Swift Current Creek Watershed Monitoring Project

Final Report

SWIFT CURRENT CREEK
Watershed Stewards

Acknowledgements

A multi-year monitoring program such as this requires hard work and dedication, two characteristics which aptly define the Swift Current Creek Watershed Stewards (SCCWS). Over the past four years, the SCCWS and multiple staff and volunteers have collected enormous amounts of crucial information about our watershed. Even though the close of the sampling project has come and gone, the work has just begun. The data collected over the past four years will aid the SCCWS and its partners to develop a Source Water Protection Plan that will maintain and improve the health and function of our watershed. This plan will benefit everyone who relies on the Swift Current Creek for their daily and future water needs. Over the years, the SCCWS have proven that they are an innovative, driven, and enthusiastic group of people whose main focus is in fostering awareness of our watershed. I have thoroughly enjoyed working for the SCCWS, a strong group of thoughtful and committed people dedicated to improving the environment around them.

First, I would like to thank the architect of this project, Cher King. Cher worked tirelessly to develop the easy-to-follow sampling protocols for water, fish and macroinvertebrates, determining sample sites, and creating the first interim report that was to be the basis of the following three reports. Thank you for all of your hard work, dedication, and passion to the development of this environmental project, the first of its kind in Saskatchewan! Thanks also to the 2005 and 2006 project managers Jenna King and Ron Jensen, your hard work has provided the SCCWS with important information about our watershed and we would not be where we are today without your help.

Another person who is passionate about our environment and who is an integral component to this project is Arlene Unvoas. Arlene is the ‘heart’ of the monitoring project and she has been the stewards’ coordinator for the last four years. Arlene always has time to listen to any problems encountered with the project and she is always enthusiastic and willing to provide ideas and solutions to make the project run more smoothly. She works harder, I believe, than anyone else involved with the project. Her passion for the environment and determination to build new partnerships has allowed the Swift Current Creek Watershed Stewards to grow from a small collection of environmentally aware individuals to a well-respected, progressive organization throughout south-west Saskatchewan. Thank you, Arlene, for all of your hard work throughout the years.

Second, I would like to thank everyone who helped with the project over the last four years. At any one time there are one to eleven volunteers helping the project manager collect data from the field. Without the help of hard working employed staff, summer staff, and volunteers, this project would not have come to fruition. My sincere thanks to the City of Swift Current, Prairie Farm Rehabilitation Administration (PFRA) and Saskatchewan Watershed Authority (SWA) who provided the SCCWS with excellent workers over the years! Big thanks to SCCWS, PFRA, and SWA employees who took time out of their own busy schedules to help with data collection. Personally, the volunteers made data collection an event I looked forward to. I believe I speak for all the previous project managers when I say working with each one of you was an excellent experience, thank you.

Third, thank you to everyone who provided the SCCWS with much needed sampling equipment. Thank you to Doug Smith for the use of your van for fish sampling, Ron Jensen for your beach seine net and hand net, Rick West with Fisheries and Oceans Canada (DFO) for the use of a beach seine net and Keith Hanson for providing a dissecting microscope. Thanks to SWA for providing myself with a positive work environment and also to Rod Piche for the use of the warehouse for storage and workspace!

Fourth, I would like to thank the SCCWS management and technical committees for volunteering your time and providing advice and solutions to the many questions and dilemmas throughout the sample seasons.

Special thanks to Bix Biederbeck and Iain Phillips who provided valuable advice on the structure and content of this final report. A report of this size with three years of sample data is daunting and Bix and Iain were my guides through the 'forest' of data.

Finally, thank you to all the landowners for access to your land for field sampling. This project would not have been possible without your participation.

Sincerely,

Alicia Tait,
2007 Program Manager,
Swift Current Creek Watershed Stewards,
July 31, 2008

The Board of the Swift Current Creek Watershed Stewards would like to thank Alicia Tait for the many hours she dedicated to the completion of this project and this report.

THE SCCWS WOULD LIKE TO THANK THE FOLLOWING SPONSORS

CARDS

Saskatchewan Ministry of Agriculture

Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

Saskatchewan Watershed Authority

Fisheries and Oceans Canada / Pêches et Océans Canada

Swift Current Saskatchewan Wildlife Federation

City of Swift Current – where life makes sense

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THANK YOU FOR ALL YOUR SUPPORT THROUGHOUT THE YEARS!

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Executive Summary

The Swift Current Creek Watershed Stewards (SCCWS) monitoring project gathered data for four years and began in 2004; however, only the last three years (2005-2007) are included in the statistical analysis for this final report. The 2004 data was eliminated from statistical analyses due to a significant change in sampling protocols from 2004 to the latter sampling years. It was extremely important that the SCCWS have three years of consistent data for sound multi-year comparisons of the data. Therefore, this final report incorporates the sample data collected from the 2005-2007 sample years only.

The water quality data was analyzed using the 2006 Saskatchewan Water Quality Objectives. The Saskatchewan Water Quality Objectives analyzes water quality for four uses: irrigation, livestock watering, aquatic life and general water quality. According to the water quality index, water quality for irrigation has improved from 2005 at 4 of 7 sample sites. Similarly, the water quality for livestock watering has remained in excellent condition at 5 of the 7 sample sites and improved at 2 of the 7 sample sites. Water quality for aquatic life has improved at 4 of 7 sample sites from 2005. This improvement in water quality may be the result of the new WWTP (waste water treatment plant) that became operational in 2006. However, there is a marked decrease in water quality at the sample site within Swift Current city limits (located upstream from the WWTP). Overall general water quality has seen an increase in water quality at 6 of the 7 sample sites while water quality at the remaining sample site was consistently in good condition from 2005-2007.

Macroinvertebrate sampling showed no annual trends in abundance, diversity, richness, dominant family, modified Hilsenhoff's Biotic Index (FBI), and evenness; however an annual trend could be assessed for percent EPT (a measure of pollution intolerant macroinvertebrates: Ephemeroptera, Plecoptera, Trichoptera). An increase in percent EPT was observed in 2007 when compared to the previous two years. This find may be indicative of improving water quality and substrate conditions. Multivariate analyses indicated that nitrogen was a dominant ecosystem stressor in the Swift Current Creek (SCC) in two of the three sample years. High levels of nitrate and nitrite nitrogen were associated with low taxonomic richness and low EPT scores in macroinvertebrate communities. The high nitrite and nitrate nitrogen levels affected 2 of the 6 sample sites.

The statistical analyses carried out on the three years of data collected on white suckers and fathead minnows could only be conducted on white suckers. In order to include the fish data into the final statistical analyses, 100 individuals of each sentinel species (white sucker and fathead minnow) at each sample site were required. The minimum amount of white sucker individuals (100) were collected every year at each sample site; however, fathead minnows fell short of meeting the 100 individuals mark at several sample sites over the years. As a result, the fathead minnow data was omitted from the statistical analyses to prevent a skew in the final results. The final analysis of the fish data showed no annual trends in the length, weight or condition factor of white suckers. In addition to this, there was not enough variation in the water data to test for possible effects on the white sucker population. In order to attain more rigorous data, it is suggested that the SCCWS implement more years of sampling as well as more frequent data collection for both the white suckers and water quality.

1 INTRODUCTION

In the summer of 2003, the Swift Current Creek Watershed Stewards (SCCWS) decided to undertake a watershed monitoring project in response to ongoing public concerns about water quality in the Swift Current Creek. These concerns continued among stakeholders and watershed residents despite several years of participation in successful public education and awareness initiatives. Furthermore, several attempts to compile existing water quality data from several sources proved impossible for addressing the specific concerns of the Swift Current Creek stakeholders. Without any scientific basis for discussion, finger-pointing continued among groups. In order to address these concerns and data gaps, the Swift Current Creek Watershed Monitoring Project was developed. The project was a multi-year, watershed scale monitoring project grounded in nationally approved, scientific data collection methods, yet adapted specifically to the social economic, and ecological concerns voiced in the Swift Current Creek Watershed. The overall objective of the program was to assess the current health of the Swift Current Creek Watershed.

This report presents the detailed methods, results, and discussion of the project's three main components (water, fish and macroinvertebrates) over the last three years.

2 BACKGROUND INFORMATION

2.1 Swift Current Creek Watershed Stewards History

The SCCWS is a non-profit organization that promotes ecological sustainability within the watershed. We are watershed residents partnering with government representatives to locally design and deliver programs and initiatives that follow an ecosystem and watershed approach to cooperative planning and management of our resources. We are building the capacity for our community to promote the stewardship ethic for the long-term.

Incorporated in 2001, the SCCWS has a member base of 25 people. Our membership is based on the concept of stakeholder representation, where members are part of our social and economic community and are able to contribute skills, experience, technical and financial support to build capacity for our initiatives. Through applied research, information, and local knowledge, the mission of the SCCWS is to enhance water quality and stream health within the Swift Current Creek Watershed by promoting awareness and understanding among water users. The SCCWS will achieve our mission by working through three specific phases of activities that correspond with our three corporate goals.

Our three goals include:

Goal 1: Educate water users of the watershed, on a continuous basis, about issues and impacts which affect water quality.

Goal 2: Monitor water quality and riparian health to assist in cooperative solutions regarding water management issues.

Goal 3: Foster an attitude of individual responsibility toward watershed stewardship through project implementation with individual landowners.

2.2 Development of the Project

Through evaluation of the results and implications of past sampling initiatives for the SCC, it was clear to the SCCWS there was a need to create a project that would address the following stakeholder concerns:

1) Are there water quality and watershed health problems in our watershed?
2) If so, for which areas are the problems the greatest?
3) Can we improve on any watershed health problems that exist?

As a relatively new organization, the SCCWS did not have the technical capacity to design and implement a monitoring project that would be rigorous enough to stand up to the critique of multiple stakeholders while providing definitive results. Thus, the organization reached out to technical experts within federal and provincial government agencies to assist in creating protocols that recognize the complexity of the watershed environment and the perceived problems within the watershed.

From the economic and community perspective, members of the SCCWS, who are local agricultural producers, government representatives, and watershed residents, continued to communicate and educate one another on their knowledge of the watershed to identify the gaps in their understanding of water quality and watershed health.

The SCCWS launched the project in 2004. At the time, the monitoring component was to run for 4 years from 2004 to 2007 inclusive. Upon the completion of the 2007 sample year, the SCCWS realized that the data collected from the first sample year (2004) was not consistent with the 2005-2007 sample data. The 2004 data pointed out flaws in the sampling protocols as well as the need to establish four more sample sites. For example, water sampling did not begin in 2004 until July; whereas, the following sample years began water sampling in May. Protocols for fish and macroinvertebrate sampling also changed. In 2004, barrier nets were not put up 100m above and below the hub to 'quarantine' the fish in the sample area as they were in subsequent years. In addition, the sorting of macroinvertebrates was conducted on dead macroinvertebrates whereas, succeeding years performed sorting on live macroinvertebrates. Live sorting proved to be more efficient as the invertebrates were more easily spotted moving on the sorting screens. Thus, it is likely that more macroinvertebrates were spotted using this technique. These changes in protocols between 2004 and the following sample years have forced the SCCWS to discard the 2004 sample data from the final analysis. Although this is unfortunate, it is important that the SCCWS have three years of consistent data to all statistical multi-year comparisons. Therefore, this final report incorporates the sample data collected from the 2005, 2006, and 2007 sample years only.

2.3 Characteristics of the Study Area

This section of the final report contains the background information necessary to interpret the results of the final report. Section 2.3.1 provides comments on the watershed in general locations of point and non-point sources of stressors to environmental quality and comments on stressors that may have influenced sample results over the last three years. The next sections provide information on the physical and biological characteristics of the watershed at multiple scales (Fig.1) including watershed scale (2.3.2) reach scale (2.3.3) and cross section or site scale (2.3.4).

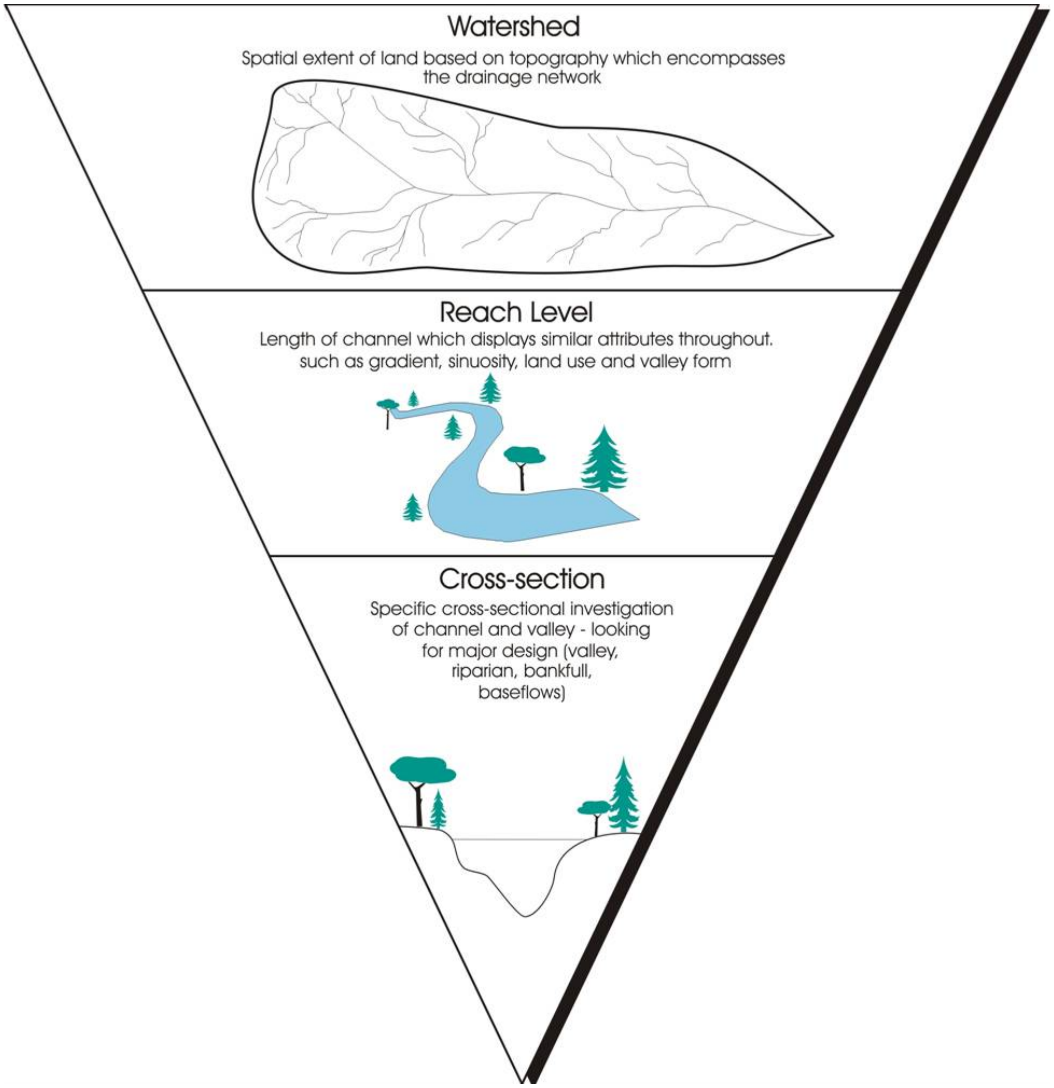

Figure 1: Scales of observation for watershed studies (Adapted from Carruthers Creek: State of the Watershed Report)

The SCC is the largest tributary to the South Saskatchewan River in Saskatchewan (Fig. 2). Originating in Cypress Hills, the SCC continues north-easterly to the town of Waldeck and then turns directly northward to Lake Diefenbaker (Fig. 3). The Swift Current Creek Watershed is part of the Prairies ecozone, which is characterized by open grasslands with little topographic relief and a semiarid climate (short hot summers, long cold winters, low precipitation and high evaporation) as proposed by Acton, Padbury, & Stushnoff (1998).

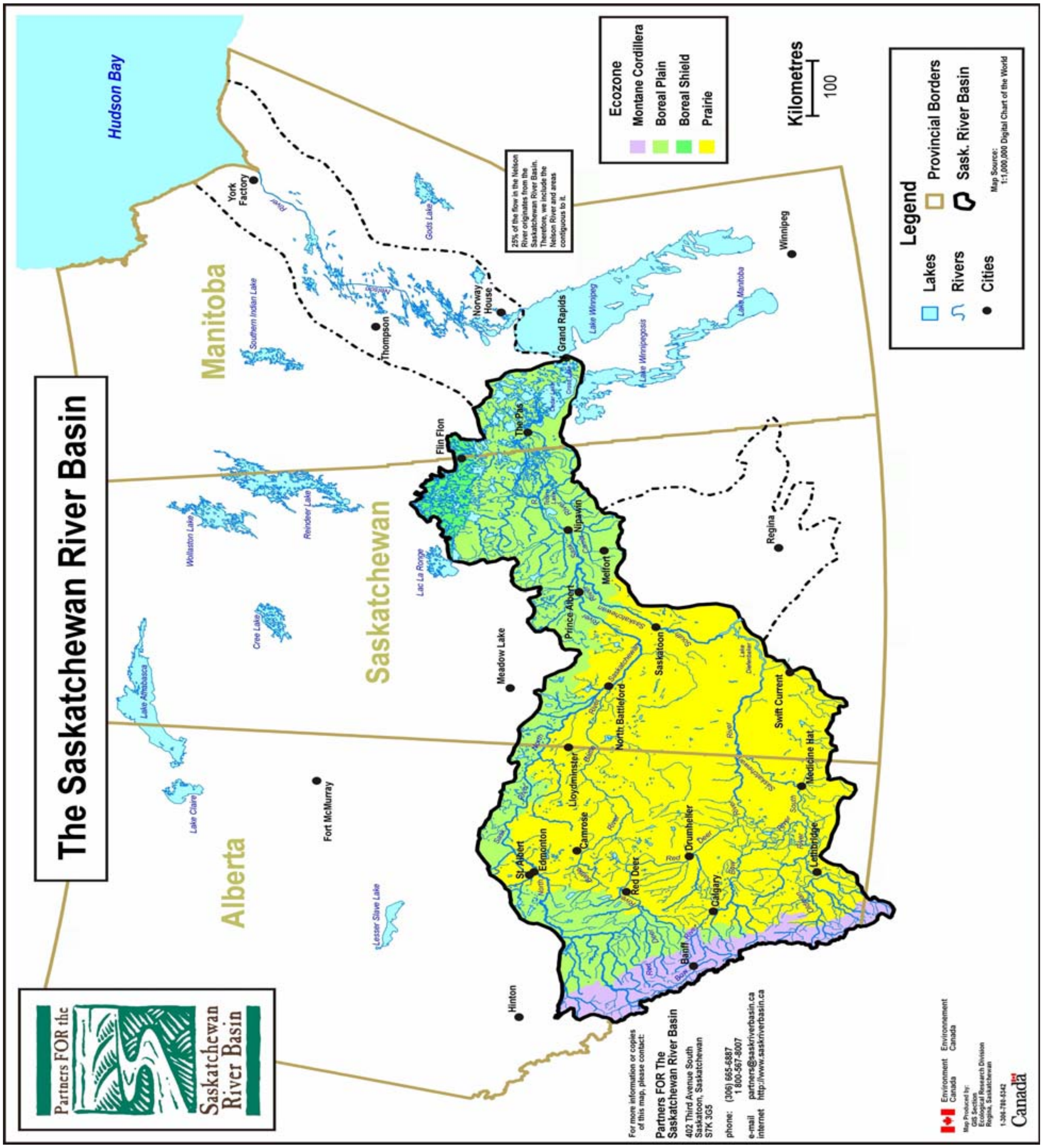

Figure 2: The Saskatchewan River Watershed
(Map from Partners FOR the Saskatchewan River Basin).

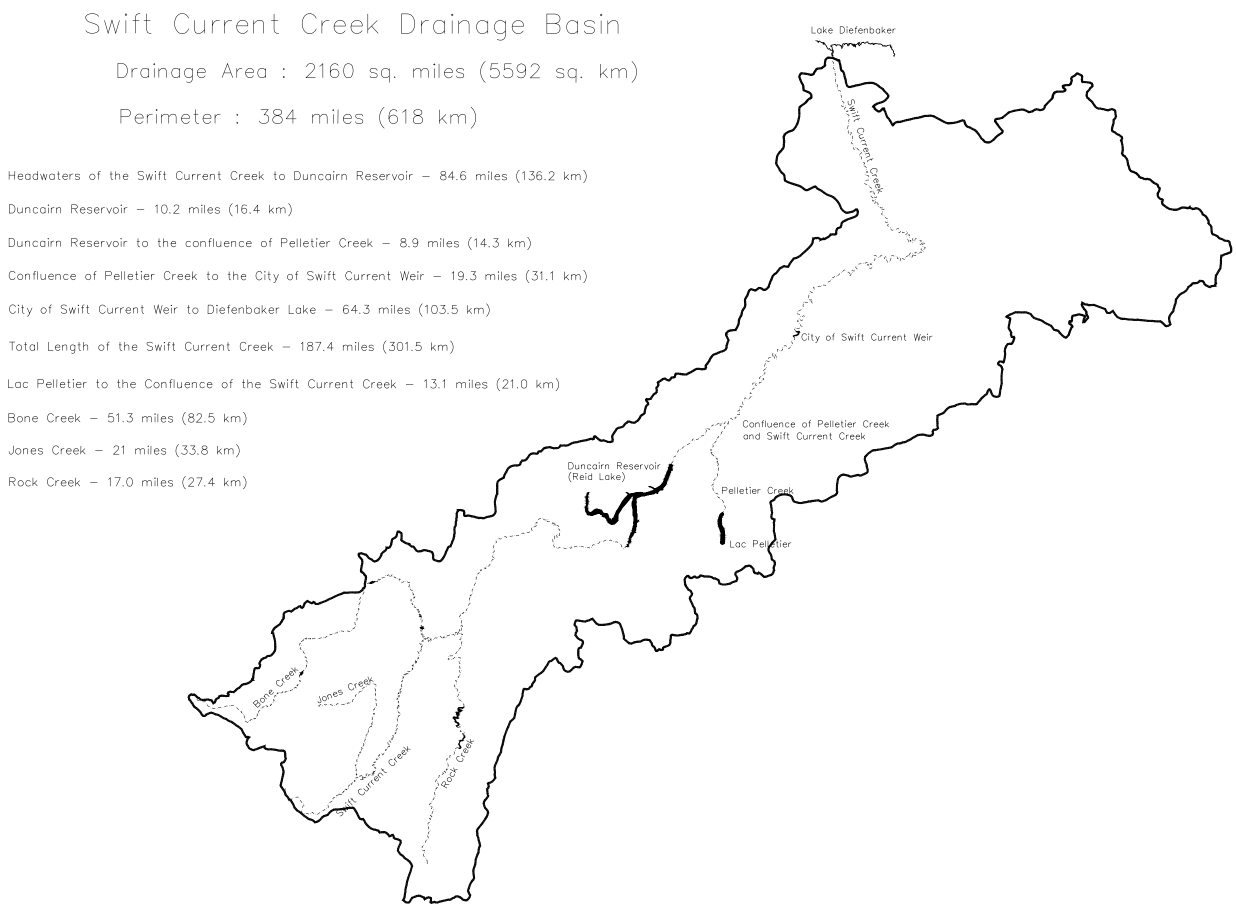

Figure 3: Information Map of the Swift Current Creek Drainage Basin (Randy McKeil, 2005)

Table 1: Average Temperature (in Celsius) and Total Rainfall (in mm) for 2005-2007

	AVERAGE TEMPERATURE (Celsius)		
	2005	2006	2007
May	9.8	12.5	11.6
June	14.7	16.2	15.9
July	18.6	21.2	22.8
August	16.4	19.2	17.7

	TOTAL RAINFALL (mm)		
	2005	2006	2007
May	22.4	43.5	37.3
June	123.2	99.9	56
July	21.4	26.3	12.1
August	52.1	24.1	23.4

2.3.1 Point and non-point sources of stressors

There are a variety of water resource uses of the creek system, including agricultural use for crop and hay land irrigation and livestock watering, municipal use for irrigation, drinking water supply and integration of municipal wastes, industrial water use (i.e. oil and gas development), and recreational use. These water uses can, in some cases, become environmental stressors.

Agricultural land use is the most probable non-point source of stressors on the environmental quality for the SCC system since agriculture is wide-spread throughout the watershed. Probable point sources of stressors on environmental quality include oil and gas developments in close proximity to the creek as well as two municipalities (Shaunavon and Swift Current) discharging effluent and/or storm runoff into the creek. The several dams and reservoirs created for irrigation and our drinking water supply may also act as stressors on environmental quality within the watershed. The dams and reservoirs include Duncairn Dam and Reid Lake, Swift Current weir and reservoir and the old CPR dam.

Creek flows during the summer months are typically low, except during water releases for irrigation. In 2007, there were two water releases for irrigation. Thanks to the newly installed WWTP there were no effluent releases by the City of Swift Current in 2007 as there was in 2006.

2.3.2 Watershed-scale characteristics

According to Acton, Padbury, & Stushnoff (1998), the Swift Current Creek Watershed has a total drainage area of 5592 km^2 and a perimeter of 618 km. The mainstem of the creek is about 302 km long and the tributaries (Bone Creek, Jones Creek, and Rock Creek) are cumulatively about 144 km long. SCC is a fourth order stream. The longitudinal profile of the SCC illustrates an overall slope of approximately 0.2% with a maximum elevation of 1143m at the headwaters and a minimum elevation of 556m at Lake Diefenbaker (Fig. 4).

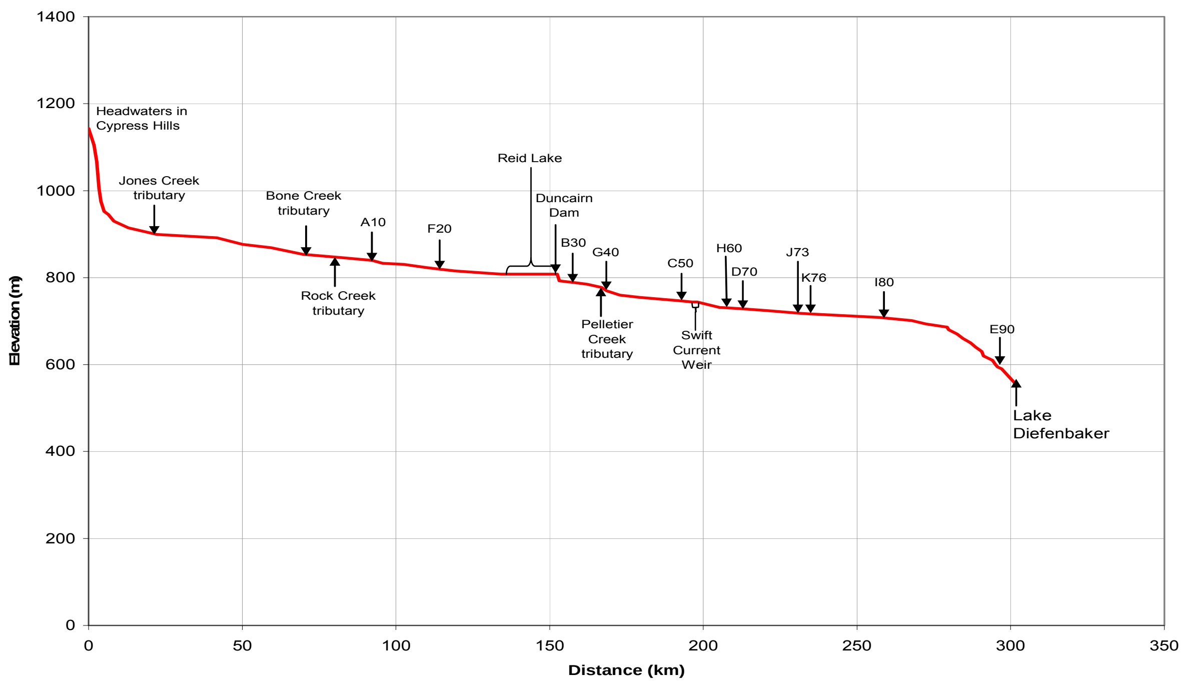

Figure 4: Longitudinal profile of the Swift Current Creek

2.3.2.1 Physical Aspects

The Department of Mineral Resources (1959) states that the physical geography of the Swift Current Creek Watershed is controlled by its history of glaciation. The watershed area is defined by the bedrock (Upper Cretaceous Bearpaw Formation) that has been re-worked and modified by glaciers, glacial movement, and running water. The wide valley seen in most areas along the SCC originated as a glacial meltwater wide valley. This valley originated as a glacial meltwater channel; thus, the present creek channel is cut-in or incised into the larger meltwater valley.

This history dictates the diverse soils and surface characteristics such as texture, water drainage, terrain slope, amount of sand and gravel in the area, potential for wind and water erosion, salinity and surface pH (Table 2, Fig. 5) (Department of Mineral Resources 1959). Two types of soils information are relevant to the monitoring project: first, the characteristics of the stream channel and stream valley bottoms, and second, the characteristics of the upland/plateau areas.

According to Mitchell and Clayton (1944), the soils in the creek channel and in the wide valley bottoms of the stream are mainly alluvial, which means that bedrock and glacial material around the valleys were deposited by the water flowing through the valley bottoms creating soils of variable material and texture. The alluvial nature of the soil continues from the headwaters of the system through the watershed meaning that they are weakly developed soils formed by surrounding upland materials eroding from the steep valley sides into the valley channels. This indicates that the deep creek valley leading to Lake Diefenbaker was formed in glacial times and remnants of these soils remain today.

The soils and surface characteristics of the upland/plateau areas are variable throughout the watershed (Mitchell and Clayton 1944). In the headwater areas leading to the confluence of SCC and the south arm of Reid Lake (Township 11, Range 17), the soils and surficial materials are boulders, stones and other debris deposited by glaciers (morainal). In the areas surrounding the upland of Reid Lake through to the City of Swift Current, the soils were created from materials deposited by wind processes (eolian). From Swift Current through to Leinan area, the soils and surficial materials are morainal; whereas the soils from Leinan to Lake Diefenbaker are glacio-fluvial or soils created from material deposited from glacial rivers and glacial lakes.

