APPENDIX D

BENTHICS

Water Quality Assessment of Silver Creek

Preface to Water Quality Assessment of Spring (Silver) Creek (May 2002)

The following report is included in the Subwatershed Phase I Report because it provides an excellent description of macroinvertebrate communities that were found at 10 different sampling points in the Silver Creek Subwatershed. However, CVC is hesitant to endorse the model that is used in this report to predict water quality on the basis of percent natural area. The following three points outline the general concerns that CVC has with the use of the model. These concerns have been documented in detail in a technical memo from CVC to the Region of Halton (July 11, 2002).

1. The term 'water quality' as used in the report represents the health of the macroinvertebrate communities. 'Water quality' here does not specifically represent water chemistry (i.e. nutrient loads or metals contamination) or microbiological (human health such as *E. coli*) conditions in the watershed. Macroinvertebrate communities are very important and provide a great deal of insight to the health of streams and creeks, however there are many other factors that also contribute to the health of aquatic ecosystems, which have been evaluated in the main part of the Silver Subwatershed Phase I Report. In general, results from macroinvertebrate community assessments are most valuable when used as one of many tools to assess ecosystem health.
2. It may be perceived from this report that stream order and stream bank (riparian) vegetation is the only factor that will impact macroinvertebrate communities. CVC strongly disagrees with this assumption both from a scientific and from a planning perspective. The amount of imperviousness (areas where water cannot infiltrate into the ground) in a drainage area, point sources of pollution (such as treated wastewater from sewage treatment plant), natural and man-made impoundments (i.e. beaver versus man-made dams), contamination of the groundwater upwelling into a watercourse, the substrate type on the bottom of watercourses and watercourse gradient (i.e. steep and fast flows versus flat and slow flows) are examples of factors which can impact macroinvertebrates in the Credit River watershed. These other factors should not be overlooked when assessing the existing health of macroinvertebrate communities or when evaluating impacts to these communities from land use changes, impoundments, or new point sources.
3. The model that has been used in this report to attempt to predict 'water quality' for all the watercourses in the subwatershed has only been applied to a specific type of watercourse; a permanent flowing stream or creek. Other types of watercourse such as river and intermittent flowing watercourses have been documented in the subwatershed but it has not been shown that model can be applied these other types of watercourses.

The above points should no distract the reader from the valuable information this report provides in terms of the macroinvertebrate communities found at the sites sampled by Dr. Griffiths. A comparison of the results in this report and the results from the Silver Creek Subwatershed Phase I macroinvertebrate sampling program are presented in Section 4.7.5.

Water Quality Assessment Of Silver Creek.

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May 2002

Water Quality Assessment Of Silver Creek.

Introduction:

A subwatershed study of Silver Creek, part of the Credit River Watershed, is currently being conducted by the Credit Valley Conservation Authority for the Municipality of Halton Hills. The subwatershed background report notes that current water quality conditions, assessed through water chemisty, benthic macroinvertebrates or fishes, can be characterized only at a limited number of sites in the Silver Creek watershed. The absence of water quality information throughout the subwatershed was identified as an information gap that needed to be addressed during the subwatershed study.

In response to the need for water quality information, this component study assessed the water quality conditions at ten specific sites in the Silver Creek subwatershed and examined the relationship between water quality conditions and riparian vegetation in order to evaluate and map the water quality conditions throughout the subwatershed (Griffiths 2001a, b).

Methods:

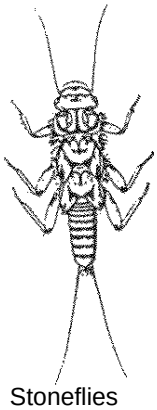
Water Quality Measure:

Benthic macroinvertebrates, those large invertebrates that tunnel into and crawl over the bottom substrates of streams (Figure 1), were used to measure water quality. These organisma provide an excellent means for evaluating local water quality conditions because:

i) they are abundant in all types of aquatic systems, living on or within the substrate;
ii) they are easily collected and readily identified;

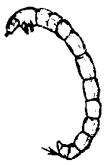
INSECTS:

Mayflies
Family: Heptageniidae



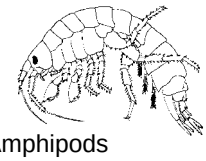
Stoneflies
Family: Perlidae

Caddisflies
Family: Hydropsychidae

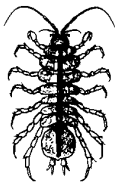


Midges
Family: Chironomidae

CRUSTACEANS:



Amphipods
Family: Gammaridae



Isopods
Family: Asellidae

MOLLUSCS:

Snails
Family:Physiidae

Bivalves
Family: Sphaeriiidae

ANNELIDS:

Worms
Family: Tubificidae

Leeches
Family: Glossiphonidae

PLATYHELMINTHES:

Flatworms
Class: Tricladida

Figure 1: Common benthic macroinvertebrates in Ontario streams.

iii) they remain in a localized area because of their restricted mobility and habitat preference;

iv) their abundance is not affected by sport or commerical fisheries;

v) they are continuously subjected to the full rigor of the local environment throughout their aquatic life-cycle, which varies from several weeks to a few years;

vi) they show a wide range of tolerances to various degrees and types of pollution; and

vii) they integrate the effects of all pollutants and environmental conditions over time and thus provide a holistic measure of ecological impact.

Although benthic macroinvertebrates have little social relevance, they are an important food source for fish and waterfowl, organisms that the public relates with unimpaired environmental conditions.

Sampling Methods:

Benthic macroinvertebrates were collected from 10 sites in the Silver Creek watershed (Figure 2) using BioMAP sampling protocols (Griffiths 1999) between mid-September and mid-October 2001. Two quantitative samples and a single qualitative sample were collected at each site. The quantitative samples were collected typically from a riffle section using a T-sampler (Figure 3) that enclosed an area of 0.05 m^2 and had a 600μm mesh collecting net. All macroinvertebrates and debris retained in the collecting net were placed in a labeled, 3L bottle filled with stream water and transported to a field site in a cooler.

The qualitative sample was collected by disturbing various substrates occurring at the sampling site (e.g. sand, gravel, wood, undercut banks, large rocks, aquatic vegetation, filamentous algae) and sweeping an A-frame net through the water (i.e. kick and sweep method). Contents of the A-frame net were frequently emptied into a bucket containing stream water. In addition, organisms found on large individual stones and pieces of wood were added to this sample. All macroinvertebrates collected over a period of about 10-20 minutes were included in

