Nose Creek Watershed

2013 Water Quality Monitoring Report

For the Nose Creek Watershed Partnership

Palliser Environmental Services Ltd.
March 2014

Nose Creek Watershed Partnership

Palliser Environmental Services Ltd.

Acknowledgements

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Executive Summary

In 2013, the Nose Creek Watershed Partnership (NCWP) completed the fifth year of a surface water quality monitoring program for the Nose Creek watershed as recommended in the Nose Creek Watershed Water Management Plan. Six sites in the watershed were sampled twice monthly during April, May and June and once per month from July to October. In addition, the City of Calgary collected water samples monthly at four sites from January to December. Water monitoring results were compared to the Bow River Basin Council Water Quality Objectives established for the Nose Creek (BRBC 2008).

In 2013, and similar to previous years, water temperatures in Nose and West Nose creeks were below the acute objective of 29^{o}C and the chronic objective of 24^{o}C (see table below). The pH compliance rate was also high at Nose Creek (97%) and West Nose Creek (96%) and was the same as or comparable to pH in previous years. Temperature and pH do not appear to be a concern at Nose or West Nose creeks based on established objectives. However, the temperature objectives do not consider cooler temperatures required for trout species which are known to inhabit the lower reach (within the Calgary City Limits) of Nose Creek and West Nose Creek. A lower temperature objective may be more suitable to meet the requirements of coldwater fish species. Cooler water temperatures can be obtained by establishing and maintaining riparian vegetation, particularly trees and shrubs to provide shade.

At Nose Creek, seven samples did not meet the acute dissolved oxygen guideline of 5 mg/L. The compliance rate for acute dissolved oxygen in 2013 (90%) was similar to 2009, 2011 and 2012, lower than 2010 but higher compared to 1999-2001. At West Nose Creek, all samples met the acute 5 mg/L guideline for dissolved oxygen. Compliance with the acute and chronic dissolved oxygen guidelines has always been greater at West Nose Creek compared to Nose Creek. The diurnal fluctuation of dissolved oxygen at Nose Creek and West Nose Creek is not well understood. However, it is likely that low dissolved oxygen concentrations prevail during the night and on days with heavy cloud cover due to the large amount of instream vegetation (i.e., algae and rooted aquatic macrophytes) that consume oxygen.

Electrical conductivity at Nose Creek ranged from 405 to 3306 µS/cm and 49% of samples met the water quality objective of less than 1000 µS/cm. Compliance rates were higher at West Nose Creek (93%) compared to Nose Creek in 2013 and in previous years. High electrical conductivity within the City of Calgary, particularly during the winter months is a concern. Sources contributing to high conductivity probably include road salt. Twenty-five percent (25%) and 50% of samples met the TDS water quality objectives of less than 500 mg/L at Nose Creek and West Nose Creek, respectively, which was a compliance rate higher than previous years, with the exception of 2011 which had a higher compliance rate at both creeks. Total dissolved solids followed a trend similar to electrical conductivity.

Total phosphorus ranged from 0.03 to 0.70 mg/L at Nose Creek and 4% of samples complied with the water quality objective of less than 0.05 mg/L. Historical compliance rates for total phosphorus have been less than 12% at Nose Creek. At West Nose Creek concentrations ranged from 0.02 to 0.37 mg/L and 19% of samples complied with the water quality objective. Historical compliance rates for total phosphorus at West Nose Creek have been greater than at Nose Creek, ranging from 15 to 52%. Much of the phosphorus in the creeks is in the dissolved form and is readily available to plants. Phosphorus concentrations are a concern at both creeks since it enriches freshwater (a process known as eutrophication), contributing to the growth of aquatic plants. Although aquatic plants produce oxygen through photosynthesis during the day; however, on cloudy days or during the night, the plants consume oxygen for respiration and can deteriorate fish habitat conditions. In addition, oxygen is used during the decomposition of plant material, again decreasing oxygen resources for fish and other aquatic life. Sources of phosphorus include organic and inorganic fertilizers that are used for agricultural crop

production and urban lawn maintenance, livestock manure, pet feces, poorly designed or failing septic systems, and treated municipal effluent. Application of phosphorus at the appropriate rates will limit the amount of excess phosphorus that can be transported to Nose or West Nose creeks.

For nitrate-nitrite nitrogen, 78% and 76% of samples met the water quality objective of less than 1.5 mg/L at Nose Creek and West Nose Creek, respectively. Nitrate-nitrite nitrogen concentrations are not a concern at Nose and West Nose creeks as compliance was high in 2013 and in previous years. For total ammonia, 95% and 100% of samples met the water quality objective at Nose Creek and West Nose Creek, respectively. Total ammonia concentrations are not a concern at Nose and West Nose creeks as compliance was high in 2013 and in previous years.

Total suspended solids concentrations ranged from <4 to 233 mg/L in Nose Creek and from <2 to 133 mg/L in West Nose Creek. The range of total suspended solids concentrations in Nose Creek in 2013 was similar to concentrations reported in 2009, lower compared to 2000-2001, and higher compared to concentrations reported in 2010, 2011 and 2012. Similarly, total suspended solids concentrations in West Nose Creek in 2013 were similar to concentrations reported in 2011 and 2012, lower compared to 2009 and 2010 and higher compared to 2000-2001. Water quality objectives for total suspended solid concentrations have not been established for Nose Creek or West Nose Creek.

Sixty-three percent (63%) and 56% of samples analysed for fecal and *E. coli* bacteria counts at Nose Creek and West Nose Creek, respectively, met the water quality objective of less than 100 CFU/100 mL (irrigation). Eighty-seven percent (87%) and 78% of samples analysed for fecal and *E. coli* bacteria counts at Nose Creek and West Nose Creek, respectively, met the water quality objective of less than 400 CFU/100 mL (contact recreation). Data from 2009 to 2013 indicates consistently elevated concentrations of *E. coli* at **NC at Mouth** during winter months (October to March). Monitoring of outfalls in the vicinity of the mouth of Nose Creek should be completed to determine the source(s) of elevated bacteria. Elevated fecal coliform counts are a concern at Nose Creek and West Nose Creek. In rural areas, bacteria sources are generally linked to wildlife (e.g., beaver, deer), waterfowl (e.g., ducks and geese) and livestock (e.g., horses and cattle). In addition to waterfowl, a high number of dogs concentrated in urban centres can contribute bacteria to Nose Creek either directly or via stormwater runoff from areas like dog parks.

Summary of historical (1999-2001, 2009, 2010, 2011, 2012) water quality compliance rates (%) in comparison with 2013 for Nose Creek and West Nose Creek.

Parameter	Nose Creek						West Nose Creek					
	1999-2001	2009	2010	2011	2012	2013	1999-2001	2009	2010	2011	2012	2013
Temperature	100	100	100	100	100	100	100	100	100	100	100	100
pH	95	97	79	99	95	97	100	100	100	100	96	96
Dissolved Oxygen-acute	84	91	97	90	88	90	86	100	100	100	96	100
Dissolved Oxygen-chronic	69	79	92	79	76	74	76	95	100	96	93	100
Electrical Conductivity	38	29	27	63	32	49	91	90	76	86	81	93
Total Dissolved Solids	15	0	9	36	10	25	6	0	0	80	10	50
Total Phosphorus	2	0	12	4	5	4	15	52	33	25	41	19
Dissolved Phosphorus	24	32	37	9	23	7	19	62	43	32	41	19
Nitrate-Nitrite Nitrogen	89	83	94	93	83	78	85	88	93	82	83	76
Total Ammonia	91	83	88	100	98	95	97	100	100	100	96	100
Fecal Coliform - irrigation	42	38	56	67	58	63	45	38	53	64	44	56
Fecal Coliform - recreation	76	65	84	90	70	87	83	71	87	89	67	78

Water quality improvements for Nose Creek and West Nose Creek may be obtained by implementing best management practices in rural and urban areas, including off-stream watering for livestock, streamside fencing, stormwater management (reductions in volumes generated, treatment of water in storm ponds), stoop and scoop at dog parks and private yards, reductions in use of lawn fertilizer and effective street cleaning prior to spring runoff and rainfall. In addition, maintaining and improving riparian area condition will reduce water temperatures via shade from trees and shrubs and aid in the filtration of runoff water prior to flowing into the creeks.

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1.0 INTRODUCTION

The Nose Creek Watershed Partnership completed the Nose Creek Watershed Water Management Plan (Plan) in 2007. On completion, the City of Airdrie, City of Calgary, Rocky View County, Town of Crossfield and Alberta Environment agreed to implement the recommendations within the Plan to the best of their ability. One of the recommendations in the plan was to integrate the current water quality monitoring that is conducted by various agencies, municipalities and organizations into a comprehensive program that avoids duplication of effort and promotes sharing of information. Palliser Environmental Services Ltd. was retained to develop a comprehensive long-term water monitoring strategy for the Nose Creek watershed that is consistent with the recommendations and implementation actions of the Nose Creek Watershed Water Management Plan (2007) and the water quality objectives set for Nose Creek by the Bow River Basin Council (BRBC) (2008). The 2008 BRBC water quality guidelines for dissolved phosphorus, total phosphorus and pathogens (as indicated by *E. coli*), dissolved oxygen and total suspended solids were revised in 2010/2011 for Nose Creek.

Effective watershed management includes monitoring the state of air, land and water resources. Monitoring water resources in terms of its physical, chemical and biological character allows managers to determine if the water quality meets requirements for various uses, including human, livestock and ecological (aquatic) needs. Water monitoring can also provide insight into land management practices as runoff quality is reflected in surface water bodies (e.g., stormwater from urban and rural landscapes). Flow volumes may increase or decrease according to changes in land cover. Water monitoring is a critical decision-support system for any water management program. With appropriate water quality data, land managers can make decisions that will help protect the integrity of water bodies for future generations.

The Bow River Basin Council has identified reach-specific desired outcomes for the Bow River watershed (BRBC). For the Nose Creek watershed the desired outcomes are:

- Surface water quality that is appropriate for irrigation of crops.
- Surface water quality that is appropriate for livestock watering.
- Surface water quality where water withdrawal systems are protected from high levels of algae and/or macrophytes.
- Surface water quality that maintains the existing cool-water aquatic ecosystem fauna structure and abundance (e.g., healthy pike populations and benthic invertebrates) (BRBC 2008).

Short- to long-term performance monitoring and management recommendations for the Nose Creek as identified by the BRBC (2008) are summarized in Appendix A.

Palliser Environmental Services Ltd. (PESL) was contracted in 2013 to monitor six sites identified in the Long-Term Water Monitoring Strategy. The City of Calgary monitored four sites in the watershed as part of their monitoring program.

2.0 BACKGROUND

2.1 Water Quality Parameters

The Nose Creek watershed water monitoring program monitors 11 parameters that describe the physical and chemical state of stream quality: temperature, pH, dissolved oxygen, electrical conductivity, total dissolved solids, total phosphorus, dissolved phosphorus, nitrate+nitrite nitrogen, total ammonia, fecal coliform bacteria, and total suspended solids. A short description (sources, concerns) of each water quality variable is presented below. In addition, the water monitoring program measures discharge (water volume) at water quality sites.

Temperature

Water temperature has direct and indirect effects on nearly all aspects of aquatic ecology. The amount of oxygen that can be dissolved in water is partly governed by temperature. Cold water can hold more oxygen than warm water. Temperature also influences the rate of photosynthesis by algae and aquatic plants (BRBC 2008) and is an important determinant of total ammonia (NH_3) concentrations. Fish species also have specific preference and tolerances for water temperatures. Cold water species (trout and whitefish) select summer water temperatures from 10 to 18^{o}C whereas cool water species (e.g., pike, fathead minnow, brook stickleback) select summer water temperatures from 18 to 26^{o}C (Nelson and Paetz 1992).

pH

This is a logarithmic scale based on the Hydrogen Ion concentration by which water and other substances are measured to determine if they are acidic, neutral or alkaline. The midpoint of the scale is pH 7.0 and is neutral. Readings from 0 to <7.0 are acidic and the lower the number the more strongly acid the solution. Battery acid has a pH value of approximately 0. Readings from >7.0 to 14 are alkaline, with the higher numbers indicating a strongly basic or alkaline solution. Chlorine bleach has a pH of approximately 13. pH is an important determinant of total ammonia (NH_3) concentration as increasing the acidity of a solution by one pH unit can cause the total ammonia to increase tenfold. The provincial pH guideline for the protection of freshwater aquatic life is 6.5 to 8.5. The federal pH guideline for the protection of freshwater aquatic life is 6.5 to 9.0 (Alberta Environment 1999).

Dissolved Oxygen

Oxygen is vital to freshwater organisms. Oxygen is soluble in water and the solubility increases with decreasing water temperature (i.e., cold water holds more oxygen). Oxygen enters the water directly from the atmosphere or by aquatic plant/algae photosynthesis. Oxygen is removed by the respiration of animals and plants and by organic decomposition. The provincial oxygen guideline for the protection of freshwater aquatic life is 5 mg/L (acute: 1 day minimum) and 6.5 mg/L (chronic: 7 day mean). The federal cold water biota oxygen guideline for the protection of freshwater aquatic life is 6.5 mg/L (other life stages) to 9.5 mg/L (early life stages) (Alberta Environment 1999).

Electrical Conductivity

Electrical Conductivity (EC) is the measure of minerals (e.g., sodium, chloride, magnesium, potassium) dissolved in the water (total dissolved solids), or the salinity. EC is measured as the resistance of a solution to electrical flow; therefore, the purer the water is (i.e., the lower its salinity) the greater its resistance to electrical flow will be. EC, when applied to water, refers to the electrical charge of a given water sample and is expressed as micro Seimens per centimeter (μS/cm) (USEPA 1978; Cole 1994). Sources can include soil and mineral weathering, surface runoff from saline soils, groundwater discharge, municipal and industrial effluents, agricultural runoff and aerosol fallout. Excessive salts applied to soils may interfere with extraction of water by plants. High total dissolved solids may also affect taste and palatability of drinking water and at high concentrations may have a laxative effect. High conductivity water is also undesirable in most industrial process waters. The irrigation guideline for electrical conductivity is 1000 µS /cm (Alberta Agriculture 1983); however, this does not provide adequate protection for crops sensitive to salinity such as strawberries, raspberries, beans and carrots. To protect these crops a guideline limit of 700 µS/cm is recommended (CCREM 1987).

