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February 6, 2002 Project No. 0N050468

Mr. Pete Mason
Manager of Watershed Resources Environment
Grand River Conservation Authority
400 Clyde Road
P.O. Box 729
Cambridge, Ontario
N1R 5W6

Dear Mr. Mason:

RE: Benthic Invertebrate Communities of the Grand River Watershed
Project No. ONO50468

Enclosed please find three (3) hard copies of the final report, Benthic Invertebrate Communities of the Grand River Watershed. The report examines data collected over three years (1999-2001), with particular emphasis on changes occurring over the 2000-2001 period. In general, indices of benthic community composition suggest that water and habitat quality in the Grand River watershed have been good throughout the study period. Water chemistry data indicate that water quality generally improved in 2001, with fewer sites exceeding the provincial water quality objectives than in 2000. However, benthic indices indicate that water quality improved in the tributaries while decreasing in the main stern during 2001. This may have been a result of reduced washoff and lower phosphorus levels in the tributaries, due to the low level of precipitation in 2001.

We trust this meets your requirements. Should you require further information, or if you have any questions relating to the results that we have enclosed here, please do not hesitate to contact us.

Yours truly,

JACQUES WHITFORD ENVIRONMENT LIMITED

Bruce Kilgour
Senior Consultant

BENTHIC INVERTEBRATE COMMUNITIES
OF THE
GRAND RIVER WATERSHED

PROJECT NO. ONO50468

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FINAL REPORT TO

GRAND RIVER CONSERVATION AUTHORITY

ON

BENTHIC INVERTEBRATE COMMUNITIES OF THE GRAND RIVER WATERSHED

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February 5, 2002

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1. INTRODUCTION

The Grand River Conservation Authority (GRCA) is in the 3rd year of a comprehensive study of the benthic invertebrates of the Grand River system. Benthos have been a focus of monitoring for several reasons:

- they represent a biological integrator of conditions;
- they are limited in their mobility and therefore reflect local conditions;
- their short life spans (about 1 year) allow them to integrate the physical and chemical aspects of water quality over annual time periods and provide early warning of impending effects on fish communities (Kilgour and Barton, 1999); and,
- based on known tolerances of benthic taxa, it is possible to re-create the environmental conditions determining the animals present (Rooke and Mackie, 1982a,b).

Surveys in 1999 and 2000 were described by Duncan (2000) and interpreted by MEL (2001). Those reports determined that the benthic communities of the Grand River system were generally in good condition. There were, however, some locations (e.g., Laurel Creek, Nith River) that had communities devoid of Mollusca and Crustacea, suggesting historical impacts. Spatial variations in benthic communities did not vary with nutrient concentrations probably because nutrients were high throughout the system. There were marginal changes in the benthic community from 1999 to 2000, coinciding with increases in total phosphorus and nitrogen in 2000.

In the summer of 2001, benthos were collected from 20 stations in the Grand River system (Wright, 2001). This report has 3 principal objectives:

1) Calculate several indices of community composition and use those data to infer the present condition of the aquatic environment;

2) Determine if there have been significant changes in community composition from 2000 to 2001 and whether those changes correlate with changes in water quality; and,

3) Determine if spatial trends in 2001 correlated with indicators of human development (i.e., landuse and/or water chemistry).

2. METHODOLOGY

2.1 Study Design

The 20 sampling locations were principally situated on the main stem of the Grand River, but also included the Speed River, Eramosa River, Nith River, Canagagigue Creek, Fairchild Creek, and Laurel Creek (Figure 1). Samples were collected mid summer using a travelling kick sampling methodology described in Wright (2001), but following Rosenberg *et al.* (1997). Sorting was conducted on site, in a white tray, with live animals. Sorted animals were preserved with ethanol and identified to lowest practical levels in a laboratory, using binocular microscopes (Wright, 2001).

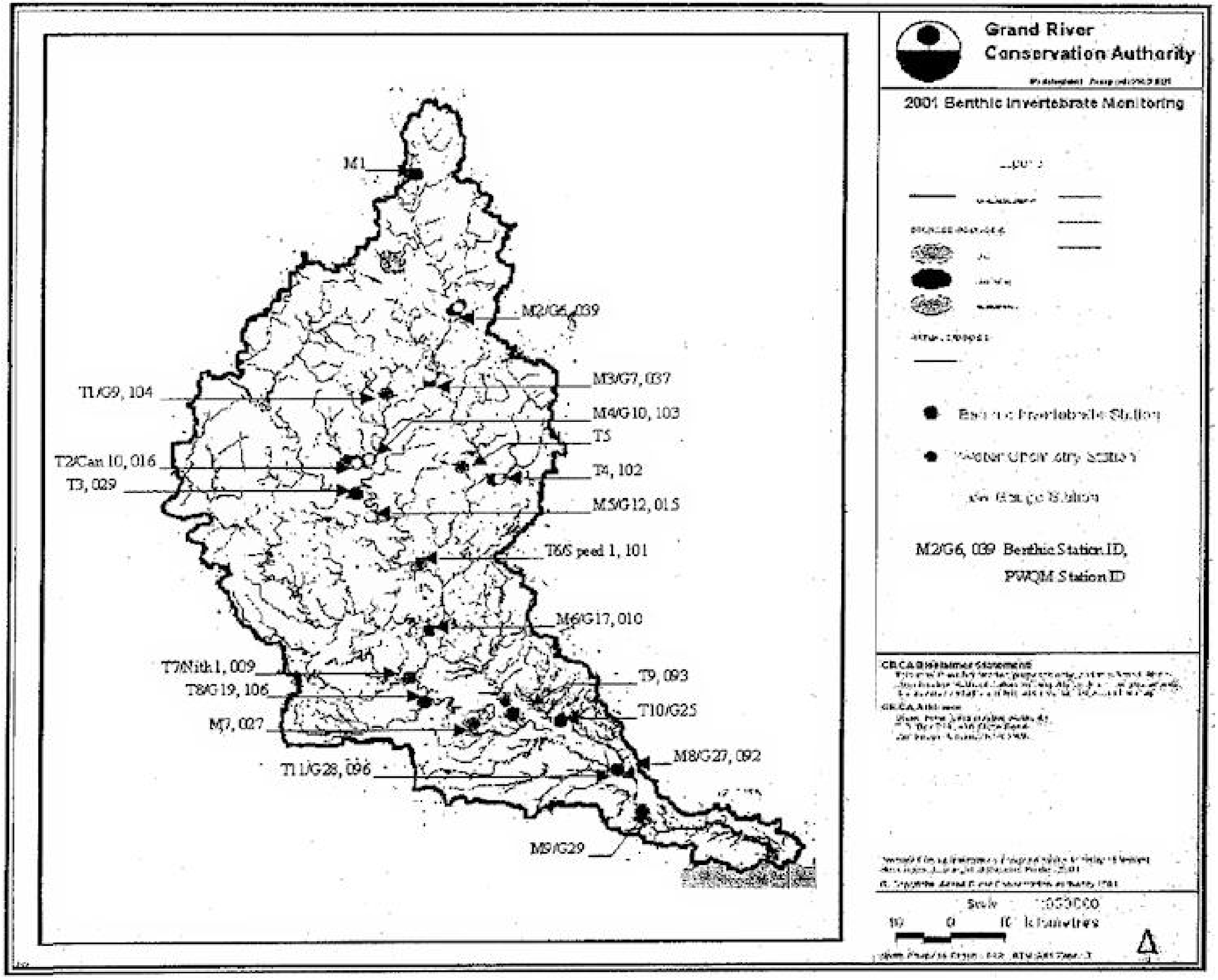
Twenty-nine stations were sampled during 1999. Of those stations, 17 were re-sampled in 2000 and 13 in 2001. The results of the 2001 sampling are presented in Appendix 1 (for previous years' results, refer to JWEL, 2001). Station naming codes were different in 2001 compared to 1999/2000 (Table 1). The present codes reflect the location of the sampling site on either the main stem of the Grand River (e.g., M1, M2, etc., beginning in the headwaters region and progressing downstream) or on a tributary (e.g., T1, T2, etc.).

Table 1. Benthic Sampling Stations.

2001 Station	1999 - 2000 Code	Location
M1	N/A	Grand River in Riverview, at Sideroad #7
M2	G6	Grand River upstream of Belwood
M3	G7	Grand River downstream of the Shand Dam
M4	G10	Grand River at Westmontrose, downstream of covered bridge
M5	G12	Grand River in Bridgeport, upstream of Laurel Creek confluence
M6	G17	Grand River in Glen Morris, at County Road 28
M7	N/A	Grand River in Brantford, at Erie Avenue/Hwy. 4
M8	G27	Grand River in York, upstream of McKenzie Creek at Reg. Road 9
M9	G29	Grand River in Cayuga, upstream of the highway bridge
T1	G9	Irvine Creek in Nichol Township, at the Irvine Street bridge
T2	Can 10	Canagagigue Creek downstream of Elmira, at Hwy. 22
T3	N/A	Conestogo Creek at Hwy. 22
T4	N/A	Eramosa River in Guelph, at Stone Road
T5	N/A	Speed River in Guelph at Hwy. 7 (Woodlawn Road)
T6	Speed 1	Speed River in Preston, downstream of King Street
T7	Nith 1	Nith River in Paris, upstream of Hwy. 24 (in Lions Park)
T8	G19	Whitemans Creek in Brantford Township, at Potruff Road
T9	N/A	Fairchild Creek in Onondaga Township, at Old Onondaga Road
T10	G25	Big Creek in Onondaga Township, at Big Creek Road
T11	G28	McKenzie Creek west of York, at Regional Road 9

N/A = not applicable (this location was not sampled in 1999-2000)

Figure 1. Sampling locations in the Grand River system (2001).