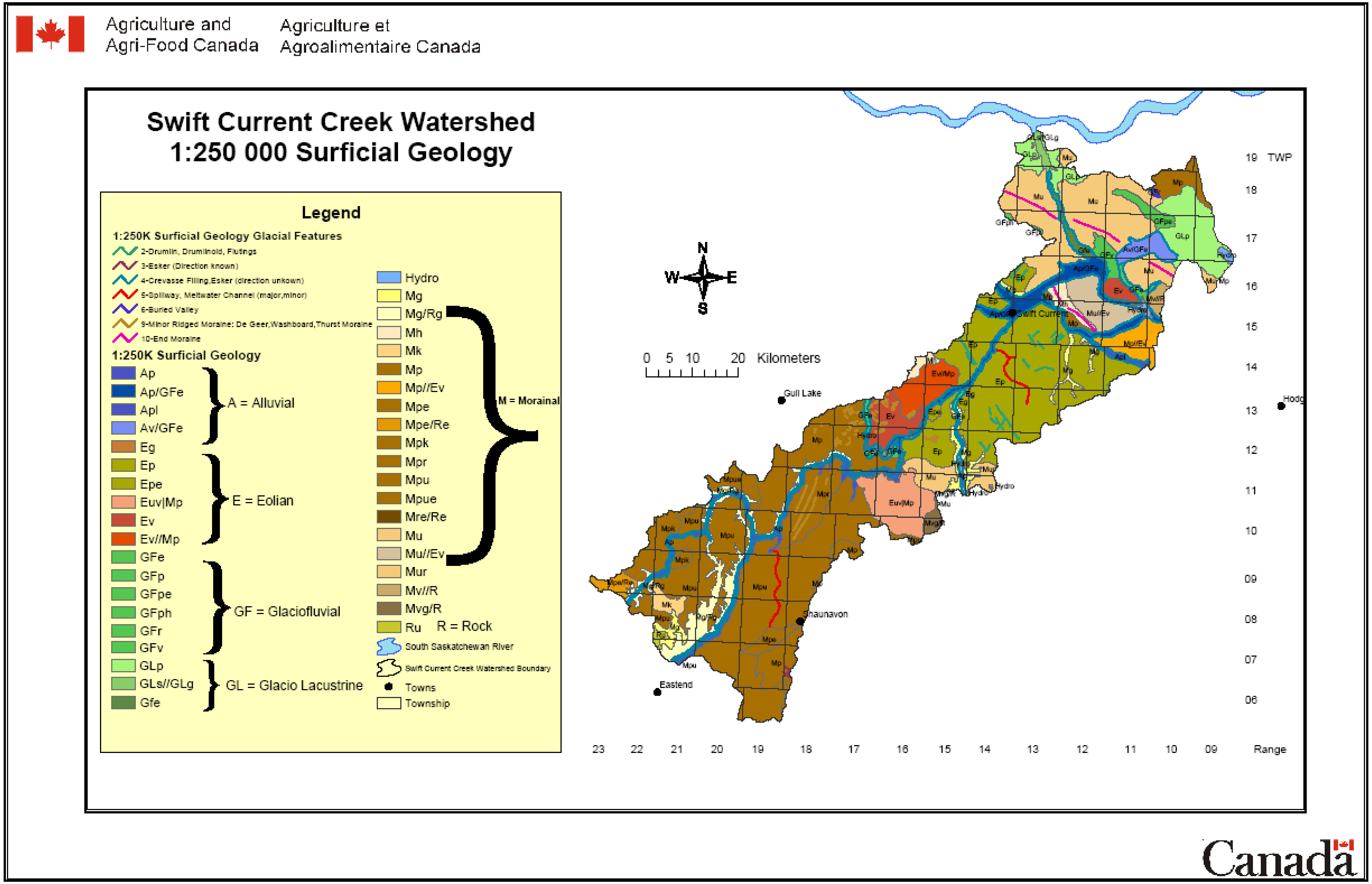

Figure 5: Swift Current Creek Watershed Surficial Geology Map (Yasul, 2004)

Table 2:Soils and Surficial Geology of the Swift Current watershed sampling sites
*Note that Brown Chernozemic soils are dominant throughout the watershed

Site	Surface Texture	Water Drainage in Area	Sand and Gravel in Area	Wind Erosion	Terrain Slope	Water Erosion	Salinity	Surface pH Class
A10	Silty Clay Loam	Accumulates	Yes	Moderate	2 to 10%	Low	Moderate	6.8 to 7.5
F20	Silty Clay Loam	Accumulates	Yes	Moderate	No Info	Low	Moderate	No Info
B30	Sandy Loam- Clay Loam	Accumulates	Yes	High	2 to 5%	Low	Strong	>7.5
G40	Sandy Clay Loam	Accumulates	Yes	High	No Info	Low	Strong	No Info
C50	Clay Loam-Clay	Accumulates	Yes	High	0.5 to 5%	Low	Weak	6.8 to 7.5
H60	Sandy Clay Loam	Accumulates	Yes	High	No Info	Low	No Info	No Info
D70	Loam-Clay Loam	Accumulates	Yes	Low	0.5 to 5%	Low	Strong	> 7.5
I80	Loam	Accumulates	Yes	Low	No Info	Low	No Info	No Info
E90	Loam	Runoff	Unknown	Moderate	15 to 30%	Very High	Non-Saline	>7.5

2.3.2.2 Habitat Classification

Based on a habitat classification paper issued by the U.S. Fish & Wildlife Service (1979), SCC is a riverine system that is comprised of three types of subsystems: intermittent areas, lower perennial areas, and upper perennial areas. The following section discusses the characteristics of each of these subsystems and how the subsystems relate to the sampling sites in this project.

In intermittent areas, the creek channel only contains flowing water for part of the year. Thus, for the SCC, the intermittent areas would be mostly contained to smaller tributaries flowing into the SCC and some of the headwater areas of Bone Creek, Jones Creek, Rock Creek and the south fork of the SCC. We do not have a sampling location in an intermittent area.

In lower perennial areas, the gradient of the stream channel is low and water velocity is slow, but flows throughout the year. The substrate consists mainly of sand and mud and the floodplain is well developed. In these areas, the fauna is composed mostly of species that reach their maximum abundance in still water and true planktonic organisms are common. Eight out of nine of our monitoring sites (A10 to I80) can be classified as lower perennial areas.

In upper perennial areas, the stream gradient is higher and the water velocity is faster. The substrate consists of rock, cobble, and gravel with occasional sandy patches. The fauna of these areas is characteristic of running water with few or no planktonic forms. Sampling site E90 conforms to the characteristics of an upper perennial area.

The terrestrial plants and animals in the watershed are not considered in this monitoring project. However, we provide a list of species taken from the Swift Current Creek Watershed Background Report pertaining to this area.

Vegetation:

- Vegetative species: spear grass (*Poa annua*), blue grama grass (*Bouteloua gracilis*), wheat grass (*Agropyron elongatum*), junegrass (*Koeleria macrantha*), alkali grass (*Puccinellia distans*), wild barley (*Hordeum jubatum*), greasewood (*Sarcobatus wermiculatus*), red samphire (S*alicornia rubra*), sea blite (*Suaeda depressa*), and dryland sedge (Carex spp.)
- A variety of shrubs and herbs including sagebrush (*Artemesia tridentata*), and prickly pear cactus (*Opuntia polyacantha*)
- *Scrubby aspen (Populus spp*.), wi*llow (Salix spp.), cottonwood (Populus spp*.), and box-elder (*Acer negundo*)

Animals:

- Mammal species: mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*), coyote (*Canis latrans*), pronghorn antelope (*Antilocapra americana*), badger (*Taxidea taxus*), white-tailed jack rabbit (*Lepus townsendii)*, Richardson's ground squirrel (*Spermophilus richardsonii*) and northern pocket gopher (*Thomomys talpoides*), Swift fox (*Vulpes velox*).
- Bird species: sage grouse (*Centrocercus urophasianus*), ferruginous hawk (*Buteo regalis*), Swainsons's hawk (*Buteo swainsoni*), American avocet (*Recurvirostra americana*), burrowing owl (*Athene cunicularia*), great blue heron (*Ardea herodias*), black-billed magpie (*Pica hudsonia*), northern oriole (*Icterus galbula*), brown thrasher (*Toxostoma rufum*), and killdeer (*Charadrius vociferous*), bald eagle (*Haliaeetus leucocephalus*) and golden eagle (*Aquila chrysaetos*).
- Short-horned lizard (*Phrynosoma douglassi*), western rattlesnake (*Crotalus viridis*), northern leopard frog (*Rana pipiens*)

Fish:

- Fish species: northern pike (*Esox lucius*), walleye (*Stizostedion vitreum vitreum*), and white sucker (*Catostomus commersoni*)
- Minnow species: shorthead redhorse (*Moxostoma macrolepidotum*), longnose dace (*Rhinichthys cataractae*), northern redbelly dace (*Phoxinus eos*), iowa darter (*Etheostoma exile*), creek chub (*Semotilus atromaculatus*), brook stickleback (*culaea inconstans*), brassy minnow (*Hybognathus hankinsoni*), fathead minnow (*Pimephales promelas*).

Aquatic Macroinvertebrates

No previous survey of any kind exists for this creek system.

2.3.3 Reach-Scale Characteristics

For most watershed or hydrological studies, the researcher would divide the watershed into different geological reaches or lengths of channel that display similar attributes throughout such as gradient, sinuosity, land-use and valley form. The SCCWS did not divide the watershed into reaches based on these characteristics, but rather we divided the reaches based on the position of our sampling locations. Furthermore, our sampling locations were based on criteria such as the locations of past data collection, whether the location was useful for our research questions, and whether or not the site was easily accessible year-round. Therefore, we recognize that the resulting reaches may not match the reaches that have been defined in other studies of the same watershed.

Spatially, the sampling sites were chosen to represent major division in land-use or potential land-use impacts throughout the watershed (Fig. 6).

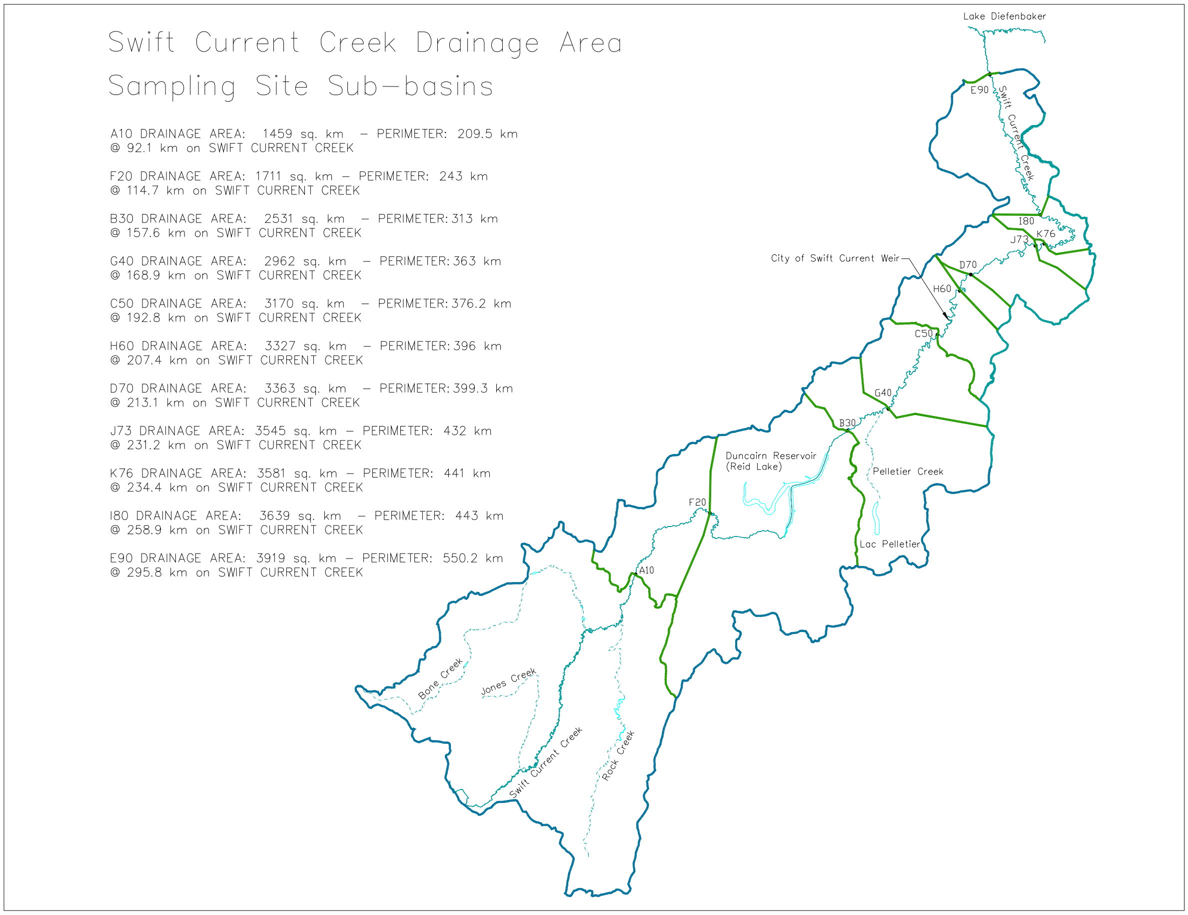

Figure 6: Map of the sampling sub-basins within the Swift Current Creek Watershed

The monitoring project was designed to be iterative, which means that the SCCWS adapted the sampling design each year based on the results from the previous year. Additional sampling sites have been added along the creek based on finding 'effects' or differences among sampling sites for either the water quality or bioassessment components. Thus, we have designed the sampling site with letters (A through E) and numbers (10-90). The letters designate the order of the sampling locations in time (starting at the beginning of the alphabet in 2004) and the numbers or the locations in space (10 is most upstream and 90 is the most downstream). For example, in 2005 an additional site was placed between A10 and B30, we labeled it F20 indicating that it was added after the original stations, but is midway between two previous sections. Within a given sample year, all of the locations were sampled a total of five times beginning in May and finishing in September. However, the types of samples taken at a particular site varied on each sampling trip according to the quality control requirements for the project.

In 2007, two sites that were implemented in 2006, J73 and K76, were eliminated. These two sites were initially added to determine why there were unusually high dissolved organic phosphorus levels in the creek. However, these two sites provided no explanation of the high phosphorus levels and were subsequently removed from the sample list.

2.3.4 Cross-section or site scale characteristics

When considering cross-sectional scale characteristics of a section of stream, we are looking for the major design of the valley, riparian zone, and bankfull channel characteristics. At each of our sampling sites, the available floodplain was three meters above the average summer water depth.

The present stream channel is moderately confined or incised in most areas; the broad valley and floodplains above the current channel are artifacts of glacial re-working of the land surface. The SCC is most often a single channel that is straight to sinuous depending on local topography, with the exception of braided sections in the upper perennial area close to Lake Diefenbaker.

Initial riparian assessments will be conducted on sites that are being established. The SCCWS did not add any sites to the sample forum in 2007and thus no riparian assessments were carried out.

3 MONITORING APPROACH AND METHODS

The Swift Current Creek Watershed Monitoring Project was designed to assess the health of our watershed using two types of analyses: water quality index and bioassessment. Within the bioassessment methods, we used fish surveys and benthic macroinvertebrate surveys. For each type of data collection, the SCCWS have written protocol manuals that provide step-by-step instruction on planning and implementing the field season. This chapter, "Monitoring Approaches and Methods" provides the reader with a general overview of each type of sampling and the actual protocols that were followed from 2005-2007.

From 2005-2007 the SCCWS sampled water quality from May to September at all 9 sites. Fish community and population sampling occurred in late July at 5 of the 9 sites and macroinvertebrate community sampling occurred in late August at 6 of the 9 sites in the watershed. These sampling locations were chosen based on the following criteria: historical data collection sites, year-round accessibility, expected water uses, and potential point and non-point sources of stressors. If possible, the sites would have similar depth, substrate, flow, vegetative cover, and expected water quality aside from land-use factors that were suspected to be degrading water quality. We tried to minimize the potential for confounding factors such as tributaries, point and non-point source discharges, natural environmental and habitat variables, as well as historical damage. Where this was not possible, we have thoroughly documented the potential confounding factor. We recognize that the sites are not 'perfectly representative,' but given the diversity of the locations in our watershed, we consider them appropriate for the intended use of the data: a watershed water quality scan.

Spatially, the sampling sites were chosen to represent major divisions in land-use or potential land-use impacts throughout the watershed (Fig. 6). Site A10 is the most upstream site and serves as a reference for all other sampling sites in the watershed. This site is not intended to be pristine, but rather indicative of the upstream land-use. Site F20 was added to narrow the possible sources of increased nitrogen and phosphorus and to determine what impacts Duncairn Dam has on the water quality through a comparison with B30. Site B30 is downstream of Duncairn Dam and allowed us to consider the impact of the dam on creek health. Site G40 was added to narrow the possible sources of increased nitrogen and phosphorus. Site C50 is immediately upstream of the City of Swift Current, but downstream of several mixed farms and ranches along the creek. This site helps identify agricultural impacts and allows comparisons with sites downstream of the City of Swift Current to determine urban impacts on the creek. Site H60 was added to determine urban impacts on the creek before the sewage lagoons and WWTP and determine the source of increased sodium and TDS levels. Site D70, downstream of the City of Swift Current, allowed us to consider the urban impact (sewage lagoons and WWTP) on creek health. Site I80 was added to help determine the source of sodium and TDS levels. Site E90, the farthest downstream site, considers the cumulative impacts of land-use and current management practices on stream health.

3.1 Water Quality Testing

The analysis of water samples is an important tool in assessing the quality of surface water and its suitability for various uses. Water quality in surface water bodies varies widely depending upon its source, mean water depth, flow rate, and the type and quantity of pollutants added through point and non-point sources. Water quality is also affected by climatic factors such as temperature, sunlight, and wind.

The water quality of a specific water body may or may not be suitable for all uses. The Saskatchewan Surface Water Quality Objectives (Saskatchewan Environment, 2006) are used to assess the suitability of water for any particular use based on its physical, chemical, and microbiological characteristics. Water quality data can also be used to calculate a 'Water Quality Index', which is used to rate the quality of a specific water body in relation to others and can also indicate possible limitations for a particular use.

3.1.1 Sample Collection and Handling

The SCCWS collected water samples with the purpose of calculating the Saskatchewan Water Quality Index (SWQI) for each water use described in the Saskatchewan Surface Water Quality Objectives. The SCCWS collected three types of data at nine sites (A10, F20, B30, G40, C50, H60, D70, I80 and E90) along the SCC. First, standard hydrometric techniques (pygmy flow meter, wading rod, and measuring tape) were used to measure the wetted area of the stream channel. Water velocity measurements were used to calculate the stream flow (cubic feet per second). Second, the SCCWS recorded several in-stream water characteristics including pH, conductivity, temperature, and dissolved oxygen using field equipment provided by PFRA from Swift Current. Third, the SCCWS gathered and processed grab samples of water from each site. These grab samples were sent by courier to the Saskatchewan Research Council (SRC) lab for processing within 24 hours. Table 2 summarizes the parameters measured by SRC at all sampling sites over the last three years.

Table 3: Parameters measured at all nine sampling sites in 2007.

	A10	F20	B30	G40	C50	H60	D70	I80	E90
Aluminum (mg/L)	√	√	√	√	√	√	√	√	√
Ammonia as nitrogen (mg/L)	√	√	√	√	√	√	√	√	√
Arsenic (µg/L)	√	√	√	√	√	√	√	√	√
Boron (mg/L)	√	√	√	√	√	√	√	√	√
Chloride (µg/L)	√	√	√	√	√	√	√	√	√
Chromium (mg/L)	√	√	√	√	√	√	√	√	√
Copper (mg/L)	√	√	√	√	√	√	√	√	√
E. coli (ct/100mL)	√	√	√	√	√	√	√	√	√
Fecal Coliform (ct/100mL)	√	√	√	√	√	√	√	√	√
Inorganic Phosphorus, dissolved (mg/L)	√	√	√	√	√	√	√	√	√
Mercury (µg/L)	√	√	√	√	√	√	√	√	√
Nitrite + Nitrate nitrogen (mg/L)	√	√	√	√	√	√	√	√	√
pH	√	√	√	√	√	√	√	√	√
Phosphorus, dissolved (mg/L)	√	√	√	√	√	√	√	√	√

Sodium (mg/L)	√	√	√	√	√	√	√	√	√
Sulfate (mg/L)	√	√	√	√	√	√	√	√	√
Total coliform (ct/100mL)	√	√	√	√	√	√	√	√	√
Total dissolved solids (mg/L)	√	√	√	√	√	√	√	√	√
Total Kjeldahl nitrogen (mg/L)	√	√	√	√	√	√	√	√	√
Total nitrogen (mg/L)	√	√	√	√	√	√	√	√	√
Total phosphorus, dissolved (mg/L)	√	√	√	√	√	√	√	√	√

3.1.2 Quality Assurance and Quality Control Procedures

To ensure the quality of the data we collected, the SCCWS implemented quality assurance and quality control measures (QA/QC) through creating and sharing a data collection protocol with all staff members responsible for taking samples, as well as taking blank and duplicate samples. For more information on the specific QA/QC plan, refer to the water sampling protocol document (SCCWS, 2004).

3.1.3 Data Analysis

When the data were returned to the SCCWS from SRC, the data were entered and checked in an Excel spreadsheet. SCCWS staff reviewed the overall results of the QA/QC samples to ensure that:

1) There was no contamination in field processing of the samples (blanks vs. samples).
2) There was no contamination in lab processing of the samples (duplicates vs. samples).

Following the data check, we created parameter and guideline tables for use in calculating the Saskatchewan Water Quality Index (SWQI) (Saskatchewan Environment 2006). These tables were specified by the water uses of aquatic life and wildlife, irrigation, and livestock watering as defined in the Saskatchewan Surface Water Quality Objectives, as well as a general water quality parameter as defined by the Saskatchewan Watershed Authority. Table 3 to Table 6 outlines the Saskatchewan Surface Water Quality according to the 2006 guidelines. For each of these uses the values should not exceed what are shown in the tables.
General water use objectives through Saskatchewan Watershed Authority have not changed.

Table 4 – Table 7: Water Quality Parameters and Guidelines for calculation of the Saskatchewan Water Quality Index (SWQI) for particular water uses

Table 4: Water Use: Protection of Aquatic Life and Wildlife (Saskatchewan Environment)

#	Parameter		2006 guidelines	Units
1	Nitrogen as Ammonia	compute	compute	mg/L
2	Arsenic	>	5	µg/L
3	Chloride	>	100	mg/L
4	Chromium	>	0.001	mg/L
5	Dissolved Oxygen	<	5.5	mg/L
6	Mercury	>	0.026	µg/L
7	pH	<>	6.5 – 8.5	unit
8	Sodium	>	100	mg/L

Table 5: Water Use: Livestock Watering (Saskatchewan Environment)

#	Parameter		2006 guidelines	
1	Copper	>	0.5	mg/L
2	Nitrite + Nitrate Nitrogen	>	100	mg/L
3	Sulfate	>	1000	mg/L
4	Total Dissolved Solids	>	1000	mg/L

Table 6: Water Use: Irrigation (Saskatchewan Environment)

#	Parameter		2006 guidelines	units
1	Boron	>	0.5	mg/L
2	Chloride	>	100	µg/L
3	Fecal Coliform	>	100	ct/100mL
4	Sodium	>	115	mg/L
5	Total Coliform	>	1000	ct/100mL
6	Total Dissolved Solids	>	700	mg/L

Table 7: Water Use: General Water Protection (Saskatchewan Watershed Authority)

#	Parameter		2006 Guidelines	Units
1	Aluminum	>	5	mg/L
2	Ammonia as Nitrogen	compute	compute	mg/L
3	Arsenic	>	50	µg/L
4	Chloride	>	100	mg/L
5	Chromium	>	0.02	mg/L
6	Dissolved Oxygen	<	5	mg/L
7	Fecal Coliform	>	200	ct/100mL
8	Mercury	>	0.1	µg/L
9	Nitrite + Nitrate Nitrogen	>	1	mg/L
10	pH	<>	6.5-9	Units
11	Phosphorus Dissolved	>	0.1	mg/L
12	Sodium	>	100	mg/L
13	Sulfate	>	500	mg/L
14	Total Dissolved Solids	>	700	mg/L

We calculated the site-specific SWQI's in Excel using the WQI calculator macro available on the Canadian Council of Ministers of the Environment (CCME) water quality index website at http://www.ccme.ca/initiatives/water.htm?category_id=102. The background technical support information and a user's manual for the WQI calculator macro are also available on the same website.

3.2 Bioassessment

The SCCWS adapted the Environmental Effects Monitoring (EEM; Environment Canada 2002 & 2005) approach used to provide Pulp and Paper Mills and Metal Mines with the guidance they need in order to help them determine what, if any, effects their industrial effluents might have in the receiving aquatic ecosystems. The EEM approach also allows these companies to measure the effectiveness of environmental protection measures they put into place. By adapting the EEM approach to our watershed study, we used an approach that recognizes that, regardless of the cause of a particular stressor on the creek ecosystem, effects within environmental quality can be seen when specific indicators are compared between locations within the creek ecosystem. Thus, to see if environmental quality is degraded between point A and point B, we need only measure the same characteristics at point A and point B and compare the results. Then, if there is a difference in environmental quality seen, one can begin to investigate what is causing the difference.

This approach is important to note, as it does not assume that there will be differences among locations, but allows the 'data to speak for itself.' For EEM, the data collection and analysis conforms to a nationally approved, scientifically valid protocol for each type of data collection. Most of EEM use biological indicators rather than the average water quality indicators because of the natural variability in the two types of data. First, water quality indicators are highly variable and can change drastically over space and time. This variability can often confuse results and interpretation, requiring high sample sizes and very costly processing. Second, biological indicators are said to "integrate the cumulative response to environmental stress." In other words, these indicators are living organisms that eat, sleep and reproduce within a given environment and throughout their lives they assimilate to their environment. Thus, if environmental quality is degraded between point A and point B, there are measurable biological indicators (fish and macroinvertebrates) that will show this difference.

The objective of an EEM study then, is to evaluate the effects of environmental quality on organisms in the creek, as well as the habitat for organisms in the creek. In this study, we use two types of biological indicators: fish and benthic macroinvertebrates.

3.2.1 Fish Survey

The fish survey is one part of the bioassessment which provides information on the effects of environmental quality on the fish communities that live in our sampling areas. This information provides a proxy for assessing the health of the sampling locations.

3.2.1.1 Sample Collection

The SCCWS performed two types of fish sampling at 5 sites (A10, B30, C50, D70, & E90) along SCC in late July from 2005- 2007. According to EEM protocols, fish sampling should occur once per year at each location, should be performed following the spring flood, and should be done in fall (if doing non-lethal sampling) as this allows for more time handling each fish (Environment Canada 2005). All three field seasons followed similar timelines with fish sampling occurring in late July as volunteer staff is only available in the summer.

The first type of sampling was fish population sampling using two sentinel species specifically chosen for the following characteristics: non-migratory, non-sport, or commercial fish that are abundant in numbers and representative of native species to the area. The two sentinel species chosen were fathead minnow (*Pimephales promelas*) (Fig. 7A) and white sucker (*Catostomus commersoni*) (Fig. 7B) as they are both expected to have healthy population sizes through the watershed, are easy to catch in seine nets and are not fished commercially. The second type of sampling was fish community sampling, in which we recorded the number and identification of each fish species caught in our nets.

Figure 7A. fathead minnow (*Pimephales promelas*)

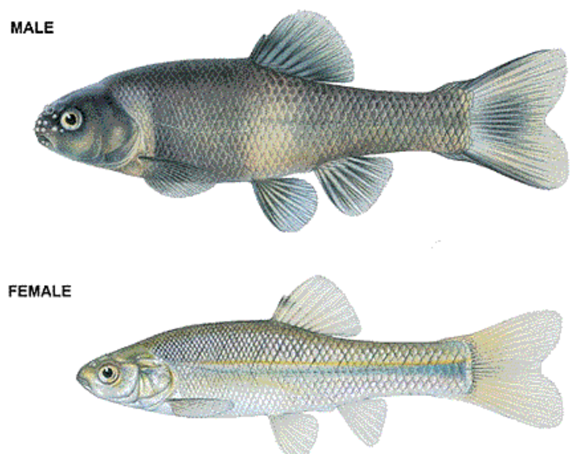

Figure 7B. white sucker (*Catostomus commersoni*)

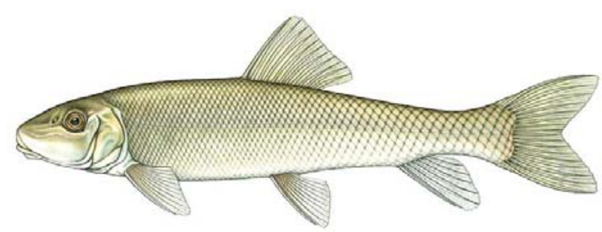

Figure 7: Images of A) fathead minnow and B) white sucker

Upon arriving at each site, the first task was putting up block nets 100 m upstream and downstream of the hub to quarantine the sampling area (Fig. 8). Due to high water flows metal t-posts had to be used to secure the block nets. The block net was cleaned occasionally to alleviate some weight on the nets.

Figure 8: Block nets being set up

The technique for seining involved one person on each side of the seine pulling the net against the current. We would start with the net at one bank of the creek and one staff member would walk straight across to stretch the net out and sometimes reach the opposite bank. They would then walk upstream for a specific distance (20m-40m) with the other workers splashing to try and corral the fish into the net. The distance of seining was recorded to determine the total sampling effort at each site. After the seine net was pulled to shore, the collected fish were transferred to 20L pails of fresh water and transferred to the sorting site. At the sorting site, collected fish were divided into separate pails: fathead minnow, white sucker and community species for sample processing.

Due to the assumed fish population sizes in our watershed and our desire to not decimate these populations, we opted to use the non-lethal sampling methods for EEM proposed by Gray, Curry, & Munkittrick (2002). Using this protocol, we continued to fish at each location until we had caught a minimum of 100 individuals for both fathead minnows and white suckers. If we caught over 100 fish in one haul, we counted all individuals in the haul.

Electroshock fishing was used in 2005 and 2006 but was discontinued in the 2007 sample season. In 2005 and 2006 electrofishing was used at sites C50 and E90; these sites had large rocks which made seining impractical. However, electroshock fishing proved to be unsuccessful in both years due to high conductivity levels. Due to the impracticality of electroshock fishing, seine netting was the sole source of non-lethal fish sampling in the 2007 season.

3.2.1.2 Sample Processing

Sections of the sampling site were seined until the required minimum of 100 individuals of each sentinel species was collected. In cases where the entire sampling site was seined without obtaining the minimum number of individuals, the site was deemed to be under-populated and individuals collected were processed. For each of the individual seine hauls performed, we processed three separate tubs of fish; one for fathead minnows, one for white sucker and one for everything else (community). When processing the fish, we grouped the three tubs together for each seine haul and processed one haul at a time. We first processed the tubs of fathead minnow and white sucker and then continued on with the counting and identification of the other fish species. We recorded fork length and total length to the nearest millimeter and then weighed each sentinel fish on a tarred electronic top pan balance shielded from the environment. We did not record the size or weight of any other fish species. Community fish species were identified to genus species, enumerated and released. All fish collected were sampled using non-lethal procedures and were released outside the sampling area.

3.2.1.3 Data Analysis

Once the data was collected, we entered and checked individual data points in an Excel spreadsheet. The overall data results were emailed to Dr. Karen Machin of the Western College of Veterinary Medicine, University of Saskatchewan for analysis. The statistical analyses included:

- Kolmogorov-Smirnov (K-S) test for length frequency
- ANOVA analysis for length, weight, and condition factor, Tukey's HSD test if appropriate
- ANCOVA analysis for Condition factor by sample site with examination for significant regression, significant interaction between sampling sites
- If slope is equal - examine for differences between sample sites, which are larger, % area difference
- What was the p for slope of adjusted mean differences?
- If interaction, plot data for interpretability.

3.2.1.4 Supporting Measurements

At each of the sampling locations, we recorded the basic weather, in-stream measurements (depth, width, temperature, conductivity, dissolved oxygen, pH) as well as any notes on the sampling efforts and site maps.