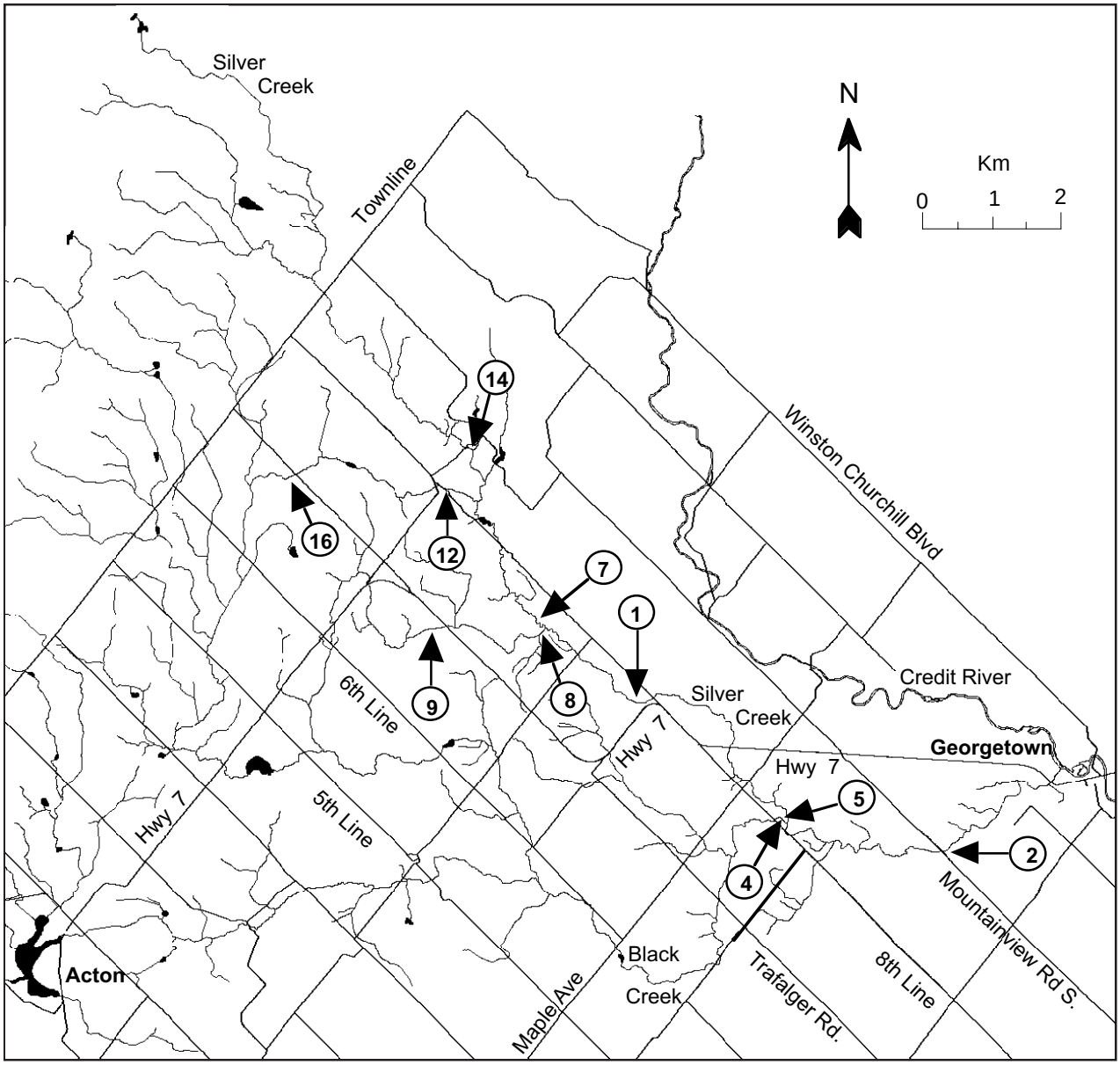


Figure 2: Location of sampling sites along Silver Creek.

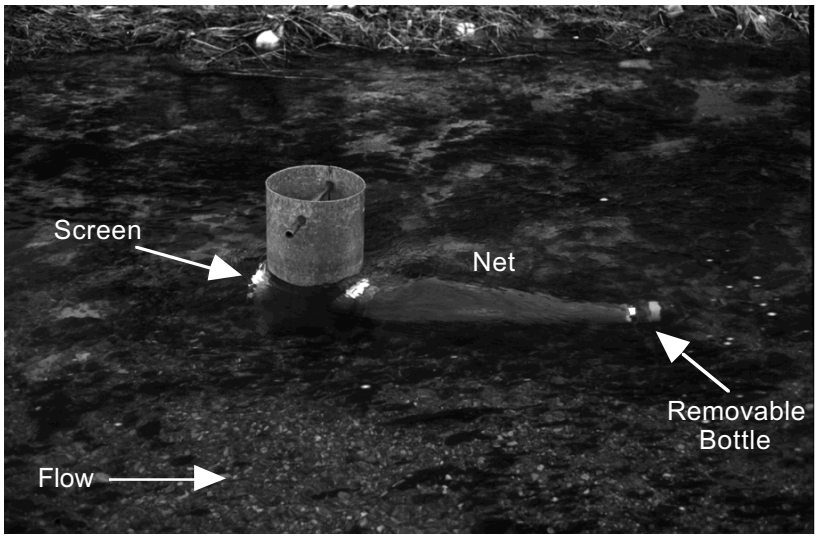


Figure 3: T-sampler screwed into bottom sediments of stream.

the sample. The contents of the bucket were emptied into a labelled jar which was placed on ice in a cooler.

Each sample was poured into a white enamel tray. Using forceps, the macroinvertebrates were removed from the debris and placed in 30mL bottles containing 80% ethanol. All samples were processed the day that they were collected. Later, the specimens were identified to the lowest practical level -- genus usually, species for specific groups (e.g. Perlidae; Baetidae, Elmidae; *Hydropsyche*; Annelids) using the keys and references noted in Griffiths (1999). Individuals with a body width <500μm were not enumerated because the sampling equipment retains but a small proportion of benthos in this size category.

In addition to the benthic samples, conductivity and water temperature, were measured at each site and a variety of site characteristics (e.g. fish, algae, macrophytes, substrate type, riparian vegetation) were recorded. It is assumed that the water temperature measurements were near the maximum daily values and that the conductivity measurements were near the daily minimum values, which typically occur between 4 and 8 PM (Griffiths 1999). Furthermore, the width of the watercourse under bankfull conditions was estimated, since this was the main

environmental scaling variable required to interpret the biological information in terms of water quality.

Data Analysis:

Water quality conditions at each site were chiefly assessed using the BioMAP(d) water quality index (Griffiths 1999). This water quality index combines a measure of an organism's sensitivity to pollution with a measure of its abundance across all taxa at a site. Griffiths (1999) has assigned sensitivity values to 637 taxa occurring in Ontario watercourses. Water quality was classified as either unimpaired (site supports species characteristic of habitat) or impaired (species characteristic of habitat were replaced with more pollution-tolerant species) based on pre-established threshold values (Appendix 1). To identify the potential cause of impaired water quality conditions, a variety of biological metrics (density, taxa richness, proportion of insect, etc.) were calculated and compared to standards developed by Griffiths (1999) (Appendix 2). Furthermore, specific environmental conditions (maximum summer water temperature, occurrence of algae or plants, oxygen conditions, groundwater inflow, etc.) were elucidated from the abundance of individual taxa based on an understanding of their known ecological relationships.

Results:

Headwater streams of Silver Creek north of Townline were found to be lacking water during August suggesting that these watercourses have limited groundwater input. In contrast, headwater streams south of Townline were found to be flowing. Conductivity of these waters was noted to be between 600 and 700 μS/cm suggesting that groundwater accounted for most of the water in these watercourses. The tributary crossing 9th Line and south of Townline was found to be flowing northward away from main channel of Silver Creek. This tributary thus was not part of the watershed and was erased from the watershed map.

