Swift Current Creek Watershed Stewards

Swift Current Creek Water Monitoring Project 2017: Final Report

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Swift Current Creek Watershed Stewards

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Kevin Steinley,

Executive Director, Swift Current Creek Watershed Stewards

Rural Municipality of Webb No. 138

Rural Municipality of Excelsior No.166

Rural Municipality of Lac Pelletier No. 107

Rural Municipality of Bone Creek No. 108

A few of the many volunteers (standing from left to right) Tim Cloutier, Melaine Toppi, Katherine Janz, Aleena James, Jason Paradis, and Will Chalk. Kneeling (left to right) Darcy Lightle and Rob Kelly

Executive Summary

The 2017 Swift Current Creek Monitoring Project (SCCMP) gathered water quality, riparian health, fish population and health, and macroinvertebrate population data at sites along the Swift Current Creek (SCC). The results generated were analyzed to determine water quality and watershed health within the Swift Current Creek Watershed (SCCW) in 2017. These results were also compared to those generated in 2007 to determine if changes in land use and management within the watershed over the last ten years have had an impact on water quality and watershed health.

Water quality data was analyzed using the 2006 Saskatchewan Water Quality Objectives (SWQO) for water uses important to the SCCW: irrigation, livestock watering, protection of aquatic life and wildlife, and general water quality. The 2006 objectives were used to analyze the results generated in the 2007 project and to ensure proper comparisons between projects they were used again in 2017. In 2017 Irrigation Water Quality Indices were lower at all sites than the 2007 indices due to increased levels of Total Dissolved Solids (TDS). However, the 2017 water quality trend as move downstream mirrors the trend observed in 2007. In 2007 all sites up to D70 just north of Swift Current had Livestock Water Quality Index scores of 100 per cent; in 2017 the index dropped at D70, continued to drop downstream at site I80 north of Waldeck, and then improved downstream toward the confluence with the South Saskatchewan River. In 2017 all sites up to the north end of Swift Current had scores of 100 per cent. The Protection of Aquatic Life and Wildlife Index scores in 2017 were virtually the same as those observed in 2007, with the exception of the site at start of sampling and north of Waldeck. The General Water Quality Index scores were lower in 2017 than 2007 as well.

The lower index scores observed were due to increased concentrations of many water quality parameters especially TDS due to lower flows in the creek brought on by low rainfall and increased evaporation during the summer of 2017. The water quality results identified areas of the creek that need further testing to determine stressors to water quality, which would highlight the types of practices that could be put in place to eliminate or mitigate the risks.

Despite water quality issues created by low water levels, fish sampling showed good results. One of the sentinel species, White Sucker (*Catostomus commersoni*), was found in large numbers at all five sites sampled and many healthy Young of Year (YOY) were also found. This identified the creek as a good habitat for this species and that creek health is being maintained. Although the other sentinel species, Fathead Minnow, was only found at two sites, the presence of many healthy YOY showed that the creek was maintaining a good habitat for this species as well. Condition factors of the White Suckers were similar to that of 2007 showing no impacts from changes in land use and management in the last ten years. The species diversity was slightly lower in 2017 than 2007. This may be due to less sampling effort completed in 2017 because seine nets were needed to reach the numbers required for condition factor analysis of the sentinel species. Overall, the results of fish sampling indicated that the SCC is maintaining an optimal habitat for aquatic life.

Benthic macroinvertebrate sampling results indicate that sites downstream of Duncairn Dam Reservoir are impaired. Conditions improved with increased distance from the dam because of how the dam changes the amounts of sediments and therefore changes the habitats for different benthic macroinvertebrate species than what would had naturally been present (Phillips et al

2016 as cited by J-M Davies [WSA] in email document to K Steinley dated June 11 2018 11:21 AM; unreferenced, see Acknowledgements). The only site upstream of the reservoir (A10) was classified as healthy.

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Agriculture and Agri-Food Canada........AAFC
Agri-Environmental Group Plan........AEGP
Aquatic Invasive Species........AIS
Beneficial Management Practice........BMP
Biotic and Environmental Patterns........BIOENV
Canadian Pacific Railway........CPR
Catch per Unit Effort........CPUE
Cubic Feet per Second........CFS
Dissolved Oxygen........DO
Environmental Effects Monitoring........EEM
Ethanol........ETOH
Farm and Ranch Water Infrastructure Program........FRWIP
Farm Stewardship Program........FSP
Global Positioning System........GPS
Ministry of Agriculture........MoA
Ministry of Environment........MoE
Nephelometric Turbidity Unit........NTU
Non-Young of the Year........Non-YOY
Parametric Anaylsis........ANOVA
Parts per Trillion........PPT
Per cent Ephmeroptera, Plectoptera, Trichoptera........ % EPT
Potential of Hydrogen........pH
Riparian Health Assesment........RHA
Saskatchewan Prairie Conservation Action Plan........PCAP
Saskatchewan Watershed Authority........SWA
Swift Current Creek........SCC
Swift Current Creek Monitoring Projects........SCCMP
Swift Current Creek Source Water Protection Plan........SWPP
Swift Current Creek Watershed Stewards........SCCWS
Swift Current Creek Watershed........SCCW
Swift Current Water Treatment Plant........WTP
Swift Current Waste Water Treatment Plant........WWTP
Total Dissolved Solids........TDS
Water Security Agency........WSA
Water Quality Index........WQI
Young of the Year........YOY

List of Appendices - Are on USB Stick included with Report

1.0 Introduction

The Swift Current Creek (SCC), named "Riviere au Courant" by Métis (City of Swift Current 2018d) and its surrounding watershed is a key part of the semi-arid region of Southwest Saskatchewan. Watersheds play a critical role in the function and productivity of the surrounding ecosystems and landscapes. The diversity and importance of watershed function in terms of drainage, habitat, water quality, and flows means that these areas are crucial in many natural and human activities, both terrestrial and aquatic. A watershed is an area of drainage which is divided from other drainage areas in terms of flow direction from precipitation and run-off, with water flowing towards one drainage location. Often there are tributary or secondary streams and creeks that flow into larger systems.

Users of any waterbody want to know the water they use is safe, so the health of these systems in terms of water quality, vegetation and soil health, and diversity of species of flora and fauna, needs to be determined. Monitoring projects have been put into place to address these concerns and to provide information against which future data can be measured, with the idea of maintaining or improving the health and integrity of the watershed. The Swift Current Creek Watershed Stewards (SCCWS) launched a monitoring program of the Swift Current Creek Watershed (SCCW) in 2004 which lasted until 2007. From that initial point, monitoring projects were completed in 2013 and in 2017 to continue assessing watershed health and to determine if the SCC is maintaining a healthy ecosystem. Ten years after the completion of the initial project that ended in 2007, the question of "has the creek and watershed health improved, been maintained, or degraded?" was asked and SCCWS embarked on a project to answer this question.

The 2017 monitoring project updated information on the health of the creek and noted any changes or problem areas since the monitoring first began in 2004. In conjunction to the SCCWS monitoring project the City of Swift Current partnered with SCCWS to investigate if the city's water and waste water treatment plants are functioning properly and are maintaining or improving water quality within the creek downstream of the facilities. In 2013 a comparative project was completed with a site upstream and one downstream of the Swift Current Waste Water Treatment Plant (WWTP) to determine if its operation, which began in 2006, was impacting water quality downstream. Improperly treated waste water adversely affects biological factors such as fish and benthic macroinvertebrate communities. Performing biomonitoring in conjunction with water quality can often tell a better story than water quality alone does. Conducting these two projects together in 2017 both the City of Swift Current and SCCWS gained valuable data and insights about overall health of the SCCW and how the city and its facilities impacts to the SCC. The insights gained allowed the setting of new targets for the health of the overall watershed.

1.1 Background information

a.) The Swift Current Creek Watershed Stewards

The Swift Current Creek Watershed Stewards Incorporated was formed in 2001 and is a stakeholder driven non- profit organization whose mission is to "Enhance water quality and stream health of the SCCW by promoting awareness and understanding among water users." From its early beginnings in 2004 through to 2007, SCCWS monitored the health of the creek and its watershed and educated stakeholders about the SCCW and the practices that improve watershed health. SCCWS continues to fulfill this mission by working towards the following three goals:

1. Educate users of the SCCW on a continuous basis about issues and impacts that affect water quality.
2. Monitor water quality and riparian health to assist in co-operative solutions regarding water management.
3. Foster an attitude of individual responsibility toward watershed stewardship.

In the year 2007 SCCWS worked in co-operation with Water Security Agency (WSA), formerly the Saskatchewan Watershed Authority (SWA), to start work on the Swift Current Creek Watershed Source Water Protection Plan (SWPP). This plan was released in 2009 and has 62 actions listed which, when implemented, work to improve water quality and watershed health. This document continues to be the basis by which SCCWS sets its yearly work plan ensuring funding from the WSA to see the actions in the plan completed.

Also, since 2007 SCCWS has been involved with the Agri-Environmental Group Plan or AEGP to deliver the Farm Stewardship Program (FSP) and the Farm and Ranch Water Infrastructure Program (FRWIP). These programs provide funding to agriculture producers in the watershed to implement Beneficial Management Practices (BMPs) that enhance water quality and watershed health of the SCCW. These funding programs are administered by the Ministry of Agriculture (MoA) and seek to minimize or eliminate negative environmental impacts to the environment by means of implementing BMPs. This program helped SCCWS achieve many water quality and riparian health initiatives that were recommended in the 2007 project.

Since its inception, SCCWS has completed many projects that helped meet the mission statement and goals of SCCWS. Each project created awareness and educated the public, allowing the stewards to gain more insight into the watershed and its complexity, highlighting the dependence the southwest region has on its water as a valuable resource, and generating increased interest in maintaining a healthy watershed.

b.) Monitoring projects

In response to public concerns about the water quality and stream health of the SCC, SCCWS completed an extensive watershed- wide monitoring project that commenced in 2004 and finished in 2007. This project gathered three years of data for various indicators of water quality and watershed health. These results were from water sampling, riparian health assessments (RHAs), and bio-assessments which included fish community populations and benthic macroinvertebrate communities. After three years of monitoring SCCWS found that overall the health of the creek and its watershed was good but various problems existed.

SCCWS completed a small-scale monitoring project in 2013 based on the 2004-2007 protocols at sites upstream and downstream of the WWTP (constructed in 2006) in response to questions regarding the treatment of raw effluents that enter the creek. This project was to determine if the WWTP was improving the water quality in the creek by properly treating waste water. The study found that the operation of WWTP did not have a negative impact on water quality downstream or creek health and the plant was operating effectively. The study found that the health downstream of the WWTP was better than the health of the upstream site, especially from the results of the bio-assessments in that study.

2017 marked ten years since the last large-scale monitoring project on the SCC and SCCWS decided to embark on another monitoring project. During the ten-year span since 2007 many changes have taken place within the watershed and the creek itself. 2007 to 2016 was a period that saw more precipitation than almost any other ten-year period on record. In fact, 2010 and 2016 are the first and second years respectively with the most precipitation in the last one hundred years (J Nimegeers [Agriculture and Agri-Food Canada Swift Current Research and Development Centre] in email document to K Steinley dated November 1, 2017 9:00 AM; unreferenced, see Acknowledgements). The summer of 2017 was the fourth driest growing season in the last one hundred years, with precipitation being less than half of the average amounts (J Nimegeers [Agriculture and Agri-Food Canada Swift Current Research and Development Centre] in email document to K Steinley dated November 1, 2017 9:00 AM; unreferenced, see Acknowledgements).

c.) City of Swift Current water treatment plant and waste water treatment plant

The Swift Current water treatment plant (WTP) provides treated water from the SCC to the city's residents, businesses, and local industries as well as outlying areas and farms within the Rural Municipality of Swift Current (City of Swift Current 2018a). Swift Current is the sole and largest urban community that falls along the creek with many other smaller communities surrounding (City of Swift Current 2018c). The city's WTP weir is located where the creek enters the city from the south and in 2012 the plant was updated with specialized equipment for water clarification, pH adjustments, and an ultraviolet system to kill pathogens in the water (City of Swift Current 2018a).

The operation of the waste water treatment plant (WWTP) began in 2006. It uses biological nutrient removal (BNR) to treat the waste water produced in the city (City of Swift Current 2018b). The treated water produced is extremely high-quality effluent or treated waste water that is a reusable source which reduces strain on the lagoon systems. The treatment process follows strict guidelines set forth by WSA (City of Swift Current 2018b). These processes help the city maintain the ecosystem of the SCC and improve the health downstream of the plant.

d.) Watershed development, uses, and changes

SCCW contains significant production of oil and gas with a large percentage occurring near the headwater region on the west side of the watershed. Over the last ten years there have been significant changes in oil and gas development: approximately 1650 new gas wells and 2500 oil wells have been drilled within the watershed since 2007 (Saskatchewan Ministry of the Economy, in email document to K Steinley dated November 14, 2017 11:24 AM; unreferenced, see Acknowledgments). Much of this activity has occurred west of Shaunavon near the headwaters of the SCC in the eastern Cypress Hills. This is worth noting as water quality should be at its most pristine here since there should be a limited number of stressors to water quality in this area. Figure 1 following shows the plant diversity and purity of the headwaters in Pine Cree Regional Park.

A major point in the watershed, Duncairn Dam Reservoir, is shown in Figure 2. There has been increased residential and recreational development on the shores of the reservoir and around Reid Lake as small resort villages have been built. Lac Pelletier Regional Park has also seen increased residential and recreational development as the park (Figure 3) is extensively used during the summer months for recreational water activities.

Figure 1. Headwaters of the Swift Current Creek in Pine Cree Regional Park

Figure 2. Duncairn Dam Reservoir

Figure 3. Northwest point of Lac Pelletier Regional Park

Agriculture is the largest industry in the watershed and along the creek itself. Over the last ten years producers have made changes to crop rotation and increased the use of minimum tillage and other soil conservation practices. Livestock producers have also made changes which include extending the grazing season, grazing corn and swath grazing, and calving later in the spring. Since 2006 many producers have implemented projects to benefit the health of the SCCW with the assistance of SCCWS through its involvement with the AEGP.

Given all of the changes within the SCCW over the last ten years SCCWS determined that 2017 was a good time to complete a monitoring program to determine if these changes have had a positive or negative impact on the health of the creek and watershed. This report follows the same or similar protocols and analysis as the 2004-2007 and 2013 reports in terms of water, fish and macroinvertebrate sampling, and riparian health assessments. Where applicable the results generated in 2017 have been compared to those generated in the previous monitoring projects. This report will also look at areas and issues of concern and provide recommendations of how to investigate these issues as SCCWS moves forward.

1.2 Development of the 2017 project

During the 2004 to 2007 monitoring projects SCCWS attempted to answer the following questions:

1. Are there water quality and watershed health problems in the Swift Current Creek Watershed?
2. If there are problems, which problems are the greatest?
3. Can we improve any watershed health problems that exist?

The 2017 project attempted to answer the same questions while keeping in mind the changes that have taken place over the last ten years to ask another question:

4. Have the changes in the watershed impacted water quality and watershed health over the last ten years?

The 2009 SWPP includes actions that the monitoring projects addresses. These include determining the significant stressors in the watershed and target activities that work to remove or mitigate those stressors that have the greatest cumulative impacts. Through the results of the monitoring project SCCWS will be able to determine if there are stressors, where they occur, and the impacts they cause.

Another action included in the SWPP is to apply a riparian monitoring protocol and direct programming to improve riparian function. Again, this project will identify those riparian areas whose function is good and those areas that need improvement. Finally, the report has two other actions: monitor water quality throughout the watershed and encourage sharing of all water quality monitoring results to stakeholders through a common database.

To answer these questions, determine the changes over the past ten years, and to deliver on the actions in the SWPP, SCCWS followed protocols for water sampling, riparian health assessments, and fish and macroinvertebrate assessments that were used during the 2004 to 2007 project. With this monitoring project SCCWS will set a baseline of water quality and watershed health for future monitoring projects and identify areas and issues that need further investigation in order to develop projects that help SCCWS meet its mission and goals for the future.

1.3 Site description and watershed scale characteristics

The SCC is the largest tributary to the South Saskatchewan River with a mainstream length of 187.4 miles or 302 kilometers and three smaller tributaries: Bone, Jones, and Rock Creek, which confluence into the SCC north of Shaunavon, SK (McKeil [AAFC Prairie Farm Rehabilitation Administration (PFRA)] 2005 as cited by Tait [SCCWS] 2008). The SCC itself is classified as a fourth order stream, which is to say it is a medium size stream. The highest elevation at the headwaters is 1143 m and the lowest elevation is 556 m at the confluence of Lake Diefenbaker. The drainage area of the watershed is 2160 sq. miles or 5592 sq. kilometers and a total perimeter of 384 miles or 618 kilometers (McKeil [AAFC PFRA] 2005; Acton, Padbury, & Stushnoff 1998 as cited by Tait [SCCWS] 2008).

Travelling downstream of the headwaters the creek continues northeast to the Duncairn Dam Reservoir. Flowing though the dam the creek meets the confluence of Pelletier Creek and Lac Pelletier Regional Park, where it then continues to the City of Swift Current Weir. Coming out of the city the creek flows eastward past the village of Waldeck and then turns northward to Lake Diefenbaker (McKeil [AAFC PFRA] 2005 as cited by Tait [SCCWS] 2008). Here the creek empties into the South Saskatchewan River west of the Beaver Flat Resort Village at the mouth of the SCC. Figure 4 shows the map and locations of the SCCW and all sites used in the monitoring project in 2017.

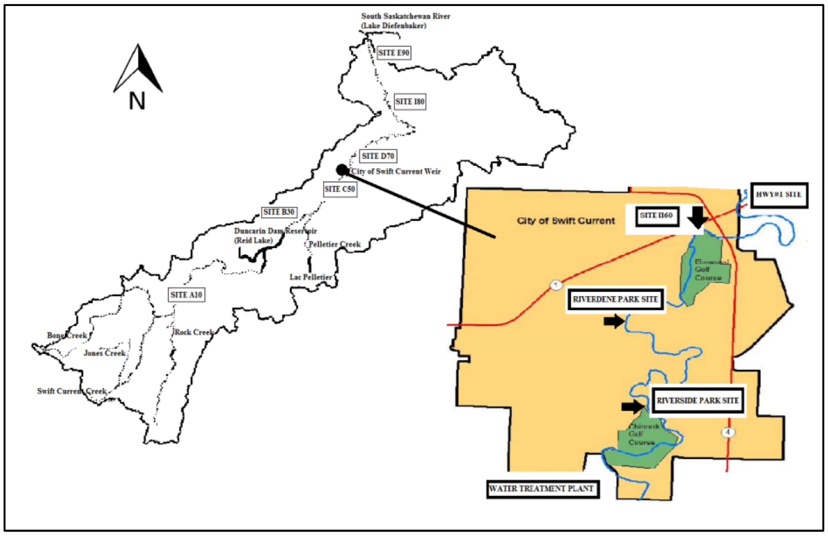

Figure 4. Map of Swift Current Creek Watershed and sites within the City of Swift Current (Map adapted from McKeil [AAFC PFRA] 2005 as cited by Tait [SCCWS] 2008)

The SCCW is part of the prairie eco-zone which is characterized by open grasslands with little topographic relief and a semiarid climate in which a pattern of short hot summers and long cold winters are observed. There is also low precipitation and high evaporation (Acton et al. 1998 as cited by Tait [SCCWS] 2008). Table 1 following gives a summary of the weather patterns seen during the monitoring project of 2017, which was a hot and dry summer.

Table 1. Average weather conditions for the 2017 monitoring year*

Average weather conditions in Swift Current, SK in summer of 2017					
Month	**Average high (°C)**	**Average low (°C)**	**# Days over 30 °C**	**Rainfall (mm)**	**Evaporation (mm)**
May	19.7	5.0	0	21.0	244.4
June	22.4	8.9	1	35.3	277.4
July	28.7	12.5	14	11.0	331.4
August	25.8	10.9	6	28.0	263.6
September	20.3	6.3	4	4.4	256.3

Information provided by J Nimegeers [Agriculture and Agri-Food Canada Swift Current Research and Development Centre] in email document to K Steinley dated November 1, 2017 9:00 AM; (unreferenced, see Acknowledgements).

1.4 Reach scale

Monitoring locations were selected using sites from prior monitoring projects completed by SCCWS. These sites were chosen if it was thought the location could be an important indicator of watershed health, or if the site represented a major division in land use, or if the site could represent potential land use impacts that typically occur throughout the watershed. Accessibility to sites for sampling personnel was also a factor in site selection. The City of Swift Current recommended three new sites to be established in 2017. These were named according to their location in the city rather than the alphabetical and numerical pattern used in the previous projects. Tables 2 and 3 give a summary of the average elevation, depth and flow rates for each monitoring site sampled in 2017 over the five-month sampling period.

Creek flows (included in Tables 2 and 3) within the SCC have normally been low, however due to periods of increased precipitation in the last ten years there have been times that flows have increased due to planned dam releases in order to keep Duncairn Dam from exceeding Full Supply Level (FSL). This was true in early 2017 due to large amounts of precipitation in 2016 but, given the lower rainfall in 2017, flows in the creek subsided quickly during the summer. Flows increased slightly in September because water was released from the reservoir at the Swift Current WTP as it was drawn down for inspection and maintenance (B Schafer [Agriculture and Agri-Food Canada], in email document to K Steinley dated October 4, 2017 8:37 AM; unreferenced, see Acknowledgments).

Table 2. Site descriptions of the 2017 monitoring sites up to the City of Swift Current

Descriptions of monitoring sites on Swift Current Creek summer 2017 up to city of Swift Current					
Sites	**A10**	**B30**	**C50**	**Riverside Park**	**Riverdene Park**
GPS location	N 49°53.772' W 108°27.221'	N 50°06.305' W 108°00.332'	N 50°14.571' W 107°48.668'	N 50°16.710' W 107°47.268'	N 50°17.409' W 107°47.413'
Elevation (m)	840	789	739	732	732
Average depth (m)	0.27	0.55	0.31	0.49	0.48
Average flow (cfs)	7.8	37.1	37.1	32.5	32.5

cfs = cubic feet per second

Table 3. Site descriptions of the 2017 monitoring sites from the City of Swift Current to site E90

Descriptions of monitoring sites on Swift Current Creek summer 2017 downstream of city of Swift Current					
Sites	**H60**	**HWY#1**	**D70**	**I80**	**E90**
GPS location	N 50°18.202' W 107°46.451'	N 50°18.380' W 107°46.064'	N 50°19.513' W 107°44.641'	N 50°24.394' W 107°35.309'	N 50°36.252' W 107°43.507'
Elevation (m)	732	732	732	709	556
Average depth (m)	0.53	0.78	0.43	0.67	0.42
Average flow (cfs)	30	36.7	27.1	30	24.4

1.5 Point and non-point sources of stressors

Stressors affecting water quality and watershed health were identified in the 2007 final report. There are many land uses in the SCCWS including oil and gas drilling, livestock production, dryland crop and hay production, irrigation of forages and crops, and recreational uses. The City of Swift Current and smaller communities use creek water for drinking water, integration of municipal wastes, and recreation. According to Tait [SCCWS] (2008) these uses in abundance can become environmental stressors.

Agriculture land use is the dominant use in the SCCW with oil and gas development the second most important use. Agriculture is the most probable non-point stressor to the SCC (Tait [SCCWS] 2008). However, changes to agricultural practices such as minimum tillage, continuous cropping, extended grazing systems, and less livestock confinement may have caused the agriculture related non-point stressors to be reduced or eliminated. Point source stressors include oil and gas developments which have increased in the watershed. Other point sources include municipalities releasing effluent into the creek or areas close to the creek and irrigation waste water being drained into the creek (Tait [SCCWS] 2008). According to Tait [SCCWS] (2008) there are several dams and reservoirs created for many purposes which may act as stressors as well. These include Duncairn Dam, the weir and reservoir at the Swift Current WTP, the Canadian Pacific Railway (CPR) weir in the City of Swift Current, and several old weirs and reservoirs along the creek**.**

2.0 Methods and materials

2.1 Water quality assessment

The previous Swift Current Creek Monitoring Projects (SCCMP) was designed to assess the health of the Swift Current Creek using two types of analysis: Water Quality Indexes (WQI's) and bio-assessments. The 2017 projects were carried out in similar design and methodology to the previous projects. SCCWS developed written protocols for all types of data collection done in 2017 based on the past monitoring projects and their recommended revisions (see Appendix 19). These protocols provide step by step instructions on planning and implementing field data and sample collection.

a.) Water samples

Water samples were taken over a period of five months beginning in May and ending in September. Sampling occurred near the end of each month to keep sampling timing consistent. In total there were ten sites for water quality assessments, with three new sites in the City of Swift Current chosen based on location downstream from the WTP, city storm water discharge, and the WWTP. Seven sites were sampled every month for the five months of the project. Two of the three new sites that occurred in the city parks were sampled for four months and the final new site downstream of the WWTP near Highway #1 was sampled for three months.

Standard samples were collected with a 1 litre plastic bottle and a preserved sterile bacteria bottle provided from the Provincial Disease Control Laboratory in Regina, SK. To obtain the samples the collector waded to the center of the creek at the site hub. Hubs were placed by estimation and accessibility of the previous monitoring work done from 2004-2007 and at the new sites the hubs were placed by accessibility, all while ensuring a good location for the parameters being tested.

Facing upstream to avoid debris the bottle was placed approximately 20 cm below the water surface, partially filled, capped and shaken, then poured out behind the collector (downstream) in order to rinse the bottle before obtaining a sample. This rinsing method was done three times. The collector was also careful not to touch the inside of any of the sample bottles or lids, especially the bacteria bottle. The final sample was capped securely underwater. In the case of bacterial testing the sealed, sterilized, and preserved bottle was not rinsed prior to obtaining a sample. This sample was also placed inside a protective case provided from the lab for shipping. All samples were labelled with a reference number from the lab that corresponded to the chemical analysis forms for each sample. Field data such as date, time, and water temperature were recorded on separate field sheets. The chemical and bacteria sample bottles from each site were both placed in large labelled ZipLock® bags and placed in a cooler with ice packs until all sites were completed for the day. Sampling of all sites was performed over the course of two days. However, samples were shipped the same day they were collected as some of the tests conducted were time sensitive.

Chemical analysis forms were completed and also placed in ZipLock® bags to avoid water damage and placed in the cooler with the samples along with fresh ice packs. The cooler was labelled appropriately with “time critical” and “keep cool” stickers, taped securely shut, and sent by courier to ensure quick delivery.

The Provincial Disease Control Lab has quality control protocols that include testing blanks with high purity water and random samples that are tested in duplicates for a set number of samples. This confirms the sample to sample variation is acceptable. In addition to this, the lab also tests control samples of known concentrations that are made in the lab to verify the concentrations are being read and measured correctly (P Bailey [Provincial Disease Control Lab], in email document to D Peters dated June 2, 2017 11:16 AM; unreferenced, see Acknowledgments).

b.) Water parameters

Standard parameters such as dissolved oxygen [DO in (mg/L)], pH, water temperature (°C), and conductivity (µS/cm) were taken at each site during collection of water samples. In addition to these, salinity (ppt) and total dissolved solids [(TDS in mg/L)] were also taken beginning in July as a meter that measured these parameters was used. To determine DO and water temperature a Thermo Scientific Orion RDO® optical dissolved oxygen sensor was used and a ROSS Ultra®, ROSS Ultra Triode™, ROSS®, and PerpHecT® ROSS electrode was used for pH on the same Thermo Scientific Orion meter. This meter was on loan from the City of Swift Current WWTP. Conductivity was read using a Hach Senslon 5 Cond meter which was on loan from the Swift Current WSA office until July. Starting in July and for the rest of the summer the meter used in May and June was unavailable. A YSI EcoSense® EC300 portable conductivity, salinity, and temperature instrument was used on loan from the Swift Current Agriculture and Agri-food Canada (AAFC) office for July to September. At seven of the ten sites sampled in September a Hach HQ40d multi meter on loan from WSA due to the failure of the Orion meter. The Hach HQ40d meter measured DO and pH in a similar manner to that of the Orion meter and was also calibrated using the same method.

To obtain accurate reading using the Thermo Scientific Orion meter for dissolved oxygen, water temperature, and pH the unit was turned on and the probes calibrated. The RDO® probe was calibrated by following the user guide and then removed from its calibration/storage sleeve and a protective end was placed on the probe before placing in the water. The ROSS® pH probe was also calibrated according to the user guide before use with two buffer solutions of 10.0 and 7.0 pH units. Once calibrated the probe was placed carefully in the water as it had no protective casing besides a storage sleeve used in transport. Each probe was approximately 10-15 cm below the waters’ surface to take readings. The meter was set to measure all three parameters at once on a single screen. Once all readings were stabilized each probe was rinsed with distilled water before being placed back in the appropriate storage sleeves and the entire unit turned off and placed in a case.

For conductivity readings The Hach Senslon 5 Cond meter was turned on and the probe submerged to a depth of at least 10 cm. To determine conductivity the meter was used as per the manufacturers' manual. The YSI Eco300 meter was used in a similar manner where the meter was used in accordance to the manufacturers' manual for TDS and salinity. Units were displayed automatically on all meters. All meters were used to measure water quality parameters in the creek at the right bank, center, and left bank, which were determined by facing downstream.

2.2 Site assessments- Riparian health assessment

Riparian health assessments were completed to determine the riparian health of sampling sites and the ability to of this area to function properly. Riparian areas are the transitional areas between aquatic ecosystems and surrounding terrestrial areas (Saskatchewan PCAP Greencover Committee 2008). The variation in riparian areas can be considerable in terms of water, soil, and vegetation interactions; as these are all features that are common to these riparian areas according to Saskatchewan PCAP Greencover Committee (2008).

