Nose Creek Invertebrate Water Quality Assessment

Environmental Science 502
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1.0 Introduction

The study area, Nose Creek, is located within southern Alberta and flows within the M.D. of Rocky View, the City of Airdrie, and the City of Calgary. Sourced by groundwater and precipitation, it extends approximately 75 km, running roughly from north to south. Headwaters of the creek are located near Carstairs, Alberta. West Nose Creek is the main tributary of Nose Creek, running a total length of 65 km. This tributary joins with Nose Creek west of the Calgary International Airport, near Deerfoot Trail. The main creek (Nose Creek) enters the Bow River near the Calgary Zoo, giving it relevance to water issues within the City of Calgary.

Monitoring of Nose Creek has been historically conducted by Alberta Environment (AENV) and the City of Calgary, at 5 sites designated along the creek for this purpose *(Palliser Environmental Services Ltd*, 2008). Our study, which deals with aquatic invertebrates within Nose Creek, was coordinated with these 5 sample sites. Where possible, other sampling, for the purpose of the entire Nose Creek study (performed by the Environmental Science 502 class, 2008/2009, supervised by Dr. C. Ryan), also involved these 5 sampling sites, or areas close to the sites. Almost all of the historic water quality monitoring in Nose Creek has consisted of monthly grab samples. Nose Creek has 62 licenses for water withdrawal and West Nose Creek has 9 licenses for water withdrawal. This pilot study of Nose Creek invertebrates will hopefully contribute to a further understanding of the biotic and abiotic aspects of the creek and provide further information regarding the water quality of Nose Creek (*Madawaska Consulting*, 2003). To date, although invertebrates have been studied in the Bow River (*Bowman,* 2001) and Fish Creek (*Leung,* 2009), no studies have been conducted on Nose Creek invertebrates.

Within Alberta, there is a large diversity of freshwater invertebrates, some of which exist underneath the surface of streams, rivers, or creeks. Classification of these invertebrates covers extremely large subgroups, for example, Arachnida, Crustacea, and Insecta (*Clifford,* 1991). In the kingdom Animalia, invertebrates make up the majority of the organisms in both abundance as well as species (*Huntly et al.,* 2005). The presence of these this diverse group of organisms is undoubtedly related to human population distributions, along with natural processes (*Clifford*, 1991). Invertebrates, specifically benthic (or bottom of a water body) invertebrates, integrate and reflect the interaction of various factors of their environment and provide a broad description of the overall water quality (*Iliopoulou-Georgudaki et al.,* 2003). Employing macroinvertebrates as biomonitors, as well as tools for assessing certain aquatic ecological areas of interest, has been used in different forms (indexes, multivariate techniques) throughout modern history to further understand environmental conditions within a given area (*Verberk et al.,* 2008).

The use of freshwater macroinvertebrates in biomonitouring offers several advantages. First, invertebrates are a ubiquitous group of organisms found in virtually every habitat occurring on the planet (*Mandaville*, 2002). As such, they are affected by many different perturbations in these habitats. In addition, invertebrates are extremely species rich; the large number of species produces a range of responses allowing for the use of different species to monitor different environmental changes (*Mandaville,* 2002). These groups of organisms are also fairly sedentary and long lived. As invertebrates remain relatively local in their respective areas (*Lydy et al.*, 2000), interactions within their respective environments is what makes them useful bio-indicators for determining the spatial extent of an environmental perturbation (*Mandaville*, 2002). Their generally long lifespan allows the temporal changes in abundance and age structure to be determined, integrating conditions temporally providing evidence of past conditions in a given habitat (*Mandaville,* 2002). Invertebrates (as well as other biotic communities) are without a doubt affected by floodplain connectivity, riparian vegetation, water temperature and chemistry, availability of nutrients and energy, evolutionary traits, and historical disturbances along with land use activities (*Konrad et al.,* 2008). One example of an environmental interaction of invertebrates is the use of water body floors (or substrate) as a location to lay eggs, as well as being used as a shelter from predators (*Bo et al.*, 2007). Another example that involves complex interactions between the biotic and abiotic factors affecting invertebrates is the effect of an event like a drought, which can increase the seasonal populations of insects and crayfish (invertebrates) by negatively affecting fish populations (*Dorn*, 2008).

For our study of Nose Creek invertebrates, the aim is to exploit the use of aquatic invertebrates as bio-indicators to determine relative water quality of different sites (the 5 sites utilized by the NCWP). The Family Biotic Index (FBI) was used in order to determine a level of organic pollution, which involves carbon containing pollutants that can be possibly oxidized by invertebrates (*Wallace et al.,* 1996). Also, the percent EPT (Ephemeroptera, Plecoptera, and Trichoptera) was employed because of its use as a measure of pollution sensitive taxa (*Wallace et al.*, 1996). Along with these indices, the density and diversity of the sampled invertebrates at each site was used to determine the relative community structure. Overall, using the biomonitoring properties of the sampled aquatic invertebrates in Nose Creek will help in future studies of these organisms within the area, and will also assist in making conclusions about other environmental aspects involved in this environmental science study.

2.0 Methods

2.1 Site Description

Invertebrates were sampled from four sites on Nose Creek and one site on West Nose Creek on October 19th, 2008. These five sites matched five sites that are used for historical data and that were used the same day to test pH, creek discharge, and various anion and cation concentrations. Below is a table that explains the names of the sites used throughout this study, location descriptions, UTM coordinates, and some physical characteristics of each site.

Table 1. Site names, locations, UTM Easting and Northing (m), Creek Width (m), and Discharge (m^3/s) for each site where invertebrates were sampled.

Site Name	Site Location	UTM Coordinates (m) (Zone11)	Creek Width (m)	Discharge (m^3/s)
N1	Nose Creek North of Airdrie	0707169m E 560621m N	9.3	0.299
N2	Nose Creek South of Airdrie	0708759m E 5683895m N	10.2	0.262
N3	Nose Creek at Calgary City Limits	0707998m E 5673014m N	6.6	0.303
N5	Nose Creek at Mouth of Bow River	0708937m E 5659070m N	16	0.752
WN1	West Nose Creek west of Nose Creek	0699725m E 5674835m N	2.8	0.233

N1 was a site in the rural area outside the city of Airdrie to the north. The first observation made was the presence of cow manure along the riparian area and in the creek bed. There were also various refuse items disposed of in the creek such as a cooler and two tires. Nose Creek was very shallow with a low velocity. This site visually appeared to be the least healthy of all sites. N2 was within the city limits of Airdrie on the southern end behind a shopping complex. The riparian area was composed of grasses on both shores, the water was very opaque, and the creek bottom consisted of mud and small pebbles. N3 was at the north city limits of Calgary at 15th Street N.E. The riparian area visually appeared to be healthy consisting of grasses, shrubs, and young trees. The water was clear and the creek bed was made of mud and stones. N3 appeared to be the healthiest site visited. N5 was where Nose Creek empties into the Bow River in Calgary near the Calgary Zoo. Water at this site was fast flowing, slightly murky and the riparian area primarily consisted of large stones and smaller pebbles in close proximity with the creek, while shrub and tall grass species were present beyond the rocky sections. The creek bed was composed of a mix of coarse and fine sediments ranging from fluvial eroded pebbles to larger stones and woody debris. Finally, WN1 was North West of where West Nose Creek runs into Nose Creek near the confluence. Water here was very murky, shallow, extremely slow flowing, and had a slight sulfurous odor. The riparian area consisted of grass alone, overhanging the creek, and the creek bed consisted of mud. Below is a map that displays the location of each site (Figure 1).

