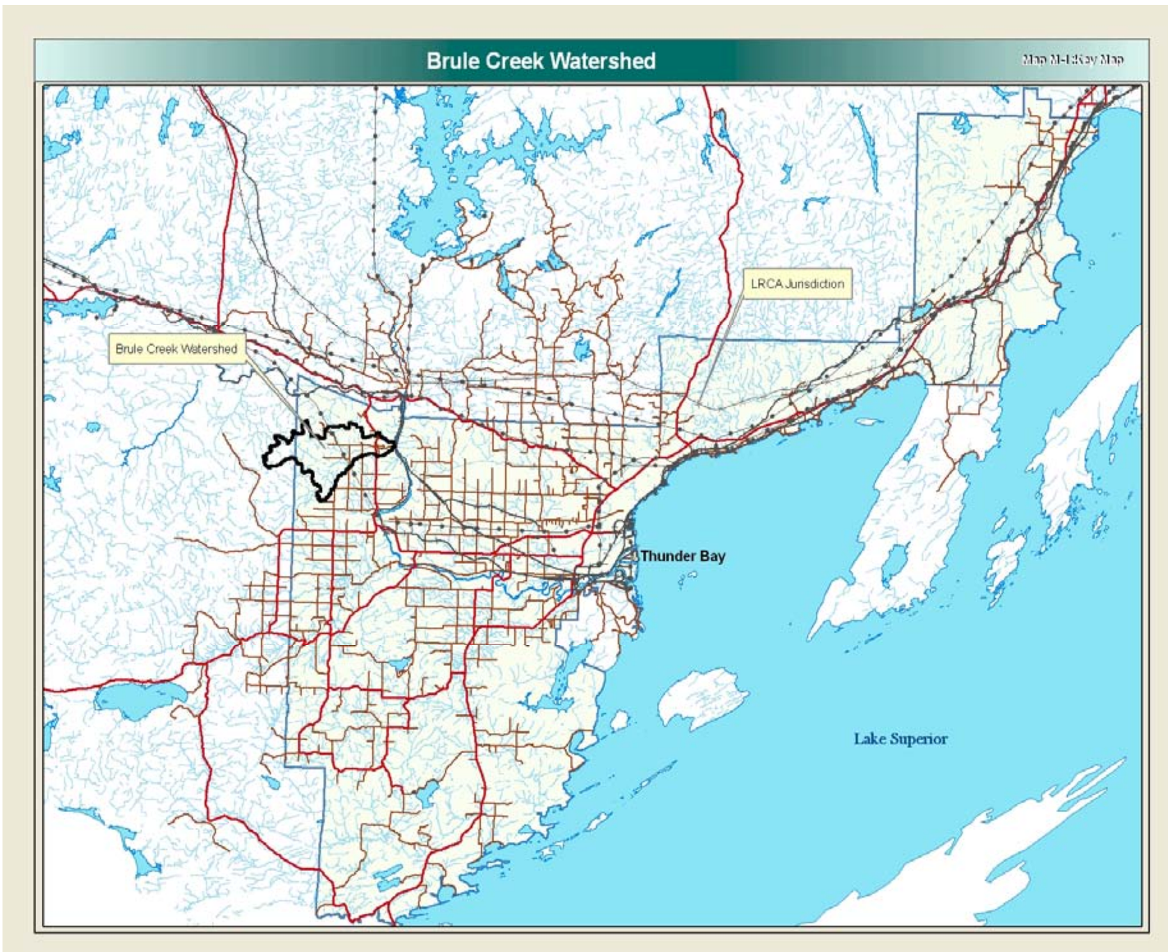
Brule Creek Watershed Assessment

2007



Lakehead Region Conservation Authority
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Brule Creek Watershed Assessment

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Executive Summary

The Brule Creek Watershed has an area of 56.95 square kilometres (km^2) and was located north of Kakabeka Falls in the Township of Conmee. The watershed contains a few small inland lakes: Gold Lake, Marble Lake, Cedarlimb Lake, and the largest, Stephens Lake. Each of these lakes contributes to the stream flow of the Kaministiquia River, which then drains into Lake Superior.

For this report, four sample sites located within the Brule Creek Watershed were chosen based on a variety of attributes; accessibility, physical features, land use, areas that may experience human impacts as well as inlet points which were used as a base reference.

The physical features of this watershed include: wooded areas, wetlands, rural residential dwellings and farmlands. The watershed also crosses Highway 11/17 and the Canadian National (CN) Railway. The watershed can be characterized as mostly undeveloped with some timber harvesting.

The surficial geology that comprises the Brule Creek Watershed was mainly glaciofluvial till deposits, scattered rock knob outcroppings with patches of organic terrain from marshlands. The forest surrounding the watershed was composed of hardwoods and softwoods with rich herb and shrub diversity.

At each of the four sample locations, surface water samples and field measurements were collected on July 20th and August 8th, 2007. Surface water samples were analyzed by ALS Laboratory Group for total suspended solids, turbidity, conductivity, total phosphorus and a full metal scan. Field and laboratory results were compared to the Ministry of Environment (MOE) Provincial Water Quality Objectives (PWQO). Iron was found to be above the PWQO guideline level at each of the sample sites and was likely due to natural sources, such as iron-rich rocks. Aluminum was also found to be above the PWQO guidelines at Sample Site 1 and Sample Site 3; this also may be caused by natural sources. In addition, total phosphorus was found to be in excess at Sample Site 3. Phosphorus levels may be high due to a significant amount of vegetation at this sample site.

Field measurements indicated that pH levels during the assessment were all within the PWQO recommended range. The pH levels were slightly basic, ranging from 7.23 to 8.20. The water temperatures measured during the assessment ranged from 13.76 degrees Celsius to 17.98 degrees Celsius. Both the benthic life and aquatic vegetation appeared to be dynamic. The species found along the watershed indicated an overall healthy ecosystem.

There was little evidence of human disturbances throughout the sites, although a farmer did block half of his private culvert with a board on the upstream side, which was probably done to raise pond water levels. Natural disturbances found within the watershed included beaver damming, a minimal amount of erosion, and logs and other debris in the creek. During the study most of the water crossings appeared to be functional, however culvert 3b was bent upward on the upstream side and culvert 3a was rusted and eroded on the downstream side. Culvert 4a was also found to be dry at the time of sampling.

As of August 2007, the data collected during the assessment of the Brule Creek Watershed suggests that it is a relatively healthy watercourse that is not being significantly affected by surrounding activities, such as forestry or residential use. It is recommended that Brule Creek be monitored in the future as personnel and funding permit.

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1.0 Introduction

1.1 Watershed Assessment Objectives

The purpose of the Brule Creek Watershed Assessment was to establish a baseline inventory of the watershed's characteristics and to identify the physical condition of Brule Creek's water quality and quantity. In general, there was very little documentation of the condition of many of the smaller steams in the Thunder Bay area.

The goal of the report was to document the conditions of the watershed as observed in the summer of 2007, and ultimately use the information to develop and maintain programs to sustain a healthy ecosystem, consistent with the Natural Hazards and Natural Heritage Policies of the Province of Ontario. This report attempts to provide an understanding of the ecological form and function of the watershed.

The main objectives of assessing this watershed are as follows:

- Determine creek accessibility.
- Select representative sample sites of the watershed.
- Collect field measurements at the chosen sites including: pH, turbidity, width, depth, flow, conductivity, dissolved oxygen, water and air temperatures.
- Collect water samples for laboratory analysis.
- Identify and classify the flora and fauna observed along the watershed.
- Summarize information regarding the natural features of the watershed such as: land uses, recreational uses, transportation corridors, soil types and pollution.
- Conduct and document an inventory of active erosion sites.
- Survey the condition of bridge/culvert stream crossings and structures.
- Interpret results to create a record of the status and health of the watershed.

1.2 Watershed Description

A watershed is comprised of land drained by a river and its tributaries. A sub-watershed is comprised of the land drained by an individual tributary to the main watercourse (MOE 1993). All water that flows into Brule Creek from a lake or stream and all precipitation runoff from the land surrounding these areas define the Brule Creek Watershed. Brule Creek was identified as a sub-watershed, as it does not directly drain into an ocean, however it was connected to a watershed that eventually does. Watersheds also act as boundaries for land use planning in order to examine the relationships between the natural environment and human activities.

The Brule Creek Watershed has an area of 56.95 square kilometers (km^2) and is located west of Thunder Bay in the Township of Conmee; as shown on the Key Plan Map, M-1. The watershed was riddled with small streams and wetlands, and also contained several small lakes. Notable lakes were Gold Lake, Marble Lake, Cedarlimb Lake, and Stephens Lake, which was the largest in the watershed. All the streams converge roughly in the middle of the watershed and drain into the Kaministiquia River system as shown on the Site Plan Map M-2.

The physical features of the watershed included: wooded areas, wetlands, residential dwellings and farming property. The watershed can be characterized as mostly undeveloped with some timber harvesting. The watershed could not be properly zoned due to lack of zoning maps.

1.3 Surficial Geology

The surficial geology of an area determines and can affect how water flows and travels through a watershed. Surface slopes and soil types can affect how fast water is absorbed and can change its runoff coefficient. All of the sample sites occurred in a clayey glaciolacustrine plain. Characteristics of this geology are low undulating to moderate undulating relief and usually dry drainage. Surficial geology is summarized on Map M-3.

An Area of Natural Scientific Interest (ANSI) is located in this watershed, known as the Mokomon ANSI. The ANSI is comprised of a small but representative section of the Marks Moraine. The ANSI is located along Brule Creek beginning at UTM coordinate 5373397 N, 306943 E, which is in the southeastern area of the watershed, south of the confluence with the Kaministiquia River. The Marks Moraine is a 50 km long feature formed during glacial retreat and varies from 1.6 to 4.6 kilometers in width. A moraine is formed by the accumulation of sorted and unsorted till that is deposited by a retreating glacier. This glacier can alter the topography and vegetation types in that area.

Characteristic elements within the site include: ice contact stratified drift, a capping of clay silty till and a broken ridge cut by fluvial channels. The portion of the moraine within the ANSI contains a hummocky ridge of high ground and has two distinct units that make up the site; the northern unit consists of ice stratified drift deposits, and the southern unit is composed of outwash sand and very little gravel.

Presently there is a gravel pit situated south of Mokomon Road that was occasionally used, and construction of the CN railway in the past may have moved portions of the moraine from the northeast corner (Ministry of Natural Resources ANSI Sheet).

Other forms of geological processes exhibited within Brule Creek included: rock knob scattered throughout, sandy till ground moraine in the centre and pockets of organic terrain in marshlands to the north, east and south. Rock knob is characterized as an irregular bedrock surface and many slopes with varying steepness. Most of the watershed was comprised of ground moraine till deposits with varying composition. Organic terrain is formed from the constant cycling of plant life that eventually forms a thick layer of rich, moist organic soil.

Local surficial relief ranges from low to medium, with occasional highs. The majority of the watershed exhibited dry to moderate drainage that indicates swift moving surface and groundwater. There was also evidence of glaciofluvial delta deposits on the southern end of the watershed. Surficial geology maps used to document this information can be found in the *Ontario Geological Survey Map 5047 Data Base Map*.

1.4 Soils

The soils of Brule Creek mainly consisted of till of varying size that was deposited by a retreating ice lobe thousands of years ago. Although till is generally composed of an assortment of particle sizes (clay, silt, sand, gravel, cobbles, and boulders), till deposits in this area have a high sand and boulder content. The thickness of till deposit can vary from 1 to 3 meters, and essentially mask the effect of bedrock topography. Typically, till deposits fill depressions and holes first, causing the ground to be thicker in those areas, and thinner over the top of bedrock ridges. Soils characterization is illustrated on Map M-4.

Scattered instances of organic terrain can be found throughout the watershed. These areas were an accumulation of peat and muck in wetland areas. These organic terrains overlay the till deposits in poorly drained depressions, and can vary in thickness depending on productivity.

Soil erosion was an important factor to consider when conducting the watershed assessments. Erosion is defined as the displacement of soil by action of wind, water and ice, and human alterations on the soil. The degree of erosion depends on the type of soil and the degree of slope found at the site. Additionally, moisture and vegetation have significant impacts on reducing erosion. Organic terrain has a low erosion hazard, while exposed sand or dirt may have a higher erosion hazard. Vegetation is an important factor in the prevention of erosion. The root system of plants helps hold the soil in place, while the plant portion serves as a buffer to wind and rain that may erode surface soils. Erosion along the majority of Brule Creek was low. There was a significant amount of vegetation at all culverts and bridges to prevent sediment from shifting.

1.5 Forest Ecosystem Classification

The Ministry of Natural Resources Forest Resource Inventory (FRI) indicates that the majority of the Brule Creek watershed is mixed wood forest, containing a variety of conifer and deciduous trees located on different soil types at varying elevations. The FRI is illustrated on Map M-5.

