BOULDER CREEK AND ST. VRAIN CREEK

Annual Water Quality Analysis for 2016

PREPARED FOR **KEEP IT CLEAN PARTNERSHIP**

PREPARED BY **WRIGHT WATER ENGINEERS, INC.**

July 2017

Report Preparation

This report was prepared by the Keep It Clean Partnership and Wright Water Engineers, Inc. The following individuals supported this effort by providing water quality data and/or review of the report:

Candice Owen and Bret Linenfelser, City of Boulder
Jim Widner and Alex Ariniello, Town of Superior
Rebecca Wertz, Justin Elkins and Cameron Fowlkes, City of Louisville
Mick Forrester and Jessica Lewand, City of Lafayette
Todd Fessenden and Wendi Palmer, Town of Erie
Judith Gaioni, Drew Albright, Kathryne Marko and Cal Youngberg, City of Longmont
Dave Rees, Timberline Aquatics (Biological Monitoring Data and MMI Analysis)
Jane Clary and Natalie Phares, Wright Water Engineers, Inc.

Table of Contents

Tables

Figures

Appendices

Executive Summary

In 2014, the Keep It Clean Partnership (KICP) developed the *Boulder Creek and St. Vrain Creek Coordinated Watershed Monitoring Framework* ("Monitoring Plan"), providing improved coordination of multiple independent monitoring efforts being conducted in the watershed. This report is the third joint water quality analysis report resulting from the Monitoring Plan and provides a summary of flow and field conditions during 2016, water quality analysis, a limited summary of biological monitoring results, and conclusions and recommendations for future monitoring and reporting efforts. The primary water quality parameters discussed in this report include nutrients and *E. coli*, with limited discussion of arsenic, selenium and copper, along with several general water quality indicators (e.g., total suspended solids, dissolved oxygen, pH). Key findings from analysis of the 2016 data include:

- ***E. coli***: Most stream segments evaluated in this report are identified as impaired for *E. coli*, except South Boulder Creek and Left Hand Creek. Boulder Creek between 13th Street and the confluence with South Boulder Creek is included in an *E. coli* Total Maximum Daily Load (TMDL), which drives additional regulatory requirements under municipal stormwater permits.
- **Total Phosphorus**: In June 2015, the Water Quality Control Commission adopted total phosphorus standards for multiple stream segments in the Boulder Creek/St. Vrain Creek basin. These standards apply above wastewater treatment plant (WWTP) discharges and are attained on all segments evaluated in this report. Below WWTP discharges, these standards do not yet apply; however, no stream segments evaluated in this report would be expected to attain these "interim values" for total phosphorus under current conditions.
- **Total Nitrogen**: Above WWTP discharges, the streams in the watershed attain the "interim values" for total nitrogen that were developed in Regulation 31 in 2012, with the exception of Rock Creek. Below WWTP discharges, no stream segments evaluated in this report would be expected to attain the "interim values" for total nitrogen under current conditions.
- **pH**: Boulder Creek below Coal Creek has elevated pH, causing an impairment listing on the 303(d) List for Segment 10 of Boulder Creek.
- **Total Recoverable Arsenic**: Although temporary modifications have been adopted for segments with "water + fish" standards for arsenic through December 31, 2021, available data collected for Boulder Creek and South Boulder Creek indicate that the stringent 0.02 µg/L standard is not attainable at any monitoring location. Less stringent stream standards for arsenic apply to other segments in the watershed.
- **Selenium**: Rock Creek and the portion of Coal Creek below Rock Creek are identified as impaired for elevated selenium based on River Watch data. It is recommended that additional monitoring be conducted to better characterize selenium in these areas and that a site-specific standard potentially be proposed in the future.
- **Aquatic Life**: Based on biological monitoring results for 2016, significant improvement in aquatic life conditions has occurred in the watershed at most locations relative to post-flood conditions in 2013. Nonetheless, several streams include locations that would be identified as impaired for aquatic life on the 2016 303(d) List.