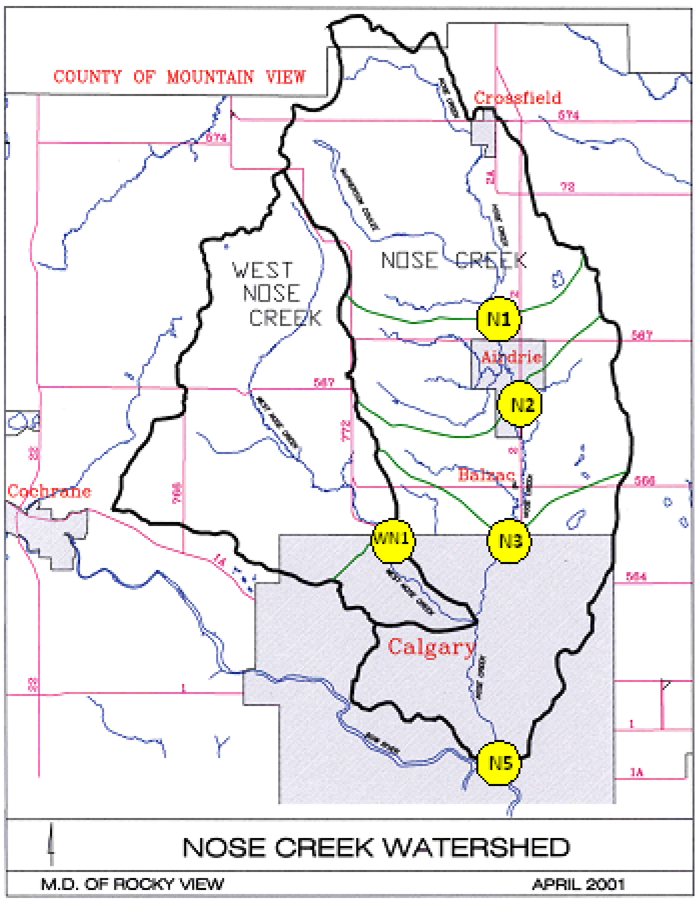

Figure 1. Map of Municipal District of Rocky View including Nose Creek and West Nose Creek Watershed areas. Invertebrate sampling locations denoted by yellow circles. N represents Nose Creek and WN represents West Nose Creek. Original map taken from E. McMahon, NCWP Coordinator.

2.2 Field Methods

Three samples were taken at 25%, 50% and 75% of the creek width at each site making a total of fifteen samples. Surber samplers, one foot by one foot in area, were used for each sample. They were placed on the bottom of the creek so that the net was opened by the flow of the river while one person dug up the bottom of the creek for exactly three minutes. The net was then emptied into a sieve and separated from as much debris possible. Invertebrates were then individually picked out and transferred to a jar with a mixture of one quarter water and three quarters of 80% ethanol. Jars were then labeled on the top and a matching label was placed inside each sample.

Figure 2. Pictures of field work in (a) West Nose Creek and (b) South Airdrie site on October 19, 2008.

2.3 Laboratory Methods

Invertebrates were first separated from debris and moved from jars to smaller sampling containers. From the beginning of December, 2008 until the end of January, 2009 invertebrates were identified to family using various dichotomous keys from the Aquatic Invertebrates of Alberta guide. Some invertebrates were identified more specifically to genus in order to find an accurate family biotic index tolerance value.

Figure 3. Images of the (a) laboratory identification of invertebrates using dissecting microscopes and the *Aquatic Invertebrates of Alberta: An Illustrated Guide* (Clifford, 1991) and (b) Gastropod shells identified in the laboratory.

2.4 Analytical Methods

Four different parameters were used to analyze the relative water quality of each site; diversity, density, Hilsenoff's Family Biotic Index and % EPT. Diversity was calculated by summing the number of different families in each sample and taking the mean of the three samples for each site. Density was calculated by adding the total number of species in one sample per square foot and finding the mean of the three samples for each site. FBI values were found by assigning a tolerance value for each invertebrate and applying the following equation FBI = $\sum \frac{(ni)(ai)}{Nt}$ where n_i is the number of individuals in family i, a_i is the pollution tolerance value of family i, and N_t is the total number of individuals in the sample (*Hilsenhoff*, 1988). This was done for each sample and the mean was determined for each site. Using the mean FBI value at each site, the relative water quality was determined and used to quantify the degree of organic pollution at each site. Refer to Table A4 (Appendix I) for water quality classification system. Percent EPT was found by using this formula: %EPT = $\sum \frac{EPT}{Nt}$ where EPT are the number of individuals of orders Ephemeroptera, Plecoptera and Trichoptera and N_t is total number of individuals per sample. Values were obtained for each sample and a mean was taken for each site (*Wallace et al.* 1996). Standard errors were found for each of the four parameters. In addition, correlation coefficients were calculated using the four invertebrate parameters (invertebrate diversity, density, FBI, and %EPT) and mass flux data (sulphate, potassium, chloride, dissolved oxygen, phosphate, nitrate, and ammonium) to compare chemical creek characteristics with the invertebrate community composition and relative water quality classification assigned to each site.

Normality and equal variance assumptions were tested for diversity, density, FBI and %EPT data before performing a statistical test between sites. Normality was tested using normality plots, and a Levene's test was used to test for equal variance. Diversity data met both assumptions therefore an ANOVA was carried out on the data. Subsequently a Tukey's test was performed on the data to indicate where the differences were located. Density did not meet the normality assumption so the data were transformed using a Box-Cox transformation, which then met both assumptions. Original FBI data met both assumptions so an ANOVA followed by a Tukey's test were completed. Percent ETP data did not meet either assumption when untransformed or when transformed. Therefore, a non-parametric Kruskal-Wallis Test was applied to the original data. In all statistical tests, $p \leq 0.05$ was considered statistically significant, and all tests were done in Minitab v. 15. Correlation coefficients between 0.80 and 0.89 were considered moderately correlated and a correlation coefficient ≥ 0.90 was considered significantly correlated.