Total Dissolved Solids

Total dissolved solids (TDS) is a measure of the amount of material dissolved in water other than pure water and are operationally defined as solids that can pass through a filter. TDS includes inorganic salts and small amounts of organic matter. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphate and, particularly in groundwater, nitrate (from agricultural use). Conductivity measurements are converted to TDS values by a factor that varies with the type of water, typically 0.55 to 0.75. For irrigation water, the TDS should not exceed 500 to 3500 mg/L, depending on the crop. For livestock water, the TDS should not exceed 3000 mg/L (AENV 1999).

Total and Dissolved Phosphorus

Phosphorus is an essential nutrient required for plant growth. Sources of phosphorus can include animal manures (e.g., cattle, waterfowl), commercial inorganic fertilizers, sewage treatment plants, food processing plants, urban runoff, atmospheric deposition, and natural levels found in soils and bottom sediments. Total phosphorus (TP) measures the nutrient in all forms whether particulate or dissolved, organic or inorganic. Dissolved phosphorus (DP) indicates the phosphorus not associated with sediment particles. Dissolved phosphorus is a closer measure of the nutrient more readily available for plant growth, though the phosphorus in particulate form is potentially available for plant growth through time. The particulate phosphorus concentration gives an indication of the sediments suspended in the water column.

Excessive nutrients in water can cause eutrophic conditions with increased algae and weed growth. In some circumstances, increased plant abundance can change the chemistry of the water, affect oxygen concentrations (through photosynthesis /respiration and decay of organic matter), affect aesthetics and affect the physical movement of water. Dense growths of filamentous algae and aquatic plants can physically block culverts and clog water intakes. Certain strains of algae can impart an off-taste to drinking water and in some instances blue-green algae produce a toxin that can cause health issues for humans and is toxic to livestock and waterfowl. Phosphorus concentrations are expressed as milligrams per litre (mg/L) of water (USEPA 1978; Cole 1994). Total phosphorus concentration guidelines for rivers (Environment Canada 2004) range from 0.025 to 0.050 mg/L, with Alberta and Manitoba guidelines at 0.050 mg/L, Ontario and Quebec at 0.030 mg/L and Australia and New Zealand at 0.035 to 0.037mg/L. These are typically for the protection of aquatic life.

Nitrate+Nitrite Nitrogen

Nitrate is the principal and most stable form of inorganic nitrogen in aquatic environments. Nitrite is an intermediate form in the nitrification/denitrification pathway and can be toxic; however, it is usually found in low concentrations because of its instability in the presence of oxygen. Nitrate and nitrite are typically reported as a combined concentration due to the instability of nitrite. Natural sources of nitrogen in surface water bodies can include atmospheric deposition. Human sources of nitrogen include municipal and industrial wastewater, septic tanks and runoff from agricultural practices. Nitrate is necessary for plant growth; however, elevated concentrations can also result in the excessive growth of algae and aquatic plants. High concentrations of nitrate can pose a toxic risk for infants and livestock watering. The nitrate-nitrite water quality objective for Nose Creek is <1.5 mg/L chosen from the City of Calgary Total Loading Management Target that corresponds to 5 mg/L oxygen for the period April 1 to September 30 (BRBC 2008). The nitrate+nitrite guideline for the protection of livestock water is <100 mg/L and the nitrite guideline for the protection of livestock water is <10 mg/L (AENV 1999).

Total Ammonia

Total ammonia is the most reduced form of inorganic nitrogen in water and includes the ionized (NH_4^+) and un-ionized forms (NH_3). Un-ionized ammonia (NH3) is the toxic form and its concentration depends on pH and water temperature. In most well-oxygenated waters, ammonia is quickly converted to nitrate. Ammonia is produced by the decomposition of organic matter. Ammonia can be found in municipal and industrial wastewater effluent and in runoff downstream of fields with intensive manure or fertilizer applications (BRBC 2008). Measurement of total ammonia in the aquatic environment is often expressed as `total ammonia-nitrogen` and is the sum of ammonia (NH_3) and ammonium (NH_4). The total ammonia target for Nose Creek is the CCME guideline which varies depending on water temperature and pH.

Fecal Coliform Bacteria

Fecal coliform bacteria (FCB) are specific to the intestinal tracts of warm-blooded animals (cattle, birds, pets etc.) and humans and are thus a more specific test for animal waste or sewage contamination. FCB can enter surface waters through fecal contamination by wildlife, domestic animals and through wastewater discharges or surface water runoff. Fecal coliform bacteria are not necessarily harmful to human health, but they indicate fecal contamination and the possible presence of other pathogenic organisms including *Escherichia coli* (*E. coli*), *Salmonella*, *Giardia* and *Cryptosporidium* which can have serious health implications affecting drinking water, irrigation, livestock watering and recreation (BRBC 2008). FCB can be a concern for fresh garden produce particularly leafy crops such as lettuce. Fecal coliform bacteria levels are expressed as the number of bacteria colonies per 100 mL of water. The irrigation guideline for fecal coliform bacteria is 100 colonies per 100 mL (Alberta Environment 1999). The BRBC has adopted a contact recreational guideline that no single value should exceed 400 *E. coli* per 100 mL in Nose Creek

Total Suspended Solids

Total suspended solids (TSS) are a measure of the suspended particles such as silt, clay, organic matter, plankton and microscopic organisms which are held in suspension in water. Total suspended solids concentrations are expressed as milligrams per litre (mg/L) of water (USEPA 1978). Suspended solids can transport nutrients and contaminants downstream and may be aesthetically undesirable. Excessively high TSS in irrigation water can cause the formation of crusts on top of the soil which can inhibit water infiltration, and plant emergence and impedes soil aeration. The formation of films on plant leaves can reduce sunlight and impede photosynthesis. TSS residues can reduce the marketability of some leafy crops such as lettuce. High TSS can interfere with the treatment of drinking and industrial process water. High concentrations of suspended and deposited sediment can reduce benthic invertebrate abundance and species richness. Deposited sediment can fill in deep pools and bury spawning gravels leading to reduced survival of fry fish. Sub-lethal effects on fish can include avoidance/re-distribution, reduced feeding/growth, respiratory impairment, reduced tolerance to disease and increased physiological stress. In very high concentrations, suspended sediment can result in mortality of fish (Waters 1995). For the protection of aquatic life, the AENV (1999) chronic guideline indicates TSS should not increase by more than 10 mg/L above background.

2.2 Bow River Basin Water Quality Objectives for Nose Creek

Table 1 summarizes the water quality objectives or targets identified for the Nose Creek watershed by the Bow River Basin Council (BRBC).

Table 1 - Summary of indicators identified in the BRBC Watershed Management Plan (2008). Dissolved phosphorus and pathogen water quality targets/objectives were updated in 2011 by BRBC.

Indicator	WQO/Target
Water Temperature	WQO: should not exceed 29°C at any time or a 7 day mean of 24°C.
Dissolved Oxygen	Provisional WQO: ≥5.0 mg/L (acute daily minimum); ≥6.5 mg/L (7-day average)
Total Phosphorus	Provisional WQO: 0.05 mg/L (AENV 1999).
Total Dissolved Phosphorus	Provisional WQO: 0.02 mg/L.
Nitrate + Nitrite Nitrogen	WQO: <1.5 mg/L. Target: eliminate levels that cause nuisance aquatic plant growth.
Total Ammonia	Target: Should not exceed CCME guidelines for aquatic life. Guideline is variable depending on temperature and pH (table available in CCME fact sheet).
Pathogens as indicated by *E. coli*	Provisional WQO: Meet recreational guideline - no single value to exceed 400 *E. coli* per 100 mL or <200 *E. coli*/100 mL (geometric mean 5 samples/30 day)[a]
Total Suspended Solids	A severity-of-ill-effects (SEV) guideline was developed in 2011; however, the SEV guideline is only suitable for monitoring instream disturbances and is not intended for long-term water quality monitoring. Calculation of a compliance rate was therefore not possible.
Attached Algae (Periphyton biomass defined as chlorophyll *a*)	WQO: No periphytic algal biomass that adversely affects users. Target: 150 mg/m^2 maximum value during open water season.
Pesticides and degradation products	WQO: not recommended at this time. Target: should not exceed CCME guidelines for aquatic life in the river.
Riparian Condition	Target for Nose Creek: a 'Healthy with Problems' rating. Target for West Nose Creek: a 'Healthy' rating
Runoff, soil erosion and impervious areas	Target: impervious and runoff recommendations as detailed in the Nose Creek Watershed Water Management Plan.

[a]: Due to sampling frequency, only the 400 CFU/100 mL. objective can be evaluated within the NCWP monitoring program

3.0 METHODS

Six sites within the Nose Creek watershed were sampled twice monthly during April, May and June and once per month from July to October 2013 (Figure 1). More frequent sampling during April to June was completed to account for the spring runoff and the higher rainfall during these months. A total of 10 samples were collected at each site in 2013 with the exception of **NC u/s Crossfield** which had 8 samples as the site dried up in late summer. Five sites were located on Nose Creek and one site was on West Nose Creek (Table 2). Grab samples were collected at each site with bottles supplied by ALS Laboratories (Calgary) and using standard protocols (e.g., triple rinsing and preservation, where required). Water samples were kept on ice in coolers and transported to ALS Laboratories.

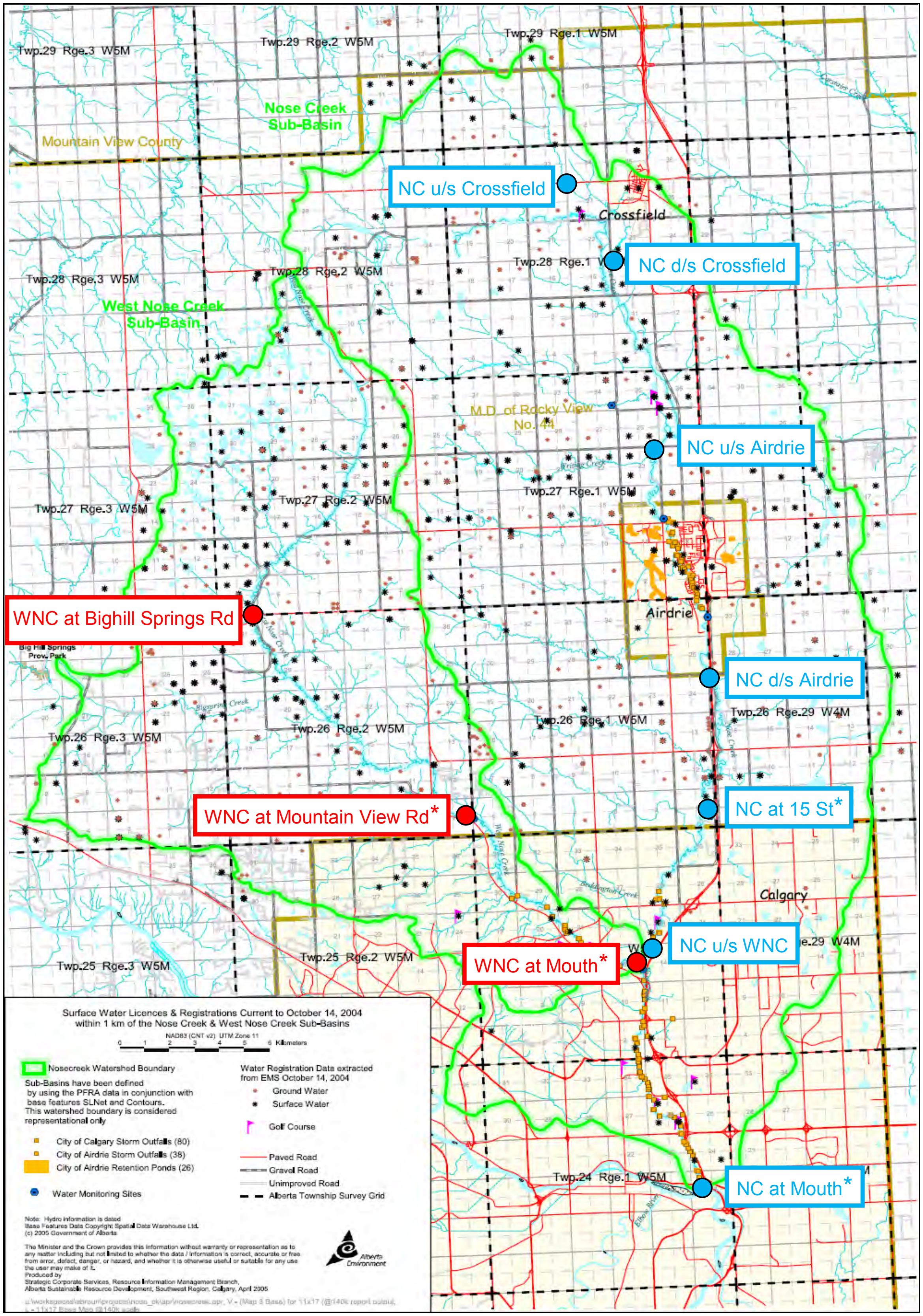

Figure 1 - Location of water quality monitoring sites for Nose Creek (blue) and West Nose Creek (red). Sites marked with asterisk sampled by City of Calgary.

ALS Laboratories is a CALA[1] accredited lab for criteria and standards established by the Association under their Certificate of Laboratory Proficiency. Samples were analysed using APHA[2] approved methods for total ammonia-N (NH_4 + NH_3), total phosphorus (TP), dissolved phosphorus (DP), total suspended solids (TSS) and fecal coliform bacteria (FCB). At each site, *in situ* water quality was completed for dissolved oxygen, percent oxygen saturation, water temperature, pH, total dissolved solids and electrical conductivity using a Hanna (Model HI 9828) multi-parameter meter. Water samples from Nose Creek were collected from 10:55 am to 11:35 am (**NC u/s Crossfield**), 10:50 am to 12:10 pm (**NC d/s Crossfield**), 11:55 pm to 1:50 pm (**NC u/s Airdrie**), 1:30 pm to 3:30 pm (**NC d/s Airdrie**), 9:20 am to 10:15 am (**NC u/s WNC**), 9:55 am to 10:56 am (**NC at 15 St**) and 8:54 am and 9:49 am (**NC at Mouth**). Water samples from West Nose Creek were collected from 12:45 pm to 2:35 pm (**WNC at Bighill Springs Rd**), 10:13 am to 11:08 am (**WNC at Mountain View Rd**) and 10:13 am to 10:08 am (**WNC at Mouth**).