2.2 Indices of Composition

For each sample collected in 2001, several indices of benthic community composition were calculated. They included:

- number of taxa
- number of EPT taxa
- diversity (Shannon's H')
- evenness (J')
- Hilsenhoff's (1987) biotic index (HBI)
- Griffiths' (1998) BioMAP Water Quality Index (WQI).

These indices are commonly used in assessment of benthic invertebrates. The WQI is somewhat unique in being principally used in Ontario.

Shannon's H' was calculated as:

$$H' = \Sigma p_i \log_2 p_i \qquad [1]$$

where p_i is the fraction of animals in a sample belonging to taxon *i.*

Evenness was calculated as:

$$J' = H' / H'_{\max} \qquad [2]$$

where $H'_{\max}$ is the maximum possible diversity given the number of taxa in the sample.

Evenness varies between 0 and 1, with higher values typically associated with unimpaired conditions.

The biotic index was calculated using (Hilsenhoff, 1987):

$$BI = \frac{\Sigma t_i n_i}{\Sigma n_i} \qquad [3]$$

where t_i is the tolerance of taxon *i* to organic enrichment and n_i is the number of taxon *i* in the sample. Taxa that are highly sensitive to nutrient additions are assigned low tolerance values (0 to 4), while those that are insensitive to high nutrient concentrations are assigned high tolerance values (5 to 10). Values of the HBI, therefore, range from 0 to 10 with values near 0 indicating oligotrophic (low nutrient) conditions, and values near 10 indicating highly eutrophic (high nutrient) conditions. The HBI has been used as a general, screening-level indicator of impairment, not just an, indicator of increased nutrients, with low values indicating unimpaired conditions and high values indicating impaired conditions (Barbour *et al.,*1992*;* Barton, 1996). Taxa tolerance values used in this assessment were taken from Bode (1988) and Hilsenhoff (1988).

Hilsenhoff (1988) proposed the following classification system based on observed index values from riffle areas (Table 2). This classification scheme cannot be specifically applied to this survey because the samples here were collected from all microhabitats, not just riffles. Rather, values derived by Barton (1996) for kick samples can be used (Table 3).

Table 2. Expected ranges of Hilsenhoff's (1987) biotic index in riffle areas.

HBI Range	Water Quality	Degree of Organic Pollution Likely
0.00 to 3.50	Excellent	Organic pollution unlikely
3.51 to 4.50	Very Good	Possible slight organic pollution
4.51 to 5.50	Good	Some organic pollution probable
5.51 to 6.50	Fair	Fairly substantial pollution likely
6.51 to 7.50	Fairly Poor	Substantial pollution likely
7.51 to 8.50	Poor	Very substantial pollution likely
8.51 to 10.00	Very Poor	Severe organic pollution likely

The BioMAP water quality index was calculated using (Griffiths, 1998):

$$WQI = \frac{\Sigma\,(e^{SV_i}) \bullet (\ln n_i + 1)}{\Sigma\,(\ln n_i + 1)} \qquad [4]$$

where *e* is the number 2.718, SV_i is the sensitivity value of taxon *i,* n_i is the number of individuals of taxon *I*, and ln is the natural logarithm. The WQI is based on the assumption that the general effect of pollution (or stress) is to shift the longitudinal zonation of benthic macroinvertebrates in the upstream direction. Griffiths (1998) suggests that benthic communities from impaired headwater streams will have taxa more typically found in large rivers, while benthic communities from impaired large rivers will have taxa more typically found in lakes. Sensitivity values (SV_i) are therefore based on the expected position of taxa in an undisturbed river continuum. Taxa typically found in headwater systems are assigned tolerance values of 4 while those typically associated with large rivers are assigned values of 0.

The BMP WQI is used by the southwestern region of the Ontario Ministry of Environment to assess effects on, benthic communities. Like HBI, the WQI can be used in screening-level assessments (Barton and Kilgour, 1999). In larger rivers and streams, Griffiths (1998) associates WQI < 7 with degraded conditions. Although the specific value denoting impairment has been argued (Barton and Kilgour, 1999), scores of the WQI at the lower end of the scale will tend to be associated with degraded water quality.

2.3 Condition of Benthic Communities

To put observed variations in benthic community composition into perspective, we compared all stations to a set of numeric, published criteria that roughly define acceptable conditions. These criteria are given in Table 3. Anything less than about 15 taxa is unusual according to both Barton (1996) and Griffiths (1998) for both riffle, and kick samples. In an old study of the effects of sewage treatment plants on diversity, Wilm and Dorris (1968) showed that diversity values between 0 and 1 were indicative of severe nutrient enrichment and severe degradation of riffle benthic communities. It is unusual to have no EPT taxa (i.e., mayflies, stoneflies or caddisflies) in a stream site (Barbour *et al.,* 1992; Barton, 1996). Therefore, any site devoid of EPT taxa can be considered potentially impaired. The WQI is designed to vary with stream size (smaller streams have larger values). A WQI value <7 would be indicative of impairment in any river or stream according to Griffiths (1998).

Table 3. Biological criteria used to establish impact.

Index	Impact	Source
Taxa Richness	<15	Barton (1996), Griffiths (1998)
EPT taxa richness	0	Barton (1996)
Diversity (H')	<1.0	Wilm and Dorris (1968)
HBI	>8.0	Barton (1996) for travelling kick samples
HBI	>7.5	Hilsenhoff (1988) for riffle samples
WQI	<7	Griffiths (1998) for large rivers

2.4 Environmental Data

There were a variety of environmental descriptors for each site including basic physical habitat features such as the % riffle, run and pool, plant types, stream cover/canopy, bottom substrate composition, and neighbouring landuses (Wright, 2001). Substrate in this report was. classified according to the coarsest material found at the site. Sites with silt, clay, muck, marl or, detritus only were classified as (1) for having fine material, sites with sand were classified as (2), and sites with material coarser than sand were classified as (3). Again, based on data collected by Wright (2001), flows were classified as (1) for still, (2) for slow, (3) for medium and (4) for fast flows. Wright (2001) presents sketch maps as well as photographs of the sampled reaches.

Kilgour and Stanfield (2000) recommend using the area covered by each landcover and surficial geology Class in the upstream catchment as predictors of biological indices. Landcover/use and surficial geology were provided by the GRCA in 2000 for each subcatchment in the watershed (Figure 2). Each landcover/use class and surficial geology class were summed for catchments upstream of each site as in JWEL (2001) (Appendix 2).

Water chemistry data were available for 16 of the 20 sites in 2001, including seven sites along the main stem (M2/G6 through M8/G27). The tributaries sampled included Irvine Creek, Canagagigue Creek, Conestogo Creek, Eramosa River, Speed River, Nith River, Whitemans Creek, Fairchild Creek and McKenzie Creek. A summary of the 2001 water chemistry data is presented in Appendix 2, along with the relevant Provincial Water Quality Objectives (PWQO).

2.5 Relating Condition to Environmental Conditions

In this analysis, relationships between variations in indices of benthic community composition and habitat variables were tested using correlation analysis. Habitat variables included:

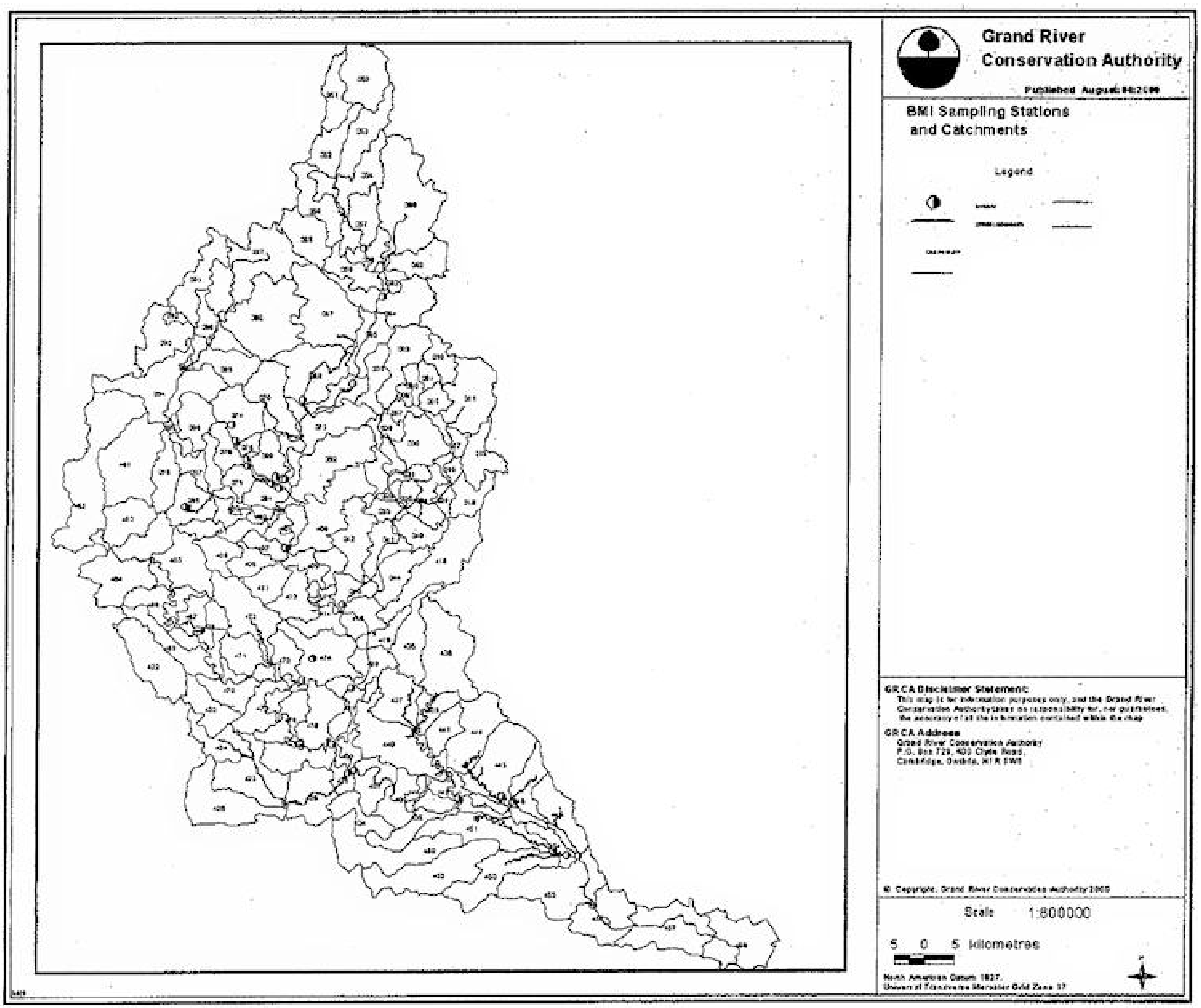
- upstream catchment area;
- percent of upstream catchment with poorly drained soils;
- percent of upstream catchment as urban area;
- percent of upstream catchment as pasture; and,
- percent of upstream catchment as water.