1.0 Introduction

The overall St. Vrain Creek watershed (8-digit hydrologic unit code [HUC] = 10190005) covers approximately 980 square miles and includes many governmental jurisdictions and water-related organizations (e.g., conservancy districts). Streams in the watershed include Boulder Creek, South Boulder Creek, Coal Creek, Rock Creek, Left Hand Creek, St. Vrain Creek and many smaller tributaries. Multiple local governments and organizations conduct instream water quality, biological and flow monitoring in various parts of the watershed. In 2014, the Keep It Clean Partnership (KICP) developed the *Boulder Creek and St. Vrain Creek Coordinated Watershed Monitoring Framework* ("Monitoring Plan") for the following purposes:

- To provide better coordination of existing multi-jurisdictional monitoring efforts,
- To provide consolidated documentation of the monitoring that is occurring in the watershed,
- To provide guidance for standardized field procedures and analytical methods, and
- To identify and recommend additional monitoring to fill data gaps to support progress toward attainment of stream standards.

Due to the size of the watershed, the remote nature of the upper basin locations, and varying levels of participation among governmental jurisdictions, the Monitoring Plan cannot practically address all stream reaches. The Monitoring Plan is designed to address key water quality parameters, flow, and biological conditions at selected locations in the watershed where supported by local jurisdictions. These locations generally span the western edge of the urbanized portion of the watershed eastward to I-25. The scope of the Monitoring Plan is limited to flowing streams, although both the City of Boulder and the City of Longmont also monitor lakes and reservoirs. This report provides an overview of the Monitoring Plan and scope of the analysis, a summary of flow and field conditions during 2016, water quality analysis, a limited summary of biological monitoring results, and conclusions and recommendations for future monitoring and reporting efforts. Because of differences in the breadth of the monitoring programs conducted by various jurisdictions, this report focuses primarily on several general water chemistry parameters, nutrients, *E. coli,* arsenic and selenium, based on the priorities identified by the KICP. Additionally, selected findings from biological monitoring conducted by Timberline Aquatics on Boulder Creek, South Boulder Creek, Coal Creek, Rock Creek, Left Hand Creek and St. Vrain Creek for KICP municipalities are provided.

Appendix A provides maps identifying monitoring locations, and Appendices B through D provide tabular and graphical summary statistics supporting the analysis. Appendix E provides a summary of designated uses and stream standards adopted for streams in the basin in Regulation 38, and Appendix F provides stream segments identified as impaired on the currently applicable "303(d) List." Appendix G provides Quality Assurance/Quality Control results, and Appendix H provides a list of stream restoration projects being implemented in the watershed as part of response and recovery from the September 2013 flood.

2.0 Overview of Monitoring Program and Scope of Analysis

KICP Monitoring Program

The *Boulder Creek and St. Vrain Creek Coordinated Watershed Monitoring Framework* (KICP and WWE 2014) is an on-going, voluntary, ambient-based program that is independently managed and implemented by each participating jurisdiction (Table 1). The Monitoring Plan is focused on developing a coordinated baseline for the overall watershed. In the future, monitoring objectives and activities may be added to assess measureable results from implementation of structural or non-structural best management practices (BMPs) in the watershed.

Table 2 summarizes the primary monitoring locations included in this annual report, Table 3 summarizes municipal wastewater treatment plant (WWTP) locations, and Table 4 summarizes the monitoring program analytes and frequencies.

The overall basin monitoring program includes these general components:

- **Water quality monitoring:** Water quality monitoring includes instream sample collection during ambient conditions. This includes voluntary programs as well as samples collected to meet Regulation 85 requirements.[1]

- **Flow measurements**: Two types of flow measurements are conducted (or retrieved) as part of this monitoring program. The first includes continuous daily flow measurements conducted at fixed, long-term gauges shown on Figure A-1 in Appendix A. These gauges and associated data are maintained by the U.S. Geological Survey (USGS) or the Colorado Division of Water Resources (DWR). Additionally, One-Rain gauge sites used in early alert flood warning systems may be used to supplement flow data; however, data downloads are restricted to subscribers and have not been included in this report. The second type of flow monitoring includes instantaneous flow monitoring with hand-held monitoring equipment, which is used to supplement fixed gauge data in key areas. Manual flow monitoring is conducted only when it is safe for field staff to enter the stream. Chapter 3 provides a summary of streamflow conditions for the USGS, DWR, and the municipally-operated stream gauge at Coal Creek (which was formerly a USGS gauge).

