to the Niobrara River; also soon thereafter because remnants of this discharge of sediment were no longer present and the bar deposition observed downstream appeared to represent current flow-through of sediment through the dam. Should better management practices be implemented at the headwaters of this stream, estimating sediment capacity and adjustment of this creek may have merit; however, this is beyond the responsibility of the owner.

We considered several models for modeling sediment generation and transport and included:

- HEC-RAS *for the determination of threshold stream shear and power for sediment transport*
- CONCEPTS *for establishing areas of erosion and deposition and estimate of sediment quantities*
- AGNPS *for modeling watershed and Creek erosion along with alternatives of small agricultural BMPs*
- XPSWMM *for modeling sediment transport and deposition*

Our geomorphic observations pertaining to the current state of sediment moving through the stream indicated dynamic equilibrium within the creek, except in the headwaters. The current discharge from the low level discharge base outlet appeared to be transporting enough sediment through the dam for flow conditions observed. Adjusting the discharge may have little effect on the sediment moving through the creek or could even put the sediment conveyance into imbalance. If the correct adjustments are not made at the correct right time, excess sedimentation upstream of the dam or erosion downstream of the dam could occur. These adjustments occur naturally in a functional two-stage channel, whereas the regulated discharge would require almost a continuous monitoring of the flows in the creek and through the dam. Modeling of the sediment transport will have little use unless the entire watershed is assessed, which is beyond the scope and responsibility of the dam owner. The geomorphic indicators found in this stream provided a better indication of how sediment moves through the dam and this creek. Modeling of the flow through this limited reach of stream will provide little more than an academic study. Therefore, we do not recommend a sediment transport model, other than the fluvial geomorphology to assessment future of sediment transport through the dam.

Higher discharges from the dam will probably have little affect because the hydraulic slope in the creek decreases upstream, and therefore, tractive shear to move the sand decreases such that a narrow channel maintaining depth will result. In other words, the creek will reestablish a more natural two-stage channel. The likely evolution of the reservoir will be that sediment will continue to deposit and it will become a creek with wetlands on either side of it. Dredging of the reservoir will be costly (at least $100 per cubic yard) and short term at best. Although sand transport will continue as a natural process, the rate and volume of sediment transported through the system could be reduced through better watershed and farming practices in the upper portion of the watershed to reduce erosion of the sand slopes.

Without viewing the watershed as a system, constructing a sediment transport model other than the geomorphic model, will have limited benefit. The cost of setting up and completing a sediment transport model could easily exceed $150,000, which probably will not include calibration and monitoring in order to suit the model to the environment.

The likely evolution of the reservoir will be that sediment will continue to deposit, and it will become a creek with wetlands on either side of it. Dredging of the reservoir will be costly (at least $100 per cubic yard) and short term at best. Considering that there is an estimated 45,000 cubic yards in the 8.2 acre reservoir, which is only a fraction of the original reservoir, the cost of dredging the sediment could be in excess of $4.5 million.

In order to formulate management actions associated with the dam and future controlled releases, a hydrologic and hydraulic analysis should be conducted for the watershed upstream of the dam. This analysis should also consider all of the current means of discharge through the dam. The likely flood events which should be considered are the Probable Maximum Flood and more frequent events such as the 100 year (1% probability of occurring annually) flood. We estimate the cost of this analysis to be $40,000 to $60,000.

4.3 Substrate Analysis of Plum Creek Site 2

An instream mapping effort was conducted for Plum Creek site PC2 to illustrate the value of mapping stream segments, as well as show existing substrate locations and distributions along the reach. Figures 5 and 6 illustrate Plum Creek site PC2's depths and substrate distributions, respectively. Substrate along site PC2 was dominated by gravel (approximately 35%) and cobble (approximately 30%). Bedrock and sand were also commonly distributed along the site (Fig. 6). Interestingly, the substrate map demonstrates a stream's ability to "self-cleanse" by flushing finer substrates through the system. That is, Figure 6 shows that Plum Creek site PC2's flow flushed sand from the channel's erosional zones, which now are dominated by bedrock, cobble and gravel.

4.4 Settleable Solids and Water Quality

Water quality was generally assessed for basic parameters at one site, PC3, the Appelt property. Settleable solids (mg/L) were assessed for all three study sites on Plum Creek to characterize general sediment transport in the stream. The concentration reported at site PC1, above the McGowan Dam (Will Williams' property) was 0.5 mg/L. Settleable solids were 0.1 mg/L and 1.0 mg/L at sites PC2 and PC3, respectively. Evergreen creek was not sampled.

Total coliforms were > 2419.6 MPN/100 mL. Fecal coliforms were 1430 MPN/g, and microcystin was not detected. The pH value for the stream was 8.09 SU and total ammonia nitrogen was 0.11 mg/L. Total phosphorus was 0.34 mg/L and total Kjeldahl nitrogen (TKN) was 0.86 mg/L. Nitrate/nitrate nitrogen levels were 1.1 mg/L (Nebraska State Surface Water Quality Standard is 10 mg/L). According to Mr. Will Williams, nitrates are so high in domestic water wells along Plum Creek, residents cannot safely drink the water. Analysis of water quality parameters were conducted by Midwest Laboratories of Omaha, Nebraska.

4.5 Instream and Riparian Habitat

The alteration of the physical structure of the habitat is one of five major factors from human activities described by Karr (Karr et al. 1986; Karr 1991) that degrade aquatic resources. Habitat, as structured by instream and surrounding topographical features, is a major determinant of aquatic community potential (Southwood 1977, Plafkin et al. 1989, and Barbour and Stribling 1991). Both the quality and quantity of available habitat affect the structure and composition of resident biological communities. Effects of such features on biological assessment results can be minimized by sampling similar habitats at all stations being compared. However, when all stations are not physically comparable, habitat characterization is particularly important for proper interpretation of biosurvey results.

Aquatic habitat is an important component in lotic systems and often influences overall biotic potential (Fausch et al. 1988; Plafkin et al. 1989; Lyons 1991). Thus, it is important to consider existing habitat conditions of streams when assessing biological communities. Our study stream was located in agricultural areas in Brown County above where it enters a *Wild and Scenic Designation* of the Niobrara River. Rangeland and attempts at row crop farming are prevalent throughout the watershed.