These variables were chosen because they reflected dominant "gradients" in the system (Appendix 3) and because they have been shown in other areas to correlate with benthic invertebrates. Other variables such as concentrations of metals and nutrients in water were correlated with these selected predictors (Appendix 3).

2.6 Changes Over Time

Repeat benthic collections were made at 13 of the 35 benthic sampling stations. Paired t-tests Were used to determine if changes in indices of benthic community composition between 2000 and 2001 were significant. Changes in water chemistry were also examined for the 10 stations for which data were available from both 2000 and 2001. Linear relationships between changes in indices of composition and changes in water quality variables were tested with correlation analysis. Water quality variables included Cu, Cd, Zn, and total phosphorous. They were selected on the basis of a Principal Components Analysis (PCA) that was designed to identify redundant variables (Appendix 3).

Figure 2. Sampling Locations Showing upstream Catchments.



3. RESULTS AND DISCUSSION

3.1 General

A total of 164 benthic taxa were identified from 20 stations in the Grand River system in 2001 (Appendix 1) compared to 157 taxa from 29 stations in 1999-2000. These taxa included water mites (Acari), scuds (Amphipoda), sowbugs (Isopoda), crayfish (Decapoda), beetles (Coleoptera), worms (Lumbricidae, Tubificidae, Naididae), larval flies (Empididae, Simuliidae, Tipulidae and Chironomidae), larval mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera), aquatic bugs (Corixidae, Gerridae, Mesoveliidae, Pleidae and Veliidae), dragonflies and damselflies (Odonata), snails (Gastropoda) and clams (Bivalvia). A list of taxa collected at each station is given in Appendix 1.

Branchiobdellida were the most unusual animals in the study. They were found at Station M2/G6 (Grand River upstream of Bellwood) in 2001. They are small (< 8 mm) worms (sometimes classified as leeches, other times as Oligochaetes), that are commensal on crayfish (Clifford, 1991). Other animals were fairly typical of southern Ontario, while some are good indicators of environmental conditions. For example, stoneflies require cold, clear water. During the 1999-2000 studies, stoneflies were found at several stations, and in relatively high numbers at some stations (e.g., G23, T10/G25, M8/G27 and T11/G28). Stoneflies were much less abundant during the 2001 study, being found in lower numbers, and at only four stations (M5/G12, M7, T3 and T8/G19). A variety of pollution tolerant animals were present including tubificid worms (5 stations), and the chironomids *Chironomus* (3 stations) and *Endochironomus* (1 station), but none were found in large numbers typical of highly nutrient-enriched conditions.

Isopods (sowbugs) were not found at any stations in 1999 and 2000, which is somewhat unusual for this study area. In contrast, and more typically, isopods *(Caecidotea intermedius)* were found at 10 of 20 stations in 2001 (Table 4). It is not clear why isopods were not found in the first two years of the study, but were in 2001.

3.2 Index Values

Index values for 2001 are presented in Table 4. In general, indices of benthic community composition have reflected good water and habitat quality over the three years studied. In 2001, all stations had more than 15 taxa, of which at least one was a mayfly, stonefly or caddisfly. The number of taxa reported here is an underestimate, because of the sorting method used (live in the field). Had sorting been conducted in a laboratory setting with microscopes, a greater number of taxa (smaller mites, small worms and chironomids, etc.) would have been observed. It is unlikely that the field sorting method would have underestimated the number of EPT taxa since they are relatively large.

In this study Hilsenhoff's biotic index was typically < 7, indicating little-serious nutrient enrichment. As shown in Table 4, only one station (T10/G25, the Big Creek station) had an HBI > 7 in 2001. Three sites (M4/G10, M9/G29 and T10/G25) did not meet the criterion set for the BioMAP WQI (i.e., WQI < 7). H' diversity also indicated good water quality with all stations scoring > 1, and the majority scoring > 2 (Table 4). H' diversity < 1 is typically found in streams with severe nutrient enrichment (Wilm and Dorris, 1968).

Table 4. Relative (%) abundance of major taxonomic groups of benthic macroinvertebrates, for each station in the Grand River system.

STATION	M1	M2	M3	M4	M5	M6	M7	M8	M9	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Former ID Code		G6	G7	G10	G12	G17		G27	G29		Can 10				Speed1	Nith 1	G19		G25	G28
TAXON																				
Tricladida	2	1	0	1	0	5	0	0	1	1	1	7	1	3	2	1	0	0	1	1
Hirudinea	1	0	0	0	2	1	1	0	1	0	0	0	0	0	1	0	0	0	0	1
Branchiobdellida	0	1	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0
Oligochaeta	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	1	0	1	1	0
Acari	3	3	0	0	0	0	1	0	0	5	1	9	6	0	1	1	0	0	1	0
Amphipoda	0	7	0	1	1	3	0	30	14	8	10	2	0	2	15	0	0	27	59	5
Isopoda	0	1	19	0	4	44	1	0	0	2	22	0	0	46	23	0	0	0	1	0
Decapoda	1	1	0	1	2	0	1	0	0	0	0	1	8	1	1	1	2	3	2	4
Odonata	0	2	0	1	2	0	0	18	5	0	0	0	1	0	2	0	1	1	12	0
Coleoptera	45	6	0	11	8	1	5	8	13	2	5	7	8	4	5	7	24	23	7	6
Hemiptera	0	0	0	23	0	0	2	2	40	0	0	0	0	0	0	0	0	1	7	1
Ephemeroptera	0	30	9	46	51	13	65	17	17	13	19	53	30	16	26	34	17	21	3	13
Lepidoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megaloptera	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	2	0	0
Plecoptera	0	0	0	0	2	0	2	0	0	0	0	1	0	0	0	0	8	0	0	0
Trichoptera	32	6	4	1	8	24	17	14	2	29	33	17	24	14	5	32	41	10	0	28
Ceratopogonidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	13	36	11	15	4	1	5	1	6	34	3	5	11	2	3	15	4	2	1	3
Miscellaneous Diptera	2	3	55	0	14	5	0	0	0	3	0	1	10	5	17	7	2	1	0	0
Gastropoda	0	1	1	0	0	1	2	5	1	2	0	1	0	4	1	1	1	0	7	31
Bivalvia	0	1	0	0	0	4	0	3	0	0	0	0	1	0	0	0	0	11	0	9
Total No. of Animals	172	145	209	170	209	198	192	204	155	182	201	198	153	207	193	157	186	187	183	191
Number of Taxa	25	42	17	33	42	25	36	34	28	42	32	36	37	29	26	40	30	24	29	29
Number of EPT Taxa	7	11	4	9	17	14	21	13	5	16	15	18	11	12	9	17	16	5	1	12
H' Diversity	3.80	4.83	2.31	3.84	4.26	3.11	4.13	3.84	336	4.60	3.89	4.48	4.53	3.27	3.35	4.53	4.32	3.48	3.20	3.80
J' Evenness	0.82	0.90	0.56	0.76	0.79	0.67	0.80	0.75	0.78	0.85	0.78	0.87	0.87	0.67	0.71	0.85	0.88	0.76	0.66	0.78
WQI	12.52	9.00	8.87	6.99	11.45	10.87	11.78	8.54	5.42	10.10	10.13	12.48	11.76	10.42	9.04	12.76	16.32	7.50	5.90	11.29
HBI	5.23	5.17	5.72	6.07	4.32	5.72	2.62	5.69	5.59	5.07	5.94	4.50	4.52	6.12	5.31	4.65	3.84	5.98	7.13	5.75

Although the various indices of composition did not identify significant impairment, there were some communities with unusual compositions. In this survey, no Mollusca were found at T2/Can 10, in Canagagigue Creek. Mollusca were absent from all stations in Canagagigue Creek in 1999 as well. The data from T2/Can 10 indicate that Molluscs are still absent from, or in low abundance in Canagagigue Creek. There were a few stations that lacked or had low abundances of both Crustacea and Mollusca, including T7/Nith 1 (Nith River), T8/019 (Whitemans Creek), and M1 (Grand River in Riverview). The lack of both groups could be significant because they are wholly aquatic arid may indicate historical impacts to water quality, even if the present community contains sensitive taxa.