A total of 136 taxa were found at the 10 sites (Appendix 3). The mean number of taxa per sample (sample richness) ranged from a low of 10.5 at Sites 14 and 16 to a high of 31 at Site 4 on Black Creek (Table 1). The total number of taxa per site (site richness) ranged from 25 at Site 16 on Snow Creek to 50 on Black Creek. The mean density of macroinvertebrates ranged from 21.5 animals per 0.05 m^2 at Site 12 on Snow Creek to 587 animals per 0.05 m^2 at Site 4 on Black Creek.

Unimpaired water quality conditions were indicated at the four upstream sites, i.e. Sites 16, 12, 14 and 9 (Table 1). Site 9, on a small unnamed tributary of Silver Creek, had the highest BioMAP(d) score of the 10 sites sampled. This creek flowed through a small, well-treed valley. The macroinvertebrate fauna consisted of many rare and uncommon species including the caddisflies: *Parapsyche*, *Hydropsyche ventura*, *Diplectrona modesta*, *Dolophilodes*, *Rhyacophila* spp., mayflies: *Baetis tricaudatus*, *Serratella serratoides*, and *Heptagenia pulla*, and stoneflies: *Sweltsa onkos* and *Soyedina vallicularia* (Appendix 3). These taxa are indicative of clear, cold, permanently-flowing conditions. An afternoon water temperature of 16°C measured in August 2001 supports this interpretation. The unusually high proportion of pollution-sensitive, creek-dwelling organisms (>50%) at this site (Table 1) suggests optimal environmental conditions with little stress. Meanwhile, the presence of watercress and horsetails indicates the influx of groundwater into the watercourse. The conductivity of 700 μS/cm suggests that groundwaters account for most of the flow. In addition, the amphipod, *Gammarus lacustris*, was found. While common in nothern Ontario, this may be the most southerly population of this species in North America. The fauna in this reach likely represents one of the few remaining examples of "prisitine conditions".

Site 16 was located in the headwaters of Snow Creek that was surrounded by a maple/cedar swamp. The bottom substrate of the small watercourse flowing through the swamp was composed of silts, leaves and woody debris. The lake-like characteristics of swamp watercourses, i.e. low gradient and high organic content (leaves, woody debris), accounts for the high proportion of pollution-tolerate, lake-dwelling organisms (Table 1) and, in particular, the occurrence of the midge taxa: *Tribelos*, *Procladius*, *Microtendipes* and *Natarsia* (Appendix 3), which typically occur in

Table 1: Physicochemical and biological characteristics of sampling sites in Black Creek and Silver Creek. Watercourse classifications based on bankfull width of the site: C=creek; S=stream; R=river; LR=large river (see Griffiths 1999). BioMAP (d) scores in bold type indicate unimpaired water quality conditions.

	Sites									
	Snow 16	Snow 12	Silver 14	Silver 7	Trib 9	Trib 8	Silver 1	Silver 5	Black 4	Silver 2
Conductivity (μS/cm)	920	630	600	630	700	720	630	700	1070	830
Bankfull Width (m)	>64	6.5	6.5	5	3.5	3	6	5	7	8
Classification	Ch	S	S	S	C	C	S	S	S	S
BioMAP (d) score	**9.4**	**27.1**	**26.1**	6.3	**32.7**	10.1	11.6	**14.6**	**17.9**	**16.5**
Sample Richness	10.5	11	10.5	28	15	19.5	21.5	24.5	31	26.5
Site Richness	25	29	27	42	28	43	41	39	50	41
Mean Density (0.05 m^{-2})	148	21.5	50.5	275	53.5	74.5	107	401	587	247
% Insects	99.7	92.5	100	44.4	98.9	82.1	78.0	96.0	92.2	81.2
% Elmid beetles	3.4	0.0	6.6	8.1	4.6	15	30	24	15	12
% Hydropsychids	0.0	32	1.5	0.4	1.6	0.0	17	53	51	19
% Chironomids	69	19	19	10	4.6	13	16	1.7	6.9	27
% Crustaceans	0.0	4.5	0.0	0.6	1.1	0.0	1.1	0.5	0.3	0.9
% Molluscs	0.0	1.5	0.0	23	0.0	8.4	1.0	0.7	0.4	1.2
% Bivalves	0.0	0.0	0.0	2.9	0.0	5.4	0.7	0.2	0.0	1.2
%Snails	0.0	1.5	0.0	20	0.0	3.0	0.3	0.5	0.4	0.0
% Annelids	0.3	0.0	0.0	33	0.0	9.4	20	1.4	6.2	17
% Tubificids	0.0	0.0	0.0	33	0.0	9.4	20	1.4	0.2	7.4
% Flatworms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.9	0.0
% Sensitive (Creek taxa)	0.0	26.1	36.5	0.2	60.3	0.0	0.0	0.3	1.6	2.0
% Tolerant (Lake taxa)	24.6	1.6	0.8	35.2	0.0	15.7	19.9	1.6	0.6	3.6

the littoral habitat of lakes. The abundant supply of leaf material to the watercourse accounts for the high abundance of the shredding mayfly, *Paraleptophlebia*. Meanwhile, the presence of the caddisfies: *Molanna* (possibly *M. blenda*) and *Lype diversa*, indicates cool summer water temperatures, an abundance of woody debris and the presence of upwelling groundwaters. An afternoon water temperature of 10°C was measured in August 2001 suggesting an influx of cold groundwaters. The elevated conductivity of the water indicates the occurrence of leached leaf compounds which also accounts for the tea-colour of the water. As bankfull width is the distance across of the watercourse marking the 1 in 2 year return flow, bankfull width incorporated the width of the swamp which was estimated to be greater than 64 m. As a consequence, the watercourse at this site was classification as a large river.

Site 12 was located along a downstream reach of Snow Creek that flows over fractured limestone in a well-treed, steep ravine. The low density of benthic macroinvertebrates reflects both the limited habitat space (bedrock to surface with small pockets of cobble and gravel) and limited nutrient inputs. The presence of the beetle, *Ectopria*, caddisflies: *Hydropsyche ventura*, *Diplectrona modesta*, *Lype diversa*, and *Rhyacophila vibox*, mayfly: *Heptagenia pulla*, and stoneflies: *Sweltsa onkos* and *Leuctra* (Appendix 3) suggests clear, cold, permanently-flowing conditions. The presence of mosses on the rocks and the conductivity of 630μS/cm indicate an influx of groundwaters.

Site 14 was located along an upper reach of Silver Creek that like Site 12 flows over fractured limestone in a treed, steep ravine. The presence of the caddisflies: *Hydropsyche ventura*, *Diplectrona modesta*, *Lepidostoma*, and *Rhyacophila fuscula*, mayfly: *Heptagenia pulla*, stoneflies: *Sweltsa onkos* and *Soyedina vallicularia* and true fly: *Diamesa* (Appenidx 3) suggests clear, cold, permanently-flowing conditions. The presence of mosses on the rocks and the conductivity of 600μS/cm indicate an influx of groundwaters.

