Bighill Creek Water and Sediment Quality
Baseline Study
Phase II: 2019-2020

By

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EXECUTIVE SUMMARY

This report documents phase II of the surface water and sediment quality conditions in Bighill Creek. This study was conducted from July 2019 to August 2020. Surface water samples were collected at six locations along the Creek (Sites 1 to 6) in July, September, and October 2019 and in January and May 2020. Creek sediments were collected at four locations (Site 1, Site 5, Site 6, and Site 7) in July, September, October, and May. Local spring water samples (Spr1 and Spr2) were also collected in July, September, October, and May. Water quality indicators were measured in the field and in the laboratory. Data were compared to the Canadian Council of Ministers of the Environment (CCME) (2003), Alberta Environment and Sustainable Resource Development (AESRD) (2014), and Government of Alberta (2018) guidelines for the protection of aquatic life, for livestock watering, and for irrigation use.

The Bighill Creek surface water data showed the following results:

- Flow rates reached a median of 0.238 m^3/s. This value was 1.7 times that recorded in 2017-2018.
    - The median is the central or middle value of a population distribution. As many water quality parameters are not normally distributed, non-parametric statistics such as the median best describe the centre of a dataset.
- pH ranged from 7.77 to 8.59.
- Day time water temperatures reached a median of 6.92°C.
- Day time dissolved oxygen concentrations reached a median of 11.79 mg/L.
- Biochemical oxygen demand concentrations were generally below detection limit (2.0 mg/L) except at Site 1 in July (2.3 mg/L), Site 1 in January (2.3 mg/L), Site 1 in May (2.8 mg/L) and Site 6 in May (3.1 mg/L).
- Total organic carbon concentrations reached a median of 7.5 mg/L. This concentration was 2.9 times the median recorded in 2017-18.
- Total dissolved solid concentrations reached a median of 380 mg/L.
- Total suspended solid concentrations reached a median of 6.6 mg/L.
- Electrical conductivity reached a median of 0.573 mS/cm.
- True colour reached a median of 32.0 PtCo units. This value was 3.6 times the median recorded in 2017-18.
- Chlorophyll concentrations reached a median of 3.33 µg/L.
- Fecal coliform counts reached a median of 49.5 Most Probable Number /100 mL. This concentration was 3.8 times the median recorded in 2017-18.
- Total phosphorus concentrations reached a median of 0.0310 mg/L. This concentration was 1.8 times the median recorded in 2017-18.
- Total dissolved phosphorus concentrations reached a median of 0.0180 mg/L. This concentration was 3.7 times the median recorded in 2017-18.
- Total Kjeldahl nitrogen concentrations reached a median of 0.68 mg/L. This concentration was 1.7 times the median recorded in 2017-18.
- Nitrate + nitrite nitrogen concentrations reached a median of 0.60 mg/L. This concentration was approximately half the median recorded in 2017-18.

- Total ammonia nitrogen concentrations reached a median of 0.068 mg/L. This concentration was 2.3 times the median recorded in 2017-18.
- Total metal concentrations were below the guidelines.
- Phenol concentrations reached a median of 0.0014 mg/L.

The Bighill Creek sediment data showed the following results:

- Sediment texture ranged from clay to loamy sand.
- Sediment salinity showed that soluble chloride concentration exceeded the guideline at Site 5 in September and Site 7 in May.
- Available nitrogen concentrations were below detection limits in all samples except at Site 7 in September when available N concentration reached 2.4 mg/kg.
- Available phosphorus concentrations reached a median of 1.1 mg/kg.
- Available potassium concentrations reached a median of 110 mg/kg.
- Total metal results showed that total arsenic, total chromium, and total lead concentrations exceeded the guidelines at Site 1 in July 2019. These exceedances were not found in 2017-18, indicating an increase in these concentrations since June 2017.
- Polycyclic aromatic hydrocarbon (PAH) results showed that, as in 2017-18, a few PAHs exceeded guidelines:
  - At Site 5, concentrations of acenaphthylene, benzo(a)pyrene, dibenz(a,h)anthracene, and pyrene exceeded the guidelines in July, September, and October 2019. Concentrations of benzo(a)anthracene, chrysene, fluoranthene, and phenanthrene exceeded the guidelines in July and October 2019. Concentrations of anthracene exceeded the guideline in October 2019. Site 5 is located downstream of the Town of Cochrane where residential and industrial activities take place. Effluents from these activities may have contributed to these PAH exceedances.
  - At Site 7, concentrations were below guidelines except in May 2020 when concentrations of acenaphthene, acenaphthylene, and dibenz(a,h)anthracene were below the detection limit. However, the detection limit (0.011 mg/kg) was above the guidelines and actual concentrations may exceed the guidelines.
- Phenol concentrations were below detection limits except in September and in May when actual concentrations were reported. Concentrations in July appear to be higher than concentrations for all sampling events. However, they were below the detection limit (<2.0 mg/kg) and actual concentrations were unknown.

The results of this study showed that the water and sediment quality of Bighill Creek was largely comparable to the quality found in 2017-2018. The following parameters and concentrations increased since 2017:

- Surface water flow
- Total organic carbon
- True colour
- Fecal coliform counts
- Nutrients:

    - Total phosphorus
    - Dissolved phosphorus
    - Total Kjeldahl nitrogen
    - Total ammonia nitrogen
- Total metals in sediments
- Polycyclic aromatic hydrocarbons in sediments

After phase I of this study was completed in 2018, a few changes were recommended to enable gathering more information. The following changes were implemented during phase II in 2019-20:

- The addition of a surface water sampling location (Site 6) upstream of Site 1, as a result of exceedances recorded at Site 1 in 2017-18. This brought the total number of surface water samples to six instead of five.
- The addition of a sediment sampling location (Site 7) upstream of Site 5, as a result of PAH exceedances recorded at Site 5 in 2017-18.
- Creek sediments were collected at four sites in 2019-20 instead of two sites in 2017-18.
- Creek sediments were sampled four times in 2019-20 instead of twice a year in 2017-18.
- Spring water was sampled four times in 2019-20 instead of twice a year in 2017-18.

Concentrations of many parameters at Site 6 and Site 1 were higher than concentrations at other sites and affected the general trend of the data. These parameters included total organic carbon, total suspended solids, nutrients, chlorophyll a, fecal coliforms, and phenols. Site 1 was located at Highway 567 and Site 6 was located further upstream between Highway 567 and Township Road 272. Both Site 1 and Site 6 were located upstream of Bighill Springs Provincial Park and were surrounded by agricultural, industrial, and residential land uses that likely affected the water quality of the Bighill Creek. Concentrations of these parameters were lower within the Bighill Springs valley. This was likely due to a combination of factors including the many springs along the valley that pour into the Creek, the shape of the valley, and the healthy riparian zone protecting the Creek.

The results in this report reflect the impact of different land uses on the health of the Bighill Creek and its valley. As cities grow and populations increase, land uses change, move, adapt, grow, and the natural ecosystems around them also change and adapt to maintain a healthy balance. Every activity, whether agricultural, industrial, commercial, residential, or recreational, has a footprint, and the goal is to minimize impacts that are harmful to the environment. This study has enabled us to quantify many water quality indicators between 2017 and 2020. These data are invaluable for long term management and safeguarding of the Creek and its valley.

These findings show the importance of regular monitoring of the health of the natural ecosystems surrounding us. The more data collected, and knowledge gathered, the sooner we will recognize correlations between land use and ecosystem health and will then address them accordingly.

This baseline study is designed to provide the information necessary to help protect the aquatic and riparian environments, the downstream receiving waters, as well as to support reclaiming the watershed as a recreational zone and for the reintroduction of a sport fishery. It is complemented by a fish inventory conducted by Trout Unlimited in June 2018, a riparian assessment conducted by the Alberta Habitat Management Society in summer 2018, and continuous stewardship efforts of the Bighill Creek Preservation Society to improve the trail system in the provincial and county reserve areas along the Creek.

ACKNOWLEDGEMENTS

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INTRODUCTION

The Bighill Creek watershed is naturally, historically, and regionally significant. Its main source is in the Bighill Springs Provincial Park, and the valley it pours into is a unique U-shaped 15 km valley that reaches the Bow River in the Town of Cochrane. The tufa formations, ancient buffalo jumps, ecological quality and diversity of the Creek and riparian zone, and cool water temperatures in summer and fall render this watershed a significantly valuable habitat and wildlife corridor.

The Bighill Creek Preservation Society (BCPS) continues to monitor the general health of the Bighill Creek Valley as it adapts to increasing development and population pressure around the valley.

Water quality is an important indicator of the health of a watershed. Historical data show a lack of consistent information regarding water quality of Bighill Creek along the valley and into the Town of Cochrane. The BCPS conducted a baseline water and sediment quality study in 2017-18 and was able to continue gathering data in 2019-20. This document reports the findings of phase II of this project: in 2019-20.

Photo 1. Site 1 in July 2019. Facing upstream. See Figure 1 and Table 1 for site locations.

METHODS

Sampling Locations

During phase I of this study (2017-2018), surface water samples were collected at five locations along Bighill Creek between Highway 567 and the confluence with the Bow River (see Fouli, 2018). During phase II (2019-2020), two additional sampling locations were identified: a surface water sample was collected upstream of Highway 567 and south of Township Road 272 (Site 6), and a sediment sample was collected at Glenpatrick Road in Cochrane (Table 1 and Figure 1). Site 6 is located adjacent to a horse ranch and surrounded by farm fields.

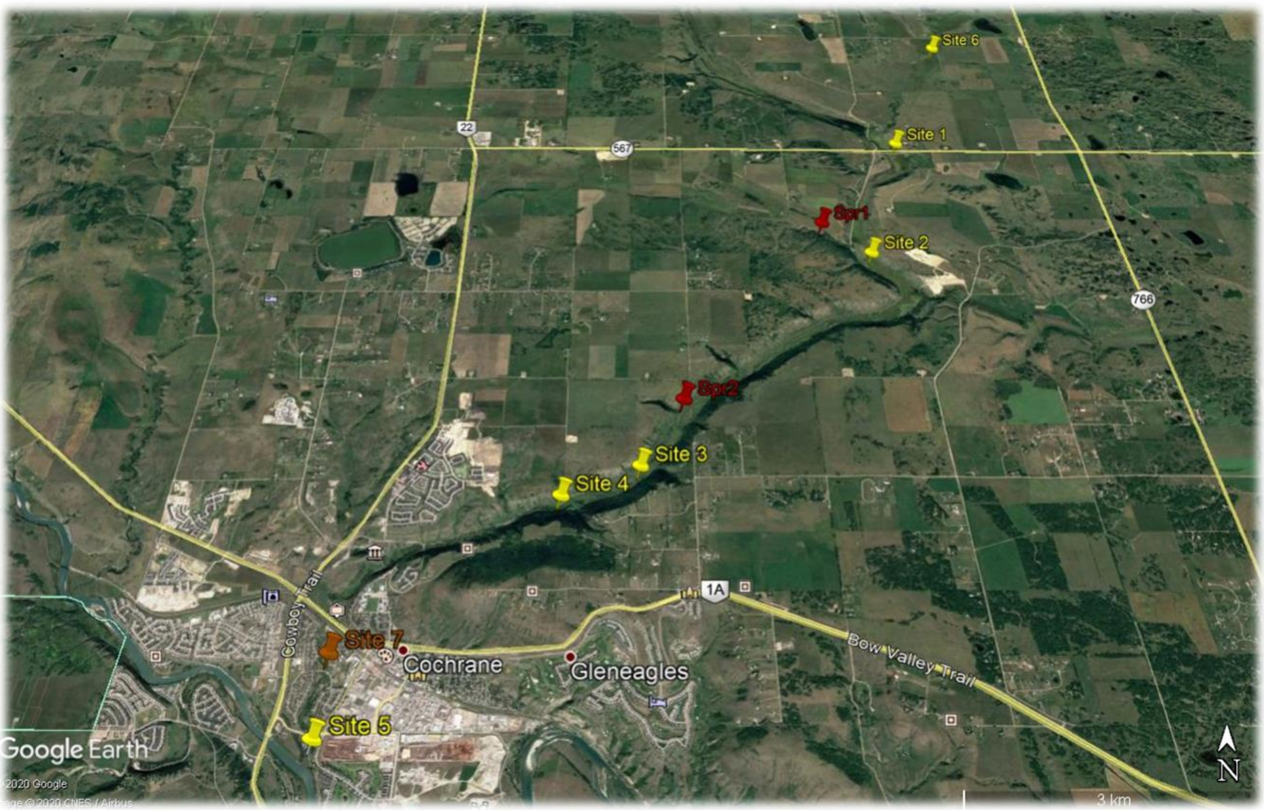

Figure 1. Sampling Locations in 2019 and 2020. Yellow and red pins indicate surface and spring water sampling locations, respectively. The brown pin indicates Creek sediment sampling location. Sediments were also sampled at Site 1, Site 5, and Site 6.

In addition, as in 2017-18, two spring water samples were collected at Spr1 and Spr2 (Figure 1 and Table 1). All sampling sites were selected in agreement with the BCPS to assess the impacts of different land uses on surface water and sediment quality.

Surface water samples were collected at sites 1-6 on the following dates: 10 July 2019, 5 September 2019, 24 October 2019, 10 January 2020, and 2 May 2020. Sediment samples were collected at Site 1, Site 5 and Site 7 on 10 July 2019, 5 September 2019, 24 October 2019, and 2

May 2020, and at Site 6 on 24 October 2019 and 2 May 2020. Spring water was sampled on 10 July 2019, 5 September 2019, 24 October 2019, and 2 May 2020.

Photo 2. Site 1 in May 2020. Facing downstream.

Analyses

1. Field Data

Surface water velocity was measured at each site using a digital handheld velocity meter for measuring flow in open channels. It consists of a turbo propeller with a positive displacement sensor which is placed in a stream or on the bottom of a streambed and a digital display (Global Water, FP111). Flow rates were obtained by multiplying the average velocity with the cross-sectional area of the channel.

In situ water quality data were collected using a handheld multimeter (YSI Environmental, 556 Multiparameter System). This multiprobe system takes simultaneous measurements of pH, temperature, electrical conductivity (EC), and dissolved oxygen (DO).