Sites at Riverside Park, Riverdene Park, and Highway #1 were not completed as these were added to the project by the city for water quality monitoring only. Assessments were done using the *Riparian Health Assessment –Streams and Small Rivers protocols* set by the Saskatchewan Prairie Conservation Action Plan Greencover Committee in 2008. Assessments completed in 2004 and 2005 used the Cows and Fish Program (Alberta Riparian Habitat Management Society) *Riparian Health Assessment for Streams and Small Rivers* field workbook. This was the original document used for the development of the *Riparian Health Assessment - Streams and Small Rivers* (Saskatchewan PCAP Greencover Committee, 2008) workbook [the workbook] used in 2017.

a.) Riparian health assessment background and methodology

A healthy riparian area implies that all aspects of the area are functioning properly and in good condition. A riparian health assessment (RHA) measures how well the area (and the entire stream or a portion of a stream) can complete key ecological functions. These functions include: the ability to trap sediments, build and maintain streambanks, store flood water and energy, recharge aquifers, filter and buffer water, reduce and dissipate stream energy, maintain biodiversity, and create primary productivity (Saskatchewan PCAP Greencover Committee 2008). There are three categories on the scoring of overall riparian health:

- < 60% - unhealthy (non-functional)
- 60 - 79% - healthy with problems (functioning at risk)
- 80 - 100% - healthy (proper functioning)

In the assessments there are twelve questions to consider: seven are based on vegetation and five based on soils and hydrology of the area. Total points are calculated to determine specific percentage health of both vegetation and soil scores. Vegetation scores can total up to 33 points. If there is no woody material in a reach then the score can be adjusted to eliminate these categories. Soils and hydrology scores can total 30 points out of the total 63. (Please refer to Appendix 11 for a more detailed outline of what each assessment question encompasses.)

b.) Field methodology

A reach consisting of 200 m (100 m upstream of the site hub and 100 m downstream) was measured out using a Westward® 100 m/330 ft. measuring tape. This was also the reach used for bio-assessments of fish and benthic macroinvertebrates. Scores based on types, species and use of vegetative cover, presence of invasive species, percentage of bare ground and streambank alteration caused by human activity, amount of stream incisement and access to floodplains were assigned according to the workbook. Scores were totalled for the reach at each site to determine the overall health and function of the riparian area. Scores were converted to percentages to classify the riparian area as healthy, healthy with problems, or unhealthy.

2.3 Bio-assessments

a.) Fish survey

i.) Seine collection

Fish collection was completed by SCCWS staff with the assistance of Outside Environmental Consulting Ltd, personnel from AAFC, and the city of Swift Current WTP and WWTP staff. Collection protocols followed those outlined in Tait [SCCWS] (2008). A reach of 100 m upstream and 100 m downstream of the site hub was blocked off in order to capture fish without immigration of new individuals or emigration of those fish contained. Intervals of 20 m from the hub were pre-staked before sampling on the banks using a Westward® 100 m/330 ft. measuring tape. Surveyors' stakes were placed at appropriate locations in a visible area from the water. This allowed personnel operating the seine nets to easily determine where to start and stop collecting samples. Barrier nets were installed on metal T-Bar fence posts pounded into the banks and creek bed with the weighted line placed on the creek bottom and the top floating on the water. These nets were wide enough to reach across to both banks as shown in Figure 5. Seine sweeps were done using an 8 m bag seine net pulled upstream in either 20 m or 40 m intervals.

Figure 5. Installing barrier nets at Site B30

Seining required 4-6 people in the water with two people pulling the net forward by hooking a bottom loop onto one foot to ensure the net stayed as close to the bottom as possible and using a looped handle on the top of the net to pull it forward. The rest of the people in the water ensured that the net did not snag on rocks or debris and untangled the net as needed. They also went ahead of the seine net along the banks and splashed water towards the center of the creek to move fish towards the net. This method of fish collection is shown in Figure 6.

Figure 6. Seine sampling at Site E90

At the end of a seine pull the two people pulling the net walked towards each other and to bring the net together to collect fish into the bag area of the net. The top of the net was kept above water to ensure no fish would escape. The net's bag was then emptied into a tub. Debris and crayfish *(Orconectes virilis)* were sorted out immediately and returned to the creek as crayfish started to eat small fish and minnows in the buckets compromising length and weight measurements and population numbers. This was important as some pulls had significant numbers of crayfish as seen in Figure 7. Fish were then sorted by species into appropriately labelled 5-gallon pails with fresh water for population sampling or community sampling. Tubs and buckets were kept in the shade of tents to avoid fish death from overheating in the direct sunlight and water was refreshed as required to rejuvenate depleted oxygen levels. Figures 7 and 8 illustrate how collection of fish was accomplished from this method.

Figure 7. Large numbers of crayfish removed at Site D70

Figure 8. Emptying first seine pull at Site C50

ii.) Electrofishing Method

Where seine fishing was not possible, fishing using a backpack electroshocker was an alternative method used to catch fish for population counts. Electrofishing was used at site E90 in shallow waters where a seine net could not be used as there were areas with rocks and uneven creek bed. Electrofishing uses electric currents emitted into the water to temporarily stun fish. The fish then float to the surface and can be caught with a small hand-held dip net. Electrofishing was done by the trained and certified Outside Environmental Consulting staff with their own equipment. Waders that do not conduct electricity must be worn and not have any holes or leaks. Electrical grade rubber gloves are worn to avoid accidental contact with the water. Hand-held dip nets are all wooden handled with rubber insulation.

Outside Environmental Consulting used a Smith-Root Type 15C POW electroshocker with a frequency setting of 60 HZ-6 ms and 100 HZ-500 ms cycles per second and volt selector was 400 Volts. The settings were monitored and adjusted as needed to minimize injuries to fish (D Lightle (Outside Environmental Consulting Ltd]) in email document to D Peters dated November 22, 2017 7:09 PM; unreferenced, see Acknowledgments). The person manning the electroschocker and assistants worked their way upstream applying current for a short time in areas under rocks and in deep pools. Any fish that came to the surface were caught with nets manned by the assistants and identified, counted, and released immediately. Assistants would walk in line with the person manning the shocker and watch for large rocks, deep pools, or unsteady footing to keep the safest route possible. Each time a current was applied a loud noise was sounded by the electroshocker to warn that electric current was being discharged. The electrofishing method is seen in Figure 9.

Figure 9. Electrofishing at Site E90

Physical and chemical data of the water was collected during fish sampling at each site. This included water chemistry parameters such as dissolved oxygen (mg/L), conductivity (µS/cm), pH, salinity (ppt), and total dissolved solids (mg/L). Physical parameters included water temperature (°C), general observations, condition of the water, and flow types such as runs, riffles, and pools.

ii.) Fish Population Sampling

Two types of sampling were conducted for fish: population and community. Population sampling of target sentinel species, the White Sucker *(Catostomus commersonii)* (Figure 10) and Fathead Minnow *(Pimephales promelas)* (Figure 11) was conducted in accordance with previous SCCWS monitoring projects (Tait [SCCWS] 2008). These species were selected as sentinel species based on historical data of healthy populations, ease of capture and identification, and that these species are non-migratory, and not sport or commercially fished (Tait [SCCWS] 2008). Proper data analysis for population statistics required that a minimum of 100 individuals were caught. If over 100 fish of a sentinel species were caught, each individual fish was processed from the seine sweep that generated the first 100 fish. Surplus individuals were identified and counted, but not measured or weighed. When 100 of each of the sentinel species were caught no more seines were required (Tait [SCCWS] 2008). If no individuals of one of the sentinel species were found in any seines the site was deemed to be lacking in that species and seining was stopped once 100 of the other sentinel species were caught.

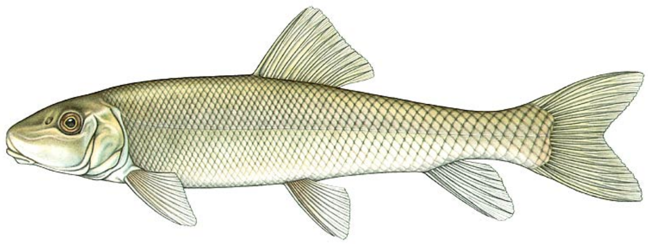

Figure 10. White Sucker (http://utahspecies.com/images/white_sucker800.jpg)

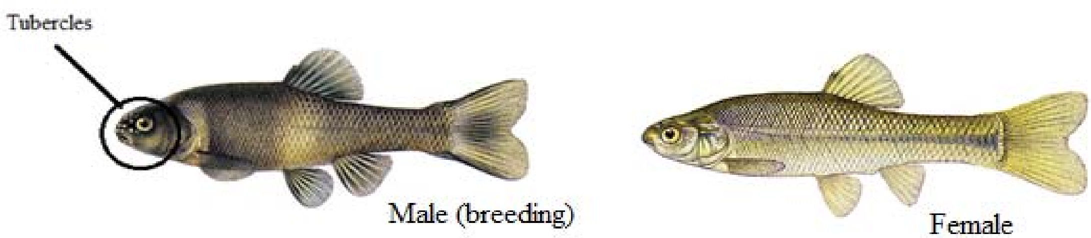

Figure 11. Male and female Fathead Minnow (http://aquaticpath.umd.edu/fhm/index.html)

A special collection permit for fish and benthic macroinvertebrates was obtained, stating that certain species and numbers of fish needed to kept for identification standards and then sent to the Ministry of Environment by the consultant. Young of the year fish (YOY) born in 2017 and non -young of the year fish (Non-YOY) born before 2017 were identified and the numbers of each were recorded. The sentinel species (Fathead Minnow and White Sucker) were processed for population sampling in accordance to the live release method of to the Environmental Effects Monitoring (EEM) protocol for non-lethal sampling (Gray et al. 2002 as cited by Tait [SCCWS] 2008). All fish, except specimens kept to satisfy provincial permit conditions or those requiring identification, were kept alive and released once processing was complete and efforts were made to limit mortality. If identification could not be done in field that specimen was kept for later identification. Only these types of specimens were kept with lethal measures and were preserved in accordance to the collection permit in 95% denatured ethyl alcohol.

Seine collections were sorted into a series of labelled tubs and 5-gallon buckets all filled with fresh creek water according to sentinel species and community. Each tub or bucket was labelled with Rite-in-the-Rain® paper (data sheets also printed on this waterproof paper) with the seine number, sentinel species type, or community. For example, a bucket labelled "Seine 1 WHSC" had all of the white suckers sorted from the first seine sweep. The next seine sweep would be in numerical order and continue until sampling efforts were done. Once all of the individuals from a seine sweep were processed, the bucket they were in was labelled with a "COMPLETE" label to avoid duplicate processing or not processing samples at all. A set up of the sorting procedure can be seen in the following Figure 12.

Figure 12. Sorting and processing seine sweeps at site A10

Community fish were sorted into one large labelled tub similar to that of the sentential species and each individual was identified and placed in a complete tub until released. All fish taken from each seine, with the exception of a few specimens taken for identification, were released outside of the barrier nets either upstream or downstream to eliminate the risk of reporting false population numbers by catching the same individuals repeatedly if more seine sweeps were required. Fresh water was also continuously added to the buckets to replenish oxygen levels and maintain an ideal temperature in the sorting tubs and buckets. Figure 13 shows a sorting tub with label as described above.

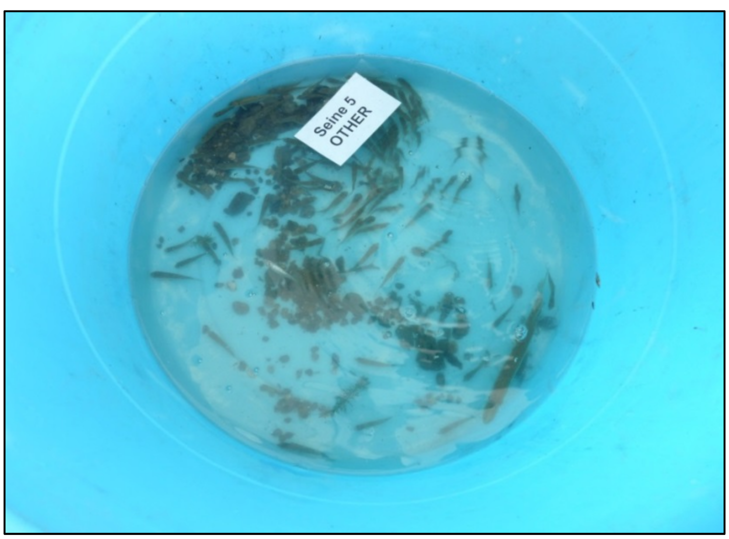

Figure 13. Sorting tub with seine 5 community species at site C50

White Sucker and Fathead Minnow processing included three measurements: fork length (cm), total length (cm), and weight (g). To measure length the fish was placed in a wetted measuring apparatus which included a 15 cm ruler and cradle made on three sides of Plexiglas to hold the fish. The tip of the snout was placed at the zero point or the very end of the ruler and the fork and total lengths were measured. The measurement of fork length is from the tip of the snout to the deepest point of the notch in the tail fin. Total length is from the snout to the very tip of the tail. Total length is best read after the fork measurement by squeezing the ends of the tail together and reading the measurement at the tip of the tail. These measurements were in centimeters to the nearest two decimal places and then converted to millimeters during data processing. If a fish was larger than 15 cm a larger wooden cradle was used to measure these fish up to 100 cm in length. An example of measuring can be seen in Figure 14.

Figure 14. Measuring a large White Sucker

Fish were weighed immediately after measurement using an OHAUS Scout® Pro Balance scale. To obtain accurate readings the scale was calibrated according to the manual before weighing began and again after a long period of time between processing of seines catches. The scale was also checked periodically for accuracy during weighing. The scale is sensitive to wind and uneven ground so it was placed on a large level table inside a tent with tarps placed to shelter it. The scale was zeroed before each fish was weighed and weight was recorded to the nearest 0.01 g, which was indicated by an asterisk on the bottom left hand side of the screen. If a fish was too large to be placed on the scale a small spring-loaded scale was used. Fish were then placed in "COMPLETE" pails and the released. Teams of two to four people worked together, with one or two people measuring and weighing fish and the others recording the values on prepared field sheets. Weighing of fish both small and large can be seen in Figures 15 and 16.

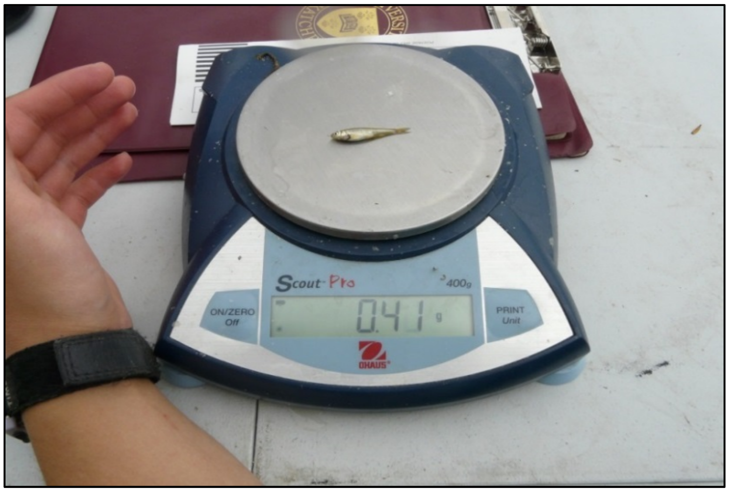

Figure 15. Weight taken on Fathead Minnow in 2013 at Site D70


Figure 16. Weighing of large White Suckers caught at Site D70

iii.) Community sampling

All species were identified on site by Outside Environmental Consulting Ltd. Species required to be submitted under the provincial permit were submitted to MoE for positive identification. Community species were identified to genus species level and if possible were determined to be YOY or non-YOY. These numbers were entered on prepared field sheets before the fish were released. If new or rarely occurring species were found they were added to the list and photographs were taken for records.

iv.) Statistics for population and community

All population survey and community data was analyzed by a senior habitat and population ecologist at WSA who also analyzed the 2013 data. The Kruskal-Wallis One Way Analysis of

Variance of Ranks was performed for the population of both White Sucker and Fathead Minnow, while in previous projects parametric analyses were completed. As populations in 2017 were skewed towards YOY in White Suckers and the size distribution data did not meet the assumptions required to complete a Parametric Analysis (J Sereda [WSA] in email document to D Peters dated February 7 2018 7:51 AM; unreferenced, see Acknowledgements). Assumptions for parametric analysis (ANOVA) used in the 2007 assessment were:

1. Samples collected are independent of one another;
2. Data is normally distributed and;
3. Equal variance in data between sites.

As noted in the 2007 report, the 2007 data violated some of these assumptions, but the violations were minor allowing the parametric analysis to still be applied to obtain accurate results and analysis. The 2017 data violated these assumptions more because size distributions were heavily skewed to YOY and variances were large, thus the non-parametric analysis was used instead of the parametric analysis. The results of the analysis and comparison of the fish populations and health between sites does not change using non-parametric tests versus using parametric tests (J Sereda [WSA] in email document to D Peters dated February 7 2018 7:51 AM; unreferenced, see Acknowledgments).

Condition factor (K) was calculated for both sentinel species using the formula $K=100*(bm/l^3)$; where bm stands for body mass in grams (g) and l stands for the length of the fish in centimeters (cm). According to J Sereda [WSA] in email document to D Peters dated January 29 2018 3:48 PM; unreferenced, see Acknowledgements) the data collected did not meet the assumptions required to complete a parametric analysis. Therefore, the Kruskal-Wallis One Way Analysis of Variance of Ranks was again performed for condition factor differences. Community sampling included species richness as the Shannon Diversity Index and equitability indices. Data from 2007 was also calculated and compared to the results of 2017. The catch per unit effort (CPUE) was also calculated to observe any changes in the total abundance of fish caught at each location to compare the 2017 results with the 2007 results.

2.3 b.) Benthic macroinvertebrate survey

i.) Habitat assessment and site data collection

Site data and benthic macroinvertebrate collection was completed following the protocols set out in the manual *Saskatchewan Northern Great Plains Ecosystem Health Assessment Manual 2012: Version 1.0* prepared by Hoemsen (2012) that was obtained from Ministry of Environment (MoE) and SWA (now WSA) in 2013. (Please see a copy of the manual, Appendix 17, for more detailed references to the methods used.) Benthic macroinvertebrate collection was done a week after fish sampling at the beginning of September. Field collection required a total of three people for each day since the samples were not pre-sorted before being sent for enumeration identification.

According to Hoemsen [MoE and SWA] (2012) the assessments of site and habitat during benthic macroinvertebrate collection are helpful in determining what type of community may be present. Riparian health assessments are an important part of information collected and were completed prior to fish sampling and benthic macroinvertebrate collection in August. In addition to riparian assessments, the following list shows all of the other physical, chemical, and relevant data collected at each monitoring site for benthic macroinvertebrate collection that were provided on field sheets with the manual:

- Location by GPS (Garmin GPS map 60Cx) taken at the site hub and the downstream macroinvertebrate transects
- Water chemistry - DO (mg/L), conductivity (µS/cm), temperature (°C), salinity (ppt), turbidity (NTU), total dissolved solids (TDS), and pH. The same water meters were used as those in the water quality section and a Hach turbidity meter was also used on loan from WSA.
- Flow types - Categorized into runs, riffles, and pools. They represent the flow, depth, and substrate types to create natural habitats in streams (Hoemsen [MoE and SWA] 2012).
- Habitat types - stream bottom substrates categorized by size: clay (hard-packed), silt (<0.6 mm), sand (0.6-2 mm), gravel (2-65 mm), cobble (65-350 mm), boulders (>350 mm), and bedrock (solid bottom).
- Physical characteristics - velocity obtained from AAFC flow stations. Flow rate was also conducted at each site using a buoyant object and stopwatch as will be described in this section.
- Stream characterization and condition assessment - embeddedness, channel flow status, sediment deposition, bank stability, in-stream canopy cover, riparian vegetation, aquatic vegetation characterization, abundance of woody debris, detritus, macrophytes, and algae.
- River characterization
- Photographs of upstream, downstream, across transect, and sediment sizes and types
- Weather conditions and any other site information observed

ii.) Sample collection in wadeable streams

This section is a description of the wadeable stream method followed from the *Saskatchewan Northern Great Plains Ecosystem Health Assessment Manual 2012: Version 1.0* prepared by Hoemsen (2012). Discussions with WSA staff helped determine how to set up a smaller sampling area than described in the manual so that transects used for sample collection were all in the same reach as fish sampling. Transects started and ended at least 100 m away from any road crossing or bridge and were marked out four times, each 50 m apart from one another, totalling the four transects or 200 m of sampling area. The first transect was measured 100 m downstream of the site hub and each transect measured back 50 m from that point.

Upon arrival at each site a Westward® 100 m/330 ft. measuring tape was used to measure the four transects, starting 100 m downstream of the site hub. Each transect was measured 50 m apart and marked with survey stakes. Once sampling areas were established, flow and water chemistry readings were conducted. Flow was taken at the most downstream transect using a buoyant object such as an orange, measuring tape, and stop watch. Two people stood facing each other in the creek at a distance of 5 m, the person upstream would then set the orange in the water and release it. A recorder on the banks with a Sportline® stopwatch timed how long it took the orange to travel the 5 m to the downstream person. This was done a total of three times and the average calculated for the flow rate in m/s. Water chemistry was taken at the site hub with the same meters and methods used for water quality sampling with the addition of a turbidity measurement. The turbidity meter was provided with glass vials which are filled directly from the creek and placed inside the meter with the proper alignment and turbidity is calculated in NTUs with the push of a button. All of these measurements were recorded on data sheets provided in the manual that were printed on waterproof Rite-in-the Rain® paper.

Collection of macroinvertebrates followed the traveling kick and sweep method using a conventional D-frame net with a 30 cm base and 500 µm mesh. This sampling method maximizes the types of habitats sampled in a reach all while minimizing debris and sediments from entering the net (Hoemsen [MoE and SWA] 2012). Starting at the downstream transect, which was always labeled as transect 1, the collector would enter the creek and take five subsamples along the transect. These occurred at left bank (1/5 of the width), left center (2/5), center (1/2), right center (3/5), and right bank (4/5). Facing upstream with the net opening facing upstream and the collector standing in front of the opening, the collector would be timed for ten seconds at each position on the transect to stir up the sediments with their feet while keeping the net moving forward along the creek bed to limit any escaping organisms under the water and catching them in the net. If there was little or no flow the net would be swept in a figure eight motion above the feet. After ten seconds of collection the net was swept forward out of the water to prevent losing sample catches. This was done at all five spots, with samples from all locations in a transect staying in the net and carried above the water during movement to each new spot along the transect. The traveling kick and sweep method is shown in Figure 17.

Figure 17. The traveling kick and sweep method used at Site D70 in 2013

After the fifth subsample was taken the entire contents of the net were integrated into a wide-mouth 1-L glass jar using a funnel. The sides of the net were rinsed to make ensure that all of the sample collected was captured in the jar. The net was then thoroughly inspected for any remaining organisms which were picked off the net using forceps and placed in the jar. The sample was then preserved by filling the jar ¾ full with 95% ethanol (EtOH). A rite-in-the-rain® waterproof label was placed inside the jar with the date of sampling, sample code (SCCWS 2017), site, water body, and transect number. Parafilm® was used to seal the top of the jar before the lid was placed. More Parafilm® was used to line the lid to prevent leaks or evaporation out of the jar and two labels made using permanent marker were placed on the top of the lid and on the side of jar with the same information as the inside label. Jars were then placed in a sectioned cardboard box and placed in the fridge once back at the SCCWS office. An example of a benthic macroinvertebrate observed during sampling can be seen in Figure 18.

Figure 18. Odonata nymph caught during sampling at Site A10

iii.) Preparing samples for laboratory processing

Collection was completed over the course of a week and each site's samples were placed in the fridge until sampling was completed and the samples were ready for shipping. No pre-sorting was done on site by SCCWS as the samples were taken to a pre-sorter who was contracted to clean and sort the samples in preparation for the enumeration and identification completed by Aquatax Consulting according to protocol set out by WSA. Once results were completed the data sheets were then sent to WSA for statistical analysis.

iv.) Statistical analysis

Communities of benthic macroinvertebrates collected were compared to reference groupings determined by stream order and ecoregion in which the five sample sites occurred (Phillips 2017 as cited by Phillips [WSA] 2018). With the use of backwards Discriminant Function Analysis, the membership of sample sites to each of the biological groupings was predicted (Phillips [WSA] 2018). For each sample site benthic summary metrics were developed and evaluated for their applicability to Saskatchewan and were calculated and compared to Test Site metric variables of their appropriate reference groups using Test Site Analysis (Bowman and Somers 2006 as cited by Phillips [WSA] 2018). These included Total Abundance, Number of Coleoptera, % Ephmeroptera, Plectoptera, and Trichoptera (presented as %EPT), and % Shredders as included in Phillips (2017). According to Phillips [WSA] (2018) the Test Site Analysis formally evaluates the magnitude of difference between test sites and reference sites which are presented as "D". It uses a non-central hypothesis test which defines the normal range as the probability region enclosing 95% of the reference sites or "*p*" value (Kilgour et al. 1998 as cited by Phillips 2018). In this evaluation a small probability ($p \leq 0.05$) suggests that the site is impaired or unhealthy while a large probability ($p > 0.05$) suggests that the site is not impaired or is healthy (Kilgour et al. 1998 as cited by Phillips 2018). However, according to Phillips [WSA] (2017) which follows Bowman and Somers' (2006) three-tiered condition which applies the following conditions: impaired is ($p \leq 0.05$), possibly impaired ($0.05 < p < 0.95$) and within reference condition. For a full description on the statistical methods used please refer to Phillips (2017) as cited in the *Biomonitoring reporting on the Swift Current Creek for the Swift Current Creek Watershed Stewards 2017.*

2.0 Results and discussion

3.1 Site assessments - riparian health assessment

The conducting of RHAs is crucial in obtaining a quick snapshot or measure of the riparian health which could provide indicators, problems, or issues that may be present in the overall watershed (Hansen [SCCWS] 2013). They deserve attention as they are important to the benefits of agriculture and biodiversity and they can also represent concerns for water quality (Saskatchewan PCAP Greencover Committee 2008). The RHAs are not designed for in-depth and comprehensive analysis and investigation of ecological processes and issues, but they do provide the first step in clarifying whether an issue or problem exists and in identifying areas of concern (Hansen [SCCWS] 2013). In the past RHAs were not all conducted in the year 2007 but rather from 2004 through to 2007.

a.) Site assessments - Riparian health assessment at A10

Site A10 (Figure 19) is the most upstream location of the monitoring project and closest to the headwaters of the SCC. It was assessed on August 16, 2017. The main land use is rotational grazing for livestock. There is an oil and gas pipeline that crosses the property and runs under the creek. The highway #37 bridge runs across the creek just upstream of the reach. There is also an old concrete bridge that is no longer in use just upstream of the site.

Figure 19. Site A10 facing downstream showing an off-site watering system

Site A10 rated a vegetative score of 64%. There were adequate amounts of vegetation cover along the banks with the exception of a cattle creek crossing on the north side where the banks are bare and little vegetation is present up to the waters' edge. Sedges *(Carex spp.)* were observed at the waters' edge in multiple places and invasive species such as Canada Thistle *(Cirsium arvense)*, Smooth Brome *(Bromus inermis)*, and even Nodding Thistle *(Carduus nutans)* were also observed. These species, along with high numbers of disturbance indicator species found, indicate a degrading ecosystem since they invade and displace native species (Hansen 2013). The most common species found at the site included preferred trees and shrubs (as determined by the Saskatchewan PCAP Greencover Committee 2008) such as Wolf Willow (*Elaeagnus commutate)* and other willow species *(Salix* spp.*).* Dominant non-preferred shrub species was Western Snowberry (*Symphoricarpos occidentalis*). A total of 35 species were documented in the area assessed (See Table 4).

The soils and hydrology rating for this site was 83%. The majority of the reach is recovering from cattle use with the help of an off-site watering system located further downstream (also pictured in Figure 19 above). Rotational grazing is also used and cattle were not present for the majority of the summer. Pugging and hummocking were not present until September but trails and the crossing into the creek exposed bare ground throughout May to August. This was only a small portion of the reach however, with the remaining banks downstream being well covered with some trails. Lateral cutting in the upstream portion covered a minimal area as well but the channel is slightly incised. This puts the reach in a Stage 2 which indicates the 1-2-year high flow event will only be able to access narrow floodplain less than or equal to twice the bank full channel width. Perennial riparian vegetation is well established. This stage includes: (a) an improving phase that is re-establishing in a narrower floodplain at a new, lower level; or (b) a degrading phase where it is beginning to down cut into the existing floodplain (Saskatchewan PCAP Greencover Committee 2008). Figures 20 and 21 below show the cattle crossing area in August as compared to September.


Figure 20. Cattle crossing portion of Site A10 in August


Figure 21. Pugging and hummocking from cattle at creek crossing in September at site A10

Overall Site A10 scored a riparian health score of 73%. This is within the healthy with problems range due to invasive species being present with large occurrences of disturbance species. A small percentage of the bank shows incisement, erosion, and sedimentation due to the cattle crossing. The rest of the bank is well covered in vegetation but the dominant species are not native species but invasive and disturbance species.

Table 4. List of species observed at Site A10

Type and species of riparian vegetation found at site A10 summer 2017		
Vegetation type	**Latin name**	**Common name**
Preferred trees and shrubs		
	Cornus stolonifera	Red Osier Dogwood
	Elaeagnus commutata	Wolf Willow
	Prunus virginiana	Chokecherry
	Salix spp.	Willow
Non-preferred trees and shrubs		
	Rosa woodsii	Wood's Rose
	Symphoricarpos occidentalis	Western Snowberry
Invasive (noxious) species		
	Agropyron cristatum	Crested Wheatgrass
	Artemesia absinthium	Absinth
	Bromus inermis	Smooth Brome
	Carduus nutans	Nodding Thistle
	Cirsium arvense	Canada Thistle
Disturbance-increaser undesirable herbaceous species		
	Amaranthus retroflexus	Redroot Pigweed
	Convulvulus sepium	Bindweed
	Kochia scoparia	Kochia
	Medicago lupulina	Black Medic
	Melilotus alba	Sweet White Clover
	Phalaris arundinacea	Reed Canary Grass
	Plantago spp.	Plantain
	Sonchus arvensis	Perennial Sow Thistle
	Taraxacum officinale	Dandelion
	Thalpsi arvense	Stinkweed
	Trifolium pratense	Clovers
	Urtica dioica	Stinging Nettle
	Vaccarina hispanica	Cow Cockle
	Solanum triflorum Nutt.	Wild Tomato
Native graminoids		
	Carex spp.	Sedge spp.
Native forbs		
	Achillea millefolium	Common Yarrow
	Artemesia frigida	Pasture Sage
	Artemesia ludoviciana	Prairie Sage
	Asclepias speciose Torr.	Showy Milkweed
	Glycyrrhiza lepidota	Wild Licorice
	Helianthus spp.	Sunflower
	Mentha arvensis	Wild Mint
	Rumex crispus	Curled Dock
	Solidago canadensis	Canada Goldenrod
	Stachys palustris	Marsh Hedge Nettle

Site A10 scored in the healthy with problems range in 2004 as well. Similar dominant species were noted such as smooth brome, western snowberry, and wolf willow. Vegetative scores improved since 2004 from 58% to 64% as the cattle crossing area becoming more covered with vegetation, but it was with disturbance and invasive species. Soils and hydrology scored similarly with 89% in 2004 and 83% in 2017. The overall score was 77% in 2004, in 2017 the site had score of 73%, so Site A10 is still healthy with problems.

b.) Site assessments-riparian health assessment at B30

Site B30 is directly downstream of the outflow at Duncairn Dam. The site was assessed on August 16, 2017. Since 2004 multiple gravel pits have been established on all sides near the site and there is increased heavy truck traffic over the bridge upstream of the sample reach. Cattle grazing to the north and west of the reach are fenced off from the creek until approximately 300-350 m downstream where it is fenced across the creek. The 721 Grid road is on the south bank and hay land is on the north bank. Hay was cut and round baled in 2017 but a buffer strip was left along the banks of the creek. Figures 22 and 23 show the upstream view on the north side and the downstream view near the end of the reach where the cattle fence crosses.