3.2.2 Invertebrate Community Surveys

This section provides information on the third type of field data collection: the benthic macroinvertebrate bioassessment. Monitoring of benthic invertebrates has been shown to provide valuable information concerning the health of aquatic ecosystems. The composition and structure of benthic macroinvertebrate communities in flowing waters is closely linked to the surrounding terrestrial landscape. In a benchmark paper on the use of macroinvertebrates as indicators of water quality (U.S. Environmental Protection Agency, 1989), macroinvertebrates were considered good indicators because:

- they are sedentary and are thus indicative of local conditions
- they integrate the effects of short and long term environmental conditions
- they are abundant in streams and relatively easy to sample
- they are relatively easy to identify to a useful taxonomic level
- they are an important link in the stream food web
- many have been classified as pollution tolerant or intolerant

According to the National Water Research Institute (NWRI; 1999), the main objectives of a macroinvertebrate biosurvey are to determine the extent of habitat degradation due to organic enrichment, sedimentation, or other forms of impacts; it may also be used to provide an evaluation of food resources for fish. A macroinvertebrate biosurvey involves collecting and processing benthic macroinvertebrate samples and determining the macroinvertebrate community structure. From the macroinvertebrate community composition, inferences can be made about the health of the stream at the sites sampled.

In this component of our project, we used the framework provided under the Canadian Environmental Effects Monitoring Program to create data collection methods that would allow us to assess and compare results among our sampling sites.

3.2.2.1 Sample Collection

The method of sample collection for benthic macroinvertebrates is quite different from either water or fish sampling, where the total area of the creek that was sampled was relatively small. For macroinvertebrate data to be useful in characterizing a given site, many small samples must be taken and these small samples are put together to get a true picture of the organisms that live in a given section of the creek. The need to sample a larger area is due to the nature of the bugs themselves; they are small, they move very little, and the communities change greatly over a small distance.

Thus, to get a good idea of the bug communities in a general section of the creek, we expanded our actual sampling site to cover an area of creek that was about 300 m in length (for details on these methods, please review the benthic invertebrate monitoring protocol). Within this larger sampling area, we split the creek into 3 sampling sections of about 60m in length, separated by 2 non-sampling sections of about 60 m in length (Fig. 9).

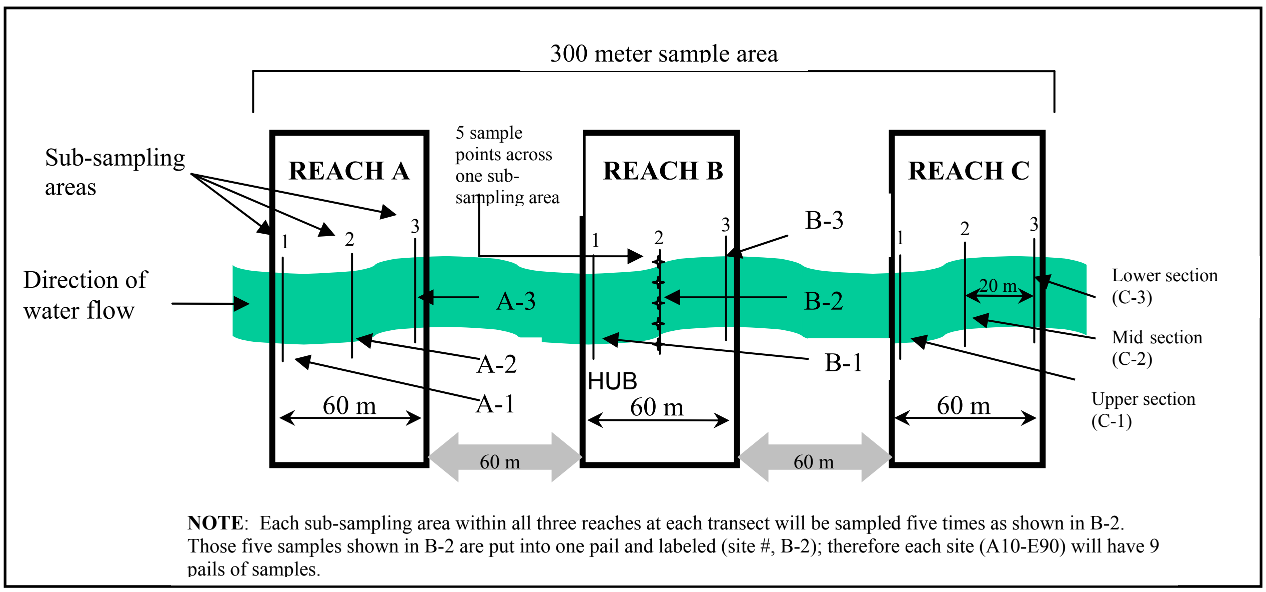

Figure 9: Spatial distribution of sub-sampling area within a sampling site

Within each of the 3 sampling sections at a site, we created 3 sub-sampling areas by splitting the 60 m section of creek into 3 parts: an upper section, a mid section and a lower section. Thus, for each of our main sampling sites (A10, B30, G40, C50, D70 and E90), we took a total of 3 replicate sections. Three sub-samples per section equalled 9 samples at each sample site (A10-E90), and with 6 sample sites there was a total of 54 samples.

To further ensure that each of our 9 samples at a site was truly representative of the organisms that inhabited that section of creek, we split each sub-sample into 5 points across the width of the creek left bank, left centre (¼ of the width), centre (½ of the width), right centre (¾ of the width) and right bank. At each point across the creek, we disturbed an area of approximately 30 cm by 30 cm and 5 cm deep for a total of 10 seconds. The organisms from all 5 points across the creek were combined to make one sample.

We planned the macroinvertebrate sampling for late summer, on the advice that we would find the greatest diversity of organisms at this time, and consistently carried out our sampling in the third week of August from 2005-2007.

3.2.2.2 Sample Processing

There are two types of sample processing for each sample: field processing and lab processing. There are also two types of lab processing: first, preserving the samples for storage and second, sorting, counting, and identifying the organisms in each sample. Each of these processing steps is addressed below.

After collecting the sample in the field, all samples were taken to a warehouse where each sample was washed through three sorting screens to separate the different particle sizes. The macroinvertebrates are picked from each of the screens and preserved in a 500 ml jar of 10% formalin. Each of the jars are labeled with the correct transect number, site and date for administrative purposes.

The second part of lab processing is the actual sample sorting, counting, and identification of organisms. This task was carried out by each of the project managers from 2005-2007. For more information on the protocol see the "Revised Guidance for Sample Sorting and Sub-sampling Protocols for EEM Benthic Invertebrate Community Surveys" by the National Water Research Institute, 2002. Only the main details of this process are provided below:

Sample Sorting

1. Each sample is washed and spread out in a large, white tray that is separated into 6 sections.
2. A dice is used to determine which section will be counted first. If there are 300 or greater organisms in the first section, the counting stopped. If there are under 300 organisms in the first section, the dice is used to randomly select another section until the quota of ≥300 organisms is filled.
3. The remaining organisms from the sample are stored in a jar with 10% formalin preservative.

Sample Counting and Identification

4. All of the 300 organisms from each sample are individually identified down to their Family and counted.
5. The organisms are placed in plastic micro-centrifuge tubes by Family (or other taxon level) for each sample and labeled with waterproof paper. The organisms are stored in 70% ethanol, and parafilm is placed over the lid to prevent evaporation of the ethanol and desiccation of the samples.

3.2.2.3 Data Analysis

The following community descriptors were calculated, reported, and used to determine health among sites:

- Total invertebrate abundance
- Taxon richness
- Simpson's Evenness Index
- Simpson's Diversity Index
- Modified Hilsenhoff's Biotic Index (FBI)
- Mulitvariant analysis (PCA and BIOENV)
- Percent EPT
- Percent contribution of dominant family

These statistical analyses were selected based on EEM protocol and recommendations made by Iain Phillips, M.Sc. Aquatic Macroinvertebrate Ecologist with Saskatchewan Watershed Authority (personal communication, November 15, 2006) and Karen Machin Associate Professor of the Western College of Veterinary Medicine at the University of Saskatchewan (personal communication, December 12, 2007).
Dr. Machin provided the background information and calculations for each of the endpoints.

3.2.2.4 Supporting Measurements

To understand and interpret the results of a benthic macroinvertebrate survey, several types of supporting measurements are needed. First, we took several different in-stream water quality measurements such as conductivity, temperature, dissolved oxygen, and pH. Second, we collected basic habitat characteristics such as embeddedness (percentage of rock surface buried in sand and silt), consolidation (level of difficulty in moving the streambed), and estimating substrate size (mean diameter of streambed materials) and type (silt/clay, sand, gravel and rock. Third, we measured the stream flow.

4 WATER SAMPLING RESULTS

4.1 Saskatchewan Water Quality Index and Parameters

Under many monitoring projects, water quality is assessed using spatial or temporal trends in specific biological, physical, or chemical parameters. For example, researchers may track the total dissolved phosphorus level at a given location over time to assess change or they may choose to track the pH level along the length of a watercourse. In either case, each potential parameter is analysed separately and the interpretation of the individual parameter trends considered as a whole provides the final assessment of quality. These methods are also very technical and often do not provide meaningful information to community people who want the answer to their question “Is our water quality good or bad?” It is important for resource managers and the public to understand water quality assessments and thus, the Canadian Council of Ministers of the Environment (CCME) task force designed the national Water Quality Index (WQI) as a method of summarizing large amounts of technical water quality data into an easily communicated index of water quality. As each province has its own guidelines for water quality, Saskatchewan has adapted the national WQI into the Saskatchewan Water Quality Index (SWQI) and outlines water quality assessment in terms of intended water usage.

There are four primary water usages outlined in the Saskatchewan Water Quality Objectives:

1. *Irrigation*: Water does not adversely affect irrigated crops
2. *Livestock Watering*: Water quality does not adversely affect the growth and well-being of livestock
3. *Recreation*: Water allows for indirect (canoeing) and direct (swimming) contact activities without adversely affecting humans
4. *Protection of Aquatic Life*: Water supports fish, insect, and plant life

Each of these water uses are measured by a series of parameters identified in the Saskatchewan Surface Water Quality Objectives (Saskatchewan Environment 2006). Once calculated, the index is ranked to a corresponding water quality using categories (Table 7)

Table 8: Water Quality Rating for the Saskatchewan Water Quality Index

Index Range	Rating	Water Quality is…
0 - 44	Poor	almost always threatened or impaired; conditions usually depart from natural or desirable levels
45 - 64	Marginal	frequently threatened or impaired; conditions often depart from natural or desirable levels
65 - 79	Fair	usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
80 - 94	Good	protected with only a minor threat or impairment; conditions rarely depart from natural or desirable levels
95 - 100	Excellent	protected with a virtual absence of threat or impairment; conditions are very close to pristine or natural levels

The Swift Current Creek Watershed Stewards (SCCWS) opted to analyse data for three of the primary water usages including protection of aquatic life, irrigation, and livestock watering. We did not include recreational use as we felt that as long as the water quality was sufficient in the other categories, analysing recreational water quality was redundant. However, the SCCWS chose to analyse the data using a fourth water use: general water protection. The general water protection usage was created by Saskatchewan Watershed Authority to include all parameters of the protection of aquatic life use (which is the official provincial index), in addition to a series of parameters known to be important in assessing watershed water quality (such as nutrient levels). The SCCWS analysed all three years of water data using the parameters and guidelines suggested by experts in 2006 and outlined in the guidelines (see Table 3 through Table 6 on pages 24 and 25).

4.2 Supporting Measurements

The SCCWS collected the following types of data in addition to the specific parameters outlined in Tables 3 to 6: total Kjeldahl nitrogen, total nitrogen, total coliforms, temperature, conductivity, water depth, water velocity, and discharge. For the calculation of the SWQI, these data were not specifically included; however, they may assist with interpretation of the results.

4.2.1 Water Quality Index Results

4.2.1.1 Irrigation Use

According to the Saskatchewan Surface Water Quality Objectives, the parameters outlined for crop irrigation are intended "…to afford long-term protection of all agricultural soils and most crops likely to be irrigated on a continuous basis. They are also intended to protect the health of human and animal consumers of irrigated crops" (Saskatchewan Environment 2006).

Water quality for irrigation purposes has fluctuated throughout the past three years. Overall, water quality in 2007 has improved from 2005 at all sampling sites. However, water quality at sites I80 and E90 were in better condition in 2006 than in 2007. Water quality at sites B30, C50, H60 and D70 has improved from both 2005 and 2006 sample years (Fig. 10). Over the last three years, the water quality for irrigation shows a similar pattern; the water quality starts low at A10, peaks at B30 and steadily declines to E90 (Figure 10). One explanation for high water quality at B30 could be attributed to Duncairn dam. Site B30 is downstream from Duncairn and the constant release of water from the dam means that there is a steady stream of fresh water flowing through site B30.

For clarity purposes, the following points break down the minimum and maximum values of water quality across all sites over the last three years and within each site from 2005-2007.

- Water quality for irrigation was the lowest in 2005 at site E90 (27.5, poor) and the highest in 2007 at site B30 (100, excellent).
- Water quality at site A10 ranged from 44.7 (poor) in 2005 to 67.2 (fair) in 2006.
- Water quality at site B30 ranged from 80.4 (good) in 2005 to 100 (excellent) in 2007.
- Water quality at site C50 ranged from 47.3 (marginal) in 2005 to 89.1 (good) in 2007.
- Water quality at site H60 ranged from 37.3 (poor) in 2005 to 80.2 (good) in 2007.
- Water quality at site D70 ranged from 38.3 (poor) in 2005 to 76.4 (fair) in 2007.
- Water quality at site I80 ranged from 29.4 (poor) in 2005 to 53.3 (marginal) in 2006.
- Water quality at site E90 ranged from 27.5 (poor) in 2005 to 50.2 (marginal) in 2006.
- Irrigation water quality at site B30 shows a narrow range of fluctuation over the past three years.
- Irrigation water quality at site H60 shows a wide range of fluctuation over the past three years.

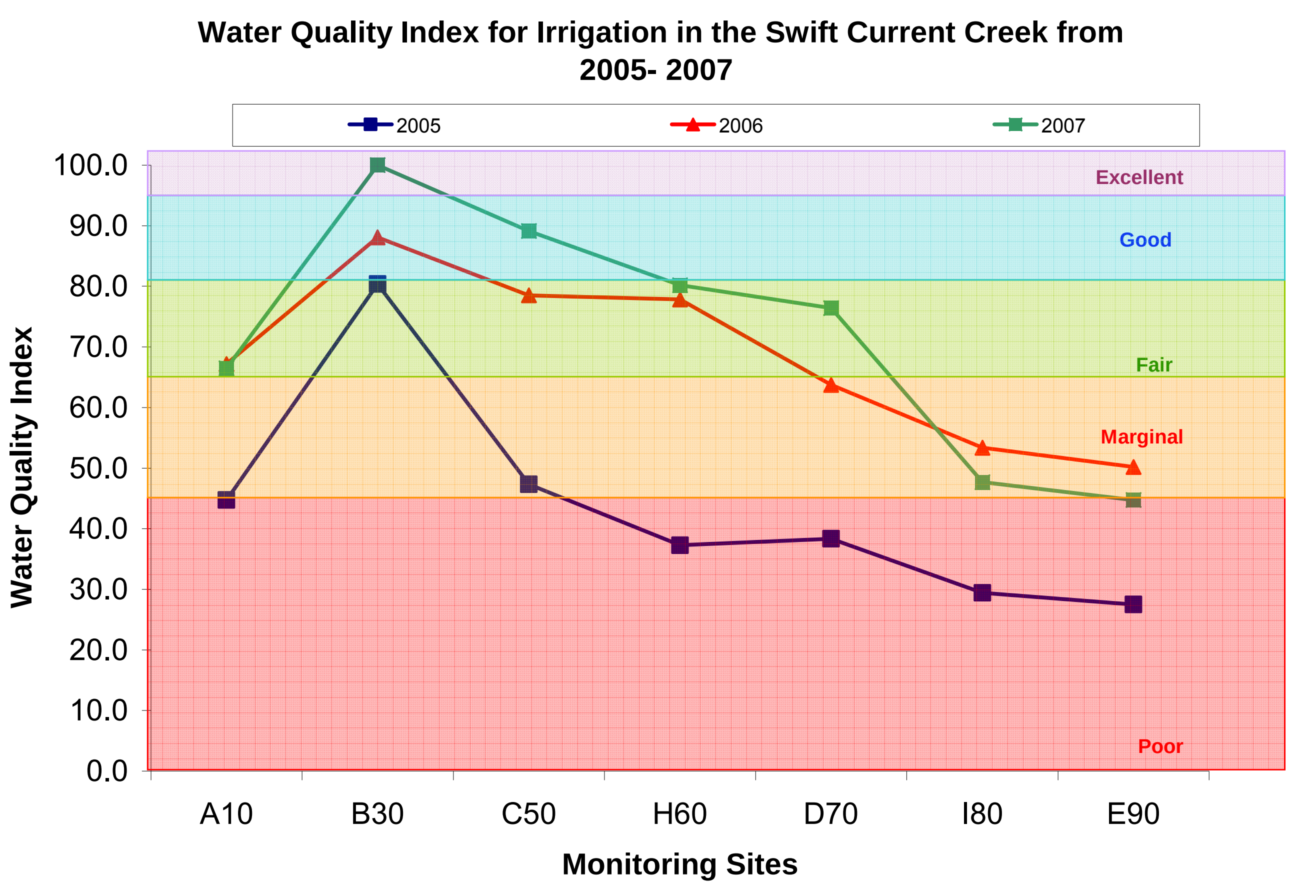

Figure 10: Water Quality Indices for Irrigation in Swift Current Creek from 2005-2007.

Table 9: Water quality index results for irrigation water use in the SCC at seven monitoring sites from 2005-2007.

Water Use	A10	B30	C50	H60	D70	I80	E90
				Sites			
Irrigation 2005	**Poor**	**Good**	**Marginal**	**Poor**	**Poor**	**Poor**	**Poor**
	44.7	**80.4**	**47.3**	**37.3**	**38.3**	**29.4**	**27.5**
Deviations:	Fecal Coliform (4/4)	Fecal Coliform (3/4)	Fecal Coliform (4/4)	Fecal Coliform (4/4)	Fecal Coliform (4/4)	Fecal Coliform (4/4)	Fecal Coliform (4/4)
	Total Coliform (3/4)		Total Coliform (2/4)	Total Coliform (4/4)	Total Coliform (4/4)	Total Coliform (2/4)	Total Coliform (2/4)
				TDS (1/4)	TDS (4/4)	TDS (4/4)	TDS (4/4)
						Sodium (4/4)	Sodium (4/4)
Irrigation 2006	**Fair**	**Good**	**Fair**	**Fair**	**Marginal**	**Marginal**	**Marginal**
	67.2	**88.1**	**78.5**	**77.8**	**63.7**	**53.3**	**50.2**
Deviations:	Fecal Coliform (1/4)						
	Total Coliform (3/4)	Total Coliform (2/4)	Total Coliform (3/4)	Total Coliform (2/4)	Total Coliform (2/4)	Total Coliform (2/4)	Total Coliform (3/4)
				TDS (1/4)	TDS (3/4)	TDS (4/4)	TDS (4/4)
					Sodium (1/4)	Sodium (3/4)	Sodium (4/4)
Irrigation 2007	**Fair**	**Excellent**	**Good**	**Good**	**Fair**	**Marginal**	**Poor**
	66.5	**100**	**89.1**	**80.2**	**76.4**	**47.7**	**44.7**
Deviations:	Fecal Coliform (2/4)					Fecal Coliform (1/4)	Fecal Coliform (1/4)
	Total Coliform (3/4)		Total Coliform (2/4)	Total Coliform (2/4)	Total Coliform (3/4)	Total Coliform (3/4)	Total Coliform (3/4)
					TDS (2/4)	TDS (4/4)	TDS (4/4)
						Sodium (3/4)	Sodium (3/4)
		Aluminum (1/4)		Aluminum (4/4)	Aluminum (4/4)	Aluminum (1/4)	Aluminum (1/4)

4.2.1.2 Livestock Watering

According to the Saskatchewan Surface Water Quality Objectives, the parameters outlined for livestock watering are intended "…to afford protection to most livestock species as well as to the consumers of products derived from these livestock" (Saskatchewan Environment 2006).

Water quality for livestock watering purposes has remained more or less the same throughout the past three years. Over the past three years water quality at sites A10, B30, C50, H60, and D70 has remained in excellent (100) condition. In addition, the water quality at sites I80 and E90 has improved slightly since 2005 (Fig. 11). One possible explanation for the improvement in livestock watering is that TDS in the water column have decreased from 2005. Table 9 illustrates that as the number of failed tests when analyzing for TDS decreases from 2005-2007, the water quality at sites I80 and E90 increases. In 2005, TDS at I80 exceeded three out of four tests and three out of four tests at E90 (Table 9). In 2006, water quality improved slightly when TDS at I80 exceeded three out of four tests and three out of four tests at E90 (Table 9). In 2007, water quality improved again with TDS exceeding two out of four tests at both I80 and E90 sample sites (Table 9).

For clarity purposes, the following points break down the minimum and maximum values of water quality across all sites over the last three years and within each site from 2005-2007.

- Water quality for livestock watering was the lowest in 2005 at site E90 (79.5, fair) and the highest in 2005, 2006 and 2007 at sites A10, B30, C50 and D70 (100, excellent).
- Water quality at site A10 remained in excellent condition (100) from 2005-2007
- Water quality at site B30 remained in excellent condition (100) from 2005-2007
- Water quality at site C50 remained in excellent condition (100) from 2005-2007
- Water quality at site H60 remained in excellent condition (100) from 2005-2007
- Water quality at site D70 remained in excellent condition (100) from 2005-2007
- Water quality at site I80 ranged from 81.8 (good) in 2005 to 83.8 (good) in 2007
- Water quality at site E90 ranged from 79.5 (fair) in 2005 to 83.9 (good) in 2007.
- Livestock water quality at site A10, B30, C50, and D70 shows essentially no fluctuation over the past three years.
- Livestock water quality at site E90 shows a significant range of fluctuation over the past three years.

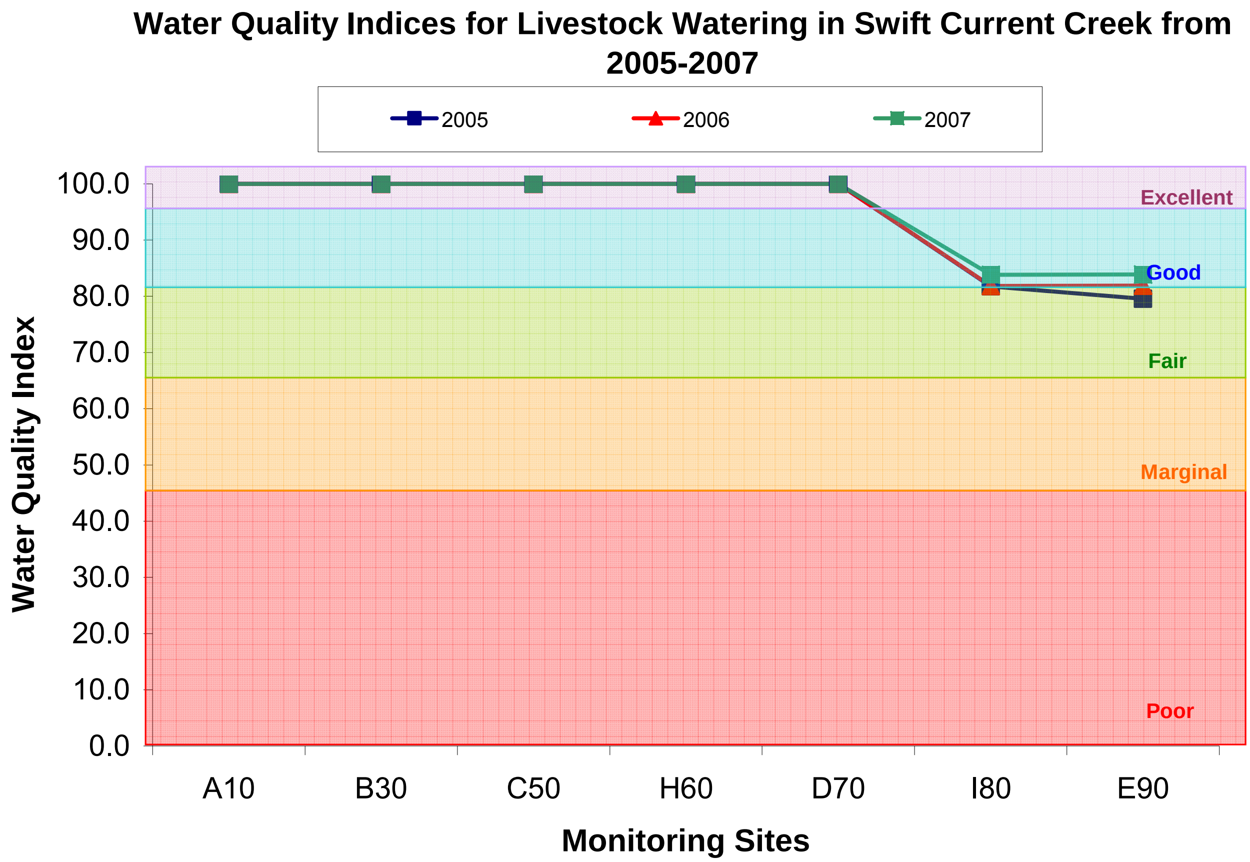

Figure 11: Water Quality Indices for Livestock Watering in Swift Current Creek from 2005-2007.

Table 10: Surface Water Quality Index results for livestock watering at seven monitoring sites from 2005-2007.

Water Use	A10	B30	C50	Sites H60	D70	I80	E90
Livestock Watering 2005	Excellent 100	Excellent 100	Excellent 100	Excellent 100	Excellent 100	Good 81.8	Fair 79.5
Deviations:						TDS (3/4)	TDS (4/4)
Livestock Watering 2006	Excellent 100	Excellent 100	Excellent 100	Excellent 100	Excellent 100	Good 82.8	Good 80.5
Deviations:						TDS (3/4)	TDS (3/4)
Livestock Watering 2007	Excellent 100	Excellent 100	Excellent 100	Excellent 100	Excellent 100	Good 83.8	Good 83.9
Deviations:						TDS (2/4)	TDS (2/4)

4.2.1.3 Aquatic Life and Wildlife

According to the Saskatchewan Surface Water Quality Objectives, the parameters outlined for the Protection of Aquatic Life and Wildlife are intended "…to afford a reasonable degree of protection to fish and other aquatic life at all stages of development" (Saskatchewan Environment 2006).

Over the past three years water quality at sites B30, D70, and E90 has improved from 2005; however, the water quality at site H60 has deteriorated from the 2006 record high (Fig. 12). This deterioration in water quality can largely be attributed to three parameters that exceeded the safe concentration limits for healthy aquatic life and wildlife: arsenic, pH and ammonia as nitrogen. Table 10 illustrates that as the number of failed tests analyzing these three parameters (arsenic, pH and ammonia as nitrogen) increases from 2005-2007 the water quality at site H60 decreases. In 2006, H60 failed ¾ of the pH tests and ¼ of the arsenic tests. In 2007, the pH at H60 improved (¼ failed tests) but arsenic levels increased (¾ failed tests). In addition to increased arsenic concentrations, ammonia as nitrogen also failed ¼ of the tests. The increase in arsenic and the presence of ammonia as nitrogen caused the water quality at H60 to fall below the 2006 standard. In regards to the elevated arsenic levels, Twyla Legault, Water Quality Division, PFRA (personal communication, November 15, 2007) has advised the SCCWS that the arsenic concentrations found in the creek are a result of natural, not man-made, sources. According to Twyla Legault many creeks on the Prairies get some of their baseline flow from groundwater and there are a number of groundwater aquifers on the Prairies that contain elevated levels of arsenic. In most cases this arsenic is picked up as groundwater flows through glacial tills containing arsenopyrite which occur in many areas of Saskatchewan.

For clarity purposes, the following points break down the minimum and maximum values of water quality across all sites over the last three years and within each site from 2005-2007.

- Water quality for aquatic life and wildlife was the lowest in 2005 at sites D70 (60, marginal) and E90 (59.9, marginal) and the highest in 2006, at site H60 (83.9, good).
- Water quality at site A10 ranged from 74.4(fair) in 2007 to 81.4 (good) in 2006.
- Water quality at site B30 ranged from 70.9 (fair) in 2005 to 81.8(good) in 2007.
- Water quality at site C50 ranged from 75.6 (fair) in 2005 to 81.9 (good) in 2006.
- Water quality at site H60 ranged from 74.5 (fair) in 2005 to 83.9 (good) in 2006.
- Water quality at site D70 ranged from 60.0 (marginal) in 2005 to 76.5 (fair) in 2007.
- Water quality at site I80 ranged from 73.0 (fair) in 2006 to 75.9 (fair) in 2005.
- Water quality at site E90 ranged from 59.9 (marginal) in 2005 to 72.7 (fair) in 2007.
- Aquatic water quality at site I80 shows a narrow range of fluctuation over the past three years.
- Aquatic water quality at site D70 shows a wide range of fluctuation over the past three years.

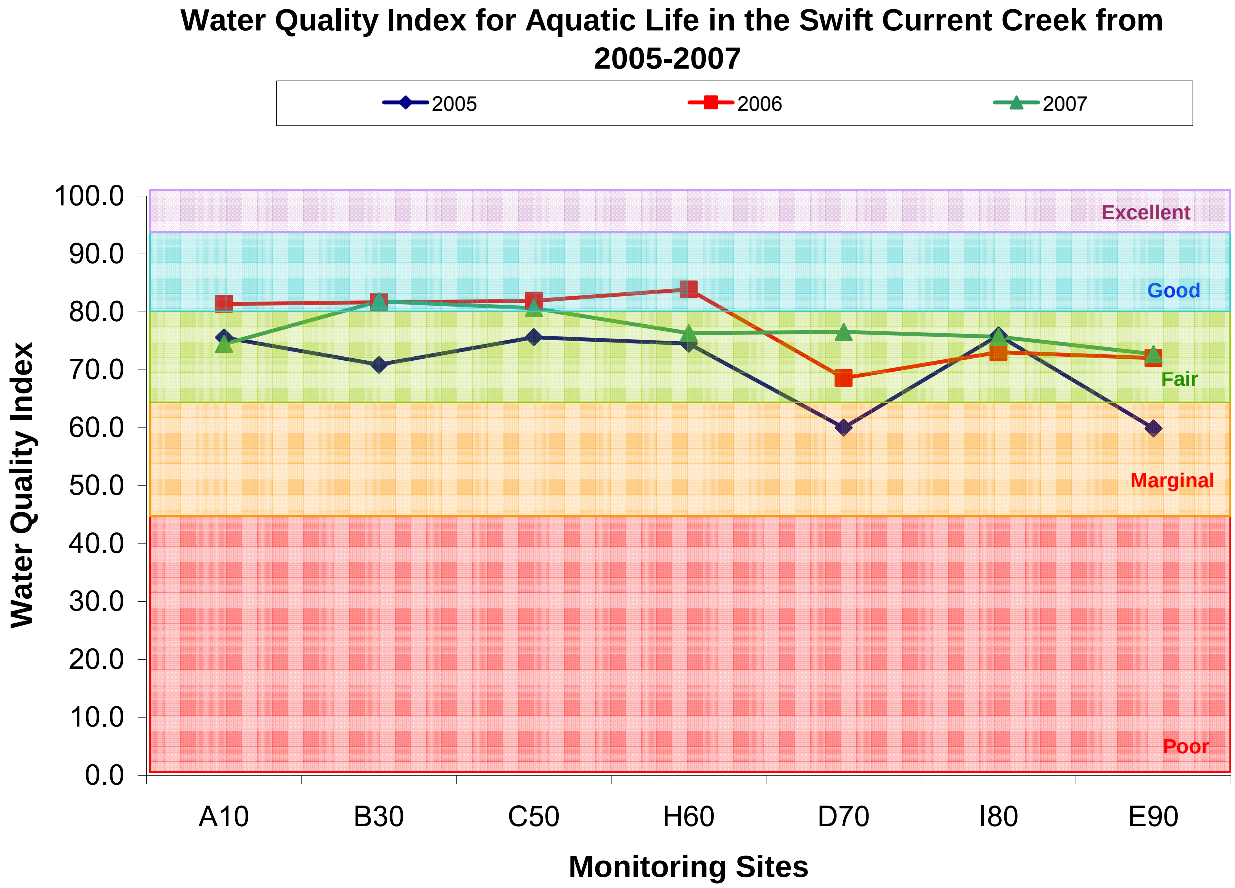

Figure 12: Water Quality Indices for Aquatic Life in Swift Current Creek from 2005-2007.