- **Biological Monitoring**: Biological monitoring is conducted in the spring and fall for portions of Boulder Creek, South Boulder Creek, Coal Creek, Rock Creek, St. Vrain Creek, and Left Hand Creek. Detailed annual reports on these monitoring efforts are provided by Timberline Aquatics; however, a subset of the biological monitoring results is also provided in this report. The information contained in this report is limited to data needed to assess attainment of Colorado Policy 10-1 for aquatic life (e.g., multi-metric index [MMI] and associated metrics).

[1] Regulation 85 is Colorado's Nutrients Management Control Regulation, which establishes discharge permit limits and/or monitoring requirements for point sources and other provisions for nonpoint sources.

Table 1. Summary of Routine Instream Monitoring Programs in the Basin

General Waterbody	Program Description	Primary Monitoring Plan
Boulder Creek and Tributaries (from headwaters to below Coal Creek); Reservoirs—upper source water sites, Barker Reservoir, Boulder Reservoir; Dry Creek/Little Dry Creek	Extensive program including nutrients, fecal indicator bacteria, metals, and other physical constituents; flow; and biological monitoring. Sampling frequencies vary by waterbody. Main stem monitored monthly.	City of Boulder, Boulder Creek Monitoring Program, Prepared by the City of Boulder Department of Public Works Utilities Division Water Quality and Environmental Services. Updated 2016.
Rock Creek/Coal Creek	Monthly monitoring for TP, TKN, NO3/NO2, TN, TP and flow. Also pH, temperature, hardness, fecal indicator bacteria. Biological monitoring.	Regulation 85 Nutrient Sampling and Analysis Plan (separate plans for Lafayette, Superior, Louisville, Erie), 2013.
St. Vrain Creek (vicinity of Longmont); Left Hand Creek (lower portion below Hover Gauge); Selected ditches: Dry Creek, Spring Gulch #1, Spring Gulch #2, Oligarchy Ditch	Extensive program including nutrients, fecal indicator bacteria, metals, and other physical constituents; flow; and biological monitoring. Sampling frequencies vary by waterbody. Monthly monitoring for TP, TKN, NO3/NO2, TN, TP and flow.	Regulation 85 Nutrient Sampling and Analysis Plan, City of Longmont, Public Works and Natural Resources Division of Environmental Services, CDPS Permit No. CO-0026671, February 2013.
Monitoring Conducted in Watershed by Others (Non-KICP Partners)		
Boulder Creek above and below Boulder Supply Canal; Left Hand Creek above and below Boulder Feeder Canal; St. Vrain Creek above and below St. Vrain Supply Canal (+ other ditches/reservoirs)	Extensive program including nutrients, metals, and other physical constituents; flow, and biological monitoring. Sampling frequencies vary by waterbody.	Standard Operating Procedures for Northern Water's Water Quality Monitoring Programs. Northern Water, June 2014.
Multiple Stream Segments (includes upper Left Hand Watershed Oversight Group)	Multiple parameters at varying frequencies	River Watch QAPP
Multiple Stream Segments	Multiple parameters at varying frequencies	Water Quality Control Division QAPP

Note: Table 1 describes overall monitoring programs conducted by entities in the watershed. Data evaluated in this report focuses on selected constituents addressed in monitoring conducted by KICP partner programs.

Table 2. 2016 KICP Water Quality Instream Monitoring Locations[2]

