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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 Draft Hydrogeology Level 2 Report – Proposed Lowndes Dolostone Quarry, East Flamborough, City of Hamilton

Dear Mr. Flint,

Please accept this letter as INTERA Engineering Ltd. (INTERA) report on hydrogeologic review of the draft three-volume *Hydrogeology Level 2 Report* for the proposed Lowndes Holdings Corporation dolostone Quarry. The draft *Hydrogeology Level 2 Report* was prepared in June, 2005 by Gartner Lee Limited (GLL) and was provided to me under July 28, 2005 cover letter from Gunther Funk of GLL. The GLL July 28, 2005 letter also addresses several hydrogeologic issues that were raised in my March 28, 2005 letter to FORCE that provided hydrogeologic review of the proposed Lowndes Holdings Corporation dolostone Quarry, based on planning–related information available at that time.

The proposed Quarry is to be developed in the Amabel Formation dolostone to depths of about 36 m in Part of Lot 1, and Lots 2 and 3, Concession 11, geographic Township of East Flamborough, now the City of Hamilton. This review and report have been undertaken and prepared in response to our e-mail correspondence of July 25 and August 23, 2005, and our consulting services agreement of August 24, 2005.

This report was prepared by Kenneth G. Raven, M.Sc., P.Eng., Principal and Senior Hydrogeologist of INTERA Engineering Ltd. This report reviews the GLL letter of July 28, 2005 and draft *Hydrogeology Level 2 Report* documentation. This review, similar to my earlier review, judges the adequacy of the proponent's hydrogeologic characterization, assessment and modeling predictions, and provides an assessment of potential adverse hydrologic and hydrogeologic impacts of the proposed Quarry operation based on my independent analysis of the data and my experience at similar sites in Ontario.

This letter report, which builds on my March 28, 2005 report to FORCE, is organized by the following sections:

1. Additional Primary Documents Reviewed
2. Conclusions of the INTERA March 28, 2005 Review
3. The GLL Hydrogeology Level 2 Report
4. Continuing Hydrogeologic Issues
5. Conclusions

1. ADDITIONAL PRIMARY DOCUMENTS REVIEWED

In addition to the documents listed in my March 28, 2005 letter, the following additional key documents are the focus of this review:

- *Proposed Mountsberg Dolostone Quarry, City of Hamilton, Ontario*, Letter from Gunther Funk, Gartner Lee Limited to Kenneth Raven, INTERA Engineering Ltd., July 28, 2005.
- *Proposed Dolostone Quarry, Hamilton, Volume 1: Hydrogeological Level 2 Report,* Draft Report prepared by Gartner Lee Limited for Lowndes Holdings Corp, June, 2005.
- *Proposed Dolostone Quarry, Hamilton, Volume 2: Groundwater Flow Model,* Draft Report prepared by Gartner Lee Limited for Lowndes Holdings Corp, June, 2005.
- *Proposed Dolostone Quarry, Hamilton, Volume 3: Appendices,* Draft Report prepared by Gartner Lee Limited for Lowndes Holdings Corp, July, 2005.

2. CONCLUSIONS OF THE INTERA MARCH 28, 2005 REVIEW

The conclusions of the INTERA March 28, 2005 review are worth repeating here as a basis for discussion of the GLL July 28, 2005 letter and the GLL *Hydrogeology Level 2 Report*. These conclusions were as follows.

1. The proponent's hydrogeologic characterization is preliminary and uses unsealed monitoring wells to estimate hydrogeologic impacts from the proposed Quarry. These monitoring wells, which are not in accordance with industry standards, underestimate the amount of drawdown that will be created by future Quarry dewatering.

2. The preferred method for accurately predicting the magnitude and extent of the water table drawdown that will be created by the proposed Quarry is by using a calibrated 3-D groundwater flow model that is based on site-specific geologic and hydrogeologic data. No such model has been proposed, developed or used for this Quarry by the proponent.

