Hydrogeological Flows and GIS Groundwater Monitoring Systems: A Dolomite Quarry Impact Study

ENSC301 Environmental Assessment

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DoloStrong's proposal to develop a dolomite aggregate mine in the Niagara Escarpment has undergone the first stage of assessment outlining its project scope, development intentions, and technical procedures. Five self-identified valued ecosystem components (VECs) were put forth as important factors to consider when conducting an environmental assessment. The stages of the assessment process were submitted to Conservation Halton, the NPCA, and other responsible authorities for review. After conducting its initial evaluation, Conservation Halton has concluded that DoloStrong must provide additional information on preventative strategies and mitigation procedures to be used in the case of groundwater contamination due to dolomite quarrying. While Conservation Halton acknowledges the relevance of mining aggregate resources for the maintenance of regional roads, further VEC impact studies conducted by the proponent are necessary for the safe and sustainable development of such resources in the Milton region.

Aggregate mining has many negative implications on ecological and human health. In the case of the DoloStrong quarry, four residential communities, Killbride, Lowville, Kelso and Campbellville, will be directly affected due to their close proximity to the proposed project site (**Figure 1**). Two conservation areas, Crawford Lake and Rattlesnake Point, are connected to this site via Limestone Creek. Crawford Lake is an important fish habitat and heritage site, while Rattlesnake Point is home to a wide range of vegetation types (Conservation Halton, 2013). Due to the ecological integrity of this area, any development project must prove it can act in accordance to current regulatory environment standards. Quarrying requires excavations beneath the water table. With deeper excavations, inflow of ground and surface water increases. When this water is pumped out it can compromise clean aquifers, disseminating polluted water throughout the aquifer (Rayne, Bradbury, & Muldoon, 2001). DoloStrong is advised to consult the methods of the following two impact studies to achieve scientific predictions of procedural impacts. After completion, the responsible authorities will consult the findings to discuss DoloStrong's advancement to the next stage of development.

Conservation Halton has identified groundwater as an important indicator VEC to monitor the impacts of aggregate mining on watershed quality in the Milton area. Groundwater, as defined by OMAFRA (2006), "is water that seeps into the ground and passes through subsurface materials such as bedrock and sediments. Eventually it reaches a spring, stream, lake or wetland, where it discharges to the surface, becoming surface water." Groundwater flows are determined by the porosity of geologic formations. Higher porosity results in greater containment of water. The permeability of the formation is determined by the level of connections between these pores. If a formation is highly permeable, groundwater will flow freely through the pores (OMAFRA, 2006). In the Halton region, dolomite is the predominant geological formation and serves as an important aquifer (Rayne, Bradbury, & Muldoon, 2001) for the water supplies to communities like Campbellville and Milton which use small well fields that tap into dolomite formations (Halton-Hamilton Source Protection, 2014). The protection of these water sources is integral for community health. When sources are compromised, restoration is very difficult and expensive. Contaminants can cause a host of human illnesses and can be toxic to aquatic life (Ministry of Environment and Energy, 1999). To maintain the integrity of aquatic habitat and drinking water quality DoloStrong is advised to follow the methods of two impact studies. Each study establishes guidelines to achieve baseline data. This data will be used to assess likely scenarios of quarry impacts on groundwater conditions and the surrounding ecosystem.

IMPACT STUDY 1 – GIS Chemistry and Land Cover Model

Using the Provincial Groundwater Monitoring Network (PGMN) for reference, the characterization of an aquifer can be conceptualized through the synthesis of digitalized physical information (NPCA, 2005). To interpret how groundwater contamination will affect residential drinking water, trends of the existing environment must be interpreted. Baseline data for the proposed DoloStrong site will be collected using a host of environmental datasets, records, reports, and visual map displays. Once an extensive geographical model has been plotted, the historical, geological, topological, ecological, and chemical records of the site will visually show a cohesive picture of both groundwater conditions and ecosystem health. Next, the picture will be manipulated to demonstrate the events of various likely scenarios given the proposed DoloStrong procedures. The idea is that a digital model based on existing ecosystem conditions can be contorted to simulate the effects of groundwater contamination, thus providing the proponent with a visual comprehension of the impacts of their procedures.

