PHASE 2 Technical Memorandum for Red and Assiniboine Ammonia Criteria Study

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To: City of Winnipeg Project Management Committee
Study Team Members

Subject: **Fish Population Technical Memorandum # FP 03**

Title: **ABUNDANCE, COMPOSITION, AND DISTRIBUTION OF BENTHIC INVERTEBRATES IN THE RED AND ASSINIBOINE RIVERS WITHIN THE CITY OF WINNIPEG, 1999**

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EXECUTIVE SUMMARY

This memorandum is one of a series that have been produced to explain fish distributions in the Red and Assiniboine rivers within the City of Winnipeg Ammonia Criteria Study Area. Data presented in the memorandum **Fish Habitat Technical Memorandum # FH 02: Benthic Invertebrate and Sediment Data to Characterize Fish Habitat in the Red and Assiniboine Rivers** were used to produce this report comparing the benthic invertebrate community observed among different zones in the Study Area, among different bottom substrate types, between sampling periods (seasons), and to historical data available for the Red River.

Two surveys were conducted to describe the benthic invertebrate community and bottom substrate in the Red and Assiniboine rivers. The first survey was conducted in winter (February - March), 1999, and the second in fall (August - October), 1999. The study area was divided into five major zones, which were divided further into segments previously designated by the physical habitat surveys; two additional zones were used as reference areas for the benthic component of the Ammonia Criteria Study. A description of the extent of each zone is as follows:

- Zone 1A - extended between Ste. Agathe and St. Adolphe on the Red River; used as a reference area upstream of all wastewater discharges within the Study Area;
- Zone 1 - extended from St. Adolphe downstream to the South End Water Pollution Control Centre (SEWPCC) on the Red River;
- Zone 2 - extended from the SEWPCC downstream to the North End WPCC (NEWPCC) on the Red River;
- Zone 3 - extended from the NEWPCC downstream to the St. Andrews Locks near the town of Lockport on the Red River;
- Zone 3A - extended from the St. Andrews Locks near Lockport downstream to just downstream of the City of Selkirk on the Red River; used as a reference area downstream of all wastewater discharges within the Study Area;

- Zone 4 - extended from the West End WPCC (WEWPCC) on the Assiniboine River downstream to the confluence of the Assiniboine and Red rivers; and,
- Zone 5 - extended from Headingley downstream to the WEWPCC on the Assiniboine River.

During the first survey, the benthic invertebrate community and bottom substrate composition were quantitatively sampled in 32 segments using a 'petit' Ponar dredge; 26 segments were sampled on the Red River and six segments on the Assiniboine River. Usually three dredge samples (replicates) were taken at each site to assess within-site benthic organism and substrate variability. During the second survey, the benthic invertebrate community and bottom substrate composition were quantitatively sampled in 37 segments using a 'petit' Ponar dredge; 28 segments were sampled on the Red River and nine on the Assiniboine River. Generally three replicates were taken at each site. Benthic invertebrate community composition was also qualitatively sampled in 16 segments using artificial substrate samplers (samplers) during the second survey; 10 segments were sampled on the Red River and six on the Assiniboine River. Three samplers were installed at each site.

During the winter and fall surveys, benthic invertebrates were spatially heterogeneous. In the winter, 24 taxa were identified from soft-medium bottom substrates in the Red River and 10 taxa were identified in the Assiniboine River. The greatest number of taxa were observed in Zone 2 and the fewest in Zone 4. Total invertebrate abundance was greatest immediately downstream of the NEWPCC outfall. In the fall, 25 taxa were identified from soft-medium bottom substrates in the Red River and 15 taxa were identified in the Assiniboine River. The greatest number of taxa were again observed in Zone 2, however, the fewest were observed immediately downstream of the SEWPCC outfall. Total invertebrate abundance was again greatest immediately downstream of the NEWPCC outfall. From hard bottom substrates, 26 taxa were identified in the Red River and 29 taxa in the Assiniboine River. The greatest number of taxa were reported from Zone 4 and the fewest from Zone 1. Total invertebrate abundance was greatest in Zone 5. Insecta (primarily Trichoptera) was the most important group in both rivers.

Among soft-medium bottom substrates sampled during the present surveys, organic

content was highest in the Red River. The Assiniboine River was characterized as having a greater fraction of sand than any of the zones in the Red River. Perhaps the lower number of taxa observed in soft-medium bottom substrate in the Assiniboine River was a result of the lower organic content, sandy bottom substrate providing less adequate habitat for benthic invertebrates than the higher organic content, silty clay bottom substrate in the Red River.

The dry weight of major taxonomic groups of benthic invertebrates has been reported for segments (Red and Assiniboine rivers) in Davies and Zrum (2000). Due to the extremely variable nature of these data, a further examination of the two benthic surveys with respect to invertebrate biomass was not conducted for this technical memorandum.

Bivalve sampling was initiated in Zone 3, as this was the zone most likely to have experienced ammonia exceedences in the past due to its proximity to the NEWPCC outfall. There were no bivalves collected at any of the sampling sites selected. Due to logistical constraints, and the lateness in the fall season (i.e., unlikely to collect bivalves as they would be buried too deep in the bottom substrate to be effectively sampled), sampling was not pursued in any of the other zones within the Study Area.

Prior to the present surveys, benthic invertebrates in soft-medium substrate in the Red River were sampled by R. McV. Clarke (DFO) in 1973 and 1974 and by the City of Winnipeg (Laboratory Services Division of the Water and Waste Department) from 1971 to 1980 and in 1992, 1994, 1996. Comparison of results from the present surveys with those done previously is difficult, primarily due to differences in sampling, identification, and enumeration techniques. Any comparisons made should be considered with caution. Surveys conducted by the City of Winnipeg from 1971 to 1980 observed temporal and spatial variation in the predominance of types of organisms; a trend toward greater or fewer numbers of taxa at any particular site was not evident over the 10 year period. In 1996, the City of Winnipeg reported that there were pollution-intolerant taxa observed throughout the Red River, including downstream of the SEWPCC and NEWPCC outfalls.

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1.0 INTRODUCTION

Fish distribution, abundance, and health are dependent on the quality and quantity of habitat. Fish habitat is generally a function of physical (e.g., substrate, water depth, water velocity, and riparian conditions), chemical (e.g., dissolved oxygen, turbidity, water temperature, pH, and ammonia concentration), and/or biological (e.g., benthic invertebrate community abundance and composition) factors. To explain differences in distribution, abundance, and condition of fish inhabiting various locations, we must have an understanding of how habitat parameters differ among those sites.

This memorandum is one of a series that have been produced to explain fish distributions in the Red and Assiniboine rivers within the City of Winnipeg Ammonia Criteria Study Area (Figure 1). Data presented in the memorandum **Fish Habitat Technical Memorandum # FH 02: Benthic Invertebrate and Sediment Data to Characterize Fish Habitat in the Red and Assiniboine Rivers** were used to produce this report. The purpose of this memorandum is to compare the benthic invertebrate community observed among different zones in the Study Area, among different bottom substrate types, between sampling periods (seasons), and to historical data available for the Red and Assiniboine rivers.

The objective of the benthic program was to provide a characterization of benthic populations and benthic biomass in those portions of the Red and Assiniboine rivers that lie within the Study Area. The dry weight of major taxonomic groups of benthic invertebrates has been reported for segments (Red and Assiniboine rivers) in Davies and Zrum (2000). Due to the extremely variable nature of these data, a further examination of the two benthic surveys with respect to invertebrate biomass was not conducted for this technical memorandum.

2.0 METHODS

2.1 STUDY AREA

The study area for the City of Winnipeg Ammonia Criteria Study is shown in Figure 1. The study area was divided into five major zones, which were divided further into segments. Two additional zones were used as reference areas for the benthic component of the Ammonia Criteria Study. A description of the extent of each zone is as follows:

- Zone 1A - extended between Ste. Agathe and St. Adolphe on the Red River; used as a reference area upstream of all wastewater discharges of concern within the Study Area;
- Zone 1 - extended from St. Adolphe downstream to the South End Water Pollution Control Centre (SEWPCC) on the Red River;
- Zone 2 - extended from the SEWPCC downstream to the North End WPCC (NEWPCC) on the Red River;
- Zone 3 - extended from the NEWPCC downstream to the St. Andrews Locks near the town of Lockport on the Red River;
- Zone 3A - extended from the St. Andrews Locks near Lockport downstream to just downstream of the City of Selkirk on the Red River; used as a reference area downstream of all wastewater discharges within the Study Area;
- Zone 4 - extended from the West End WPCC (WEWPCC) on the Assiniboine River downstream to the confluence of the Assiniboine and Red rivers; and,
- Zone 5 - extended from Headingley downstream to the WEWPCC on the Assiniboine River.

2.2 BENTHIC SURVEY I

Prior to conducting the benthic surveys, it was decided that the second survey (to be conducted in fall, 1999) was to be more comprehensive than the first (to be conducted the previous winter). The winter benthic program was less extensive and was conducted for comparison to the fall benthic program.

The first benthic survey was conducted on the Red and Assiniboine rivers from February 25 to March 19, 1999 (Figure 2). The sampling program encompassed select segments of the rivers within the Study Area and included the following tasks:

- sampling at a site within a segment where there was likely to be soft to medium bottom substrate (typically silty clay or sandy) (i.e., where it was physically possible to collect a benthic sample using a 'petit' Ponar dredge);
- determining UTM coordinates for the sampling site;
- collecting three benthic samples at the site and measuring the depth each sample was taken at;
- collecting a sediment sub-sample from each benthic sample for organic content and particle size analysis; and,
- recording the number of non-recoverable samples at a site and providing a qualitative bottom substrate characterization.

Access to sampling locations was by snowmobile, with sleds towed to accommodate sampling equipment. Open-water sampling in the vicinity of and downstream of the NEWPCC outfall was conducted by boat (Figure 3). Due to dangerous ice conditions, areas immediately downstream of the SEWPCC and WEWPCC outfalls were avoided. UTM co-ordinates (Zone 14U, NAD 27 or NAD 83) were determined with a hand-held navigational quality GPS (Global Positioning System) unit. Nominal horizontal accuracy of the GPS unit was ± 50 m.

Benthic samples were collected using a 'petit' Ponar dredge (0.023 m^2 opening) with attached lead weights. Usually three dredge samples (replicates) were taken at each location to determine within-site benthic organism and substrate variability. Nine benthic samples were collected immediately downstream of the NEWPCC outfall to better characterize the aquatic habitat encompassing the NEWPCC non-mixed plume.

A separate hole of adequate diameter was drilled for each Ponar sample. The sample was retrieved to the ice surface and carefully placed in a plastic bag. A sub-sample of approximately 100 ml of substrate was taken with a 5 cm diameter core tube (0.002 m^2 surface area) and frozen for subsequent organic content and particle size analysis. The remaining Ponar sample (0.021 m^2) was placed in a cooler to avoid or limit freezing and

then processed the same day in the laboratory at North/South Consultants Inc. Samples were washed through a 500 µm mesh rinsing bag with a PVC codend and all invertebrates retained were transferred to plastic jars and fixed with 10 % formalin. Fixed samples were transferred to 70 % ethanol, stained with Rose Bengal to facilitate removal of organisms, and sorted under a magnifying lamp. Invertebrates from two replicates were identified to major group, family, or sub-family and enumerated by an invertebrate taxonomist (six replicates from the vicinity of the NEWPCC outfall). The third replicate (including substrate sub-sample) was archived for any necessary future analyses (three replicates from the NEWPCC outfall).

The dry weight of benthic invertebrates (major taxonomic groups) was determined using a method modified from Downing and Rigler (1984). Total organic content analysis was determined by weight loss after sample combustion at 500 EC for 12 hours. Particle size analysis was done according to procedures for silty sediments outlined in Holme and McIntyre (1984).

During the first survey, 26 segments were sampled on the Red River and six segments on the Assiniboine River. A total of 149 Ponar dredges were attempted during the winter sampling period; 80 grabs were successful (54 % recovery) and 69 grabs were non-recoverable (46 % non-recovery) due to either hard bottom substrate or slush build-up under the ice.

2.3 BENTHIC SURVEY II

The second benthic survey was conducted on the Red and Assiniboine rivers between August 03 and October 02, 1999 (Figure 4), and included the same tasks as the first survey (see Section 2.2). The fall benthic program was designed to provide additional information which would be used to refine the description of fish habitat in the Red and Assiniboine rivers by:

- sampling more extensively within the Study Area;
- sampling bottom substrates too hard to penetrate with a Ponar dredge (typically gravel or cobble); and,

- sampling areas which are de-watered during periods of reduced flow (e.g., during winter).

Artificial substrate samplers (samplers) were chosen as the sampling device to obtain a qualitative estimate of the benthic invertebrate community composition and dry weight on hard bottom substrates in the rivers. The samplers were installed in segments with known hard bottom substrate in the Red and Assiniboine rivers from August 03 to August 06, 1999. Three samplers were also installed on hard substrate within the NEWPCC non-mixed plume (Figure 5). The samplers were left in the rivers for a colonization period of approximately 7 - 8 weeks, with retrieval occurring from September 28 to October 02, 1999 (with the exception of three samplers, which were provided to the Toxicity Workstream). Access to all locations during the second benthic survey was by boat.

Each Ponar sample was brought to the surface and carefully placed in a 500 µm mesh rinsing bag with a PVC codend. Samples were sieved over the side of the boat and all invertebrates retained by the screen were transferred to plastic jars and fixed with 10 % formalin. Further processing of the fall Ponar samples (invertebrates and sediment sub-samples) and identification of invertebrates were the same as for winter samples (see Section 2.1). In addition to sampling in the NEWPCC non-mixed plume (Figure 5), sampling was also conducted immediately downstream of the SEWPCC and WEWPCC outfalls during the second survey. Sampling in the WEWPCC non-mixed plume was unsuccessful due to a high number of non-recoverable Ponar dredges indicating hard bottom substrate (large cobble) (Davies and Zrum 2000).

The samplers consisted of a “bag” (43 cm X 25.5 cm) constructed with galvanized welded wire mesh (2.5 cm^2) containing 20 - 30, 3 - 10 cm diameter “river rocks”. Three samplers were installed at each site with hard bottom substrate in a “triangle” shape, approximately 10 - 20 m off a river bank. The three samplers were tied together in tandem with sideline, leaving approximately 10 - 20 m between samplers. One of the three samplers was secured to a river bank with sideline. Tie-off points on the river banks were as close to the water surface as possible and marked with fluorescent flagging tape. UTM coordinates of installation sites were determined with a hand-held navigational quality GPS unit.

Upon retrieval, samplers were brought to the surface slowly. When the sampler became

visible beneath the water, a 500 μm mesh rinsing bag with a PVC codend was lowered and enclosed around the sampler before it could break the surface. By retrieving samplers in this manner, the loss of organisms was limited. The sampler was disassembled, each rock cleaned individually, and all organisms and residue removed were washed through the 500 μm mesh rinsing bag. Further processing of samples and identification of invertebrates were the same as for winter samples (see Section 2.2). All flagging tape and sideline was removed from sites during retrieval of the samplers.

During the second survey, 28 segments on the Red River and nine segments on the Assiniboine River were sampled using the Ponar dredge. A total of 181 Ponar dredges were attempted during the fall sampling period; 115 grabs were successful (64 % recovery) and 66 grabs were non-recoverable (36 % non-recovery) due to either hard bottom substrate or high flow. Samplers were placed in 10 segments on the Red River and six on the Assiniboine River. Of the 48 samplers installed, 34 were successfully retrieved (71 % retrieval) and three were provided to the Toxicity Workstream. Eleven samplers were lost due to vandalism and/or debris flowing downstream causing sideline to break away from tie-off points. Sites where samplers were lost were thoroughly inspected and any debris remaining from the samplers was removed.

2.4 BIVALVE SURVEY

Removal of the dam at Lockport occurred on October 15, 1999, and water levels in the Red and Assiniboine rivers in the vicinity of the City of Winnipeg to Lockport were subsequently lowered slowly. The bivalve survey was not conducted until October 20, 1999 (Figure 6), to allow sufficient time for water levels to decline and potentially increase sampling efficiency. The sampling program encompassed select segments on the Red and Assiniboine rivers within the Study Area and included the following tasks:

- sampling at a site within a segment where there was likely to be suitable bivalve habitat (smooth surfaced, relatively compact silty clay bottom substrate);
- determining UTM coordinates for the sampling site;
- collecting bivalves along 5 transects at the sampling site;
- measuring the depth of each transect at the sampling site; and,

- providing a qualitative bottom substrate characterization for the sampling site.

The Red and Assiniboine rivers were too deep and turbid for a visual search, therefore, bivalves were collected at a sampling site by raking the substrate with a 17-tooth “clam rake” attached to a 6 m aluminum boat with nylon rope of sufficient length. At each sampling site, 5 equidistant transects across the river were raked. Each transect was approximately 200 m in length and the rake was pulled in an upstream direction. Any bivalves collected were to be identified to species on-site and individuals of sufficient size (specifically, individuals likely to have life spans long enough to have included the time periods when ammonia exceedences occurred) and species of interest (specifically, fat mucket, *Lampsilis siliquoidea*) were to be retained. All other individuals were to be returned to the area they were collected from. Individuals retained were to be fixed in 10 % formalin and stored in 70 % ethanol. Bivalves were to be aged and growth rates compared among zones and years. Biomass was also to be compared among zones, if possible.

2.5 R. McV. CLARKE (DFO) BENTHIC SURVEYS

2.5.1 Background Information

The Department of Fisheries and Oceans (DFO) initiated a program in 1973 to assess the effects of untreated municipal effluent, secondary treated municipal effluent, and chlorinated secondary treated municipal effluent upon aquatic biota. A program on the Red River in the vicinity of Winnipeg was designed to assess the effects of the discharge of each type of effluent on the diversity of the benthic invertebrate community.

In 1973, the program assessed the effects of untreated and treated municipal effluent on the benthic invertebrate community (Figure 7). Twelve transects were located upstream and downstream of the four main sewage outlets existing at the time in the municipalities of Fort Garry and St. Norbert. Sampling in this area was conducted to investigate the effects of untreated sewage. An additional nine transects were located upstream and downstream of the NEWPCC outlet to investigate the effects of treated sewage. In 1974, the SEWPCC initiated secondary treatment to the previously untreated municipal effluent that was discharged from the four main sewage outlets in southern Winnipeg. DFO

repeated the benthic program conducted during the spring and summer of 1973 in 1974, with the addition of a limited sampling program conducted through the ice in late March, 1974. Benthic invertebrates at each site were investigated using two sampling devices; an Ekman dredge and artificial substrate samplers.

2.5.2 Sampling Methodology

In 1973, 21 transects, each with three stations, were located upstream and downstream of effluent discharge points along the Red River at Winnipeg (Figure 7) (Clarke 1973, unpublished). The three stations of each transect were positioned as follows: quarter-channel; middle-channel; and, quarter-channel. At each of the two quarter-channel stations, two Ekman dredge samples were obtained. Each Ekman sample was washed through a No. 40 sieve (approximately equivalent to a 425 μm sieve), the retained material was transferred to a whirl-pak, and alcohol and Rose Bengal were added. At each of the three stations at each transect, an artificial substrate sampler (a rock filled “wine basket” on a plastic sheet) was installed for a four week colonization period. After that time, each sampler was lifted to the surface and the attached invertebrates and sediments were washed from the rocks and sieved, transferred to a whirl-pac, and alcohol and Rose Bengal were added. All samples were returned to the laboratory for sorting and identification.