Figure 22. Facing upstream and traffic bridge at Site B30

Figure 23. Facing downstream at the end of the reach area at Site B30

This site had a vegetation score of 70% with dominant species including invasive species such as Smooth Brome, and preferred species Cattails *(Typha latifolia)* as graminoids (Figure 24). Wolf Willow as a preferred shrub and Canada Goldenrod *(Solidago canadensis)* (a forb) were also present in majority, along with approximately 32 other species documented as a sample of the reach. While cover for the reach was good, there is a lack of deep rooted species to help stabilize banks, prevent erosion, and help minimize sedimentation. The smooth brome dominated the site which lowers the score as there is a presence of invasive species. Table 5 shows a list of some of the species found.

Soils and hydrology scored 90% as there was little to no alteration by human activity in terms of bare ground. Bank alteration was also minimal (scored at less than 5%) since a vegetative buffer was left in place and livestock were excluded from this reach. Lateral cutting was observed at the more downstream point and appeared to continue along an outside edge further down the creek after the fence. Channel incisement was scored at a stage 2, the same as Site A10 with perennial riparian vegetation well established.

The overall score for site B20 was 79% or healthy with problems. In 2004 the site also rated as healthy with problems with a 68% score. The increase in score is due to the soils and hydrology component which scored much higher in 2017 than 2004. Vegetation also scored higher compared to 2004. The riparian area is deemed functioning at this site but is at risk due to ill health factors such as invasive species and lack of deep rooted species and preferred trees and shrubs. Regeneration was observed for woody species at the site with small willows but the area covered was minimal.

Figure 24. Cattails at Site B30. Aquatic vegetation also plentiful at this site.

Table 5. List of species observed at Site B30

Type and species of riparian vegetation found at site B30 summer 2017		
Vegetation type	**Latin name**	**Common name**
Preferred trees and shrubs	*Elaeagnus commutata*	Wolf Willow
	Prunus virginiana	Chokecherry
	Salix spp.	Willow
Non-preferred trees and shrubs		
	Rosa woodsii	Wood's Rose
	Symphoricarpos occidentalis	Western Snowberry
Invasive (noxious) weeds		
	Bromus inermis	Smooth Brome
	Carduus nutans	Nodding Thistle
	Cirsium arvense	Canada Thistle
	Sonchus arvensis	Perennial Sow Thistle
Disturbance-increaser undesirable herbaceous species		
	Agropyron cristatum	Crested Wheatgrass
	Agropyron repens	Quackgrass
	Medicago sativa	Alfalfa
	Melilotus alba	Sweet White Clover
	Melilotus officinalis	Sweet Yellow Clover
	Poa pratensis	Kentucky Bluegrass
	Thalpsi arvense	Stinkweed
	Urtica dioica	Stinging Nettle
Native graminoids		
	Calamagrostis inexpansa	Northern Reed Grass
	Carex spp.	Sedge spp.
	Equisetum arvense	Common Horsetail
	Equisetum pratense	Meadow Horsetail
	Glyceria striata	Fowl Manna Grass
	Juncus balticus	Baltic Rush
	Phalaris arundinacea	Reed Canary Grass
	Poa spp.	Bluegrass
	Scirpus validus	Great Bulrush
	Typha latifolia	Cattail
Native forbs		
	Artemesia ludoviciana	Prairie Sage
	Glycyrrhiza lepidota	Wild Licorice
	Mentha arvensis	Wild Mint
	Rumex occidentalis	Western Dock
	Solidago canadensis	Canada Goldenrod

c.) Site assessments-riparian health assessment at C50

Site C50 is located upstream of the City of Swift Current's reservoir and water treatment plant. A single-family dwelling is adjacent to the creek and the sample reach began 100 m upstream of the site hub and ended 100 m downstream just past the house. The assessment was done on August 18, 2017. The "Black Bridge" shown in Figure 25 is located upstream of the site and a private road coming into the back of the yard runs parallel to the creek in the upland area. Crop land was the major upland use upstream of the site. This site scored 55% for the vegetation rating. Smooth brome was again abundant, Reed Canary Grass *(Phalaris arundinacea),* and sedges were also present in abundance. Willows and Wolf Willow were present as well as Cottonwood *(Populus deltoides)* directly adjacent to and behind the house. The riparian area is well vegetated up to the water's edge but again invasive and disturbance increaser species (plant species that increase with grazing) are dominant. Table 6 shows the species found in the area assessed. A total of 31 species were documented.

Figure 25. The upstream portion featuring the Black Bridge of Site C50

Table 6. List of species observed at Site C50

Type and species of riparian vegetation found at site C50 summer 2017		
Vegetation type	**Latin name**	**Common name**
Preferred trees and shrubs		
	Cornus stolonifera	Red Osier Dogwood
	Elaeagnus commutata	Wolf Willow
	Populus deltoides	Cottonwood
	Salix interior	Sandbar Willow
	Salix spp.	Willow
Non -preferred trees and shrubs		
	Rosa woodsii	Wood's Rose
	Symphoricarpos occidentalis	Western Snowberry
Invasive (noxious) weeds		
	Arctium minus	Common Burdock
	Cirsium arevense	Canada Thistle
	Bromus inermis	Smooth Brome
	Sonchus arvensis	Perennial Sow Thistle
Disturbance-increaser undesirable herbaceous species		
	Agropyron cristatum	Crested Wheatgrass
	Hordeum jubatum	Foxtail Barley
	Medicago sativa	Alfalfa
	Melilotus alba	White Clover
	Poa pratensis	Kentucky Blue Grass
	Urtica dioica	Stinging Nettle
Native graminoids		
	Carex spp.	Sedge
	Equisetum arvense	Common Horsetail
	Juncus balticus	Baltic Rush
	Phalaris arundinacea	Reed Canary Grass
	Scirpus spp.	Bulrush
	Typha latifolia	Cattail
Native forbs		
	Ambrosia spp.	Ragweed
	Artemesia ludoviciana	Prairie Sage
	Aster spp.	Aster
	Glycyrrhiza lepidota	Wild Licorice
	Helianthus spp.	Sunflower
	Rumex crispus	Curled Dock
	Rumex occidentalis	Western Dock
	Solidago canadensis	Canada Goldenrod

Soils and hydrology scored 73% with some alteration of the banks by human activity and human caused bare ground occurring. This in turn structurally altered the reach, though less than 15% of the total reach was altered. The private road is in the uplands of the reach and the most alteration occurs at the house site which is near the banks of the creek. There is no fencing or livestock present but a small area for pumping water is used. Rip-rap placed directly behind the house has vegetation growth over the majority and there is some stream channel incisement at this site.

The total overall score for Site C50 in 2017 was 63% to rate healthy and functioning but with problems. The score in 2004 was 77% and though this score is higher it also is in the same healthy with problems range. The dominant invasive species Smooth Brome lowered the score in 2017, as does some human alteration to the streambank, even though this alteration is less than 15% of the entire reach. Native and desirable species are present and diversity is great at this site but there is a lack of the deep rooted or preferred trees and shrubs. Many pockets of willows were seen at the site and suggest some regeneration of the woody species and large poplar trees were present around the yard site, as shown in Figure 26.

Figure 26. Facing downstream at Site C50 towards yard

d.) Site assessments-riparian health assessment at H60

Site H60 is located within city limits just upstream of the WWTP. The main land uses for this site are streets and roadways including the Highway #4 bridge, service roads, dealerships, and businesses on the north side and the Elmwood Golf Course on the south side. The creek runs through the golf course which uses the water for irrigation. Storm water discharges are also present upstream of the reach assessed. This site was assessed in 2005 and again in 2013 by the same contracted consultant. Assessment was done on August 17, 2017.

A vegetative score of 61% was assigned to the site with the majority of the banks having good vegetative coverage. The dominant graminoids present were Common Reed Grass *(Phragmites communis)* and the invasive Smooth Brome once again was present. Other invasive species observed were Common Burdock *(Arctium minus),* Absinth (*Artemesia* *absinthium*), Baby's Breath *(Gysophila paniculata),* Scentless Chamomile *(Matricaria perforate),* and Canada Thistle. Many disturbance increaser species were also observed at this site which is likely due to the ever-changing dynamics of city construction, landscaping, and road maintenance. Some of these included Perennial Sow Thistle *(Sonchus arvensis),* Stinging Nettle (*Urtica dioica),* and Stinkweed *(Thalpsi arvense).* Preferred trees and shrubs were present and both mature and regeneration stages of these were observed. The trees and shrubs present included willows *(Salix spp.)*, Wolf Willow, and mature Manitoba Maple *(Acer negundo).* Table 7 shows the species observed at this site with a total of 26 documented. Figure 27 Shows baby's breath found at the site.

Figure 27. Baby's Breath *(Gysophila paniculata)* found at Site H60

Table 7. List of species observed at Site H60

Type and species of riparian vegetation found at site H60 summer 2017		
Vegetation type	**Latin name**	**Common name**
Preferred Trees and Shrubs		
	Acer negundo	Manitoba Maple
	Elaeagnus commutata	Wolf Willow
	Salix spp.	Willow
Non-preferred trees and shrubs		
	Rosa woodsii	Wood's Rose
	Symphoricarpos occidentalis	Western Snowberry
Invasive (noxious) weeds		
	Arctium minus	Common Burdock
	Artemesia absinthium	Absinth
	Bromus inermis	Smooth Brome
	Cirsium arvense	Canada Thistle
	Gysophila paniculata	Baby's Breath
	Sonchus arvensis	Perennial Sow Thistle
	Matricaria perforate	Scentless Chamomile
Disturbance-increaser undesirable herbaceous species		
	Agropyron cristatum	Crested Wheatgrass
	Melilotus alba	Sweet White Clover
	Phalaris arundinacea	Reed Canary Grass
	Thalpsi arvense	Stinkweed
	Brassica kaber	Wild Mustard
	Urtica dioica	Stinging Nettle
Native graminoids		
	Carex spp.	Sedge spp.
	Glyceria grandis	Tall Manna Grass
	Phragmites communis	Common Reed Grass
	Agropyron spp.	Wheatgrasses
	Typha latifolia	Cattail
Native forbs		
	Artemesia ludoviciana	Prairie Sage
	Glycyrrhiza lepidota	Wild Licorice
	Rumex crispus	Curled Dock
	Solidago canadensis	Canada Goldenrod

Soils and hydrology health scored 67%. Construction, road maintenance, and access points are in the uplands of the north side but minimal bare ground was observed in the riparian area on the north side. There was bank erosion and slumping occurring on the south bank and lateral cutting present. The banks on both sides have been altered by human activity, the main one being golf course activity; with the south slope having some rip-rap and an area for irrigation. Incisement in this section of the reach was determined at a stage 2.

The overall score for Site H60 was 63%, the same as 2013, and in 2005 the score was 65%. The scores indicate this site is healthy with problems. One concern is the number of invasive species present. For example, the number of Common Burdock plants has been increasing within the city. Vegetation scores in the past were 73% in 2013, higher than 2017, which was better than 58% score in 2005. The score has improved since 2005 but problems still exist and may worsen with new developments, construction, and disturbances in the area. Soils and hydrology scores in 2013 and 2017 were both lower than that of the 2005 assessment which was a 75%. Alteration to the banks play a huge role in regards to this site's ill health as well. Figure 28 shows alterations made in the upstream portion of the reach.

Figure 28. Irrigation intake at Site H60

e.) Site assessments-riparian health assessment at D70

Similar to Site C50, D70 is also a single-family dwelling along the creek. Located downstream of the city and the WWTP this site has had issues with lateral cutting, a low-level crossing, culvert installation, and unstable banks and erosion. These issues all occur just upstream of the reach assessed but were likely included in the reaches assessed in the past, which was 2004 and 2013. Horses are present and often cross the creek into adjacent pastureland on a low-level crossing downstream in the reach. Corrals and open access for horses are located near the downstream end of the reach. The site was assessed on August 17, 2017. Figure 29 shows the closed low level crossing, culvert, and resulting lateral cutting to banks in the distance described above.

Figure 29. The upstream point of the reach with active lateral cutting and a scour twisting around from culverts installed at the now closed crossing.

The 2017 vegetative score was 64%. Overall the reach has good coverage up to the water's edge with good deep rooted and soil binding plants such as Cattails, sedges, Reed Canary and Manna (*Glyceria striata*) grasses. Preferred species of trees and shrubs are present in ideal numbers and regeneration is apparent. Browsing on these by the horses is minimal to not at all. Smooth Brome is present in large amounts as it has been at all sites and invasive plants include Common Burdock, Canada Thistle, and Absinth. A new invasive plant, Common Tansy *(Tanacetum vulgare)* was found at this site in 2013 and was still present in 2017. A spent tansy head is pictured in Figure 30 from October 2017 below. In total 43 species were documented and a sample of the species found is included in Table 8.

Figure 30. Common tansy flower head and leaves. Flowers are unmistakeable yellow "buttons" but this specimen had been hit with frost in early October of 2017

Table 8. List of species found at Site D70

Type and species of riparian vegetation found at site D70 summer 2017		
Vegetation type	**Latin name**	**Common name**
Preferred trees and shrubs		
	Acer negundo	Manitoba Maple
	Amelanchier alnifolia	Saskatoon
	Cornus stolonifera	Red Osier Dogwood
	Elaeagnus commutata	Wolf Willow
	Populus deltoides	Cottonwood
	Prunus virginiana	Chokecherry
	Salix spp.	Willow
Non-preferred trees and shrubs		
	Rosa woodsii	Wood’s Rose
	Symphoricarpos occidentalis	Western Snowberry
Invasive species		
	Agropyron cristatum	Crested Wheatgrass
	Arctium minus	Common Burdock
	Artemesia absinthium	Absinth
	Bromus inermis	Smooth Brome
	Cirsium arvense	Canada Thistle
	Matricaria perforata	Scentless C hamomile
	Tanacetum vulgare	Common Tansy
Disturbance-increaser undesirable herbaceous species		
	Convulvulus sepium	Bindweed
	Hordeum jubatum	Foxtail Barley
	Melilotus alba	Sweet White Clover
	Phalaris arundinacea	Reed Canary Grass
	Plantago spp.	Plantain
	Sonchus arvensis	Perennial Sow Thistle
	Brassica kaber	Wild Mustard
	Taraxacum officinale	Dandelion
	Thalpsi arvense	Stinkweed
	Trifolium pratense	Clovers
	Urtica dioica	Stinging Nettle
Native graminoids		
	Carex spp.	Sedge spp.
	Equisetum hyemale	Common Scouring Rush
	Glyceria striata	Fowl Manna Grass
	Juncus balticus	Baltic Rush
	Typha latifolia	Cattails
	Scirpus validus	Great Bulrush
	Equisetum arvense	Common Horsetail
Native forbs		
	Artemesia frigida	Pasture Sage
	Artemesia ludoviciana	Prairie Sage
	Aster spp.	Aster
	Gaillardia aristata	Gaillardia
	Helianthus spp.	Sunflower
	Lemna minor	Common Duckweed
	Mentha arvensis	Wild Mint
	Rumex crispus	Curled Dock
	Solidago canadensis	Canada Goldenrod

Soils and hydrology scored 63% with most of the points lost due to active lateral cutting of the bank, human caused bare ground, and the reach being altered by human activity. Extreme lateral cutting was upstream of the assessment reach but has affected the health of the reach downstream in terms of flow, sedimentation, deposition, and stability of the banks. Horses present in the reach also caused pugging and hummocking with varying degrees throughout the reach. The incisement was scored as a stage 2 because of steep outside banks with minimal floodplain to access on the south side of the reach.

In total the reach scored 63% and rated healthy with problems. This is a decrease from the 2013 score of 65%, but both scores are lower than the 2004 score of 70%. This may be due to the lateral cutting progressing year after year and the increased presence of invasive species which indicates a degrading ecosystem. Impact from the horses seems minimal with a few trails and areas of hoof damage causing pugging and hummocking. Species diversity is high at this site but many invasive and disturbance species appear to dominate.

f.) Site assessments-riparian health assessment at I80

The reach assessed at site I80 in 2017 was approximately 150 m downstream of the 624 Grid bridge and the reach carried downstream for about 200 m or more. This reach was approximately one kilometer from the original site assessed in 2005. Therefore, comparison of the assessments cannot be made for 2005. Land use in the 2005 location was cattle pasture and in 2017 was cropland. The adjacent cropland was seeded and harvested in 2017.

Vegetation scored 45% with much of the vegetation being Smooth Brome and Reed Canary Grass. There was excellent cover over the banks and to the water’s edge despite the species not being ideal for deep rooted and soil binding (See Figure 34). Banks were steep in the majority of this reach as well. Preferred trees and shrubs included Thorny Buffaloberry (*Shepherdia argentea)* but there was a lack of saplings in the reach and some mature tree bluffs in the uplands. Other disturbance and invasive species observed here included Crested Wheat Grass (*Agropyron cristatum)* and Canada Thistle shown in Figure 31. Table 9 below shows a sample of species documented for this reach, with a total of 16 species listed.

Figure 31. Canada Thistle at Site I80

Table 9. List of species found at Site I80

Type and species of riparian vegetation found at site I80 summer 2017		
Vegetation type	**Latin name**	**Common name**
Preferred trees and shrubs		
	Shepherdia argentea	Thorny Buffaloberry
Non-preferred trees and shrubs		
	Rosa woodsii	Wood's Rose
	Symphoricarpos occidentalis	Western Snowberry
Invasive species (noxious weeds)		
	Agropyron cristatum	Crested Wheatgrass
	Artemesia absinthium	Absinth
	Bromus inermis	Smooth Brome
	Cirsium arvense	Canada Thistle
Disturbance-increaser undesirable herbaceous species		
	Phalaris arundinacea	Reed Canary Grass
	Urtica dioica	Stinging Nettle
Native graminoids		
	Carex spp.	Sedge spp.
	Equisetum arvense	Common Horsetail
	Typha latifolia	Cattails
Native forbs		
	Artemesia frigida	Pasture Sage
	Glycyrrhiza lepidota	Wild Licorice
	Solidago canadensis	Canada Goldenrod
	Rumex crispus	Curled Dock

Soils and hydrology scored 70% as there was minimal human caused bare ground and active lateral cutting. The most significant land use is crop land above the riparian buffer on the north bank; therefore, alteration by human activity had a low score. The channel is moderately incised and the 1-2-year flow may not be able to access the floodplain. Higher flows (less than a 5-10-year event) could access narrow floodplain less than twice the bankfull channel width.

Overall this new reach of Site I80 scored 57% which rates it as unhealthy. This is due to the dominating presence of invasive and disturbance increaser vegetation which lack deep roots and soil binding capabilities along the banks. There was also a lack of preferred trees and shrubs and regeneration of these species observed. The site's ill-health is because of invasive vegetation and the cropland on the north bank altering the bank (Figure 32). This was the only site to score this low on the scale but also the only site adjacent to active cropland and cultivation.

Figure 32. Facing upstream of the reach with cultivated land to the north.

g.) Site assessments-riparian health assessment at E90

Site E90 is the last monitoring site before the SCC empties into the South Saskatchewan River. It is located north of Swift Current and east of Stewart Valley. The main land use is pasture for cattle both upstream of the site and within the site. Cattle were present in the site all summer long but the number of head was low and not heavily stocked. The reach covered approximately 200 m starting from about 100 m downstream of a fence crossing the creek towards the east. The reach is unique as it displays a braided section with large boulders, steep cut banks, and diverse vegetation right to the water's edge. The assessment done in 2004 described a similar area done as in 2017. Figure 33 below shows the uniqueness of this site.

Figure 33. Braided channel at site E90 with diverse vegetation, large rocks, trees and shrubs

Vegetation score was 70% within this reach. Native graminoids and forbs were abundant as well as preferred trees and shrubs as shown in Figures 34 and 35. Graminoids included species such as Alkali Cordgrass (*Spartina gracilis),* Mat Muhly *(Muhlenbergiia richardsonis),* and Sea-side Arrow Grass *(Triglochin maritima).* Native forbs included Prairie Coneflower *(Ratibida columnifera),* Biennial Wormwood *(Artemesia biennis),* and Dotted Blazing Star *(Liatris punctate).* Invasive and disturbance increaser species were still present but not as dominantly as they were at the other six sites. New tree and shrub species were found such as birch *(Betula spp.)* and Common Juniper *(Juniperus communis).* The woody species of preferred trees and shrubs were also showing maturity and regeneration sites which is excellent to observe. Table 10 shows a sample of the species documented at this site, which was 49 species in total. The score assigned in 2004 was 79%, slightly higher than in 2017 but it is still rated healthy with problems.

Figure 34. Abundant preferred tree and shrub species in the site E90 reach

Figure 35. Vegetation right to the water's edge at site E90

Table 10. List of species at Site E90

Type and species of riparian vegetation found at site E90 summer 2017		
Vegetation type	**Latin name**	**Common name**
Preferred trees and shrubs		
	Amelanchier alnifolia	Saskatoon
	Betula occidentalis	Water Birch
	Cornus stolonifera	Red Osier Dogwood
	Elaeagnus commutata	Wolf Willow
	Juniperus communis	Common Juniper
	Prunus virginiana	Chokecherry
	Ribes americanum	Wild Black Currant
	Salix interior	Sandbar Willow
	Salix spp.	Willow
	Shepherdia argentea	Canada Buffaloberry
Non-preferred trees and shrubs		
	Artemesia cana	Sagebrush
	Crataegus spp.	Hawthorn
	Rosa woodsii	Wood's Rose
	Symphoricarpos occidentalis	Western Snowberry
Invasive (noxious) weeds		
	Arctium minus	Common Burdock
	Artemesia absinthium	Absinth
	Cirsium arvense	Canada Thistle
	Bromus inermis	Smooth Brome
Disturbance-increaser undesirable herbaceous species		
	Brassica kaber	Wild Mustard
	Convulvulus sepium	Bindweed
	Medicago lupulina	Black Medic
	Melilotus alba	White Sweet Clover
	Potentilla anserina	Silverweed
	Sonchus arvensis	Perennial Sow Thistle
	Tragopogon dubius	Goat's Beard
	Trifolium repens	Yellow Sweet Clover
Native graminoids		
	Agropyron spp.	Wheatgrass
	Calamagrostis inexpansa	Northern Reed Grass
	Carex spp.	Sedge spp.
	Equisetum arvense	Common Horsetail
	Equisetum hyemale	Common Scouring Rush
	Glyceria striata	Fowl Manna Grass
	Juncus balticus	Baltic Rush
	Muhlenbergia richardsonis	Mat Muhly
	Spartina gracilis	Alkali Cord Grass
	Triglochin maritima	Sea-side Arrow Grass
	Typha latifolia	Cattail
	Scirpus spp.	Rush
Native forbs		
	Artemesia ludoviciana	Prairie Sage
	Solidago canadensis	Canada Goldenrod
	Glycyrrhiza lepidota	Wild Licorice
	Helianthus spp.	Sunflower
	Ratibida columnifera	Prairie Coneflower
	Gaillardia aristata	Gaillardia
	Helianthus annus	Annual Sunflower
	Artemesia biennis	Biennial Wormwood
	Artemesia frigida	Pasture Sage
	Rumex crispus	Curled Dock
	Liatris punctata	Dotted Blazing Star

Soils and hydrology scored 93%, the highest of all sites assessed. This score was attained as there was minimal bare ground that was human caused such as cattle trails and a driving trail in the uplands. The driving trail left a small imprint as it was still covered in vegetation. A small number of cattle were grazing in this site for the summer but trails were minimal. The most human caused bare ground was observed on an outside meander with rocks. Alteration of the streambanks by human activity was not present or had minimal presence. Active lateral cutting was less than 5% the reach having signs of active lateral cutting. Since the main land use in the uplands is pasture, the reach was also scored as minimally altered by human activity. Some areas of pugging and hummocking were observed but the vast majority of the reach had less than 5% of these physical alterations. The stream channel incisement score indicated a stable, unincised, wide valley bottom channel. There is lateral cutting on outside curves but bankfull flows or 1-2-year events can access the floodplain more than twice the bankfull channel width. In 2004 the soils score was also high at 94%.

Overall this site scored the highest of all at 81% and rated as a healthy riparian area. Site E90's health can be attributed to the lack of human alteration with the exception of cattle grazing, a high score for minimal stream channel incisement, diversity of vegetation, and the presence of preferred trees and shrubs. There is vegetation diversity with the dominating presence of native and preferred species and less invasive and disturbance increaser species at this site. The 2017 score dropped slightly from the 2005 score going from 88% in 2005 to 81% in 2005. This site has been assessed as healthy every time it has been assessed since 2004.

3.2 a.) Saskatchewan Water Quality Index and Parameters

In previous monitoring projects SCCWS attempted to answer the question of the water quality of the Swift Current Creek by calculating Water Quality Indexes (WQI) for four separate water uses that are important to the SCC and its watershed. These include:

1. Water for irrigation use
2. Livestock watering
3. Protection of aquatic life
4. General water quality

The concept of any water quality index is to quantitatively summarize the general state of water quality relative to a specified use. It is a tool that can provide a simple summary for communication to a non-technical audience (Davies 2006; Horton and Brown 1965; Brown et al. 1970 as cited by Davies 2006). However, Davies (2006) went on to point out some weaknesses of indexes. They include sensitivity to number and type of measurements and the number of sampling dates. Indexes can be affected by having several small excursions from the guidelines of the index versus one large issue with water quality parameters. Parameters need to be balanced to provide a composite picture of water quality as the poorest parameter can be offset by better parameters.

Despite the shortcomings of indices, SCCWS calculated indices based on the 2006 guidelines to allow comparison of the results generated in 2017 with those from 2004-2007. There have been changes and also new indices have been developed since 2006. This report will discuss these changes from the 2006 guidelines and the impact the changes have when reviewing each index and comparing changes in water quality from 2007 to 2017. Table 11 shows the rating and the corresponding scores as well as a description of the water in each category. Each index score is based on a score of 100.

Table 11. Water quality ratings for the water quality indices calculated

Saskatchewan water quality index ratings		
Rating	**Index**	**Description of water quality**
Poor	0-44	Almost always threatened or impaired; conditions usually depart from natural or desirable levels
Marginal	45-64	Frequently threatened or impaired; conditions often depart from natural or desirable levels
Fair	65-79	Usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
Good	80-94	Protected with only a minor threat or impairment; conditions rarely depart from natural or desirable levels
Excellent	95-100	Protected with a virtual absence of threat or impairment; conditions are very close to pristine or natural levels

(Table adapted from Saskatchewan Environment 2006 as cited by Tait [SCCWS] 2008)

3.2 b.) Water Quality Index Results

The index results for each of the indices under discussion also include water parameters such as dissolved oxygen (DO) and pH which are included in two indexes. Water temperature also plays a key part in the levels of DO and pH. Dissolved oxygen is a measure of oxygen available in forms that aquatic organisms such as fish can readily use, and it varies throughout the seasons due to temperature, time of day, and flow rates (Nelson and Paetz 1992; Cooke 2013 as cited by Peters [SCCWS] 2013). The lowest levels of DO before stress and death can occur to fish is 5.0 mg/L (Cooke 2013 as cited by Peters [SCCWS] 2013), none of the monitoring sites observed DO levels less than 5.0. Water at pH of 6-9 pH units is needed for organisms to function and have basic regulatory processes used to sustain life (Robertson-Bryan Inc. 2004 as cited by Peters [SCCWS] 2013). Tables 12 and 13 give a summary of dissolved oxygen and pH, and Table 14 includes the average water temperatures taken during water sampling.

Table 12. Average dissolved oxygen levels in SCC 2017

Average dissolved oxygen (mg/L) in Swift Current Creek summer 2017				
Site	June	July	August	September
A10	7.41	6.96	7.44	8.94
B30	13.01	7.14	6.40	8.34
C50	9.77	8.95	8.55	9.67
Riverside	11.48	-	9.48	10.01
Riverdene	9.70	-	8.75	9.79
H60	8.56	8.81	7.83	9.59
Highway #1	8.06	-	7.14	9.50
D70	13.51	9.52	8.19	10.31
I80	8.28	7.91	7.44	10.50
E90	9.73	9.42	8.12	10.97

Table 13. Average pH values in SCC 2017

Average pH values in Swift Current Creek summer 2017								
Month	**June**		**July**		**August**		**September**	
Site	**Field average**	**Lab**	**Field average**	**Lab**	**Field average**	**Lab**	**Field average**	**Lab**
A10	8.4	8.4	8.5	8.4	8.3	8.3	8.4	8.4
B30	8.9	8.9	8.2	8.3	8.9	8.8	8.6	8.9
C50	8.8	8.8	8.6	8.7	8.8	8.8	8.3	8.8
Riverside	8.7	8.7	-	-	-	8.5	8.4	8.5
Riverdene	8.6	8.6	-	-	8.5	8.5	8.5	8.5
H60	8.6	8.6	8.1	8.5	8.4	8.4	8.4	8.5
Highway #1	8.3	8.4	-	-	8.3	8.3	8.4	8.4
D70	8.7	8.7	8.2	8.6	8.4	8.4	8.3	8.4
I80	8.3	8.4	8.5	8.5	8.2	8.3	8.4	8.5
E90	8.5	8.5	8.4	8.5	8.3	8.4	8.5	8.5

Table 14. Average water temperatures at time of water sampling in SCC 2017

Average water temperature (°C) in Swift Current Creek summer 2017				
Site	**June**	**July**	**August**	**September**
A10	17.47	20.17	17.57	8.17
B30	17.47	17.50	18.00	10.97
C50	19.33	21.17	19.13	9.60
Riverside	19.83	-	20.70	9.87
Riverdene	19.10	-	21.50	10.07
H60	18.23	22.50	20.43	9.30
Highway #1	18.40	-	19.40	10.53
D70	19.17	18.73	19.63	10.70
I80	18.80	17.70	19.03	10.37
E90	17.97	15.67	17.77	11.20

i.) Irrigation

Table 15 shows the parameters and their guidelines for the irrigation water use index from the Saskatchewan Environment 2006 guidelines as adapted from Tait [SCCWS] (2008). Figure 36 shows the 2017 index for each site obtained.