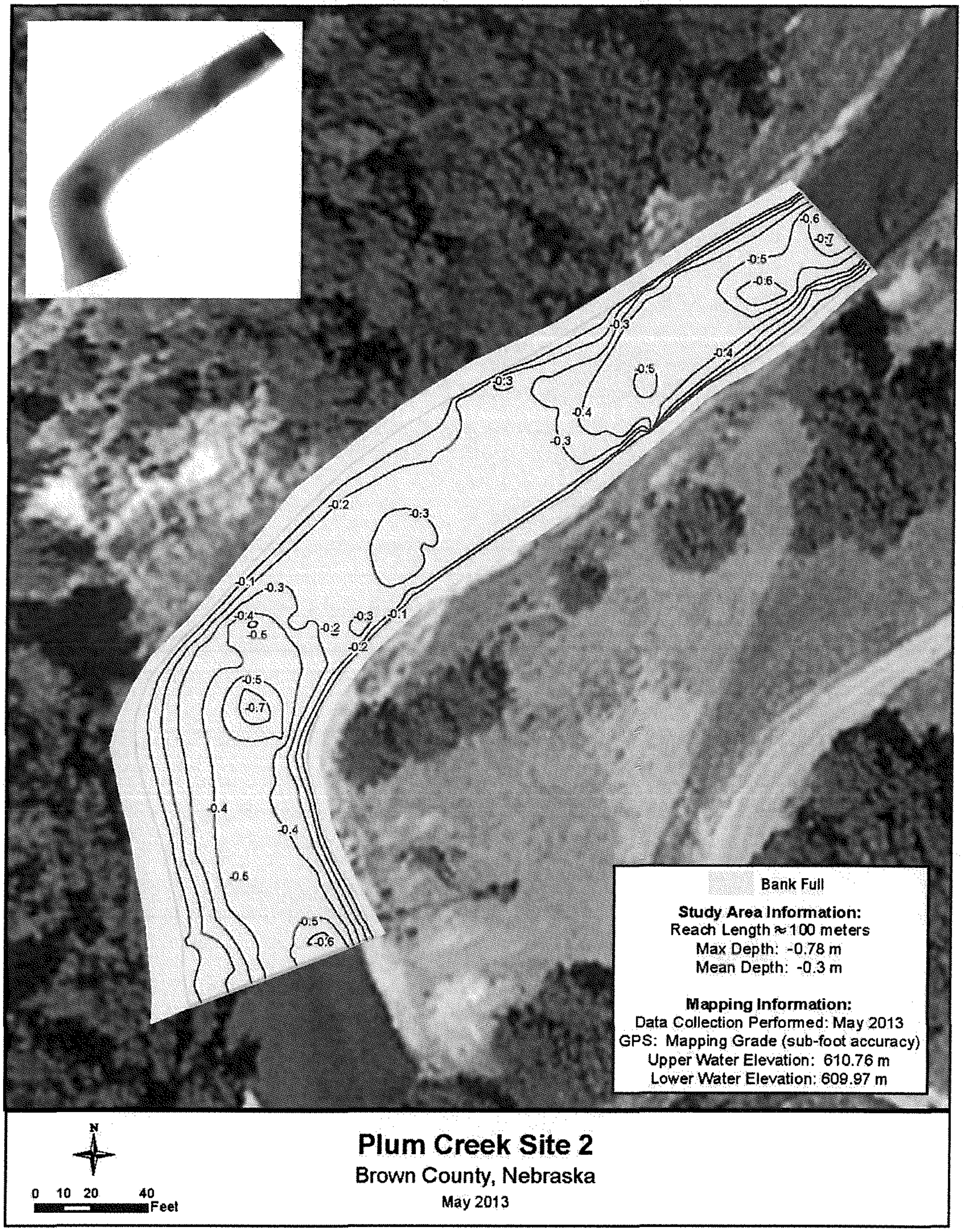

FIGURE 5. – Depth contour map of Plum Creek site PC2, approximately two miles downstream of McGowan Reservoir, Brown County, Nebraska, May 2013.

FIGURE 6. – Substrate map of Plum Creek site PC2, approximately two miles downstream of McGowan Reservoir, Brown County, Nebraska, May 2013.

Average depths ranged from 0.17 to 0.44 m at sites EV1 and PC1, respectively (Table 2). As expected, mean channel width increased downstream, ranging from 5.06 m at site EV1 to 18.68 m at site PC3 (Table 2). Site EV1 exhibited a relatively narrow channel with shallower depths compared to other sites, reflecting a significant difference in overall habitat. Discharge along Plum Creek ranged from 40.93 to 72.02 m^3/sec at stations PC1 and PC3, respectively (Table 2).

TABLE 2. – Physical habitat results for sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-29, 2013.

Parameter	EV1	PC1	PC2	PC3
Mean depth (m)	0.17	0.44	0.36	0.41
Maximum depth (m)	0.50	0.98	0.71	0.74
Mean width (m)	5.06	13.36	17.14	18.68
Station length (m)	100	100	100	100
Discharge (m^3/sec)	3.19	40.93	56.15	72.02
Maximum velocity (m/sec)	8.70	9.20	12.20	14.60

Table 3 presents substrate compositions reported for Plum Creek and Evergreen Creek study sites. In general, results indicated that Evergreen Creek and Plum Creek exhibited different substrate compositions from site to site. Sand represented the predominant substrate at sites EV1, PC1 and PC3 (Fig. 7). Site PC2, the first treatment site below the dam, exhibited predominance of cobble and gravel substrates (Fig. 7). In general, these data demonstrated that sand deposition and predominance occurred significantly in Evergreen Creek and Plum Creek above the McGowan Dam. This was attributed to natural deposition events, as well as existing agricultural effects (e.g., row crop agriculture within Sandhills areas adjacent to headwater streams, livestock use along stream corridors, etc.). Interestingly, site PC2 was more representative of a moderate gradient stream with less sand deposition. Site PC3 exhibited 48% sand composition, with 33% gravel and bedrock (Table 3; Fig. 7). The predominance of sand substrate was likely due, in part, to past sluicing activities; however, a percentage of such was also a result of natural deposition. Given a stream's ability to flush finer substrate depositions (i.e., with its gradient, flow and natural erosion factors), and with proper management, substrate compositions within lower reaches of Plum Creek may improve over a period of time by the natural flushing of finer substrates.

TABLE 3. – Substrate compositions (%) for sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-29, 2013.

Substrate Type	EV1	PC1	PC2	PC3
Fines (< 0.5 mm)	24.24	13.61	5.98	7.92
Sand (0.5 – 2 mm)	66.67	58.50	14.67	58.42
Gravel (2 – 64 mm)	9.09	22.45	25.54	16.34
Cobble (64 – 2565 mm)	0	2.72	39.13	0.50
Boulder (> 256 mm)	0	1.36	4.35	0
Bedrock	0	1.36	10.33	16.83

Statistical comparisons of stream depth among all Evergreen Creek and Plum Creek study sites showed that Evergreen Creek site EV1 exhibited significantly lower mean depths than all Plum Creek sites (Fig. 8; ANOVA and Tukey-Kramer multiple comparison test; $P < 0.05$). Average depth at site PC1 was significantly greater than that measured at site PC2 (Fig. 8; ANOVA and Tukey-Kramer multiple comparison test; $P < 0.05$). No other differences in mean stream depth were observed.

Statistical comparisons of stream substrate sizes among all Evergreen Creek and Plum Creek study sites showed that Evergreen Creek site EV1 exhibited significantly smaller substrate than that measured at Plum Creek sites PC2 and PC3, and that such reported for site PC2 was considerable greater than all other study sites (Fig. 9; Kruskal-Wallis one-way ANOVA and Tukey-Kramer multiple comparison test; $P < 0.05$). These differences were attributed to sand predominance at all sites (especially sites EV1 and PC1, the paired and upstream reference sites), except Plum Creek site PC2 below the dam.

Sites PC1 and EV1 exhibited the greatest percentages (9 and 13, respectively) of overhead canopy (Table 4). Dominant riparian vegetation was, in general, forbs at site EV1 and grasses at all Plum Creek sites. Results indicated that sites EV1 and PC3 exhibited less stable and greater eroding stream banks than those observed at sites PC1 and PC2 (Table 4). Overall, bank stability on all Plum Creek sites was susceptible to degradation and reflected natural morphology of riparian zones within the basin.

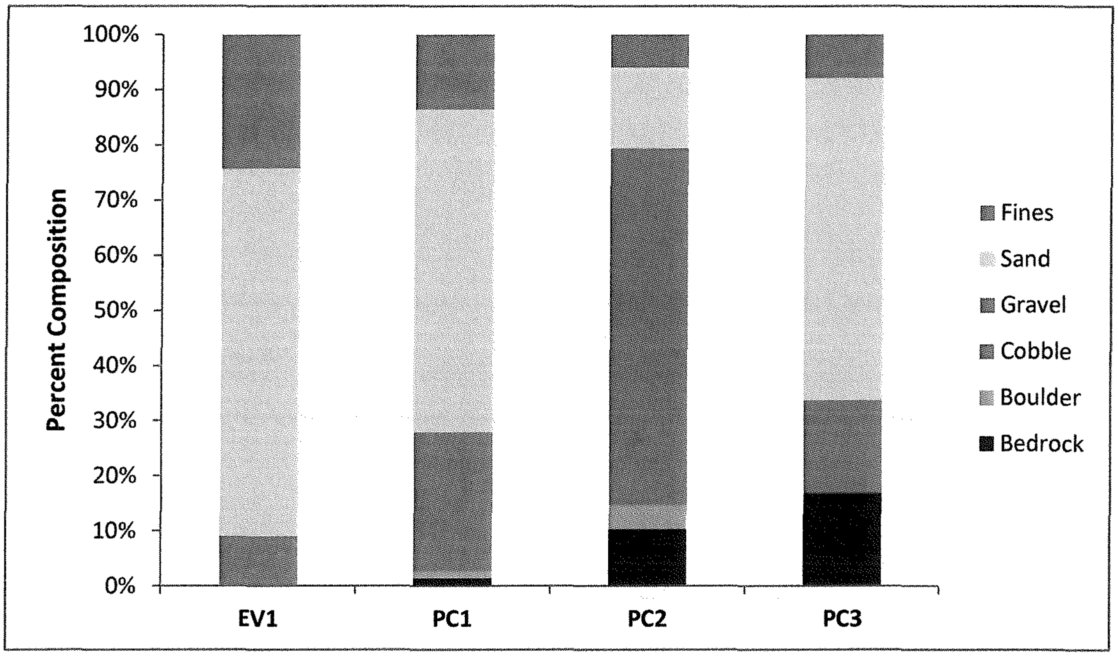

FIGURE 7. – Comparison of substrate compositions (%) for sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-29, 2013.