3. The proponent estimates that drawdown of the local groundwater levels for the first Quarry excavation lift will be limited to 1 m at 250 m from the Quarry face with essentially negligible drawdown at 600 m from the Quarry face. These are not credible drawdown estimates for either the first lift or the entire Quarry operation. My independent analysis indicates that drawdown for the full Quarry operation will be close to 31 m at the Quarry face, decreasing to about 13 m at a distance of about 1000 m from the Quarry face. At full size, I estimate that the Quarry may pump about 8,200 to 16,400 m^3/day of groundwater from the Amabel Formation dolostone aquifer.

4. The proposed measures to mitigate Quarry-induced drawdown (i.e., infiltration channels excavated to bedrock) will be largely ineffective.

5. The drawdowns that will occur in response to Quarry dewatering will adversely affect water levels in nearby residential and communal water supply wells which are typically drilled to only 15 m depth. Water supply wells for nearby housing developments on Glenron Road, at Timberun Court, at Bronte Creek Estates, at the Lawson Park Campground and at private residences along Mountsberg Road, Milburough Line Road and Concession Road 11E are all at risk of being dewatered or adversely affected by the proposed Quarry dewatering.

6. The Provincially Significant Wetlands, Environmentally Significant/Sensitive Areas (Mountsberg East Wetlands) and nearby creeks and streams (that have been identified as fish habitat) are also at risk of being dewatered and adversely affected by the proposed Quarry operation. This is because these surface waters appear to be in direct hydraulic connection to the shallow bedrock that provides baseflow to these important wetlands, creeks and streams. Diminished baseflow to local surface waters is likely to occur over an area with radius of 2500 m of the Quarry centre.

7. The Carlisle municipal water supply wells that draw drinking water from the Amabel Formation dolostone aquifer, are also at risk of being adversely affected by the proposed Quarry. Pumping of large volumes of groundwater from the Quarry will change the well capture zones and WHPAs of the Carlisle wells. The new well capture zones may encounter potential contaminant sources and other groundwater quality and quantity issues not previously identified or considered prior to Quarry operation.

8. There are assessment requirements under the Province's new Watershed-Based Source Protection Planning initiative specifically directed to proposed new quarries that must be considered and completed. Under this initiative, because the proposed Quarry is located within the 2 year capture zone or WHPA for the Carlisle wells, the risk posed by the Quarry and final Quarry land use to these wells needs to assessed and/or the development of the Quarry restricted. Since the Quarry will be allowed to flood following aggregate extraction, the resulting surface water also potentially poses a bacteriological/pathogenic threat to the Carlisle

municipal wells that may necessitate upgrading of treatment requirements for these wells. None of these issues have been discussed or addressed by the proponent.

3. THE GLL HYDROGEOLOGY LEVEL 2 REPORT

The GLL *Hydrogeology Level 2 Report* is a three-volume draft report that summarizes significant additional hydrogeological testing, monitoring, interpretation and assessment for the proposed Lowndes dolostone Quarry. The important new work that is described in the *Hydrogeology Level 2 Report* and that is relevant to this review includes:

- Completion of straddle-packer injection testing of 10 deep boreholes at the site to quantify the vertical profile of transmissivity and hydraulic conductivity of the Amabel Formation dolostone, and to determine zones of preferential water production in the bedrock.
- Installation of sealed groundwater monitoring wells in 11 deep boreholes, for use in subsequent water level monitoring of drawdowns created by long-term (7-day) pumping tests.
- Installation of additional mini-piezometers and staff gauges to monitor water levels in wetlands and nearby streams to assess potential for future dewatering in response to Quarry excavation.
- Completion of 7-day pumping tests from two newly installed large diameter wells (TW-12 and TW-13), with water level monitoring, to assess hydraulic properties of Amabel Formation dolostone and potential for future drawdown impacts created Quarry operation.
- Collection of groundwater and surface water samples for chemical testing, in particular the sampling and testing of groundwater discharge during the 7-day pumping tests.
- Development of a conceptual hydrogeologic model for the site and surrounding area to guide development of a numerical MODFLOW model of groundwater flow.
- Development, calibration and application of a 3-D MODFLOW model of groundwater flow to estimate future Quarry pumping rates and hydrogeologic and hydrologic impacts of Quarry operation, under Quarry development scenarios considering mitigation and without mitigation.