Grab water and sediment samples were collected with bottles and jars supplied by an accredited laboratory (Bureau Veritas). They were kept on ice in coolers and transported to the laboratory.

2. Laboratory Analyses

Bureau Veritas Inc. (formerly Maxxam Analytics) (4000 – 19 Street NE, Calgary, AB T2E 6P8, Tel: (403) 291-3077, Toll free: (800) 386-7247, Fax: (403) 735-2240) provided physical, chemical, and biological analyses of surface water including fecal coliforms, biochemical oxygen demand (BOD), chlorophyll a, true colour, total phosphorus (TP), total dissolved phosphorus (TDP), total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), total organic carbon (TOC), total suspended solids (TSS), routine analysis (anions and cations), total metals, and phenols.

A more limited analysis was performed on the spring water samples including fecal coliforms, TP, TDP, TKN, TAN, and routine analyses.

Creek sediments were analysed for soil texture, salinity, available nitrogen, available phosphorus, available potassium, total metals, polycyclic aromatic hydrocarbons (PAH), and phenols.

Data were compared to the Alberta Surface Water Quality Guidelines and the current Canadian Water Quality Guidelines (CCME, 2003; AESRD, 2014 and Government of Alberta, 2018).

To ensure accuracy and precision within the sampling program, duplicate samples and field blank samples were taken to assess cross-contamination potential and sample precision. The internal laboratory quality control consisted of method blanks, matrix spikes, calibration checks and relative percent difference between internally split samples.

3. Statistics

The median of each dataset was calculated and reported. The median is the central or middle value of a population distribution. As many water quality parameters are not normally distributed, non-parametric statistics such as the median best describe the centre of a dataset.

Where replicated measurements were conducted, the standard error of the mean was calculated and plotted on the figures. It represents the standard deviation of the sample distribution and shows the level of fluctuation around the mean.

Photo 3. Spr1 in October 2019. Facing upstream.

Photo 4. Spr1 in May 2020. Drs. Ken Stevenson and Ymène Fouli collecting water quality data.

RESULTS AND DISCUSSION

Water

1. Water Flow

Surface water flow in Bighill Creek ranged from 0.003 m^3/s (Spr2 in October) to 1.042 m^3/s (Site 4 in July), with a median of 0.238 m^3/s (Figure 2). This value was 1.7 times the median recorded in 2017-18 (Fouli, 2018).

Precipitation and runoff are the main causes of increased water flow in Bighill Creek. Annual precipitation at Springbank Airport, AB was 400 mm and 422 mm in 2017-18 and in 2019-20, respectively (Environment Canada, 2020 and Government of Alberta, 2020). Precipitation between May and October (summer precipitation) was 303 mm and 346 mm in 2017 and 2019, respectively, with highest precipitation in June 2017 (32% of summer precipitation) and June 2019 (39% of summer precipitation).

Peak surface water flows in Bighill Creek exceeded those recorded in Grand Valley Creek (0.091 m^3/s) in 2005 (Sosiak, 2006). They also exceeded flows in West Nose Creek measured in 2013 (Palliser Environmental, 2014). However, they were comparable to data collected between 2011 and 2019 at a University of Calgary gauging station located near Site 4: mean of 0.305 m^3/s and median of 0.227 m^3/s (Hayashi, 2020).

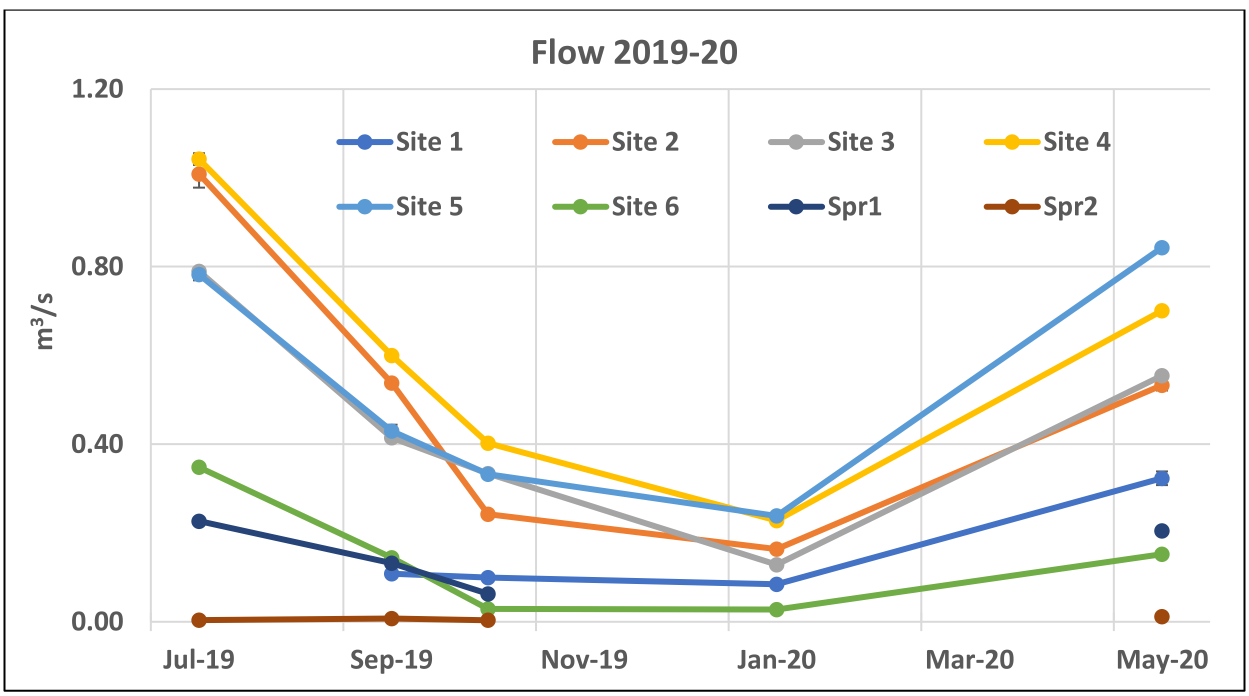

Figure 2. Surface water flow (m^3/s) in Bighill Creek in July, September, October 2019 and January and May 2020 at Sites 1-6 and Spr1-2. See Figure 1 and Table 1 for site locations and descriptions, respectively.

Flows in Bighill Creek were high in July 2019 due to precipitation and snowmelt runoff, and sample collection was not safe before early-mid July. On 10 July the water level was too high to safely obtain a velocity measurement at Site 1. Flows in July 2019 were on average 1.7 times flows in September 2019. Flows were high in spring 2020 and sampling was also delayed to ensure safe access to the Creek for measurements. However, they were not as high as in spring 2019: flows in July 2019 were on average 1.3 times flows in May 2020 (Figure 2).

Spring water flow ranged from 0.003 m^3/s (Spr2 in October) to 0.227 m^3/s (Spr1 in July) with a median of 0.037 m^3/s. Median spring flow was 0.75 times the median recorded in 2017-18 (Fouli, 2018). Flows at Spr1 were higher than at Spr2. Spr1 is located at the headwaters of the springs within the Provincial Park and is the sum of several springs upstream. Spr2, however, is a unique spring with a smaller channel located on the north side of the valley between Site 2 and Site 3 (Figure 2).

2. pH

The pH of water represents the balance between acids and bases and describes the activity of hydrogen ions in solution. It influences the availability of nutrients, concentrations of total ammonia, the relative toxicity of many trace elements, and can affect the general composition of an aquatic environment.

The pH in Bighill Creek ranged from 7.77 (Site 1 in January) to 8.59 (Site 5 in October) a median of 8.25 (Figure 3 and Table 2). These pHs were comparable to those recorded in 2017-18 (Fouli, 2018), and were also comparable to pH data obtained near Site 5 by the City of Calgary (2013). Values were within the CCME water quality guideline of 6.5 to 9.0 (CCME, 1999a).

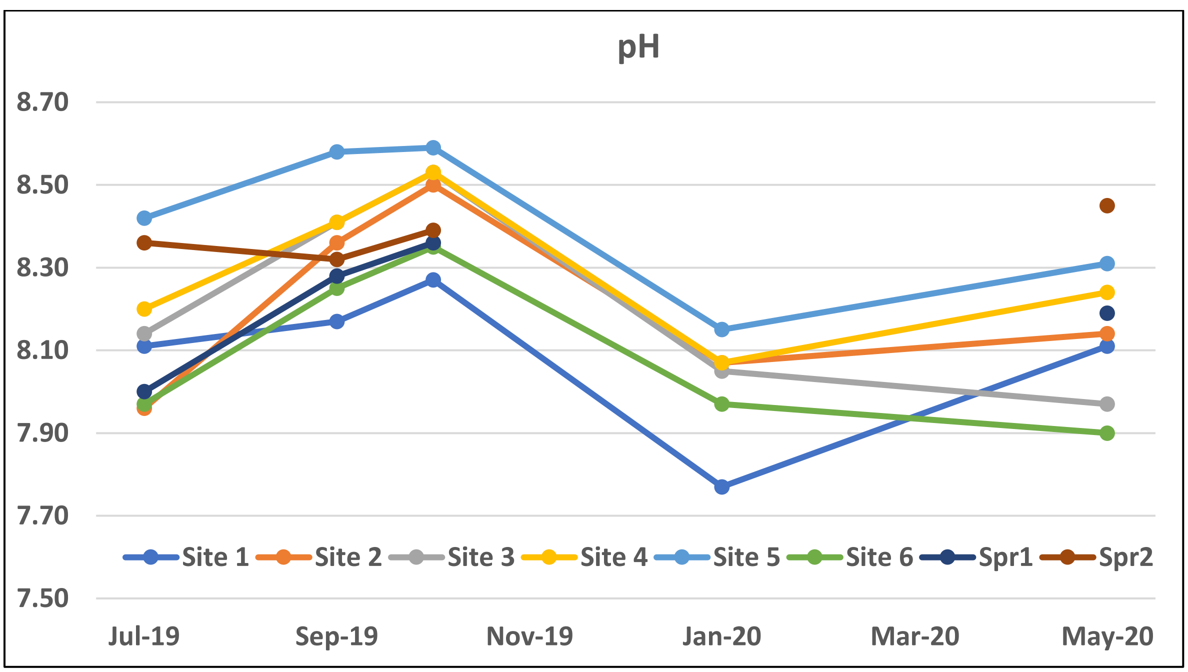

Figure 3. pH in Bighill Creek surface water.

3. Water Temperature

Water temperature is important as it strongly influences chemical and biological processes in surface water bodies. A change in the temperature of a surface water system can affect plant photosynthesis, fish communities, as well as algal and benthic communities, diversity, and productivity. Higher water temperatures decrease oxygen solubility and decrease the availability of dissolved oxygen to fish. Temperature also affects total ammonia concentrations in water.

Day time surface water temperatures measured in Bighill Creek ranged from -0.9°C (Site 1 in January) to 17.02°C (Site 5 in July) with a median of 6.92°C (Figure 4). These were comparable to day time surface water temperatures recorded in 2017-18 (Fouli, 2018). The City of Calgary recorded a temperature median of 10.70°C near Site 5 during their sampling program from 2000 to 2013 (City of Calgary, 2013). Trout Unlimited reported temperatures ranging from 9.3 °C to 17.3 °C in June 2018 (Trout Unlimited, 2018).

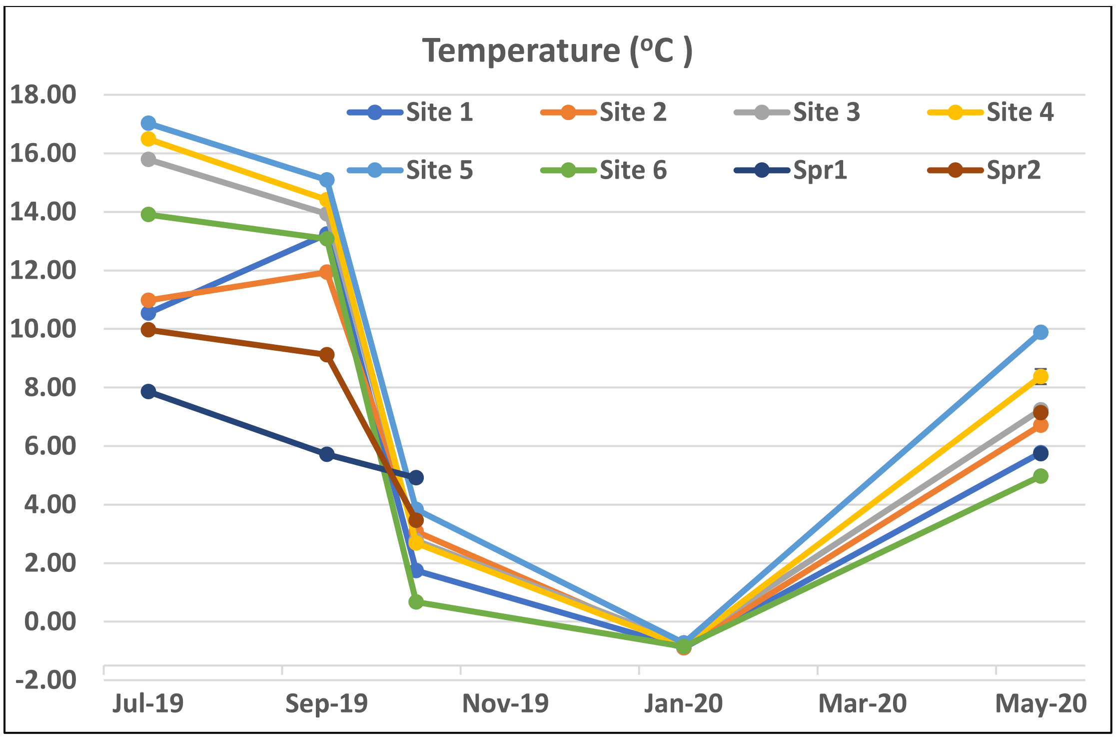

Figure 4. Day time water temperature (°C) in Bighill Creek in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

The day time surface water temperature was highest in July and lowest in January (Figure 4). In September, the water temperature at Site 2 (11.94°C) was lower than the temperatures measured at Site 1 (13.24°C) and Site 3 (13.94°C) on the same day. This is likely due to the contribution of cooler spring water from Spr1 (5.72°C), located upstream of Site 2 and at the main headwater for Bighill Springs. In October, the water temperature at Site 2 (3.08°C) was higher than the temperatures measured at Site 1 (1.74°C) and Site 3 (2.77°C). This is likely due to the contribution of warmer spring water from Spr1 (4.92°C).