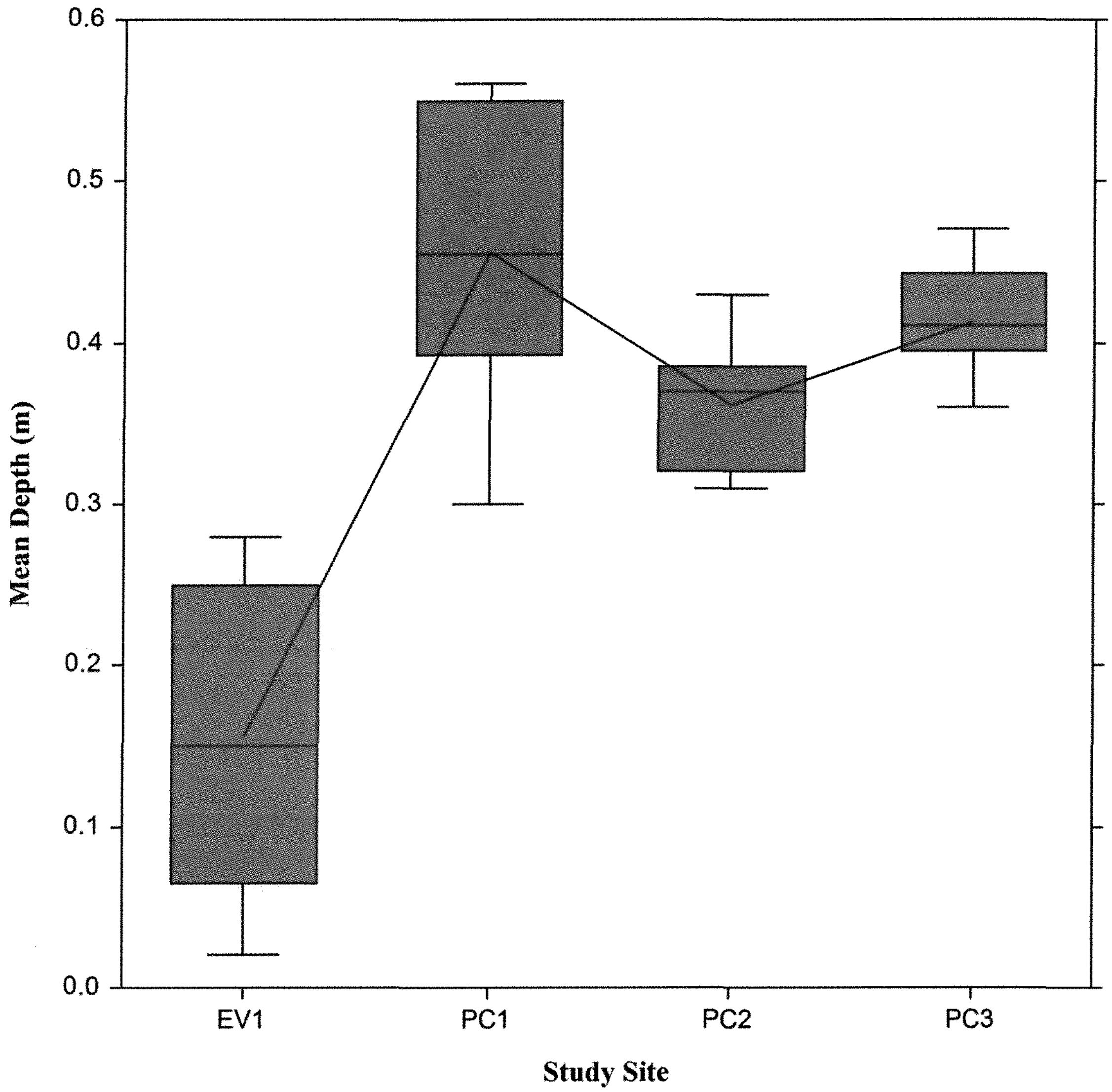

FIGURE 8. – Comparison of mean stream depths among sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-29, 2013.

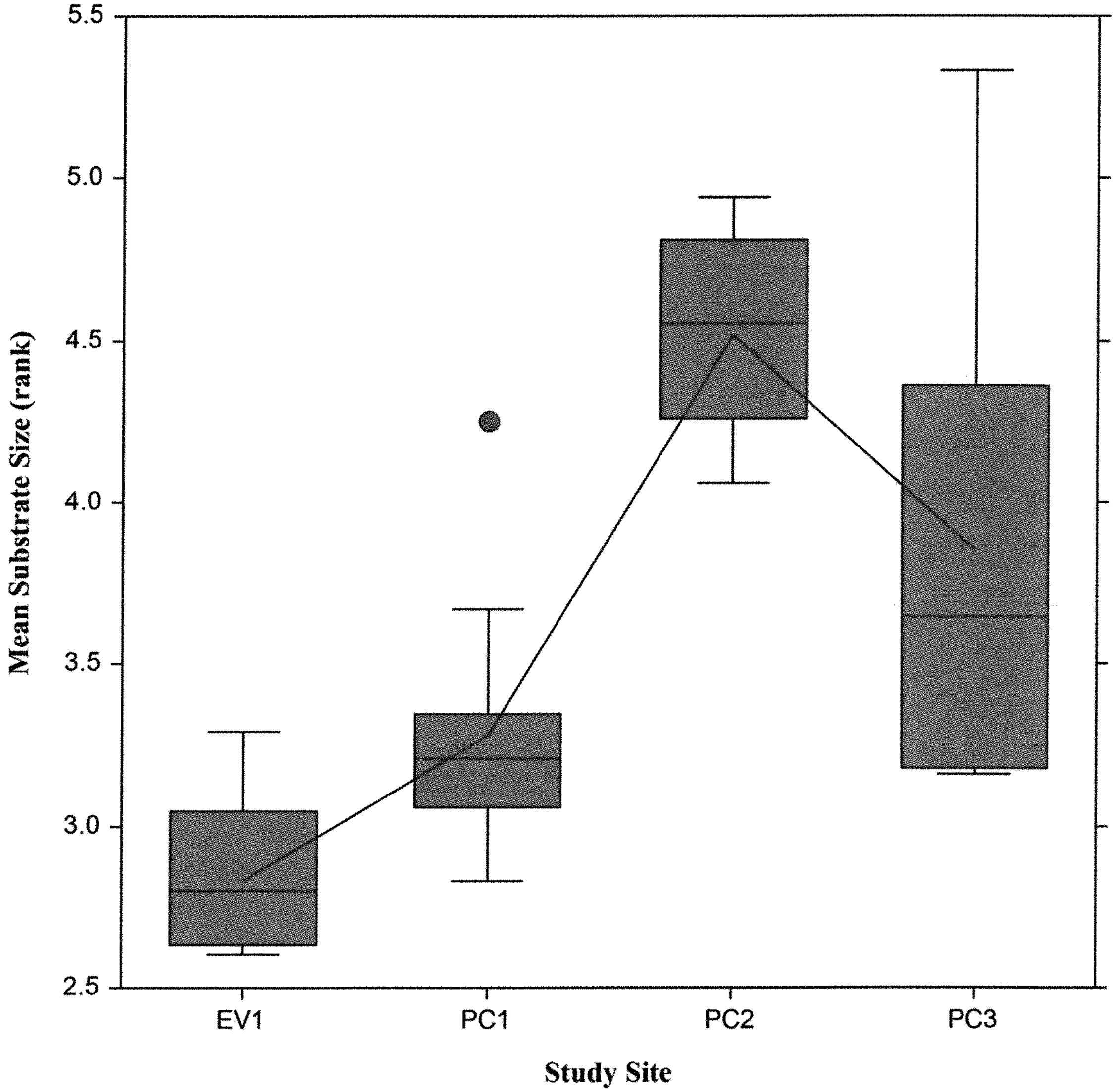

FIGURE 9. – Comparison of mean stream substrate size (using Armour et al. 1983; Platts et al. 1983, 1987) among sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-29, 2013. The red dot represents a single outlying data point reported at site PC1 that was disqualified from inclusion in the analysis.