BASELINE DATA

Review of Historical Records: It is important for the proponent to consult the expertise of environmental professionals throughout the impact assessment and development process. Environmental consultants, such as Pinchin Environmental, offer many services ranging from hydrogeological and groundwater management to risk assessment modeling (Pinching Environmental Ltd., 2013). The first step will be to establish baseline data of groundwater quality within the proposed site through a review of historical environmental conditions. Pre-existing federal, provincial, municipal, and conservation records within a $2km^2$ radius around the project boundary should be compiled. This search boundary is selected to ensure cohesive knowledge generation about the history of the area and to account for contaminant diffusion. The Ontario Ministry of the Environment (MOE) has made environmental records available to the public through an Open Data Catalogue. This catalogue shows the locations of wells with information on well depth, monitoring timescale, pumping action, and known sedimentation or contamination (Figure 3). Additional interactive data maps are provided through the MOE portal such as watershed locations, aquifer type, water level, and water chemistry (MOE, 2014). This report will visually demonstrate the proximity of all contaminants, spills, underground tanks, wells, hazardous materials, soil, and water chemistry that have ever been recorded within the boundary. These layers of data will be integrated into a database solely for the DoloStrong site. Compiling digital data into an interactive map and an assessment report should take approximately two weeks.

Review of Reports: The next step would be to consult any literature on current groundwater concerns and management programs within this region. According to the Halton drinking water source protection plan, a water budget and water quantity risk assessment is currently underway for two of the municipal well fields within the Halton Area, Kelso and Campbellville (Halton-Hamilton Source Protection, 2014). This study should be consulted for up to date information of well chemistry. Optimal water level, soil and water chemistry guidelines found in the NPCA groundwater quality reports and the PWQO, or Provincial Water Quality Objectives (NPCA, 2005; MOEE, 1999), should be integrated into the map so that stream and well sites can be ranked in terms of quality. If conditions become dangerous, the affected region would be flagged as “risky”. This step should take consultants approximately a week.

APPLYING THE MODEL

Predictive Models: Through the creation of digitally simulated events in accordance to proposed procedures, DoloStrong can visually observe the impacts that the quarry will have on the surrounding ecosystem. A change in land cover map layer can be overlaid with the topology base layer (Figure 2) showing the extent of habitat destruction. Quarry emissions can be factored into an analysis of well chemistry changes. Elevation models will show how landscape slope will impact stream flow in or out of the excavation. Locations of vulnerable wells and streams will demonstrate areas that need to be avoided throughout development.

Monitoring: It is important to acknowledge that the NPCA and MOE update their environmental records monthly. This provides a constant flow of information to be integrated into the proponent’s GIS model. Frequent groundwater sampling is essential for monitoring quarry impacts. However, overreliance on publicly sourced datasets can be timely as the digitalizing process is subject to the schedule of another party. DoloStrong is advised to conduct independent borehole samplings of groundwater chemistry and levels if their project proceeds.

Usefulness: Publicly accessible groundwater data is an important resource to utilize in baseline studies, contributing to an overall understanding of the site’s history and ecological environment. Computer modeling allows for multiple scenarios to be considered and easily compared against baseline data layers. Not only can water quality data be indexed and accessed at the click of a button, but it can be ranked according to health and safety standards, providing a geographical display of risk factors.

IMPACT STUDY 2 – Conceptualized Hydrogeological Model through Hydrochemical and Hydraulic Pressure Investigations

Conducting independent field tests will provide the proponent with the most updated, site-relevant information. It is essential for DoloStrong to acknowledge the indirect effects that quarrying can have on sedimentation, water flow directionality, hydraulic pressure changes, and water table alterations through its water intensive practices. Digitally constructing the hydrogeological context of the DoloStrong site will provide the proponent with a working model of existing stream flows, chemistry and geological formations. Methods to analyze bedrock permeability, soil porosity, water salinity and hydraulic pressures will essentially provide a map of how and where groundwater flows and what contaminants it contains. Applying quarry procedures to will allow DoloStrong to predict exactly how groundwater functions will be impacted. Existing data provided by the provincial water quality monitoring network (PWQMN) can be used to build a base map showing nitrate, phosphorous, suspended particles and chloride concentrations at several key sampling sites along Ontario streams (MOE, 2014). These monitoring sites are identified by coordinates their connection to important reservoirs. In connection to this project, the closest identified sampling site is at Oakville Creek, upstream from the Kelso Reservoir. A map of existing site conditions will give DoloStrong a starting base for exploration. Like the previous study, this monitoring can be conducted through a consultant firm but due its intensive methods and permit requirements it is likely to take over a month to complete.

