentrations. Total zinc concentrations (i.e., dissolved + particulate) which are the bio-available concentrations that should be reported in assessing surface water quality impact, were not analysed in these samples. Total zinc concentrations are usually greater than dissolved concentrations.
6. The Zhang MODFLOW modeling memorandum is the basis for the prediction of pilot scale GRS testing drawdown and the selection of trigger values for groundwater sentinel well drawdowns. Based on my review of this work, I believe that the magnitude and radial extent of the drawdowns predicted for the GRS pilot test have been underestimated. This underestimation is due to the fact that the regional model used by GLL assumes only a cumulative bedrock transmissivity for the Amabel of $90 \text{ m}^2/\text{day}$, when values of 200 to 500

m²/day have been measured near the proposed GRS pilot test area (TW-10 and TW-12 2004 pumping tests, Lotowater 2006/2007 testing of TW-14) and much higher values also exist at the site (e.g., 1350 m²/day at TW-13). Larger transmissivity values will create a much flatter drawdown curve, which means the drawdown will propagate more easily away from the GRS pumping wells giving greater drawdown further away from the GRS pumping wells. Larger transmissivity values also mean that the GRS wells will have to be pumped at higher rates to achieve the target drawdown to the base of the Quarry.

GLL cite (bottom of page 23 of hydrogeological work plan report) the 2004 pumping test of TW-12 and in particular the drawdowns observed in GLL BH-1D, as support for the general reliability of the MODFLOW predictions and of the limited drawdown likely to occur at the Stonebrook Estates wells. As has been previously noted, the drawdowns measured in many monitoring wells including GLL BH-1D were underestimated in the 2004 pumping test because many of these monitoring wells did not intersect the permeable production zones in the Amabel dolostone bedrock, where the drawdown was greatest.

7. As there are reasonable grounds to believe that the magnitude and extent of the groundwater drawdowns have been under-predicted in the GLL MODFLOW modeling, it will be extremely important to ensure that monitoring of drawdowns in the proposed sentinel groundwater monitoring wells is closely scrutinized during the pilot scale GRS pumping tests.
8. It is important to remember that the proposed pilot scale GRS test will only provide information on the practicality and performance of a short-term GRS system in the immediate vicinity of the proposed test area. Such a pilot test will not demonstrate the practicality and performance of a long-term, full scale GRS for the Quarry. The results of the pilot scale GRS testing will be controlled by the hydraulic properties of the bedrock in the immediate vicinity of the pilot test pumping wells TW-14, TW-15 and TW-16. Given the wide range and heterogeneity of bedrock hydraulic properties evident at the site and the numerous mechanisms by which a GRS could fail, it would be foolhardy to assume that the results from the pilot scale GRS that represents less than 5% of the expected Quarry perimeter, would reliably represent the full scale GRS operation for the Quarry.
9. While groundwater triggers for the GRS pilot test are quantitatively defined in Table 6 of the final hydrogeological work plan report, there is ambiguity concerning the specific response actions that will be taken if the triggers are exceeded. The choices of response actions to exceedences of water level drawdown triggers include provision of temporary water supply or decreasing pumping rates, with the decision apparently resting with the participating agencies (MOE and the City of Hamilton or Region of Halton) (page 22 and 23 of final hydrogeological work plan report). There should be a clearer set of conditions that determine when and how these different responses would be selected and under what conditions the GRS pilot test should be terminated.

4. CONCLUSIONS

The final hydrogeologic work plan and the new information contained therein confirm my earlier opinions on the great difficulty and potential hazards of undertaking the pilot scale GRS and of implementing such a system to a full Quarry scale. Consequently, it remains important that stakeholders other than the proponent be allowed to monitor the field implementation of the proposed GRS and that the data from this test be made available for review by third parties.

All of the hydrogeologic concerns and issues that were expressed in my November 26, 2006 letter to you, remain for the proposed GRS pilot test and full scale implementation of GRS at the proposed St. Marys Flamborough Quarry.

Respectfully submitted,

Intera Engineering Ltd.



Kenneth Raven, P.Eng., P.Geo.
Principal

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Prepared By:	Kenneth Raven	
Reviewed By:	Kenneth Raven	