TABLE 4. – Mean values for habitat features measured on stations of Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-28, 2013.

Parameter	EV4	PC1	PC2	PC3
Overhead canopy (%)	19.10	17.25	8.45	0.80
Dominant riparian vegetation	Forbs	Grasses	Grasses	Grasses
Pool quality	None	Fair	Fair	None
Pool : riffle : run (%)	0 : 25 : 75	5 : 15 : 80	5 : 45 : 50	0 : 5 : 95
Land use	Grazing	Forest	Forest	Meadow
Bank stability	Moderate	Stable	Stable	Moderate

Sites on Plum Creek supported relatively fair to good instream habitat. Pool habitat was only observed at sites PC1 and PC2, and such were only rated as fair (Table 4; Armour et al. 1983; Platts et al. 1983, 1987). In general, instream habitat on all Plum Creek and Evergreen Creek sites was primarily represented by small riffle areas intermixed with predominant run habitats (Table 4); comprising from 50 to 95% of the study reaches.

All study sites supported predominant coverage of riparian vegetation, estimated at almost 100% along the reaches (Table 5). Only an estimation of the extent of aquatic vegetation is made normally, but we wanted to describe every aspect of sedimentation impact scientifically possible, and flora presence appeared to be an indication of increasing establishment and stability which could allude to a natural restoration process in action. Besides being an ecological assemblage that responds to perturbation, aquatic vegetation provides refugia and food for aquatic fauna.

In prairie wetlands, three growth forms of vascular plants usually are defined, including emergent, floating-leaved, and submersed plants. All three of these growth forms were observed in our sites on Plum Creek. To varying degrees, these form discrete zones within wetlands. Wetlands containing all three forms (and many sub forms and species) are generally those with a core area that is flooded permanently, but whose water levels otherwise vary greatly from year to year. In such wetlands, nutrients are more available and support substantial invertebrate densities and waterbird use. All sites had a majority of native species which is unusual for several locations across Nebraska with highly disturbed sites (R. Kaul 2013, pers. comm.).

TABLE 5. – Dominant instream and streamside cover compositions (%) for sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-29, 2013.

Vegetation Type	EV1	PC1	PC2	PC3
Streamside submergents (%)	10	25	12	10
Dominant submergent	algae	*Potamogeton*	*Ranunculus*	*Potamogeton*
Shoreline hydrophytes (%)	85	45	62	65
Dominant hydrophyte	*Carex*	*Carex*	*Carex, Spartina*	*Carex*
Dominant trees	*Juniperus*	*Juniperus*	*Populus,* elm	*Juniperus*
Dominant shrubs	absent	*Amorpha*	absent	*Amorpha*

Riparian and aquatic flora at site PC1 were indicative of a low impact habitat condition for the Nebraska Sandhills ecoregion. A well-established tree community was on both sides of site PC1, comprised primarily of eastern red cedar inter-mixed with bur oak, American elm and green ash. Sedges were prominent along the west bank near the bank edge. Site PC2 consisted of generally open reach throughout the 100-m reach, with trees lining unstable banks in the upper portion of the reach and bluffs to the west. Eastern red cedar was present with a significant representation of American and Siberian elm. At site PC3, the riparian zone consisted primarily of grass with downy brome. Recently, several cedar trees were removed from the sand bar next to our 100-m reach. A diverse mix of sedges comprised the shoreline and shallow banks of both sides of site PC3. The greatest percentage of flora was native at all study sites with PC1 and PC2 exhibiting the highest numbers.

Ranunculus longirostris, whitewater crowfoot (Table 5; Appendix Table A4) was the most dominant submergent found at all sites except Evergreen Creek site EV1. It was most common at sites PC1 and PC2. Floating pondweed, *Potamogeton nodusus* was observed in a quiet area below the large riffle at site PC3. This was the only site it was documented. Five different *Carex* species were observed on Plum Creek with only two to three weeks away from adequate fruit formation to actually discern specific species, so only general separations were made by assigning a number to each separate species observed (Appendix Table A4).

High stream flows (e.g., spring runoffs) can erode unstable bank materials, thereby limiting aquatic biological communities (US EPA 1995a, 1995b). Lenat et al. (1981) and Lenat and Barbour (1994) showed that eroding stream banks were the most encountered habitat changes in lotic systems. Habitat survey results showed that Plum Creek was limited by relatively poor habitat conditions that probably resulted from natural erosion of unstable stream banks. It appeared that since the sedimentation assault of 2010, dynamic equilibrium of sediment transport has been stabilized (Ripp 2013). Many riparian zones are capable of rapid recovery after human perturbations (gates left open for a period of days in 2010) cease because the biota have evolved adaptations to survive and even reproduce despite frequent natural disturbance events characteristic of riverine systems (Wilson 1970; Barnes, 1983; Gecy and Wilson 1990). This approach is often referred to as *passive or natural restoration* (Kaufman et al. 1997).

4.6 Periphyton Communities

Periphytic algae are a ubiquitous and ecologically important component of many streams and rivers (Gregory 1983) because they ultimately provide food needed to sustain higher trophic levels (Minshall 1978; Stewart and Loar 1994; Lamberti 1996; Finlay et al. 2002). They are also important in the transformation process of nutrients (Elwood et al. 1981; Lock et al. 1984) and provide habitat for a variety of aquatic organisms (Dudley et al. 1986). Thus, evaluation of periphyton communities is important when assessing organisms in higher trophic levels

Periphyton growth can be light-limited (Quinn et al. 1997a, 1997b; Kiffney and Bull 2000) or nutrient-limited (Perrin and Richardson 1997; McCormick and Stevenson 1998; Cascallar et al. 2003), or both, and is influenced by temperature (Robinson and Minshall 1998; Francoeur et al. 1999; Morin et al. 1999; Weckstroem and Korhola 2001).

A total of 13 periphyton taxa were identified from samples collected at Plum Creek sites (Appendix Table A1). Periphyton communities at site PC1 (upstream reference) were dominated by diatoms (48%) and the blue-green alga, *Oscillatoria brevis* (Fig. 10; Appendix Table A1). Site PC2 was also dominated by diatoms (86%; Fig. 10). Site PC3 was represented by only three taxa and was dominated by the diatom, *Stenopterobia sigmatella* (95%; Fig. 10; Appendix Table A1). Periphyton density at Plum Creek sites were 4,874, 455 and 5,134 cells/cm^2 at sites PC1, PC2 and PC3, respectively (Appendix Table A1). Densities were greatest at Plum Creek sites PC1 and PC3.

A total of 11 periphyton taxa were identified from samples collected at Evergreen Creek site EV1 (Appendix Table A1). Periphyton communities at this site were also dominated by diatoms (94%; Fig. 10). Periphyton density was estimated at 2,145 cells/cm^2, which was lower than densities reported at Plum Creek sites PC1 and PC3, but higher than that observed at site PC2 (Appendix Table A1).

Species richness decreased in a downstream manner from Evergreen Creek site EV1 to Plum Creek site PC3 (Fig. 11; Appendix Table A1). Periphyton H' values were relatively moderate at Evergreen Creek site EV1 and Plum Creek sites PC1 and PC2, but low at site PC3 (Appendix Table A1). H' values decreased in a downstream manner, ranging from 2.21 at Evergreen Creek site EV1 to 0.18 at Plum Creek site PC3 (Appendix Table A1). Periphyton H' values greater than 3.0 are indicative of algae communities from unpolluted environments (Wilhm and Dorris 1968; Staub et al. 1970). Low to moderate H' values measured from our study sites may be attributed to poor water quality, reduced water clarity (i.e., increased turbidity), limited epilithic habitat, or natural (seasonal) variability. Periphyton communities in Plum Creek may have also been limited by increased streamflow and subsequent scouring during the time of our survey.