In 1974, 22 transects, each with three stations, were located upstream and downstream of effluent discharge points along the Red River in Winnipeg (Figure 7) (Clarke 1974, unpublished). Sampling was conducted in a similar fashion to that used in 1973. However, a No. 38 sieve (approximately equivalent to a 425-500 μm sieve) was used and samples were fixed with 10 % formalin.

2.5.3 Methodological Considerations

Comparison of results from the present surveys with those done previously by DFO is difficult for the following reasons:

A. Sieve size for washing samples free of sediments was approximately 425 μm (1973) or approximately 425-500 μm (1974), compared to the 500 μm sieve used in the

present surveys. A sieve size of 500 μm is recommended for the collection of organisms from sediments (APHA 1992).

B. In 1973, benthic samples were not fixed with a formalin solution, possibly resulting in the deterioration of organisms and difficulty in identification.

C. Sampling, identification, and enumeration techniques were not adequately reported, resulting in unclear methods.

2.6 CITY OF WINNIPEG BENTHIC SURVEYS

2.6.1 Background Information

The City of Winnipeg (Laboratory Services Division of the Water and Waste Department) initiated a program in 1971 to assess the health and diversity of the benthic invertebrate community in the Red River in the vicinity of Winnipeg. Annual surveys were conducted until 1980. Ten sample stations between St. Adolphe and Lockport were sampled annually; an additional station at Selkirk was sampled in 1980 (Figure 8). In 1991, the City of Winnipeg identified a need to reinitiate a program to investigate the benthic invertebrate community in the Red River within and downstream of Winnipeg. Reconnaissance surveys were conducted in 1992 and 1994, with a full-scale sampling program being conducted in 1996. Benthic invertebrates at each station were investigated using a 'petit' Ponar dredge.

2.6.2 Sampling Methodology

Ten sampling stations were consistently used by the City of Winnipeg during their benthic invertebrate surveys (Figure 8). At each station, three Ponar samples were collected from the left river bank and three from the right river bank (Ross and Hemphill 1997). Each sample was poured into a motorized cement mixer, diluted with tap water, and swirled until a slurry was produced. The slurry was poured into a conical elutriation device to wash and sort the organisms from the sediments. The sample was washed through a No. 4 (approximately equivalent to a 4.75 mm sieve) and No. 8 sieve (approximately equivalent to a 2.36 mm sieve) to remove larger materials (e.g., sticks, gravel) and impinged on a No.

30 sieve (approximately equivalent to a 600 μm sieve). The organisms were picked off the sieve, and transferred to a vial containing 70 % ethanol.

Organisms were identified to either order, family, or genus and enumerated for each sample site using a magnifying lamp or a stereoscopic microscope.

2.6.3 Methodological Considerations

Comparison of results from the present surveys with those done previously by the City of Winnipeg is difficult for the following reasons:

A. Use of a motorized cement mixer and conical elutriation device to facilitate increased sample flow through the No. 30 sieve may have resulted in missing or damaged body parts of organisms necessary for proper identification.

B. Use of elutriation or floatation techniques to improve organism sorting efficiency, without repeated floatation with freshwater washes and examination of remaining material, is selective against case-bearing Trichoptera, Mollusca, and microbenthos (Merritt and Cummins 1996).

C. Sieve size for washing samples free of sediments was approximately 600 μm, compared to the 500 μm sieve used in the present surveys. A sieve size of 500 μm is recommended for the collection of organisms from sediments (APHA 1992).

D. Benthic samples were not fixed with a formalin solution, possibly resulting in the deterioration of organisms and difficulty in identification.

E. Although the long-term program conducted by the City of Winnipeg provided information that was directly comparable among study years, the data are not directly comparable to the present study.

3.0 RESULTS AND DISCUSSION

3.1 BENTHIC SURVEY I

3.1.1 Benthic Invertebrates

Soft - Medium Bottom Substrate

Benthic invertebrates collected in Ponar dredge samples were spatially heterogeneous, varying with bottom substrate type (described in Section 3.1.2). During the winter survey, 24 and 10 taxa of invertebrates were identified from soft - medium bottom substrates in the Red and Assiniboine rivers, respectively (Table 1A).

Total invertebrate abundance varied considerably among and within the zones sampled (Figure 9). In the Red River, total invertebrate abundance was greatest immediately downstream of the NEWPCC outfall (4794 individuals/m^2), followed by Zone 2 (3178 individuals/m^2) and Zone 3 (2095 individuals/m^2). In contrast, Zone 5, Zone 4, and Zone 1 had the lowest total invertebrate abundance (0, 976, and 1071 individuals/m^2, respectively). However, total invertebrate abundance within zones varied substantially, as indicated by the high standard deviation observed for total invertebrate abundance within each zone. The relative abundance of invertebrate taxa differed among zones (Figure 9). Insecta were relatively more important in Zone 1, Zone 2, and Zone 3. The predominant insect group in these zones was Chironomidae (Table 1B). The relative proportion of invertebrate taxa in the remaining zones differed, with Oligochaeta, primarily the family Tubificidae, being the most important (Table 1B).

Within Zone 1, there were 14 taxa identified. The most abundant group of invertebrates was Diptera (612 individuals/m^2), followed by Oligochaeta and Ephemeroptera (235 and 119 individuals/m^2, respectively) (Table 1A). Diptera was composed primarily of chironomids, specifically the sub-families Tanypodinae and Chironominae. The family Chironomidae is often referred to as a pollution-tolerant group of organisms and their presence may be associated with organic enrichment (eutrophication). However, their distribution and abundance, like all benthic organisms, can be affected by factors other than water quality (e.g., water velocity, type of bottom substrate, etc.) (Merritt and

Cummins1996). Although the two dominant groups within Zone 1 are considered to be pollution-tolerant, pollution-intolerant groups (e.g., ephemeropterans, trichopterans, plecopterans) were also present.

Within Zone 2, there were 19 taxa identified. The most abundant group of invertebrates was Oligochaeta (1208 individuals/m^2), followed by Diptera and Crustacea (1070 and 490 individuals/m^2, respectively) (Table 1A). Oligochaeta was composed primarily of the families Tubificidae and Naididae. Although tubificids are considered to be pollution-tolerant, naidids are regarded to be less so. Again, pollution-intolerant groups, such as larvae of ephemeropterans, trichopterans, and plecopterans, were also observed.

There were 14 taxa identified from benthic grabs collected immediately downstream of the NEWPCC outfall. The most abundant group of invertebrates was Oligochaeta (3063 individuals/m^2), followed by Crustacea and Diptera (817 and 802 individuals/m^2) (Table 1A). Less pollution-tolerant groups represented were the insect orders, Ephemeroptera, Trichoptera, Coleoptera, and Hemiptera, and the bivalve family, Sphaeriidae. In the remaining portion of Zone 3, 11 taxa were identified from benthic grabs. Chironomids were most abundant (937 individuals/m^2), followed by tubificids (857 individuals/m^2) and sphaeriids (167 individuals/m^2) (Table 1A). Other groups represented included ephemeropterans, trichopterans, and coleopterans.

Downstream of the St. Andrews Locks, in Zone 3A, there were also 11 invertebrate taxa identified. The most abundant group of organisms was again Oligochaeta (925 individuals/m^2). Other abundant groups were Chironomidae (329 individuals/m^2), Crustacea (339 individuals/m^2), and Ephemeroptera (100 individuals/m^2).

In the Assiniboine River, 10 taxa were identified from Zone 4 only. The most abundant group of invertebrates was Oligochaeta (833 individuals/m^2), represented by the families Tubificidae, Lumbriculidae, and Naididae (Table 1A). Other groups represented in much lower abundances included Diptera, Trichoptera, and Sphaeriidae (56, 48, and 24 individuals/m^2, respectively).

3.1.2 Bottom Substrates

Soft - Medium Bottom Substrate

Organic content of sediments collected in Ponar dredge samples varied among zones (Table 2). Sediments with the highest organic content were observed in Zone 3A (5.3 %) (downstream of the St. Andrews Locks) and the lowest were found in Zone 4 (2.9 %) (Figure 10). Organic content of sediments immediately downstream of the NEWPCC outfall was slightly higher (4.5 %) than in the remaining portion of Zone 3 (3.5 %).

Particle size composition of sediments collected in Ponar dredge samples also varied among zones (Table 2). Sediments with the greatest fraction of silt/clay (< 63 μm) were observed in Zone 1 (95.7 %) (Figure 10). The Assiniboine River (Zone 4) was characterized as having a greater fraction of sand (> 63 μm to < 2 mm) (52.3 %) than any of the other zones within the Study Area. Sediments immediately downstream of the NEWPCC outfall and in the remainder of Zone 3 typically had a greater fraction of gravel (> 2mm) (4.3 and 6.3 %, respectively).

3.2 BENTHIC SURVEY II

3.2.1 Benthic Invertebrates

Soft - Medium Bottom Substrate

Benthic invertebrates collected in Ponar dredge samples were spatially heterogeneous, varying with bottom substrate type (described in Section 3.2.2). During the fall survey, 25 taxa of invertebrates were identified from soft - medium bottom substrates in the Red River and 15 taxa in the Assiniboine River (Table 3A).

Total invertebrate abundance varied considerably among and within the zones sampled (Figure 11). As during the winter survey, total invertebrate abundance was greatest immediately downstream of the NEWPCC outfall (3310 individuals/m^2), followed by Zone 2 (1648 individuals/m^2). In contrast to the winter survey, Zone 5 had one of the higher total

invertebrate abundances (1440 individuals/m^2). Lower total invertebrate abundances were observed in Zone 1A, immediately downstream of the SEWPCC outfall, and in Zone 4 (500, 610, and 752 individuals/m^2, respectively). However, total invertebrate abundance within zones varied substantially, as indicated by the high standard deviation observed for total invertebrate abundance within each zone. The relative abundance of invertebrate taxa differed among zones (Figure 11). Oligochaeta was relatively more important in Zone 1A, immediately downstream of the NEWPCC outfall, Zone 3A, and in the Assiniboine River. The predominant oligochaete group in these zones was Tubificidae (Table 3B). The relative proportion of invertebrate taxa in the remaining zones differed (Table 3B). In Zone 1 and immediately downstream of the SEWPCC outfall the two most important groups were Bivalvia (only Sphaeriidae) and Insecta (primarily Trichoptera in Zone 1 and Ephemeroptera immediately downstream of the SEWPCC outfall) (Table 1B). Insecta was less important in the remainder of Zone 2, however, the relative importance of sphaeriids and oligochaetes increased.

Within Zone 1A, there were nine taxa identified. The most abundant group of invertebrates was Oligochaeta (286 individuals/m^2), followed by Trichoptera, Diptera, and Bivalvia (71, 48, and 48 individuals/m^2, respectively) (Table 3A). Oligochaeta was composed primarily of the family Tubificidae. Although the dominant group within Zone 1A is considered to be pollution-tolerant, less pollution-tolerant groups were represented by trichopterans, bivalves, and ephemeropterans.

Within Zone 1, there were 13 taxa identified. The most abundant group of invertebrates was Bivalvia (488 individuals/m^2), followed by Trichoptera and Gastropoda (304 and 74 individuals/m^2, respectively) (Table 3A). Bivalvia was composed exclusively of the family Sphaeriidae. Less pollution-tolerant groups dominated the invertebrate community observed in Zone 1.

There were seven taxa identified from benthic grabs collected immediately downstream of the SEWPCC outfall. The most abundant group of invertebrates was Ephemeroptera (324 individuals/m^2), followed by Bivalvia and Trichoptera (229 and 19 individuals/m^2, respectively) (Table 3A). Ephemeroptera was composed exclusively of the family Ephemeridae. Less pollution-tolerant groups dominated the invertebrate community observed immediately downstream of the SEWPCC outfall. In the remaining portion of

Zone 2, 16 taxa were identified from benthic grabs. Sphaeriids were most abundant (847 individuals/m^2), followed by tubificids (437 individuals/m^2) and ephemeropterans (95 individuals/m^2) (Table 3A). Other groups represented included gastropods, trichopterans, and chironomids.

There were 11 taxa identified from benthic grabs collected immediately downstream of the NEWPCC outfall. The most abundant group of invertebrates was Oligochaeta (2714 individuals/m^2), followed by Nematoda and Bivalvia (270 and 79 individuals/m^2) (Table 3A). Less pollution-tolerant groups represented were the insect orders, Ephemeroptera, Trichoptera, Plecoptera, and Coleoptera. In the remaining portion of Zone 3, 11 taxa were also identified from benthic grabs. Tubificids were most abundant (371 individuals/m^2), followed by ephemeroptera (181 individuals/m^2) and trichopterans (162 individuals/m^2) (Table 3A). Other groups represented included chironomids and sphaeriids.

Downstream of the St. Andrews Locks (Zone 3A) there were only eight invertebrate taxa identified. The most abundant group of organisms was again Oligochaeta (1071 individuals/m^2). Other groups observed in lower abundances included Ephemeroptera (95 individuals/m^2), Chironomidae (63 individuals/m^2), and Sphaeriidae (63 individuals/m^2).

In the Assiniboine River, 12 taxa were identified from Zone 4 and 10 taxa from Zone 5. The most abundant group of invertebrates in Zone 4 was Oligochaeta (510 individuals/m^2), represented by the families Tubificidae and Naididae (Table 3A). Other groups represented in much lower abundances included Diptera, Sphaeriidae, and Trichoptera (81, 67, and 57 individuals/m^2, respectively). The most abundant group of invertebrates in Zone 5 was again Oligochaeta (only Tubificidae) (964 individuals/m^2) (Table 3A). Other groups observed in lower abundances included Bivalvia (Sphaeriidae and Unionidae), Ephemeroptera, and Chironomidae (202, 155, and 60 individuals/m^2, respectively).

Hard Bottom Substrate

Benthic invertebrates collected in artificial substrate samples were spatially heterogeneous. During the fall survey, 26 taxa of invertebrates were identified from hard bottom substrates in the Red River and 29 taxa in the Assiniboine River (Table 4A).

Total invertebrate abundance varied considerably among and within the zones sampled (Figure 12). Abundance was greatest in Zone 5 in the Assiniboine River (525 individuals/sampler), followed by Zone 4 (394 individuals/sampler) and Zone 3A (380 individuals/sampler). Lower total invertebrate abundances were observed in Zone 1, Zone 1A, and Zone 3 (80, 131, and 164 individuals/sampler, respectively). However, total invertebrate abundance within zones varied substantially, as indicated by the high standard deviation observed for total invertebrate abundance within each zone. The relative abundance of invertebrate taxa was similar among zones (Figure 12). Insecta was the most important group in both the Red and Assiniboine rivers. The predominant insect group in all zones was Trichoptera (primarily the family Hydropsychidae) (Table 4B).

Within Zone 1A, there were 11 taxa identified. The most abundant group of invertebrates was Trichoptera (127 individuals/sampler) (Table 4A). All other groups in Zone 1A were observed in abundances # 1 individual/sampler. The order Trichoptera is considered to be pollution-intolerant.

Within Zone 1, there were nine taxa identified. The most abundant group of invertebrates was Trichoptera (74 individuals/sampler) (Table 4A). All other groups in Zone 1 were observed in abundances # 2 individuals/sampler.

In Zone 2, 17 invertebrate taxa were identified from samplers. The most abundant group was Trichoptera (289 individuals/sampler), followed by Ephemeroptera and Diptera (11 and 4 individuals/sampler, respectively) (Table 4A).

There were 14 taxa identified from samplers collected immediately downstream of the NEWPCC outfall. The most abundant group of invertebrates was Trichoptera (287 individuals/sampler), followed by Diptera, Hydrozoa, and Turbellaria (8, 2, and 2 individuals/sampler, respectively) (Table 4A). In the remaining portion of Zone 3, 18 taxa were identified from samplers. Again, Trichoptera were most abundant (137 individuals/sampler) (Table 4A). Less abundant groups observed included Tubificidae, Chironomidae, and Ephemeroptera (8, 7, and 6 individuals/sampler, respectively).

Downstream of the St. Andrews Locks, in Zone 3A, there were 14 invertebrate taxa identified. The most abundant group of organisms was again Trichoptera (344

individuals/sampler) (Table 4A). Other groups observed in lower abundances included Ephemeroptera (23 individuals/sampler), Coleoptera (5 individuals/sampler), and Diptera (5 individuals/m^2).

In the Assiniboine River, 26 taxa were identified from Zone 4 and 18 taxa from Zone 5. The most abundant group of invertebrates in Zone 4 was Trichoptera (347 individuals/sampler) (Table 4A). Other groups represented in much lower abundances included Ephemeroptera (21 individuals/sampler), Diptera (14 individuals/sampler), and Plecoptera (4 individuals/sampler). The most abundant group of invertebrates in Zone 5 was again Trichoptera (463 individuals/sampler) (Table 4A). Other groups observed in lower abundances included Diptera, Plecoptera, and Ephemeroptera (28, 16, and 8 individuals/m^2, respectively).

3.2.2 Bottom Substrates

Soft - Medium Bottom Substrate

Organic content of sediments collected in Ponar dredge samples varied among zones (Table 5). Sediments with the highest organic content were observed immediately downstream of the SEWPCC outfall (5.6 %), followed by Zone 3A (downstream of the St. Andrews Locks) (4.9 %) (Figure 13). The lowest organic content of sediments was observed in zones 4 and 5 (the Assiniboine River) (2.0 and 1.9 %, respectively). Organic content of sediments immediately downstream of the NEWPCC outfall was slightly lower (4.0 %) than in the remaining portion of Zone 3 (4.3 %).

Particle size composition of sediments collected in Ponar dredge samples also varied among zones (Table 5). Sediments with the greatest fraction of silt/clay (< 63 μm) were observed in Zone 1A (92.1 %) (Figure 13). The Assiniboine River was characterized as having a greater fraction of sand (> 63 μm to < 2 mm) (Zone 4, 68.4 %; Zone 5, 56.3 %) than any of the other zones within the Study Area. Sediments found in Zone 1 and downstream to the St. Andrews Locks had a greater fraction of gravel (> 2mm) (1.1 to 9.2 %) than observed in other zones.

3.3 BIVALVE SURVEY

Bivalve sampling was initiated in Zone 3 (Segments 58, 61, 63, and 66), as this was the zone most likely to have experienced ammonia exceedences in the past due to its proximity to the NEWPCC outfall. There were no bivalves collected at the four sampling sites selected. Due to logistical constraints, and the lateness in the fall season (i.e., unlikely to collect bivalves as they would be buried too deep in the bottom substrate to be effectively sampled), only one sampling site was selected in each of the other zones within the Study Area; no bivalves were collected.

3.4 COMPARISONS AMONG BENTHIC SURVEYS

3.4.1 AMONG ZONES

Benthic Survey I

The benthic survey conducted in February - March, 1999, used a Ponar dredge to sample soft-medium bottom substrates in the Red and Assiniboine rivers. During this survey, 26 segments were sampled on the Red River and six segments on the Assiniboine River. In addition to sampling within zones, open-water sampling in the vicinity of and immediately downstream of the NEWPCC outfall was conducted.

During the winter survey, benthic invertebrates were observed to be spatially heterogeneous, with 24 taxa identified from soft-medium bottom substrates in the Red River and 10 taxa identified in the Assiniboine River. The greatest number of taxa were reported from Zone 2 (19 taxa), which extended from downstream of the SEWPCC outfall to upstream of the NEWPCC outfall on the Red River. The fewest number of taxa were observed in Zone 5 (0 taxa), which extended from Headingley to upstream of the WEWPCC outfall on the Assiniboine River, followed by Zone 4 (10 taxa), which extended from downstream of the WEWPCC outfall on the Assiniboine River to the confluence of the Assiniboine and Red rivers. The total abundance of invertebrates varied considerably among and within the zones sampled. Total invertebrate abundance was greatest immediately downstream of the NEWPCC outfall, followed by Zone 2 and Zone 3. In contrast, Zone 5, Zone 4, and Zone 1 had the lowest total invertebrate abundance

reported. Relative abundance of invertebrate taxa also differed among zones. The group Insecta (primarily Chironomidae) was relatively more important in zones 1 through 3. The relative importance of invertebrate taxa differed in the remaining zones, but Oligochaeta (primarily Tubificidae) was most important.