3.0 Results

3.1 Invertebrate Diversity

Invertebrate diversity decreased moving from N1 to N2, reaching its maximum at N3; the lowest diversity was found at N5 and WN1 (Figure 4 and Table 2). The mean number of taxa at N3 was significantly greater than the mean number of taxa at N5 and at WN1 ($F = 6.31$, df = 4, 14, $p < 0.05$, $R^2 = 71.64$ %); 10.0 $\pm$ 0.580 taxa, 3.00 $\pm$ 1.15 taxa, and 3.67 + 1.67 taxa respectively (Figure 4 and Table 2). In addition, the mean number of taxa at N1 (9.67 $\pm$ 1.45 taxa) was significantly greater than the mean number of taxa at N5 (3.00 $\pm$ 1.15 taxa) ($F = 6.31$, df = 4, 14, $p < 0.05$, $R^2 = 71.64$ %); (Figure 4 and Table 2).

3.2 Invertebrate Density

N1 had the greatest invertebrate density, 244 $\pm$ 175 individucals/1ft^2 , while WN1 exhibited the lowest invertebrate density found to be 16.7 $\pm$ 13.2 individuals/1ft^2 (Figure 5 and Table 2). There were however, no significant differences between the mean densities (individuals/1ft^2) at any of the five sample sites ($F = 2.62$ df = 4, 14, $p > 0.05$ for all cases, R^2 = 51.91 %).

3.3 Family Biotic Index

The mean FBI value at N5 was significantly greater than the mean FBI value at N3 and WN1 ($F = 5.27$, df = 4, 14, $p < 0.05$, R^2 = 67.84 %); 7.94 $\pm$ 0.287, 5.94 $\pm$ 0.280, and 6.22 $\pm$ 0.275 respectively (Figure 6 and Table 2).

Table A4 (Appendix I) displays the water quality and degree of organic pollution corresponding to the Family Biotic Index range. N1 and N5, based on the mean FBI value, can be classified as having very poor water quality corresponding with the likelihood of severe organic pollution occurring (Figure 7 and Table A4). N2 can be categorized as having poor water quality with very substantial pollution likely, and N3 and WN1 fall into the fairly poor water quality classification with substantial pollution likely (Figure 7 and Table A4). Relative water quality increased from the North Airdrie (N1) site to the City Limits (N3) site from very poor to fairly poor and then decreased from fairly poor to very poor between the city limits (N3) and the mouth of Nose Creek at the Bow River (N5) (Figure 7).

3.4 Percent Ephemeroptera, Plecoptera, and Trichoptera

The mean % EPT at N3, 30.5 $\pm$ 10.7 %, was significantly greater than the mean % EPT at the other four sample sites ($H = 13.57$, df = 4, $p < 0.05$); N1 had a mean % EPT of 2.10 $\pm$ 0.91 % and 0% EPT was found at N2, N5, and WN1 (Figure 7 and Table 2).

Table 2. The sample size, mean, and SE for invertebrate diversity, density, FBI value, and % EPT determined at each site along Nose Creek and West Nose Creek.

Parameter	**Diversity**			**Density**			**FBI**			**% EPT**		
Site ↓	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE
N1	3	9.67	1.45	3	224	175	3	7.45	0.598	3	2.10	0.910
N2	3	5.33	1.45	3	18.0	12.5	3	6.77	0.159	3	0	0
N3	3	10.0	0.580	3	51.3	18.9	3	5.94	0.280	3	30.5	10.7
N5	3	3.00	1.15	3	20.0	7.23	3	7.94	0.287	3	0	0
WN1	3	3.67	1.67	3	16.7	13.2	3	6.22	0.275	3	0	0

n = sample size

3.5 Invertebrate and Anion/Cation Correlations

Invertebrate diversity was moderately correlated with sulphate flux, dissolved oxygen, and nitrate concentration (Table 3). Sulphate and nitrate correlations were negative; as the sulphate flux and nitrate concentration in Nose Creek increase towards N5 the invertebrate diversity would tend to decrease (Figure 2 and Table A3). Invertebrate density was moderately correlated with dissolved oxygen and significantly correlated with phosphate and ammonium concentrations (Table 3). As phosphate and ammonium concentrations decrease towards N5, density tends to decrease as well (Figure 3 and Table A3). Finally, FBI was significantly correlated with potassium and chloride flux (Table 3). As potassium flux and chloride flux increase between N3 and N5, FBI tends to increase, corresponding to poorer water quality.

Table 3. Correlation coefficient matrix between invertebrate parameters and mass flux anion and cation parameters.

Parameters	**SO_4^{2-}**	**K^+**	**Cl^-**	**DO**	**PO_4^{3-}**	**NO_3^-**	**NH_4^+**
Diversity	**-0.795**	-0.589	-0.414	**0.849**	0.503	**-0.832**	0.450
Density	-0.484	0.076	0.343	**0.848**	**0.972**	-0.619	**0.918**
FBI	0.630	**0.924**	**0.952**	-0.133	0.310	0.528	0.284
% EPT	-0.303	-0.569	-0.631	0.398	-0.320	-0.252	-0.401

(-) denotes a negative correlation between parameters
0.80 – 0.89 = moderate correlation
$\geq$ 0.90 = significant correlation
Bold denotes meaningful correlations used in this study

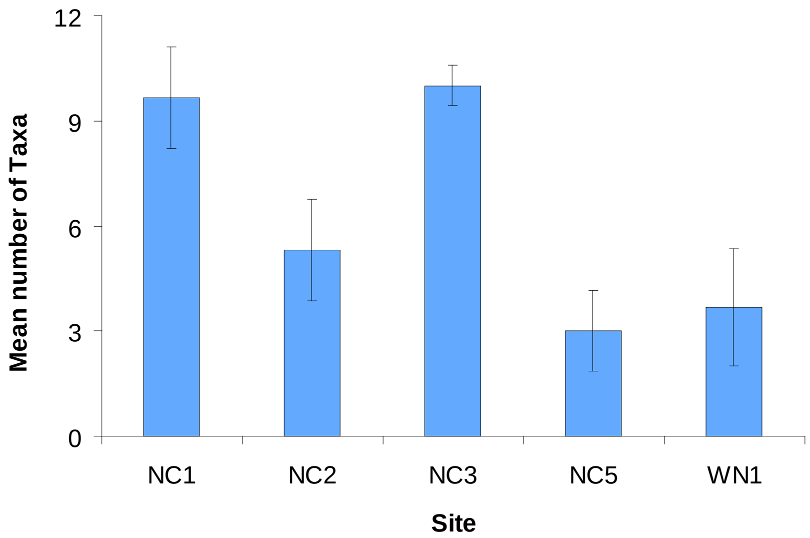

Figure 4. Mean number of taxa (+ SE) at each site along Nose Creek and West Nose Creek.