4. CONTINUING HYDROGEOLOGIC ISSUES

Based on my review of the additional works described in the GLL *Hydrogeology Level 2 Report*, I offer the following comments and identify the following continuing hydrogeologic issues and concerns for the proposed Quarry.

4.1 Monitoring Well Completions and Extent of Drawdown During Pumping Tests

The completion of the deep open boreholes as 3 m-length interval screens validates my earlier concerns about use of open unsealed boreholes as monitoring wells. However, detailed review of the completion depths for those wells with borehole hydraulic conductivity profiles (i.e., BH1-D, BH4-D, BH6-D, BH7-D, BH8-D, BH9-D, BH-B, BH-C, BH-D and BH-F), shows that all monitoring intervals were completed at the bottom of each borehole in the generally less permeable sections of the Amabel Formation dolostone. None of the GLL monitoring intervals (both shallow and deep) were completed over the permeable water production zone that the GLL conceptual hydrogeologic model (see Figure 2, Volume 2) indicates is found at depths of about 15 to 25 m. Installation of monitoring well intervals in the less permeable sections of the bedrock will result in significant underestimation of the drawdown impact of the pumping tests and of the predictions of Quarry drawdown based on these pumping tests. No reason is given in the GLL Report for this significant oversight and omission

The configuration of the monitoring wells is such that they are inadequate for detecting representative water level drawdowns in the important water production zone during the 7-day pumping tests, and hence are inadequate for determining representative bedrock hydraulic properties and the Quarry drawdowns that are interpreted from such pumping tests. The current configuration of the deep monitoring intervals at depths of 33 to 45 m below ground surface, and therefore 10 to 25 m deeper than the permeable water production zone, ensures that the measured water level drawdowns and hence interpreted bedrock transmissivities in response to pumping will be minimum values. The maximum drawdowns which will occur within the permeable water production zone, will be greater than those measured in the deep monitoring intervals. GLL have not measured drawdowns in sealed monitoring intervals that intersect the main water production zone remote from the pumping wells in their long-term pumping tests.

The consequence of the existing configuration of shallow and deep monitoring intervals is that the magnitude and extent of drawdowns in the bedrock from the GLL 7-day pumping tests have been underestimated in the *Hydrogeology Level 2 Report.* This underestimation is apparent when comparing the drawdown created by the 72-hour pumping test (Figure 7, Volume 1 Report), with the drawdown created in the deep and shallow bedrock from the 7-day pumping test (Figures 8 and 9, Volume 1 Report). The extent of the zero drawdown contour for the 72-hour test is equivalent to or larger than that for the 7-day test. Given the much higher pumping rates and duration of pumping for the 7-day test, the zero drawdown contour for this test should be much greater than for the 72-hour test.

This underestimation of the bedrock drawdown from the 7-day test implies that the 72-hour test actually provides a more representative set of drawdown data for the bedrock than from the 7-day test. This is true because the long open monitoring intervals used in the 72-hour test, while unsealed, at least accessed the permeable water production zone in the bedrock at depths of 15 to 25 m BGS. None of the sealed GLL monitoring intervals used in the 7-day test even access the permeable water production interval. The 72-hour and 7-day pumping tests should have been completed with monitoring intervals that were sealed over the permeable water production zone.

Consequently, I maintain that the pumping tests completed by GLL at the proposed Lowndes dolostone Quarry have underestimated the actual drawdowns that will occur in the bedrock in response to Quarry operations.

4.2 3-D MODFLOW Model Estimates of Quarry Impact

The 3-D MODFLOW model of groundwater flow is described in Volume 2 of the *Hydrogeology Level 2 Report.* This model is of regional extent and includes four layers to represent the overburden and upper Amabel bedrock, the water producing horizon in the Amabel dolostone, the deeper Amabel dolostone, and the underlying bedrock of the Clinton Cataract Group. The model includes appropriate surface and lateral boundary conditions. The model was constructed and calibrated in accordance with industry standard procedures. Calibration was performed to existing regional and local site water levels in wells, to on-site pumping tests, and to measured base flows in local streams. Overall, the model provides a valuable tool with which to assess the impact of the proposed Quarry on the local groundwater and surface water systems.