Table 11: Water quality index results for aquatic life and wildlife at seven monitoring sites from 2005-2007.

Water Use	A10	B30	C50	H60	D70	I80	E90
	Sites						
Aquatic Life 2005	**Fair**	**Fair**	**Fair**	**Fair**	**Marginal**	**Fair**	**Marginal**
	75.6	**70.9**	**75.6**	**74.5**	**60**	**75.9**	**59.9**
Deviations:	pH (3/4) Arsenic (2/4) Mercury (4/4)	pH (2/4) Arsenic (1/4) Mercury (4/4) Aluminum (1/4)	pH (4/4) Arsenic (1/4) Mercury (4/4)	pH (2/4) Arsenic (1/4) Aluminum (4/4)	pH (1/4) Arsenic (2/4) Sodium (2/4) Mercury (4/4) Aluminum (4/4)	Arsenic (3/4) Sodium (4/4) Aluminum (1/4)	pH (2/4) Arsenic (3/4) Sodium (4/4) Mercury (4/4) Aluminum (1/4)
Aquatic Life 2006	**Good**	**Good**	**Good**	**Good**	**Fair**	**Fair**	**Fair**
	81.4	**81.7**	**81.9**	**83.9**	**68.5**	**73**	**72**
Deviations:	pH (3/4) Arsenic (3/4)	pH (3/4) Arsenic (3/4)	pH (3/4) Arsenic (3/4)	pH (3/4) Arsenic (1/4)	pH (1/4) Arsenic (1/4) Sodium (3/4) Ammonia as Nitrogen (1/4)	pH (2/4) Arsenic (2/4) Sodium (4/4)	pH (3/4) Arsenic (2/4) Sodium (4/4)
Aquatic Life 2007	**Good**	**Good**	**Good**	**Fair**	**Fair**	**Fair**	**Fair**
	74.4	**81.8**	**80.6**	**76.3**	**76.5**	**75.7**	**72.7**
Deviations:	pH (3/4) Arsenic (3/4) Ammonia as Nitrogen (1/4)	pH (3/4) Arsenic (3/4)	pH (3/4) Arsenic (4/4)	pH (1/4) Arsenic (3/4) Ammonia as Nitrogen (1/4)	pH (2/4) Arsenic (2/4) Sodium (1/4)	pH (1/4) Arsenic (2/4) Sodium (3/4)	pH (4/4) Arsenic (1/4) Sodium (4/4)

4.2.1.4 General Water Quality

The parameters and guidelines described in the Surface Water Quality Objectives for the Protection of Aquatic Life and Wildlife are not comprehensive. Thus, Saskatchewan Watershed Authority (SWA) calculates an index termed the "General Protection Index" that includes all parameters of the aquatic life and wildlife index, as well as guidelines for aluminum, fecal coliform bacteria, nitrate plus nitrite nitrogen, dissolved phosphorus and sulfate.

Over the past three years, water quality at sites A10, C50, D70, H60, I80 and E90 has improved since 2005; however, water quality at site B30 was always good and consistent (Fig.13). The only difference in water quality between 2006 and 2007 is the presence of ammonia as nitrogen in the water in 2007 (Table 11).

For clarity purposes, the following points break down the minimum and maximum values of water quality for General Protection across all sites over the last three years and within each site from 2005-2007.

- Water quality for general water use was the lowest in 2005 at site E90 (55.1, marginal) and the highest in 2007, at site H60 (91.3, good).
- Water quality at site A10 ranged from 66.5 (fair) in 2005 to 84.5 (good) in 2006.
- Water quality at site B30 ranged from 81.4 (good) in 2006 to 86.9 (good) in 2007.
- Water quality at site C50 ranged from 67.9 (fair) in 2005 to 88.0 (good) in 2007.
- Water quality at site H60 ranged from 62.1 (marginal) in 2005 to 91.3 (good) in 2007
- Water quality at site D70 ranged from 67.7 (fair) in 2005 to 86.6 (good) in 2007.
- Water quality at site I80 ranged from 59.2 (marginal) in 2005 to 76.7 (fair) in 2007
- Water quality at site E90 ranged from 55.1 (marginal) in 2005 to 77.8 (fair) in 2007.
- General water quality at site B30 shows a narrow range of fluctuation over the past three years.
- General water quality at site H60 shows a wide range of fluctuation over the past three years.

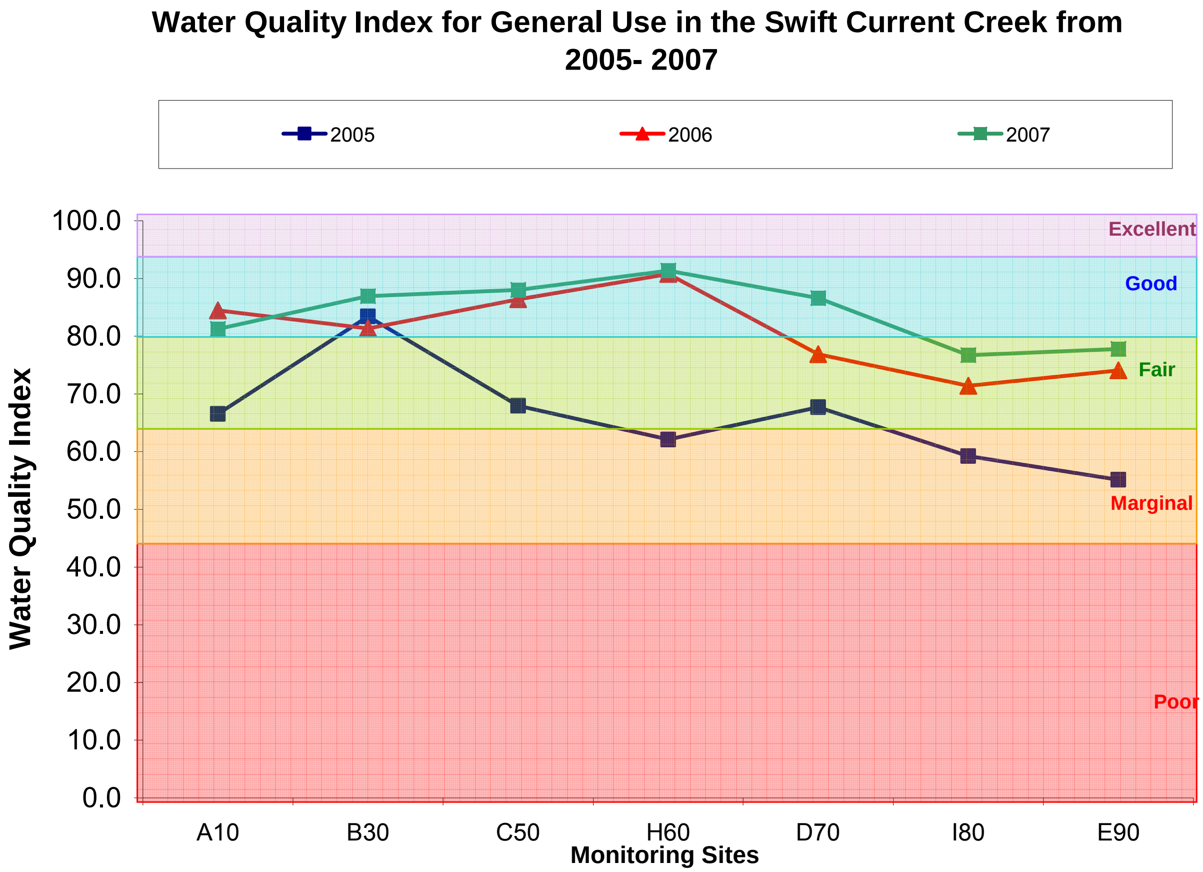

Figure 13: Water Quality Indices for General Water Use in Swift Current Creek from 2005-2007.

Table 12: Water quality index results for general water use in the SCC at seven monitoring sites from 2005-2007

Water Use	A10	B30	C50	H60	D70	I80	E90
General Protection 2005	**Fair**	**Good**	**Fair**	**Marginal**	**Fair**	**Marginal**	**Marginal**
	66.5	**83.4**	**67.9**	**62.1**	**67.7**	**59.2**	**55.1**
Deviations:	pH (3/4) Phosphorus Dissolved (1/4) Fecal Coliform (4/4)	pH (2/4) Phosphorus Dissolved (3/4) Fecal Coliform (2/4)	pH (4/4) Phosphorus Dissolved (3/4) Fecal Coliform (4/4)	pH (2/4) Fecal Coliform (4/4) TDS(1/4)	pH (1/4) Sodium (2/4) Fecal Coliform (4/4) TDS (4/4)	Sodium (4/4) Phosphorus Dissolved (2/4) Fecal Coliform (4/4) TDS (4/4)	pH (4/4) Sodium (4/4) Sulfate (2/4) Fecal Coliform (4/4) TDS (4/4)
General Protection 2006	**Good**	**Good**	**Good**	**Good**	**Fair**	**Fair**	**Fair**
	84.5	**81.4**	**86.4**	**90.8**	**76.9**	**71.4**	**74.1**
Deviations:	pH (3/4) Phosphorus Dissolved (3/4) Fecal Coliform (1/4)	pH (3/4) Phosphorus Dissolved (4/4)	pH (3/4) Phosphorus Dissolved (4/4)	pH (3/4) TDS(1/4)	pH (1/4) Sodium (3/4) Ammonia as Nitrogen (1/4) Phosphorus Dissolved (1/4) TDS (3/4)	pH (2/4) Sodium (4/4) Sulfate (2/4) Phosphorus Dissolved (3/4) TDS (4/4)	pH (3/4) Sodium (4/4) Sulfate (2/4) Phosphorus Dissolved (1/4) TDS (4/4)
General Protection 2007	**Good**	**Good**	**Good**	**Good**	**Good**	**Fair**	**Fair**
	81.3	**86.9**	**88.0**	**91.3**	**86.6**	**76.7**	**77.8**
Deviations:	pH (3/4) Phosphorus Dissolved (2/4) Fecal Coliform (1/4) Ammonia as Nitrogen (1/4)	pH (3/4) Phosphorus Dissolved (4/4)	pH (3/4) Phosphorus Dissolved (4/4) Fecal Coliform (4/4)	pH (1/4) Ammonia as Nitrogen (1/4)	pH (2/4) Sodium (2/4) TDS (2/4)	pH (1/4) Sodium (4/4) Fecal Coliform (1/4) TDS (4/4)	pH (4/4) Sodium (4/4) Sulfate (2/4) TDS (4/4)

4.2.2 Water Chemistry Results

To illustrate the range of variability among parameters, the following bullets show the lowest and highest values for each parameter sampled over the past three years.

- The lowest level of chloride was 5 mg/L and occurred at site A10 in May and July 2006 and in July 2007 and at site B30 in August 2005. The highest level of chloride was 68mg/L and occurred at site I80 in July 2006.
- The lowest pH level was 8.33 and occurred at site D70 in July 2007. The highest pH level was 9.47 and occurred at site A10 in July 2006.
- The lowest level of sodium was 41 mg/L and occurred at site A10 in May 2006. The highest level of sodium was 215 mg/L and occurred at site E90 in July 2006.
- The lowest level of sulfate was 110 mg/L and occurred at site A10 in July 2006. The highest level of sulfate was 690 mg/L and occurred at site I80 in July 2006.
- The lowest level of ammonia as nitrogen was 0.02 mg/L and occurred at sites A10 in May 2006 and May 2007; site F20 in May 2006; site H60 in May 2006 and site I80 in May 2007. The highest level of ammonia as nitrogen was 1.2 mg/L and occurred at site D70 in May 2006.
- The lowest level of dissolved inorganic phosphorus was 0.03mg/L and occurred at site E90 in July 2006. The highest level of dissolved inorganic phosphorus was .93mg/L and occurred at site B30 in September 2006.
- The lowest level of dissolved phosphorus was 0.01 mg/L and occurred at site E90 in September 2005. The highest level of dissolved phosphorus was 0.9 mg/L and occurred at site C50 in May 2005.
- Nitrite and nitrate nitrogen levels were generally very low and were below the 0.01 mg/L limit of detection. This was true for all but 4 of 45 samplings in 2005, all but 9 samplings in 2006 and all but 6 samplings in 2007. The highest level of nitrite and nitrate nitrogen was 401 mg/L and occurred at site C50 in September 2006.
- The lowest level of total Kjeldahl nitrogen was 0.11 mg/L and occurred at site I80 in September 2005. The highest level of Kjeldahl nitrogen was 2.4 and occurred at site D70 in May 2006.
- The lowest level of total nitrogen was 0.16 mg/L and occurred at site H60 in August 2007. The highest level of total nitrogen was 402 mg/L and occurred at site C50 in September 2006.
- The lowest and highest levels of mercury over all sites throughout the three sample years were <0.05 µg/L.
- The lowest level of arsenic was 2.1µg/L and occurred at site E90 in September 2005. The highest level of arsenic was 15µg/L and occurred at site G40 in September 2006.
- The lowest level of aluminum was 0.0046 mg/L and occurred at site B30 in July 2006. The highest level of aluminum was 0.52 mg/L and occurred at site D70 in May 2005.
- The lowest level of boron was 0.02 mg/L and occurred at site A10 in July 2006. The highest level of boron was 0.19 mg/L and occurred at site E90 in July 2006.
- The lowest and highest levels of chromium over all sites throughout the three sample years were 0 mg/L.
- The lowest and highest levels of copper over all sites throughout the three sample years were 0 mg/L.
- The lowest level of total dissolved solids was 50 mg/L and occurred at site C50 in May 2007. The highest level of total dissolved solids was 1390 mg/L and occurred at site I80 in July 2006.
- The lowest level of fecal coliforms was 1 ct/100mL and occurred at site B30 in May 2005 and at C50 in September 2005. The highest level of fecal coliforms was 890 ct/100mL and occurred at site A10 in July 2007.

- The lowest level of total coliforms was 80 ct/100mL and occurred at site H60 in May 2006. The highest level of total coliforms was 17600 ct/100mL and occurred at site E90 in July 2006.

The following water chemistry parameters are important watershed health indicators that have repeatedly shown values at some of the sample sites that were over the acceptable guidelines set out by Saskatchewan Environment in the Surface Water Quality Objectives report. In the following paragraphs each of the parameters will be discussed individually and graphically in terms of what each parameter is, how it affects the health of our watershed, and if possible provide suggestions to its source.

- Chloride
- Sodium
- Sulfate
- Nitrite and nitrate nitrogen
- Total nitrogen
- TDS
- Inorganic phosphorus
- Aluminum

All other parameters that are not displayed in the following sections can be seen in Appendix 9-11.

4.2.2.1 Chloride

Chlorides are salts resulting from the combination of the gas chlorine with a metal (KDW 2007). The presence of chlorides in surface and groundwater can result from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, irrigation drainage, landfill leachates, septic tank effluents, effluent wastewater, animal feeds, and industrial effluents (WHO, 2003).

The concentrations of chloride in the SCC show a similar pattern among all three sample years. Between sites A10 and C50 the chloride concentrations are relatively uniform and low. At site H60, chloride begins to rise until it generally peaks at D70; thereafter, chloride usually declines to E90. One reason for the peak at D70 may be attributed to the WWTP. Chloride is present in wastewater and site D70 is immediately downstream from the WWTP; thus, the possibility exists that the effluent released from the WWTP contains enough chloride to raise the levels at site D70.

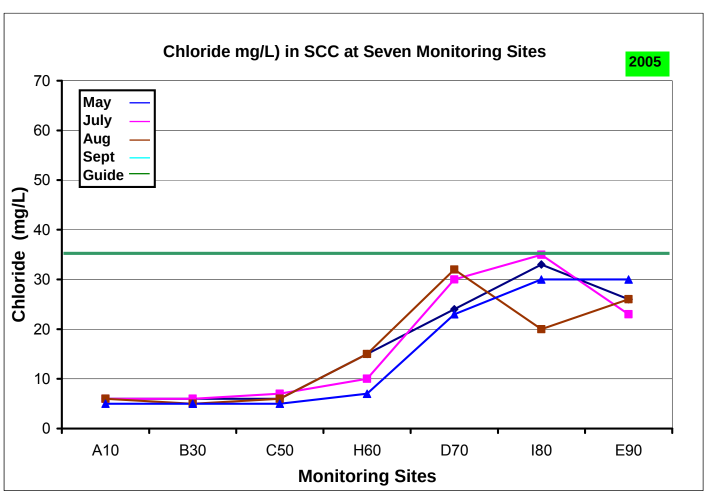

Figure 14: Chloride levels in Swift Current Creek in 2005

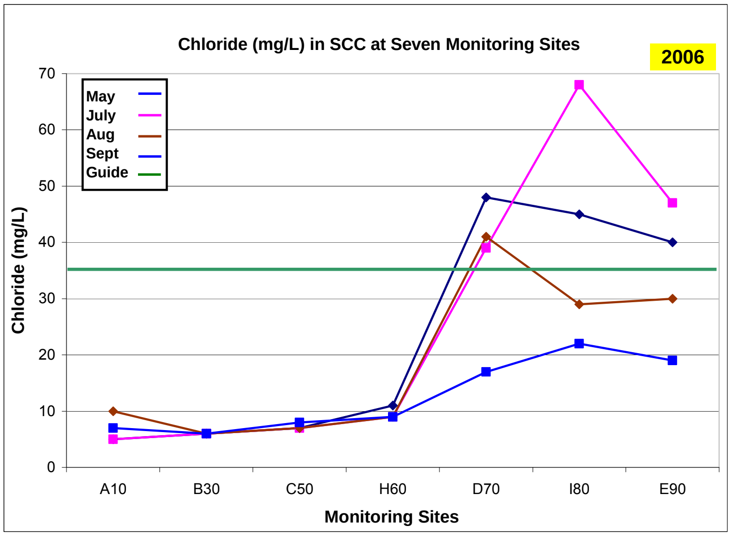

Figure 15: Chloride in Swift Current Creek in 2006

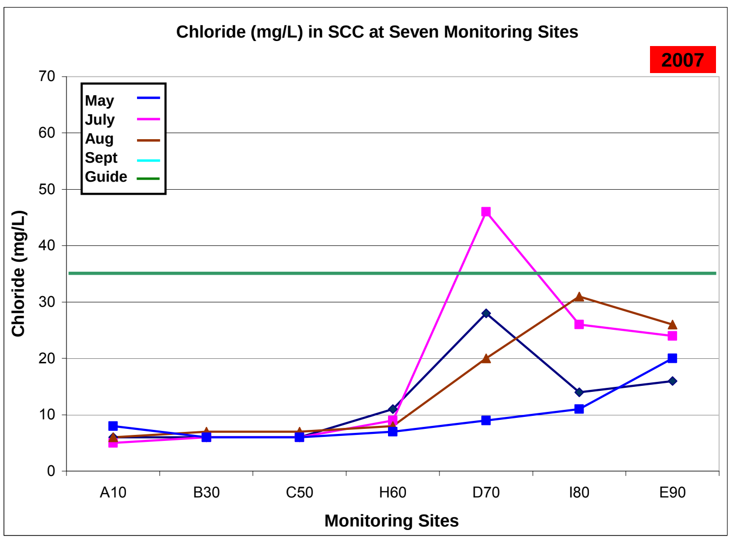

Figure 16: Chloride in Swift Current Creek in 2007

4.2.2.2 Sodium

Sodium is a highly reactive chemical element that is a member of the alkali metals. Sodium is present in large quantities in the earth's oceans as sodium chloride and is also an essential element for animal life. Sodium ions are necessary for the regulation of blood and body fluids, transmission of nerve impulses, heart activity, and certain metabolic functions (The British Columbia Groundwater Association 2007).

Overall, the concentration of sodium increases from upstream to downstream. All samples from sites A10 to D70, except for May 2006 at D70, are below the guideline of 120mg/L. The sodium concentrations at sites I80 and E90 are generally above the acceptable sodium guidelines. One explanation for the high sodium levels at these two sites is the presence of sodium, dissolved and leached out of soils containing bedrock (i.e. Bearpaw shale) in underground springs flowing into the creek. As the springs flow into the creek, the sodium concentration is naturally raised in the creek.

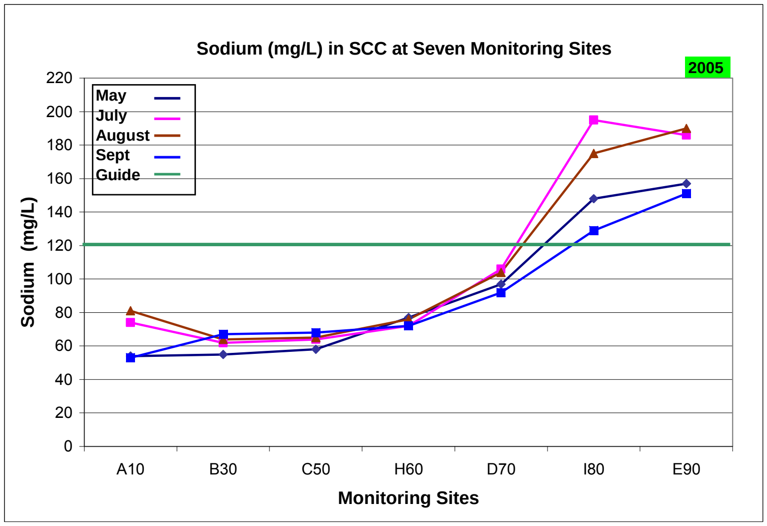

Figure 17: Sodium in Swift Current Creek in 2005

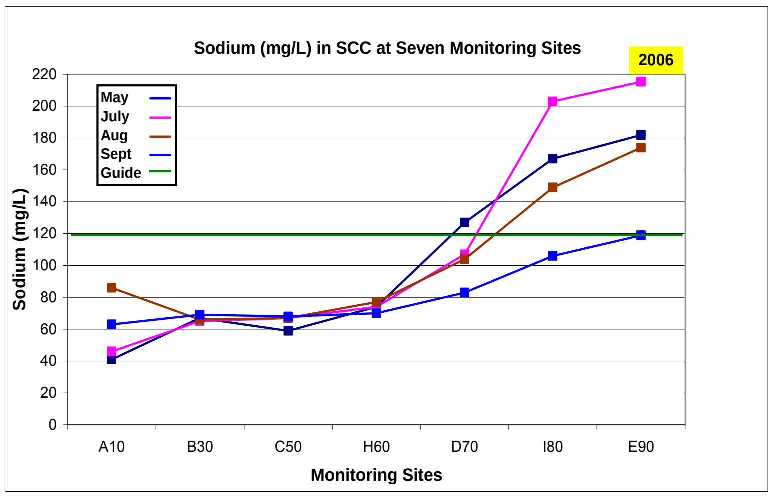

Figure 18: Sodium in Swift Current Creek in 2006

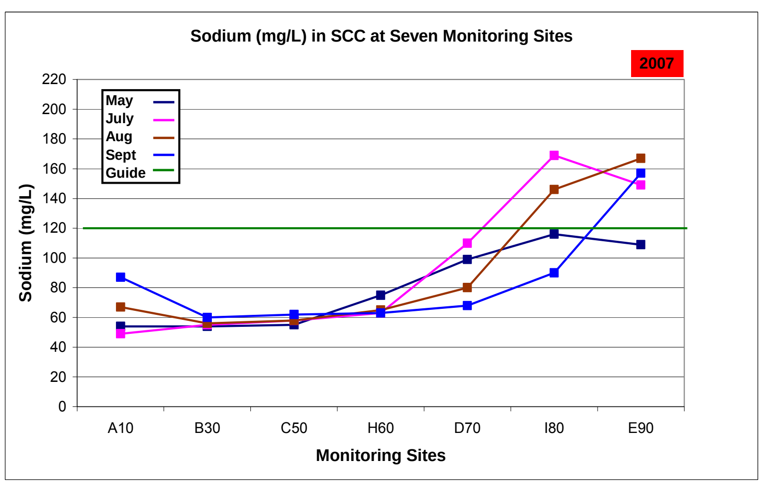

Figure 19: Sodium in Swift Current Creek in 2007

4.2.2.3 Sulfate

The U.S. Environmental Protection Agency (2006) states that sulfate is a naturally occurring substance that contains both sulphur and oxygen. Sulfate is present in various mineral salts that are found in soil. There are several sources of sulfate in water: soil leaching, decaying plant and animal matter, treating water with alum, sulfate fertilizers and the combustion of fossil fuels and sour gas processing. In general, sulfate in drinking water is non-toxic; however, amounts over the guideline (500mg/L) will cause intestinal discomfort and diarrhea.

Overall, the concentration of sulfate increases from upstream to downstream. In Figures 20, 21, and 22 sulfate remains below the acceptable guideline from site A10 to D70 throughout all three sample years. Water samples from sites I80 and E90 show sulfate levels above the acceptable guideline for at least two out of the four sample months. Sulfate is also present in groundwater springs that discharge into the SCC. These groundwater springs are present at both the I80 and E90 sample sites and are likely the main, if not sole, contributors to the sulfate levels in the creek downstream from Swift Current.

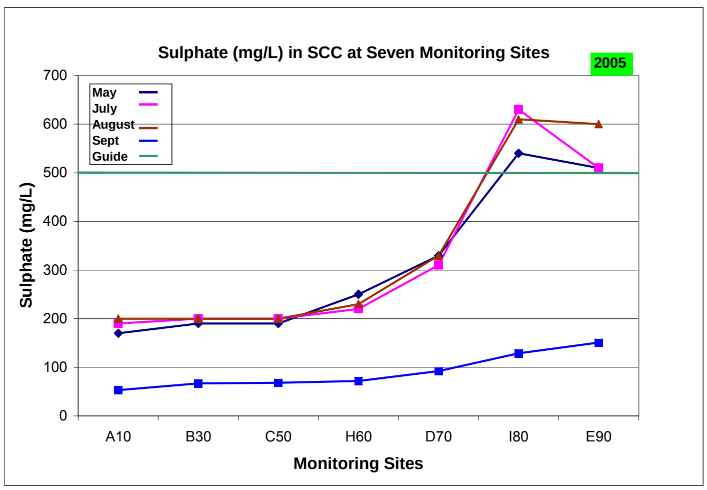

Figure 20: Sulfate in Swift Current Creek in 2005

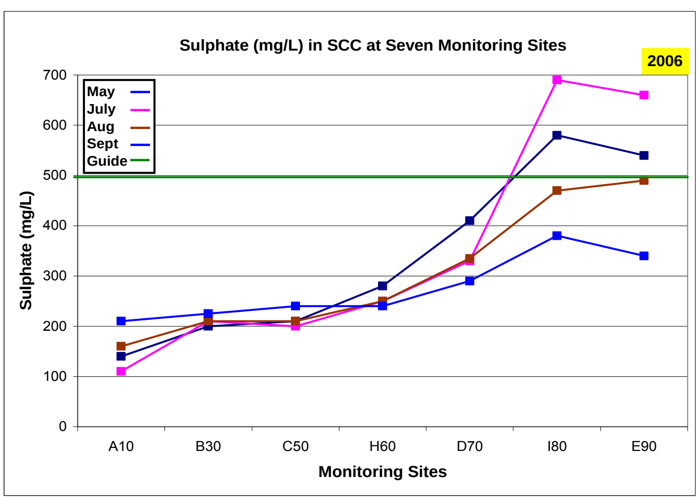

Figure 21: Sulfate in Swift Current Creek in 2006

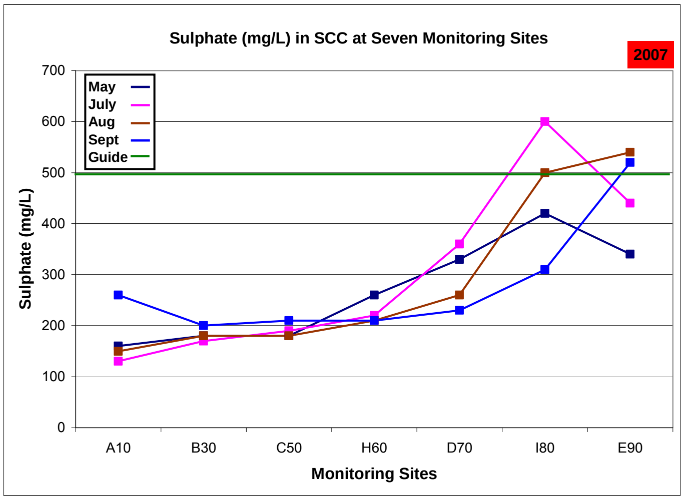

Figure 22: Sulfate in Swift Current Creek in 2007

4.2.2.4 Nitrite and Nitrate Nitrogen

According to the Kentucky Division of Water (2008), nitrogen is essential for all living organisms as it is a component of protein. Nitrogen exists in the environment in many forms and changes forms as it moves through the nitrogen cycle. Nitrogen is a very unstable intermediate in the nitrification process, thus, it never occurs in high concentrations in natural environments. Nitrogen is present in fertilizer, sewage, livestock facilities, and it also occurs naturally in the soil from decaying plant and animal matter and in humus. Problems occur when excessive rainfall or irrigation causes nitrite and nitrate nitrogen to leach from the soil into nearby water bodies. Nitrogen in water acts as a nutrient and causes plants and algae to multiply rapidly. When the algae eventually die off, organisms begin to consume the algae. These organisms require oxygen to consume the algae and this leads to severe oxygen depletion in the system. This process is referred to as eutrophication and may result in decreased taxonomic richness as well as death in many aquatic organisms.

Overall, the concentration of nitrite and nitrate nitrogen was below the acceptable guideline (100mg/L) in all sample years. In 2006, the nitrite and nitrate nitrogen level at site C50 in September was 401 mg/L. The laboratory tested this parameter twice with the same result and the SCCWS rigorously followed all stream sampling protocols to prevent sample contamination. Thus far the reason for this peak has not been identified. Although livestock and wildlife contribute to the nitrate and nitrite nitrogen levels in the creek, there are no livestock operations present in close proximity to this site; in addition, it is difficult to determine how much wildlife frequents the creek at this location. Since the nitrite and nitrate nitrogen levels have been below the guideline for all three years except once, it is highly likely that the spike in nitrogen at site C50 in September of 2006 is just an anomaly.