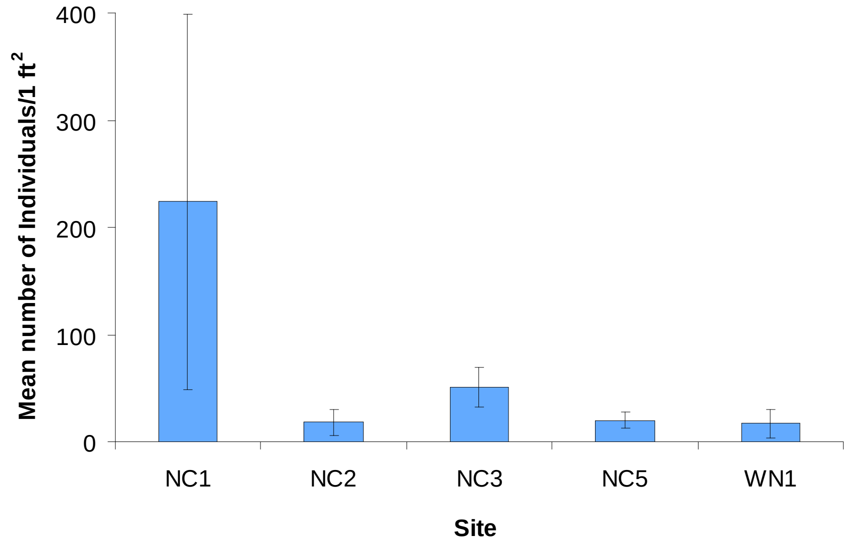

Figure 5. Mean density (number of individuals/1ft^2) of invertebrates (+ SE) at each site along Nose Creek and West Nose Creek.

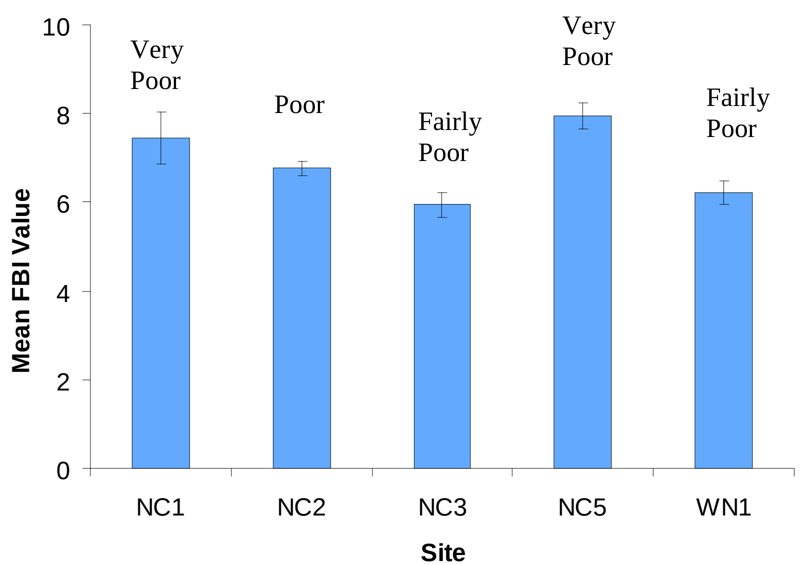

Figure 6. Mean FBI value (+ SE) obtained at each site along Nose Creek and West Nose Creek with the corresponding water quality classification.

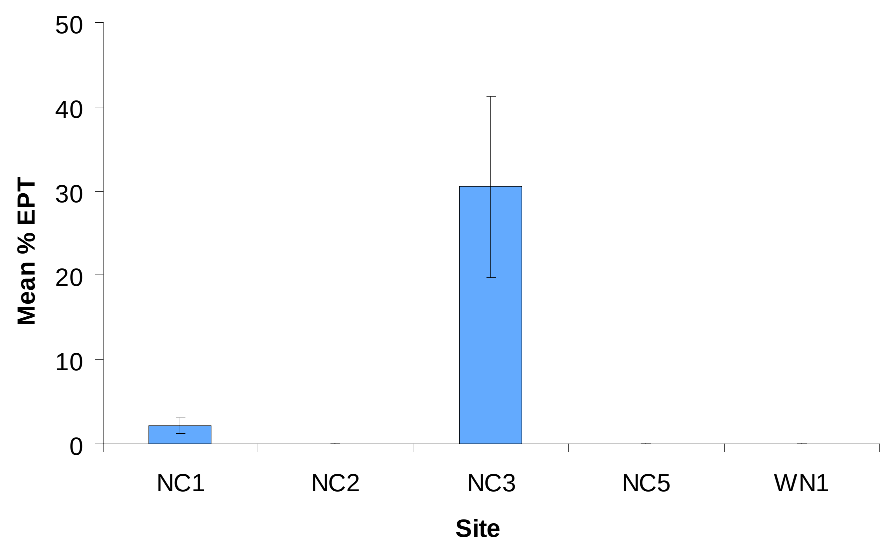

Figure 7. Mean % EPT (Ephemeroptera, Plecoptera, and Trichoptera) at each site (+ SE) along Nose Creek and West Nose Creek.

4.0 Discussion

The use of benthic invertebrate populations as indicators of environmental quality has recently increased, especially for agriculturally impacted areas (Stone et al. 2005; Berkman et al. 1986). Berkman et al. (1986) note that the reason for the current trend toward invertebrate monitoring for assessing water quality, is due to their sensitivity toward low-level disturbances and functioning capability as continuous monitors. In addition, benthic invertebrates play a significant role in the performance of aquatic ecosystems (Phillips et al. 2008). Invertebrates occupy every operative feeding group and play critical roles in the recycling of organic matter back into the food chain (Phillips et al. 2008). As such, using the results presented in this study, it may be possible to determine what types of pollution are present in the creek, how the pollution is impacting the invertebrate community, and indentifying the possible sources of any pollution present in the creek. Sampling sites in this study occurred in both agricultural and urban areas. Therefore, the effects of agricultural and urban development could both contribute to the degradation of Nose Creek water quality, however in different ways.

4.1 Urban Effects on Invertebrates

Two sites in the current study were located in an urban setting, South Airdrie (N2) and the mouth of Nose Creek (N5). These sites, when compared to the upstream sites of North Airdrie (N1) and the City limits (N3), had lower mean invertebrate diversity, density, and % EPT, indicating that certain urban anthropogenic factors undoubtedly affect the invertebrate composition of Nose Creek. The presence of impervious areas, such as roads and pathways, infrastructure (bridges and overpasses), and channelization of the creek route associated with urban settings can have a significant impact on the habitat of aquatic invertebrates, and this trend was seen in the results (*Friberg et al.,* 1994). The effects of urbanization on stormwater drainage are related to the change in quality, runoff rate, and the volume of stormwater entering the natural drainage system (*Gresens et al.,* 2007). As such, the runoff in an urban area can contribute to significant pollution loading of nutrients, bacteria, sediment, heavy metals, oil, grease, and in the spring, road salt (*Gresens et al.,* 2007).

