



**HYDROLOGICAL LEVEL 2
TECHNICAL REPORT
ST. MARYS FLAMBOROUGH
QUARRY**

File No. 160960345

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1.0 Introduction

Stantec Consulting Ltd. (Stantec) was retained to complete a Hydrological Assessment and Hydrological Report that would accompany applications for Amendments to the Town of Flamborough Official Plan and Zoning By-law No. 90-145-Z and for a Category 2, Class “A” Below Groundwater Quarry License under the Aggregate Resources Act. Category 2 Class ‘A’ licenses are for aggregate operations with extraction below the established water table. Work began in August, 2005 for the original proponent, Lowndes Holdings Corp., and continued for the current landowner, St. Marys Cement Ltd.

The Hydrological Level 2 Technical Report provides baseline information to support the Environmental Impact Statement (EIS)/Natural Environment Level 2 Report (Stantec and Savanta Inc., 2008) for the above applications, as well as the Hydrogeological Level 2 Report completed by AECOM.

The subject lands addressed by the Hydrological Assessment and Report are located on Part of Lot 1, Lots 2 and 3, Concession 11, Geographic Township of East Flamborough, City of Hamilton, and are shown on **Figure 1 (Appendix A)**.

The resource proposed for extraction is the high quality dolostone of the Amabel Formation. The Amabel dolostone is a light to medium grey to buff, thick to massively bedded, porous, fossiliferous dolomitized limestone. The Amabel Formation dolostone at the site varies in thickness from 29 to 40 m (AECOM, 2009).

The initial quarry site plan (Long Environmental Consultants, 2004) involved the excavation of 96 ha (62%) of the site. The limit of extraction has been revised to reflect the results of natural environment field work. The revised proposed quarry limits occupy approximately 66.4 ha (42.0%) of the 158.2 ha site (Harrington Hoyle, 2008).

1.1 BACKGROUND RESOURCES

A variety of background resources were consulted to characterize the site and assess the significance of hydrologic features, including:

- Water Survey of Canada (WSC) database (accessed January, May, November 2004, and August 2005)
- Environment Canada Climate database (accessed September 2005, and March 2008)

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- Bronte Creek Watershed Study (BCWS) - (Conservation Halton, 2002)
- Ministry of Natural Resources (Provincially Significant Wetlands, Quaternary Watershed boundaries)
- Surficial Soils and Microdrainage (Stovel and Associates Inc., 2006)
- Hydrogeological Level 2 Report (AECOM, 2009)
- Draft Mountsberg Quarry Terrain Evaluation (Gartner Lee Ltd., 2005)
- EIS/Level 2 Natural Environment Report (Stantec and Savanta Inc., 2008)

To supplement information available from historical sources and the studies cited above, an *in situ* hydrological monitoring program was designed and implemented in September, 2005, the results of which are summarized in Section 4.0 of this report.

2.0 Regional Setting

2.1 OVERVIEW

The subject lands are located within the upper Bronte Creek Watershed. The majority of the site falls within the Mountsberg Creek subwatershed, except for the southeast corner, which is part of the Flamboro Creek subwatershed. A Provincially Significant Wetland (PSW), the Lower Mountsberg Creek Wetland Complex, occupies the headwaters of tributaries to Mountsberg Creek, and Flamboro Creek, at the north and east portions of the property (**Figure 2, Appendix A**).

The subject lands fall within the planning area of the former Town of Flamborough in the City of Hamilton. The property is bounded by residential development to the north and west (including a horse farm), Concession Road 11 to the south, and forest to the east. The ground elevation on the southern part of the property, closest to Concession 11, is approximately 281.5 masl and rises to about 294.2 masl in the center portion of the property, sloping downward to the north to an elevation of approximately 285 masl in the wetland (**Figure 3, Appendix A**). The elevation of the Bronte Creek watershed varies from 75 masl at Lake Ontario to about 358 masl near Darbyville.

An assessment of regional features was conducted by Stantec for a 3 km-radius area surrounding the site and identifies local natural features that create the environmental setting for the site, such as significant woodlots and wetlands supporting wildlife or fish populations. Designated natural features are found in this zone, including Environmentally Sensitive Areas, Provincially Significant Wetlands, and deer wintering areas (**Figure 2, Appendix A**).

2.2 REGIONAL PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The Niagara Escarpment divides Bronte Creek into its upper and lower reaches and is the dominant physical feature of the Bronte Creek watershed (**Figure 4, Appendix A**). The Escarpment was formed from the differential erosion of sedimentary rocks, and further shaped and partially buried by glacial, fluvial, and post-glacial activity. The erosive action of pre-glacial streams, and the glaciers that heavily dissected the Escarpment face gave rise to the valleys that now act as conduits or pathways, channelling tributaries from above the Escarpment to the main branch of Bronte Creek.

Resistant cap rock forms a gently rolling plateau in the western reaches of the Bronte Creek watershed. Thin layers of coarse Halton Till cover portions of the limestone plain. A portion of the Galt Paris Moffat Moraine lies on the northwestern watershed divide. Closer to the Escarpment, the Waterdown Moraine system forms hummocky terrain, in a complex of sand,

silt, and gravel outwash deposits. Other glacial features such as drumlins and eskers, occur throughout the headwaters.

Thick spillway deposits of sand and gravel bury the shale closest to the Escarpment, forming part of an important aquifer system. To the east, a thin layer of clay-rich Halton Till covers a portion of the watershed, forming a bevelled, and, occasionally, drumlinized till plain. Approximately 12 km from the Lake Ontario shoreline, a narrow band of hummocky till, associated with the Trafalgar Moraine, forms a local watershed divide diverting the lower tributaries of Bronte Creek into a single main channel. The lower reach of the creek is constrained within a deep, narrow shale bedrock valley that is up to 30 m in depth, and as little as 100 m in width at some locations.

Below the escarpment, the bedrock is composed of more erodible shale. The soft red shale of the Queenston Formation is well-exposed in a broad plain running parallel to the Lake Ontario shoreline. Numerous valleys have been incised into the bedrock by postglacial and fluvial erosion.

2.2.1 Soils

The soils of the Bronte Creek watershed are largely derived from glacial and glaciofluvial deposits that have in turn acquired their matrix from the local dolostone and shale bedrock. The action of wind and water has reworked these deposits to produce local concentrations of silt, clay, and muck.

The western portions of the watershed located above the Niagara Escarpment are dominated by loamy soils that are usually well-drained and of coarse texture. Significant areas of muck soils occupy the low-lying areas, particularly between drumlins. These organic soils are poorly drained. Closer to the Escarpment, soil matrices become increasingly coarse from incorporated outwash sand and gravel. These often occupy former spillways of gravel overlain by sand. Below the Escarpment, clay loam soils are predominant. These soils are derived from silty clay tills and local outcrops of shale. The streambeds of the watershed are characterized by gravel and boulder beds accompanied by accumulation of muck in local floodplains.

The area surrounding and including the subject lands is located within the Flamborough Plain physiographic region (Chapman and Putnam, 1984). It is predominantly bouldery till with bedrock ridge outcrops. To the west, there are large areas of shale and dolomite at the surface. Generally, where bedrock is covered, the overlying material is outwash gravel. Agriculture is a dominant land-use in the physiographic region but much of the land within a 3 km radius is forested. There are also local wetlands with pockets of peat and muck.

The shallow overburden on site is comprised of sandy gravel and sandy silt till (JEGEL, 2004). The following soils description is summarized from the Agricultural Report prepared by Stovel and Associates (2004).

The majority of soils on the subject property have developed from a stony, morainal till deposit. Some outwash deposits, lacustrine deposition and organic soils were also identified. The subject lands contain Class 2-7 soils, with only 12 ha of Class 2 or 3 soils, with the remainder of the site (approximately 91%) in Class 4-7 and organic soils. Seven soil series were present on the site (Dumfries, Killean, Lily, Burford, Toledo, Farmington and Muck). The well-drained Dumfries series occupies the majority of the site. Imperfectly to poorly-drained soils and muck are located on wetter parts of the property.

2.3 GEOLOGY

In the Flamborough area, the upper most bedrock unit is the dolostone of the Amabel Formation. The younger and overlying strata (Guelph and Eramosa formations), which are included in the Albemarle Group are encountered to the northwest and west, but are absent in the area. The Amabel Formation is underlain by bedrock of the Clinton and Cataract groups. The uppermost unit is Fossil Hill/Merritton Formation (frequently referred to as the Reynales Formation) of the Clinton Group, which is underlain by the Cabot Head Formation. Other formations that make up the Clinton Group and Cataract Groups, which are stratigraphically above the Cabot Head Formation, are not present. The strata dip gently to the southwest (Karrow, 1986), with the oldest formations subcropping along the Niagara Escarpment and the younger formations to the west.

The Amabel Formation is described as a light to medium grey, medium to thickly bedded, aphanitic, fossiliferous dolostone. In the Bruce Peninsula the unit has been subdivided into three members (Warton, Colpoy Bay and Lions Head) based on distinctive lithology and fossil assemblages. The thickness of the Amabel Formation within the property ranges from 29 to 40 m and averages about 34 m (AECOM 2009).

The Flamborough Plain physiographic region is described as a limestone plain with little overburden, scattered drumlins and numerous swamps (Chapman and Putnam, 1984). The overburden thickness varies from bedrock exposure in the north central area of the property, to 10.8 m at the northeast corner of the property and 7.9 m at the southwest corner of the property (AECOM, 2009). The property is hummocky with a central upland area, which slopes to adjacent, low-lying wetland areas to the north and southeast

The on-site till is identified as the Wentworth Till (Karrow, 1987). This till unit is composed of 49% sand, 33% silt, and 18% clay (Karrow, 1986). It represents the core of the drumlin hills within the subwatershed, as well as the surface cover present over much of the site. West of the

subject lands, it also comprises the hummocky topography of the Galt and Paris moraines. A complete characterization of the site geology is provided by JEGEL (2004) and AECOM (2009).

2.4 REGIONAL HYDROGEOLOGY

Groundwater is obtained from aquifers in both the sedimentary bedrock and overlying glacial sediments in the Bronte Creek watershed. The regional groundwater flow gradient follows a general north to south trend. The on-site groundwater gradient generally follows the regional trend. Upward hydraulic gradients and discharge conditions are commonly found in low-lying areas throughout the watershed, while downward gradients and recharge conditions are found at topographic highs.

Above the Niagara Escarpment, most wells penetrate into the Amabel Formation to obtain water. Deep bedrock valleys filled with coarse sands and gravels intersect the Escarpment and the Amabel Formation. Groundwater discharged from bedrock into the highly permeable sediments filling these buried valley systems is significant enough to be used as a source of drinking water for a portion of the Town of Milton. Moraines, eskers, and outwash areas can act as local aquifers and recharge and discharge areas.

Within the property boundary, groundwater moves from a potentiometric high in the vicinity of the Mountsberg Creek Wetland Complex in the north, to a low in the southwest corner of the property. The groundwater gradient is approximately 0.004 m/m across the site (AECOM, 2009). The water table is typically found within the bedrock throughout most of the site, however, in the vicinity of the Mountsberg Creek and Flamboro Creek wetlands, which reflect topographic lows, water levels tend to converge at ground surface (AECOM, 2009).

2.4.1 Bedrock Hydrogeology

The Amabel Formation is a regionally significant aquifer extending from Niagara Falls to the Bruce Peninsula. The permeability of the aquifer is primarily due to the dissolution of dolomite along fractures and bedding planes. Fracture patterns can be highly variable, and, therefore, hydraulic conductivity can vary greatly.

Above the Escarpment, the relatively small tributaries of Bronte Creek are generally shallow, slow moving, and rarely incise into the bedrock surface. Nevertheless, groundwater can contribute significant flow to these tributaries, providing coldwater habitat even during periods of drought. The tributaries serve as localized groundwater discharge areas in a vast area of poor drainage dominated by extensive wetlands. Much of the area above the escarpment functions as a recharge area.

At the Escarpment edge, the Amabel formation contributes significant volumes of water to the small tributaries of Bronte Creek that originate as springs at the toe of the Escarpment. Below

the Escarpment, Bronte Creek forms a major topographic low carved deeply into glacial sediments and bedrock. While significant groundwater does move from bedrock and glacial sediments into the main channels of the creek, the significance of these contributions to baseflow is less than that to area above the Escarpment.

Where bedrock is at or close to surface, connectivity between the Amabel Formation, and the local streams, tributaries, and wetlands is evident. The level of connectivity is highly variable, ranging from a very strong connection to a very subtle connection with little dependence on groundwater originating from this formation. The bedrock formations of the Clinton Cataract Group have a low permeability and therefore act as an aquitard unit relative to the Amabel Formation.

The on-site horizontal hydraulic conductivity of the Amabel Formation varies from 9×10^{-9} m/s to as high as 5×10^{-3} m/s (Gartner Lee Ltd. [GLL], 2008). The average bulk hydraulic conductivity for this bedrock aquifer has been established at 1.4×10^{-4} m/s. The water table beneath the site fluctuates seasonally and lies within a few metres of surface, within either the overburden soils or the uppermost part of the bedrock, varying with the local topography and drift thickness across the site.

2.5 REGIONAL HYDROLOGY

The subject lands are located within the upper Bronte Creek Watershed. Subwatershed boundaries and watercourses are shown in **Figure 5 (Appendix A)**. The majority of the subject lands fall within the Mountsberg Creek subwatershed, except for the southeast corner, which is part of the Flamboro Creek subwatershed. The Bronte Creek watershed comprises portions of the Region of Halton (City of Burlington, Town of Oakville, Town of Milton) the City of Hamilton, and Wellington County. It drains an area of approximately 312 km² (Conservation Halton, 2002), and is composed of ten subwatersheds (**Figure 5, Appendix A**).

The Bronte Creek watershed is comprised of three climatic regions (Conservation Halton, 2002):

- the Lake Erie Counties Region, which consists of a narrow band at the mouth of the watershed that is modified by Lake Ontario;
- the South Slopes Region, found in the middle portion of the watershed below the Niagara Escarpment; and
- the Huron Slopes Region, located above the Niagara Escarpment in the upper reaches of the watershed.

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The headwater areas of Bronte Creek near Morriston contain a significant number of wetland areas that, along with the physiography and soil types, are the determining factors for stream flow response. In addition to these wetlands, a number of man-made ponds and reservoirs, including the Mountsberg Reservoir, affect streamflow.

The main branch of Bronte Creek is approximately 50 km in length, has an average hydraulic gradient of 0.5%, and discharges to Lake Ontario at the Town of Oakville. The watershed elevation varies from 75 masl at Lake Ontario to about 358 masl near Darbyville. Flow in the creek is monitored at Carlisle by the Water Survey of Canada (Station 02HB022; 43° 23' 20" N; 79° 59' 17" W). This station has been in operation since 1989, monitoring a gross drainage area of 117 km². Average, maximum, and minimum daily flows at this station are presented in **Figure 6 (Appendix A)**. Average flows at this station generally vary from summer lows of approximately 0.5 m³/s to spring maximums approaching 4 m³/s. However, spring runoff peak flows greater than 16 m³/s, and extreme summer lows below 0.10 m³/s have been observed.

The headwaters of Mountsberg Creek originate within the Badenoch-Moffat Swamp complex PSW and ESA. This subwatershed includes the settlement areas of Brookville, Carlisle, Darbyville and Moffat and covers an area of 46.7 km² within the Bronte Creek Watershed. Rural and agricultural land uses predominate within this watershed characterized by a mean hydraulic gradient of 0.3%. Summer creek temperatures upstream of the Mountsberg Reservoir suggest a mix of marginal coolwater/warmwater temperatures from the headwaters downstream to Moffat (Conservation Halton, 2002). Flows in this reach can become intermittent during drought conditions. West of Moffat, five tributaries are found between Town Line and Watson Road. These tributaries are associated with the Galt Moraine and contribute permanent baseflow, and, where unimpeded by on-line ponds, cold water to the main branch of Mountsberg Creek. The headwaters of a tributary of Mountsberg Creek are located in the wetlands in the northern portion of the subject lands, and flow offsite into Mountsberg Creek.

The Flamboro Creek watershed encompasses an area of 8.7 km² and is characterized by a mean hydraulic gradient of 0.5%. The creek originates in the Carlisle North Wetland complex/ESA of the Flamborough Plain and flows into Bronte Creek downstream of Progreston. Downstream of the wetland system, the creek becomes deeply incised within the Bronte Creek Escarpment Valley, and extends downstream to Bronte Creek. Summer temperatures in Flamboro Creek suggest coolwater and marginal coolwater/warmwater habitats (Conservation Halton, 2002). Groundwater discharge contributes to coolwater conditions in the headwaters, while a large, on-line pond associated with the Carlisle Golf and Country Club results in downstream warming, which, in turn, is mitigated by considerable groundwater discharge found within the Bronte Creek valley.

3.0 Surface Water Monitoring Approach

Surface water monitoring was initiated for this site in the fall of 2003 in association with Gartner Lee Limited (now AECOM). This program included measurements for flow, temperature and water levels in the watercourses surrounding the site. Staff gauges were established in March 2003 along the principal surface water courses on and in the immediate vicinity of the subject lands (**Figure 7, Appendix A**). The surface water data gathered included monthly flow measurements at stations along tributaries to Mountsberg Creek (Tributaries A, B, and D), as well as Mountsberg Creek itself, and Flamboro Creek. Water levels and flows were monitored at all of the locations during the pump tests in April and November 2004, and as part of the fisheries program. Temperature dataloggers were strategically placed at five locations within the vicinity of the subject lands to determine the thermal regime of surface water features that have the potential to be cool/cold water.

A comprehensive surface water monitoring program was established in September, 2005 for both Mountsberg and Flamboro Creek to characterize flows and/or surface water levels on the subject lands, as well as off-site. Continuous flow and temperature monitoring stations were established at several points within the watersheds. Existing GLL staff gauges were supplemented by automated Solinst pressure transducers to record continuous water level and temperature fluctuations. Therefore, the monitors installed ran in parallel to the existing staff gauges.

At each station where flow was present, rating curves were developed to determine the relationship between water depth and flow. The development of rating curves involved the *in situ* measurement of flow and the corresponding flow depth at each location. Flow was measured *in situ* using the velocity-area method. At each station, a cross-section was established, and flow velocity (measured using a Marsh-McBirney flow meter) and corresponding depth readings were recorded at equidistant points along the cross-section. The sum of the product of velocity, depth, and width at each point of measurement along the cross-section yielded the measured flow rate. Each flow measurement corresponded to a given depth measured at each datalogger (the dataloggers have been attached to rebar within the creeks). As the monitoring program progressed, more data points were added to the rating curves at each station in order to establish a relationship between flow and creek depth across as wide a range of flows as possible. Once established, the rating curves are used to calculate flow at any given point in time for the flow depths logged by the pressure transducers.

3.1 MOUNTSBERG CREEK

Seven pressure transducers were installed within the Mountsberg Creek tributary network to continuously record flow depth and temperature. These stations are named SW-MC2, SWM2, SWT3, SWTD, SW-MC3, and SW-MC4 (**Figure 8, Appendix A**):

- SW-MC2 (Mountsberg Creek upstream of the subject lands) – this station was established at the Mountsberg Road culvert and measures flows and temperatures in Mountsberg Creek upstream of the subject lands;
- SWM2 (Mountsberg Creek branch upstream of Tributary A) – this station measures flow and temperature immediately upstream of the confluence with of Tributary A, which flows across the north-east portion of the subject lands;
- SWT3 (Mountsberg Creek, Tributary A) – installed in Tributary A, this station logs flows and temperatures within a water course that drains the northern portion of the subject lands;
- SWTD (Mountsberg Creek at Tributary D) – this station monitors flow and temperature for surface water drainage from the southern half of the subject lands;
- SW-MC (Mountsberg Creek downstream of the subject lands) – this station was established at the Evergreen Drive culvert and measure flows and temperatures in Mountsberg Creek downstream of the subject lands;
- SW-MC3 (Mountsberg Creek at Concession 11) – this station, established at the Concession 11 culvert, characterizes changes in flows and temperatures in Mountsberg Creek below the Tributary A confluence, but above the Tributary D confluence;
- SW-MC4 (Mountsberg Creek at Concession 10) – this station, established at the Concession 11 culvert, measures changes in flows and temperatures in Mountsberg Creek below the Tributary D confluence and represents the downstream limit of monitoring in the Mountsberg Creek watershed.

3.2 FLAMBORO CREEK

Three pressure transducers were installed within the Flamboro Creek tributary network to continuously record flow depth and temperature. These stations are named SW-FC, SW-FC2, and SW-FC3 (**Figure 8, Appendix A**):

- SW-FC (Flamboro Creek at Concession 11) – this station was established at the Concession 11 culvert and measures flows and temperatures at the downstream limit of the subject lands within the Flamboro Creek watershed;

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- SW-FC2 (Flamboro Creek upstream of Concession 11) – this station, established within Flamboro Creek on the subject lands characterizes flows and temperatures upstream of Concession 11;
- SW-FC3 (Flamboro Creek at Concession 10) – this station, established at the Concession 10 culvert, measures changes in off-site flows and temperatures in Flamboro Creek and represents the downstream limit of monitoring in the Flamboro Creek watershed. However, since flows in Flamboro Creek at this location are split (immediately upstream of the 10th Concession Flamboro Creek flows into a large, privately owned pond with two outlets), this station captures only a small portion of the flow in Flamboro Creek. The majority of flow discharges through a culvert adjacent to a private driveway. Therefore, although the total discharge of Flamboro Creek at the 10th Concession was not measured, the data collected were used to identify the timing and durations of dry periods and relative flows of stream at this location

In addition, three on-site surface water features as well as three active seepage areas are monitored:

- Pond 1 is an off-line pond located within the Flamboro Creek watershed, which has been observed to hold water throughout the year;
- Pond 2 is a dug-out pond located within the Mountsberg Creek watershed, which has been observed to dry out during late summer/early fall;
- SWF-1 is a large off-line surface water feature located within the Mountsberg Creek watershed, which has been observed to contain water during late winter and spring;
- Seeps S3, S3a, and S5a are the most active seepage areas on the subject lands and are monitored to observe the variability and nature of seepage activity in the northern portion of the subject lands.

To monitor rainfall patterns, a Hydrology Services Model TB-3 rain gauge was installed within the property boundaries to yield a better estimate of on-site precipitation than can be provided by the nearest Environment Canada meteorological station.

3.3 MICRO-DRAINAGE

Stovel and Associates (2006) used existing background data to delineate surface micro-drainage patterns on the subject property. These data included the following:

- topographic mapping of the site (1 m contour interval) and near surrounding area produced by First Base Solutions (Digital Topographic Mapping, 2002);
- aerial photography (2002) of the site and near surrounding area (scale 1:10,000), and

- mapping of the location of seepage areas and watercourses provided by Long Environmental Limited (2005) and Stantec (Sept. 7, 2004).

These background data were supplemented with onsite observations of surface micro-drainage patterns. Field investigations were conducted on the following dates: April 22, May 4, May 16, June 8, October 21, November 11, and December 1, 2005. The purpose of the field investigations was to verify surface drainage patterns, ponded or wet areas, and to map localized depressions. The micro-drainage mapping provided by Stovel and Associates was modified by Stantec based on supplemental topographic information obtained from OBM mapping.

3.4 LOW FLOW HYDROLOGY

As part of the hydrological assessment, low flows for Mountberg Creek were estimated using the Log Pearson III Method, in order to evaluate the potential impact of the future Flamborough Quarry dewatering discharge. The Pearson type III distribution is a special case of the gamma distribution, which has wide application in mathematical statistics and has been increasingly used in hydrological studies as a standard method for flood and low flow frequency analysis (Viessman et al. 1989). All three moments about the mean are required to fit the distribution to a particular data set. The fitting technique involves transforming annual low flows (7-day average low flows in the 7Q20 case) to logarithmic values (i.e., $y_i = \log x_i$) and finding the mean, standard deviation, and skew coefficients of the logarithms. Low flow magnitudes are then estimated from the equation:

$$\log(Q) = \bar{y} - Ks_y \quad \{1\}$$

where

Q	=	is the low flow magnitude;
\bar{y}	=	mean of the low flow logarithmic values;
s_y	=	the standard deviation of the low flow logarithmic values;
K	=	a frequency factor.

The frequency factor, K, is literally the number of standard deviations above and below the mean required to attain the probability point of interest. If the skew coefficient, C_s , falls between -1.0 and 1.0, approximate values of frequency factors for the Pearson distribution can be obtained from the following equation:

$$K = \frac{2}{C_s} \left\{ \left[\left(z - \frac{C_s}{6} \right) \frac{C_s}{6} + 1 \right]^3 - 1 \right\} \quad \{2\}$$

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where $C_s = \frac{a}{s^3}$ {3}

and $a = \frac{n}{(n-1)(n-2)} \sum_{i=1}^n (x_i - \bar{x})^3$ {4}

where a = the best estimate of the third moment about the mean;

n = the number of observations;

x_i = the i^{th} logarithmic value; and

\bar{x} = mean of the logarithmic values, which is equivalent to \bar{y} .

Frequency factors for skew coefficients outside the range of -1.0 to 1.0 can be obtained from Pearson III frequency distribution tables.

3.5 SURFACE WATER QUALITY

Samples of surface water collected in November 2004, as well as February, June, September, and November 2005 at stations A1, M2, M3 and F4 (**Figure 7, Appendix A**) and were analyzed for water quality. Baseline levels of dissolved oxygen, conductivity, pH, alkalinity, total suspended solids, total dissolved solids, nitrogen, major ions by ICP-MS and anions (chloride, phosphate, bromide, sulphate, nitrate, nitrite) were established.

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4.0 Study Area Hydrology

4.1 OVERVIEW

The subject lands are located within the upper Bronte Creek Watershed. Subwatershed boundaries and watercourses are shown in **Figure 5 (Appendix A)**. The Bronte Creek Watershed is located at the western end of Lake Ontario within the Regional Municipality of Halton, the City of Hamilton, and Wellington County (Township of Puslinch). The Bronte Creek Watershed comprises an area of approximately 312 km² (Conservation Halton, 2002). At a local elevation of over 290 m, the Niagara Escarpment divides the watershed into its upper and lower reaches.

The Bronte Creek Watershed is classified as 64% agricultural/rural, 27% natural, with about 5% quarries and/or recreational (Conservation Halton, 2002). Approximately 5% of the watershed is developed. The watershed's soils are derived predominantly from glacial and glaciofluvial deposits that have acquired their matrix from local dolostone and shale bedrock. These deposits have been reworked by wind and water, thereby producing local concentrations of silt, clay, and muck.

The majority of the subject lands falls within the Mountsberg Creek subwatershed, except for the southeast corner, which is part of the Flamboro Creek subwatershed (**Figure 9, Appendix A**). The headwaters of a tributary of Mountsberg Creek (Tributary A) are located in the wetlands in the northern portion of the subject lands, and flow offsite into Mountsberg Creek. This subwatershed includes the settlement areas of Brookville, Carlisle, Darbyville and Moffat and covers an area of 46.7 km² within the Bronte Creek Watershed. The Flamboro Creek watershed encompasses an area of 8.7 km², originating in the Carlisle North Forests ESA of the Flamborough Plain and flowing into Bronte Creek downstream of Progression.

4.2 CLIMATE

The meteorological station in greatest proximity and at a similar elevation to the study area is located at Millgrove. Climate normals calculated over the period of 1971-2000 at Environment Canada's Millgrove Station (Climate ID 6155183; 43° 19' 12" N, 79° 58' 12" N; 255.1 masl) are presented in **Table 1 (Appendix B)**. Daily average summer (June to August) temperatures range between 18.0 and 20.6°C, with average daily minimum and maximum temperatures varying from 12.1 to 14.6°C, and 23.8 to 26.5°C, respectively. Average winter (December to February) temperatures range between -6.0 and -2.6°C, with average daily minimum and maximum temperatures varying from -9.7 to -6.1°C, and -2.2 to 0.8°C, respectively. The average annual temperature for the period of record is 7.6°C, with average daily minimums and maximums ranging from 2.8 to 12.4°C. The frost-free season is in the order of 216 days. Average annual precipitation is 973.0 mm, with 830.7 mm of this amount falling as rain.

Precipitation is evenly distributed throughout the year, with approximately 53% of average annual precipitation falling between the months of May and October, inclusive.

4.2.1 Water Budget

Using meteorological data from Environment Canada's Hamilton A Station, multiple-year water budgets were developed for the study area. Thornthwaite's Method (Thornthwaite and Mather, 1957) was applied to estimate annual evapotranspiration (ET) for the years 1971-2005 (inclusive). This period was selected since it includes the period of record for which Environment Canada has developed Climate Normals (1971-2000), as well as the most recent years of observation (2001-2005). Annual water budgets for the period 1971-2005 are presented in **Table 2 (Appendix B)**. **Tables 3 to 5 (Appendix B)** show more detailed monthly water budgets for the 1971-2000 normal year, as well as the driest (1980) and wettest year (1996) observed since 1971. Monthly and annual water surpluses were calculated by subtracting adjusted potential ET (adjusted based on latitude) from total precipitation.

The water budget data demonstrate that the annual water surplus can vary considerably from year to year. Although the standard deviations for annual average temperature, annual precipitation, and annual ET for the period 1971-2005 represent 9.5%, 12.8%, and 3.9% of their means, respectively, the standard deviation of total annual water surplus represents 34.8% of the mean. Estimated annual water surplus for the period 1971-2005 varies from a low of 104.8 mm in 1980 to a high of 685.4 mm in 1996. It is interesting to note that 5 of the last 8 years of record (1998-2005) have witnessed a below average water surplus. Of the last 8 years (1998-2005), 3 have experienced a surplus below 245.9 mm (one standard deviation below the mean). Only 2 of the 27 years prior to 1998 experienced a surplus below 245.9 mm.

The monthly breakdown of the water surplus for an average year (**Table 3, Appendix B**) demonstrates that water deficits occur during the months of June, July, and August. However, during a dry year, monthly moisture deficits may extend as early as May and persist into September (**Table 4, Appendix B**), or be limited to July and August during a wet year (**Table 5, Appendix B**).

Surplus water is directed through the watershed as either surface runoff or infiltration. AECOM (2009) determined the groundwater recharge distribution for the study area.

4.3 MOUNTSBERG CREEK AND TRIBUTARIES

Mountsberg Creek supports a diverse fish community. All reaches of Mountsberg Creek support good warmwater fish habitat including several sport fish. Within the vicinity of the subject lands, located below the Mountsberg Reservoir, the creek is classified as warmwater sportfish. The presence of the reservoir and other on-line ponds has had a warming effect on the creek.

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Mountsberg Creek is associated with the site in a few different locations. A tributary originates in the PSW at the north end of the Subject Lands as a diffuse flow through the wetland and then consolidates into a more defined watercourse (Tributary A on **Figure 7, Appendix A**) as it leaves the site. At the extreme west corner of the site, Mountsberg Creek crosses the property boundary at the confluence with Tributary A.

Tributary A, which originates in the Lower Mountsberg Creek PSW complex, also provides fish habitat. The fish community is limited to three fish species, one of which is an indicator of coolwater conditions (pearl dace). The lower reach of Tributary A may also provide spawning habitat for northern pike. The entire tributary also indirectly contributes base flow (which is potentially coldwater) and food/nutrients to Mountsberg Creek.

Instantaneous flows measured in Mountsberg Creek and its tributaries for the period 2003-2007 are shown in **Table 6 (Appendix B)**. Spring runoff flows surpassing 1 m³/s were observed in Mountsberg Creek downstream of the Tributary A confluence (SW-MC3). Low flows between 0.10 and 0.30 m³/s were generally observed in the summer and fall, although flows below 0.10 m³/s were also witnessed at times. Contributions from Tributary A to flows in Mountsberg Creek were observed to vary from 0.020 to 0.074 m³/s during the spring, while prolonged, stagnant flow conditions (flows below 0.010 m³/s) can predominate in the summer and fall. The BCWS reports that groundwater is added to the system throughout this section resulting in a marginal cooling of Mountsberg Creek, which is classified as warmwater as it leaves Mountsberg Reservoir.

Hydrological monitoring data from the hydrologic monitoring program estimates average base flow in Tributary A to be approximately 0.008 to 0.010 m³/s. The degree to which groundwater plays a role in the support of this surface water features is discussed in Section 5.2.2).

Tributaries B and C are not known to support fish habitat. No fish were observed or captured in these features (Stantec and Savanta Inc., 2008). Both of these tributaries are intermittent and likely contribute limited base flow to Mountsberg Creek.

Flows of 0.002 to 0.014 m³/s were observed in Tributary D during spring runoff. Summer storm water runoff flows of 0.077 m³/s were also observed. However, apart from snowmelt and rainfall runoff events, flows within this tributary are likely intermittent with small pools remaining below the culvert at Concession 11, and possibly further downstream, to sustain the small number of fish found here. Fish were identified in Tributary D below the 11th Concession and in the on-site pond (Pond 2). However, the fish community here is limited to the extremely tolerant brook stickleback, suggesting that the habitat conditions are less than optimal (Stantec and Savanta Inc., 2008).

4.3.1 Monitoring Results 2006-2007

Continuous flow monitoring results for all Mountsberg Creek and tributary stations for the period 2006-2007 (inclusive) are shown in **Figures 10 to 13 (Appendix A)**. Due to the very dry conditions experienced in the fall of 2005, the continuous flow monitoring data set for 2005 is limited in nature and is not discussed here, but is included in Appendix C. Monitoring of Station SW-MC was suspended in the spring of 2006 due to land access issues. With the consent of property owners, this station was re-established in the spring of 2007.