4.2.1 Quarry Pumping Rates

The 3-D model provides reasonable but underestimated predictions of Quarry groundwater pumping rates and drawdowns for the GLL cases without mitigation, based on estimates provided in the INTERA March 28, 2005 review. For example, for the full depth and extent Quarry, the GLL model predicted groundwater inflow rate is 11,168 m^3/day, which compares favourably with the INTERA estimates of 8,200 to 16,400 m^3/day, that were based on assumed Amabel Formation dolostone transmissivities of 255 to 510 m^2/day.

The GLL predictions of pumping rate are underestimated because the transmissivity values used in the model to calculate pumping rate (i.e., about 175 to 300 m^2/day) are less than the currently available best estimate of bedrock transmissivity (i.e., 510 m^2/day). The estimates of quarry pumping rate are directly proportional to the assumed values of bedrock transmissivity.

4.2.2 Groundwater Level Drawdowns

The GLL model estimates of groundwater drawdown for the full depth and extent Quarry are up to 5 to 7 m at 1000 m from the Quarry face and up to 1 m at 2000 m from the Quarry face. This is substantially greater than the 1 m of drawdown at 250 m from the Quarry face reported in the GLL *Preliminary Hydrogeological Assessment Report.* The model-predicted drawdowns do however compare more favourably with the earlier INTERA estimates of 12 to 13 m at 1000 m from the Quarry face and negligible drawdown at a distance of 2000 m from the Quarry face.

The GLL model predictions of Quarry drawdown are strongly delimited by the recharge created by Mountsberg Creek located west and south of the Quarry, by the Lower Mountsberg Wetland Complex located north and east of the Quarry, and by Flamboro Creek located southeast of the Quarry (see

Figure 15, Volume 1 Report). The amount of surface water that can recharge and infiltrate to the water producing horizon in the bedrock at these locations is controlled by the vertical hydraulic properties of the sediment, soil and bedrock that exists between these surface waters and the deeper bedrock. The GLL model currently assumes that the vertical hydraulic conductivity of the overburden and bedrock between these surface waters and the water producing horizon is in the range of 5×10^{-8} to 1×10^{-6} m/s (Figure 15 Volume 2 Report) or larger, based on an assumed anisotropy ratio, $K_v/K_h = 0.1$. Larger values of bedrock hydraulic conductivity are also reported to be present where existing rivers and bedrock valleys coincide (page 31, Volume 2 Report).

The important question is whether these assumed values of K_v are reasonable and representative. Although GLL do not report any values of K_v in their work, the positioning of the shallow monitoring intervals above the water production zone, provides the opportunity for estimation of K_v using the Neuman and Witherspoon ratio method. Based on transmissivity and storativity of the water production zone measured in the 72-hour pumping test, the reported shallow water level responses in BH-1S, BH-3S, BH-4S and BH-BS during the 7-day pumping test were analysed to determine K_v.. The resulting K_v values range from 2×10^{-9} to 1×10^{-8} m/s. These results are similar to values reported in the same or comparable bedrock formations at Cambridge, Smithville and Niagara Falls.

Based on these analyses using the ratio method, it is believed that the vertical hydraulic conductivity of the Amabel bedrock above the water production zone is less than that assumed in the GLL model. Applying calculated K_v values to the GLL model would result in increased drawdowns in the Amabel Formation dolostone below and beyond these surface water features.

The GLL model-based estimates of bedrock transmissivity calculated by multiplying the model layer K values by model layer thicknesses approximate 175 to 300 m^2/day. Since these transmissivity values are less than the best average estimate determined from the 72-hour pumping tests (i.e., 510 m^2/day), the model predictions of extent and magnitude of Quarry-induced drawdown are also underestimated.

In summary, the model predictions of Quarry-induced drawdown, while significantly greater than the preliminary GLL estimates, still underestimate the actual extent and amount of drawdown that the proposed Quarry will create without mitigation.