4. Dissolved Oxygen

The most fundamental parameter in water, DO is essential for aquatic life and for the metabolism of all aerobic aquatic organisms. Its levels can decrease with excessive organic matter decomposition, plant and animal respiration, excessive growth of aquatic plants, and an increase in water temperatures can reduce its solubility in water. Sources of DO are from the atmosphere and from plant photosynthesis.

Day time DO in Bighill Creek ranged from 1.48 mg/L (Site 3 in January) to 19.05 mg/L (Site 3 in May), with a median of 11.79 mg/L (Figure 5). These concentrations were comparable to those recorded in 2017-18 (Fouli, 2018), and were also comparable to concentrations found at West Nose Creek at Big Hill Springs Rd in 2013 (Palliser Environmental, 2014). The City of Calgary recorded a median of 9.70 mg/L near Site 5 in their sampling program between 2000 and 2013 (City of Calgary, 2013).

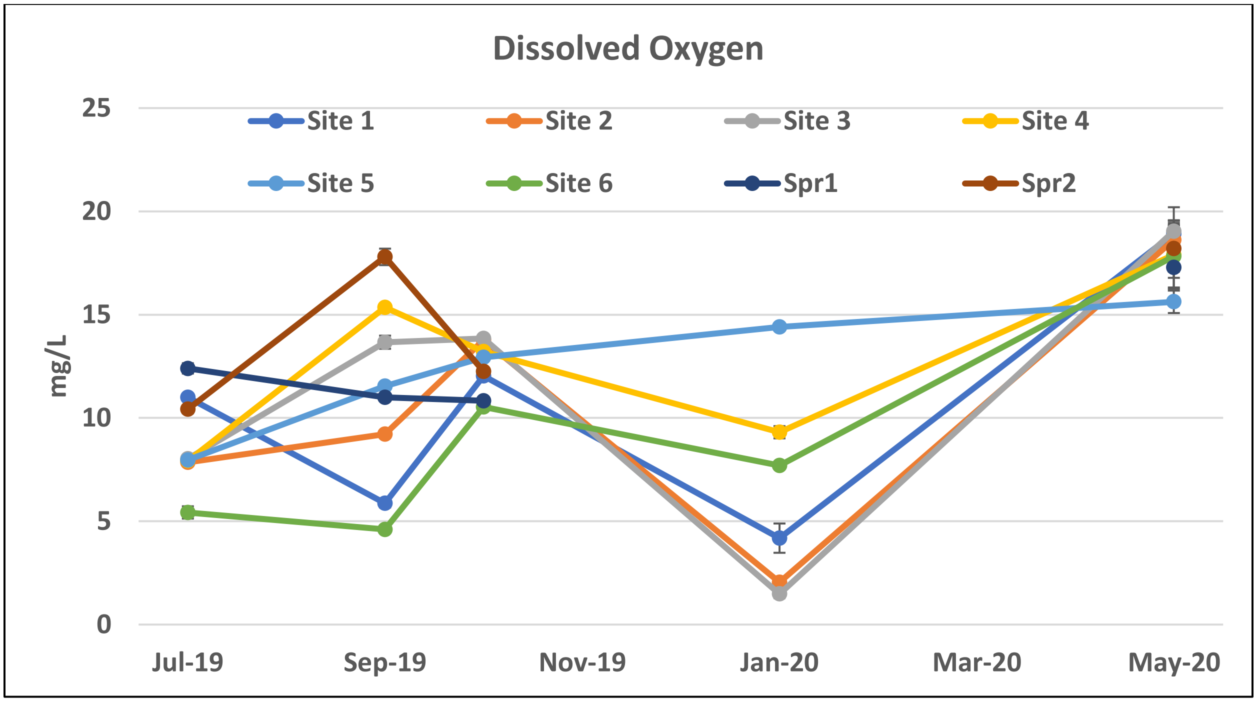

Figure 5. Day time dissolved oxygen (mg/L) in Bighill Creek surface water in July, September, and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

Most DO concentrations were above the Alberta acute (5.0 mg/L) and chronic (6.5 mg/L) guidelines as well as CCME cold water guidelines (9.5 mg/L for early life stages and 6.5 mg/L for other life stages) (CCME, 1999b). In January, concentrations of DO were below the cold water guidelines at Site 1, Site 2, and Site 3 (Figure 5). Low DO is usually associated with high water temperatures, high salinity and mineral content, and high aquatic organism respiration rates. Mineral content and concentration of total dissolved solids were relatively high as this Creek springs from groundwater which is generally higher in minerals than surface water during the winter. However, concentrations at these sites were not higher than at other sites with higher

DO levels. Most BOD concentrations were below detection limits in January except at Site 1 where more respiration occurred. The sites where lower DO concentrations were measured had lower BOD concentrations and less respiration, indicating that respiration does not explain the low DO concentrations at those sites. The reason for these extremely low DO concentrations remains unclear.

5. Biochemical Oxygen Demand

Water bodies produce and consume oxygen. They gain oxygen from the atmosphere and from plant photosynthesis. Respiration by aquatic organisms and decomposition consume oxygen. The BOD of a water body is the amount of DO consumed by microorganisms to metabolize organic matter. Sources of high BOD potentially include sewage treatment plant effluent, farmland runoff, feedlots, urban storm water runoff, failed septic tanks, among others. Pristine rivers generally have a 5-day BOD below 1 mg/L and moderately polluted rivers may have a BOD ranging from 2 to 8 mg/L (Connor, 2016). Treated municipal sewage would have a BOD below 20 mg/L whereas untreated sewage BOD could range between 200 mg/L (USA) and 600 mg/L (Europe) (Sawyer et al., 2003).

Concentrations of BOD in Bighill Creek ranged from below the detection limit (<2.0 mg/L for most sampling events) to 3.1 mg/L (Site 6 in May) (Figure 6). Most BOD concentrations were below the detection limit, which accounts for the uniform levels seen on Figure 6, except at Site 1 in July (2.3 mg/L), in January (2.3 mg/L), and in May at Site 1 (2.8 mg/L) and Site 6 (3.1 mg/L). Both in July and in May the Creek saw higher surface water flows due to precipitation and snowmelt runoff. Increased flow rates likely resulted in organic matter additions, confirmed by increased concentrations of TSS, TP and total TDP.

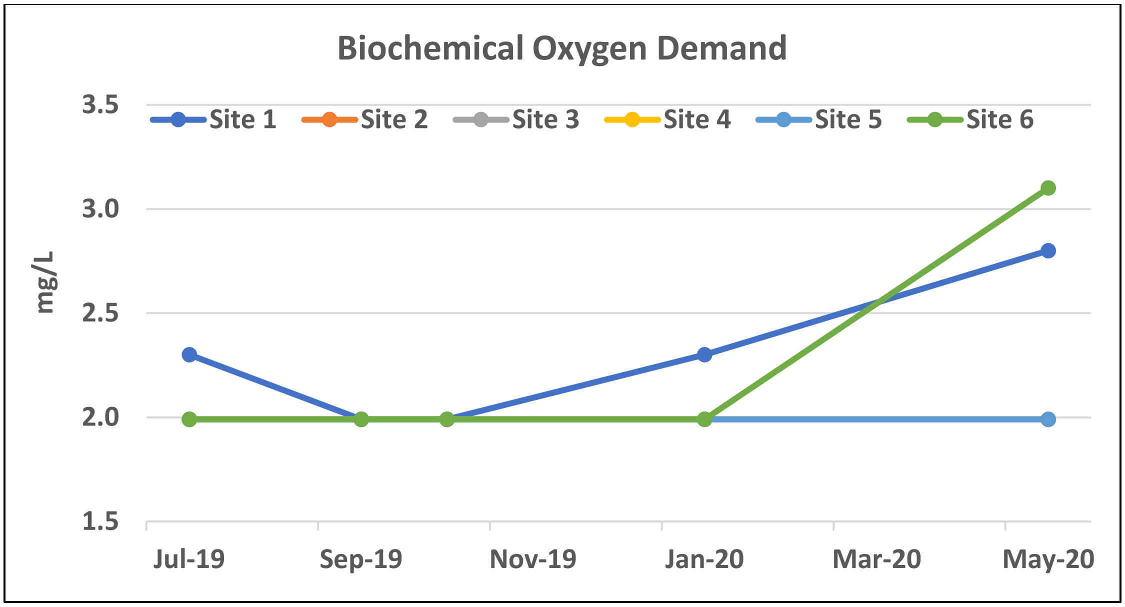

Figure 6. Biochemical oxygen demand (mg/L) in Bighill Creek surface water in July, September, and October 2019, January, and May 2020 at Sites 1-6. Detection limit was 2.0 mg/L. Concentrations at Sites 2-5 were below detection limits and are represented by the same line on this Figure.

6. Total Organic Carbon

Total Organic Carbon is an important parameter used to monitor overall levels of organic compounds present in surface water. Concentrations of TOC measured in Bighill Creek ranged from 2.7 mg/L (January at Site 2) to 21.0 mg/L (January at Site 6), with a median of 7.5 mg/L (Figure 7). These concentrations were higher than those recorded in 2017-18 (Fouli, 2018), but the median was comparable to that recorded by the City of Calgary (5.9 mg/L) near Site 5 between 2000 and 2013 (City of Calgary, 2013).

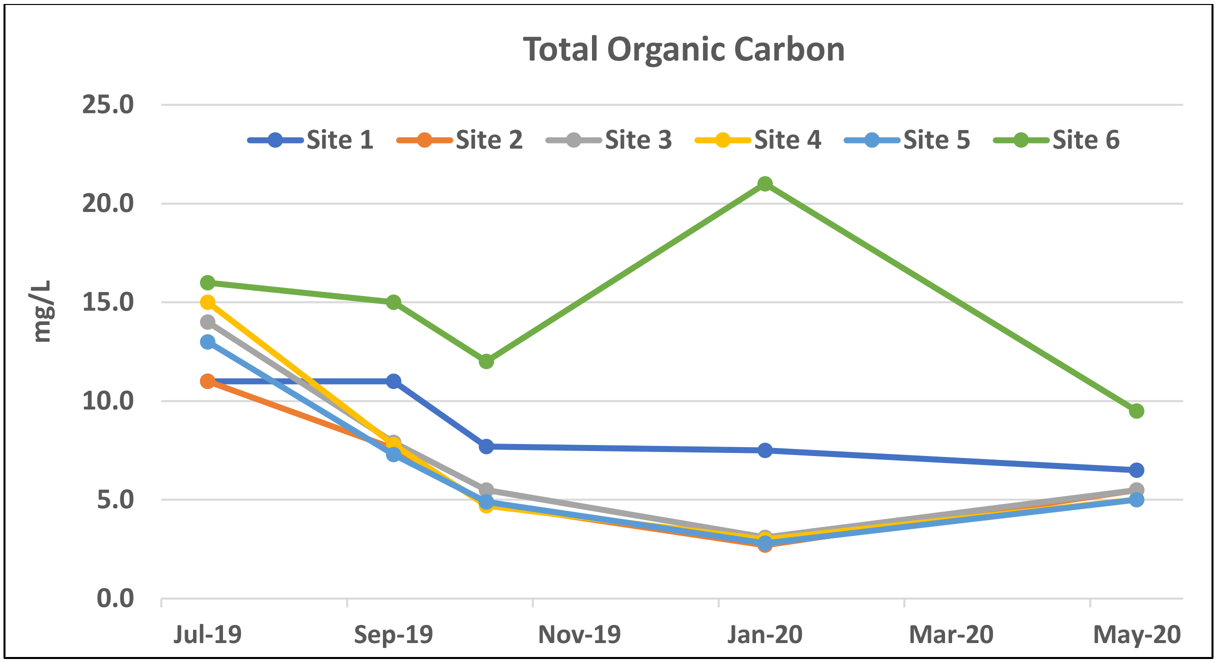

Figure 7. Total organic carbon (mg/L) in Bighill Creek surface water in July, September and October 2019, January, and May 2020 at Sites 1-6.

Concentrations of TOC generally decreased between July and May, except for concentrations measured at Site 6 which peaked in January (Figure 7). Concentrations at Site 6 were higher than all sites on all sampling dates and contributed to an increased median. Site 6 also exhibited higher concentrations of total Kjeldahl nitrogen, total ammonia nitrogen, total phosphorus, and total dissolved phosphorus compared to other sites, indicating that the organic matter inputs into the Creek are related to nutrient inputs. Site 6 is surrounded by farmland including cropland and animal farms: It is adjacent to a horse ranch and cropland, an equestrian centre is located to the north, a lambs farm to the north east, and a fertilizer company is located to the east of Site 6. These are sources of organic matter to the nearby Creek.

The concentration of TOC at Site 6 peaked in January (Figure 7). Although there was snow and ice at the Creek surface on the sampling date (10 January 2020), the surface of the Creek may not have been frozen all winter. Environment Canada (2020) historical weather data recorded at Springbank Airport, located approximately 21 km south of Site 6, showed that maximum air temperatures fluctuated between -10^{o}C and +5^{o}C for most of November 2019 to January 2020 (Figure 8). Between 1 November and 10 January, there were seven periods when maximum temperatures exceeded +5^{o}C. These temperatures may have resulted in melted snow and ice around the Creek and allowed snowmelt runoff and organic matter to be introduced into the Creek in January.