Discharge at the sites monitored by PESL was calculated using a Swoffer water velocity meter (Model 2100). The discharge was calculated using the velocity-area method. The mean number of panels (width x depth x velocity) completed at each discharge transect for Nose Creek was 16 (range: 8 to 28) and for West Nose Creek 20 (range 15 to 26). Staff gauges were installed at five locations: **NC u/s Crossfield**, **NC d/s Crossfield**, **NC u/s Airdrie**, **NC d/s Airdrie** and **NC u/s WNC** (Table 2). The water level on the staff gauge was noted each time a discharge measurement was calculated.

The City of Calgary Water Quality Services (WQS) collected water samples from Nose Creek at two sites (**Nose Creek at Mouth** and **Nose Creek at 15 St**) from January to December, collecting a sample once per month, except during July when two samples were collected but none were collected in June. At West Nose Creek, **West Nose Creek at Mountain View Rd** was sampled from March to December (once per month) and **West Nose Creek at Mouth** was sampled once per month from April to October, except during July when two samples were collected but none were collected in June (Table 2). The samples were analysed for total phosphorus, total dissolved phosphorus, total suspended solids, nitrate+nitrite nitrogen (NO_3+NO_2 –N), total ammonia and E*. coli* at the City's WQS Laboratory using APHA approved methods. The City of Calgary is a CALA accredited laboratory. The City of Calgary staff used a YSI 556 MPS (Multi-Probe System) meter to measure *in situ* pH, conductivity, water temperature and dissolved oxygen at the four sites.

All water chemistry data was summarized into tables by site and sampling date and values exceeding the guideline were shown as a bold font. Sample data for total phosphorus, dissolved phosphorus, fecal coliform and total suspended solids were divided into three groups according to season and expected water quality/quantity conditions:

Winter: November to March (low flow, low biological activity, ice-covered conditions),
Spring: April to June (higher flow, spring runoff),
Summer: July to October (moderate flow, high biological activity).

These data were summarized by median values on an annual basis (2013) and by season and presented in graph format (annual data). The data for each site were compared to water quality objectives established by the Bow River Basin Council (BRBC WQOs) to determine compliance. Overall, the data were summarized in a percent compliance format.

[1] CALA – Canadian Association for Laboratory Accreditation Inc.
[2] APHA – American Public Health Association

Table 2 – Site descriptions and locations for the Nose Creek Watershed Partnership water quality monitoring program. Sites marked with an * (asterisk) were sampled by the City of Calgary.

Site Name	UTM Coordinates		Staff Gauge Location
Nose Creek (NC)			
NC u/s Crossfield	11U703543	5701784	Installed along right downstream bank, mounted on T-post, snug to bank. Staff gauge destroyed in late 2012 after re-fencing allowed cattle access to the gauge.
NC d/s Crossfield	11U705270	5698762	Staff gauge installed on south side of post in the east side of the culvert (upstream end). Installed in 2010.
NC u/s Airdrie	11U707182	5690627	Installed on wood piling, along right downstream bank, underneath bridge. Installed in 2010.
NC d/s Airdrie	11U709175	5682704	Installed along right downstream bank and mounted on T-post, snug to bank. May move with ice. Staff gauge was washed away during high flows in 2011 and site back flooded by a beaver dam.
NC at 15 St*	11U708027	5673032	No staff gauge or discharge monitoring at this site.
NC u/s WNC	11U706614	5668605	Installed along left downstream bank on T-post, snug to bank. May move with ice.
NC at Mouth*	11U708859	5659391	No staff gauge or discharge monitoring at this site.
West Nose Creek (WNC)			
WNC at Bighill Springs Rd	11U690928	5683285	No staff gauge at this site.
WNC at Mountain View Rd*	11U699702	5674845	No staff gauge or discharge monitoring at this site.
WNC at Mouth*	11U706601	5668415	No staff gauge or discharge monitoring at this site.

4.0 RESULTS

4.1 Compliance with Water Quality Objectives

Table 3 summarizes the 2013 compliance with the water quality objectives and compares historical compliance rates from 2009-2012 and 1999-2001. Table 3 provides the precipitation for the study years. The driest summer (99 mm) and second driest winter (33 mm) was in 2012 while the wettest spring was 2013 (260 mm). The year 2009 had the lowest total precipitation (328 mm) as well as the driest spring (68 mm). Total precipitation in 2013 was high at 483 mm. The year 2011 was the wettest year (519 mm) with the third wettest spring (223 mm). The year 2010 was also a wet year (455 mm), particularly the summer (226 mm). The combined years 1999-2001 had average precipitation; although, the year 2000 was the driest (318 mm) with the second driest summer (104 mm). The year 1999 had the driest winter (32 mm).

Some trends with water quality compliance and total precipitation are apparent. Fecal coliform bacteria, dissolved oxygen (chronic) and total dissolved solids generally had higher compliance rates in wet years (2010, 2011 and 2013) compared to drier years (1999-2001, 2009, 2012). Higher fecal coliform compliance during wet years may seem counterintuitive as runoff from rural agricultural pastures and impervious surfaces in urban areas typically carries high bacteria numbers (Young and Thackston 1999); however, a large amount of rainfall could serve to dilute storm water and runoff and lower bacteria numbers; whereas, in dry years discharge from point sources of runoff (outfalls, sediment ponds) can contribute high numbers of bacteria to the base flow of streams (Gregory and Frick 2000). The higher compliance of oxygen during wet years is probably due to increased stream flows (less stagnation) and cooler water temperatures (cooler water can hold more dissolved oxygen). During dry years, evaporation of water from water bodies will increase salt concentrations hence the lower compliance rate of TDS during drier years. No other trends were apparent with compliance rates and total precipitation. Analysis of median parameter concentrations by season/year with precipitation may reveal stronger trends; however, such analysis is beyond the scope of this baseline water quality monitoring report.

Table 3 – Summary of historical (1999-2001, 2009, 2010, 2011, 2012) water quality compliance rates (%) in comparison with 2013 for Nose Creek and West Nose Creek.

Parameter		Nose Creek						West Nose Creek						BRBC WQOs
		1999-2001	2009	2010	2011	2012	2013	1999-2001	2009	2010	2011	2012	2013	
Temperature		100	100	100	100	100	100	100	100	100	100	100	100	WQO: Should not exceed 29^{o}C at any time or 7-day mean of 24^{o}C.
pH		95	97	79	99	95	97	100	100	100	100	96	96	6.5 – 9.0[b]
Dissolved Oxygen	acute	84	91	97	90	88	90	86	100	100	100	96	100	≥5.0 mg/L (1-day acute)
	chronic	69	79	92	79	76	74	76	95	100	96	93	100	≥6.5 mg/L (mean 7-day chronic)
Electrical Conductivity		38	29	27	63	32	49	91	90	76	86	81	93	<1000 µS/cm[c]
Total Dissolved Solids		15	0	9	36	10	25	6	0	0	80	10	50	<500 mg/L[d]
Total Phosphorus		2	0	12	4	5	4	15	52	33	25	41	19	<0.05 mg/L
Dissolved Phosphorus		24	32	37	9	23	7	19	62	43	32	41	19	<0.02 mg/L
Nitrate-Nitrite Nitrogen		89	83	94	93	83	78	85	88	93	82	83	76	<1.5 mg/L
Total Ammonia		91	83	88	100	98	95	97	100	100	100	96	100	Guideline depends on pH and temperature: CCME table
Fecal Coliform Bacteria (*E. coli*)	irrigation	42	38	56	67	58	63.	45	38	53	64	44	56	Not to exceed 100 CFU/100 mL: irrigation guideline
	contact	76	65	84	90	70	87	83	71	87	89	67	78	No single value to exceed 400 CFU/100 mL: contact recreation

PRECIPITATION DATA

Time Period	1999-2001	2009	2010	2011	2012	2013[f]	Comments
Total Precipitation (mm):Jan-Dec	318 – 459, mean: 397	328	455	519	368	483	Majority of precipitation during winter falls as snow. Converted to water equivalent for 'total precipitation'.
Total Precipitation (mm):spring	156 – 221, mean: 183	68	180	223	235	260	
Total Precipitation (mm):summer	104 – 206, mean: 165	166	226	216	99	147	
Total Precipitation (mm):winter	32 – 71, mean: 49	94	49	80	33	75	

[a] Madawaska Consulting 2002
[b] pH guideline is from CCREM (1987)
[c] conductivity guideline is for irrigation (Alberta Agriculture 1983)
[d] AENV (1999) guideline for irrigation
[e] Precipitation data is from Calgary International Airport (www.climate.weatheroffice.gc.ca: National Climate Data and Information Archive). Total Precipitation: the sum of the total rainfall and the water equivalent of the total snowfall.
[f] Total Precipitation (mm) by Month: January 5.1, February 3.4, March 17.2, April 9.0, May 104.8, June 146.6, July 47.0, August 21.0, September 56.0, October 23.3, November 12.3, December 37.0

4.2 Water Quantity (Discharge)

The five discharge sites at Nose Creek had varied stream widths due to a range of flows in 2013: **NC u/s Crossfield** (0.75 to 1.40 m: mean 1.13 m), **NC d/s Crossfield** (0.91 to 1.20 m: mean 1.05 m), **NC u/s Airdrie** (4.80 to 9.80 m: mean 6.44 m), **NC d/s Airdrie** (5.20 to 7.80 m: mean 5.89 m) and **NC u/s WNC** (4.35 to 5.10 m: mean 4.66 m).

In 2013, the discharge within Nose Creek varied substantially by location and date ranging from 0.0 to 1.854 m^3/s (Table 4). Four of the highest flows at the five Nose Creek sites occurred in early June, similar to 2012. On June 5 the water level was too high to safely obtain a discharge at **NC u/s WNC**. There was discharge at **NC u/s Crossfield** and **NC d/s Crossfield** during early-April, minor flow during May, flow from June to August and minor flow again during September and October. **Nose Creek u/s Airdrie** had flows from April to July, but only minor flow was observed from August to October (Table 4). **Nose Creek d/s Airdrie** and **NC u/s WNC** showed similar discharge patterns with moderate flows in April (0.273 to 0.617 m^3/s), low flow in May (0.050 to 0.149 m^3/s), high flow from June to August (0.503 to >1.854 m^3/s) and low flow during September and October (0.097 to 0.206 m^3/s). Although the two sites **Nose Creek u/s Airdrie** and **Nose Creek d/s Airdrie** are relatively close to each other, discharge at **Nose Creek d/s Airdrie** ranged from 1.2 to 1.8 times higher than the corresponding flow at **NC u/s Airdrie**. During August to October when minor flow (<0.001 m^3/S) was recorded at **NC u/s Airdrie** there were recorded flows at **Nose Creek d/s Airdrie** (0.097 to 0.503 m^3/s). This indicates that precipitation runoff and discharge from stormwater ponds and outfalls in Airdrie can contribute a substantial amount of flow to Nose Creek. The highest measured discharge in Nose Creek was 1.854 m^3/s on June 5th at **NC d/s Airdrie** (Table 4); although, a higher flow probably occurred at **NC u/s WNC** when a measurement could not be obtained due to high flow.

The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The high water levels and flood conditions at **NC u/s Airdrie** on July 17 was probably the result of the effluent release which ended the day before.

Table 4 - Water discharge (m^3/s) at sites within Nose Creek and West Nose Creek, from April to October 2013. Shaded cell indicates maximum discharge for site.

Date	Nose Creek					West Nose Creek
	NC u/s Crossfield	NC d/s Crossfield	NC u/s Airdrie	NC d/s Airdrie	NC u/s WNC	WNC at Big Hill Springs Rd
Apr-10	0.004	0.029	0.239	0.359	0.617	0.064
Apr-24	0.031	0.047	0.220	0.273	0.392	0.054
May-8	minor flow	0.008	0.060	0.089	0.149	0.041
May-22	minor flow	minor flow	0.053	0.050	0.065	0.048
Jun-5	0.219	0.413	1.066	1.854	flood	0.428
Jun-19	0.034	0.128	0.301	0.538	0.931	0.182
Jul-17	0.018	0.049	flood	0.794	1.064	0.317
Aug-14	0.002	0.002	minor flow	0.503	0.727	0.156
Sep-24	no flow	minor flow	minor flow	0.097	0.206	0.064
Oct-23	no flow	minor flow	minor flow	0.103	0.190	0.067

flood: water levels very high and unsafe
minor flow: water movement visible but too slow to register on velocity meter, discharge probably <0.001 m^3/s
no flow: no visible water movement, but standing water may be present
dry: no moving or standing water, substrate is exposed and dry

Of the five monitoring years (2009 to 2013) at Nose Creek, 2009 had the lowest discharge (low spring precipitation) and 2011 had the highest discharge (higher spring and summer precipitation). Discharge in 2010, 2012 and 2013 (moderate spring and summer precipitation) was intermediate compared to 2009 and 2011. The 2013 discharge monitoring did not capture the high flows associated with the June flooding as the June measurement was taken on the 19th and the flooding began June 20th and 21st.

The discharge site at West Nose Creek ranged in width from 1.95 to 2.80 m with a mean width of 2.24 m. The discharge at the West Nose Creek site ranged between 0.041 and 0.428 m^3/s with the highest flow in early June (during numerous precipitation events) and the lowest flow in early-May, prior to any precipitation. Of the five monitoring years (2009 to 2013) at **WNC at Big Hill Springs Rd**, 2009 had the lowest discharge (low spring precipitation) and 2011 had the highest discharge (higher spring and summer precipitation). Discharge in 2010, 2012 and 2013 (moderate spring and summer precipitation) was intermediate between 2009 and 2011. The consistent discharge from July to September 2012 during a low-precipitation summer suggests a base flow from groundwater sources at **WNC at Big Hill Springs Rd.** A similar observation was made in 2009.

4.3 Water Quality Parameters

Temperature

Water temperature in 2013 at Nose Creek ranged from 0.0 to 22.3°C (N=70) at the seven sites (Table 5). The lowest temperatures (0.0 to 0.1°C) occurred in November, December, February and March at **NC at 15 St** and **NC at Mouth** and the warmest water temperature (22.3°C) occurred August 14th at **NC d/s Airdrie** (Table 5), similar to 2011 and 2012. All of the water sample temperatures at Nose Creek were below the water quality objective of 29°C (acute) and 24°C (7-day chronic). The water temperature compliance rate at Nose Creek in 2013 (100%) was the same as historical compliance data from 2009 to 2012 and 1999 to 2001 (Table 3). The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The release of treated effluent from Crossfield did not appear to affect temperature at Nose Creek. On June 19th (prior to release), the temperature was 17.2°C upstream of the release point (**NC d/s Crossfield**) and 16.6°C downstream of the release point (**NC u/s Airdrie**). On July 17th (the day after release stopped) the temperature was 18.0°C upstream of the release point and 17.8°C downstream of the release point (Table 5).