Table 15. Irrigation water use index guidelines

Irrigation water use water quality index guidelines				
#	**Parameter**	**level**	**2006 Guideline**	**Units**
1	Boron	>	0.5	mg/L
2	Chloride	>	100	µg/L
3	E.coli	>	100	ct/100 ml
4	Sodium	>	115	mg/L
5	Total Coliforms	>	1000	ct/ 100 ml
6	Total Dissolved Solids	>	700	mg/L

(Saskatchewan Environment 2006 as cited by Tait [SCCWS] 2008)

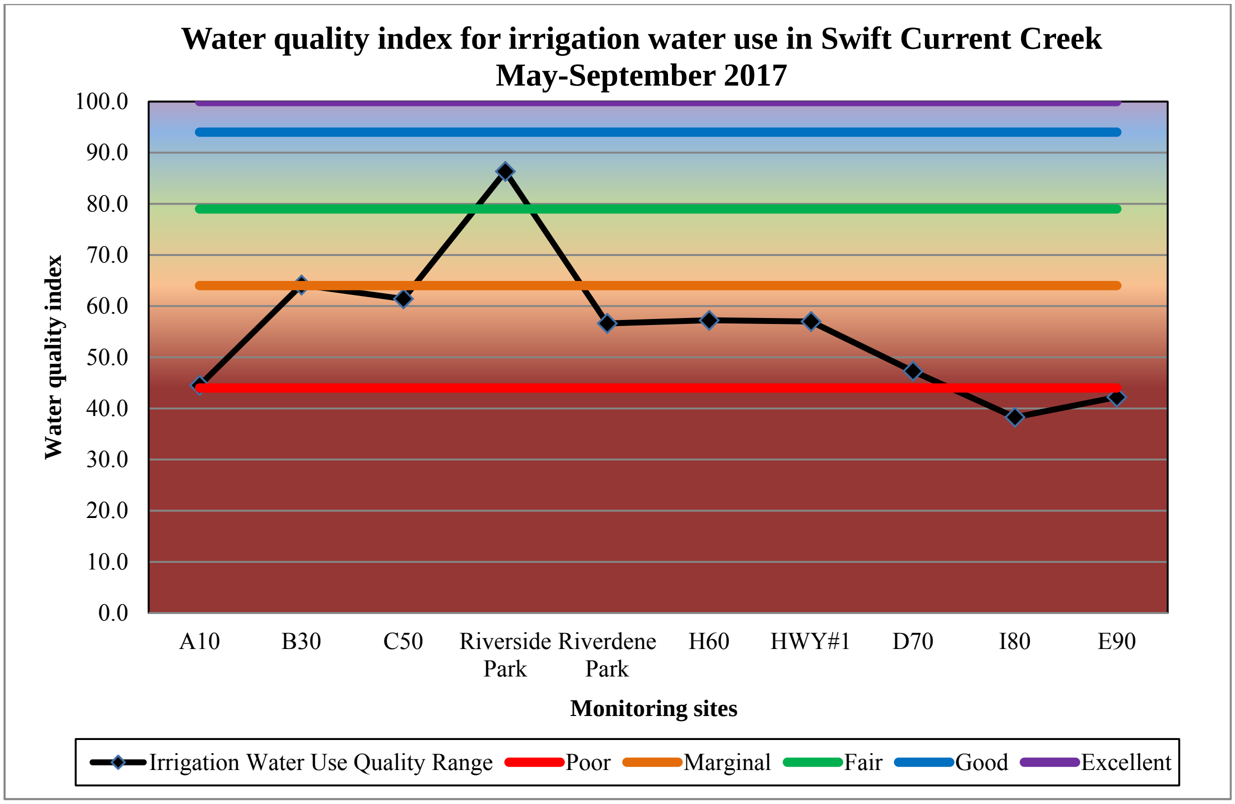

Figure 36. Water quality index for irrigation water use

Index scores in 2017 were lower than in 2007 due to increased levels of Total Dissolved Solids (TDS). Every sample taken in 2017 was over the 700 mg/L guideline in the 2006 irrigation index. This was because of higher concentrations in the water due to lower water levels. Water levels were lower in 2017 due to low creek flows and increased evaporation because of higher than normal temperatures. The worst index score was at site I80 with a score of 38.3 which gives it a poor rating. The highest score was at Riverside Park with a score of 86.3 which gives it a good rating. This was the only site that scored in this range. Seven sites: A10, B30, C50, H60, D70, Riverdene Park and Highway #1 all rated as marginal and site E90 rated as poor.

The marginal ratings are a concern given the reliance on irrigation in some of the areas in the watershed. Irrigation is also important within the city of Swift Current itself for city green spaces and gardening. However, there are some changes to the guidelines based on the 2015 Surface Water Quality Objectives as released by WSA. The scores did improve using the 2015 guideline, though not significantly, as most of the sites have high levels of coliforms and the guidelines for fecal (*E. coli*) and total coliforms did not change from 2006 to 2015. Using the 2015 guidelines Site B30 and Highway #1 received a rating of good. Sites C50, H60, Riverdene Park, D70 and E90 moved to fair from marginal, and site A10 maintained a marginal rating. Site I80 moved from poor to marginal. Riverside Park moved to a rating of excellent with a 100% score. This site is the first sampled within the city downstream of the WTP. Figure 37 shows the comparison between 2007 and 2017 at five monitoring sites.

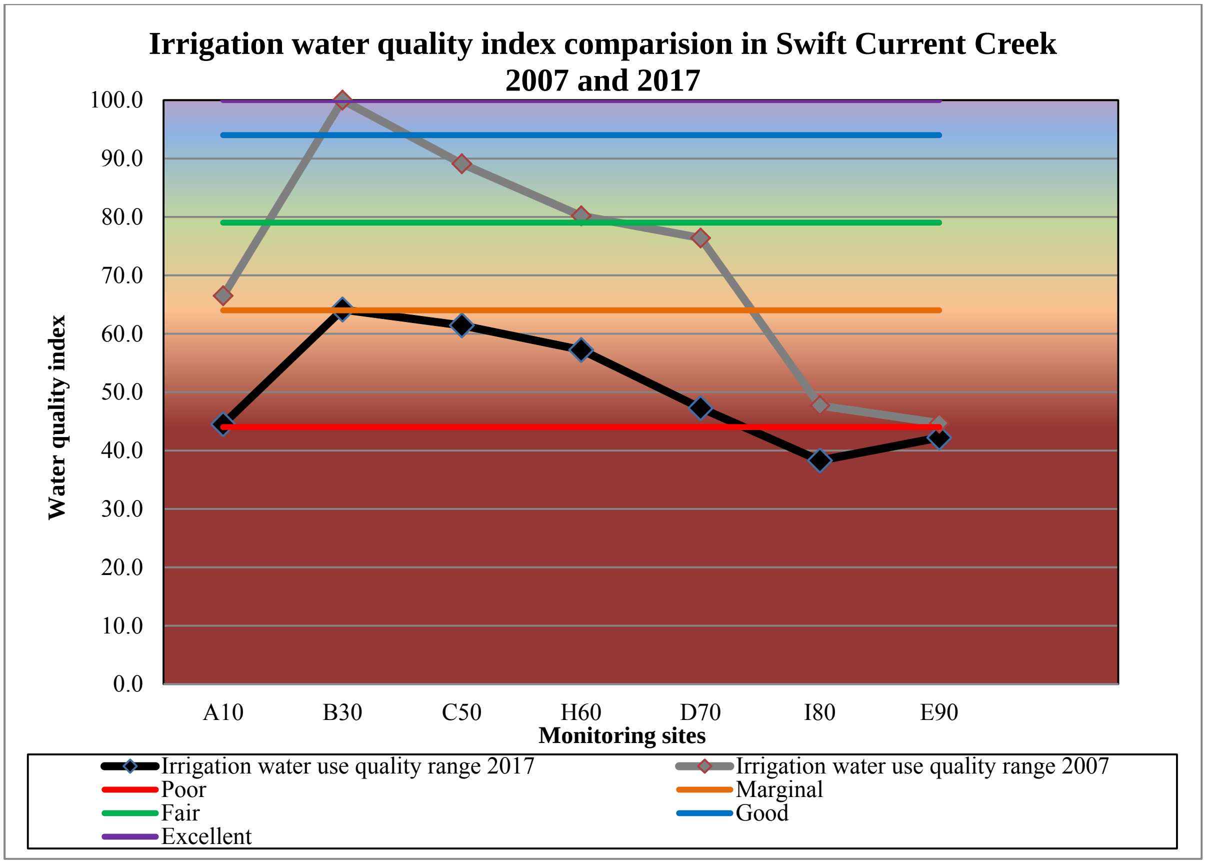

Figure 37. Water quality index for irrigation water use comparison 2007 and 2017

ii.) Livestock Watering

Table 16 shows the parameters and guidelines used to for the livestock watering use from Saskatchewan Environment (2006) as cited by Tait [SCCWS] (2008). 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 as cited by Tait [SCCWS] 2008).

Table 16. Livestock water use index

Livestock water use water quality index guidelines				
#	**Parameter**	**level**	**2006 Guidelines**	**Units**
1	Copper	>	0.5	mg/L
2	Nitrite and Nitrate Nitrogen	>	100	mg/L
3	Sulfate	>	1000	mg/L
4	Total Dissolved Solids	>	1000	mg/L

(Saskatchewan Environment 2006 as cited by Tait [SCCWS] 2008)

There was no change in ratings from 2007 as sites from A10 to H60 all scored excellent. Site D70 rated good as it had three occurrences of TDS over the limit. Site I80 rated as marginal due to high TDS for all five samples and one very high copper level. Site E90 scored fair as all TDS levels were over the guideline. Riverside and Riverdene Parks rated as excellent and Highway #1 scored good as it had one TDS result over the 700 mg/L guideline. Figure 38 shows all values in their respective ranges for each site, and Figure 39 shows the comparison of 2007 to 2017.

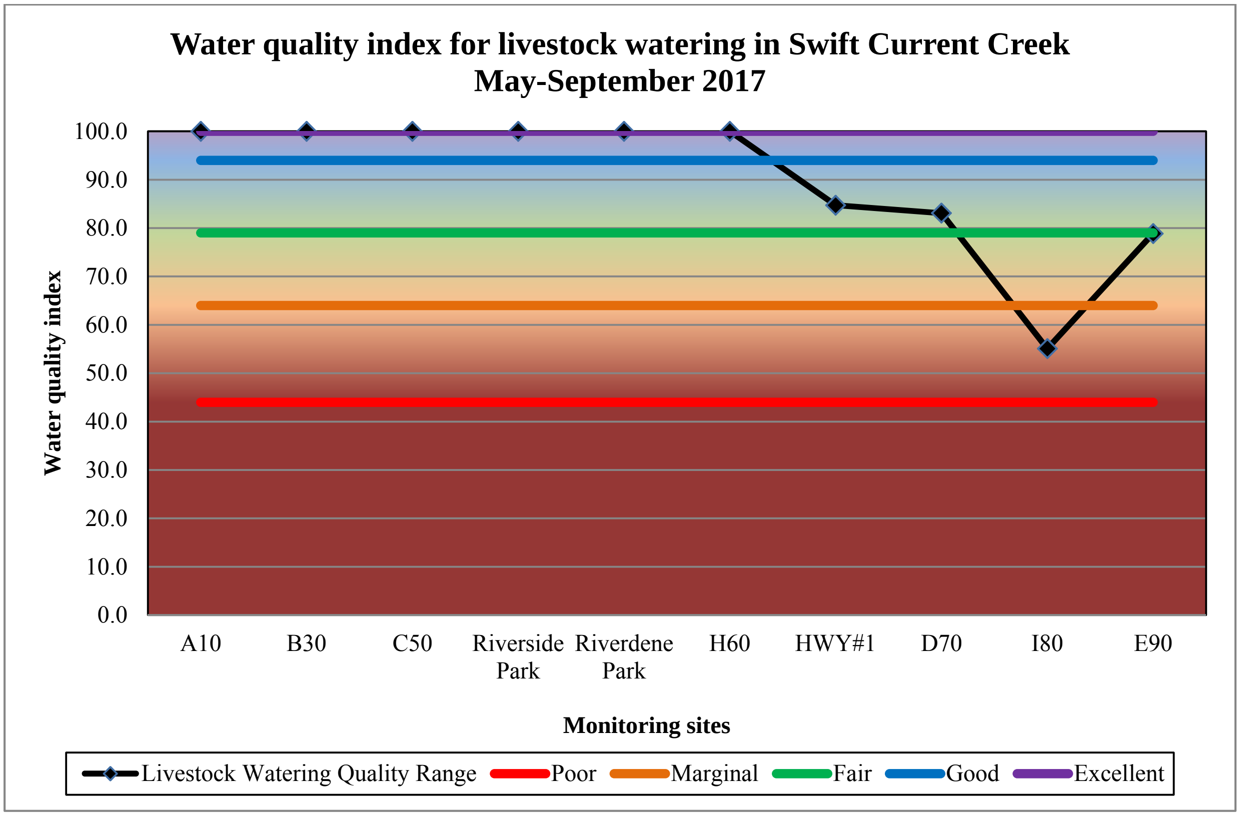

Figure 38. Water quality index for livestock watering

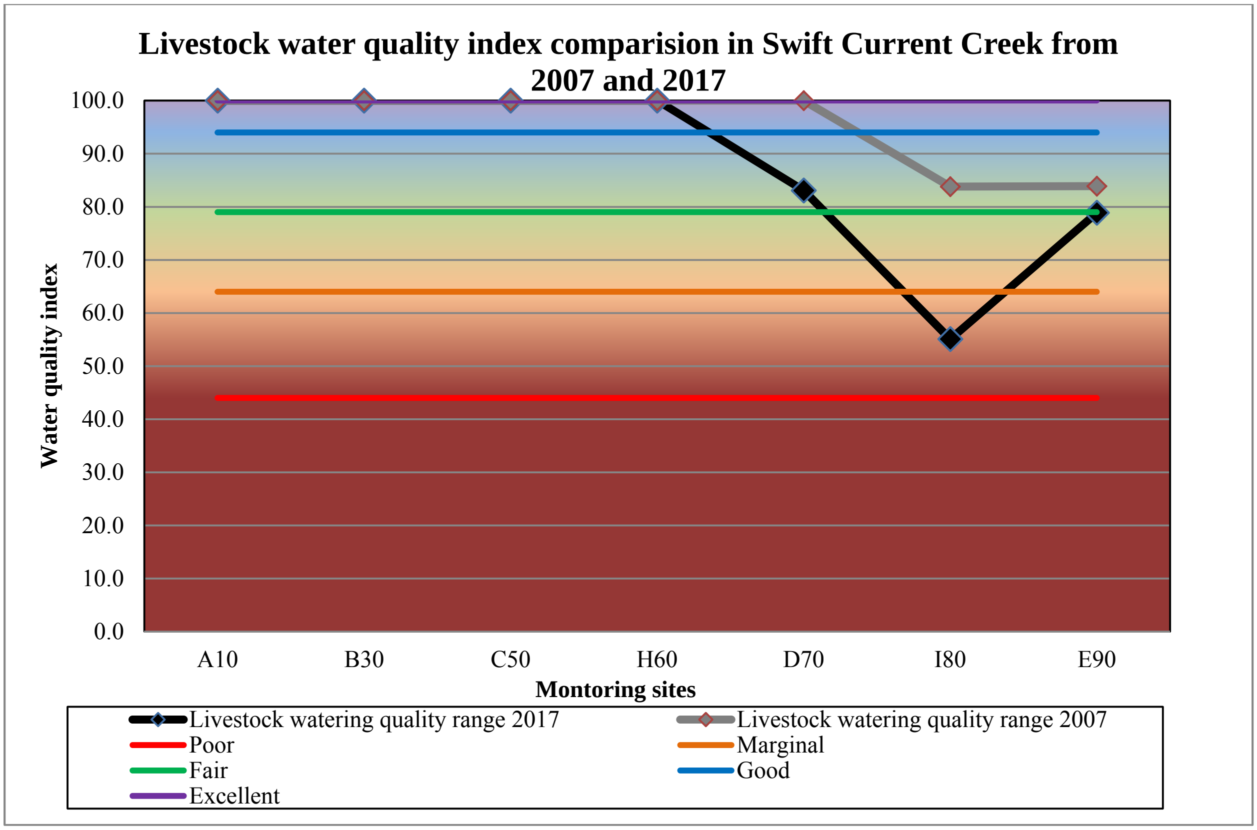

Figure 39. Water quality index for livestock watering comparison of 2007 and 2017

The guidelines for livestock watering in the *2015 Surface Water Quality Objectives Interim Edition EPB 356, June 2015,* by WSA have a number of changes from the 2006 guidelines. Guidelines for aluminum at 5000 µg/L, arsenic at 25 µg/L and boron at 5 mg/L were added. The guideline for copper levels for livestock consumption was defined at 0.1 µg/L. Since most of the water in the creek may be used to water livestock this number should be included in the index for the purpose of this report. The biggest change in the 2015 guidelines from the 2006 guidelines was that the lower limit for TDS that was acceptable was changed to 3000 mg/L from 1000 mg/L. This caused the ratings for all sites except for I80 to score 100% and rate as excellent. Site I80 scored marginal due to the concentration of copper being way over the guideline in June 2017.

iii.) Protection of aquatic life and wildlife

Table 17 shows the parameters and guidelines used to for the protection of aquatic life and wildlife index from Saskatchewan Environment (2006) as cited by Tait [SCCWS] (2008). According to the Saskatchewan Surface Water Quality Objectives as cited by Saskatchewan Environment (2006) as cited by Tait [SCCWS] (2008), 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. This is important in maintaining healthy populations and seeing a diverse array of species within the creek habitats of the city and outside the city.

Mercury levels are part of the Protection of Aquatic life and Wildlife Index. However Mercury is difficult to accurately measure in water and the lab could only report that levels were less than 0.04 mg/L; which is greater than the level of 0.026 mg/L set out in the Protection of Aquatic Life and Wildlife index. (J-M Davies [WSA] in email document to K Steinley dated June 11 2018 11:21 AM; unreferenced, see Acknowledgements).Therefore it is impossible to tell how many occurrences may have actually exceeded the limit as the actual concentration of mercury was not reported just the level it was less than. This did not lower the index calculated as the calculator did not count these as being over the limit. A more delicate test for Mercury that would be able to determine levels between 0.026 mg/L and 0.04 mg/L might show that the levels are higher than the index limit and the indices calculated would be lower than what were calculated from 2017 testing.

Table 17. Parameter limits in the protection of aquatic life and wildlife index

Protection of aquatic life and wildlife water quality index guidelines				
#	**Parameter**	**level**	**2006 Guideline**	**Units**
1	Nitrogen as Ammonia	Compute*	Compute	mg/L
2	Arsenic	>	5	µg/L
3	Chloride	>	100	mg/L
4	Chromium	>	.001	mg/L
5	Dissolved Oxygen	<	5.5	mg/L
6	Mercury	>	0.026	µg/L
7	pH	< >	6.5-8.5	pH units
8	Sodium	>	100	mg/L

* Compute refers to the guideline being dependant on other characteristics such as water temperature and pH in order to calculate the appropriate guideline
(Saskatchewan Environment 2006 as cited by Tait [SCCWS] 2008)

When the Protection of Aquatic life and Wildlife Index was calculated in 2007, the lowest detectable level for Mercury was 0.05 mg/L which all samples in that year tested less than. In 2017 all but one sample was less that the 0.04 mg/L detectable level. This means that Mercury levels are not skewing the index for one year and not the other and we can compare the 2007 indices to the 2017 indices. The scores for this index generally improved in 2017 from the 2007 scores except for site I80 which decreased due to high chromium in June. This improvement is due to more ideal levels in the pH of the water from 2007 to 2017. Sites A10, Riverside and Riverdene Parks, and Highway #1 all rated as excellent in 2017. This shows that sites within the city are potentially maintaining quality habitat and health for aquatic life and wildlife. As mentioned, Riverside Park is immediately downstream of the water WTP, so no ill effects of the WTP were observed. Riverdene Park is upstream of WWTP but the rating shows that even in the midst of the city the potential for excellent ratings do exist. The last site in proximity to the city, Highway #1, is immediately downstream of the WWTP. This is expected to have improved ratings as the water leaving the plant is treated and fewer pollutants enter the creek.

This is significant as residents of the city want to enjoy activities along the creek such as fishing and wildlife viewing. Wildlife present within the urban setting can give people the knowledge that there are enough places for wildlife to co-exist and thrive in the city. There are a number of places within the city of Swift Current where people also fish frequently. The following Figure 40 shows the sites against their ratings within the index.

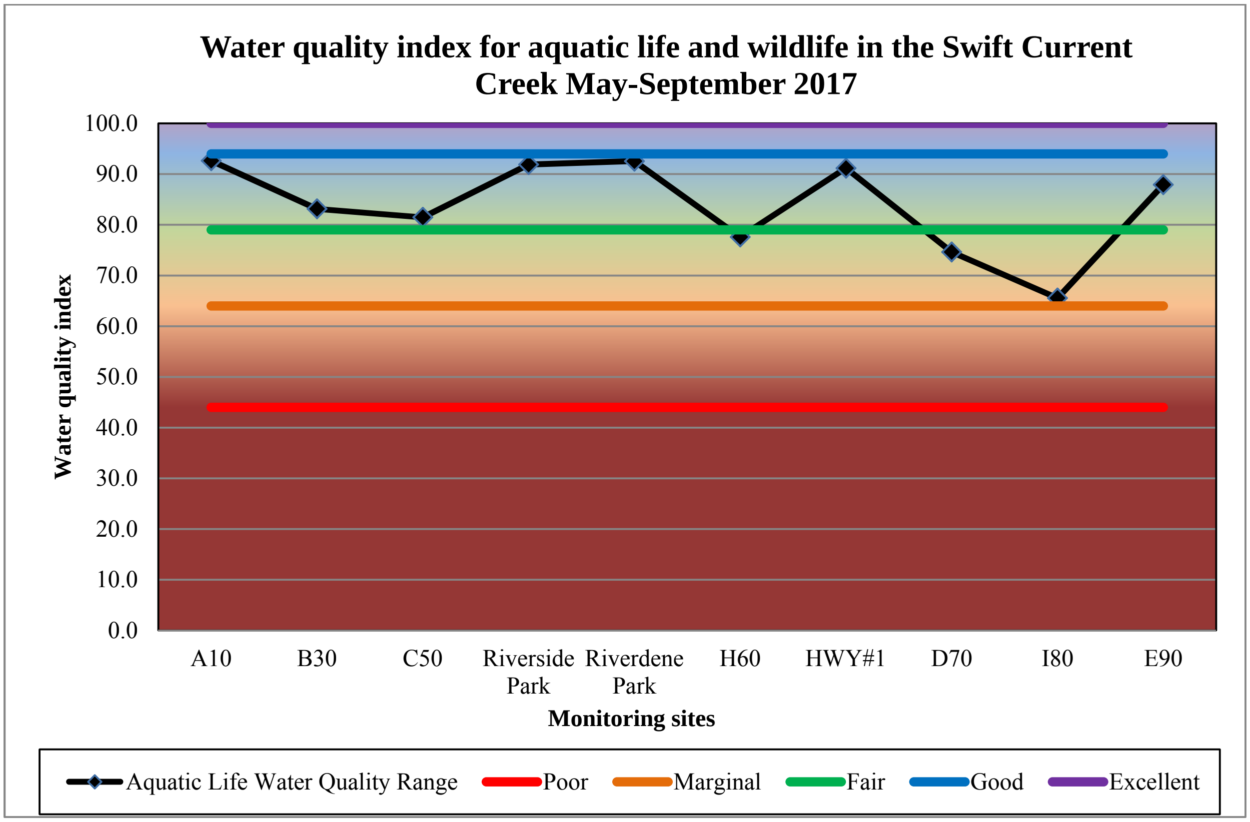

Figure 40. Water quality index for aquatic life and wildlife

Sites B30, C50 and E90 rated as good, and H60, D70 and I80 rated as fair. These sites had ratings which were lower because many had several tests that surpassed the guidelines such as arsenic concentration exceeding 5 µg/L and pH that were higher than the guideline of 8.5 pH units. Sources such as storm water outfalls and bank alterations may also play a part in the quality of water observed at sites H60 and D70.

The 2015 updated guidelines for aquatic life and wildlife have not significantly changed from the guidelines from 2006; therefore, SCCWS has not re-calculated the aquatic life and wildlife index based on 2015 guidelines. Comparison of the scores from 2007 to the 2017 scores for this index can be seen in Figure 41.

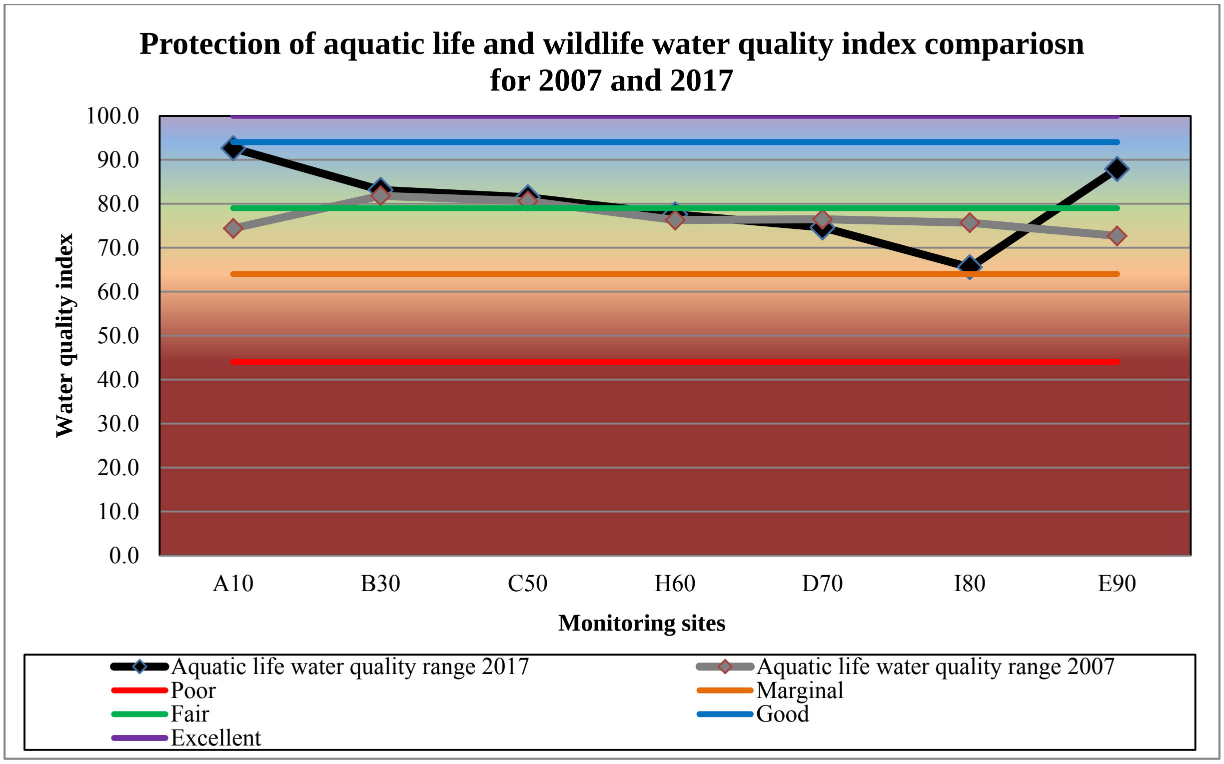

Figure 41. Water quality index for aquatic life and wildlife comparison 2007 and 2017

iv.) General Water Quality

The three previous indices are not comprehensive indices to measure water quality. In 2007 SCCWS used an index called the general protection index that included all parameters of the aquatic life and wildlife index as well as guidelines for aluminum, *E. coli* bacteria, nitrate plus nitrite nitrogen, dissolved phosphorous, and sulfate. The following Table 18 shows the parameters and guidelines used to calculate the general water protection index from WSA. In 2017 most of the sampling sites scored slightly poorer than 2007 due to increased TDS concentrations at all sites. Site A10 improved as pH was in the correct range. Site I80 also improved as the excursions from the guidelines were not as large as they were in 2007. Sites A10, C50, H60, D70, I80, Riverside and Riverdene Parks, and Highway #1 all rated as good, with the best score at H60 and Riverside Park at 90. Site E90 had the worst score at 76 which gives it a rating of fair. Figure 42 following below shows the monitoring sites and where they rated in this index.