Benthic Survey II

The benthic survey conducted in August - October, 1999, used a Ponar dredge to sample soft-medium bottom substrates and artificial substrate samplers to sample hard bottom substrates in the Red and Assiniboine rivers. During this survey, soft-medium bottom substrates were sampled in 28 segments on the Red River and nine on the Assiniboine River. Hard bottom substrates were sampled in 10 segments on the Red River and six on the Assiniboine River. In addition to sampling within zones, sampling in the vicinity of and immediately downstream of the NEWPCC outfall (soft-medium and hard) and in the vicinity of and immediately downstream of the SEWPCC outfall (soft-medium only) was conducted.

During the fall survey, benthic invertebrates were observed to be spatially heterogeneous among soft-medium bottom substrates, with 25 taxa identified in the Red River and 15 taxa identified in the Assiniboine River. The greatest number of taxa were reported from Zone 2 (16 taxa), which extended from downstream of the SEWPCC outfall to upstream of the NEWPCC outfall on the Red River. The fewest number of taxa were observed immediately downstream of the SEWPCC outfall (7 taxa) on the Red River.

The total abundance of invertebrates varied considerably among and within the zones sampled. Total invertebrate abundance was greatest immediately downstream of the NEWPCC outfall, followed by Zone 2. In contrast to the winter survey, Zone 5 had one of the higher total invertebrate abundances. Zone 1A, immediately downstream of the SEWPCC outfall, and Zone 4 had the lowest total invertebrate abundances reported. Relative abundance of invertebrate taxa also differed among zones. The group Oligochaeta (primarily Tubificidae) was relatively more important in Zone 1A, immediately downstream of the NEWPCC outfall, in Zone 3A, and in the Assiniboine River. The relative importance of invertebrate taxa differed in the remaining zones, with Bivalvia (only Sphaeriidae) and Insecta more important in Zone 1 (Trichoptera) and immediately downstream of the SEWPCC outfall (Ephemeroptera). The importance of Oligochaeta

(primarily Tubificidae) and Bivalvia increased and Insecta decreased in the remainder of Zone 2.

During the fall survey, benthic invertebrates were also observed to be spatially heterogeneous among hard bottom substrates, with 26 taxa identified in the Red River and 29 taxa in the Assiniboine River. The greatest number of taxa were reported from Zone 4 (26 taxa) on the Assiniboine River, followed by Zone 5 on the Assiniboine River and Zone 3 on the Red River (18 taxa each). The fewest number of taxa were reported from Zone 1 (9 taxa) on the Red River. The total abundance of invertebrates varied among and within zones sampled. Total invertebrate abundance was greatest in Zone 5, followed by the remaining portion of the Assiniboine River in the Study Area (Zone 4) and Zone 3A. In contrast, lower total invertebrate abundance were recorded in zones 1, 1A, and 3 on the Red River. Unlike soft-medium bottom substrates, the relative abundance of invertebrate taxa was similar for hard bottom substrates among zones. Insecta was the most important group in both the Red and Assiniboine rivers. The predominant insect group in all areas sampled (including immediately downstream of NEWPCC outfall) was the less pollution-tolerant Trichoptera (primarily the family Hydropsychidae).

3.4.2 AMONG BOTTOM SUBSTRATE TYPES

Benthic Survey I

The organic content of soft-medium bottom substrates varied among zones. In general, organic content was higher in the Red River than in the Assiniboine River. Corresponding with this was a difference in particle-size composition of soft-medium bottom substrates among zones. The Assiniboine River was characterized as having a greater fraction of sand than any of the zones in the Red River. The fewest number of invertebrate taxa and the lowest total invertebrate abundance were observed in the Assiniboine River during the winter benthic survey. Perhaps the lower organic content of the sediments in the Assiniboine River did not provide sufficient nutrition for organisms that ingest sediments (e.g., Oligochaeta) and/or sediments with a higher fraction of sand did not provide adequate habitat for organisms (e.g., Chironomidae, Oligochaeta, Bivalvia), thereby resulting in fewer taxa being represented and in lower numbers.

Benthic Survey II

The organic content of soft-medium bottom substrates also varied among zones during the fall survey period. Organic content was noticeably higher in the Red River than in the Assiniboine River. Corresponding with this was a difference in particle-size composition of soft-medium bottom substrates among zones. The Assiniboine River was again characterized as having a greater fraction of sand than any of the zones in the Red River. In general, the Assiniboine River as a whole had fewer invertebrate taxa (15 taxa) than the Red River as a whole (25 taxa). However, in contrast to the winter survey, Zone 5 in the Assiniboine River had one of the higher total invertebrate abundances, but Zone 4 still had one of the lowest observed.

Artificial substrate samplers of a standardized design provide favourable habitat with relatively uniform substrate composition and area and permit the collection of benthic invertebrates at sites of choice, regardless of bottom conditions (Mason et al. 1973). The use of samplers permited effective sampling in areas which could not have been effectively sampled with a Ponar dredge. By providing a habitat of relatively uniform substrate composition and area, it becomes possible to begin to distinguish between low invertebrate abundances and low numbers of invertebrate taxa as potentially a result of inadequate substrate for attachment, predation, or poor water quality.

In artificial substrate samples collected during the fall survey period, the number of taxa of invertebrates observed in the Red River (26 taxa) was comparable to the number observed in soft-medium bottom substrate in the river for the same survey period (25 taxa). However, in the Assiniboine River, the number of taxa observed (29 taxa) was substantially higher than the number observed in soft-medium bottom substrate in the river (15 taxa). Perhaps the lower number of taxa observed in soft-medium bottom substrate in the Assiniboine River is a result of the lower organic content, sandy bottom substrate providing less adequate habitat for benthic invertebrates than the higher organic content, predominantly silty clay bottom substrate in the Red River.

3.4.3 BETWEEN SAMPLING PERIODS (SEASONS)

In soft-medium bottom substrate, a comparable number of invertebrate taxa were observed

between winter (24 taxa) and fall (25 taxa) benthic surveys in the Red River. As during the winter survey, total invertebrate abundance was greatest immediately downstream of the NEWPCC outfall, followed by Zone 2. The most abundant group of invertebrates immediately downstream of the NEWPCC outfall in both surveys was Oligochaeta (predominantly tubificids). During the winter survey, the most abundant group of invertebrates in Zone 2 was Oligochaeta; in the fall, sphaeriids were most abundant, followed by oligochaetes.

In the Assinboine River, a slightly lower number of invertebrate taxa were observed in soft-medium substrate sampled during the winter benthic survey (10 taxa) in comparison to during the fall (15 taxa). In both surveys, Zone 4 had one of the lowest total invertebrate abundances observed and oligochaetes dominated the benthic community. In contrast to the winter survey, Zone 5 had one of the higher total invertebrate abundances observed during the fall. There were no organisms observed in Zone 5 in the winter, but the fall community was dominated by Oligochaeta (primarily tubificids), similar to Zone 4 for both surveys.

3.4.4 TO HISTORICAL DATA (RED RIVER)

Prior to the present surveys, benthic invertebrates in soft-medium bottom substrate in the Red River were sampled by R. McV. Clarke (DFO) in 1973 and 1974 and by the City of Winnipeg (Laboratory Services Division of the Water and Waste Department) from 1971 to 1980 and in 1992, 1994, and 1996. Comparison of results of the present surveys to those done by Clarke is extremely difficult, primarily due to inadequate reporting of methods (see Section 2.4.3). For this reason, data from Clarke will not be used. Comparison with those surveys carried out by the City of Winnipeg is also difficult for a number of reasons, but primarily due to differences in sampling, identification, and enumeration techniques (see Section 2.5.3). Therefore, although comparisons are made, they should be considered with caution.

Ross and Hemphill (1997) reported that results from the surveys conducted from 1971 to 1980 were similar. The benthic invertebrate community at the upstream end of the City of Winnipeg (i.e., Zone 1 in present surveys) was dominated by pollution-intolerant organisms (e.g., Ephemeroptera). Moving downstream, the number of pollution-intolerant

taxa generally declined, with organisms more pollution-tolerant (e.g., Gastropoda, Bivalvia) becoming predominant. At Bronx Park (i.e., Zone 2, upstream of the NEWPCC outfall, in present surveys), they observed a significant increase in the number of organisms extremely pollution-tolerant (e.g., Tubificidae), with an area of recovery extending from the North Perimeter Bridge, downstream to Lockport (i.e., Zone 3 in present survey). Temporal (among years) and spatial (among sites) variation in the predominance of types of organisms was observed and a trend toward greater or fewer numbers of taxa at any particular site was not evident over time.

In 1996, 23 invertebrate taxa (11 orders) were identified from the Red River and the less tolerant insect orders Megaloptera, Trichoptera, Hemiptera, and Coleoptera were detected for the first time (Ross and Hemphill 1997). An increased abundance of organisms more pollution-tolerant and extremely pollution-tolerant was noted at the South Perimeter Bridge and the Red River Floodway Control (both within Zone 1). However, they reported that there were pollution-intolerant taxa observed throughout the Red River, including downstream of the SEWPCC and NEWPCC outfalls.

In soft-medium bottom substrate in the Red River, the present surveys observed 24 taxa during the winter survey and 25 taxa during the fall survey, both slight increases over the number of taxa reported in 1996. During the present winter survey, the number of taxa observed increased from Zone 1 to Zone 2, with both pollution-tolerant (chironomids, oligochaetes) and pollution-intolerant (ephemeropterans, trichopterans) organisms represented in samples. Although the number of taxa generally declined downstream of the NEWPCC outfall, pollution-intolerant groups were observed in all areas sampled. Similar results were obtained during the present fall survey.

Within artificial substrate samplers used in the present fall survey to sample invertebrates inhabiting hard bottom substrates in the Red River, 26 invertebrate taxa were identified. The number of taxa observed varied throughout the Study Area, with the greatest number being observed in Zone 3, downstream of the NEWPCC outfall. Insecta, predominantly Trichoptera, was the most abundant group observed throughout the Red River within the Study Area.

4.0 CONCLUSIONS

1. During the winter survey, benthic invertebrates were spatially heterogeneous, with 24 taxa identified from soft-medium bottom substrates in the Red River and 10 taxa identified in the Assiniboine River. The greatest number of taxa were reported from Zone 2 (extended from downstream of the SEWPCC outfall to upstream of the NEWPCC outfall on the Red River) and the fewest from Zone 4 (extended from downstream of the WEWPCC outfall on the Assiniboine River downstream to the confluence of the Assiniboine and Red rivers).

2. Total invertebrate abundance in winter (soft-medium bottom substrates) was greatest immediately downstream of the NEWPCC outfall, followed by Zone 2 and Zone 3 (extended from the NEWPCC downstream to the St. Andrews Locks near the town of Lockport on the Red River). In contrast, Zone 5 (extended from Headingly downstream to the WEWPCC on the Assiniboine River), Zone 4, and Zone 1 (extended from St. Adolphe downstream to the SEWPCC on the Red River) had the lowest total invertebrate abundance.

3. During the fall survey, benthic invertebrates were spatially heterogeneous, with 25 taxa identified from soft-medium bottom substrates in the Red River and 15 taxa identified in the Assiniboine River. The greatest number of taxa were reported from Zone 2 and the fewest from immediately downstream of the SEWPCC outfall.

4. Total invertebrate abundance in fall (soft-medium bottom substrates) was greatest immediately downstream of the NEWPCC outfall, followed by Zone 2. In contrast to the winter survey, Zone 5 had one of the higher total invertebrate abundance. Lower total invertebrate abundances were observed in Zone 1A (extended between Ste. Agathe and St. Adolphe on the Red River; used as a reference area upstream of all wastewater discharges within the Study Area), immediately downstream of the SEWPCC outfall, and in Zone 4.

5. During the fall survey, benthic invertebrates were observed to be spatially heterogeneous among hard bottom substrates, with 26 taxa identified in the Red River and 29 taxa in the Assiniboine River. The greatest number of taxa were

reported from Zone 4 and the fewest from Zone 1 (extended from St. Adolphe to upstream of the SEWPCC outfall on the Red River).

6. Total invertebrate abundance was greatest in Zone 5, followed by Zone 4 and Zone 3A (extended from the St. Andrews Locks near Lockport downstream to just downstream of the City of Selkirk on the Red River; used as a reference area downstream of all wastewater discharges within the Study Area). Lower total invertebrate abundances were observed in Zone 1, Zone 1A, and Zone 3. Insecta (primarily Trichoptera) was the most important group in both rivers.

7. Among soft-medium bottom substrates, organic content was higher in the Red River than the Assiniboine River, which had a greater fraction of sand than any of the zones in the Red River. Perhaps the lower number of taxa observed in soft-medium bottom substrate in the Assiniboine River was a result of the lower organic content, sandy bottom substrate providing less adequate habitat for benthic invertebrates than the higher organic content, predominantly silty clay bottom substrate in the Red River.

8. In soft-medium bottom substrate, a comparable number of invertebrate taxa were observed between winter and fall benthic surveys in the Red River. In the Assiniboine River, a slightly lower number of taxa were observed in the winter in comparison to the fall.

9. Surveys conducted by the City of Winnipeg from 1971 to 1980 observed temporal and spatial variation in the predominance of types of organisms; a trend toward greater or fewer numbers of taxa at any particular site was not evident over the 10 year period. In 1996, the City of Winnipeg reported that there were pollution-intolerant taxa observed throughout the Red River, including downstream of the SEWPCC and NEWPCC outfalls. The present study also showed that pollution-intolerant organisms occurred throughout the Red River, as well as the Assiniboine River.

5.0 REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION (APHA). 1992. Standard Methods for the Examination of Water and Wastewater. Eighteenth edition. A.E. Greenberg, L.S. Clesceri, and A.D. Eation (ed.). Washington, D.C.

CLARKE, R.McV. 1973. The effects of municipal wastes on the aquatic biota in receiving waters: project outline. Resource Management Branch, Fisheries and Marine Service, Operations Directorate, Central Region, Freshwater Institute. Unpublished.

CLARKE, R.McV and R. BOYCHUK. 1974. The effects of municipal wastes from Winnipeg on aquatic biota: project outline. Aquatic Toxic Studies Division, Resource Management Branch, Fisheries and Marine Service, Operations Directorate, Central Region, Freshwater Institute. Unpublished.

DAVIES, S. and L. ZRUM. 2000. Benthic invertebrate and sediment data to characterize fish habitat in the Red and Assiniboine rivers. Fish Habitat Techinical Memorandum # FH 02. A report prepared for the City of Winnipeg by North/South Consultants Inc. iv + 191 p.

DOWNING, J.A. and F.H. RIGLER (ed.). 1984. A manual on methods for the assessment of secondary productivity in fresh waters. Second edition. IBP Hand Book 17. Blackwell Scientific Publications.

HOLME, N.A. and A.D. McINTYRE (ed.). 1984. Methods for the study of marine benthos. Second edition. IBP Hand Book 16. Blackwell Scientific Publications.

MASON, W.T., C.I. WEBER, P.A. LEWIS, and E.C. JULIAN. 1973. Factors affecting the performance of basket and multiplate macroinvertebrate samplers. Freshwater Biology 3: 409 - 436.

MERRITT, R.W. and K.W. CUMMINS (ed.). 1996. An introduction to the aquatic insects of North America. Third edition. Kendall/Hunt Publishing Company, Dubuque, Iowa. 862 p.

ROSS, R.D. and L.M. HEMPHILL. 1997. 1996 Benthic survey: a study of the zoobenthos of the Red River in Winnipeg. City of Winnipeg, Water and Waste Department, Laboratory Services Division, Research Branch. Unpublished.

TABLES AND FIGURES

Table 1A. Invertebrates (individuals/m^2) collected in Ponar dredge samples from the Red and Assiniboine rivers, February - March,1999. Individual abundances may not add up to total due to rounding of numbers.

Zone	1A		1		SEWPCC		2		NEWPCC	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**n.s.**		**14**		**n.s.**		**17**		**6**	
Annelida										
Oligochaeta										
F. Tubificidae	-	-	218	378	-	-	782	1304	3048	1993
F. Lumbriculidae	-	-	7	25	-	-	45	97	16	25
F. Naididae	-	-	10	28	-	-	381	1226	0	0
Total Oligochaeta	**-**	**-**	**235**	**376**	**-**	**-**	**1208**	**2539**	**3063**	**2009**
Insecta										
Trichoptera										
F. Brachycentridae	-	-	0	0	-	-	0	0	0	0
F. Hydropsychidae	-	-	41	110	-	-	75	273	8	19
F. Leptoceridae	-	-	0	0	-	-	0	0	0	0
F. Limnephilidae	-	-	0	0	-	-	0	0	0	0
F. Polycentropodidae	-	-	0	0	-	-	8	32	0	0
Total Trichoptera	**-**	**-**	**41**	**110**	**-**	**-**	**82**	**304**	**8**	**19**
Ephemeroptera										
F. Ametropodidae	-	-	0	0	-	-	0	0	0	0
F. Baetidae	-	-	0	0	-	-	0	0	0	0
F. Caenidae	-	-	0	0	-	-	0	0	0	0
F. Ephemeridae	-	-	119	157	-	-	144	164	48	43
F. Heptageniidae	-	-	0	0	-	-	19	48	0	0
F. Leptophlebiidae	-	-	0	0	-	-	0	0	0	0
F. Polymitarcyidae	-	-	0	0	-	-	0	0	0	0
F. Siphlonuridae	-	-	0	0	-	-	0	0	0	0
F. Tricorythidae	-	-	0	0	-	-	0	0	0	0
Total Ephemeroptera	**-**	**-**	**119**	**157**	**-**	**-**	**163**	**166**	**48**	**43**
Plecoptera										
F. Perlidae (*Acroneuria* sp.)	-	-	0	0	-	-	0	0	0	0
F. Perlodidae	-	-	10	20	-	-	17	23	0	0
F. Pteronarcyidae	-	-	0	0	-	-	0	0	0	0
Total Plecoptera	**-**	**-**	**10**	**20**	**-**	**-**	**17**	**23**	**0**	**0**
Coleoptera										
F. Dytiscidae	-	-	0	0	-	-	0	0	0	0
F. Elmidae	-	-	0	0	-	-	57	135	16	25
Total Coleoptera	**-**	**-**	**0**	**0**	**-**	**-**	**57**	**135**	**16**	**25**
Hemiptera										
F. Corixidae	-	-	0	0	-	-	6	16	8	19
Megaloptera										
F. Corydalidae	-	-	0	0	-	-	0	0	0	0
F. Sialidae (*Sialis* sp.)	-	-	3	13	-	-	0	0	0	0
Total Megaloptera	**-**	**-**	**3**	**13**	**-**	**-**	**0**	**0**	**0**	**0**

Table 1A. (continued)