4.2.3 Surface Water and Wetlands

The GLL model shows quite clearly that the proposed Quarry will significantly affect local surface waters and wetlands. The model results for the full Quarry without mitigation show the following impacts to surface water and wetlands.

- Groundwater discharge to the wetlands next to Mountsberg Creek will be decreased by 86.8%.
- Groundwater discharge to the wetlands near Flamboro Creek will be reduced by 79%.

- The volume of river water that recharges the groundwater system in the Mounstberg Creek subwatershed will increased by 342%.

Since groundwater discharge is the major contributor of baseflow to creeks and wetlands, the 86.8% and 79 % reductions in groundwater discharge to the wetlands will effectively result in dewatering or drying up of these wetlands.

The increased volumes of Mounstberg Creek water that will recharge the groundwater system in the vicinity of the Quarry are calculated from the model as 0.030 to 0.090 m^3/s. Since the baseflow in Mounstberg Creek approximates 0.67 to 0.80 m^3/s, the baseflows in the Creek will be reduced by 3.7 to 13%.

4.2.4 Local Wells

The GLL model results for the full Quarry without mitigation show that upwards of 36 local wells will potentially experience a decline in water supply. Furthermore, approximately 12 or one third of these wells will be completely dewatered. Since in our opinion, the actual extent and amount of drawdown that the proposed Quarry will create without mitigation has been underestimated by the model, the number of local wells that will be actually affected by the proposed Quarry have also been underestimated in the GLL *Hydrogeology Level 2 Report.*

We remain concerned that the Timber Run Court, Glenron Road and Bronte Creek Estates subdivision developments within 500 m of the proposed Quarry, a large seasonal campground/trailer park (Lawson Park) within 1000 m of the proposed Quarry, the Stonebury housing development within 1200 m of the proposed Quarry, and numerous private residences along Mountsberg Road, Milburough Line Road and Concession 11E Road will be adversely affected with many wells being completely dewatered if the Quarry is developed without mitigation.

4.3 Impact on Village of Carlisle Municipal Wells

The GLL *Hydrogeology Level 2 Report* assesses the potential impact of the proposed Quarry on the municipal water supply wells that draw drinking water from the Amabel Formation dolostone aquifer. The GLL model is used to estimate the time-of-travel capture zones for the municipal wells using the common and accepted method of reverse particle tracking. The results of the reverse particle tracking are shown in Figure 16 of the Volume 1 Report.

The new capture zones considering the Quarry operation are displaced significantly to the west and do not access the Quarry site. The GLL-defined 25 year capture zones for the Carlisle wells do not extend to the Quarry. Based on these results, GLL concludes that the unmitigated Quarry operation would not affect the Carlisle municipal water supply wells. The GLL Report does not discuss the potential impact of mitigated Quarry operation on Carlisle wells or of future impact of a re-flooded Quarry on Carlisle wells.

There remains concern that the Quarry operation may impact the water quality in the Carlisle wells both during Quarry operation and from a future re-flooded Quarry. The shifting of the well capture zones means that the municipal wells will draw water from new source areas. These new source areas will require revision of the well head protection plan that is being developed for the Carlisle wells by SNC-Lavalin and Charlesworth & Associates for the City of Hamilton. These new source areas may have potential or real contaminant sources that may result in the deterioration of Carlisle well water quality. GLL in their letter of July 28, 2005 acknowledge these potential effects and agree that "the significance of the new capture zones will need to be determined."

The GLL July 28 letter also notes the significant difference in the size and extent of the 2 year time-of-travel capture zones defined using their model and those defined by SNC-Lavalin and Charlesworth & Associates for the City of Hamilton. The GLL 2-year capture zone was much smaller than that presented in the City consultant's report.

The reasons for the difference in size and extent of the 2-year capture zones are not apparent to GLL. In my opinion the reason for the smaller GLL 2-year capture zone size is the GLL use of too large a value for bedrock porosity. Time-of-travel capture zones are inversely proportional to porosity values. Reducing porosity by a factor of 10 will increase time-of-travel capture zone size by a factor of 10.