3.3 Environmental Data

As in 1999-2000, most of the 2001 benthic sampling sites had riffle, pool and run habitats. Two stations (M4/G10 and T10/G25) were considered 100% pool. All stations had at least some coarse substrate in the channel. Flowing waters were present at most stations (Appendix 2).

Water chemistry data for 2001 indicate that most of the sample sites exceeded the PWQO for TP levels (30 µg/L) and several sites also exceeded the PWQO for A1 (75 µg /L). Two stations, T9 (Fairchild Creek) and T11/G28 (McKenzie Creek), had concentrations of TP, A1 and Fe in excess of their respective PWQOs (Fe PWQO=300 µg /L). Station T4 (the Eramosa River, in Guelph) had Cd concentrations in excess it PWQO of 0.20 µg/L.

Land use in the Grand River watershed is dominated by row crops (71%), with forest (16%), pasture (7%), and urban areas (4%) being subdominant. Water accounted for 1% of the catchments, while wetlands accounted for 2%. The sample sites generally reflected these conditions (Appendix 2). There was considerable variation in surficial geology of upstream catchments for the sample sites. Poorly drained soils accounted for between 8 and 92% of the catchments, while moderately well drained soils accounted for between 0 and 76%, and well-drained soils accounted for between 5 and 55% of the upstream catchments (Appendix 2). Overall, the Grand River watershed consists primarily of poorly drained soils (53%) with 21% being moderately well drained and only 25% well-drained.

A principal components analysis (PCA) of landcover and water quality data is provided in Appendix 3. The analysis showed that in catchments with more well drained soils, the receiving streams had higher pH and lower concentrations of metals such as Fe and Mn, and lower TSS, whereas catchments with more poorly drained soils had lower pH and higher concentrations of Fe, Mn and TSS. That pattern suggested that in better-drained catchments there was less runoff of suspended solids and associated metals. A second important trend in the data involved a general correlation between nutrient variables (e.g., phosphorus, nitrogen) and % urban area. Catchments with higher amounts of urban area had higher concentrations of total phosphorus, orthophosphate, TKN and ammonia than catchments with lower amounts of urban area.

3.4 Spatial Variations

There were no significant correlations between indices of benthic community composition and landcover attributes (Table 5). That. finding contrasted the results from the 200 survey which showed that number of taxa, H' diversity and number of EPT taxa varied with catchment area (JWEL, 2001). The difference in results from 2000 to 2001 implies that the catchment-area effect observed in 2000 was not as significant as first implied. Rather, general water quality may have more control over benthic community composition than catchment area or the associated water volume. Given that the sites were generally high order, arid none were first-order tributaries, the lack of a relationship between catchment area and indices of benthic community composition might not be too surprising.

Table 5. Correlations between indices of benthic community composition and landcover attributes.

Benthic Community Index	Total Area (ha)	% Water Cover	% Poorly Drained Soils	% Urban Area	% Pasture Area
Correlation (r)					
Abundance	0.05	0.24	0.09	0.26	-0.18
No. Taxa	0.04	-0.10	0.19	-0.29	-0.25
EPT Taxa	0.18	-0.03	-0.02	0.01	-0.44
H' Diversity	-0.05	-0.31	0.06	-0.33	-0.24
J' Evenness	-0.10	-0.40	-0.02	-0.31	-0.22
WQI	-0.23	-0.27	-0.30	-0.32	-0.24
HBI	-0.26	0.04	0.25	0.03	0.18
Probability					
Abundance	0.819	0.313	0.716	0.267	0.455
No. Taxa	0.852	0.662	0.434	0.207	0.283
EPT Taxa	0.435	0.899	0.947	0.967	0.055
H' Diversity	0.834	0.182	0.804	0.161	0.299
J' Evenness	0.669	0.079	0.941	0.187	0.359
WQI	0.324	0.251	0.204	0.166	0.310
RBI	0.264	0.881	0.289	0.905	0.459

3.5 Changes Over Time

Changes in indices of benthic community composition for the 13 stations sampled, in both 2000 and 2001, are illustrated in Figure 3. With the exception of number of taxa, there were no significant changes in indices of benthic community composition across the whole watershed (Figure 3). Number of taxa generally increased in 2001. Although there were few basin-wide changes, there were apparent differences in changes between main-stem and tributary stations. Stations in tributaries generally had increases in number of EPT taxa, WQI, and H’ diversity, and decreases in HBI, indicating improvements in water quality. Stations in the main stem, however, had decreases in EPT taxa, WQI and H’ diversity, and increases in HBI. (Figure 3).

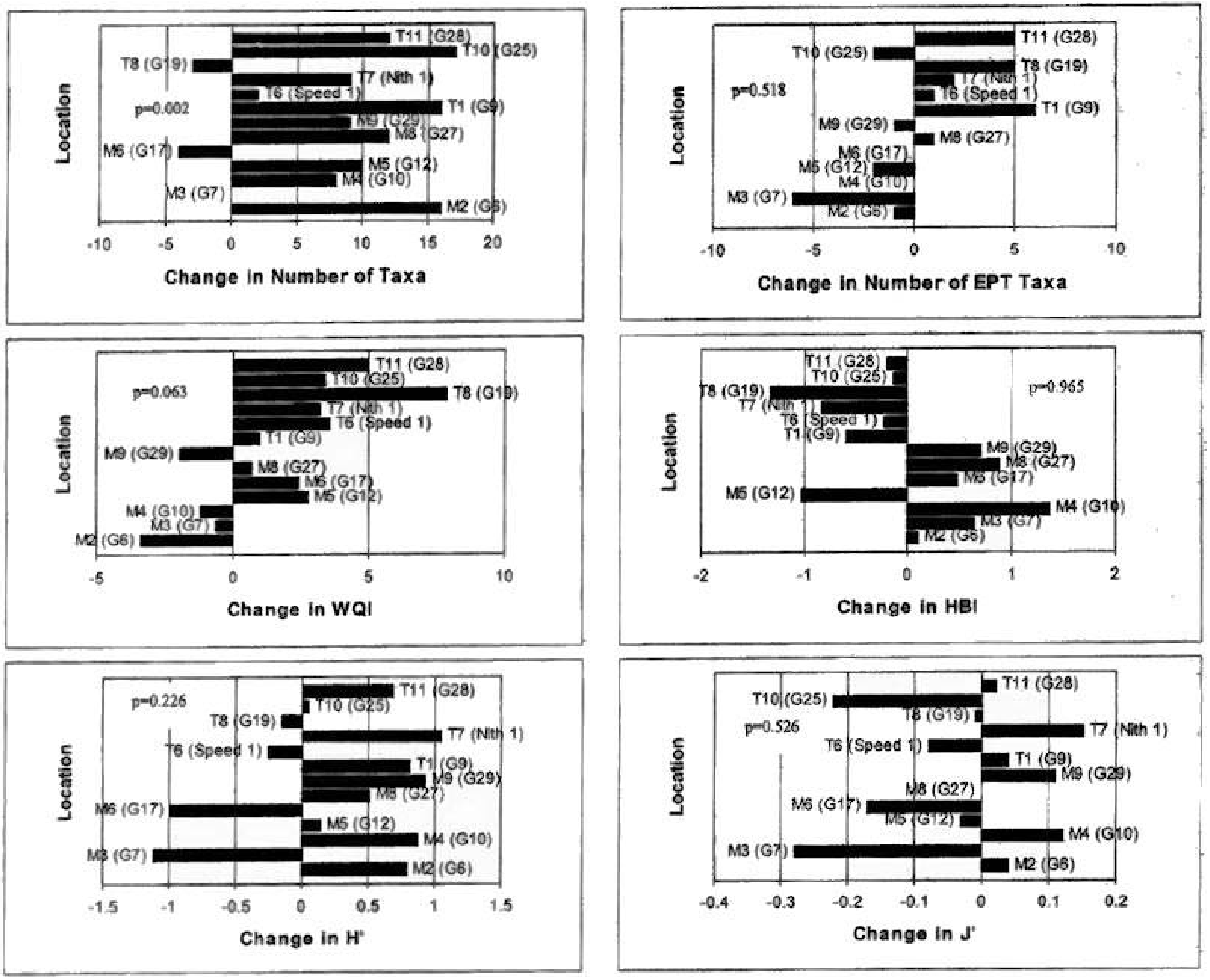


Figure 3. Changes over time in indices of benthic community composition within the Grand River system between 2000 (former ID code in brackets) and 2001.

It is not clear why tributary and main-stem stations differed in their changes from 2000 to 2001, but the dry summer of 2001 and associated low-water levels may provide one possible explanation. Barton (pers. comm.) has previously shown that impacts to benthic communities in urban areas are not as great during dry summers as during wet summers. He has concluded that the lack of washoff from urban areas during dry summers results in lower concentrations of metals and nutrients in streams. Those reductions then correlate with improvements in the benthic community. Here, we saw greater improvements in the tributaries. That observation was consistent with a lack of washoff, since washoff volume would be a more significant fraction of base flow in tributaries, and thus have a greater effect.