Water temperature in 2013 at West Nose Creek ranged from 0.0 to 18.4°C (N=27) (March to December (Table 5) at the three sites (Table 5). The lowest temperatures (0.0 to 0.1°C) occurred in March, November and December and the warmest water temperature (18.4°C) occurred August 14th at **WNC at Big Hill Springs Rd** (Table 5). All of the water temperatures at West Nose Creek were below the water quality objective of 29°C (acute) and 24°C (7-day chronic). The water temperature compliance rate in 2013 (100%) at West Nose Creek was the same as historical compliance data from 2009 to 2012 and 1999 to 2001 (Table 3).

Water temperatures in streams and rivers undergo a diurnal[3] cycle with the maxima usually occurring in the afternoon and the minima occurring during the latter half of the night. In small streams in the summer the diurnal fluctuations in temperature are not usually greater than 6°C (Hynes 1970; Hauer and Hill 1996). The water temperatures collected from June to August during this study would represent maximum or near maximum temperature for those collected in

[3] Diurnal: Having a daily cycle or pattern that re-occurs every 24 hours, synonymous with the term 'diel.'

the afternoon (i.e., **NC u/s Airdrie**, **NC d/s Airdrie** and **WNC at Big Hill Springs Rd**) while those collected in the morning would represent temperatures somewhere between the minimum and maximum. In all likelihood, the compliance rate would remain the same (100%) if the maximum temperature had been collected at each site. In 2009, Morris (2009) continuously monitored water temperature every 30 minutes at **NC u/s Airdrie** and **NC at Mouth** from June 23 to September 4, a low-flow, low-precipitation year. The maximum (acute) temperature of 29^{o}C was never exceeded at either site and the chronic 7-day temperature of 24^{o}C was not reached at **NC at Mouth** and water temperatures only briefly exceeded 24^{o}C for 1 and 2 days in July (Morris 2009).

Since 2007, brown trout (*Salmo trutta*) and mountain whitefish (*Prosopium williamsoni*) have been captured in Nose Creek from the confluence with the Bow River, upstream to the confluence with West Nose Creek. At West Nose Creek, brown trout, brook trout (*Salvelinus fontinalis*) and mountain whitefish have been captured in the lowermost portion within Confluence Park. The current water temperature objective for Nose Creek (Objective: should not exceed 29^{o}C at any time or a 7-day mean of 24^{o}C) is too warm if trout populations are to remain and expand their range within Nose and West Nose creeks. It is recommended that the water temperature objective that the Bow River Basin Council has adopted for the Bow River Central (Objective: should not exceed 22^{o}C at any time or a 7-day mean of >18^{o}C) is more appropriate for the lower reaches of Nose Creek and West Nose Creek. A review of water temperature data from 2009 to 2012 indicates both creeks are almost always in compliance with the more stringent water temperature objective.

pH

In 2013, the pH of water samples from Nose Creek ranged from 6.81 to 9.24 (N=71). At Nose Creek, 97% of the samples were within the pH target compliance objective (6.5 to 9.0), with the non-compliances occurring April 10th at **NC d/s Airdrie** and August 14th at **NC u/s Airdrie**. No samples at Nose Creek were below the lower limit of the target compliance objective (i.e., <6.5) (Table 6). The pH compliance rate at Nose Creek in 2013 (97%) was similar to 2012 (95%), 2011 (99%), 2009 (97%) and 1999-2001 (95%) and higher when compared to 2010 (79%) (Table 3). The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The release of treated effluent from Crossfield did not appear to affect pH at Nose Creek. On June 19th (prior to release), the pH was 8.27 upstream of the release point (**NC d/s Crossfield**) and 7.74 downstream of the release point (**NC u/s Airdrie**). On July 17th (the day after release stopped) the pH was 8.20 upstream of the release point and 7.94 downstream of the release point (Table 6).

In 2013, the pH of water samples from West Nose Creek ranged from 8.02 to 9.19 (N=27). At West Nose Creek, 96% of the samples met the target compliance objective for pH. No samples at West Nose Creek were below the lower limit of the target compliance objective (i.e., <6.5) (Table 6). The single non-compliance occurred on April 10th at **WNC at Big Hill Springs Rd** when the pH was 9.19. The pH compliance rate at West Nose Creek in 2013 (96%) was similar when compared to historical data in 2012 (96%), 2011 (100%) 2010 (100%), 2009 (100%) and 1999-2001 (100%) (Table 3).

pH tends to undergo a diurnal fluctuation during the active growing season that is mediated by plant photosynthesis. The highest pH values occur during peak photosynthesis (afternoon) and the lowest pH values occur during plant respiration (late evening/early morning). During photosynthesis plants absorb carbon dioxide (CO_2), eliminate bicarbonates, precipitate carbonates and form hydroxyl ions which lead to an increase in pH. Conversely, at night plants undergo a process of respiration which releases CO_2 and lowers the pH. In 2009, Morris (2009) continuously monitored pH every 30 minutes at **NC u/s Airdrie** and **NC at Mouth** from June 23 to September 4, a low-flow, low-precipitation year. The pH never fell below 6.5 at either site, and the pH never exceeded 9.0 at the **NC at Mouth** site. At **NC u/s Airdrie**, the pH was generally above 9.0 from late-June to late-July and was below 9.0 from late-July to early-September (Morris 2009). The continuously high pH in 2009 at **NC u/s Airdrie** may have been due to the fact that the site had no flow (i.e., site was stagnant) and was subject to intensified photosynthesis for much of the study whereas in 2010 and 2011 the site was continuously flowing. In this study, **NC u/s Airdrie**, **NC d/s Airdrie** and **WNC at Big Hill Springs Rd** samples were collected between 11:55 am to 3:30 pm and probably represent the maximum or near maximum pH. At the other sites in this study the maximum pH may not have been reached at the time of sampling and the compliance rate may be overestimated if the late-day pH maximum was greater than 9.0.

Table 5 - Water temperature (°C) data from Nose Creek and West Nose Creek, January to December 2013. Blank cells indicate no sample was taken (nf: indicates 'no flow', standing water may have been present).

Temperature (°C)	21-Jan	25-Feb	25-Mar	10-Apr	15-Apr	24-Apr	08-May	22-May	27-May	05-Jun	19-Jun	04-Jul	17-Jul	29-Jul	14-Aug	26-Aug	23-Sep	24-Sep	21-Oct	23-Oct	18-Nov	16-Dec
NOSE CREEK																						
NC u/s Crossfield				1.4		4.0	10.2	8.8		15.0	16.2		15.7		16.7			nf		nf		
NC d/s Crossfield				1.5		5.0	13.1	10.2		15.2	17.2		18.0		17.8			7.0		5.2		
NC u/s Airdrie				2.1		8.1	16.6	11.6		15.1	16.6		17.8		19.7			8.4		6.1		
NC d/s Airdrie				3.0		8.9	16.3	12.5		15.7	16.8		18.0		22.3			12.1		7.5		
NC at 15 St		0.1	0.1		0.1				12.4			20.7		15.9		16.5	10.2		4.6		0.0	0.0
NC u/s WNC				0.8		4.8	10.9	10.3		13.9	16.6		18.1		19.1			9.8		6.7		
NC at Mouth		0.0	0.0		1.5				11.7			19.8		15.5		16.0	11.4		5.6		0.0	0.0
WEST NOSE CREEK																						
WNC at Big Hill Springs Rd				0.7		6.0	13.1	9.4		15.5	15.0		15.4		18.4			8.1		5.6		
WNC at Mountain View Rd			0.2		0.2				11.4			17.2		13.8		14.3	8.9		4.1		0.0	0.0
WNC at Mouth					0.8				10.5			17.5		13.8		14.5	9.9		4.9			

Table 6 - pH data from Nose Creek and West Nose Creek, January to December 2013. A red value indicates the pH exceeded the pH water quality objective for that site and date. Blank cells indicate no sample was taken (nf: indicates 'no flow', standing water may have been present).

pH	21-Jan	25-Feb	25-Mar	10-Apr	15-Apr	24-Apr	08-May	22-May	27-May	05-Jun	19-Jun	04-Jul	17-Jul	29-Jul	14-Aug	26-Aug	23-Sep	24-Sep	21-Oct	23-Oct	18-Nov	16-Dec
NOSE CREEK																						
NC u/s Crossfield				8.35		8.41	8.40	8.34		7.90	7.80		7.81		7.94			nf		nf		
NC d/s Crossfield				8.76		8.64	8.78	8.23		8.03	8.27		8.20		8.18			7.94		8.80		
NC u/s Airdrie				8.66		8.61	8.42	8.63		7.97	7.74		7.94		**10.07**			8.10		8.81		
NC d/s Airdrie				**9.24**		8.89	8.48	8.73		8.01	8.20		8.17		8.24			8.61		8.78		
NC at 15 St		7.8	8.0		8.3				8.1			8.3		8.4		8.7	8.6		8.6		8.3	7.9
NC u/s WNC				7.58		8.83	8.17	8.40		8.16	8.17		8.26		8.46			6.81		7.86		
NC at Mouth	8.1	8.2	8.2		8.3				8.2			8.4		8.4		8.5	8.5		8.4		8.3	8.1
WEST NOSE CREEK																						
WNC at Big Hill Springs Rd				**9.19**		8.29	8.38	8.65		8.28	8.02		8.16		8.36			8.04		8.59		
WNC at Mountain View Rd			8.2		8.4				8.2			8.4		8.4		8.5	8.3		8.4		8.2	8.2
WNC at Mouth					8.4				8.2			8.4		8.4		8.2	8.4		8.3			

Dissolved Oxygen

Dissolved oxygen in Nose Creek ranged from 1.60 to 14.30 mg/L (N=70) in 2013 (Table 7). At Nose Creek, seven samples were less than the 1-day 5.0 mg/L acute dissolved oxygen objective, resulting in a 90% compliance rate. Four of the lowest dissolved oxygen concentrations (1-day 5.0 mg/L acute) at Nose Creek occurred between June 19th and August 14th. Overcast conditions on June 19th and July 17th likely resulted in a reduction of dissolved oxygen through reduced photosynthesis. Eleven samples were less than the 7-day 6.5 mg/L chronic dissolved oxygen objective[4], resulting in a 74% compliance rate. At Nose Creek, the acute oxygen compliance rate in 2013 (90%) was similar to 2012 (88%), 2011 (90%) and 2009 (91%), lower than 2010 (97%) but higher than 1999-2001 (84%) (Table 3). The chronic oxygen compliance rate in 2013 (74%), was similar to 2012 (76%), 2011 (79%) and 2009 (79%) but was lower than 2010 (100%) and higher than 1999-2001 (69%) (Table 3). The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The release of treated effluent from Crossfield did not appear to lower dissolved oxygen at Nose Creek and may have actually increased concentrations slightly. On June 19th (prior to release), the oxygen was 4.6 mg/L upstream of the release point (**NC d/s Crossfield**) and 5.6 mg/L downstream of the release point (**NC u/s Airdrie**). On July 17th (the day after release stopped) the oxygen was 2.4 mg/L upstream of the release point and 6.1 mg/L downstream of the release point (Table 7).

Dissolved oxygen in West Nose Creek ranged from 7.00 to 16.90 mg/L (N=27) in 2013 (Table 7). At the three West Nose Creek sites, no sample was less than the 1-day 5.0 mg/L acute dissolved oxygen objective or the 6.5 mg/L chronic dissolved oxygen objective. The maximum dissolved oxygen concentration at West Nose Creek (16.90 mg/L) occurred on May 8th at **WNC at Big Hills Springs Rd** and the lowest dissolved oxygen (7.0 mg/L) occurred on June 19th at **WNC at Big Hills Springs Rd**. At West Nose Creek, the acute oxygen compliance rate in 2013 (100%) was similar to 2012 (96%), 2011 (100%), 2010 (100%) and 2009 (100%) and higher than 1999-2001 (86%) (Table 3). The chronic oxygen compliance rate in 2013 (100%) was similar to 2012 (93%), 2011 (96%), 2010 (100%) and 2009 (95%) and higher than 1999-2001 (76%) (Table 3).

In 2009, Morris (2009) recorded fluctuations in oxygen concentration at **NC u/s Airdrie** from June 23 to September 4 and observed that oxygen concentrations often fell below 5 mg/L during the night. At **NC at Mouth**, oxygen concentrations were always above 5 mg/L from June 23 to July 3 (no data collected after July 3) (Morris 2009). A highly variable dissolved oxygen regime at sites within Nose Creek is probably due to aquatic macrophytes and filamentous algae. In aquatic systems, algae and aquatic plants are the primary sources and consumers of oxygen. Extensive diurnal variation in oxygen concentrations is often observed in creeks and rivers with dense growths of aquatic plants. Sunlight promotes intense photosynthesis (oxygen production) during daylight hours, particularly in late afternoon, with lower oxygen concentrations often observed at night, just before dawn, as a result of plant respiration (oxygen consumption) (Hynes 1970; Hauer and Hill 1996). The large diurnal fluctuations in dissolved oxygen in 2009 at **NC u/s Airdrie** may have been exacerbated due to the fact that the site had no flow (i.e., site was stagnant) and may have been subject to intensified photosynthesis for much of the study. Nonetheless, it is likely that most of the sites within this study undergo diurnal oxygen fluctuations during the active growing season (June to September) with oxygen concentrations often falling below 5 mg/L during late evening/early morning.

[4] The 6.5 mg/L chronic dissolved oxygen objective is a 7-day running average. Samples in this study were taken approximately from one to three times monthly; therefore, it was assumed oxygen values less than 6.5 mg/L did not meet the chronic guideline for one week but in most cases the mean 7-day oxygen concentration was likely greater than 6.5 mg/L. Therefore, chronic compliance rates in this report are likely underestimated.

Electrical Conductivity

In 2013, electrical conductivity (EC) ranged from 405 to 3306 µS/cm (N=70) in Nose Creek (Table 8). The highest EC in Nose Creek (3306 µS/cm) occurred at **NC at Mouth** on April 15th, while the lowest EC (405 µS/cm) occurred at **NC u/s Crossfield** on April 10th. In 2013, 49% of the Nose creek samples met the compliance target of less 1000 µS/cm which was less than 2011 (63%), but higher than 2012 (32%), 2010 (27%), 2009 (29%) and 1999-2001 (38%) (Table 3). The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The release of treated effluent did not appear to influence conductivity at Nose Creek. On June 19th (prior to release), the conductivity was 912 µS/cm upstream of the release point (**NC d/s Crossfield**) and 896 µS/cm downstream of the release point (**NC u/s Airdrie**). On July 17th (the day after release stopped) the conductivity was 925 µS/cm upstream of the release point and 978 µS/cm downstream of the release point (Table 8).