Zone	1A		1		SEWPCC		2		NEWPCC	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**n.s.**		**14**		**n.s.**		**17**		**6**	
Odonata										
F. Gomphidae	-	-	7	17	-	-	3	12	0	0
Diptera										
F. Athericidae	-	-	0	0	-	-	0	0	0	0
F. Chironomidae	-	-	588	383	-	-	1048	615	794	552
SubF. Chironominae	-	-	150	176	-	-	519	513	516	480
SubF. Orthocladiinae	-	-	54	109	-	-	173	158	95	124
SubF. Tanypodinae	-	-	384	292	-	-	357	255	183	179
F. Ceratopogonidae	-	-	17	35	-	-	19	34	8	19
F. Chaoboridae	-	-	7	17	-	-	0	0	0	0
F. Dolichopodidae	-	-	0	0	-	-	0	0	0	0
F. Empididae	-	-	0	0	-	-	3	12	0	0
F. Simuliidae	-	-	0	0	-	-	0	0	0	0
F. Tipulidae	-	-	0	0	-	-	0	0	0	0
Total Diptera	**-**	**-**	**612**	**412**	**-**	**-**	**1070**	**621**	**802**	**547**
Crustacea										
Amphipoda (*Hyalella* sp.)	**-**	**-**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Copepoda	**-**	**-**	**0**	**0**	**-**	**-**	**6**	**16**	**8**	**19**
Cladocera	**-**	**-**	**0**	**0**	**-**	**-**	**485**	**1710**	**810**	**1983**
Total Crustacea	**-**	**-**	**0**	**0**	**-**	**-**	**490**	**1710**	**817**	**2002**
Arachnida										
Hydracarina	**-**	**-**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Mollusca										
Bivalvia										
F. Sphaeriidae	-	-	44	51	-	-	82	89	24	26
F. Unionidae	-	-	0	0	-	-	0	0	0	0
Total Bivalvia	**-**	**-**	**44**	**51**	**-**	**-**	**82**	**89**	**24**	**26**
Gastropoda										
F. Ancylidae	-	-	0	0	-	-	0	0	0	0
F. Hydrobiidae (*Amnicola* sp.)	-	-	0	0	-	-	0	0	0	0
F. Valvatidae (*Valvata* sp.)	-	-	0	0	-	-	0	0	8	19
Total Gastropoda	**-**	**-**	**0**	**0**	**-**	**-**	**0**	**0**	**8**	**19**
Hydrozoa (*Hydra* sp.)	**-**	**-**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Nematoda	**-**	**-**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Turbellaria (*Planaria* sp.)	**-**	**-**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
TOTAL INVERTEBRATES	**n.s.**	**n.s.**	**1071**	**694**	**n.s.**	**n.s.**	**3178**	**3047**	**4794**	**3775**

[1] +/- 1 standard deviation

n.s. = not sampled during the February - March, 1999, survey period

Table 1A. (continued)

Zone	3		3A		4		5	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**6**		**6**		**6**		**1**	
Annelida								
Oligochaeta								
F. Tubificidae	857	417	925	600	373	542	0	-
F. Lumbriculidae	0	0	0	0	222	544	0	-
F. Naididae	0	0	0	0	238	538	0	-
Total Oligochaeta	**857**	**417**	**925**	**600**	**833**	**1605**	**0**	**-**
Insecta								
Trichoptera								
F. Brachycentridae	0	0	0	0	0	0	0	-
F. Hydropsychidae	16	39	0	0	48	74	0	-
F. Leptoceridae	0	0	0	0	0	0	0	-
F. Limnephilidae	0	0	0	0	0	0	0	-
F. Polycentropodidae	8	19	0	0	0	0	0	-
Total Trichoptera	**24**	**40**	**0**	**0**	**48**	**74**	**0**	**-**
Ephemeroptera								
F. Ametropodidae	0	0	0	0	0	0	0	-
F. Baetidae	0	0	0	0	0	0	0	-
F. Caenidae	0	0	0	0	0	0	0	-
F. Ephemeridae	63	111	92	76	0	0	0	-
F. Heptageniidae	0	0	0	0	0	0	0	-
F. Leptophlebiidae	0	0	8	19	0	0	0	-
F. Polymitarcyidae	0	0	0	0	0	0	0	-
F. Siphlonuridae	0	0	0	0	0	0	0	-
F. Tricorythidae	0	0	0	0	0	0	0	-
Total Ephemeroptera	**63**	**111**	**100**	**79**	**0**	**0**	**0**	**-**
Plecoptera								
F. Perlidae (*Acroneuria* sp.)	0	0	0	0	0	0	0	-
F. Perlodidae	0	0	8	19	0	0	0	-
F. Pteronarcyidae	0	0	0	0	0	0	0	-
Total Plecoptera	**0**	**0**	**8**	**19**	**0**	**0**	**0**	**-**
Coleoptera								
F. Dytiscidae	0	0	0	0	0	0	0	-
F. Elmidae	8	19	0	0	8	19	0	-
Total Coleoptera	**8**	**19**	**0**	**0**	**8**	**19**	**0**	**-**
Hemiptera								
F. Corixidae	0	0	0	0	0	0	0	-
Megaloptera								
F. Corydalidae	0	0	0	0	0	0	0	-
F. Sialidae (*Sialis* sp.)	0	0	0	0	0	0	0	-
Total Megaloptera	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**

Table 1A. (continued)

Zone	3		3A		4		5	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**6**		**6**		**6**		**1**	
Odonata								
F. Gomphidae	0	0	0	0	0	0	0	-
Diptera								
F. Athericidae	0	0	0	0	0	0	0	-
F. Chironomidae	937	555	329	322	40	47	0	-
SubF. Chironominae	437	439	87	126	8	19	0	-
SubF. Orthocladiinae	0	0	14	35	0	0	0	-
SubF. Tanypodinae	500	266	227	205	32	49	0	-
F. Ceratopogonidae	8	19	8	19	16	25	0	-
F. Chaoboridae	0	0	16	25	0	0	0	-
F. Dolichopodidae	0	0	0	0	0	0	0	-
F. Empididae	0	0	0	0	0	0	0	-
F. Simuliidae	0	0	0	0	0	0	0	-
F. Tipulidae	0	0	0	0	0	0	0	-
Total Diptera	**944**	**553**	**352**	**355**	**56**	**47**	**0**	**-**
Crustacea								
Amphipoda (*Hyalella* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Copepoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Cladocera	**0**	**0**	**339**	**573**	**0**	**0**	**0**	**-**
Total Crustacea	**0**	**0**	**339**	**573**	**0**	**0**	**0**	**-**
Arachnida								
Hydracarina	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Mollusca								
Bivalvia								
F. Sphaeriidae	167	204	46	56	24	26	0	-
F. Unionidae	0	0	0	0	0	0	0	-
Total Bivalvia	**167**	**204**	**46**	**56**	**24**	**26**	**0**	**-**
Gastropoda								
F. Ancylidae	0	0	0	0	0	0	0	-
F. Hydrobiidae (*Amnicola* sp.)	0	0	0	0	0	0	0	-
F. Valvatidae (*Valvata* sp.)	8	19	0	0	0	0	0	-
Total Gastropoda	**8**	**19**	**0**	**0**	**0**	**0**	**0**	**-**
Hydrozoa (*Hydra* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Nematoda	**24**	**26**	**0**	**0**	**8**	**19**	**0**	**-**
Turbellaria (*Planaria* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
TOTAL INVERTEBRATES	**2095**	**916**	**1770**	**556**	**976**	**1662**	**0**	**-**

[1] +/- 1 standard deviation

n.s. = not sampled during the February - March, 1999, survey period

Table 1B. Relative abundance (%) of invertebrates collected in Ponar dredge samples from the Red and Assiniboine rivers, February - March,1999. Individual abundances may not add up to total due to rounding of numbers.

Zone	1A	1	SEWPCC	2	NEWPCC	3	3A	4	5
	%	%	%	%	%	%	%	%	%
Number of Replicates	**n.s.**	**14**	**n.s.**	**17**	**6**	**6**	**6**	**6**	**1**
Annelida									
Oligochaeta									
F. Tubificidae	-	20.3	-	24.6	63.6	40.9	52.3	38.2	0.0
F. Lumbriculidae	-	0.6	-	1.4	0.3	0.0	0.0	22.8	0.0
F. Naididae	-	1.0	-	12.0	0.0	0.0	0.0	24.4	0.0
Total Oligochaeta	**-**	**21.9**	**-**	**38.0**	**63.9**	**40.9**	**52.3**	**85.4**	**0.0**
Insecta									
Trichoptera									
F. Brachycentridae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Hydropsychidae	-	3.8	-	2.3	0.2	0.8	0.0	4.9	0.0
F. Leptoceridae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Limnephilidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Polycentropodidae	-	0.0	-	0.2	0.0	0.4	0.0	0.0	0.0
Total Trichoptera	**-**	**3.8**	**-**	**2.6**	**0.2**	**1.1**	**0.0**	**4.9**	**0.0**
Ephemeroptera									
F. Ametropodidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Baetidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Caenidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Ephemeridae	-	11.1	-	4.5	1.0	3.0	5.2	0.0	0.0
F. Heptageniidae	-	0.0	-	0.6	0.0	0.0	0.0	0.0	0.0
F. Leptophlebiidae	-	0.0	-	0.0	0.0	0.0	0.4	0.0	0.0
F. Polymitarcyidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Siphlonuridae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Tricorythidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Total Ephemeroptera	**-**	**11.1**	**-**	**5.1**	**1.0**	**3.0**	**5.7**	**0.0**	**0.0**
Plecoptera									
F. Perlidae (*Acroneuria* sp.)	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Perlodidae	-	1.0	-	0.5	0.0	0.0	0.4	0.0	0.0
F. Pteronarcyidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Total Plecoptera	**-**	**1.0**	**-**	**0.5**	**0.0**	**0.0**	**0.4**	**0.0**	**0.0**
Coleoptera									
F. Dytiscidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Elmidae	-	0.0	-	1.8	0.3	0.4	0.0	0.8	0.0
Total Coleoptera	**-**	**0.0**	**-**	**1.8**	**0.3**	**0.4**	**0.0**	**0.8**	**0.0**
Hemiptera									
F. Corixidae	-	0.0	-	0.2	0.2	0.0	0.0	0.0	0.0
Megaloptera									
F. Corydalidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Sialidae (*Sialis* sp.)	-	0.3	-	0.0	0.0	0.0	0.0	0.0	0.0
Total Megaloptera	**-**	**0.3**	**-**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 1B. (continued)

Zone	1A	1	SEWPCC	2	NEWPCC	3	3A	4	5
	%	%	%	%	%	%	%	%	%
Number of Replicates	**n.s.**	**14**	**n.s.**	**17**	**6**	**6**	**6**	**6**	**1**
Odonata									
F. Gomphidae	-	0.6	-	0.1	0.0	0.0	0.0	0.0	0.0
Diptera									
F. Athericidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Chironomidae	-	54.9	-	33.0	16.6	44.7	18.6	4.1	0.0
SubF. Chironominae	-	14.0	-	16.3	10.8	20.8	4.9	0.8	0.0
SubF. Orthocladiinae	-	5.1	-	5.4	2.0	0.0	0.8	0.0	0.0
SubF. Tanypodinae	-	35.9	-	11.2	3.8	23.9	12.8	3.3	0.0
F. Ceratopogonidae	-	1.6	-	0.6	0.2	0.4	0.4	1.6	0.0
F. Chaoboridae	-	0.6	-	0.0	0.0	0.0	0.9	0.0	0.0
F. Dolichopodidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Empididae	-	0.0	-	0.1	0.0	0.0	0.0	0.0	0.0
F. Simuliidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Tipulidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Total Diptera	**-**	**57.1**	**-**	**33.7**	**16.7**	**45.1**	**19.9**	**5.7**	**0.0**
Crustacea									
Amphipoda (*Hyalella* sp.)	**-**	**0.0**	**-**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Copepoda	**-**	**0.0**	**-**	**0.2**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**
Cladocera	**-**	**0.0**	**-**	**15.3**	**16.9**	**0.0**	**19.1**	**0.0**	**0.0**
Total Crustacea	**-**	**0.0**	**-**	**15.4**	**17.1**	**0.0**	**19.1**	**0.0**	**0.0**
Arachnida									
Hydracarina	**-**	**0.0**	**-**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Mollusca									
Bivalvia									
F. Sphaeriidae	-	4.1	-	2.6	0.5	8.0	2.6	2.4	0.0
F. Unionidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Total Bivalvia	**-**	**4.1**	**-**	**2.6**	**0.5**	**8.0**	**2.6**	**2.4**	**0.0**
Gastropoda									
F. Ancylidae	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Hydrobiidae (*Amnicola* sp.)	-	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Valvatidae (*Valvata* sp.)	-	0.0	-	0.0	0.2	0.4	0.0	0.0	0.0
Total Gastropoda	**-**	**0.0**	**-**	**0.0**	**0.2**	**0.4**	**0.0**	**0.0**	**0.0**
Hydrozoa (*Hydra* sp.)	**-**	**0.0**	**-**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Nematoda	**-**	**0.0**	**-**	**0.0**	**0.0**	**1.1**	**0.0**	**0.8**	**0.0**
Turbellaria (*Planaria* sp.)	**-**	**0.0**	**-**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
TOTAL INVERTEBRATES	**n.s.**	**100.0**	**n.s.**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**0.0**

n.s. = not sampled during the February - March, 1999, survey period

Table 2. Organic content and particle size composition of sediments collected in Ponar dredge samples from the Red and Assiniboine rivers, February - March,1999.

Zone	1A	1	SEWPCC	2	NEWPCC	3	3A	4	5
	%	%	%	%	%	%	%	%	%
Number of Replicates	**n.s.**	**14**	**n.s.**	**16**	**6**	**6**	**5**	**6**	**0** [1]
Organic Content	**-**	**4.6**	**-**	**3.8**	**4.5**	**3.5**	**5.3**	**2.9**	**-**
Particle Size:									
> 2 mm	-	0.76	-	2.01	4.29	6.28	0.23	0.03	-
> 1 mm	-	0.12	-	0.81	7.07	0.91	0.01	0.33	-
> 500 µm	-	0.34	-	2.29	5.26	1.50	0.05	3.27	-
> 250 µm	-	0.90	-	4.33	7.22	17.36	2.66	36.65	-
> 125 µm	-	1.34	-	3.08	5.45	5.44	3.57	10.33	-
> 63 µm	-	0.80	-	1.38	0.95	1.45	0.84	1.73	-
Total Gravel	**-**	**0.76**	**-**	**2.01**	**4.29**	**6.28**	**0.23**	**0.03**	**-**
Total Sand	**-**	**3.50**	**-**	**11.88**	**25.95**	**26.66**	**7.13**	**52.31**	**-**
Total Silt/Clay	**-**	**95.74**	**-**	**86.11**	**69.75**	**67.06**	**92.64**	**47.66**	**-**

n.s. = not sampled during the February - March, 1999, survey period

[1] no replicates were collected during the February - March, 1999, survey period due to non-recoverable Ponar Dredges and partial Ponar Dredge sample

Table 3A. Invertebrates (individuals/m^2) collected in Ponar dredge samples from the Red and Assiniboine rivers, September, 1999. Individual abundances may not add up to total due to rounding of numbers.

Zone	1A		1		SEWPCC		2		NEWPCC	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**2**		**16**		**5**		**18**		**6**	
Annelida										
Oligochaeta										
F. Tubificidae	238	269	42	65	10	21	437	558	2714	3220
F. Lumbriculidae	48	67	0	0	0	0	50	82	127	127
F. Naididae	0	0	0	0	0	0	5	15	0	0
Total Oligochaeta	**286**	**337**	**42**	**65**	**10**	**21**	**492**	**605**	**2841**	**3296**
Insecta										
Trichoptera										
F. Brachycentridae	0	0	0	0	0	0	0	0	0	0
F. Hydropsychidae	48	67	289	632	19	26	45	133	32	25
F. Leptoceridae	0	0	15	38	0	0	11	26	0	0
F. Limnephilidae	0	0	0	0	0	0	0	0	0	0
F. Polycentropodidae	24	34	0	0	0	0	0	0	0	0
Total Trichoptera	**71**	**34**	**304**	**637**	**19**	**26**	**56**	**156**	**32**	**25**
Ephemeroptera										
F. Ametropodidae	0	0	0	0	0	0	0	0	0	0
F. Baetidae	0	0	0	0	0	0	0	0	0	0
F. Caenidae	0	0	0	0	0	0	11	20	16	25
F. Ephemeridae	24	34	54	119	324	251	82	199	8	19
F. Heptageniidae	0	0	12	27	0	0	3	11	8	19
F. Leptophlebiidae	0	0	0	0	0	0	0	0	0	0
F. Polymitarcyidae	0	0	0	0	0	0	0	0	0	0
F. Siphlonuridae	0	0	0	0	0	0	0	0	0	0
F. Tricorythidae	0	0	0	0	0	0	0	0	0	0
Total Ephemeroptera	**24**	**34**	**65**	**140**	**324**	**251**	**95**	**198**	**32**	**39**
Plecoptera										
F. Perlidae (*Acroneuria* sp.)	0	0	0	0	0	0	0	0	0	0
F. Perlodidae	0	0	3	12	0	0	0	0	8	19
F. Pteronarcyidae	0	0	0	0	0	0	0	0	0	0
Total Plecoptera	**0**	**0**	**3**	**12**	**0**	**0**	**0**	**0**	**8**	**19**
Coleoptera										
F. Dytiscidae	0	0	0	0	0	0	0	0	0	0
F. Elmidae	0	0	15	29	0	0	5	22	8	19
Total Coleoptera	**0**	**0**	**15**	**29**	**0**	**0**	**5**	**22**	**8**	**19**
Hemiptera										
F. Corixidae	0	0	0	0	0	0	3	11	0	0
Megaloptera										
F. Corydalidae	0	0	0	0	0	0	0	0	0	0
F. Sialidae (*Sialis* sp.)	0	0	0	0	10	21	0	0	0	0
Total Megaloptera	**0**	**0**	**0**	**0**	**10**	**21**	**0**	**0**	**0**	**0**

Table 3A. (continued)

Zone	1A		1		SEWPCC		2		NEWPCC	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**2**		**16**		**5**		**18**		**6**	
Odonata										
F. Gomphidae	0	0	3	12	10	21	5	15	0	0
Diptera										
F. Athericidae	0	0	0	0	0	0	0	0	0	0
F. Chironomidae	24	34	6	16	10	21	50	106	40	36
SubF. Chironominae	24	34	0	0	10	21	50	106	40	36
SubF. Orthocladiinae	0	0	0	0	0	0	0	0	0	0
SubF. Tanypodinae	0	0	6	16	0	0	0	0	0	0
F. Ceratopogonidae	24	34	0	0	0	0	0	0	0	0
F. Chaoboridae	0	0	6	16	0	0	0	0	0	0
F. Dolichopodidae	0	0	3	12	0	0	0	0	0	0
F. Empididae	0	0	0	0	0	0	0	0	0	0
F. Simuliidae	0	0	0	0	0	0	0	0	0	0
F. Tipulidae	0	0	0	0	0	0	0	0	0	0
Total Diptera	**48**	**0**	**15**	**29**	**10**	**21**	**50**	**106**	**40**	**36**
Crustacea										
Amphipoda (*Hyalella* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Copepoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cladocera	**0**	**0**	**0**	**0**	**0**	**0**	**19**	**79**	**0**	**0**
Total Crustacea	**0**	**0**	**0**	**0**	**0**	**0**	**19**	**79**	**0**	**0**
Arachnida										
Hydracarina	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Mollusca										
Bivalvia										
F. Sphaeriidae	48	67	488	828	229	304	847	2385	79	72
F. Unionidae	0	0	0	0	0	0	0	0	0	0
Total Bivalvia	**48**	**67**	**488**	**828**	**229**	**304**	**847**	**2385**	**79**	**72**
Gastropoda										
F. Ancylidae	0	0	0	0	0	0	0	0	0	0
F. Hydrobiidae (*Amnicola* sp.)	24	34	74	125	0	0	74	207	0	0
F. Valvatidae (*Valvata* sp.)	0	0	0	0	0	0	0	0	0	0
Total Gastropoda	**24**	**34**	**74**	**125**	**0**	**0**	**74**	**207**	**0**	**0**
Hydrozoa (*Hydra* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Nematoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**270**	**661**
Turbellaria (*Planaria* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**11**	**0**	**0**
TOTAL INVERTEBRATES	**500**	**236**	**1009**	**995**	**610**	**294**	**1648**	**2262**	**3310**	**3885**