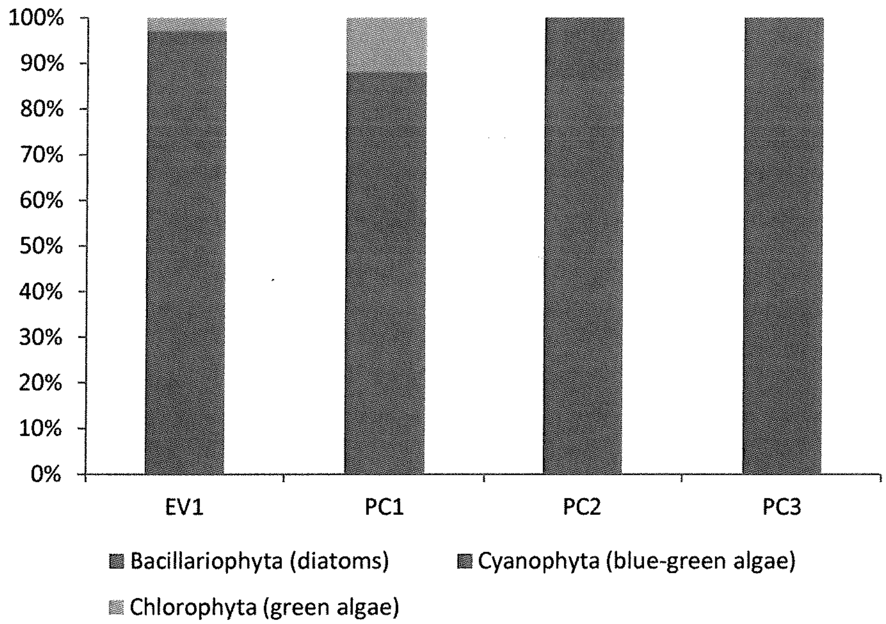

FIGURE 10. – Percent composition of periphyton collected from sites on Evergreen Creek (EV) and Plum Creek (PC), Brown County, Nebraska, May 2013.

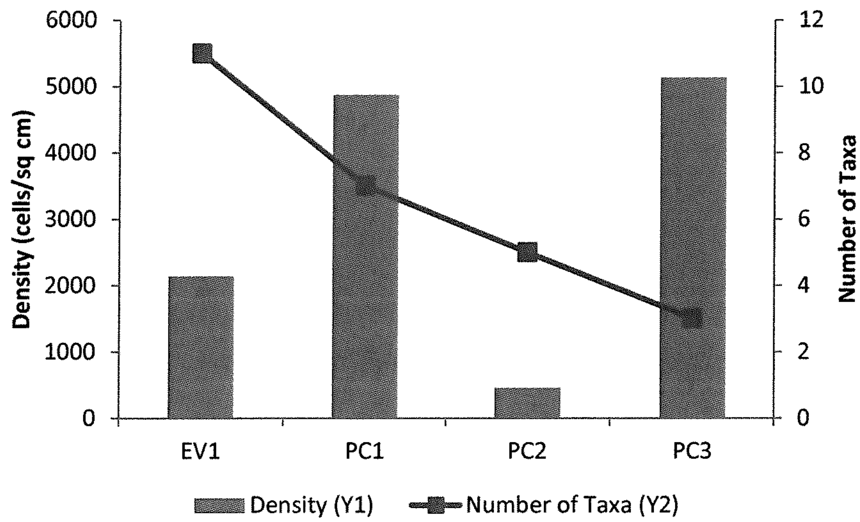

FIGURE 11. – Density estimates and species richness of periphyton collected from sites on Evergreen Creek (EV) and Plum Creek (PC), Brown County, Nebraska, May 2013.

4.7 Macroinvertebrate Communities

Benthic invertebrate communities vary greatly, both spatially and temporally, in polluted and non-polluted lotic systems (Hynes 1970; Cummins 1979). However, assessment of these communities is useful for evaluating water quality in streams due to the sensitivity of many macroinvertebrates to an array of pollutants (Weber 1973; Platts et al. 1983).

A total of 37 taxa was collected from Plum Creek study sites, and 30 taxa were reported for Evergreen Creek site EV1 (Appendix Table A2). Species richness ranged from 21 taxa at Plum Creek site PC2 to 30 at Evergreen Creek site EV1. Species richness values at all Plum Creek sites were similar, measured at 24, 21 and 22 for sites PC1, PC2 and PC3, respectively (Appendix Table A2). No significant differences of species richness (i.e., number of taxa reported) were observed among study sites on Plum Creek and Evergreen Creek (ANOVA; $P > 0.05$).

Ephemeropterans (mayflies) made up approximately 52% of mean density of all Plum Creek sites, consisting of 10 taxa represented by six families. The mayfly, *Baetis* sp. was generally predominant among all mayflies and had an average mean density of approximately 933 organisms/m^2 for all Plum Creek sites. Dipterans (true flies) made up approximately 39% of mean density at all Plum Creek sites, consisting of 10 taxa represented by three families.

Conversely, dipterans made up 41% of density at Evergreen Creek site EV1, consisting of 11 taxa represented by six families. The chironomid, *Cryptochironomus* sp. was predominant with an estimated density of 444 organisms/m^2. Ephemeropterans made up 28% of density at site EV1, consisting of six taxa represented by five families.

Macroinvertebrate density values ranged from 1,878 organisms/m^2 at Plum Creek site PC3 to 2,956 organisms/m^2 at Plum Creek site PC2 (Appendix Table A2; Fig. 12). No significant differences of macroinvertebrate density were observed among study sites on Plum Creek and Evergreen Creek (ANOVA; $P > 0.05$).

Values of H' recorded on the Plum Creek sites were similar, and were 1.78, 1.56 and 1.78 for sites PC1, PC2 and PC3, respectively (Appendix Table A2). Diversity (H') was estimated at 2.65 at Evergreen Creek site EV1. Although the H' value was measured at Evergreen Creek site EV1 was relatively higher than those reported for downstream Plum Creek sites, no significant differences of diversity were observed among study sites on Plum Creek and Evergreen Creek (ANOVA; $P > 0.05$).

Wilhm (1970) reported that unpolluted streams typically have H' values for benthic invertebrates of 2.6 to over 4.0. Relatively low H' values observed during our study were more representative of habitat conditions, natural (seasonal) variability, and possibly reflective of relatively high flow experienced during the survey. Moreover, macroinvertebrate communities examined at all study sites did not demonstrate redundancy, in general. That is, they were not dominated by only a few taxa. Redundancy in macroinvertebrate communities is reflective of ecological stress (Lenat and Barbour 1994), and such cannot be shown for Plum Creek within our study area (i.e., when considering macroinvertebrate community structures).

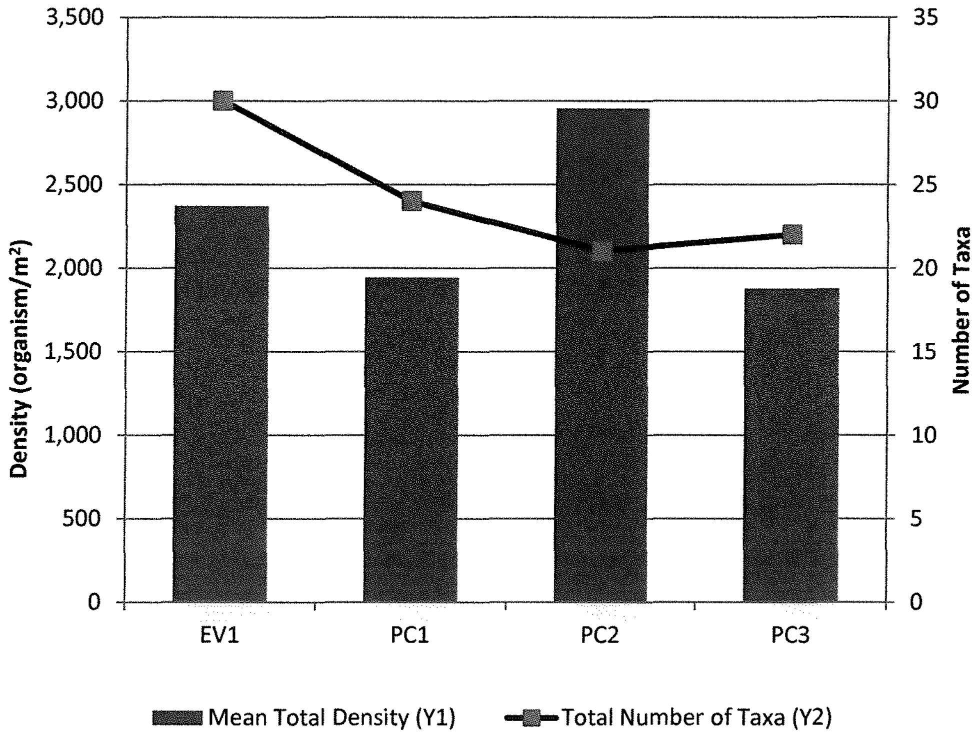

FIGURE 12. – Comparisons of mean density and species richness (number of taxa) of macroinvertebrates collected from sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-29, 2013.

