November 20, 2008

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Niagara Escarpment Commission
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Subject: Peer review of Duntroon Quarry hydrogeologic modelling: Report #2

Dear Ms. Pounder:

On June 5, 2008 we transmitted a final version of our first peer review report on the hydrogeologic analyses being undertaken to support the proposed expansion of the Duntroon Quarry, Clearview Township, County of Simcoe. Our first report contained preliminary comments on the groundwater modelling. In parallel, Mr. Daryl Cowell transmitted supplementary review comments on October 15, 2008. Jagger Hims Limited (JHL), the consultants for the proponent, Walker Aggregates, Inc., has submitted two substantial responses to our first peer review report and to Daryl Cowell's supplementary comments:

- **Duntroon Quarry Expansion Hydrogeological Evaluation: Response to Groundwater Modeling Peer Review Comments**, September 18, 2008; and
- **Duntroon Quarry Expansion Hydrogeological Peer Review Comments: Response to Supplementary Karst Review Comments from Daryl Cowell**, November 14, 2008.

We are very impressed with the scope of the responses to both sets of peer review comments. The responses are comprehensive, detailed, and thoughtful. It is clear that a significant effort has been devoted to addressing the comments. The responses go a long way towards clarifying the essential aspects of the hydrogeologic analyses. In general, we have relatively few follow-up comments. However, there are a few technical points that we are still either not clear on, or that we would like to have addressed in greater detail. Our comments are divided into two parts corresponding to the two JHL response documents.

1. **Duntroon Quarry Expansion Hydrogeological Evaluation: Response to Groundwater Modeling Peer Review Comments, Jagger Hims Limited**, September 18, 2008

1. Page 3: JHL provide substantial details on their rationale for making relatively detailed adjustments to the distribution of hydraulic conductivities specified in their modelling. They suggest that part of their motivation for this level of detail was to avoid criticism that their modelling might be considered as too general to have much predictive value. Although this motivation may have some merit, our concern is in the other direction. In our opinion, the model may be so detailed that it provides a false sense of accuracy. It is important to bear in mind that a model is a deliberate simplification. In this application, a close match to time-averaged water levels from existing observation wells does not imply that water levels for different conditions will be matched as well, nor will water levels in areas where the current monitoring network is relatively sparse. In our opinion, it may be preferable to adopt less complex distributions of hydraulic conductivity to provide a more realistic impression of the predictive capabilities of the groundwater model.

2. Figures A-1 through A-4: We are confused by the presentation of the mean hydraulic conductivities from the packer tests. The results of packer test profiling for nine (9) wells are listed on Tables 1 through 9. However, it appears that significantly more locations with reported mean hydraulic conductivities are shown in the figures. For example, 15 mean hydraulic conductivities are presented for model layers 4 and 5 (Figures A-3 and A-4):

   - OW1;
   - OW2;
   - OW3;
   - OW4;
   - OW5;
   - OW6;
   - 98-8
   - 98-9;
   - BH03-1;
   - BH03-2;
   - BH03-4;
   - BH03-5;
   - BH03-6;
   - BH03-8; and
   - BH03-9.

3. Page 4: Although model preprocessors generally require hydraulic conductivity as input, MODFLOW really works with transmissivities. It is our understanding that the transmissivities specified for each model layer were in part constrained by the products of the model layer thicknesses and the geometric means of the transmissivities estimated from packer tests conducted over the elevations corresponding to the layers. In our opinion, this may not be appropriate, as the inflows to the existing quarry and the proposed expansion will be dominated by the most transmissive intervals. The geometric mean tends to "suppress" the highest values. In our opinion, it is generally more appropriate to constrain the transmissivities of the layers with the cumulative transmissivities of the packer tests at each location.

   We raise this point because at first glance it appears that there is a weak correlation between the hydraulic conductivities specified for each layer in the calibrated model and the corresponding geometric means. As shown in Figure 1, there does not appear to be a systematic relationship between the results of the packer testing and the conductivities estimated through model calibration. In particular, the model conductivities do not appear to be approximately an order-of-magnitude higher than the estimates derived from the packer testing as is suggested in the responses. Figure 1 was assembled from the information provided in JHL's response to comments, Tables 1 through 9.