Plot ID	Instream Monitoring Location Description	Stream Name	Segment	Data Provider
BC-Can	Pool area at Anderson Ditch headgate	Boulder Creek	BC-2b	City of Boulder
BC-CU	Under foot bridge connecting Folsom Field with dirt parking lot to the north	Boulder Creek	BC-2b	City of Boulder
BC-61	Just West of 61st Street bridge	Boulder Creek	BC-9	City of Boulder
BC-aWWTP	Under bridge at 75th Street western side	Boulder Creek	BC-9	City of Boulder
BC-aDC	At diversion channel	Boulder Creek	BC-9	City of Boulder
BC-95	Downstream of Lower Boulder Ditch headgate 0.87 miles below BC-aDC sample site	Boulder Creek	BC-9	City of Boulder
BC-107	Bridge at 107th Street	Boulder Creek	BC-9	City of Boulder
BC-bCC	Bridge where Boulder Creek goes under East County Line Road 2.13 miles below BC-Ken site.	Boulder Creek	BC-10	City of Boulder
SBC-3.5	Open Space at McGuinn Ditch gate (*merged with SBC-4 in analysis*)	South Boulder Creek	BC-4b	City of Boulder
CC-Ken	Bridge where Coal Creek goes under Kenosha Rd. 0.89 miles upstream from Boulder Creek confluence.	Coal Creek	BC-7b	City of Boulder
9-BC	Boulder Creek above the North Erie WWTP discharge	Boulder Creek	BC-10	Erie
10-BC	Boulder Creek below the North Erie WWTP discharge	Boulder Creek	BC-10	Erie
11-BC	Boulder Creek Gauge 06730500	Boulder Creek	BC-10	Erie
0-CC	Above urbanized area on Coal Creek	Coal Creek	BC-7a	Louisville
1-CC	Coal Creek above the Louisville WWTP discharge	Coal Creek	BC-7b	Louisville
2-CC	Coal Creek below the Louisville WWTP discharge	Coal Creek	BC-7b	Louisville
3-CC	Coal Creek above the confluence with Rock Creek	Coal Creek	BC-7b	Lafayette
6-CC	Coal Creek above the Lafayette WWTP discharge	Coal Creek	BC-7b	Lafayette
7-CC	Coal Creek below the Lafayette WWTP discharge	Coal Creek	BC-7b	Lafayette
4-RC	Rock Creek above the Superior WWTP discharge	Rock Creek	BC-8	Superior
5-RC[3]	Rock Creek above the confluence with Coal Creek	Rock Creek	BC-8	Superior
M9.5-SV	M-9.5, St. Vrain @ N. 75th St	St. Vrain Creek	SV-3	Longmont
M8.9-SV	St. Vrain @ Golden Ponds, M-9	St. Vrain Creek	SV-3	Longmont
M8-SV	St. Vrain @ Above Effluent M-8	St. Vrain Creek	SV-3	Longmont
T-Eff	WWTP effluent channel where it enters the St. Vrain; combined with the roadside ditch flow.	St. Vrain Creek	NA/ Ditch	Longmont
M7-SV	M-7, St. Vrain @ 119	St. Vrain Creek	SV-3	Longmont
M6-SV	St. Vrain at County Line Rd., M-6	St. Vrain Creek	SV-3	Longmont
LH-95	Left Hand Creek @ 95th	Left Hand Creek	SV-5	Longmont
T11-LH	Left Hand Creek @ St. Vrain,T-11	Left Hand Creek	SV-5	Longmont
Sites Not Monitored during 2016				
M4-SV	St. Vrain above Boulder Creek Confluence	St. Vrain Creek	SV-3	Longmont

[2] Additional monitoring is also conducted in the watershed. Locations in Table 2 are the sites selected for analysis for purposes of this report.
[3] During 2016, 5-RC was monitoring separately by Lafayette (identified as "RCl") and Superior (identified as "RCs").

WWTP discharge data have also been provided, at least for nutrients, to support the analysis in this report. The municipal WWTP discharges are summarized in Table 3. For wastewater locations without "WWTP" or "WWTF" in the site name, a suffix of [W] has been added to the site name on graphs to differentiate the monitoring location as a wastewater discharge rather than an instream monitoring location.

Table 3. WWTP Discharges

KICP Sample ID	WWTP	Stream (Receiving Water)	CDPS Permit	Comment
A-CC	Louisville	Coal Creek	CO0023078	Farthest upstream WWTP discharge to Coal Creek.
B-RC	Superior	Rock Creek	CO0043010	Discharges to Rock Creek, which flows into Coal Creek between the Louisville and Lafayette discharges.
C-CC	Lafayette	Coal Creek	CO0023124	Farthest downstream WWTP discharging to Coal Creek.
E-BC	Erie	Boulder Creek	CO0045926	This location is for Erie's North WWTF. Erie's South WWTF is not currently in operation, but is identified as "D-CC," and discharged to Coal Creek.
WWTF Eff	Boulder	Boulder Creek	CO0024147	Identified by Boulder as "manhole" monitoring location for 75th Street WWTF
WWTP-LGMT	Longmont	St. Vrain Creek	CO0026671	WWTP-LGMT is the compliance monitoring location for Longmont's WWTP. The monitoring location "T-Eff" is also mostly WWTP effluent, but is combined with flows in a roadside ditch.