Sample sites were classified using the Field Guide to the Forest Ecosystem Classification for northwestern Ontario. Each site was assessed in a 10 meter radius using a dichotomous key. A dichotomous key is a series of questions to help the field technician determine the vegetation type (V-type) of that particular area. A V-type is the classification of the vegetation in a particular area. It is important to remember that these classifications are a general overview of a larger area and no site was exactly the same as another and differences or inconsistencies between the V-types should be expected.

Site 1 - V6 class: Trembling aspen (White birch) – Balsam Fir / Mountain Maple.
Site 2 - V1 class: Balsam Poplar Hardwood and Mixed wood.
Site 3 - V24 class: White Spruce – Balsam Fir / Shrub Rich.
Site 4 - V7 class: Trembling Aspen – Balsam Fir / Balsam Fir Shrub.

Each V-type above is described in further detail in Appendix E.

1.6 Climate

This section outlines the overall weather conditions and climate, as well as any weather restrictions or emergencies declared during the summer of the assessment. The weather plays an important role in water quality, impacting things such as precipitation and water temperature. Over the course of the summer of 2007, temperatures were high and very little precipitation occurred, resulting in forest fires and fire restrictions.

From November 2006 until July 3rd, 2007, Brule Creek was in a confirmed Level II Low Water Condition, indicating that precipitation was less than 60% of the monthly average. As a result, the public was asked to voluntarily reduce their water consumption by 20%. In June of 2007, the area received above average precipitation. This was the first month in a year where above average precipitation was observed in the area. The precipitation received in June resulted in a three-month average precipitation level of 60-80% of average. The additional rain resulted in the Low Water Condition to be downgraded to a Level I.

During the month of July, air temperatures averaged 24^{o}C. However, a heat spell from the 22nd to 26th broke temperature records for the area which drove the MNR to instate high to extreme fire hazards as well as issue a fire ban. However, the temperatures proceeded to drop between the 10th to 15th of July where variable rain fell in the area, resulting in high water levels in the Kaministiquia River and surrounding lakes. Despite the week of rain, it did little to cool northern Ontario, and heat persisted.

In the month of August the temperature was consistently hot with very little precipitation. Throughout the course of the month, a total of 24mm of precipitation was recorded. The average temperature during August was 24.1ºC. Over 1400 fires broke out across Ontario, prompting the MNR to implement fire restrictions and fire bans in certain areas.

The culmination of these climate effects on the watershed had lead to overall low flows, which have also contributed to higher turbidity and warmer water temperatures. The warm water temperatures in turn can affect dissolved oxygen, minerals, chemicals, and the water's ability to adapt to these changes. Water temperature is also an important variable to consider when assessing overall watershed health.

2.0 Methodology

General techniques used in the Watershed Assessment for data collection are summarized in Appendix B.

2.1 Sample Site Selection

Four sample sites were selected along Brule Creek to represent the Brule Creek Watershed. Sites were chosen in areas that had a greater potential to impact the watershed. These sites were recorded with the use of the Trimble Geo XH GPS unit. Sample sites are illustrated on Map M-2.

Sample sites were located near roadways and at locations that incorporate flow from all portions of the watershed. Sample Site 1 was located at the confluence of Brule Creek and the Kaministiquia River. This site was chosen as a representation of the entire watershed. Sample Site 2 was located downstream of Highway 11/17 to monitor the impact of road traffic and road salt on the creek. Sample Site 3 was located south of Pokki Road where streams from the south and west converge. Sample Site 3 was considered to assess water quality prior to the potential addition of runoff from farms, roads, and other areas that border Brule creek. Sample Site 4 was located south of Mokomon Road at the downstream end of a large marshland. This site acted as an indicator of the waters entering from the north.

2.2 Water Sampling

On-site analysis was performed for conductivity, pH, water and air temperature, dissolved oxygen and turbidity using an YSI 556 MPS Meter and a Global Water 770 Turbidity Meter. The Trimble Geo XH GPS unit was used to record the UTM co-ordinates and the elevation of each sample site. The width and depth of the creek was determined by using a measuring tape. The flow (metres/second) was estimated by recording the travel time of a stick, floating a pre-determined distance down the creek.

Water samples were collected in laboratory supplied bottles and analyzed by ALS Laboratory Group in Thunder Bay, Ontario. Samples were analyzed for turbidity, conductivity, TDS, phosphorus, and metals.

2.3 Flora and Fauna Inventory

Several field guides were used to identify the tree, shrub, and herb species observed at the sample sites. Benthic and animal species were also identified and documented when encountered. The flora and fauna can give an indication of the health of the Brule Creek Watershed and were documented for further studies. Common and Latin names of plant and animal species are summarized in Appendix A.

2.4 Watercourse Crossings

Known culvert locations were inspected and general culvert data was collected at each site. Bridge locations were also located and inspected. The physical characteristics were measured for each culvert (Appendix C), and bridge (Appendix D). UTM coordinates were recorded, photographs were taken and general observations were recorded at each location. Culvert and bridge locations are illustrated on Map M-2.

2.5 Equipment Used

Equipment used in the Watershed Assessment:

- Maps – road and topographic.
- Trimble Geo XH GPS unit.
- Measuring tape and measuring reel.
- YSI 556 Multi Probe System – Field tests for dissolved oxygen, water temperature, pH, conductivity and total dissolved solids.
- Global Water WQ770 Turbidity Meter.
- Stick to measure water flow.
- Stopwatch to measure water flow.
- Air temperature thermometer.
- Dip net.
- Chest waders.
- Pen, paper, clipboard.
- Sample bottles from ALS Laboratory Group.
- Cooler and ice for sample storage prior to delivery to laboratory
- Digital camera
- Field guides:
    - *A Field Guide to Trees and Shrubs*
    - *A Field Guide to Wildflowers of North Eastern and North-Central North America*
    - Trees in Canada

3.0 Applicable Criteria

In general, surface and groundwater quality in Ontario needs to be managed to ensure a fair sharing, conservation and sustainable future for the resource. The Provincial Water Quality Objectives (PWQO) dated July 1994 is a guideline produced by the Ministry of the Environment (MOE) which establishes acceptable limits for water quality and quantity, consistent with the protection of the aquatic ecosystem and groundwater. The goal of the PWQO is "*to ensure that the surface waters of the province are of the quality which is satisfactory for aquatic life and recreation*". The PWQO guidelines have been used to compare field and laboratory results for the Brule Creek Watershed in order to gauge the overall health of the watershed.

The PWQO applicable to this report have been summarized in Appendix F. A general overview of applicable water quality parameters and their relevance to water quality have been summarized in Appendix G.

Other non-chemical factors such as loss of habitat and sedimentation have been considered, however were not comparable to any quantifiable scale.

4.0 Results and Discussion

Laboratory water quality results have been summarized (Appendix H) and Laboratory Certificates of Analysis are attached. Water quality results, field measurement data and observations for each sample site have been summarized in the tables below.

4.1 Sample Site 1

Table 4.1.1: Location Reference for Sample Site 1

Location Description	The confluence of Brule Creek and the Kaministiquia River
GPS Coordinate	5373576.46 m N; 307351.96 m E
Altitude/Elevation (m)	302.84 MSL (Mean Sea Level)

Table 4.1.2: Field Measurement Data for Sample Site 1

	July 20, 2007	**August 8, 2007**
Channel Width (m)	9.14	8.40
Channel Depth (cm)	113	105
Flow (m/s)	0.066	0.045
Air Temperature (°C)	23	19
Water Temperature (°C)	17.34	15.30
pH	8.15	8.20
Conductivity (mS/cm)	0.267	0.292
Total Dissolved Solids (mg/L)	173	190
Dissolved Oxygen (mg/L)	10.35	9.94
Dissolved Oxygen Saturation (%)	108.0	99.2
Turbidity (NTU)	11.5	20.0

Bold indicates above PWQO guidelines.

Table 4.1.3: Laboratory Water Quality Results for Sample Site 1

	July 20, 2007	**August 8, 2007**
Turbidity (NTU)	4.4	0.67
Conductivity (mS/cm)	0.229	0.251
Total Phosphorus (µg/L)	24	11
Total Dissolved Solids (mg/L)	180	200
Aluminum (µg/L)	**90**	10
Cadmium (µg/L)	< 0.09	< 0.09
Iron (µg/L)	**740**	160
Lead (µg/L)	< 1	< 1

Bold indicates above PWQO guidelines.

Table 4.1.4: Flora and Fauna Observed at Sample Site 1

Tree Species	balsam fir, white spruce, black ash, balsam poplar
Shrub Species	speckled alder, green alder, pin cherry, willow, wild red raspberry, mountain maple, bladder nut, late purple aster, clover, water plantain
Herb Species	ox eye daisy, yarrow, Canada goldenrod, buttercup, dandelion, blue joint grass, northern oak fern, cow vetch, flat topped aster, ground pine, horsetail
Mosses/Aquatic plants	Schreiber's moss
Benthic species/ Insects	water striders, minnows, crayfish, leeches
Terrestrial wildlife	None seen during study
Additional comments	Site was downstream of railway

Table 4.1.5: Physical Attributes of Sample Site 1

In-stream material	Creek bed Characteristics	Bank Stability	Terrain Characteristics	Stream Cover
Rocks and large stones. Some sediment in pool.	Unsorted rocks. Upward faces covered in algae.	Overall stable. Some small areas of exposed soil.	Shallow soil.	Low cover.

4.1.6 Discussion

Sample Site 1 was located 300-metres south of the end of Mokomon Road along the Canadian National railway track. This site was also the outlet pool of culvert 1. This site represents all surface water coming from the watershed into the Kaministiquia River. The creek was clear of debris, was relatively open to the sun, and the creek bed had a wide variety of stones and rocks that created riffles on the water surface. The banks of the creek were in good condition, likely a result of the rocks and vegetation that provided protection to the soil in most areas of the site.

The pH level at Sample Site 1 was the highest of all the sites, but was well within the PWQO guidelines. The level of TDS was high, although this was not surprising as this site was located where the creek reaches came together, combining all their dissolved materials. Dissolved oxygen saturation and concentration were within PWQO guidelines. Turbidity at this site was slightly higher than the other sites but still within acceptable PWQO levels.

Chemical analysis of Sample Site 1 determined that all of the analyzed parameters were within the PWQO guidelines with the exception of iron and aluminum. Aluminum levels may be high if it were in a form that was unusable by biological organisms. Iron levels were most likely high due to natural sources, such as iron-rich rocks releasing the mineral into the water. Iron levels may also be high due to some culverts that have rusted and may be contributing iron to the water.

During the second sampling session on August 8, 2007, Sample Site 1 had no parameters exceeding PWQO standards.

4.2 Sample Site 2

Table 4.2.1: Location Reference for Sample Site 2

Location Description	East of Hwy 11/17 culverts
GPS Coordinate	5373440.88 m N; 305096.23 m E
Altitude/Elevation (m)	372.46 MSL

Table 4.2.2: Field Measurement Data for Sample Site 2

	July 20, 2007	August 8, 2007
Channel Width (m)	5.70	5.00
Channel Depth (cm)	108	106
Flow (m/s)	0.103	0.121
Air Temperature (°C)	23	20
Water Temperature (°C)	16.06	13.76
PH	7.78	8.12
Conductivity (mS/cm)	0.255	0.288
Total Dissolved Solids (mg/L)	166	187
Dissolved Oxygen (mg/L)	10.05	10.61
Dissolved Oxygen Saturation (%)	102.0	102.5
Turbidity (NTU)	23.5	8.5

Bold indicates above PWQO guidelines.

Table 4.2.3: Laboratory Water Quality Results for Sample Site 2

	July 20, 2007	August 8, 2007
Turbidity (NTU)	4.3	2.1
Conductivity (mS/cm)	0.167	0.247
Total Phosphorus (µg/L)	22	17
Total Dissolved Solids (mg/L)	140	200
Aluminum (µg/L)	40	40
Cadmium (µg/L)	< 0.09	< 0.09
Iron (µg/L)	**730**	**430**
Lead (µg/L)	< 1	< 1

Bold indicates above PWQO guidelines.

Table 4.2.4: Flora and Fauna Observed at Sample Site 2

Tree Species	balsam fir, balsam poplar, white spruce
Shrub Species	green alder, willow, wild red raspberry, Saskatoon berry, choke cherry, maple viburnum, prickly rose, beaked hazel, late purple aster, clover
Herb Species	dandelion, ox eye daisy, Canada goldenrod, fireweed, blue joint grass, spotted Joe-pye, glade fern, dwarf raspberry, yarrow, sedge, cow vetch
Mosses/Aquatic Plants	Schreiber's moss
Benthic species/Insects	large crayfish, snails, water striders
Terrestrial wildlife	None observed at time of study
Additional Comments	Located downstream of Hwy 11/17

Table 4.2.5: Physical Attributes of Sample Site 2

In-stream material	Creek bed Characteristics	Bank Stability	Terrain Characteristics	Stream Cover
Unsorted stones, sandy substrate.	Two logs in river downstream.	Vegetation up to water edge, very stable.	Grassy along water edge.	Tree canopy begins to cover stream further down.