Impaired water quality conditions were indicated at Site 7 on Silver Creek, i.e. BioMAP(d) score <10 (Table 1). This reach was surrounded by pasture and

abandoned farmland with little riparian forest. The banks were collapsing into the stream likely as a result of runoff waters being rapidly drained to the watercourse. The water was turbid and fine sediments had accumulated along the shoreline in many locations indicating the stream was having difficulty transporting the current influx of sediments. About a third of the benthos was composed of annelids (Table 1), particularly the sludgeworms: *Tubifex tubifex* and *Limnodrilus hoffmeisteri* (Appendix 3). Along with the presence of the midge, *Chironomus*, these organisms suggest organically enriched, silty conditions with relatively low dissolved oxygen conditions during the night. The elevated abundance of molluscs (>10%) resulted from clams burrowing into the accumulation of soft, fine sediments and snails, particularly *Elimia livescens* and *Ferrissia*, grazing algae from courser substrates (e.g. rocks, sticks). Together with the caddisfly, *Helicopsyche borealis*, the snails suggests nutrient enriched conditions along this reach. Stabilization of the stream banks, possibly through planting woody vegetation and reducing the direct discharge of runoff waters into the stream, and reduction of sediment inputs (soil erosion) is critical to relieving the stress on this stream reach.

Site 8 was located on Snow Creek just upstream of its confluence with Silver Creek. This reach had been channelized and straightened and formed the boundary between fields of pasture and abandoned farmland. The benthic fauna in this creek indicated impaired water quality conditions, with a BioMAP(d) score under 14 (Table 1). Annelids accounted for almost 10% of the benthic fauna with the sludgeworm, *Limnodrilus hoffmeisteri*, being the most abundant (Appendix 3). Along with the abundance of clams, this suggests the accumulation of fine sediments (silts) and organically enriched conditions. However, the presence of cool-water species such as the caddisflies: *Goera stylata*, *Diplectrona modesta*, *Pycnopsyche*, the dragonfly: *Cordulegaster*, the mayfly *Ephemerella subvaria*, the stonefly: *Amphinemura* and the true fly: *Diamesa* suggests that the inflow of groundwaters into this reach has alleviated some of these agriculturally related impacts. An improvement in water quality conditions could be realized by restoring the geomorphology (natural shape) of this reach and planting woody vegetation along the riparian corridor.

Site 1 was located on Silver Creek just north of Hwy 7 in Glen Williams and receives the flow from Sites 7 and 8. The BioMAP(d) score of 11.6 suggests that the water quality conditions in this reach is under some stress. The sludegeworm, *Limnodrilus hoffmeisteri*, accounted for almost 20% of the organisms suggesting an accumulation of silts and organic matter. A beaver dam was removed just upstream of this site within the previous month which may account for some of the silts and organic matter. This site, however, also recieves the silts and organic matter flushed from Site 7. The higher richness and density of riffle beetles (elmids), hydropsychid caddisflies, alderflies, stoneflies and reduced density of molluscs and annelids (Table 1; Appendix 3) relative to that at Site 7 shows an improvement in water quality conditions over Site 7. This site may represent the lower extent of the agricultural impacts occurring upstream in the Site 7 reach. This site should be re-sampled once the local effects caused by the removal of the beaver dam has dissipated in order to assess upstream agricultural impacts on this reach.

Site 5 was located on Silver Creek just upstream of the confluence with Black Creek in Georgetown. This site receives the flows from Site 1. The BioMAP(d) score indicated that water quality conditions were unimpaired (Table 1). However, the water was noticeably turbid and fine sediments had accumulated along the edge of the watercourse. Further, the high abundance of macroinvertebrates (400 m^{-2}), particularly elmid beetles and hydropsychid caddisflies (Appendix 3), suggests some nutrient enrichment along this reach. Meanwhile, the abundance of watercress along the watercourse and the occurrence of the caddisfly: *Chimarra*, mayfly: *Ephemerella subvaria*, and true fly: *Antocha*, suggests the influx of groundwaters. Thus it appears that the influx of cool groundwater has buffered any effects of the transported fine sediments on the fauna. Overall, this reach appears to be able to tolerate the current load of fine sediments and nutrients.

Site 4 was located on Black Creek just upstream of the confluence with Silver Creek in Georgetown. The BioMAP(d) score indicated that water quality conditions were unimpaired (Table 1). However, this site had the highest richness and abundance of benthic macroinvertebrates among the 10 sites sampled. The elevated abundance of invertebrates (>500 m^{-2}), particularly of elmid beetles and

hydropsychid caddisflies (Table 1; Appendix 3), suggests some nutrient enrichment along this reach. The elevated conductivity of the water (Table 1) clearly shows the presence of dissolved solids. These dissolved solids can be traced upstream to the Acton Sewage Treatment Plant, where the conductivity was 1320 μS/cm downstream of the plant relative to 510μS/cm at the reservoir upstream of the plant (personal observation). The abundance of watercress along the watercourse and the occurrence of the caddisfly: *Chimarra*, mayfly: *Ephemerella subvaria*, and true flies: *Dicranota* and *Antocha*, again suggests the influx of groundwaters into this reach. Thus it appears that the influx of cool groundwater has buffered to some extent the effects of nutrients on the fauna. Overall, this reach appears to be able to tolerate the current load of nutrients.

Site 2 was located along Silver Creek downstream of Mountainview Road South in Georgetown. This site receives the flow from both Sites 4 and 5. The stream flows through a very wide, deep valley and occupies only a small proportion of the bottom lands suggesting that a larger volume of water once flowed through this valley. The BioMAP(d) score indicated that water quality conditions were unimpaired (Table 1). The abundance of macroinvertebrates was about half that at Sites 4 and 5, suggesting that the slight enrichment effect noted at these upstream sites did not extend down to this reach. Although annelids accounted for 16.7% of the benthic fauna, most of these were *Stylodrilus herringianus* and *Potamothrix bavaricus* (Appendix 3). Along with the abundance of the midges, *Microtendipes* and *Stictochironomus*, these worms suggest the accumulation of mineral sediments with little organic matter. The presence of cool-water taxa such as the caddisflies: *Chimarra* and *Rhyacophila lobifera*, the mayfly: *Ephemerella subvaria*, and true fly: *Antocha*, suggest that some limited groundwater inflow may occur along this downstream reach.

Discussion:

Townline essentially separates the northern headwater tributaries of Silver Creek that rely primarily on surface waters for flow and thus are dry for part of year, from the southern headwater tributaries that rely primarily on groundwaters and thus flow throughout the year. Groundwater appears to contribute to the flow of these watercourses at least as far downstream as the Silver and Black Creek confluence. As a consequence of this groundwater influx, these watercourses tend to be ecologically more robust and thus tolerate stresses (e.g. nutrients, organic matter, sedimentation) imposed from agriculture and urbanization. Unimpaired water quality conditions were found at 7 of the 10 sampling sites. The impaired water quality conditions at Sites 7 and 8 were caused by agricultural activities. These 10 sites, however, cannot be generalized to the complete basin.