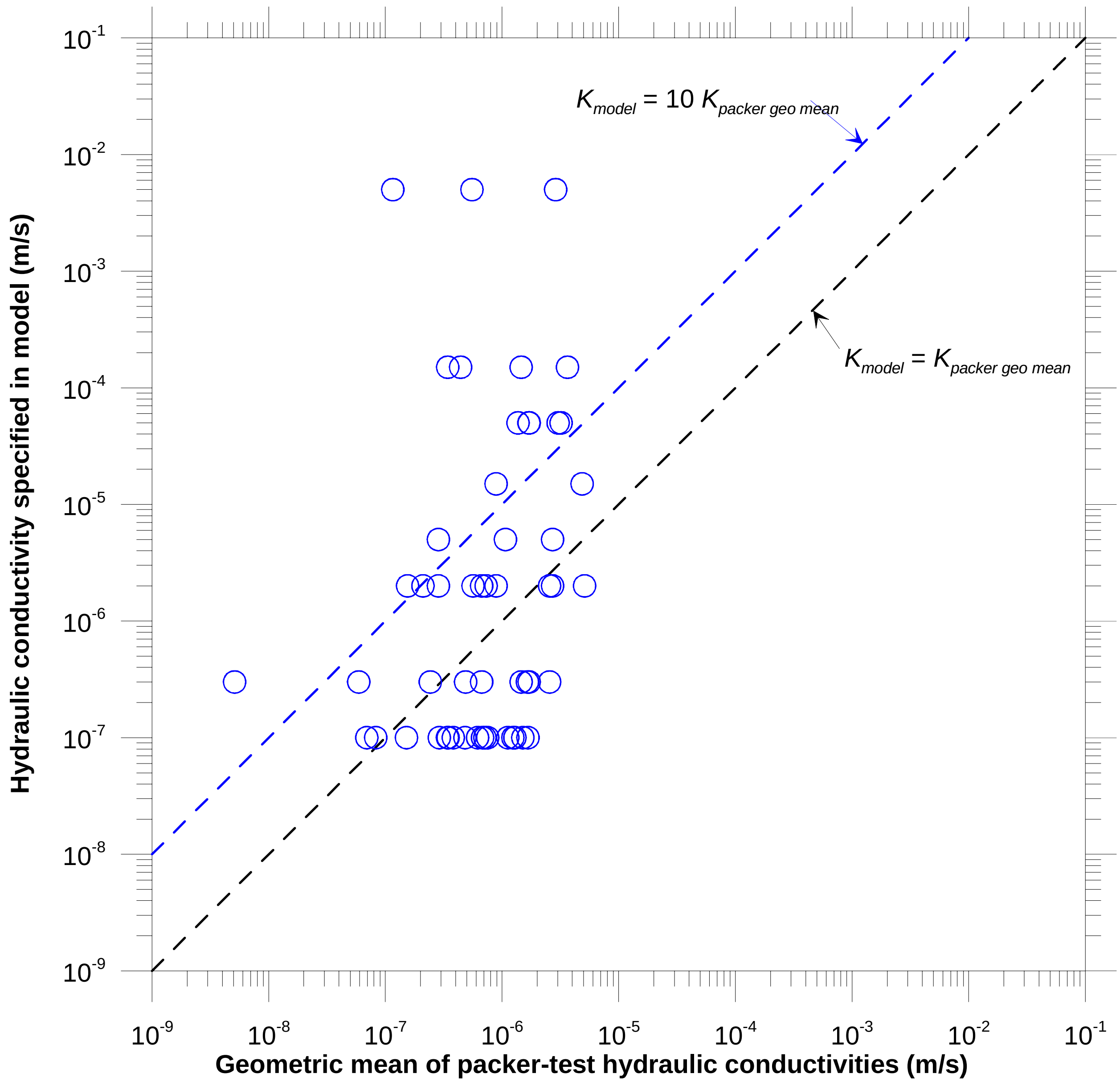

Figure 1. Comparison of hydraulic conductivities from packer testing and model calibration

4. Page 5: It is indicated that hydraulic conductivities derived for the larger rock mass "are approximately an order of magnitude greater than those derived from individual borehole packer test data". Is this an observation derived from site data, or from general experience? If it is derived from general experience, we recommend that at least one reference be cited to support this indication.