Furthermore, increased urban residential and commercial development involves the removal of ground vegetation and topographic alteration of the land leading to the increase in impervious surfaces (*Mandaville*, 2002). The runoff rates in urban areas are thus greatly increased leading to higher levels of pollutant loading in water systems. The impervious surfaces also reduce the area available for rainfall infiltration (*Mandaville*, 2002). The subsequent reduction in water infiltration into the soil may result in a lowering of the water table and a potential reduction in the amount of groundwater recharge to streams in periods of low flow. The lower values of invertebrate diversity, density, and % EPT at urban sample sites in this study, can therefore possibly be due to the adverse effects of the chemicals or nutrients present in the runoff of urban stormwater as a result of paved concrete surfaces around the South Airdrie and mouth of Nose Creek sites. Invertebrate diversity has been known to decline with 10-20% of impervious area present, supporting the inference that development along Nose Creek adds to runoff of water containing harmful chemicals to aquatic life forms (*Gresens et al*., 2007). As higher diversity and density of aquatic invertebrates can be indicative of better water conditions, the low values seen at these two urban sites also indicate that external disturbances may be present (*Lenat*, 1983).

Channelization of surface water bodies is another activity associated with development. Urban land uses in and around Nose Creek has resulted in an increase in channelization causing straightening of the creek and an overall decrease in channel length (*Ortle and Lake*, 1982). By increasing the channelization of Nose Creek, the flow velocity of water is likely increased along with reducing the hydraulic heterogeneity of the creek (*Ortle and Lake*, 1982). This negatively affects aquatic invertebrate communities by altering the substrate (or bottom surface) in which they live and lay eggs, along with changing the water level in some areas (*Konrad et al.*, 2008). Thus, the natural habitat of the invertebrate communities could drastically change within a short timeframe, and certain taxa may not be tolerant to these changes. This could reflect the results obtained regarding the community structures at these urban locations.

In addition to adversely affecting the invertebrate community, urban development also has measureable consequences on relative water quality. The relative water quality at the mouth of Nose Creek (N5) was very poor based on the *Hilsenhoff* (1988) family biotic index classification. Comparing this site to the upstream city limits (N3) site, N3 had a better relative water quality classification, classified as fairly poor, supporting the notion that urban regions could account for decreases in the relative water quality of Nose Creek. There are, however, conflicting results between the North Airdrie (N1) and South Airdrie (N2) sites. Relative water quality increased from very poor to poor between these two sites even though N1 had a greater invertebrate diversity and density compared to N2. This suggests that agriculturally impacted areas also affect the relative water quality and the invertebrate community of Nose Creek in additional ways compared to urban areas.

4.2 Agricultural Effects on Invertebrates

Of the five sampling locations, North Airdrie (N1) and West Nose Creek (WN1) sites were within rural areas; the city limits site (N3) could be considered both urban and rural since it was in close proximity to the City of Calgary and to agricultural areas upstream of the city. Absence of development and major impervious areas near West Nose Creek, and the presence of cow manure at the north Airdrie site, were indications of a more rural setting, and led to several inferences concerning the invertebrate communities found.

As the presence of livestock near the north Airdrie site was observed first hand, agricultural practices were undoubtedly taking place at various sites along the creek. High levels of nutrients such as phosphate in surface water are associated with agriculture, since animal waste contains large amounts of nutrient ions that can easily enter bodies of water either directly or indirectly (*Dyer et al.*, 2003). Excess of these nutrients (specifically phosphate and nitrate) can lead to eutrophication, which effects aquatic life by limiting the amount of dissolved oxygen within the water (*Dyer et al.*, 2003). Also, although phosphate is involved in eutrophication, it is an important nutrient in relation to the invertebrate family daphnidae, as it is involved in RNA synthesis and some protein synthesis (*Geest et al.,* 2007). The invertebrate population found at the North Airdrie site was mainly daphnidae, which is consistent with the phosphorous limitation they exhibit. Increasing the phosphorous concentration in the water has also been known to increase the reproductive rates of daphnia (*Becker and Boersma,* 2005). This would account for the high density of daphnia at the North Airdrie site. Daphnidae are also tolerant of low oxygen levels, which would also be characteristic of this site (*Becker and Boersma,* 2005).

One issue in sampling invertebrates and using indices based on taxa is that they do not take into account the individual traits of each taxon being sampled (*Verberk et al.*, 2008). Species that are found within environments with volatile and fluctuating conditions tend to have rapid development (such as the Daphnia found), and this trend may help explain the high diversity and density at N1. Although the water quality was found to be very poor, based on the FBI value, certain adaptable traits possessed by the taxa found at N1 might enable them to survive and thrive in the poor water conditions. Daphnia, for example, also have a very high pollution tolerance compared with other taxa, suggesting why such a high density was found at N1. The FBI and % EPT indices used only identify the taxa based on family, and not correlations based on their traits and common habitats.

With regard to West Nose Creek (WN1), the density, diversity, and % EPT were found to be quite low. The calculated FBI value indicated fairly poor water quality, which is inconsistent with zero % EPT found at this site; the city limits (N3) for example was also classified as having fairly poor water quality, however, 30 percent of the taxa found at this site belonged to the EPT orders. Density at this site was also the lowest of all the sampled sites. This could possibly be explained by the reproductive traits of the collected invertebrates. As this site had a riparian area covered in tall grass with no obvious signs of human development (like garbage or clearing of vegetation), the stability of the environment could influence the taxa living there. It has been found that aquatic invertebrates with long periods of development usually prefer stable environments, and this finding can help explain the density as well as the diversity found within the area (only taxa with slow development might be present in this area) (*Verberk et al.*, 2008). As for the FBI and % EPT values, the relative water quality at this rural site could possibly be due to pesticides, herbicides, sewage, or agriculture (*Liess and Von Der Ohe,* 2005, *Brisbois et al*., 2008, *Putnam et al*., 2008). Unlike the north Airdrie site, the obvious presence of agriculture (from manure) was not observed. This does not mean that agriculture was not influencing the water. Upstream sites of West Nose Creek were not sampled for aquatic invertebrates, and these areas may contribute agricultural waste to downstream sites. One other observation made while sampling benthic invertebrates at this site was the presence of a strong sulfurous odor. It is quite plausible that this odor was caused be sewage in or near the water, which would definitely contribute to organic pollution indicated with the FBI and % EPT calculations (*Spanhoff et al.*, 2006).

Nose Creek at the city limits (N3) site fell in between urban and rural. Although it was 15 Street N.E. in Calgary, it was located within grassland quite a distance from any urban infrastructure. This site appeared to be the healthiest when sampling for aquatic invertebrates. Analysis showed that the relative water quality (based on FBI and % EPT) was overall better compared to the other sites, with the exception of WN1 which was also classified as fairly poor. A high diversity and density were also characteristic of this site. The substrate present ranged from fine silt to large stones, and the water was fairly clear, which is possibly an ideal habitat for benthic invertebrates. As substrate is important for the reproduction cycles of invertebrates (a site to lay eggs) along with serving as a shelter for adult individuals, the high density could reflect these conditions observed at this sampling location (*Bo et al.*, 2007). The dynamic substrate structure could host many different species, which would correlate well with the high diversity of specimens found. Also, the flowing water could increase dissolved oxygen content, which was found to moderately correlate to density as well as diversity (*Dyer et al*., 2003). As dissolved oxygen increases, the invertebrate diversity and density also tend to increase. Overall, ideal conditions seemed to be present for the existence of aquatic invertebrates at this site.