Griffiths (2001a, b) proposed a model that linked the water quality of streams, as reflected by benthic macroinvertebrates, with the proportion of woody vegetation along the stream banks (riparian wildlands) as measured from satellite imagery. Thus the proportion of riparian wildlands in a 200x200m square upstream of all Silver Creek sites, except Site 16 located in the cold-water swamp, was estimated from Landsat 7 multi-spectral imagery as described in Griffiths (2001b). Overalying the data from this study onto the relationship found by Griffiths (2001b) for other stream sites in the Region of Halton showed a very good fit (Figure 4). In other words, an estimate of riparian wildlands along Silver Creek provides a good predictor of water quality conditions.

Water quality conditions in the Silver Creek Basin thus were estimated based on the relationship in Figure 4 (Figure 5). Of the 130 km of watercourse, 65.1% of Silver Creek had unimpaired water quality, 11.5% was indeterminate, and only 23.4% was impaired. In comparison with other subwatersheds in Ontario, Silver Creek is in very good condition overall (Griffiths 2001b). Although reaches of impaired water quality can be seen throughout the watershed, it is evident that impaired water quality conditions are concentrated above the escarpment in the

rural/agricultural part of the basin. Many of these streams are presently temporary watercourses lacking flow during summers with low rainfall. It is possible that the change in land use from natural vegetation to agriculture has resulted in the loss of surface water storage features (i.e. wetlands) and thus many of these streams now dry up during summer.

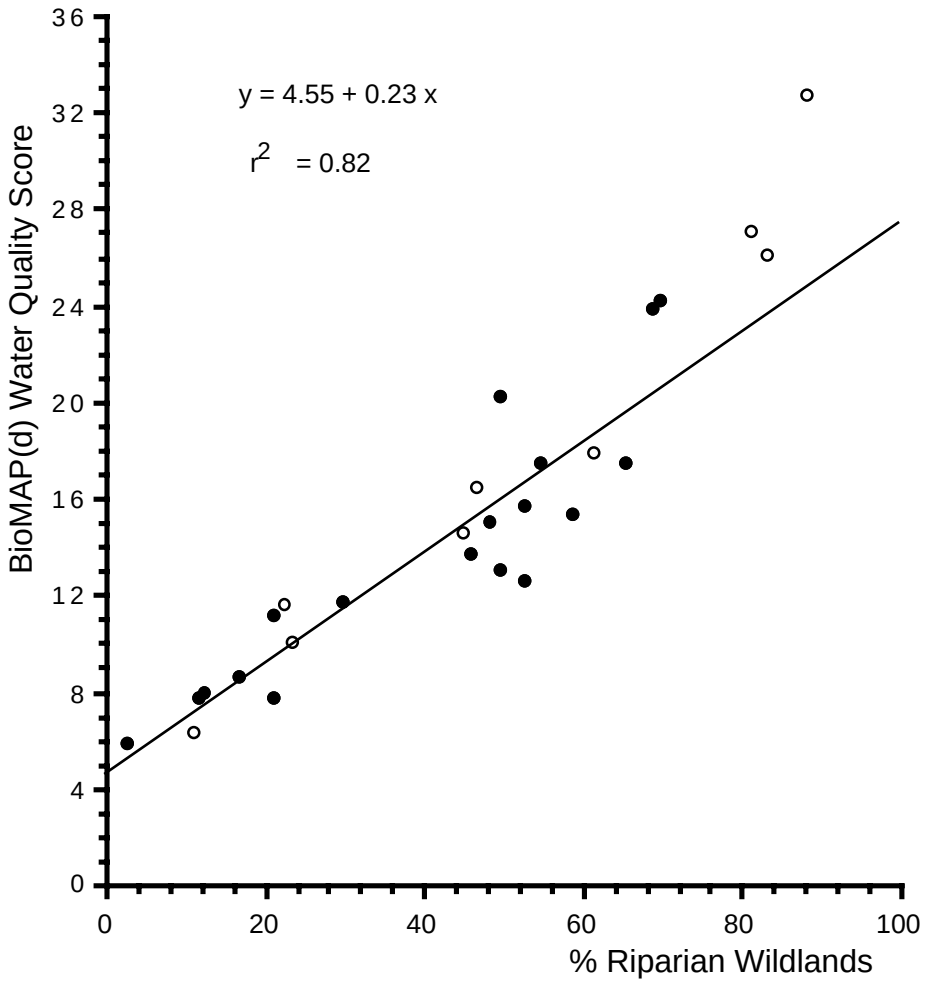
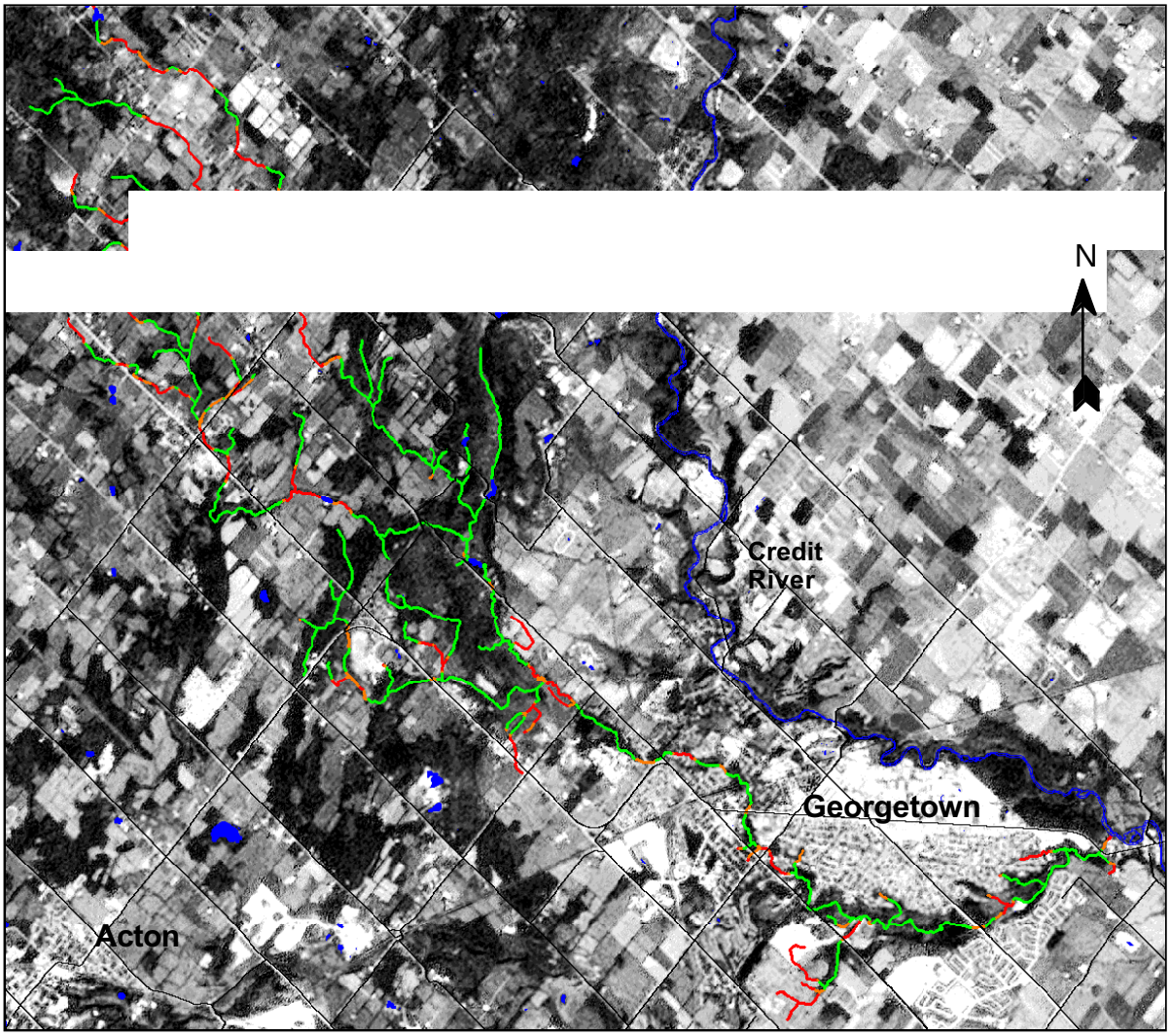