5. Page 7: It is argued that modifying hydraulic conductivity beyond the range of values supported by site-specific data does not compromise the overall integrity of the model. In our opinion, making modifications beyond the constraints of site data does compromise the integrity of the model calibration, and should be considered cautiously.

6. Page 8: There appears to be a disagreement between the interpretations of JHL and MAQ's consultants in the vicinity of OW5S. The issue is whether the groundwater level at OW5S is representative, and whether the hydraulic conductivity in the vicinity of OW5S is significant with respect to the model predictions. If the implications of the high hydraulic zone in the vicinity of OW5S is significant, we recommend that a slug test be conducted on this monitoring well to assist in assessing whether the well is representative.

7. Page 9: Are we correct in understanding that the results of backwards particle tracking are suggested as a "line of evidence" to support terminating the zone of elevated hydraulic conductivity above model layer 5? It seems to us that the particle tracking results serve to visualize the conceptualization underlying the model, and not as an indication of how the natural system actually might be.

8. Page 10: Is it not possible that water levels approximately 2 m above the adjacent quarry floor indicate the presence of a seepage face, rather than reduced hydraulic conductivity?

9. Page 10: The response suggests that the results of the pumping tests at the Camarthen Lake Farm wells, CLF1 and CLF2, are not reliable. Is there a particular reason why the results would not be reliable?

10. Page 11: Are wells PW99-2 and PW99-3 indicated in any of the additional JHL figures (A-1 through A-7)?

11. Page 12: Our understanding after reading the entire response to our Comment #2 is that no slug tests have been conducted on the monitoring wells at the site. If that is correct, we recommend that such testing be considered. Our recommendation is based on three considerations. First, since the scale of the slug tests is larger than the corresponding packer test (at least in the vertical), the results of slug testing may help resolve the apparent lack of relation between the results of the packer tests and the calibrated hydraulic conductivities. Second, results from packer tests are reported for nine wells. Significantly more observation wells are available for hydraulic testing and slug tests could provide increased spatial coverage. Finally, and most importantly in our opinion, the results of slug tests may provide insights into whether a well provides a representative impression of groundwater level conditions in the rock mass in its vicinity. Relatively slow recovery during a slug test is an important suggestion that a well may be poorly connected.

12. Page 13: At first glance, it appears that there is a poor match between the observed and calculated drawdown in the pumping well for the PW99-2 pumping test conducted in 1999. We concur that part of the mismatch may be due to well losses. Is a time-history available for water levels in the pumping well during the test? If so, it is possible to infer the likely magnitudes of the well losses? Is it at least possible to develop an independent estimate of the transmissivity from the pumping well data against which the value specified in the model may be assessed?

13. Page 16: No independent information is available to constrain the horizontal anisotropy during the model calibration. How sensitive is the model with respect to the horizontal anisotropy? How different are the residuals for the steady-state calibration if horizontal isotropy is assumed?

14. Page 17: It is indicated that the top 4 layers of the model are subdivisions of the Amabel Formation. It is indicated subsequently that the top of the first model layer is the variable ground surface. These two indications are only consistent if there is no overburden. Is the overburden thickness negligible everywhere in the model area?

15. Page 17: The water that presently discharges to the existing quarry is directed to Rob Roy Wetland #6. Is it possible to infer the presence of a groundwater mound in the vicinity of this discharge? It is hard to tell from the contours shown in Figure A-5 where the water that presently flows into the quarry would discharge under natural conditions. Does the quarry capture water that would otherwise discharge primarily to the Niagara Escarpment?