4.2.6 Discussion

Sample Site 2 was located directly downstream of Highway 11/17, in order to observe water quality changes that may occur as a result of highway traffic. The sample was taken at the outlet pool of culverts 3a and 3b, where flow was steady, and water levels were fairly deep.

The vegetation at this site was composed mostly of grasses and shrubs with little over-story influence.

The pH, as well as the dissolved oxygen concentration and saturation at this site met the criteria of the PWQO. The flow at Sample Site 2 was greater than at any of the other three locations. The increased flow may have a direct association with the slightly higher turbidity and total dissolved solids levels. As a secondary effect, local traffic may also contribute to the turbidity and total dissolved solids by introducing blown dust from the roads and other various materials into the creek.

Chemical analysis for Sample Site 2 returned iron levels (730 µg/L and 430 µg/L) which exceed the maximum PWQO guideline of 300 µg/L. The high iron content at this location may be due to iron-rich rocks in the immediate area or the rusted culverts under the highway immediately upstream of the site. Both culverts 3a and 3b exhibited signs of advanced rusting, to the point where water was flowing through a rusted-out hole in the base of culvert 3a.

The iron levels at Sample Site 2 were lower than upstream Sample Sites 3 and 4. This indicates that the excess iron levels found at Sample Site 2 may have been integrated into the creek somewhere between Sample Site 2 and Sample Sites 3 and 4.

4.3 Sample Site 3

Table 4.3.1: Location Reference for Sample Site 3

Location Description	South of Pokki Road Bridge
GPS Coordinate	5372205.20 m N; 301023.73 m E
Altitude/Elevation (m)	429.34 MSL

Table 4.3.2: Field Measurement Data for Sample Site 3

	July 20, 2007	**August 8, 2007**
Channel Width (m)	8.33	8.20
Channel Depth (cm)	140	160
Flow (m/s)	0.026	0.040
Air Temperature (°C)	23	21
Water Temperature (°C)	17.78	17.98
pH	7.54	7.76
Conductivity (mS/cm)	0.166	0.314
Total Dissolved Solids (mg/L)	108	204
Dissolved Oxygen (mg/L)	8.78	5.70
Dissolved Oxygen Saturation (%)	92.3	60.2
Turbidity (NTU)	23.5	26.5

Table 4.3.3: Laboratory Water Quality Results for Sample Site 3

	July 20, 2007	**August 8, 2007**
Turbidity (NTU)	3.6	2.5
Conductivity (mS/cm)	0.173	0.183
Total Phosphorus (µg/L)	**30**	27
Total Dissolved Solids (mg/L)	170	160
Aluminum (µg/L)	**110**	30
Cadmium (µg/L)	< 0.09	< 0.09
Iron (µg/L)	**990**	**680**
Lead (µg/L)	< 1	< 1

Bold indicates above PWQO guidelines.

Table 4.3.4: Flora and Fauna Observed at Sample Site 3

Tree Species	balsam fir, white spruce, trembling aspen
Shrub Species	green alder, willow spp., speckled alder, wild red raspberry, northern oak fern, prickly wild rose
Herb Species	blue joint grass, ox eye daisy, goldenrod, clover, late purple aster, spotted joe pye, yarrows, thistles, dwarf raspberry
Mosses/Aquatic Plants	shaggy moss
Benthic Species/Insects	frogs, water striders
Terrestrial wildlife	None observed at time of sampling
Additional Comments	Evidence of fish species

Table 4.3.5: Physical Attributes of Sample Site 3

In-stream material	Creek bed Characteristics	Bank Stability	Terrain Characteristics	Stream Cover
Decaying organics, sticks and large boulders.	Muddy, deep organic layer.	No erosion, grasses to water's edge.	Tall grasses along waters edge, alder thickets and conifer over story.	No cover.

4.3.6 Discussion

Sample Site 3 was located just upstream of Bridge 5. A large volume of slow moving water characterizes this site. It was chosen as a sample site because it represents the combined waters of the south and west portions of the watershed.

Dense grasses and alders hug the riverbanks with thick conifer over story several feet away. This sample site had the deepest water and steepest slope of the four sites making it difficult to take readings and samples from the middle of the stream. The presence of fish was notable (simply because the other sample sites and many of the streams in the watershed were too shallow for fish habitat).

Iron concentrations were recorded as being over three times the amount indicated in the PWQO guidelines. However, iron is not considered to be hazardous to human and animal health. Iron bacteria were noted at Culverts 9 and 10. Iron bacteria proliferates in waters with high iron content, and use iron to produce a slimy brown, rust colored substance similar in look to algae. This bacterium was found in abundance along the calm, slow moving waters before and after the beaver dams in the area. The iron may have come from a clear-cut portion of land that has large areas of exposed bedrock, or from a series of rusted culverts along Pokki Road.

Aluminum concentrations were also found as being above the PWQO guidelines. High levels aluminum may interfere with various aquatic species, as well as the gills on fish that reside in the creek. There is a greater risk of chronic effects to these aquatic species if exposed to high aluminum concentrations for a significant duration of time.

Phosphorus concentrations reached the limit of PWQO standards, although did not exceed them. Phosphorus is a limiting factor for many algae and plants. If phosphorus is easily available, algal blooms may occur and as a consequence consume more dissolved oxygen, taking it away from other organisms. There was evidence of algae along the riverbanks, growing on submerged branches and aquatic plants.

During the second set of samples, iron was measured as being 680 μg/L, over twice the recommended level according to the PWQO. Iron consuming bacteria may be contributing to the reduction of iron in the watercourse. Phosphorus levels decreased slightly to below PWQO standards, indicating a healthy balance had been restored.

4.4 Sample Site 4

Table 4.4.1: Location Reference for Sample Site 4

Location Description	South of Mokomon Road Culvert
GPS Coordinate	5373722.64 m N; 300941.31 m E
Altitude/Elevation (m)	439.03 MSL

Table 4.4.2: Field Measurement Data for Sample Site 4

	July 20, 2007	**August 11, 2006**
Channel Width (m)	3.76	3.80
Channel Depth (cm)	103	91
Flow (m/s)	0.082	0.025
Air Temperature (°C)	23	21
Water Temperature (°C)	16.52	13.77
pH	7.23	7.65
Conductivity (mS/cm)	0.172	0.207
Total Dissolved Solids (mg/L)	112	135
Dissolved Oxygen (mg/L)	6.78	6.95
Dissolved Oxygen Saturation (%)	69.3	67.2
Turbidity (NTU)	23.5	11.5

Table 4.4.3: Laboratory Water Quality Results for Sample Site 4

	July 20, 2007	August 8, 2007
Turbidity (NTU)	2.3	1.6
Conductivity (mS/cm)	0.220	0.187
Total Phosphorus (μg/L)	24	**37**
Total Dissolved Solids (mg/L)	180	190
Aluminum (μg/L)	40	20
Cadmium (μg/L)	< 0.09	< 0.09
Iron (μg/L)	**550**	**1420**
Lead (μg/L)	< 1	< 1

Bold indicates above PWQO guidelines.

Table 4.4.4: Flora and Fauna Observed at Sample Site 4

Tree Species	white birch, balsam fir, trembling aspen, white spruce
Shrub Species	mountain maple, green alder, speckled alder, wild red raspberry, choke cherry, beaked hazel, late purple aster
Herb Species	maple viburnum, cattail, yarrow, blue joint grass, glade fern, sedge, large leaved aster, spotted Joe-pye, ox-eye daisy, dandelion, dwarf raspberry
Mosses/Aquatic Plants	Schreiber's moss
Benthic Species/Insects	Frogs, water striders
Terrestrial Wildlife	None observed during assessment
Additional Comments	Outlet of northern marshlands in the watershed

Table 4.4.5: Physical Attributes of Sample Site 4

In-stream material	Creek bed Characteristics	Bank Stability	Terrain Characteristics	Stream Cover
Some organic debris, large rocks.	Stony bed, rocks covered in moss and algae.	Muddy banks.	Muddy and moist soils.	Lots of mid canopy cover.

4.4.6 Discussion

Sample Site 4 was located just south of culvert 7. This site was chosen as a reference for the northern reaches and to assess the water quality of this area. This differs from the other sample sites as it was the only site where there was an outlet for a large wetland. Water flow is low but consistent through this site and the wetland has slow drainage due to the grassy and herbaceous nature of the land. The area around the sample site was a transition zone between the wetland and the surrounding forests, making for some unique intermingling of plant species in a small area.

This site had the lowest dissolved oxygen (DO) measurement of all four sites, possibly because of the marshland and all of its algae, grasses and benthic insects consuming the dissolved oxygen for metabolic processes. At this sample site, iron was found to be above the standards set by the PWQO; however iron is not harmful to fish, wildlife, or humans. This can also be an indicator that iron-dwelling bacteria may be present.

After the second sampling session at Sample Site 4 on August 8, 2007, iron was recorded at over four times the amount recommended by the PWQO, and phosphorus reached concentrations of 37 μg/L, which exceed the PWQO standard of 30 μg/L.

5.0 Conclusion

While studying the Brule Creek Watershed during the summer of 2007, it was observed that the overall health and condition of the streams, ponds and wetlands were excellent. Even with possible interference from local farms, isolated cutting, and traffic along the near-by roadways, the waterways have sustained minimal damage or interruption.

During the month of July was when most of the data was acquired. In this time, there was an average air temperature of 24 degrees Celsius with plenty of sunshine and little cloud cover. Minimal precipitation in the month of July resulted in low water levels with the exception of one week near the middle of the month, from the 10th to 15th, where rain showers occurred periodically. These occasional times of precipitation resulted in high water levels in the Kaministiquia River and surrounding lakes and watersheds.

The second round of sampling was completed in August, when temperatures ranged from 19 to 21 degrees Celsius. The average water temperature in August was 15.2 degrees Celsius, which was slightly lower than the July average of 16.9 degrees Celsius. This may be due to cooler nightly temperatures as well as changes in creek depths. The width and depth of the creek was slightly reduced in August compared to July, with the exception of Sample Site 3. This occurrence may be due to the fact that this site was very deep in relation to the other sites which made it difficult to sample accurately.

Elevation is an important factor to consider in assessing a watershed. Elevation affects many things such as direction of drainage and overall water flow. The highest elevated site was Sample Site 4, at 439 meters above sea level and the lowest site being Sample Site 1 at 302 meters above sea level with a difference in height of 137 meters.

The mean creek depth from the four sample sites was 115.75cm. Average flow was very low (0.0635 m/s), due to the very gentle grade of the watershed. The pH of the four sites ranged between 7.23 and 8.20, with an average pH reading of 7.80 which met the criteria of the PWQO guidelines. In the month of August, pH levels were slightly higher than July, which indicated that the water was more basic.

Total dissolved solids (TDS) averaged at 160 mg/L, which was well below the 500 mg/L criterion. The TDS values increased from July to August, which may be due to the lower water depths. Generally, higher TDS values are an indication of human disturbance, but values were not high enough to have any significance. The conductivity of Brule Creek averaged 0.245 mS/cm. The conductivity values also increased from July to August. This correlates with high TDS values, which are generally associated with high conductivity. Also, the dissolved oxygen for the creek averaged at 87.59% saturation, well above the 54 percent outlined in the PWQO. The dissolved oxygen concentration for the creek was determined to be 8.65 mg/L, which surpassed the PWQO of 5 mg/L.

The average turbidity of the creek using the handheld turbidity meter was determined to be 18.5 NTU, whereas the average turbidity determined by the laboratory was 3.6 NTU. These results may vary due to disrupted sediment on the stream bed during sampling efforts. Another possibility may be the difference between depths when collecting the sample and the depth from the turbidity reading. The turbidity of the creek did not follow any significant trend from July to August.

The additional chemical testing by ALS Laboratory Group returned iron values that were above the PWQO guidelines at all the sites sampled. There may be several reasons for this, but the most obvious reason would be that the area contains many iron-rich rocks. Several rusted culverts within the watershed may have also added to the iron in the water. Aluminum values were also found to be above the PWQO guidelines at both Sample Sites 1 and 3. These values were likely due to natural sources also, such as the weathering of aluminum-rich rocks. Total phosphorus levels were also close to exceeding recommended guidelines. The PWQO guidelines allow a maximum total phosphorus level of 30 μg/L for rivers, and the laboratory results for Sample Site 3 returned a value of 30 μg/L. Phosphorus levels were likely high due to natural sources, such as the abundance of vegetation at this particular site. There was also a deeper, organic layer here and decaying logs and sticks in the stream that may have contributed to the total phosphorus levels. All other parameters tested by ALS Laboratory Group were within the PWQO guidelines.