Changes in water chemistry at 10 sites indicated that, in general, water quality improved in 2001. Fewer sites were found to exceed the PWQO levels for metals. (particularly aluminum, cadmium, iron, and lead). Although seven of the 10 sites still exceeded the PWQO for total phosphorus levels, most of them had lower levels than in 2000, or had only increased slightly.

There were some correlations between changes in indices of benthic community composition and changes in water quality (Table 6). A strong relationship between changes in total phosphorus levels and changes in the WQI was apparent (Figure 4). Where reductions in total phosphorus were largest (i.e., up to 60 µg/L), the WQI increased by up to 5 units suggesting improved benthic communities. Correlations were somewhat strong between WQI and Zn, number of taxa and Cd, and number of EPT taxa and Cu. Upon inspection, station T1/G9 and/or station T6/Speed 1 were found to unduly influence the relationships. With those data removed, the relationships were less significant.

Table 6. Correlations between changes in indices of benthic community composition and changes in water quality between 2000 and 2001.

Benthic Community Index	CD	CU	ZN	TP
Correlation (r)				
Abundance	-0.19	-0.31	-0.48	0.00
No. of Taxa	0.51	-0.25	0.33	0.05
No. of EPT Taxa	0.29	-0.81	-0.33	-0.42
H' Diversity	0.48	-0.28	0.19	-0.25
J' Evenness	0.39	-0.25	0.10	-0.42
WQI	-0.12	-0.31	-0.55	-0.62
HBI	-0.43	0.49	0.26	0.49
Probability				
Abundance	0.608	0.386	0.165	0.990
No. of Taxa	0.134	0.485	0.353	0.885
No. of EPT Taxa	0.411	0.005	0.349	0.226
H' Diversity	0.160	0.438	0.591	0.491
J' Evenness	0.269	0.491	0.777	0.230
WQI	0.751	0.376	0.102	0.057
HBI	0.210	0.148	0.460	0.147

4. SUMMARY

This report documents three years of benthic collections in the Grand River watershed (1999, 2000 and 2001). The objective of the report was to:

1) Calculate several indices of community composition and use those data to infer the present condition of the aquatic environment;

2) Determine if there have been significant changes in community composition from 2000 to 2001 and whether those changes correlate with changes in water quality; and,

3) Determine if spatial trends in 2001 correlated with indicators of human development (i.e., landuse and/or water chemistry).

Approximately 239 benthic taxa were collected from 35 stations in the Grand River system in 19992001. These taxa included a wide variety of worms, leeches, molluscs, insects and other arthropods, including a number of useful indicators of water quality.

In general, indices of benthic community composition suggested good water quality and habitat quality. Most sites had > 15 taxa, of which at least one was a mayfly, stonefly or caddisfly, low Hilsenhoff's biotic index values, and high BioMAP WQI. H' diversity was also generally high, indicating good water quality. The persistent absence of some wholly aquatic forms such as Mollusca and Crustacea at a few sites (Grand River in York, Nith River, Canagagigue Creek) suggest possible historical impacts.

Water chemistry generally improved in 2001, with fewer sites exceeding the provincial water quality objectives than in 2000. Water quality as indicated by the benthic community improved significantly in the tributaries and declined in the main stem of the Grand River system in 2001. Improvements in the tributaries may be associated with reduced washoff and phosphorus loading.

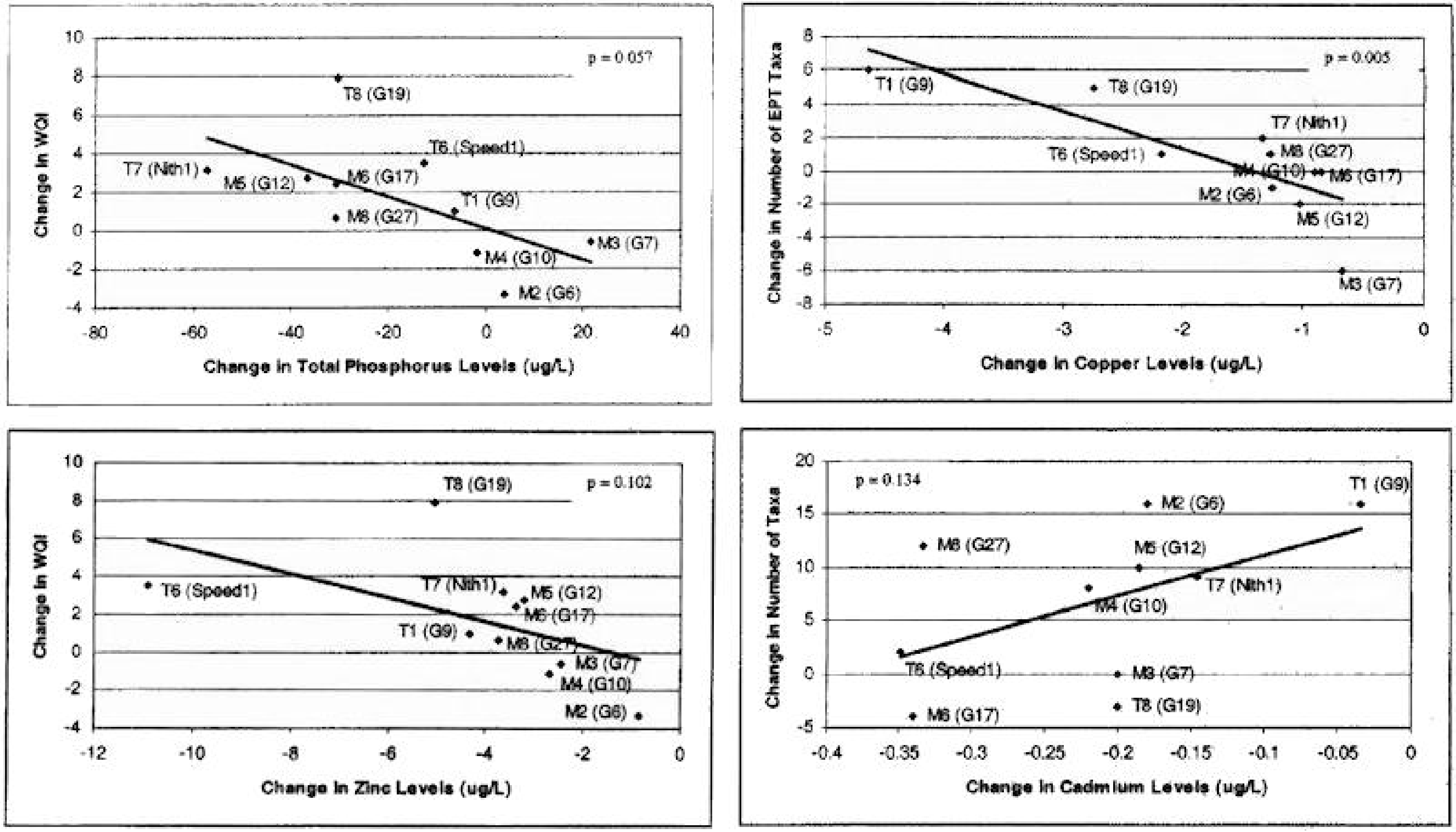


Figure 4. Correlation of changes over time in water chemistry and selected indices of benthic community composition within the Grand River system between 2000 (former ID code in brackets) and 2001.

5. CLOSURE

This report has been prepared by Jacques Whitford Environment Limited for the Grand River Conservation Authority to meet the specific objectives of the study. This report calculates indices of benthic community composition and correlates those indices with water quality and habitat data. All of the data presented here were provided to. JWEL by the GRCA. JWEL did not participate in the data collection phase of the study. JWEL accepts no liability for third party entities, for whom the report was not intended, who may rely on this report.

JACQUES WHITFORD ENVIRONMENT LIMITED

Bruce Kilgour Senior Consultant Aquatic Biology	Amy MacPherson Biologist

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APPENDIX 1

2001 BENTHIC COMMUNITY DATA

GRAND RIVER BENTHIC SURVEY JULY-AUGUST 2001

	Station*		M1	M2	M3	M4	M5	M6	M7	M8	M9	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
TAXON	HBI	WQI																				
BRANCHIOBDELLIDA																						
Branchiobdellidae																						
Cambarincola sp.(ex crayfish)	6			2									7		2							
HIRUDINEA																						
Erpobdellidae																						
unknown Erpobdellidae (juvenile)	8						2															
Erpobdella sp. (juvenile)	8	1	1				1	1									1					1
Erpobdella dubia	8	1					1	1														
Nephelopsis obscura	8	2					1															
Glossiphoniidae																						
Placobdella montifera		1									1											
Placobdella parasitica		1							1													
OLIGOCHAETA																						
Naididae																						
Ophidonais serpentina	8										1											
Tubificidae																						
Immatures without hair chaetae	10					2												1				
Branchiura sowerbyi	10	0									2									1	1	
ACARI																						
Arrenuridae																						
Arrenurus sp.	6																				1	
Hygrobatidae																						
Hygrobates sp.	6			1									1	8			1					
Lebertiidae																						
Lebertia sp.	6								1			8	1	9	8							
Limnocharidae																						
Limnochares sp.	6		6	2																		
Sperchonidae																						
Sperchon sp.	6				1		1		1			2			1	1		1				
Torrenticolidae																						
Torrenticola sp.	6			1																		
AMPHIPODA																						
Gammaridae																						
Gammarus fasciatus	6	2								61	18									50	37	9