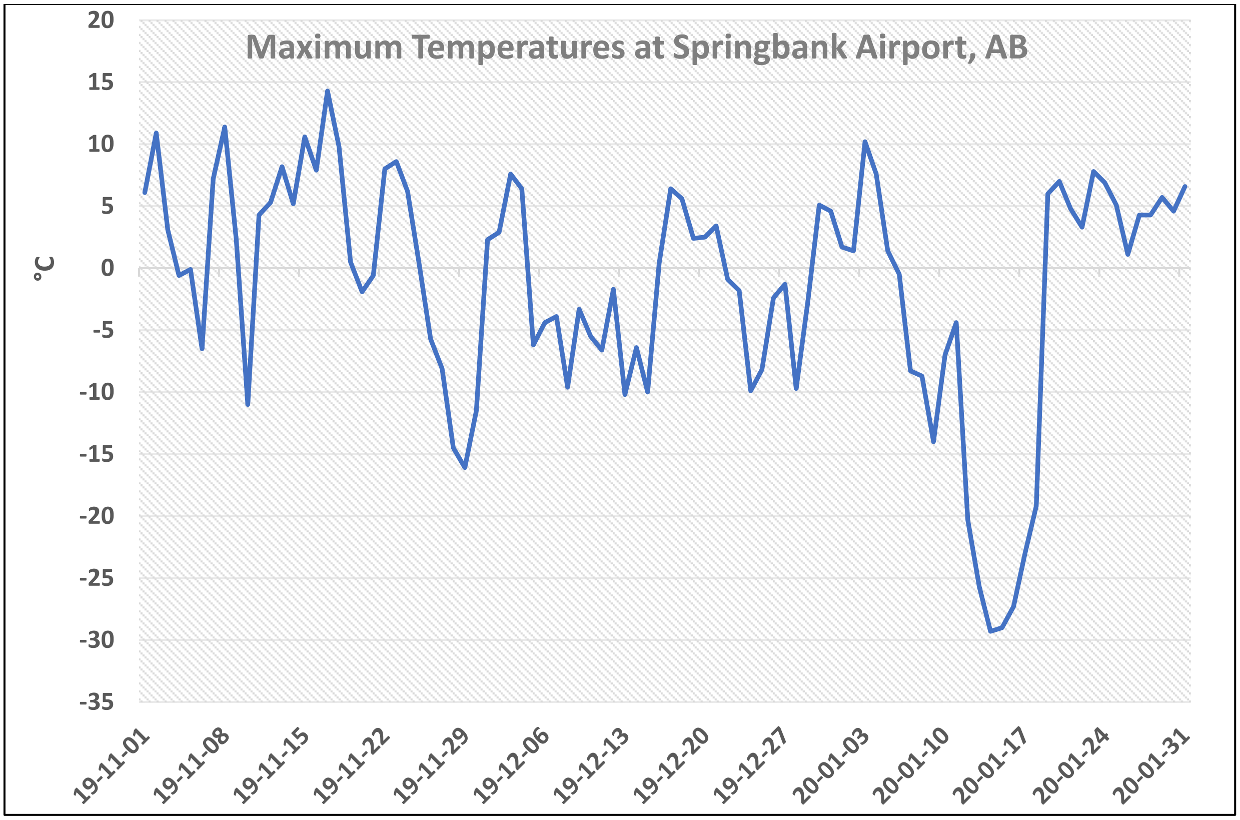

Figure 8. Maximum air temperatures at Springbank Airport, Alberta, between 1 November 2019 and 31 January 2020 (Environment Canada, 2020).

7. Total Dissolved Solids

Total dissolved solids (TDS) are a measure of inorganic salts and organic matter dissolved in water. They usually originate from natural sources, sewage, urban and agricultural runoff, and industrial wastewater. Depending on rock formations, the concentration of TDS in water can vary depending on the presence of carbonates, chlorides, calcium, magnesium, and sulphates. Concentrations of TDS were obtained from a conversion of conductivity calculated by the equipment. The guideline for livestock water is 3,000 mg/L and for irrigation water between 500 and 3,500 mg/L (AESRD, 2014).

Concentrations of TDS ranged from 180 mg/L (Site 1 in July) to 670 mg/L (Site 6 in January) with a median of 335 mg/L (Figure 9). All TDS concentrations were below both irrigation and livestock water guidelines. These concentrations were comparable to those recorded in 2017-18 (Fouli, 2018). They were also comparable to TDS concentrations measured at springs along the northern bank of the Bow River Valley at Glenbow Ranch Provincial Park (Hayashi and Morgan, 2015).

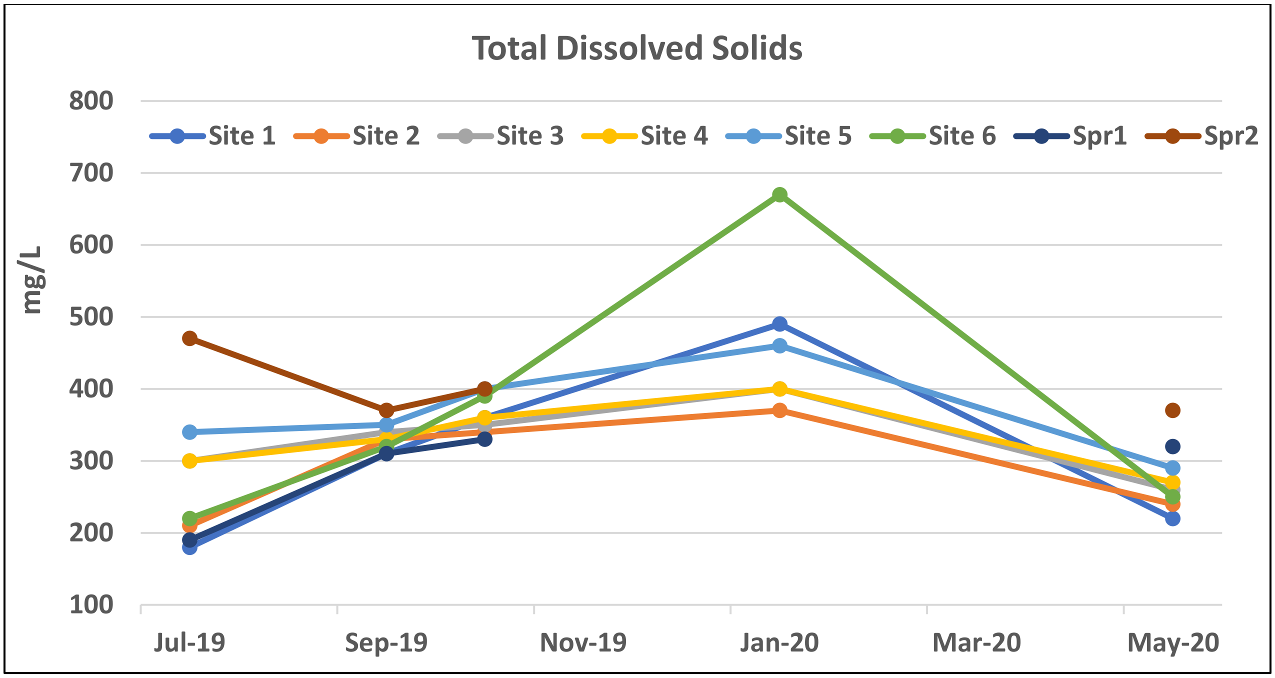

Figure 9. Total dissolved solids (mg/L) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

As in 2017-18, TDS concentrations generally remained within the 300-500 mg/L range with a slight increase in winter (Figure 9). During winter months, the main source of TDS is groundwater as snowmelt and rainfall runoff are generally insignificant. This indicates that in January the springs likely contributed to TDS concentrations, except at Site 6 where road salt likely contributed to the spike in concentrations.

8. Total Suspended Solids

Total suspended solids indicate the concentration of suspended particles in water such as fine silt and clay soil particles, organic matter, and micro-organisms. Suspended solids often carry nutrients and contaminants and in excess can be detrimental to aquatic life.

Concentrations of TSS in Bighill Creek ranged from 1.7 mg/L (Site 2 in September) to 52.0 mg/L (Site 5 in July), with a median of 6.6 mg/L (Figure 10). Concentrations were comparable to those recorded in 2017-18 (Fouli, 2018), and were also comparable to concentrations recorded by the City of Calgary (2013). Sosiak (2006) recorded a median TSS concentration of 6.8 mg/L in 2004 and 9.6 mg/L in 2005 in Grand Valley Creek located west of Cochrane.

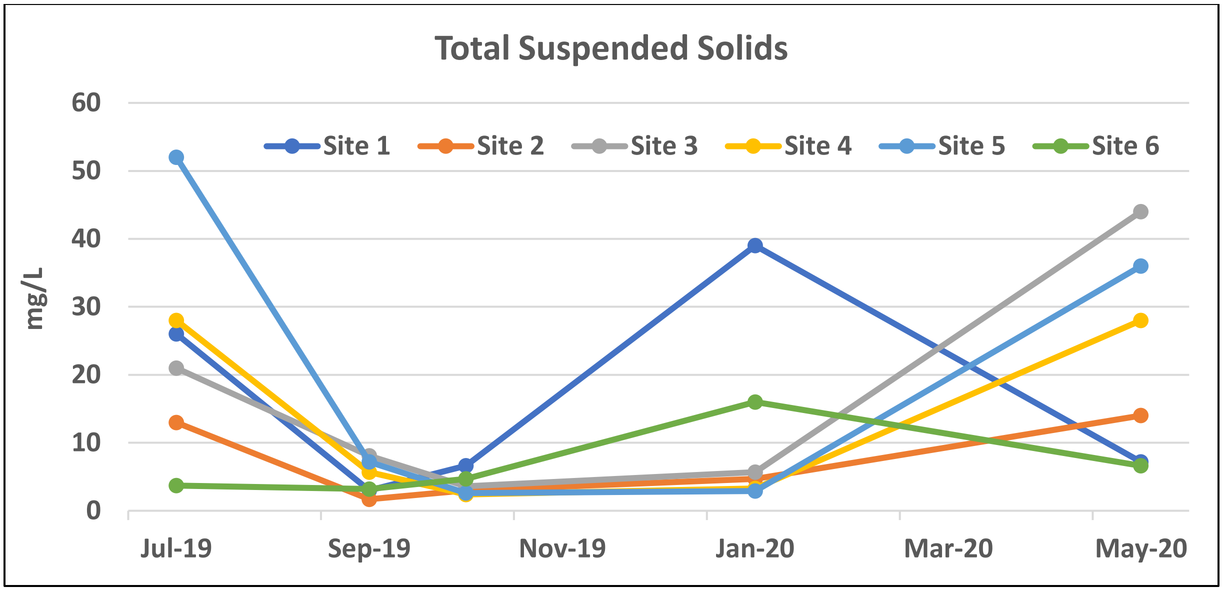

Figure 10. Total suspended solids (mg/L) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6.

Concentrations of TSS generally peaked in July and in May, likely due to spring snowmelt runoff events. In January, TSS concentrations were low except at Site 1 and Site 6 (Figure 10). This indicates a potential source of TSS located upstream and in the vicinity of these two sites. They are located north of the Bighill Springs valley in relatively flat lands surrounded by agricultural, commercial, and residential land uses. Organic parameters such as TOC, BOD and nutrients indicate the likely source of TSS is animal manure including horses, lambs, cattle, wildlife, birds, and domestic animals.

9. Electrical Conductivity

Electrical Conductivity is a measure of the ability of water to conduct an electric current. It is an indication of total dissolved solids and the sum of anions and cations as they conduct an electric current.

Electrical conductivity is dependent on temperature and was standardized to 25°C using the equation in Mutual and Hayashi (2014). Electrical conductivity at Bighill Creek ranged from 370 µS/cm (Site 1 and Spr1 in July) to 1200 µS/cm (Site 6 in January) with a median of 615 µS/cm (Figure 11). These values were comparable to those recorded in 2017-18 (Fouli, 2018). Most EC values were below the irrigation guideline of 1000 µS/cm (AESRD, 2014). Mutual and Hayashi (2014) reported EC values of 426 – 1313 µS/cm at springs in Glenbow Ranch Provincial Park. Sosiak (2006) reported comparable values in Grand Valley Creek, Alberta.

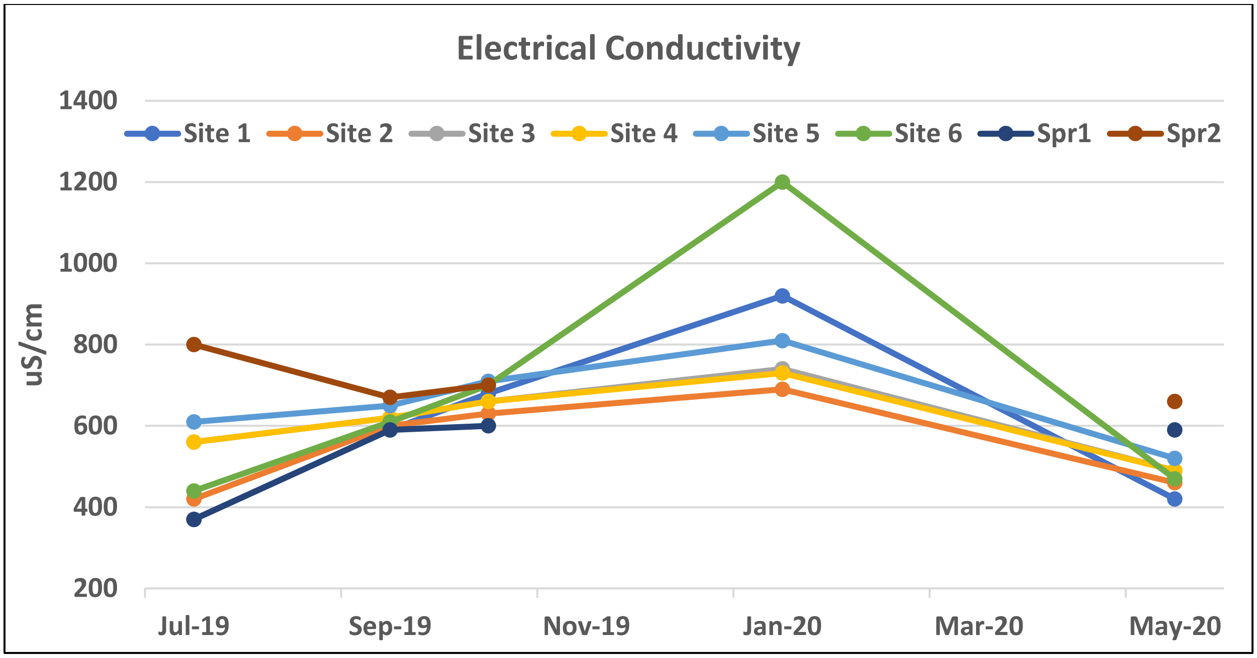

Figure 11. Electrical conductivity (mS/cm) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

Higher EC values at Spr2 in July may be a combination of groundwater minerals as well as minerals originating from rainfall runoff. High EC at Site 6 in January indicate a source of minerals such as road salts upstream of this sampling location.