The sites within the City of Calgary (**NC at 15 St**, **NC u/s WNC** and **NC at Mouth)** had a low compliance rate of 19% (N=32) compared to the compliance rate of 74% for the sites upstream of Calgary (N=38).

In 2013, electrical conductivity at West Nose Creek ranged from 442 to 1754 µS/cm (N=27), with the lowest electrical conductivity at **WNC at Mountain View Rd** on November 18th and the highest on April 15th at **WNC at Mouth**. A total of 93% of the samples from West Nose Creek were in compliance with the water quality objective of less than 1000 µS/cm. The site **WNC at Big Hill Springs Rd** and **WNC at Mountain View Rd** had a 100% compliance rate while **WNC at Mouth** had the lowest compliance rate at 71%. The electrical conductivity compliance rate at West Nose Creek in 2013 (93%) was similar to 2011 (86%), 2009 (90%) and 1999-2001 (91%) and higher than 2012 (81%) and 2010 (76%) (Table 3).

Table 7 - Dissolved oxygen from Nose Creek and West Nose Creek, January to December 2013. A red value indicates the oxygen did not meet the applicable acute oxygen water quality objective. A yellow value indicates the oxygen did not meet the chronic 7-day oxygen water quality objective. Blank cells indicate no sample was taken (nf: indicates 'no flow', standing water may have been present).

Dissolved Oxygen (mg/L)	21-Jan	25-Feb	25-Mar	10-Apr	15-Apr	24-Apr	08-May	22-May	27-May	05-Jun	19-Jun	04-Jul	17-Jul	29-Jul	14-Aug	26-Aug	23-Sep	24-Sep	21-Oct	23-Oct	18-Nov	16-Dec
NOSE CREEK																						
NC u/s Crossfield				**1.6**		9.4	10.8	8.6		6.2	**5.3**		**5.0**		**4.3**			nf		nf		
NC d/s Crossfield				8.5		11.9	10.0	7.0		6.3	6.8		8.5		6.7			**4.9**		**6.4**		
NC u/s Airdrie				8.3		12.1	11.0	8.0		**5.0**	**4.6**		**2.4**		**3.5**			7.6		8.3		
NC d/s Airdrie				8.0		14.3	11.5	**5.1**		6.6	**5.6**		**6.1**		6.7			10.4		11.5		
NC at 15 St		**4.7**	10.2		13.0				7.1			**6.0**		8.0		8.2	8.9		11.9		11.9	7.0
NC u/s WNC				9.7		12.5	9.2	**5.1**		7.0	**6.1**		**5.1**		7.1			7.5		8.7		
NC at Mouth		13.1	13.1		12.7				8.2			6.5		8.0		7.7	9.4		12.1		14.0	12.3
WEST NOSE CREEK																						
WNC at Big Hill Springs Rd				9.4		12.0	16.9	7.5		10.7	7.0		9.3		12.7			11.5		11.2		
WNC at Mountain View Rd			13.0		13.3				8.0			7.6		9.4		10.1	10.4		12.2		11.0	11.9
WNC at Mouth					14.3				9.4			8.4		9.7		7.6	9.9		12.0			

Table 8 - Electrical conductivity data from Nose Creek and West Nose Creek, January to December 2013. A red value indicates the electrical conductivity exceeds the applicable electrical conductivity water quality objective. Blank cells indicate no sample was taken (nf: indicates 'no flow', standing water may have been present).

Electrical Conductivity (µS/cm)	21-Jan	25-Feb	25-Mar	10-Apr	15-Apr	24-Apr	08-May	22-May	27-May	05-Jun	19-Jun	04-Jul	17-Jul	29-Jul	14-Aug	26-Aug	23-Sep	24-Sep	21-Oct	23-Oct	18-Nov	16-Dec
NOSE CREEK																						
NC u/s Crossfield				405		426	931	943		677	713		751		711			nf		nf		
NC d/s Crossfield				415		708	**1035**	**1040**		794	912		925		851			**1085**		**1011**		
NC u/s Airdrie				575		661	**1114**	825		**1042**	896		978		980			725		690		
NC d/s Airdrie				745		700	**1094**	**1022**		956	847		**1028**		790			**1013**		796		
NC at 15 St		**1908**	**1178**		972				**1026**			**1018**		**1079**		**1155**	922		**1143**		**1504**	**1518**
NC u/s WNC				896		916	**1416**	**1478**		**1028**	**1020**		905		910			**1183**		**1180**		
NC at Mouth		**1790**	**1292**		**3306**				**1015**			**1004**		**1148**		**1199**	**1122**		**1162**		**1718**	**3283**
WEST NOSE CREEK																						
WNC at Big Hill Springs Rd				742		623	991	977		732	792		730		621			831		719		
WNC at Mountain View Rd			625		626				826			862		848		878	868		892		442	919
WNC at Mouth					**1754**				915			989		980		916	973		**1009**			

Total Dissolved Solids

Total dissolved solids (TDS) ranged from 405 to 970 mg/L (N=48) in Nose Creek (Table 9). The maximum TDS concentration in Nose Creek (970 mg/L) at **NC u/s WNC** occurred on May 22nd while the lowest TDS concentration (405 mg/L) occurred on April 10th at **NC u/s Crossfield**. Nose Creek on average had higher TDS concentrations in comparison to West Nose Creek. At Nose Creek, the TDS compliance rate in 2013 (25%) was similar to 2011 (36%) and higher than 2012 (10%), 2010 (9%), 2009 (0%) and 1999-2001 (15%) (Table 3).

Total dissolved solids (TDS) at West Nose Creek (**WNC at Big Hill Springs Rd**) ranged from 405 to 742 mg/L (N=10) (Table 9). At West Nose Creek, the TDS compliance rate in 2013 (50%) was lower than 2011 (80%) but higher than 2012 (10%), 2010 (0%), 2009 (0%) and 1999-2001 (6%) (Table 3).

Grasby *et al.* (1997) determined that Nose Creek has a TDS load, particularly sulphate, which is significantly higher than the Bow River or its other tributaries. Using chemical and stable isotope analysis to determine sources of TDS in Nose Creek they determined that substantial amounts of water are added to Nose Creek by leaking municipal pipes via groundwater from Airdrie and Calgary. They identified three clusters of sulphate in Nose Creek in the fall that suggested different sources. Upstream of Airdrie, the source of sulphate was identified as being consistent with SO_2 emissions during processing of sour gas near Crossfield. The oxidation of organic matter in soils was identified as the primary source of increased sulphate concentrations between Airdrie and Calgary. The third source of sulphates within the City of Calgary was identified as a large flux of water added by the City of Calgary (via leaking pipes) that is oxidizing reduced forms of sulphur in the till, which is then mobilized as SO_4 and transported into Nose Creek via groundwater flow (Grasby *et al.* 1997).

Table 9 - Total dissolved solids (TDS) data from Nose Creek and West Nose Creek, April to October 2013. A red value indicates the TDS exceeds the water quality objective.

Total Dissolved Solids (mg/L)	10-Apr	24-Apr	8-May	22-May	05-Jun	19-Jun	17-Jul	14-Aug	24-Sep	23-Oct
Nose Creek										
NC u/s Crossfield	405	426	**610**	**616**	440	465	481	465	nf	nf
NC d/s Crossfield	415	460	**673**	**678**	**517**	**592**	**601**	**553**	**694**	**658**
NC u/s Airdrie	**575**	430	**730**	**534**	**658**	**582**	**629**	**638**	474	449
NC d/s Airdrie	**745**	455	**711**	**688**	**630**	**553**	**663**	**790**	**658**	**517**
NC u/s WNC	**583**	**595**	**916**	**970**	**668**	**663**	**585**	**591**	**772**	**768**
West Nose Creek										
WNC at Big Hill Springs Rd	**742**	405	**647**	**588**	472	**515**	475	405	**549**	467

Total Phosphorus

Total phosphorus, ranging from 0.03 to 0.70 mg/L (N=71), usually exceeded the target compliance objective (0.05 mg/L) at Nose Creek throughout the year and had a compliance rate of 4% (Table 10). At Nose Creek, the total phosphorus compliance rate in 2013 (4%), was similar to 2012 (5%), 2011 (4%), 2009 (0%) and 1999-2001 (2%) but lower than 2010 (12%) (Table 3). The highest TP concentration (0.70 mg/L) occurred on August 14th at **NC u/s Airdrie** and the lowest (0.03 mg/L) occurred on November 18th at **NC at 15 St**. The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The release of treated effluent from Crossfield appears to have increased total phosphorus concentrations at Nose Creek. On June 19th (prior to release), the total phosphorus was 0.22 mg/L upstream of the release point (**NC d/s Crossfield**) and 0.39 mg/L downstream of the release point (**NC u/s Airdrie**). On July 17th (the day after release stopped) the total phosphorus was 0.19 mg/L upstream of the release point and 0.68 mg/L downstream of the release point. Total phosphorus concentrations remained elevated until at least August 14th at 0.70 mg/L at **NC u/s Airdrie**. In 2012, the effect of the treated wastewater release on downstream total phosphorus concentrations was unclear. In previous years, the treated wastewater release increased total phosphorus concentrations at **NC u/s Airdrie**, particularly when the site **NC d/s Crossfield** had minor to no flow. The trend of increased total phosphorus concentrations at **NC u/s Airdrie**, even during periods outside of designated release periods may be due to the Town of Crossfield lagoon. On two separate occasions, two different landowners approached Palliser Environmental staff to inform them that the lagoon frequently overflows in the spring and after rain events as they observed flow in the channel that conveys effluent from the lagoon to Nose Creek. The channel does however drain a watershed area upstream of the lagoon; therefore, it is not known if these flows are from the lagoon or from spring runoff and/or precipitation events draining the watershed. Further monitoring of the lagoon channel and the channel upstream of the lagoon may be warranted.

The seasonal median TP concentration was above 0.05 mg/L for winter, spring and summer at all Nose Creek sites (Figure 2). The lowest median total phosphorus concentration occurred during the winter at **NC at Mouth** (0.09 mg/L) and **NC at 15 St** (0.11 mg/L). The highest median TP concentration occurred at **NC u/s Crossfield** in the summer (0.51 mg/L) and may have been due to runoff from upstream pastures. Generally, the seasonal median concentration of total phosphorus was higher in the summer at the upper watershed sites compared to the lower watershed sites (Figure 2). The higher concentration of TP at the upper sites was probably due to agricultural runoff and releases from the lagoon. The lower TP concentration at the lower sites was probably a result of phosphorus uptake by filamentous algae and aquatic plants at the lower sites which was observed to be dense.

Nineteen percent of the West Nose Creek samples had TP concentrations below the target compliance objective of 0.05 mg/L, and ranged from 0.02 to 0.37 mg/L (N=27) (Table 10). At West Nose Creek, the total phosphorus compliance rate in 2013 (19%) was similar to 2011 (25%), 2010 (33%) and 1999-2001 (15%) but lower than 2009 (52%) and 2012 (41%) (Table 3). The lowest TP concentration was 0.02 mg/L on September 23rd at **WNC at Mountain View Rd** and the highest was 0.37 mg/L on May 27th at **WNC at Mouth**. By site, the highest compliance rate was at **WNC at Mountain View Rd** (30%) and the lowest compliance rate was at **WNC at Big Hill Springs Rd** (10%). At West Nose Creek, the median total phosphorus was above the 0.05 mg/L guideline for all sites and seasons with the exception of the summer median TP concentration (0.03 mg/L) at **WNC at Mountain View Rd which** was below the guideline. The highest spring (0.23 mg/L) and summer (0.14 mg/L) median TP concentration occurred at **WNC**

at Mouth (Figure 2). Overall, the median TP concentrations at West Nose Creek were lower when compared to Nose Creek.

Phosphorus concentrations are a concern at both creeks since it enriches freshwater (a process known as eutrophication), contributing to the growth of aquatic plants. Aquatic plants produce oxygen through photosynthesis during the day; however, on cloudy days or during the night, the plants consume oxygen for respiration and can deteriorate fish habitat conditions. In addition, oxygen is used during the decomposition of plant material, again decreasing oxygen resources for fish and other aquatic life.

Sources of phosphorus include organic and inorganic fertilizers that are used for agricultural crop production and urban lawn maintenance, livestock manure, pet feces, poorly designed or failing septic systems, and treated municipal effluent. In urban areas, Waschbusch *et al.* (1999) found lawns and streets were the largest sources of phosphorus in urban stormwater.

Table 10 - Total phosphorus data from Nose Creek and West Nose Creek, January to December 2013. A red value indicates total phosphorus exceeds the water quality objective for site and date. Blank cells indicate no sample was taken.