GRAND RIVER BENTHIC SURVEY JULY - AUGUST 2001

	Station*		M1	M2	M3	M4	M5	M6	M7	M8	M9	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
TAXON	HBI	WQI																				
Talitridae																						
Hyalella azteca	8	2		10		1	3	6			3	14	21	3		4	28				71	
DECAPODA																						
Cambaridae																						
Orconectes propinquus	6	2	2	2		1	4		1	1			1	1	8	2	2	2	4	6	4	7
Orconectes virilis	6	2													4							
ISOPODA																						
Asellidae																						
Caecidotea intermedius	8	1		2	40		8	88	1			4	44			95	45				1	
COLEOPTERA																						
Elmidae																						
Dubiraphia sp. (larvae)	7		4	1		1					1	1										
Dubiraphia bivittata	8	0									14		2	1							5	
Dubiraphia minima	7	1	1			15	5			2	2	2		3						2	3	1
Microcylleopus pusillus		3	1	1																		
Optioservus sp. (larvae)	4		12										2	2	3	1			1	9		
Optioservus fastiditus	4	2				1													2	2		
Optioservus trivittatus	4	3					1		2					2	2				19	2		
Promoresia tardella	2	4																			1	
Stenelmis sp. (larvae)	5		32	2			4		2	2		1	2	1	3	4	4	3	10	18		3
Stenelmis crenata	5	2	10	2			5		5	8			4	2	2	3	5	3	12	9		7
Stenelmis musgravei	5	1		1							1							3				
Gyrinidae																						
Dineutus sp. (larvae)	4	2									2											
Haliplidae																					1	
Haliplus pantherinus	5	1																				
Hydrophilidae																						
Berosus peregrinus	5	0								1											1	
Helophorus lineatus	5	1																			1	
Helophorus orientalis	5	1																			1	
Paracymus sp.	5	2																				
Psephenidae																						1
Ectopria sp. (larvae)	5	3												3	2	1				1		
Psephenus herricki (larvae)	4	3	17	1		1	1	1	1	3												

GRAND RIVER BENTHIC SURVEY JULY-AUGUST 2001

TAXON	Station* HBI		M1	M2	M3	M4	M5	M6 MI	M7	M8	M9	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
DIPTERA																						
Athericidae																						
Atherix sp.	2	3		4																		
Chironomidae																						
Chir*onominae*																						
Chironomus sp.	10	0		1		3												1				
Cryptochironomus sp.	8	1																		1		
Dicrotendipes sp.	8	0			4												1	2				
Endochironomus sp.	10	0																			1	
Glyptotendipes sp. (gp "A")	10	0									3			1								
Microtendipes sp.	6	2	6	5		2						2	1		3							2
Paralauterborniella sp.	8	0				5																
Paratendipes sp.	8	2		1								2										
Phaenopsectra sp.	7	1		1	2							2		1	1				1	1		
Polypedilum sp.	6	0	5	5		3	2				5	2	2		3		2	1	3	1		2
Stictochironomus sp.	9	2	6																			
Tribelos sp.	5	1				2					I											
Pseudochironomus sp.	5	1													1							
Cladotanytarsus sp.	7	2		1											1			1				
Micropsectra sp.	7	3	1																			
Paratanytarsus sp.	6	1			9		1															
Rheotanytarsus sp.	6	3										22		6			1					
Sublettea sp.	4														1							
Tanytarsus sp.	6	2		11		4	5					1					1					
unknown Chironominae (damaged)	6					1				1												
Diamesinae																						
Diamesa sp.	5	3																	3			
Pagastia sp.	1	3			1							3			1	2						
Potthastia gaedi gp.	2	1										4										
Orthocladiinae																						
Cardiocladius sp.	5	2			1				5			3						2				
Cricotopus sp.	7	2		9	4	1		1	1				3		1		1	2				
Cricotopus trifascia gp.	7	3										2						9				
Eukiefferiella sp.	4	3			1																	
Orthocladius sp.	6	2									1					1						1
Psectrocladius sp.	8	1		2																		
Tvetenia sp.	5	2							4			3		2	3	1		2				

GRAND RIVER BENTHIC SURVEY JULY - AUGUST 2001

	Station*		M1	M2	M3	M4	M5	M6	M7	M8	M9	T1	T2	T3	T4	T5	I T6	T7	T8	T9	T10	T11
TAXON	HBI	WQI																				
Tanypodinae																						
Ablabesmyia sp.	8	2		8		1				1	1	2										
Conchapelopia sp.	6	2		2	1							2										
Helopelopia sp.	6	3	5			2	1											3				
Pentaneura sp.	6	2		6																		
Procladius sp.	9	0				2																
Thienemannimyia sp.	6	2										11	1		2			1				
Empididae																						
Hemerodromia sp. (pupae)	6	2						1							1			1				
Simulidae																						
Simulium venustum	5	2																	1			
Simulium vittatum	5	2	1		115		28	8		1		3	1	1	1	10	33	3				
Tipulidae																						
Antocha sp.	3	3					1					3			13			6	3			
Dicranota sp.	3	3														1						
Hexatoma sp.	2	2																1				
Tipula sp.	4	2	3																	1		
EPHEMEROPTERA																						
Baetidae																						
Acentrella sp.	?	3		4			41	2	18			1	14	20	2	15	38	14				1
Acerpenna pygmaeus	?	2		18			5					1		2		4						
Baetis brunneicolor	4	3			13							1				1			4			
Baetis flavistriga	4	1			6	1	1					3	1			3			2			
Baetis intercalaris	6	2					2	3	7	8			11				3	25	2	8		10
Baetis sp. (damaged)	6																					
Centroptilum sp.	2	3		2		4				1	1											
Caenidae																						
Caenis sp. 7	7	1		6		37	1		1		1	3		25	10				3		5	2
Ephemerellidae																						
Serratella sp. (juvenile)	2	3					3	9	6			3	1	4				1	4			
Serratella despiciens	2	3				1	4	8	8			3		8	1		2	7	I			
Ephemeridae																						
Ephemera sp. sp. (juvenile)	2			2		1																
Heptageniidae																						
Heptagenia sp.	4	3					1		5	3			1					2				
Stenacron interpunctatum	7	2		7		18	34	2					6	8		1	1	1		31		9
Stenonema sp. (juvenile)	3			5			2		4					7	9			1	4			

GRAND RIVER BENTHIC SURVEY JULY - AUGUST 2001

	Station*		M1	M2	M3	M4	M5	M6	M7	M8	M9	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
TAXON	HBI	WQI																				
Stenonema femoratum	5	1				2						1										
Stenonema mediopunctatum	3	3					2								16				1			
Stenonema pulchellum	3	1											1									
Stenonema terminatum	4	2							3					2				2				
Oligoneuridae																						
Isonychia sp.	2	2					3	1	57	10		6		5	8				11			
Polymitarcyidae																						
Ephoron album		3							6													
Ephoron leukon		3																		j		
Potamanthidae																						
Anthopotamus sp. (juvenile)		2							6	6												
Anthopotamus verticis		2							1													
Tricorythodidae																						
Tricorythodes sp.	4	2				15	7	1	3	7	24	2	4	19		9	6					2
HEMIPTERA																						
Corixidae																						
unknown Corixidae (nymph)	5					31	1			2	9										4	
Palmacorixa nana	5	2				7				2	36										2	
Sigara sp. (females only)	5	0				1															1	
Sigara lineata	5	2							3		6											
Sigara modesta	5	0																			3	
Trichocorixa borealis	5	1									11											
Gerridae																						
Gerris sp. (nymph)		1																				1
Meseveliidae																						
Mesovelia sp. (nymph)		1																			1	
Pleidae																						
Neoplea striola		0																			1	
Veliidae																						
Rhagovelia obesa (nymph)	5	2								1										1		
MEGALOPTERA																						
Corydalidae																						
Nigronia serricornis	0	3																	1			
Sialidae																						
Sialis sp.	4	2		2		1	2					2	1			1				3		

GRAND RIVER BENTHIC SURVEY JULY - AUGUST 2001

	Station*		M1	M2	M3	M4	M5	M6	M7	M8	M9	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
TAXON	HBI	WQI																				
ODONATA																						
Aeshnidae																						
Aeshna umbrosa	3	2																			1	
Boyeria sp. (juvenile)	2	2								1									1			
Corduliidae																						
unknown Corduliidae (early instar)	3																				2	
Gomphidae																						
Lanthus sp. (juvenile)															1							
Calopterygidae																						
Calopteryx sp. (juvenile)	5						2			1												
Calopteryx maculata	5	4					1															
Coenagrionidae																						
Argia sp. (juvenile)	6			3			1				3											
Argia moesta	6	2				1											2					
Enallagma antennatum	8	2									3											
Enallagrna civile	8	0									1											
Ischnura sp.	9	0								34							1			1	19	
PLECOPTERA																						
Perlidae																						
Acroneuria evoluta evoluta	0	2																				
Agnetina capitata	2	3												1								
Neoperla clymene gp.	3	3							1													
Paragnetina media	1	3					4		2										14			
TRICHOPTERA																						
Brachycentridae																						
Micrasema wataga	2	4																				5
Glossosomatidae																						
Glossosoma sp.	0	4																	14			
Helicopsychidae																						
Helicopsyche borealis	3	2		1				1		5		2	1		3	4		2				
Hydropsychidae																						
Cheumatopsyche sp.	5	2	34					1	11	11		32	27	17	22	3		2	7	17		29
Hydropsyche sp. (juv. & pupae)	4						4		5				4				2	4	19			1
Hydropsyche alhedra		3						28	6			10		1								
Hydropsyche bronta	6	3	12		3	1	10	2		2		6	21	7	6	14	1	12	7	1		6
Hydropsyche cuanis gp.	6	2																				1