16. Page 18: Estimates of quarry inflows are presented for 2004; our understanding is that this period precedes the construction of the storage pond. Are all model calculations for this period, or do they incorporate the storage pond?

17. Page 20: The text refers to crevice caves in the Niagara Escarpment. Referring to Figures A-3 and A-4, it appears that along the escarpment there are no zones of elevated hydraulic conductivity in model layers 4 and 5. Is it not reasonable to expect that the crevice caves would manifest themselves at a larger scale as an increased bulk horizontal hydraulic conductivity?

18. Page 20: It is indicated that control levels in the model for the drains that represent the existing quarry are set at 500 masl. Is there something special about this particular elevation?

19. Page 22: Our understanding of how MODFLOW works is that outflows must equal inflows for a converged solution, regardless of whether or not the magnitudes of the flows are correct. We do not understand why drain conductances have had to be adjusted to bring the flows into balance.

20. Page 24: Are the results of the sensitivity analysis with respect to drain conductances presented anywhere?

21. Page 26: Where in the main report or its appendices are the hydrographs for the surface water monitoring stations presented. Are hydrographs for the monitoring wells also included in the main report?

22. Page 26: Paraphrasing the response slightly, it is indicated that seasonal fluctuations that were inferred from time series of water levels are "considered to reflect stable conditions at those locations where quarry activities and/or other pumping activities have not affected long-term trends." What about those locations where quarry activities and/or other pumping activities *have* affected long-term trends. Are the calibration targets consistent with the conditions being simulated?

23. Page 28: What is meant by the indication that the wells BH02-3, Binczyk, Quarry Office, and Bridson DP do not have a "reasonable" dataset?

24. Page30: We are confused by the suggestion that the amount of water that is actually available for recharge does not depend on the hydraulic conductivity of the surficial materials. The infiltration rate I is given by:

$$I = (P - ET) - RO \quad [1]$$

where P is the average annual precipitation, ET is average annual evapotranspiration, and RO is the cumulative runoff. The quantity in parentheses is referred to frequently as the surplus. Does "the amount of water that is actually available for recharge" refer to the surplus P-ET? The runoff certainly depends on the properties of the surficial materials.

25. Page 31: It is indicated correctly that MODFLOW 2000 has no mechanism to convert groundwater that rises above the ground surface into runoff. In our opinion, this is appropriate. It is up to the modeller to specify appropriate combinations of recharge and hydraulic conductivity such that groundwater levels are not calculated to be above the ground surface. Furthermore, we do not think that MODFLOW-SURFACT offers advanced capabilities in this regard. Our understanding of the operation of MODFLOW-SURFACT is that when the groundwater level is calculated above a specified level (typically the ground surface) a "strong" drain is activated to draw off water to reduce the calculated water level. In our opinion, this provides a representation of ET+RO, in a lumped sense that is not constrained by an independent development of the allocation of precipitation, Equation [1] above.

26. Page 31: Our understanding of the description of the calibration process is that two "passes" of calibration are adopted. Why are two passes required? Since recharge and hydraulic conductivity are correlated, it seems to us that only one pass is appropriate.

27. Page 32: It is indicated that for the karst basins, the entire water surplus is applied as recharge. Is it possible that these basins could focus recharge such that recharge locally could exceed the average of the annual surplus for the overall model area?

28. Page 35: In our opinion it would be preferable to have the model extend over the full limits of the Beaver River watershed; however, if the flows at SW6 and SW6A are similar, we are prepared to accept that it does not make a difference.

29. Page 36: It is indicated that simulated steady-state flows should always be greater than average measured low flows. Are there any continuously monitored gauges that confirm this?

30. Page 37: It is indicated that simulated baseflow for the Beaver River is estimated to be less than half the streamflow average at this location. Does “simulated baseflow” refer to the baseflow estimated from an independent analysis of baseflow, or to the model-calculated discharge to the Beaver River?