[1] +/- 1 standard deviation

Table 3A. (continued)

Zone	3		3A		4		5	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**10**		**6**		**10**		**4**	
Annelida								
Oligochaeta								
F. Tubificidae	367	466	929	1077	500	907	964	1118
F. Lumbriculidae	0	0	8	19	0	0	0	0
F. Naididae	5	15	135	129	10	20	0	0
Total Oligochaeta	**371**	**476**	**1071**	**1201**	**510**	**904**	**964**	**1118**
Insecta								
Trichoptera								
F. Brachycentridae	0	0	0	0	0	0	0	0
F. Hydropsychidae	162	495	0	0	33	75	0	0
F. Leptoceridae	0	0	0	0	24	46	48	95
F. Limnephilidae	0	0	0	0	0	0	0	0
F. Polycentropodidae	0	0	0	0	0	0	0	0
Total Trichoptera	**162**	**495**	**0**	**0**	**57**	**80**	**48**	**95**
Ephemeroptera								
F. Ametropodidae	0	0	0	0	5	15	24	27
F. Baetidae	0	0	0	0	0	0	0	0
F. Caenidae	5	15	0	0	14	45	24	48
F. Ephemeridae	148	176	95	85	0	0	95	103
F. Heptageniidae	24	60	0	0	10	20	12	24
F. Leptophlebiidae	0	0	0	0	0	0	0	0
F. Polymitarcyidae	5	15	0	0	0	0	0	0
F. Siphlonuridae	0	0	0	0	0	0	0	0
F. Tricorythidae	0	0	0	0	5	15	0	0
Total Ephemeroptera	**181**	**185**	**95**	**85**	**33**	**50**	**155**	**162**
Plecoptera								
F. Perlidae (*Acroneuria* sp.)	0	0	0	0	5	15	0	0
F. Perlodidae	0	0	0	0	0	0	12	24
F. Pteronarcyidae	0	0	0	0	0	0	0	0
Total Plecoptera	**0**	**0**	**0**	**0**	**5**	**15**	**12**	**24**
Coleoptera								
F. Dytiscidae	0	0	0	0	0	0	0	0
F. Elmidae	10	30	0	0	0	0	0	0
Total Coleoptera	**10**	**30**	**0**	**0**	**0**	**0**	**0**	**0**
Hemiptera								
F. Corixidae	0	0	0	0	0	0	0	0
Megaloptera								
F. Corydalidae	0	0	0	0	0	0	0	0
F. Sialidae (*Sialis* sp.)	0	0	0	0	0	0	0	0
Total Megaloptera	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 3A. (continued)

Zone	3		3A		4		5	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**10**		**6**		**10**		**4**	
Odonata								
F. Gomphidae	0	0	0	0	0	0	0	0
Diptera								
F. Athericidae	0	0	0	0	0	0	0	0
F. Chironomidae	62	87	63	65	29	60	60	24
SubF. Chironominae	38	63	32	58	29	60	60	24
SubF. Orthocladiinae	0	0	0	0	0	0	0	0
SubF. Tanypodinae	24	60	32	58	0	0	0	0
F. Ceratopogonidae	0	0	0	0	52	124	0	0
F. Chaoboridae	0	0	0	0	0	0	0	0
F. Dolichopodidae	0	0	0	0	0	0	0	0
F. Empididae	0	0	0	0	0	0	0	0
F. Simuliidae	0	0	0	0	0	0	0	0
F. Tipulidae	0	0	0	0	0	0	0	0
Total Diptera	**62**	**87**	**63**	**65**	**81**	**125**	**60**	**24**
Crustacea								
Amphipoda (*Hyalella* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Copepoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cladocera	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Crustacea	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Arachnida								
Hydracarina	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Mollusca								
Bivalvia								
F. Sphaeriidae	43	52	63	94	67	125	131	180
F. Unionidae	0	0	0	0	0	0	71	91
Total Bivalvia	**43**	**52**	**63**	**94**	**67**	**125**	**202**	**184**
Gastropoda								
F. Ancylidae	0	0	0	0	0	0	0	0
F. Hydrobiidae (*Amnicola* sp.)	0	0	8	19	0	0	0	0
F. Valvatidae (*Valvata* sp.)	0	0	0	0	0	0	0	0
Total Gastropoda	**0**	**0**	**8**	**19**	**0**	**0**	**0**	**0**
Hydrozoa (*Hydra* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Nematoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Turbellaria (*Planaria* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL INVERTEBRATES	**829**	**770**	**1302**	**1189**	**752**	**823**	**1440**	**1424**

[1] +/- 1 standard deviation

Table 3B. Relative abundance (%) of invertebrates collected in Ponar dredge samples from the Red and Assiniboine rivers, September, 1999. Individual abundances may not add up to total due to rounding of numbers.

Zone	1A	1	SEWPCC	2	NEWPCC	3	3A	4	5
	%	%	%	%	%	%	%	%	%
Number of Replicates	**2**	**16**	**5**	**18**	**6**	**10**	**6**	**10**	**4**
Annelida									
Oligochaeta									
F. Tubificidae	47.6	4.1	1.6	26.5	82.0	44.3	71.3	66.5	66.9
F. Lumbriculidae	9.5	0.0	0.0	3.0	3.8	0.0	0.6	0.0	0.0
F. Naididae	0.0	0.0	0.0	0.3	0.0	0.6	10.4	1.3	0.0
Total Oligochaeta	**57.1**	**4.1**	**1.6**	**29.9**	**85.9**	**44.8**	**82.3**	**67.7**	**66.9**
Insecta									
Trichoptera									
F. Brachycentridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Hydropsychidae	9.5	28.6	3.1	2.7	1.0	19.5	0.0	4.4	0.0
F. Leptoceridae	0.0	1.5	0.0	0.6	0.0	0.0	0.0	3.2	3.3
F. Limnephilidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Polycentropodidae	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Trichoptera	**14.3**	**30.1**	**3.1**	**3.4**	**1.0**	**19.5**	**0.0**	**7.6**	**3.3**
Ephemeroptera									
F. Ametropodidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.7
F. Baetidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Caenidae	0.0	0.0	0.0	0.6	0.5	0.6	0.0	1.9	1.7
F. Ephemeridae	4.8	5.3	53.1	5.0	0.2	17.8	7.3	0.0	6.6
F. Heptageniidae	0.0	1.2	0.0	0.2	0.2	2.9	0.0	1.3	0.8
F. Leptophlebiidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Polymitarcyidae	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
F. Siphlonuridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Tricorythidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Total Ephemeroptera	**4.8**	**6.5**	**53.1**	**5.8**	**1.0**	**21.8**	**7.3**	**4.4**	**10.7**
Plecoptera									
F. Perlidae (*Acroneuria* sp.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
F. Perlodidae	0.0	0.3	0.0	0.0	0.2	0.0	0.0	0.0	0.8
F. Pteronarcyidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Plecoptera	**0.0**	**0.3**	**0.0**	**0.0**	**0.2**	**0.0**	**0.0**	**0.6**	**0.8**
Coleoptera									
F. Dytiscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Elmidae	0.0	1.5	0.0	0.3	0.2	1.1	0.0	0.0	0.0
Total Coleoptera	**0.0**	**1.5**	**0.0**	**0.3**	**0.2**	**1.1**	**0.0**	**0.0**	**0.0**
Hemiptera									
F. Corixidae	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Megaloptera									
F. Corydalidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Sialidae (*Sialis* sp.)	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0
Total Megaloptera	**0.0**	**0.0**	**1.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 3B. (continued)

Zone	1A	1	SEWPCC	2	NEWPCC	3	3A	4	5
	%	%	%	%	%	%	%	%	%
Number of Replicates	**2**	**16**	**6**	**18**	**6**	**10**	**6**	**10**	**4**
Odonata									
F. Gomphidae	0.0	0.3	1.6	0.3	0.0	0.0	0.0	0.0	0.0
Diptera									
F. Athericidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Chironomidae	4.8	0.6	1.6	3.0	1.2	7.5	4.9	3.8	4.1
SubF. Chironominae	4.8	0.0	1.6	3.0	1.2	4.6	2.4	3.8	4.1
SubF. Orthocladiinae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SubF. Tanypodinae	0.0	0.6	0.0	0.0	0.0	2.9	2.4	0.0	0.0
F. Ceratopogonidae	4.8	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0
F. Chaoboridae	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Dolichopodidae	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Empididae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Simuliidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Tipulidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Diptera	**9.5**	**1.5**	**1.6**	**3.0**	**1.2**	**7.5**	**4.9**	**10.8**	**4.1**
Crustacea									
Amphipoda (*Hyalella* sp.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Total Crustacea	**0.0**	**0.0**	**0.0**	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Arachnida									
Hydracarina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mollusca									
Bivalvia									
F. Sphaeriidae	9.5	48.4	37.5	51.4	2.4	5.2	4.9	8.9	9.1
F. Unionidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
Total Bivalvia	**9.5**	**48.4**	**37.5**	**51.4**	**2.4**	**5.2**	**4.9**	**8.9**	**14.0**
Gastropoda									
F. Ancylidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F. Hydrobiidae (*Amnicola* sp.)	4.8	7.4	0.0	4.5	0.0	0.0	0.6	0.0	0.0
F. Valvatidae (*Valvata* sp.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Gastropoda	**4.8**	**7.4**	**0.0**	**4.5**	**0.0**	**0.0**	**0.6**	**0.0**	**0.0**
Hydrozoa (*Hydra* sp.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nematoda	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0
Turbellaria (*Planaria* sp.)	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
TOTAL INVERTEBRATES	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Table 4A. Invertebrates (individuals/sampler) collected in artificial substrate samples from the Red and Assiniboi rivers, September - October, 1999. Individual abundances may not add up to total due to rounding of numbers.

Zone	1A		1		SEWPCC		2		NEWPCC	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**2**		**2**		**n.s.**		**6**		**2**	
Annelida										
Oligochaeta										
F. Tubificidae	0	0	1	1	-	-	2	4	0	0
F. Lumbriculidae	0	0	0	0	-	-	0	0	0	0
F. Naididae	0	0	0	0	-	-	0	0	0	0
Total Oligochaeta	**0**	**0**	**1**	**1**	-	-	**2**	**4**	**0**	**0**
Insecta										
Trichoptera										
F. Brachycentridae	6	4	0	0	-	-	1	2	13	2
F. Hydropsychidae	119	168	73	86	-	-	262	236	258	180
F. Leptoceridae	1	1	0	0	-	-	1	0	6	3
F. Limnephilidae	0	0	0	0	-	-	0	0	0	0
F. Polycentropodidae	1	1	1	1	-	-	26	17	10	6
Total Trichoptera	**127**	**175**	**74**	**87**	-	-	**289**	**242**	**287**	**185**
Ephemeroptera										
F. Ametropodidae	0	0	0	0	-	-	0	0	0	0
F. Baetidae	0	0	0	0	-	-	0	0	0	0
F. Caenidae	0	0	0	0	-	-	3	6	0	0
F. Ephemeridae	0	0	0	0	-	-	1	1	0	0
F. Heptageniidae	1	1	1	1	-	-	4	3	2	2
F. Leptophlebiidae	0	0	0	0	-	-	1	1	0	0
F. Polymitarcyidae	0	0	0	0	-	-	0	0	0	0
F. Siphlonuridae	0	0	0	0	-	-	0	0	0	0
F. Tricorythidae	1	1	0	0	-	-	2	5	0	0
Total Ephemeroptera	**1**	**1**	**1**	**1**	-	-	**11**	**14**	**2**	**2**
Plecoptera										
F. Perlidae (*Acroneuria* sp.)	0	0	0	0	-	-	0	0	0	0
F. Perlodidae	0	0	1	1	-	-	1	2	1	0
F. Pteronarcyidae	0	0	0	0	-	-	0	0	0	0
Total Plecoptera	**0**	**0**	**1**	**1**	-	-	**1**	**2**	**1**	**0**
Coleoptera										
F. Dytiscidae	0	0	0	0	-	-	0	0	0	0
F. Elmidae	1	1	2	1	-	-	0	0	1	1
Total Coleoptera	**1**	**1**	**2**	**1**	**-**	**-**	**0**	**0**	**1**	**1**
Hemiptera										
F. Corixidae	0	0	0	0	-	-	0	0	0	0
Megaloptera										
F. Corydalidae	0	0	0	0	-	-	0	0	0	0
F. Sialidae (*Sialis* sp.)	0	0	0	0	-	-	0	0	0	0
Total Megaloptera	**0**	**0**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**

Table 4A. (continued)

Zone	1A		1		SEWPCC		2		NEWPCC	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**2**		**2**		**n.s.**		**6**		**2**	
Odonata										
F. Gomphidae	0	0	0	0	-	-	0	0	0	0
Diptera										
F. Athericidae	0	0	0	0	-	-	0	0	0	0
F. Chironomidae	1	1	1	1	-	-	4	4	8	8
SubF. Chironominae	1	1	1	1	-	-	1	2	1	1
SubF. Orthocladiinae	0	0	0	0	-	-	1	1	1	1
SubF. Tanypodinae	0	0	0	0	-	-	1	2	6	8
F. Ceratopogonidae	0	0	0	0	-	-	0	0	0	0
F. Chaoboridae	0	0	0	0	-	-	0	0	0	0
F. Dolichopodidae	0	0	0	0	-	-	0	0	0	0
F. Empididae	0	0	0	0	-	-	0	0	0	0
F. Simuliidae	0	0	1	1	-	-	1	1	0	0
F. Tipulidae	1	1	0	0	-	-	0	0	0	0
Total Diptera	**1**	**1**	**1**	**0**	**-**	**-**	**4**	**5**	**8**	**8**
Crustacea										
Amphipoda (*Hyalella* sp.)	**0**	**0**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Copepoda	**0**	**0**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Cladocera	**0**	**0**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Total Crustacea	**0**	**0**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Arachnida										
Hydracarina	**1**	**1**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Mollusca										
Bivalvia										
F. Sphaeriidae	1	1	0	0	-	-	0	0	0	0
F. Unionidae	0	0	0	0	-	-	0	0	1	1
Total Bivalvia	**1**	**1**	**0**	**0**	**-**	**-**	**0**	**1**	**1**	**1**
Gastropoda										
F. Ancylidae	0	0	1	1	-	-	0	0	1	1
F. Hydrobiidae (*Amnicola* sp.)	0	0	0	0	-	-	0	0	0	0
F. Valvatidae (*Valvata* sp.)	0	0	0	0	-	-	0	0	0	0
Total Gastropoda	**0**	**0**	**1**	**1**	**-**	**-**	**0**	**0**	**1**	**1**
Hydrozoa (*Hydra* sp.)	**0**	**0**	**0**	**0**	**-**	**-**	**0**	**0**	**3**	**4**
Nematoda	**0**	**0**	**0**	**0**	**-**	**-**	**0**	**0**	**0**	**0**
Turbellaria (*Planaria* sp.)	**0**	**0**	**0**	**0**	**-**	**-**	**2**	**2**	**3**	**1**
TOTAL INVERTEBRATES	**131**	**176**	**80**	**87**	**n.s.**	**n.s.**	**310**	**264**	**304**	**195**

[1] +/- 1 standard deviation

n.s. = not sampled during the September - October, 1999, survey period

Table 4A. (continued)

Zone	3		3A		4		5	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**2**		**2**		**4**		**5**	
Annelida								
Oligochaeta								
F. Tubificidae	8	1	0	0	2	1	0	0
F. Lumbriculidae	0	0	0	0	0	0	0	0
F. Naididae	0	0	0	0	1	2	0	0
Total Oligochaeta	**8**	**1**	**0**	**0**	**3**	**1**	**0**	**0**
Insecta								
Trichoptera								
F. Brachycentridae	6	6	0	0	17	16	63	44
F. Hydropsychidae	129	47	326	445	328	257	398	500
F. Leptoceridae	1	1	3	4	1	3	1	1
F. Limnephilidae	0	0	0	0	0	0	0	1
F. Polycentropodidae	2	1	16	22	2	2	1	1
Total Trichoptera	**137**	**53**	**344**	**471**	**347**	**274**	**463**	**541**
Ephemeroptera								
F. Ametropodidae	0	0	0	0	0	0	0	0
F. Baetidae	0	0	0	0	0	1	0	0
F. Caenidae	2	2	2	2	2	3	4	7
F. Ephemeridae	1	1	0	0	9	10	0	0
F. Heptageniidae	2	1	21	27	7	11	4	4
F. Leptophlebiidae	1	1	0	0	0	1	0	0
F. Polymitarcyidae	0	0	0	0	0	0	0	0
F. Siphlonuridae	0	0	1	1	0	0	1	1
F. Tricorythidae	1	1	0	0	2	5	0	0
Total Ephemeroptera	**6**	**4**	**23**	**30**	**21**	**16**	**8**	**11**
Plecoptera								
F. Perlidae (*Acroneuria* sp.)	0	0	0	0	0	0	4	8
F. Perlodidae	1	1	2	1	4	4	12	19
F. Pteronarcyidae	0	0	0	0	0	0	0	0
Total Plecoptera	**1**	**1**	**2**	**1**	**4**	**4**	**16**	**28**
Coleoptera								
F. Dytiscidae	0	0	4	6	1	1	0	1
F. Elmidae	1	1	1	1	2	2	4	7
Total Coleoptera	**1**	**1**	**5**	**6**	**2**	**2**	**4**	**6**
Hemiptera								
F. Corixidae	0	0	0	0	1	1	0	0
Megaloptera								
F. Corydalidae	0	0	0	0	0	1	0	0
F. Sialidae (*Sialis* sp.)	1	1	0	0	0	0	0	0
Total Megaloptera	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**0**

Table 4A. (continued)

Zone	3		3A		4		5	
	mean	std[1]	mean	std[1]	mean	std[1]	mean	std[1]
Number of Replicates	**2**		**2**		**4**		**5**	
Odonata								
F. Gomphidae	0	0	0	0	1	2	0	0
Diptera								
F. Athericidae	0	0	0	0	2	4	1	1
F. Chironomidae	7	8	5	6	11	13	25	30
SubF. Chironominae	0	0	1	1	1	1	4	8
SubF. Orthocladiinae	1	1	3	4	0	1	0	0
SubF. Tanypodinae	6	7	2	2	10	12	21	32
F. Ceratopogonidae	0	0	0	0	0	0	0	0
F. Chaoboridae	0	0	0	0	0	0	0	0
F. Dolichopodidae	0	0	0	0	0	0	0	0
F. Empididae	0	0	0	0	0	0	0	0
F. Simuliidae	0	0	1	1	0	0	0	0
F. Tipulidae	0	0	0	0	2	3	2	3
Total Diptera	**7**	**8**	**5**	**7**	**14**	**19**	**28**	**33**
Crustacea								
Amphipoda (*Hyalella* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Copepoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cladocera	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Crustacea	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Arachnida								
Hydracarina	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Mollusca								
Bivalvia								
F. Sphaeriidae	1	1	0	0	1	1	0	0
F. Unionidae	1	1	0	0	1	1	3	5
Total Bivalvia	**1**	**1**	**0**	**0**	**1**	**1**	**3**	**5**
Gastropoda								
F. Ancylidae	0	0	0	0	0	0	0	0
F. Hydrobiidae (*Amnicola* sp.)	0	0	0	0	0	0	0	0
F. Valvatidae (*Valvata* sp.)	0	0	0	0	0	0	0	0
Total Gastropoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Hydrozoa (*Hydra* sp.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Nematoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Turbellaria (*Planaria* sp.)	**5**	**4**	**2**	**2**	**1**	**1**	**2**	**3**
TOTAL INVERTEBRATES	**164**	**69**	**380**	**518**	**394**	**314**	**525**	**620**