The 2006 flow monitoring data for the five Mountsberg Creek stations (SW-MC, SW-M2, SW-MC2, SW-MC3, and SW-MC4) are shown in **Figure 10 (Appendix A)** along with daily monitored rainfall. Greater than average precipitation was experienced in 2006 (approximately 1100 mm as compared to the climate normal of 973 mm). Consequently, several snowmelt and rainfall runoff events were observed during 2006. Spring and fall peak flows at all stations surpassed 1 m³/s, with summer base flows generally remaining above 0.200 m³/s. An average increase in flow of approximately 0.047 m³/s was observed between station SW-MC2 at Mountsberg Road and station SW-MC3 at Concession 11. Similarly, an average increase in flow of about 0.055 m³/s was observed between station SW-MC3 station SW-MC4 at Concession 10. However, only marginal to no differences in flow were observed between these stations during summer months.

An average flow of approximately 0.023 m³/s was observed in Tributary A for the monitoring period (**Figure 11, Appendix A**). This flow rate was observed to fall to approximately 0.007 m³/s in September, 2006. Similarly, an average flow of approximately 0.0013 m³/s was observed in Tributary D for the monitoring period (**Figure 11, Appendix A**). Except for a brief response to an intense rainfall event in mid-July, no flow was observed in Tributary D from early June to mid-October, 2006.

The 2007 flow monitoring data for the five Mountsberg Creek stations are shown in **Figure 12 (Appendix A)** along with daily monitored rainfall. Below average precipitation was experienced in 2007 (approximately 724 mm as compared to the climate normal of 973 mm). Consequently, flows at all stations were considerably lower than in 2006, with few rainfall events observed following the spring freshet. An average increase in flow of approximately 0.026 m³/s was observed between station SW-MC2 at Mountsberg Road and station SW-MC at Evergreen Road. Further downstream, average increases in flow of about 0.028 m³/s, and 0.019 m³/s were observed between stations SW-MC and SW-MC3, and stations SW-MC3 and SW-MC4, respectively. Once again, only marginal to no differences in flow were observed between these stations during the summer, and, particularly, fall months. This was likely the result of the considerably reduced precipitation observed in the spring, summer, and fall.

With respect to the Mountsberg Creek tributaries, an average flow of approximately 0.018 m³/s was observed in Tributary A for the monitoring period (**Figure 13, Appendix A**), which is lower than the 0.023 m³/s mean observed in 2006. Flows were observed to fall to near zero levels in the fall of 2007. Flows in Tributary D averaged only 0.0005 m³/s for the monitoring period, with zero flow observed at SW-TD from early June on.

Surface water monitoring results for Mountsberg Creek suggest that Tributary A is responsible for the majority (approximately 70%) of the increase in flow within Mountsberg Creek between station SW-MC2 at Mountsberg Road and station SW-MC at Evergreen Road. Other neighbouring catchments provide the remainder of the flow increase. The contribution of Tributary A to flow increases between stations SW-MC2 at Mountsberg Road and station SW-MC3 at Concession 11 is in the order of one third to one half of observed flow increases. Flow observations in 2006 and 2007 suggest that Tributary A contributed 5% to 8% of the total flow in Mountsberg Creek at Station MC3. The importance of flow contributions from Tributary A to Mountsberg Creek confirms the function of the Tributary A drainage area as a zone of surface runoff and groundwater discharge, while catchments to the south within and outside of the subject lands appear to function mainly as areas of groundwater recharge, contributing proportionately lesser flow to Mountsberg Creek.

4.4 FLAMBORO CREEK AND TRIBUTARIES

Flamboro Creek emanates as two tributaries from within the Carlisle North Wetland Complex/ESA. Conservation Halton (2002) determined in the Bronte Creek Watershed Study that the headwaters of Flamboro Creek between the CPR tracks and 10th Concession, one concession south of the Subject Lands, is supported by significant groundwater discharge and provides suitable coldwater habitat for brook trout. There are no sampling records for brook trout in this reach, however, anecdotal reports from local anglers confirm their presence in the headwater area. Just upstream of the next concession south, Carlisle Road, the creek flows into a large on-line pond within the Carlisle Golf and Country Club.

Conservation Halton (2002) found that with the exception of a warmwater fish community below the Carlisle Golf and Country Club pond, coldwater fish community and temperature regimes throughout most of the subwatershed are consistent with the expectations for first and second order streams on the limestone plain and glacial spillway features. Conservation Halton (2002) has designated the creek at 10th Concession as marginal coolwater habitat with high aquatic ecosystem health.

The other branch of Flamboro Creek headwaters, which flows along the eastern corner of the Subject Lands, is designated as warmwater forage fish with high aquatic ecosystem health at the 10th Concession (Conservation Halton, 2002). Anecdotal reports from landowners report that brook trout have also been caught in this reach in an on-line pond located between the 10th and

11th Concessions. Through communication with local residents it was also determined that a potential barrier to fish migration may exist in the form of a falls.

The Flamboro Creek headwaters located on the subject lands also support fish habitat. Spring flows in the order of 0.03 m³/s were observed at Concession 11 (**Table 7, Appendix B**). Summer storm water runoff flows of 0.073 m³/s were also observed. As with Tributary D, apart from snowmelt and rainfall runoff events, flows within the Flamboro Creek headwaters at Concession 11 are likely intermittent. Upstream of the 11th Concession the diffuse nature of the watercourse and limited flow results in low levels of dissolved oxygen and the low number of fish found in this reach is representative of these conditions (Stantec and Savanta Inc., 2008). The reach downstream of the 11th Concession, is characterized by a more defined channel. Higher quality habitat conditions are present further downstream from Concession 11. Although a surface water monitoring station was established in Flamboro Creek upstream of Concession 11 (SW-FC2), flows have never been observed at this station, although ponding does occur.

All three of these upper reaches of Flamboro Creek may contribute coldwater base flow to downstream sections of Flamboro Creek. However, the existence of an on-line pond between Concession 10 and 11 appears to restrict the flows downstream. Below the 10th Concession the creek displays evidence that flows are intermittent, such as a lack of a defined channel. Conservation Halton (2002) defined this branch of Flamboro Creek at Concession 10 as warmwater forage fish. The potential for fish habitat is limited in this reach.

4.4.1 Monitoring Results 2005-2007

Observed flows in Flamboro Creek for 2006 and 2007 are presented in **Figures 14 and 15 (Appendix A)**. Flows at Concession 11 averaged approximately 0.037 m³/s in 2006 with zero to near zero flow levels in August. Flows responded to snowmelt or rainfall runoff events, and did not appear to be strongly influenced by groundwater inputs. Mean flows at SW-FC3 were 0.007 m³/s over the monitoring period. However, it must be recalled that the majority of flows in Flamboro Creek at this location were not captured by this monitoring station. In 2007, flows at Concession 11 averaged approximately 0.005 m³/s in 2006 with zero flow levels observed from late June on. Mean flows at SW-FC3 were approximately 0.002 m³/s over the monitoring period.

Although surface water ponding is evident within the Flamboro Creek catchment area upstream of Concession 11, generally speaking, flows at SW-FC are produced in response to snowmelt or rainfall runoff events, and do not appear to be strongly influenced by groundwater inputs. The importance of groundwater inputs to flows in Flamboro Creek appear to occur downstream of the subject lands (between Concession 10 and the CPR tracks) as documented by Conservation Halton (2002).

4.5 ADDITIONAL SURFACE WATER FEATURES

A PSW, the Lower Mountsberg Creek Wetland Complex, occupies the headwaters of tributaries to Mountsberg Creek, and Flamboro Creek, at the north and east portions of the property (**Figure 2, Appendix A**). This wetland complex totals over 285 ha in wetland area and is 95% swamp (MNR, 1998). On site, this wetland extends along the length of the existing unopened road right-of-way to the Mountsberg Creek subwatershed boundary. Another node of this wetland complex is located within the southeast corner of the site. The southeast branch of the wetland complex contains a tributary of Flamboro Creek, which is also located within the subject lands. Approximately 21 ha of this PSW complex falls within the subject lands, with 16.5 ha in the north part of the property and 4.3 ha in the southeast section. Hydrogeological investigation suggests that the PSW is seasonally connected to the groundwater table (AECOM, 2009).

Approximately 2 km southwest of the subject lands is the locally significant Freelon Esker Wetland Complex. This silver maple swamp appears along the sides of the 4 km long, northwest-oriented Freelon Esker lying with a group of eskers in the Freelon area. Similar to the wetlands closer to the subject lands, the upper reaches of the Bronte Creek, known for coldwater fisheries and a heronry, drain this wetland (NHIC).

The locally significant Kilbride Swamp is a 17.9 ha feature lying to the southeast of the subject lands. It is listed as a regionally significant Life Science ANSI. The wetland area is a non-provincially significant wetland complex made up two individual wetlands, composed of a single wetland type (100% swamp). The upland areas are forested dominantly with sugar maple with some red oak.

A small off-line pond is found to the west of Flamboro Creek within the property boundaries (Pond 1). A small dugout pond is found near the southern property line at an elevation of 280.7 masl (Pond 2). A depression that provides temporary storage for spring runoff is found southeast of Tributary A along the northeastern property boundary (SWF-1). These surface water features, along with the three most active seeps found within the property boundary were monitored continuously to assess patterns in surface water storage.

4.5.1 Monitoring Results 2006-2007

Water level fluctuations for Pond 1, Pond 2, and SWF-1 during 2006 and 2007 are shown in **Figures 16 and 17 (Appendix A)**. Pond 1 demonstrated the steadiest water levels of the three features. Both Pond 1 and Pond 2 maintained some level of water storage during the entire 2006 monitoring period. However, ponding in SWF-1 was sustained only until the end of May, with sporadic, short-lived ponding events occurring in response to rainfall events for the remainder of the year.

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In contrast, in 2007, all surface water features failed to sustain water storage throughout the entire monitoring period. Hydro-periods for these three features were considerably reduced, with ponding disappearing from station SWF-1 by May 23. Surface water storage essentially disappeared from the dugout pond (Pond 2) at the monitoring station by July 10, while ponding ceased to occur at the Pond 1 station by September 6, and then returned by early December.

Similarly, seep activity in 2006 (**Figure 18, Appendix A**) was sustained at S5a and S3a until June 19. Both seeps became active again by early October. Between these dates, sporadic ponding at these seeps occurred in response to rainfall events. Seep S3 was only active until May 19. In comparison, in 2007, seep activity in was sustained at S5a and S3a until June 12 (**Figure 19, Appendix A**) and returned by mid to late November. S3 was once again active until May 19, albeit at reduced water depths.

4.6 EXISTING SURFACE WATER DRAINAGE

Terrain analysis of the subject lands was completed by GLL (2005). The subject lands can be divided into three terrain units (GLL, 2005):

- Natural Areas;
- Drumlins and Deeper Till Soils; and
- Sand & Gravel.

The Natural Areas unit is the most extensive. Groundwater is at or very near to surface over much of this unit, and is contained in the many fractures and bedding planes (GLL, 2005). Seasonal fluctuations of the groundwater table have been observed within the unit. This groundwater forms an unconfined aquifer. Wetlands and ponds of water are common here. Shallow groundwater flows provide base flow for the drainage pathways within this unit. Consequently, the wetlands and drainage pathways present act as groundwater discharge areas, while the rockland away from the wet areas are likely groundwater recharge areas (GLL, 2005). This groundwater flow provides for recharge to the aquifer, but also provides the ecological base for the complex functions of the unit, including the wetlands, fish habitat, woodland functions and wildlife habitat.

Since the general hydraulic gradient of groundwater is to the south, this suggests that the Mountsberg Wetland Complex on the north boundary of the subject lands is probably recharged, in part, from the drumlin surface runoff that enters the Natural Areas, and, hence, discharges to the wetland (GLL, 2005). However, observations of seep flows during spring within the Tributary A subwatershed, as well as elevated groundwater levels during summer suggest a shallow groundwater flow path from the north part of the site northward to Tributary A

and the Mountsberg Wetland Complex. Similarly, it also appears that Flamborough Creek receives shallow groundwater baseflow.

The Drumlins and Deeper Glacial Till occur to the north and west of the subject lands. Groundwater recharge from this unit into the aquifer is likely very slow. Surface runoff during rain events likely introduces more surface water into the groundwater system as the runoff flows into the low wet areas between the drumlins, and, hence, into the groundwater system. The environmental function of this unit is minimal (GLL 2005).

The Sand and Gravel unit within the subject lands has generally been cleared of trees, and is under crop or pasture land use. The main environmental function of this unit is to enhance the groundwater recharge through the surficial sand and gravel to the underlying Amabel aquifer (GLL 2005).

4.6.1 Site Micro-drainage

The micro-drainage of the subject lands was analyzed by Stovel and Associates (2006) and was modified as presented in **Figure 20 (Appendix A)**. The surface micro-drainage patterns on the subject property are complex, due to the hummocky nature of the morainal till deposit. In general, there are eight main Catchment Areas, identified as Catchments "A", "B", "C", "D", "E", "F", "G", and "H". A series of sub-catchment areas have been mapped within these main catchment Areas. Area estimates provided for these catchment areas relate only to portions located on the subject lands. Offsite components to the catchment areas have not been included in the area estimates.

Catchment Area "A" is located in the northern portion of the site and is approximately 51.0 ha in size. Catchment Area "A" includes five sub-catchments; the largest sub-catchment area relates to the swamp community in the north and northwestern portions of the site. This sub-catchment area is approximately 37.7 ha in size and comprises approximately 74% of Catchment Area "A". Surface waters for Catchment Area "A" flow southwesterly to Tributary A of Mountsberg Creek and its associated wetlands. Sub-catchment Area "A5" is approximately 2.9 ha in size and is of note, since, in the spring freshet, this area becomes inundated with water and forms SWF-1. There is no surface water drainage from this area when surface water elevations are low. Bedrock is close to the surface and drainage is likely internalized for much of the year. Only a small portion of Sub-catchment Area "A5" is located on the subject lands; most of the catchment area is found northeast of the site. Surface waters collect along the boundaries of the subject lands. The total drainage area of Tributary A (including areas outside of the subject lands) is approximately 305 ha. Therefore, Catchment Area "A" represents approximately 16.7% of Tributary A's total drainage area.

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Catchment Area "B" is approximately 4.2 ha in size and includes three sub-catchment areas. Surface waters for Catchment Area "B" flow in a southerly trending pattern and eventually discharge to a tributary of Mountsberg Creek (Tributary B, see **Figure 7, Appendix A**). Catchment Area "B" is located towards the western corner of the site. Catchment Area "B" is characterized by cultural vegetation communities and deciduous forest.

Catchment Area "C" is approximately 33.6 ha in size and includes six sub-catchment areas. Surface waters for Catchment Area "C" also flow to the south and eventually discharge to a tributary (Tributary C) of Mountsberg Creek. Catchment Area "C" is located in the southwestern portion of the site. Most of the lands associated with Catchment Area "C" consist of agricultural lands and hedgerows.

Catchment Area "D" is approximately 39.9 ha in size and includes three sub-catchment areas. Water at surface has been observed during site visits to this area. Minor flows in a southerly direction were noted, however, flow is discontinuous. It is anticipated that surface runoff is internalized within portions of this catchment area and eventually contributes to recharge. The southern extremity of Catchment Area "D" is seasonally inundated with water and contains a small dug pond (Pond 2). Most of Catchment Area "D" is forested. Only a small portion, estimated to be 6.5 ha, is cultivated for agricultural production.

Catchment Area "E" is located at eastern extremity of the site. This catchment area includes both wetland and upland communities and is approximately 21.5 ha in size. Surface water ponding is often observed in the wetland portion of this catchment area. Flamboro Creek flows through the wetland in this catchment area in a north-to-south trending pattern.

Catchment Area "F" is a small depressional area, approximately 1.9 ha in size, lying between Catchment Areas A and C. Ponding of surface water occurs at low points within this unit. No drainage outlets from this unit were observed. It is anticipated that this area likely contributes to groundwater recharge during much of the year, as surface water is largely internalized.

Catchment Area "G" is a relatively small area, approximately 5.0 ha in size. This unit slopes in a northwesterly fashion towards Catchment Area A. The unit is predominantly upland, with bedrock controlled topography. Several bedrock exposures were noted throughout this catchment area. No surface water features were observed in this unit. It is anticipated that the area functions largely as an area of groundwater recharge.

Catchment Area "H" represents the very small drainage area (approximately 1.0 ha in size) within the subject lands that drains directly to Mountsberg Creek. This catchment is located in the western corner of the site and is mainly forested.

4.7 LOW FLOW HYDROLOGY

As a component of the hydrologic assessment for Mountsberg Creek, and in accordance with MOE (1994) Green Book (*Deriving Receiving Water Based Point Source Effluent Requirements for Ontario Waters*) criteria, an estimate of the 7Q20 flow rate for Mountsberg Creek within the immediate vicinity of the subject lands was calculated. The 7Q20 flow rate represents the 7-day average low flow than can be expected to occur once in 20 years and is the statistical flow applied in the evaluation of sewage or industrial discharges to surface water. The proposed quarry operations will introduce flows from dewatering into Mountsberg Creek.

Daily flow data for Bronte Creek at Water Survey of Canada Station 02HB022 (43° 23' 20" N; 79° 59' 17" W) were analyzed to determine the 7Q20 flow for Bronte Creek at Carlisle (117 km² basin area). This flow was then pro-rated to the watershed area of Mountsberg Creek in the immediate vicinity of the subject lands (39 km²).

The 7Q20 flow rate was calculated using the Log Pearson III Method described below. Although the period of record is limited to 15 years, the Log Pearson III Method provides for adjustment of any skewness in the data set. A 7Q20 flow rate of 0.090 m³/s was calculated for Bronte Creek at Carlisle, which, when pro-rated to the drainage area of Mountsberg at the subject lands, suggests a 7Q20 of 0.031 m³/s at this location. The lowest flow measured in Mountsberg Creek thus far during *in situ* monitoring is in the order of 0.12 m³/s. Low flow analysis suggests that flows in Mountsberg Creek may fall to 25% of this observed flow.

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5.0 Surface Water Quality

5.1 OVERVIEW

Historical Provincial Water Quality Monitoring (PWQMN) data for Mountsberg Creek are presented in **Tables 8 and 9 (Appendix B)**. No PWQMN data are available for Flamboro Creek. The Mountsberg Creek data span the period 1965-1996 and represent water quality at two locations: Highway 401 and County Road 18 (**Figure 21, Appendix A**). General trends within the historical PWQMN data for the Bronte Creek watershed suggest that total phosphorus concentrations regularly (51% of the time) exceed the Provincial Water Quality Objective (PWQO) for total phosphorus of 0.03 mg/L (Conservation Halton, 2002). High concentrations of *E. coli* and other fecal coliforms are found throughout the watershed. Non-point surface runoff from agricultural operations is believed to contribute to elevated bacteriological levels (Conservation Halton, 2002). Although metal concentrations are generally found to meet PWQOs, aluminum, iron, and zinc concentrations exceed PWQOs at several points within the watershed.

Historical mean water quality for Mountsberg Creek reflects the water quality trends of the Bronte Creek watershed. Mountsberg Creek water quality generally meets PWQOs, with the exception of *E. Coli* (135 counts per 100 ml) and zinc (0.025 mg/l) at Highway 401, and total phosphorus (0.032 mg/L) at County Road 18. When only summer water quality is considered for certain parameters, 75th percentile, mean, and 25th percentile total phosphorus concentrations exceed the PWQO of 0.03 mg/L. Although groundwater discharged from the Badenoch Moffat Swamp Complex sustains coldwater conditions upstream of the Mountsberg Reservoir, it is recognized that warm water discharged from the Mountsberg Reservoir during the summer results in significant degradation of coldwater habitat in reaches downstream of this point (Conservation Halton, 2002).

Conservation Halton (2002) collected data in Mountsberg and Flamboro Creek at stations M1 and F1 (**Figure 21, Appendix A**) over the period 1999-2001. Mean water quality at the above locations meets PWQOs with the exception of aluminum (0.102 mg/L) and total phosphorus (0.069 mg/L) in Flamboro Creek (**Table 10, Appendix B**). Once again, these results are consistent with the general water quality trends observed in other portions of the Bronte Creek watershed. The tributary crossing at the 10th Concession provides permanent coolwater flow extending downstream to the on-line pond on the Carlisle Golf Course. Warmwater conditions are present downstream of this pond, with groundwater inputs from the downstream valley slopes allowing for gradual regeneration of coolwater conditions (Conservation Halton, 2002).

5.2 SURFACE WATER QUALITY

Water quality in the immediate vicinity of the subject lands was investigated through the collection of surface water samples at stations A1, M2, M3 and F4 (**Figure 7, Appendix A**). The results of this sampling are summarized in **Table 11 (Appendix B)**. When non-detectable

concentrations were encountered, mean water quality parameter concentrations were determined by assuming one half of the detection limit. Temperature monitoring results for Mountsberg Creek and its tributaries, Flamboro Creek, as well as on-site surface water features and seeps are presented in **Figures 22 to 31 (Appendix A)**.

Water quality sampling results demonstrate that average water quality at stations M2 and M3 along Mountsberg Creek is likely similar to that observed at the historical PWQMN station at County Road 18. For example, average alkalinity of 211 mg/L at M2 and 180 mg/L at M3 is similar to the average alkalinity of 179.9 mg/L observed upstream at County Road 18 (**Table 8, Appendix B**). Similar nutrient and TSS levels are also noted between all three stations. This suggests that the upstream PWQMN station at County Road 18 can serve as a long-term monitoring station for background water quality characterization. With respect to metal concentrations, most parameters fall close to or below detection limits. As with other creek and groundwater sampling results, aluminum, iron, and zinc levels are generally above detection limits, and, at times above PWQOs, as indicated by highlighted values in **Table 11 (Appendix B)**.

5.2.1 Total Dissolved Solids (TDS)

The patterns observed in TDS levels from November 2004 to September 2005 suggest that Tributary A receives a greater proportion of groundwater input from the subject lands than Mountsberg or Flamboro Creek. It is known that groundwater TDS levels are generally greater than those found in surface water (**Tables 10 and 11, Appendix B**). Mean TDS levels of 401 mg/L in Tributary A (Station A1) are between the average of Upper Amabel (336 mg/L) and Middle Amabel (545 mg/L) zone as measured during the Phase 1 pumping test for the Flamborough Quarry (Gartner Lee Ltd. 2008). Mean TDS levels in Flamboro Creek (347 mg/L) are similar to that of the Upper Amabel, while average TDS levels in Mountsberg Creek (281-290 mg/L) are below that of the Upper Amabel. The pattern of change in TDS levels suggests that groundwater input to Tributary A occurs from fall to spring, as TDS levels remained above 400 mg/L. However, by September, TDS levels in Tributary A (168 mg/L) were similar to those at M2 in Mountsberg Creek (190 mg/L). The pattern of decreasing TDS levels from spring to summer is also observed at the two Mountsberg Creek stations. The pattern observed for Flamboro Creek appears to suggest that the creek is maintained by shallow groundwater into the spring until flows are no longer observed during summer.

5.2.2 Surface Water Temperatures

Observed temperatures in Mountsberg Creek and its tributaries for 2006 and 2007 are presented in **Figures 22 to 25 (Appendix A)** along with observed air temperatures. Although temperatures are fairly consistent from upstream to downstream stations, a slight cooling of Mountsberg Creek was discerned through the temperature monitoring data. From early June to late September 2006, temperatures in Mountsberg Creek averaged 18.42 °C at SW-MC2, 18.22 °C at SW-M2, 17.90 °C at SW-MC3, and 17.65 °C at SW-MC4 (the recorded temperature data at SW-MC is incomplete and is therefore not compared to other stations). In comparison, the

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average temperature within Tributary A was 16.29 °C over the same period. These data suggest some degree of cooling is provided by Tributary A, as well as other factors, such as shading from the creek canopy. These results are consistent with observations made by Conservation Halton (2002). Since no flows were present in Tributary D for much of the monitoring period, temperature comparisons cannot be made with data recorded at SW-TD.

Similarly, from early June to late September 2007, temperatures in Mountsberg Creek averaged 20.55 °C at SW-MC2, 20.27 °C at SW-M2, 20.06 °C at SW-MC, 19.81 °C at SW-MC3, and 19.84 °C at SW-MC4. The reduced flows experienced in 2007 resulted in greater creek temperatures (approximately 2 °C) when compared to 2006 data. Additionally, a slight increase in temperature was noted as creek water flowed from SW-MC3 to SW-MC4, in contrast to the 0.25 °C decrease witnessed in 2006. The average temperature within Tributary A was 18.80 °C over the same time period. While cooler than all the Mountsberg Creek stations, this temperature represents a 2.5 °C increase over mean 2006 temperatures in Tributary A.

Temperatures in Flamboro Creek in 2006 and 2007 (**Figures 26 and 27, Appendix A**) experienced a slight increase from upstream to downstream stations. Average temperatures of 13.47 °C, 15.09 °C, and 15.24 °C were observed at stations SW-FC2, SW-FC, and SW-FC3, respectively from early June to late September, 2006. A lack of observed flows in Flamboro Creek during the summer and fall of 2007 render temperature comparisons between stations difficult. However, it is noted that temperatures averaged 7.91 °C at SW-FC2 and 9.55 °C at SW-FC from early April to early June, 2007.

On-site pond and surface water feature temperatures in 2006 and 2007 are shown in **Figures 28 and 29 (Appendix A)**. Pond 1 clearly demonstrated a lower temperature trend than Pond 2 until late July, 2006 (**Figure 28, Appendix A**). At this time, surface water levels in Pond 1 were drawn down significantly enough to be influenced by ambient temperatures (**Figure 16, Appendix A**). (It is important to note that Pond 2 is also a considerably larger body of water than Pond 1). Both ponds experienced cool surface water temperatures below 20 °C for the entire year. The cooler water temperatures experienced at Pond 1 during periods of high surface water depth in the spring, and slightly warmer temperatures experienced at Pond 1 during periods of high surface water depth in the fall suggest a groundwater influence. The greater water temperatures measured at SWF-1 reflect the lower water depths recorded here in the spring (until May 30) and the absence of water from May 30 on. Similarly, in 2007, Pond 1 clearly demonstrated a lower temperature trend than Pond 2 until the depletion or near depletion of ponded surface water within these features, at which time recorded temperatures were no longer buffered from ambient air temperature fluctuations. Temperatures averaged 13.38 °C in Pond 1 in 2006 for the entire monitoring period, and 12.70 °C in 2006 (from early April to early September). For Pond 2, temperatures averaged 14.46 °C in 2006 for the entire monitoring period, and 13.92 °C in 2006 (from early April to mid-July).

On-site seep temperatures in 2006 and 2007 are shown in **Figures 30 and 31 (Appendix A)**. Measured seep temperatures at S3a and S5a in 2006 remained below 15 °C until seep activity

ceased in mid-June (**Figure 30, Appendix A**). Seep temperatures averaged 6.86 °C at S3a and 7.73 °C at S5a from early April to mid-June, 2006. Similarly, seep temperatures at S3a and S5a in 2007 remained below 15 °C until reduction in seep activity accelerated in early June (**Figure 31, Appendix A**). Seep temperatures averaged 8.44 °C at S3a and 9.45 °C at S5a from early April to early June, 2007. This represents an approximate 1.5 °C increase over mean 2006 temperatures. The sporadic seep activity observed at S3 resulted in much greater temperature variation at this station during both years.

Observed temperatures in Mountsberg Creek (**Figure 22 to 25, Appendix A**) demonstrate a lower degree of variability than temperatures in Tributary A or Flamboro Creek. This is likely due to the greater net volumetric flow through Mountsberg Creek. Although characterized by considerably lower flows than Mountsberg Creek and minimal canopy cover, Tributary A was observed to reach lower average daily temperatures than Mountsberg Creek from late spring (early June) to early fall (late September). Temperature fluctuations in Tributary A are likely buffered as a result of groundwater inputs. However, the temperature data suggest minimal temperature buffering capacity in Tributary A during summer months. Water quality data suggest that roughly 50% of flows in Tributary A may be sustained by groundwater inputs from late fall to mid to late spring. The magnitude and duration of such inputs is likely correlated with on-site seep activity. Groundwater inputs to Tributary A approach zero during summer months. Tributary A exerts a slight cooling effect on Mountsberg Creek. Although groundwater ponding is evident in the headwaters of Flamboro Creek, flows in Flamboro Creek responded to snowmelt or rainfall runoff events, and did not appear to be strongly influenced by groundwater inputs. Such inputs occur in downstream reaches of Flamboro Creek.

5.2.3 Biologic Indicators

In addition to water quality and temperature monitoring, Stantec conducted aquatic surveys within Mountsberg and Flamboro Creek. In conjunction with water quality monitoring, results of the aquatic surveys aid in the assessment of habitat quality for both creeks. Benthic community data range from indicating good quality habitat conditions in the main channel of Mountsberg Creek (Stations M1, M2, and M3) to fairly poor habitat conditions in Flamboro Creek and tributaries to Mountsberg Creek (most notably, Stations A2, B1, C1, and D2) (**Figure 7, Appendix A**). A comprehensive discussion of the aquatic survey is provided in the EIS and Level 2 Natural Environment Technical Report (Stantec and Savanta Inc., 2008).

Benthic communities may be indicative of environmental stress when a single species or group comprises > 60% of the total community assemblage. Stations M2 and M3 in Mountsberg Creek support diverse benthic macroinvertebrate communities. Stations A2 (Tributary A) and B1 (Tributary B) are dominated by molluscs, with > 55% of these communities belonging to this group. Approximately 60% of the community at B1 is comprised of mollusc organisms. Therefore, the tolerant, filter feeding molluscs present at these stations suggest stressed benthic communities.

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Stations C1 (Tributary C), F1 and F3 (Flamboro Creek) are dominated by the pollution tolerant chironomid family (i.e., comprising 56.4%, 56.2%, and 51.0% respectively). Since the dominant organisms at these stations are among the most tolerant benthic macroinvertebrates, aquatic habitat is limited in these reaches. These data also correspond with the fisheries data. Tributary C is an intermittent tributary to Mountsberg Creek and is not known to support fish habitat, while only two tolerant warmwater baitfish species were captured (i.e., blacknose dace, brook stickleback) in the main channel of Flamboro Creek.

Stations D2 (Tributary D) and F4 (Flamboro Creek) are both dominated by a combination of tolerant nematodes, annelids, ostracods, and amphipods. All of these groups are considered to be relatively insensitive organisms that can tolerate degraded habitat conditions. As described above, the fisheries catch results for Flamboro Creek support these data. Similarly, only one tolerant warmwater baitfish species (i.e., brook stickleback) was captured in Tributary D at Station D1, while no fish were captured at Station D2.

Conversely, stations M1, M2 and M3 indicate good habitat conditions, as many of the taxa are the pollution sensitive mayflies (from the order *Ephemeroptera*), stoneflies (*Plecoptera*), and caddisflies (Trichoptera). These sensitive organisms characterize the study reaches of Mountsberg Creek in particular as an intolerant benthic community that is vulnerable to potential environmental impacts. Similarly, station M3 demonstrates the highest taxa richness, and, therefore, supports a well balanced community, with good representation by many benthic groups. This observation is supported by the fisheries data, where the main channel of Mountsberg Creek is known to provide habitat for warmwater sportfish species.

5.3 DISCHARGE WATER QUALITY

The water that will be discharged from the site will be a mixture of groundwater seepage and direct precipitation (i.e., rainfall or snowmelt). For the purposes of assessing the potential effects on surface water, the average groundwater quality from the monitoring wells in the Amabel Formation and the quality of the groundwater extracted during the Phase 1 pumping test is considered most representative (AECOM 2009). The average and 75th percentile groundwater quality from both the monitoring wells in the Amabel formation and the pumping test discharge met all PWQOs, except for zinc.

To project potential water quality within Mountsberg Creek as a result of quarry dewatering, the potential water quality of the quarry discharge was characterized by applying 75th percentile concentrations of the observed Phase 1 pumping test discharge (Gartner Lee Ltd., 2008), which is deemed representative of the future quarry discharge. The Phase 1 pumping test discharge water quality was applied since it was characterized by greater zinc concentrations than the Amabel formation, and therefore represents a more conservative estimate of quarry discharge quality.

The discharge water quality parameter concentrations presented in **Table 12 (Appendix B)** represent 75th percentile concentrations for all discharge samples. Only 1 water quality

parameter (zinc) was observed to have a 75th percentile concentration above its PWQO during the pumping test discharge. Alkalinity and conductivity were also evaluated, since there is potential for the quarry discharge to alter the hardness of the receiving water (although no PWQOs have been established for these parameters).

5.3.1 Analysis and discussion

To project potential water quality in Mountsberg Creek downstream of the quarry discharge, and in accordance with MOE guidelines, 75th percentile background water quality concentrations (calculated from PWQMN station data at County Road 18) were assumed upstream of the discharge. The 75th percentile discharge water quality concentrations presented in **Table 12 (Appendix B)** were applied to the quarry discharge. Projected quarry discharges of 24 L/s for the full quarry were assumed to occur during the 7Q20 condition (0.031 m³/s) in Mountsberg Creek. This is a conservative, worst-case scenario as this low flow condition will occur infrequently, and mitigation measures will likely reduce flows from the quarry discharge.

A mass balance approach was used for the water quality projections in **Table 12 (Appendix B)**, and the projected creek concentrations therefore represent water quality under fully mixed conditions. Results suggest that unmitigated flows to Mountsberg Creek under a 7Q20 conditions would slightly increase the alkalinity and conductivity of the receiving water, while concentrations of zinc (0.031 mg/L) would rise slightly above the Interim PWQO of 0.02 mg/L. The projected increases in alkalinity and conductivity levels are not projected to have an impact on the habitat quality of Mountsberg Creek.