Table 13: Nitrite and nitrate nitrogen values for the Swift Current Creek in 2005

Site	May *	July *	August *	Sept (P/N) *x*	Sept *
A10	<0.01	0.05	<0.01	<0.01	<0.01
F20	<0.01	<0.01	<0.01	<0.01	<0.01
B30	<0.01	<0.01	0.03	<0.01	<0.01
G40	<0.01	<0.01	<0.01	<0.01	<0.01
C50	<0.01	<0.01	<0.01	0.01	0.2
H60	0.09	<0.01	.01	<0.01	<0.01
D70	0.01	0.005	<0.01	0.06	<0.01
I80	<0.01	<0.01	<0.01	<0.01	<0.01
E90	<0.01	<0.01	<0.01	<0.01	<0.01

*--Full water chemistry analysis conducted
x--Phosphorus and nitrogen (P/N) analysis only

Table 14: Nitrite and nitrate nitrogen values for the Swift Current Creek in 2006

Site	May *	July *	August *	Sept (P/N) *x*	Sept *
A10	<0.01	0.11	<0.01	<0.01	<0.01
F20	<0.01	<0.01	0.06	<0.01	<0.01
B30	0.07	<0.01	<0.01	<0.01	<0.01
G40	<0.01	<0.01	<0.01	<0.01	<0.01
C50	<0.01	<0.01	<0.01	401	<0.01
H60	<0.01	<0.01	<0.01	<0.01	<0.01
D70	0.14	0.11	0.16	<0.01	0.04
I80	0.13	<0.01	<0.01	<0.01	<0.01
E90	0.07	<0.01	<0.01	<0.01	<0.01

*--Full water chemistry analysis conducted
x--Phosphorus and nitrogen (P/N) analysis only

Table 15: Nitrite and nitrate nitrogen values for the Swift Current Creek in 2007

Site	May *	July *	August *	Sept (P/N) *x*	Sept *
A10	<0.01	<0.01	<0.01	0.01	0.01
F20	<0..01	<0.01	0.01	0.01	0.01
B30	0.12	<0.01	<0.01	<0.01	0.01
G40	<0.01	<0.01	<0.01	<0.01	<0.01
C50	<0.01	<0.01	<0.01	0.01	<0.01
H60	0.04	<0.01	0.01	0.03	0.02
D70	0.01	0.73	0.01	0.02	0.02
I80	<0.01	<0.01	<0.01	<0.01	0.01
E90	<0.01	<0.01	<0.01	<0.01	0.02

*--Full water chemistry analysis conducted
x--Phosphorus and nitrogen (P/N) analysis only

4.2.2.5 Total Dissolved Solids

According to the World Health Organization (WHO; 1996), Total Dissolved Solids (TDS) refers to the total amount of inorganic substances– including minerals, salts, metals, cations or anions (principally sodium, calcium, magnesium, potassium, chlorides, bicarbonates, and sulfates) that are dispersed within a volume of water. TDS in drinking-water originate from natural sources (mineral springs, carbonate or salt deposits) and man-made sources (wastewater, urban run-off, industrial wastewater, road salts, and chemicals used in the water treatment process such as softeners).

There are two guidelines for TDS, one at 700mg/L and one at 1000mg/L. If the level of total dissolved solids is much below 700mg/L, the water may become corrosive and corrosive water leaks toxic metals such as: lead and copper from household plumbing. This also means that trace metals could be present at levels that may pose a health risk (WHO, 1996).

In SCC, the concentration of TDS increases from upstream to downstream. Total dissolved solids from site A10 to H60 are generally just below the acceptable lower guideline whereas TDS concentrations at I80 and E90 are above the upper guideline. The high TDS concentrations at I80 and E90 are likely a result of groundwater springs discharging into the creek. The springs contain a multitude of inorganic salts, leached out of the Bearpaw Shale, which contribute to high TDS levels. Two substances present in TDS, sodium and sulfate, show high values at both I80 and E90 sample sites. Although TDS may encompass many substances, it is likely that sodium and sulfate are the major contributors to the high TDS levels shown at I80 and E90 in all three sample years.

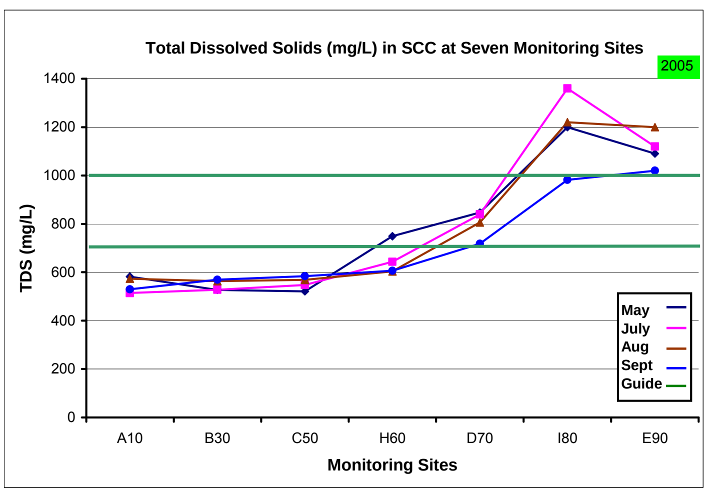

Figure 23: Total Dissolved Solids in Swift Current Creek in 2005

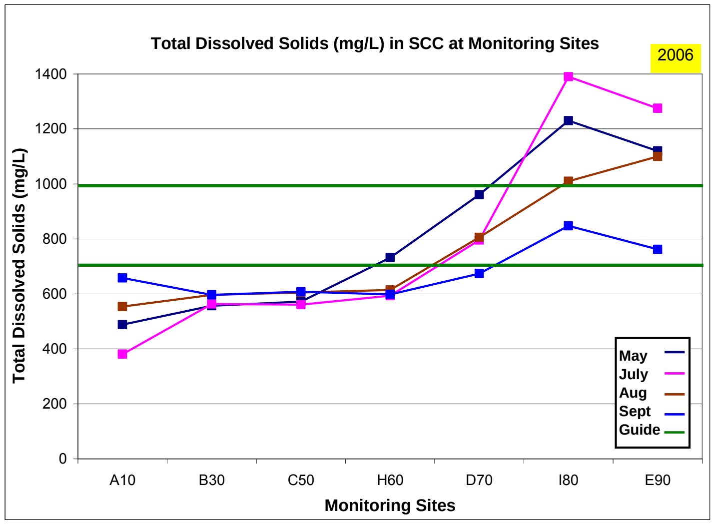

Figure 24: Total Dissolved Solids in Swift Current Creek in 2006

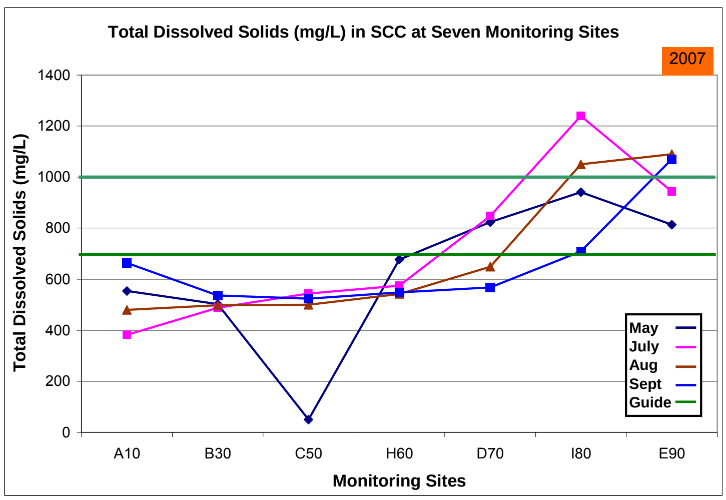

Figure 25: Total Dissolved Solids in Swift Current Creek in 2007

4.2.2.6 Inorganic Phosphorus Results

According to Murphy (2007), phosphorus is a nutrient required by all organisms for the basic processes of life and can be found in rocks, soil and organic material. In fresh waters, phosphorus is usually found in the form of phosphates. An inorganic form of phosphate, orthophosphate, is the form readily used by plants. Orthophosphate is produced by natural processes and can also be found in sewage. Excessive amounts of orthophosphate in water generate large quantities of algae; when these algae die off, bacteria decompose the algae and use up the dissolved oxygen in the water; this process is called eutrophication. Low dissolved oxygen levels can lead to fish kills and decreased recreational value. Even when inorganic phosphorus levels are low, orthophosphates can cause a bloom of nitrogen fixing blue-green algae (cyanobacteria). Many of the blue-greens are toxic to mammals and can kill the animals that drink the water.

Overall, inorganic phosphorus concentrations have decreased since 2005. In Figures 29 and 30, inorganic phosphorus generally peaks at B30 and I80 for both the 2005 and 2006 sample years while Figure 31 shows, for 2007, an inorganic phosphorus peak at B30 only. All three sample years experienced inorganic phosphorus levels over the acceptable guideline (0.1mg/L) in at least three out of the four sample months at site B30. There is currently no explanation for the large variation witnessed in inorganic phosphorus at B30.

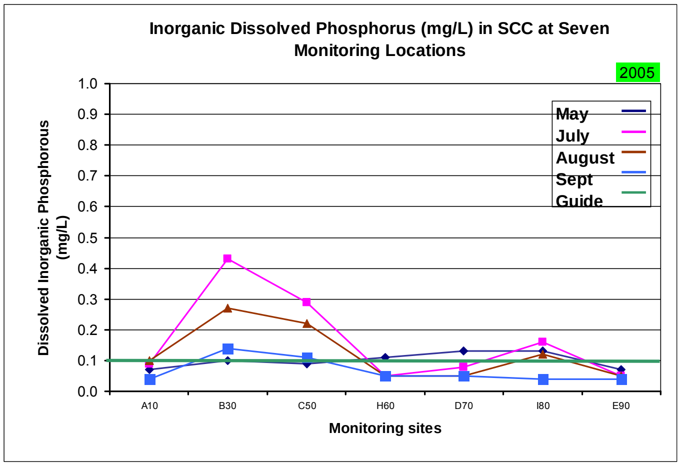

Figure 26: Inorganic phosphorus levels in Swift Current Creek in 2005

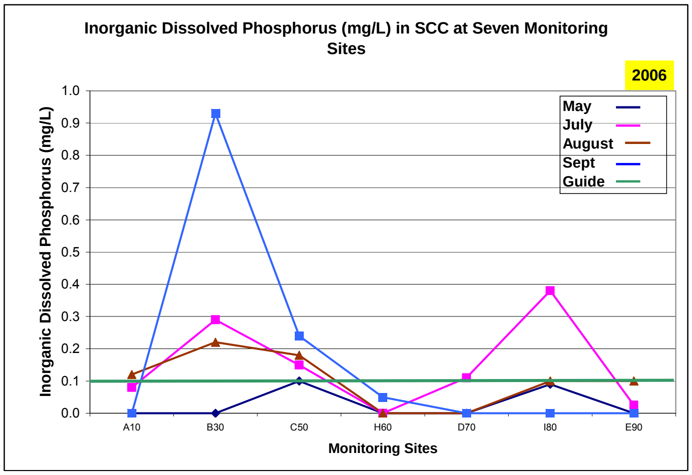

Figure 27: Inorganic phosphorus levels in Swift Current Creek in 2006

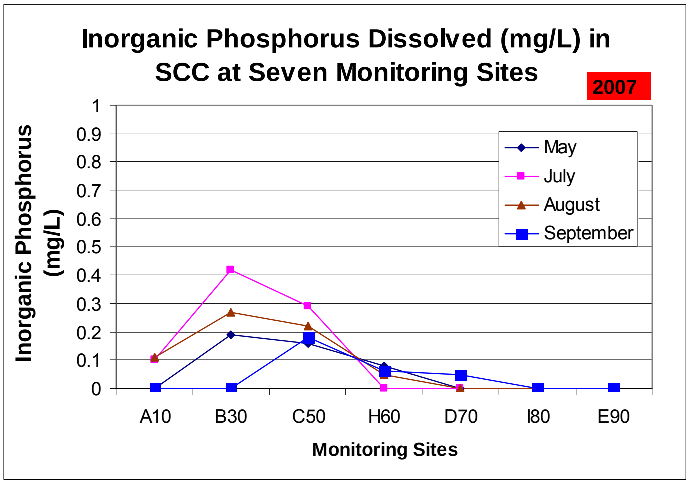

Figure 28: Inorganic phosphorus levels in Swift Current Creek in 2007

4.2.2.7 Aluminum

Aluminum is the most abundant metal found in the earth's crust. This light but strong metal is never found free in nature, it combines with other elements to form compounds (KDW 2007). Aluminum ions in streams can be a result of industrial effluents, but the most common cause of excess aluminum in water is in the wash water from WTP (water treatment plants). Aluminum in the form of alum is added to the water to bind to potentially harmful microorganisms. This binding process creates clumps that are easily removed from the water via sedimentation or filtration. However, if alum is added in excessive amounts, the pH level of the water will lower (become acidic) becoming toxic to aquatic life (KDW 2007).

Aluminum peaks at H60 in all three sample years. Site H60 is located within the City of Swift Current and is located downstream from the city's WTP. The repeated spike in aluminum may be attributed to the wash water released from the Swift Current WTP. Alum binds to potentially harmful microorganisms causing them to clump allowing easier removal from the water via sedimentation or filtration and is used in similar WTPs.. However, the SCCWS can only speculate that the WTP may be contributing to the elevated aluminum levels in the creek without further investigation.

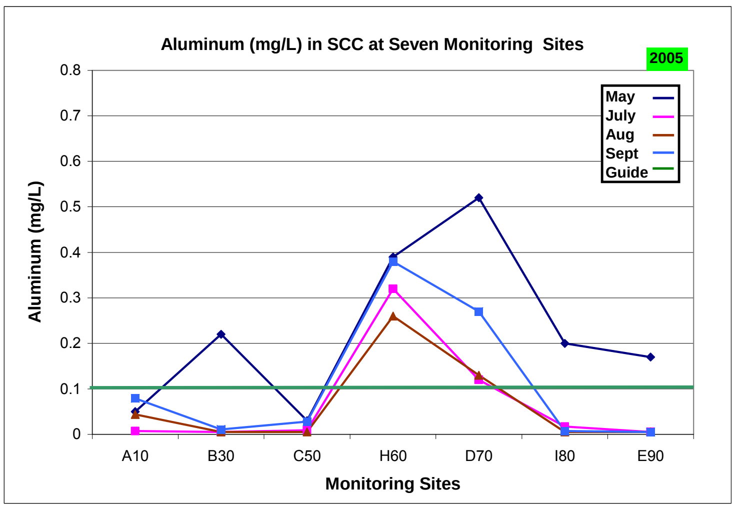

Figure 29: Aluminum levels in Swift Current Creek in 2005

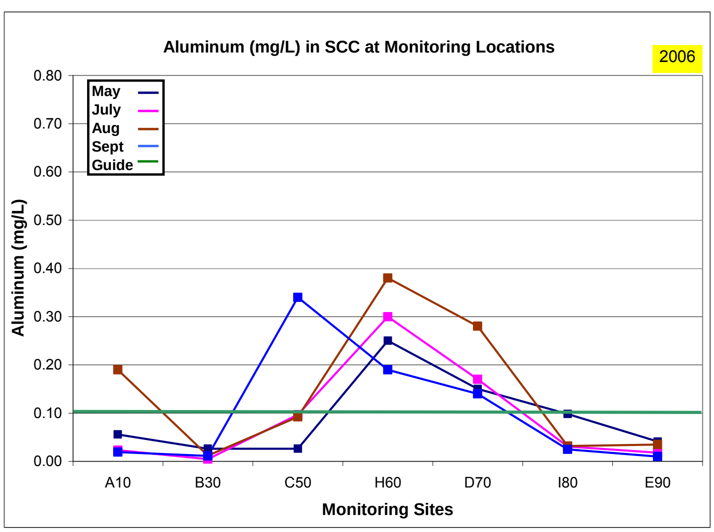

Figure 30: Aluminum levels in Swift Current Creek in 2006

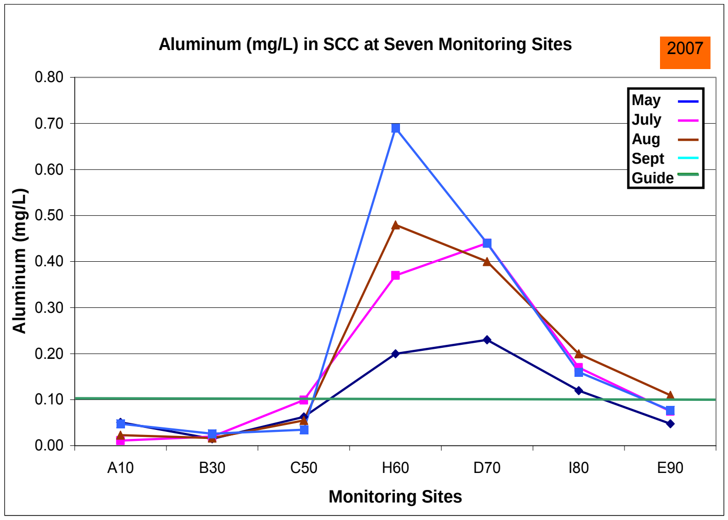

Figure 31: Aluminum levels in Swift Current Creek in 2007

4.2.3. Bacteriological Results

The bacteriological parameter, fecal coliforms, is an extremely important watershed health indicator. This parameter has repeatedly shown values at some of the sample sites that are beyond the acceptable guidelines set out by Saskatchewan Environment in the Surface Water Quality Objectives report. In the following paragraphs this parameter will be discussed in terms of what it is, how it affects the health of our watershed, and if possible speculation as to its sources.

4.2.3.1. Fecal Coliforms

According to Murphy (2007), fecal coliforms are rod shaped bacteria that live in the intestines and fecal matter of warm blooded animals. Fecal coliforms are an indicator of fecal contamination, or more specifically *Escherichia coli* which can serve as an indicator microorganism for other pathogens, such as salmonella, that may be present in feces. When water samples detect the presence of fecal coliforms in aquatic environments, it indicates that the water has been contaminated with fecal material from humans, livestock or wildlife. Fecal matter can enter a watercourse by way of waste discharge from mammals or birds, agriculture or storm runoff, and untreated human sewage.

The Washington State Department of Health (2007), states that the presence of fecal coliforms in streams can lead to human and environmental health risks. Large quantities of fecal bacteria indicate a higher risk of pathogens that may cause dysentery, typhoid fever, viral and bacterial gastroenteritis and hepatitis A. In addition to this, untreated organic matter containing fecal coliforms can lead to reduced dissolved oxygen levels in aquatic systems which can kill fish and other aquatic life.

In Figures 17, 18 and 19, fecal coliforms exceed the acceptable guideline (200 ct/100mL) at site A10 in July for all three sample years. Observations, by SCCWS personnel, have indicated the presence of livestock both in and around the creek in July from 2005-2007. Fluctuating fecal coliforms at site A10 may be as a result of multiple local producers allowing their livestock to drink directly from the creek in the month of July. If livestock continue to water directly from the creek there may be long-term impacts on water quality. As shown in Figures 32-34 the fecal coliform concentration at site A10 rises each year with a large increase from 2006 to 2007. This significant increase in fecal coliforms may be the result of the streams inability to assimilate the fecal coliforms causing them to accumulate in the system. Additional factors that may contribute to the variation in fecal concentrations and assimilation capacity at this site are: the length of time the livestock were allowed access to the creek, the flow of water in the creek, and the number of livestock allowed in the area.

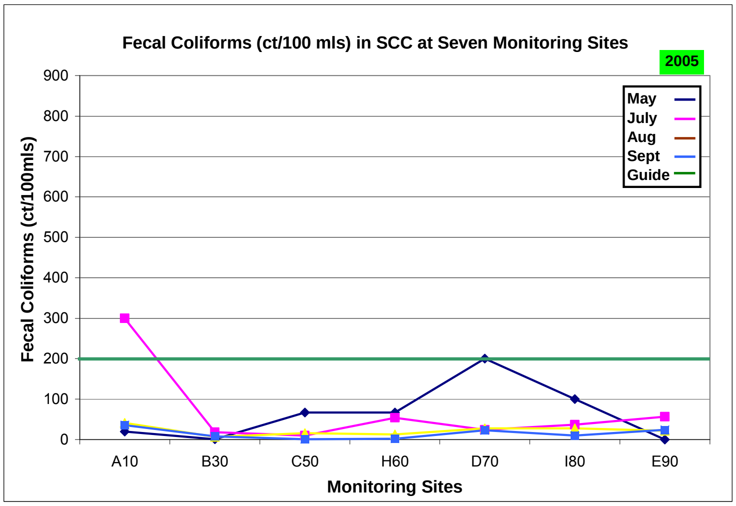

Figure 32: Fecal coliforms in Swift Current Creek in 2005

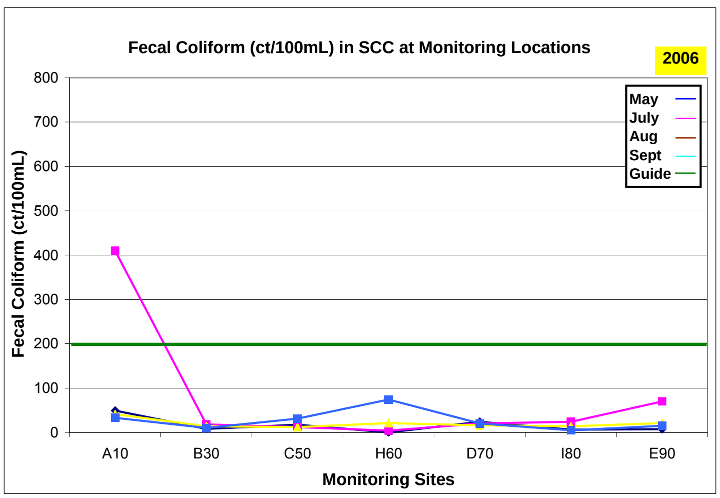

Figure 33: Fecal coliforms in Swift Current Creek in 2006

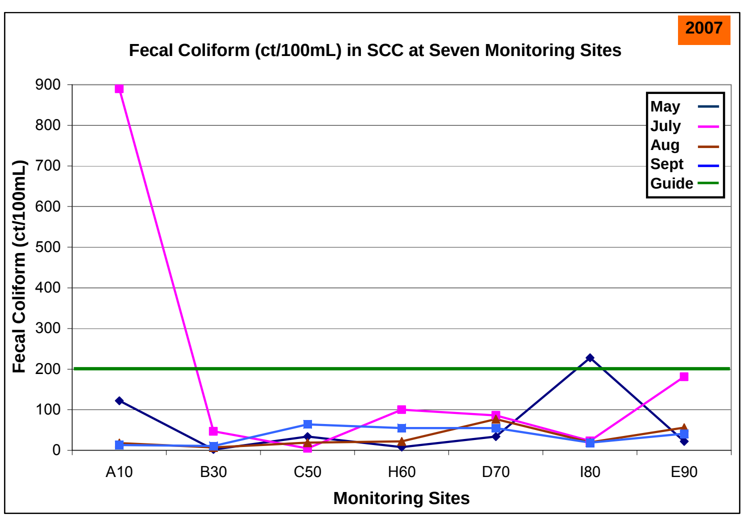

Figure 34: Fecal coliforms in Swift Current Creek in 2007

4.3 Recommendations

As a result of the studies discussed, the following are recommended:

- The SCCWS should try to obtain past water data pertaining to aluminum concentrations from the WTP. This will help pinpoint whether or not the aluminum spikes at H60 can be attributed to the WTP.
- Water sampling for two additional years. One year of water sampling after the installation of the WWTP is not long enough to determine an accurate representation of overall water quality in the SCC. Water sampling for two more years would help to determine the impact of the new WWTP on water quality in SCC.
- Encouraging producers to install off-site watering bowls to increase the quality of water supplied to their livestock as well as protect the integrity of the SCC.
- Continue to provide ongoing educational seminars to local livestock producers within the Swift Current Creek Watershed about creek health with a focus on the dangers of watering livestock directly from the creek.
- Establishing a minimally impacted sampling location would aid in interpreting impacts on and recovery of SCC.

5 FISH SURVEY RESULTS

Overall, the delivery of fish assemblage monitoring and assessment conducted from 2004-2007 was enormous, receiving support from PFRA, SWA, and the City of Swift Current. Field sampling procedures throughout the three sample years were conducted using consistent methods to enable multi-year data comparison. Over the last three years the minimum number of white suckers (100) was collected at each of the sample sites but the number of fathead minnow individuals collected at multiple sites fell short of the minimum (100). Conducting statistical analyses on insufficient data collected from the fathead minnow samples could negatively skew the data; thus analyses were conducted on white suckers only.

5.1 Fish Community Survey

The fish community survey was conducted to assess the composition, species richness and abundance characteristic of the fish assemblage in SCC. Throughout all three sample years, all captured fish were identified to species, enumerated, and then released outside the sample area. The total number of different species, including the white sucker and fathead minnow species, make up the fish community at each of the sample sites. In 2005 and 2006, site E90 had the largest community with thirteen species of fish (Table 15). In 2007, the largest recorded fish community was eleven at site C50 (Table 15). Table 15 summarizes the fish data collected from the SCC at sites A10, B30, C50, D70, and E90 in the third week of July for three consecutive years (2005-2007).

Table 16: Population of fish species in Swift Current Creek at five sample sites, July 2005-2007.

SPECIES		Sample year	LOCATIONS					Total per year	Total per species
			A10	B30	C50	D70	E90		
FTMN	Fathead Minnow	2005	111	203	107	154	33	**608**	
		2006	445	599	125	267	101	**1537**	
		2007	156	99	17	366	2	**640**	**2785**
WHSC	White Sucker	2005	111	103	71	180	180	**645**	
		2006	129	103	335	265	137	**969**	
		2007	429	166	122	286	146	**1149**	**2763**
JHDR	Johnny Darter	2005	9	0	10	2	0	**21**	
		2006	21	2	0	47	0	**70**	
		2007	0	0	0	1	0	**1**	**92**
IWDR	Iowa Darter	2005	0	3	11	37	0	**51**	
		2006	4	3	9	1	1	**18**	
		2007	0	2	1	1	0	**4**	**73**
SHRD	Shorthead Redhorse	2005	3	4	24	7	8	**46**	
		2006	7	0	32	4	24	**67**	
		2007	11	9	211	63	91	**385**	**498**
CRCH	Creek Chub	2005	3	0	57	37	21	**118**	
		2006	0	32	1	14	20	**67**	
		2007	0	0	2	0	0	**2**	**187**
LKCH	Lake Chub	2005	0	0	0	6	18	**24**	
		2006	0	0	0	19	0	**19**	
		2007	0	0	0	92	1	**93**	**136**
LNDC	Longnose Dace	2005	1	3	3	9	19	**35**	
		2006	1	0	9	0	21	**31**	
		2007	0	0	4	35	0	**39**	**105**
NRDC	Northern Redbelly Dace	2005	0	0	0	0	0	**0**	
		2006	0	48	3	0	14	**65**	
		2007	0	0	0	0	0	**0**	**65**

SPECIES		Sample year	LOCATIONS					Total per year	Total per species
EMSH	Emerald Shiner	2005	0	0	39	2	24	**65**	
		2006	7	33	93	330	0	**463**	
		2007	0	0	17	10	11	**38**	**566**
RVSH	River Shiner	2005	0	0	0	0	0	**0**	
		2006	0	0	4	0	42	**46**	
		2007	0	0	53	26	71	**150**	**196**
SPSH	Spottail Shiner	2005	0	0	85	54	30	**169**	
		2006	71	1076	122	81	25	**1375**	
		2007	0	0	4	0	0	**4**	**1548**
BRMN	Brassy Minnow	2005	0	0	4	22	42	**68**	
		2006	0	0	18	1	14	**33**	
		2007	0	0	0	0	0	**0**	**101**
WALL	Walleye	2005	0	0	0	0	6	**6**	
		2006	0	0	0	0	0	**0**	
		2007	0	0	1	0	1	**2**	**8**
YLPR	Yellow Perch	2005	0	0	0	0	1	**1**	
		2006	0	0	0	0	11	**11**	
		2007	0	0	0	0	0	**0**	**12**
SLRD	Silver Redhorse	2005	0	0	0	0	1	**0**	
		2006	0	0	0	0	0	**0**	
		2007	0	0	0	0	0	0	**0**
TINY	Too Tiny	2005	0	100	0	0	0	**100**	
		2006	49	37	0	1	0	**87**	
		2007	0	0	0	42	0	**42**	**229**
NUMBER OF FISH CAUGHT IN 2005		**2005**	**NUMBER OF FISH CAUGHT IN 2006**		**5240**	**NUMBER OF FISH CAUGHT IN 2007**		**2659**	

The three most abundant fish species that were captured from the SCC over the three sample years were white sucker (*Catostomus commersoni*), fathead minnow (*Pimephales promelas*) and the spottail shiner (*Notropis hudsonius*). The population of fathead minnows was the highest in 2006 (1537 individuals) and the lowest in 2005 (608 individuals). The white sucker population was the largest in 2007 (1149 individuals) and the smallest in 2005 (645 individuals). The largest population of spottail shiners was captured in 2006 with 1375 individuals and the smallest population was in 2007 with 4 individuals. The large change in the spottail shiner population from 2006 to 2007 may be a result of fish misidentification and not a true reflection of change in population. There are two other types of shiners that are present in our watershed: river shiner and emerald shiner. If the shiners were misidentified, it is probably due to their similarity in appearance when they are very young; older individuals are more easily discernible. Therefore, there is a possibility that individuals identified as river or emerald shiners could actually be spottail shiners and vice versa. If the differences in the shiner populations are due to misidentification the maximum difference, from 2005-2007, would be 2310 individuals.

5.2 Fish Population Surveys

The fish population surveys followed the Environmental Effects Monitoring (EEM) sampling protocols for non-lethal sampling (Gray, Curry, & Munkittrick 2002) and the revisions for non-lethal sampling (Environment Canada 2005). The protocol requires that a minimum of 100 individuals of the sentinel species (fathead minnow and white sucker) should be collected at each sample site. In 2005, the minimum amount of white sucker individuals were captured at all sites except C50 and the quota for fathead minnows was met at each site except E90. In 2006, this requirement was met for both white suckers and fathead minnows. In 2007, the quota for white suckers was met at all sites and the quota for fathead minnows was attained at sites A10 and D70 only.

Descriptors of fish populations were made using EEM endpoints for non-lethal sampling. Endpoints included total length, body mass (weight), and body condition (comparison of body mass and length). Percent young-of-year (YOY) in the sample for each site were determined as an index of reproduction. Statistical analyses were conducted to determine a relationship between length, weight and body condition of white suckers among sites and years. An additional analysis was added to determine whether or not water quality had an effect on the white sucker population.

All analyses were performed by Dr. Karen Machin, Western College of Veterinary Medicine, University of Saskatchewan.

5.2.1 Total Length

In general, the total lengths of white suckers were the longest at sites A10, B30, D70 and E90 and the shortest at site C50. The total lengths of YOY white sucker ranged from 33.19mm at site C50, in 2005, to 44.26mm at site B30, in 2005 (Figure 35). A significant interaction between sites and year was identified in white sucker YOY total length in SCC ($F = 28.90$ $df_{8,1859}$, $P < 0.0001$; Fig. 35). As a result, there was no annual trend in white sucker YOY total length.