Figure 4: Relationship between water quality as measured by the BioMAP(d) index and the percent of riparian wildlands estimated from Landsat 7 multispectral imagery for stream sites in the Region of Halton (solid circles) and in Silver Creek (open circles).

Figure 5:

Water Quality along Silver Creek



0 2,500 5,000 Metres

Image acquired September 3,

Impaired Water Quality
Indeterminate Water Quality
Unimpaired Water Quality

References:

Griffiths, R.W. 1999. BioMAP: Bioassessment of Water Quality. Published by: The Centre for Environmental Training, Glendale Campus, Niagara College, Niagara-on-the-Lake, Ontario. 110 pp.

Griffiths, R.W., 2001a. Mapping the water quality of streams using benthic macroinvertebrates and satellite imagery. Verh. Internat. Verein. Limnol.. 27: 3550-3555.

Griffiths, R.W. 2001b. Mapping the Water Quality of Watercourses in the Region of Halton: An ecosystem approach to watershed planning. Prepared for: Regional Municipality of Halton, Planning and Public Works. 37 pp.

Appendix 1: Threshold values to classify the water quality of watercourses based on BioMAP(d) and BioMAP(q) water quality indices. Based on Griffiths (1999).

	Water Quality Classification based on the BioMAP(d) WQI		Water Quality Classification based on the BioMAP(q) WQI	
	Unimpaired	Impaired	Unimpaired	Impaired
Creeks	> 16	< 14	> 3.4	< 3.2
Streams	> 12	< 10	> 3.0	< 2.6
Rivers	> 9	< 7	> 2.4	< 2.0
Large Rivers	> 7	< 5	> 1.8	<1.4
Channels	> 4.5	< 2.5	> 1.3	<0.9

Appendix 2: Range of expected values for various biological metrics from unimpaired, gravel-bottom creeks, streams, and rivers in southern Ontario. Based on Griffiths (1999).

	Creeks	Streams	Rivers
Density (No. per 0.05 m^2)	50 - 200	100 - 400	200 - 800
Richness (taxa per sample)	15 - 30	20 - 40	20 - 50
Richness (taxa per site)	20 - 40	30 - 60	40 - 80
% insects	> 90	> 80	> 70
% chironomids	10 - 30	10 - 30	10 - 40
% crustaceans	< 3	< 10	< 5
% isopods	< 1	< 3	< 3
% snails	< 1	< 5	2 -10
% bivalves	< 3	< 5	2 - 10
% annelids	< 5	< 5	2 - 10
% tubificids	< 1	< 2	< 5
% flatworms	< 3	< 3	< 5
% shredders	40 - 20	30 - 10	< 10
% filter-feeders	< 10	10 - 40	20 - 60

Appendix 3: Macroinvertebrate composition (number per 0.05 sq. m.) at sites in the Silver Creek subwatershed. Samples collected in September and October, 2001. SVs are the BioMAP sensitivity values based on Griffiths (1999). Q denotes macroinvertebrates found in the qualitative sample.

		Snow Creek 16			Snow Creek 12			Silver Creek 14			Silver Cr. Trib 9			Silver Cr. Trib 8		
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
	Insects:															
	ALDERFLIES:															
	Corydalidae:															
3	Nigronia				P									P		
	Sialidae:															
2	Sialis	P		9							P				1	
	BEETLES:															
	Dytiscidae:															
2	Neoporus															
	Elmidae:															
1	Dubiraphia quadrinotata	P	5	5											1	
2	Dubiraphia vittata															
2	Macronychus glabratus															
2	Optioservus fastiditus	P							2	5	P	2	3	P	16	6
3	Optioservus trivattatus															
2	Stenelmis crenata															
	Hydrophilidae:															
1	Hydrobius										P					
2	Paracymus								1	10						
	Psephenidae:															
3	Ectopria					1	1									
	BUGS:															
	Corixidae															
	Gerridae:															
3	Aquarius remigis				P											
	Veliidae:															
0	Microvelia				P			P								
	CADDISFLIES:															
	Branchycentridae:															
4	Micrasema															
	Glossosomatidae:															
4	Glossosoma															
	Goeridae:															
3	Goera stylata														1	
	Helicopsychidae:															
2	Helicopsyche borealis															
	Hydropsychidae:															
-	Cheumatopsyche						1				P			P		
3	Diplectrona modesta				P	4	6			1	P			P		
2	Hydropsyche betteni															
3	Hydropsyche bronta						1									
3	Hydropsyche slossonae							P						P		
3	Hydropsyche sparna										P		1			
4	Hydropsyche ventura				P		1			1	P		1			
4	Parapsyche										P					
	Lepidostomatidae:															
4	Lepidostoma							P								

Appenidx 3: continued

		Snow Creek 16			Snow Creek 12			Silver Creek 14			Silver Cr. Trib 9			Silver Cr. Trib 8		
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
	Leptoceridae:															
1	Mystacides															
2	Oecetis															
	Limnephilidae:															
3	Pycnopsyche													P		
	Molannidae:															
2	Molanna	P			P											
	Philopotamidae:															
4	Dolophilodes										P					
3	Chimarra															
	Polycentropodidae:															
-	Polycentropus						1									
	Psychomyiidae:															
3	Lype diversa		1		P	1										
	Rhyacophilidae:															
4	Rhyacophila fuscula							P		1	P	1				
3	Rhyacophila lobifera										P		7			
4	Rhyacophila vibox				P		1				P	2	1			
	DAMSELFLIES:															
	Calopterygidae:															
3	Calopteryx maculata		1											P		
	DRAGONFLIES:															
	Aeshnidae:															
2	Boyeria vinosa			1												
2	Aeshna	P														
	Cordulegasterygidae:															
3	Cordulegaster													P		
	Libellulidae:															
0	Plathemis lydia							P								
	MAYFLIES:															
	Baetidae:															
1	Baetis flavistriga															
4	Baetis tricaudatus									1	P	11	21			
3	Diphetor hageni											1	3	P		2
	Caenidae:															
1	Caenis	P														
2	Caenis anceps															
	Ephemeridae:															
3	Ephemera guttulata															
2	Ephemera simulans															
	Ephemerellidae:															
3	Ephemerella invaria													P		
3	Ephemerella subvaria							P	5	13				P	22	12
4	Serratella serratoides										P		1			
	Heptageniidae:															
3	Heptagenia pulla				P			P			P	4	2			
2	Stenacron interpunctatum															
3	Stenonema vicarium															