GRAND RIVER BENTHIC SURVEY JULY - AUGUST 2001

	Station*		M1	M2	M3	M4	M5	M6	M7	M8	M9	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
TAXON	HBI	WQI																				
Hydropsyche slossonae	4	3												2								8
Hydropsyche sparna	6	3			5		2						11			7		7	17			
Macrostemum zebratum		2							8	3								1				
Hydroptilidae																						
Hydroptila sp.	6	2	1	5				9	1			1	1	1		1	5	1				
Mayatrichia sp.		2																2				
Leptoceridae																						
Mystacides sepulchralis	4	1						3								1						
Nectopsyche sp. (juvenile)		1								1	2	1								1		
Oecetis sp.	8	2						3		2	1						2					
Limnephilidae																						
Pycnopsyche sp.	4	3	3												2							
Philopotamidae																						
Chimarra sp.	4	3	2						1	5			1	5	4			19	13			4
Polycentropodidae																						
Polycentropus sp.	6		1	2																		
Rhyacophilidae																						
Rhyacophila fuscula type	1	4		1																		
Uenoidae																						
Neophylax sp.	3	3	2																			
GASTROPODA																						
Hydrobiidae																						
Amnicola limosa	8	2																			5	
Physidae																						
Physella gyrina	8	0		1	2		1	2	1	1	1	4		1		9	1	2			2	3
Pleuroceridae																						
Elimia (Goniobasis) livescens	6	2							3	9									2			56
Valvatidae																						
Valvata tricarinata	8	2																			5	
Viviparidae																						
Viviparus georgianus		1																			1	
BIVALVIA																						
Sphaeriidae																						
Musculium transversum	8	2																				2
Pisidium casertanum	8	2																		4		4
Sphaerium sp. (juvenile)	8			1				7		6					1	1				16		11

GRAND RIVER BENTHIC SURVEY JULY - AUGUST 2001

	Station*		M1	M2	M3	M4	M5	M6	M7	M8	M9	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
TAXON	HBI	WQI																				
TURBELLARIA																						
Planariidae																						
Unidentified	6	3	4	1	1	1		9		1	1	1	2	13	1	7	4	2			2	2
TOTALS			172	145	209	170	209	198	192	204	155	182	201	198	153	207	193	157	186	187	183	191

* Station identity codes varied from year to year. A cross-referenced list of codes follows:

M1
M2 = G6 (1999, 2000)
M3 = G7 (1999, 2000)
M4 = G10 (1999, 2000)
M5 = G12 (1999, 2000)
M6 = G17 (1999, 2000)
M7
M8 = G27 (1999, 2000)
M9 = G29 (1999, 2000)
T1 = G9 (1999, 2000)
T2 = CAN10 (1999)
T3
T4
T5
16 = Speed1 (1999, 2000)
T7 = Nith1 (1999, 2000)
T8 = G19 (1999, 2000)
T9
T10 = G25 (1999, 2000)
T11 = G28 (1999, 2000)

APPENDIX 2

ENVIRONMENTAL DATA

Table 2.1. In-stream physical habitat data, 2001.

Station	Order	Riffle (%)	Run (%)	Pool (%)	Flats (%)	Substrate[1]	Current[2]
M1		20	40	40	0	3	2
M2 (G6)	6	25	50	25	0	3	2
M3 (G7)	6	50	0	50	0	3	3
M4 (G10)	6	0	0	100	0	3	2
M5 (G12)	7	0	100	0	0	3	3
M6 (G17)	7	50	20	30	0	3	3
M7		30	30	40	0	3	4
M8 (G27)	7	40	30	30	0	3	3
M9 (G29)	7	0	20	80	0	3	2
T1 (G9)	5	25	25	50	0	3	2
T2 (Can 10)	5	35	40	35	0	3	3
T3		30	50	20	0	3	2
T4		40	35	25	0	3	3
T5		25	45	30	0	3	2
T6 (Speed 1)	6	40	30	30	0	3	3
T7 (Nith 1)	6	40	35	25	0	3	4
T8 (G19)	6	45	25	30	0	3	3
T9		30	30	40	0	3	3
T10 (G25)	6	0	0	100	0	3	2
T11 (G28)	6	30	40	25	0	3	2

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[1] Substrates are classified according to the coarsest material present.
1 = fines (clay, silt, organic), 2 = sand, 3 = coarse (gravel, boulders, etc.).

[2] Flow rates are classified as 1 = still, 2 = slow, 3 = moderate, 4 = fast.

Table 2.2. Average concentrations of metals and nutrients at water quality monitoring stations, 2001.

Water Quality Station	Closest Benthic Station	°C	pH	Al (µg/L)	Ba (µg/L)	Cd (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	Pb (µg/L)	Mn (µg/L)	Zn (µg/L)	NH_4 (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
039	M2	16	8.32	44.471	13.957	--	0.090	0.541	108.771	1.536	41.771	1.653	0.031	0.728	0.001	0.814	0.029	5.143
037	M3	14	8.06	109.663	20.013	--	0.204	0.622	244.713	0.554	106.638	1.342	0.105	0.848	0.009	0.708	0.060	10.438
103	M4	17	8.58	48.286	16.986	--	0.235	1.098	109.143	1.995	35.971	1.997	0.088	2.212	0.003	0.820	0.034	9.929
015	M5	17	8.54	52.186	19.114	0.134	0.014	1.174	73.543	1.143	15.720	1.587	0.019	2.904	0.003	0.689	0.033	7.214
010	M6	17	8.63	49.843	26.929	--	0.209	2.050	87.143	1.956	22.457	7.399	0.319	3.366	0.023	1.049	0.064	5.929
027	M7	16	8.33	117.357	33.800	0.093	0.301	1.681	107.600	1.216	20.157	4.760	0.148	3.147	0.008	0.774	0.048	11.143
092	M8	17	8.25	157.100	36.014	0.106	0.328	1.623	201.586	0.912	35.000	5.047	0.121	3.246	0.009	0.829	0.062	17.571
104	T1	15	8.42	29.200	21.757	0.166	0.235	0.866	60.129	1.152	9.109	1.058	0.015	2.859	0.001	0.611	0.031	3.357
016	T2	17	8.37	129.971	28.386	--	0.395	1.731	240.414	0.416	77.000	3.840	0.163	5.304	0.131	1.140	0.239	17.929
029	T3	14	8.63	65.000	18.357	0.091	0.155	1.112	72.314	--	14.290	2.523	0.033	3.959	0.008	0.723	0.045	6.143
102	T4	15	8.15	20.900	35.214	0.285	0.312	0.410	73.186	1.583	28.847	26.557	0.026	1.332	0.001	0.423	0.027	6.643
101	T6	16	8.49	38.914	30.871	0.101	0.460	2.220	133.814	1.570	38.286	18.186	0.183	3.374	0.035	0.857	0.072	7.500
009	T7	16	8.40	83.157	40.400	0.075	0.246	1.164	116.729	--	18.529	1.449	0.032	3.244	0.004	0.554	0.029	11.500
106	T8	13	8.29	28.529	53.286	--	0.269	0.551	79.886	2.549	20.493	1.031	0.015	4.389	0.004	0.500	0.018	3.786
093	T9	15	7.98	331.286	58.986	--	0.464	2.016	546.571	2.945	117.614	5.646	0.054	2.146	0.050	0.751	0.119	48.714
096	T11	15	7.95	387.00	53.000	0.145	0.763	1.116	503.429	2.099	99.971	3.501	0.062	0.845	0.029	0.920	0.121	32.714

-- signifies that levels were below the detectable limit.

Table 2.3. Geology and landuse data.

Station	Area (ha)	Water	Wetland	Forest	Row Crops	Pasture	Barren	Urban	Well Drained	Moderately Well Drained	Poorly Drained
M1	10,516	<1	3	26	59	11	<1	1	12	76	12
M2 (G6)	74,868	2	5	19	62	12	<1	1	20	16	64
M3 (G7)	82,253	3	5	19	62	11	<1	1	22	17	61
M4 (G10)	116,463	2	3	16	68	9	<1	1	22	18	60
M5 (G12)	228,298	2	2	14	75	7	<1	1	21	18	61
M6 (G17)	357,492	1	2	16	67	8	<1	5	29	27	44
M7	484,647	1	2	15	71	6	<1	4	30	24	46
M8 (G27)	491,657	1	2	16	70	7	<1	5	27	25	48
M9 (G29)	539,280	1	2	16	69	7	<1	4	25	23	52
T1 (G9)	19,491	<1	1	11	83	5	<1	1	16	7	77
T2 (Can 10)	11,612	1	<1	9	86	<1	<1	4	27	4	70
T3	69,698	1	<1	11	81	5	<1	1	17	14	69
T4	26,026	<1	3	32	50	15	<1	1	36	56	8
T5	27731	1	2	23	63	11	<1	1	47	44	10
T6 (Speed 1)	78,075	1	2	23	56	12	<1	5	42	47	11
T7 (Nith 1)	107,907	<1	1	11	85	2	<1	1	31	15	53
T8 (G19)	40,393	<1	2	14	81	2	<1	1	35	29	36
T9	40,075	<1	2	17	69	8	2	4	7	34	59
T10 (G25)	16,801	<1	<1	10	83	6	<1	1	11	0	89
T11 (G28)	36,823	<1	1	28	59	12	<1	1	5	3	92
B2	8,503	<1	<1	8	91	<1	<1	1	16	<1	84
B3	8,503	<1	<1	8	91	<1	<1	1	16	<1	84
Can 1	5,314	<1	<1	9	90	1	<1	1	26	1	73
Can 3	5,314	<1	<1	9	90	1	<1	1	26	1	73
Can 4	5,314	<1	<1	9	90	1	<1	1	26	1	73
Can 5	9,134	1	<1	9	89	1	<1	1	29	1	70
Can 7	14,767	1	<1	11	85	<1	<1	4	34	10	57
Can 9	6,244	1	<1	10	88	1	<1	1	30	1	69
Can 11	11,612	1	<1	9	86	<1	<1	4	27	4	70

Station	(ha)	Water	Wetland	Forest	Row Crops	Pasture	Barren	Urban	Well Drained	Moderately Well Drained	Poorly Drained
Cedar 2	7,463	1	3	16	74	3	3	1	55	15	30
Cedar 4	7,463	1	3	16	74	3	3	1	55	15	30
G20	471,538	1	2	15	71	6	<1	4	30	24	46
G23	40,075	<1	2	17	69	8	1	4	7	34	59
G4	44,167	3	6	22	56	12	<1	1	16	27	57
Laurel 1	7,577	1	1	13	44	3	<1	38	53	6	41
TOTAL	671,978	1	2	16	71	7	0	4	25	21	53

Table 2.4. Surficial geology classifications. From Boyd (pers. comm.)