The functional feeding group composition at the upper two Plum Creek sites (PC1 and PC2) was dominated by collector-gatherers (Fig. 13). Plum Creek site PC3 was dominated by both collector-gatherers and predators. These types of benthic communities are sustained by a food base consisting primarily of course particulate organic matter (CPOM) and periphyton (Vannote et al. 1980). Evergreen Creek site EV1 was dominated by a relatively evenly distributed community of collector-gatherers, scrapers and predators (Fig. 8), suggesting that CPOM and periphyton were also primary forage bases for this site. Collector-filterers were less abundant at all Plum Creek and Evergreen Creek sites (Fig. 13), reflecting a less important fine particulate organic matter (CPOM) component in this system (Vannote et al. 1980).

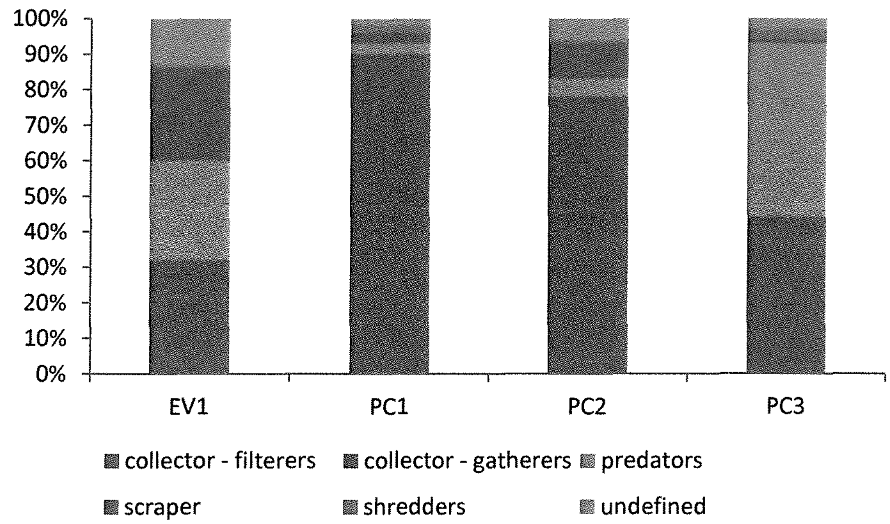

FIGURE 13. – Comparisons of functional feeding group distributions of macroinvertebrates collected from sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 28-29, 2013.

Tables 6 and 7 present results of other metrics estimated for macroinvertebrates collected at sites on Plum Creek and Evergreen Creek. Species richness (i.e., number of taxa observed) at Evergreen Creek site EV1 was 30, which was relatively higher than values observed at Plum Creek sites; ranging from 21 at site PC2 to 24 at the upstream reference site, PC1 (Table 6). We did not observed any considerable difference in macroinvertebrate species richness among Plum Creek sites, and the relatively higher value reported at the upstream paired reference site, EV1 was attributed to differences in habitat and flow. Vannote and Sweeney (1980) showed that taxa richness in small streams is primarily limited by reduced habitat diversity.

Number of EPT (Ephemeroptera, Plecoptera and Trichoptera taxa) was highest at Plum Creek site PC1, and lowest at the lower two Plum Creek sites, PC2 and PC3 (Table 6). Although EPT values generally decreased in a downstream manner along Plum Creek sites, thereby suggesting some degree of disturbance or stress, such differences were too minor to formulate a professional opinion or conclusion.

Percent Ephemeroptera values generally increased in a downstream manner along Plum Creek sites (Table 6), which suggested, in general, some degree of ecological stress. However, both percent Diptera and percent Chironomidae increased considerably in a downstream manner from Plum Creek sites PC2 to PC3 (Table 6), reflecting some degree of perturbation at the lower reach. This can be attributed to increased streamflow (scouring), natural (seasonal) variability, and differences in water quality, habitat and substrate.

TABLE 6. – Estimates of selected macroinvertebrate community assessment indices for sites on Evergreen Creek (EV) and Plum Creek (PC), Brown County, Nebraska, May 2013 (ERP = Expected Response to Perturbation; EPT = Ephemeroptera, Plecoptera and Trichoptera; Chiro. = Chironomidae; Baet. = Baetidae). Information compiled from DeShon (1995), Barbour et al. (1996), Fore et al. 1996, and Smith and Voshell (1997).

Index / Ratio	ERP	EV1	PC1	PC2	PC3
Number of Taxa	decrease	30	24	21	22
EPT (number of taxa)	decrease	10	11	8	8
Percent EPT	decrease	44	75	73	8
Percent Ephemeroptera	decrease	34	66	72	77
Percent Diptera	increase	41	21	22	84
Percent Chironomidae	increase	37	19	18	83
Percent contributions of dominant families		Chiro. (37) Baet. (21)	Baet. (51)	Baet. (58)	Chiro. (83)

Estimates of community loss and similarity were very similar from upstream to downstream (i.e., from site PC1 to site PC3) along Plum Creek within our study area (Table 7). Overall, this was indicative of unpolluted or relatively undisturbed conditions (Plafkin et al. 1989). In stressed macroinvertebrate communities, estimates of community loss tend to increase in a downstream direction, whereas community similarity values generally decrease. Thus, these results showed that macroinvertebrate communities in Plum Creek did not appear to be stressed in terms of sustained diversity.

TABLE 7. – Estimated values of community loss and similarity indices for macroinvertebrates collected from sites on Plum Creek, Brown County, Nebraska, May 28-29, 2013. Site PC1 (above McGowan Reservoir) was used as the reference site.

Index	PC1 vs PC2	PC1 vs PC3
Community Loss	0.57	0.54
Jaccard Coefficient of Community Similarity	0.36	0.35

Overall, results showed that macroinvertebrate communities in Plum Creek were typical of the study area, in general. Such were represented by relatively moderate values for species richness, density and diversity. In addition, there did not appear to be any abnormal shift in dominant functional feeding groups among upper and lower Plum Creek sites. Other than percent Diptera and percent Chironomidae values, we did not identify ecological effects related to differences in species richness, EPT numbers and relative abundances, nor percent Ephemeropterans observed at Plum Creek and Evergreen Creek study sites. The higher percent Diptera and percent Chironomidae values reported for Plum Creek site PC3 was likely a result of streamflow and habitat diversity differences (Wiley et al. 1990). Therefore, macroinvertebrate communities examined at Evergreen Creek and Plum Creek were probably most influenced by habitat, poor water quality, and limited forage represented as periphyton. However, structures of these communities may have also been related to natural variation.

Given the fact that we could not detect any significant differences (i.e., using statistical inferences) in macroinvertebrate species richness, density and diversity among all Evergreen Creek and Plum Creek study sites, we could not formulate any conclusion that existing macroinvertebrate communities, in terms of abundance and diversity, were influenced by past sluicing activities. Any variations of community structure within the study area were, in large part, likely a result of differences in streamflow and habitat diversity, as well related to upstream and adjacent agriculture and subsequent water quality and erosion effects.

4.8 Fish Communities

Many small prairie streams contain surprisingly diverse fish faunas that tend to have characteristics found in "natural" assemblages (Schlosser 1982; Ross et al. 1985; Steedman 1988). In addition, these systems are greatly influenced by the complexity of available habitat

(Gorman and Karr 1978; Schlosser 1982), as well as by community structures of lower trophic classes.

A total of 10 species of fish, representing four families, was sampled at sites on Plum Creek (Table 8). Nine species were captured at site PC3, and 8 and 9 species were sampled at sites PC1 and PC2, respectively. Our paired reference stream site, EV1 on Evergreen Creek resulted in five species. Cyprinids were most diverse in Plum Creek, represented by eight species (Table 8). In terms of relative abundance, all habitat types (i.e., riffles, runs and pools) at all Plum Creek study sites were dominated by cyprinids, in general. Cyprinids typically dominate fish communities in plains streams and rivers (Tubb et al. 1966; Scarnecchia 1988; O'Shea et al. 1990).