Table 18. Parameter limits in the general water quality index

General water quality index guidelines				
#	**Parameters**	**level**	**2006 Guideline**	**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	E.coli	>	200	ct/100 ml
8	Mercury	>	0.1	µg/L
9	Nitrite and Nitrate Nitrogen	>	1	mg/L
10	pH	<>	6.5-9	pH units
11	Phosphorous Dissolved	>	0.1	mg/L
12	Sodium	>	100	mg/L
13	Sulfate	>	500	mg/L
14	Total Dissolved Solids	>	700	mg/L

* Compute refers to the guideline being dependant on other characterises such as water temperature and pH in order to calculate the appropriate guideline
(Saskatchewan Environment 2006 as cited by Tait [SCCWS] 2008)

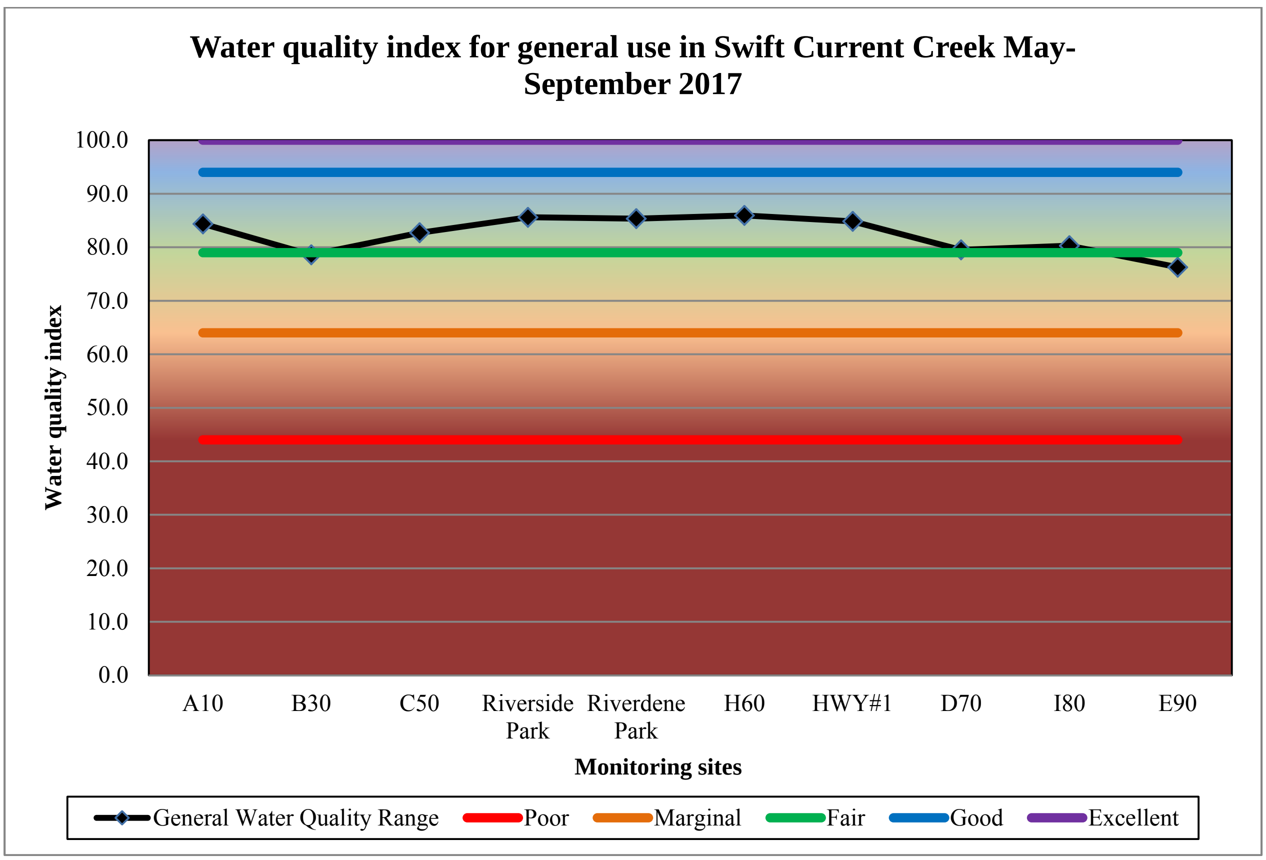

Figure 42. Water quality index for general use

There was not a general water quality index developed in 2015. However, the Saskatchewan Disease Control Laboratory did provide guidelines for drinking water when returning the results of the water samples taken. These guidelines were as follows:

- Aluminum < 100 µg/L
- Arsenic < 10 µg/L
- Chloride < 250 mg/L
- Fluoride < 1.5 mg/L
- Total Dissolved Solids < 1500 mg/L
- Sodium < 300 mg/L
- Nitrate-N Dissolved < 10 mg/L
- Sulfate Dissolved < 500 mg/L

These changes do not impact the ratings significantly as the TDS guideline in the original index was raised to 1500 mg/L from 700 mg/L. This change meant that there were only 2 TDS levels over the new guideline while all samples exceeded the old guideline. However, the guideline for aluminum concentration was lowered from 5000 ug/L in the original index to 100 ug/L in the new guidelines, only 8 of the 46 samples taken were under this guideline. All sites rated as good except for site I80 which rated fair with a score of 69. Site C50 had the highest score with this revised ranking scoring 89, which is immediately upstream of the WTP.

The General water quality index may be the best indicator of water quality within the City of Swift Current and all sites with the exception of I80 downstream of the city have a good rating. Therefore the effects of the city and its water treatment and wastewater facilities have worked to maintain the quality of water within and downstream of the city. Figure 43 shows the comparison of the general water index from 2007 and 2017. Tables 19 and 20 give an overview of the deviations in sampling for each site.

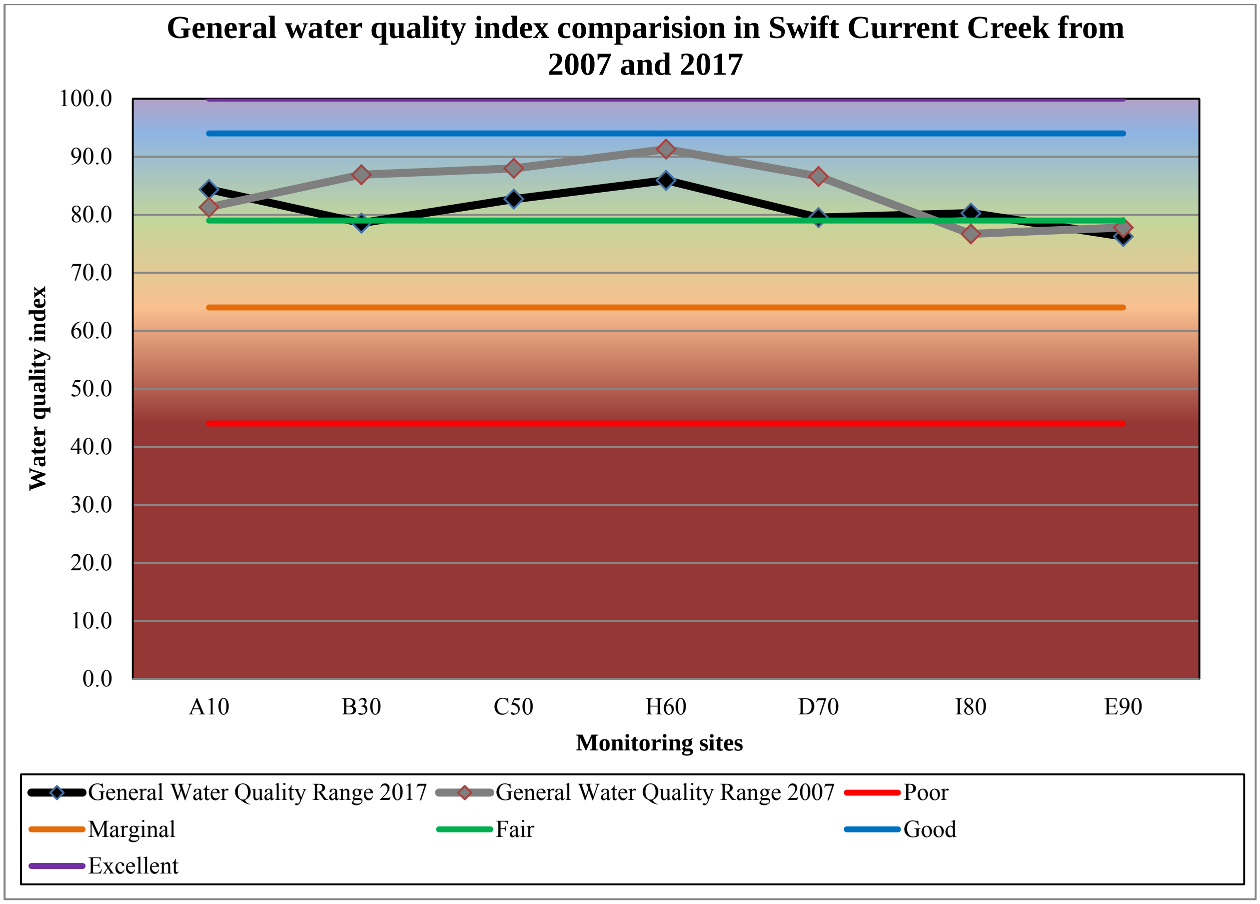

Figure 43. General water quality index comparison 2007 and 2017

Table 19. Deviations in the index scoring for all water use indices up to and within the City of Swift Current, using 2006 Guidelines (Test with excursions from guidelines/total tests taken at site)

Parameter deviations of monitoring site on Swift Current Creek summer 2017 up to City of Swift Current					
			Monitoring sites		
Water use	**A10**	**B30**	**C50**	**Riverside Park**	**Riverdene Park**
Irrigation water use	**Poor (44.5)**	**Marginal (64.1)**	**Marginal (61.4)**	**Good (86.3)**	**Marginal (56.6)**
Deviations	E.coli (4/5), total coliform (4/5), TDS (5/5)	E.coli (1/5), total coliform (2/5), TDS (5/5)	total coliform (3/5), TDS (5/5)	TDS (4/4)	E.coli (2/4), total coliform (3/4), TDS (4/4)
Water use	**A10**	**B30**	**C50**	**Riverside Park**	**Riverdene Park**
Livestock watering use	**Excellent (100.0)**	**Excellent (100.0)**	**Excellent (100.0)**	**Excellent (100.0)**	**Excellent (100.0)**
Deviations					
Water use	**A10**	**B30**	**C50**	**Riverside Park**	**Riverdene Park**
Aquatic life and wildlife	**Good (92.6)**	**Good (83.2)**	**Good (81.5)**	**Good (91.9)**	**Good (92.6)**
Deviations	arsenic (1/5)	arsenic (3/5), pH (2/5)	arsenic (4/5), pH (4/5)	pH (4/4)	pH (3/4), sodium (1/4)
Water use	**A10**	**B30**	**C50**	**Riverside Park**	**Riverdene Park**
General water use	**Good (84.4)**	**Fair (78.6)**	**Good (82.7)**	**Good (85.6)**	**Good (85.3)**
Deviations	E.coli (4/5), TDS (5/5)	E.coli (1/5), TDS (5/5)	TDS (5/5)	TDS (4/4)	E.coli (2/4), sodium (1/4), TDS (4/4)

Table 20. Deviations in the index scoring for all water use indices from sites at the north end of the City of Swift Current and downstream of the city, using 2006 Guidelines (Test with excursions from guidelines/total tests taken at site)

Parameter deviations of monitoring site on Swift Current Creek summer 2017 downstream of the City of Swift Current					
		Monitoring sites			
Water use	**H60**	**HWY#1**	**D70**	**I80**	**E90**
Irrigation water use	**Marginal (57.2)**	**Marginal (57.0)**	**Marginal (47.3)**	**Poor (38.3)**	**Poor (42.2)**
Deviations	E.coli (2/5), total coliform (5/5), TDS (5/5)	sodium (1/3), total coliform (3/3), TDS (3/3)	E.coli (1/5), sodium (3/5), total coliform (4/5), TDS (5/5)	E.coli (3/5), sodium (5/5), total coliform (4/5), TDS (5/5)	E.coli (3/5), sodium (5/5), total coliform (3/5), TDS (5/5)
Water use	**H60**	**HWY#1**	**D70**	**I80**	**E90**
Livestock watering use	**Excellent (100.0)**	**Good (84.7)**	**Good (83.1)**	**Marginal (55.1)**	**Fair (78.9)**
Deviations		TDS (1/3)	TDS (3/5)	TDS (5/5)	TDS (5/5)
Water use	**H60**	**HWY#1**	**D70**	**I80**	**E90**
Aquatic life and wildlife	**Fair (77.6)**	**Good (91.2)**	**Fair (74.6)**	**Marginal (65.5)**	**Good (87.9)**
Deviations	arsenic (1/5), pH (3/5), sodium (2/5)	sodium (3/3)	arsenic (2/5), pH (2/5), sodium (5/5)	arsenic (2/5), mercury (1/5), pH (2/5), sodium (5/5)	pH (4/5), sodium (5/5)
Water use	**H60**	**HWY#1**	**D70**	**I80**	**E90**
General water use	**Good (85.9)**	**Good (84.4)**	**Fair (79.5)**	**Good (80.3)**	**Fair (76.3)**
Deviations	sodium (2/5), TDS (5/5)	sodium (3/3), sulfate (1/3), TDS (3/3)	sodium (5/5), sulfate (2/5), TDS (5/5)	sodium (5/5), sulfate (5/5), TDS (5/5)	E.coli (3/5), sodium (5/5), sulfate (4/5), TDS (5/5)

v.) Development of a Southwest Water Quality Index

As shown in the discussion of the indices developed in 2006 and used in the previous monitoring project report and with the changes to guidelines in 2015, there is a lot of room for interpretation of the indices as they pertain to water quality. Small changes to guidelines or objectives can have a significant impact of the indices and the interpretation and application of the results. A water quality index is a good way to provide results of a water sampling project in a form that can be easily read and understood by all who have a stake in the quality of the water they use. Having four separate indices is beneficial for those looking at quality for a specific use but makes it difficult for stakeholders to make overall decisions on water quality. In order to clarify water quality issues in the Swift Current Creek Watershed, SCCWS is proposing to establish a water quality index specific to the watershed and can be applied to all of southwest Saskatchewan.

This index will also allow SCCWS and its stakeholders to compare water quality in future monitoring projects to the results generated in 2017. Water from the SCC has four main uses: municipal drinking water supplies, livestock watering, irrigation, and protection of aquatic life and wildlife. Approximately 19,000 of the 26,000 residents of the SCCW rely on the SCC for their drinking water. The parameters set out by the Saskatchewan Disease Control Laboratory for drinking water will take precedent. For parameters without guidelines from the Provincial lab, SCCWS will use the most stringent of the guidelines to create its index. Table 21 shows the proposed guidelines.

Table 21. Proposed water quality index guidelines from SCCWS

Proposed development of the southwest water quality index				
#	**Parameter**	**Level**	**Guideline**	**Units**
1	Aluminum	>	100	µg/L
2	Ammonia as Nitrogen	Compute*	compute	
3	Arsenic	>	10	µg/L
4	Boron	>	0.5	mg/L
5	Chloride	>	100	mg/L
6	Chromium	>	1	µg/L
7	Copper	>	500	µg/L
8	Dissolved Oxygen	<	5	mg/L
9	*E. coli*	>	100	ct/100 ml
10	Mercury	>	0.026	µg/L
11	Nitrate and Nitrate Nitrogen	>	1	mg/L
12	pH	< >	6.5-8.5	
13	Phosphorous Dissolved	>	0.1	mg/L
14	Sodium	>	100	mg/L
15	Sulfate	>	500	mg/L
16	Total Coliform	>	1000	ct/100 ml
17	Total Dissolved Solids	>	1500	mg/L

* Compute refers to the guideline being dependant on other characterises such as water temperature and pH in order to calculate the appropriate guideline

Comparing the index calculated using 2017 results to the index calculated using the 2007 results, water quality decreased slightly at sites B30, C50, H60, and D70. This is the result of the aluminum levels being over the 100 µg/L guideline in 2017. Site I80's score dropped by more than over twenty points in 2017 from the 2007 index, due to sulfate and TDS levels being over the guidelines in 2017 when they were under in 2007. Site E90's score did not change from 2007 to 2017 and had the same issues each year. Site A10 was the only site to improve with the score going from 69 in 2007 to 70 in 2017. In 2007 the issues were high pH and phosphorous and in 2017 aluminum was the parameter that lowered the scores.

3.2 c.) Water Chemistry Results

The following water chemistry parameters are important watershed health indicators that have often been over acceptable limits during sampling both in 2004 to 2007, and in 2017. Each parameter will be discussed along with the possible sources for each chemical, how each chemical affects water quality and watershed health, and the limit for each parameter for the different indexes that were used to compare water quality and watershed health in 2017 to that from 2004 to 2007. The results can also indicate if there are any impacts from the City of Swift Current's water treatment facilities and urban activity.

i.) Chloride

Chloride is often used as an indicator of increased urbanization in a watershed. Chlorides are salts resulting from the combination of chlorine gas with a metal (KDW 2007 as cited by Tait [SCCWS] 2008). The source of chloride can be both natural and human-caused. There are areas in the SCCW that have saline soils that would contribute to increased levels in surface water. Anthropogenic sources of chloride are many but some of the most common to the SCCW are the application of road salt, effluent leaching and release of treated water, and drainage of excess irrigation water (WHO 2003 as cited by Tait [SCCWS] 2008).

Chloride levels (Figure 44) are part of three water quality indices: irrigation water use, protection of aquatic life and wildlife, and general water protection. The guideline for the maximum amount in all three indices is 100 mg/L. The highest level recorded during the 2017 project was 67 mg/L at I80 in July. In 2007 the highest level recorded was 46 mg/L at D70 in July.

Observations of 2017 chloride levels were:

- Chloride concentrations are low from sites A10 to H60 including Riverside and Riverdene Parks.
- Concentrations increase at the Highway #1 site and peaks at site D70 in May and July. Peaks also at site I80 in June and July and then at D70 again in September.
- Concentration then decreases at site E90, which is downstream of I80.
- The increases at the Highway #1 site and D70 are likely due to the WWTP as chloride is present in wastewater. However, levels increase from the Highway #1 site to D70. One possible reason for this may be due to erosion on the streambank which is depositing potentially saline soil into the creek. Road salts contain a lot of chloride and salts used on the highway could be contributing to higher chloride levels in the creek. Drains for storm water and run-off are also present between the two sites from the new city's development and Swift Current Mall which could also be adding chloride.
- Increased levels at site I80 could be due to excess irrigation water drainage which, at its peak, would take place in May and June.
- Increased levels from the Highway #1 site, D70 and I80 are likely diluted by the time the water flows reach site E90.
- The concentration changes in chloride as move downstream mirrors the pattern seen in 2007.
- A10 to C50 and E90 2017 chloride levels were generally the same as 2007.

- H60 to D70 levels were higher in 2017 than 2007 possibly due to increased use of road salts.
- I80 is higher in all months in 2017 compared to 2007.

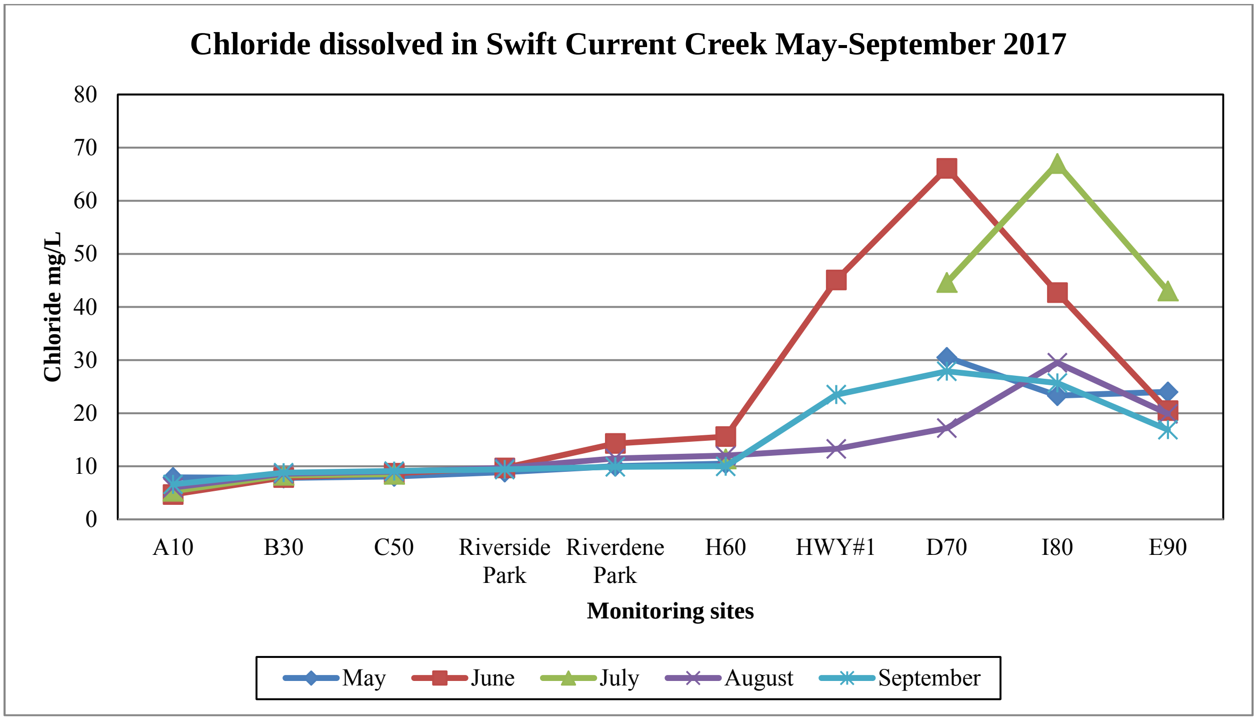

Figure 44. Chloride levels in Swift Current Creek

ii.) Sodium

Sodium is a highly reactive chemical element that is a member of the alkali metals. It is present in oceans as sodium chloride (NaCl) and is an essential element for life (The British Columbia Groundwater Association 2007 as cited by Tait [SCCWS] 2008). Sodium levels (Figure 45) are part of the irrigation water use with a maximum amount of 115 mg/L and the protection of aquatic life and wildlife and general water protection indices with maximum amounts of 100 mg/L for each.

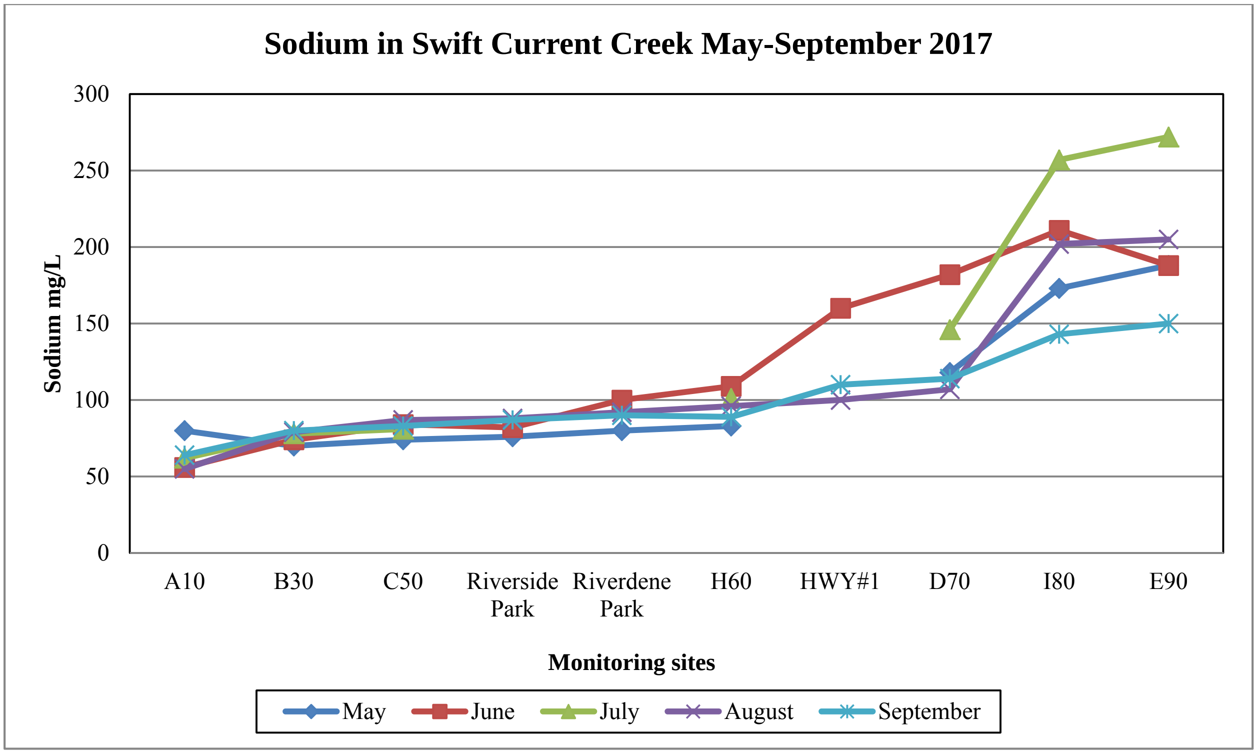

Figure 45. Sodium levels in Swift Current Creek

Concentrations increase from site A10 to E90 as dissolved sodium leaching out of soils containing bedrock in underground springs flow into the creek which naturally raises sodium concentrations as the creek flows downstream. The highest concentration recorded in 2017 was 272 mg/L in July at site E90. The highest level recorded in 2007 was 169 mg/L at E90 in July. Observations of sodium levels in 2017 are:

- Concentrations were over the 100 mg/L guideline (general water and aquatic life and wildlife protection) for all tests at sites D70, I80 and E90.
- Concentrations were over the 100 mg/L guideline at site H60 in June, July and August.
- Riverdene had concentrations over 100 mg/L in June and the Highway #1 site had concentrations over 100 mg/L in June and September.
- The pattern of increasing concentration as move downstream mirrors what was observed in 2007.
- Concentrations were higher in 2017 at all sites compared to 2007.

iii.) Sulfate

Sulfate is a naturally occurring substance that contains sulphur and oxygen. It is present in various mineral salts found in our soils. There are several sources of sulfate in water: soil leaching, decaying plant and animal material, water treatments using alum, sulfate fertilizers, and the combustion of fossil fuels and sour gas processing. In drinking water for human consumption sulfates are non-toxic; however, at concentrations over the 500 mg/L guideline for general water protection index it could cause intestinal discomfort and diarrhea (U.S Environmental Protection Agency 2006 as cited by Tait [SCCWS] 2008).

Sulfates are important to determining the quality of water for livestock, as levels that exceed the guideline of 1000 mg/L can result in stress and death of the animal. Since sulfate levels rise moving from upstream to downstream along the creek it must be explored if impacts of the city of Swift Current are contributing anything to these changes. The following points highlight some of the main observations in the water sampling over the five-month period in 2017, a drought year for the southwest that included low creek flows.

- Site D70 had concentrations over 500 mg/L in June and July.
- Site I80 had concentrations over 500 mg/L in every month of sampling.
- Site E90 had concentrations over 500 mg/L in every month except September.
- Highway #1 site had concentrations over 500 mg/L in June.

The highest concentration was observed at site I80 in July at 967 mg/L. This is significant as there were no samples which have concentrations over 1000 mg/L. This sample was close range to the 1000 mg/L limit, which may have caused issues for livestock watering. In 2007 the highest concentration recorded was 600 mg/L at I80 in July. Figure 46 shows the values and other highlighted in this section.

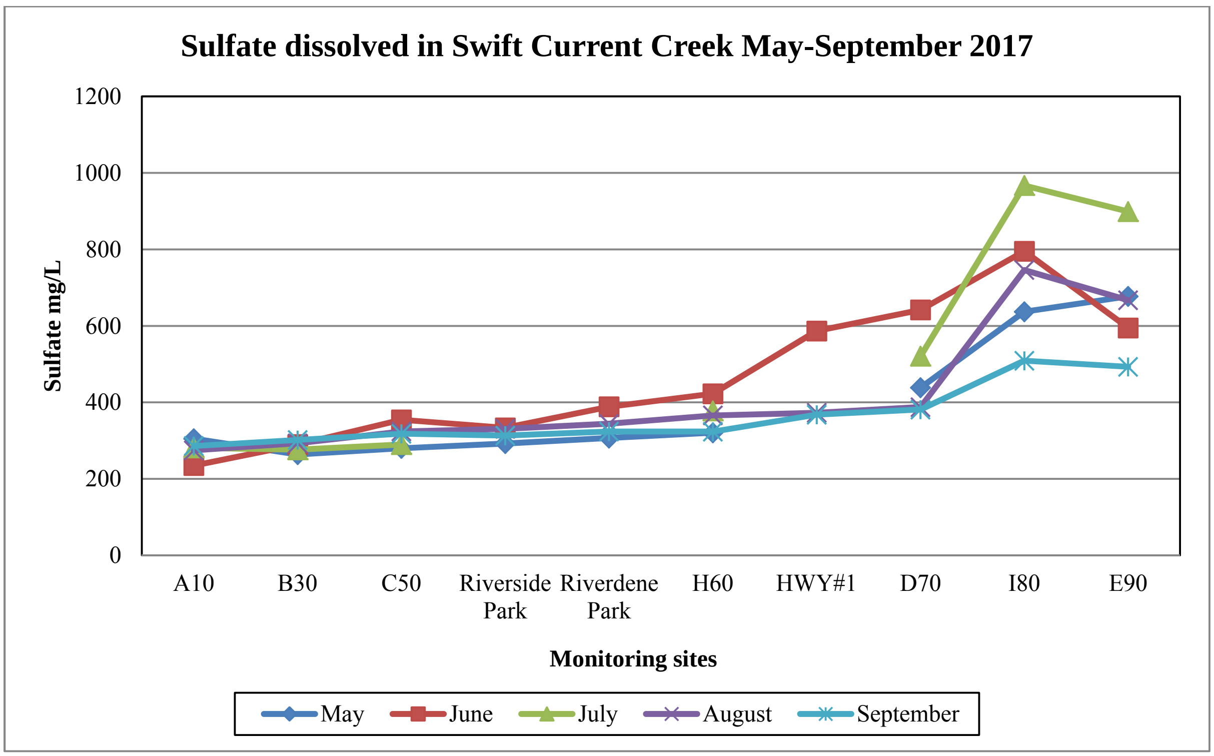

Figure 46. Sulfate (dissolved) levels in Swift Current Creek

- The pattern of increasing sulfate levels as move downstream and then decrease at E90 shown in Figure 48 is similar to what was observed in 2007. However, the increased levels at D70 to E90 are larger in 2017 than 2007.
- Sulfate levels in 2017 were higher than all sites and all months in 2007.

iv.) Nitrite and Nitrate Nitrogen

Nitrogen is essential for all living organisms as it is an essential building block of protein (Kentucky Division of Water 2008 as cited by Tait [SCCWS] 2008). Nitrogen exists in the environment in many forms and changes as it moves through the nitrogen cycle. Nitrate, total nitrogen, and ammonia as nitrogen were tested in 2017. There are many potential man-made sources of nitrogen as it is present in fertilizer, sewage, livestock manure, and also occurs naturally in the soil from decaying plant and animal matter (Tait [SCCWS] 2008).