Appenidx 3: continued

		Snow Creek 16			Snow Creek 12			Silver Creek 14			Silver Cr. Trib 9			Silver Cr. Trib 8		
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
	Isonychidae:															
2	Isonychia															
	Leptohyphidae:															
2	Tricorythodes															
	Leptophlebiidae:															
3	Paraleptophlebia	P	52	15		1	1	P	1	1	P	2	1	P	3	1
	STONEFLIES:															
	Capnidae:															
3	Paracapnia				P							2	1	P	2	
	Chloroperlidae:															
4	Sweltsa onkos				P		2	P	7	32	P	17	7			
	Leuctridae:															
4	Leuctra					3	4									
	Nemouridae:															
4	Amphinemura													P		
4	Soyedina vallicularia							P					1			
	Perlidae:															
3	Acroneuria carolinensis				P			P						P		
3	Paragnetina media				P											
	Perlodidae:															
3	Clioperla clio													P		
	Taeniopterygidae:															
3	Taeniopteryx														1	
	TRUE FLIES:															
0	Ceratopogonidae	P												P	3	5
	Chironomidae:															
0	Chironomus															
1	Clinotanypus															
2	Conchapelopia															
2	Corynoneura															1
2	Cricotopus						1							P		
3	Cricotopus trifascia															
1	Cryptochironomus															2
2	Crypotendipes													P		
3	Diamesa				P		8	P	11		P	2	2			
3	Eukiefferiella															
3	Helopelopia								1							
3	Macropelopia										P					
2	Microtendipes	P	27	27					1							1
3	Natarsia	P	4	17											2	1
1	Nilothauma															
-	Orthocladius															
3	Pagastia						1	P								
2	Parakiefferiella														1	7
3	Parametriocnemus						1									
1	Paratanytarsus						1									
-	Polypedilum angulum														1	
1	Polypedilum fallax														1	
0	Polypedilum halterale															

Appenidx 3: continued

		Snow Creek			Snow Creek			Silver Creek			Silver Cr. Trib			Silver Cr. Trib		
			16			12			14			9			8	
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
1	Polypedilum scalaenum														1	
1	Potthastia															
0	Procladius	P	40	33												
3	Rheotanytarsus															
3	Stempellinella															
2	Stictochironomus															
2	Tanytarsus		1													
1	Tribelos	P	22	18												
2	Trissopelopia		1	12												
2	Tvetenia										P		1			
2	Empididae												1		1	
0	Psychodidae									1						
2	Simuliidae												5			
	Tabanidae:															
2	Chrysops													P	11	10
	Tipulidae:															
3	Antocha							P	1							
3	Dicranota							P	3		P		1	P	1	
2	Hexatoma				P			P								
2	Limnonia				P			P					2			
1	Pilaria															
3	Pseudolimnophila	P		4											5	
-	Tipula	P			P			P	2					P	2	
	Crustaceans:															
	AMPHIPODS:															
	Gammaridae:															
3	Gammarus lacustris										P	1				
	Hyalellidae:															
2	Hyalella	P														
	CRAYFISHES:															
	Cambaridae:															
1	Cambarus robustus				P	1		P								
2	Orconectes propinquus															
	ISOPODS:															
	Asellidae:															
1	Caecidotea															
	Molluscs:															
	BIVALVES:															
	Sphaeridae:															
2	Musculium transversum															
-	Pisidium	P													3	3
1	Sphaerium simile	P													1	1
2	Sphaerium striatinum															
	SNAILS:															
	Ancylidae:															
2	Ferrissia															

Appenidx 3: continued

		Snow Creek 16			Snow Creek 12			Silver Creek 14			Silver Cr. Trib 9			Silver Cr. Trib 8		
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
	Lymnaeidae:															
0	Pseudosuccinea columella															
	Physidae:															
0	Physella	P					1							P		1
	Planorbidae:															
0	Helisoma anceps															
	Pleuroceridae:															
2	Elimia livescens															3
	Annelids:															
	LEECHES:															
	Erpobdellidae:															
2	Mooreobdella microstoma															
	Glossiphonidae:															
-	Actinobdella inequiannulata															
2	Glossiphona complanata		1													
2	Helobdella stagnalis	P												P		
	WORMS:															
	Lumbriculidae															
4	Stylodrilus herringianus															
	Tubificidae:															
0	Limnodrilus hoffmeisteri														2	10
2	Potamothrix bavaricus															
0	Tubifex tubifex															
0	immature (w/o hair chaete)															
0	immature (with hair chaete)														1	
	Platyhelminthes:															
	FLATWORMS:															
3	Tricladida															
	Number of taxa	27	19	14	26	14	20	27	19	14	30	19	23	32	31	20
	Number of organisms		223	149		63	40		95	74		85	70		119	74

Appendix 3: Macroinvertebrate composition (number per 0.05 sq. m.) at sites in the Silver Creek subwatershed. Samples collected in September and October, 2001. SVs are the BioMAP sensitivity values based on Griffiths (1999). Q denotes macroinvertebrates found in the qualitative sample.

		Silver Creek 7			Silver Creek 1			Black Creek 4			Silver Creek 5			Silver Creek 2		
SVs	Taxa	Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
	Insects:															
	ALDERFLIES:															
	Corydalidae:															
3	Nigronia				P		1		1		P	1	2			
	Sialidae:															
2	Sialis				P	1	1					1				
	BEETLES:															
	Dytiscidae:															
2	Neoporus	P														
	Elmidae:															
1	Dubiraphia quadrinotata											1				
2	Dubiraphia vittata	P	21	20	P		1	P	1						3	2
2	Macronychus glabratus							P								
2	Optioservus fastiditus			1	P		6	P	15	10				P		
3	Optioservus trivattatus				P	7	30	P	16	68	P	49	19	P	14	5
2	Stenelmis crenata		1	1	P	7	19	P	20	51	P	61	39	P	17	4
	Hydrophilidae:															
1	Hydrobius															
2	Paracymus															
	Psephenidae:															
3	Ectopria		13													
	BUGS:															
	Corixidae	P														
	Gerridae:															
3	Aquarius remigis				P			P			P					
	Veliidae:															
0	Microvelia															
	CADDISFLIES:															
	Branchycentridae:															
4	Micrasema			1					8	10				P	4	5
	Glossosomatidae:															
4	Glossosoma											3				
	Goeridae:															
3	Goera stylata															
	Helicopsychidae:															
2	Helicopsyche borealis		6	10		1	2		21	14	P	16	4		7	6
	Hydropsychidae:															
-	Cheumatopsyche				P	2	12	P	184	188	P	203	75	P	9	6
3	Diplectrona modesta															
2	Hydropsyche betteni								4			36	12			
3	Hydropsyche bronta		1	1	P		25	P	18	129	P	38	6	P	17	27
3	Hydropsyche slossonae				P		5	P	15	30		55	4	P	15	4
3	Hydropsyche sparna				P		4	P	23	4		10	1	P	1	2
4	Hydropsyche ventura															
4	Parapsyche															
	Lepidostomatidae:															
4	Lepidostoma															