The culverts along Brule Creek were, for the most part, in good condition with minor damage to them. The damage consisted of small dents to corners, or rust holes on the upper surface. A special note should be made about Culvert 3b along Highway 11/17, where the entire base of the culvert on the upstream side was bent upwards, which considerably restricted the flow. Also, the downstream end of Culvert 3b had rusted and created a hole in the bottom of the culvert that diverted flow from the creek. During the assessment, an engineering team was seen evaluating the damaged culvert. There were very few signs of erosion along the banks of the crossings, as the banks were stony and impervious or covered in vegetation.

The bridge crossings on Brule Creek were also in good condition. They were wide enough to accommodate high water flows and constant traffic, and tall enough to accommodate safe vehicle travel. The banks were reinforced with wooden barriers and large rocks and all bridges were well marked with reflective signs and visible warnings along the roadways. More in-depth information for all of the culverts and bridges has been attached in Appendix C and Appendix D.

There was a large diversity of vegetation observed and recorded throughout the study, but consistently the same species of vegetation occurred at each of the sample sites. There was a wide variety of species ranging from conifers, to broadleaf, shrubs and herbs. However, aquatic plant vegetation was minimal within the stream. Each sample site appeared to have many of the same species and distribution with only minimal variation between the sites. This may be caused by the soil type and topography being common along the entire range of the creek. Common tree species include Balsam fir *(Abies balsamia)*, white spruce *(Picea glauca)*, green alder *(Alnus viridis spp. crispa)*, and balsam poplar *(Populus balsamifera)*. The shrub layers of the area were generally rich in wild red raspberry *(Rubus idaeus var. strigosus)*. Ox-eye daisy *(*Chrysanthemum *leucanthemum)*, yarrow *(Achillea millefolium)*, blue joint grass *(Calamagrostis canadensis)* and late purple aster *(Symphyotrichum patens)* were also common throughout the sample area.

During the assessment period, very few live animals were seen, although some tracks, scat and dwellings were observed throughout the study. Grouse were observed on the sides of the gravel roads and beaver dams were present in areas along the creek where it came close to Pokki Road. Local residents also mentioned seeing deer in the area. Typical birds of the area as well as squirrels and chipmunks were occasionally observed and garter snakes were also seen. At the bridge crossing on Pokki Road, brook trout were observed living in the deep, slow moving portion of the creek. The evidence of wildlife in the area suggested a healthy and diverse ecosystem that has had very little impact by farming or development.

In conclusion, the large diversity of plant and benthic species and healthy soil characteristics leads to conclusion that Brule Creek is a healthy, stable ecosystem that can sustain a resident population of aquatic species. The majority of the parameters analyzed by the ALS Laboratory Group were below the PWQO guidelines which is an indicator that the Brule Creek is a healthy contributing tributary within the Lake Superior watershed.

6.0 Future Recommendations

Brule Creek Watershed was in good health at the time of study during the months of July and August 2007, however additional testing of Brule Creek is recommended to create a more thorough assessment. The Brule Creek Watershed should be monitored for terrestrial and aquatic species, erosion, water quality, and culvert condition as time and resources permit.

A copy of this report should be made available to the residents of Conmee Township. This report will be kept on file at the Lakehead Region Conservation Authority office for review by interested parties. Copies will be made on a cost recovery basis.

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Appendix A: Common and Latin Names

Common and Latin Names of Plant and animal Species found at the Brule Creek sample sites

Trees	
Abies balsamea	balsam fir
Acer spicatum	mountain maple
Betula papyrifera	white birch
Fraxinus nigra	black ash
Picea glauca	white spruce
Populus balsamifera	balsam poplar
Populus tremuloides	trembling aspen
Shrubs	
Alnus crispa	green alder
Alnus rugosa	speckled alder
Amelanchier spp	serviceberries
Cornus stolonifera	red osier dogwood
Corylus cornuta	beaked hazel
Prunus pensylvanica	pin cherry
Prunus virginiana	choke cherry
Rosa acicularis	prickly rose
Rubus idaeus var. strigosus	wild red raspberry
Rubus pubescens	dwarf raspberry
Salix spp.	willow
Staphylea trifolia	bladdernut
Viburnum acerifolium	maple viburnum
Herbs	
Achillea millefolium	yarrow
Alisma subcordatum	water plantain
Anemone quinquefolia	wood anemone
Aster spp.	flat-topped aster
Calamagrastis canadensis	blue joint grass
Carex spp.	Sedge spp.
Chrysanthemum leucanthemum	ox-eye daisy
Eupatorium maculatum	spotted Joe-pye weed
Eurybia macrophylla	large-leaved aster
Epilobium angustifolium	fireweed
Equisetum spp.	horsetail
Lycopodium clavatum	ground pine
Ranunculus repens	buttercup
Solidago canadensis	Canada goldenrod

Symphyotrichum patens	late purple aster
Taraxacum officinale	dandelion
Trifolium	clover
Typha latifolia	common cattail
Vicia spp.	vetch

Ferns

Athryium pycnocarpon	glade fern
Gymnocarpium robertianum	northern oak fern

Mosses

Pleurozium schreberi	Schreiber's moss

Aquatic Invertebrates/Minnows/Frogs

Gerrida hemiptera	water strider
Hirudinea spp.	leech
Mollusca gastropoda	snails
Orconectes rusticus	rusty crayfish
Phoxinus phoxinus	minnow
Rana pipiens	leopard frog

Appendix B: Techniques for Data Collection

Location
The sample sites were chosen using a 1:4000 scale topographic map. The sample sites are also described in road access as well as hiking and driving distances.

Latitude, Longitude, and Elevation
The coordinates for each site were measured with a Garmin 12 XL hand held GPS unit.

Channel width & depth
The width and depth were measured by a nylon measuring tape with a weighted end.

Flow
The velocity of the creek was measured by placing a piece of floating debris (stick) in the stream and measuring the amount of time it took to travel a specified distance. The flow was later calculated to metres per second.

Air Temperature
The air temperature was measured with a basic alcohol air thermometer.

Water Temperature
Water temperature was measured with the YSI 556 MPS. The readings were taken after the probe was submerged and all variables on the meter are stabilized.

Conductivity
Conductivity was measured with the YSI 556 MPS. The accuracy of the reading was ±0.001 mS/cm or ±1.0%; whichever is greater. The readings were recorded once the probe was completely submerged and all readings stabilized.

Total Dissolved Solids
The total dissolved solids (TDS) are measured from the conductivity reading.

Dissolved Oxygen
The YSI 556 MPS determined dissolved oxygen for the samples. The readings were recorded once the probe was submerged in the water and all variables were stabilized.

Tree, Shrub & Herb Species
Vegetative species are closely linked to the overall health of the ecosystem. The greater the diversity of the area, the better the health is of the ecosystem. Identification was made in the vicinity of the sample sites, approximately 10m for shrub and herb and 200m for tree species.

Aquatic Plants
Aquatic plants were determined through careful observation and identification via a field guide.

Benthic species / Terrestrial
Through the use of dip nets and observations, the benthic species was identified by observation and verified by the use of field guides.

In Creek Material
The bed material was described through observation and recorded for each site.

Bed Description
The bed description was given though a set of categories or varying grain sizes.

Boulder	> 25.6 cm in diameter
Cobbles	6.4 - 25.6 cm in diameter
Gravel	0.2 – 6.4 cm in diameter
Sand	< 0.2 cm in diameter
Silt	Finer inorganic material than sand
Muck	Mainly organic combination of silt and clay
Clay	Inorganic origin with no apparent structure

Bank Stability / Erosion
Evidence of erosion or the potential of erosion was observed, categorized as either stable or unstable. A bank is stable if there is little to no erosion present, well vegetated or has a low slope. Unstable is defined as having visible signs of erosion, little to no vegetation on the bank or a steep slope.

Stream Cover / Forest Density
A measure of the forest and vegetation found within the sampling site stream bank and is no more than 5 m from the water's edge.

Dense	75-100% shaded by canopy
Partly Open	25-74% shaded by canopy
Open	0-25% shaded by canopy

Forest and Surficial Geology Characteristics

The surficial geology that comprises the watershed is as follows:

- Bedrock Knob (RN) – Irregular bedrock surface, muck, boulders, sand-rich
- Glaciolacustrine Plain (LP) – Fine grained material, impervious excellent drainage
- Organic Terrain (OT) – Muck and peat marshes, swamps, ferns and bogs, poor drainage

The vegetation present at each sampling site is categorized by the following characteristics:

- Conifer Mixed wood – mainly conifer with some hardwood species
- Hardwood Mixed wood – majority of tree species are hardwood (poplar, birch, etc)

Appendix C: Culverts

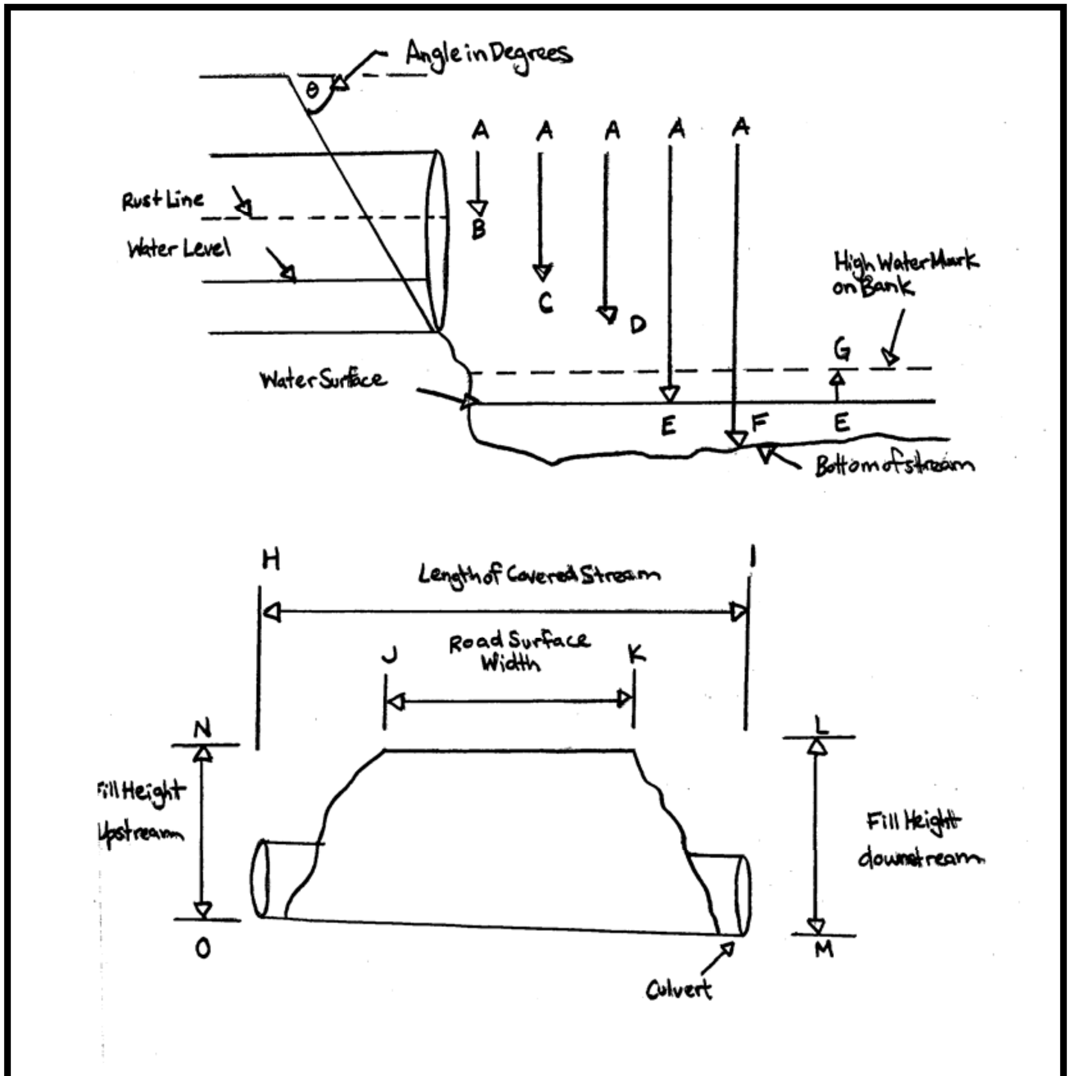

Diagram of Culvert Measurements

Table C -1: Culvert Measurements Overview Chart

Culvert Number	J – K Road Surface Width (m)	H – I Length of Covered Stream (m)	N – O Fill Height Upstream (m)	L – M Fill Height Downstream (m)	A – D Width of Opening (cm)	A – B Inside Top to High Water (cm)	A – C Inside Top to Water Surface (cm)	A – E Height above Outlet Pool (cm)	E – G Outlet Pool Water Surface to Outlet Pool High Water Mark (cm)	A – F Inside Top to Bottom of Stream (cm)	Fill Slope Angle (°)
1	20.18	25.36	3.78	5.21	98.6	60.5	92.2	92.2	19.1	115.1	Upstream: 60 Downstream: 60
2	8.69	30.23	8.71	8.71	429.2	343	394	N/A	22.9	430	Upstream: 45 Downstream: 60
3a	12.92	54.35	10.66	10.05	271.8	175.3	238.8	64.8	63.5	329.8	Upstream: 70 Downstream: 70
3b	52.85	52.85	9.85	10.21	291.5	223.4	267.5	13.75	22.5	27.5	Upstream: 70 Downstream: 70
4a	5.49	9.83	1.04	1.04	91	60	N/A	N/A	N/A	N/A	Upstream: 85 Downstream: 85
4b	5.49	12.32	1.04	1.04	91	77.5	88.8	20	25	115.8	Upstream: 85 Downstream: 85
5	6.86	18.16	2.69	2.89	183	170	179	5	5	203	Upstream: 50 Downstream: 50
6	6.60	17.68	1.67	2.26	108.5	96	101	5	7.5	127	Upstream: 45 Downstream: 45
7	2.99	16.15	1.73	1.35	91	72.5	82.5	10	12.5	102.5	Upstream: 50 Downstream: 50
8	6.19	15.56	0.90	0.75	91	40	40	12.5	0	102	Upstream: 40 Downstream: 20
9	5.60	13.18	0.83	0.60	76	N/A	22.5	3.75	0	67.5	Upstream: 20 Downstream: 20
10	5.17	12.10	0.65	0.91	91	53.75	65	5	11	100	Upstream: 25 Downstream: 25

Culvert 1

Location: Accessed by an approximate 300 m hike south along CN tracks from the end of Mokomon Road.