4.3 Nose Creek Chemistry and Invertebrates

River systems can vary extensively in terms of their physical and chemical characteristics. This includes physical differences between temperature, discharge, and morphology, and chemical variations in dissolved anion and cation concentrations and the abundance and distribution of nutrients (*Johnson and Ostrofsky*, 2004). This is also true for different sections of the same river or stream and Nose Creek is consistent with this trend. Between sample sites along Nose Creek, there are differences between the flux and concentrations of anions and cations (See Table A3 in Appendix I for exact flux and concentrations of anions and cations). Consequently, correlation coefficients were calculated to determine if the parameters of this study were interconnected with the chemistry of Nose Creek.

Nitrate has been found to have significant effects on aquatic life (including invertebrates) and these effects depend on the relative amount present in the water, along with age and body size of the organism (*Camargo et al*., 2005). Excess nitrate can lead to eutrophication, which limits the amount of dissolved oxygen in the water of use by organisms and is also known to have toxic effects on aquatic life (*Dyer et al.*, 2003, *Barton*, 1996). These results are consistent with the results of this study. Nitrate concentration in Nose Creek was moderately correlated (negative correlation) with invertebrate diversity; as the nitrate concentration in Nose Creek increased towards the Bow River, the invertebrate diversity tended to decrease. Potential sources of this nitrate could be from agricultural fertilizers being transported downstream, septic or sewage tank leaks, commercial and industrial wastewater, and acid rain (*Bleifuss,* 1998). In addition, chloride can interact with the biological role of nitrate in aquatic invertebrates (when both nitrate and chloride are abundant, chloride blocks the reception of nitrate into binding sites of the invertebrate) (*Alonso and Camargo,* 2008). These results are consistent with the results of this study. The chloride flux and nitrate concentration were the highest at the mouth of Nose Creek. Sources of excess chloride, which could include road salt and animal waste, are usually associated with anthropogenic factors that affect water quality. In this study, a significant positive correlation was found between chloride and FBI, revealing that the relative water quality based on the invertebrate composition is directly linked to the chloride flux (*Blasius and Merritt*, 2002, *Leung,* 2008). The mouth of Nose Creek had very poor water quality (according to the FBI value) and the highest chloride flux compared to the other sites. This correlation supports the possible adverse effects that animal waste (which contains chloride) and road salt could be having on Nose Creek.

As agricultural influences were identified as possible factors in this invertebrate study, fertilizer runoff containing nitrogen, potassium, and phosphorous could be entering the creek at certain locations. This is supported by the strong correlation between potassium and FBI. An increasing FBI suggests degradation in water quality, and since potassium is associated with fertilizer, this correlation further suggests that agricultural activities are possibly having negative influences on the water in Nose Creek. In addition to potassium, ammonium, a natural occurring form of nitrogen, also had a significant correlation with invertebrate density in this study. Ammonium is a major constituent of animal manure (*Sawyer and Helmers,* 2008). This suggests that, at the North Airdrie (N1) site, where there was visual evidence of manure in Nose Creek, the high invertebrate density was a result of high concentrations of ammonium and phosphate in the water. Phosphate, as mentioned earlier, was also significantly correlated with invertebrate density. This further supports the reason for the large amount of daphnia present at this site. Concentrations of phosphate and ammonium were the highest at the North Airdrie site. Other possible sources of ammonium are land-applied manure, manure stockpiles, septic systems, raw sewage, and fertilizer sprays (*Sawyer and Helmers,* 2008). Therefore all of the ammonium at this site might not be the direct result of manure in the creek at this site. Although these nutrients are important for invertebrate growth and development, other nutrients are also important for invertebrate life cycles, and excess can lead to detrimental effects and conflicting chemical cycles of aquatic organisms (*Barton*, 1996, *Bowman*, 2001).

Sulphate, for example, is another compound commonly found at elevated levels in polluted environments (*Fung et al.,* 2008). These elevated levels are generally the result of chemical products like ammonium sulphate fertilizers and human activities such as the combustion of fossil fuels and sour gas processing release sulphur oxides to the atmosphere, some of which is converted to sulphate and deposited in water systems (*Fung et al.,* 2008). In this study, the presence of sulphate in the water might be having negative effects on the invertebrates in Nose Creek. Sulphate flux was moderately correlated (negative correlation) with diversity; as sulphate flux increases towards the mouth, invertebrate diversity tends to decrease. This could be a reason for the lower invertebrate diversity found at the mouth of Nose Creek (N5), although the interaction of several factors together would have to be considered to understand the full effects of different anion and cation concentrations between sampling sites.

The use of benthic macroinvertebrates to assess Nose Creek water quality undoubtedly provides another useful avenue in addition to traditional sampling done by AENV and the City of Calgary. Almost all of the historic water quality monitoring it Nose Creek has consisted of monthly grab samples monitoring factors such as anion and cation concentrations, total suspended solids, and total and fecal coliform (*Palliser Environmental Services Ltd.,* 2007). Benthic invertebrate sampling can therefore be used as another indicator of relative water quality. Benthic invertebrate bio-indicators can be used to specifically reveal changes in the physical environment such as long term temperature precipitation fluctuations (*Hodkinson and Jackson*, 2005). In addition, invertebrates can be used to detect chemical changes in a particular environment, specifically related various levels and forms of pollution, as well as any modifications in the ecological status of a habitat relating to time and place (*Hodkinson and Jackson*, 2005). Invertebrate responses to changes in the environment can be seen at different levels, ranging from the individual to the total invertebrate community. *Hodkinson and Jackson* (2005) indicate that the appropriate level chosen to evaluate environmental impacts in an area depend on the specific factor(s) though to be acting. Individuals may assist as short-term bio-indicators of impacts, whereas population density levels of single species could also be used for detecting additional, more complex ecosystem alterations (*Hodkinson and Jackson,* 2005).

5.0 References

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7.0 Appendix I

Table A1. Invertebrate identification data from each sample collected from the five sites along Nose Creek (N) and West Nose Creek (WN1) on October 19, 2008. Identification is to order (letter abbreviation) and family level.

Site	E - Caenidae	E- Baetidae	E - Tricorythidae	T- Hydropsychidae	D- Chironomidae	D - Tabanidae	C - Elmidae	C - Dytiscidae	C - Gyrinidae	Cl - Daphnidae
1 N5 #1					16					
1 - N5 #2					8					
1 - N5 #3					29			1		
2 - N3 #1	2		4	2	7	3	3			
2 - N3 #2	9		4	1	15		6	1	1	
2 - N3 #3	7		7	3	2	1	1			
3 - WN1 #1					3	1	2			
3 - WN1 #2					3					
3 - WN1 #3							1			
4 - N2 #1					1					
4 - N2 #2					3					
4 - N2 #3					28					
5 - N1 #1		1			12					11
5 - N1 #2	1	1			44					523
5 - N1 #3	1	1			11					8

Table A1 cont. Invertebrate identification data from each sample collected from the five sites along Nose Creek (N) and West Nose Creek (WN1) on October 19, 2008. Identification is to order (letter abbreviation) and family level.