10. True Colour

The colour of water can be used as an indicator for environmental impacts such as changes in physical, chemical, and biological characteristics of a watercourse arising from anthropogenic activities. Studies have shown a positive correlation between water colour and primary production in freshwater (Del Giogio and Peters, 1994). The colour of light and turbidity of water determine the depth of penetration of light in water. True colour depends on the dissolved fraction of water which can include natural minerals and dissolved organic substances. Colour also depends on factors affecting the solubility and stability of the dissolved and particulate fractions of water such as pH and temperature.

True colour measured in Bighill Creek ranged from 7.0 PtCo units (Site 2 in January) to 97.0 PtCo units (Site 6 in July), with a median of 32.0 PtCo units (Figure 12). These values were higher than those recorded in 2017-18 (median of 9 PtCo units), likely due to the introduction of Site 6 where true colour values were higher than other sites across all sampling events (Figure 12). Site 6 exhibited higher TOC and nutrients which resulted in higher true colour values.

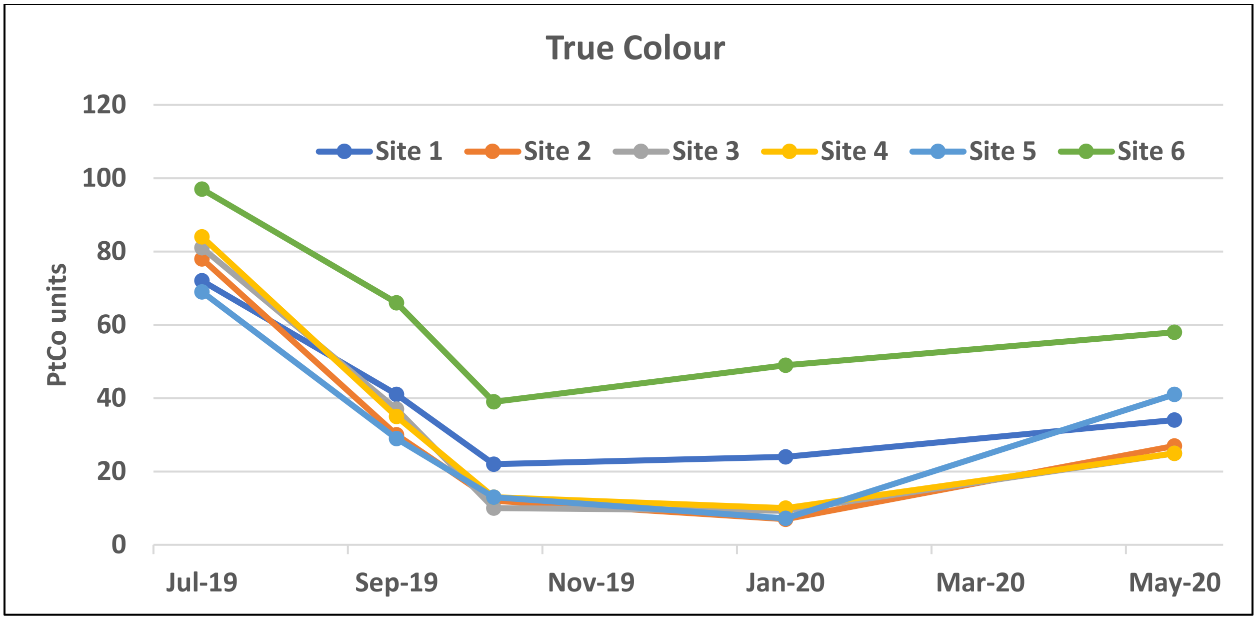

Figure 12. True colour (PtCo units) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

True colour values were highest in July across all sites, indicating higher turbidity as a result of high surface water flows due to rainfall and snowmelt runoff.
The City of Calgary (2013) recorded a mean of 20.1 PtCo units near Site 5 over the years 2000-2013.

11. Chlorophyll a

Chlorophyll a is an estimate of phytoplankton biomass in freshwater. It estimates the amount of algae floating in the water column and indicates whether nutrients such as phosphorus (P) and nitrogen (N) may be in excess. According to AESRD (2013), chlorophyll concentrations above 25 µg/L indicate a hypereutrophic environment with very high productivity, 8-25 µg/L indicate a eutrophic environment that is highly productive, 2.5-8 µg/L indicate a mesotrophic environment that is moderately productive, and below 2.5 µg/L indicate an oligotrophic environment that has low productivity.

Chlorophyll concentrations in Bighill Creek ranged from 0.66 µg/L (Site 2 in January) to 21.00 µg/L (Site 1 in May) with a median of 3.33 µg/L (Figure 13). These concentrations were comparable to those recorded in 2017-18 (Fouli, 2018).

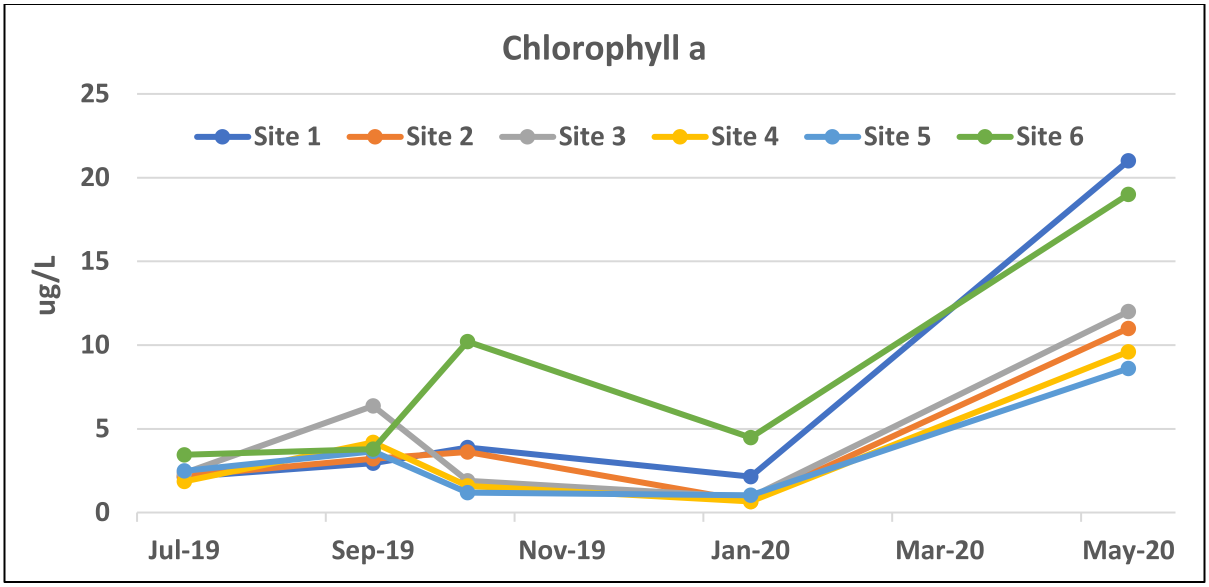

Figure 13. Chlorophyll (µg/L) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6.

Most concentrations were in the mesotrophic zone except a few in the oligotrophic zone (July, October, and January) and a few in the eutrophic zone (Site 6 in October and all samples measured in May). A eutrophic environment indicates potential excess in nutrient concentrations. This is confirmed with elevated concentrations of TKN, TAN, and TP at Site 6 in October, resulting in elevated chlorophyll concentrations. Despite elevated nutrient levels in January, chlorophyll a concentrations were lower than in October, likely due to lower water temperatures and little sunlight under the snow and ice covering the water surface.

Chlorophyll median concentration in May (11.5 µg/L) was higher than the total median, indicating a eutrophic environment. Higher runoff and an increase in nutrients and organic matter from snowmelt likely resulted in this increase.

12. Fecal Coliforms

Fecal coliforms are bacteria that generally originate in the intestines of warm-blooded animals. Their presence in an aquatic environment indicates that the water has been contaminated with fecal material of man or other animals. They are an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste. For irrigation and contact recreation uses, the guidelines are 100 and 200 organisms in 100 mL, respectively.

Fecal coliform counts in Bighill Creek ranged from 0.9 Most Probable Number (MPN)/100 mL (Spr1 in May) to over 2400 MPN/100 mL (Site 1 and Spr1 in July) with a median of 49.5 MPN /100 mL (Figure 14). This median was 3.8 times the median recorded in 2017-18 (Fouli, 2018). This indicates a significant increase in fecal coliform counts since 2017. The City of Calgary (2013) measured total coliforms and recorded a median of 1251.5 MPN/100 mL during its sampling program near Site 5. Sosiak (2006) reported fecal coliform counts in Grand Valley Creek reaching 10,000 and 22,000 in spring 2004 which likely reflected spring runoff from agricultural land uses.

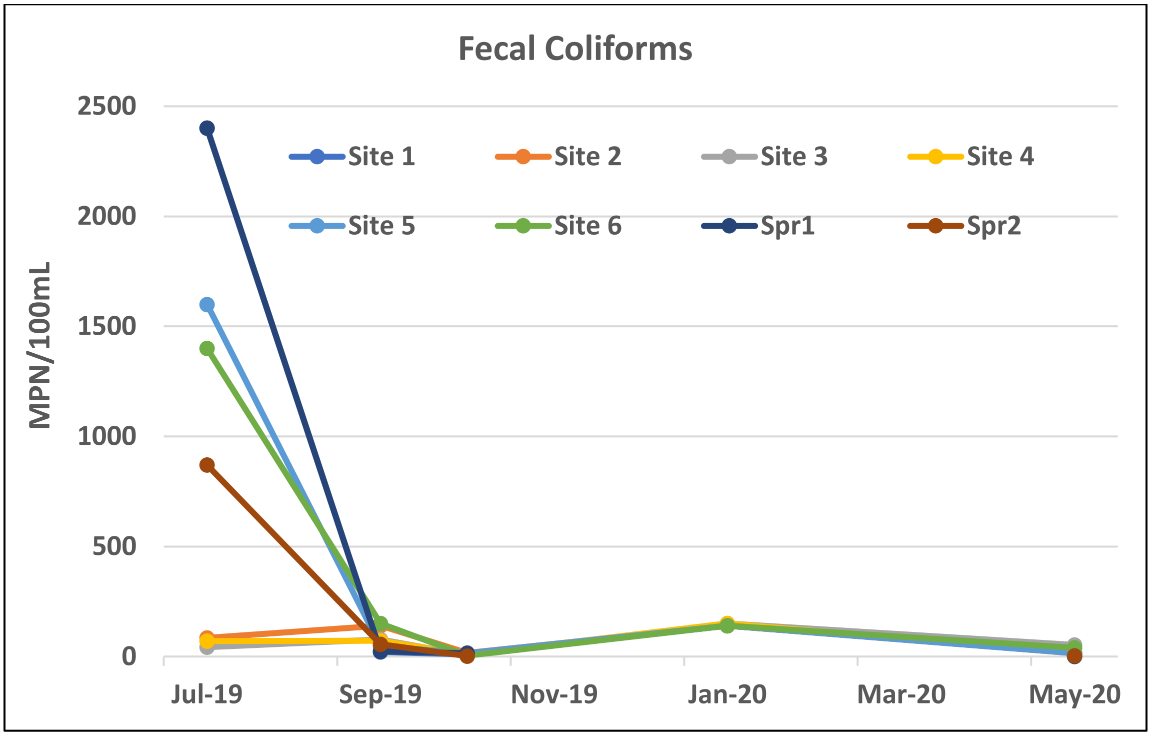

Figure 14. Fecal coliform counts (Most Probable Number/100 mL) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr 1-2.

Counts in July were higher than other sampling dates, likely due to spring snowmelt and rainfall runoff. Counts were especially high at Site 1 (>2400 MPN/100 mL), Spr1 (>2400 MPN/100 mL), Site 5 (1600 MPN/100mL) and Site 6 (1400 MPN/100). Land uses near and upstream of these sites increased fecal coliform levels, likely through the movement of runoff from animal manure including horses, cattle, lambs, wildlife, birds, and domestic animals. This is reflected in high nutrient concentrations described below.

13. Nutrients

1. Total Phosphorus

An essential nutrient for all living organisms, P plays a major role in biological metabolism. Compared to other macronutrients, it is the least abundant in water bodies (Wetzel, 2001). Water bodies containing low P concentrations can support relatively diverse and abundant aquatic life. However, elevated P concentrations can adversely affect aquatic ecosystems (Chambers et al., 2001). Sources include P in soils and sediments, atmospheric deposition, animal manures, mineral fertilizers, failed septic systems, sewage treatment plants, and in urban runoff.

Total phosphorus consists of particulate and dissolved forms of P, both organic and inorganic. The previous guideline for TP (0.05 mg/L) has been withdrawn and narrative statements have been developed based on a use-protection approach to protect aquatic life (AESRD, 2014). Concentrations "should be maintained so as to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality. Where priorities warrant, develop site-specific nutrient objectives and management plans" (AESRD, 2014).

Concentrations of TP at Bighill Creek ranged from below the detection limit (<0.0030 mg/L at Spr1 in September and October) to 0.1700 mg/L (Site 6 in May) with a median of 0.0310 mg/L (Figure 15). These concentrations were comparable to those recorded in 2017-18 (Fouli, 2018). The City of Calgary (2013) recorded a median of 0.04 mg/L near Site 5. Concentrations of TP were also comparable to those measured in Grand Valley Creek in 2004 and 2005 (Sosiak, 2006).