The GLL capture zones are defined using a bedrock porosity of 10% for all bedrock layers (Table 3, Volume 2 Report). This bedrock porosity value is too large for use in capture zone modeling for the Carlisle wells, where groundwater flows through permeable horizontal bedding plane fractures and discontinuities. More representative bedrock porosity values of about 1% should be used in capture zone modeling of the Carlisle wells. Decreasing porosity to 1% would result in an increase in size of the 2-year capture by 10 fold, similar to that presented by SNC-Lavalin and Charlesworth & Associates.

The GLL July 28 letter discusses quarries in the context of Ontario's new Watershed-Based Source Protection Planning initiative and indicates that MOE has agreed to not classify quarries as threats to source water quality. As there has been no such communication from MOE, our comments on the potential threat to water quality posed by the Quarry as outlined in the INTERA March 28, 2005 review remain unchanged. In particular, as the Quarry remains within the 2-year capture zone for the Carlisle wells, the risk posed by the Quarry and final Quarry land use to these wells needs to be assessed and/or the development of the Quarry restricted.

4.4 Feasibility of Proposed Mitigation Plan

The GLL *Hydrogeology Level 2 Report* correctly concludes that unmitigated development of the Quarry will have unacceptable impact on the Lower Mounstberg Creek Wetland Complex and local residential wells. Consequently, development of the Quarry should not proceed without some form of mitigation.

The GLL proposed mitigation is recirculation of extracted Quarry water. This mitigation was proposed in the GLL *Preliminary Hydrogeological Assessment Report*, and was described as recirculation of pumped water to several short linear trenches excavated to bedrock surface. In our March 28, 2005 review we noted that these recirculation trenches would be ineffective as proposed because they would not allow enough water to recharge the deeper more permeable bedrock to maintain water levels close to pre-Quarry levels.

The mitigation that is now proposed for the Quarry is recirculation to a more extensive set of perimeter trenches excavated to the bedrock surface with boreholes drilled in the bottom of the trench to the water production zone found at mid-depth within the Amabel Formation dolostone. The boreholes are now necessary, as simulations using the GLL MODFLOW model show that recharge from conventional trenches would be ineffective in preventing drawdown from extending out from the Quarry to the surrounding wetlands. This is because the vertical hydraulic conductivity of the upper bedrock above the water production zone is not high enough to allow the necessary volumes of water to recharge the permeable deep bedrock.

The *Hydrogeology Level 2 Report* conceptually evaluates the feasibility of implementing this groundwater recirculation system (GRS), using the GLL model. The GLL model shows that, provided water can be provided uniformly to the water production zone (which is a significant challenge in the fractured bedrock setting of the Quarry), the drawdowns around the Quarry can be maintained at pre-Quarry levels. The volume of water that is required to be recirculated for the full Quarry is determined from the model as 29,365 m^3/day. This is a large volume of water, a volume that is 2.7 times greater than the total predicted volume of water to be pumped from the full Quarry without mitigation (i.e., 10,860 m^3/day).

Since the proposed Quarry should not be developed without mitigation, the single most important hydrogeological issue in this review is the engineering feasibility of implementing the GRS as described in the *Hydrogeology Level 2 Report.* The GRS has only been conceptually evaluated by GLL using a computer model, based on a very simple representation of the bedrock. It has not been demonstrated by the proponent that it can be practically implemented at this site. Furthermore, the GLL Report does not provide examples of its successful long-term application at other Quarries of similar size and hydrogeologic setting.

The successful application of the GRS at the proposed Lowndes dolostone Quarry will not be straightforward or simple. The very high permeability of the Amabel dolostone bedrock requires the long-term pumping and injection of very large volumes of water in the GRS to maintain groundwater levels adjacent to the Quarry. A successful GRS must be robust and capable of addressing the natural variability and uncertainty of hydrogeologic materials, and the inevitable changes in bedrock hydraulic properties that will occur over the operating phase of the Quarry. This is not a trivial requirement. The following practical implementation concerns will need to be addressed in order to have confidence in the applicability of the GRS at this site. Until these concerns have been addressed, the GRS should be considered an unproven mitigation measure for the site.