Excessive rain fall or irrigation may cause nitrite and nitrate nitrogen to leach from soils into the creek and surrounding waterbodies that would drain into the SCC (Tait 2008 [SCCWS]). Nitrogen in the water can act as a nutrient which aids plants and algae to multiply and grow rapidly. Often referred to as a "bloom," algae will take full benefit of excess nutrients from nitrogen and grow in massive amounts. As the algae dies microorganisms begin to consume the decaying matter. These microorganisms require oxygen to consume the algae which rapidly depletes the oxygen supply in the ecosystem. This process is called eutrophication and may result in the death of many organisms that rely on the oxygen in the water such as fish, amphibians, reptiles, and macroinvertebrates (Tait [SCCWS] 2008).

General water quality is the only index that has a guideline for nitrite and nitrate nitrogen. Protection of aquatic life and wildlife has a guideline for ammonia as nitrogen which is calculated based on water temperature and pH. The limit of nitrite and nitrate for the general water index is 1 mg/L. The Highway #1 site and D70 had the highest concentrations of nitrite and nitrate nitrogen at 0.44 mg/L and 0.66 mg/L respectively in September (see Figure 47). These sites are in closest proximity to the WWTP and there is likely still some residual from the sewage that was treated and released, but the levels are below guidelines set out in the general water quality index. There were also some peaks observed at site B30 in May and August, large amounts of aquatic vegetation and algae were observed at this site throughout the entire summer.

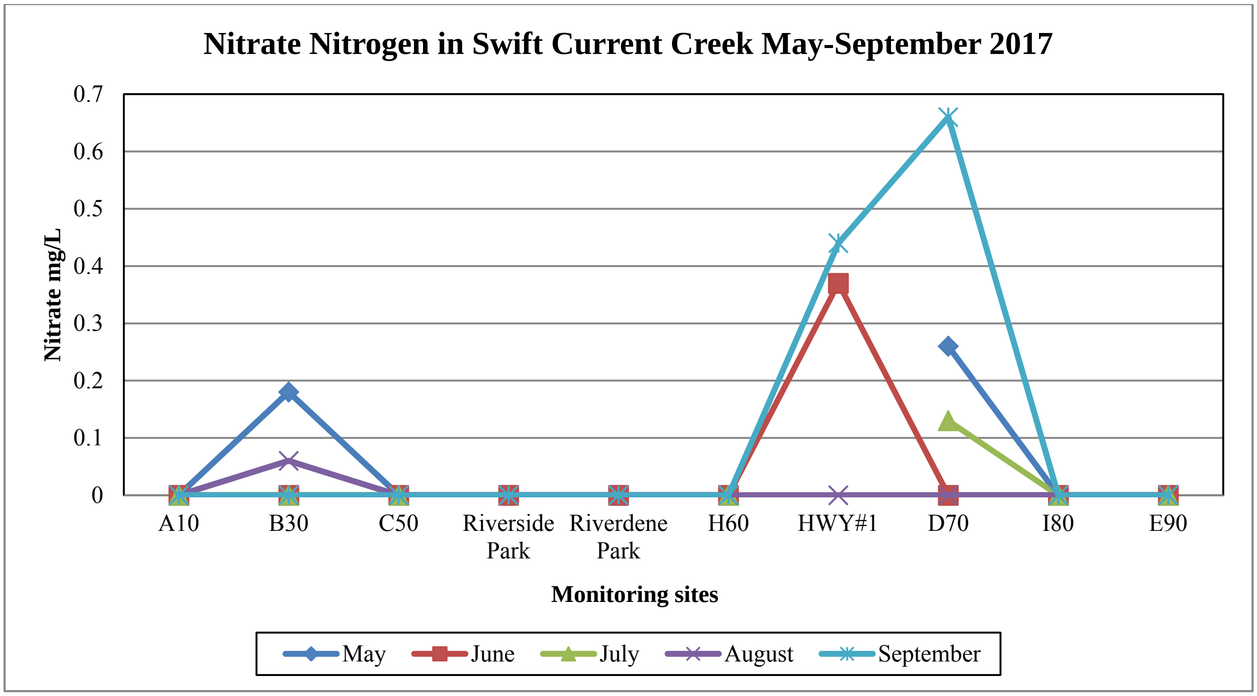

Figure 47. Nitrate Nitrogen levels in Swift Current Creek

- The pattern of nitrate nitrogen levels increasing at B30, decreasing through the city, increasing after WWTP and then decreasing as move down stream is the same as what was observed in 2007.
- Some concentrations were higher in 2017 than 2007, with the July peak at D70 in 2017 being less than what was observed in 2007.

v.) Total Dissolved Solids

Total Dissolved Solids (TDS) refers to the concentration of inorganic substances including minerals, salts, and metal cations or anions in the water. These minerals include sodium, magnesium, potassium, chlorides, bicarbonates and sulfates dispersed in water (WHO 1996 as cited by Tait [SCCWS] 2008). The following sources can contribute to TDS in water: natural sources such as mineral springs and carbonate or salt deposits; and man-made sources including wastewater, urban run-off, road salts, and salts used for water softening (Tait [SCCWS] 2008). TDS levels provide a good indication about the quality of water; low levels indicate low levels of salts and minerals in the water. High levels of TDS indicate high total levels of salts and minerals and further testing is required to determine what salts and minerals are causing the high concentrations, as many that are present can be fatal in high concentrations to livestock drinking the water.

The irrigation water use Index and general water protection index have TDS guidelines of 700 mg/L. TDS levels generally held steady from sites A10 to H60 with no pattern changes moving downstream along the creek. Levels did not increase as sampling moved downstream. The concentrations at the Highway #1 site to E90 were generally over 1000 mg/L with most being in the 700 to 1400 mg/L range. The livestock watering index has 1000 mg/L as the maximum guideline. Two of the highest TDS readings occurred in July at 1895 mg/L at site I80 and E90 at

1773 mg/L. July is the most likely time for higher concentrations as a result of ground water springs with high levels of inorganic salts leaching out of the Bearspaw shale and discharging into the creek (Tait [SCCWS] 2008) (see Figure 48).

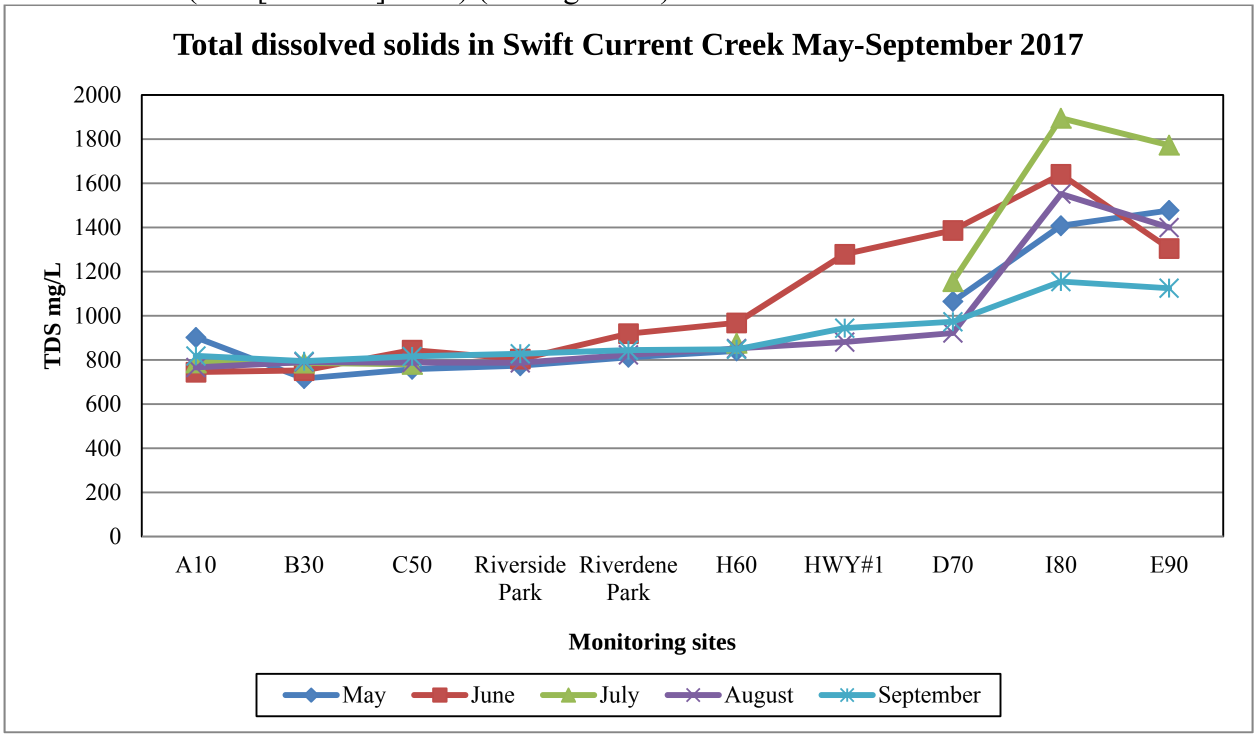

Figure 48. Total dissolved solids levels in Swift Current Creek

The 2017 graph mirrors what was observed in 2007, TDS concentrations increase as you move downstream, increasing significantly at D70. In July of 2017 there were issues with livestock water quality especially in dug-outs and reservoirs:

- Higher temperatures and stronger winds caused more evaporation.
- Slow flow in creek not diluting water with a higher TDS load.
- Less recharge from springs.
- With the increased moisture in 2016 it is possible that minerals closer to surface were caught in run-off and ground water discharge in the fall of 2016.

WSA guidelines that were released in 2015 changed the objectives for TDS levels for livestock watering to 3000 mg/L. At this level all sites are within the objective. The 2015 objectives for irrigation are 500 to 3500 mg/L depending on the crop irrigated. Sites within the city were marginally high for TDS being in the 750-900 mg/L range with the Highway #1 site reaching 1279 mg/L in June. This is noteworthy as the city of Swift Current uses water from the creek to water parks and golf courses; however, these levels are acceptable for the grass species grown in city parks and golf courses. Many residents in proximity to the creek use water from it to irrigate lawns and gardens. However, many of the fruits and vegetables have low tolerance to TDS levels in the water. The reason for the different tolerance levels to TDS is that different crops react differently to salt concentrations in the soil. Prolonged irrigation of soil using water with high levels of TDS will increase the salt concentrations of the soil making it more difficult for plants that are unable to survive in saline soils to establish and grow.

vi.) Inorganic (Ortho) Phosphorous

Phosphorous is required by all organisms for the basic processes of life and can be found in rocks, soil, and organic material (Murphy 2007 as cited by Tait [SCCWS] 2008). Also, according to Murphy (2007) as cited by Tait [SCCWS] (2008), orthophosphate is an inorganic form of phosphate which is normally found in fresh water systems and is a form that is most readily used by plants, is produced by natural processes, and can also be found in sewage and agricultural fertilizers. It can cause problems in much the same manner as excess nitrogen causing large quantities of algae eutrophication. Even when the phosphorous levels are low orthophosphates can cause blue-green algae (cyanobacteria) to grow and these will fix toxic nitrogen in the water which can be fatal to aquatic organisms as well as animals or livestock that consume the water (Murphy 2007 as cited by Tait [SCCWS] 2008). In 2017 the possibilities of increased blue-green algae blooms were high due to the increased concentrations of phosphorous, lower water flow, and higher temperatures. Figure 49 shows the levels of orthophosphate throughout the sampling period and explanations of the findings.

The general water quality Index guideline is 0.1 mg/L for orthophosphate. Concentrations were highest at sites B30 and then C50 with the highest being at B30 in June at 0.45 mg/L. All samples taken at sites B30 and C50 were above the guideline. The dissolved phosphorous concentrations were high at these sites in 2007 as well. At this time there is no explanation for the high concentrations at these sites as compared to the rest.
In 2007 Inorganic Dissolved Phosphate was measured and not orthophosphate as measured in 2017. As orthophosphate is a type of inorganic phosphate no comparison can be made between the results from 2017 to those of 2007. The graph shows the same pattern as inorganic phosphorous in 2007. Low levels at A10, increasing at B30 and C50, and then low to zero as move downstream.

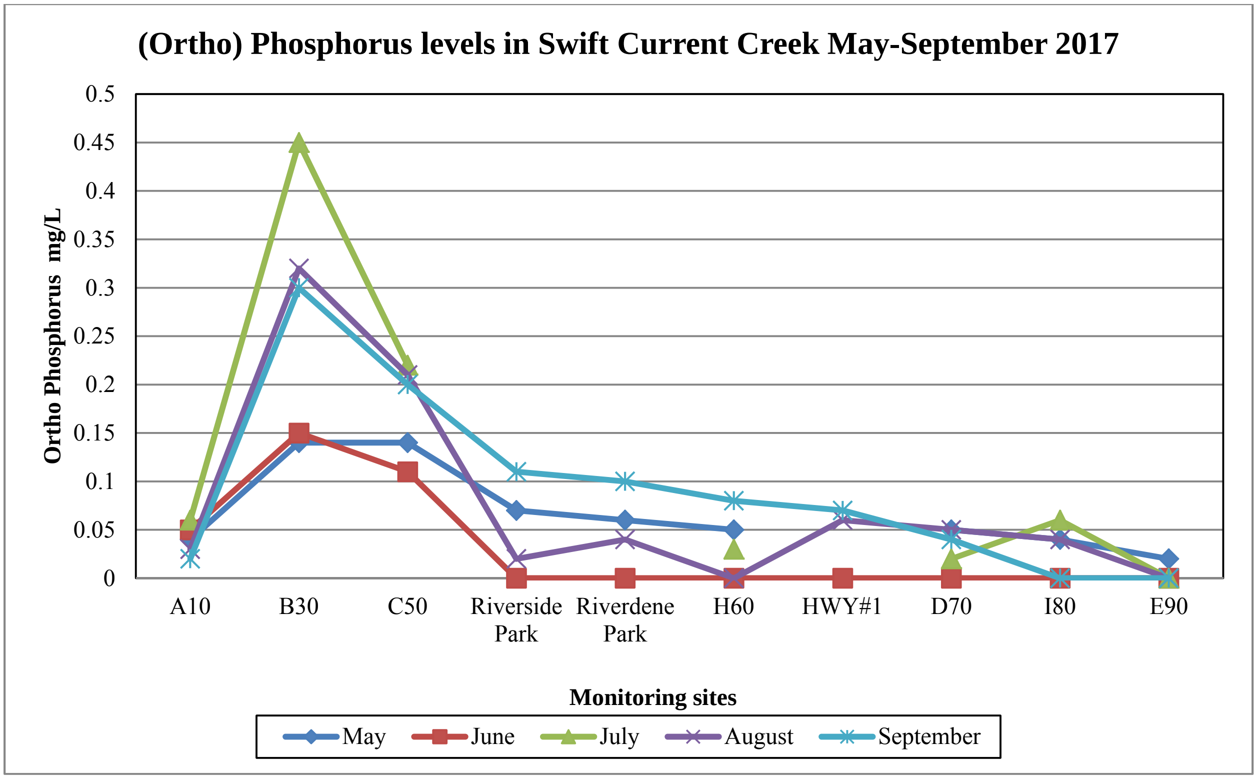

Figure 49. Orthophosphorus levels in Swift Current Creek

vii.) Aluminum

The element of aluminum can only be found in compounds in nature and never in a pure form (KDW 2007 as cited by Tait [SCCWS] 2008). Aluminum present in waterways can be a result of effluents and wash water from wastewater treatment plants (KDW 2007 as cited by Tait [SCCWS] 2008 as cited by Peters [SCCWS] 2013). The most common cause of high aluminum can be from water treatment processes such as those used at the WTP and WWTP. It is added in the form of alum to bind to potentially harmful microorganisms and aluminum sulfate is used in primary treatments to allow particles to stick together in order to be filtered out (Tait [SCCWS] 2008 as cited by Peters [SCCWS] 2013; City of Swift Current 2018a). Alum added in excessive amounts will lower the pH of the water making it more acidic and threaten aquatic life (KDW 2007 as cited by Tait [SCCWS] 2008).

The general water quality index guideline for aluminum is 5 mg/L or 5000 µg/L. No samples were over this guideline, as shown in Figure 50. Concentrations are higher at site A10 and then drop downstream at site B30 until the sampling sites within the city where concentrations increase again. This was expected given the use of alum and aluminum sulfate in the WTP. The highest concentration was found at site I80 in May at 4.228 mg/L. Though under the guideline, this concentration is inordinately higher than the other samples taken throughout the summer. This could be due to increased suspended sediment at this site in June, due to increased flows creating more sediment at this spot. (J-M Davies [WSA] in email document to K Steinley dated June 11 2018 11:21 AM; unreferenced, see Acknowledgements). Total Suspended Solids (TSS) was not tested for in this project. A permanent WSA monitoring station between I80 and E90 showed excessively high levels of TSS in June which is when most of the anomalies at I80 were observed. Aluminum concentrations increase with Fluoride concentrations as it binds with aluminum (Health Canada 1998): sites B30 and C50 have lower fluoride concentrations than A10 creating lower aluminum concentrations. Site A10 may have higher concentrations than the two downstream sites as aluminum concentrations increase with increases in organic matter (Health Canada 1998). There were higher *E. coli* counts at site A10 indicating higher organic matter at that site.

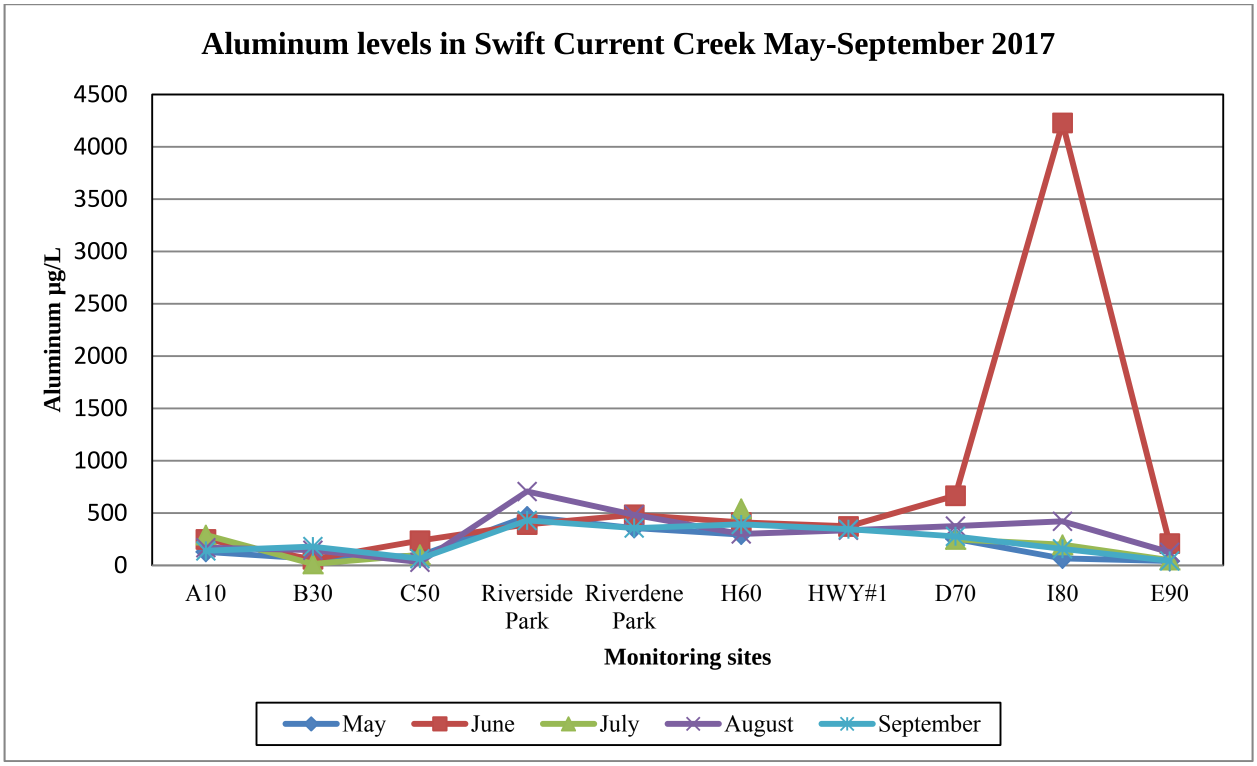

Figure 50. Aluminum levels in Swift Current Creek

The 2017 graph mirrors the pattern observed in 2007, slightly higher concentrations at A10, lower at B30 and C50, increased concentrations at sites within the city and after WWTP. Concentrations are reduced at I80 and E90 with a few exceptions. Overall aluminum concentrations were higher in 2017 than 2007.

viii.) pH

pH is the measure of potential of hydrogen and is used to measure the acidity or alkalinity of a solution. The unit of pH stands for the power of hydrogen (Nave CR 2001 as cited by Fondriest Environmental Inc. 2013). It affects aquatic organisms by allowing basic regulatory processes to function which are needed to sustain life (Robertson-Bryan Inc. 2004 as cited by Peters [SCCWS] 2013). The level of pH is dependent on other parameters such as water temperature and dissolved oxygen. For proper primary respiration exchange of gases and salts from aquatic organisms with the surrounding water to occur the pH levels must be in tolerable ranges. Levels outside tolerable ranges be lethal or sub-lethal (such as stunted growth) (Robertson-Bryan Inc. 2004 as cited by Peters [SCCWS] 2013). Man-made factors that affect pH include agricultural, wastewater, and industrial runoff (Fondriest Environmental Inc. 2013). Fondriest Environmental

(2013) also states that natural causes can be surrounding rock and minerals in carbonate forms. Figure 51 below shows the pH levels through the sampling 2017 season, which were all in a tolerable range for aquatic life.

The protection of aquatic life and wildlife index guideline has a range of 6.5 to 8.5 pH units while the general water quality guideline has a range of 6.5 to 9 pH units. Fish species such as Yellow Perch (*Perca flavescens)* and Northern Pike *(Esox lucius)* can survive at a pH range of 3.5- 4.0 but are unlikely to reproduce (Canadian Council of Ministers of the Environment [CCME] 2003). A prolonged exposure to water with a pH range of 9.5 to 10 may be lethal to salmonids such as trout (Canadian Council of Ministers of the Environment [CCME] 2003). Waters in South-Central Saskatchewan naturally have a pH range up to and above 9 and aquatic life have adapted to these levels (J-M Davies [WSA] in email document to K Steinley dated June 11 2018 11:21 AM; unreferenced, see Acknowledgements). Therefore the lethal levels listed by CCME may not be applicable to the SCC, however there were no samples that had pH levels over 9 in the 2017 project. There were no sites that had pH below the low range of 6.5. The highest pH level recorded was 8.9 at site B30 in June and September. Site C50 had levels between 8.5 and 8.8 for all months except May. In both 2007 and 2017 there was too much variability in pH levels between sites and date of sampling to be able to see a trend. 2017 pH levels are similar to those observed in 2007. pH levels can fluctuate based on the time of day samples were taken, with levels generally higher during the day than at night (J-M Davies [WSA] in email document to K Steinley dated June 11 2018 11:21 AM; unreferenced, see Acknowledgements). Most of our samples were taken during the morning as they needed to be shipped the same day as collection. This means that the levels of pH in the water samples were possibly slightly higher than average, however levels were all still below 9 showing that they are still in the acceptable range.

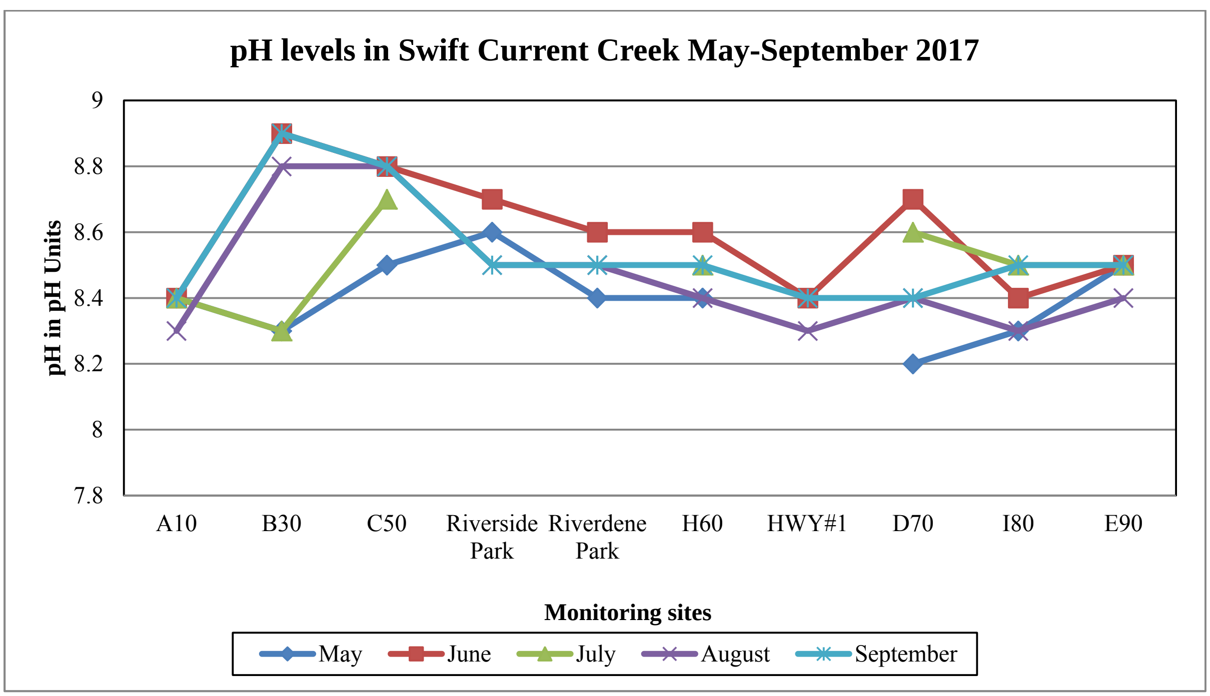

Figure 51. pH levels in Swift Current Creek

ix.) Arsenic

Arsenic is a naturally occurring substance in soils and can be widely distributed in air, water, and surrounding soils (WHO 2017). Arsenic tends to be higher in South Central Saskatchewan surface waters and is not something completely unique to the Swift Current area (J-M Davies [WSA] in email document to K Steinley dated June 11 2018 11:21 AM; unreferenced, see Acknowledgements). Man-made sources can be caused or elevated by certain types of industry, but none of these industry activities occur in the SCCW (WHO 2017). According to the World Health Organization (2017) arsenic in an inorganic form is toxic and is often monitored for drinking water and environmental health.

The protection of aquatic life and wildlife index guideline is 5 µg/L and the general water protection index guideline for arsenic is 50 µg/L. Arsenic levels hold steady moving downstream along the creek and tended to increase throughout the summer and then decrease in September. The highest levels were at site I80 in June at 10.3 µg/L and these levels were also over the guideline in July. Site A10 saw concentrations over the guidelines in July and site B30 was over in June to September. Site C50 was over in June through to September, H60 in July, and D70 in July and August. Arsenic levels are shown in Figure 52. Note that Riverside and Riverdene Parks were not tested in July, and Highway #1 was not tested in May or July.

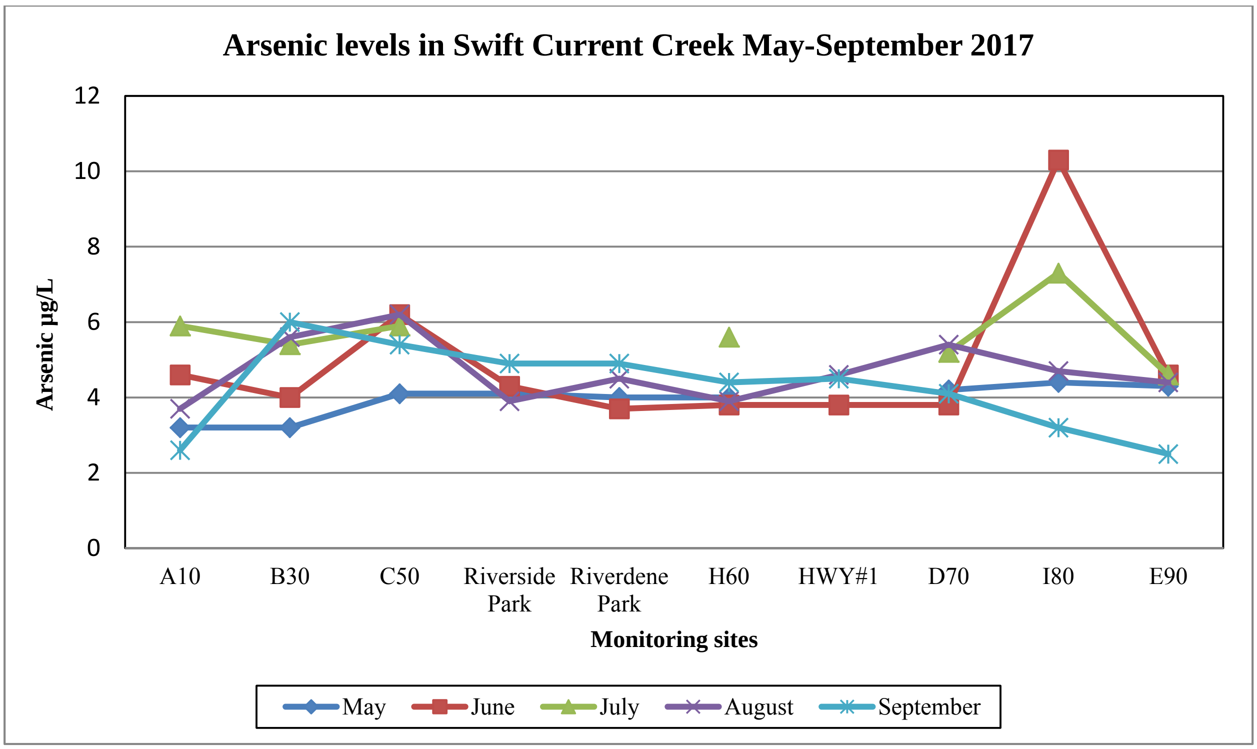

Figure 52. Arsenic levels in Swift Current Creek

Arsenic levels in 2017 were generally lower than those observed in 2007. The trend along the creek is the same for both years, levels drop as move down stream and sample later in the year except for June and July at I80.