UTM Coordinates: 5373586.04 N 307338.67 E; 304.45 MSL

Description: This concrete culvert was created by the CN railway to accommodate train passage over the creek. This culvert covered 25.4 meters of stream and had an opening width of 99 centimeters. Concrete wings held back rubble and stones while provided a funnel for incoming water. The culvert was perched and drained into a medium depth pool that continues to the Kaministiquia River. Water flowed quickly through this culvert due to the wide and rocky streambed. Vegetation was dominated by tree species with some shrubs and grasses along the bank.

Inflow

Outflow

Culvert 2

Location: Crosses Ilkka Drive, 1km east of Highway 11/17

UTM Coordinates: 5373386.73m N; 305386.66m E; 376.43 MSL

Description: This was the largest culvert in the watershed; it covered 30.2 meters of stream and had an opening width of 429 centimeters. The river was composed of a rocky bottom with sandy substrate. Light riffles on the upstream side and grasses and shrubs on both banks characterize this area. The road was relatively high above the water and the fill angle was steep but well vegetated with no signs of erosion. Overall, it was in very good repair.

Inflow

Outflow

<u>Culvert 3a, 3b</u>

Location: Intersection of Highway 11/17 and Mokomon Road.

UTM Coordinates: 5373459.57m N, 305066.35m E, 380.95 MSL

Description: Culverts 3a and 3b were two of the longest culverts in the watershed, and allowed water to flow beneath Highway 11/17. Culvert 3a covered 54.4 meters of stream and had an opening width of 272 centimeters. Culvert 3b covered 52.9 meters of stream and had an opening width of 292 centimeters. The south culvert (3b) had been damaged and the bottom end was bent up, which restricted the flow through the culvert. Culvert 3a takes in the bulk of the flow and the watercourse had diverted itself to compensate. The inflow pool was sandy and clayey with long waterweed patches. Downstream, the culverts flow into a medium depth pool with rocks and sandy substrate. Tall grasses surround the banks, which prevent any erosion from occurring. There are large rocks inside the culverts, indicating higher flows previously.

Inflow

Outflow

Culvert 4a, 4b

Location: Maxwell Road, 140m north of Mokomon Road

UTM Coordinates: 5373833.2m N, 303601.52m E, 417.97 MSL

Description: Two nearly parallel culverts move water across this low traffic residential road. The north culvert (4a) was dry at the time of measurement and covered 9.8 meters of stream. Culvert 4b covered 12.3 meters of stream and both culverts had an opening width of 91 centimeters. All flow passed through the south culvert. The upstream end was very overgrown with vegetation, and a single photo of both could not be obtained. The culverts were in good condition, although the north culvert at the inflow end was bent down at the top.

Inflow

4a Outflow

4b Outflow

Culvert 5

Location: Ender's Road, approximately 40 meters south of Mokomon Road

UTM Coordinates: 5373629.03 N, 301053.39 E, 434.29 MSL

Description: Culvert 5 was surrounded on both sides by thick vegetation and was marked by a painted wooden post on the side of the road. It covered 18.2 meters of stream and had an opening width of 183 centimeters. Tall grasses surrounding both ends made its visibility very low. The flow going through the culvert was extremely slow and the upstream end was nearly choked with grasses growing in the streambed. Both ends were shaded by alders and shrubs and close to 90% covered. The inside middle of the culvert was bent down, possibly due to heavy traffic on the road.

Inflow

Outflow

Culvert 6

Location: Farmer's private property, 110m south of Mokomon Road

UTM Coordinates: 5373732.67m N, 300940.83m E, 438.11 MSL

Description: Located on private property, permission was granted to document this culvert for the report. The culvert covered 17.7 meters of stream and had an opening width of 109 centimeters. The upstream end was a marshy pond with lots of wildlife and plant growth. The farmer had placed a board on the upstream end to raise water levels in the pond. While this did not seem to cause a problem, during storm events it may restrict flow through the culvert. The culvert was surrounded by concrete and was in good condition, except for a bent upper portion on the downstream side.

Inflow

Outflow

Culvert 7

Location: Crosses Mokomon Road approximately 4km west of Highway 11/17

UTM Coordinates: 5373639.89m N, 302039.45m E, 428.52 MSL

Description: This culvert was solid steel, instead of the standard corrugated aluminum alloy. The culvert covered 16.2 meters of stream and had an opening width of 91 centimeters. It was painted lime green on the outside and pink on the inside. The inside paint also came off on surfaces that contacted it. This culvert drains out of a marshland north of Mokomon Road. Flow was very slow and drains into a pool with a rocky bottom. The outlet end had a dent on the corner, but the rest of the culvert was in excellent condition. Banks around this culvert were rocky, with some vegetation, and the banks were stable.

Inflow

Outflow

Culvert 8

Location: Pokki Road, approximately 200 meters west of Ender's Road.

UTM Coordinates: 5372193.6m N, 301811.15m E, 436.83 MSL

Description: This culvert had been blocked downstream by a thick beaver dam. As a result, there was no flow going through this culvert, and the water level seemed to be at its highest point. It covered 15.6 meters of stream and had an opening width of 91 centimeters. Vegetation was thick on both sides and was growing in and around the water. The river bottom was muddy with lots of organics, and mud had begun spilling into the bottom of the culvert as well. Banks on both ends of this culvert were stable due to the high amount of vegetation.

Inflow

Outflow

Culvert 9

Location: Pokki Road approximately 2.5km west of Ender's Road.

UTM Coordinates: 5372284.86m N, 299243.76m E, 438.19 MSL

Description: This culvert had been blocked by a beaver dam at the inflow end. Also, further up the creek, another large dam had created a wide marshland. The water at this culvert was muddy and thick, with algae and grasses present around and in the water. The outflow end had very little water flowing through it and there were lots of loose twigs and sticks, possibly from the dam, all along the bottom of the stream. The culvert covered 13.2 metres of stream and had an opening width of 76 centimetres. The culvert was in good condition, but rusted on the bottom end. The banks were stable, vegetated and there was no evidence of erosion.

Inflow

Outflow

Culvert 10

Location: Pokki Road approx 20m west of culvert 9

UTM Coordinates: 5372285.11 N, 299211.53 E, 438.37 MSL

Description: This culvert was very close to culvert 9 and was also influenced by the beaver dams in the area. It covered 12.1 meters of stream and had an opening width of 91 centimeters. Sticks and twigs surround the culvert, however did not seem to interfere with the flow. There was an oily substance located on the surface of the water, which may have been iron bacteria. The culvert was in poor condition, with rust almost all the way up, and the outflow end was damaged at the top. Slow flow had pushed muddy substrate into the culvert, which covered the bottom. Thick grass and shrubs surround this culvert and help to stabilize the bank.

Inflow

Outflow

Appendix D: Bridges

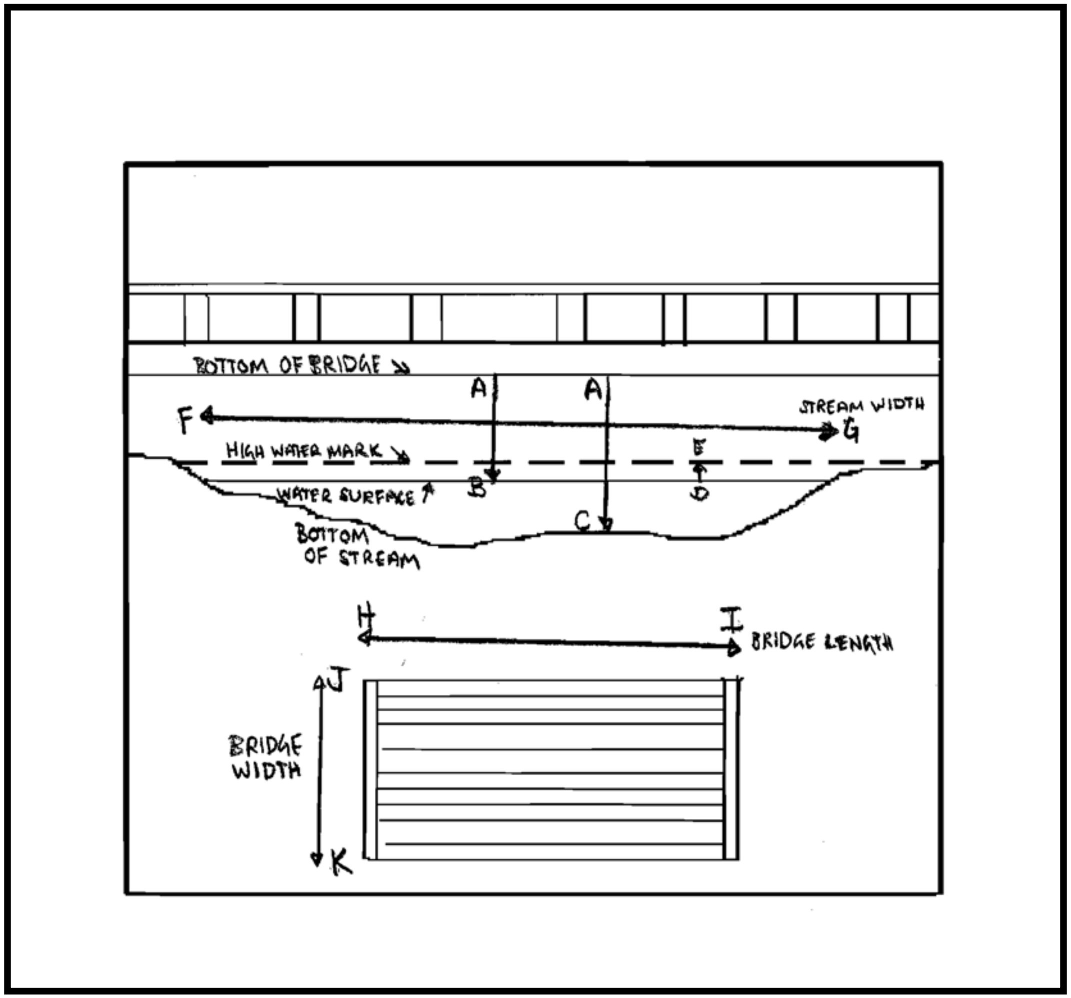

Diagram of Bridge Measurements

Table D.1: Culvert Meas1urements Overview Chart

Bridge Number	A – B Bottom of Bridge to Water Surface (m)	A – C Bottom of Bridge to Bottom of Stream (m)	D – E Outlet Pool Water Surface to Outlet Pool High Water Mark (cm)	F – G Width of Stream (m)	H – I Length of Bridge (m)	J – K Width of Bridge (m)
1	2.06	3.08	15	3.80	6.40	12.75
2	2.87	3.28	11.4	5.33	6.38	13.01
3	1.82	3	7.5	2.96	8.45	7.26
4	2.325	2.45	8.75	4.74	6.14	11.75
5	1.45	2.5	20	8.55	16.06	5.48

Bridge 1

Location: 2.1 km east of Highway 11/17 on Mokomon Road

UTM Coordinates: 5373636.72 N; 307029.12 E; 314.53 MSL

Description: Bridge 1 is the last crossing located on Mokomon Road closest to the CN railway and is well marked with both signs on the bridge and signs on the road. Riffles are present on the downstream end due to large rocks and stones in the water. Grasses and shrubs cover the banks but do not reach the waters edge because of the stony shore. Upstream there are two fallen logs partly submerged in the river but otherwise there is no plant matter in the river. Mid canopy trees shade the river up and downstream, but are not shown in the photo. The bridge is in good repair; however the wooden road surface is beginning to splinter.