PREDICTIVE MODELING

Mapping the Fracture Zones: In order to understand groundwater directionality, dolomite aquifer capture and fracture zones must be seasonally measured for thickness. Horizontal fracture zones are paths of high permeability that allow for groundwater free flow (Rayne, Bradbury, & Muldoon, 2001). Knowing where and to what extent these zones are permeable will allow DoloStrong to predict how groundwater will enter and exit the quarry. Seasonal mapping is necessary to demonstrate the effects of precipitation variation and groundwater recharge (Rayne, Bradbury, & Muldoon, 2001). The hydraulic conductivity of fracture zones can be measured with straddle packers that measure vertical pumping intervals of groundwater through boreholes (**Figure 4**) (Rayne, Bradbury, & Muldoon, 2001).

Mapping the Chemistry: Once stream flows have been mapped, areas of critical chemistry will be identified so the proponent understands which contaminants will be flowing through the excavation. Characterization of chemistry concentration can be achieved through installing eleven 400m deep boreholes and surface water sampling stations dispersed throughout the site (Bath et al., 1996). The location of these stations should represent diversity of topology and geography so that a broad representation is delivered. Sampling should occur before, during, and after rainfall to encompass any precipitation changes in salinity. Increased salinity can thicken groundwater making it move slowly (Bath et al., 1996). The samples will be referenced against PWQO to interpret quality and risk level (MOEE, 1999).

Usefulness: Not only is this study important for demonstrating the potential for contaminated groundwater to reach well fields, it can also reveal through flow analysis which watershed and fish habitats are the most likely to be impacted by the quarry. The tissue of fish living in these habitats can be examined for contaminants (namely mercury). This can then be compared against provincial fish consumption advisories to gauge whether contaminants are dangerous and likely to biomagnify to upper trophic levels of predators, becoming toxically concentrated. Targeting specific habitats to monitor will make pollution management rapid and fish conservation efforts effective. Finally, understanding the network of groundwater flows will guide DoloStrong's activities in an informed and sustainable direction, maintaining artificially augmented water levels and chemistry so that critical areas remain unaffected.