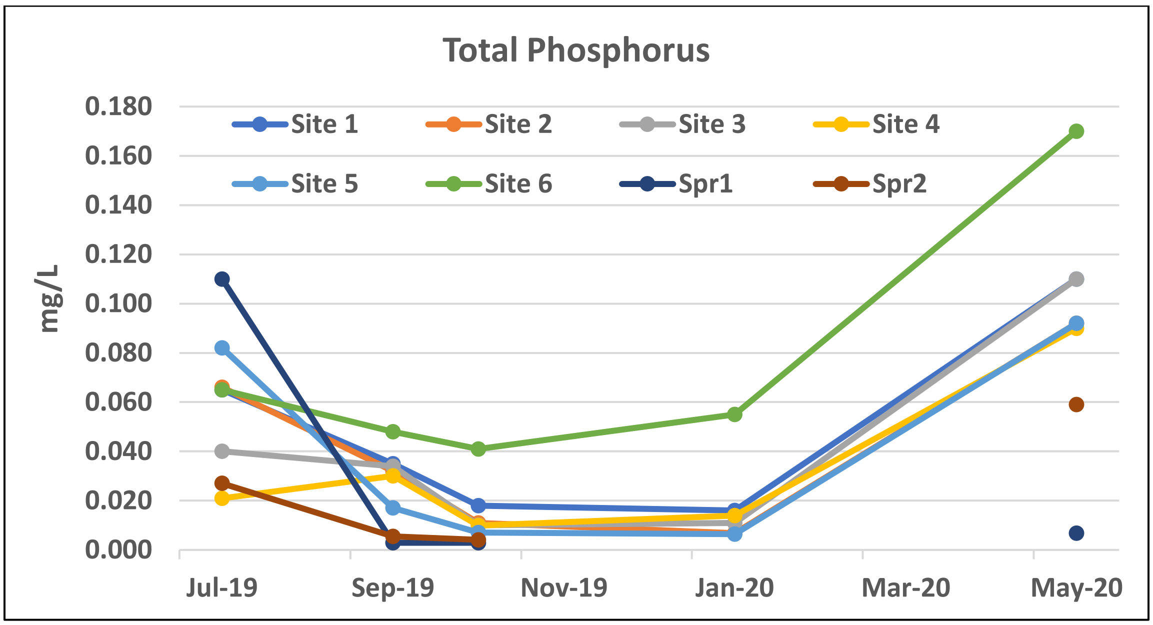

Figure 15. Total phosphorus (mg/L) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

The general trend of the data was similar to that found in 2017-18 with increased TP concentrations in spring. Concentrations of TP were likely abundant in snowmelt and rainfall runoff, resulting in higher concentrations in May. In addition, TP was higher at Site 6 in September, October, January, and May, indicating a source of TP in the vicinity and/or upstream of Site 6.

As with fecal coliform results, concentrations of TP were higher at Spr1 than at other sites in July. Spr1 is located at the main headwaters of the Bighill Springs and the water is considered pristine. However, these data indicate there is a source of fecal coliforms and TP upstream of Spr1 such as animal manure.

2. *Total Dissolved Phosphorus*

Total dissolved phosphorus (TDP) is a highly reactive form of P that is quickly absorbed by aquatic plants and algae. It is therefore a better measure of P available for plant and algal growth compared to TP.

Concentrations of TDP in Bighill Creek ranged from below the detection limit (<0.0030 mg/L at Spr1 in September, October and May, and Spr2 in October) to 0.1500 mg/L (Site 6 in May), with a median of 0.0180 mg/L (Figure 16). This median was 3.7 times the median recorded in 2017-18 (0.0047 mg/L) (Fouli, 2018), indicating an increase in TDP concentrations since 2017. This median was also comparable to the median found in Grand Valley Creek in 2004 (Sosiak, 2006). More recently, the City of Calgary recorded a median of 0.02 mg/L near Site 5 (City of Calgary, 2013).

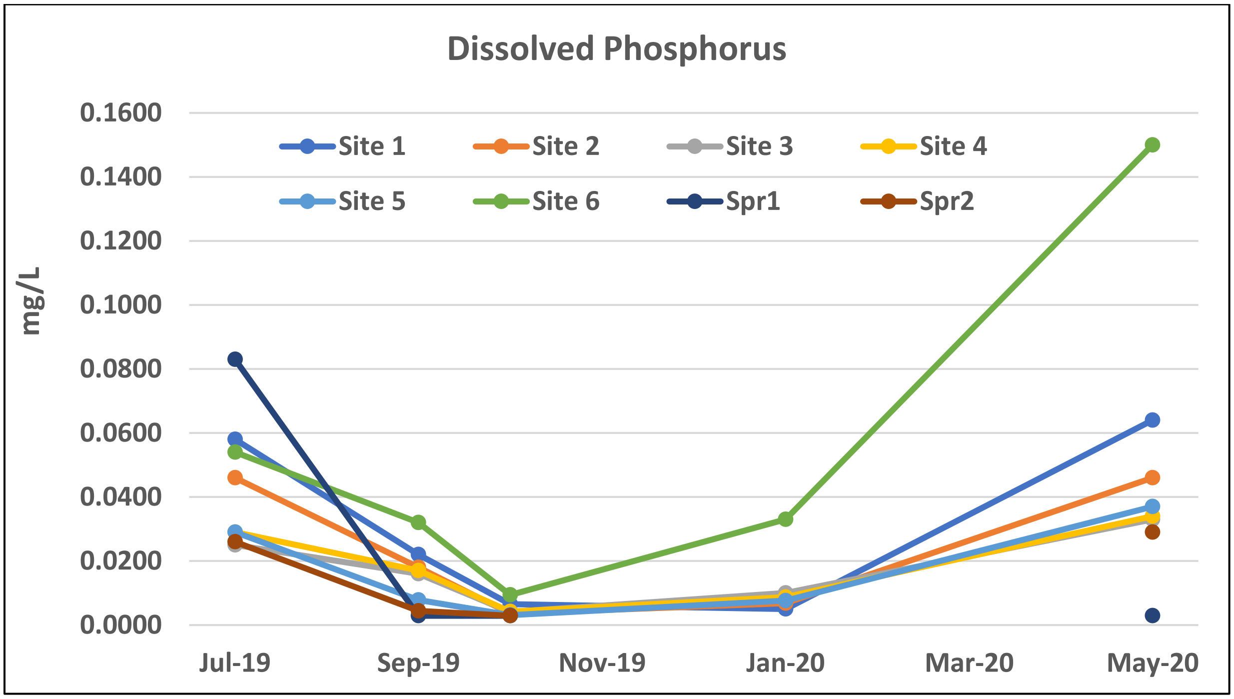

Figure 16. Total dissolved phosphorus (mg/L) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

As in 2017-18, TDP concentrations peaked during rainfall and snowmelt runoff events in July and May (Figure 16). In four out of five sampling events, the highest concentrations were measured at Site 6, indicating a source of TDP in the vicinity and/or upstream of Site 6.

As with fecal coliform and TP results, concentrations of TDP were higher at Spr1 than other sites in July. These data indicate there is a source of fecal coliforms, TP and TDP upstream of Spr1 such as animal manure.

3. Total Kjeldahl Nitrogen

Nitrogen is another essential nutrient for all forms of life including aquatic plants and animals. Elevated N concentrations can result in eutrophication and excessive growth of algae and aquatic plants. Sources of N include atmospheric deposition, municipal and industrial wastewater, septic tanks, and runoff from farm fields where animal manure or mineral fertilizers are applied. The Kjeldahl procedure is a digestion that releases N from all N containing compounds in the sample and is essentially an indicator of total N present (excluding nitrate+nitrite).

Concentrations of TKN in Bighill Creek ranged from below the detection limit (<0.050 mg/L at Spr1 in September and October) to 2.8 mg/L (Site 6 in January), with a median of 0.68 mg/L (Figure 17). The median was 1.7 times the median recorded in 2017-18 (Fouli, 2018), indicating an increase in the nitrogen content of the water since 2017. Sosiak (2006) measured TKN concentrations in Grand Valley Creek and recorded a median of 0.3-0.7 mg/L in 2004 and 2005. The City of Calgary (2013) recorded a median of 0.25 mg/L near Site 5.

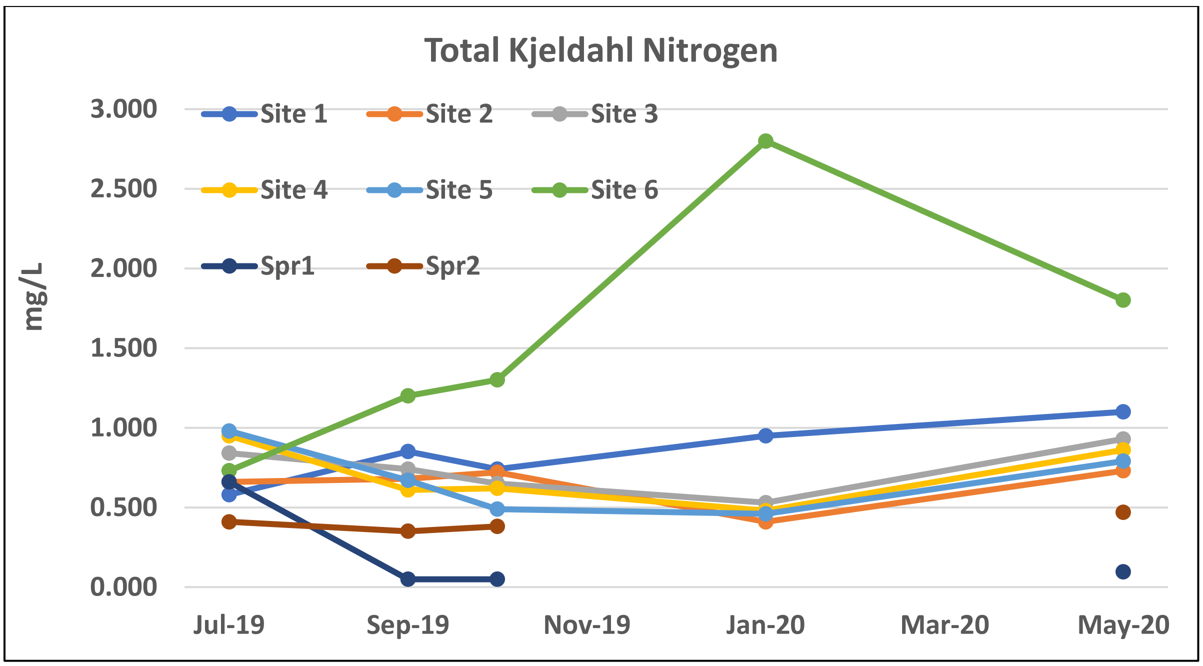

Figure 17. Total Kjeldahl nitrogen (mg/L) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

Median TKN concentrations in July and May were 0.70 mg/L and 0.83 mg/L, respectively, indicating a relatively small increase in TKN concentrations between July 2019 and May 2020 (Figure 16). However, concentrations at Site 6 shaped the data as they were the highest in four out of five sampling events. This was also the case for TOC, true colour, TP, and TDP. In addition, both TOC and TKN concentrations at Site 6 peaked in January (Figure 17). Temperature fluctuations during the fall and winter may have resulted in snowmelt runoff, allowing organic matter and nitrogen to enter the Creek from surrounding agricultural and industrial land uses.

4. Nitrate + Nitrite Nitrogen

Nitrate and nitrite N are often measured together due to the instability of nitrite in the presence of oxygen and its low concentrations. Although nitrate is required for plant growth, elevated concentrations can result in detrimental eutrophication of the aquatic system.

Nitrate + nitrite concentrations in Bighill Creek ranged from below the detection limit (<0.014 mg/L at Site 6 and Site 3 in July) to 2.9 mg/L (Spr1 in September and October) with a median of 0.60 mg/L (Table 2). These concentrations were approximately half those recorded in 2017-18 (Fouli, 2018), indicating a decrease in nitrate + nitrite concentrations since 2017. However, the median was higher than the median recorded by the City of Calgary (2013) near Site 5 (0.25 mg/L).

The elevated concentrations in January at Site 2, Site 3, Site 4 and Site 5, the elevated concentrations at Spr1 and Spr2 in July, September, October and May, as well as the relatively low concentrations at Site 1 and Site 6 indicate a groundwater contribution of nitrate + nitrite to the Creek. This was also reported during phase I of this study in 2017-18.

5. Total Ammonia Nitrogen

Known for its suffocating odour at ambient temperature and pressure, ammonia is an important source of available N in the environment because it is oxidized by microorganisms during nitrification (Weil and Brady, 2017). Ammonia is therefore produced by the decomposition of organic matter. It comes in two forms: ammonium is the cation and ionized form NH_4^+ whereas ammonia is the non-ionized form NH_3. The latter is the toxic form of ammonia N. Total ammonia N is found mainly in municipal and industrial wastewater effluent and in runoff downstream of intense manure or mineral fertilizer use. The guideline varies with pH and temperature (CCME, 2010).

Concentrations of total ammonia nitrogen (TAN) in Bighill Creek ranged from below the detection limit (<0.015 mg/L at Spr1 in September and Spr2 in May) to 1.40 mg/L (Site 6 in January) with a a median of 0.068 mg/L (Figure 18). This median was 2.3 times the median recorded in 2017-18 (Fouli, 2018), indicating an increase in TAN concentrations in the Creek since 2017. These concentrations were also higher than those recorded by the City of Calgary (2013) near Site 5 (median 0.02 mg/L). All TAN concentrations were below CCME guidelines.