4.4.1 Source of Additional Water for Recirculation

The GLL model indicates that 29,365 m^3/day of water will need to be recirculated to the permeable water production zone in order for the GRS to be effective in maintaining groundwater levels away from the full Quarry. Since the maximum volume of water that will be pumped from the full Quarry considering groundwater inflows, precipitation and water losses without the GRS will only be 10,860 m^3/day (see Table 7, Volume 1 Report), an important and unanswered question is where will the other 18,505 m^3/day of water come from during the implementation phase of the GRS. The GLL Report (page 59, Volume 1 Report) states that the additional water will be provided from precipitation and groundwater inflows. However, the GLL water balance for the Quarry does not support this.

4.4.2 Potential for Bedrock Permeability Enhancement

There is a very high probability that the water used for re-injection will result in the enhancement of the permeability of the carbonate bedrock between the injection wells and the Quarry. This permeability enhancement or karstification will occur due to dissolution of the carbonate bedrock by re-injected groundwater. The re-injected groundwater collected from the Quarry floor will be continually exposed to the atmospheric sources of carbon dioxide which will form carbonic acid and to other sources of acidity (e.g., organics in surface water/runoff, oxidation of trace sulphides in quarry rock) that will be consumed during closed-system dissolution of the carbonate bedrock. The dissolved carbonate bedrock will precipitate on the floor of the Quarry as calcite and dolomite. This dissolution process, which normally occurs quite slowly in nature forming karst features, will be accelerated by the large volumes of water proposed to be injected in the GRS.

Increasing the permeability of the bedrock between the GRS and the Quarry will substantially increase the volume of injected water necessary to maintain the water levels in the bedrock, or will result in lower water levels for a fixed water injection rate. Because water flow in the bedrock occurs along fractures, and such water flow is proportional to the cube power of the opening size, small increases in the opening of such fractures by dissolution will result is large increases in the required GRS water flows. Increased water flows in turn, also create increased dissolution of bedrock. Consequently, there is a very real threat that the operation of the GRS will result in substantial increases in bedrock permeability due to dissolution that will prevent the GRS from maintaining elevated water levels adjacent to the Quarry as proposed.

4.4.3 Preferential Shallow Flow To Quarry

The GRS, in order to be of maximum use, will be constructed close to the perimeter of the Quarry. Figure 17 of Volume 1 of the GLL Report suggests the trench and conduits would be located about 30 to 35 m from the Quarry face. Bedrock within this distance of the Quarry face has the potential to be subject to permeability enhancements due to stress release of the Quarry face and due to blasting effects. Increases in the shallow bedrock hydraulic conductivity on the Quarry side of the GRS will result in the preferential flow of injected water directly to the Quarry face and therefore an inability of the GRS to maintain water levels in the deeper water production zones. Failure to maintain water levels in the GRS will result in propagation of drawdown within the deeper water production zones away from the Quarry that will create drawdowns in off-site wells that intersect this permeable feature. These are real situations that can occur and that the GLL model cannot predict.

4.4.4 Drawdown in Deep Permeable Bedrock

The GRS as described in GLL *Hydrogeology Level 2 Report* has borehole conduits drilled to the water production zone at 15 to 25 m depth. If there are permeable bedrock horizons below this depth that connect to the Quarry at depths of 30 to 40 m, the GRS will be ineffective in mitigating drawdowns in these deeper bedrock units away from the Quarry because of the reduced vertical hydraulic conductivity that exists in the Amabel Formation dolostone. The fact that drawdowns during the 7-day pumping test were observed in deep monitoring wells BH1-D, BHC and BHD completed at depths below 35 m, (see Table 2, MOE Report, Appendix E3, Volume 3 Report), indicates that deep permeable horizons in the bedrock below depths of 30 m exist at the site. Consequently, the potential for propagation of drawdowns in the deep bedrock below the influence of the GRS also exists at this site. Such propagation will create drawdowns in off-site wells that intersect these deep permeable features

4.4.5 Summary

The proposed but unproven mitigation plan of groundwater recirculation will be difficult to implement at the Quarry for the reasons stated above. Demonstration of feasibility using a simplified computer model is not proof that the GRS can be made to function as required at a complex real site that is highly fractured and subject to natural variability and processes that may significantly alter bedrock hydraulic properties. Failure of the GRS will result in creation of drawdowns in the water table that will result in drawdowns in nearby water supply wells and dewatering of wetlands and surface waters, as predicted by GLL for the case of full Quarry without mitigation.