We estimated K_n (body condition) values for selected species of fish sampled on Plum Creek using length-weight data. In general, most species had acceptable body conditions, with K_n values greater than 0.8, with the exception of longnose dace at site PC3, which had a mean K_n of 0.74. This may be attributed to natural variability, seasonal variation or to limited forage. Stonecat sampled at sitesPC1 had a K_n factor value of 0.95 and factors continually increased as our sampling effort proceeded downstream (PC 2 = 1.18; PC = 2.06). Creek chub k_n factor decreased from sites PC2 to PC3 (PC2 = 1.51; PC3 = 0.99); however, the decrease may not be as pronounced as site PC2, which had a small sample size. The slight variability in condition factors among sites could not be attributed directly to water quality history; however, factors affecting forage availability may be more likely.

Appendix Table A3 compares a brief summary of historical sampling efforts and presents a qualitative review of fish community comparisons. Estimates of CPUE (catch-per-unit-effort) were reported as fish/km per species. Environmental agency surveys were primarily conducted in late summer, so seasonal variation in fish presence may be a factor in complete assemblage determination. In similar fish community assessments in the Niobrara River, Hesse and Newcomb (1982) found that sand shiners, river shiners and bigmouth shiners comprised 88.6, 10.3 and 1.1%, respectively, of the total catch. As in the Hesse studies, some species appeared in samples during certain times of the year and not in others because certain habitats were more available and apparent seasonal variation in fish presence (Gutzmer et al. 2002).

TABLE 8. – Fish species sampled from sites on Evergreen Creek (EV) and Plum Creek (PC), Brown County, Nebraska, May, 2013 (X = present; - = absent). Nomenclature was based on Nelson et al. (2004).

Scientific name	Common Name	EV1	PC 1	PC 2	PC 3
Cyprinidae (carps and minnows)					
Hybognathus hankinsoni	Brassy minnow	x	x	x	x
Notropis dorsalis	Bigmouth shiner	x	x	x	x
Cyprinella lutrensis	Red shiner		-	x	x
Notropis stramineus	Sand shiner	x	-	x	x
Rhinichthys cataractae	Longnose dace	x	x	x	x
Semotilus atromaculatus	Creek chub	x	x	x	x
Catostomidae (suckers)					
Catostomus commersonii	White sucker	-	x	x	x
Moxostoma macrolepidotum	Shorthead redhorse	-	x	-	x
Ictaluridae (catfishes)					
Noturus flavus	Stonecat	-	x	x	x
Centrarchidae (sunfishes)					
Lepomis cyanellus	Green sunfish	-	x	x	-
Total number of fish sampled		**60**	**158**	**81**	**257**
Relative abundance (fish/km)		**6,000**	**15,800**	**8,100**	**25,700**
Total number of fish/m²		**0.20**	**0.16**	**0.09**	**0.17**
Total Number of Species		**5**	**8**	**9**	**9**

Seining results for pool habitat at site PC3 showed considerably greater relative abundance, which was attributed to greater catches of sand shiners at the site (Appendix Table A3). Results also reflected that importance of pool habitat presence increased downstream of site PC3; however, this habitat type was not as available at sites PC1 and PC2. In general, electrofishing sampling efforts for relative numbers were least at Evergreen Creek site EV1. This trend was also documented for seining (Appendix Table A3), suggesting that relative abundance of fish at Evergreen Creek site EV1 was fairly limited. An elevated road culvert below this site prohibited fish movement upstream, which could be a limiting factor as well.

Overall, species richness in the Plum Creek was considered to be what would be expected for a plains stream exhibiting seasonal high flow events, particularly with recent daily rainfall events. These types of streams are influenced by harsh environmental factors, thereby selecting for species-poor assemblages of fish adapted to severe conditions (Poff and Ward 1989; Baltz and Moyle 1993). In addition, slight pulses of runoff in small prairie streams, because of their unstable geomorphological structures and substrates, can reduce species diversity due to limited microhabitats (Fausch et al. 1984; Harvey 1987; Paller 1994; Stauffer and Goldstein 1997). NCE sampling in 2013 for species composition and relative abundance was comparable to previous sampling investigations by other agencies in the same general locations. Approximately 21 species have been documented in Plum Creek since 1977, with the range of four to 12 species during a typical sampling event. Abundance ranged from 17 individuals sampled by NGPC in 2012 to 276 individuals collected in 1998 (NCE documented 261 in 2013) over the years sampled.

In general, relative abundance of fish in the Plum Creek was moderate and remained relatively constant from site to site (PC 1, PC2 and PC3), with the exception of Evergreen Creek site EV1, which exhibited slightly lower sampling abundance. Carpenter and Kitchell (1987) showed that fish have highly dynamic recruitment, thus making it difficult to distinguish between natural variability and human induced causes of differences in community structures (Grossman et al. 1982, 1990). Therefore, notable differences in fish abundance found within Plum Creek versus Evergreen Creek were observed. The fact Evergreen Creek is a lower order stream, with a barrier to migration evident, some natural variability and available habitat must be considered. However, data tended to indicate that these fish communities were also influenced by limited habitat, restricted periphyton and macroinvertebrate communities, and to some extent, fluctuating or periodic water quality episodes related to physical impacts such as increased sediment loads, but also other non-point source contributions from agricultural in the Plum Creek watershed.

5. General Summary

Scientific analyses were conducted of the physical, chemical and biological features of the lower portion of Plum Creek, Brown County Nebraska May 28 through June 5, 2013 at three specific site locations. Site PC1 was above the McGowan Dam and site PC2 was located on the Greg Wilke property and third site was located on the Jason Appelt property (PC3).

Plum Creek appeared to be in dynamic equilibrium with sediment transport as upstream concentrations were 0.5 m/L (PC1) and downstream concentrations were 0.1 mg/L (PC2) and 1.0 mg/L (PC3), respectively. Downstream accumulations of residual sediment piles were sparse to non-existent and the stream exhibited significant sediment removal since observations of sediment build-up by NCE in September of 2012. As stream ecologists we are confident much of the sediment deposition in Plum Creek below the McGowan dam has been removed by natural flow and fluvial processes in the stream under natural conditions.

It appeared that colonizing and sustaining populations of fish, periphyton and macroinvertebrates were present at all sample sites and this appeared representative of current and improving conditions of Plum Creek. Aquatic and wetland flora communities were established and an increase in diversity and abundance of native flora appeared to be the trend with an extensive floral analysis conducted during our investigation. In general, it was difficult to compare Evergreen Creek conditions (paired reference site) to the above sampling site (PC1) and the two downstream locations, PC2 and PC3 holistically. Flow and habitat conditions were in contrast enough to make any firm inferences regarding sediment impacts at the downstream locations.

Overall, fish species documented and relative abundance of those species at all four sites appeared similar to previous sampling efforts with no major deviations noted. The lack of recent stocking of salmonids appeared evident with no representation in our samples. A more than one time assessment may reveal additional species and overall numbers with a late summer, early fall sampling assessment. The same may also be true for other biota observed.

Extensive row-crop agriculture in the form of corn production was prevalent throughout the upper reaches of the Plum Creek watershed and appeared to be on the increase with current market pricing. Many areas not typically farmed are being converted from rangeland (high in sand composition) to pivot irrigated corn fields with exposed sediment conduits for erosion (see Evergreen Creek Photographic Record, Photo #18) in Appendix. With all the potential erosional opportunities, sediment transport is predicted to increase in the coming years given current watershed land use. A best management plan approach may be in order to minimize future sedimentation of the Plum Creek drainage.

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APPENDIX

TABLE A1. – List of taxa, densities, species richness, and diversity (H') for periphyton sampled at sites on Evergreen Creek (EV) and Plum Creek (PC), Brown County, Nebraska, May 2013.