References

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APPENDIX A

Site Location References

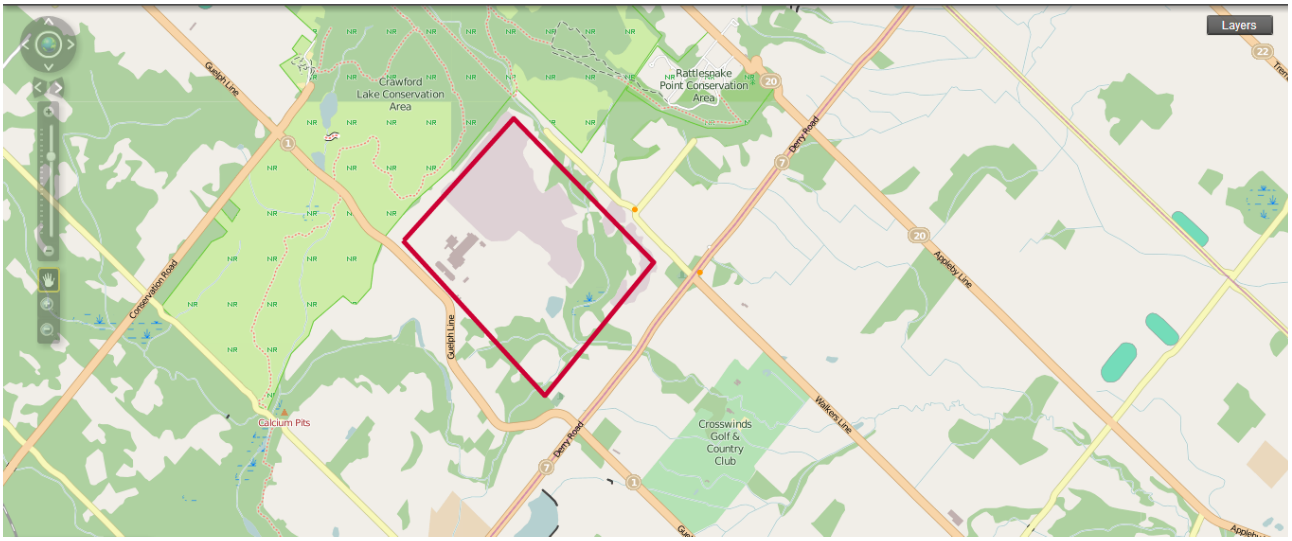

Figure 1. DoloStrong Site Map

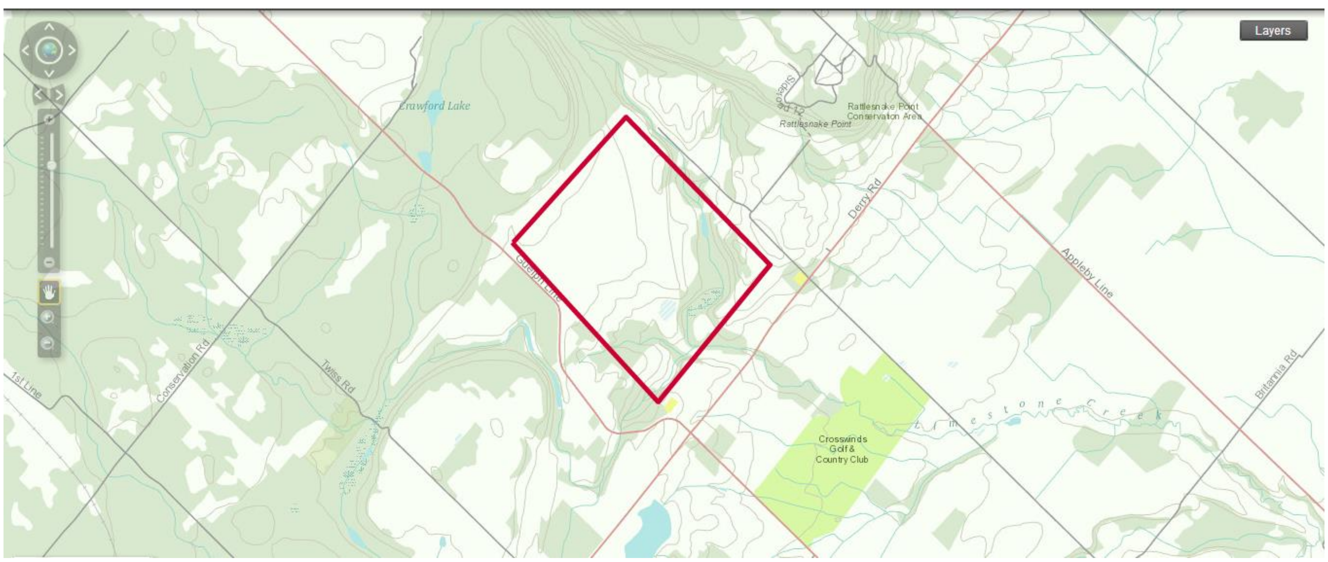

Figure 2. DoloStrong Topology Site Map

APPENDIX B

GIS Site Information