[1] +/- 1 standard deviation

n.s. = not sampled during the September - October, 1999, survey period

Table 4B. Relative abundance (%) of invertebrates collected in artificial substrate samples from the Red and Assiniboin rivers, September - October, 1999. Individual abundances may not add up to total due to rounding of numbe

Zone	1A	1	SEWPCC	2	NEWPCC	3	3A	4	5
	%	%	%	%	%	%	%	%	%
Number of Replicates	**2**	**2**	**n.s.**	**6**	**2**	**2**	**2**	**4**	**5**
Annelida									
Oligochaeta									
F. Tubificidae	0.0	1.3	-	0.7	0.0	4.9	0.0	0.4	0.0
F. Lumbriculidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Naididae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.2	0.0
Total Oligochaeta	**0.0**	**1.3**	**-**	**0.7**	**0.0**	**4.9**	**0.0**	**0.6**	**0.0**
Insecta									
Trichoptera									
F. Brachycentridae	4.6	0.0	-	0.4	4.1	3.4	0.0	4.3	12.0
F. Hydropsychidae	91.2	91.2	-	84.4	84.9	78.7	85.7	83.1	75.9
F. Leptoceridae	0.8	0.0	-	0.3	2.0	0.3	0.8	0.3	0.2
F. Limnephilidae	0.0	0.0	-	0.1	0.0	0.0	0.0	0.0	0.1
F. Polycentropodidae	0.4	1.3	-	8.2	3.3	0.9	4.1	0.4	0.2
Total Trichoptera	**96.9**	**92.5**	**-**	**93.3**	**94.2**	**83.2**	**90.5**	**88.1**	**88.3**
Ephemeroptera									
F. Ametropodidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Baetidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.1	0.0
F. Caenidae	0.0	0.0	-	1.1	0.0	0.9	0.4	0.5	0.8
F. Ephemeridae	0.0	0.0	-	0.2	0.0	0.6	0.0	2.3	0.0
F. Heptageniidae	0.4	1.3	-	1.4	0.5	0.9	5.5	1.8	0.7
F. Leptophlebiidae	0.0	0.0	-	0.2	0.0	0.3	0.0	0.1	0.0
F. Polymitarcyidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Siphlonuridae	0.0	0.0	-	0.0	0.0	0.0	0.1	0.0	0.1
F. Tricorythidae	0.4	0.0	-	0.7	0.0	0.6	0.0	0.6	0.0
Total Ephemeroptera	**0.8**	**1.3**	**-**	**3.5**	**0.5**	**3.4**	**6.1**	**5.3**	**1.6**
Plecoptera									
F. Perlidae (*Acroneuria* sp.)	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.7
F. Perlodidae	0.0	0.6	-	0.3	0.3	0.3	0.5	1.0	2.2
F. Pteronarcyidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Total Plecoptera	**0.0**	**0.6**	**-**	**0.3**	**0.3**	**0.3**	**0.5**	**1.0**	**3.0**
Coleoptera									
F. Dytiscidae	0.0	0.0	-	0.0	0.0	0.0	1.1	0.1	0.1
F. Elmidae	0.4	2.5	-	0.1	0.2	0.3	0.1	0.4	0.7
Total Coleoptera	**0.4**	**2.5**	**-**	**0.1**	**0.2**	**0.3**	**1.2**	**0.6**	**0.8**
Hemiptera									
F. Corixidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.1	0.0
Megaloptera									
F. Corydalidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.1	0.0
F. Sialidae (*Sialis* sp.)	0.0	0.0	-	0.0	0.0	0.3	0.0	0.0	0.0
Total Megaloptera	**0.0**	**0.0**	**-**	**0.0**	**0.0**	**0.3**	**0.0**	**0.1**	**0.0**

Table 4B. (continued)

Zone	1A	1	SEWPCC	2	NEWPCC	3	3A	4	5
	%	%	%	%	%	%	%	%	%
Number of Replicates	**2**	**2**	**n.s.**	**6**	**2**	**2**	**2**	**4**	**5**
Odonata									
F. Gomphidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.2	0.0
Diptera									
F. Athericidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.6	0.1
F. Chironomidae	0.4	0.6	-	1.1	2.5	4.0	1.2	2.7	4.8
SubF. Chironominae	0.4	0.6	-	0.3	0.3	0.0	0.1	0.1	0.8
SubF. Orthocladiinae	0.0	0.0	-	0.4	0.3	0.3	0.7	0.1	0.0
SubF. Tanypodinae	0.0	0.0	-	0.4	1.8	3.7	0.4	2.5	4.0
F. Ceratopogonidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Chaoboridae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Dolichopodidae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Empididae	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Simuliidae	0.0	0.6	-	0.2	0.0	0.0	0.1	0.0	0.0
F. Tipulidae	0.4	0.0	-	0.1	0.0	0.0	0.0	0.4	0.5
Total Diptera	**0.8**	**1.3**	**-**	**1.3**	**2.5**	**4.0**	**1.3**	**3.6**	**5.4**
Crustacea									
Amphipoda (*Hyalella* sp.)	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Total Crustacea	**0.0**	**0.0**	**-**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Arachnida									
Hydracarina	0.8	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Mollusca									
Bivalvia									
F. Sphaeriidae	0.4	0.0	-	0.1	0.0	0.3	0.0	0.1	0.0
F. Unionidae	0.0	0.0	-	0.1	0.2	0.3	0.0	0.1	0.5
Total Bivalvia	**0.4**	**0.0**	**-**	**0.1**	**0.2**	**0.6**	**0.0**	**0.3**	**0.5**
Gastropoda									
F. Ancylidae	0.0	0.6	-	0.0	0.3	0.0	0.0	0.0	0.0
F. Hydrobiidae (*Amnicola* sp.)	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
F. Valvatidae (*Valvata* sp.)	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Total Gastropoda	**0.0**	**0.6**	**-**	**0.0**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**
Hydrozoa (*Hydra* sp.)	0.0	0.0	-	0.0	0.8	0.0	0.0	0.0	0.0
Nematoda	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0
Turbellaria (*Planaria* sp.)	0.0	0.0	-	0.6	1.0	3.0	0.4	0.1	0.3
TOTAL INVERTEBRATES	**100.0**	**100.0**	**n.s.**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

n.s. = not sampled during the September - October, 1999, survey period

Table 5. Organic content and particle size composition of sediments collected in Ponar dredge samples from the Red and Assiniboine rivers, September,1999.

Zone	1A	1	SEWPCC	2	NEWPCC	3	3A	4	5
	%	%	%	%	%	%	%	%	%
Number of Replicates	**2**	**16**	**5**	**18**	**6**	**10**	**6**	**10**	**4**
Organic Content	**3.8**	**3.6**	**5.6**	**4.2**	**4.0**	**4.3**	**4.9**	**2.0**	**1.9**
Particle Size:									
> 2 mm	0.00	9.15	6.04	1.07	3.75	6.00	0.01	0.04	0.03
> 1 mm	0.02	3.47	0.68	1.47	0.21	0.36	0.02	0.18	0.02
> 500 µm	0.12	6.36	0.66	6.77	0.61	0.68	0.06	3.78	1.01
> 250 µm	0.52	13.83	1.11	12.50	7.02	0.90	7.56	19.06	21.98
> 125 µm	3.39	3.97	1.31	4.29	12.65	3.08	5.85	35.42	21.52
> 63 µm	3.82	1.38	0.85	4.40	5.34	3.34	2.39	9.96	11.72
Total Gravel	**0.00**	**9.15**	**6.04**	**1.07**	**3.75**	**6.00**	**0.01**	**0.04**	**0.03**
Total Sand	**7.86**	**29.02**	**4.61**	**29.43**	**25.82**	**8.35**	**15.87**	**68.40**	**56.26**
Total Silt/Clay	**92.14**	**61.84**	**89.35**	**69.49**	**70.43**	**85.65**	**84.12**	**31.56**	**43.71**

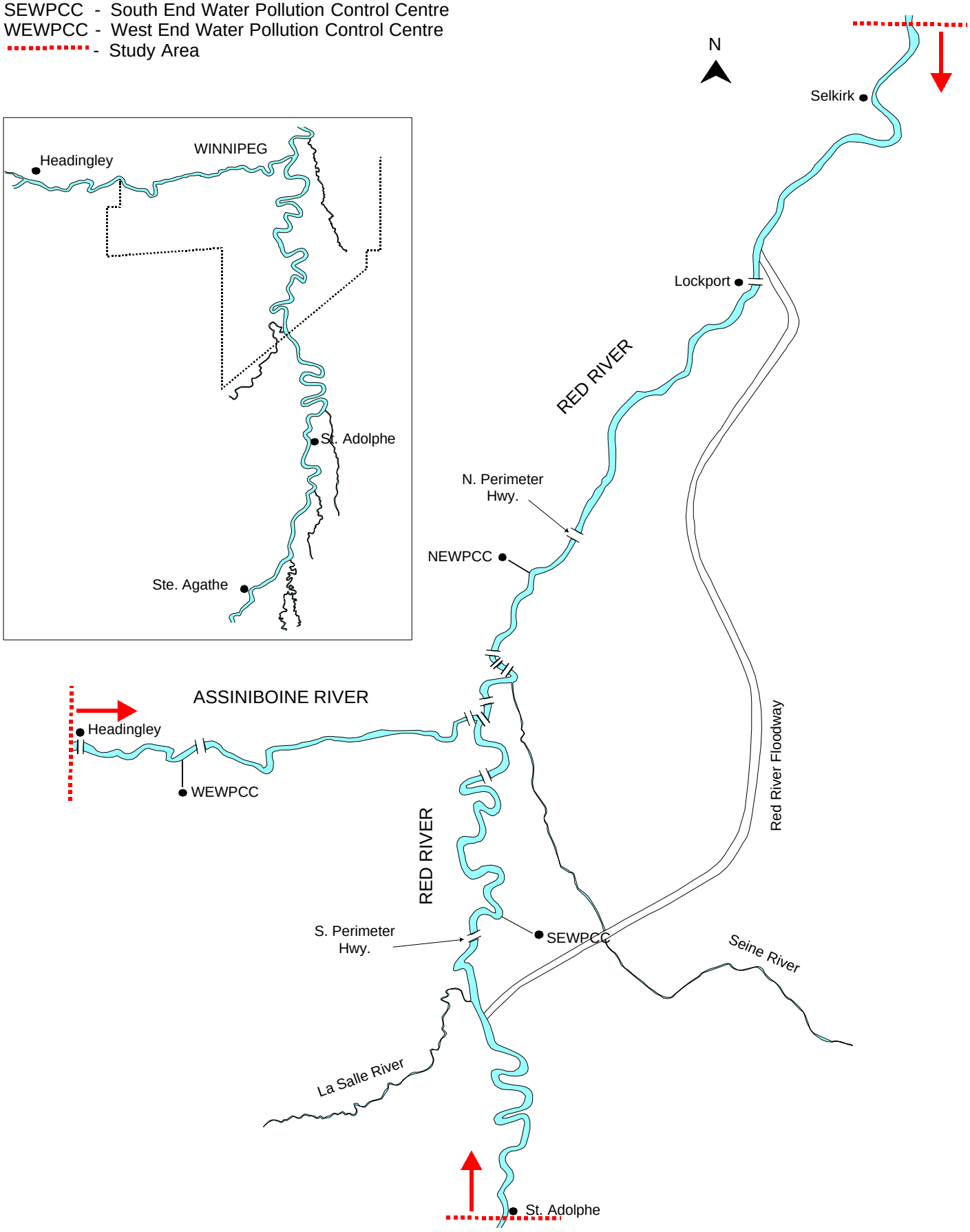

Figure 1. Study Area for the City of Winnipeg Ammonia Criteria Study.

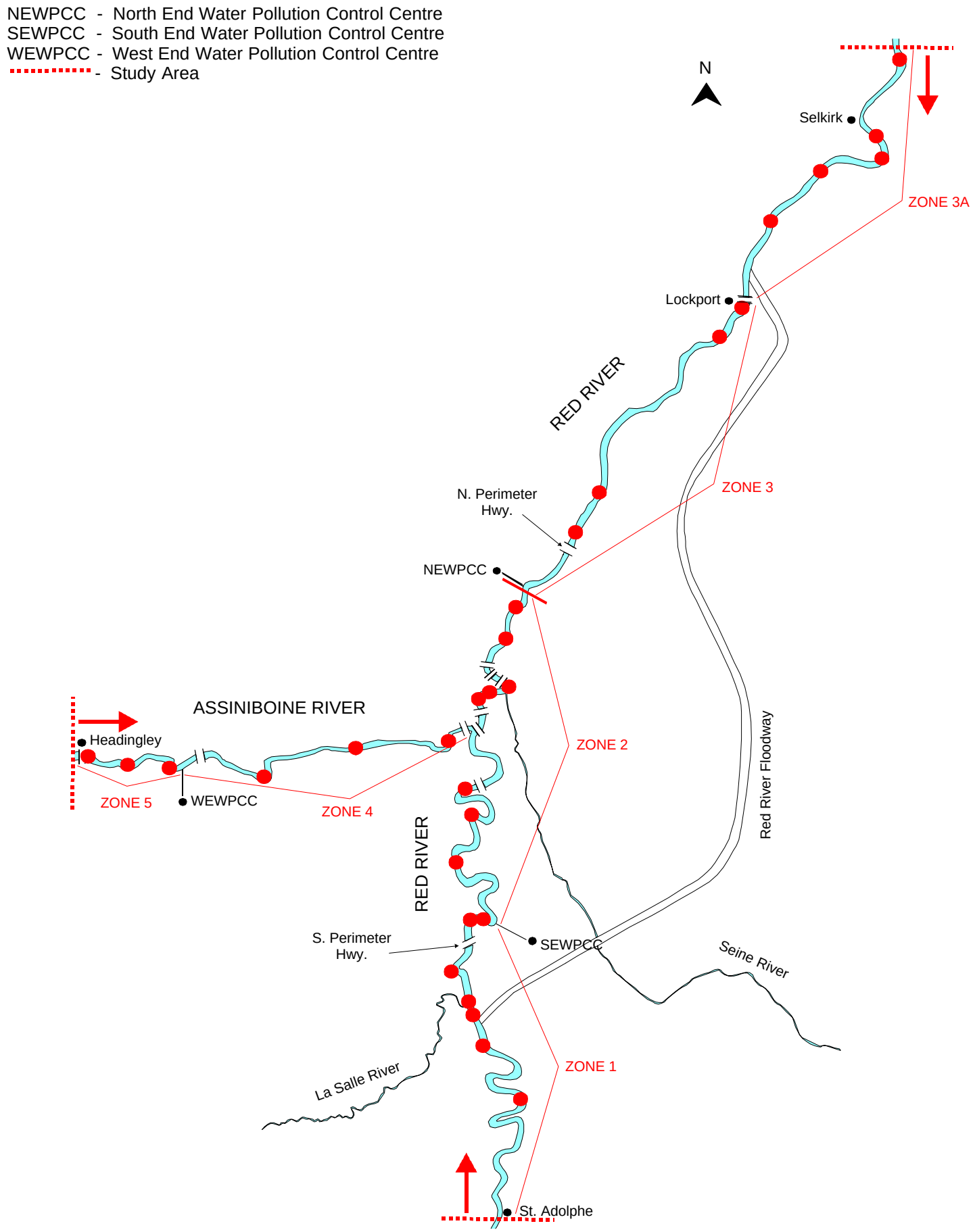

Figure 2. Ponar dredge sampling locations, February - March, 1999.

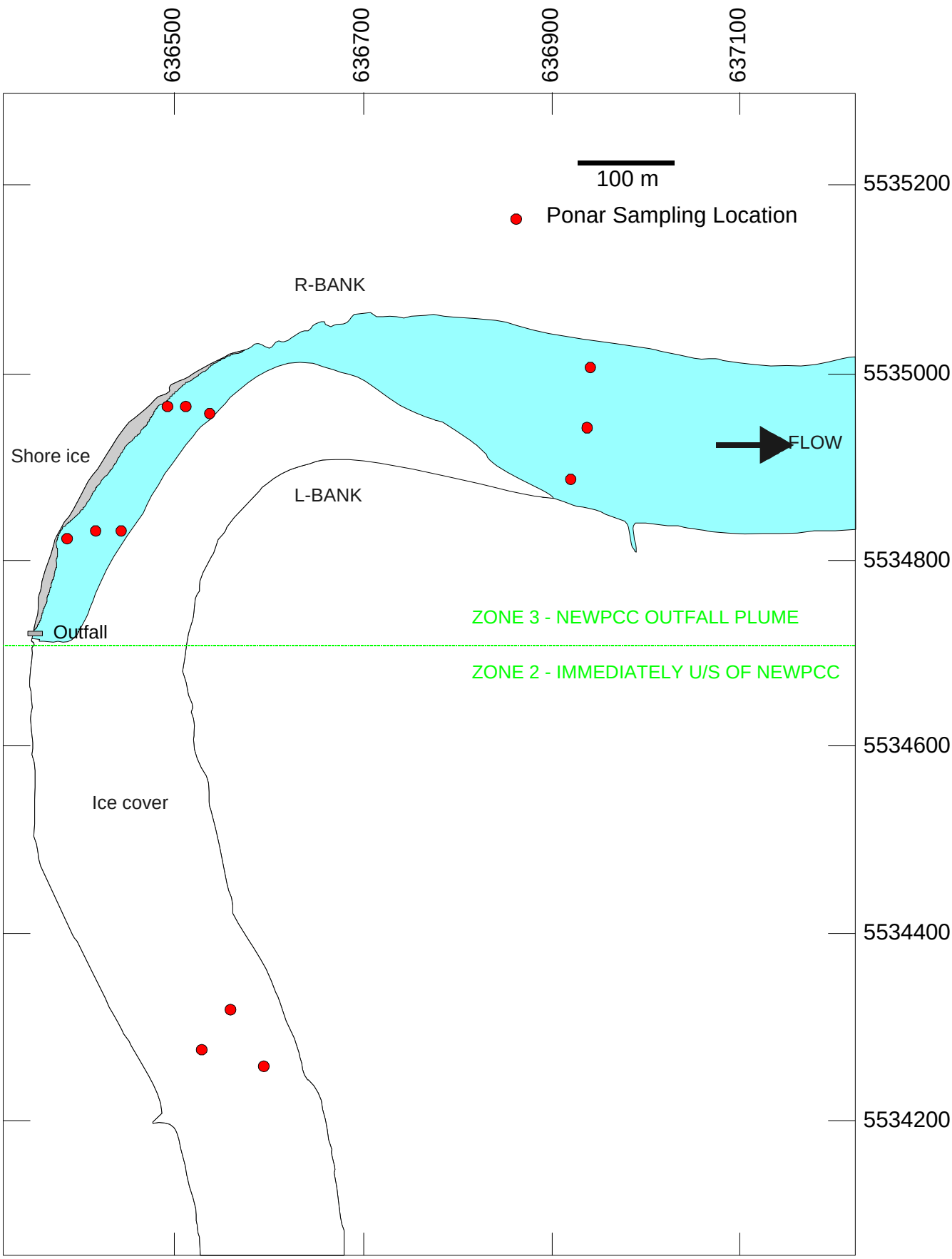

Figure 3. Ponar sampling locations immediately upstream and downstream of the NEWPCC outfall, March, 1999 (grid in UTMs).