5. CONCLUSIONS

Based on this review, I offer the following conclusions.

1. The GLL *Hydrogeology Level 2 Report* estimates the extent of drawdown to be created by unmitigated development of the proposed Lowndes Quarry based primarily on completion of a 7-day pumping test, and development and application of a 3-D groundwater flow model. While the new model-based estimates of the magnitude and extent of drawdown are substantially greater in the *Hydrogeology Level 2 Report* than in the *Preliminary Hydrogeological Assessment Report*, and address some of our earlier concerns, these new drawdowns still underestimate the future drawdowns that the unmitigated Quarry will create.

2. The new bedrock water level drawdowns in the GLL *Hydrogeology Level 2 Report* are underestimated for two principal reasons. Firstly, the 7-day pumping tests did not record any water level responses in sealed monitoring intervals intersecting the permeable water production zone away from the pumping wells, and hence have underestimated the hydraulic properties of this important zone used in the 3-D model to calculate drawdowns. Secondly, the 3-D groundwater flow model uses unreasonable high estimated values of vertical hydraulic conductivity for the shallow bedrock below local surface waters and wetlands allowing unreasonably high volumes of surface water to recharge the bedrock and delimit bedrock water level drawdowns at these locations.

3. The GLL *Hydrogeology Level 2 Report* correctly concludes that the development of the Quarry without mitigation would have an unacceptable impact on local residential water supply wells and the Flamboro and Mounstberg Creek Wetlands.

4. The GLL 3-D groundwater flow model shows that the capture zones and hence well head protection areas for the Carlisle municipal water supply wells will change if the Quarry is developed without mitigation. These new source areas for the Carlisle water supply may have potential or real contaminant sources that may result in the deterioration of Carlisle well water quality. The impact of these new water source areas on Carlisle well water quality and water treatment requirements will need to be investigated if the Quarry is developed without mitigation.

5. The GLL model defines the Quarry as being beyond the 25-year capture zone for the Carlisle municipal wells in contrast to being within the 2-year capture zone defined by the City of Hamilton consultants. In our opinion, the Quarry remains within the 2-year capture zone, as the GLL capture zones are defined using an unrealistic and high value of bedrock porosity. As the Quarry remains within the 2-year capture zone for the Carlisle wells, the risk posed by the Quarry and final Quarry land use to these wells needs to be assessed and/or the development of the Quarry restricted, in accordance with Ontario's new Watershed-Based Source Protection Planning initiatives.

6. Since the proposed Quarry should not be developed without mitigation, the single most important hydrogeologic issue in this review is the engineering feasibility of implementing the proposed mitigation plan of groundwater recirculation (GRS) as described in the *Hydrogeology Level 2 Report.* The GRS has only been conceptually evaluated by GLL using a computer model. It has not be shown or proven that this conceptual mitigation measure can be practically implemented at this site.

7. The successful application of the GRS at the proposed Lowndes dolostone Quarry will not be straightforward or simple. There are practical implementation concerns including the source of the additional water (18,505 m^3/day) for the GRS, bedrock permeability enhancement due to carbonate dissolution, preferential shallow water flow to the Quarry face, and drawdown in

deep permeable bedrock that can render the GRS ineffective in preventing propagation of drawdown away from the Quarry to the surrounding wetlands. Until these concerns have been addressed, the GRS should be considered an unproven mitigation measure for the site.

8. From a hydrogeologic perspective, planning approval for the proposed Lowndes dolostone Quarry should not be given based on reliance on unproven mitigation measures for the site, especially when the hydrogeologic and hydrologic consequences of unsuccessful mitigation are so widespread, damaging and apparent.

Sincerely,

INTERA Engineering Ltd.

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Principal