Appenidx 3: continued

		Silver Creek 7			Silver Creek 1			Black Creek 4			Silver Creek 5			Silver Creek 2		
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
	Leptoceridae:															
1	Mystacides							P								
2	Oecetis			1												
	Limnephilidae:															
3	Pycnopsyche															
	Molannidae:															
2	Molanna															
	Philopotamidae:															
4	Dolophilodes															
3	Chimarra				P			P	10	1		15		P		
	Polycentropodidae:															
-	Polycentropus							P								
	Psychomyiidae:															
3	Lype diversa															
	Rhyacophilidae:															
4	Rhyacophila fuscula															
3	Rhyacophila lobifera														1	
4	Rhyacophila vibox															
	DAMSELFLIES:															
	Calopterygidae:															
3	Calopteryx maculata				P			P			P					
	DRAGONFLIES:															
	Aeshnidae:															
2	Boyeria vinosa							P			P					
2	Aeshna															
	Cordulegasterygidae:															
3	Cordulegaster															
	Libellulidae:															
0	Plathemis lydia															
	MAYFLIES:															
	Baetidae:															
1	Baetis flavistriga								1					P		2
4	Baetis tricaudatus															
3	Diphetor hageni											1	1			
	Caenidae:															
1	Caenis	P	23	51					1							
2	Caenis anceps						1	P								
	Ephemeridae:															
3	Ephemera guttulata				P	2	1									
2	Ephemera simulans					1										
	Ephemerellidae:															
3	Ephemerella invaria															
3	Ephemerella subvaria	P			P	1	4	P	16	36	P	40	14	P		1
4	Serratella serratoides															
	Heptageniidae:															
3	Heptagenia pulla															
2	Stenacron interpunctatum		3					P						P		1
3	Stenonema vicarium										P	9	7			

Appenidx 3: continued

		Silver Creek 7			Silver Creek 1			Black Creek 4			Silver Creek 5			Silver Creek 2		
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
	Isonychidae:															
2	Isonychia				P		2	P	10			8	5	P		
	Leptohyphidae:															
2	Tricorythodes								2							
	Leptophlebiidae:															
3	Paraleptophlebia	P	2													
	STONEFLIES:															
	Capnidae:															
3	Paracapnia															
	Chloroperlidae:															
4	Sweltsa onkos															
	Leuctridae:															
4	Leuctra															
	Nemouridae:															
4	Amphinemura															
4	Soyedina vallicularia															
	Perlidae:															
3	Acroneuria carolinensis				P											
3	Paragnetina media				P			P	3	2		1	1	P		
	Perlodidae:															
3	Clioperla clio															
	Taeniopterygidae:															
3	Taeniopteryx						2									
	TRUE FLIES:															
0	Ceratopogonidae	P	3	5							P	1				
	Chironomidae:															
0	Chironomus			4	P							1			1	
1	Clinotanypus			1												
2	Conchapelopia					1	1		12	5			1	P	2	
2	Corynoneura															
2	Cricotopus	P	4	11					1	5						15
3	Cricotopus trifascia								1							1
1	Cryptochironomus	P	1	5			1									
2	Crypotendipes	P	2	10												
3	Diamesa											1				
3	Eukiefferiella								3	2						
3	Helopelopia															
3	Macropelopia															
2	Microtendipes			2	P	9	3		9	22				P	7	97
3	Natarsia					3										
1	Nilothauma			1						2					2	6
-	Orthocladius						2									4
3	Pagastia							P								
2	Parakiefferiella	P	6	7		2									2	2
3	Parametriocnemus			1				P	4	2		5		P		
1	Paratanytarsus															
-	Polypedilum angulum															
1	Polypedilum fallax															
0	Polypedilum halterale		2													

Appenidx 3: continued

		Silver Creek			Silver Creek			Black Creek			Silver Creek			Silver Creek		
			7			1			4			5			2	
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
1	Polypedilum scalaenum															
1	Potthastia								1							
0	Procladius															
3	Rheotanytarsus									8				P	2	1
3	Stempellinella														1	2
2	Stictochironomus	P	2												2	12
2	Tanytarsus					1										
1	Tribelos															
2	Trissopelopia															
2	Tvetenia				P	1			2	2		10		P		1
2	Empididae			2						1						
0	Psychodidae															
2	Simuliidae								2							
	Tabanidae:															
2	Chrysops	P	11	10								1				
	Tipulidae:															
3	Antocha				P		18	P	4	85		15	1	P	36	38
3	Dicranota									1						
2	Hexatoma										P					
2	Limnonia															
1	Pilaria	P														
3	Pseudolimnophila															
-	Tipula				P		1	P	5		P					
	Crustaceans:															
	AMPHIPODS:															
	Gammaridae:															
3	Gammarus lacustris															
	Hyalellidae:															
2	Hyalella			1		1		P								
	CRAYFISHES:															
	Cambaridae:															
1	Cambarus robustus		1				1						2		1	
2	Orconectes propinquus		1		P			P							2	
	ISOPODS:															
	Asellidae:															
1	Caecidotea							P	3							
	Molluscs:															
	BIVALVES:															
	Sphaeridae:															
2	Musculium transversum						1							P		
-	Pisidium			1												
1	Sphaerium simile			3												
2	Sphaerium striatinum	P	1	13	P		1						1	P		
	SNAILS:															
	Ancylidae:															
2	Ferrissia	P	12	24								3	1	P		1

Appenidx 3: continued

		Silver Creek 7			Silver Creek 1			Black Creek 4			Silver Creek 5			Silver Creek 2		
		Q	1	2	Q	1	2	Q	1	2	Q	1	2	Q	1	2
SVs	Taxa															
	Lymnaeidae:															
0	Pseudosuccinea columella										P					
	Physidae:															
0	Physella		1					P	3	1	P					2
	Planorbidae:															
0	Helisoma anceps		1	1	P											
	Pleuroceridae:															
2	Elimia livescens	P	7	69	P		1							P	1	3
	Annelids:															
	LEECHES:															
	Erpobdellidae:															
2	Mooreobdella microstoma								1							
	Glossiphonidae:															
-	Actinobdella inequiannulata		1	1												
2	Glossiphona complanata															
2	Helobdella stagnalis															
	WORMS:															
	Lumbriculidae															
4	Stylodrilus herringianus							P	38	25	P			P	12	37
	Tubificidae:															
0	Limnodrilus hoffmeisteri		34	19		23	5		2			2	5			16
2	Potamothrix bavaricus															29
0	Tubifex tubifex	P	79	34												
0	immature (w/o hair chaete)				P										2	
0	immature (with hair chaete)															
	Platyhelminthes:															
	FLATWORMS:															
3	Tricladida								8	1	P	13	1			
	Number of taxa	26	34	34	36	24	31	37	44	30	26	36	25	33	32	33
	Number of organisms		271	319		71	159		488	713		624	210		173	340