3.3 Bio-assessments- Fish sampling

3.3 a.) Sentinel Species size distribution and condition factor

i.) White Sucker

The White Sucker (pictured in Figure 10) was chosen as a sentinel species for this project due to its widespread populations in shallow waters of streams, rivers, and lakes and high tolerance of varied environments (Nelson and Paetz 1992 as cited by Peters [SCCWS] 2013). This species is a first and second level benthic consumer and the majority of its diet is benthic macroinvertebrates (Stewart and Watkinson 2004). The White Sucker lives in many different habitats in a stream or lake system and the YOY are an important source of food for predatory fish (Stewart and Watkinson 2004). Numbers caught in 2007 and in 2017 indicate that it is an abundant species of the SCC ecosystem. White Sucker size and distribution were examined to assess the age class structure of the population in the SCC at each monitoring site and due to the YOY skew (individuals being less than 50 mm in length) the results were significantly different at each site (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments). The Kruskal-Wallis One Way Anova of Variance of Ranks had a value of $p < 0.005$ between all sites and the order of rank in which the largest to smallest median size is as follows, according to the statistical analysis performed by Sereda (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments): Sites B30>D70>A10>C50>E90. Figure 53 shows this age class structure of the population between the 2017 sites. For comparison purposes, adjacent sites were paired moving from upstream to downstream and the White Sucker populations were skewed towards fish ≤ 50 mm in length at all sites. Catch per unit effort was greatest at sites D70 and E90. In 2007 the rankings of each site for sucker length were B30>A10>E90>D70>C50.

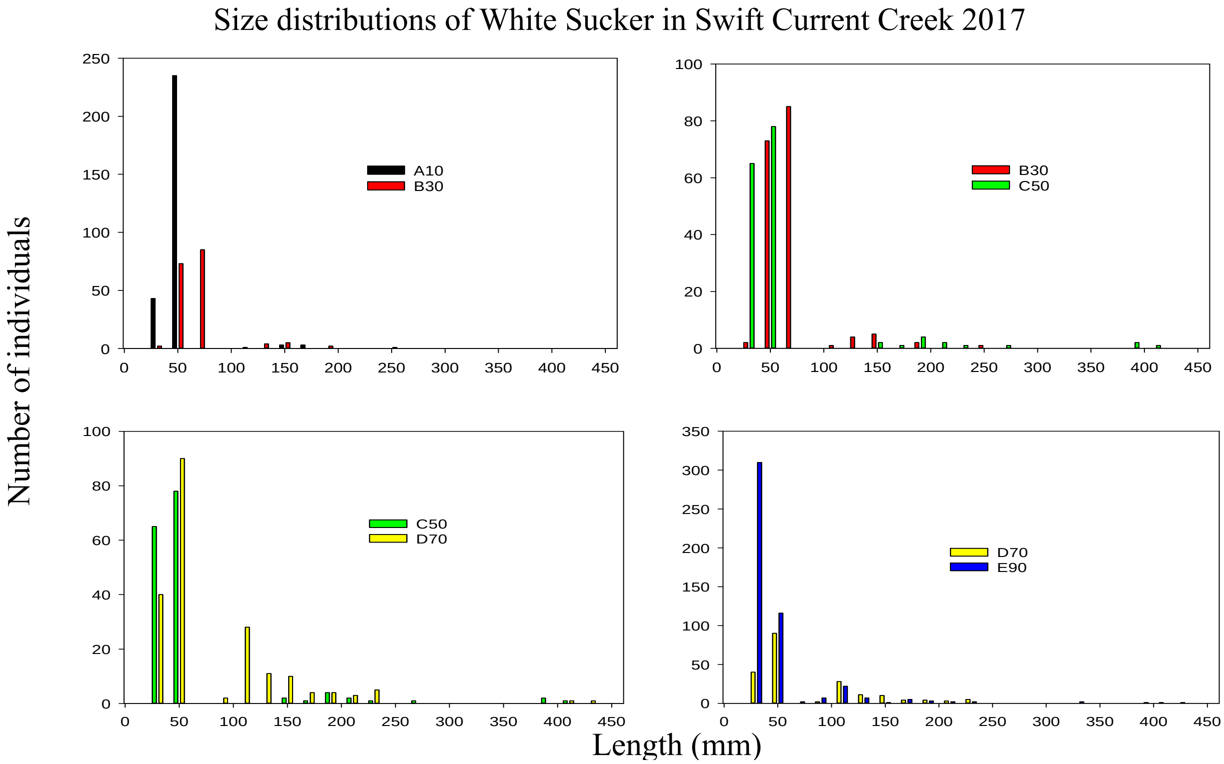

Figure 53. Size distribution of White Suckers (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments).

Condition factor also used the same the Kruskal-Wallis One Way Anova of Variance of Ranks to test for differences in condition factors of White Suckers between data collected in 2007 and 2017. In 2017 the condition factor was significantly different ($p < 0.05$) between the sites and according to Sereda (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments) the ranking of largest to smallest condition factors was B30>E90>C50>A10>D70. For sites A10 and D70 the condition factor was lower in 2017 as compared to 2007 but all other sites condition factors were similar in 2017 to factors calculated in 2007 (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments). Despite differences in comparisons, condition factors were all well above one at all sites which indicates that the White Sucker population is in good health and no trends in conditions could be found in regards to upstream and downstream sites (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments). Figure 54 shows the condition factor comparison of 2007 and 2017, with all exceeding the value of one (1.0), indicating healthy populations.

Both size distribution and condition factors for White Suckers indicate that the population has healthy individuals. The population of fish less than or equal to 50 mm in length indicates that the species is maintaining reproduction and successful spawning. The five monitoring sites all demonstrate different aspects of ecosystems for habitat, food sources, brood rearing, and spawning areas. It is also apparent that the White Sucker is a dominant species of the SCC as it constituted the majority of the total number of fish caught at each site.

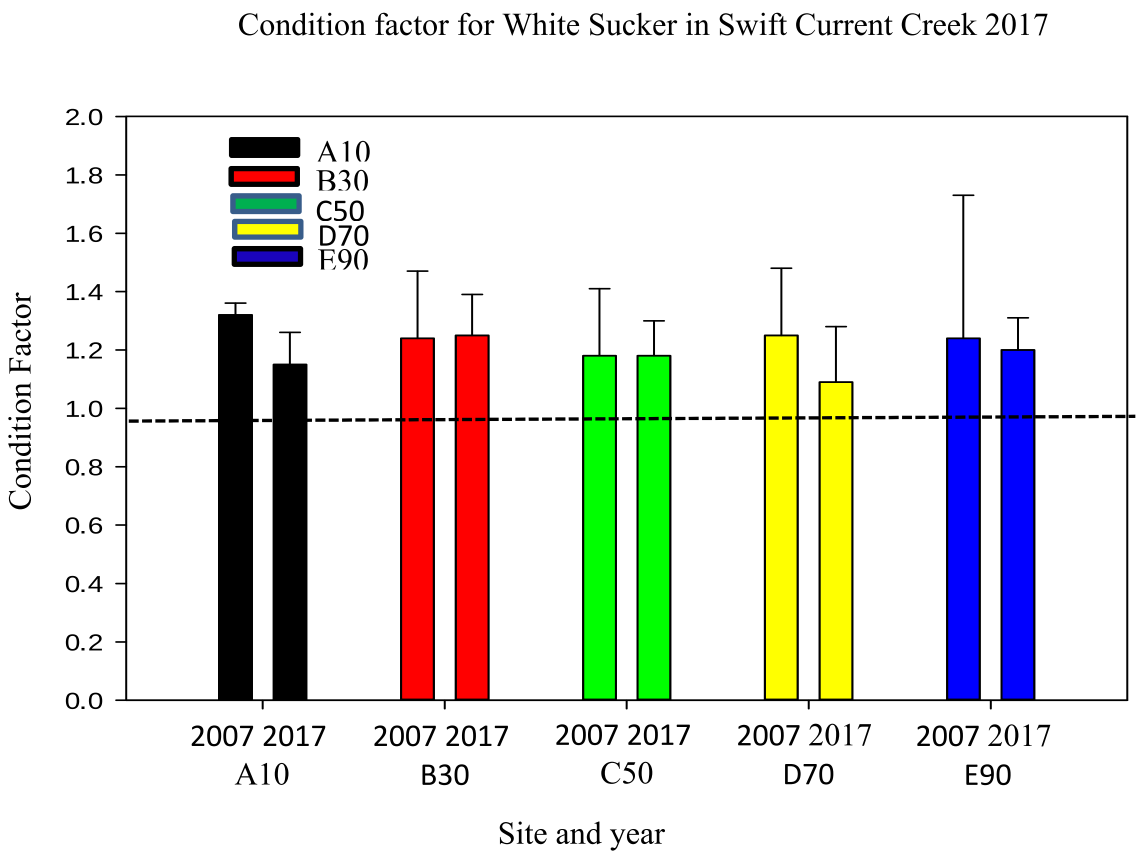

Figure 54- Condition factor for White Suckers captured in Swift Current Creek, 2017. Shown are mean condition factors ± 1 SD (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments).

ii.) Fathead Minnow

The Fathead Minnow exhibits sexual dimorphism with the male sporting an enlarged, tubercle covered head during the breeding season while females remain more drab and dull in appearance (Phillips et al. 1982 as cited by Peters [SCCWS] 2013). Figure 11 highlights these differences. The White Sucker and Fathead Minnow have similar food sources and tolerances to low oxygen levels and habitats (Phillips et al. 1982 as cited by Peters [SCCWS] 2013). This should make the Fathead Minnow a dominant species in the SCC as it can tolerate a wide range of habit types and water turbidities and prefers quiet areas of water usually with aquatic vegetation for cover (Stewart and Watkinson 2004). The preferred substrate bottom for spawning is silty sand or mud in which males will construct or clear out a nest area, sometimes under submerged objects so females can lay eggs which adhere to the "roof" of the nest (Stewart and Watkinson 2004). However, in 2017 Fathead Minnows were caught at only two of the five monitoring sites. In 2007 there were three sites that had numbers sufficient for proper statistical analysis of populations and condition factors. The same statistical tests and analysis were performed for Fathead Minnows that were performed for White Sucker on the two sites that Fathead Minnows were found B30 and D70.

According to Sereda (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments) the population had bimodal distributions at both locations where Fathead Minnows were found. This indicated two distinct cohorts: YOY and fish over age one year. In the Kruskal-Wallis One Way Anova of Variance of Ranks distribution was significantly different (p = 0.03) between sites B30 and D70; though the difference was minimal with median lengths of 50 and 49 mm for B30 and D70 respectively (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments). Figure 55 shows the length distribution of the Fathead Minnows from sites B30 and D70. Due to the low numbers of Fathead Minnows caught in 2007 there was no discussion of Fathead Minnow size in the 2007 report, therefore no comparison between 2007 and 2017 can be made.

Length distribution of Fathead Minnows in Swift Current Creek 2017

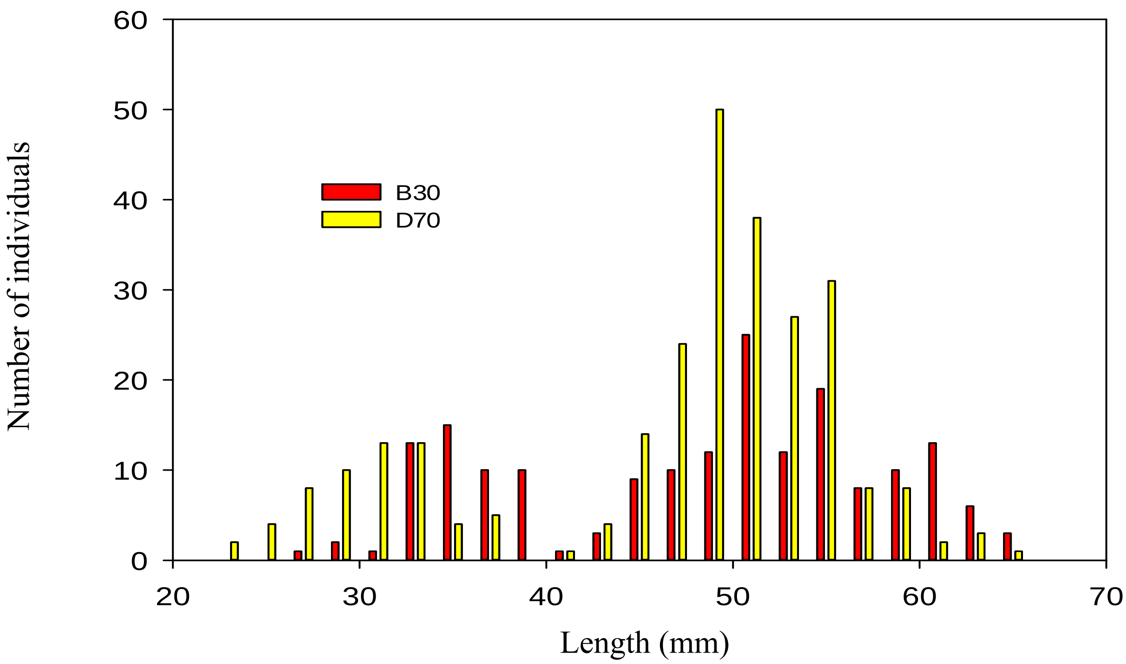

Figure 55- Length distribution of Fathead Minnows (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments).

The condition factor (K) was calculated for the two sites with Fathead Minnows in 2017 and compared to those sites with Fathead Minnows in 2007. In 2007 all condition factors were well above the value of one (1.0) which indicates good health with the exception of site C50 which was just over 1 (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments).

Since only two sites had the required number of Fathead Minnows in 2017 a comprehensive comparison could not be completed. The Kruskal-Wallis One Way Anova of Variance of Ranks to test for differences in body condition of the minnows at sites B30 and D70 was done and showed significant differences ($p<0.01$). Once again even though the differences were significant the condition factors at both sites exceed the value of one to indicate healthy Fathead Minnow populations, as seen in Figure 56. Condition factors in 2017 scored lower than 2007 at sites B30 and D70, however the populations are still considered healthy.

Site B30 features predominantly large sized substrate such as gravel, rock, and cobble with an abundance of aquatic vegetation which is said to be a preferred habitat of Fathead Minnows according to Stewart and Watkinson (2004). Flows at site B30 were faster compared to other sites, but site D70 has less flow and more sand and mud substrate than other sites. This combination of the preferred habitat types at these sites is possibly why Fathead Minnows were found in abundance at these sites. Site A10 also had sand and mud substrate and low flows, as well as the lower section of site E90, but no Fathead Minnows were found at either site.

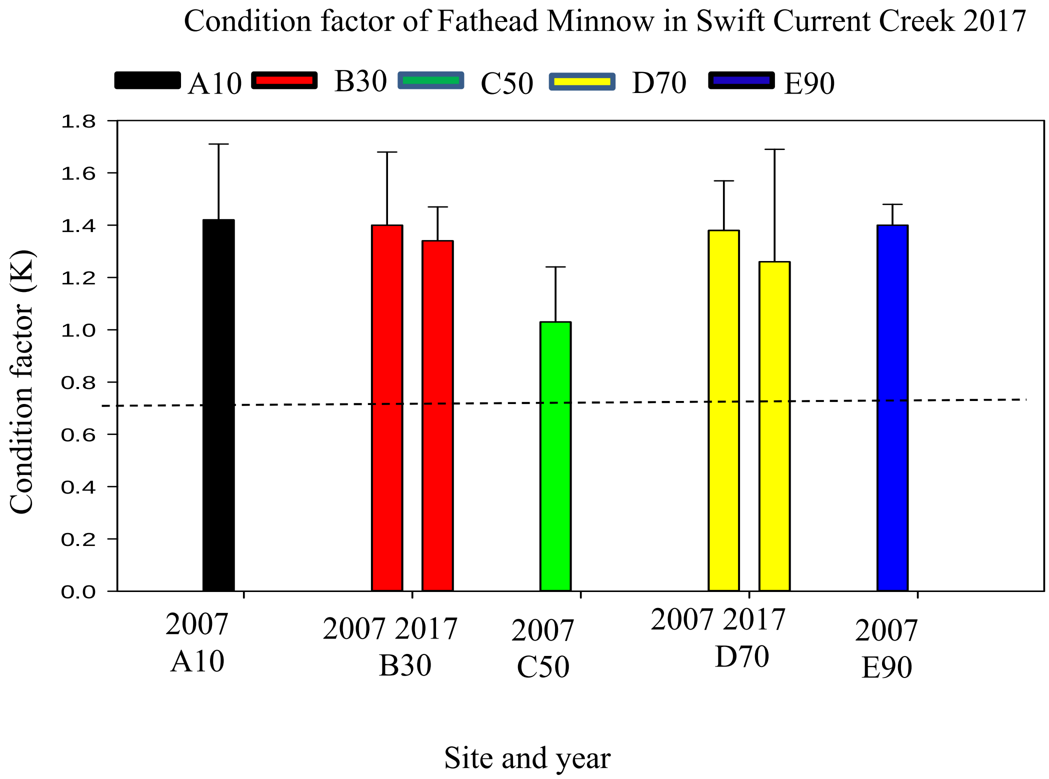

Figure 56- Condition factor for Fathead Minnow in 2007 and 2017 (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments).

3.3 b.) Community species

The five monitoring sites all have different habitat types, flows, temperature, substrate, vegetation cover, and depths which can accommodate a number of different species. A species accumulation curve (Figure 57) plots the cumulative number of species captured which should increase as sampling effort increases (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments). Once all (or at least all common) species have been captured or detected this point is indicated by a plateau on the curve. Curves were developed by Sereda (J Sereda [WSA] in email document to D Peters dated January 29

3:48 PM: unreferenced, see Acknowledgments) to compare 2007 to 2017 sampling efforts and all sites reached a plateau within 3-6 seine pulls, which indicate the sites were sufficiently sampled in order to obtain the largest number of species. Note for site D70 in both years there is no plateau observed on the curve. Numbers and species at this site were high with minimal seine pulls (less than 3); however additional sampling effort may have revealed more species diversity and the site could be deemed as under-sampled (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments).

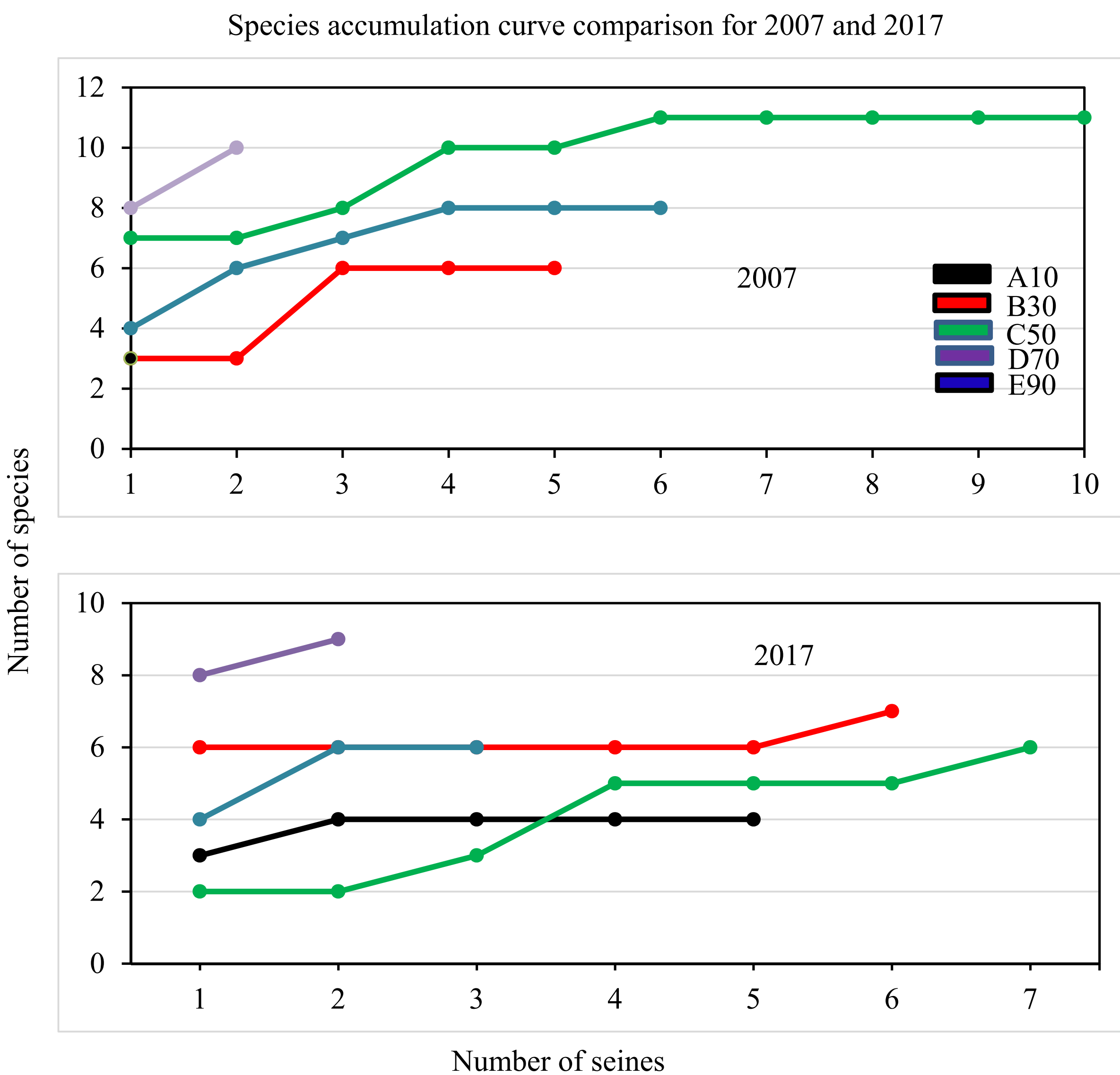

Figure 57. Species accumulation curve comparison for 2007 and 2017 community (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments).

Species diversity is the most common metric used to determine the communities of fish in an ecosystem. According to Sereda (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments) it can be assumed that the higher the diversity, the healthier and more resilient the community. Species richness, or the number of species present, is the simplest and most commonly used measurement of diversity. A diversity index is the mathematical measure of species diversity. It can provide additional information about the composition within a community by accounting for both the richness and relative abundance of the different species. If a community is dominated by one or a handful of species and there is little diversity in the composition the community could be deemed less healthy than a community that has many species with similar populations.

Species richness and Shannon diversity and equitability indices were calculated for the five sites sampled in 2007 and 2017. According to Sereda (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments) the Shannon Diversity index value increases as both the richness and evenness of the community increase. The Shannon equitability assumes a value that lies between 0 and 1 with 1 being complete evenness of populations (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments). The Catch per unit effort (CPUE) was calculated to look at any changes in total fish abundance at each site. All indices are shown in Table 22.

In 2007 the species richness ranged from 3-11 while 2017 had a range of 4-9. The accumulation curve in Figure 59 shows that sampling effort was sufficient (with the exception of site D70 where minimal sampling effort was needed but abundance was obtained). The variation in richness likely reflects the detection of less common or rare species in some instances. It is also important to note the Brassy Minnow *(Hybognathus hankinsoni)*, which is a species of interest, was found D70 in 2013 and again in 2017 at that site. The Shannon's Diversity index ranged from 0.92-1.37 in 2007 and 0.36-1.17 in 2017. Similarities between the year were apparent except for site E90 where the index decreased 4-fold from 2007 to 2017 (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments). (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments). E90 exhibited a large shift in species dominance (decrease in equitability) due to the overwhelming abundance of White Sucker (accounting for 91% of the total catch) in the CPUE which increased 12-fold in 2017. Fish abundance as CPUE increased 4-10-fold at sites B30, C50, and E90 from 2007 to 2017, and only marginally increased at site D70 even though this site had the largest abundance in both sample years. Site A10 saw a decrease of fish abundance of approximately 5-fold with no plausible explanation for this result.

Table 22. Sampling location, the number of seines (sampling effort), species richness, Shannon's diversity and evenness, and catch per unit effort (CPUE) for each site sampled in 2007 and 2017 (J Sereda [WSA] in email document to D Peters dated January 29 3:48 PM: unreferenced, see Acknowledgments).

Comparison of community species in Swift Current Creek from 2007 to 2017										
Site	**No. of seines**		**Richness**		**Shannon's Diversity**		**Shannon Equitability**		**CPUE**	
	2007	**2017**	**2007**	**2017**	**2007**	**2017**	**2007**	**2017**	**2007**	**2017**
A10	1	5	3	4	0.92	0.84	0.84	0.45	696	115.2
B30	5	7	6	7	0.93	0.88	0.52	0.45	56.6	222.4
C50	10	7	11	6	1.37	1.17	0.57	0.65	43.3	160.8
D70	2	2	10	9	1.06	1.04	0.46	0.47	816	881.5
E90	6	3	8	6	1.25	0.36	0.64	0.20	54	663.6

Community composition could also be attributed to similarities between species for tolerances to water quality, breeding habitats, and food sources. The Shorthead Redhorse *(Moxostoma macrolepidotum)* can be a key indicator of water quality; this species prefers shallow, fast and clear water and has low tolerance for turbid and polluted water (ODNR 2013 as cited by Peters [SCCWS] 2013). Where numbers were high for the Shorthead Redhorse the water was clear, and faster flowing, and other species with similar preferences were also present in higher numbers. Numbers for this species increased in 2017 from 2007 with the greatest occurrences found at site C50. This may indicate that water in the SCC has low turbidity and pollution and is suitable for this fish species which is intolerant to high levels of both.

The Longnose Dace *(Rhinichthys cataractae)* pictured in Figure 58 is also a good indicator species due to its ability to tolerate abrupt environmental changes in dissolved oxygen, temperature, and turbidity for short periods of time (Grabarkiewicz and Davis 2008 as cited by Peters [SCCWS] 2013). This is a moderate to intermediate tolerant species (Halliwell 1999, Pirhalla 2004 as cited by Grabarkiewicz and Davis 2008 as cited by Peters [SCCWS] 2013). It was not found at all sites in 2007. In 2017, only site A10 did not have any Longnose Dace numbers. Increased numbers of the Longnose Dace found at most sites in 2017 indicates that a large part of the creek is suitable for this species that prefers shallow, moderately flowing creek habitat. Total numbers and species in comparison to 2007 and 2017 can be seen in Table 23.

Figure 58- Longnose Dace *(Rhinichthys cataractae)* caught at site E90

From samples of fish caught at D70, downstream of the city the Ministry of Environment confirmed the presence of Prussian Carp *(Carassius gibelio)*. This invasive species is predominately female, as they are able to clone themselves and reproduce at staggering rates putting native fish species and their aquatic ecosystems at risk (Somers as cited by Woodward 2018). The species is believed to originate from Asia or Europe and can be pets in aquariums or used in koi ponds. Scientists have suggested that this species was disposed of into Alberta waterways (Woodward 2018). Six years ago the first Prussian Carp was seen in Lake Diefenbaker and it has been since found sporadically throughout the Saskatchewan River system (Woodward 2018). This is of concern as the SCC empties into the South Saskatchewan River, allowing these fish to travel upstream in the creek to be distributed throughout the watershed.

Table 23. Fish community counts from 2007 and 2017

Fish species caught in 2007 and 2017 in Swift Current Creek							
Species	**Sample year**	**Sites**					**Total per year**
		A10	**B30**	**C50**	**D70**	**E90**	
Brassy Minnow (BRMN)	2007	0	0	0	0	0	0
	2017	0	0	0	24	0	24
Brook Stickleback (BRST)	2007	0	0	0	0	0	0
	2017	0	22	0	0	0	22
Creek Chub (CRCH)	2007	0	0	2	0	0	2
	2017	0	0	0	0	0	0
Emerald Shiner (EMSH)	2007	0	0	17	10	11	38
	2017	0	0	0	0	0	0
Fathead Minnow (FTMN)	2007	156	99	17	366	2	640
	2017	0	1172	0	305	0	1477
Flathead Chub (FLCH)	2007	0	0	0	0	0	0
	2017	0	0	0	0	1	1
Iowa Darter (IWDR)	2007	0	2	1	1	0	4
	2017	0	1	2	6	0	9
Johnny Darter (JHDR)	2007	0	0	0	1	0	1
	2017	0	0	0	0	0	0
Lake Chub (LKCH)	2007	0	0	0	92	1	93
	2017	0	0	0	0	0	0
Longnose Dace (LNDC)	2007	0	0	4	35	0	39
	2017	0	11	45	3	37	96
Northern Pike (NRPK)	2007	0	1	1	1	0	3
	2017	6	0	4	4	0	14
Northern Redbelly Dace (NRDC)	2007	0	0	0	0	0	0
	2017	0	0	0	0	0	0
Prussian Carp *(Carassius gibelio)*	2007	0	0	0	0	0	0
	2017	0	0	0	1	0	1
River Shiner (RVSH)	2007	0	0	53	26	71	150
	2017	27	60	550	329	124	1090
Shorthead Redhorse (SHRD)	2007	11	9	211	63	91	385
	2017	178	117	339	8	3	645
Silver Redhorse (SLRD)	2007	0	0	0	0	0	0
	2017	0	0	0	0	0	0
Spottail Shiner (SPSH)	2007	0	0	4	0	0	4
	2017	0	0	0	0	0	0
Walleye (WALL)	2007	0	0	1	0	1	2
	2017	0	0	0	0	7	7
White Sucker (WHSC)	2007	429	166	122	286	146	1149
	2017	365	174	186	1082	1807	3614
Yellow Perch (YLPR)	2007	0	0	0	0	0	0
	2017	0	0	0	0	0	0
fish too small to ID	2007	0	0	0	42	0	42
	2017	0	0	0	1	12	13
Total fish in 2007	**2659**						
Total fish in 2017	**7013**						

3.4 Bio-assessments- Benthic macroinvertebrate sampling

The benthic macroinvertebrate community provides critical information about stream health, the presence of watershed health issues, and levels of pollution since these communities are more sedentary than other aquatic organisms. Sediments can hold and trap sources of pollutants. Since benthic macroinvertebrates are small aquatic insects, larvae, and crustaceans that dwell in sediments they are proven ecosystem health indicators (Spellman 2009 as cited by Peters [SCCWS] 2013). Observing the macroinvertebrate community can help to determine if stream health has improved, declined, or remained relatively unchanged during a longer period of time (Spellman 2009 as cited by Peters [SCCWS] 2013).

a.) Habitat assessment

Riparian assessments were only a part of habitat assessments conducted for benthic macroinvertebrate sampling. Protocols and scoring systems were used from the *Saskatchewan Northern Great Plains Ecosystem Health Assessment Manual 2012: Version 1.0* prepared by Hoemsen 2012. Table 24 summarizes key habitat characteristics which are important as they provide information to the number of species found, types, and community structures that may be present within the macroinvertebrate or benthic community (Peters [SCCWS] 2013). In the Northern Great Plains ecoregion, within which the SCC is found, the water temperature, turbidity, and discharge are highly variable therefore benthic habitats can vary but are typically silt-dominated (Phillips et al. 2016). Silts, sand, and mud were the dominate substrate at most sites with combinations of these substrates mixed with larger sized substrate such as gravel, cobble, rock, and boulders observed at various transects within sampling sites.