Taxa	EV1	PC1	PC2	PC3
Bacillariophyta (diatoms)				
Aulacodeira islandica	260	--	--	--
Fragilaria capucina	65	--	--	--
Diatoma mesodon	--	--	65	--
Tabellaria fenestrate	65	--	--	--
Mastogloia dansei	260	--	195	65
Cymbella amphicephala	130	195	--	--
Gomphonema truncatum	--	325	--	--
Cocconeis placentula	--	1,040	--	--
Navicula sp.	260	--	65	130
Nitzschia recta	325	--	65	--
Stauroneis phoenicenteron	260	584	--	--
Amphora ovalis	--	195	--	--
Cymatopleura elliptica	390	--	--	--
Stenopterobia sigmatella	--	--	--	4,939
Cyanophyta (blue-green algae)				
Nostoc sp.	65	--	--	--
Oscillatoria brevis	--	1,950	--	--
Chlorophyta (green algae)				
Genicularia sp.	65	--	65	--
Closterium parvulum	--	585	--	--
Total Density (cells/cm^2)	**2,145**	**4,874**	**455**	**5,134**
Total Number of Taxa	**11**	**7**	**5**	**3**
Shannon-Wiener Diversity (H') Value	**2.21**	**1.64**	**1.48**	**0.18**

TABLE A2. – Taxa list, density (organisms/m^2), and diversity (H') for benthic invertebrates collected from sites on Plum Creek (PC) and Evergreen Creek (EV), Brown County, Nebraska, May 2013.

Taxa	EV1	PC1	PC2	PC3
Ephemeroptera (mayflies)				
Baetidae				
Apobaetis sp.	--	--	8	--
Baetis sp.	16	985	1,730	83
Camelobaetidius sp.	--	--	20	4
Paracloedes sp.	499	40	--	--
Procloeon sp.	71	--	--	--
Isonychiidae				
Isonychia sp.	--	--	63	16
Heptageniidae				
Heptagenia sp.	--	16	283	--
Leucrocuta sp.	40	--	--	12
Ephemerellidae				
Serratella sp.	169	28	--	--
Leptohyphidae				
Tricorythodes sp.	24	220	16	24
Caenidae				
Caenis sp.	--	--	--	4
Odonata (dragonflies and damselflies)				
Gomphidae				
Lanthus sp.	4	--	--	--
Ophiogomphus sp.	28	12	--	4

TABLE A2. – Continued.

Taxa	EV1	PC1	PC2	PC3
Plecoptera (stoneflies)				
Perlidae				
Claassenia sp.	--	4	28	--
Perlesta sp.	16	16	--	--
Perlodidae				
Isoperla sp.	59	16	--	--
Trichoptera (caddisflies)				
Brachycentridae				
Brachycentrus sp.	44	102	4	4
Hydropsychidae				
Hydropsyche morosa	83	4	--	8
Leptoceridae				
Nectopsyche sp.	--	24	--	--
Coleoptera (beetles)				
Hydrophilidae				
Hydrophilus sp.	20	--	--	--
Elmidae				
Heterelmis sp.	118	12	--	--
Stenelmis sp. (larvae)	20	--	4	8
Stenelmis sp. (adult)	67	--	--	--
Diptera (true flies)				
Ceratopogoninae				
Bezzia sp.	28	--	--	--

TABLE A2. – Continued.

Taxa	EV1	PC1	PC2	PC3
Chironomidae				
Chironomini				
Cryptochironomus sp.	444	--	12	836
Procladiini				
Procladius sp.	--	4	--	--
Tanypodini				
Tanypus sp.	--	4	4	--
Orthocladiinae				
Cardiocladius sp.	95	4	106	75
Cricotopus sp.	--	16	28	48
Eukiefferiella sp.	8	8	12	495
Orthocladius sp.	95	306	350	110
Stilocladius sp.	4	--	--	--
Rheocricotopus sp.	--	4	--	--
Tanytarsini				
Tanytarsus sp.	8	--	--	--
Unidentified pupae	220	16	20	4
Simuliidae				
Simulium sp. (larvae)	36	44	122	4
Simulium sp. (pupae)	4	4	4	--
Tipulidae				
Tipula sp.	8	--	--	4
Empididae				
Chelifera sp.	20	--	--	--

TABLE A2. – Continued.

Taxa	EV1	PC1	PC2	PC3
Stratiomyidae				
Stratiomys sp.	4	--	--	--
Turbellaria (flatworms)				
Tricladida				
Dugesia tigrina	32	--	--	--
Nematoda (nematodes)				
Aulolaimoides sp.	12	8	102	20
Monochulus sp	--	--	4	16
Monhystera sp.	--	--	4	--
Annelida (aquatic earthworms and leeches)				
Naididae				
Ophidonais serpentina	48	16	--	16
Pristina plumaseta	28	32	--	67
Branchiobdellidae				
Megmatodrilus sp.	--	--	8	--
Cladocera (water fleas)				
Daphnidae				
Daphnia pulex	--	--	24	16
Mean Total Density (organism/m^2)	2,372	1,945	2,956	1,878
Total Number of Taxa	30	24	21	22
Shannon-Wiener Diversity (H') Value	2.65	1.78	1.56	1.78

TABLE A3. – Summary comparison of fish sampled on Plum Creek by Nebraska Game and Parks Commission (NGPC), Nebraska Department of Environmental Quality (NDEQ), and New Century Environmental, LLC (NCE), 1997-2013 (all sampling assumes 100-m segments electroshocked).

Fish Summary	PC3 Below Dam				PC2 Below Dam		PC1 Above	Lower Plum Creek		
Surveyors	NGPC	NCE	NGPC	NGPC	NCE	NGPC	NCE	NDEQ	NDEQ	NDEQ
Common Name	Appelt	Appelt	Wilke	Wilke	Wilke	Harthoorn	Williams	NDEQ	NDEQ	NDEQ
	2012	2013	1977	2012	2013	2012	2013	1998	2000	2008
Bigmouth shiner	59	5		13	2		6	34	2	15
Black bullhead								24	1	
Bluegill								1		
Brassy minnow		1					33	30	0	23
Brown trout			12							
Channel catfish				2		5				
Common carp	3		2			7		4	0	4
Creek chub	4	36	19		12		19	10	9	25
Fathead minnow	2									
Flathead chub	4		85	4						
Golden shiner	3							2		
Green sunfish	2			4	2		2	37	5	
Largemouth bass										14
Longnose dace		5		4	33		38	76	20	37
Red shiner	15	3		20	4	2				
River carpsucker	8					1				
Sand shiner		187			3					
Shorthead redhorse	12	8	13	12			7	1	5	
Stonecat	1	10		13	25		1	4	4	5
White sucker	15	7	47	9	1	2	31	53	45	73
Total Fish	128	261	178	81	82	17	137	276	91	196
Number of Species	12	10	6	9	8	4	8	12	8	8
Fish/km	12,800	26,100	17,800	8,100	8,200	1,700	13,700	27,600	9,100	19,600

TABLE A4. – Summary of riparian and instream flora observed along Evergreen Creek (EV) and Plum Creek (PC) sites, Brown County, Nebraska, May 2013. Green shading denotes critical wetland hydrophyte establishment within riparian zone and blue shading denotes critical submergent macrophyte establishment instream.

Scientific Name	Common Name	EV1	PC1	PC2	PC3
Acanthus					
Justicia americana	water willow		x		
Anacardiaceae					
Rhus glabra	smooth sumac		x		
Toxicodendron radicans	poison ivy			x	
Apiaceae					
Sium suave	water parsnip		x		
Berula erecta	water parsnip		x		
Cicuta bulbifera	water-hemlock		x		
Myrrhis odorata	sweet cicely			x	
Asclepidaceae					
Asclepias syriaca	common milkweed			x	
Polygonatum biflorum	solomon seal		x		
Asteraceae					
Solidago sp.	golden rod		x		x
Erigeron philadelphicus	marsh fleabane		x		
Helianthus anuus	common sunflower		x		
Solidago sp.	golden rod			x	
Xanthium strumarium	cocklebur		x	x	
Bidens frondosa	beggar-tick			x	
Cirsium sp. 1	thistle	x	x	x	x
Taraxacum officinale	dandelion			x	
Aster sp. (immature)	aster	x	x	x	x
Erigeron philadelphicus	marsh fleabane			x	x
Eupatorium perfoliatum	boneset			x	
Iva annua	marsh elder				x
Taraxacum officinale	dandelion	x			x
Artemisia tridentata	sage brush arti				x
Erigeron philadelphicus	marsh fleabane		x		x
Ratibida columnifera	prairie coneflower				x
Cirsium sp. 2	thistle	x	x		
Solidago sp.	golden rod	x			
Iva annua	marsh Elder	x			
Ambrosia psilostachya	western ragweed	x		x	