Inflow

Outflow

Bridge 2

Location: 1 km east off of Highway 11/17 on Mokomon Road

UTM Coordinates: 5373416.62 N; 306031.73 E; 357.32 MSL

Description: The second bridge crossing on Mokomon Road is located just east of the highway 11/17. Large stones and boulders in the river make riffles larger than at Bridge 1; flow seems faster but otherwise it is similar to Bridge 1. Moderate mid canopy cover and grasses cover the shoreline and the banks are stable with stones and rocks. Also well marked with bridge and road signs.

Inflow

Outflow

Bridge 3

Location: Maxwell Road, 450 m south of Mokomon Road.

UTM Coordinates: 5373179.9 N, 303580.85 E; 397.79 MSL

Description: Bridge 3 is well marked with both signs on the road and signs on the bridge. The bridge itself is in good repair and has a steady medium flow going through it. Upstream flow becomes constricted due to the rocks and stones in the stream bed. Cover on both sides was approximately 20% from surrounding vegetation. No evidence of erosion was observed on the banks.

Inflow

Outflow

Bridge 4

Location: 900m south of Mokomon Road on Ender's Road

UTM Coordinates: 5372727.09 N; 302035.25 E; 417.24 MSL

Description: Well marked with reflective signs, this bridge is in good condition. Two fallen logs upstream may slow flow, and the banks are stony with larger boulders downstream and about 30% cover. Under the bridge, support beams are submerged and lay across the river. There was lots of in stream vegetation upstream and a collapsed and ripped silt fence is lying on the bank, although it does not appear to have an effect on how much sediment is entering the stream. Gravel material on the bridge surface is eroding into the stream.

Inflow

Outflow

Bridge 5

Location: Bridge 900m west of Ender's Road on Pokki Road

UTM Coordinates: 5372221.98 N 301044.47 E; 430.91 MSL

Description: Bridge was in excellent condition, and supports a large volume of water slowly flowing through it. It is the only paved bridge in the watershed and is also well marked. River bottom is deep and filled with mud and organics, evidence of branches and trees as well as large paving stones or boulders. There is vegetation up to and on the stream bank, with some trees growing over and into the water. Bank stability was good. Some wood rot was observed on the deck, however did not seem to affect bridge stability.

Inflow

Outflow

Appendix E: Forest Ecosystem Classification

The Field Guide to the Forest Ecosystem Classification for Northwestern Ontario, 1997, was used in order to assess the forest types at each sample location.

Site 1: V6 Balsam Poplar, hardwood and mixed wood

Description:

Hardwood mixed wood stands with balsam fir as the main conifer tree species. The canopy is typically diffuse and two-tiered with aspen or aspen-birch in the overstory and balsam fir constituting a secondary stratum. The understory is generally herb and shrub rich. Occurring mainly on deep, fresh, well to rapidly drained, upland mineral soils

Figure 2 Site 1 Forest Composition Study

Common Overstory Species:

Trees: balsam fir, trembling aspen, white birch, white spruce, black spruce, jack pine

Common Understory Species:

Shrubs: *Abies balsamia, Acer spicatum, Rubus pubescens, trembling aspen, Diervilla lonicera, Corylus cornuta, Linnaea borealis, Lonicera canadensis, Sorbus decora, Rosa rcicularis*

Herbs: *Aralia nudicaulis, Streptopus roseus, Maianthemum canadense, Cornus canadensis, Clintonia borealis, Aster macrophyllus, Viola renifolia, Trientalis borealis, Galium triflorum, Mitella nuda, Anemone quinquefoilia*

Mosses: *Pleurozium schriberi, Plagiomnium cuspidatum, Rhytidiadelphus triquetrus, Ptilium crista-castrensis*

Forest Floor Cover:
Broadleaf litter: 81 Moss: 7 Wood: 7

Comments

Some stands may key to this type solely as a result of herb richness. Balsam fir is frequently abundant in the shrub layer. V6 differs from v7 and is similar to v8, primarily on the basis of mountain maple (*Acer spicatum*) abundance. V6 occurs more frequently in the east than in the west.

Site 2: V1 balsam poplar hardwood and mixed wood

Description:
Hardwood and mixed wood stands containing balsam poplar in the overstory. The understory is typically herb and shrub rich with a broad diversity of species. This typically occurs on deep, fresh to moist mineral soils, often of lacustrine origin.

Figure 3 Site 2 Forest Composition Study

Common Overstory Species:

Trees: balsam poplar, trembling aspen, balsam fir, white birch, white spruce, black spruce, jack pine, white cedar, black ash

Common Understory Species:

Shrubs: *Rubus pubescens, Abies balsamia, Rosa acicularis, Ribes triste, Actaea rubra, Cornus stolonifera, Alnus rugosa, Rubus idaeus, Acer spicatum, Amelanchier spp.*

Herbs: Aralia nudicaulis, Mitella nuda, Gallium triflorum, Maianthemum canadense, Streptopus roseus, Aster macrophyllus, Petasites palmatus, Equisetum spp., Clintonia borealis, Cornus canadensis, Trientalis borealis, Fragaria virginiana, Aster ciliolatus, Mertensia paniculata, Viola renifoilia, Anemone quinquefoilia

Mosses: Pleurozium schreberi, Plagiomnium cuspidatum

Forest Floor Cover:

Broadleaf litter: 77 Moss: 7 Graminoid litter: 6 Wood: 5

Comments

Typically, in V1 stands, balsam poplar is the main tree species although occasionally other hardwoods (especially trembling aspen) are more abundant. V1 stands often have an uneven age distribution in the overstory resulting in broken, irregular canopies. Soils tend to be fine-textured and poorly drained (although potentially very productive); calcareous soils are common.

Site 3: V24 White spruce-Balsam fir/shrub rich

Description:

This is a conifer type with white spruce and/or balsam fir as the main canopy species. The understory tends to be shrub rich with balsam fir, *Acer spicatum*, *Corylus cornuta* and, on the wetter sites, *Alnus rugosa* potentially abundant. The herb layer varies from rich to poor. This occurs on deep, fresh to moist, mineral soils across a range of texture classes.

Figure 5 Site 3: Forest Composition Study

Common Overstory Species:

Trees: white spruce, balsam fir, black spruce, jack pine, white birch

Common Understory Species:

Shrubs: *Abies balsamia, Rubus pubescens, Amelanchier spp. Sorbus decora, Acer spicatum, Corylus cornuta, Diervilla lonicera, Linnea borealis, Rosa acicularis*

Herbs: *Clintonia borealis, Aralia nudicaulis, Cornus Canadensis, Gallium triflorum, Maianthemum canadense, Streptopus roseus, Aster macrophyllus, Trientalis borealis, Mitella nuda, Anemone quinquefoilia, Viola renifolia, Petasites palmatus, Fragaria virginiana*

Mosses: *Pleurozium screiberi, Ptilium crista-castrensis, Rhytidiadelphus triquetrus, Dicranum polysetum*

Forest Floor Cover

Conifer litter: 34 Moss: 32 Broadleaf litter: 23 Wood: 7

Comments

Stands of V23 often develop as patches within lowland black spruce forests. The canopy can be very open, with widely spaced trees. Extensive cover by sedge species is characteristic on these low lying, wet sites. Microtopography ranges from flat to very undulating, the latter condition due to hummock-forming *sphagnum spp*. in the moss layer. Most V23 stands are found on peat deposits although, in site regions 3s, 4s, and 5s, mineral soils are encountered.

Site 4: V7 Trembling Aspen – balsam fir/balsam fir shrub

Description:
Hardwood mixed woods, typically with a two tiered canopy. In general, trembling aspen constitutes the overstory with balsam fir in the secondary canopy. Understory development is variable with balsam fir, *Aralia nudicaulis* and *Diervilla lonicera* often abundant. This occurs mainly on deep, fresh, well-drained, fine-textured mineral soils.

Figure 3 Site 4: Forest Composition Study

Common Overstory Species:

Trees: balsam fir, trembling aspen, white birch, white spruce, black spruce, jack pine

Common Understory Species:

Shrubs: *Abies balsamia, Rubus pubecense, Diervilla lonicera, Acer spicatum, Rosa acicularis, Populus tremuloides, Corylys cornuta, Linnaea borealis, Sorbus decora*

Herbs: *Maianthemum canadense, Aralia nudicaulis, Cornus canadensis, Clintonia borealis, Aster macrophyllus, Stretopus roseus, Trientalis borealis, Viola renifolia, Mitella nuda, Petasites palmatus, Anemone quinquefolia, Gallium triflorum*

Mosses: *Pleurozium schreiberi, Rhytidiadelphus triquetrus*

Forest Floor Cover:

Broadleaf litter: 81 Moss: 7 Conifer litter: 6 Wood: 5

Comments

Stands of V7 tend to contain a diversity of species in the herb and shrub strata. They generally lack dense cover by broadleaved tall shrubs although *Corylus cornuta* and *Alnus crispa* can be abundant in areas. On average, crown closure by balsam fir is somewhat greater than in v6. Relative to stands of v6, those of v7 occur more frequently on fine-textured, calcareous, lacustrine deposits.

Appendix F: MOE Water Quality Guidelines

The following are taken from the Ministry of the Environment water quality guidelines, Provincial Water Quality Objectives (PWQO), July 1994.

Alkalinity:
Alkalinity should not be decreased by more than 25% of the natural concentration.

Dissolved oxygen:
Dissolved oxygen concentrations should not be less than the values specified below for cold water biota (e.g. salmonid fish communities) and warm water biota (e.g. centrarchid fish communities):

Dissolved Oxygen Concentration				
Temperature	Cold Water Biota		Warm Water Biota	
°C	% Saturation	mg/L	% Saturation	mg/L
0	54	8	47	7
5	54	7	47	6
10	54	6	47	5
15	54	6	47	5
20	57	5	47	4
25	63	5	48	4

In waters inhabited by sensitive biological communities, or in situations where additional physical or chemical stressors are operating, more stringent criteria may be required. For example, a sensitive species such as lake trout may require more specific water quality objectives.

In some hypolimnetic waters, dissolved oxygen is naturally lower than the concentrations specified in the above table. Such a condition should not be altered by adding oxygen-demanding materials causing a depletion of oxygen.

pH:
The pH should be maintained in the range of 6.5 – 8.5:

- to protect aquatic life
- both alkaline and acidic waters may cause irritation to anyone using the water for recreational purposes

Turbidity:
Suspended matter should not be added to surface water in concentrations that will change the natural Secchi disc reading by more than **10 percent**.

Phosphorus:
Current scientific evidence is insufficient to develop a firm Objective at this time. Accordingly, the following phosphorus concentrations should be considered as general guidelines, which should be supplemented by site-specific studies:

To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20µg/L;

A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10µg/L or less. This should apply to all lakes naturally below this value.

Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30µg/L.

Aluminium:
Aluminium amounts should not exceed the following:

PH values	**Interim PWQO (µg/L)**
4.5 to 5.5	15
>5.5 to 6.5	No more than 10 % of natural background
> 6.5 to 9.0	75

Antimony:
The amount of Antimony should not exceed 20 µg/L.

Arsenic:
The amount of Arsenic should not exceed 5 µg/L.

Barium:
There are currently no PWQO guidelines limiting the intake of Barium.

Beryllium:
Beryllium amounts should not exceed the following:

Hardness as $CaCO_3$ (mg/L)	**Interim PWQO (µg/L)**
< 75	11
>75	1100

Boron:
The amount of Boron should not exceed 200 µg/L.

Bismuth:
There are currently no PWQO guidelines limiting the intake of Bismuth.

Cadmium:
Cadmium amounts should not exceed the following:

Hardness as CaCO3 (mg/L)	**PWQO (µg/L)**
0 - 100	0.1
>100	0.5

Calcium:
There are currently no PWQO guidelines limiting the intake of Calcium.

Chromium:
Chromium amounts should not exceed the following:

	Interim PWQO (µg/L)
Hexavalent Chromium (Cr VI)	1
Trivalent Chromium (Cr III)	8.9

Cobalt:
The amount of Cobalt should not exceed 0.9 µg/L.

Copper:
The amount of Copper should not exceed 5 µg/L.

Iron:
The amount of Iron should not exceed **300µg/L**.

Lead:
Lead amounts should not exceed the following:

Hardness as CaCO3 (mg/L)	**Interim PWQO (µg/L)**
< 30	1
30 to 80	3
> 80	5

Magnesium:
There are currently no PWQO guidelines limiting the intake of Magnesium.