With respect to zinc concentrations, although zinc levels above the Interim PWQO of 0.02 (and the PWQO of 0.03 mg/L) may be temporarily produced under 7Q20 conditions, projected zinc concentrations are below both lethal and sublethal toxicological benchmarks. Zinc concentrations lethal (causing 50% mortality) to invertebrates and fish have been cited at levels greater than 0.100 mg/L (MOE1979). Growth inhibition of the algae *Selenastrum capricornutum* has occurred at zinc concentrations of 0.7 mg/L (Bartlett et al. 1974). *Daphnia magna* exposed to zinc for three weeks experienced 16% inhibition of reproduction at a level of 0.07 mg/L (Biesinger and Christensen 1972).

Fish appear to be more sensitive to zinc than other aquatic life (MOE 1979). A no effect level of 0.03 mg/L has been quoted for zinc (Brungs 1969) and is the basis for the PWQO of 0.03 mg/L (MOE 1979). It is important to note that this no effect level was established on the basis of 10-month bioassay in soft water. Zinc toxicity decreases with increased hardness. Water quality sampling of Mountsberg Creek indicates hardness greater than 100 mg/L during low flow conditions. Therefore, although predicted zinc levels in Mountsberg Creek may exceed both the interim PWQO of 0.02 mg/L and the PWQO of 0.03 mg/L, known sublethal toxicological benchmarks for zinc combined with the hardness of the quarry discharge water suggest that the pump test discharge will not affect aquatic life under conservative, 7Q20 receiving water conditions.

6.0 Potential Impacts and Mitigation

6.1 DESCRIPTION OF THE PROPOSED QUARRY

The proposed quarry occupies approximately 66.4 ha (42.0%) of the subject lands. The proposed limits of extraction are shown on **Figure 32 (Appendix A)**. Additional development of the site will be required in the form of an access road exiting to Milborough Line.

Extraction below the groundwater table is proposed, and will require dewatering. Pumping water from the proposed quarry in order to permit “dry” operations (i.e., dewatering) will lower the water table and groundwater levels around the perimeter of the quarry. Without mitigation this drawdown would lead to effects on local natural features (e.g., wetlands that are dependent upon ground water levels, either seasonally or permanently and watercourses that receive baseflow from groundwater inputs).

The proposed quarry installation will also lead to changes in the existing surface water catchments where they overlap with the quarry. This changed landscape has the potential to affect the existing volumes of overland runoff and will affect downstream or down slope resources, where they are dependent upon the maintenance of existing surface water inputs.

In addition to altered catchments and contributions of surface flows, the quarry will result in a surface water discharge from the dewatering activities. Groundwater modeling simulations estimate this surplus water to total approximately 750,000 m³/yr (or about 24 L/s) at full quarry development (AECOM, 2009). This surplus will be discharged to Tributary C and Tributary D of Mountsberg Creek and can approximate existing, natural runoff conditions in these features. The specific discharge locations will be determined and designed in association with certificates and approvals required by the Ministry of the Environment and Conservation Halton for this purpose. The water quality of the quarry discharge is not anticipated to affect aquatic life in Mountsberg Creek.

6.2 PROVINCIALLY SIGNIFICANT WETLAND

6.2.1 Potential Impacts

The proposed extraction limit does not intrude into the PSW. Additionally, the road and berms associated with the Milborough Line access will not result in the development of the PSW. A minimum 30 m setback has been included as part of the extraction limit. Accordingly, there will be no direct impact to the PSW.

Indirect impacts to the PSW could arise in two different ways:

- Changes to water balance and quality – reduction in groundwater discharge, altered groundwater table associated with drawdown and/or

with mounding associated with extraction and progressive rehabilitation scenarios;

- Changes in surface water catchment, flows and delivery points, change in water temperature and quality; and
- Potential modification to seep characteristics.

6.2.2 Mitigation Options – Changes to Water Balance and Quality

Water levels in the wetland appear to be a reflection of the groundwater table elevation. Modeling prepared by AECOM (2009) indicate that unmitigated extraction below the groundwater table would result in unacceptable levels of drawdown on and adjacent to the site, potentially resulting in reductions to groundwater discharge to the PSW. To mitigate this potential effect, AECOM (2009) has proposed a Groundwater Recirculation System (GRS) that can maintain groundwater levels at existing levels in the wetlands.

The Tributary A portion of the wetland, located at the north end of the site, is likely more heavily influenced by seasonal groundwater inputs. Since the regional groundwater gradient is from north to south, this part of the wetland may rely more on groundwater contributions from north of the site than from the site. With GRS mitigation, no negative impacts to the groundwater volume to this portion of the wetland are anticipated.

The seeps adjacent to the Flamboro Creek portion of the wetland appear to be supplied by shallow seasonal groundwater flow. These seeps are located several hundred metres from the proposed extraction area. With GRS mitigation, no negative impacts to the groundwater volume to this portion of the wetland are anticipated.

The extraction envelope will primarily affect the *Sand and Gravel* terrain unit with some removal of the *Natural Areas* terrain unit. Both these units are dominated by recharge, and little surface runoff from these areas is expected to support the wetlands. The *Drumlin and Glacial Till* unit that supplies significantly more surface runoff is located north of the site and will not be affected by the proposed quarry.

6.2.3 Mitigation Options – Changes in Surface Water Catchment

Table 13 (Appendix B) shows the current and future subcatchment areas within the subject lands as affected by the proposed extraction footprint (**see Figure 32, Appendix A**). Reductions in subcatchment area vary from 0 ha in some subcatchments to a 14.0 ha reduction in subcatchment D1. Approximately 7.5 ha of the extraction footprint is associated with subcatchments draining to Tributary A to the north. Another 6.92 ha of the extraction footprint is associated with subcatchments F and G, which drain internally. The remaining 50.93 ha of the extraction footprint are associated with subcatchments that drain to the south of the subject lands, and, ultimately, to Tributary D.

The 7.5 ha total reduction in catchment area for Tributary A is minimal in comparison to its total drainage area of approximately 3 km². Therefore, potential impacts resulting from the changes in surface water catchment will be mitigated.

6.3 AQUATIC HABITAT

6.3.1 Potential Impacts

The proposed extraction limit, access road, and berms do not directly affect any aquatic habitat. On site, aquatic habitat is located within and is buffered by wetland habitat, and is located a minimum of 75 m from the proposed extraction area. Accordingly, there will be no direct impact to the aquatic habitat.

Indirect impacts to aquatic habitat could arise in two different ways:

- Changes to water balance and quality – reduction in groundwater discharge, altered groundwater table associated with drawdown and/or with mounding associated with extraction and progressive rehabilitation scenarios
- Changes in surface water catchment, flows and delivery points, change in water temperature and quality

6.3.2 Mitigation Options – Changes to Water Balance and Quality

Watercourses in the vicinity of the site, particularly Tributary A, receive some of their flow from groundwater. The GRS proposed by AECOM will be developed in a manner to mimic existing conditions. Therefore, predicted effects on aquatic habitat will be avoided and/or minimized.

The potential water quality impacts of mixing the direct discharge into Mountsberg Creek were assessed using a mass balance approach. Results suggest that unmitigated flows to the Mountsberg Creek under a 7Q20 low flow scenario would slightly increase the alkalinity and conductivity of the receiving water, while concentrations of zinc would be slightly above the Interim PWQO of 0.02 mg/L. The projected increases in alkalinity and conductivity levels, as well as zinc concentrations are not predicted to have an impact on the habitat quality of Mountsberg Creek. With mitigation, surplus discharge will be substantially reduced.

6.3.3 Mitigation Options – Changes in Surface Water Catchment

Table 13 (Appendix B) shows the current and future subcatchment areas within the subject lands as affected by the proposed extraction footprint (**see Figure 32, Appendix A**). Reductions in subcatchment area vary from 0 ha in some subcatchments to a 14.0 ha reduction in subcatchment D1. Approximately 7.5 ha of the extraction footprint is associated with subcatchments draining to Tributary A to the north. Another 6.92 ha of the extraction footprint is associated with subcatchments F and G, which drain internally. The remaining 50.93 ha of the

extraction footprint are associated with subcatchments that drain to the south of the subject lands, and, ultimately, to Tributary D.

Hydrologic monitoring of Tributary D has demonstrated that this channel acts as an ephemeral drainage feature, conveying surface runoff during the spring freshet or during periods of significant rainfall (**see Figures 11 and 13, Appendix A**). The hydrology of Tributary C upstream of Concession 11 is very similar to that of Tributary D. The loss of subcatchment area should therefore not interfere with the function of this drainage feature, since quarry dewatering during periods of excess runoff will direct surplus water through Tributary C and D. The 7.5 ha total reduction in catchment area for Tributary A is minimal in comparison to its total drainage area of approximately 3 km². Therefore, potential impacts resulting from the changes in surface water catchment will be mitigated.

7.0 Recommended Adaptive Management and Monitoring Programs

Adaptive management programs are intended to achieve specified performance goals including for example, the maintenance of pre-quarry (baseline) seasonal ground water levels (where required), surface water temperatures and surface water quality in adjacent natural features (wetlands and watercourses). A highly flexible GRS system has been proposed incorporating a wide range of adjustments and refinements that can be implemented as needed. From a surface water perspective meeting these performance goals will result in no contribution to increased flooding or erosion downstream, no contribution to PWQO exceedances, and maintenance of water temperatures and quality in adjacent sensitive stream habitats.

The Adaptive Management Program will recognize the need to adapt surface water monitoring and water resource mitigation to the variable conditions that will be experienced in the vicinity of the subject lands and over the course of the monitoring program. Key components of an Adaptive Management Program include:

- **Potential Effects:** Development of a conceptual model to describe how quarrying activities and management actions will affect components of the environment.
- **Triggers and Management Actions:** A management policy that lays out rules specifying management actions (e.g., mitigation measures) based on current information on indicator variables. The development of mitigation measures through engineering and supporting scientific studies is proposed to limit potential impacts of the proposed quarry extension on local environmental receptors.
- **Monitoring Plan:** A monitoring plan to observe how the environment responds to aggregate extraction and management actions relative to key indicator variables.
- **Management System:** A management system which implements the policy (Triggers and Management Actions) and depends on the concurrent observations made on key indicator variables.

A baseline surface water monitoring program has been established for the proposed Flamborough Quarry. From a surface water monitoring perspective, it is expected that the existing surface water monitoring program will become a component of the adaptive management program. The program may be enhanced to a greater level of detail (spatial, temporal or parameters), depending upon the surface water triggers identified. Contingency measures for surface water will also be developed if abnormal environmental conditions occur or mitigation measures do not have the expected effect.

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8.0 Summary and Conclusions

Stantec Consulting Ltd. (Stantec) was retained to complete a Hydrological Assessment and Hydrological Report for the proposed Flamborough Quarry. The Hydrological Report provides baseline information to support the Environmental Impact Statement EIS and Level 2 Natural Environment Technical Report.

The subject lands are located within the upper Bronte Creek Watershed. The majority of the site falls within the Mountsberg Creek subwatershed. Surface water monitoring was initiated for this site in the fall of 2003 in association with Gartner Lee Limited. A comprehensive surface water monitoring program was established in September, 2005 for both Mountsberg and Flamboro Creek to characterize flows and/or surface water levels on the SMC property, as well as off-site. Continuous flow and temperature monitoring stations were established at several points within the watersheds.

Spring runoff flows surpassing 1 m³/s were observed in Mountsberg Creek downstream of the Tributary A confluence. Low flows between 0.10 and 0.30 m³/s were generally observed in the summer and fall, although flows below 0.100 m³/s were also witnessed at times. Contributions from Tributary A to flows in Mountsberg Creek were generally observed to vary from 0.020 to 0.074 m³/s during the spring, while prolonged, stagnant flow conditions (flows below 0.010 m³/s) can predominate in the summer and fall.

Hydrological monitoring data from the hydrologic monitoring program estimates average base flow in Tributary A to be approximately 0.008 to 0.010 m³/s. Monitoring program results suggest that seasonal groundwater contributions to Tributary A may be as great as 50%. Tributaries B and C are not known to support fish habitat. Both of these tributaries are intermittent and likely contribute limited base flow to Mountsberg Creek. Flows of 0.002 to 0.014 m³/s were observed in Tributary D during spring runoff. Summer storm water runoff flows of 0.077 m³/s were also observed.

Pumping water from the proposed quarry will lower the water table and groundwater levels around the perimeter of the quarry. Without mitigation this drawdown would lead to effects on local natural features. The proposed quarry installation will also lead to changes in the existing surface water catchments where they overlap with the quarry. In addition to altered catchments and contributions of surface flows, the quarry will result in a surface water discharge from the dewatering activities.

The proposed GRS (AECOM 2009) is intended to mitigate against any changes in the local ground water levels and their relationship to dependent ecological features. With the successful implementation of the GRS, no negative impacts to the groundwater volume to Mountsberg Creek and its tributaries, as well as the Mountsberg Wetland Complex are anticipated. The potential water quality impacts of the proposed quarry dewatering into Mountsberg Creek were assessed using a mass balance approach. The projected increases in alkalinity and conductivity

levels, as well as zinc concentrations are not projected to have an impact on the habitat quality of Mountsberg Creek. With mitigation, surplus discharge would be substantially reduced. The loss of subcatchment area to Tributary C and Tributary D should not interfere with the function of these ephemeral drainage features, since quarry dewatering during periods of excess runoff will direct surplus water through Tributary C and D. The 7.5 ha total reduction in catchment area for Tributary A is minimal in comparison to its total drainage area of approximately 3 km². Therefore, potential impacts resulting from the changes in surface water catchment will be mitigated.

STANTEC CONSULTING LTD


Jim Perrone, M.Sc., P. Eng.
Water Resources Engineer



The seal is circular with a double-line border. The outer ring contains the text "LICENSED PROFESSIONAL ENGINEER" at the top and "PROVINCE OF ONTARIO" at the bottom. The center of the seal features a horizontal line with the name "J.T. PERRONE" printed below it.

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HYDROLOGICAL LEVEL 2 TECHNICAL REPORT**ST. MARYS FLAMBOROUGH QUARRY**

References

January 2009

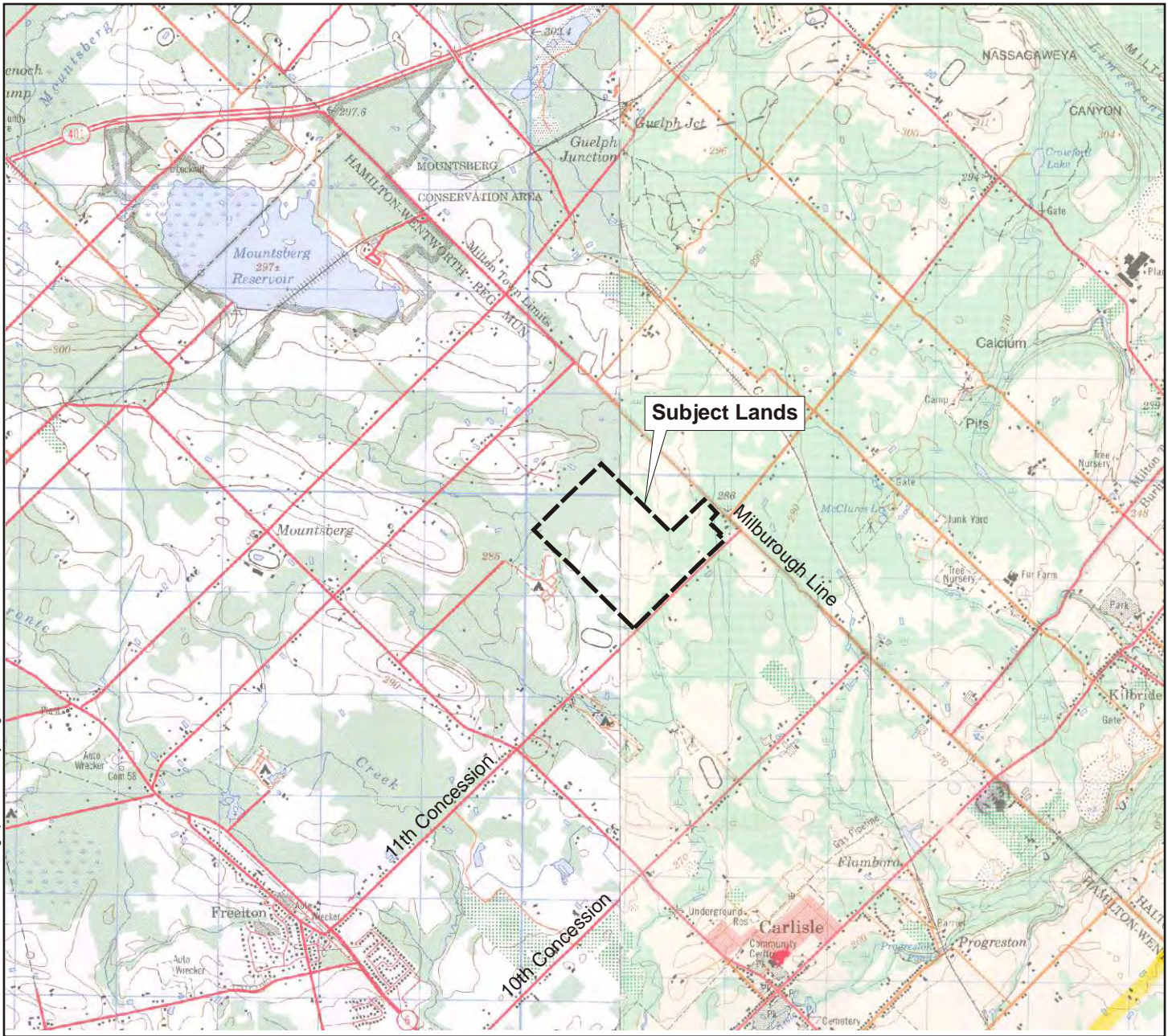
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Appendix A

Figures

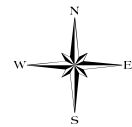
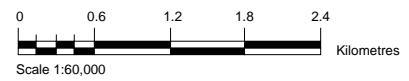
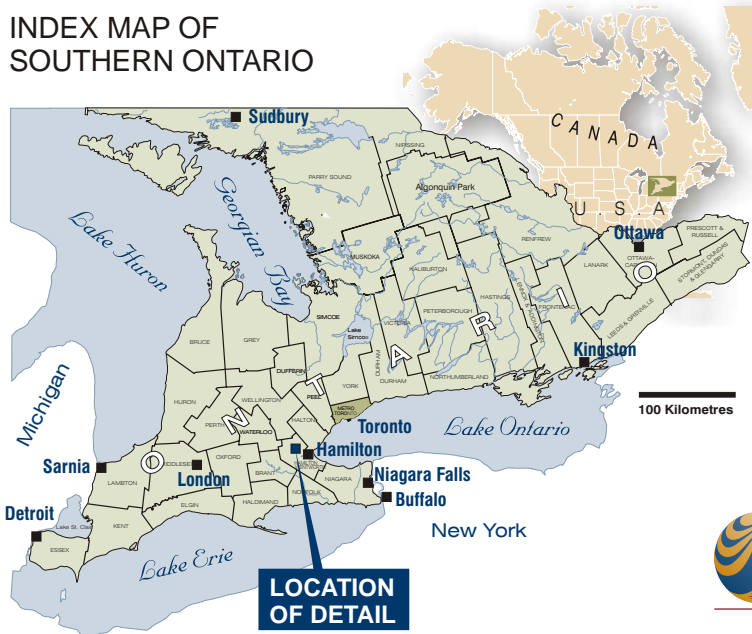
- Figure 1 Location of Subject Lands
- Figure 2 Designated Natural Features
- Figure 3 Site Topography
- Figure 4 Physiography of Southern Ontario
- Figure 5 Bronte Creek Watershed and Subwatershed Boundaries
- Figure 6 Mean, Maximum, and Minimum Daily Flows in Bronte Creek at Carlisle
- Figure 7 Location of Existing Monitoring Equipment
- Figure 8 Location of Surface Water Monitoring Stations
- Figure 9 Mountsberg Creek and Flamboro Creek Subwatersheds
- Figure 10 Mountsberg Creek Flows, 2006
- Figure 11 Mountsberg Tributary Creek Flows, 2006
- Figure 12 Mountsberg Creek Flows, 2007
- Figure 13 Mountsberg Creek Tributary Flows, 2007
- Figure 14 Flamboro Creek Flows, 2006
- Figure 15 Flamboro Creek Flows, 2007
- Figure 16 On-Site Surface Water Feature Levels, 2006
- Figure 17 On-Site Surface Water Feature Levels, 2007
- Figure 18 On-Site Seep Levels, 2006
- Figure 19 On-Site Seep Levels, 2007
- Figure 20 Site Microdrainage
- Figure 21 Location of Historical Water Quality Monitoring Locations
- Figure 22 Mountsberg Creek Temperatures, 2006
- Figure 23 Mountsberg Creek Tributary Temperatures, 2006
- Figure 24 Mountsberg Creek Temperatures, 2007
- Figure 25 Mountsberg Creek Tributary Temperatures, 2007
- Figure 26 Flamboro Creek Temperatures, 2006
- Figure 27 Flamboro Creek Temperatures, 2007
- Figure 28 On-Site Surface Water Feature Temperatures, 2006
- Figure 29 On-Site Surface Water Feature Temperatures, 2007
- Figure 30 On-Site Seep Temperatures, 2006
- Figure 31 On-Site Seep Temperatures, 2007
- Figure 32 On-site Subcatchment Alteration

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Source: NRCan Topographic Maps, Cambridge, 40 P/8 and Energy, Mines and Resources Canada, Hamilton-Burlington, 30 M/5 - Original Scale 1:50,000.

INDEX MAP OF SOUTHERN ONTARIO



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**SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT**

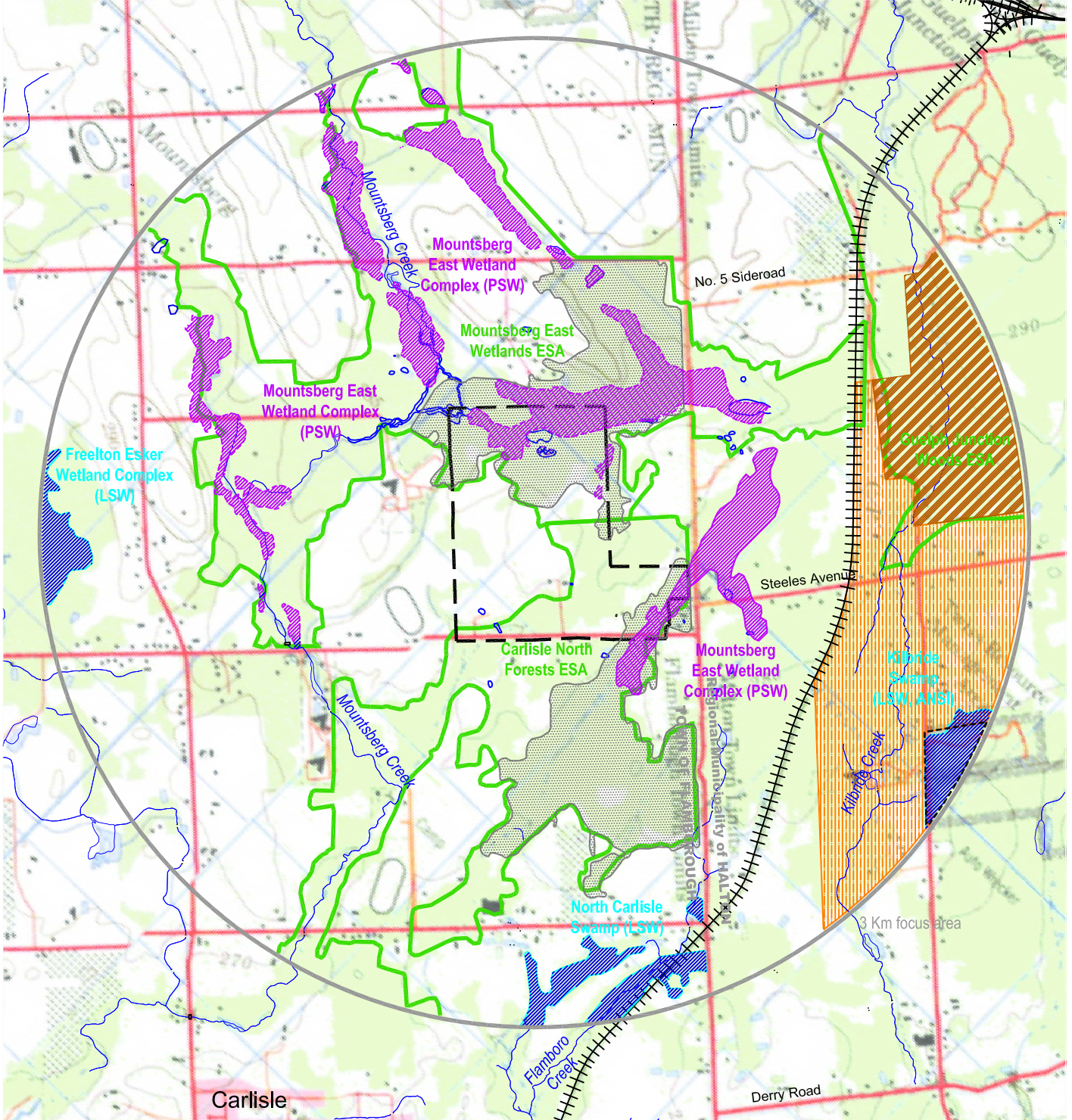
FIGURE NO.
1.0

TITLE
**LOCATION OF
SUBJECT LANDS**

Initiated: March, 2008
Revised:



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SOURCE: Ministry of Natural Resources Wetland Evaluations, MNR NHC Mapping
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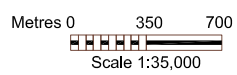
- Subject Lands
- ESA
- Provincially Significant Wetland (NRVIS)
- Locally Significant Wetlands (NRVIS)
- Public Land (in parks and open land system)
- Escarpment Protection Area
- Escarpment Rural Area
- Deer Wintering Yard

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Figure No.
2.0

Title
**DESIGNATED
 NATURAL FEATURES**

Initiated: March, 2008
 Revised: January, 2009

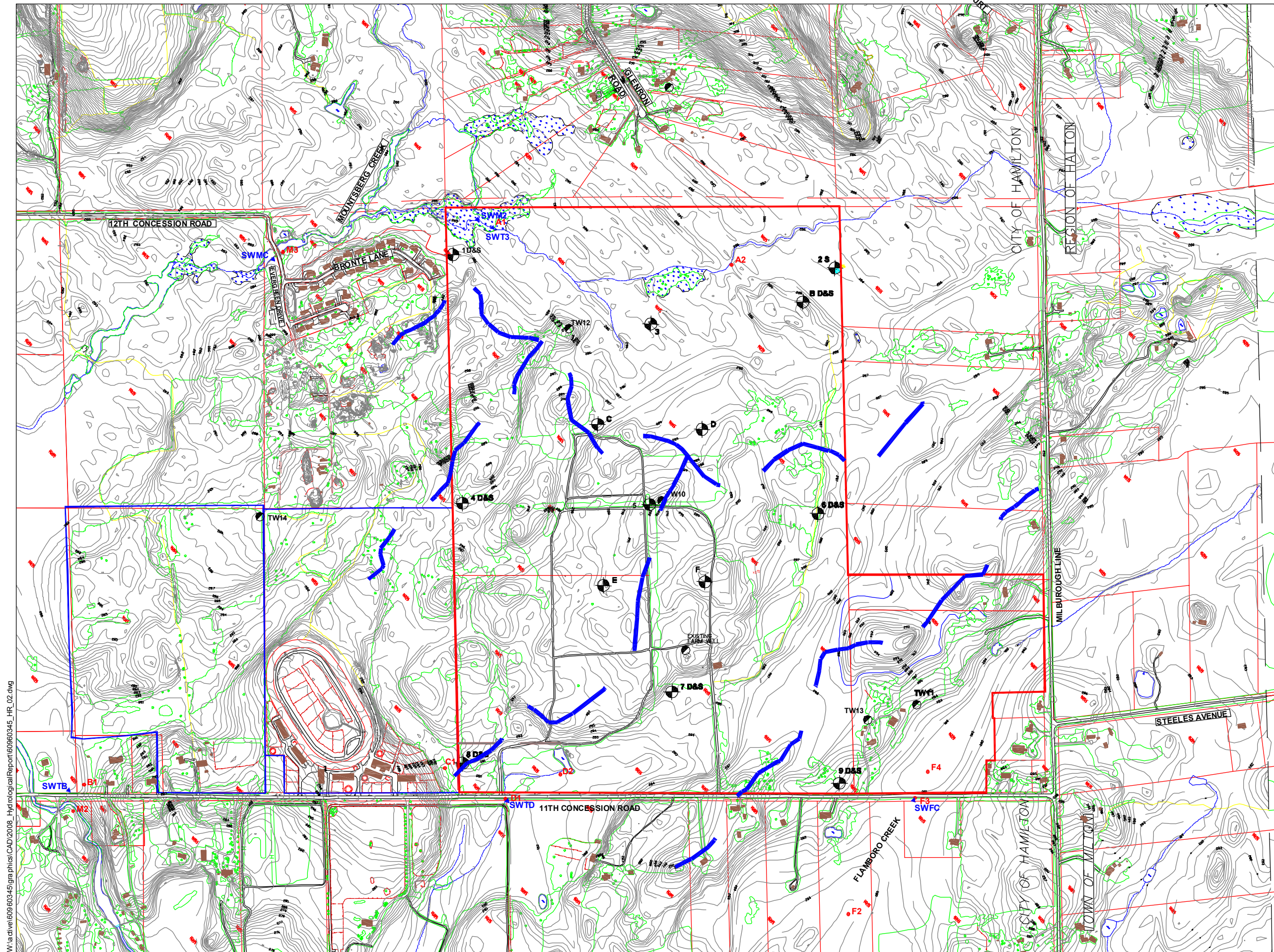




Stantec



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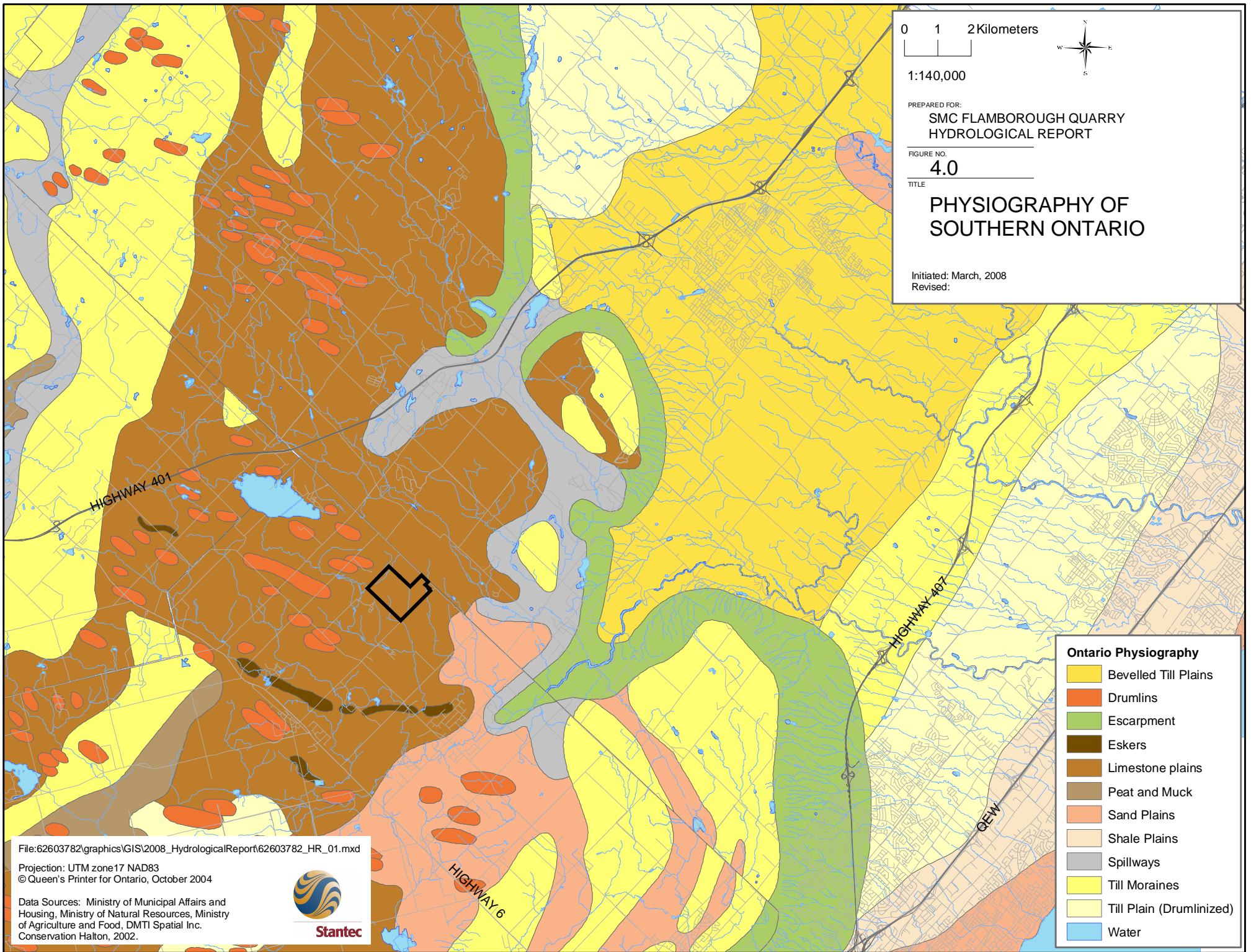
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Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

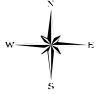
Figure No.
3.0

Title
SITE TOPOGRAPHY

Initiated: March, 2008
Revised:



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1:140,000

PREPARED FOR:
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

FIGURE NO.
4.0

TITLE
**PHYSIOGRAPHY OF
SOUTHERN ONTARIO**

Initiated: March, 2008
Revised:

Ontario Physiography

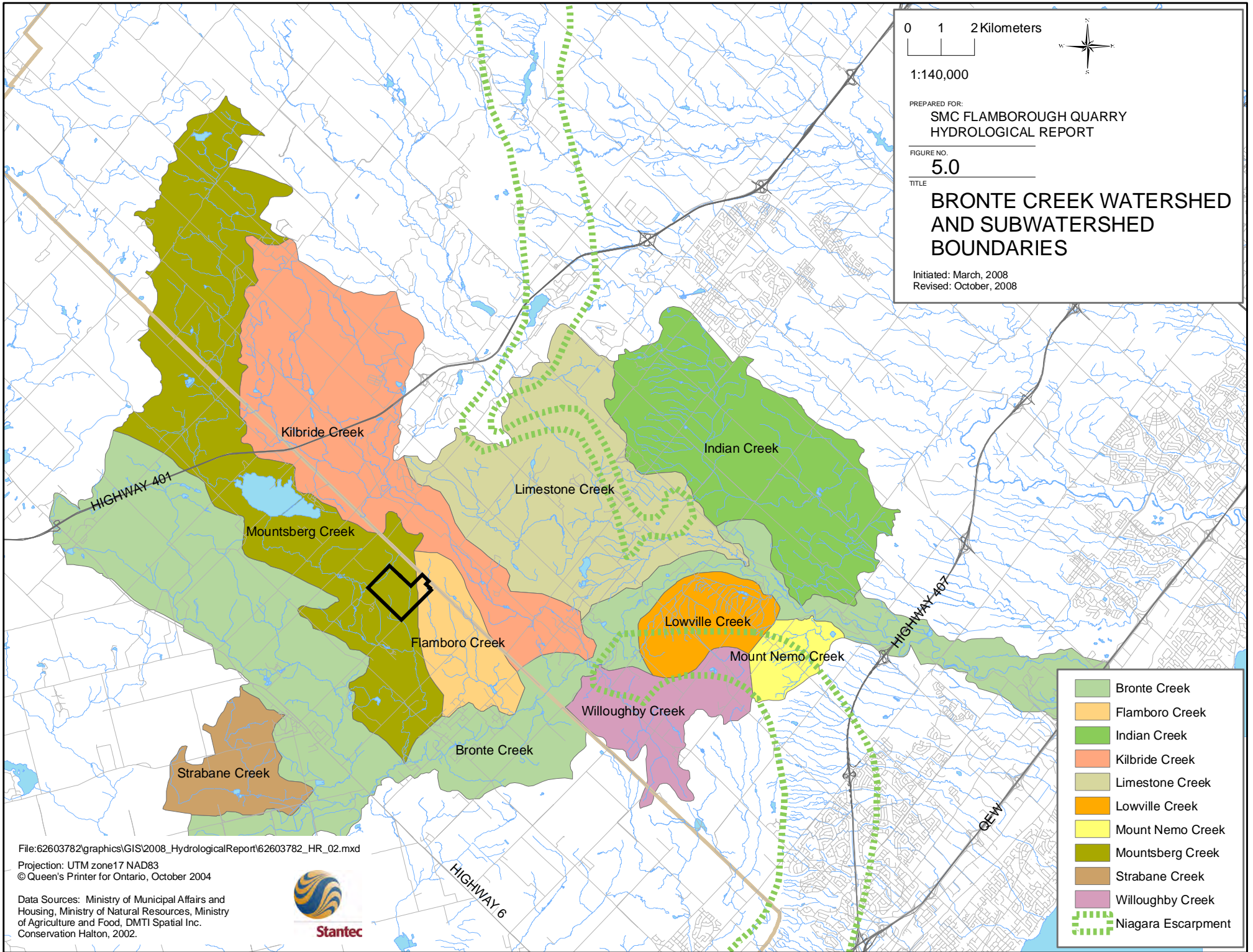
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- Drumlins
- Escarpment
- Eskers
- Limestone plains
- Peat and Muck
- Sand Plains
- Shale Plains
- Spillways
- Till Moraines
- Till Plain (Drumlinized)
- Water

File:62603782\graphics\GIS\2008_HydrologicalReport\62603782_HR_01.mxd

Projection: UTM zone17 NAD83
© Queen's Printer for Ontario, October 2004

Data Sources: Ministry of Municipal Affairs and Housing, Ministry of Natural Resources, Ministry of Agriculture and Food, DMTI Spatial Inc. Conservation Halton, 2002.