Table 24. Habitat characteristics per transect for macroinvertebrate sampling

Habitat characteristics per monitoring site for macroinvertebrate sampling on the Swift Current Creek 2017

Site	Transect #	Habitat	Habitat type and substrate	Average depth (m)	*Embeddedness	*Channel flow status	*Sediment deposition score	Bank vegetation and % cover*	% Canopy cover	Aquatic vegetation
A10	**1**	Run/ pool	70% mud; 25% sand; 5% gravel. Silt and sand dominate	0.65	11	12	15	scrubland/ pasture 100 % cover	0-24%	Emergent macrophytes; submerged algae; woody debris and detritus absent
A10	**2**	Run/ pool	10 % mud; 70% sand; 10% gravel; 5% cobble. Sand and silt dominate	0.66	-	-	-	scrubland/ pasture 100 % cover	-	Submerged macrophytes and algae; woody debris and detritus absent
A10	**3**	Run	15% mud; 75% sand; 15% gravel; 5% cobble. Sand and silt dominate	0.40	-	-	-	scrubland/ pasture 80% cover	-	Rooted floating/ submerged macrophytes and submerged algae; woody debris present; detritus absent
A10	**4**	Run/ pool	20% mud; 70 % sand; 15 % gravel; 5% cobble. Sand and gravel/silt dominate	0.42	-	-	-	scrubland/ pasture 90% cover	-	Submerged/ emergent macrophytes; submerged algae; woody debris present; detritus absent
B30	**1**	Run	5% mud; 5 % sand; 10% gravel; 50% cobble; 30% boulder. Cobble and boulder dominate	0.47	16	19	19	scrubland/ pasture 95% cover	0-24%	Submerged/ emergent macrophytes; submerged algae; woody debris and detritus absent
B30	**2**	Run	5% mud; 5 % sand; 10 % gravel; 70 % cobble;	0.55	-	-	-	scrubland/ pasture 100% cover	-	Submerged macrophytes;

			20 % boulder. Cobble and boulder dominate							submerged algae; woody debris and detritus absent
B30	**3**	Run	5 % mud; 5% sand; 50 % gravel; 30 % cobble; 10% boulder. Gravel and cobble dominate	0.48	-	-	-	scrubland/ pasture 100% cover	-	Submerged/ Emergent macrophytes; submerged algae; woody debris and detritus absent;
B30	**4**	Run	5% ,mud; 5 % sand; 10 % gravel; 50 % cobble; 20% boulder. Cobble and boulder dominate	0.55	-	-	-	scrubland/ pasture 100% cover	-	Submerged/ emergent macrophytes; submerged algae; woody debris and detritus absent
C50	**1**	Run	0% mud; 50% sand; 40% gravel; 5% cobble; 5% boulder. Sand and gravel dominate.	0.48	15	18	18	Scrubland 100% cover	25-49%	Submerged macrophytes; submerged/ free floating algae; woody debris absent; detritus present
C50	**2**	Run	5% mud; 30% sand; 20% gravel; 40% cobble; 5% boulder. Cobble and sand dominate.	0.48	-	-	-	Scrubland 95% cover	-	Emergent/submerged macrophytes; submerged algae; woody debris and detritus present
C50	**3**	Run/ riffle	0% mud; 10% sand; 20% gravel; 30 % cobble; 40% boulder. Cobble and boulder dominate.	0.28	-	-	-	Scrubland 95% cover	-	Emergent/ submerged macrophytes; submerged algae; woody debris and detritus present
C50	**4**	Riffle	0% mud; 10% sand; 10% gravel; 40 % cobble; 40% boulder. Cobble and boulder dominate.	0.41	-	-	-	Scrubland 90% cover	-	Emergent/submerged macrophytes; submerged algae; woody debris and detritus present
D70	**1**	Run	5% mud; 35% sand; 50% gravel; 10% cobble; 0% boulder. Gravel and sand dominate.	0.32	14	15	14	Scrubland/ pasture/ 90% cover	25-49%	Emergent/ submerged macrophytes; submerged/ free floating algae; woody debris and detritus present
D70	**2**	Run/ pool	5% mud; 50% sand; 40% gravel; 5% cobble; 0% boulder. Sand and gravel dominate.	0.49	-	-	-	Scrubland/ pasture 90 % cover	-	Emergent/ submerged macrophytes; submerged algae; woody debris present; detritus absent
D70	**3**	Pool/run	20% mud; 50% sand; 15% gravel; 10% cobble; 5% boulder. Sand and silt dominate.	0.50	-	-	-	Scrubland/ pasture/ deciduous trees 95% cover	-	Emergent/ submerged macrophytes; submerged algae; woody debris and detritus absent
D70	**4**	Riffle	5% mud; 15% sand; 50% gravel; 28% cobble; 2% boulder. Sand and cobble dominate.	0.17	-	-	-	Scrubland/ pasture/ deciduous trees 90% cover	-	Submerged macrophytes; submerged algae; woody debris and detritus present
E90	**1**	Run	5% mud; 30% sand; 25% gravel;15% cobble; 25% boulder. Sand and boulder dominate.	0.66	13	18	14	Scrubland/ Pasture 95% cover	0-24%	Emergent macrophytes; submerged algae; woody debris and detritus present
E90	**2**	Run	60% mud; 39% sand; 0% gravel; 0% cobble; 1% boulder. Silt and sand dominate.	0.45	-	-	-	Scrubland/ Pasture 95% cover	-	Emergent/ submerged macrophytes; submerged algae; woody debris and detritus present
E90	**3**	Run	60% mud; 35% sand; 0% gravel; 0% cobble; 5% boulder. Silt and sand dominate.	0.74	-	-	-	Scrubland/ Pasture 90% cover	-	Emergent/ submerged macrophytes; submerged algae; woody debris and detritus present
E90	**4**	Riffle	5% mud; 5% sand; 15% gravel; 15% cobble; 60% boulder. Boulder and cobble/gravel dominate.	0.28	-	-	-	Scrubland/ Pasture 95% cover	-	Emergent/ submerged macrophytes; submerged algae; woody debris and detritus present

For embeddedness, channel flow status and sediment deposit scores the entire reach was assessed and an overall score was given; not assessed per transect

Embeddedness measures the extent to which finer particles such as sands and silts surround or cover larger rocks and boulders (Hoemsen [MoE & SWA] 2012). The scores for embeddedness range from poor (0-5), to marginal (6-10), to suboptimal (11-15), and optimal (16-20). Site A10 scored lowest being at the lowest end of suboptimal. Sites C50, D70, and E90 scored in the higher range of suboptimal but it was noted that some areas of the reach at D70 and E90 were more marginal. Site B30 scored in the optimal range. Channel flow status measures the level of water within the channel and if it reaches the base of the channel or goes higher on both sides of the channel. Channel flow uses the same scoring descriptors as embeddedness (Hoemsen [MoE & SWA] 2012). 2017 scores were optimal at all sites with the exception of A10, which was suboptimal for about half of the sample reach. Sediment deposition looks at the accumulation of sediments in pools and how it alters the bottom of the stream and follows the same scoring descriptors as embeddedness and channel flow status (Hoemsen [MoE & SWA] 2012). The majority of the sites sampled in 2017 were in the suboptimal range with the exception of B30 and C50 which were optimal. No extensive deposition was noted at any of the sites. Water chemistry taken at each site during sampling is seen in Table 25.

Table 25. Water chemistry at five benthic macroinvertebrate sample sites on Swift Current Creek 2017

Water chemistry for benthic macroinvertebrate sampling at five sites on Swift Current Creek 2017					
Site	**Water temperature (°C)**	**Conductivity (µS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/L)**	**Salinity (ppt)**
A10	15.2	924	74.8	7.45	0.5
B30	19.4	974	78.4	10.61	0.5
C50	14.9	995	29.8	8.08	0.5
D70	18.2	1121	46.2	5.93	0.6
E90	13.4	711	41.0	9.32	0.9

b.) Statistical analysis

According to Rosenberg and Resh (1993) as cited by Phillips [WSA] (2018) the biological condition of freshwater habitats is commonly evaluated using communities of benthic (substrate dwelling) organisms or macroinvertebrates and the traits they possess in terms of sensitivity to water quality and other environmental characteristics. According to Phillips et al. (2016) the use of benthic macroinvertebrates as a measure of river and stream health requires an understanding of the physical structuring of those communities without human interference. A comprehensive reference condition approach-based method was developed by Phillips (2017). This method selected communities to compare test sites against and applied the Test Site Analysis (TSA). This analysis evaluates whether or not the metrics of the community are outside the variation expected without human activity. Table 26 shows that total abundance was high at each sample site but site B30 surpassed all sites and the reference condition with a total abundance of 39,066 organisms. This site is immediately downstream of the Duncairn Dam Reservoir (Reid Lake) and was classified as the only "impaired" site of benthic macroinvertebrates with the high abundance as a driving metric (Phillips [WSA] 2018). Low abundances of the % EPT (% **E**phemeroptera, **P**lecoptera, **T**richoptera) also contributed to this site's classification, as shown with the other factors in Table 27. Travelling downstream from this site the remaining three sites C50, D70, and E90 showed gradual improvement. Site A10 above the Duncairn Dam was the only site classified as "healthy" (Phillips [WSA] 2018).

Table 26. Metric values and biological groupings for Swift Current Creek sites

	Swift Current Creek Site 2017				
Site:	A10	B30	C50	D70	E90
Biological Grouping:	**1**	**2**	**2**	**2**	**2**
Site Values					
Total abundance	2221	39066	4040	2545	2025
Number of Coleoptera	60	0	46	20	5
% EPT	0.0459	0.0071	0.0696	0.0715	0.2415
% Shredders	0	0.1865	0.099	0.1179	0.0988

(Phillips [WSA] 2018)

Table 27. Probability of impairment at test sites known to be impacted from human activity compared against reference sites from their respective reference groupings

	Swift Current Creek Site 2017				
Site:	A10	B30	C50	D70	E90
Biological Grouping:	**1**	**2**	**2**	**2**	**2**
D in metric-based TSA	2.50	33.00	3.50	2.80	2.70
p-value for equivalence to reference	0.97	<0.001	0.30	0.87	0.92
Total abundance	1.00	<0.001	1.00	1.00	1.00
Number of Coleoptera	1.00	1.00	1.00	1.00	1.00
% EPT	1.00	0.18	0.18	0.18	0.20
% Shredders	1.00	1.00	1.00	1.00	1.00
Total <0.05	0	1	0	0	0

(Phillips 2018)

According to Phillips et al. (2016) as cited by Phillips [WSA] (2018) the dominant organism and amphipod *Hyalella azteca* (Order Amphipoda: Family Dogielinotidae) and the various members of the midge family Chironomidae (Order Diperta: Family Chironomidae) found at Site B30 is not an uncommon finding for a site downstream of a major reservoir in the Northern Great Plains. This is due to the characteristic impact of Duncairn Dam (Reid Lake) on the downstream benthic macroinvertebrate communities in terms of human caused stressors. In a study by Phillips et al. 2016 it was found that *H. azteca* and Chironomidae were abundant at low-turbidity sites. These were both very common and the majority of organisms found at site B30. Chironomidae was also very abundant at the other sample sites. According to Phillips et al. (2016) abundant algae and macrophytes in low-turbidity conditions provide suitable habitat and a food web structure for of *H. azteca* and Chironomidae, which were identified in large numbers at site B30. Characterizing B30 as impaired could be due to the low numbers of % EPT but it is sensitive to a range of human stressors such as the impacts of being immediately downstream of a large reservoir. Only two of the three %EPT orders were found (Ephemeroptera [mayflies] and Trichoptera [caddisflies]) at this site and were the only two orders found at all five sites (Phillips et al. 2016 as cited by Phillips [WSA] 2018; Merrit et al. 2008 as cited by Phillips [WSA] 2018). These three orders are highly sensitive species; especially to human impact as they require high amounts of dissolved oxygen and cooler water conditions (Merrit et al. 2008 as cited by Phillips [WSA] 2018). Dissolved oxygen levels, especially at B30, were often oversaturated so other factors maybe the reason for the site's impairment.

The effects of turbidity on macroinvertebrate communities can be attributed to the influence of turbidity on light penetration of water (Jones 2010 as cited by Phillips et al. 2016). While the reach at B30 itself may be deemed impaired, the reservoir contributes changes to sediment transport, light penetration, and water availability which can significantly alter the benthic macroinvertebrate environment (Phillips [WSA] 2018). This abundance of organisms can be positive as it provides greater food sources for fish and other wildlife, and exports aquatic nutrients into the environment (Phillips [WSA] 2018). It can also be said that the traits of Northern Great Plains River and stream systems can also have an increase in %EPT taxa in high turbidity environments. This is not a contradiction of the expected decrease in turbidity-sensitive taxa; for example, Ephemeroptera can be represented here by the burrowing mayfly species (Roy et al. 2003; Freeman and Schorr 2004; Chatzinikolaou et al. 2003; Evans-White et al. 2009 as cited by Phillips et al. 2016).

Since site A10 upstream of the reservoir does not have the same environmental conditions and did not have the abundance of macroinvertebrates as B30, it was deemed healthy in terms of all the references. Sites C50, D70, and E90 were classified as stressed also but classifications improved as moved downstream. This may indicate that the biggest impact to the benthic communities and environment is the Duncairn Dam Reservoir and the resulting alterations to the SCC downstream. Turbidity controls primary production and biomass (Cloern 1987; Hall et al. 2015 as cited by Phillips et al. 2016) and in the case of the SCC reservoirs has lower sediment loads at the outflows than in the inflow (Jones 2010 as cited by Phillips et al. 2016).
In the 2005 and 2006 macroinvertebrate results the %EPT was found to have minimal differences but improved in 2007. The two orders (mayflies and caddisflies) that were found in all three years of prior sampling (2005-2007) were the same two found in 2017. These orders require rock/gravel substrate and flowing, unpolluted, cool water for optimal survival (Tait [SCCWS] 2008). Site B30 has substrate that is a rock/gravel consistency and stronger water flows, which would be ideal for mayflies and caddisflies. The lack of these two orders may point to the condition of the water quality. Aquatic (benthic) macroinvertebrate communities can change in terms of species composition and diversity, as well as abundance of individuals depending on the type and amount of pollutants in the water system (Hilsenhoff 1988 as cited by Phillips 2017).
A BIOENV statistical analysis of the 2004-2007 study found that nitrogen was a common environmental stressor among all sites. According to Tait [SCCWS] (2008) high levels of various forms of nitrogen reduced water quality which decreased taxonomic richness not only at site B30 but also C50 and D70 in 2005 and 2007 respectively. Ortho-phosphorus was also noted in 2017 as having higher levels at the B30 and C50 sites. As mentioned by Phillips [WSA] (2018) organic pollution plays a key part in the benthic environment. It can enter the creek through excess fertilizer running-off from agricultural and irrigations lands, sewage release, and run-off from livestock facilities. Nitrogen can also occur naturally, which becomes an issue when excessive rainfall or irrigation causes leaching of nitrate from the soil into nearby water sources (KWD 2008 as cited by Tait [SCCWS] 2008).

In 2013 the D70 site was assessed for benthic macroinvertebrate community and deemed healthy, despite being immediately downstream of the WWTP. In 2017 the site was not as healthy as site A10 but healthier than C50, whose health falls between sites B30 and D70. It may be suggested that the WWTP has improved the quality of wastewater coming from the city of Swift Current released into the creek. Given a combination of nitrate run-off from non-point sources such as irrigated and non-irrigated agricultural soils, and from the City of Swift Current from fertilizer in lawns and the golf courses, the WWTP was still thought of as a potential point source in 2007 (Tait [SCCWS] 2008). The results of the 2013 project proved that the operation of the WWTP has improved water quality downstream of the City of Swift Current. This was evident from the results of the benthic macroinvertebrate sampling done at site H60 in 2013 which was immediately upstream of the WWTP. This site was classified as stressed and borderline to the reference conditions but not impaired. The indication of good health at site D70 in 2013 was the Total Species Abundance (TSA) which was D = 2.5 in a 95% confidence interval for the sites biological grouping ($p = 0.97$) (Phillips 2013; Peters [SCCWS] 2013). There were low numbers of species present but it did not appear to impair the results.
With changes in methodology and statistical analysis over the course of ten years direct comparisons cannot be made but the results from 2017 sampling suggest that the benthic macroinvertebrate communities have improved since the early 2000's. However, the 2017 results show that there are still issues in the overall health of the benthic environments. As cited by Phillips [WSA] (2018) for the 2017 project, the results indicate that the overall condition of the SCC is not critical and the Number of Coleptera and % Shredders are still within the reference points. This further indicates that the lower reaches (i.e. downstream of the Duncairn Dam Reservoir) on Swift Current Creek are not impaired (Phillips [WSA] 2018).

3.0 Conclusion and recommendations

SCCWS completed the 2017 Swift Current Creek Water Monitoring Project in an attempt to answer 4 questions:

1. *Are there water quality and watershed health problems in the Swift Current Creek Watershed?*

The WQI's calculated indicate some issues with water quality in the SCC, with some of the sites sampled having more issues than others. The site with the most issues was I80. From D70 to I80 there are a number of point and non-point stressors to water quality that could be responsible for this. Phillips [WSA] (2018) points to the impacts of Duncairn Dam Reservoir as the key factor in the decline of the diversity of benthic macroinvertebrate communities of the lower level of the creek, even though numbers were high in the amounts collected. Fish and other organisms can use this "impaired" benthic macroinvertebrate environment for increased food sources. There is also an increased transport of nutrients, which can have a positive impact. Increased fish populations at site B30 showed this may be indeed true. Fish populations were healthy along the whole creek which would indicate the water quality is still of good quality to sustain and improve aquatic life and wildlife. Some recommendations for further investigation are:

- Benthic macroinvertebrate sampling at more sites upstream of Duncairn Dam to determine their populations before the impacts of Duncairn Dam take effect.

- Establish a minimally affected site upstream of site A10. This would help to further interpret the impacts of Duncairn Dam as indicated in the 2007 recommendations for benthic macroinvertebrates.
- Water quality testing at the WWTP discharge and WTP discharge and implement run-off sampling for peak irrigation and heavy rainfall events at sites B30, C50, H60, D70 and I80.
- Include testing for Total Suspended Solids in the samples collected in future projects as levels of TSS can impact the levels of certain water quality parameters. This will help to determine if spikes observed are indeed due to stressors impairing water quality or if they are due to increased sediments suspended in the creek during sampling.

2. *If there are problems, which problems are the greatest?*

Some problems that were identified during testing in 2017 can be attributed to the drought conditions that caused low flows which in turn created high levels of TDS and sulfates due to soil leaching and increased evaporation. Results from both water quality sampling and benthic macroinvertebrate analysis suggest that pollution loading in the forms of organic and nitrogen sources are still significant factors contributing to the major issues facing the SCC. Water quality sampling from sites within the city show concentrations of aluminum, sodium, and chloride increase as the creek flows through the city. The site that showed the most issues with water quality all summer long was I80. Recommendations are as follows:

- Continue educating and promoting programs to implement beneficial management practices for livestock producers and farmers along the SCC.
- Obtain historical city data on aluminum, chloride, and sodium concentrations.
- Establish additional monitoring between sites D70 and I80 to identify the main sources of water quality degradation in that area of the creek and how to eliminate or mitigate these stressors.
- Include testing for Total Dissolved Solids when testing between sites D70 and I80 to determine if TSS levels are responsible for some of the water quality issues observed at I80.

3. *Can we improve any watershed health problems that exist?*

SCCWS, the City of Swift Current and its residents, livestock producers, farmers, and industry in the watershed have made huge strides since the early 2000's to implement improvements to water quality and watershed health. To improve the watershed health problems, all stakeholders need to continue implementing Beneficial Management Practice to ensure that this improvement is sustained. Recommendations are as follows:

- Continue with the awareness and education for BMP's that agriculture producers can implement as these are proven to help lessen the negative impacts to the environment.
- In partnership with the City of Swift Current implement awareness and education programs to encourage city residents to take more steps to conserve water, and make changes to current practices to improve water quality. An example of this is the establishment of a Rain Garden near the creek to promote practices to reduce pollution

going into the creek and to reduce the amount of pollution entering the creek from the city.

- Encourage urban and rural residents to catch rain water from buildings to use in their yard or gardens to reduce the pressures on treatment plants or individual wells.
- Collaborate with the city to share data about the operation of the WTP and WWTP.
- Educate landowners, industry and city residents about invasive plant identification and management.

4. *Have the changes seen within the Swift Current Creek Watershed since 2007 had an impact on water quality and watershed health?*

The results of the 2017 sampling seem to suggest that water quality has decreased slightly from 2007. However, this appears to because of reduced precipitation and increased evaporation in 2017 lowering water quality rather than the changes in land use and management impacting water quality. Comparing how water quality changes as we move downstream and as the summer moved on we see similar patterns in 2017 to what was observed in 2007. This tells us the factors that affected water quality in 2007 still have an impact on water quality in 2017. While this does not completely rule out these changes having an impact, we can deduce these changes have not made a significant impact to lowering water quality or that the negative impacts have been counteracted by positive impacts. Recommendations are:

- Identify areas with possible stressors and complete targeted water quality monitoring in these areas to determine impacts and if these are a localized or creek-long issue.
- Implement water quality sampling at the head of the creek and between there and site A10 to help determine impacts, if any, of oil and gas development in that area.
- Establish partnerships with the oil and gas industry, agriculture producers and businesses, recreation and residential communities on waterbodies to continue promotion of issues affecting water quality and watershed health and the practices that can be implemented to improve both.

4.1 Riparian health

Riparian health assessments (RHAs) give an overall indication of the health of the creek and watershed. The following conclusions can be made about assessments completed in 2017:

- Site E90 had the highest overall score in 2017 with 88%, rating as healthy. This was also the case in 2004 when assessments were last done indicating the health of this site is being maintained. The score was 7% lower in 2017 than 2004 and continuing assessments will be key in monitoring any further changes.
- Site I80 had the worst overall score at 57% and is the only site to rate as unhealthy. The exact site assessed in 2017 differed from prior assessments but the lack of preferred species and woody vegetation caused the low score for vegetation. This site had the lowest diversity of species documented at all sites assessed.
- Overall the sites rated as healthy with problems as they had in the previous monitoring projects. The problems can be attributed to invasive species becoming more dominant creating a lack of preferred species. Documented species diversity varied with most sites

having a range of 31 to 49 species. Site I80 was the exception as it had the lowest number of species documented with 16.
- The assessments varied from having increased or decreased scores from prior monitoring projects. However, the sites appear to be maintaining riparian health but invasive species were becoming increasingly dominant and bank erosion issues appeared in parts of the reaches assessed. Continued assessments and documentation of the health would be beneficial to monitor the progress of the riparian health in these sites. Where RHA scores are decreasing, BMP's should be implemented to improve the state of the riparian areas. An off-site watering system installed at A10 to limit the cattle access to the creek in conjunction with rotational grazing are two examples of BMPs that have had positive results on riparian health.

4.2 Saskatchewan water quality index and parameters

Comparing the Water Quality Indexes calculated in 2017 to those calculated in 2007, the following observations were made:

- Irrigation water index
    - Riverside Park had the highest index, while all other sites rated as marginal. Riverside Park is directly downstream of the WTP, which indicates the excess treated water released by the WTP is not affecting water quality immediately downstream of it, but as the creek continues through the city, chemicals and other pollutants enter the creek reducing water quality.
    - Water quality was low at site A10 but improves as move downstream towards the city.
    - The index scores were lower than in 2007 due to high TDS levels, brought on by hot temperatures and lack of precipitation, and increased evaporation which decreased water levels.
- Livestock watering
    - Scores from sites A10 to H60 were all excellent which did not change from 2007.
    - Downstream of the WWTP at site D70 had a few parameters that were over the guidelines but rated still overall as good.
    - Site I80 rated as the worst site with a score of fair with one sample testing high for copper. Site E90 also rated as fair due to consistently high TDS levels.
    - Sites within the City of Swift Current all rated as good.
    - 2015 changes in the guidelines that increased the acceptable maximum levels of TDS changed ratings at all sites to excellent with the exception of site I80.
- Protection of aquatic life and wildlife
    - All sites rated good except I80.
    - Trend was consistent with 2007 but site I80 dropped lower in 2017.
    - Indicates the operations of the WTP and WWTP and their effects on parameters that make up this index are not enough to cause concerns about their impacts on aquatic life and wildlife.

- General water quality
    - All sites rated as good with a few having scores close to fair.
    - Most are lower than 2007 but site I80 is better in 2017 as excursions from guidelines were not as large in 2017 compared to those in 2007. However, this site is still severely impaired.
    - The city does not seem to have an impact on general water quality but between sites D70 and I80 there are stressors lowering the scores.

The index that had the worst scores overall was irrigation due to levels of TDS being over the guidelines. As the conditions experienced in 2017 contributed to these levels it cannot be determined if human-caused factors increased these levels or if the function of the City of Swift Current and its factors contributed to the high levels of TDS. Natural and human-caused impacts both play a part in the TDS concentrations seen in 2017 but a hot and dry year with low flows and no precipitation make it difficult to determine which factors contributed more.

4.3 Water chemistry

Most of the water chemistry results did not raise significant concerns about water quality along the whole creek and did not raise concerns about the operations of Swift Current's WTP and WWTP.

- Objectives for parameters that are indicators of the impact of treatment plant operations on water quality such as chloride, sulfate, nitrate nitrogen, orthophosphates, and pH were below all index guidelines.
- Chloride is used in treatment processes but levels observed show that it is not impacting water quality as concentrations did not increase immediately downstream at Riverside Park.
- All sites downstream of the city and the WWTP had higher sodium levels throughout the summer, indicating there may be sources of sodium loading from the city or a combination of natural and human-caused sources.
- TDS and arsenic both had levels exceeding the guidelines, but given the conditions observed this summer it cannot be concluded that the city alone has more impact on these parameters than natural processes. Arsenic is known to occur in the soils surrounding the watershed which increases concentrations naturally.
- Aluminum is added for water treatment and levels increased as expected due to the release of excess treated water downstream, which was observed. Sites downstream of the city do show there is some impact on water quality and watershed health of the creek flowing through agricultural, livestock, and urban areas and picking up higher levels of some water quality parameters as a result. The creek flows in proximity to parks, residential areas, sewage lagoons, the City of Swift Current's landfill, and other municipality's lagoons and landfills.
- Changes in land use and management practices have not impacted water quality or watershed health or positive changes have counterbalanced the negative changes.
- Continued sampling at the three sites within the city would be beneficial to set a baseline of water quality, especially after any work or improvements done to either the WTP or WWTP. Establishment of an additional site downstream of site H60 and upstream of the

WWTP would also be beneficial in monitoring any other sources of contamination especially the Swift Current Landfill.

- Shared information between the City of Swift Current and the SCCWS would also be beneficial in understanding any urban impacts to the creek water quality and health.

Monitoring the area of the creek between D70 and I80 would determine some of the stressors impacting water quality at I80 and identify possible solutions to eliminate or mitigate these stressors.

4.4 Bio-assessments- Fish population and diversity

The following are observations of the population and health of the sentinel species of White Sucker and Fathead Minnow:

- Populations overall along the entirety of the creek were healthy, having large numbers of White Sucker with the majority being YOY. This indicates the population is maintaining reproduction and the system is suitable for healthy YOY numbers.
- Fathead Minnow, though only seen at two sites, were also determined to have a healthy population based on the individuals processed. Diversity at all sites was all above the index of one (1.0), meaning diversity is healthy. Site D70 showed the greatest diversity with potential for more if CPUE increased.

Recommendations (J Sereda [WSA] in email document to D Peters dated February 14, 2018 2:46 PM; unreferenced, see Acknowledgements) for improving future sampling perhaps is better pairing of site conditions. Statistically the number of fish captured is less important than making sure the habitat conditions at each site are as similar as possible. This will have a great effect on species composition and the number of fish present. It's also preferable to standardize sampling methods and effort such as establishing a reasonable CPUE maximum. For example: only having a maximum of four seines at each location as opposed to conducting as many seines as possible to obtain both numbers for sentinel species. In the past SCCWS has had a maximum of ten seines but due to time and effort it may be more plausible to lower this standard.

4.5 Bio-assessments- Benthic macroinvertebrates

Benthic macroinvertebrate environment and community varied at each site done in the 2017 project, but looking at the data from 2005 and 2006 the classification has improved moving into 2017 based on the following:

- In 2013 after the WWTP was in operation a site upstream (H60) and one downstream (D70) of the WWTP were sampled. The results of this sampling showed that the WWTP may be improving the quality of waste water being released back into the creek as site D70 had a healthier benthic macroinvertebrate population than Site H60.
- In 2017 all sites downstream of the Duncairn Dam Reservoir were deemed as stressed, but only one as being impaired at site B30, which is the first site downstream of the reservoir.
- The next site at C50 was also deemed as one of the worst sites and A10 as the only site classified as healthy and was the only site upstream of the reservoir sampled.
- If water quality and pollution inputs are the major contributor to the benthic communities and environments (the source of nitrogen was deemed a major contributor in the 2007

report), further investigation into these organic sources and inputs should be conducted in the future to weight their impact versus the impact of the reservoir.

- According to Phillips [WSA] (2018) there is little that can be done to remedy the impact of reservoirs in the Northern Great Plains river systems even though their existence creates the conditions to significantly alter the benthic environments. The positive impacts of the reservoir on water management within the watershed may outweigh the negative impacts on these environments. This area also provides a source of food for other aquatic life increasing fish populations and diversity.
- Comparing the data from 2004-2007, 2013, and 2017 further monitoring of water quality and benthic macroinvertebrates would be beneficial to observe if the system is becoming more degraded, maintaining itself, or even seeing improvement.
- Phillips [WSA] (2018) indicates through the reference conditions that the SCC has not reached a point of full impairment ten years since the first assessments were conducted.

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