Manganese:
There are currently no PWQO guidelines limiting the intake of Manganese.

Molybdenum:
The amount of Molybdenum should not exceed 40 µg/L.

Nickel:
The amount of Nickel should not exceed 25 µg/L.

Potassium:
There are currently no PWQO guidelines limiting the intake of Potassium.

Selenium:
The amount of Selenium should not exceed 100 µg/L.

Silicon:
There are currently no PWQO guidelines limiting the intake of Silicon.

Silver:
The amount of Silver should not exceed 0.1 µg/L.

Strontium:
There are currently no PWQO guidelines limiting the intake of Strontium.

Thallium:
The amount of Thallium should not exceed 0.3 µg/L.

Tin:
There are currently no PWQO guidelines limiting the intake of Tin.

Titanium:
There are currently no PWQO guidelines limiting the intake of Titanium.

Tungsten:
The amount of Tungsten should not exceed 30 µg/L.

Uranium:
The amount of Uranium should not exceed 5 µg/L.

Vanadium:
The amount of Vanadium should not exceed 6 µg/L.

Zinc:
The amount of Zinc should not exceed 20 µg/L.

Zirconium:
The amount of Zirconium should not exceed 4 µg/L.

Appendix G: Test Parameters

Water Temperature

Water temperature does not change as readily as air temperature, but takes into account the temperature of the source water, solar radiation, depth, flow and amount of shading by vegetation. Water temperature is important for a variety of reasons. When fish species adapt to the current temperature, a fluxuation of this temperature can add stresses to the inhabiting fish. The temperature has an important role in influencing chemical, biological and physical processes. Change in temperature influences the waters ability to hold dissolved gasses, the warmer the water, the less gas it can hold. Warmer water is a better host to bacteria and adds to the natural diversity of the habitat.

pH

pH measures the acidity or the alkalinity of the water on a logarithmic scale of 0 to 14. The pH of water must be between 6.5 and 8.5 in order to meet PWQO guidelines. Drinking water should be slightly basic to neutral. A healthy balance of pH is required for aquatic species to thrive; being on either end of the pH scale is harmful to the plants, organisms, aquatic and terrestrial life.

Dissolved Oxygen

Aquatic species require oxygen for respiration that aquatic plants and the atmosphere replenish. If there is an imbalance of dissolved oxygen in the water, this can be harmful to the ecosystem's diversity and the species that exist. Deficient levels of oxygen will decrease fish population, where as supersaturation can lead to gas bubble disease. PWQO has a range of dissolved oxygen in water dependant upon temperature; at 20° C the minimum amount of dissolved oxygen is 5 mg/L.

Conductivity

Conductivity is a measure of the water's resistance to electrical conductance in water, measured in micro seimens per centimetre. This reading is used to determine the total dissolved solids in the sample. TDS may originate from natural sources including: mineral springs, salt deposits, and carbon deposits also originate from anthropogenic uses such as: sewage or urban run-off. High levels of total dissolved solids are not necessarily a risk to water quality; however it may affect the aesthetic quality of the water. Low TDS may indicate corrosive waters, which may involve the leaking of metals such as: lead and copper. If these metals have elevated levels, it may pose as a health hazard.

Specific Conductivity

Specific conductivity is similar to conductivity, however the water temperature is taken into account and the reading is corrected. By adjusting the temperature, comparisons can be made with different samples.

Total Dissolved Solids

The level of the total dissolved solids in water is an indicator of disturbances upstream such as erosion or pollution. The amount of dissolved solids is expected to be higher at the confluence of the watercourse as all of the dissolved solids have accumulated to this point. PWQO requires that the total dissolved solids be less than 500 mg/L, with the Ontario range of water bodies being between 150 mg/L to 500mg/L.

Total Suspended Solids
Total suspended solids are particles larger than what is measured in dissolved solids, however they are indefinitely suspended in the water. High levels of suspended solids may initiate siltation of the riverbed, smothering of aquatic life, increased turbidity, and absorption of heavy metals, nutrients and organic compounds.

Turbidity
Turbidity is classified as the cloudy condition that reduces transparency caused by suspended solids in the water. Any suspended solids such as silt, clay, debris and microscopic organisms will affect the turbidity. Turbidity is related to the diversity in the water by determining the amount of sunlight reaching under the surface to plant and fish species. Drinking water standards for water treatment plants are below 1 Nephelometric Turbidity Units (NTU), where PWQO requires the turbidity must not change more than 10% of base levels.

Total Phosphorous
Phosphorus is important for living organisms, although it contributes to an increased tropic level of water bodies. It is also important for the decomposition of dead organisms, and it is then converted to its initial state of oxidation in the phosphorus cycle. Low phosphorus in water can limit plant growth, where as too much can create eutrophication or algal blooms. Phosphates can enter into the environment via minerals in the ground, but majority of it will come from human sources like fertilizers, pesticides and detergents. PWQO guidelines have a level of 20 μg/L in lakes and 30 μg/L in rivers and streams.

Aluminium
Aluminium, the most abundant metal on Earth, is found in soil, in water and in air. Aluminium and its compounds are often used in food as additives, in drugs, in consumer products and in the treatment of drinking water. Aluminium poisoning has been linked to neurological dementia in kidney dialysis patients and, in recent years, its role in Alzheimer's disease, Parkinson's disease and Lou Gehrig's disease. The intake of large amounts of aluminium can also cause anaemia, osteomalacia (brittle or soft bones), glucose intolerance, and cardiac arrest in humans. The PWQO guideline for Aluminium varies with pH; the maximum concentration is 15 μg/L.

Antimony
Antimony is a metallic element that is a blue-white colour in its stable form. Acute intoxication is characterized by abdominal pain, vomiting, diarrhea, dehydration, muscular pain, shock, haemoglobinuria, anuria and uraemia. In addition, severe myocardial symptoms and convulsions have been observed with acute doses of antimonials, and some deaths were attributed to liver necrosis. The maximum concentration of antimony under PWQO guidelines is 20 μg/L.

Arsenic
Arsenic is a natural element found widely in the earth's crust. It may be found in some drinking water supplies, including wells. Long-term exposure (over many years or decades) to high levels of arsenic in drinking water may cause thickening and discolouration of the skin; nausea and

diarrhea; decreased production of blood cells; abnormal heart rhythm and blood vessel damage; or numbness in the hands and feet. Short term exposure (days/weeks) to very high levels of arsenic can result in abdominal pain, vomiting and diarrhea; muscular cramping or pain; weakness and flushing of skin, skin rash; numbness, burning or tingling sensation on the palms of the hands and soles of the feet; or loss of movement and sensory response. The maximum concentration of arsenic under PWQO guidelines is 5 μg/L.

Barium
Barium is present as a trace element in both igneous and sedimentary rocks. Although it is not found free in nature, Barium occurs in a number of compounds. Barium compounds have a wide variety of industrial applications. They are used in the plastics, rubber, electronics and textiles industries. At high concentrations, barium causes strong vasoconstriction by its direct stimulation of arterial muscle, peristalsis due to the violent stimulation of smooth muscle, and convulsions and paralysis following stimulation of the central nervous system. Depending on the dose and solubility of the barium salt, death may occur in a few hours or a few days. There are currently no PWQO guidelines limiting the intake of barium.

Beryllium
Beryllium is a hard grey metal that is extracted from the earth, refined and reduced to a very fine powder. It occurs as a chemical component of certain rocks, coal and oil, soil, and volcanic dust. People exposed to beryllium are at risk of developing serious, debilitating diseases. Chronic beryllium disease (CBD or berylliosis) is a painful scarring of the lung tissue. Less common than CBD, acute (short—term) beryllium disease causes lung inflammation resembling pneumonia. In severe cases, both diseases may be fatal. The maximum concentration of beryllium under PWQO guidelines depends on hardness. If $CaCO_3$ is >75 mg/L the maximum concentration of beryllium is 1100 μg/L and if the $CaCO_3$ is <75 mg/L the maximum concentration of Beryllium is 11 μg/L.

Boron
Boron is non-metallic element that is not found in nature in its elemental form but can be found in a number of compounds. Exposure to boron in small doses may cause irritation to the nose, throat and eyes. In larger doses, boron can affect the stomach, liver, kidneys and brain and may eventually lead to death. The maximum level of boron under PWQO guidelines is 200 μg/L.

Bismuth
Bismuth is a brittle metal with a pinkish colour, which is often found in its native form. Exposure to Bismuth at low doses may cause gastrointestinal disorders, low stomach acid, heartburn, bloating, calcification, warts, diarrhea, and gastric ulcers. At large doses it may cause mental confusion, memory problems, tremors, staggering gait, muscle twitching, slurring speech, joint problems, hypoadrenalism, hearing and visual disturbances, hallucinations and coma. There are currently no PWQO guidelines limiting the intake of bismuth.

Cadmium
Cadmium is an extremely toxic metal even in low concentrations that can enter into the environment from mining, fertilizers and rechargeable batteries. Cadmium poisoning can lead to

itai-itai disease, which initiates bone softening, joint pain and kidney failure. The maximum concentration of cadmium under PWQO guidelines is 0.2 μg/L.

Calcium

Calcium is the third most abundant metal in the Earth's crust. Calcium is also the most abundant metal in the human body and is the main constituent of bones. Calcium is a dietary requirement and there are no adverse health effects from intake of large doses of Calcium. There are currently no PWQO guidelines limiting the intake of Calcium.

Chromium

Chromium is a lustrous, hard metal. Chromium (III) is an essential nutrient, but higher intake may cause skin rashes. Chromium(VI) is know to cause various health effects such as skin rashes, upset stomachs and ulcers, respiratory problems, weakened immune systems, kidney and liver damage, alteration of genetic material, lung cancer and death. The maximum concentration of chromium under PWQO guidelines is 1 μg/L for Chromium (VI) and 8.9 μg/L for Chromium (III).

Cobalt

Cobalt is a hard, lustrous, silver-grey metal and is found in various ores. Health effects resulting from exposure to high concentrations include vomiting and nausea, vision problems, heart problems and thyroid damage. The maximum concentration of cobalt under PWQO guidelines is 0.9 μg/L.

Copper

Copper occurs in nature as a metal and in minerals. Copper is an essential element to human metabolism although intake at higher doses can cause adverse health effects. Acute copper poisoning health effects include vomiting, diarrhea, jaundice, haemolysis, haemoglobinuria, haematuria, and oliguria. In severe cases, the stool and saliva may appear green or blue; in the terminal phases, anuria, hypotension, and coma precede death. The maximum concentration of copper under PWQO guidelines is 5 μg/L.

Iron

Iron can occur in streams naturally if there are rich iron rocks present in the watercourse. Iron in rocks can be identified by a red colour or tint, and iron in water can be identified by a metallic taste. The PWQO guideline stipulates that the levels of iron in the water must be below 300 μg/L.

Lead

Lead is a very toxic metal to all forms of life, causing neurological damage and even death. Although natural occurrences can occur from precipitation and the weathering of ores; the majority of lead in watercourses comes from anthropogenic sources. The PWQO requirement for lead varies with different alkalinity as $CaCO_3$ (mg/L); the maximum lead concentration is 25 μg/L.

Magnesium
Magnesium is very abundant in nature, and is found in important quantities in many rocky minerals. It is a dietary requirement, but too much can lead to muscle weakness, lethargy and confusion. There are currently no currently no PWQO guidelines limiting the intake of Magnesium.

Manganese
Manganese is a very common compound that can be found everywhere on earth. It is essential for humans to survive, but toxic when concentrations in the body are too high. Manganese can cause Parkinson, lung embolism and bronchitis. There are currently no PWQO guidelines limiting the intake of manganese.

Molybdenum
Molybdenum is a by-product of copper and tungsten mining, used as an alloy for various metals, occurs naturally in soil and rock. Potential health impacts associated with Molybdenum include neurotoxicity and reproductive toxicity. The maximum concentration of copper under PWQO guidelines is 40 μg/L.

Nickel
Nickel is a compound that occurs in the environment only at very low levels. An uptake of large quantities of nickel may cause higher risks of cancer, respiratory failure, birth defects and heart disorders. The maximum concentration of nickel under PWQO guidelines is 25 μg/L.

Potassium:
Potassium is a soft silvery white metal, which is a key plant element and is found in most fertilizers. Potassium is also a dietary requirement, but many potassium compounds may cause adverse health effects. Such compounds include potassium alum or potassium cyanide. There are currently no PWQO guidelines limiting the intake of potassium.

Selenium
Selenium is one of the rarer elements on the surface of the earth. It occurs naturally in the environment and is also released by human activities. The health effects of various forms of selenium can vary from brittle hair and deformed nails, to rashes, heat, swelling of the skin and severe pains. Selenium poisoning may become so severe in some cases that it can even cause death. The maximum concentration of selenium under PWQO guidelines is 100 μg/L.