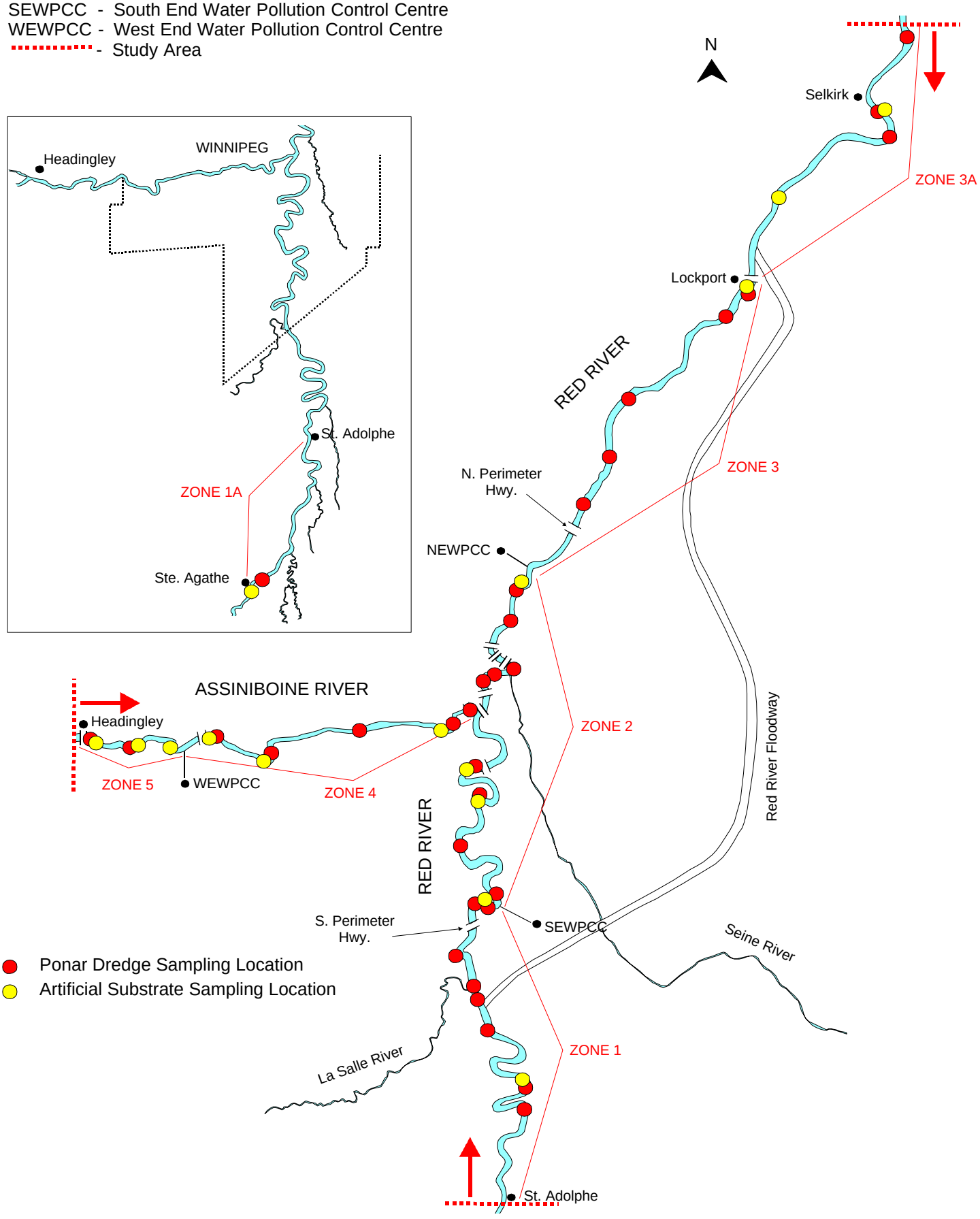

Figure 4. Ponar Dredge and Artificial Substrate sampling locations, September - October, 1999.

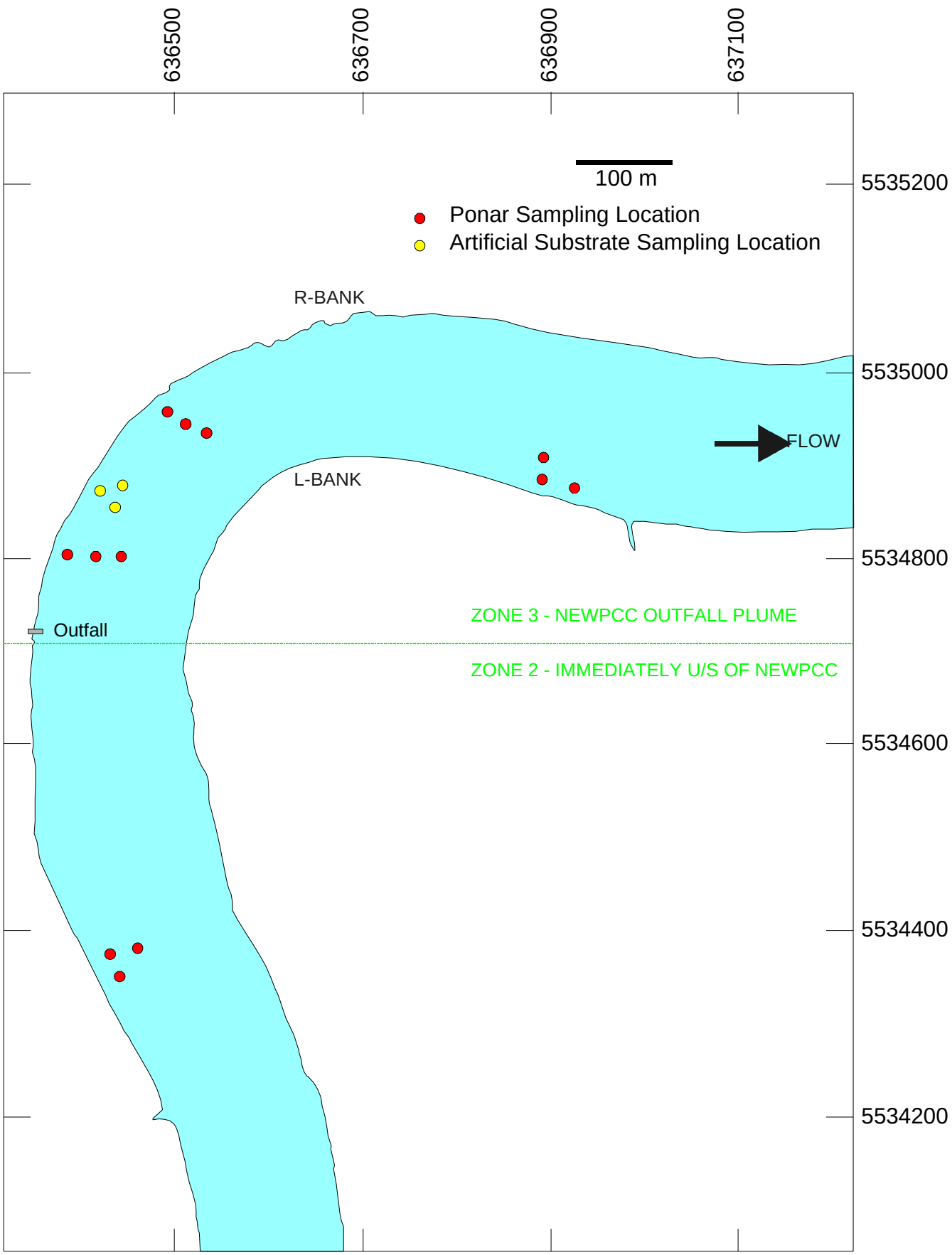

Figure 5. Ponar and artificial substrate sampling locations immediately upstream and downstream of the NEWPCC outfall, September, 1999 (grid in UTMs).

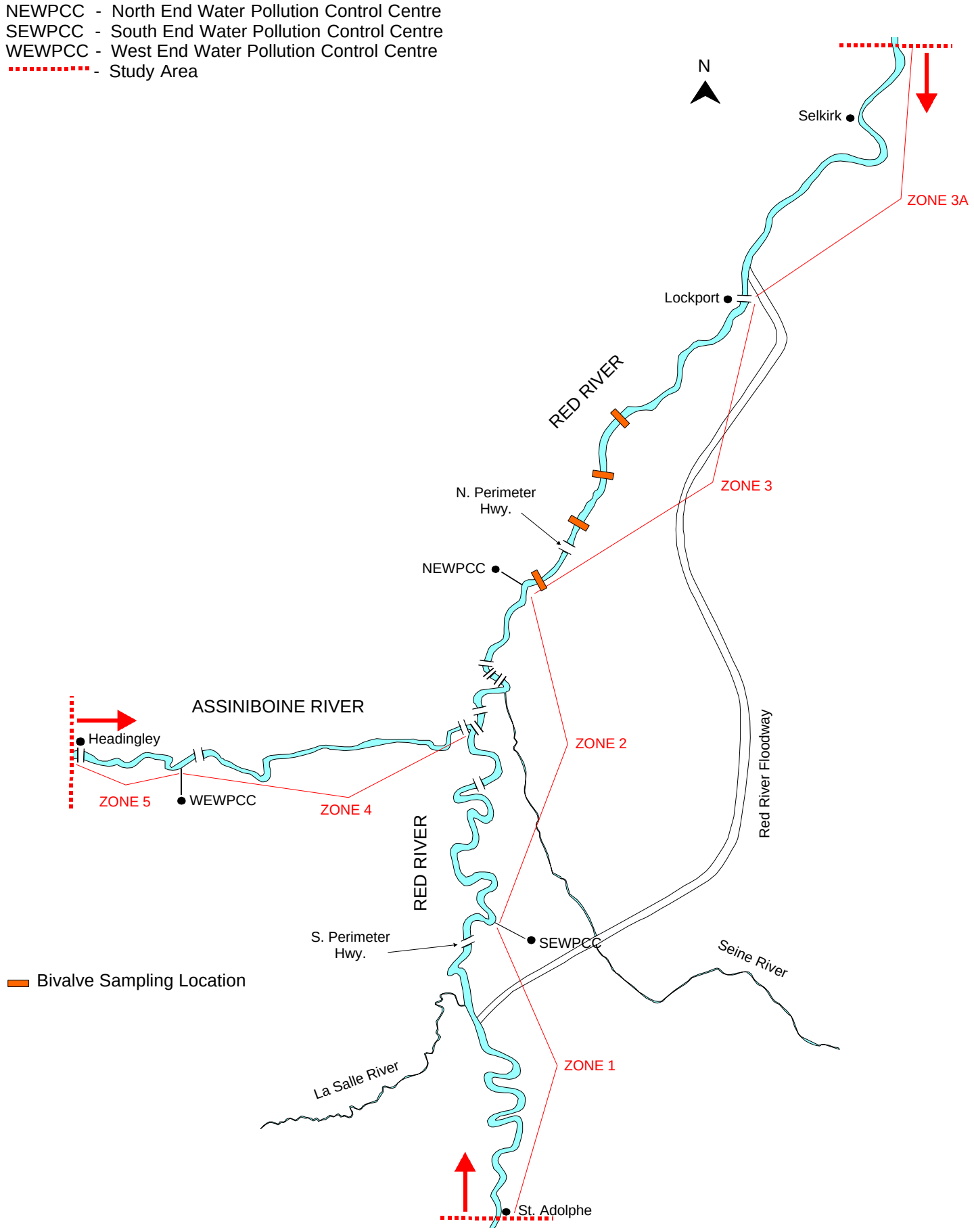

Figure 6. Bivalve sampling locations, October 20, 1999.

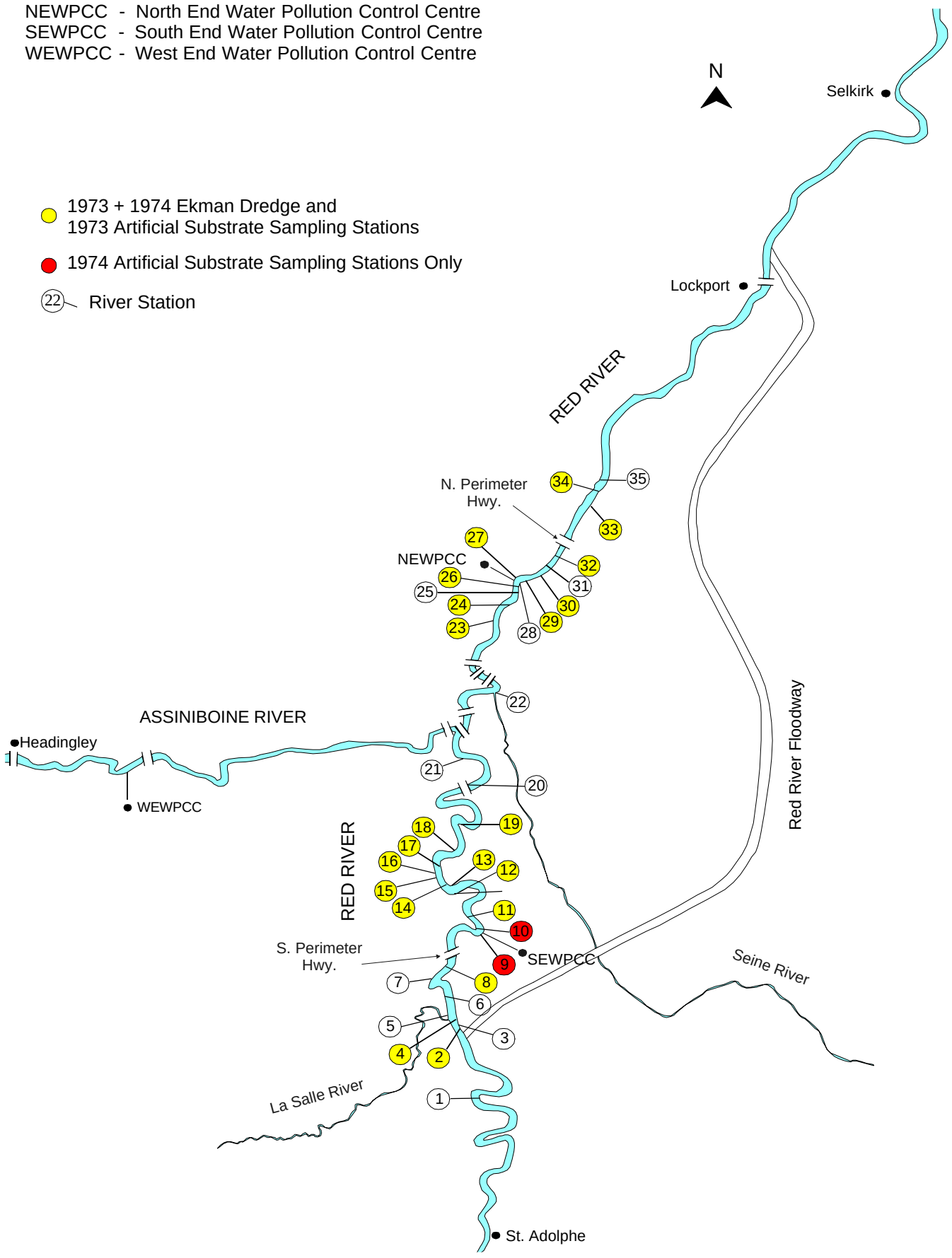

Figure 7. Sampling stations used by R. McV. Clarke (DFO) to assess the effects of municipal effluent on the benthic invertebrate community, 1973 and 1974.

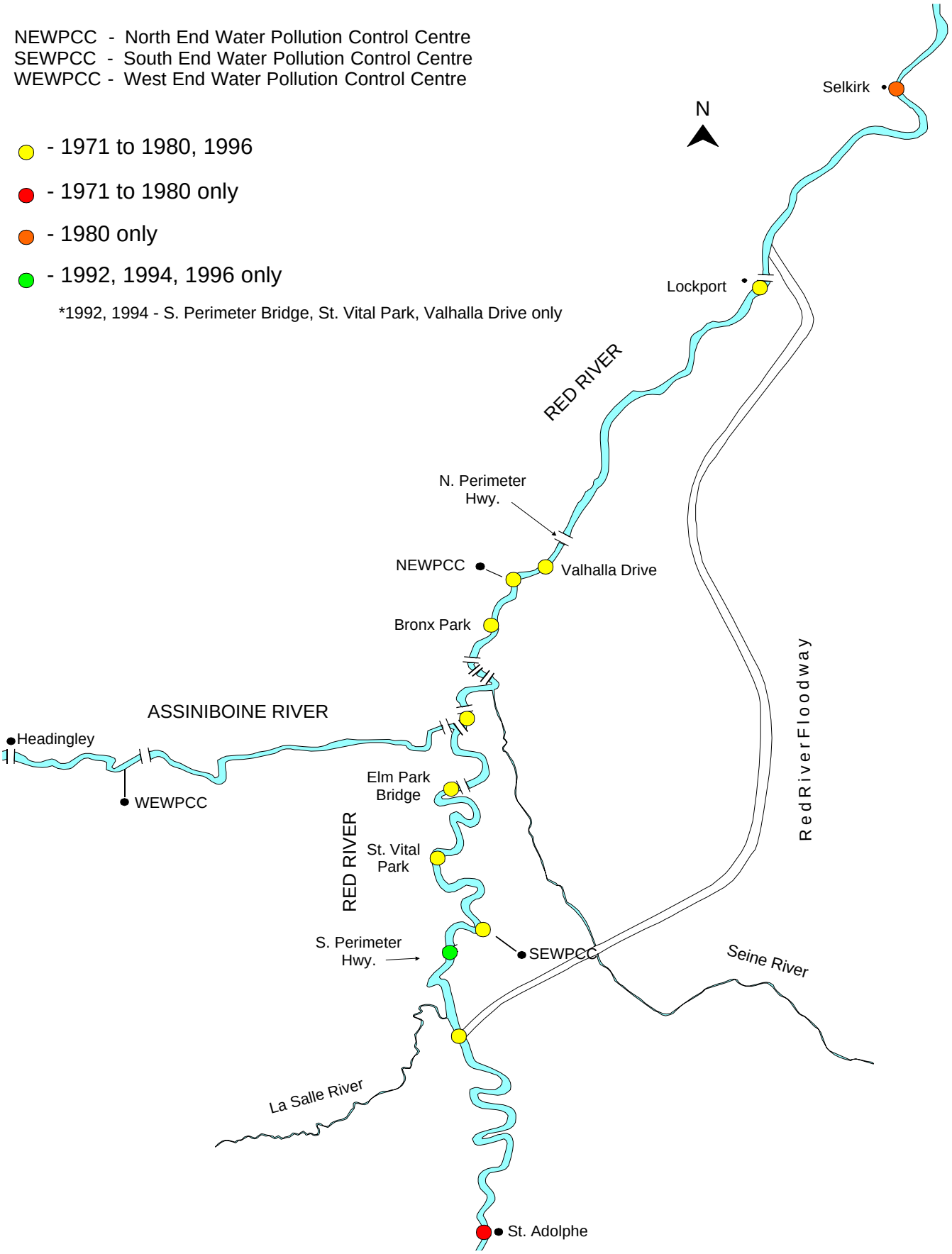

Figure 8. Sampling stations used by the City of Winnipeg (Water and Waste Department) to assess the effects of municipal effluent on the benthic invertebrate community, 1971 - 80, 1992, 1994, and 1996.