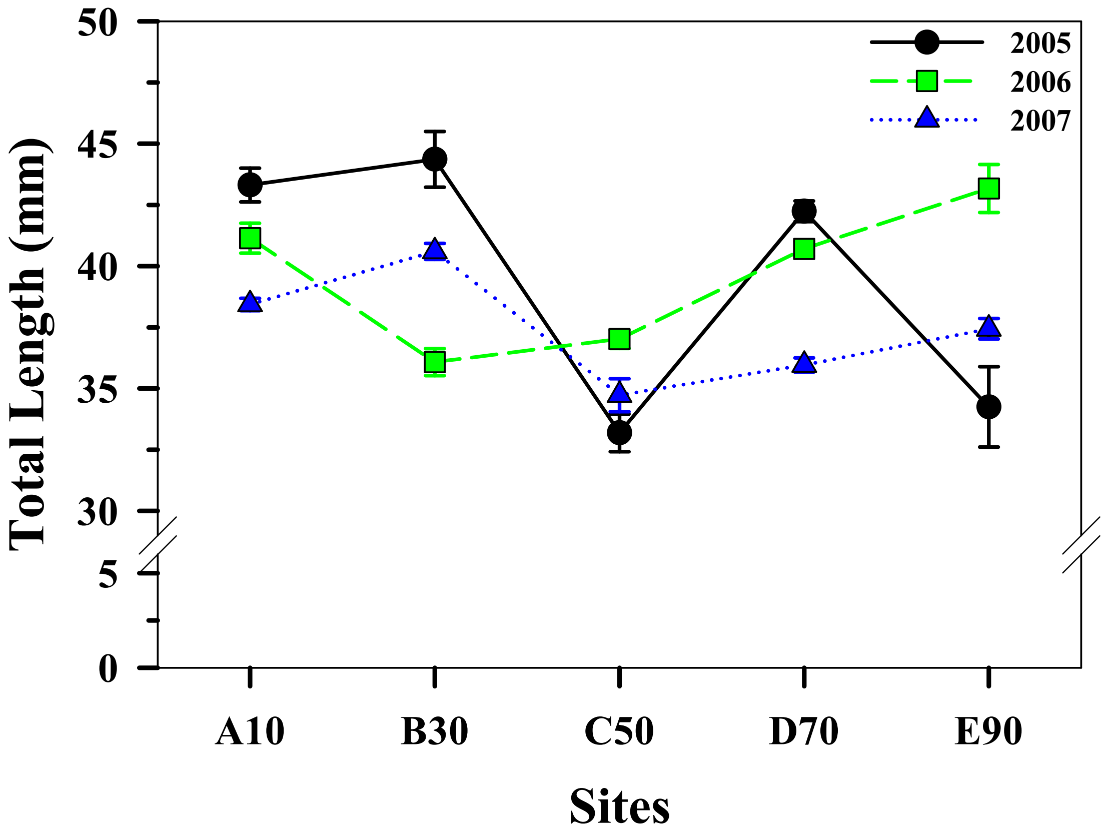

Figure 35: Relationships of young-of-year white sucker total length (mm) among sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

5.2.2 Body Weight

In general, white sucker body weight tended to be the lowest at site C50 with the remaining two upstream and two downstream sample sites having higher body weights. The lowest white sucker body weight was .36g at site C50 in 2005 and the highest body weight was .86g at sites B30 and E90 in 2005 and 2006, respectively (Figure 36). There was a significant interaction between sites and year in white sucker YOY body weight (F = 16.99 $df_{8,1859}$, P < 0.0001; Fig. 36); as a result, no annual trend could be discerned.

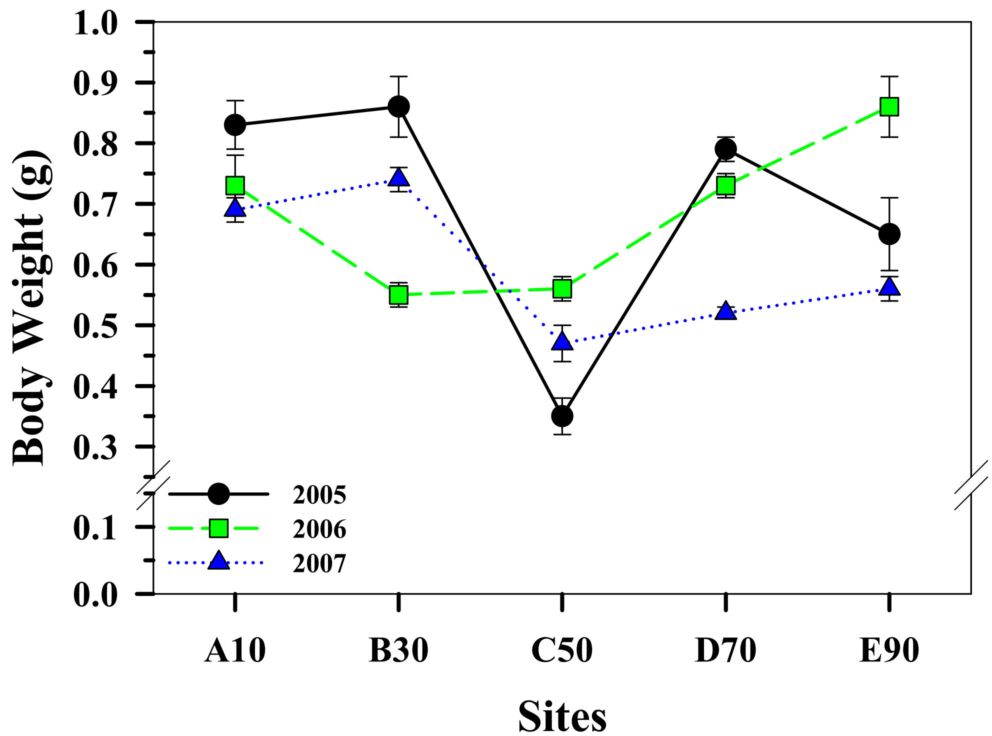

Figure 36: Relationships of young-of-year white sucker body weight (g) among sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

5.2.3 Condition Factor

Condition factor (k) is a measure of weight and length. In general, a longer, heavier fish has an ideal body condition and may result in a longer, healthier life. Overall the condition factor (k) of all white suckers varied little among sites and years. Condition factor varied from 0.0009 at site C50 in 2005 to 0.0012 at site A10 in 2007 (Figure 37). There was no significant interaction found for condition factor (F = 0.48, $df_{8,2409}$, P = 0.87; Fig 37); therefore, an one-way ANOVA was performed to test for differences among years. This analysis revealed that there was not a significant difference in condition factor among years (F = 0.81, $df_{2,2421}$, P = 0.45; Fig. 37).

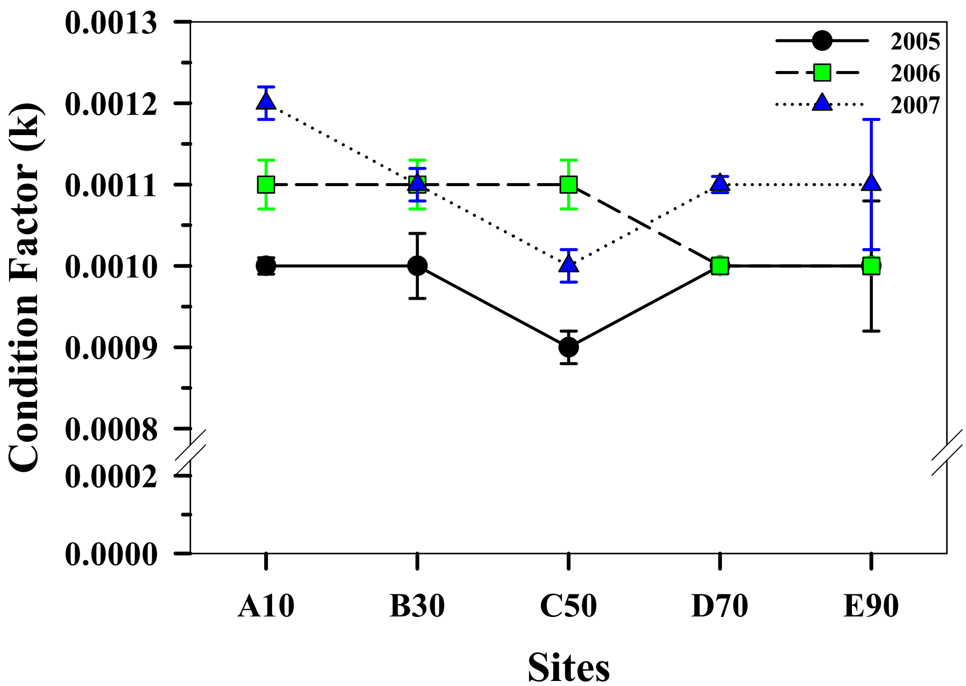

Figure 37: Relationships of condition factor (k) of all white suckers collected from sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

5.3 Water Quality Factors Affecting White Sucker

In order to understand the effects that water quality can have on white suckers, the SCCWS requested that the collected water quality variables such as metals and nutrients be analyzed alongside the white sucker length, weight and condition factor. Unfortunately, there was not enough variation in the water data to test for possible effects on the white sucker population (only 1 water quality sample per fish collection sample). To resolve this problem the SCCWS would need to implement more simultaneous fish and water sampling in order to determine the affects of water quality on white suckers.

5.4 Recommendations

As a result of the studies discussed, the following are recommended:

- To more easily detect annual trends in white suckers and assess the relationships between water quality and white suckers, the SCCWS were advised to collect both more years and more frequent data for both white suckers and water quality.
- Collecting fish data at least twice a year from June-July, or June and August will not only provide the SCCWS with more comprehensive data but the YOY will be more easily identifiable.
- Establishing a minimally impacted sampling location would aid in interpreting impacts on and recovery of SCC.

6 BENTHIC MACROINVERTEBRATE COMMUNITY RESULTS

Macroinvertebrate community surveys are useful tools for indirectly assessing water quality by comparisons of indices among various habitats. In this project, we collected macroinvertebrate community samples from six sites: A10, B30, G40, C50, D70, and E90. At each of the six sites, we took 9 field samples (3 sub-samples with 3 replicates) for a total of 54 samples in each sample season (162 samples from 2005-2007).

In section 6.1, we provide a brief description of the calculated analyses and how they relate to water quality and environmental conditions. In Section 6.2, we describe the endpoint results, and in section 6.3, we introduce the results of the macroinvertebrate community analysis which looks at the statistical comparisons between sites. Section 6.4 presents the conclusions and recommendations.

6.1 Indices or EEM Endpoints for Invertebrates

The following is a list of the benthic macroinvertebrate data analysis completed:

- Total invert abundance (EEM endpoint)
- Taxon richness (EEM endpoint)
- Simpson's Evenness Index (EEM endpoint)
- Simpson's Diversity Index
- Percent EPT
- Percent contribution of dominant family
- Modified Hilsenhoff's Biotic Index (FBI)
- Mulitvariate analyses (PCA and BIOENV)

Species abundance is a measure of the abundance of individuals in a community. Abundance is calculated by averaging the total individuals for all nine samples at each site.

Taxon richness is a count of the number of different taxa sampled in a given area. The total number of taxa or taxon richness generally increases with increasing water quality, habitat diversity, and habitat suitability.

Simpson's Evenness Index measures the abundance of each family within a community to determine how uniformly distributed families are within a community. The more evenly distributed a community is, the healthier the community. Simpson's Evenness Index ranges from values of 0 (uneven) to 1 (perfectly even). For example, the same number of individuals enumerated for each family (25, 25, 25, and 25 respectively) within a sample would have perfect evenness and thus, a score of 1.

Simpson's Diversity Index (D) is a measure of community diversity. Diversity indices provide information about community composition by accounting for taxon richness and the relative abundances (and evenness) of those taxon. At the same species richness, diversity increases as the evenness in relative abundance among taxa increases. Similarly, at the same evenness in abundance across the species, the index value increases with the number of taxa.

Percent EPT is a measure of pollution intolerant macroinvertebrates; Ephemeroptera, Plecoptera, Trichoptera (EPT). On a scale of 0-100 %, high percentages of these taxa indicate good stream conditions; whereas, low percent EPT indicates degraded conditions. If any one particular member of the EPT is absent, this is an indicator of concern.

The percent contribution of the dominant family to the total numbers within a sample provides a measure of community balance at the family level. A community more dominated by one family generally indicates environmental stress (and is likely related to a lack of diversity in the community).

The Modified Hilsenhoff's Biotic Index (here referred to as the Family Biotic Index [FBI]) measures the degree of organic pollution. The FBI is calculated using the formula:

$$\mathbf{FBI= \sum (x_i *t_i)/(n),}$$

where x_i = number of individuals within a taxon, t_i = tolerance value of a taxon, and n = total number of individuals in the sample. Each macroinvertebrate family is assigned a tolerance value based on their pollution tolerance, these values range from 0 for organisms very intolerant of organic wastes to 10 for organisms very tolerant of organic wastes. Family tolerance values are assigned by the U.S. Environmental Protection Agency (1989) and can be obtained in Benthic Macroinvertebrates in Freshwaters – Taxa Tolerance Values, Metrics, and Protocols (Mandaville, 2002). Table 16 shows which biotic index values correspond to the following water quality evaluation and the degree of organic pollution.

Table 17: Evaluation of water quality using biotic index values

Biotic Index	Water Quality	Degree of Organic Pollution
0.00 - 3.75	Excellent	No apparent organic pollution
3.76 - 4.25	Very Good	Possible slight organic pollution
4.26 - 5.00	Good	Some organic pollution
5.01 – 5.75	Fair	Fairly significant organic pollution
5.76 – 6.50	Fairly Poor	Significant organic pollution
6.51 – 7.25	Poor	Very significant organic pollution
7.26 - 10.00	Very Poor	Severe organic pollution

If no tolerance value was available, the family was not used in the FBI calculation. This affected several invertebrate families, including Chrysomelidae, Notonectidae, Gerridae, Hydraenidae, and Chordodidae all of which had only a few individuals scattered among sampling sites. A tolerance value was not available for Erpobdellidae as well, but it was relatively common at only two sites, A10 and B30. Therefore, missing tolerance values for these families likely had little impact on overall FBI scores.

A multivariate analysis is a form or ordination analysis using non-metric multidimensional scaling to determine how similar replicate samples are among sites and among years. The two multivariate analyses chosen to complete the statistical analysis on the macroinvertebrates were the principal component analysis (PCA) and the matching of biotic and environmental patterns (BIOENV). The PCA is a data reduction method where multiple variables are reduced to a few explanatory axes consisting of multiple variables. The BIOENV analysis was used to correlate environmental variables with the invertebrate community. Mean environmental variables and invertebrate variables were used in the BIOENV procedure.

6.2 Results of Endpoint Analysis

According to Karen Machin (2008), statistical analyses were carried out on all invertebrates except for those that were terrestrial in origin. In addition, analyses were conducted on amphipod families assigned to Talitridae. A variety of benthic invertebrates were collected and identified from the SCC including worms (annelids and nematodes), crustaceans (amphipods), insects (midges, beetles, flies, mayflies, caddisflies, stoneflies, dragonflies), and molluscs (clams and snails). Table 17 summarizes the benthic invertebrate taxa collected from the SCC at sites A10, B30, G40, C50, D70, and E90 in the third week of August for three consecutive years (2005-2007).

For each of the above sample sites, macroinvertebrate indices were sorted according to family and enumerated for each site and year. The total population of macroinvertebrates collected for each sample year as well as for all three sample years is shown in color at the bottom of Table 17. The information from this table as well as information from water chemistry variables was then used in statistical analyses to determine a correlation between macroinvertebrate communities and certain water variables such at nitrite and nitrate nitrogen.

Additional measurements were taken at each site to describe the stream and habitat characteristics contributing to the macroinvertebrate environment. These descriptive qualities are outlined in the following Tables 18, 19, and 20.

Table 18: Summary of benthic macroinvertebrates collected from the Swift Current Creek at sites A10, B30, G40, C50, D70, and E90 in August 2005-2007.

Group (common name)	year	A10	B30	G40	C50	D70	E90	Total	Total per taxa
Amphipoda (side swimmers)	**2005**	3682	3737	2800	257	2575	108	**13159**	**29589**
	2006	2539	2498	1520	2164	1322	214	**10257**	
	2007	1896	3470	321	441	13	32	**6173**	
Annelids (segmented worms)	**2005**	23	359	641	129	52	16	**1220**	**2274**
	2006	2	24	511	87	69	13	**740**	
	2007	6	7	143	44	70	44	**314**	
Arachnida (spiders)	**2005**	0	0	0	0	0	2	**2**	**10**
	2006	1	0	1	3	0	1	**7**	
	2007	1	0	0	0	0	0	**1**	
Cladocera (water fleas)	**2005**	1	0	0	0	0	0	**1**	**60**
	2006	0	0	0	0	0	0	**0**	
	2007	57	1	0	1	0	0	**59**	
Coleoptera (beetles)	**2005**	346	82	285	125	64	132	**1034**	**1947**
	2006	179	68	68	145	62	68	**590**	
	2007	133	14	62	54	12	48	**323**	
Decapoda (crayfish)	**2005**	0	0	0	0	0	0	**0**	**78**
	2006	0	0	11	27	0	6	**44**	
	2007	0	0	29	0	0	5	**34**	
Diptera (flies)	**2005**	879	486	145	267	125	108	**2010**	**3717**
	2006	431	46	122	125	124	50	**898**	
	2007	352	14	168	84	92	99	**809**	
Ephemeroptera (mayflies)	**2005**	18	5	165	141	94	54	**477**	**1210**
	2006	19	26	78	3	79	20	**225**	
	2007	85	14	198	129	19	63	**508**	
Gastropoda (snails and limpets)	**2005**	24	174	83	1	27	15	**324**	**595**
	2006	41	96	29	7	5	11	**189**	
	2007	26	24	28	0	3	1	**82**	
Hemiptera (true bugs)	**2005**	96	138	39	3	65	28	**83**	**575**
	2006	23	136	10	28	12	8	**217**	
	2007	115	26	34	55	1	44	**275**	
Hirudinea (leeches)	**2005**	57	27	4	0	1	3	**92**	**188**
	2006	21	11	1	0	0	0	**84**	
	2007	7	5	0	0	0	0	**12**	
Hydrachnidia (water mites)	**2005**	0	0	0	0	0	0	**0**	**87**
	2006	1	1	0	0	0	0	**2**	
	2007	2	0	0	0	0	0	**85**	
Megaloptera (alderflies)	**2005**	0	0	0	1	0	0	**86**	**94**
	2006	4	0	3	0	0	1	**8**	
	2007	0	0	0	0	0	0	**0**	
Nematomorpha (round worms)	**2005**	1	0	3	0	0	0	**4**	**91**
	2006	0	0	1	0	0	1	**87**	
	2007	0	0	0	0	0	0	**0**	
Odonata (dragonflies/damselflies)	**2005**	330	100	90	28	76	34	**658**	**1009**
	2006	81	32	54	18	42	36	**263**	
	2007	175	20	52	4	1	6	**88**	
Pelecypoda (clams)	**2005**	18	151	202	3	138	45	**557**	**914**
	2006	17	90	64	3	100	21	**295**	
	2007	6	36	3	0	15	2	**62**	
Trichoptera (caddisflies)	**2005**	47	50	256	12	2	162	**89**	**843**
	2006	10	11	227	102	0	6	**356**	
	2007	13	23	237	20	0	105	**398**	
Total population (3 years)	**43282**	**2005 population**	**19796**	**2006 population**	**14262**	**2007 population**	**9224**		

Table 19: Parameters measured at sites during benthic macroinvertebrate sampling in August 2005.

			Water					Vegetation		Substrate characteristics							
				Instream Measurements						Embeddedness (%)				Silt/ Clay (%)	Sand (%)	Gravel (%)	Rock (%)
Date	Site	Stream Type	Flow (cfs)	pH	Cond * (µmhos)	Dissolved* Oxygen (mg/L)	Water * Temp (ºC)	Macrophyte Coverage (%)	Canopy Coverage (%)	Upper-sect	Mid-sect	Lower-sect	Consolidation	<0.062 mm	0.062 <> 2mm	2 <> 64mm	>64 mm
08-24-2005	**A10**[1]	Run & Pool	1.048	8	668	10.2	16.9	85	<5	None	None	None	Difficult	20	15	60	5
08-22-2005	**B30**[2]	Run	6.745	8.98	680	7.06	24	60	<5	50	60	90	Easy	15	75	0	10
08-29-2005	**G40**[3]	Run & Pool	7.416	9.08	624	14	20.5	85	5	50	60	80	Difficult	40	10	25	25
08-25-2005	**C50**[4]	Riffle/ run & back eddy	10.700	n/r	530	8.3	13.6	45	<5	60	40	60	Easy/Difficult	25	20	25	30
08-23-2005	**D70**[5]	run	9.852	8.3	908	8.03	19.4	40	5	60	70	0	Easy	60	15	10	15
08-26-2005	**E90**[6]	rapid	10.524	8.67	1270	12.7	17.3	15	<1	35	35	20	Very Difficult	5	5	15	75

nr – not recorded;
* - average of 5 measurements at each sample collection site along a transect;
1 – sampled at transect A2;
2 – sampled at transect A2;
3 – sampled at transect A3;
4 – sampled at transects A3 and A2;
5 – sampled at transect A2;
6 – sampled at transect A3.

Table 20: Parameters measured at sites during benthic macroinvertebrate sampling in August 2006.

			Weather					Water						Vegetation		Substrate characteristics								Comments
							Stream Type		Instream Measurements							Embeddedness (%)				Silt/ Clay (%)	Sand (%)	Gravel (%)	Rock (%)	
Date	Site	Rep	Cloud Cover	Precipitation	Air Temp (ºC)	Wind Speed km/hr		Flow (cfs)	pH	Cond (µmhos)	Dissolved Oxygen (mg/L)	Water Temp (ºC)	Macrophyte Coverage (%)	Canopy Coverage (%)	Upper-sect	Mid-sect	Lower-sect	Consolidation	<0.062 mm	0.062 <> 2mm	2 <> 64mm	>64 mm	
21-08-2006	G40	A					Run & Pool		9.06	692	14.29	22.12	60	10	70	85	85	Easy to move	30	20	25	25	High water at center of A3. Mossy material in A1.
21-08-2006	G40	B	clear	0	28	15	Run	23	9.01	690	13.87	22.23	60	<5	50	50	50	Difficult to move	20	20	30	30	Not much vegetation. Lots of limpets.
21-08-2006	G40	C					Riffle & Run		8.94	680	14.06	21.94	50	5	15	30	65	Easy to move	25	20	35	20	Silty at banks and rocky in the center. Mossy plant material in C3, lots of veg in C1.
22-08-2006	A10	A					Run & Pool		9.61	720	17.52	24.4	75	<5	NR	NR	70	Difficult to move in spots	30	30	30	10	Very low, dirty water. A2 was a very time intensive sample.
22-08-2006	A10	B	cirrus	0	32	20	Run	0	9.69	718	16.74	24.44	80	<5	NR	90	80	Difficult to move	25	25	20	30	Less sand/silt, but more vegetation. Lots of vegetation in B2.
22-08-2006	A10	C					Run		9.45	658	12.68	21.8	50	<5	NR	NR	NR	Easy to move	25	50	20	5	Lots of sand in sample. Hard to sort through sand.
23-08-2006	E90	A					Riffle		8.78	1292	13.03	23.45	15	<5	15	30	25	Easy to move	5	10	20	65	Sample taken by rubbing on rocks. Braided stream so sample taken at 2 banks and 3 centers.
23-08-2006	E90	B	25%	0	30	10	Riffle & Run	10.61	8.73	1282	12.72	23.05	25	<5	15	15	30	Easy to move	20	10	10	60	All points involved rubbing rocks.
23-08-2006	E90	C					Pool		8.62	1291	13.27	22.3	50	<5	60	70	100	Easy to move	35	15	10	40	Lots of silt at banks.
24-08-2006	B30	A					Run		8.45	656	9.07	19.25	50	10	65	65	65	Easy to move	45	25	15	15	
24-08-2006	B30	B	75%	0	21	20	Run	18.579	8.46	672	10.38	19.7	75	<5	35	60	60	Difficult in spots	15	10	25	50	Lots of diversity in sample, screens just crawling with bugs.
24-08-2006	B30	C					Run & Pool		8.25	676	11.01	19.9	90	<5	NR	80	NR	Very difficult to move	70	20	5	5	Not much vegetation or sand in sample, lots of diversity of bugs and large sized bugs.
25-08-2006	D70	A					Run		8.33	1016	8.88	18.95	40	5	NR	NR	15	Hard to move in spots	20	40	30	10	Lots of dragonflies and mayflies.
25-08-2006	D70	B	cirrus	0	24	15	Run	6.98	7.91	1002	8.81	18.65	50	5	NR	NR	NR	Easy to move	50	35	10	5	
25-08-2006	D70	C					Run		8.20	1004	9.09	18.75	50	5	50	NR	NR	Easy to move	40	40	15	5	Lots of sand and not many bugs
28-08-2006	C50	A					Riffle & Run		8.63	622	9.54	18.81	20	5	40	85	55	Easy to move	35	25	15	25	A2 + A3 lots of silty and clay material. A1 rubbed rocks.
28-08-2006	C50	B	cirrus	0	25	30	Run	26.183	8.62	636	9.06	18.35	5	5	60	50	40	Difficult to move	15	25	40	20	Silty at banks.
28-08-2006	C50	C					Run		8.65	628	8.70	18.05	25	<5	100	100	60	Easy to move	65	25	5	5	Lots of silt and little vegetation. Lots of dead clams, limpets and snail material.

Table 21: Parameters measured at sites during benthic macroinvertebrate sampling in August 2007.

			Weather					Water					Vegetation		Substrate characteristics								
							Stream Type		Instream Measurements				Macrophyte Cover (%)	Canopy Cover (%)	Embeddedness (%)				Silt/ Clay (%)	Sand (%)	Gravel (%)	Rock (%)	Comments
Date	Site	Rep	Cloud Cover	Precip	Air Temp (°C)	Wind Speed (km/hr)		Flow (cfs)	pH	Cond (µmhos)	Dissolved Oxygen (mg/L)	Water Temp (°C)			Upper-section	Mid-section	Lower-section	Consolidation	<0.062 mm	0.062 <> 2mm	2 <> 64mm	>64 mm	
20-08-2007	A10	A	overcast	nil	22	25-30	run	0	8.88	600	11.87	20.62	70	0	no rocks	no rocks	no rocks	easy	40	5	50	30	cattle in the creek, extreme algal growth, very smelly water
20-08-2007	A10	B					run		8.77	600	8.88	19.45	70	0	no rocks	50	50	difficult	30	30	30	10	extreme algal growth, very smelly water
20-08-2007	A10	C					run		8.43	552	6.02	18.82	80	0	no rocks	no rocks	30	easy	60	30	10	0	visible cow paddies in water, banks starting to slump, extreme algal growth, very smelly water
23-08-2007	B30	A	slight overcast	nil	19	30-35	run	25.9	8.66	672	13.05	19.8	50	0	50	50	50	difficult	30	20	20	30	1 long nose dace
23-08-2007	B30	B					run & pool		8.49	606	8.22	17.22	50	0	50	50	60	difficult	10	10	20	60	1 stickleback, 1 longnose dace
23-08-2007	B30	C					run		8.41	634	14	19.14	60	0	no rocks	no rocks	no rocks	easy	50	40	10	0	Large thick mats of vegetation in middle of channel
22-08-2007	D70	A	cloudy	nil	14	40	run	11.2	8.41	746	7.99	15.6	5	0	40	50	50	difficult	20	30	10	40	
22-08-2007	D70	B					run & pool		8.27	728	7.7	15.49	5	0	no rocks	no rocks	no rocks	n/a	70	30	0	0	very hard to move around, sink up to knees
22-08-2007	D70	C					run		8.1	756	8.29	15.73	5	0	50	50	60	difficult	5	50	15	30	
21-08-2007	G40	A	slight overcast	nil	10	10	run & pool	28.4	8.82	596	9.8	14.7	40	0	70	70	70	very difficult	20	15	25	40	Deep hole in A3 transect, A2 fathead minnow and white sucker
21-08-2007	G40	B					run		8.63	588	8.62	14.21	30	0	70	60	70	very difficult	10	10	20	60	B2 transect has white sucker
21-08-2007	G40	C					run		8.7	600	10.63	15.05	30	0	70	70	70	very difficult	10	10	20	60	2 longnose dace at C2
24-08-2007	C50	A	slight overcast	nil	20	calm	run & pool	19	8.38	588	10.74	15.94	20	0	50	50	60	difficult	50	30	20	0	Garbage in creek found umbrella
24-08-2007	C50	B					run		8.88	556	9.04	15.04	30	0	40	40	50	difficult	10	20	30	40	Garbage in creek TV casing
24-08-2007	C50	C					run		8.52	574	9.01	15.01	40	0	60	60	70	difficult	10	30	30	30	High grass on bank edge
27-08-2007	E90	A	overcast	slight rain	17	calm	riffle	12.7	8.25	1204	10.04	15.20	40	0	50	60	70	difficult	10	20	30	40	lots of frogs
27-08-2007	E90	B					run		8.31	1216	10.15	15.50	15	0	15	20	30	difficult	10	10	20	60	lots of frogs
27-08-2007	E90	C					run		8.34	1224	10.43	15.32	10	0	no rocks	no rocks	60	easy	60	30	5	5	rod thermometer broke

Table 22: Mean values (± 1 SE) of macroinvertebrate diversity indices collected from Swift Current Creek, Saskatchewan, Canada, (A) 2005, (B) 2006 and (C) 2007. Variables marked with an asterisk are calculations used to determine effects on benthic invertebrate communities in the Environmental Effects Monitoring (EEM) program. Simpson's diversity index is considered a supporting variable in the EEM program.