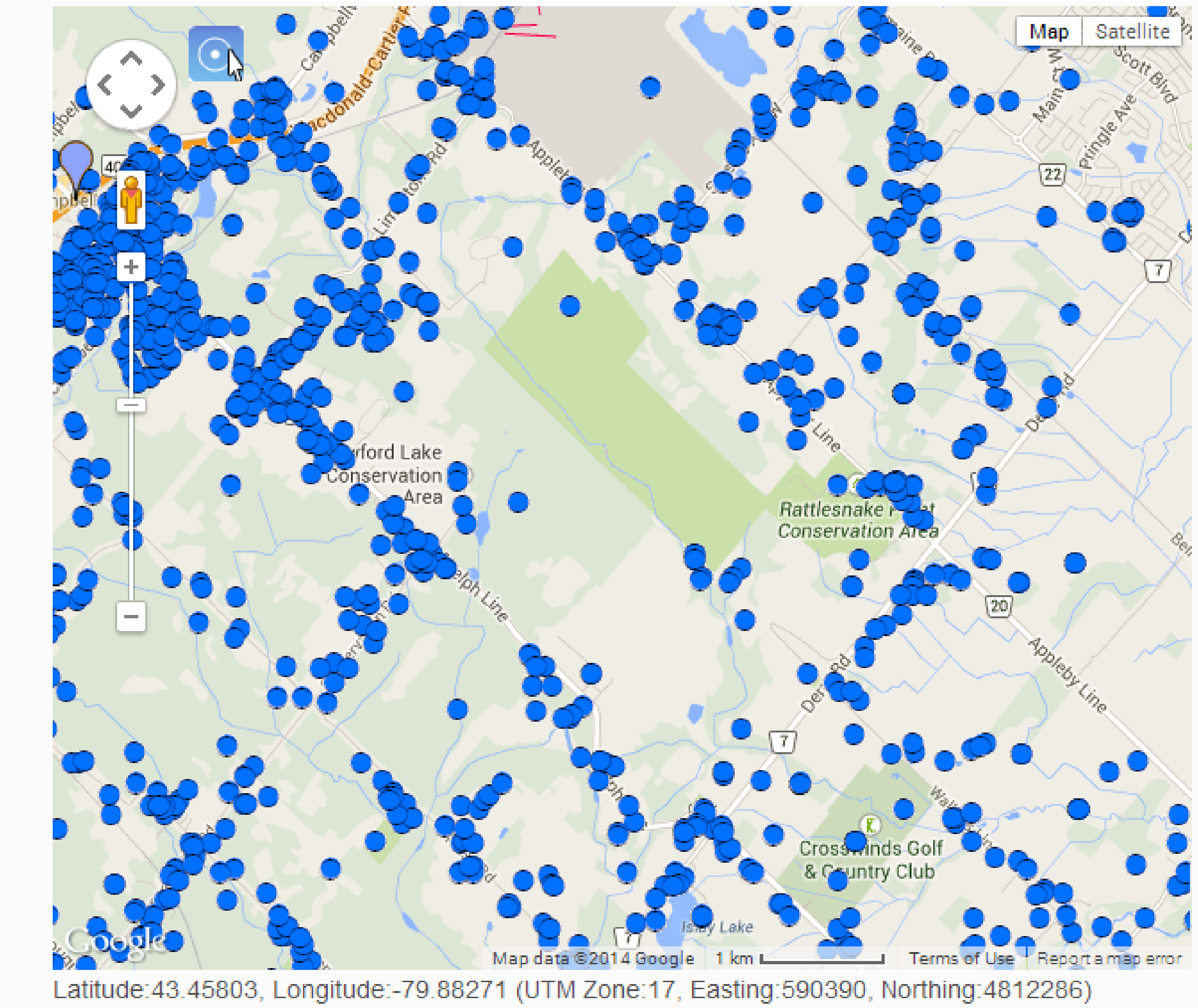

Figure 3. Ministry of Environment Ontario (2014) Water Well Record Data for DoloStrong Site

APPENDIX C

Impact Study 2 Hydrogeological Model

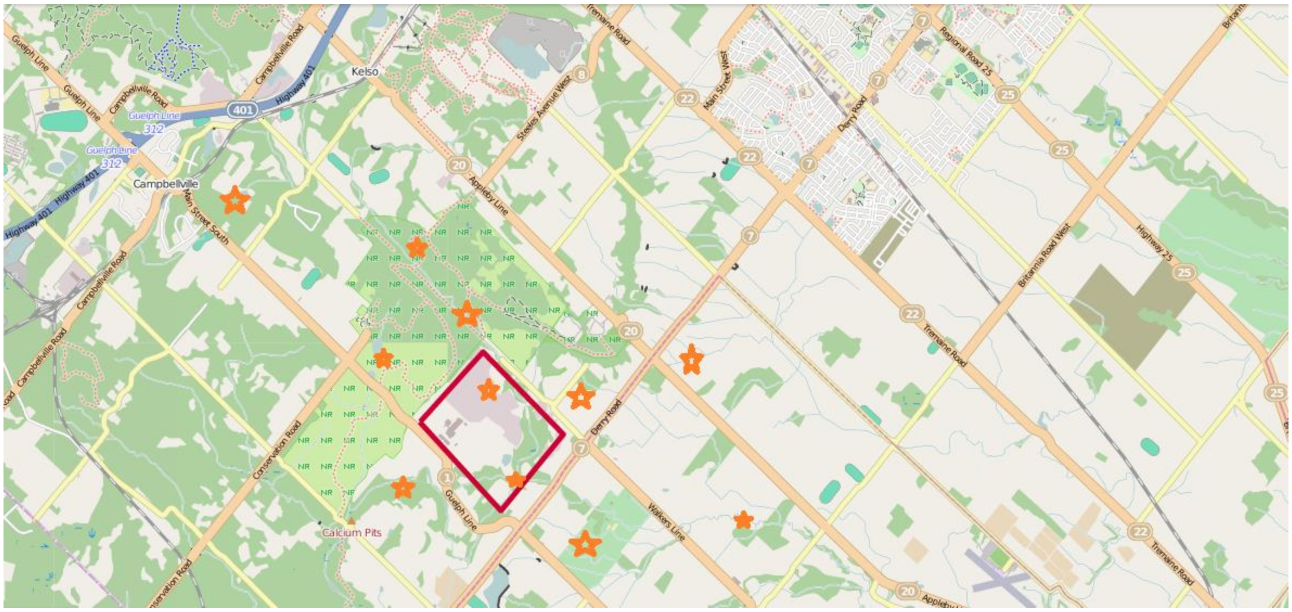

Figure 4. Borehole Fracture Zone and Chemistry Monitoring Sites