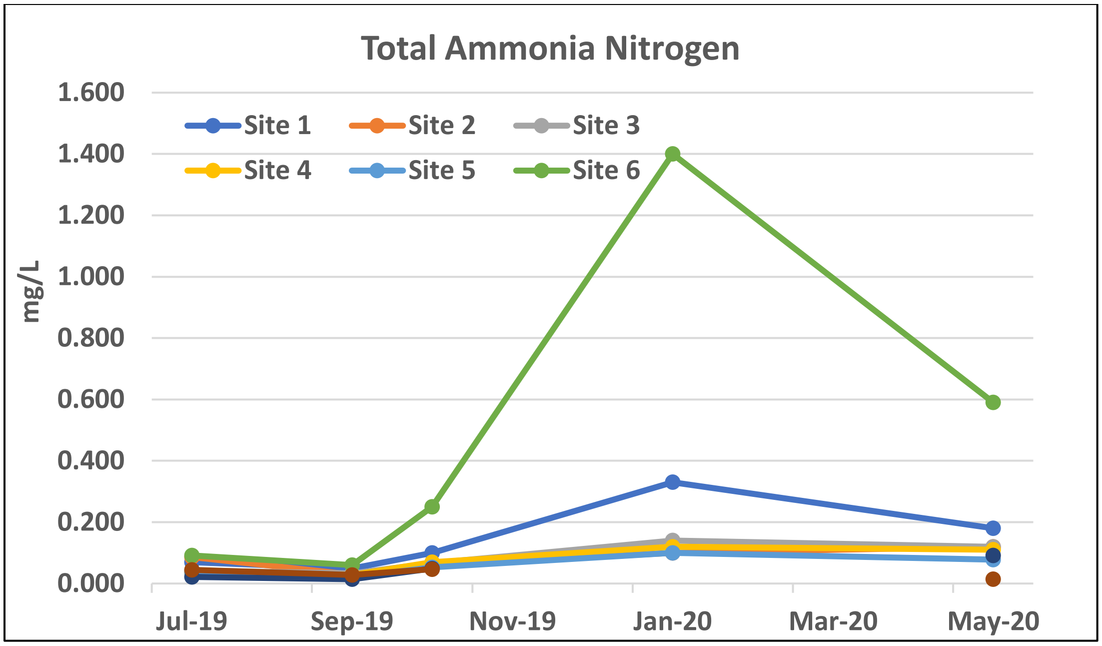

Figure 18. Total ammonia nitrogen (mg/L) in Bighill Creek surface water in July, September and October 2019, January and May 2020 at Sites 1-6 and Spr1-2.

Concentrations of TAN generally remained low except at Site 6 and Site 1 where concentrations dominated during all sampling events and particularly in January (Figure 18). This follows the same pattern as concentrations of TOC and TKN. The source of TAN is therefore in the vicinity and/or upstream of Site 6 which is surrounded by residential, agricultural, and industrial land uses.

14. Total Metals

Metals occur naturally in aquatic systems as a result of soil and rock weathering, and volcanic eruptions. Major anthropogenic sources include mining and metal processing, industrial fossil fuel combustion, transportation emissions, waste incineration, industrial waste, agricultural runoff, paints, treated timer and other sources. In a low pH environment, metals are more soluble and mobile and toxicity levels increase (Simate and Ndlovu, 2014).

Total metal concentrations in Bighill Creek are presented in Table 3. All total metal concentrations were below the guidelines (Government of Alberta, 2018).

15. Phenols

Phenols are chemicals that consist of a hydroxyl group bonded directly to an aromatic hydrocarbon group. They occur naturally in amino acids, hormones, serotonin, in plants and end up in trace amounts in aquatic environments as a result of the decomposition of aquatic vegetation. Major anthropogenic sources include domestic sewage and industrial effluents such as the pulp and paper, wood, steel and metal, and petroleum industries (Environment Canada, 1997). Once phenols reach water systems, their major fate processes are photooxidation,

oxidation, and microbial degradation. The guideline for the protection of aquatic life is 0.004 mg/L (CCME, 1999c).

Concentrations of phenols in Bighill Creek ranged from below the detection limit (<0.0015 mg/L for over half the sampling events) to 0.0078 mg/L (Site 6 in May), with a median of 0.0014 mg/L (Figure 19). These concentrations were lower than those recorded in 2017-18 (Fouli, 2018), indicating a decrease in phenol concentrations since 2017.

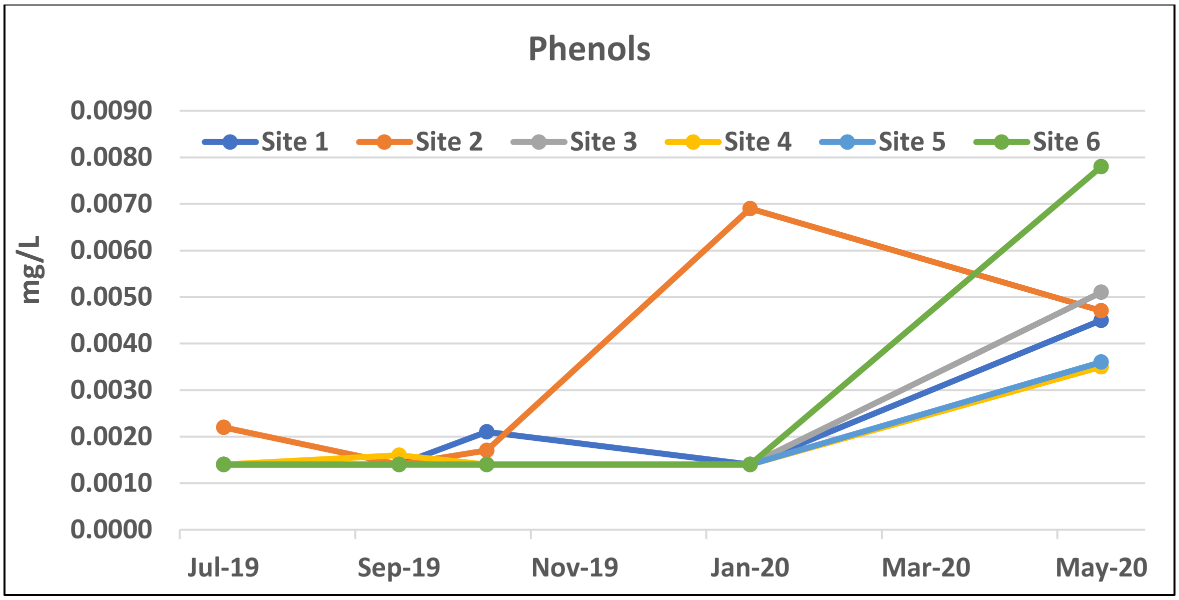

Figure 19. Phenols (mg/L) in Bighill Creek surface water in July, September and October 2019, January, and May 2020 at Sites 1-6. Detection limit was 0.0015 mg/L.

All phenol concentrations measured between July and October were below the guideline, as well as all but one concentration in January (Site 2). The concentration of phenols peaked at Site 2 in January. The reason for this exceedance is unclear.

Most phenol concentrations in May were above the guideline. Spring snowmelt runoff may have brought phenol-containing residential or industrial effluents as well as naturally occurring phenols into Bighill Creek.

Photo 5. Site 2 in January 2020. Facing upstream. Dr. Ken Stevenson breaks the ice covering the Creek surface.

Photo 6. Site 2 in May 2020. Facing downstream.

Sediments

Sediments are organic and inorganic materials that constitute the bed of a stream or river. They originate from erosion of minerals surrounding the stream and are deposited through sedimentation. They include mineral matter such fine clay, silt, and sand, coarse materials such as gravel, cobbles and boulders, and bedrock. They also include organic matter such as aquatic plants, animal matter, pieces of vegetation such as leaves and branches. Large material can affect flow patterns and microhabitats. Their degradation results in the formation of organic particles and the release of dissolved nutrients and organic matter. They may act as a source of chemicals (nutrients and potential contaminants) to aquatic organisms. Sediment diversity of shapes and sizes can provide a range of surfaces available for colonization, habitat formation, and flow patterns, resulting in a diverse and abundant aquatic life.

1. Texture

Aquatic plants and microorganisms depend on carbon and mineral nutrients for their sustenance. These nutrients are often adsorbed to sediment surface areas. Clay particles have a higher surface area than silt or sand particles, and higher clay content generally means more organic matter and nutrients can be adsorbed and available for freshwater life.

Sediment texture was measured in July, September, October and May at Site 1, Site 5, Site 6 and Site 7 and ranged from clay (Site 6) to loamy sand (Site 5) (Table 4). During phase I of this study in 2017-18, the texture ranged from loam to sandy loam. The larger number of sediment sample locations and events in 2019-20 revealed a wider range of sediment textures.

2. Salinity

Alberta is known for its marine evaporite salt deposits (Dumont, 2008). The southern portion of the prairie provinces has naturally elevated salinity and high TDS (CEPA, 1999) due to high concentrations of sodium, bicarbonate, sulphate, and chloride (Last and Ginn, 2005).
As with water salinity, sediment salinity can affect aquatic plant growth. The concentrations of salts were measured for Bighill Creek sediments and are presented in Table 5.

Soluble chloride concentrations exceeded the guideline (120 mg/L) at Site 5 in September (130 mg/L) and Site 7 in May (150 mg/L) (Table 5). These sites are located within the Town of Cochrane. Above background concentrations are common in populated areas with dense roadways, and chloride concentrations are a common indicator of increasing urbanization.

3. Nutrients

The concentration of nutrients in aquatic sediments plays an important role in aquatic plant growth. Rattray et al. (1991) found that where nutrients in water were limited (oligotrophic conditions) plants turned to sediments to find their nutrients, and where the water was rich in nutrients (eutrophic conditions) plants did not take up sediment nutrients.

Available nutrient concentrations in Bighill Creek sediments were measured in July, September, October 2019, and in May 2020 at Site 1, Site 5, Site 6, and Site 7.

1. *Available Nitrogen*

All available N concentrations in Bighill Creek Sediments were below the detection limit (<2.0 mg/kg) except at Site 7 in September when available N concentration reached 2.4 mg/kg (Figure 20).

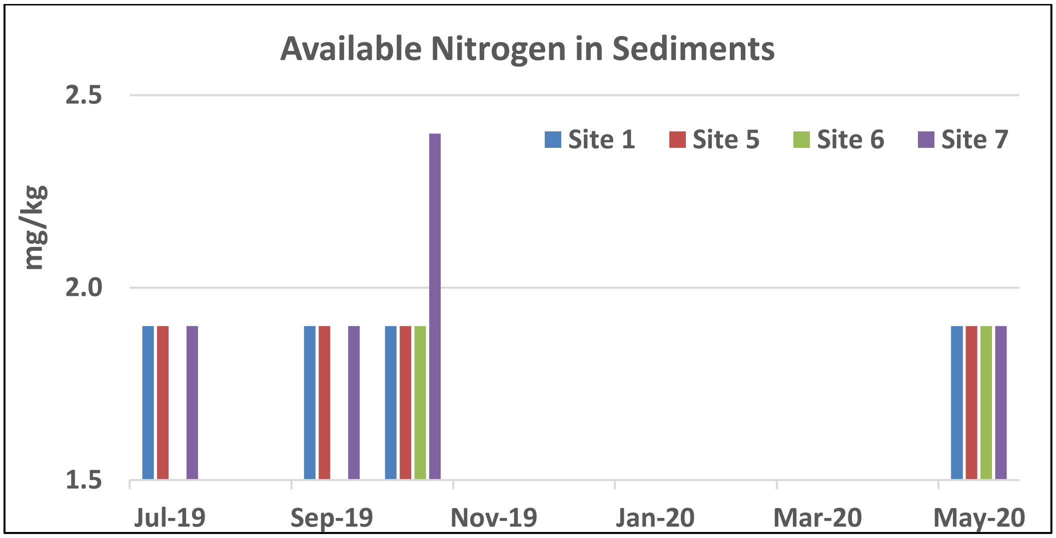

Figure 20. Available nitrogen (mg/kg) in Bighill Creek sediments in July, September, October 2019 and May 2020 at Site 1, Site 5, Site 6, and Site 7.

Photo 7. Site 3 in May 2020. Facing downstream.

2. Available Phosphorus

Available P concentrations measured in Bighill Creek sediments ranged from below the detection limit (<1.0 mg/kg) to 6.4 mg/kg (Site 1 in July) with a median of 1.1 mg/kg (Figure 21). These concentrations were comparable to those recorded in 2017-18 when the median was 1.2 mg/kg (Fouli, 2018).

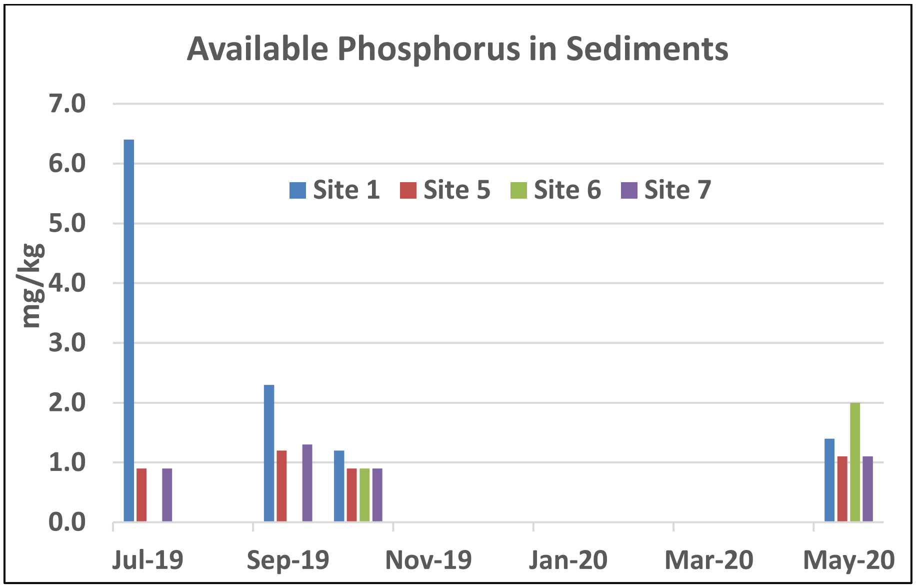

Figure 21. Available phosphorus (mg/kg) in Bighill Creek sediments in July, September, October 2019 and May 2020 at Site 1, Site 5, Site 6, and Site 7.

Photo 8. Spr2 in May 2020. Facing upstream.

3. Available Potassium

Available potassium concentrations in Bighill Creek sediments ranged from 55 mg/kg (Site 7 in July) to 420 mg/kg (Site 6 in May) with a median of 110 mg/kg (Figure 22). These concentrations were comparable to those recorded in 2017-18 when the median was 109 mg/kg (Fouli, 2018).