A. 2005

Site	Richness*	Abundance*	Evenness*	Simpson DI	FBI[1]	%EPT[2]
A10	18.56 ± 0.85	613.67 ± 58.11	0.11 ± 0.01	0.48 ± 0.04	7.67 ± 0.05	0.4 ± 0.1
B30	15.33 ± 0.88	590.11 ± 78.45	0.13 ± 0.04	0.46 ± 0.04	7.77 ± 0.04	1.2 ± 0.5
G40	22.00 ± 0.96	524.78 ± 37.83	0.12 ± 0.01	0.58 ± 0.04	7.30 ± 0.19	9.8 ± 5.3
C50	10.22 ± 1.42	107.33 ± 37.94	0.40 ± 0.05	0.71 ± 0.02	7.33 ± 0.13	7.5 ± 3.6
D70	13.78 ± 0.85	357.56 ± 87.23	0.15 ± 0.03	0.41 ± 0.05	7.59 ± 0.08	1.8 ± 0.6
E90	15.22 ± 1.87	78.78 ± 20.23B	0.40 ± 0.04	0.80 ± 0.03	6.08 ± 0.28	22.1 ± 5.9

B. 2006

Site	Richness*	Abundance*	Evenness*	Simpson DI	FBI[1]	%EPT
A10	14.78 ± 0.72	374.3 ± 19.9	0.13 ± 0.01	0.45 ± 0.03	7.65 ± 0.03	0.9 ± 0.2
B30	14.44 ± 0.90	337.6 ± 10.9	0.13 ± 0.01	0.47 ± 0.04	7.44 ± 0.06	1.2 ± 0.2
G40	16.00 ± 0.96	299.7 ± 25.8	0.17 ± 0.02	0.59 ± 0.03	7.50 ± 0.23	10.3 ± 4.5
C50	10.11 ± 0.46	301.0 ± 30.7	0.17 ± 0.02	0.34 ± 0.08	7.58 ± 0.17	3.7 ± 2.1
D70	12.33 ± 0.53	201.6 ± 34.7	0.20 ± 0.05	0.49 ± 0.06	7.50 ± 0.09	4.5 ± 1.1
E90	10.89 ± 0.87	50.6 ± 9.7	0.45 ± 0.08	0.74 ± 0.04	6.92 ± 0.14	6.5 ± 1.4

C. 2007

Site	Richness*	Abundance*	Evenness*	Simpson DI	FBI[1]	%EPT
A10	15.4± 0.4	319.4 ± 10.5	0.14 ± 0.01	0.47 ± 0.02	7.58 ± 0.07	3.4 ± 0.1
B30	8.1 ± 0.5	406.0 ± 24.6	0.14 ± 0.01	0.90 ± 0.01	7.89 ± 0.02	1.0 ± 0.3
G40	11.9 ± 0.9	141.7 ± 32.1	0.45 ± 0.04	0.20 ± 0.01	6.67 ± 0.24	24.7 ± 6.3
C50	7.9 ± 0.8	92.4 ± 16.8	0.39 ± 0.06	0.40 ± 0.05	6.85 ± 0.20	15.2 ± 6.0
D70	6.9 ± 0.8	25.2 ± 6.1	0.66 ± 0.06	0.25 ± 0.03	6.82 ± 0.25	9.6 ± 3.0
E90	8.9 ± 0.6	49.9 ± 7.2	0.51 ± 0.04	0.24 ± 0.03	6.11 ± 0.34	31.3 ± 8.8

[1]FBI = Hilsenoff's modified family biotic index
[2]EPT = Ephemeroptera, Plecoptera, and Trichoptera

Macroinvertebrate abundance was lowest at site D70 in 2007 (25.2) and greatest at site A10 in 2005 (613.67) (Table 21). Macroinvertebrate abundance generally decreased from upstream to downstream sites. Analysis of the sample data indicates a significant interaction in macroinvertebrate abundance between sites and years ($F = 14.4$, $df_{10,144}$, $P < 0.0001$; Fig. 38) making annual trends in abundance indiscernible. In general, a significant interaction exists if lines overlap among years or look as if they might overlap (Fig. 38). If an interaction exists then it is impossible to determine a trend. It is impossible to determine a trend because abundance depends on site and year and in any given year the value at a site may be increasing, while decreasing at another site in the same year but doing the opposite the next year. The interaction seen in Figure 38 was driven by the sharp decrease in abundance at site C50 in 2005 and again at B30 in 2007. Due to this interaction, no annual trend could be discerned.

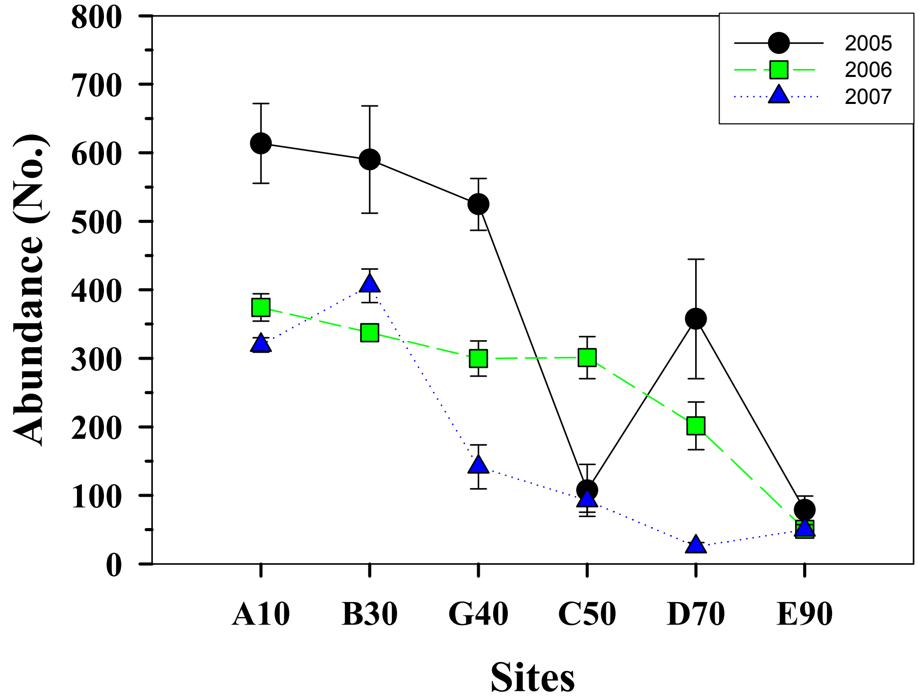

Figure 38: Relationships of macroinvertebrate abundance among sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

Taxonomic richness was greatest at site G40 in 2007 (22 species) and lowest at site D70 in 2007 (7 species) (Table 21). Over the three sample years taxonomic richness declined from upstream to downstream. Analysis of the sample data indicates that there is a significant interaction between sites and year in SCC ($F = 3.81$ $df_{10,144}$, $P < 0.0002$; Fig. 39). The interaction in Figure 37 is a result of an increase in richness at site A10 in 2007 and a decrease in richness at site C50 in 2005. As a result of this overlap, no annual trend in macroinvertebrate taxonomic richness could be determined (Table 21).

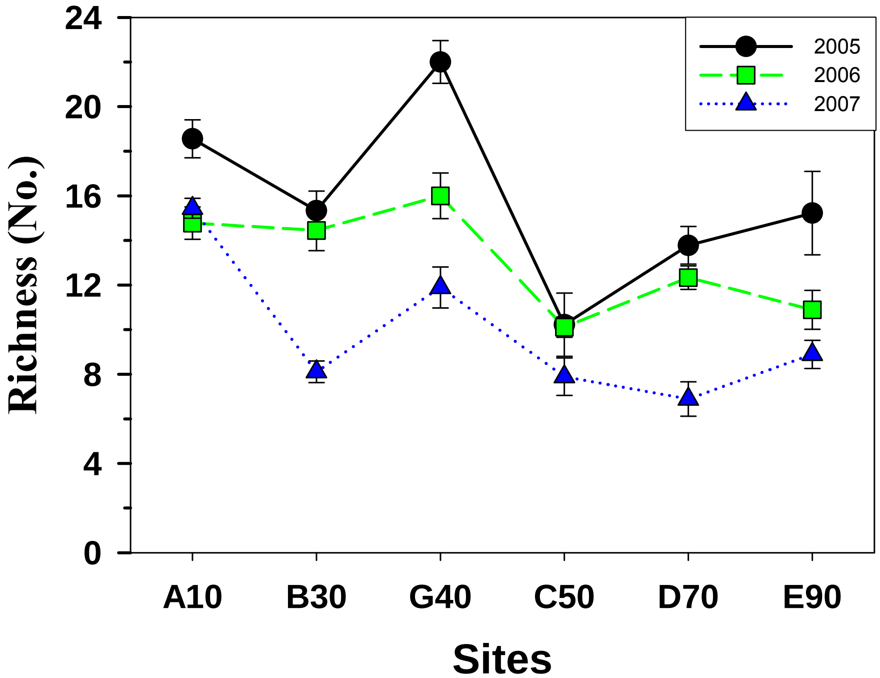

Figure 39: Relationships of macroinvertebrate taxonomic richness among sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

Evenness measures how uniformly individuals are distributed among the species, e.g., same number of individuals (25, 25, 25, 25) for each species within a sample would have high evenness. Overall, evenness among macroinvertebrates appears to increase from upstream to downstream. Results from SCC show that macroinvertebrate evenness was highest at site D70 in 2007 (0.66 ± 0.06) and the lowest at site A10 in 2005 (0.13 ± 0.01) (Table 21). Analysis of macroinvertebrate evenness shows a significant interaction between sites and year in SCC ($F = 12.7$, $df_{10,144}$, $P < 0.0001$). The major cause of this interaction is the sharp increase in evenness at site C50 in 2005 (Fig 40). Due to this interaction no annual trend in Simpson's Evenness could be determined.

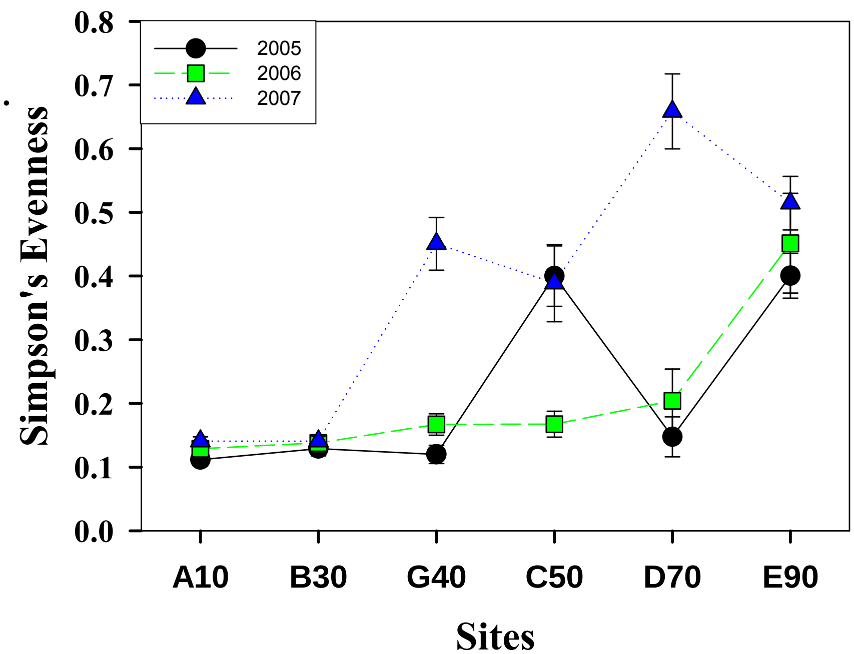

Figure 40: Relationships of Simpson's Evenness among macroinvertebrates among sampling sites and years at Swift Current Creek, Saskatchewan, Canada

Simpson's Diversity Index (D) is a measure of community diversity. This measure was the highest at site B30 in 2007 (0.90 ± 0.01) and the lowest at site C50 in 2007 (0.20 ± 0.01) (Table 21). The Simpson's Diversity Index was similar in 2005 and 2006; the diversity gradually increased from upstream to downstream. However, in 2007 the pattern of diversity started high upstream and gradually decreased further downstream. This is a highly significant interaction due to the overlap between the three sample years ($F = 20.6$, $df_{10,144}$, $P < 0.0001$; Fig. 41). Due to this interaction no annual trend in Simpson's Diversity could be determined.

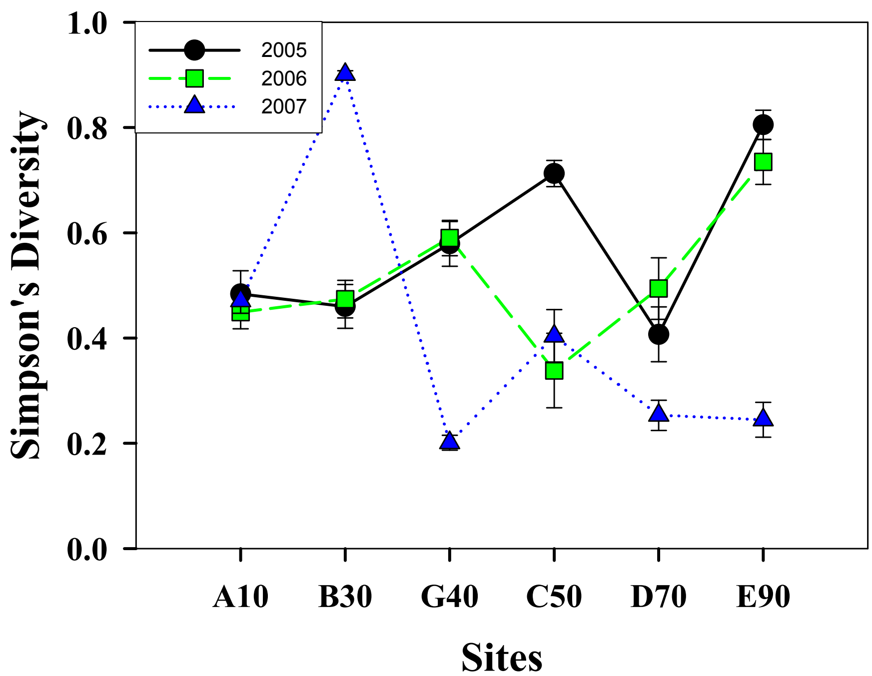

Figure 41: Relationships of Simpson's Diversity among macroinvertebrates among sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

High abundance of EPT (Ephemeroptera, Plecoptera, Trichoptera) indicates good stream conditions; whereas, low percent EPT is indicative of negatively impacted stream conditions. Percent EPT was relatively low at all sites but was highest at site E90 in 2007 (31.3 ± 8.8) and lowest at site A10 in 2005 (0.4 ± 0.1) (Table 21). According to the statistical analyses, no interaction, or possibly a marginally significant interaction was revealed. Since an interaction was identified, a one-way ANOVA was performed to test for differences among years. Results of the one-way ANOVA show that years differ significantly in relation to percent EPT ($F = 1.73$, $df_{2, 154}$, $P < 0.0001$). Percent EPT was considerably larger in 2007 than in the previous two years and there appeared to be no difference in percent EPT between the 2005 and 2006 sampling years (Fig. 42). Thus, percent EPT increased in 2007 compared to the previous two years.

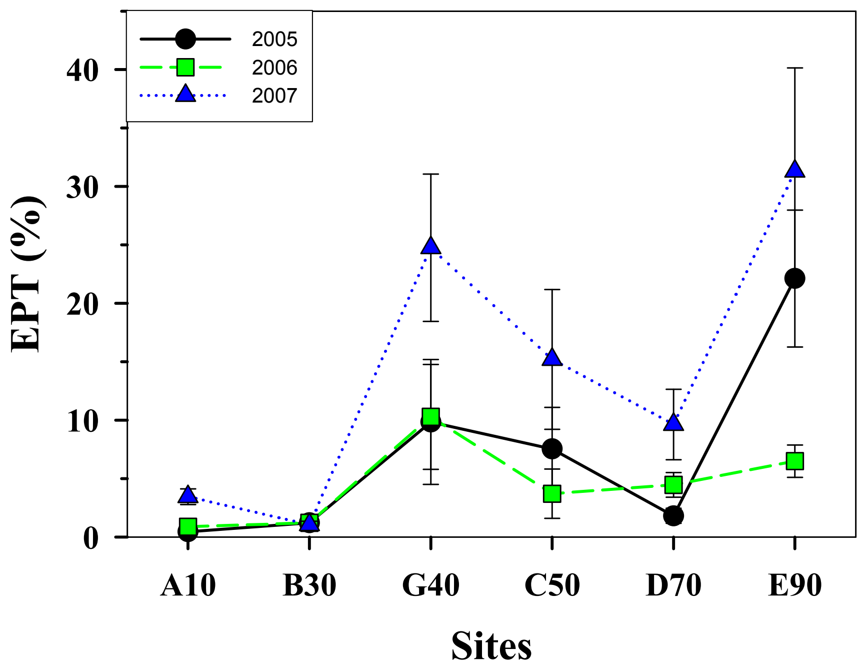

Figure 42. Pattern of percent EPT (Ephemeroptera, Plecoptera, and Trichoptera) among sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

In the percent contribution of dominant family analysis, a sample with a high dominance value can indicate degraded conditions or environmental stress. Over the three sample years, Talitridae was the dominant macroinvertebrate family in the majority of samples followed by Chironomidae, Hydropsychidae and Naididae. Percent contribution of the dominant macroinvertebrate family was highest at site B30 in 2007 with approximately 95% of the macroinvertebrates comprised of the amphipod family Talitridae. Site E90 had the lowest value at 33% in 2005, comprised of 5 different families (Hydropsychidae, Chironomidae, Talitridae, Haliplidae and Sphaeriidae). Percent dominant family values tended to decline as you moved downstream (Fig 43). Analysis of percent dominant family shows a significant interaction among sites and years ($F = 7.24$, $df_{10,144}$, $P < 0.0001$; Fig. 43). The major cause of this interaction was the sharp decrease in dominance at site G40 in 2007 and an increase in dominance at site D70 in 2005 (Fig. 43). As a result of this overlap, no annual trend in percent dominant family could be determined.

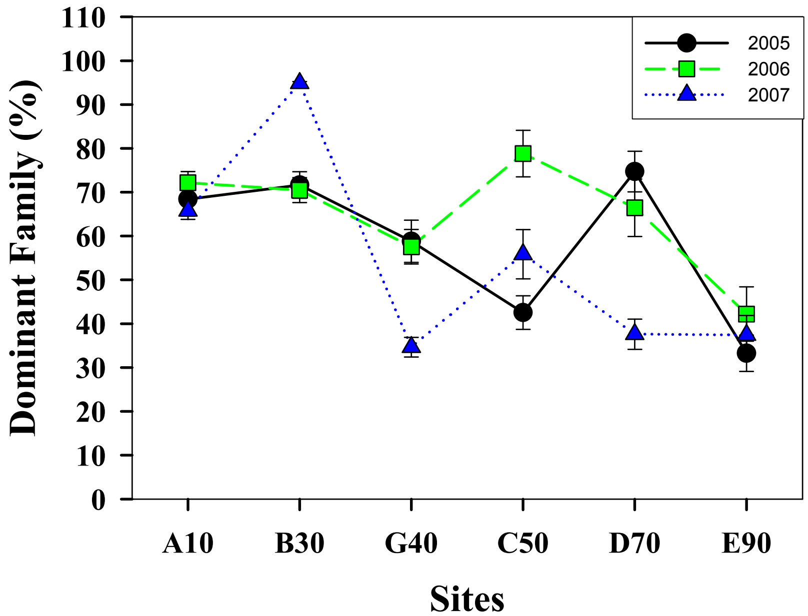

Figure 43: Pattern of percent dominant family among sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

The Modified Hilsenhoff Family Biotic Index (FBI) was relatively similar among sampling sites and years but tended to improve as you moved downstream. The FBI scores are evaluated on a score of 0-10, 0 being no organic pollution and 10 being severe organic pollution. Overall, the water quality at all six sites over the three sample years had fairly poor to poor water quality and significant to very significant organic pollution (Table 21). Site B30 in 2007 had the highest FBI (7.89 ± 0.02), while sampling site E90 in 2005 had the lowest FBI (6.08 ± 0.28), which corresponds to poor water quality and very significant organic pollution, respectively (Table 21). Five out of six sample sites (A10, B30, G40, C50, and D70) in 2005 and 2006 showed FBI scores in the 7 and above range and one site (E90 for both years) showed an FBI score in the 6 range. In 2007, only two sites out of the six sample sites (A10 and B30) showed FBI values in the 7 range whereas the remaining four sites (G40, C50, D70, and E90) showed values in the 6 range. Thus, it appears that the water quality at sites G40, C50, D70, and E90 improved slightly from 2005 and 2006. Analysis of the Modified Hilsenhoff Family Biotic Index (FBI) scores shows a significant interaction among sampling sites and years ($F = 2.90$, $df_{10,144}$, $P = 0.0025$; Fig. 44). The major cause of this interaction was the decrease in FBI scores at site G40 in 2005 and 2007 as well as the considerable drop in a FBI score at site E90 in 2005 (Fig. 44). As a result of this significant overlap, no annual trend in modified FBI values could be determined.

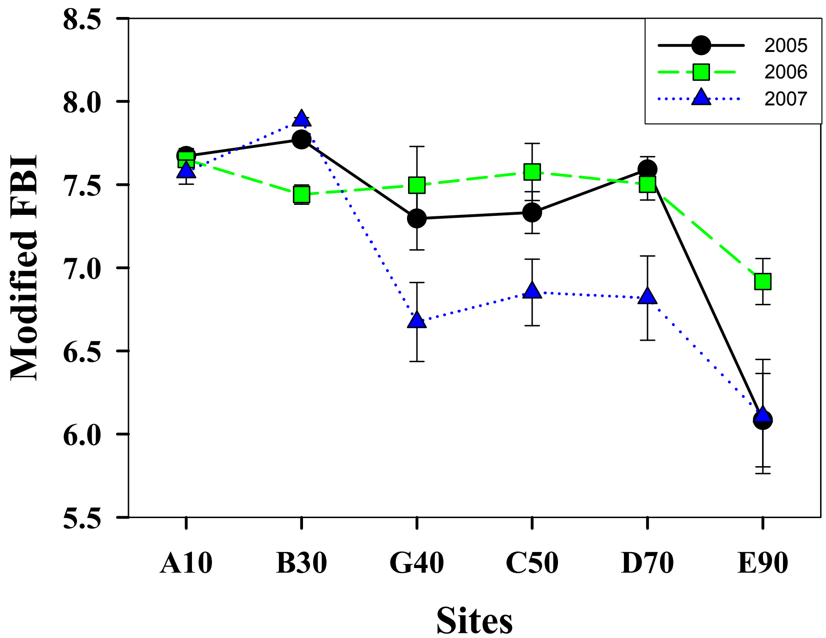

Figure 44: Pattern of modified Family Biotic Index scores among sampling sites and years at Swift Current Creek, Saskatchewan, Canada.

6.3 Macroinvertebrate Community Analysis Results

There were two types of macroinvertebrate community analyses conducted, the principle component analysis (PCA) and the BIOENV analysis. The PCA analysis was conducted on the environment/water chemistry data. This method was used to identify the variations in water chemistry among the sample sites. The BIOENV analysis was conducted in an attempt to identify any correlation between the macroinvertebrate community and the environmental/water chemistry data analyzed by the previously mentioned PCA method.

The principle component analysis (PCA) was used to analyze three years of collected environmental and water chemistry data. The PCA is a method used to characterize large amounts of data down to a manageable number of variables that can be interpreted. These variables are then plotted on axes to further explore the correlation between the sample sites and the environmental/water data. In this case, there are two explanatory axes PC1 (x-axis) and PC2 (y-axis). In PCA these axes explain in consecutive order (PC1 then PC2) the greatest amount of variation in the sample data, for example PC1 might explain 55% of the variation in the data whereas PC2 may explain 25% of the variation in the data. Variation in the data allows us to distinguish among sites. If no variation existed you would not be able to separate or distinguish among sites and thus, there would be no correlation between the biological data and the environmental data.

According to Machin (2008), before the PCA was performed, all data were examined for co-linearity among variables based on Spearman Rank correlation. Highly correlated variables ($P > 0.90$) were removed from the analysis to reduce clutter and improve explanatory power. In this case, conductivity was highly correlated with total dissolved solids, boron, sodium and sulfate, thus only conductivity was used in the PCA. Mercury and chromium were similar for each sampling location and were eliminated from the analysis since there was no variation. Once the data was checked for correlated variables, it was then checked for normality and transformed (ln) if necessary. To ensure that all the variables were on the same scale (i.e. pH and conductivity), normalization of each variable was performed.

The BIOENV analysis was used to determine if certain environmental variables (i.e. conductivity, chloride and nitrite + nitrate nitrogen) were correlated with the invertebrate community. The mean environmental and water chemistry values (chloride, pH, sodium, sulfate, ammonia, dissolved inorganic phosphorus, nitrite + nitrate, total nitrogen, aluminum, arsenic, boron, chromium, copper, total dissolved solids, conductivity, water temperature, discharge, dissolved oxygen) and mean invertebrate densities from each sampling location were used in the BIOENV procedure. In this method, the closer to 1 the Spearman rank correlation analysis is the stronger the correlation or association between the macroinvertebrate community and the environmental and water chemistry data. This method allows the SCCWS to determine if there is an association between water chemistry and the macroinvertebrate communities in the Swift Current Creek.

6.3.1 Macroinvertebrate Community 2005

The PCA revealed that chloride, dissolved inorganic phosphorus (DIP), conductivity and water temperature were important factors to differentiate the sample sites. According to Figure 45 and Table 22 there were high levels of chloride and conductivity and low levels of water temperature and DIP at sites D70 and E90 in 2005. In addition, there were high levels of arsenic, nitrite +nitrate nitrogen and total nitrogen at sites C50, B30 and G40 and low levels of aluminum, copper and dissolved oxygen (Figure 45 and Table 22). Site A10 showed intermediate levels of the above water chemistry variables.

Table 23: Coefficients of each environmental and water chemistry variable in a principal component (PC) axis and cumulative variations of PC1-PC2 for Swift Current Creek, Saskatchewan, 2005. Bolded values, those ≥0.350, are the best variables explaining the variation in each axis.

Variable	PC1	PC2
Chloride	**0.369**	0.021
pH	-0.277	-0.102
Dissolved inorganic phosphorus	**-0.363**	0.000
Ammonia	-0.177	-0.190
Nitrite + Nitrate	-0.257	**0.380**
Total nitrogen	-0.252	**0.353**
Aluminum	0.142	**-0.369**
Arsenic	0.231	**0.401**
Copper	0.243	**-0.378**
Conductivity	**0.381**	-0.027
Dissolved oxygen	-0.122	**-0.378**
Water temperature	**-0.350**	-0.200
Discharge	-0.315	-0.247
Cumulative variation	47.0%	74.5%

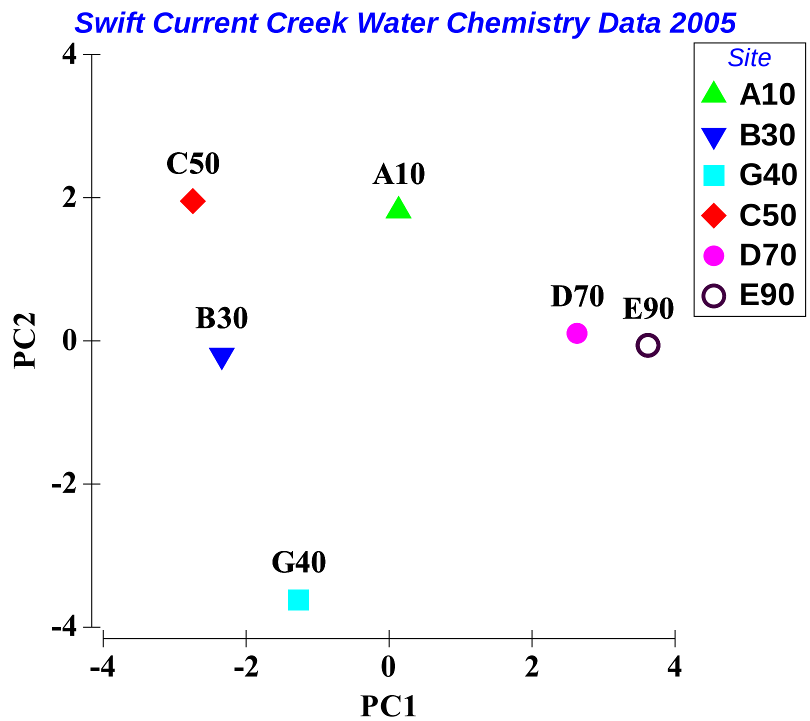

Figure 45: Principal components analysis of environmental and water chemistry variables at sampling stations on Swift Current Creek, Saskatchewan, 2005.

Results from the BIOENV analysis show two sets of environmental and water chemistry variables that best correlated with macroinvertebrate communities. A combination of nitrite + nitrate nitrogen and conductivity was considered the best set of variables that explains the macroinvertebrate communities in the SCC in 2005 (Spearman rank correlation (ρ) was 0.65, P = 0.002). The second set of variables nitrite + nitrate nitrogen, conductivity, and total nitrogen were the next best set of environmental and water chemistry variables that best correlated with macroinvertebrate communities (ρ= 0.61). Based on the law of parsimony, the simpler of two competing theories is to be preferred, it appears the first set of variables is likely the best set of variables that explains macroinvertebrate communities. This is graphically demonstrated in Figures 46 and 47. In these graphs the closer the two graphs mirror each other the higher the likelihood that those environmental/water chemistry variables might be influencing the macroinvertebrate communities at each sampling location. The two figures somewhat resemble each other with site E90 on the right side of both graphs and sites A10, B30, G40 and D70 clumped together and in somewhat similar locations in both graphs.

Information from Table 20 and the previous two analyses (PCA and BIOENV), indicate that site E90 had the highest conductivity and one of the lowest nitrite + nitrate nitrogen levels whereas C50 had the lowest conductivity and the highest nitrite + nitrate nitrogen levels. C50 also had the lowest taxonomic richness which is a sensitive measure of ecological condition. Therefore, the low taxonomic richness may be related to high nutrient levels at this site.

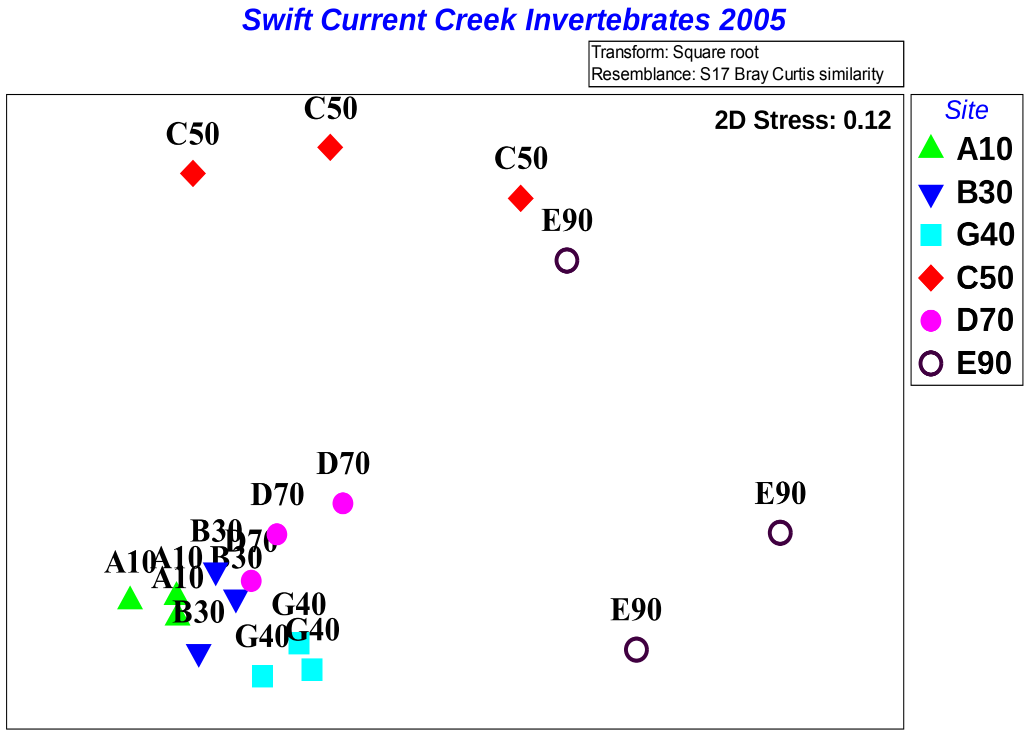

Figure 46: Nonmetric multidimensional scaling (MDS), an ordination technique, of invertebrate communities based on invertebrate abundance in Swift Current Creek, Saskatchewan, 2005. MDS represents 111 taxa based on root-transformed abundances and Bray-Curtis similarities (stress = 0.12).