Phosphorus, Total (mg/L)	21-Jan	25-Feb	25-Mar	10-Apr	15-Apr	24-Apr	08-May	22-May	27-May	05-Jun	19-Jun	04-Jul	17-Jul	29-Jul	14-Aug	26-Aug	23-Sep	24-Sep	21-Oct	23-Oct	18-Nov	16-Dec
Nose Creek																						
NC u/s Crossfield				**0.52**		**0.29**	**0.12**	**0.14**		**0.35**	**0.43**		**0.45**		**0.56**			**nf**		**nf**		
NC d/s Crossfield				**0.61**		**0.39**	**0.15**	**0.17**		**0.32**	**0.22**		**0.19**		**0.16**			**0.29**		**0.17**		
NC u/s Airdrie				**0.65**		**0.31**	**0.36**	**0.24**		**0.35**	**0.39**		**0.68**		**0.70**			**0.13**		**0.12**		
NC d/s Airdrie				**0.42**		**0.22**	**0.16**	**0.12**		**0.26**	**0.21**		**0.40**		**0.32**			**0.11**		**0.07**		
NC at 15 St		**0.06**	**0.30**		**0.29**				**0.45**			**0.51**		**0.49**		**0.29**	**0.13**		**0.07**		0.03	**0.16**
NC u/s WNC				**0.38**		**0.21**	**0.22**	**0.13**		**0.22**	**0.22**		**0.32**		**0.19**			**0.11**		**0.08**		
NC at Mouth	**0.05**	**0.09**	**0.25**		**0.20**				**0.41**			**0.27**		**0.23**		**0.13**	**0.08**		0.04		0.04	**0.12**
West Nose Creek																						
WNC at Big Hill Springs Rd				**0.10**		**0.09**	**0.09**	**0.07**		**0.20**	**0.15**		**0.14**		**0.08**			0.03		**0.05**		
WNC at Mountain View Rd			**0.26**		**0.13**				**0.22**			**0.21**		**0.15**		0.03	0.02		0.03		**0.05**	**0.10**
WNC at Mouth					**0.09**				**0.37**			**0.18**		**0.17**		**0.14**	0.03		0.05			

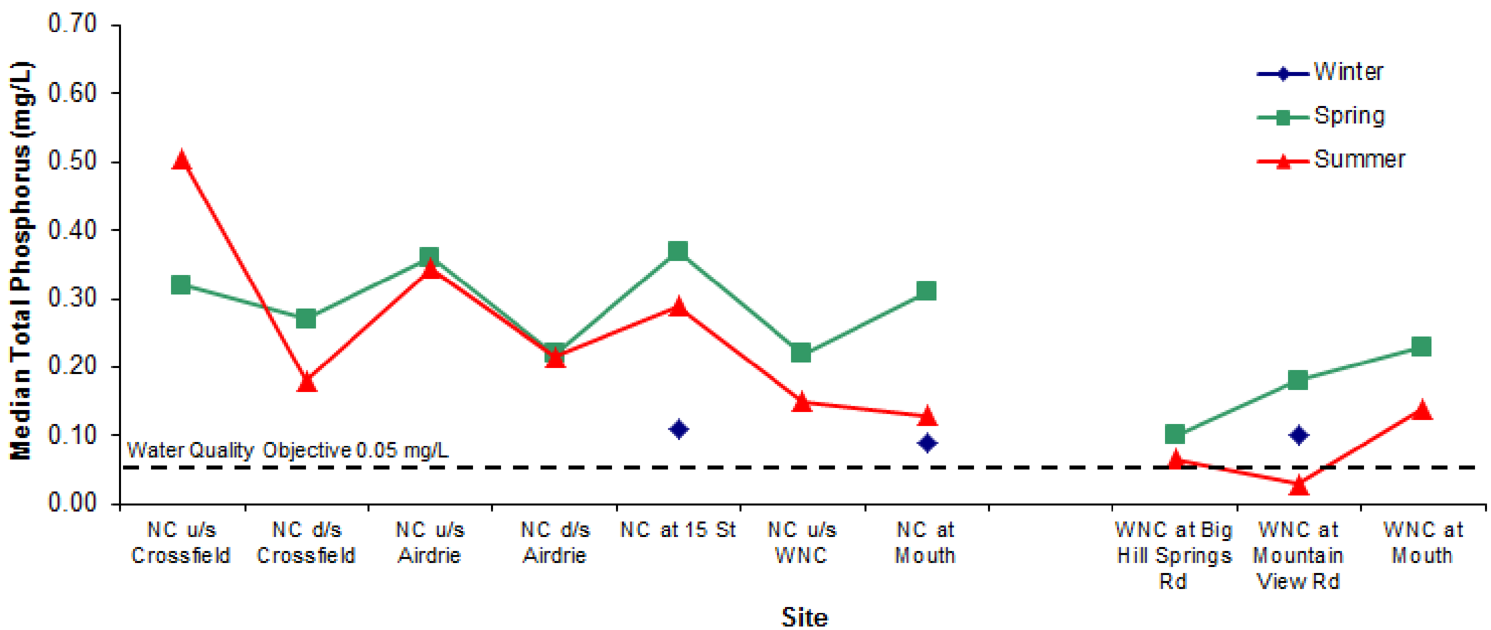

Figure 2 - Seasonal median total phosphorus in Nose Creek and West Nose Creek (upstream to downstream) in 2013.

Dissolved Phosphorus

Dissolved phosphorus (DP) in Nose Creek ranged from 0.01 to 0.69 mg/L (N=71), and often exceeded the target compliance objective (0.02 mg/L) throughout the year with a compliance rate of 7% (Table 11). At Nose Creek, the dissolved phosphorus compliance rate in 2013 (7%) was similar to 2011 (9%) but lower than 2012 (23%), 2010 (37%), 2009 (32%) and 1999-2001 (24%) (Table 3). The highest DP concentration (0.69 mg/L) occurred on August 14th at **NC u/s Airdrie**. The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The release of treated effluent from Crossfield appears to have increased dissolved phosphorus concentrations at Nose Creek. On June 19th (prior to release), the total phosphorus was 0.16 mg/L upstream of the release point (**NC d/s Crossfield**) and 0.36 mg/L downstream of the release point (**NC u/s Airdrie**). On July 17th (the day after release stopped) the total phosphorus was 0.16 mg/L upstream of the release point and 0.64 mg/L downstream of the release point. Dissolved phosphorus concentrations remained elevated until at least August 14th at 0.69 mg/L at **NC u/s Airdrie**.

All of the seasonal median dissolved phosphorus concentrations were above the 0.02 mg/L objective at Nose Creek (Figure 3). The higher summer median concentration of DP at **NC u/s Airdrie** was likely due to the release of effluent from the Town of Crossfield. Generally, the seasonal median DP concentration was higher in spring and summer at the upper watershed sites compared to the lower watershed sites (Figure 3). The higher concentration of DP at the upper sites (**NC u/s Crossfield** and **NC u/s Airdrie**) was probably due to agricultural runoff and releases from the lagoon, respectively. The lower DP concentration at the lower sites was probably a result of phosphorus uptake by filamentous algae and aquatic plants at the lower sites which was observed to be dense.

Dissolved phosphorus (DP) in West Nose Creek ranged from <0.01 to 0.17 mg/L (N=27) (Table 11). Nineteen percent of the West Nose Creek samples had DP concentrations below the target compliance objective of 0.02 mg/L (Table 10). At West Nose Creek, the dissolved phosphorus compliance rate in 2013 (19%) was similar to 1999-2001 (19%), but lower than 2012 (41%), 2011 (32%), 2010 (43%) and 2009 (62%) (Table 3). The lowest DP concentration was <0.01 mg/L on September 21st at **WNC at Mouth** and the highest was 0.17 mg/L on May 27th at **WNC at Mouth**. Seventy-nine percent (79%) of the total May rainfall fell from May 23rd to 25th. The increased watershed runoff probably resulted in the increased dissolved phosphorus on May 27th. By site, the highest compliance rate was at **WNC at Mouth** (29%) and the lowest compliance rate was at **WNC at Mountain View Rd** (10%). All of the seasonal median dissolved phosphorus concentrations were above the 0.02 mg/L objective at West Nose Creek with the exception of site **WNC at Mountain View Rd** (0.02 mg/L). Overall, the median DP concentrations at West Nose Creek were lower when compared to Nose Creek (Figure 3).

Table 11 - Dissolved phosphorus data from Nose Creek and West Nose Creek, January to December 2013. Blank cells indicate no sample was taken.

Phosphorus, Dissolved (mg/L)	21-Jan	25-Feb	25-Mar	10-Apr	15-Apr	24-Apr	08-May	22-May	27-May	05-Jun	19-Jun	04-Jul	17-Jul	29-Jul	14-Aug	26-Aug	23-Sep	24-Sep	21-Oct	23-Oct	18-Nov	16-Dec
Nose Creek																						
NC u/s Crossfield				0.49		0.27	0.07	0.03		0.32	0.41		0.42		0.48			nf		nf		
NC d/s Crossfield				0.53		0.10	0.06	0.04		0.27	0.16		0.16		0.13			0.06		0.03		
NC u/s Airdrie				0.51		0.15	0.24	0.06		0.34	0.36		0.64		0.69			0.09		0.07		
NC d/s Airdrie				0.29		0.05	0.02	0.01		0.19	0.13		0.32		0.24			0.04		0.07		
NC at 15 St		0.03	0.22		0.14				0.26			0.33		0.30		0.18	0.06		0.02		0.08	0.10
NC u/s WNC				0.25		0.03	0.01	0.01		0.15	0.08		0.25		0.13			0.02		0.08		
NC at Mouth	0.03	0.04	0.17		0.06				0.16			0.18		0.15		0.04	0.02		0.01		0.01	0.04
West Nose Creek																						
WNC at Big Hill Springs Rd				0.04		0.09	0.02	0.01		0.15	0.09		0.11		0.06			0.01		0.02		
WNC at Mountain View Rd			0.16		0.03				0.14			0.14		0.09		0.02	0.02		0.01		0.04	0.06
WNC at Mouth					0.02				0.17			0.10		0.05		0.03	0.01		<0.01			

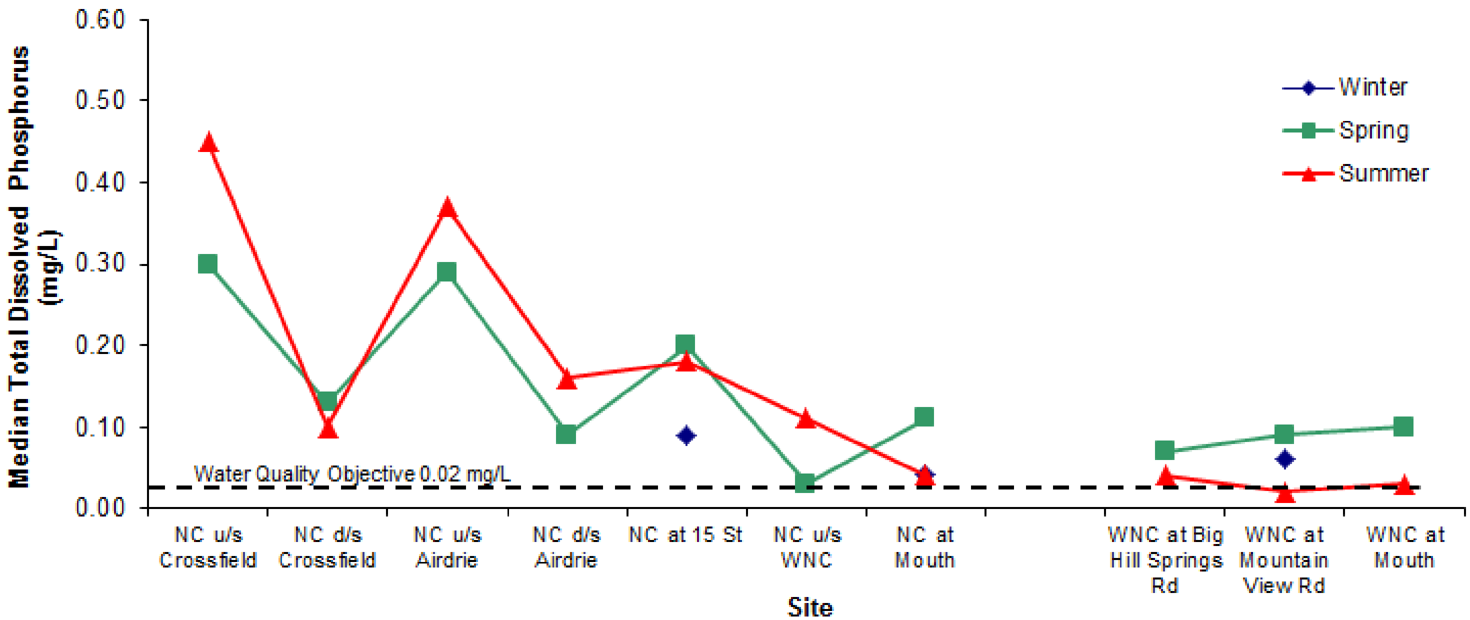

Figure 3 - Seasonal median total dissolved phosphorus in Nose Creek and West Nose Creek in 2013.

Nitrate-Nitrite

At Nose Creek, nitrate-nitrite (<0.005 to 2.30 mg/L) was usually below the guideline of 1.5 mg/L with an overall compliance rate of 78% in 2013 (N=23) (Table 12). The five samples exceeding the guideline all occurred at **NC at Mouth** during the colder months of October to February. The higher concentrations of nitrate-nitrite during the colder months are probably due to reduced utilization by plants/algae and increased inputs from groundwater. At Nose Creek, the nitrate-nitrite compliance rate in 2013 (78%) was similar to 2012 (83%) and 2009 (83%) but lower the 2011 (93%), 2010 (94%) and 1999-2001 (89%) (Table 3).

At West Nose Creek, nitrate-nitrite was also usually below the guideline of 1.5 mg/L with an overall compliance rate of 76% in 2013 (N=17) (Table 12). The four samples exceeding the guideline occurred in late-summer from July to October at **WNC at Mouth**. At West Nose Creek, the nitrate-nitrite compliance rate in 2013 (76%) was similar to 2012 (83%), 2011 (82%) and 1999-2001 (85%) but slightly lower than 2010 (93%) and 2009 (88%) (Table 3).

Total Ammonia-N

At Nose Creek, total ammonia-N had an overall compliance rate of 95% in 2013 (N=21) (Table 13). A single sample exceeded the guideline on September 23rd at **NC at 15 St**. A single sample from August 26th at **NC at 15 St** had a detection limit that was greater than the total ammonia-N guideline[5], thus, there is some uncertainty as to whether this sample met the guideline. At Nose Creek, the total ammonia-N compliance rate in 2013 (95%) was similar to 2012 (98%), 2011 (100%) and 1999-2001 (91%) and slightly higher than 2010 (88%) and 2009 (83%) (Table 3).

At West Nose Creek, total ammonia-N was often below the detection limit and had an overall compliance rate of 100% in 2013 (N=16) (Table 13). At West Nose Creek, the total ammonia-N compliance rate in 2013 (100%) was similar to 2012 (96%), 2011 (100%), 2010 (100%), 2009 (100%) and 1999-2001 (97%) (Table 3).

[5] Total ammonia guidelines vary and are dependent on pH and water temperature.

Table 12 - Nitrate-nitrite nitrogen data for Nose Creek and West Nose Creek, January to December 2013. A red value indicates the nitrate-nitrite nitrogen exceeds the water quality objective for that site and date. Blank cells indicate no sample was taken.