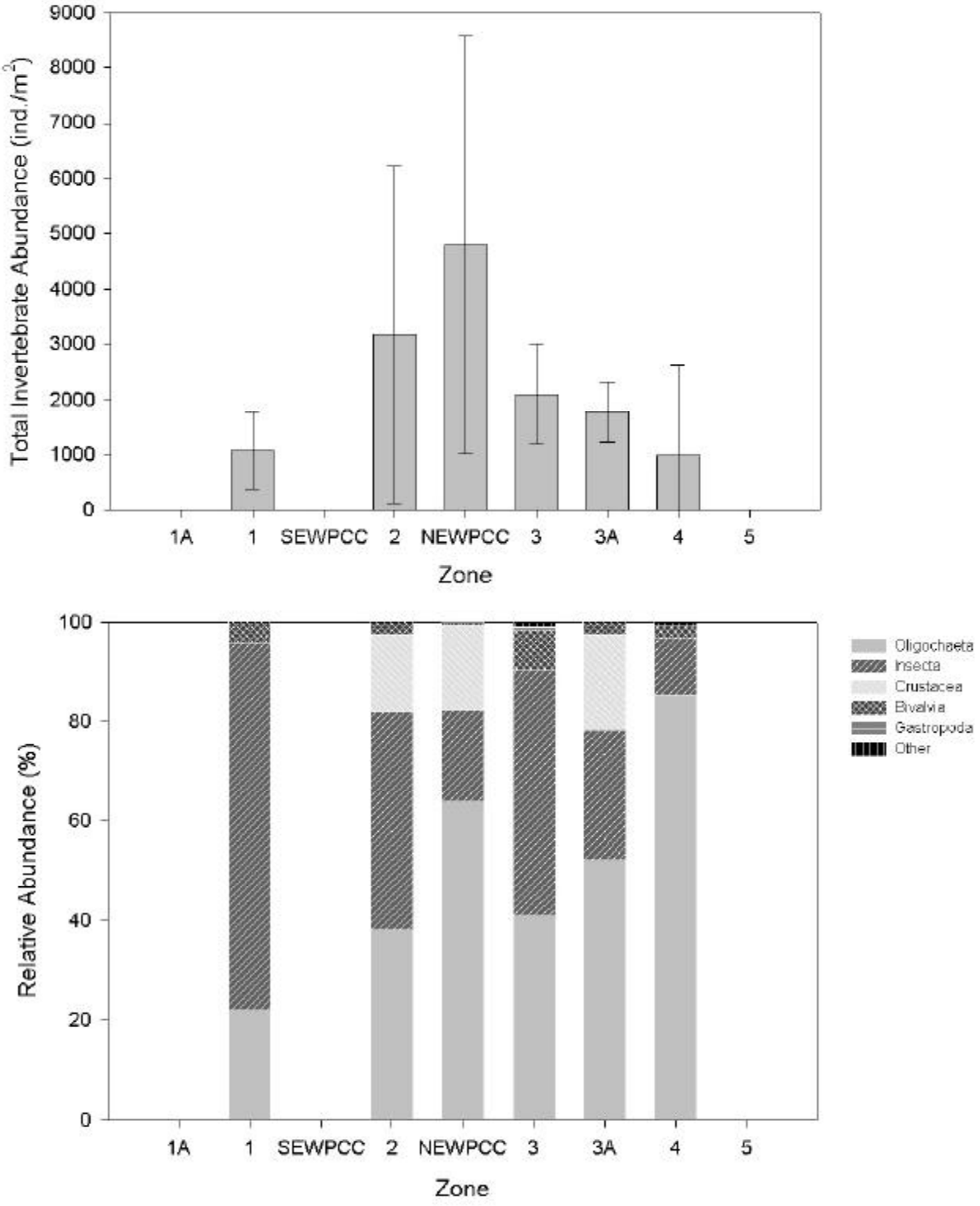

Figure 9. Total abundance and relative abundance of invertebrates collected in Ponar dredge samples in the Red and Assiniboine rivers, February - March, 1999.

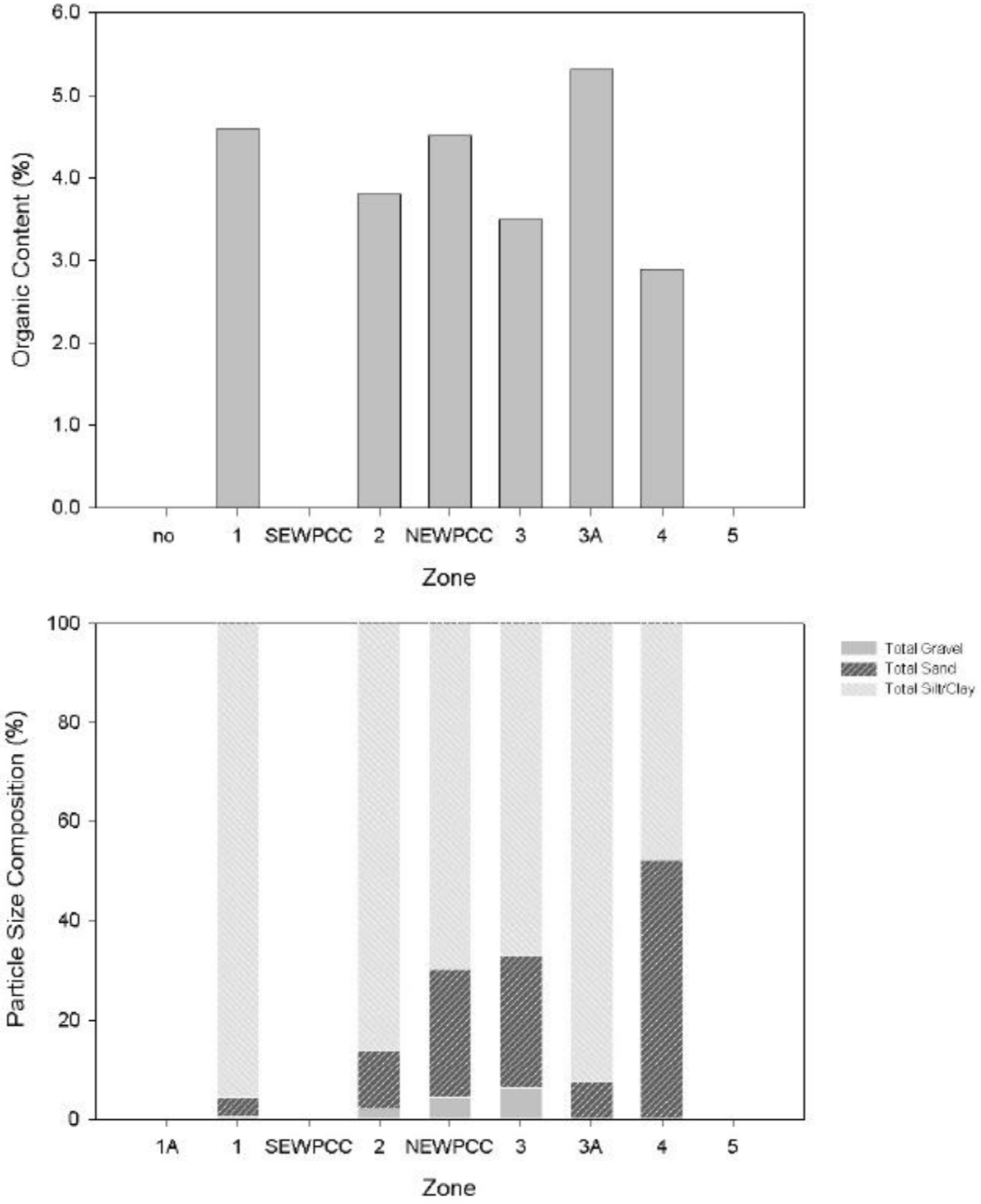

Figure 10. Organic content and particle size composition of sediments collected in Ponar dredge samples in the Red and Assiniboine rivers, February - March, 1999.

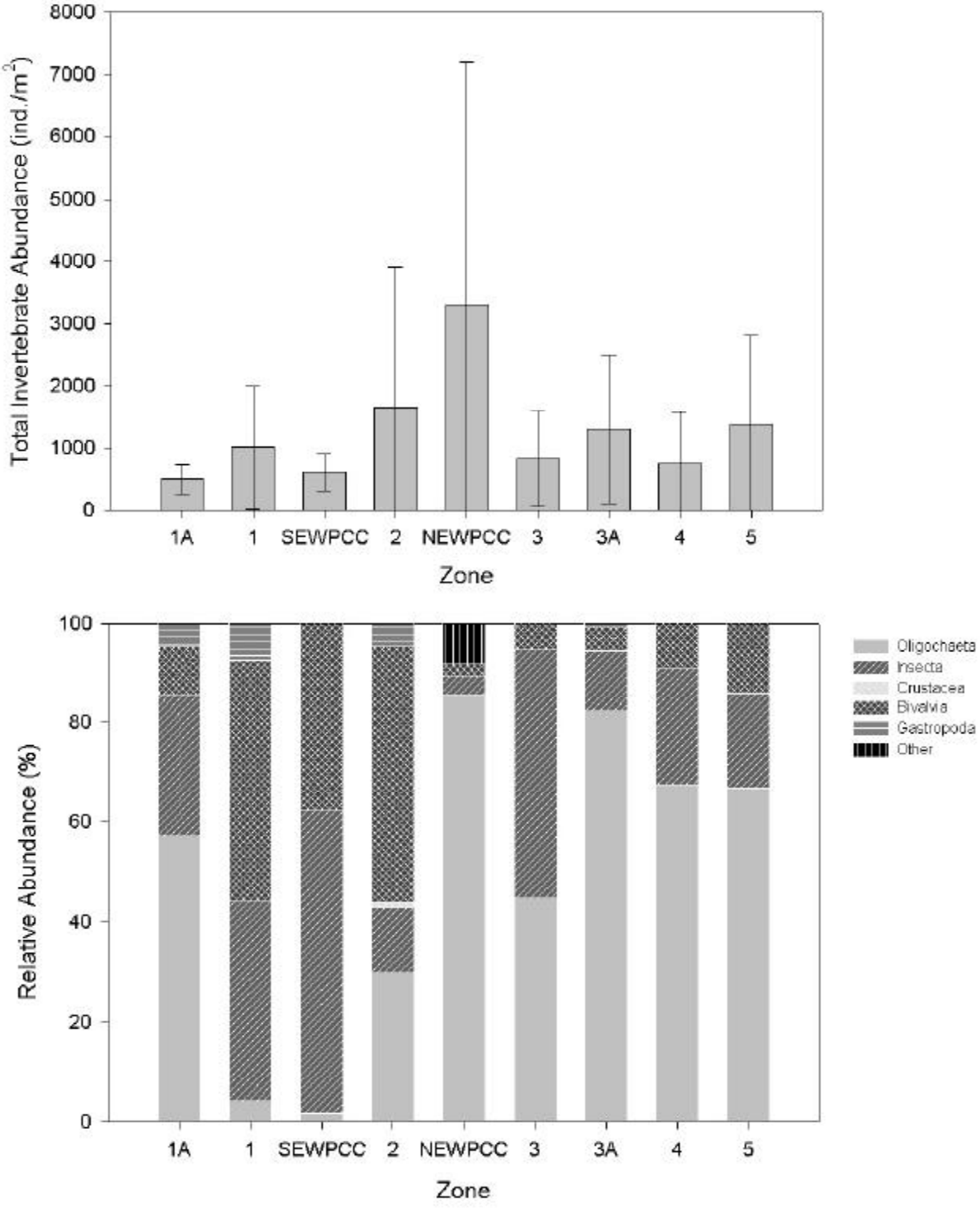

Figure 11. Total abundance and relative abundance of invertebrates collected in Ponar dredge samples in the Red and Assiniboine rivers, September, 1999.

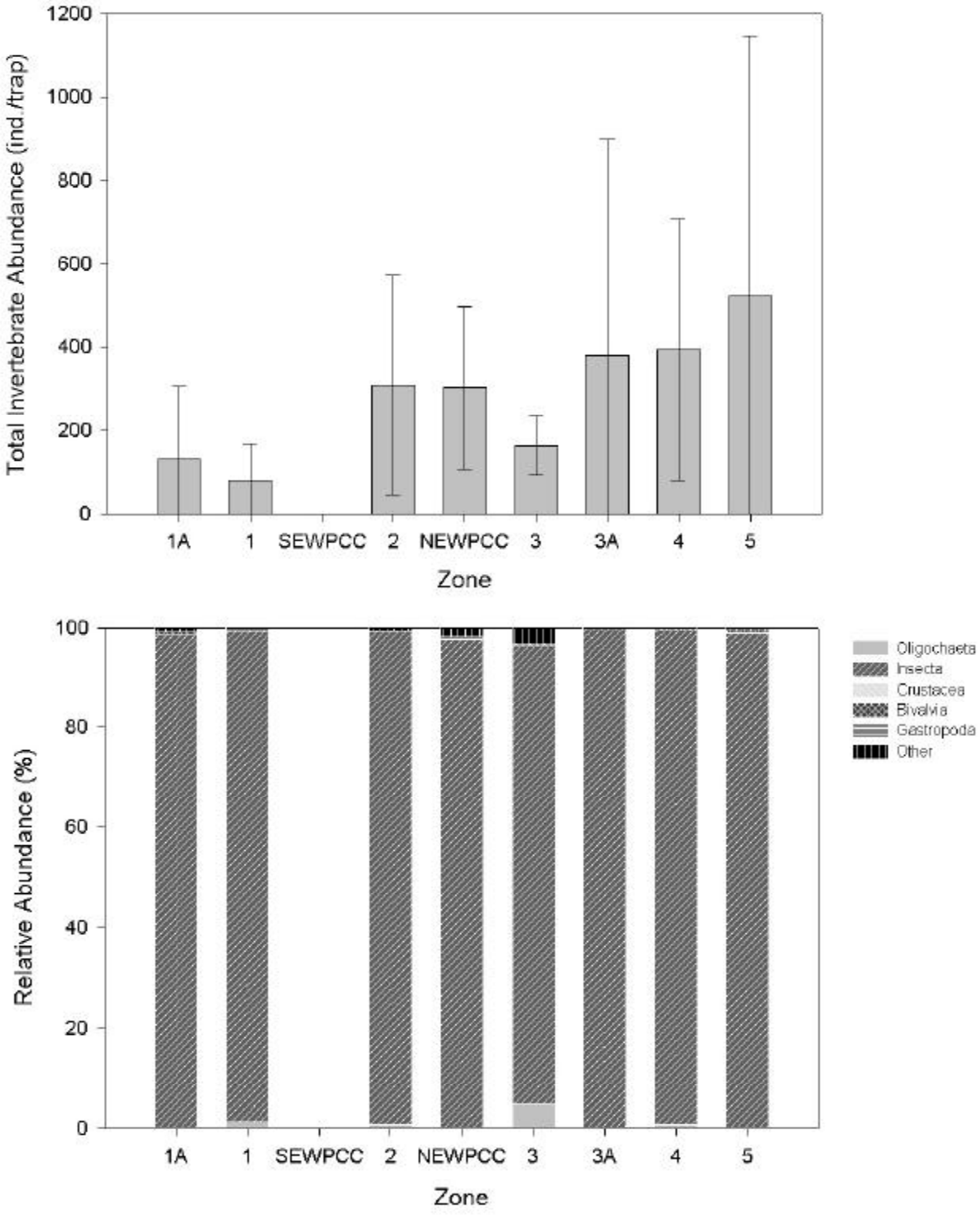

Figure 12. Total abundance and relative abundance of invertebrates collected in artificial substrate samples in the Red and Assiniboine rivers, September - October, 1999.

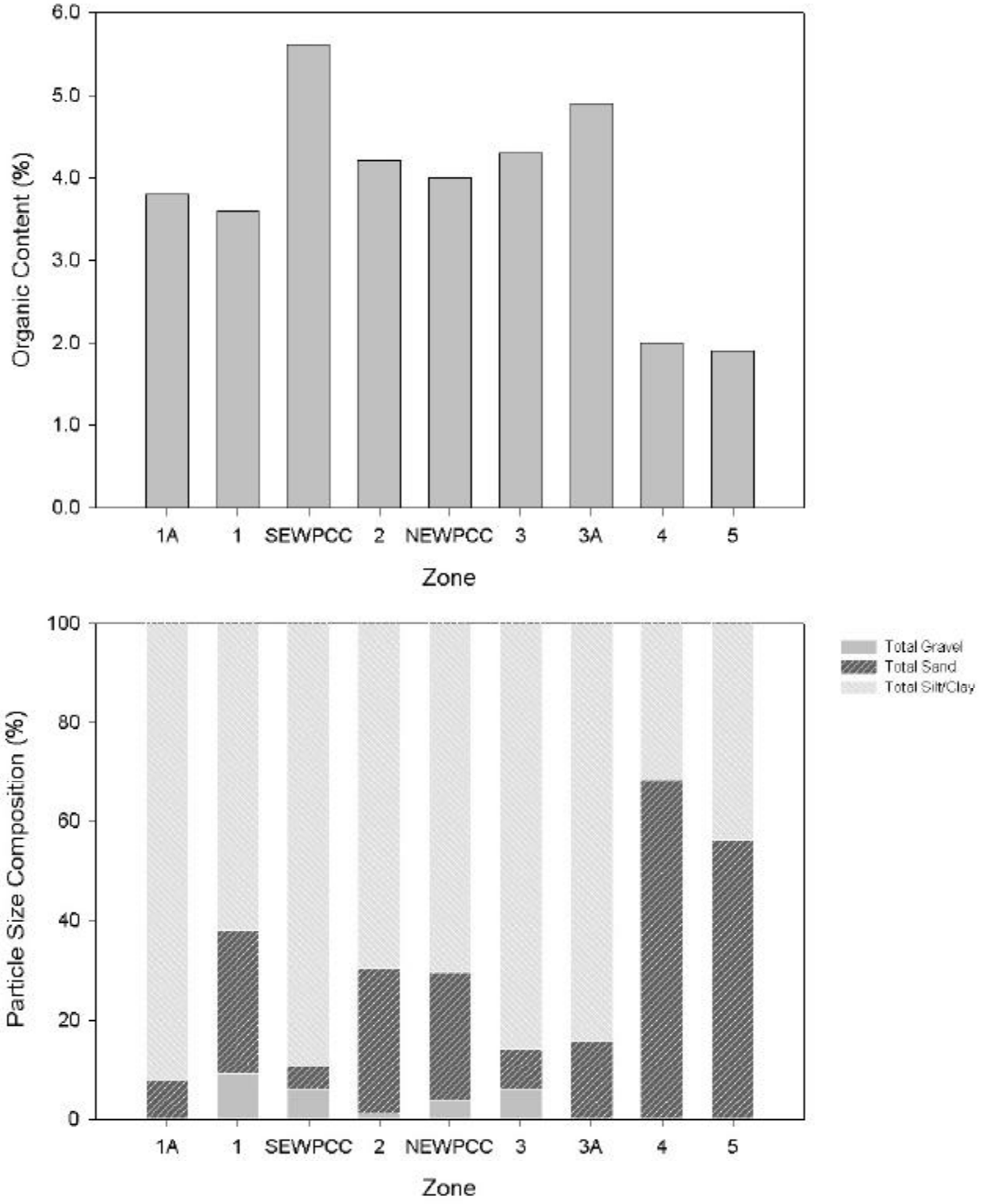

Figure 13. Organic content and particle size composition of sediments collected in Ponar dredge samples in the Red and Assiniboine rivers, September, 1999.