Category	Geology	General Description	General Drainage	Comment
1	Amabel Lockport	exposed bedrock	moderate to high	fractured bedrock at surface can be as porous as gravel
2	Bertie formation	exposed bedrock	poor	
3	Canning till	tight till	poor	
4	Catfish Creek till	sand till	moderate	
5	Clinton & Cataract groups	exposed bedrock	moderate to high	fractured bedrock at surface can be as porous as gravel
6	Dundee & Onondaga & Bois blanc formations	exposed bedrock	poor	
7	Elma till	sand till	moderate	
8	Eolian deposits	beach sand deposits	good	
9	Fluvial deposits	granular deposits	good	
10	Glaciofluvial ice-contact deposits	sand and gravel deposits	good	
11	Glaciofluvial outwash deposits	sand and gravel deposits	good	
12	Glaciolacustrine deposits beach bar	beach sand deposits	good	
13	Glaciolacustrine deposits deep water	clay deposits	poor	
14	Glaciolacustrine deposits shallow water	clay deposits	poor	
15	Guelph deposits	exposed bedrock	moderate to high	fractured bedrock at surface can be as porous as gravel
16	Halton tills	tight till	poor	
17	Man-made deposits	Landfills	poor	
18	Maryhill till	tight till	poor	
19	Modern beach deposits	beach sand deposits	good	
20	Modern fluvial deposits	granular deposits	good	
21	Morington till	tight till	poor	
22	Organic deposits	organics	poor	generally where organics are found the water table is high.
23	Port Stanley till	sand till	moderate	
24	Salina formation	exposed bedrock	poor	
25	Stratford till	tight till	poor	
26	Tavistock till	tight till	poor	
27	Wartburg till	tight till	poor	
28	Wentworth till	sand till	moderate	
29	Water	water	poor	
30	Unclassifed	N/A	N/A	

APPENDIX 3

PRINCIPAL COMPONENTS ANALYSIS OF ENVIRONMENTAL DATA

Principal components analysis (PCA) was used to summarize variations in water quality and landcover attributes. Rather than calculate and assess correlations between all possible pairs of environmental variables, PCA can be used to summarize major associations among variables in a more elegant fashion. Here, we used SYSTAT software to carry out the analysis.

Table 3.1 below summarizes the results of the analysis of 2001 water quality and landcover. Four principal component axes were considered important on the basis that they accounted for > 10% of the variation in environmental data. Variables that are strongly correlated with any principal component are highlighted. Variables that correlated the best (e.g., % poorly drained soils with axis 1), were selected for correlation analysis with indices of benthic community composition.

The first PCA axis reflected a gradient well to poorly drained soils. As the area with moderately well and well-drained soils increased, the area with poorly drained soils decreased. In catchments with well-drained soils, streams had higher pH and lower concentrations of metals such as Fe, Mn, Cr and Al, and lower TSS. The second PCA axis reflected a gradient of increasing to decreasing urban area. Catchments with high urban area had streams with higher concentrations of nutrients (e.g., TP, PO_4, NH_4, TKN) and Cu. The third PCA axis reflected of increasing to decreasing amounts of pasture. In catchments with high amounts of pasture, there also tended to higher amounts of forest, wetland and water (reservoirs, lakes, ponds) and less NO_3. In contrast, where there was higher amounts of cropland, NO_3 tended to higher. The fourth PCA axis reflected a gradient of increasing to decreasing amounts of water (lakes, reservoirs, ponds). Catchments with higher water cover tended to have streams with lower concentrations of Ba. The cause-effect relationship between water cover and Ba concentrations is not obvious, and is probably spurious.

Table 3.2 below summarizes the results of analysis of changes in water quality from 2000 to 2001. The first principal component axis reflected a gradient of increasing to decreasing nutrient concentrations. Sites with high total phosphorus concentrations had high TSS, TKN, PO_4, Fe, Cr and Al. The second principal component axis reflected a gradient of high to low Cd concentrations. Sites with high Cd had low concentrations of Pb, NH_4 and TKN. The third and fourth principal component axes reflected concentration gradients of Zn and Cu respectively.

Table 3.1. Results of Principal Components Analysis of landcover and water quality data. Grand River Conservation Authority, 2001 monitoring program.

Variable	Principal Component Axis			
	1	2	3	4
Order	0.36	0.19	0.51	-0.11
Area	0.41	0.30	-0.23	0.03
Water	0.18	-0.09	-0.64	**0.67**
Wetland	0.16	-0.36	-0.79	0.35
Forest	-0.40	0.40	-0.73	-0.30
Cropland	0.14	-0.40	0.89	0.01
Pasture	-0.18	0.21	**-0.92**	0.07
Barren	0.50	0.59	-0.22	-0.33
Urban	0.47	**0.83**	0.09	0.12
% Poorly Drained	**-0.80**	-0.28	0.15	0.33
% Moderately well drained	0.73	0.29	-0.38	-0.39
% well drained	0.80	0.23	0.16	-0.22
Temp.	0.26	0.53	0.06	0.42
pH	0.82	0.00	0.18	0.21
Al	0.85	0.42	-0.06	-0.15
Ba	-0.33	0.24	0.27	-0.76
Cd	-0.23	0.06	0.08	-0.50
Cr	-0.61	0.63	0.10	-0.40
Cu	0.39	0.87	0.16	0.02
Fe	0.87	0.46	-0.10	-0.06
Pb	0.00	0.02	-0.36	-0.35
Mn	-0.74	0.33	-0.21	0.29
Zn	0.39	0.77	-0.20	-0.24
NH_4	0.35	0.76	-0.08	0.29
NO_3	0.48	0.24	0.79	-0.10
PO_4	-0.18	0.58	0.59	0.40
TKN	-0.13	0.78	0.04	0.54
TP	-0.40	0.62	0.49	0.39
TSS	-0.78	0.51	0.06	-0.07
% variance explained	26.24	23.03	18.48	11.40

Notes: Values in bold are used in correlation analysis with indices of benthic community composition. Values in shaded cells are strongly associated with those in bold print.

Table 3.2. Results of Principal Components Analysis of changes in water quality data from 2000 to 2001. Grand River Conservation Authority, 2001 monitoring program.

Variable	Principal Component			
	1	2	3	4
Al	0.60	0.42	0.00	-0.36
Ba	-0.27	0.41	0.57	0.12
Cd	0.02	**0.79**	-0.48	0.29
Cr	0.60	0.57	-0.23	0.22
Cu	0.15	-0.50	-0.16	**-0.70**
Fe	0.97	0.20	0.09	0.08
Pb	0.42	-0.62	-0.41	0.48
Mn	-0.03	-0.48	-0.43	0.58
Zn	0.22	0.17	**-0.76**	-0.24
NH_4	0.36	-0.74	0.04	-0.29
NO_3	0.08	-0.43	0.49	0.54
PO_4	0.90	-0.07	0.36	0.05
TKN	0.66	-0.73	-0.08	-0.01
TP	**0.94**	0.22	0.13	-0.04
TSS	0.94	0.24	0.12	0.07
% of variance explained	34.08	23.98	13.27	11.99

notes: Values in bold are used in correlation analysis with indices of benthic community composition. Values in shaded cells are strongly associated with those in bold print.

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January 9, 2001 Project No ONO50373

Mr Pete Mason
Grand River Conservation Authority
400 Clyde Avenue
Cambridge, Ontario
N1R 5W6

Dear Pete,

RE: Analysis of 1999 and 2000 benthic community data

Enclosed, please find 3 copies of our report on the analysis of the 1999 and 2000 benthic data for the Grand River watershed. The report provides the calculated indices that I had previously proposed, and discusses general water quality trends in the basin. In general, indices suggest that water quality in the basin is good.

The report also looks at correlations between the benthic indices and various habitat attributes. It also tested for significance in changes between 1999 and 2000. In general, variations in benthic community indices correlated only with catchment area, and none of the measured physical habitat or water quality variables.

Some of the correlation with catchment area may reflect an influence of landuse. Changes between 1999 and 2000 were significant, and seemed to reflect increased nutrient concentrations that were also observed at 5 stations.

If you have any questions or comments, please do not hesitate to call me.

Sincerely,

JACQUES WHITFORD ENVIRONMENT LIMITED

Bruce Kilgour, PhD
Senior Consultant