Nitrate-nitrite nitrogen (mg/L)	21-Jan	25-Feb	25-Mar	15-Apr	27-May	04-Jul	29-Jul	26-Aug	23-Sep	21-Oct	18-Nov	16-Dec
Nose Creek												
NC u/s Crossfield												
NC d/s Crossfield												
NC u/s Airdrie												
NC d/s Airdrie												
NC at 15 St		0.91	0.43	0.22	0.27	0.40	0.31	<0.005	0.22	0.40	1.01	1.22
NC u/s WNC												
NC at Mouth	**2.30**	**1.80**	0.95	0.79	0.71	1.22	1.11	1.20	1.20	**1.63**	**2.10**	**2.00**
West Nose Creek												
WNC at Big Hill Springs Rd												
WNC at Mountain View Rd			1.00	0.85	0.21	0.81	0.87	0.92	0.95	1.30	0.87	0.71
WNC at Mouth				1.10	0.85	**1.51**	**1.50**	**1.62**	1.40	**1.90**		

Table 13 - Total ammonia-N data for Nose Creek and West Nose Creek, January to December 2013. A red value indicates the total ammonia-N exceeds the water quality objective for that site and date. A yellow value indicates the detection limit of the total ammonia-N analysis was greater than the guideline; therefore, it is uncertain if the sample meets the guideline.

Total-ammonia-N (mg/L)	21-Jan	25-Feb	25-Mar	15-Apr	27-May	04-Jul	29-Jul	26-Aug	23-Sep	21-Oct	18-Nov	16-Dec
Nose Creek												
NC u/s Crossfield												
NC d/s Crossfield												
NC u/s Airdrie												
NC d/s Airdrie												
NC at 15 St		0.16		0.13	<0.10	<0.10	<0.10	<0.10	**0.31**	0.21	0.20	0.40
NC u/s WNC												
NC at Mouth	<0.90	<0.10		0.30	0.22	<0.10	0.14	<0.10	0.13	<0.10	0.20	0.39
West Nose Creek												
WNC at Big Hill Springs Rd												
WNC at Mountain View Rd				0.12	<0.10	<0.10	<0.10	<0.10	0.21	<0.10	<0.10	0.10
WNC at Mouth				0.13	0.29	<0.10	<0.10	0.15	0.15	<0.10		

Fecal Coliform Bacteria

Bacteria concentrations ranged from <1 to >2,520 CFU/100 mL in Nose Creek (N=71) (Table 14) in 2013. The highest concentration of fecal coliform (>2,520 CFU/100 mL) occurred on May 27th at **NC at 15 St** and **NC at Mouth** and occurred after heavy rain from May 23rd to 25th. Eighty-seven percent of the Nose Creek samples had fecal coliform concentrations below the *contact recreation objective* of 400 CFU/100 mL. The site **NC at Mouth** had the lowest compliance rate at 58%, whereas, the sites **NC u/s Crossfield**, **NC d/s Crossfield**, **NC d/s Airdrie** and **NC u/s WNC** had a 100% highest compliance. At Nose Creek, the 400 CFU/100 mL fecal coliform compliance rate in 2013 (87%) was similar to 2011 (90%) and 2010 (84%) and higher than 2012 (70%), 2009 (65%) and 1999-2001 (76%) (Table 3). Sixty-three percent of the Nose Creek samples had fecal coliform concentrations below the *irrigation guideline* of 100 CFU/100 mL. The site **NC at Mouth** had the lowest compliance rate at 17%, whereas, the site **NC u/s Crossfield** had the highest compliance rate at 88%. At Nose Creek, the 100 CFU/100 mL fecal coliform compliance rate in 2013 (63%) was similar to 2012 (58%), 2011 (64%) and 2010 (53%) but higher than 2009 (38%) and 1999-2001 (45%) (Table 3).

Most of the median spring and summer concentrations of bacteria were below both the 100 and 400 CFU/100 mL guidelines for irrigation and contact recreation. The highest spring median concentration of bacteria occurred at **NC at Mouth** (1454 CFU/100 mL) and the highest summer concentration at **NC u/s Airdrie** (650 CFU/100 mL). High bacteria counts at **NC u/s Airdrie** was probably due to livestock and wildlife (e.g., waterfowl) as the area upstream is dominated by pasture lands, and contains large wetland areas. The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The release of treated effluent from Crossfield did not appear to affect fecal bacteria concentrations at Nose Creek. On June 19th (prior to release), the fecal bacteria count was 102 CFU/100 mL upstream of the release point (**NC d/s Crossfield**) and 200 CFU/100 mL downstream of the release point (**NC u/s Airdrie**). On July 17th (the day after release stopped) the fecal coliform count was 76 CFU/100 mL upstream of the release point and 200 CFU/100 mL downstream of the release point. This is a result similar for the monitoring years 2009 to 2011. A water sample was obtained in 2011 from the channel draining the Town of Crossfield sewage lagoon during the effluent release and fecal coliform bacteria were low at 4 CFU/100 mL. The median winter bacteria count at **NC at Mouth** were elevated in 2013 (548 CFU/100 mL) compared to the upstream **NC at 15 St** site. This result is similar to higher counts in 2012 (461 CFU/100 mL), 2011 (687 CFU/100 mL), 2010 (649 CFU/100 mL) and 2009 (2076 CFU/100 mL) at **NC at Mouth** (Palliser Environmental 2010, 2011, 2012, 2013). The cause of elevated bacteria counts at **NC at Mouth** is not known but the data suggests a nearby, point source (i.e., an outfall influenced by the Calgary Zoo). Median winter bacteria counts at **NC at 15 St** have been consistently low from 2009 to 2013, ranging from 3.5 to 34 CFU/100 mL.

Bacteria concentrations ranged from <1 to >2520 CFU/100 mL in West Nose Creek (N=27) in 2013 (Table 14). The highest bacteria counts were at **WNC at Mountain View Rd** and **WNC at Mouth** on May 27th and occurred after heavy rain from May 23rd to 25th. Seventy-eight percent of the West Nose Creek samples had fecal coliform concentrations below the *contact recreation objective* of 400 CFU/100 mL. The site **WNC at Mountain View Rd** had the lowest compliance rate at 70%, whereas, the site **WNC at Big Hill Springs Rd** had the highest compliance rate at 90%. At West Nose Creek, the 400 CFU/100 mL fecal coliform compliance rate in 2013 (78%) was similar to 1999-2001 (83%), higher than 2012 (67%) and 2009 (71%) but lower than 2011 (89%) and 2010 (87%) (Table 3). Fifty-six percent of the West Nose Creek samples had fecal coliform concentrations below the *irrigation guideline* of 100 CFU/100 mL. The site **WNC at Big Hill Springs Rd** had the highest compliance rate at 70%, whereas, the site **WNC at Mouth** had the lowest compliance rate at 43%. At West Nose Creek, the 100 CFU/100 mL fecal coliform compliance rate in 2013 (56%) was similar to 2010 (53%), higher than 2012 (44%), 2009 (38%) and 1999-2001 (45%) but lower than 2011 (64%) (Table 3).

Seasonally, all of the spring, summer and winter median concentrations of bacteria at West Nose Creek were below the 400 CFU/100 mL guideline for contact recreation with the exception of **WNC at Mountain View Rd** and **WNC at Mouth** where spring bacteria concentrations were approximately 1300 CFU/100 mL. The site **WNC at Bighill Springs Rd** was below the 100 CFU/100 mL guideline for irrigation during spring and summer as was the site **WNC at Mountain View Rd** during the winter (Figure 4).

Elevated fecal coliform counts are a concern at Nose Creek and West Nose Creek. In rural areas, bacteria sources are generally linked to wildlife (e.g., beaver, deer, muskrat), waterfowl (e.g., ducks and geese), birds, livestock (e.g., cattle, horses and poultry) and humans (Hagedorn *et al.* 1999; Hyer and Moyer 2003). In urban areas, dogs (including dog parks), cats, waterfowl (particularly geese), birds and humans are sources of fecal coliform (Whitlock *et al.* 2002; Sercu *et al.* 2009). Runoff from nonpoint sources such as parking lots, lawns and pastures are a major source of bacteria particularly after storm events in areas with high watershed development and large areas of impervious surfaces (Gregory and Frick 2000). Recent studies on the Milk River suggest the presence of 'environmental bacteria' or those that can be attributed to growth in the environment rather than originating directly from a host source (L. Tymenson, AARD, unpublished).

Table 14 - Bacteria data (fecal and *E. coli*) for Nose Creek and West Nose Creek, January to December 2013. A red value indicates the bacteria count exceeds the contact and irrigation water quality objective (400 CFU/100 mL and 100 CFU/100 mL, respectively). A yellow value indicates the bacteria count exceeds the irrigation water quality objective (100 CFU/100 mL).

Bacteria (CFU/100mL)	21-Jan	25-Feb	25-Mar	10-Apr	15-Apr	24-Apr	08-May	22-May	27-May	05-Jun	19-Jun	04-Jul	17-Jul	29-Jul	14-Aug	26-Aug	23-Sep	24-Sep	21-Oct	23-Oct	18-Nov	16-Dec
NOSE CREEK																						
NC u/s Crossfield				2		29	32	7		91	56		104		12			nf		nf		
NC d/s Crossfield				<1		3	5	118		96	32		6		89			300		167		
NC u/s Airdrie				8		<1	5	52		97	102		76		500			800		800		
NC d/s Airdrie				3		93	10	24		400	200		200		69			16		21		
NC at 15 St		9	<1		10				>2520			135		110		64	57		6		21	4
NC u/s WNC				4		<1	<5	18		48	168		114		37			44		29		
NC at Mouth	548	2420	1203		387				>2520			365		126		130	47		435		66	365
WEST NOSE CREEK																						
WNC at Big Hill Springs Rd				1		<1	20	60		116	700		300		44			53		32		
WNC at Mountain View Rd			6		3				>2520			579		206		411	55		21		124	27
WNC at Mouth					17				>2520			185		107		866	83		39			

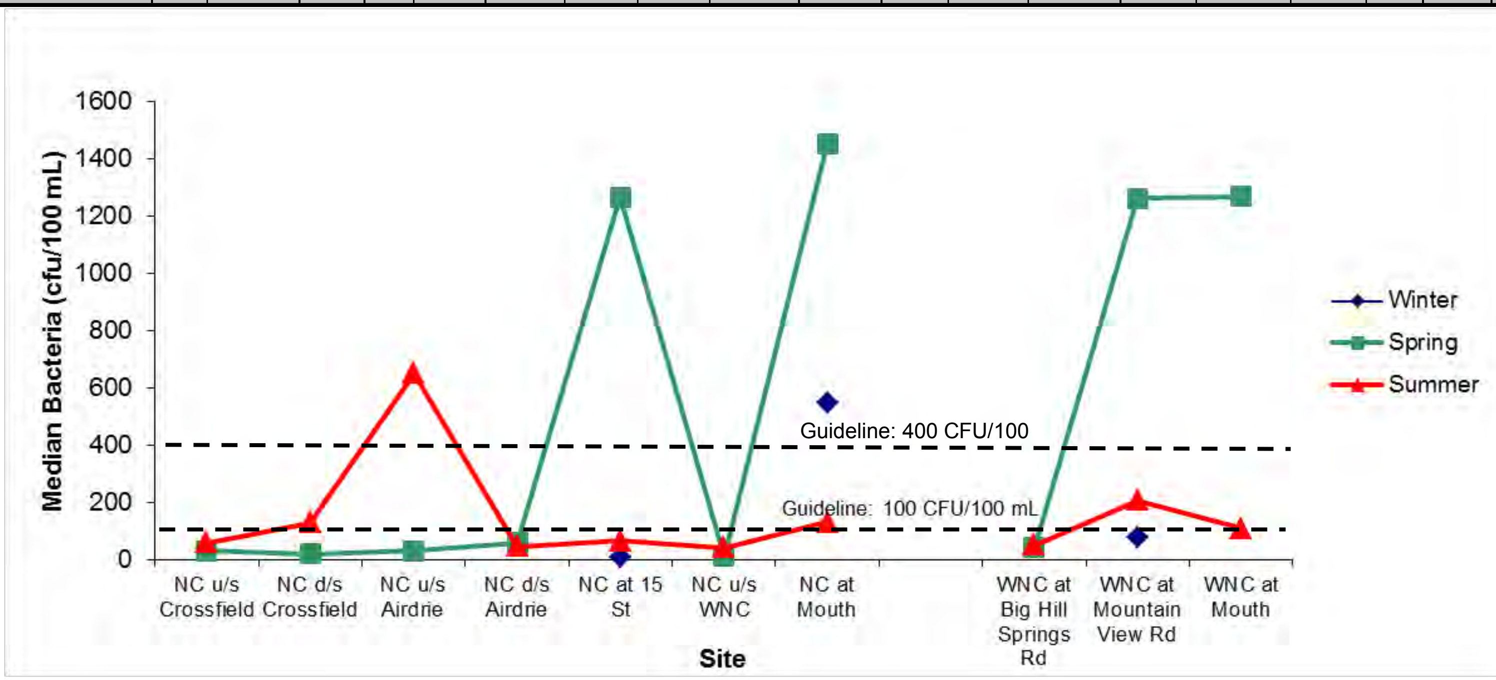

Figure 4 - Seasonal median bacteria concentration in Nose Creek and West Nose Creek in 2013. Data points for **NC d/s Airdrie**, **NC u/s WNC** and **WNC at Big Hill Springs Rd** represent fecal coliform bacteria. Other data points represent *E. coli.*

Total Suspended Solids

In 2013, total suspended solids (TSS) ranged from <4 to 233 mg/L in Nose Creek (N=71) (Table 15). The range of TSS concentrations at Nose Creek in 2013 was similar to 2009 (4 to 221 mg/L), higher than 2012 (2.6 to 116 mg/L), 2010 (<3 to 138 mg/L) and 2011 (<3 to 86) but lower than 2000-2001 (0.6 to 1620 mg/L). The highest concentration of TSS occurred at **NC at Mouth** (233 mg/L) on May 27th during higher flow and was probably the result of runoff from storm water outfalls due to heavy rain from May 23rd to 25th. The Town of Crossfield released treated effluent into Nose Creek from June 26th to July 16th. The release of treated effluent from Crossfield did not appear to affect TSS concentrations at Nose Creek. On June 19th (prior to release), the total suspended solids was 5 mg/L upstream of the release point (**NC d/s Crossfield**) and <4 mg/L downstream of the release point (**NC u/s Airdrie**). On July 17th (the day after release stopped) the total suspended solids was <4 mg/L upstream of the release point and <4 mg/L downstream of the release point (Table 5). Seasonally, the spring, summer and winter median TSS concentration generally increased from upstream to downstream which is probably the result of the increase in watershed area at each downstream site in conjunction with TSS contributions from stormwater outfalls in Airdrie and Calgary (Figure 5). Generally, the median summer concentration of TSS was higher than the spring concentrations (due to spring runoff) and the median winter TSS concentration was substantially lower than the spring or summer concentrations (Figure 5).