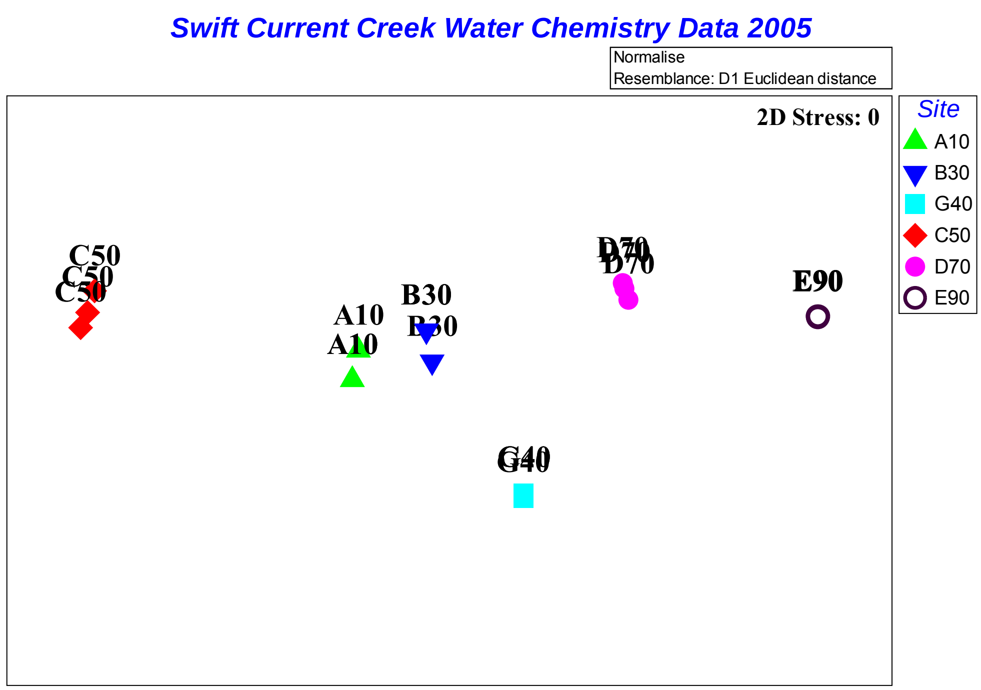

Figure 47: Nonmetric multidimensional scaling (MDS), an ordination technique, of invertebrate communities based on nitrite+nitrate and conductivity in Swift Current Creek, Saskatchewan, 2005. MDS is based on normalised values and Euclidean distances (stress = 0.0).

6.3.2. Macroinvertebrate Community 2006

In the 2006 PCA there was a slight adjustment; chloride and ammonia were not included in the analysis as they were highly correlated with conductivity and nitrite + nitrate nitrogen. The PC1 revealed that total nitrogen, aluminum and arsenic were important factors in differentiating the sampling locations. According to Figure 48 and Table 23 there were high levels of total nitrogen and aluminum and low levels of arsenic at site D70 in 2006. Sites G40 and B30 had high levels of arsenic and low levels of aluminum and total nitrogen. Sites E90, A10 and C50 had intermediate levels of the above variables. In addition, principle component 2 (PC2) shows high environmental levels of dissolved oxygen, water temperature and discharge at G40, B30 C50 and D70 and low levels of pH at E90 and A10 (Figure 48 and Table 23).

Table 24: Coefficients of each environmental and water chemistry variable in a principal component (PC) axis and cumulative variations of PC1-PC2 for Swift Current Creek, Saskatchewan, 2006. Bolded values, those ≥0.350, are the best variables explaining the variation in each axis.

Variable	PC1	PC2
pH	-0.072	**-0.370**
Dissolved inorganic phosphorus	-0.263	0.317
Nitrite + Nitrate	0.328	-0.206
Total nitrogen	**0.470**	0.067
Aluminum	**0.433**	-0.002
Arsenic	**-0.425**	-0.177
Copper	0.175	0.274
Conductivity	0.201	0.030
DO	-0.150	**0.394**
H2OTemp	0.305	**0.428**
Discharge	-0.206	**0.519**
Cumulative variation	37.7%	64.2%

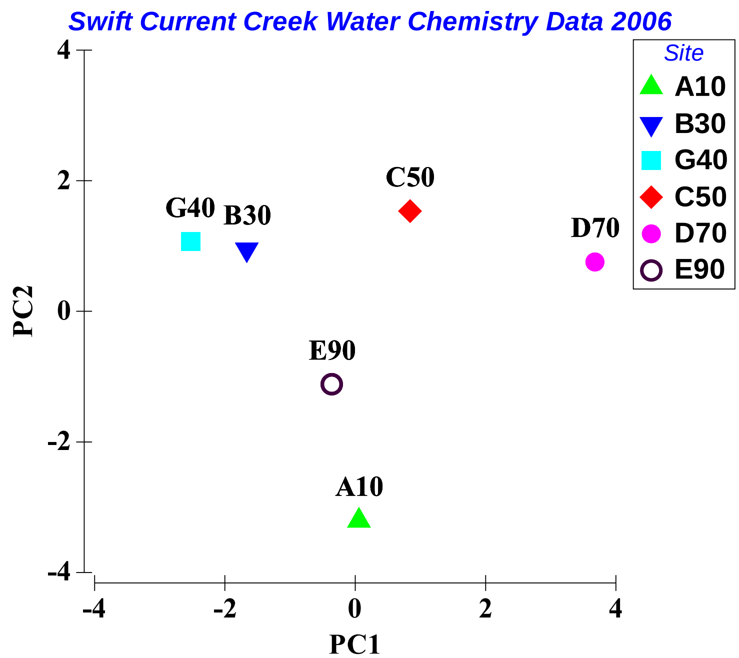

Figure 48: Principal components analysis of environmental and water chemistry variables at sampling stations on Swift Current Creek, Saskatchewan, 2006.

Results from the BIOENV analysis show two sets of environmental and water chemistry variables that best correlated with macroinvertebrate communities. The first, conductivity, was considered the best variable to explain the macroinvertebrate communities in the SCC in 2006 (Spearman rank correlation (ρ) was 0.59, P = 0.002). The second set of variables that best correlated with macroinvertebrate communities were copper and conductivity (ρ= 0.56). Based on the law of parsimony, the simpler of two competing theories is to be preferred; it appears the first set of variables is likely the best set of variables that explains macroinvertebrate communities.
Figures 49 and 50 graphically demonstrate the correlation between macroinvertebrate communities and environmental/water chemistry. In general, the closer the two graphs mirror each other the higher the likelihood that those environmental/water chemistry variables might be influencing the macroinvertebrate communities at each sampling location. In this case, the Spearman Rank correlation analysis was the lowest of the three sample years (.56) and thus, the graphs only slightly resemble each other. On both graphs, site E90 is located on the right hand side and sites A10, B30, G40 and C50 are relatively clumped together and are located on the left hand side of graphs.

According to Machin (2008), Site A10 had the lowest conductivity and copper values, site C50 had intermediate conductivity with the highest copper values and site E90 had the highest recorded conductivity values for 2007. Similar to the previous two years, site C50 had the lowest taxonomic richness; however, this site also showed the lowest Simpson's diversity and the highest percentage of dominant family. This suggests that copper concentrations may have a negative impact on the macroinvertebrate community.

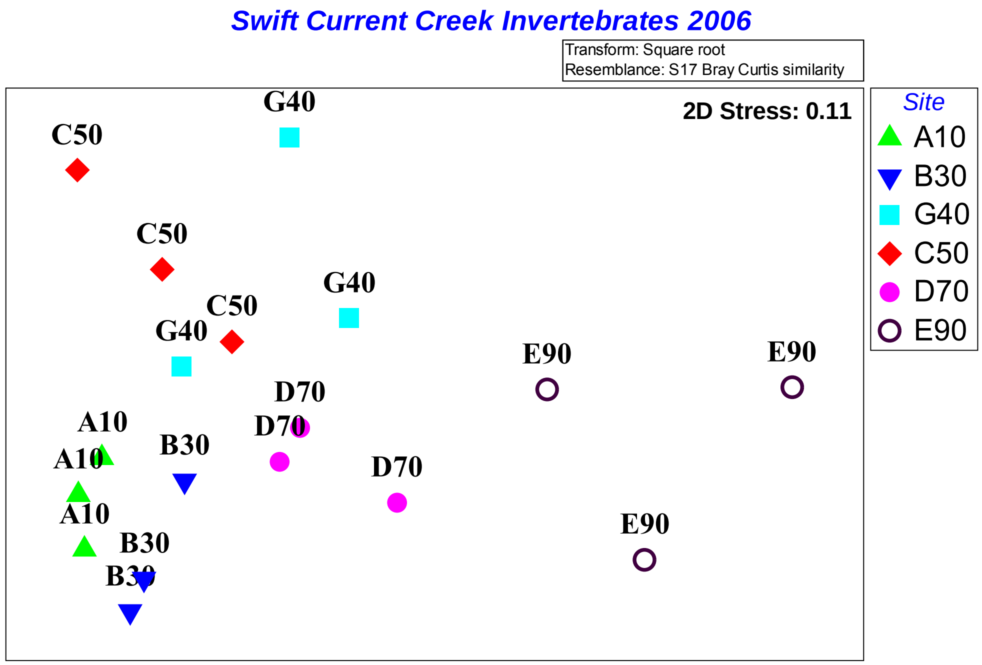

Figure 49: Nonmetric multidimensional scaling (MDS), an ordination technique, of invertebrate communities based on invertebrate abundance in Swift Current Creek, Saskatchewan, 2006. MDS represents 111 taxa based on root-transformed abundances and Bray-Curtis similarities (stress = 0.11).

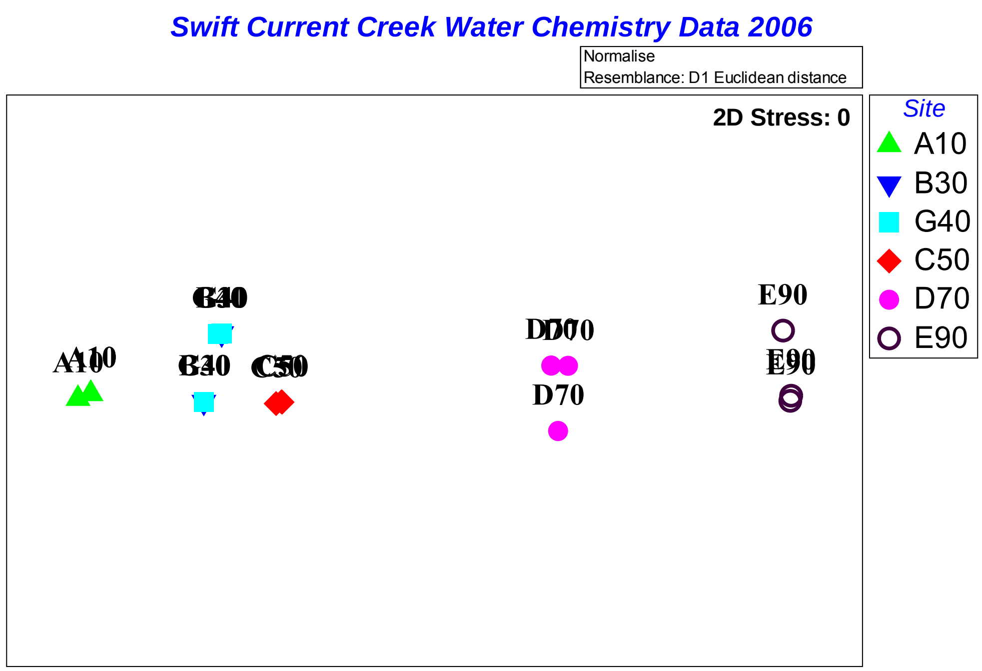

Figure 50: Nonmetric multidimensional scaling (MDS), an ordination technique, of invertebrate communities based on conductivity in Swift Current Creek, Saskatchewan, 2006. MDS is based on normalised values and Euclidean distances (stress = 0.0).

6.3.3. Macroinvertebrate Community 2007

The PCA revealed that chloride, copper, DIP, and arsenic were the primary factors (PC1) differentiating the sampling locations. According to Figure 51 and Table 24 there were high levels of chloride and copper and low levels of DIP and arsenic at sites A10, B30, G40 and C50 in 2007. Sites D70 and E90 have high levels of DIP and arsenic and low levels of chloride and copper; site E90 had the highest levels of DIP and arsenic out of all of the sampling sites in 2007. A secondary set of variables (PC2) that differentiated the sampling locations were ammonia, conductivity and water temperature. Sites B30, G40, C50 and E90 had high levels of ammonia and low levels of conductivity and water temperature. Site D70 and A10 had high levels of conductivity and water temperature as well as low levels of ammonia (Figure 51 and Table 24).

Table 25: Coefficients of each environmental and water chemistry variable in a principal component (PC) axis and cumulative variations of PC1-PC2 for Swift Current Creek, Saskatchewan, 2007. Bolded values, those ≥0.350, are the best variables explaining the variation in each axis.

Variable	PC1	PC2
Chloride	**0.455**	-0.129
pH	-0.308	0.214
Dissolved inorganic phosphorus	**-0.441**	-0.088
Ammonia	0.189	**0.466**
Nitrite + Nitrate	0.313	0.006
Total nitrogen	0.151	0.251
Arsenic	**-0.357**	0.292
Copper	**0.363**	-0.243
Conductivity	-0.145	**-0.467**
Dissolved oxygen	0.133	-0.206
Water temperature	-0.222	**-0.494**
Cumulative variation	40.4%	66.8%

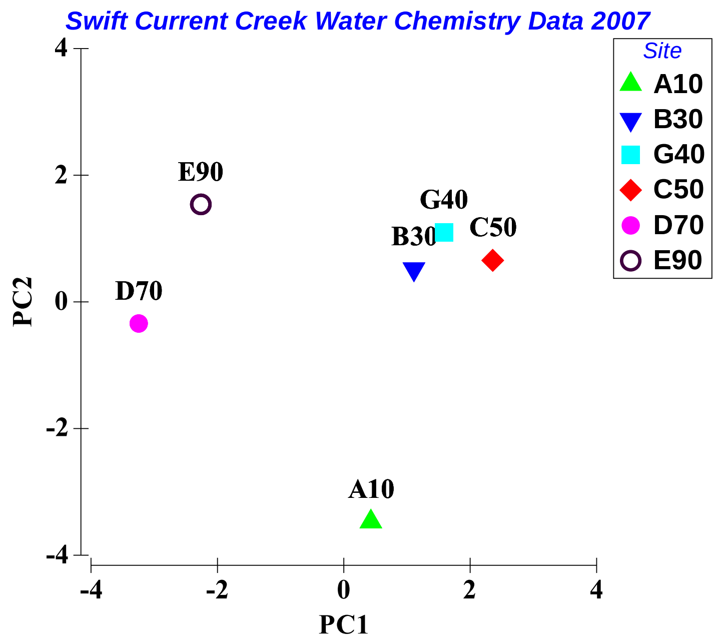

Figure 51: Principal components analysis of environmental and water chemistry variables at sampling stations on Swift Current Creek, Saskatchewan, 2007.

Results from the BIOENV analysis show two sets of environmental and water chemistry variables that best correlated with macroinvertebrate communities. A combination of chloride, pH, and total nitrogen were considered the most relevant variables that explain the macroinvertebrate communities in the SCC in 2007 (Spearman rank correlation (ρ) was 0.72, P = 0.002). The second best set of environmental/water chemistry variables that correlated with macroinvertebrate communities (ρ= 0.71) was chloride, pH ammonia, total nitrogen and arsenic. Based on the law of parsimony, the simpler of two competing theories is to be preferred; thus, it appears the first set of variables is likely the best set of variables that best explains macroinvertebrate communities. This is graphically demonstrated in Figures 52 and 53. In general, the closer the two graphs mirror each other the higher the likelihood that those environmental/water chemistry variables might be influencing the macroinvertebrate communities at each sampling location. The two figures somewhat resemble each other with site D70 on the far left side, E90 in the middle and B30 and A10 in the bottom right corner of both graphs. The Spearman Rank correlation was the highest in 2007 with a value of 0.72. Thus, the macroinvertebrate communities in 2007 were more closely associated or correlated to the environmental/water chemistry variables in 2007 than in the previous two sample years.

Overall, site D70 had one of the highest ammonia and total nitrogen levels and intermediate arsenic levels; whereas, site E90 shows low values of all three variables. In addition to this, D70 had the lowest taxonomic richness and one of the lowest EPT scores; whereas, site E90 had intermediate taxonomic richness and the highest EPT score. Cumulatively, this information suggests that high concentrations of ammonia or total nitrogen may negatively impact macroinvertebrate communities (i.e. low taxonomic richness/diversity).

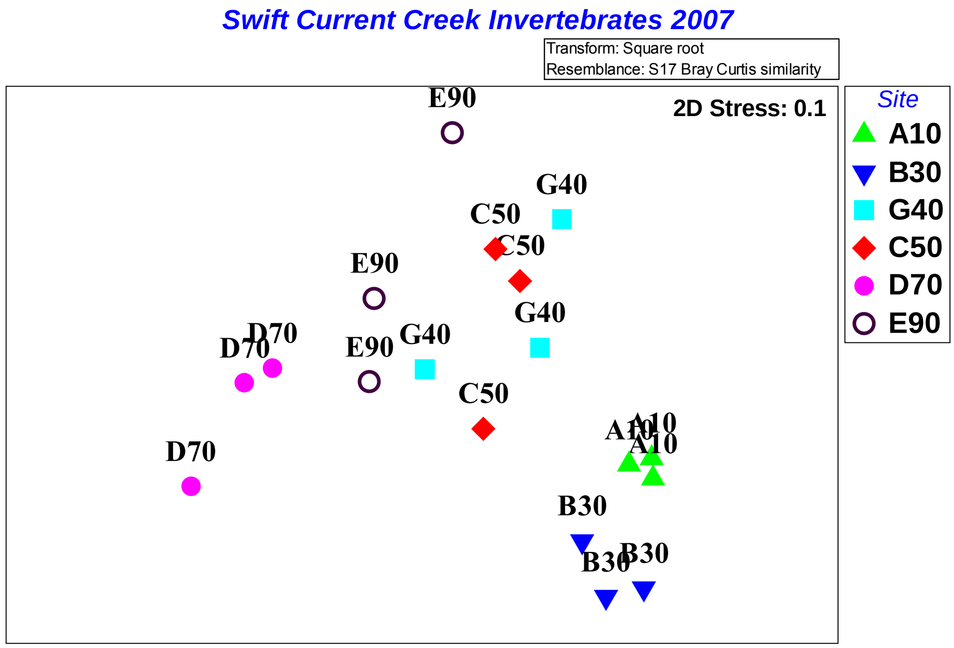

Figure 52: Nonmetric multidimensional scaling (MDS), an ordination technique, of invertebrate communities based on invertebrate abundance in Swift Current Creek, Saskatchewan, 2006. MDS represents 111 taxa based on root-transformed abundances and Bray-Curtis similarities (stress = 0.10).

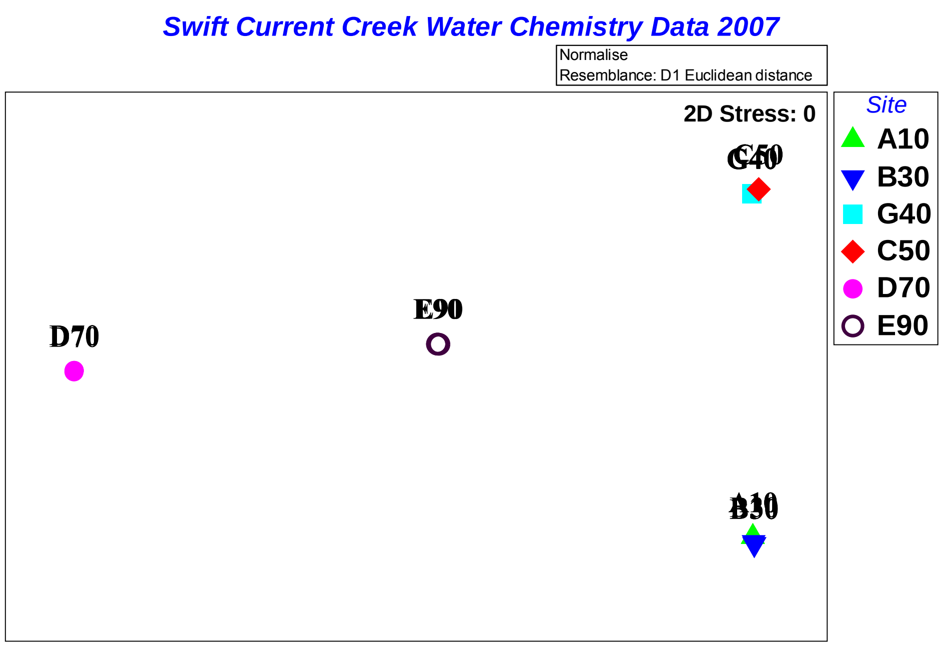

Figure 53: Nonmetric multidimensional scaling (MDS), an ordination technique, of invertebrate communities based on chloride, pH and total nitrogen in Swift Current Creek, Saskatchewan, 2006. MDS is based on normalised values and Euclidean distances (stress = 0.0).

6.4 Recommendations

As a result of the studies discussed, the following are recommended:

- Macroinvertebrate sampling for two additional years. One year of sampling after the installation of the WWTP is not long enough to determine the change in water quality on the macroinvertebrate community. Thus, two additional years would help elucidate trends in endpoints.
- Establishing a minimally impacted sampling location would aid in interpreting impacts on and recovery of SCC.
- In order to determine ways to reduce high nitrogen concentrations, as suggested by BIOENV statistical results, the SCCWS would need to collect water samples from the WWTP discharge water and implement water sampling during peak irrigation time at Site C50.

7 CONCLUSIONS

7.1 Water quality sampling

Are there water quality and watershed health problems in our watershed?
All water quality data collected from 2005- 2007 was analyzed against the 2006 Saskatchewan Water Quality Objectives for four uses: irrigation, livestock watering, aquatic life and general water quality. According to this water quality index, the water quality for irrigation, aquatic life, livestock watering and general water quality has improved at the majority of sample sites. A total of twelve water quality parameters were chosen to aid the SCCWS in determining the health of the SCC Watershed. From these twelve parameters eight showed levels above allowable concentration limits for fresh water in the SCC.

If so, for which areas are the problems the greatest?
Four parameters were determined to have the most impact on water quality, nitrogen, fecal coliforms, chloride and aluminum. The following paragraphs explain the presence of these four parameters in the SCC (SCC).

The nitrogen affecting the water quality in the creek is likely from both natural and anthropogenic sources. Excessive rainfall and irrigation can cause nitrates to leach from the soil, thereby raising the nitrogen levels in the creek. Irrigation is present throughout the watershed and could be responsible in part for the increased nitrogen levels in the creek. Another source of nitrogen could be from over fertilization of lawns and golf courses in Swift Current which enters the SCC via storm drains and surface runoff.

Fecal coliforms were shown to progressively impact water quality at site A10 from 2005-2007. The concentration of fecal coliforms in the water at this site rose from 2005-2006 and doubled from 2006-2007. As previously stated, this impact may be the result of multiple producers allowing their livestock to water directly from the creek.
Two ways in which chlorides can enter surface water are via irrigation drainage and effluent wastewater. Chloride levels in SCC showed a tendency to rise at site H60 and peak at site D70. Site D70 is located downstream of the WWTP; thus the high chloride concentrations shown at site D70 may be a result of the effluent released from the WWTP. In addition to this, irrigation is prevalent in the area and could be contributing to the chloride concentrations shown at site D70.

The most common cause of aluminum ions in surface water is the excess aluminum present in wash water from WTP's. WTP's add alum to the water to act as a binding agent. Alum binds to potentially harmful microorganisms causing them to clump allowing easier removal from the water via sedimentation or filtration. Aluminum levels in SCC showed a sharp increase at site H60 a site located downstream from the WTP. This peak in aluminum downstream from the WTP indicates that the high aluminum concentrations may be coming from the WTP.

Can we improve on any watershed health problems that exist?
Since the beginning of the study, improvements to the watershed have been made. Improved water quality downstream of the site D70 as measured by the WQI for all parameters can be attributed to the installation of the new WWTP which became operational in 2006.

Areas of future work can be facilitated through the implementation of Agri-Environmental Group Plan which assists producers with Beneficial Management Practices (BMP's). Contacting the livestock producers surrounding A10 and encouraging them to install watering systems would dramatically reduce the fecal coliforms at this site and improve water quality in the SCC.

7.2 Fish Sampling

Are there water quality and watershed health problems in our watershed?
The fish sampling that was carried out under this study could not definitively answer this question for the reasons described below.

The fluctuating numbers and species of fish during the June sampling period from 2005-2007 is a difficult phenomenon to explain. Since fish are very mobile it is difficult to pinpoint stressors or provide explanations for variations in population or species as it relates to watershed health. In general, all species have limits of tolerance. These limits dictate the conditions in which any particular species can exist. At any given time, fish may favor or avoid a particular spot based on its water temperature/flow, food availability, and whether or not the area has suitable spawning habitat. For example, white suckers predominantly inhabit fast flowing waters but are also found in spots with minimal flow, whereas fathead minnows almost entirely require regions where the water flow is slow. Consequently, you would find white suckers in most fathead minnow habitat but in areas where the water is flowing fast, fathead minnows would be scarce or absent. Thus, dependent on our sample locations (which are static) the temperature/flow, food availability and spawning habitat from year to year, we will find varying population sizes of both sentinel species. This variation is not necessarily a reflection of watershed health but more likely of watershed change. An example of watershed change could be ice thaw scraping the bottom of the creek clearing spawning areas and decreasing food availability at one site in one year and not the next. Thus the absence of fish in any particular area does not necessarily mean that the water quality is degraded, it may just be unsuitable in one area for that particular species at this moment in time for reasons such as the lack of a food source.

Unfortunately, the fish data collected from 2005-2007 was not comprehensive enough to provide definite statistical results into the sentinel fish populations in the SCC. This lack of definite statistical difference can be attributed to the SCCWS sole sample period in June of each of the three years. In addition to this, the mobility of fish compounds the lack of sample data. Fish are able to evade capture from sample nets and they are constantly migrating from place to place in search of food, mates and spawning ground. These two factors were the main contributors to the lack of definitive statistical results. In order to provide a more accurate picture of the white sucker and fathead minnow populations in the creek, the SCCWS would need to implement, at a minimum, one (preferably two) other sampling periods in either June or August.

For which areas are the problems the greatest? Can we improve on any watershed health problems that exist?

As stated above, the fish sampling that was carried out under this study could not definitively address the question of watershed health. Therefore, this study cannot speak to the potential health problems of the watershed (or possible improvements).

7.3 Macroinvertebrate Sampling

Are there water quality and watershed health problems in our watershed? If so, for which areas are the problems the greatest?

The macroinvertebrate sampling that was carried out under this study had mixed results as described below.

Statistical results of the following seven endpoint analyses provided limited insight into the health of the SCC since significant interactions occurred in most of the macroinvertebrate endpoints which negated the possibility to test for annual trends in these metrics.

- Total invert abundance (EEM endpoint)
- Taxon richness (EEM endpoint)
- Simpson’s Evenness Index (EEM endpoint)
- Simpson’s Diversity Index
- Percent contribution of dominant family
- Modified Hilsenhoff’s Biotic Index (FBI)
- Mulitvariate analyses (PCA and BIOENV)

The only macroinvertebrate endpoint that could be tested for an annual trend was percent EPT. This annual trend showed that percent EPT has increased significantly from the previous two sample years. The 2005 and 2006 sample years did not differ from each other. In general these three orders: Emphemeroptera, Plecoptera and Tricoptera require rock/gravel substrate and flowing, unpolluted, cool water in order to survive. Thus, this increase in EPT in 2007 from the previous two years indicates that water quality is likely improving in the SCC where species from these orders are found.

According to the BIOENV statistical results, there appears to one dominant ecosystem stressor on macroinvertebrate communities in the SCC: nitrogen. Nitrogen in its various forms is associated with decreased taxonomic richness at sites C50 and D70 in 2005 and 2007 respectively. In view of the fact that the SCC watershed is bordered by agricultural activities we must consider their impact on water quality and subsequently on the macroinvertebrate community. Nitrogen, as previously stated, is an ecosystem stressor and is present in fertilizer, sewage, livestock facilities and also occurs naturally in the soil. Naturally occurring nitrogen becomes a problem when excessive rainfall or irrigation causes nitrate to leach from the soil and into nearby water bodies (KWD 2008). Site C50 is surrounded by cropland and multiple producers irrigate these lands in the summer. Thus, it is highly likely that irrigation coupled with excessive rainfall (Table 1) may cause enough nitrate to leach from the soil to contribute to decreased taxonomic richness in the macroinvertebrate community in the SCC. Site D70, which is located immediately downstream of the WWTP, could be impacted by nitrate runoff from a number of sources. Non-point sources include irrigated and non-irrigated agriculture soils and /or Swift Current resident lawns and golf courses. One potential point source may be the water released by the WWTP.

Can we improve on any watershed health problems that exist?
In order to determine ways to reduce high nitrogen concentrations, as suggested by BIOENV statistical results, the SCCWS would need to collect water samples from the WWTP discharge water and implement water sampling during peak irrigation time at Site C50.

8 RECOMMENDATIONS

8.1 Water Quality Recommendations

As a result of the studies discussed, the following are recommended:

- The SCCWS should try to obtain past water data pertaining to aluminum concentrations from the WTP. This will help pinpoint whether or not the aluminum spikes at H60 can be attributed to the WTP.
- Water sampling for two additional years. One year of water sampling after the installation of the WWTP is not long enough to determine an accurate representation of overall water quality in the SCC. Water sampling for two more years would help to determine the impact of the new WWTP on water quality in SCC.
- Encouraging producers to install off-site watering bowls to increase the quality of water supplied to their livestock as well as protect the integrity of the SCC.
- Continue to provide ongoing educational seminars to local livestock producers within the Swift Current Creek Watershed about creek health with a focus on the dangers of watering livestock directly from the creek.
- Establishing a minimally impacted sampling location would aid in interpreting impacts on and recovery of SCC.

8.2 Fish Collection Recommendations

As a result of the studies discussed, the following are recommended:

- To more easily detect annual trends in white suckers and assess the relationships between water quality and white suckers, the SCCWS were advised to collect both more years and more frequent data for both white suckers and water quality.
- Collecting fish data at least twice a year from June-July, or June and August will not only provide the SCCWS with more comprehensive data but the YOY will be more easily identifiable.

- Establishing a minimally impacted sampling location would aid in interpreting impacts on and recovery of SCC.

8.3 Macroinvertebrate Collection Recommendations

As a result of the studies discussed, the following are recommended:

- Macroinvertebrate sampling for two additional years. One year of sampling after the installation of the WWTP is not long enough to determine the change in water quality on the macroinvertebrate community. Thus, two additional years would help elucidate trends in endpoints.
- Establishing a minimally impacted sampling location would aid in interpreting impacts on and recovery of SCC.

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