0 1 2 Kilometers



1:140,000

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SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

FIGURE NO.
5.0

TITLE
**BRONTE CREEK WATERSHED
AND SUBWATERSHED
BOUNDARIES**

Initiated: March, 2008
Revised: October, 2008

- Bronte Creek
- Flamboro Creek
- Indian Creek
- Kilbride Creek
- Limestone Creek
- Lowville Creek
- Mount Nemo Creek
- Mountsberg Creek
- Strabane Creek
- Willoughby Creek
- Niagara Escarpment

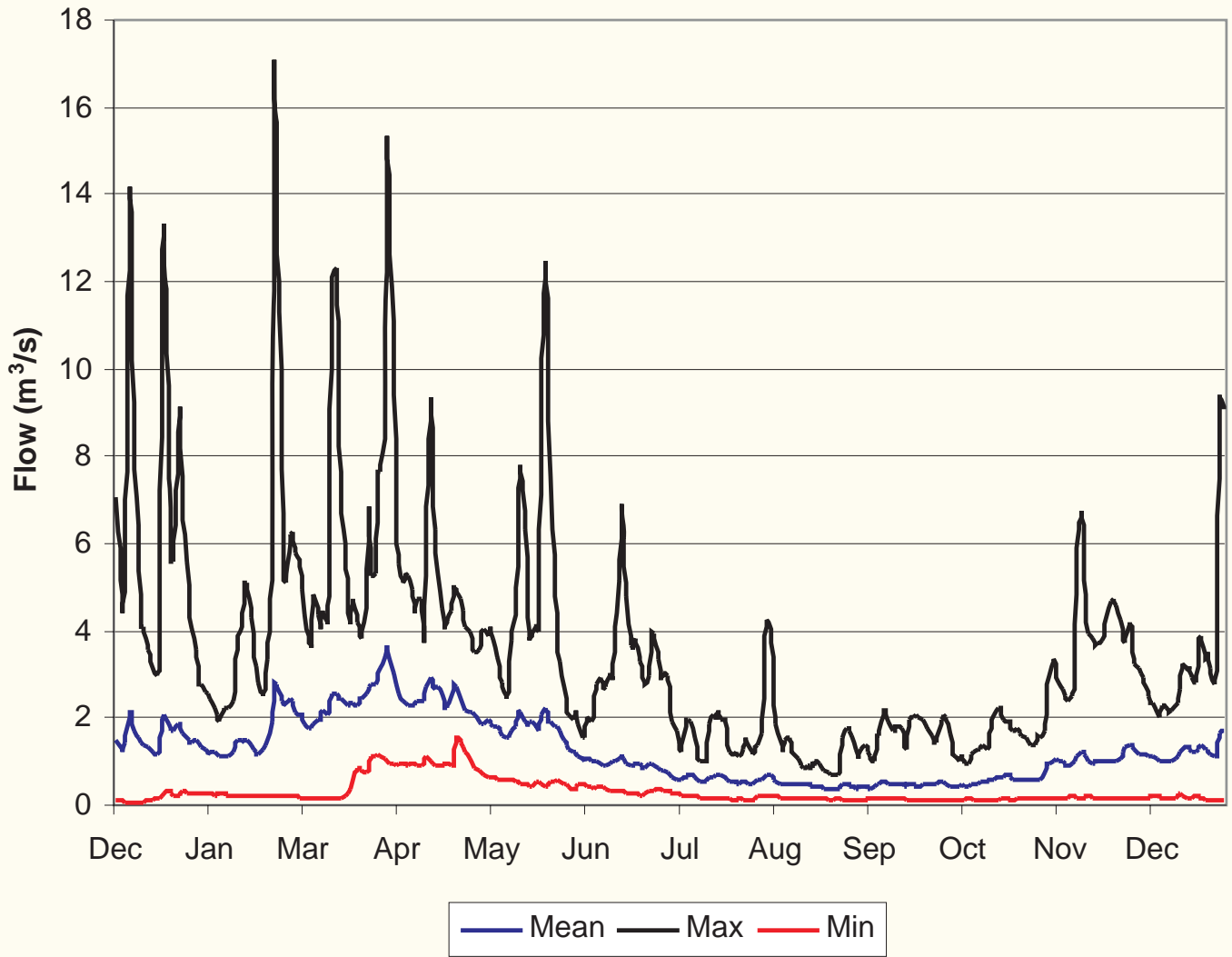
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Data Sources: Ministry of Municipal Affairs and Housing, Ministry of Natural Resources, Ministry of Agriculture and Food, DMTI Spatial Inc. Conservation Halton, 2002.



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HYDROLOGICAL REPORT

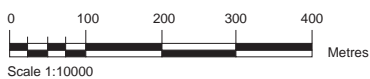
FIGURE NO.
6.0

TITLE
**MEAN, MAXIMUM, AND MINIMUM DAILY
FLOWS IN BRONTE CREEK AT CARLISLE**

Initiated: March, 2008.
Revised: November 5, 2008

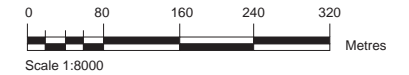


Stantec





- Subject Lands
- T1 Reaches
- Surface Monitoring Stations
- Redd Survey
- Benthic Station
- Fish Inventory and/or Fisheries Habitat Assessment
- Temperature Data Logger
- Staff Gauge
- Seep Locations



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Source: GoogleEarthPro.

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 HYDROLOGICAL REPORT

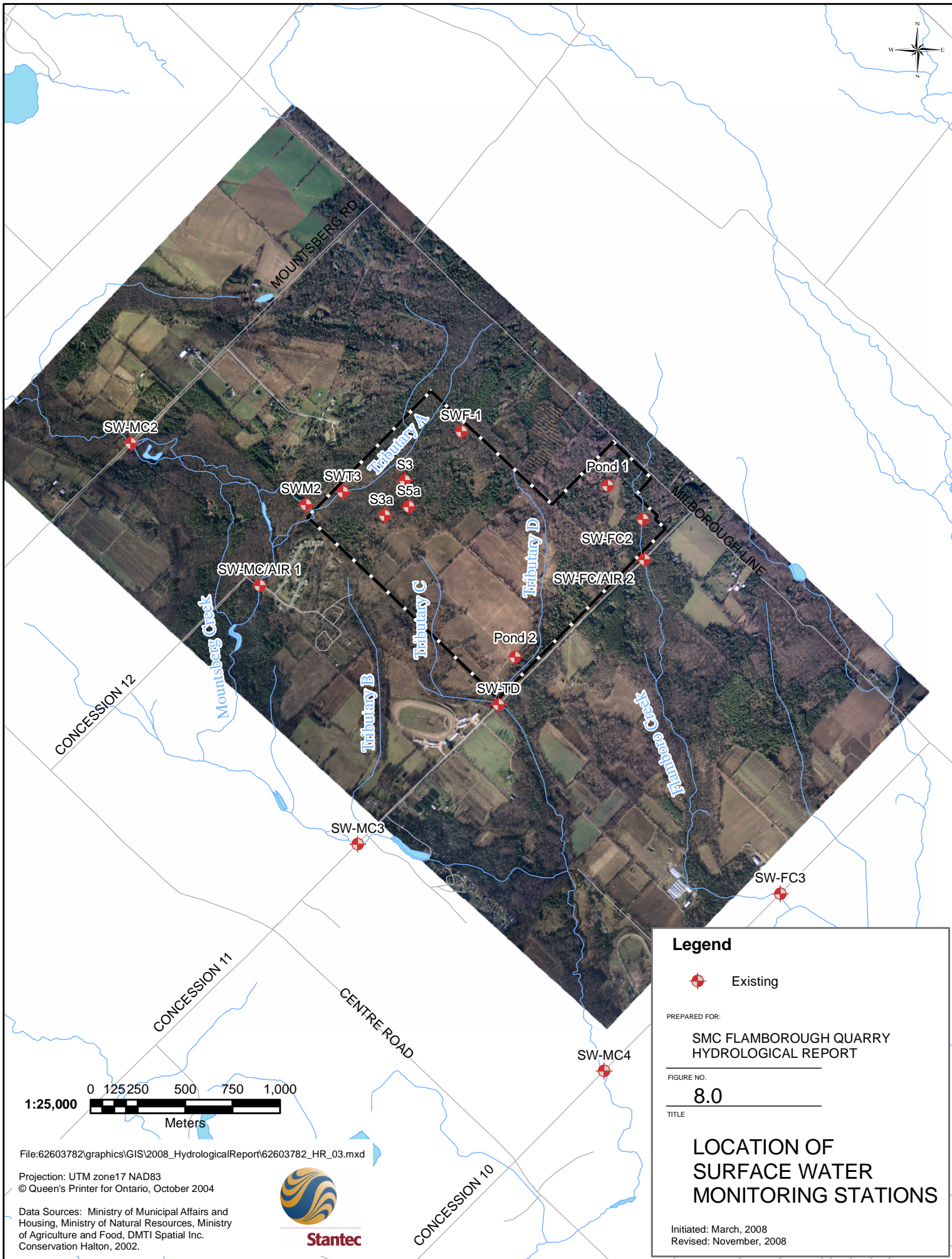
FIGURE NO.
7.0

TITLE
LOCATION OF EXISTING MONITORING EQUIPMENT


Initiated: March, 2008
 Revised: November 5, 2008

M1
 Located at 10th Concession Road Crossing

Located at 10th Concession Road Crossing **F1**



Legend

 Existing

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**SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT**

FIGURE NO.

8.0

TITLE

**LOCATION OF
SURFACE WATER
MONITORING STATIONS**

Initiated: March, 2008

Revised: November, 2008

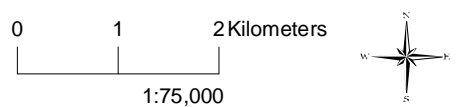
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Data Sources: Ministry of Municipal Affairs and
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Conservation Halton, 2002.



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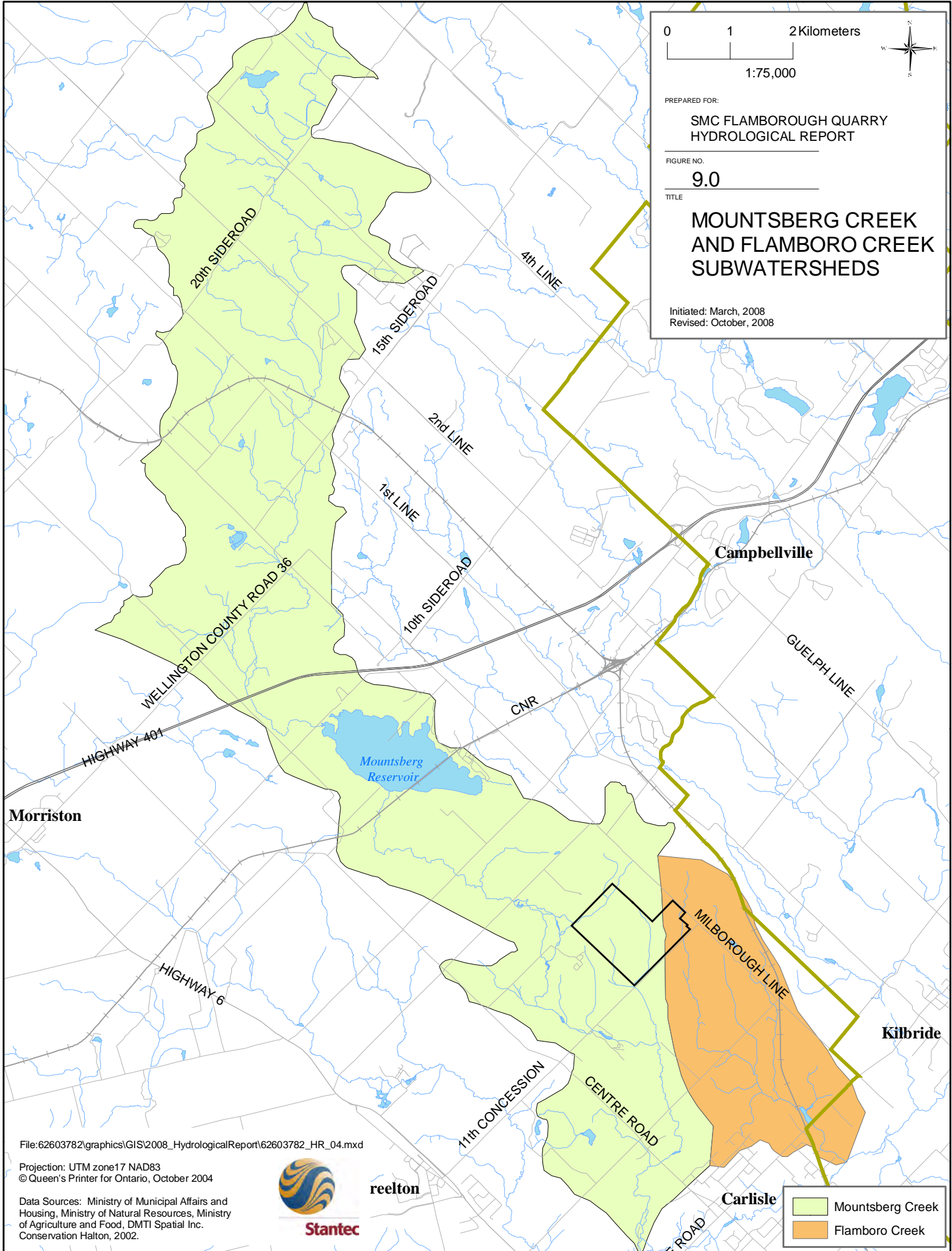


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HYDROLOGICAL REPORT**

FIGURE NO.
9.0

TITLE
**MOUNTSBERG CREEK
AND FLAMBORO CREEK
SUBWATERSHEDS**

Initiated: March, 2008
Revised: October, 2008



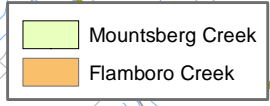
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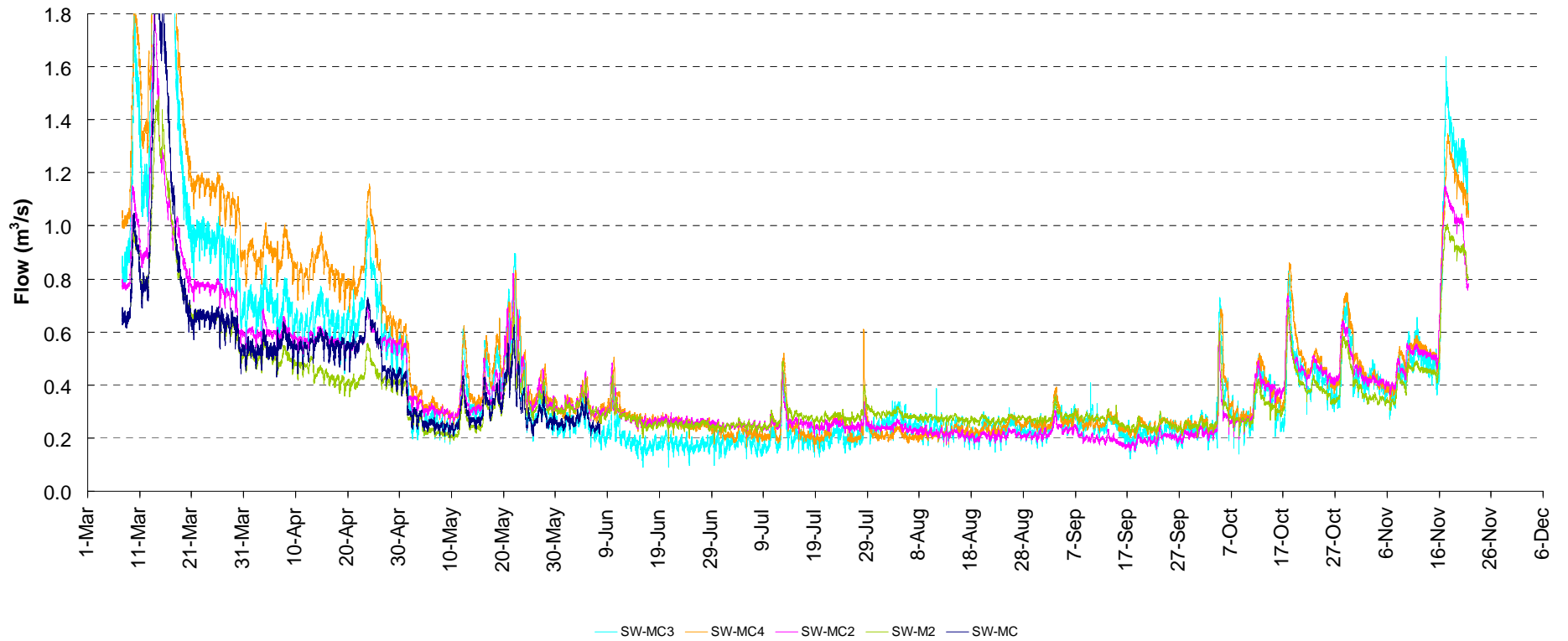
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October 2008
1609-60345

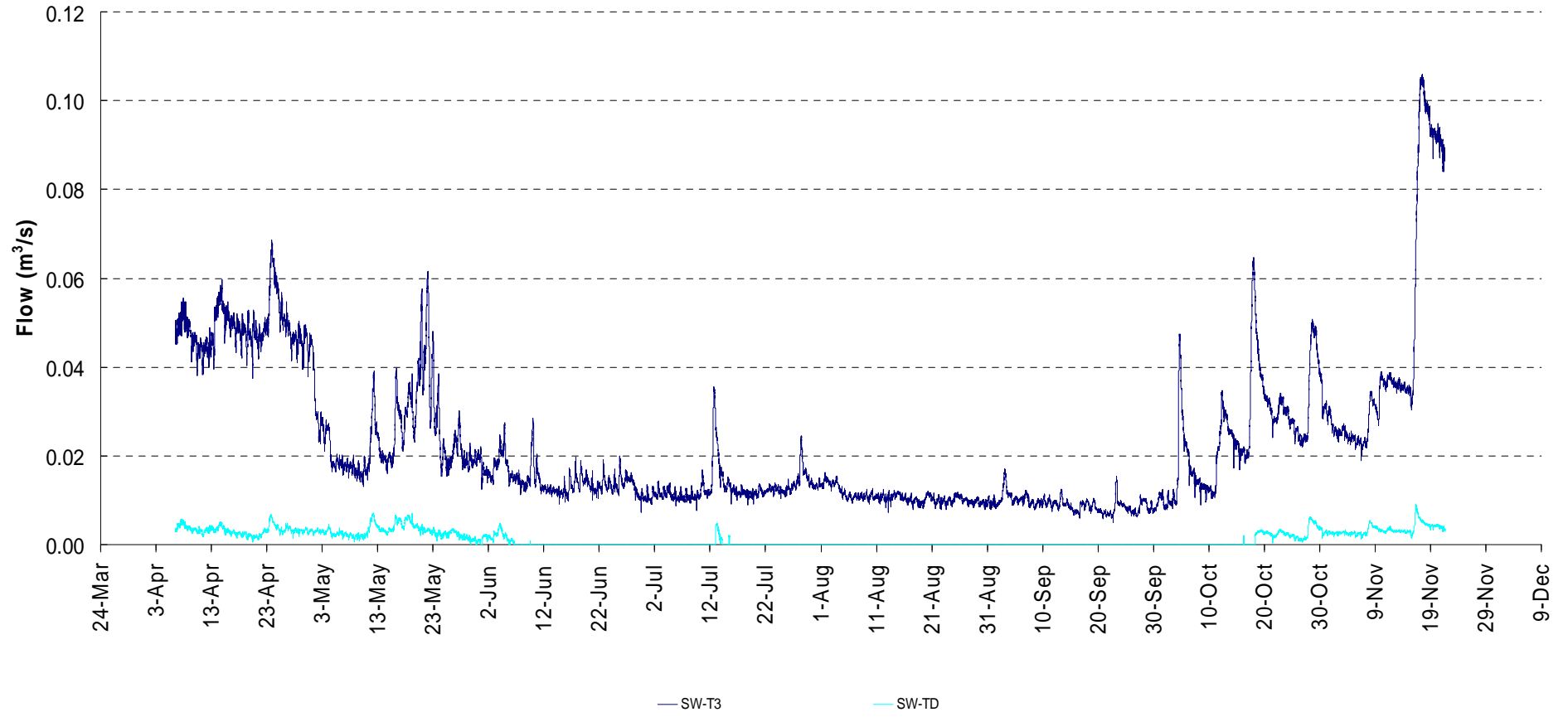


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HYDROLOGICAL REPORT

Figure No.
10

Title
MOUNTSBERG CREEK FLOWS, 2006

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October 2008
1609-60345

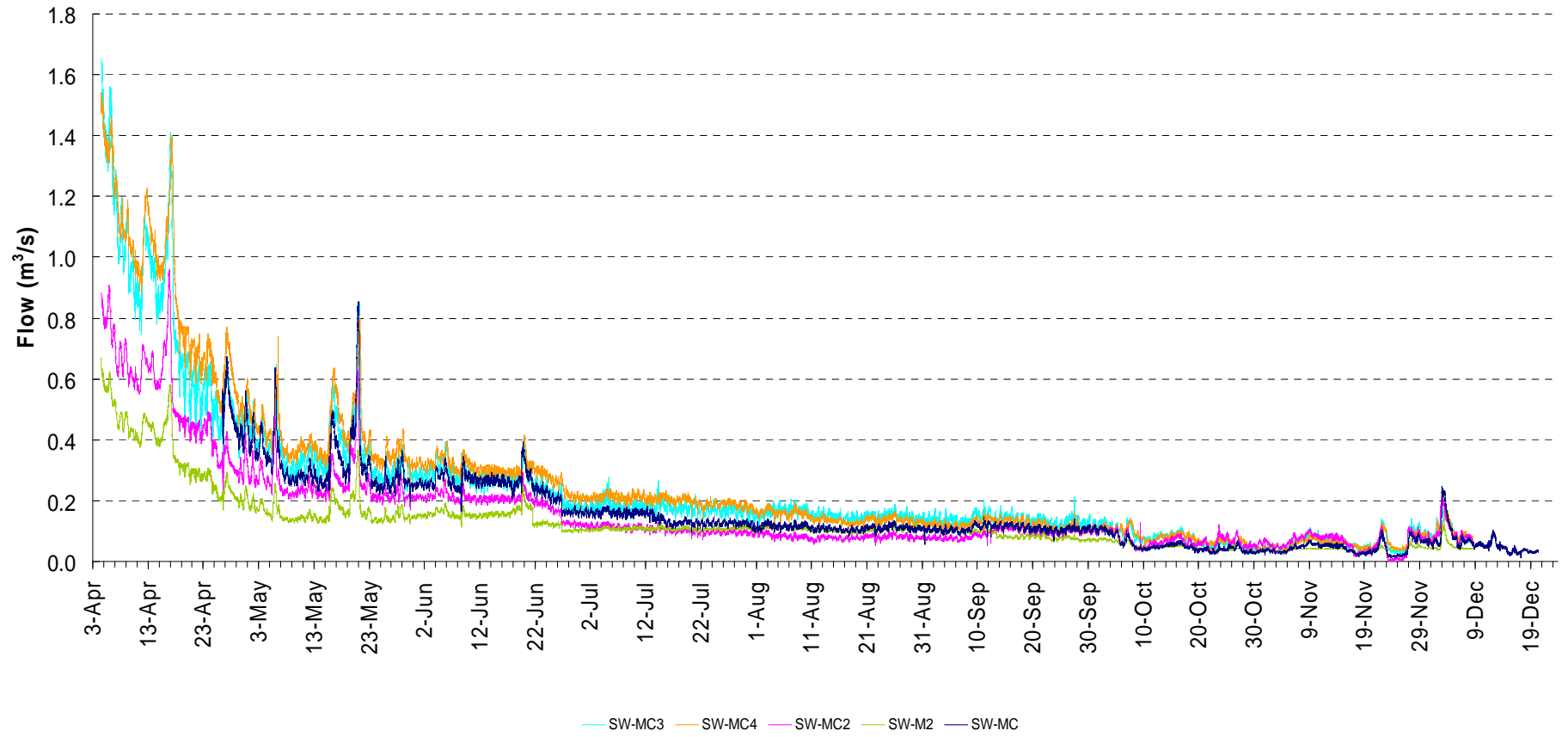


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SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
11