Site	Am-Hyalellidae	Am - Gammaridae	Ar - Erpobdellidae	R-Glossiphoniidae	H - Haplotaxidae	H-Naididae	L - Lumbriculidae	O - Coenagrionidae	O - Lestidae
1 N5 #1				1		2			
1 - N5 #2									
1 - N5 #3	1								
2 - N3 #1	5	4							
2 - N3 #2	2	1	1		48				
2 - N3 #3	7	1		3	2				
3 - WN1 #1	2				33				
3 - WN1 #2					2				
3 - WN1 #3								1	
4 - N2 #1				1	1				
4 - N2 #2					2			1	
4 - N2 #3		1			2				
5 - N1 #1	1				2		1		
5 - N1 #2	3							1	1
5 - N1 #3	12							1	

Table A1 cont. Invertebrate identification data from each sample collected from the five sites along Nose Creek (N) and West Nose Creek (WN1) on October 19, 2008. Identification is to order (letter abbreviation) and family level.

Site	Hm - Corixidae	Co - Podaridae	Cy - Cyclopidae	B - Ancylidae	He - Valvatidae	N - Hydrobiidae	Pl - Planorbidae	Pl - Lymnaeidae	Pl - Physidae	V - Sphaeriidae
1 N5 #1										
1 - N5 #2										
1 - N5 #3				1			1			
2 - N3 #1				1						
2 - N3 #2										
2 - N3 #3										
3 - WN1 #1						1		1		
3 - WN1 #2										
3 - WN1 #3										
4 - N2 #1							1			
4 - N2 #2										
4 - N2 #3					2	1	6		2	1
5 - N1 #1							1	8	1	
5 - N1 #2										
5 - N1 #3	8	3	7					5	1	

Table A2. The taxonomic codes used in identification Table A1.

Taxon Code	**Order**	**Common Name**
E	Ephemeroptera	Mayfly
P	Plecoptera	Stonefly
T	Trichoptera	Caddisfly
D	Diptera	True Fly
C	Coleoptera	Beetle
Cl	Cladocera	Water Flea
Am	Amphipoda	Fairy Shrimp
Ar	Arhynchobdellida	Leech
R	Rhynchobdellida	Leech
H	Haplotaxida	Segmented worm
L	Lumbriculida	Segmented worm
O	Odonata	Dragon/Damselfly
Hm	Hemiptera	Water Bug
Co	Collembola	Springtail
Cy	Cyclopoida	Crustacean
B	Basommatophora	Snail Shell
He	Heterostropha	Snail Shell
N	Neotaenioglossa	Snail Shell
Pl	Pulmonata	Snail Shell
V	Veneroida	Snail Shell

Table A3. The sulphate, potassium, and chloride flux (kg/day), dissolved oxygen, phosphate, nitrate, and ammonium concentration (mg/L) obtained from the mass flux group results.

Site	**SO_4^{2-} flux (kg/day)**	**K^+ flux (kg/day)**	**Cl^- flux (kg/day)**	**DO (mg/L)**	**$[PO_4^{3-}]$ (mg/L)**	**$[NO_3^-]$ (mg/L)**	**$[NH_4^+]$ (mg/L)**
N1	2936.7	299.01	2620	13.5	0.86	0.22	2.57
N2	4075.8	208.86	1193	9.35	0.11	0.45	0.80
N3	4362.8	194.10	936.4	12.3	0.01	0.44	0.05
N5	15490	403.48	3062	10.2	0.01	1.16	0.05
WN1	2047.7	149.27	476.9	13.9	0.01	0.70	0.05

Table A4. Water quality and degree of organic pollution corresponding to a Family Biotic Index range. Table adopted from Hilsenhoff (1988).

Family Biotic Index	**Water Quality**	**Degree of Organic Pollution**
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

8.0 Appendix II

Minitab V. 15 Statistical Outputs

DIVERSITY STATISTICS:

General Linear Model: Diversity versus Site

```
Factor  Type   Levels  Values
Site    fixed       5  City Limits, Mouth, N. Airdrie, S. Airdrie, W NC

Analysis of Variance for Diversity, using Adjusted SS for Tests
Source  DF   Seq SS   Adj SS  Adj MS     F      P
Site     4  131.333  131.333  32.833  6.31  0.008
Error   10   52.000   52.000   5.200
Total   14  183.333
S = 2.28035   R-Sq = 71.64%   R-Sq(adj) = 60.29%

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable Diversity

All Pairwise Comparisons among Levels of Site

Site = City Limits  subtracted from:
Site         Lower  Center    Upper  ------+---------+---------+---------+
Mouth       -13.12  -7.000  -0.8780  (------*-------)
N. Airdrie   -6.46  -0.333   5.7887          (-------*------)
S. Airdrie  -10.79  -4.667   1.4553     (------*-------)
W NC        -12.46  -6.333  -0.2113  (-------*-------)
                                     ------+---------+---------+---------+
                                        -8.0       0.0       8.0      16.0

Site = Mouth  subtracted from:
Site         Lower  Center   Upper  ------+---------+---------+---------+
N. Airdrie   0.545  6.6667  12.789                  (------*-------)
S. Airdrie  -3.789  2.3333   8.455            (-------*-------)
W NC        -5.455  0.6667   6.789          (-------*------)
                                    ------+---------+---------+---------+
                                       -8.0       0.0       8.0      16.0

Site = N. Airdrie  subtracted from:
Site         Lower  Center   Upper  ------+---------+---------+---------+
S. Airdrie  -10.46  -4.333  1.7887     (-------*------)
W NC        -12.12  -6.000  0.1220   (------*-------)
                                    ------+---------+---------+---------+
                                       -8.0       0.0       8.0      16.0
Site = S. Airdrie  subtracted from:
Site   Lower  Center  Upper  ------+---------+---------+---------+
W NC  -7.789  -1.667  4.455        (-------*-------)
                             ------+---------+---------+---------+
                                -8.0       0.0       8.0      16.0

Tukey Simultaneous Tests
Response Variable Diversity
All Pairwise Comparisons among Levels of Site

Site = City Limits  subtracted from:

            Difference       SE of           Adjusted
Site          of Means  Difference  T-Value   P-Value
Mouth           -7.000       1.862   -3.760    0.0242
N. Airdrie      -0.333       1.862   -0.179    0.9997
S. Airdrie      -4.667       1.862   -2.506    0.1649
W NC            -6.333       1.862   -3.402    0.0421


Site = Mouth  subtracted from:
```

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
N. Airdrie	6.6667	1.862	3.5806	0.0319
S. Airdrie	2.3333	1.862	1.2532	0.7231
W NC	0.6667	1.862	0.3581	0.9959

Site = N. Airdrie subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
S. Airdrie	-4.333	1.862	-2.327	0.2132
W NC	-6.000	1.862	-3.223	0.0556