Silicon
Silicon is the most abundant element on earth after oxygen. In drinking water only silicic acid is present, which is relatively safe. However, there are a number of silicon compounds that are carcinogenic. There are currently no PWQO guidelines limiting the intake of silicon.

Silver
Silver does not react with pure water. Is is stable in both water and air. Moreover, it is acid and base resistant, but it corrodes when it comes in contact with sulphur compounds. Silver oxide is harmful upon swallowing, because it irritates the eyes, respiratory tract and skin. Silver nitrate is much more harmful, because it is a strong oxidant. It causes corrosion and at oral uptake it leads

to vomiting, dizziness and diarrhoea. The maximum concentration of silver under PWQO guidelines is 0.1 μg/L.

Strontium
Strontium is a bright silvery metal that is softer than calcium and even more reactive in water. Acute effects of strontium include vomiting and diarrhea if ingested, and may also cause irritation to the skin. Chronic skin contact may cause dermatitis. There are currently no PWQO guidelines limiting the intake of strontium.

Thallium
Thallium is a silvery-grey metal that is very toxic by inhalation, ingestion and skin absorption. It may act as a systemic poison, neurotoxin, and may cause birth abnormalities. It is also a respiratory and eye irritant. The maximum concentration of thallium under PWQO guidelines is 0.3 μg/L.

Tin
Tin is a soft, pliable, silvery-white metal. Acute effects of tin include skin or eye irritation, headaches, stomach aches, dizziness, and breathlessness. Long-term effects include liver damage, malfunctioning of immune systems, chromosomal damage, shortage of red blood cells, and brain damage. There are currently no PWQO guidelines limiting the intake of tin.

Titanium
Titanium is a white-silvery metallic colour and is not found unbound to other elements in nature. There are no known health hazards of Titanium in water, but it has adverse health effects in powder form. There are currently no PWQO guidelines limiting the intake of Titanium.

Tungsten
Tungsten is a lustrous, silvery-white metal. Acute health effects include irritation to the skin and eyes causing watering and redness. There are no known long-term health effects. The maximum concentration of tungsten under PWQO guidelines is 30 μg/L.

Uranium
Uranium is a hard, dense, malleable, ductile, silver-white, radioactive metal. No harmful radiation effects of natural levels of uranium have been found. However, chemical effects may occur after the uptake of large amounts of uranium and these can cause health effects such as kidney disease. Exposure to uranium radionuclides that form during radioactive decay, may cause cancer. The maximum concentration of uranium under PWQO guidelines is 5 μg/L.

Vanadium
Vanadium is a rare, soft, ductile grey-white element found combined in certain minerals and used mainly to produce certain alloys. The uptake of vanadium by humans mainly takes place through foodstuffs, such as buckwheat, soy beans, olive oil, sunflower oil, apples and eggs. Some acute health effects associated with the high intake of vanadium include inflammation of stomach and intestines, sickness and headaches, dizziness, skin rashes, nosebleeds and throat pains. Chronic exposure may cause eye, skin and respiratory problems. The maximum concentration of vanadium under PWQO guidelines is 6 μg/L.

Zinc

Zinc is a lustrous bluish-white metal. Overdoses do not occur very regularly. Symptoms include nausea, vomiting, dizziness, fevers and diarrhea. The maximum concentration of Zinc under PWQO guidelines is 20 μg/L.

Zirconium

Zirconium is a very strong, malleable, ductile, lustrous silver-grey metal. Zirconium and its salts generally have low systemic toxicity. The maximum concentration of Zinc under PWQO guidelines is 4 μg/L.

Appendix H: Laboratory Test Results

Laboratory Water Quality Results for Sample Site 1

	PWQO	July 20, 2007	August 8, 2007
Turbidity (NTU)	<10% of Natural	4.4	0.67
Conductivity (mS/cm)	N/A	0.229	0.251
Total Phosphorus (µg/L)	30	24	11
Total Dissolved Solids (mg/L)	N/A	180	200
Aluminum (µg/L)	75	**90**	10
Antimony (µg/L)	20	< 5	< 5
Arsenic (µg/L)	5	2	< 1
Barium (µg/L)	N/A	10	20
Beryllium (µg/L)	11	< 1	< 1
Bismuth (µg/L)	N/A	< 1	< 1
Boron (µg/L)	200	< 50	< 50
Cadmium (µg/L)	0.1	< 0.09	< 0.09
Calcium (µg/L)	N/A	32700	40600
Chromium (µg/L)	8.9	4	1
Cobalt (µg/L)	0.9	< 0.5	< 0.5
Copper (µg/L)	5	< 1	1
Iron (µg/L)	300	**740**	160
Lead (µg/L)	3	< 1	< 1
Magnesium (µg/L)	N/A	10200	13200
Manganese (µg/L)	N/A	36	11
Molybdenum (µg/L)	40	< 1	2
Nickel (µg/L)	25	2	2
Potassium (µg/L)	N/A	1000	1000
Selenium (µg/L)	100	3.8	0.5
Silicon (µg/L)	N/A	4600	4200
Silver (µg/L)	0.1	< 0.1	< 0.1
Strontium (µg/L)	N/A	51	68
Thallium (µg/L)	0.3	< 0.3	< 0.3
Tin (µg/L)	N/A	< 1	< 1
Titanium (µg/L)	N/A	< 2	< 2
Tungsten (µg/L)	30	< 10	< 10
Uranium (µg/L)	5	< 5	< 5
Vanadium (µg/L)	6	2	< 1
Zinc (µg/L)	20	6	5
Zirconium (µg/L)	4	< 4	< 4

Bold indicates above PWQO guidelines.

Laboratory Water Quality Results for Sample Site 2

	PWQO	July 20, 2007	August 8, 2007
Turbidity (NTU)	<10% of Natural	4.3	2.1
Conductivity (mS/cm)	N/A	0.140	0.247
Total Phosphorus (µg/L)	30	22	17
Total Dissolved Solids (mg/L)	N/A	140	200
Aluminum (µg/L)	75	40	40
Antimony (µg/L)	20	< 5	< 5
Arsenic (µg/L)	5	2	1
Barium (µg/L)	N/A	20	20
Beryllium (µg/L)	11	< 1	< 1
Bismuth (µg/L)	N/A	< 1	< 1
Boron (µg/L)	200	< 50	< 50
Cadmium (µg/L)	0.1	< 0.09	< 0.09
Calcium (µg/L)	N/A	24400	40600
Chromium (µg/L)	8.9	3	2
Cobalt (µg/L)	0.9	< 0.5	< 0.5
Copper (µg/L)	5	< 1	2
Iron (µg/L)	300	**730**	**430**
Lead (µg/L)	3	< 1	< 1
Magnesium (µg/L)	N/A	8800	12600
Manganese (µg/L)	N/A	50	35
Molybdenum (µg/L)	40	< 1	1
Nickel (µg/L)	25	< 2	3
Potassium (µg/L)	N/A	< 1000	1000
Selenium (µg/L)	100	1.5	0.7
Silicon (µg/L)	N/A	3700	6300
Silver (µg/L)	0.1	< 0.1	< 0.1
Strontium (µg/L)	N/A	36	65
Thallium (µg/L)	0.3	< 0.3	< 0.3
Tin (µg/L)	N/A	< 1	< 1
Titanium (µg/L)	N/A	< 2	< 2
Tungsten (µg/L)	30	< 10	< 10
Uranium (µg/L)	5	< 5	< 5
Vanadium (µg/L)	6	< 1	< 1
Zinc (µg/L)	20	4	6
Zirconium (µg/L)	4	< 4	< 4

Bold indicates above PWQO guidelines.

Laboratory Water Quality Results for Sample Site 3

	PWQO	July 20, 2007	August 8, 2007
Turbidity (NTU)	<10% of Natural	3.6	2.5
Conductivity (mS/cm)	N/A	0.173	0.183
Total Phosphorus (µg/L)	30	**30**	27
Total Dissolved Solids (mg/L)	N/A	170	160
Aluminum (µg/L)	75	**110**	30
Antimony (µg/L)	20	< 5	< 5
Arsenic (µg/L)	5	2	2
Barium (µg/L)	N/A	10	10
Beryllium (µg/L)	11	< 1	< 1
Bismuth (µg/L)	N/A	< 1	< 1
Boron (µg/L)	200	< 50	< 50
Cadmium (µg/L)	0.1	< 0.09	< 0.09
Calcium (µg/L)	N/A	32400	28900
Chromium (µg/L)	8.9	2	< 1
Cobalt (µg/L)	0.9	< 0.5	< 0.5
Copper (µg/L)	5	1	< 1
Iron (µg/L)	300	**990**	**680**
Lead (µg/L)	3	1	< 1
Magnesium (µg/L)	N/A	4100	10000
Manganese (µg/L)	N/A	132	194
Molybdenum (µg/L)	40	< 1	< 1
Nickel (µg/L)	25	2	2
Potassium (µg/L)	N/A	< 1000	< 1000
Selenium (µg/L)	100	1.3	0.4
Silicon (µg/L)	N/A	8000	6800
Silver (µg/L)	0.1	< 0.1	< 0.1
Strontium (µg/L)	N/A	55	46
Thallium (µg/L)	0.3	< 0.3	< 0.3
Tin (µg/L)	N/A	< 1	< 1
Titanium (µg/L)	N/A	4	< 2
Tungsten (µg/L)	30	< 10	< 10
Uranium (µg/L)	5	< 5	< 5
Vanadium (µg/L)	6	1	< 1
Zinc (µg/L)	20	5	6
Zirconium (µg/L)	4	< 4	< 4

Bold indicates above PWQO guidelines.

Laboratory Water Quality Results for Sample Site 4

	PWQO	July 20, 2007	August 8, 2007
Turbidity (NTU)	<10% of Natural	2.3	1.6
Conductivity (mS/cm)	N/A	0.220	0.187
Total Phosphorus (µg/L)	30	15	**37**
Total Dissolved Solids (mg/L)	N/A	180	190
Aluminum (µg/L)	75	40	20
Antimony (µg/L)	20	< 5	< 5
Arsenic (µg/L)	5	1	2
Barium (µg/L)	N/A	10	10
Beryllium (µg/L)	11	< 1	< 1
Bismuth (µg/L)	N/A	< 1	< 1
Boron (µg/L)	200	< 50	< 50
Cadmium (µg/L)	0.1	< 0.09	< 0.09
Calcium (µg/L)	N/A	32700	35900
Chromium (µg/L)	8.9	2	< 1
Cobalt (µg/L)	0.9	< 0.5	< 0.5
Copper (µg/L)	5	1	< 1
Iron (µg/L)	300	**550**	**1420**
Lead (µg/L)	3	< 1	< 1
Magnesium (µg/L)	N/A	10000	4600
Manganese (µg/L)	N/A	14	177
Molybdenum (µg/L)	40	< 1	< 1
Nickel (µg/L)	25	2	2
Potassium (µg/L)	N/A	< 1000	< 1000
Selenium (µg/L)	100	1.4	< 0.4
Silicon (µg/L)	N/A	3700	8600
Silver (µg/L)	0.1	< 0.1	< 0.1
Strontium (µg/L)	N/A	51	64
Thallium (µg/L)	0.3	< 0.3	< 0.3
Tin (µg/L)	N/A	< 1	< 1
Titanium (µg/L)	N/A	< 2	< 2
Tungsten (µg/L)	30	< 10	< 10
Uranium (µg/L)	5	< 5	< 5
Vanadium (µg/L)	6	< 1	< 1
Zinc (µg/L)	20	4	5
Zirconium (µg/L)	4	< 4	< 4

Bold indicates above PWQO guidelines.

Brule Creek Watershed Assessment Checklist

	Checked
Photos	
Upstream from sample site	
Downstream from sample site	
Upstream from culvert	
Downstream from culvert	
Measurements at Sample Site	
Channel width (m)	
Channel depth (cm)	
Flow (m/s)	
Air Temperature (oC)	
Water Temperature	
YSI meter	
Observed Flora and Fauna at Sample Site	
Tree Species	
Shrub Species	
Herb Species	
Mosses/Aquatic plants	
Benthic Species/Insects	
Terrestrial wildlife	
Additional Comments	
Physical Attributes at Sample Site	
Instream bed material	
Creek bed characteristics	
Bank Stability	
Terrain characteristics	
Stream Cover	
Culvert Measurements (Bring Diagram)	
Top of culvert to rust line	
Top of culvert to water level	
Top of culvert to bottom of culvert	
Top of culvert to water surface on river (if perched)	
Top of culvert to bottom of stream	
Water surface to high water mark on bank	
Length of covered stream	
Road surface width	
Fill height Upstream	
Fill height Downstream	
Description of culvert (Bring Example)	
Bridge Measurements	
Top of bridge to water surface	
Top of bridge to bottom of bridge	
Water surface to high water mark on bank	
Width of bridge	
Length of bridge	
Width of stream	