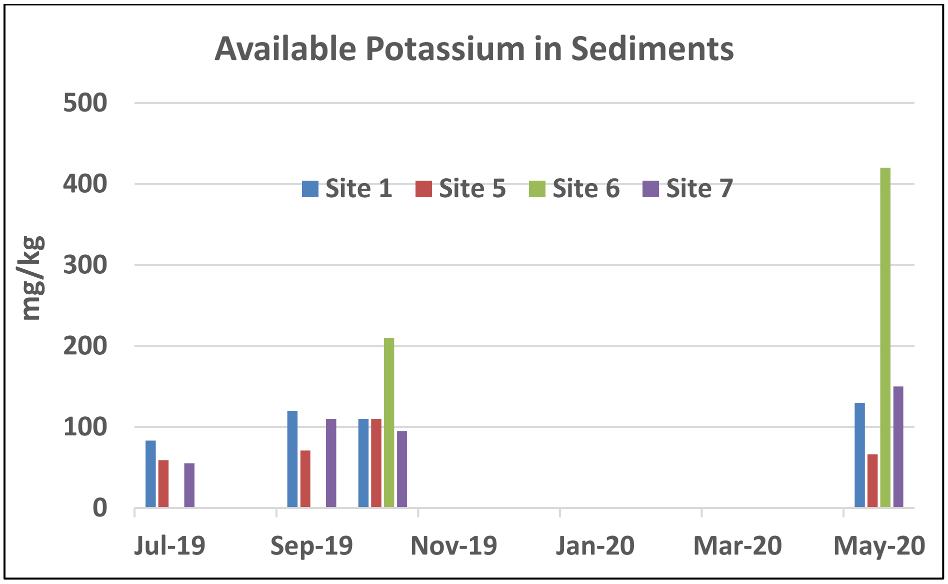

Figure 22. Available potassium (mg/kg) in Bighill Creek sediments in July, September, October 2019 and May 2020 at Site 1, Site 5, Site 6, and Site 7.

Concentrations of available potassium at Site 6 were significantly higher than concentrations at other sites. This may be due to the clay texture of sediments at Site 6 as potassium can be adsorbed to, or released from, the surface of clay particles.

Photo 9. Site 4 in October 2019. Facing upstream.

4. Total Metals

Metals can find their way to aquatic sediments naturally or anthropogenically, via point and nonpoint sources. Guidelines vary depending on the metal and concentrations were compared to the Interim Sediment Quality Guidelines (CCME, 2003 and AESRD, 2014). Concentrations of total metals in Bighill Creek sediments are shown in Table 6.

Total arsenic, total chromium, and total lead concentrations exceeded the guidelines at Site 1 in July 2019. These exceedances were not found in 2017-18, indicating a potential increase in these concentrations since June 2017. Metal concentrations in sediments are highly variable, and more data are needed to verify a potential increase.

5. Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) are organic compounds that are present in coal, crude oil, and gasoline. They are also present in the environment as a result of incomplete combustion of forest fires, coal cooking, oil, gas, and wood stoves. Major sources of PAH contamination of freshwater include oil spills and refinery effluents, domestic sewage, landfills, storm water runoff, and wood preservatives. The fate of PAHs in the environment is determined by the following processes: volatilization, photolysis, hydrolysis, microbial degradation, adsorption and sedimentation (Southworth, 1979). Guidelines vary depending on the PAH and concentrations were compared to the Interim Sediment Quality Guideline (CCME, 1999 and AESRD, 2014).

Concentrations of PAH in Bighill Creek sediments are presented in Table 7. As in 2017-18, a few PAHs exceeded guidelines at Site 5. For instance, concentrations of acenaphthylene, benzo(a)pyrene, dibenz(a,h)anthracene, and pyrene exceeded the guidelines in July, September, and October 2019 (Table 7). Concentrations of benzo(a)anthracene, chrysene, fluoranthene, and phenanthrene exceeded the guidelines in July and October 2019. Concentrations of anthracene exceeded the guideline in October 2019. Site 5 is located downstream of the Town of Cochrane where residential and industrial activities take place. Effluents from these activities may have contributed to these PAH exceedances.

Site 7 was established upstream of Site 5 and within the Town of Cochrane to monitor the extent of PAH exceedances observed at Site 5. Concentrations at Site 7 were below guidelines except in May 2020 when concentrations of acenaphthene, acenaphthylene, and dibenz(a,h)anthracene were below the detection limit. However, the detection limit (0.011 mg/kg) was above the guidelines and actual concentrations may exceed the guidelines (Table 7).

6. Phenols

Phenol concentrations in Bighill Creek sediments are presented on Figure 23. Concentrations were below detection limits except in September and in May when actual concentrations were reported. Concentrations in July appeared to be higher than concentrations for all sampling events. However, they were below the detection limit (<2.0 mg/kg) and actual concentrations were unknown.

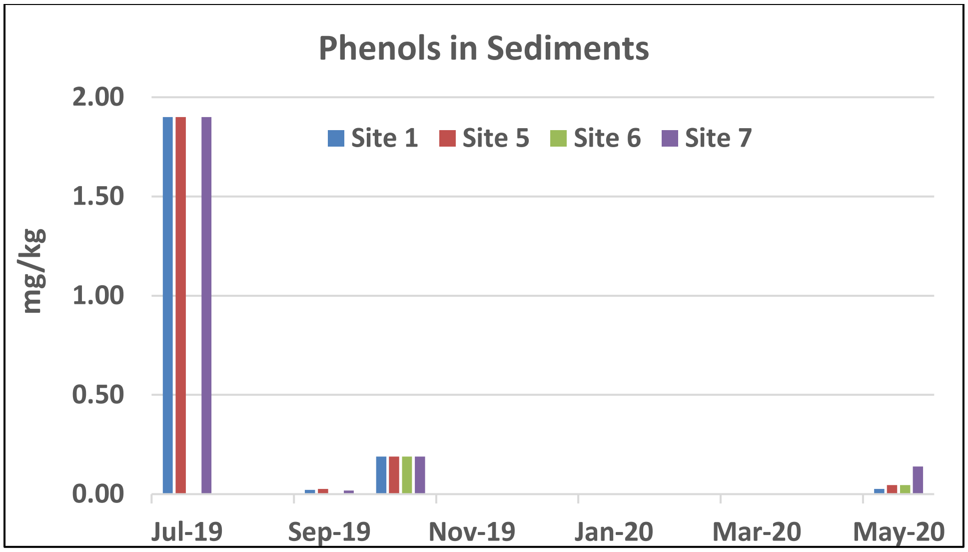

Figure 23. Phenols (mg/kg) in Bighill Creek sediments in July, September, October 2019 and May 2020 at Site 1, Site 5, Site 6, and Site 7.

Photo 10. Site 5 in July 2019. Facing downstream.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study showed that the water and sediment quality of Bighill Creek was largely comparable to the quality found during phase I conducted in 2017-2018. The following parameters and concentrations increased since 2017:

- Surface water flow
- Total organic carbon
- True colour
- Fecal coliform counts
- Nutrients:
    - Total phosphorus
    - Dissolved phosphorus
    - Total Kjeldahl nitrogen
    - Total ammonia nitrogen
- Total metals in sediments
- Polycyclic aromatic hydrocarbons in sediments

After phase I of this study was completed in 2018, a few changes were recommended to enable gathering more information. The following changes were implemented during phase II in 2019-20:

- The addition of a surface water sampling location (Site 6) upstream of Site 1, as a result of exceedances recorded at Site 1 in 2017-18. This brought the total number of surface water samples to six instead of five.
- The addition of a sediment sampling location (Site 7) upstream of Site 5, as a result of PAH exceedances recorded at Site 5 in 2017-18.
- Creek sediments were collected at four sites instead of two in 2017-18.
- Sediment samples were submitted four times a year instead of twice a year in 2017-18.
- Spring water was sampled four times in 2019-20 instead of twice a year in 2017-18.

Concentrations of many parameters at Site 6 and Site 1 were higher than concentrations at other sites and affected the general trend of the data. These parameters included total organic carbon, total suspended solids, nutrients, chlorophyll a, fecal coliforms, and phenols. Site 1 is located at Highway 567 and Site 6 is located further upstream between Highway 567 and Township Road 272. Both Site 1 and Site 6 are located upstream of Bighill Springs Provincial Park and are surrounded by agricultural, industrial, and residential land uses that are affecting the water quality of the Bighill Creek upstream and downstream. Concentrations of these parameters were lower within the Bighill Springs valley. This was likely due to a combination of factors including the many springs along the valley that pour into the Creek, the shape of the valley, and the healthy riparian zone protecting the Creek.

The results in this report reflect the impact of different land uses on the health of the Bighill Creek and its valley. As cities grow and populations increase, land uses change, move, adapt, grow, and the natural ecosystems around them also change and adapt to maintain a healthy balance. Every activity, whether agricultural, industrial, commercial, residential, or recreational, has a footprint, and the goal is to minimize impacts that are harmful to the environment. This study has enabled us to quantify many water quality indicators between 2017 and 2020. These data are invaluable for long term management and safeguarding of the Creek and its valley.

These findings show the importance of regular monitoring of the health of the natural ecosystems surrounding us. The more data collected, and knowledge gathered, the sooner we will recognize correlations between land use and ecosystem health and will then address them accordingly.

This baseline study is designed to provide the information necessary to help protect the aquatic and riparian environments, the downstream receiving waters, as well as to support reclaiming the watershed as a recreational zone and for the reintroduction of a sport fishery. It is complemented by a fish inventory conducted by Trout Unlimited in June 2018, a riparian assessment conducted by the Alberta Habitat Management Society in summer 2018, and continuous stewardship efforts of the Bighill Creek Preservation Society to improve the trail system in the provincial and county reserve areas along the Creek.

Photo 11. Site 5 in January 2020. Facing downstream. Dr. Ken Stevenson breaks the ice covering the Creek surface.

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Photo 12. Site 5 in May 2020. Facing downstream. Sediment sampling.

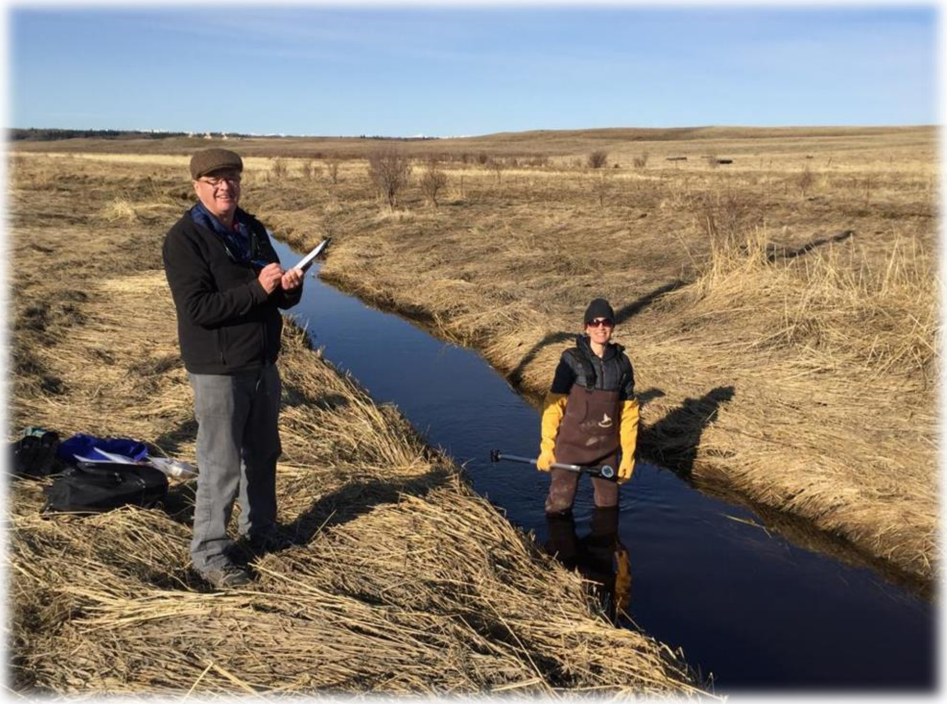

Photo 13. Site 6 in May 2020. Facing downstream.

Photo 14. Site 6 in July 2019. Facing downstream.

TABLES

Table 1. Bighill Creek surface water, spring water, and sediment sampling locations.

Site #	Site Description	Substrate Sampled	GPS Coordinates (UTM - NAD 83)
Site 1	At Highway 567	Water and sediment	11U 683397mE 5683226mN
Site 2	Downstream of Bighill Springs Provincial Park	Water	11U 682754mE 5680575mN
Site 3	Access Point along the Creek	Water	11U 679479mE 5676563mN
Site 4	Off Ranche Road	Water	11U 678544mE 5676097mN
Site 5	Confluence with Bow River	Water and sediment	11U 676107mE 5672952mN
Site 6	South of Township Road 272	Water and sediment	11U 684344mE 5685889mN
Site 7	Glenpatrick Road	Sediment	11U 676073mE 5673933mN
Spr1	Bighill Springs Provincial Park	Water	11U 682014mE 5681198mN
Spr2	Access Point along the Creek	Water	11U 679998mE 5677680mN

Table 2. Routine analyses of Bighill Creek surface and spring water in July, September, October 2019 and January and May 2020.

(See excel sheet attached)

Table 3. Concentrations of total metals in Bighill Creek surface water in July, September, October 2019, January, and May 2020.

(See excel sheet attached)

Table 4. Sediment texture at Site 1, Site 5, Site 6, and Site 7 in July, September, October 2019, and May 2020.

(See excel sheet attached)

Table 5. Concentrations of minerals in Bighill Creek sediments in July, September, October 2019, and May 2020 at Site 1, Site 5, Site 6, and Site 7.

(See excel sheet attached)

Table 6. Concentrations of total metals in Bighill Creek sediments in July, September, and October 2019, and in May 2020 at Site 1, Site 5, Site 6, and Site 7.

(See excel sheet attached)

Table 7. Concentrations of polycyclic aromatic hydrocarbons in Bighill Creek sediments in July, September, October 2019, and May 2020 at Site 1, Site 5, Site 6, and Site 7.

(See excel sheet attached)