Site = S. Airdrie subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
W NC	-1.667	1.862	-0.8951	0.8924

DENSITY STATISTICS:

General Linear Model: Density (transformed) versus Site

Factor	Type	Levels	Values
Site	fixed	5	City Limits, Mouth, N. Airdrie, S. Airdrie, W NC

Analysis of Variance for Density (transformed), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	4	14.375	14.375	3.594	2.62	0.099
Error	10	13.704	13.704	1.370		
Total	14	28.078				

S = 1.17063   R-Sq = 51.19%   R-Sq(adj) = 31.67%

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Density (transformed)
All Pairwise Comparisons among Levels of Site
Site = City Limits subtracted from:

```
Site         Lower  Center  Upper  ---------+---------+---------+-------
Mouth       -4.119  -0.976  2.167       (----------*---------)
N. Airdrie  -2.261   0.882  4.024             (----------*---------)
S. Airdrie  -4.572  -1.429  1.714      (---------*----------)
W NC        -4.938  -1.795  1.348     (---------*---------)
                                   ---------+---------+---------+-------
                                         -3.0       0.0       3.0
```

Site = Mouth subtracted from:

```
Site         Lower   Center  Upper  ---------+---------+---------+-------
N. Airdrie  -1.285   1.8578  5.001                (---------*----------)
S. Airdrie  -3.595  -0.4527  2.690        (---------*----------)
W NC        -3.962  -0.8189  2.324       (---------*----------)
                                    ---------+---------+---------+-------
                                          -3.0       0.0       3.0
```

Site = N. Airdrie subtracted from:

```
Site         Lower  Center   Upper  ---------+---------+---------+-------
S. Airdrie  -5.453  -2.310  0.8323   (---------*----------)
W NC        -5.819  -2.677  0.4661  (---------*----------)
                                    ---------+---------+---------+-------
```

```
                                                      -3.0       0.0       3.0
```

Site = S. Airdrie subtracted from:

```
Site   Lower   Center  Upper  ---------+---------+---------+-------
W NC  -3.509  -0.3662  2.777         (----------*---------)
                              ---------+---------+---------+-------
                                    -3.0       0.0       3.0
```

Tukey Simultaneous Tests
Response Variable Density (transformed)
All Pairwise Comparisons among Levels of Site
Site = City Limits subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
Mouth	-0.976	0.9558	-1.021	0.8401
N. Airdrie	0.882	0.9558	0.922	0.8820
S. Airdrie	-1.429	0.9558	-1.495	0.5874
W NC	-1.795	0.9558	-1.878	0.3862

Site = Mouth subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
N. Airdrie	1.8578	0.9558	1.9437	0.3561
S. Airdrie	-0.4527	0.9558	-0.4736	0.9881
W NC	-0.8189	0.9558	-0.8567	0.9062

Site = N. Airdrie subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
S. Airdrie	-2.310	0.9558	-2.417	0.1876
W NC	-2.677	0.9558	-2.800	0.1064

Site = S. Airdrie subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
W NC	-0.3662	0.9558	-0.3831	0.9947

FBI STATISTICS:

General Linear Model: FBI versus Site

Factor	Type	Levels	Values
Site	fixed	5	City Limits, Mouth, N. Airdrie, S. Airdrie, W NC

Analysis of Variance for FBI, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Site	4	8.3531	8.3531	2.0883	5.27	0.015
Error	10	3.9595	3.9595	0.3959		
Total	14	12.3125				

S = 0.629244   R-Sq = 67.84%   R-Sq(adj) = 54.98%

Unusual Observations for FBI

```
Obs      FBI      Fit   SE Fit  Residual  St Resid
 10  5.60000  6.77494  0.36329  -1.17494     -2.29 R

R denotes an observation with a large standardized residual.


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable FBI
All Pairwise Comparisons among Levels of Site
Site = City Limits  subtracted from:

Site         Lower  Center  Upper  -------+---------+---------+---------
Mouth        0.313  2.0027  3.692                   (-------*-------)
N. Airdrie  -0.178  1.5108  3.200                (--------*-------)
S. Airdrie  -0.851  0.8383  2.528             (-------*--------)
W NC        -1.410  0.2796  1.969          (-------*--------)
                                   -------+---------+---------+---------
                                       -2.0       0.0       2.0


Site = Mouth  subtracted from:

Site         Lower  Center     Upper  -------+---------+---------+---------
N. Airdrie  -2.181  -0.492   1.19741        (--------*-------)
S. Airdrie  -2.854  -1.164   0.52486     (-------*--------)
W NC        -3.412  -1.723  -0.03380  (-------*--------)
                                      -------+---------+---------+---------
                                          -2.0       0.0       2.0


Site = N. Airdrie  subtracted from:

Site         Lower  Center   Upper  -------+---------+---------+---------
S. Airdrie  -2.362  -0.673  1.0168       (--------*-------)
W NC        -2.921  -1.231  0.4581    (--------*-------)
                                    -------+---------+---------+---------
                                        -2.0       0.0       2.0


Site = S. Airdrie  subtracted from:

Site   Lower   Center  Upper  -------+---------+---------+---------
W NC  -2.248  -0.5587  1.131        (-------*--------)
                              -------+---------+---------+---------
                                  -2.0       0.0       2.0


Tukey Simultaneous Tests
Response Variable FBI
All Pairwise Comparisons among Levels of Site
Site = City Limits  subtracted from:

            Difference       SE of           Adjusted
Site          of Means  Difference  T-Value   P-Value
Mouth           2.0027      0.5138   3.8981    0.0195
N. Airdrie      1.5108      0.5138   2.9406    0.0859
S. Airdrie      0.8383      0.5138   1.6316    0.5116
W NC            0.2796      0.5138   0.5442    0.9802


Site = Mouth  subtracted from:

            Difference       SE of           Adjusted
Site          of Means  Difference  T-Value   P-Value
N. Airdrie      -0.492      0.5138   -0.957    0.8678
S. Airdrie      -1.164      0.5138   -2.266    0.2322
W NC            -1.723      0.5138   -3.354    0.0454


Site = N. Airdrie  subtracted from:
```

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
S. Airdrie	-0.673	0.5138	-1.309	0.6923
W NC	-1.231	0.5138	-2.396	0.1933

Site = S. Airdrie subtracted from:

Site	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
W NC	-0.5587	0.5138	-1.087	0.8092

% EPT STATISTICS:

Kruskal-Wallis Test: %EPT versus Site

Kruskal-Wallis Test on %EPT

Site	N	Median	Ave Rank	Z
City Limits	3	25.8064516	14.0	2.60
Mouth	3	0.0001000	5.0	-1.30
N. Airdrie	3	2.5641026	11.0	1.30
S. Airdrie	3	0.0001000	5.0	-1.30
W NC	3	0.0001000	5.0	-1.30
Overall	15		8.0	

H = 10.80 DF = 4 P = 0.029
H = 13.75 DF = 4 P = 0.008 (adjusted for ties)

* NOTE * One or more small samples