Title
MOUNTSBERG TRIBUTARY
CREEK FLOWS, 2006

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October 2008
1609-60345

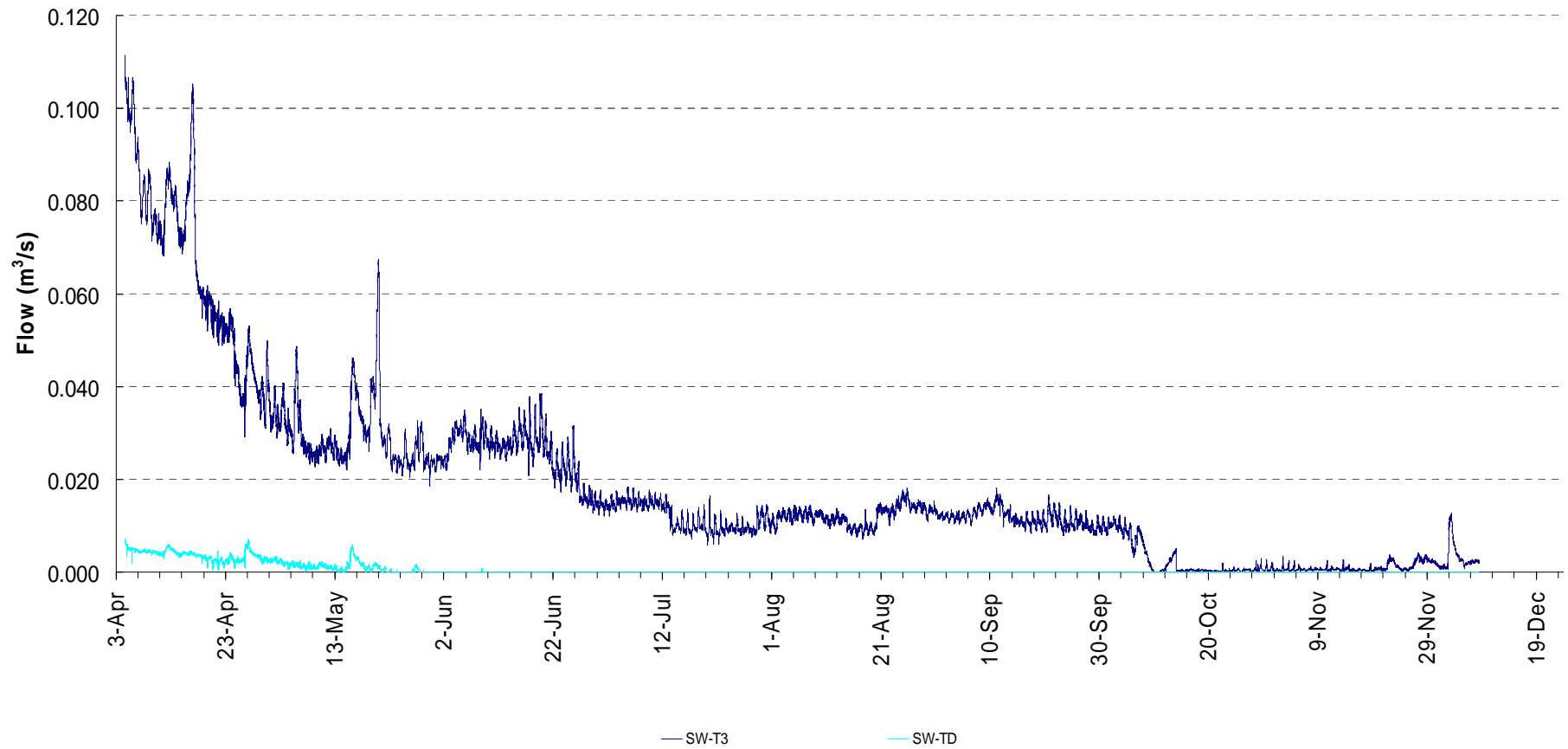


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HYDROLOGICAL REPORT

Figure No.
12

Title
MOUNTSBERG CREEK FLOWS, 2007

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October 2008
1609-60345

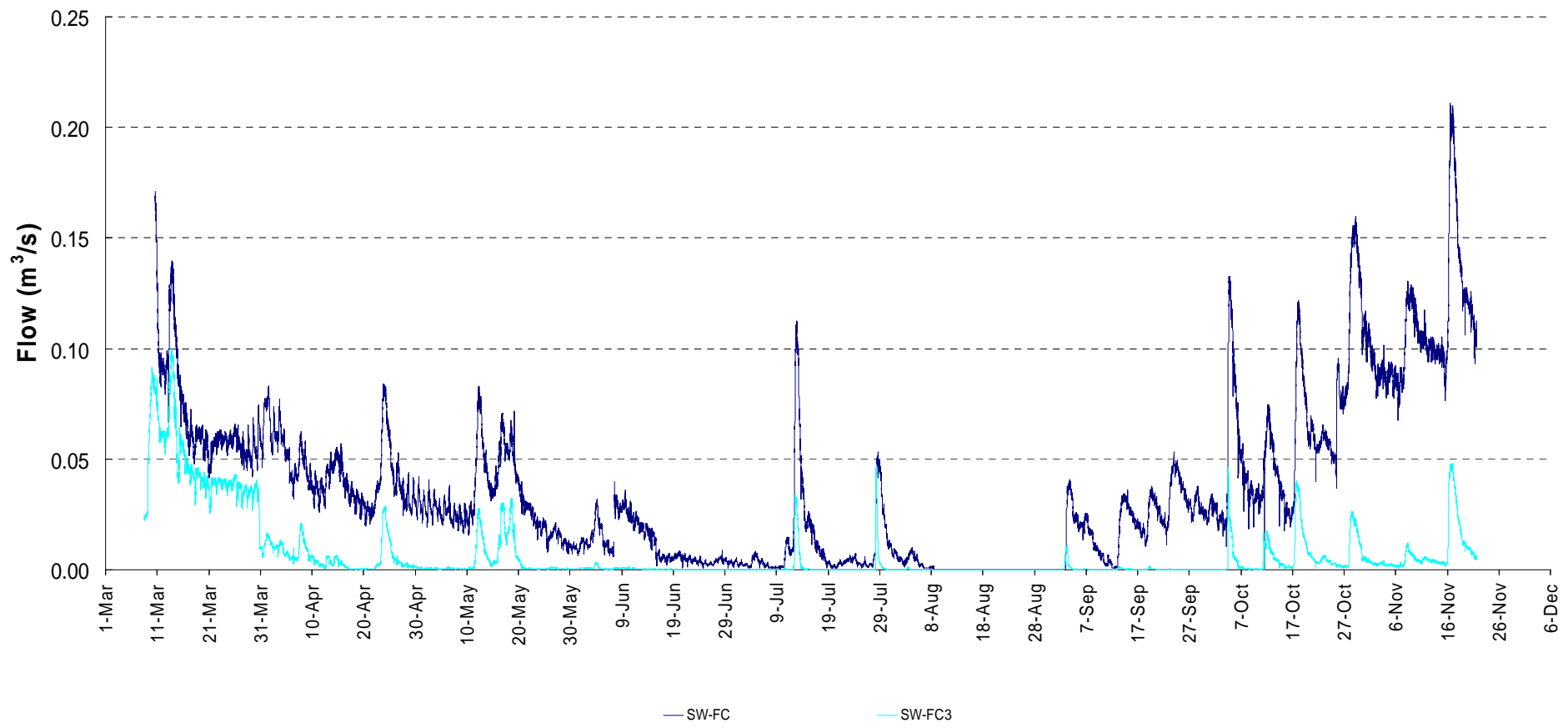


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HYDROLOGICAL REPORT

Figure No.
13

Title
MOUNTSBERG TRIBUTARY
CREEK FLOWS, 2007

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October 2008
1609-60345

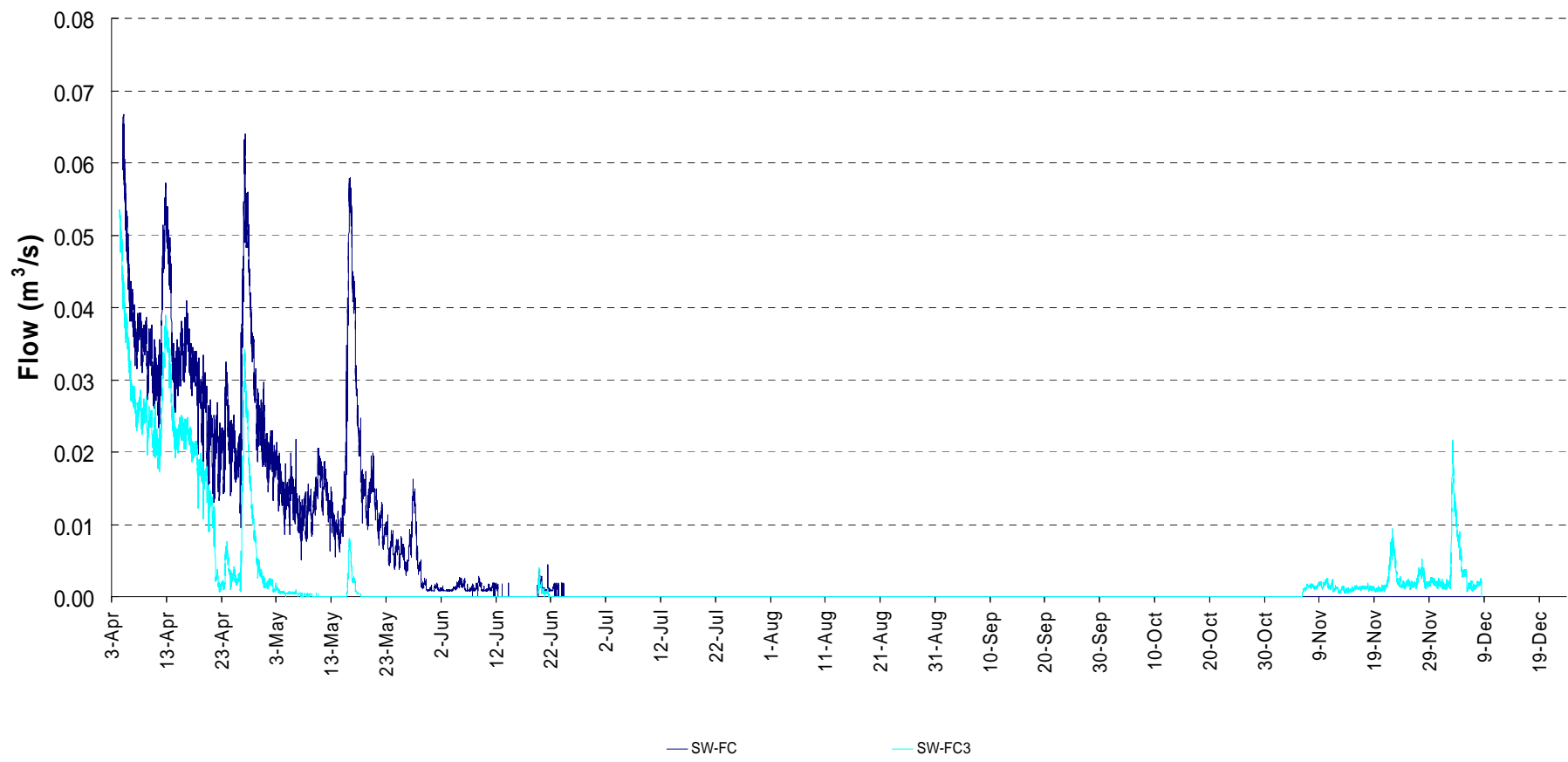


Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
14

Title
FLAMBORO CREEK FLOWS, 2006

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October 2008
1609-60345



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Figure No.
15

Title
FLAMBORO CREEK FLOWS, 2007



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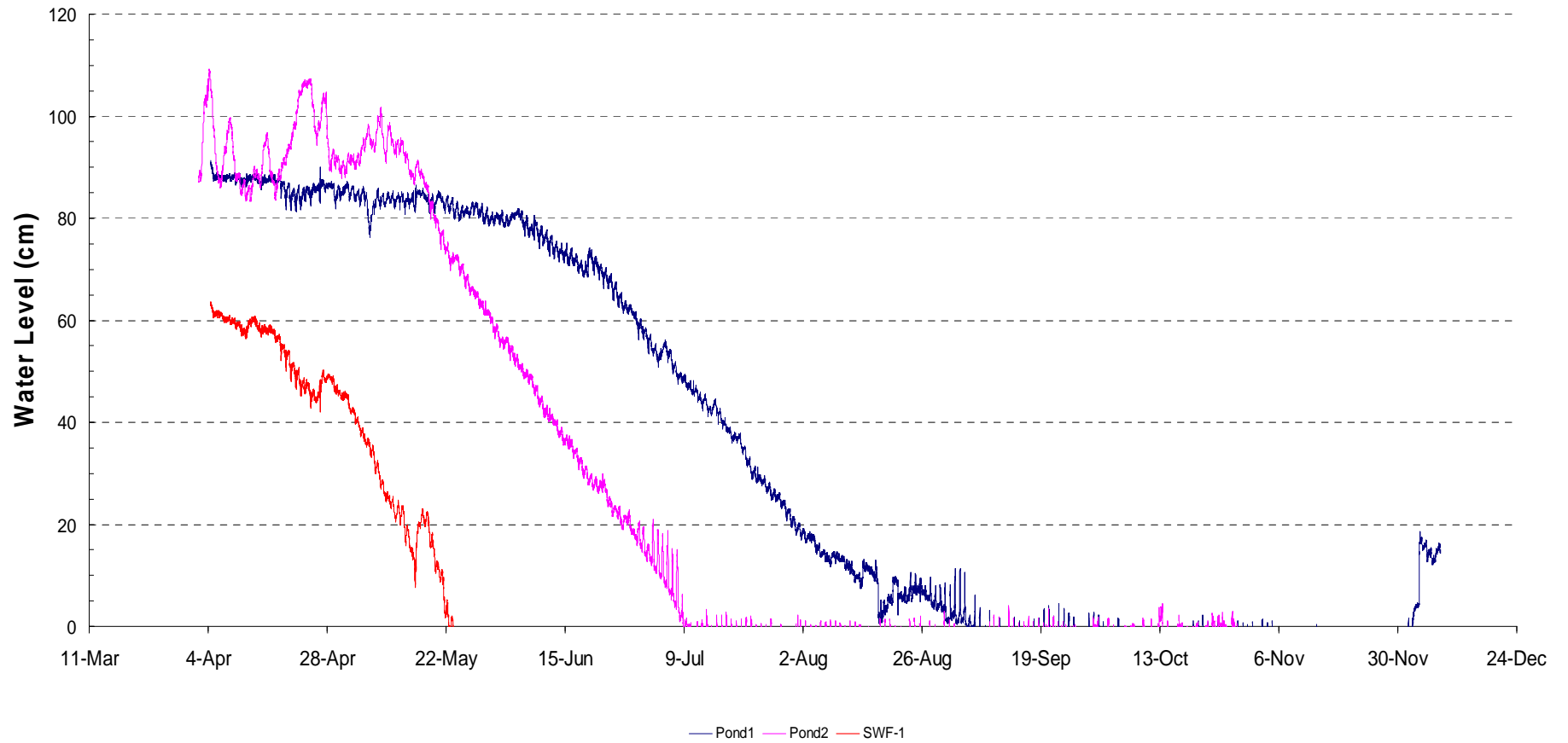


Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
16

Title
ON-SITE SURFACE WATER
FEATURE LEVELS, 2006

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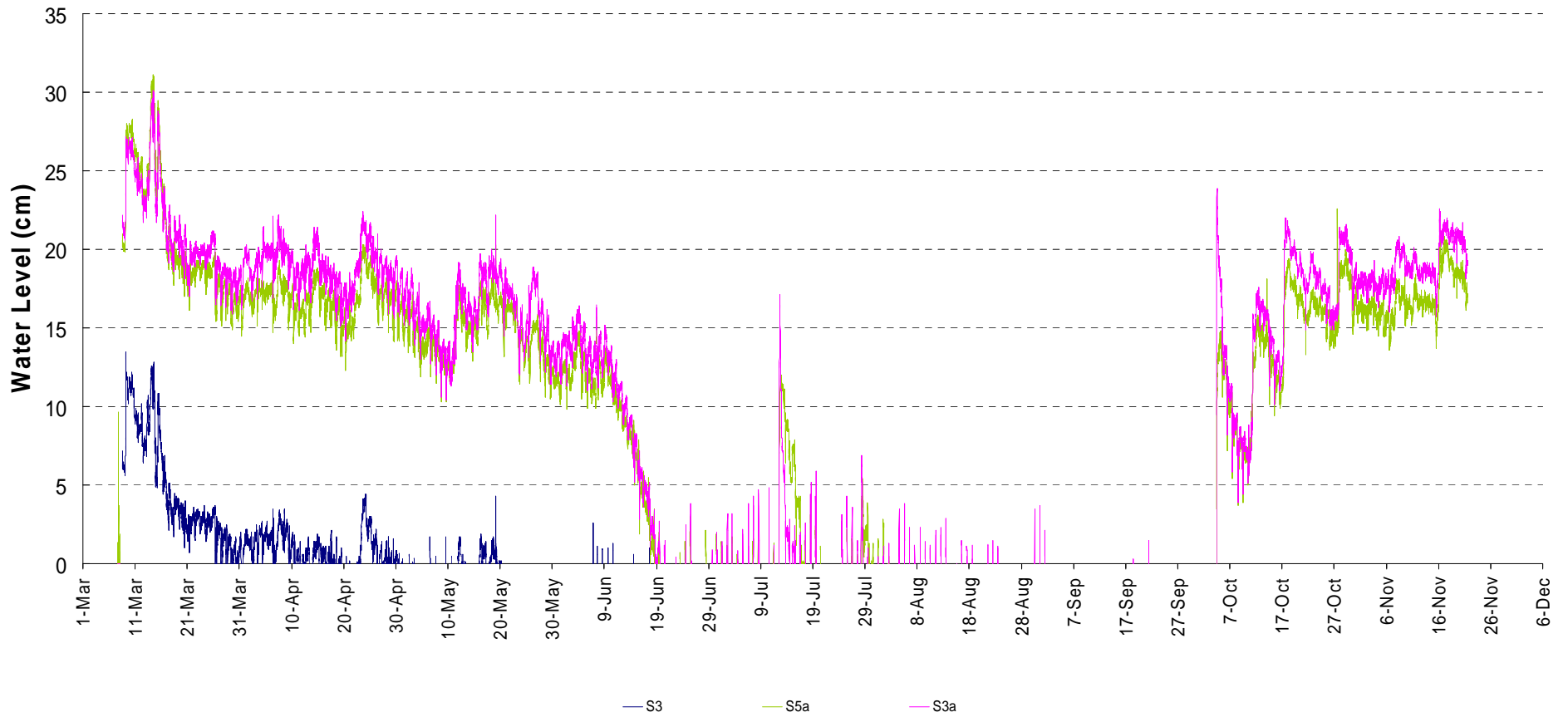
October 2008
1609-60345



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SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
17

Title
ON-SITE SURFACE WATER
FEATURE LEVELS, 2007



October 2008
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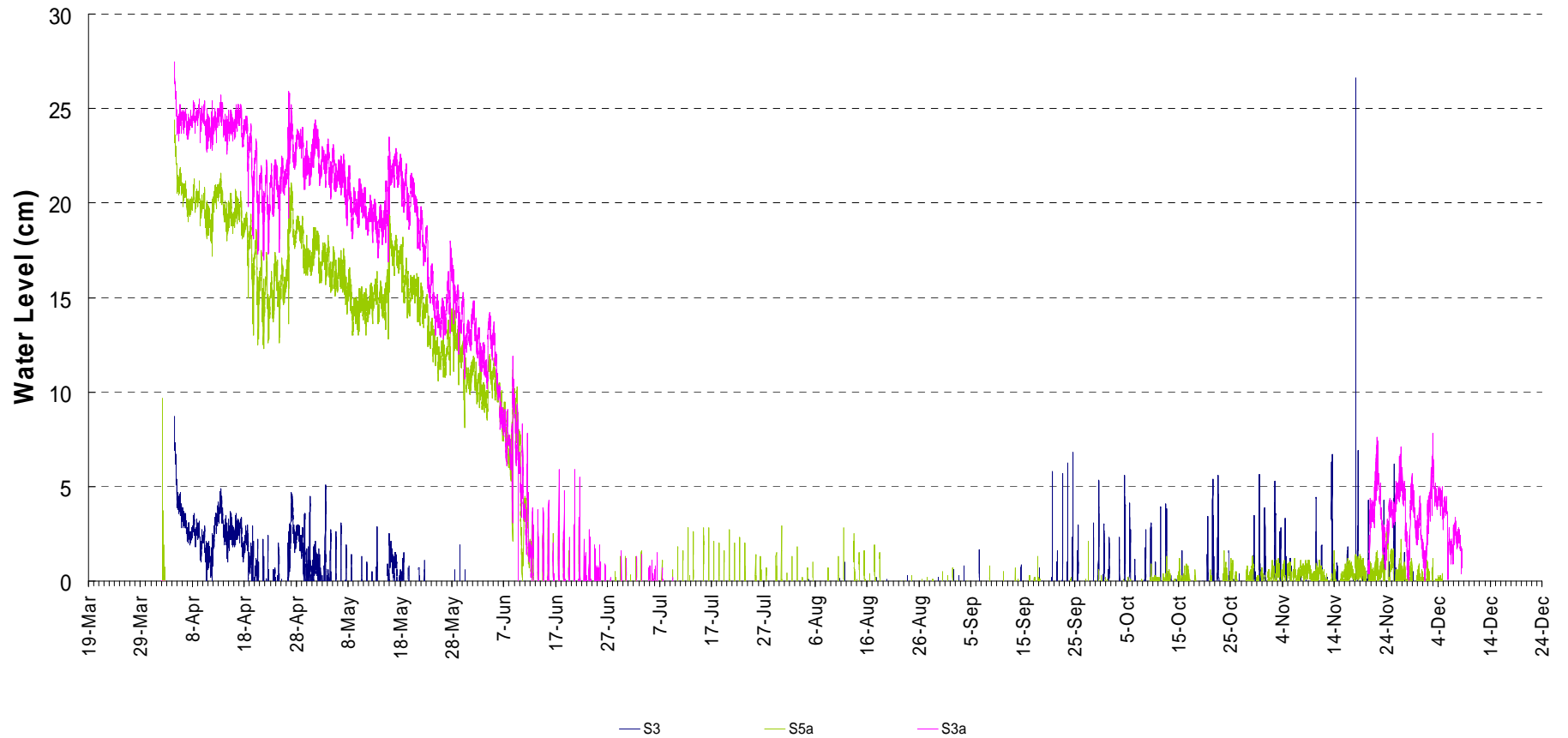


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HYDROLOGICAL REPORT

Figure No.
18

Title
ON-SITE SEEP LEVELS, 2006

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October 2008
1609-60345

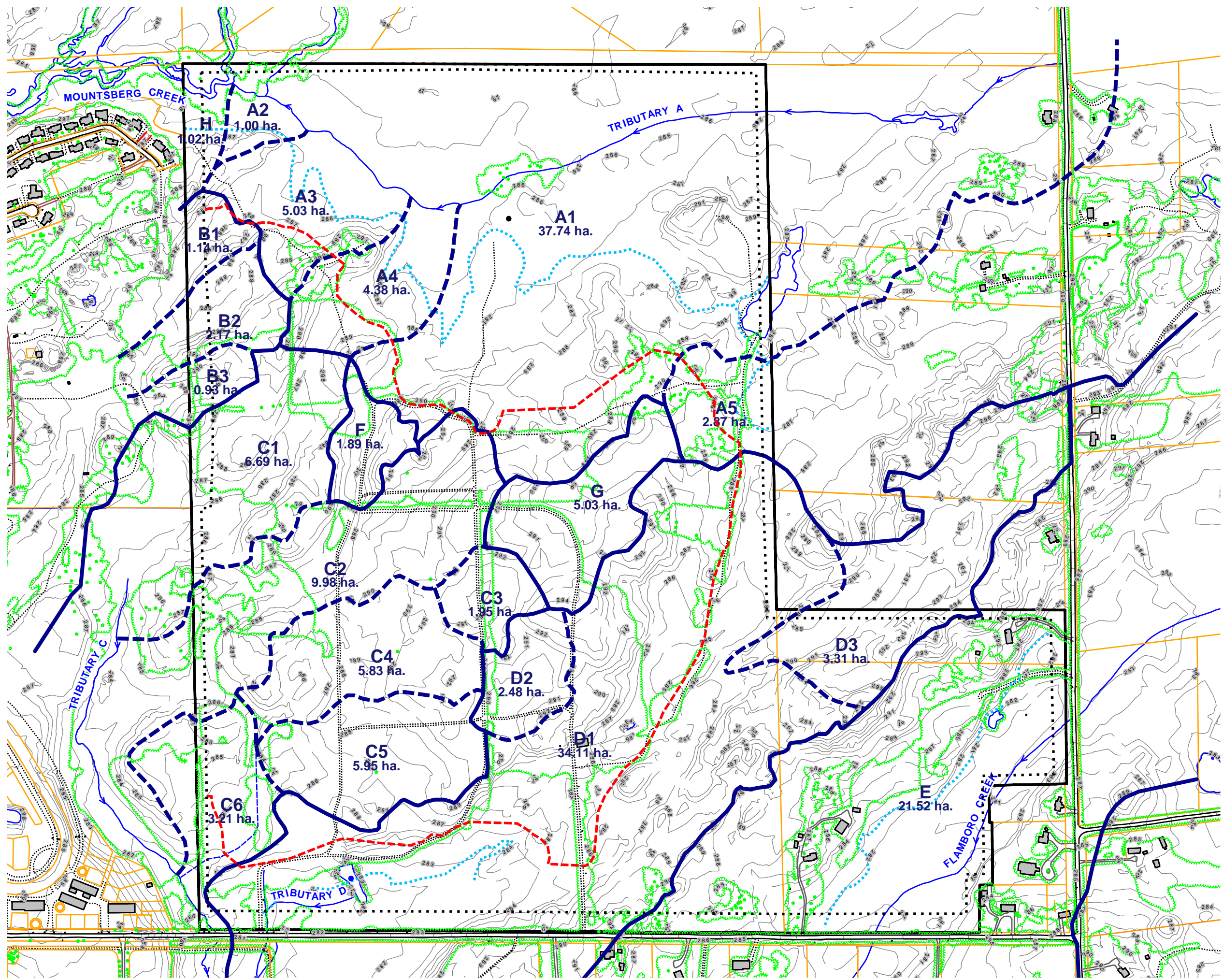


Client/Project
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HYDROLOGICAL REPORT

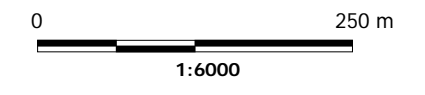
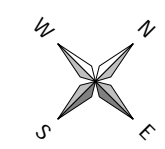
Figure No.
19

Title
ON-SITE SEEP LEVELS, 2007

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1/12/2009 9:46:20 AM By: bcowper Revised 01-12-2009 By: bcowper



- Legend**
- Subject Lands
 - - - Limit of Extraction
 - Major Catchment Area
 - Minor Catchment Area
 - Wetland Boundary (Clipsham, December 3, 2007)
 - Topographic Contours (mAMSL, OBM)



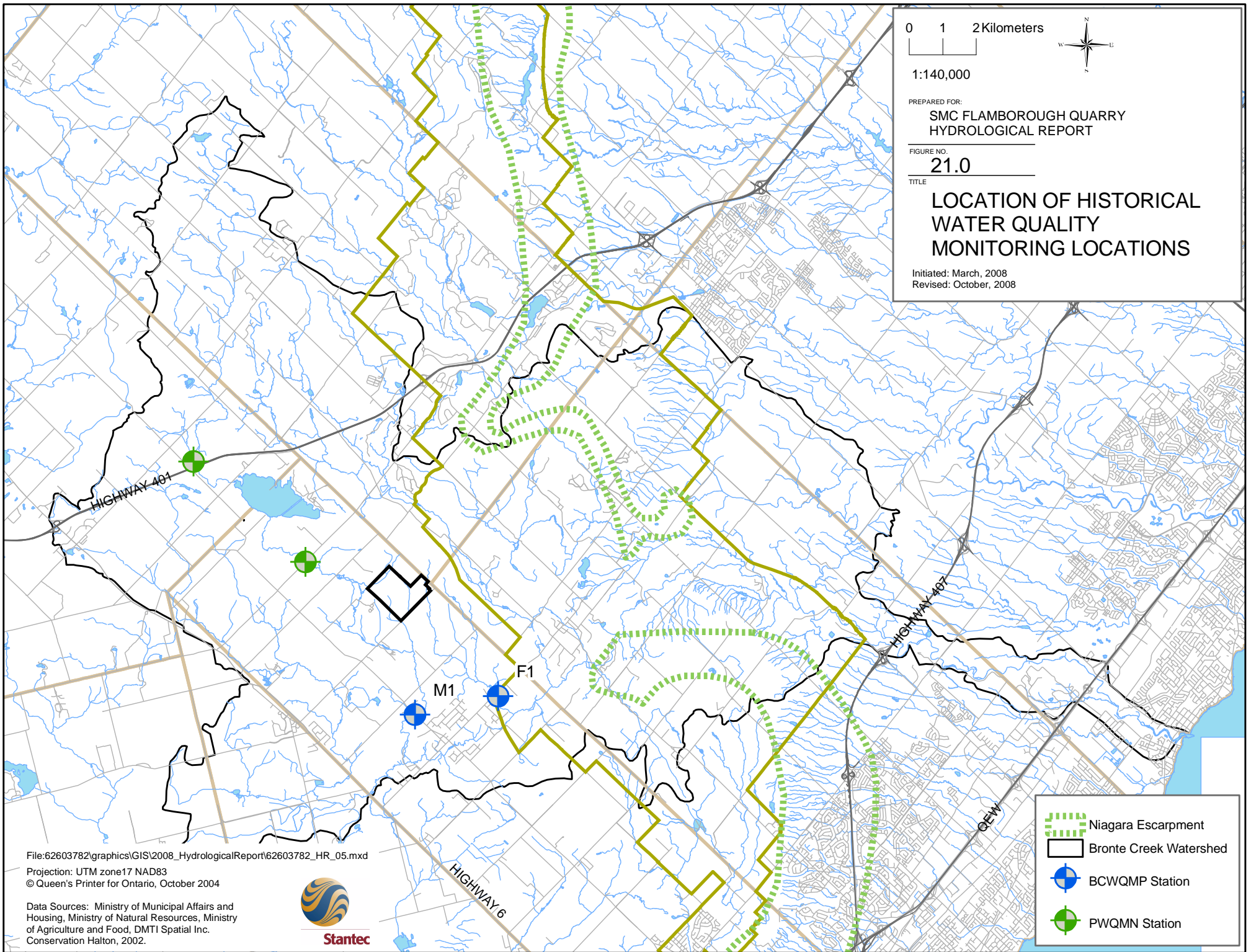
Stantec

January 2009
160960345

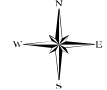
Client/Project
St. Marys Cement
Proposed Flamborough Quarry

Figure No.
20

Title
Site Microdrainage



0 1 2 Kilometers







1:140,000

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SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

FIGURE NO.
21.0

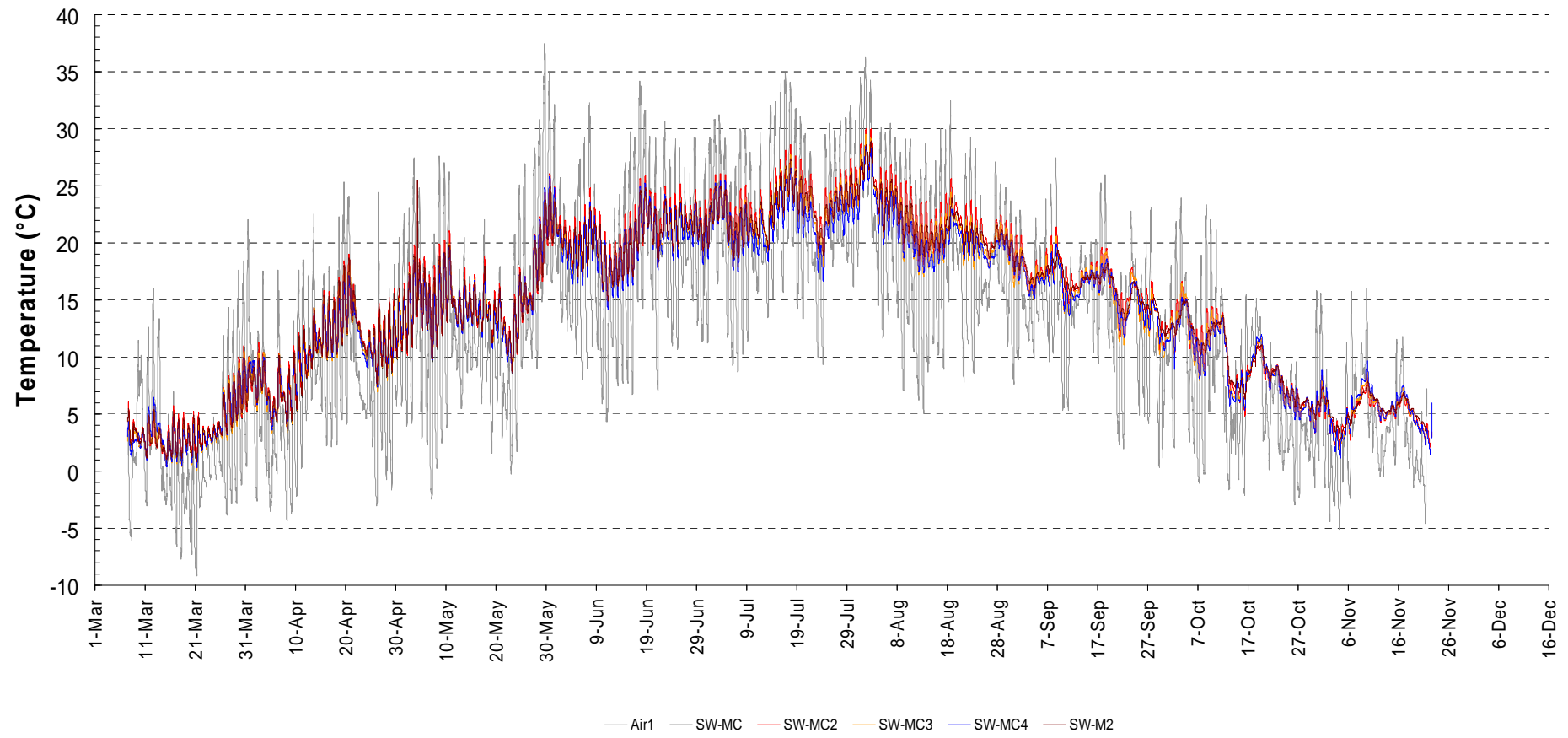
TITLE
**LOCATION OF HISTORICAL
WATER QUALITY
MONITORING LOCATIONS**

Initiated: March, 2008
Revised: October, 2008

-  Niagara Escarpment
-  Bronte Creek Watershed
-  BCWQMP Station
-  PWQMN Station