31. Page 39: Are we correct in interpreting the flow average as:

$$\text{Flow average} = \text{Runoff} + \text{Interflow} + \text{Baseflow} \qquad [2]$$

    and that the term *Baseflow* is what can be simulated with a steady-state groundwater simulation?

32. Tables 10-30: The water budgets report the “water budget for the Escarpment”. On Page 34, the calculated groundwater discharges at the Escarpment are broken down for the Pretty River, Batteaux Creek north, Batteaux Creek south, and Beaver River. Is it possible to identify these separate flows for the simulations summarized on Tables 10 through 30?

2. Duntroon Quarry Expansion Hydrogeological Peer Review Comments: Response to Supplementary Karst Review Comments from Daryl Cowell, November 14, 2008

1. Tables 1-9: We are puzzled by the some of the water budget results presented on the tables in the responses to the supplementary comments.

   - For Tables 2, 3, 4, 7, 8 (and Table 5-14 of the 2007 report), we note that:

     $$\text{Groundwater Outflow} = \text{Groundwater Inflow} + \text{Recharge} \qquad [3]$$

     where Recharge = Precipitation-Evaporation.

   - For Table 1, the Groundwater Outflow is a small fraction of the sum of the Groundwater Inflow and the Recharge. Where does the rest of the water go?

   - For Tables 5, 6, and 10, the Groundwater Outflow is relatively close to the sum of the Groundwater Inflow and the Recharge, but the flows do not quite balance. Why do the flows not balance?

   - For Table 9, the Groundwater Outflows are significantly larger than the sum of the Groundwater Inflow and the Recharge. Where does the outflow come from?

2. Page 1: We are not experts with the MODFLOW Lake Package. The text refers to both horizontal and vertical leakances. In contrast, for the other head-dependent stress packages a single conductance is specified. Are the horizontal and vertical leakances somehow related to the conductances?

3. Page 2: It is indicated that the method of calculation of leakances for the Lake3 Package is representative. In our opinion this is an overstatement. Rather, the similarities of the results obtained with the different approaches indicates that the flows to and from the existing quarry and proposed quarry extension confirms that the quarry flows are controlled by the properties of the formation. This suggests that the conductances are sufficiently high for the Lake3 Package that a constant-head condition is approximated.

4. Page 3: It is indicated that the expansion lake could not be modelled either as constant-head grid blocks or with the River Package "because the proposed two levels of quarrying complicate the simulation." We do not understand why not? Is it an issue of model convergence or of model refinement?

5. Page 5: Are we correct in understanding that the results listed on Table 3 are for a simulation that includes the MAQ quarry lake, and that although the flows in the MAQ quarry lake are calculated they are not reported?

6. Page 6: It is indicated that the "drain conductance was set as high as possible in order to maintain a balanced water budget in the area." Flows must balance for a converged solution. Does this statement suggest that the drain conductance was set as high as possible to avoid non-convergence?

7. Page 6: The results suggest that a lake in the existing quarry will drain to the west without significantly affecting the level or flows to an expansion quarry lake. In summary, what is the difference between conditions when there is and is not an expansion lake?

8. Page 7: The results of the sensitivity analyses for the hydraulic conductivity zone north of the proposed Duntroon Expansion Quarry suggest that the presence (or absence) of this zone has a significant effect on the predicted water budgets for the Expansion lake. Although it may be likely that such a high conductivity zone exists, in our opinion, the implications of these results is that additional hydraulic testing is required to better constrain the predictions.

9. Page13: It is noted that the models that incorporate the Lake3 Package do not include any surface water runoff component. What magnitudes of runoff flows are expected?

Closing

We hope that our follow-up review comments assist in clarifying the groundwater modelling analyses conducted for the proposed extension of the Duntroon Quarry. Resolution of these comments will be the last step before we complete our peer review.

If you have any questions regarding our proposal, please contact Mr. Christopher Neville at (519) 579-2100, or by E-mail at *cneville@sspa.com*.

Sincerely,

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