In 2013, total suspended solids (TSS) ranged from <2 to 133 mg/L in West Nose Creek (N=27) (Table 15). The 2013 range of TSS was similar to 2012 (2.4 to 142 mg/L), 2011 (<3 to 108.7 mg/L), lower than 2010 (3 to 249 mg/L) and 2009 (4 to 262 mg/L), but higher than 2000-2001 (1.6 to 72.3 mg/L). The lowest concentrations of suspended sediment (<2 mg/L) at West Nose Creek occurred at **WNC at Mountain View Rd** (August 26th and September 23rd) and the highest concentration of suspended solids occurred at **WNC at Mouth** (133 mg/L) on May 27th. The elevated TSS concentrations on May 27th occurred during higher flow and were probably the result of runoff from storm water outfalls due to heavy rain from May 23rd to 25th. Generally, the median spring TSS concentrations at West Nose Creek were higher than winter or summer concentrations, probably due to runoff. The highest median summer concentration of TSS (42 mg/L) occurred at **WNC at Mouth** (Figure 5); and the highest median spring concentration of TSS (72 mg/L) also occurred at **WNC at Mouth**. In 2013, TSS concentrations at West Nose Creek increased from upstream to downstream which is probably the result of the increase in watershed area at each downstream site in conjunction with TSS contributions from stormwater outfalls in Calgary. This trend occurred in 2011 but did not occur in 2012.

Note that no water quality guidelines or water quality objectives have been established for total suspended solids.

Table 15 - Total suspended solids data from Nose Creek and West Nose Creek, January to December 2013. Blank cells indicate no sample was taken.

Total Suspended Solids (mg/L)	21-Jan	25-Feb	25-Mar	10-Apr	15-Apr	24-Apr	08-May	22-May	27-May	05-Jun	19-Jun	04-Jul	17-Jul	29-Jul	14-Aug	26-Aug	23-Sep	24-Sep	21-Oct	23-Oct	18-Nov	16-Dec
NOSE CREEK																						
NC u/s Crossfield				<4		<4	<4	4		<4	<4		<4		<4			nf		nf		
NC d/s Crossfield				<4		19	8	<4		4	5		<4		5			137		85		
NC u/s Airdrie				18		33	22	<4		<4	<4		<4		16			7		21		
NC d/s Airdrie				14		15	35	17		15	37		33		23			12		15		
NC at 15 St		7	5		35				97			118		65		29	44		12		11	5
NC u/s WNC				19		15	46	35		20	53		40		28			23		34		
NC at Mouth	17	27	27		42				233			54		45		43	20		14		10	18
WEST NOSE CREEK																						
WNC at Big Hill Springs Rd				8		13	6	<4		11	22		7		<4			<4		6		
WNC at Mountain View Rd			71		95				49			49		18		<2	<2		7		10	19
WNC at Mouth					57				133			49		42		78	15		12			

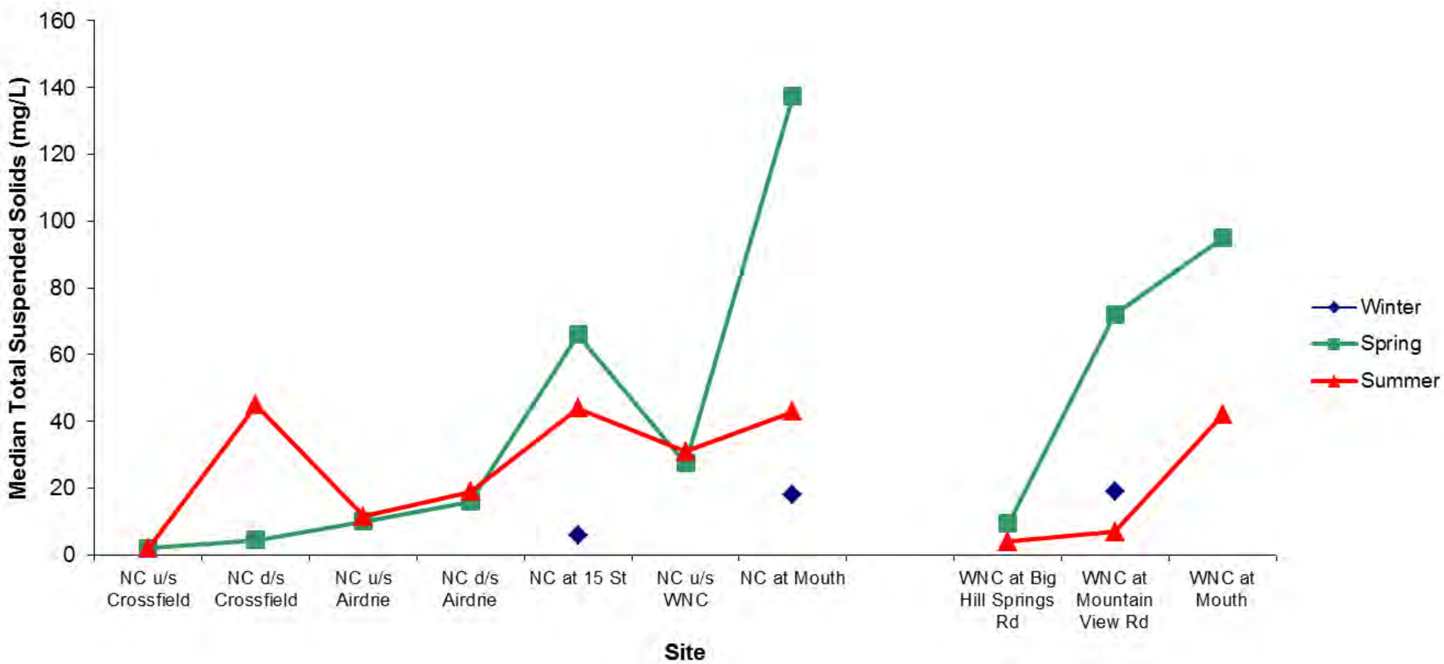

Figure 5 - Seasonal median total suspended solids in Nose Creek and West Nose Creek (upstream to downstream) in 2013.

5.0 SUMMARY AND RECOMMENDATIONS

Due to the timing of sample collection, there is no clear indication of the impact of the major rainfall event and subsequent flooding that occurred on June 20th and 21st 2013 on water quality in Nose and West Nose creeks. Samples were collected prior to the rainfall event (June 19) and following the event on July 17th. Generally, the water quality compliance rate of most parameters at Nose Creek were similar to 2012, with the exception of total dissolved phosphorus which had a lower compliance rate (7%) compared to 23% in 2012. At West Nose Creek, the compliance rate of total phosphorus and total dissolved phosphorus was also lower in 2013 (19%) compared to 2012 (41%). The higher concentrations of phosphorus at the upper sites in Nose Creek were probably due to agricultural runoff and the release of treated effluent from the Town of Crossfield lagoon. The lower total phosphorus concentration at the lower sites was probably a result of phosphorus uptake by dense growths of filamentous algae and aquatic plants observed at the lower sites. Phosphorus concentrations are substantially lower in West Nose Creek compared to Nose Creek.

Total suspended solids concentrations generally increased from upstream to downstream; this trend is likely the result of increased watershed area at each downstream site in conjunction with sediment contributions from stormwater outfalls in the City of Airdrie and City of Calgary. The following summarizes the results of the water quality parameters monitored at Nose Creek and West Nose Creek in 2013:

- All **temperatures** in Nose Creek and West Nose Creek were below the acute water temperature objective of 29°C and the chronic water temperature objective of 24°C in 2013.

- The **pH** compliance rate was 97% at Nose Creek and 96% at West Nose Creek in 2013. Compliance rates were similar to or higher than those observed in previous years (Table 16).

- Seven **oxygen** samples were less than the acute guideline of 5 mg/L at Nose Creek while at West Nose Creek, no sample was less than 5 mg/L. The compliance rate for acute oxygen at Nose Creek was 90% and was 100% at West Nose Creek. Compliance rates were similar to or higher than those observed in previous years (Table 16).

- **Electrical conductivity** at Nose Creek ranged from 405 to 3306 µS/cm and 49% of samples met the water quality objective of less than 1000 µS/cm in 2013. At West Nose Creek, electrical conductivity ranged from 442 to 1754 µS/cm and 93% of samples met the water quality objective of less than 1000 µS/cm (Table 16).

- **Total dissolved solids** at Nose Creek ranged from 405 to 970 mg/L and 25% of samples met the water quality objective of less than 500 mg/L in 2013. Total dissolved solids at West Nose Creek ranged from 405 to 742 mg/L and 50% of samples met the water quality objective of less than 500 mg/L (Table 16).

- **Total phosphorus** at Nose Creek ranged from 0.03 to 0.70 mg/L and only 4% of the samples met the water quality objective of less than 0.05 mg/L in 2013. Total phosphorus at West Nose Creek ranged from 0.02 to 0.37 mg/L and 19% of samples met the water quality objective of less than 0.05 mg/L. Compliance rates were similar to or lower than those observed in previous years (Table 16).

- **Nitrate-nitrite Nitrogen** at Nose Creek ranged from <0.005 to 2.30 mg/L and 78% of the samples met the water quality objective of less than 1.5 mg/L in 2013. Nitrate-nitrite Nitrogen at West Nose Creek ranged from 0.21 to 1.90 mg/L and 76% of samples met the water quality objective of less than 1.5 mg/L. Compliance rates were similar to or lower than those observed in previous years (Table 16).

- The **Total Ammonia** compliance rate at Nose Creek was 95% in 2013. Total Ammonia at West Nose Creek was often below the detection limit and 100% of the samples met the water quality objective. Compliance rates were similar to or higher than those observed in previous years (Table 16).

- **Bacteria (fecal and *E. coli*)** at Nose Creek ranged from <1 to >2,520 CFU/100 mL and 63% of samples met the *irrigation* guideline of less than 100 CFU/100 mL in 2013. Eighty-seven percent of the Nose Creek samples had fecal coliform concentrations below the *contact recreation* guideline of 400 CFU/100 mL in 2013. Bacteria at West Nose Creek ranged from <1 to 2,520 CFU/100 mL and 56% of samples met the irrigation water quality objective of less than 100 CFU/100 mL. Seventy-eight percent of the West Nose Creek samples had fecal coliform concentrations below the *contact recreation* guideline of 400 CFU/100 mL. Compliance rates were similar to or higher than those observed in previous years at Nose Creek. Compliance rates were similar to, lower than or higher than those observed in previous years at West Nose Creek (Table 16).

- **Total suspended solids (TSS)** at Nose Creek ranged from <4 to 233 mg/L which was similar to 2009 but higher than 2010, 2011 and 2012. Total suspended solids at West Nose Creek ranged from <2 to 133 mg/L which was similar to 2011 and 2012 and lower than 2009 and 2010 (Table 16). No water quality objectives have been established for total suspended solids concentrations in Nose Creek or West Nose Creek.

Table 16. Summary of historical (1999-2001, 2009, 2010, 2011, 2012) water quality compliance rates (%) in comparison with 2013 for Nose Creek and West Nose Creek.

Parameter	Nose Creek						West Nose Creek					
	1999-2001	2009	2010	2011	2012	2013	1999-2001	2009	2010	2011	2012	2013
Temperature	100	100	100	100	100	100	100	100	100	100	100	100
pH	95	97	79	99	95	97	100	100	100	100	96	96
Dissolved Oxygen-acute	84	91	97	90	88	90	86	100	100	100	96	100
Dissolved Oxygen-chronic	69	79	92	79	76	74	76	95	100	96	93	100
Electrical Conductivity	38	29	27	63	32	49	91	90	76	86	81	93
Total Dissolved Solids	15	0	9	36	10	25	6	0	0	80	10	50
Total Phosphorus	2	0	12	4	5	4	15	52	33	25	41	19
Dissolved Phosphorus	24	32	37	9	23	7	19	62	43	32	41	19
Nitrate-Nitrite Nitrogen	89	83	94	93	83	78	85	88	93	82	83	76
Total Ammonia	91	83	88	100	98	95	97	100	100	100	96	100
Fecal Coliform - irrigation	42	38	56	67	58	63	45	38	53	64	44	56
Fecal Coliform - recreation	76	65	84	90	70	87	83	71	87	89	67	78

The following recommendations are provided for the Nose Creek watershed monitoring program:

- The results of the water monitoring program in 2013 should be disseminated to the Nose Creek Watershed Partnership membership. The report could be posted on the NCWP website, and the results could be summarized in a simple 4-page factsheet. Monitoring results could also be communicated to all stakeholders at an annual meeting or other community meeting.

- Stormwater monitoring at select locations within Nose Creek and West Nose Creek should be undertaken to begin to address point sources of phosphorus and fecal coliform bacteria within the Nose Creek watershed.

6.0 CLOSURE

We trust the information provided is sufficient to describe the water quality of the Nose Creek watershed in 2013. If you have any questions, please do not hesitate to contact Palliser Environmental Services Ltd. at 403-921-5667.

Yours truly,

Palliser Environmental Services Ltd.

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APPENDIX A

Bow River Basin Council: Summary of Monitoring and Management Requirements for Nose Creek

Total Suspended Solids WQO and research: A total suspended solids WQO should be developed for Nose Creek. Research is required to identify the anthropogenic causes of total suspended solids in Nose Creek and how it compares in quantity to natural causes (NCWP; Long-Term: 2013-2014).

Dissolved Oxygen Monitoring: Enhanced monitoring of DO is required to better characterize and understand low nocturnal DO concentrations (AENV/City of Calgary; Short-Term Goal: 2008-10).

Periphyton Biomass: Future water quality monitoring should include the collection of periphyton biomass (as chlorophyll *a*). (AENV; Short-Term: 2008-10)

Peak and Base Flows: Further research is needed to compare the frequency and magnitude of base and peak flows. Storm events should remain within the range of pre-development conditions (pre-1970s) (NCWP; Short-Term: 2008-10).

Total Phosphorus Reductions: Responsible for working to reduce total phosphorus and total dissolved phosphorus. Conduct research into the primary productivity of Nose Creek (NCWP; Medium-Term: 2011-2012).

Enhanced stream and stormwater flow monitoring at various points throughout the system is needed to assist in the identification of the impervious and runoff targets (City of Calgary; Short-Term Goal: 2008-10)