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October 2008
1609-60345

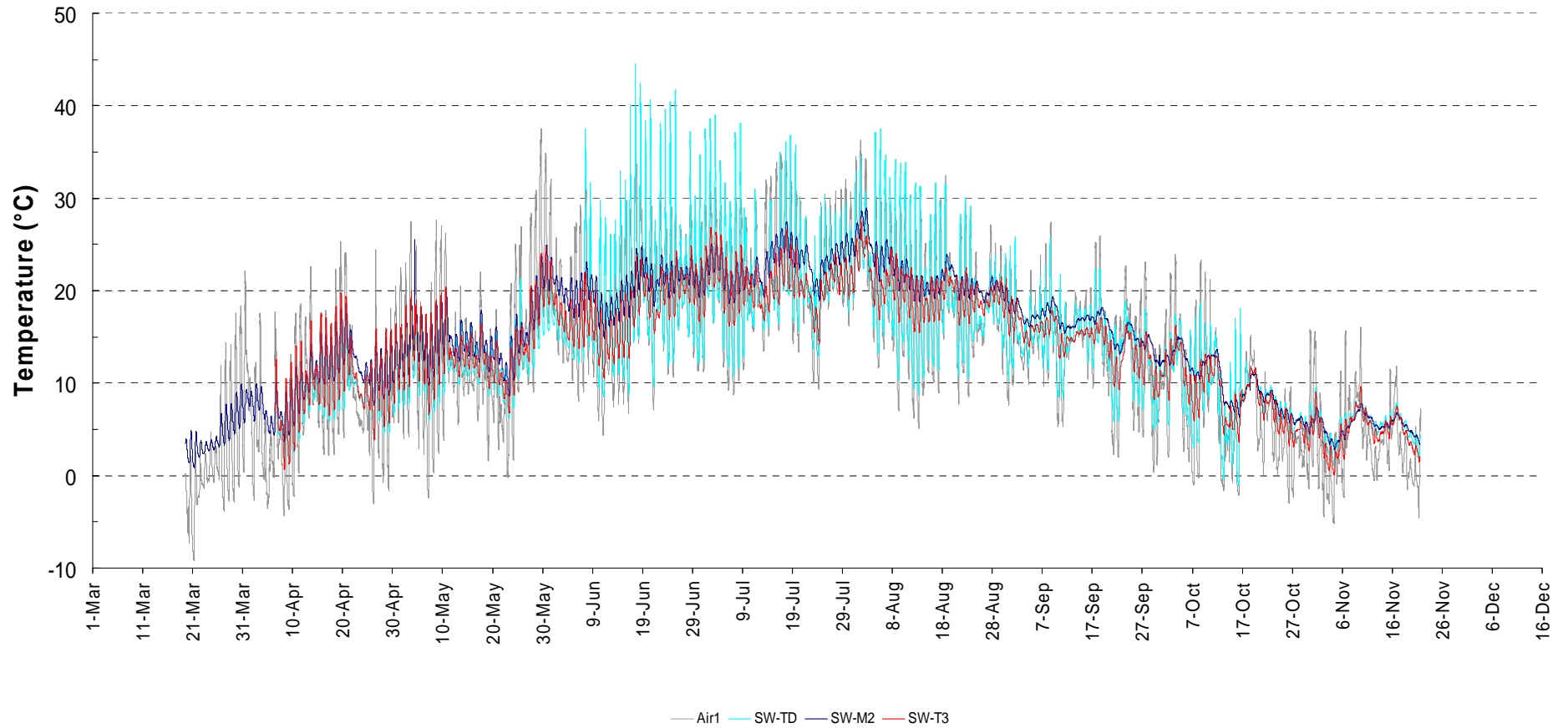


Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
22

Title
MOUNTSBERG CREEK
TEMPERATURES, 2006

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October 2008
1609-60345

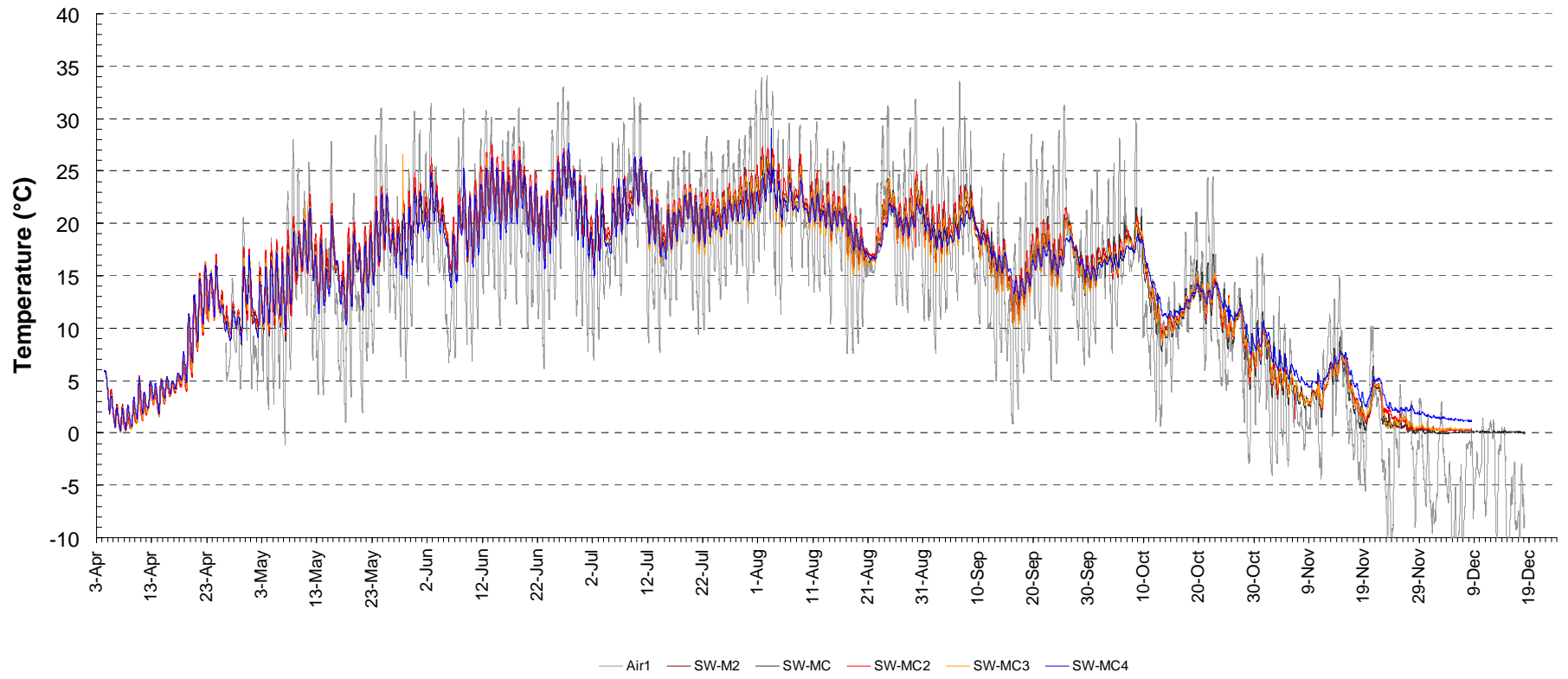


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HYDROLOGICAL REPORT

Figure No.
23

Title
MOUNTSBERG CREEK TRIBUTARY
TEMPERATURES, 2006

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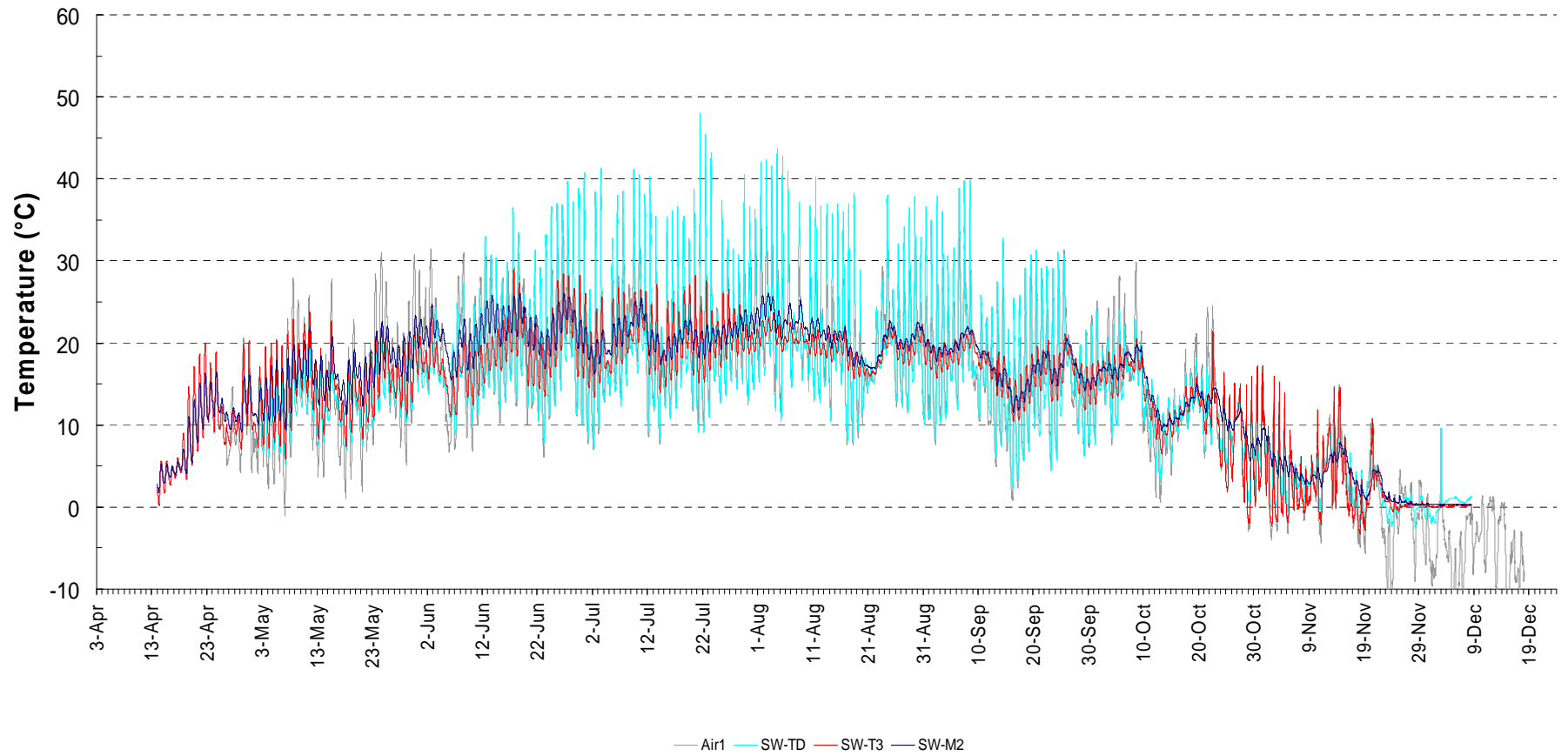
October 2008
1609-60345



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SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
24

Title
**MOUNTSBERG CREEK
TEMPERATURES, 2007**



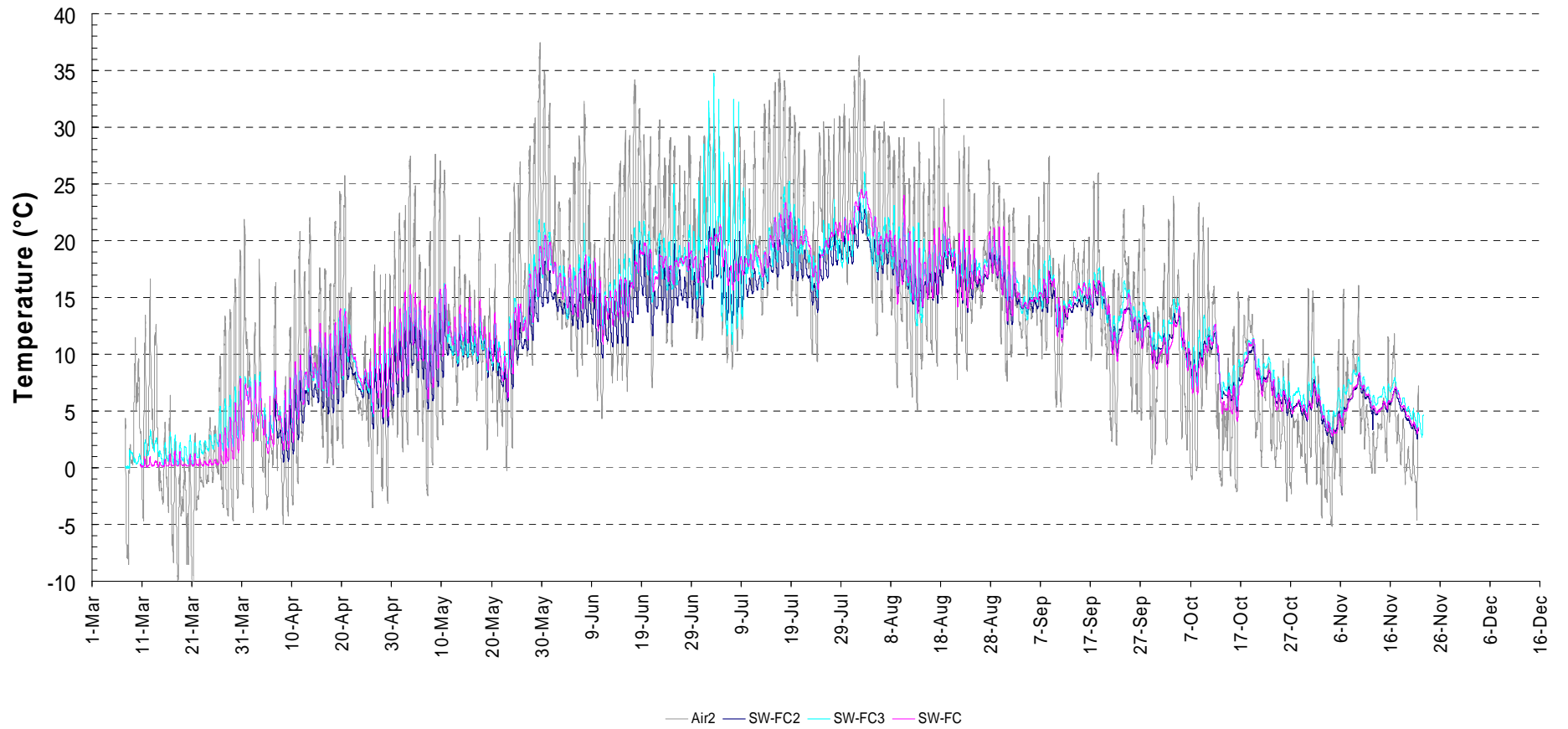
October 2008
1609-60345



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SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
25

Title
MOUNTSBERG CREEK TRIBUTARY
TEMPERATURES, 2007



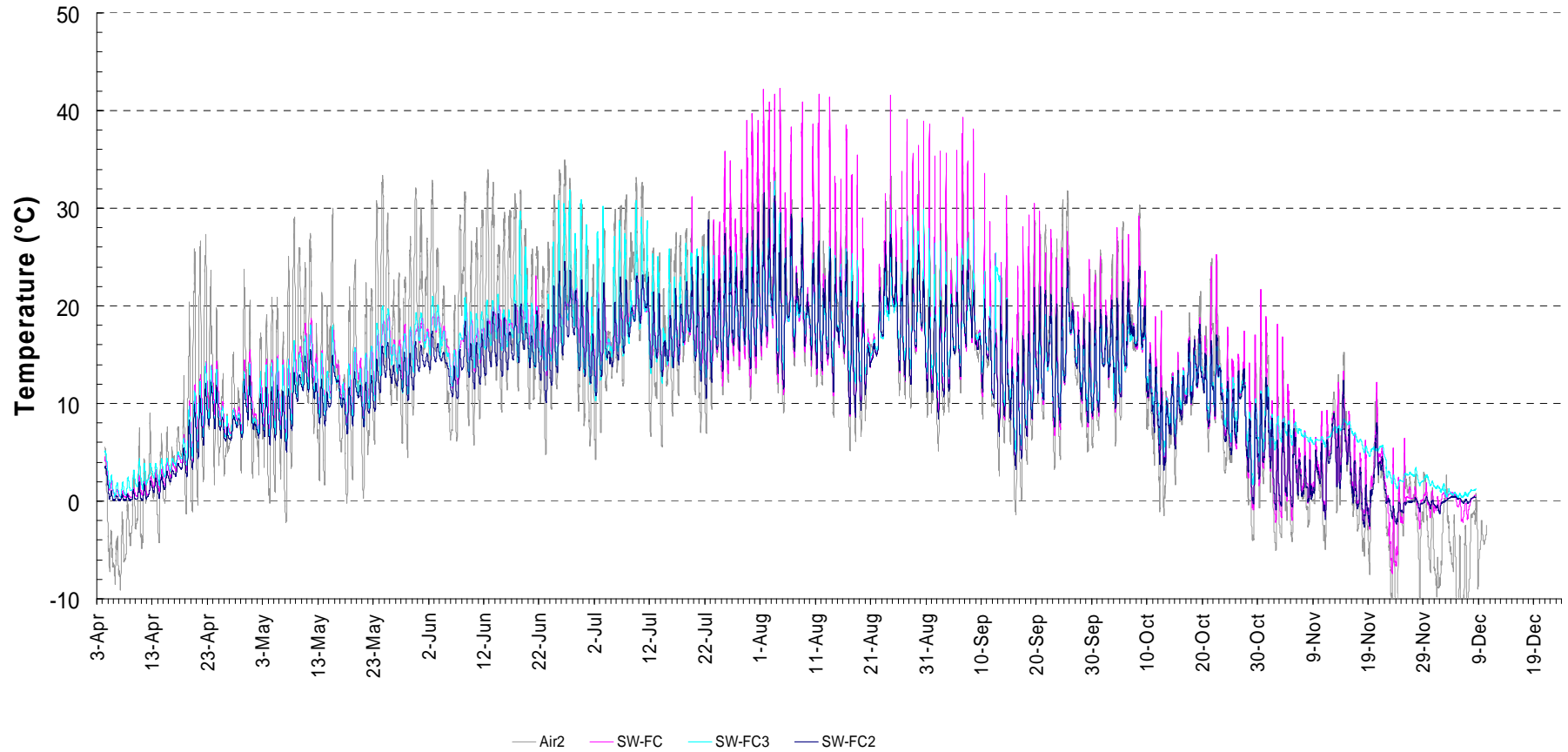
October 2008
1609-60345



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HYDROLOGICAL REPORT

Figure No.
26

Title
FLAMBORO CREEK
TEMPERATURES, 2006



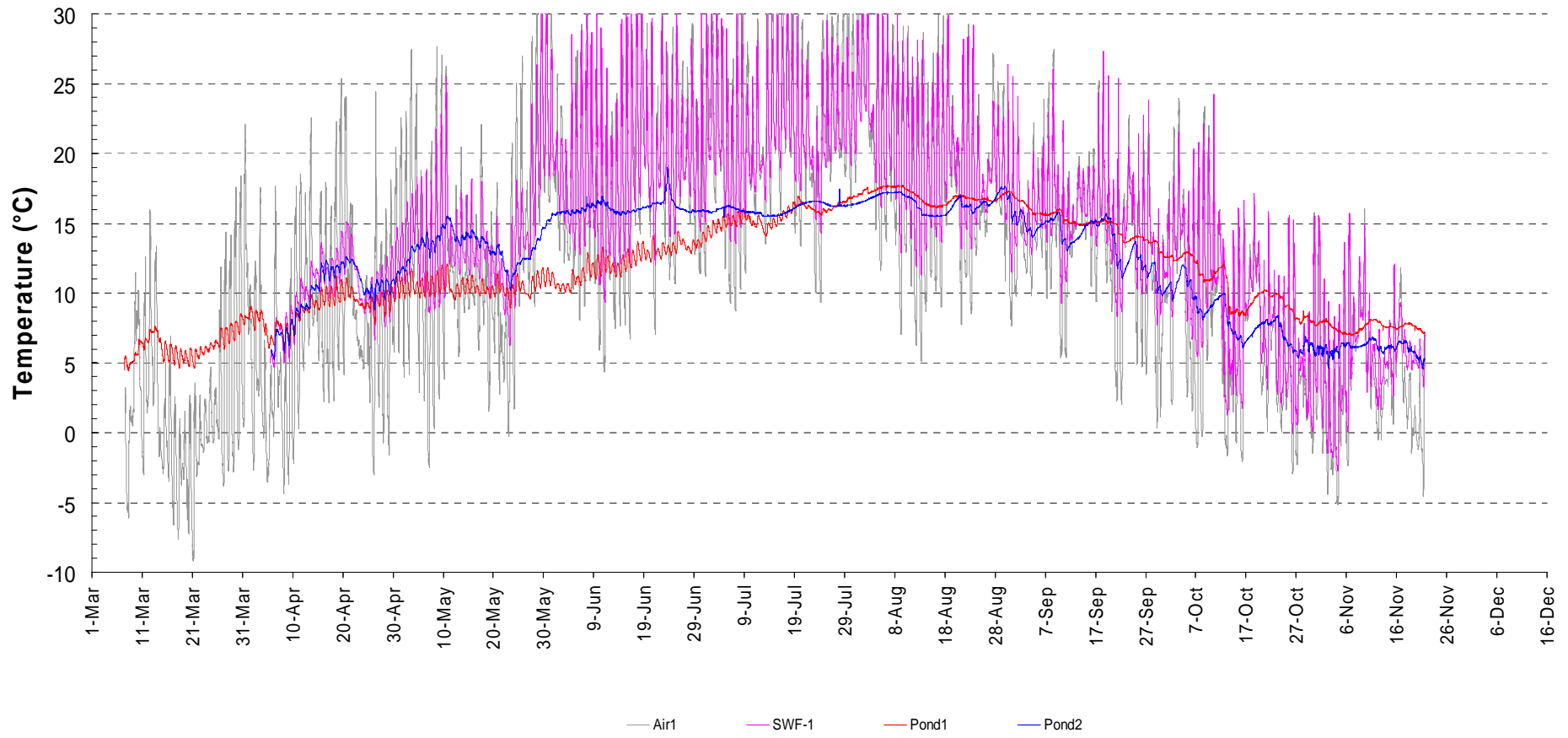
October 2008
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HYDROLOGICAL REPORT

Figure No.
27

Title
FLAMBORO CREEK
TEMPERATURES, 2007



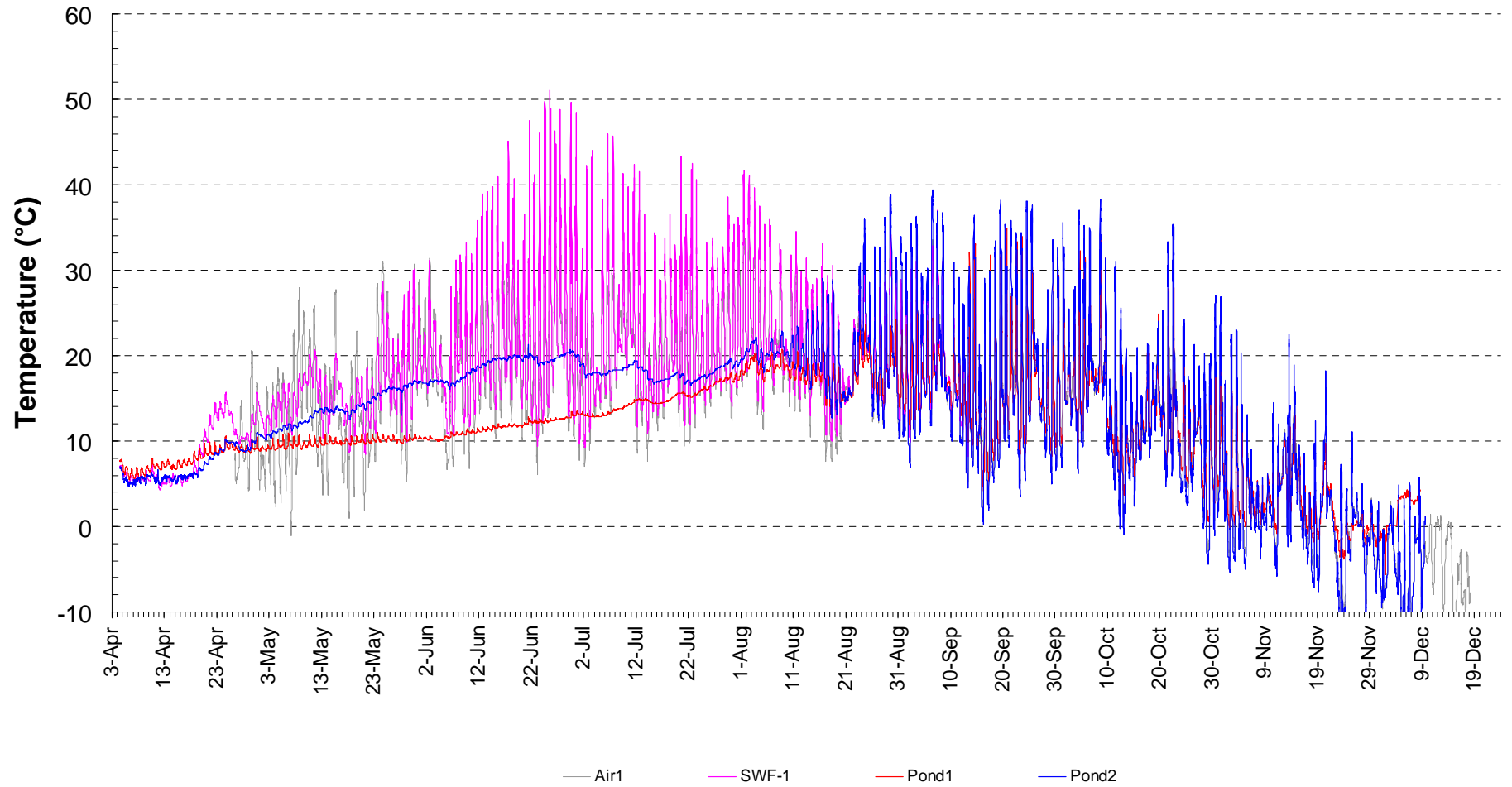
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1609-60345



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HYDROLOGICAL REPORT

Figure No.
28

Title
ON-SITE SURFACE WATER
FEATURE TEMPERATURES, 2006



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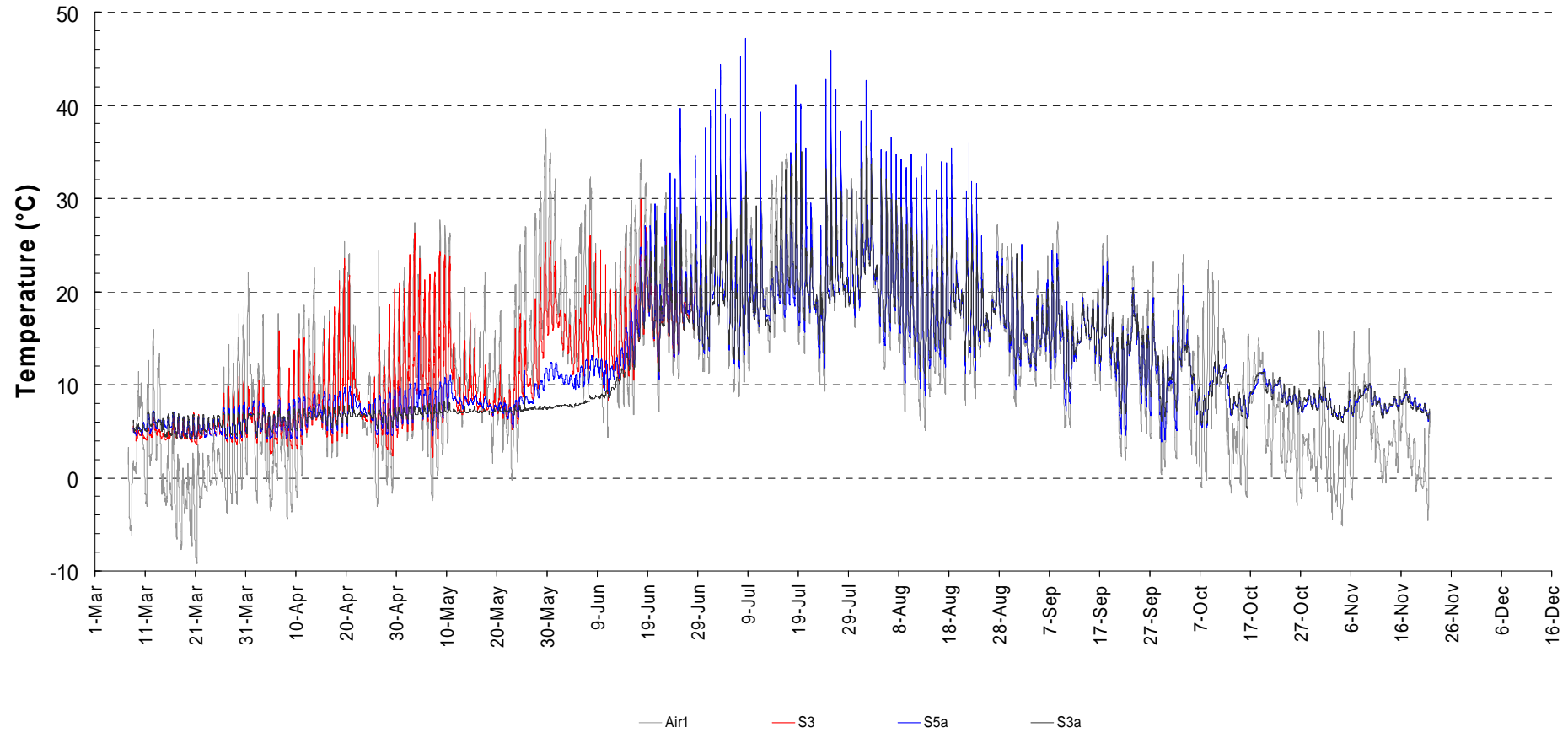


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HYDROLOGICAL REPORT

Figure No.
29

Title
ON-SITE SURFACE WATER
FEATURE TEMPERATURES, 2007

\\C:\d1215-01\work_group\01609\active\160960345\drawing\CAD\CHARTS_20081028\CHARTS.dwg [ON-SITE SEEP TEMPERATURES 2006]
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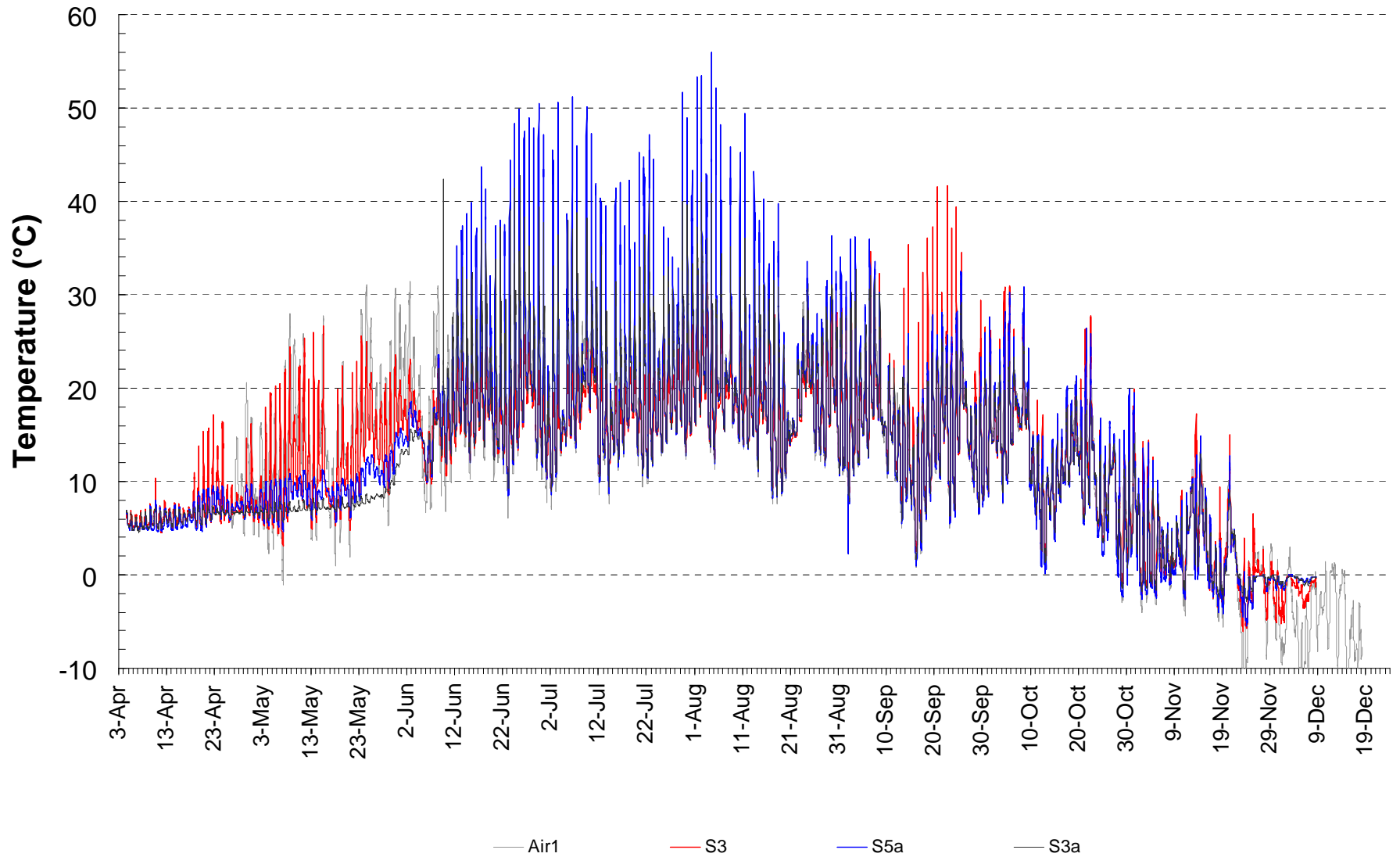
October 2008
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Figure No.
30

Title
ON-SITE SEEP
TEMPERATURES, 2006



October 2008
1609-60345

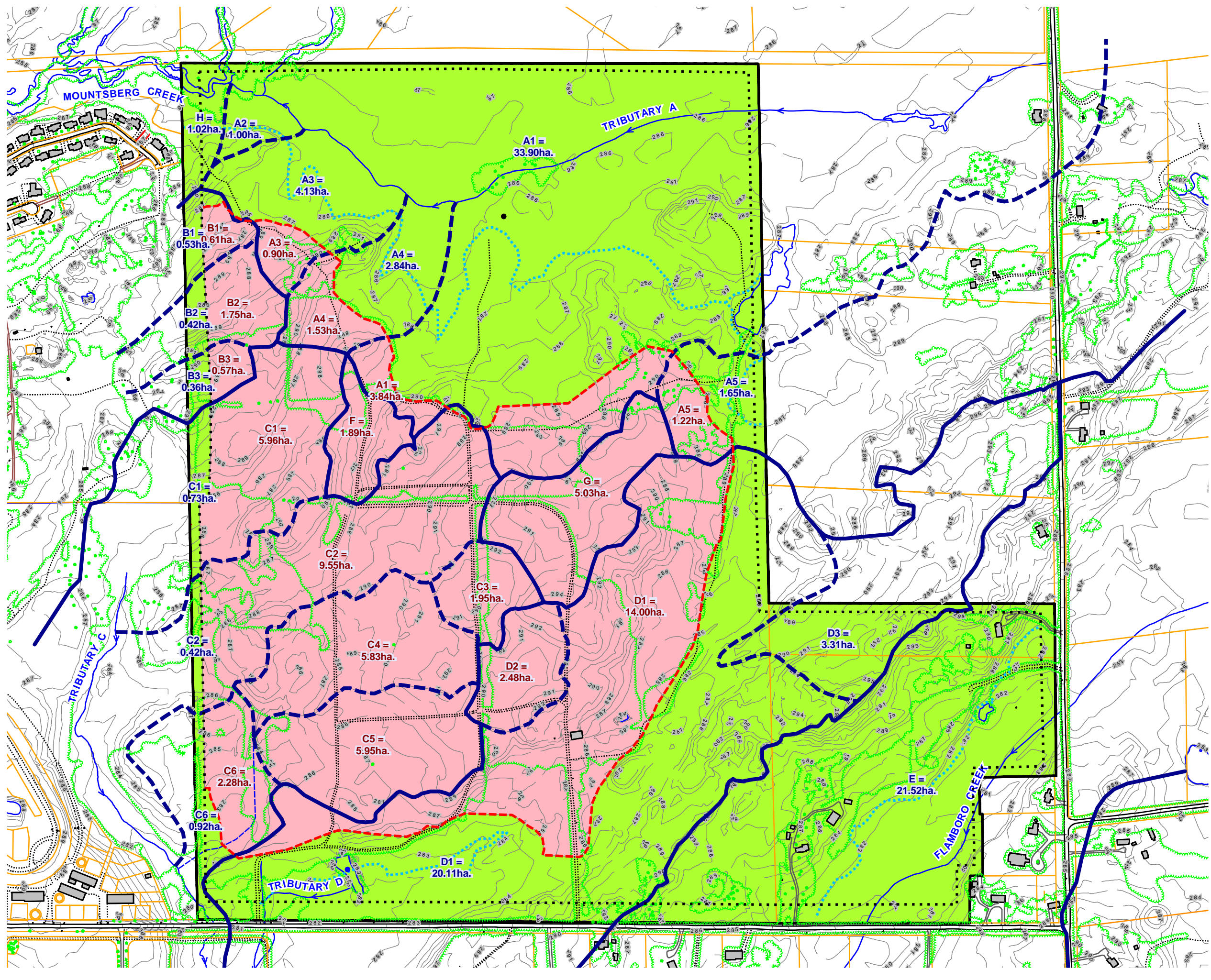


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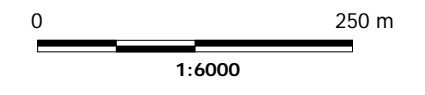
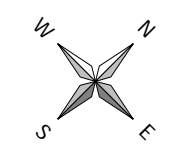
Figure No.
31

Title
ON-SITE SEEP
TEMPERATURES, 2007

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- ### Legend
- Subject Lands
 - Regulatory Setback Line
 - - - Limit of Extraction
 - Major Catchment Area
 - Minor Catchment Area
 - Wetland Boundary (Clipsham, December 3, 2007)
 - Topographic Contours (mAMSL, OBM)
 - Micro-drainage Within Extraction Area
 - Micro-drainage Outwith Extraction Area



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Client/Project
St. Marys Cement
Proposed Flamborough Quarry

Figure No.
32

Title
On-site Subcatchment Alteration

Appendix B

Tables

HYDROLOGICAL LEVEL 2 TECHNICAL REPORT

ST. MARYS FLAMBOROUGH QUARRY

Appendix B - Tables

January 2009

Table 1 Climate Normals 1971-2000, Environment Canada Millgrove Station (Station ID 6155183)

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-6	-5.3	-0.3	6.4	13	18	20.6	19.8	15.6	9.2	3.2	-2.6	7.6
Standard Deviation	2.6	2.6	2.2	1.6	1.9	1.2	1.3	1.1	1	1.6	1.6	2.7	
Daily Maximum (°C)	-2.2	-1.3	4.1	11.4	18.7	23.8	26.5	25.4	21	14.1	6.8	0.8	12.4
Daily Minimum (°C)	-9.7	-9.3	-4.6	1.3	7.2	12.1	14.6	14.1	10.1	4.4	-0.4	-6.1	2.8
Extreme Maximum (°C)	13.5	15	25	30.5	32.5	35.5	37.5	37	35.6	30.6	22.8	20.5	
Extreme Minimum (°C)	-30.6	-27	-24	-13.3	-5.6	0	3.9	1.1	-3.9	-10.6	-17.2	-28	
Precipitation													
Rainfall (mm)	32.1	31.1	52.8	74.2	87.1	89.7	83.4	83.1	96.5	78.8	77.9	44.3	830.7
Snowfall (cm)	39.2	31.1	22.5	5.3	0	0	0	0	0	0.2	9.2	34.9	142.3
Precipitation (mm)	71.3	62.2	75.2	79.4	87.1	89.7	83.4	83.1	96.5	78.9	87	79.2	973
Extreme Daily Rainfall (mm)	50.8	47	50.8	46.6	57.2	59.9	76.2	80	108	97.8	54.4	30.5	
Extreme Daily Snowfall (cm)	44	32	30.5	15.2	1.3	0	0	0	0	12.7	18.2	44.4	
Extreme Daily Precipitation (mm)	50.8	47	50.8	46.6	57.2	59.9	76.2	80	108	97.8	57.4	44.4	

Table 2 Annual Water Budget for Subject Lands, Environment Canada Climate ID 6155183

Year	Average Temperature (°C)	Total Precipitation (mm)	Adjusted ET (mm)	Surplus (mm)
2005	8.3	1049.8	637.4	412.4
2004	7.8	942.0	601.5	340.5
2003	7.3	1016.0	592.6	423.4
2002	8.9	858.8	614.0	244.8
2001	8.9	886.5	632.8	253.7
2000	7.9	1041.7	606.2	435.5
1999	9.0	857.5	632.9	224.6
1998	9.6	836.5	638.2	198.3
1997	7.2	976.9	567.5	409.4
1996	7.1	1260.7	575.3	685.4
1995	7.7	1080.2	594.1	486.1
1994	7.2	1026.8	605.4	421.4
1993	6.8	954.0	582.7	371.3
1992	6.6	1213.3	534.6	678.7
1991	8.4	984.7	614.3	370.4
1990	8.4	1097.7	591.1	506.6

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ST. MARYS FLAMBOROUGH QUARRY

Appendix B - Tables

January 2009

Table 2 Annual Water Budget for Subject Lands, Environment Canada Climate ID 6155183

Year	Average Temperature (°C)	Total Precipitation (mm)	Adjusted ET (mm)	Surplus (mm)
1989	7.1	884.3	578.9	305.4
1988	7.9	902.4	605.4	297.0
1987	8.5	1057.2	609.0	448.2
1986	7.7	1102.7	592.1	510.6
1985	7.3	1134.6	585.4	549.2
1984	7.6	1007.5	584.1	423.4
1983	8.1	957.1	602.1	355.0
1982	7.3	1080.7	582.3	498.4
1981	7.7	870.9	589.4	281.5
1980	7.0	687.7	582.9	104.8
1979	7.3	771.8	575.5	196.3
1978	6.7	890.1	586.1	304.0
1977	7.5	1007.0	607.9	399.1
1976	6.8	936.1	561.5	374.6
1975	8.2	922.6	605.4	317.2
1974	7.4	807.2	571.4	235.8
1973	8.3	944.8	608.7	336.1
1972	6.6	1105.5	554.5	551.0
1971	7.6	833.3	578.1	255.2
Mean	7.7	971.0	593.7	377.3
Stdev	0.7	123.9	23.1	131.4
Stdev (% of mean)	9.5	12.8	3.9	34.8
Climate Normal (1971-2000)	7.6	973.0	605.0	368.0

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ST. MARYS FLAMBOROUGH QUARRY

Appendix B - Tables

January 2009

Table 3 Average (Climate Normal) Water Budget for Subject Lands, Climate ID 6155183

Month	Average Temperature (°C)	Total Precipitation (mm)	Adjusted ET (mm)	Surplus (mm)
January	-6	71.3	0.0	71.3
February	-5.3	62.2	0.0	62.2
March	-0.3	75.2	0.0	75.2
April	6.4	79.4	31.9	47.5
May	13	87.1	76.1	11.0
June	18	89.7	98.9	-9.2
July	20.6	83.4	126.0	-42.6
August	19.8	83.1	120.6	-37.5
September	15.6	96.5	84.6	11.9
October	9.2	78.9	52.1	26.8
November	3.2	87	14.9	72.1
December	-2.6	79.2	0.0	79.2
Annual	7.6	973.0	605.0	368.0

Table 4 Dry Year (1980) Water Budget for Subject Lands, Climate ID 6155183

Month	Average Temperature (°C)	Total Precipitation (mm)	Adjusted ET (mm)	Surplus (mm)
January	-4.7	30.0	0.0	30.0
February	-7.4	27.0	0.0	27.0
March	-2.0	61.4	0.0	61.4
April	6.4	120.2	31.4	88.8
May	14.3	49.6	84.1	-34.5
June	15.6	63.8	96.7	-32.9
July	20.6	74.2	128.7	-54.5
August	21.7	30.6	125.3	-94.7
September	15.9	82.0	79.7	2.3
October	7.3	81.8	30.1	51.7
November	2.2	31.9	6.8	25.1
December	-5.3	35.2	0.0	35.2
Annual	7.0	687.7	582.9	104.8

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ST. MARYS FLAMBOROUGH QUARRY

Appendix B - Tables

January 2009

Table 5 Wet Year (1996) Water Budget for Subject Lands, Climate ID 6155183

Month	Average Temperature (°C)	Total Precipitation (mm)	Adjusted ET (mm)	Surplus (mm)
January	-7.2	112.6	0.0	112.6
February	-5.8	56.0	0.0	56.0
March	-2.9	58.7	0.0	58.7
April	4.6	159.8	22.2	137.6
May	11.7	140.8	68.0	72.8
June	18.7	133.2	119.0	14.2
July	19.8	124.1	123.7	0.4
August	20.6	45.8	119.2	-73.4
September	16.0	181.0	80.9	100.1
October	9.5	91.0	40.4	50.6
November	0.7	46.3	1.9	44.4
December	-0.5	111.4	0.0	111.4
Annual	7.1	1260.7	575.3	685.4

Table 6 Flows Measured in Mountsberg Creek, its Tributaries (m³/s)

	SW-MC	SW-M2	SW-MC2	SW-MC3	SW-MC4	SW-T3	SW-TD
23-Mar-04	0.914	frozen	-	-	-	frozen	-
21-Apr-04	0.727	0.374	-	-	-	0.060	0.009
22-Apr-04		0.480	-	-	-	0.074	0.011
23-Apr-04	0.838	0.528	-	-	-	0.057	0.014
26-Apr-04	0.794	0.502	-	-	-	0.037	0.006
3-Jun-04	0.505	0.493	-	-	-	no flow	0.075
18-Jun-04	0.651	0.404	-	-	-	no flow	0.077
26-Jul-04	0.230	0.191	-	-	-	no flow	no flow
25-Aug-04	0.247	0.201	-	-	-	no flow	no flow
23-Sep-04		0.201	-	-	-	no flow	no flow
28-Oct-04	0.124	0.120	-	-	-	no flow	no flow
8-Dec-04	0.247	0.203	-	-	-	no flow	no flow
20-Jan-05	frozen	frozen	-	-	-	frozen	frozen
28-Feb-05	frozen	frozen	-	-	-	frozen	frozen
24-Mar-05	0.903	flooded	-	-	-	frozen	frozen
15-Apr-05	0.966	flooded	-	-	-	0.021	0.007

HYDROLOGICAL LEVEL 2 TECHNICAL REPORT

ST. MARYS FLAMBOROUGH QUARRY

Appendix B - Tables

January 2009

Table 6 Flows Measured in Mountsberg Creek, its Tributaries (m³/s)

	SW-MC	SW-M2	SW-MC2	SW-MC3	SW-MC4	SW-T3	SW-TD
19-May-05	0.267	flooded	-	-	-	0.029	0.002
17-Jun-05	0.334	0.294	-	-	-	0.020	no flow
*1-Sep-05	0.137	0.108	-	0.144	0.144	0.008	no flow
19-Oct-05	0.088	-	0.074	0.090	0.044	-	no flow
18-Nov-05	0.099	0.085	-	0.125	-	0.013	no flow
2-Dec-05	0.183	-	0.171	0.250	0.309	-	-
14-Feb-06	0.757	0.492	0.684	1.065	-	-	-
8-Mar-06	0.653	0.589	0.720	0.848	0.788	-	-
5-Apr-06	-	0.534	-	0.691	0.789	0.039	-
6-Apr-06	-	-	-	-	-	-	0.004
13-Apr-06	-	0.507	-	-	-	0.050	0.003
26-Apr-06	0.590	-	0.532	0.708	0.763	-	0.004
4-May-06	-	0.261	-	-	-	0.012	-
25-May-06	0.357	0.231	0.344	-	0.340	0.019	0.001
15-Jun-06	-	0.081	0.273	0.300	0.281	0.003	no flow
21-Nov-06	-	-	-	1.311	-	0.002	-
26-Apr-07	0.533	-	-	-	-	-	-
28-May-07	0.384	-	-	-	-	-	-
21-Jun-07	0.356	-	-	-	-	-	-
3-Aug-07	0.175	-	0.161	0.197	0.156	-	-
25-Oct-07	0.051	-	0.014	0.043	0.038	-	-

Table 7 Flows Measured in Flamboro Creek (m³/s)

	SWFC	SWFC3
23-Mar-04	0.033	-
21-Apr-04	0.029	-
22-Apr-04	0.031	-
23-Apr-04	0.027	-
26-Apr-04	0.028	-
3-Jun-04	0.030	-
18-Jun-04	0.073	-
26-Jul-04	no flow	-
25-Aug-04	no flow	-
23-Sep-04	no flow	-
28-Oct-04	no flow	-
8-Dec-04	no flow	-

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ST. MARYS FLAMBOROUGH QUARRY

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Table 7 Flows Measured in Flamboro Creek (m³/s)

	SWFC	SWFC3
20-Jan-05	frozen	-
28-Feb-05	frozen	-
24-Mar-05	frozen	-
15-Apr-05	0.021	-
19-May-05	0.015	-
17-Jun-05	0.065	-
*1-Sep-05	no flow	-
18-Nov-05	0.003	-
2-Dec-05	0.003	-
14-Feb-06	0.024	-
8-Mar-06	-	0.024
6-Apr-06	0.012	0.005
13-Apr-06	0.035	0.004
26-Apr-06	0.024	0.005
25-May-06	0.009	0.001
15-Jun-06	0.009	no flow
21-Nov-06	0.018	-

HYDROLOGICAL LEVEL 2 TECHNICAL REPORT

ST. MARYS FLAMBOROUGH QUARRY

Appendix B - Tables

January 2009

Table 8 PWQMN Results for Mountsberg Creek, 1965-1996

	Units	PWQO	at HWY 401						at County Road 18					
			Max	75th	Mean	25th	Min	n	Max	75th	Mean	25th	Min	n
Alkalinity	mg/L		388.2	266.4	251.1	225	92.8	175	456.5	207	179.9	135.3	88.7	178
Aluminum	mg/L	0.075	0.260	0.041	0.046	0.020	0.010	21	0.287	0.040	0.047	0.021	0.010	22
E. Coli	Ec/100 ml	100	5500	536	135	36	4	25	3600	168	63	12	4	26
Fecal Coliform	FC/100 ml		29000	220	50	10	1	207	22000	196	42	10	1	231
Chloride	mg/L		89.9	22.6	18	13.6	0.3	242	205	25.4	19.5	16.1	9	268
Conductivity	□mhos/cm		866	593	550	517	245	242	815	510	450	375	246	267
Copper	mg/L	0.005	0.607	0.003	0.002	0.001	0.000	171	0.042	0.002	0.001	0.002	0.002	175
Iron	mg/L	0.3	0.700	0.220	0.165	0.060	0.020	21	1.300	0.140	0.168	0.085	0.040	22
Lead	mg/L	0.005	0.013	0.005	0.004	0.003	0.001	171	0.046	0.005	0.005	0.003	0.001	174
Ammonia	mg/L		0.390	0.028	0.012	0.004	0.001	221	0.440	0.040	0.022	0.010	0.002	247
Nitrates	mg/L		4.200	0.534	0.328	0.165	0.020	243	1.870	0.349	0.145	0.090	0.010	270
Nitrites	mg/L		0.070	0.305	0.005	0.004	0.001	242	0.185	0.016	0.007	0.004	0.001	269
TKN	mg/L		3.200	0.650	0.520	0.420	0.180	242	5.700	0.080	0.650	0.520	0.310	269
BOD	mg/L		6.8	1.1	0.8	0.6	0	233	8	1.6	1	5	0.1	262
DO	mg/L	4-7	16	10	8.8	7.6	2.6	192	17.2	11	9.3	7.7	2.6	214
pH		6.5-8.5	9.39	8.31	8.2	8.05	7.05	192	9.21	8.36	8.25	8.11	7.65	195
Phosphate	mg/L		0.260	0.020	0.009	0.004	0.001	241	0.320	0.010	0.004	0.002	0.001	269
Total Phosphorus	mg/L	0.03	0.322	0.048	0.027	0.018	0.007	242	1.000	0.046	0.032	0.022	0.005	269
Sodium	mg/L		53.6	14.4	12.5	6.6	4.9	21	16	15.3	14.2	13.2	12.3	22
TSS	mg/L		91		3		0.5	232	48		5.8		0.2	247
Temperature	°C		24	17	11	2	0.5	184	26	18.5	11	2	0	212
Turbidity	NTU	50	42	2.46	1.58	0.98	0.28	227	32	3.9	2.4	1.63	0.3	253
Zinc	mg/L	0.02	0.380	0.031	0.025	0.012	0.002	171	0.210	0.015	0.014	0.006	0.001	175
Water quality not meeting PWQOs														

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January 2009

Table 9 Summer PWQMN Results for Mountsberg Creek, 1965-1996

	Units	PWQO	at HWY 401						at County Road 18					
			Max	75th	Mean	25th	Min	n	Max	75th	Mean	25th	Min	n
Un-ionized Ammonia	mg/L	0.02	0.017	0.001	0.000	0.000	0.000	40	0.013	0.003	0.002	0.001	0.000	39
Total Phosphorus	mg/L	0.03	0.100	0.058	0.050	0.036	0.021	67	1.000	0.060	0.046	0.035	0.015	73
DO	mg/L	4-7	13.8	9.2	8	7.2	3.4	52	15.4	8.8	7.1	6.2	3.4	57
Temperature	°C		24	20.4	18.3	17	14	54	26	22	20	19	11.5	60
Water quality not meeting PWQOs														

Table 10 Bronte Creek Water Quality Monitoring Program Results for Mountsberg and Flamboro Creek, 1999-2001

	Units	PWQO	Mountsberg Creek (M1)						Flamboro Creek (F1)					
			Max	75th	Mean	25th	Min	n	Max	75th	Mean	25th	Min	n
Alkalinity	mg/L		220	178	166	139	127	16	295	286	257	225	187	16
Aluminum	mg/L	0.075	0.074	0.035	0.031	0.017	0.007	16	0.327	0.124	0.102	0.039	0.023	16
Barium	mg/L		0.035	0.029	0.028	0.025	0.024	16	0.053	0.043	0.039	0.035	0.028	16
Beryllium	µg/L	1100	0.017	0.009	0.008	0.005	0.003	16	0.065	0.021	0.020	0.013	0.007	16
Cadmium	µg/L	0.5	0.374	0.238	0.172	0.045	0.016	16	0.583	0.214	0.167	0.024	0.009	16
Calcium	mg/L		63.9	54.1	44.8	35.9	27.6	16	86.8	81.7	78.2	75.1	71.5	16
Chloride	mg/L		39.4	35.2	32.3	27.0	25.4	16	31.0	29.6	27.1	24.6	22.6	16
Chromium	µg/L	8.9	0.586	0.245	0.200	0.077	0.013	16	0.463	0.340	0.257	0.100	0.049	16
Cobalt	µg/L	0.9	0.935	0.414	0.307	0.077	0.010	16	0.521	0.372	0.297	0.154	0.111	16
Conductivity	µmhos/cm		530	490	430.13	380	369	16	644	589	565.19	530	505	16
Copper	µg/L	5	0.62	0.45	0.36	0.27	0.04	16	1.38	1.00	0.73	0.47	0.03	16
Hardness	mg/L		327	227	205	164	120	16	457	312	311	283	263	16
Iron	mg/L	0.3	0.270	0.152	0.128	0.066	0.033	16	0.600	0.382	0.297	0.148	0.106	16

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ST. MARYS FLAMBOROUGH QUARRY

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January 2009

Table 10 Bronte Creek Water Quality Monitoring Program Results for Mountsberg and Flamboro Creek, 1999-2001

	Units	PWQO	Mountsberg Creek (M1)						Flamboro Creek (F1)						
			Max	75th	Mean	25th	Min	n	Max	75th	Mean	25th	Min	n	
Lead	□g/L	5	4.87	1.24	1.31	0.62	0.02	16	4.84	3.88	2.28	0.78	0.18	16	
Magnesium	mg/L		29.7	25.4	23.3	21.0	19.6	16	29.1	28.0	26.7	25.0	23.3	16	
Manganese	mg/L		0.112	0.062	0.052	0.027	0.013	16	0.235	0.176	0.109	0.051	0.035	16	
Molybdenum	□g/L	40	1.60	0.83	0.63	0.22	0.06	16	2.12	0.98	0.82	0.37	0.05	16	
Nickel	□g/L	25	0.780	0.460	0.323	0.130	0.060	16	1.320	0.470	0.358	0.150	0.000	16	
Ammonia	mg/L		0.032	0.018	0.013	0.004	0.002	16	0.280	0.136	0.117	0.040	0.002	16	
Nitrates	mg/L		0.843	0.394	0.350	0.219	0.078	16	0.506	0.352	0.230	0.066	0.017	16	
Nitrites	mg/L		0.014	0.010	0.007	0.002	0.001	16	0.310	0.020	0.034	0.007	0.001	16	
TKN	mg/L		0.78	0.72	0.63	0.54	0.34	16	1.64	0.92	0.86	0.56	0.40	16	
DO	mg/L	4-7	8.7	8.3	7.7	7.1	6.5	15	9.2	8.3	6.8	5.2	3.5	15	
pH		6.5-8.5	9.10	8.17	8.06	7.90	7.10	15	9.15	8.14	8.10	7.90	7.75	15	
Phosphate	mg/L		0.02	0.012	0.008	0.003	0.001	16	0.038	0.026	0.016	0.003	0.001	16	
Total Phosphorus	mg/L	0.03	0.052	0.032	0.027	0.016	0.008	16	0.170	0.096	0.069	0.026	0.019	16	
Potassium	mg/L		1.9	1.6	1.2	0.9	0.3	16	2.9	2.4	1.9	1.4	1.2	16	
Sodium	mg/L		31.8	19.5	17.7	15.0	12.5	16	36.6	14.5	15.1	12.8	12.4	16	
Strontium	mg/L		0.116	0.098	0.087	0.078	0.064	16	0.152	0.142	0.129	0.116	0.096	16	
Temperature	C		22.0	19.0	16.3	14.5	8.5	15	22.2	20.3	16.7	11.0	9.0	14	
Titanium	□g/L		0.569	0.454	0.279	0.032	0.008	16	7.410	1.710	1.484	0.366	0.048	16	
TDS	mg/L		344		279		240	6	384		349		328	6	
TSS	mg/L		6.5		3.4		2.0	6.0	25.0		15.2		9.5	6	
Turbidity	FTU		8.3	4.0	2.7	1.2	0.4	16	22.5	16.1	10.4	3.7	2.6	16	
Vanadium	□g/L	6	1.340	0.552	0.433	0.152	0.022	16	1.640	0.653	0.537	0.278	0.109	16	
Zinc	□g/L	20	31.1	15.8	12.9	7.0	4.9	16	4.8	2.6	2.0	1.0	0.4	16	
			Water quality not meeting PWQOs												

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Table 11 Baseline surface water quality

Sample ID	Date	Alkal. mg CaCO ₃ /L	Turb. NTU	TSS mg/L	TDS mg/L	Br ⁻ mg/L	Cl ⁻ mg/l	NO ₂ -N mg/L	NO ₃ -N mg/L	SO ₄ ⁻ mg/L	PO ₄ ⁻³ mg/L	TOC mg/L	DOC mg/L	NH ₃ -N mg/L	TKN mg/L	P mg/L
A1	Nov. 2004	171	0.6	2	622	<0.5	36.6	<0.2	<0.2	234	<1	13.2	13.3	0.12	0.64	<0.05
	Feb. 2005	243	0.8	<1	402	<0.5	37	<0.2	<0.2	53.3		9.5	10.2	<0.03	0.65	<0.05
	June 2005	298	3.9	3	410	<3.5	36.6	<0.1	<1	<0.5	<3	13.2	12.8	<0.5	1.1	
	Sep. 2005	134	4.2	4	168	<1	40	<0.3	<0.2	19	<1	9.1	9	0.09	1.4	0.061
	Nov. 2005	167	0.9	<1	398	<1	44	<0.01	<0.1	166	0.012	15.5	15.7	<0.05	0.8	0.02
	Mean	203	2.1	2.0	400	0.7	39	0.1	0.2	77	0.6	12	12	0.1	0.9	0.033
F4	Nov. 2004	241	4	12	338	<0.5	10.1	<0.2	<0.2	36.3	<1	11	10	0.07	0.69	0.07
	Feb. 2005	249	0.4	<1	310	<0.5	33.8	<0.2	<0.2	37.4		5.6	5.2	<0.03	0.18	<0.05
	June 2005	304	1.4	2	392	<0.35	38.8	<0.1	<0.1	15.2	<0.3	13.2	6.2	0.09	0.4	
	Sep. 2005	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Nov. 2005	203	0.3	<1	326	<1	34	<0.01	<0.1	70	0.01	13.8	13.8	<0.05	0.7	<0.02
	Mean	249	1.5	3.8	342	0.3	29	0.1	0.1	32	0.2	11	9	0.1	0.5	0.035
M2	Nov. 2004	172	2.8	8	278	<0.5	33.4	<0.2	<0.2	28	<1	7.6	6.8	0.03	0.6	<0.05
	Feb. 2005	227	3.8	9	362	<0.5	43.7	<0.2	0.7	51.4		8	7.2	<0.03	0.67	<0.05
	June 2005	307	1.6	4	293	<0.35	47.4	<0.1	0.1	18.2	<0.3	7.5	7.2	0.21	0.7	
	Sep. 2005	136	1.4	6	190	<1	39	<0.3	<0.2	15	<1	8.6	8	<0.05	0.9	0.065
	Nov. 2005	197	1.6	<1	316	<1	41	<0.01	0.3	72	0.009	9.1	9.1	<0.05	0.7	0.02
	Mean	208	2	5.5	288	0.3	41	0.1	0.3	37	0.3	8	8	0.1	0.7	0.034
M3	Nov. 2004	174	0.6	2	270	<0.5	33.2	<0.2	<0.2	28.2	<1	7.8	6.6	<0.03	0.5	<0.05
	Feb. 2005	218	3.6	9	352	<0.5	44.8	<0.2	0.6	51.3		8.2	7.2	0.04	0.62	<0.05
	June 2005	192	1.7	7	321	<0.35	43	<0.1	0.1	22	<0.3	9.5	8	0.28	0.9	
	Sep. 2005	137	1.1	<1	218	<1	39	<0.3	<0.2	7	<1	8.7	8.2	<0.05	1.2	0.032
	Nov. 2005	201	0.6	<1	356	<1	45	<0.01	<0.1	52	0.009	8.4	8.5	<0.05	0.6	<0.02
	Mean	184	1.5	3.8	303	0.3	41	0.1	0.2	32	0.3	9	8	0.1	0.8	0.023

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M5	Nov. 2005	204	0.6	<1	296	<1	40	<0.01	0.4	58	0.009	7.7	7.8	<0.05	0.7	<0.02
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Table 11 Baseline surface water quality continued

Sample ID	Date	Ag mg/L	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Bi mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L	Mg mg/L
A1	Nov. 2004	<0.0001	0.013	<0.002	0.013	0.047	<0.0005	<0.0001	102	<0.0001	<0.0001	<0.0005	0.0008	0.18	0.4	35.2
	Feb. 2005	<0.0001	0.011	<0.002	0.006	0.028	<0.0005	<0.0001	73.6	<0.0001	0.0001	<0.0005	0.0019	0.21	1	27.9
	June 2005	<0.001	0.060	<0.003	<0.03	0.03	<0.001	<0.003	75	<0.0003	<0.001	<0.01	<0.01	0.7	0.6	0.13
	Sep. 2005	<0.0005	0.033	<0.001	0.023	0.023	<0.0005	<0.001	29	<0.0001	<0.0005	<0.005	0.002	0.36	1.5	25
	Nov. 2005	<0.0005	0.027	0.001	0.016	0.028	<0.0005	<0.001	93	<0.0001	<0.0005	<0.005	0.002	0.11	1.1	37
	Mean	0.0002	0.029	0.001	0.015	0.031	0.0003	0.001	74.5	0.0001	0.0002	0.0020	0.002	0.3	0.9	25.0
F4	Nov. 2004	<0.0001	0.006	<0.002	<0.005	0.024	<0.0005	<0.0001	67.9	<0.0001	0.0004	<0.0005	0.0008	1.23	0.9	25.3
	Feb. 2005	<0.0001	<0.005	<0.002	0.006	0.017	<0.0005	<0.0001	68.7	<0.0001	<0.0001	<0.0005	<0.0005	<0.03	0.4	27.3
	June 2005	<0.001	0.010	<0.003	<0.03	0.02	<0.001	<0.003	74	<0.0003	<0.001	<0.01	<0.01	0.1	<0.5	0.13
	Sep. 2005	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Nov. 2005	<0.0005	0.015	0.001	0.016	0.028	<0.0005	<0.001	72	<0.0001	<0.0005	<0.005	<0.001	<0.05	0.9	30
	Mean	0.0002	0.008	0.001	0.010	0.022	0.0003	0.001	70.7	0.0001	0.0003	0.0018	0.002	0.4	0.6	28.4
M2	Nov. 2004	<0.0001	0.076	<0.002	0.006	0.031	<0.0005	<0.0001	42	<0.0001	<0.0001	<0.0005	0.0011	0.22	1.5	22.2
	Feb. 2005	<0.0001	0.090	<0.002	0.008	0.037	<0.0005	<0.0001	69.8	<0.0001	0.0001	<0.0005	0.0007	0.19	1.6	25

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Table 11 Baseline surface water quality continued

Sample ID	Date	Ag mg/L	Al mg/L	As mg/L	B mg/L	Ba mg/L	Be mg/L	Bi mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L	Mg mg/L
	June 2005	<0.001	0.030	<0.003	<0.03	0.03	<0.001	<0.003	56	<0.0003	<0.001	<0.01	<0.01	0.1	1.4	0.078
	Sep. 2005	<0.0005	0.065	<0.001	0.023	0.024	<0.0005	<0.001	30	<0.0001	<0.0005	<0.005	0.002	0.23	1.5	26
	Nov. 2005	<0.0005	0.068	<0.001	0.013	0.033	<0.0005	<0.001	71	<0.0001	<0.0005	<0.005	<0.001	0.18	2	31
	Mean	0.0002	0.066	0.001	0.013	0.031	0.0003	0.001	53.8	0.0001	0.0002	0.0020	0.002	0.2	1.6	20.9
M3	Nov. 2004	<0.0001	0.014	<0.002	<0.005	0.03	<0.0005	<0.0001	42.5	<0.0001	<0.0001	<0.0005	0.0006	0.09	1.5	22.3
	Feb. 2005	<0.0001	0.060	<0.002	0.009	0.039	<0.0005	<0.0001	70.2	<0.0001	<0.0001	<0.0005	0.0006	0.12	1.7	25.3
	June 2005	<0.001	0.030	<0.003	<0.03	0.03	<0.001	<0.003	53	<0.0003	<0.001	<0.01	<0.01	0.2	1.9	0.083
	Sep. 2005	0.0005	0.026	<0.001	0.023	0.023	<0.0005	0.003	30	<0.0001	<0.0005	<0.005	<0.001	0.12	1.5	25
	Nov. 2005	<0.0005	0.017	<0.001	0.012	0.031	<0.0005	<0.001	69	<0.0001	<0.0005	<0.005	0.001	0.063	1.9	30
	Mean	0.0003	0.029	0.001	0.012	0.031	0.0003	0.001	52.9	0.0001	0.0003	0.0020	0.002	0.119	1.7	20.5
M5	Nov. 2005	<0.0005	0.015	<0.001	0.012	0.032	<0.0005	<0.001	68	<0.0001	<0.0005	<0.005	<0.001	0.051	2	31

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Table 11 Baseline surface water quality continued

Sample ID	Date	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	Pb mg/L	Sb mg/L	Se mg/L	Si mg/L	Sn mg/L	Sr mg/L	Ti mg/L	TI mg/L	U mg/L	V mg/L	Zn mg/L
A1	Nov. 2004	0.037	0.005	14.3	0.001	<0.0005	<0.0005	<0.002		<0.001	0.121	<0.005	<5x10 ⁻⁵	0.0005	0.0006	0.012
	Feb. 2005	0.182	0.001	16	<0.0001	<0.0005	<0.0005	<0.002	3.19	<0.0001	0.086	<0.0005	<5x10 ⁻⁵	0.0011	<0.0005	0.01
	June 2005	0.130	<0.003	20	<0.003	<0.001	<0.003	<0.005	3.9	<0.003	0.086	<0.01	<1x10 ⁻⁵	0.0008	<0.003	0.02
	Sep. 2005	0.094	<0.001	23	<0.001	<0.0005	<0.001	<0.002	3.3	<0.001	0.069	<0.005	<5x10 ⁻⁵	0.0003	<0.001	<0.005
	Nov. 2005	0.018	0.002	22	<0.001	<0.0005	<0.001	<0.002	3.2	<0.001	0.094	<0.005	<5x10 ⁻⁵	0.0005	<0.001	0.025
	Mean	0.092	0.002	19.1	0.001	0.0003	0.0006	0.001	3.4	0.0006	0.091	0.0026	0.00003	0.0006	0.0007	0.014
F4	Nov. 2004	1.32	<0.0001	3.8	<0.001	<0.0005	<0.0005	<0.002		<0.001	0.064	<0.005	<5x10 ⁻⁵	0.0001	<0.0005	0.008
	Feb. 2005	0.006	<0.0001	15.1	<0.0001	<0.0005	<0.0005	<0.002	2.82	<0.0001	0.063	<0.0005	<5x10 ⁻⁵	0.0003	<0.0005	0.005
	June 2005	0.130	<0.003	13	<0.003	<0.001	<0.003	<0.005	3.4	<0.003	0.072	<0.01	<0.0001	<3x10 ⁻⁴	<0.003	<0.01
	Sep. 2005	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Nov. 2005	0.008	<0.001	14	<0.001	<0.0005	<0.001	<0.002	3.2	<0.001	0.062	<0.005	<5x10 ⁻⁵	0.0001	<0.001	0.029
	Mean	0.366	0.001	11.5	0.001	0.0003	0.0007	0.002	3.1	0.0007	0.065	0.0026	0.00003	0.0002	0.0007	0.012
M2	Nov. 2004	0.045	<0.0001	14.6	<0.001	<0.0005	<0.0005	<0.002		<0.001	0.088	<0.005	<5x10 ⁻⁵	0.0005	0.0006	0.024
	Feb. 2005	0.074	<0.0001	19.5	<0.0001	0.0006	<0.0005	<0.002	2.44	<0.0001	0.119	<0.0005	<5x10 ⁻⁵	0.0008	<0.0005	0.039
	June 2005	0.078	<0.003	22	<0.003	<0.001	<0.003	<0.005	0.8	<0.003	0.100	<0.01	<0.0001	0.0006	<0.003	0.01
	Sep. 2005	0.068	<0.001	23	<0.001	<0.0005	<0.001	<0.002	2.9	<0.001	0.074	<0.005	<5x10 ⁻⁵	0.0003	<0.001	0.02

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Table 11 Baseline surface water quality continued

Sample ID	Date	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	Pb mg/L	Sb mg/L	Se mg/L	Si mg/L	Sn mg/L	Sr mg/L	Ti mg/L	Tl mg/L	U mg/L	V mg/L	Zn mg/L
	Nov. 2005	0.06	<0.001	22	<0.001	<0.0005	<0.001	<0.002	2.4	<0.001	0.12	<0.005	<5x10 ⁻⁵	0.0007	<0.001	0.028
	Mean	0.065	0.001	20.2	0.001	0.0004	0.0006	0.001	2.1	0.0006	0.100	0.0026	0.00003	0.0006	0.0007	0.024
M3	Nov. 2004	0.016	<0.0001	14.7	<0.001	<0.0005	<0.0005	<0.002		<0.001	0.089	<0.005	<5x10 ⁻⁵	0.0005	0.0005	0.007
	Feb. 2005	0.076	<0.0001	20.4	<0.0001	<0.0005	<0.0005	<0.002	2.39	<0.0001	0.124	<0.0005	<5x10 ⁻⁵	0.0008	<0.0005	0.033
	June 2005	0.083	<0.003	22	<0.003	<0.001	<0.003	<0.005	0.7	<0.003	0.1	<0.01	<0.0001	0.0006	<0.003	0.02
	Sep. 2005	0.025	<0.001	22	<0.001	<0.0005	<0.001	<0.002	2.1	<0.001	0.11	<0.005	<5x10 ⁻⁵	0.0007	<0.001	0.018
	Nov. 2005	0.058	<0.001	23	<0.001	<0.0005	<0.001	<0.002	3.1	<0.001	0.074	<0.005	<5x10 ⁻⁵	0.0005	<0.001	<0.005
	Mean	0.052	0.001	20.4	0.001	0.0003	0.0006	0.001	2.1	0.0006	0.099	0.0026	0.00003	0.0006	0.0007	0.016
M5	Nov. 2005	0.018	<0.001	24	<0.001	<0.0005	<0.001	<0.002	2.0	<0.001	0.12	<0.005	<5x10 ⁻⁵	0.0007	<0.001	0.026

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Table 12 Predicted Downstream Water Quality in Mountsberg Creek for Parameters of Interest

	Units	PWQO	Upstream Water Quality (County Road 18)			Discharge Quality	Predicted Downstream Concentration
			Max	75th	Mean		
Alkalinity	mg/L		456.5	207	179.9	278	238.0
Conductivity	umhos/cm		815	510	450	569	535.7
Zinc	mg/L	0.02	0.210	0.015	0.014	0.052	0.031

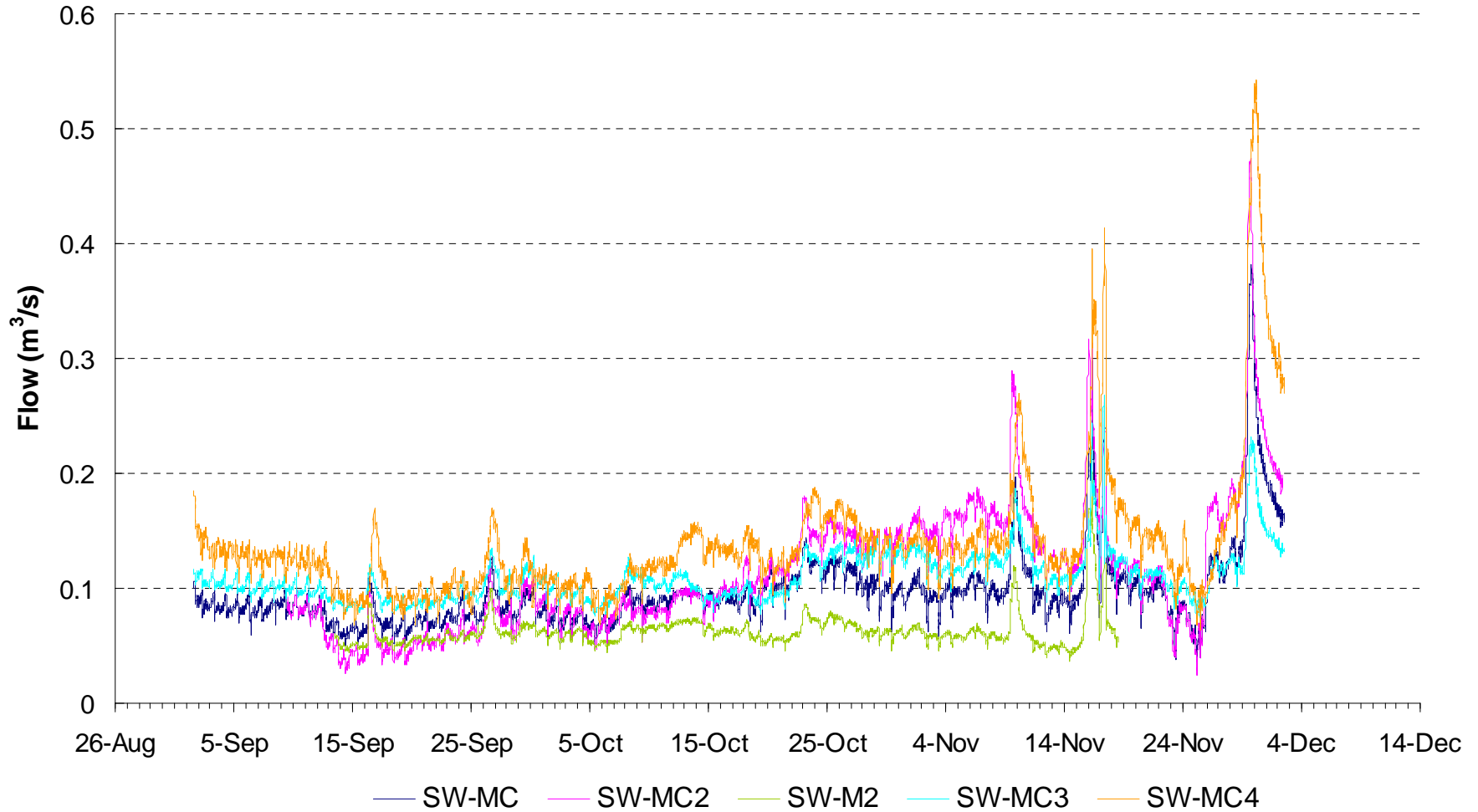
Table 13 Subcatchment Area Alteration Within Subject Lands From Extraction Footprint

Catchment	Existing	Extraction	Future
	Area (ha)	Footprint (ha)	Area (ha)
A1	37.74	3.84	33.90
A2	1.00	0.00	1.00
A3	5.03	0.90	4.13
A4	4.37	1.53	2.84
A5	2.87	1.22	1.65
B1	1.14	0.61	0.53
B2	2.17	1.75	0.42
B3	0.93	0.57	0.36
C1	6.69	5.96	0.73
C2	9.97	9.55	0.42
C3	1.95	1.95	0.00
C4	5.83	5.83	0.00
C5	5.95	5.95	0.00
C6	3.20	2.28	0.92
D1	34.11	14.00	20.11
D2	2.48	2.48	0.00
D3	3.31	0.00	3.31
E	21.52	0.00	21.52
F	1.89	1.89	0.00
G	5.03	5.03	0.00
H	1.02	0.00	1.02
Total	158.2	65.3	92.9

Appendix C

2005 Monitoring Data

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2008-11-14 09:44AM By: bcowper



November 2008
1609-60345



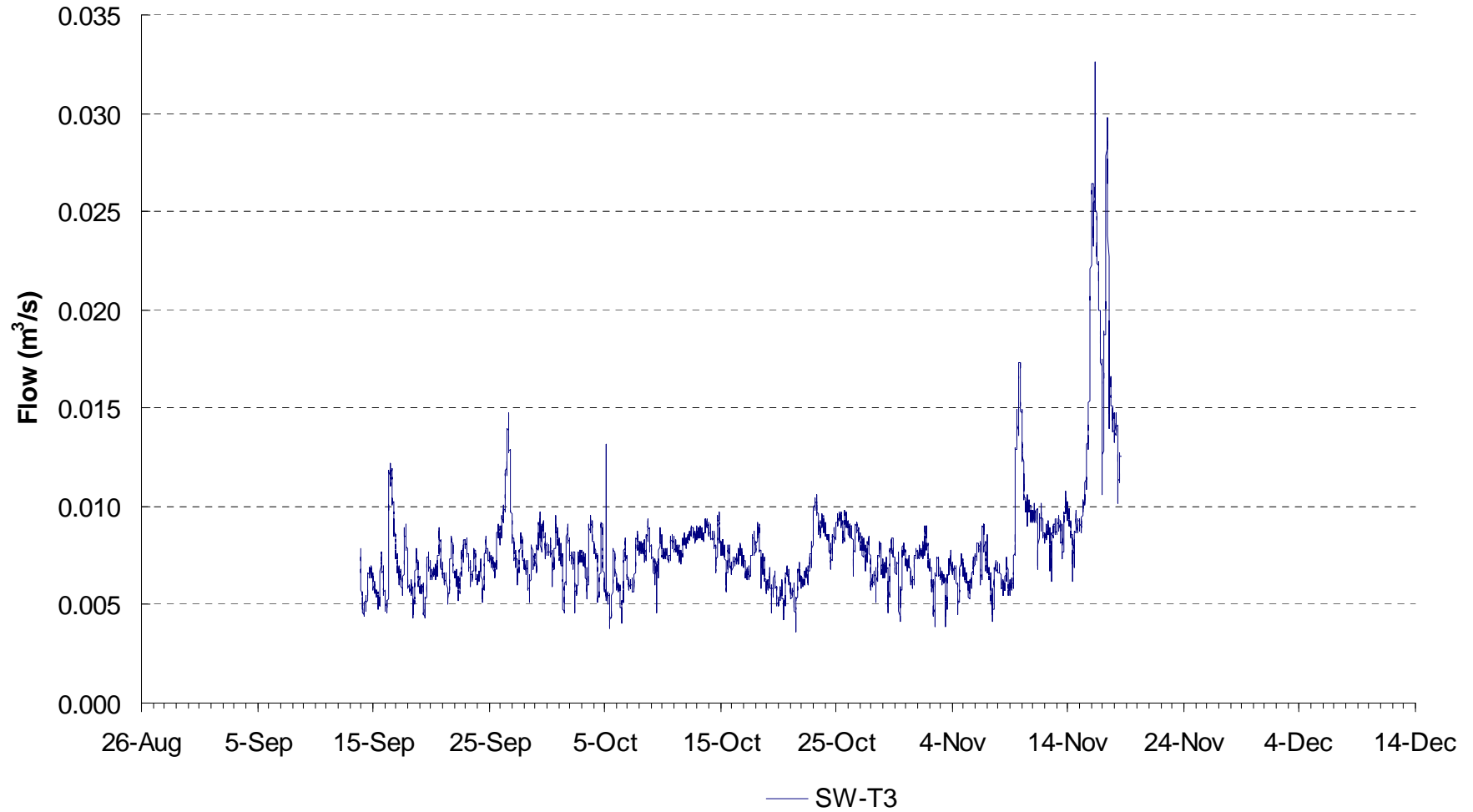
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Client/Project
SMC FLAMBOROUGH QUARRY
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Figure No.
C1

Title
MOUNTSBERG CREEK FLOWS, 2005

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2008-11-14 08:49AM By: bcowper



November 2008
1609-60345

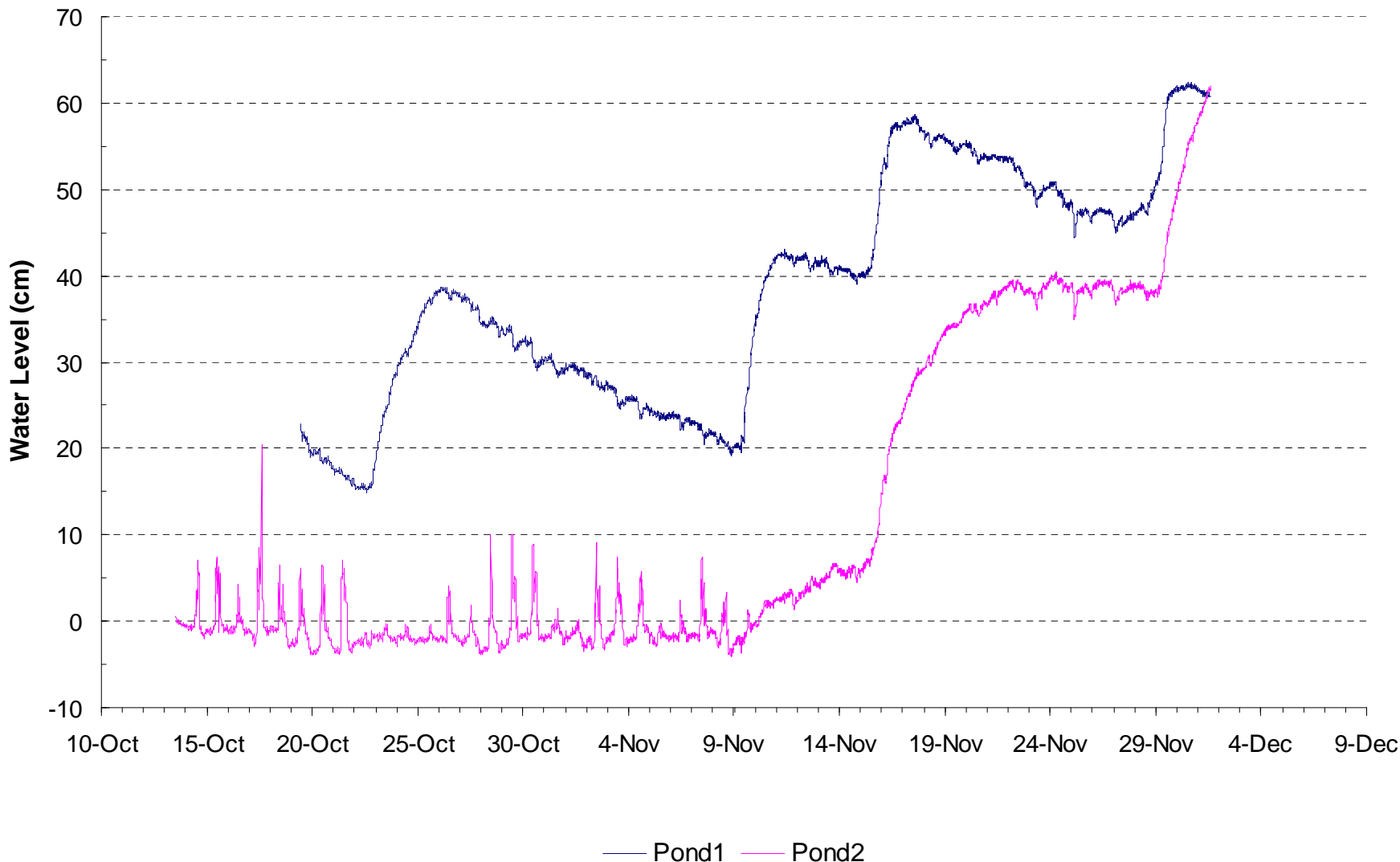


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SMC FLAMBOROUGH QUARRY
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Figure No.
C2

Title
MOUNTSBERG CREEK TRIBUTARY
FLOWS, 2005

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November 2008
1609-60345

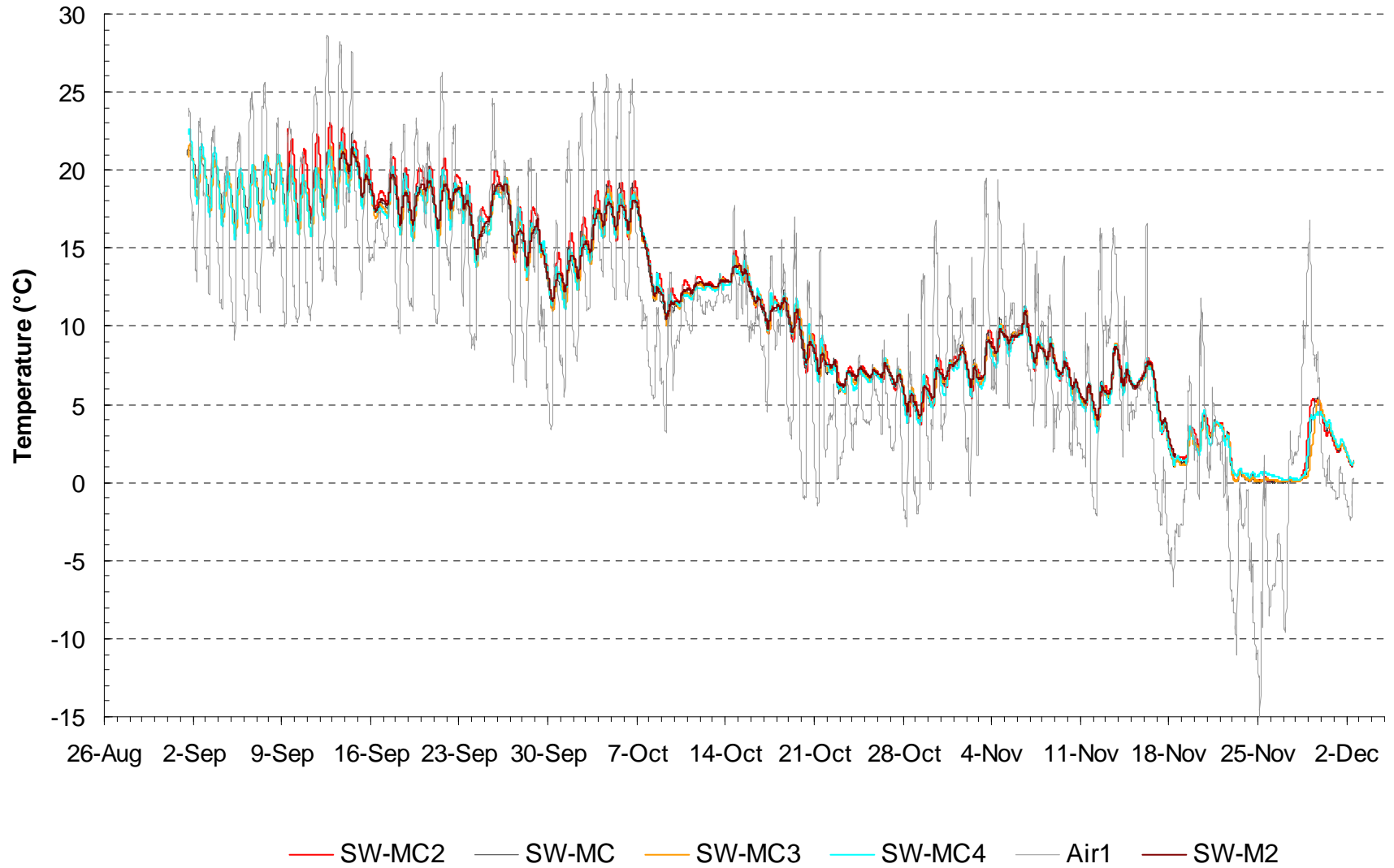


Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
C3

Title
MOUNTSBERG CREEK
POND LEVELS, 2005

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2008-11-14 09:56AM By: bcowper



November 2008
1609-60345

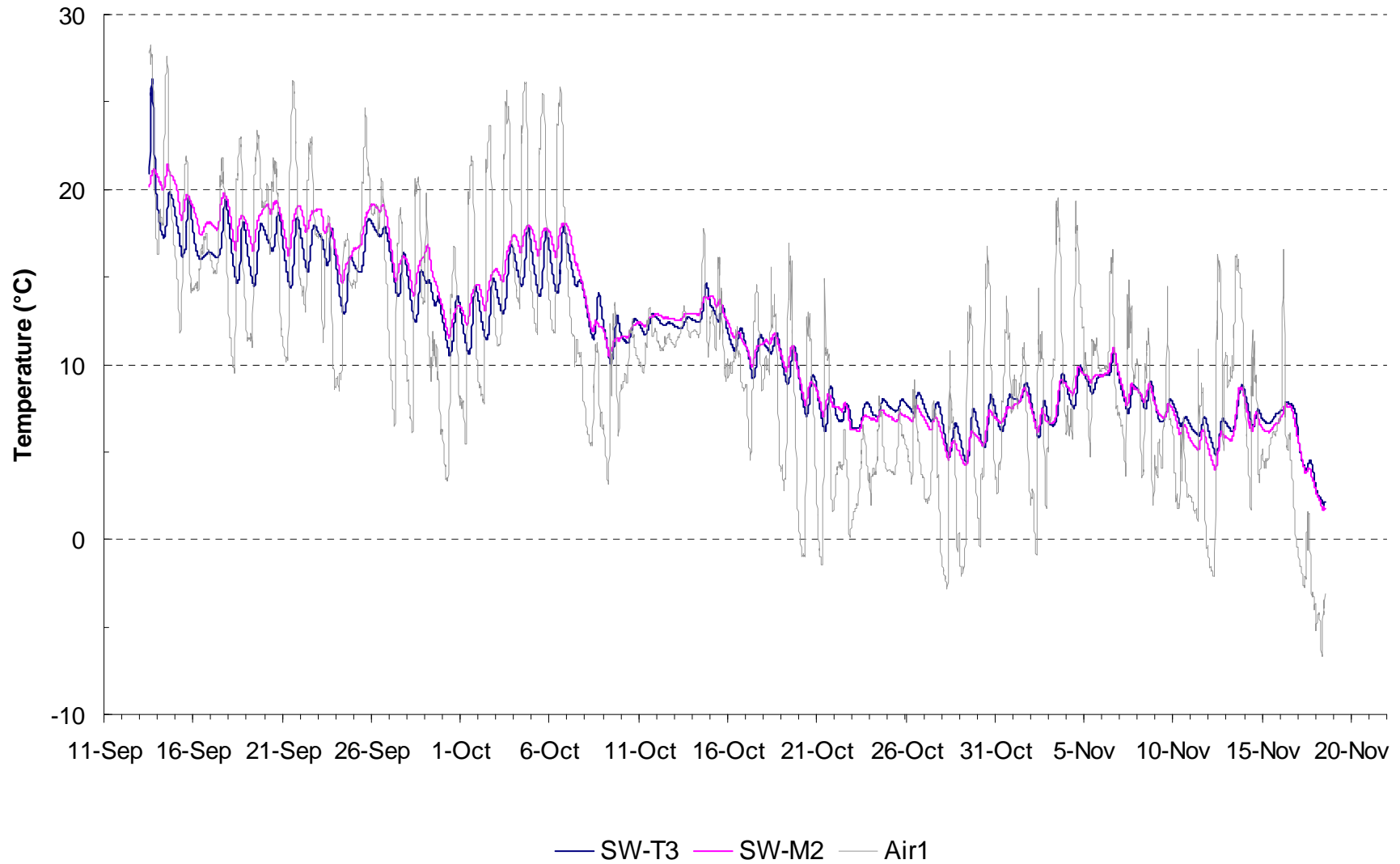


Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
C4

Title
**MOUNTSBERG CREEK
TEMPERATURES, 2005**

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2008-11-14 10:18AM By: bcowper



November 2008
1609-60345

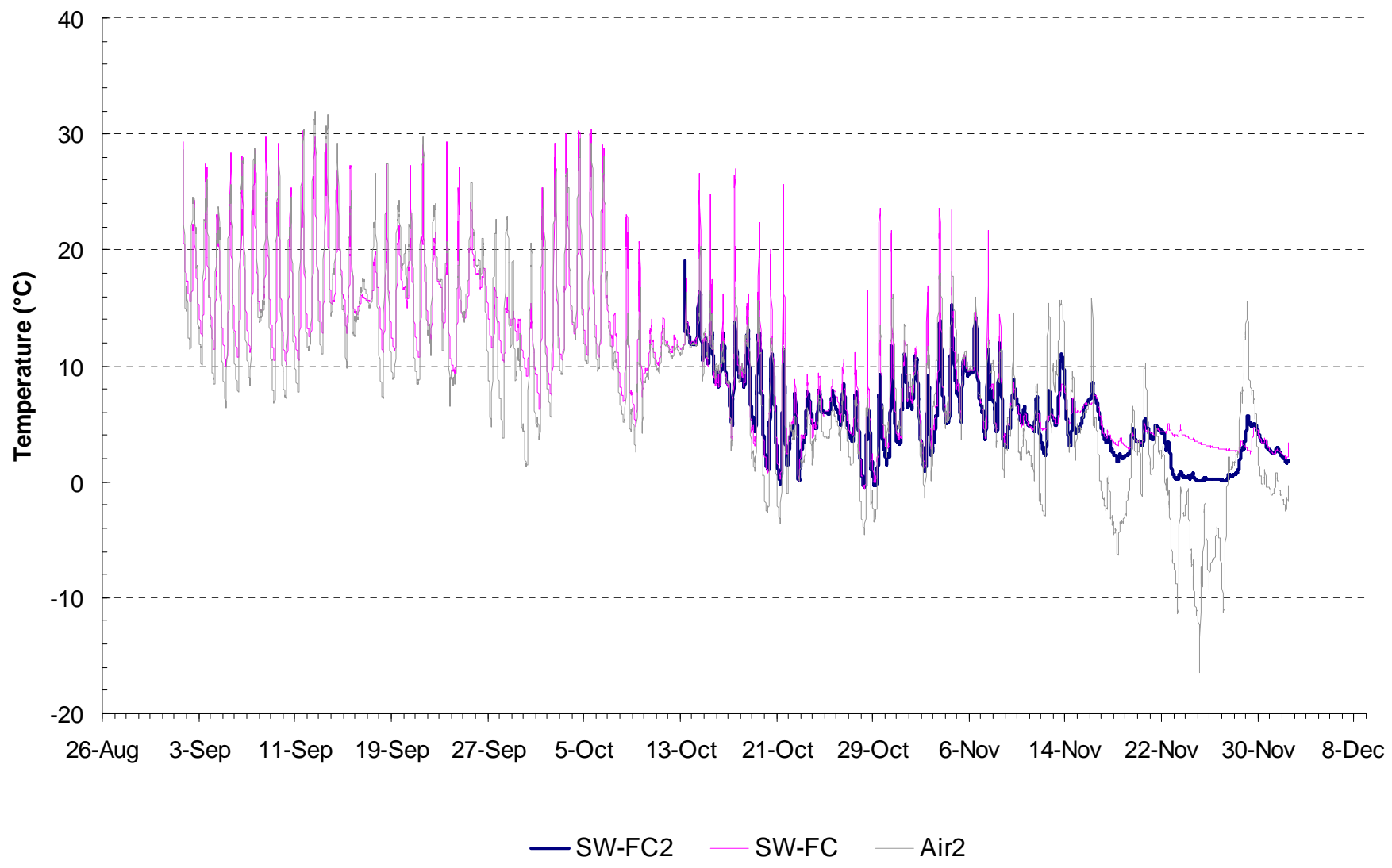


Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
C5

Title
MOUNTSBERG CREEK TRIBUTARY
TEMPERATURES, 2005

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2008-11-14 10:24M By: bcowper



November 2008
1609-60345

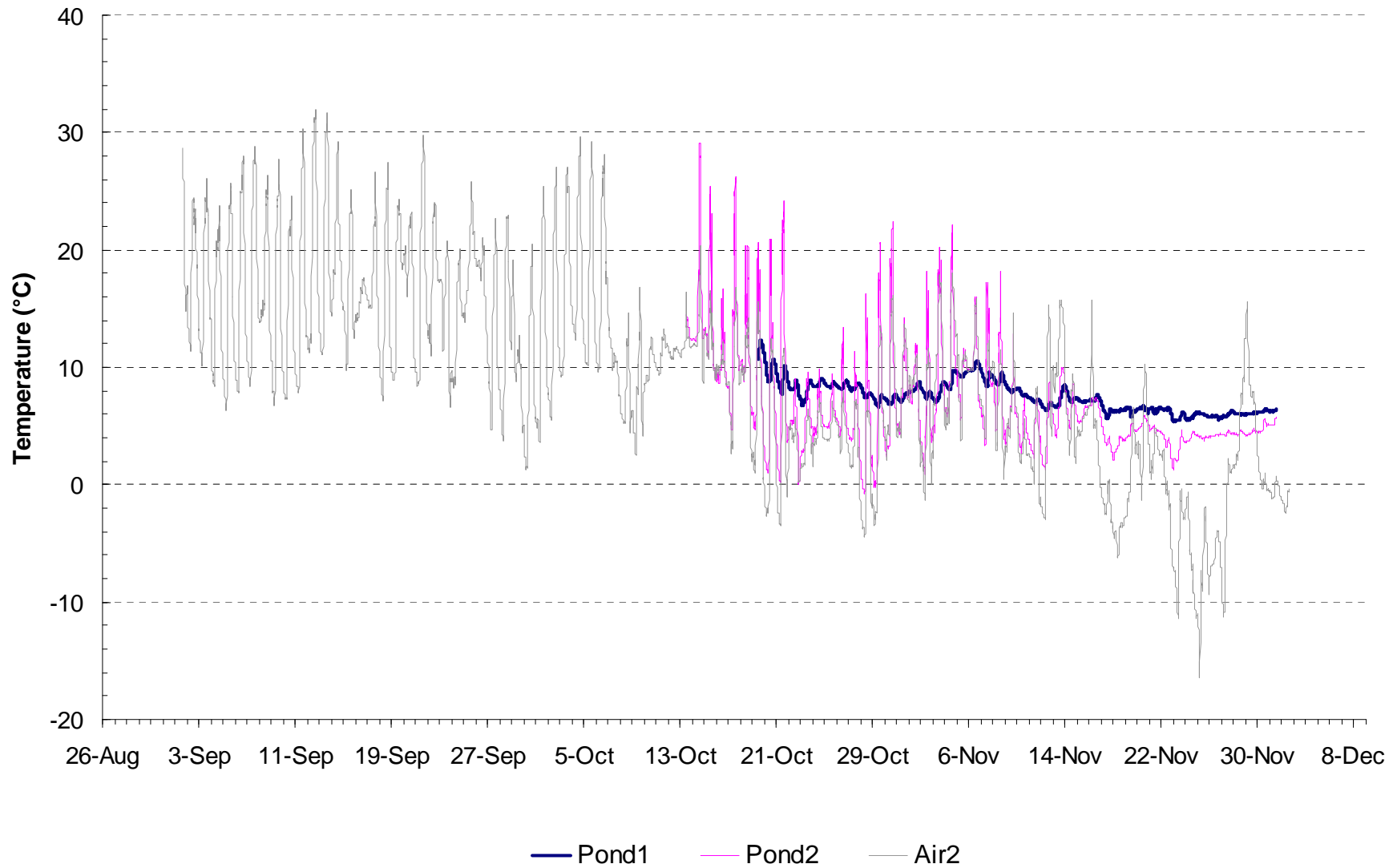


Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
C6

Title
FLAMBOROUGH CREEK
TEMPERATURES, 2005

\\C:\1715-01\work_group\16090\active\160960345\drawing\CAD\CHARTS 20081028\CHARTS App C.dwg [ON-SITE TEMPS 2005]
2008-11-14 10:36AM By: bcowper



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1609-60345



Client/Project
SMC FLAMBOROUGH QUARRY
HYDROLOGICAL REPORT

Figure No.
C7

Title
ON-SITE POND
TEMPERATURES, 2005

Jim Perrone, M.Sc., B. Sc., P. Eng.

Water Resources Engineer, Stantec Consulting Ltd.

Jim Perrone is a Water Resources Engineer and environmental modelling specialist. As a hydrologist, Jim's efforts have involved watershed water quantity and quality monitoring, as well as the analysis and modeling of hydrology and water quality. At Stantec, Jim has established and maintained hydrologic monitoring networks along several surface water bodies including Bailey Creek (Adjala), East Carlton Creek (Markham), and 14-Mile Creek (Oakville) for various projects. He has developed, modified, and calibrated a variety of mathematical models to characterize aquatic and terrestrial environments and assisted in study design development, environmental assessments, environmental permitting and environmental monitoring studies. His expertise has been applied to the pulp and paper, mining, and agricultural sectors. His work has been published in several scientific journals.