Table 4. 2016 KICP Monitoring Program Analytes

Parameter	Frequency	Method Detection Limit (MDL)
pH	monthly	1 SU
DO	monthly	0.1 mg/L
Temperature	monthly	-15°C
Conductivity	monthly	0.1 mmhos/cm
Hardness, Total as CaCO3	monthly	1 mg/L
Alkalinity, Total	monthly	1 mg/L
Flow	monthly (inst. meters); daily @ gauges	Stream dependent
E. coli	monthly	1 MPN/100 mL
TSS	monthly	2 mg/L
NH3, as N	monthly	50 µg/L
NO3+NO2, as N	monthly	20 µg/L
TKN, as N	monthly	100 µg/L
TN, as N	monthly	100 µg/L
TIN, as N	monthly	NA
TP, as P	monthly	10 µg/L
Benthic monitoring*	twice per year, spring and fall	
Metals: (1) As, (2) Se, (3) Metals w/stream standards	TBD (min. quarterly)	varies

*Benthic monitoring discussed in this report is limited to parameters needed to assess attainment with Aquatic Life Policy 10-1.

MONITORING PROGRAMS CONDUCTED BY OTHERS

The primary focus of this report is monitoring data collected by municipalities who are members of the KICP. Other data sets that could be integrated into this report in the future include River Watch, Northern Colorado Water Conservancy District, rotational basin monitoring conducted by the Water Quality Control Division (Division), Denver Water and additional routine monitoring by the KICP at other locations in the watershed. Examples of other data and special studies that may be of interest to KICP include:

- City of Boulder's source water monitoring program that includes streams and reservoirs in the upper basin of Boulder Creek, as well as monitoring for Barker Reservoir and Boulder Reservoir and tributaries.
- City of Longmont's monitoring for several reservoirs, ditches and creeks. These data are included in the KICP database, but are not analyzed in this report.

- The Division's routine rotational monitoring or special monitoring in the basin. During 2016, the Division did not monitor locations within the KICP study area, but sampling by the Division is anticipated in 2017.

- River Water monitoring program. River Watch volunteers have conducted monitoring in several areas of the watershed, primarily Gamble Gulch and the upper portion of Left Hand Creek basin. Samples have also been collected on Coal Creek, Boulder Creek, St. Vrain Creek and South Boulder Creek in the past. At the time this report was completed, River Watch data for 2016 in the KICP study area had not yet been uploaded to STORET; however, monitoring was conducted as part of the River Watch program in 2016 in the watershed. The Left Hand Watershed Oversight Group (LWOG) completed a summary analysis of River Watch data collected in the upper portion of the Left Hand Creek basin in 2017.

- Northern Colorado Water Conservancy District's routine monitoring program, accessible at http://www.northernwater.org/WaterQuality/WaterQuality.aspx.

- The City of Boulder's special monitoring program for neonicotinoids.

- Supplemental *E. coli* monitoring programs being conducted by the cities of Lafayette, Louisville and Boulder.

- Boulder County Parks and Open Space's targeted monitoring program for agricultural sites and practices (limited data).

Given the upcoming 2018 303(d) List Hearing, water quality data were retrieved from STORET for the watershed for monitoring locations located in HUC 10190005. For 2016, 228 water quality results were added to STORET for a nutrient study at locations in the upper St. Vrain Watershed in Rocky Mountain National Park and for a Lakes Study conducted by EPA. The remainder of the monitoring results for 2016 were associated with Regulation 85 nutrient monitoring reported by cities active in KICP.

A brief overview of a few specific monitoring programs conducted by others in 2016 is provided below. As the KICP continues to move towards an integrated watershed approach, it may be beneficial to more fully incorporate findings from these concurrent monitoring programs into a more comprehensive analysis in this KICP report.

Left Hand Watershed Oversight Group 2016 Data Summary

Monitoring results for the Lefthand Watershed Oversight Group (LWOG) during 2016 are summarized in the *Status of Monitoring Activities for the Lefthand Watershed Oversight Group* (Patterson 2017). During 2016, LWOG's programs expanded, with increasing emphasis on long-term stream restoration following the 2013 flood, and continued interest in mitigating the impacts of acid mine runoff. During 2016, several monitoring components were added to help document the effectiveness of stream restoration projects. As these restoration projects are

getting underway during 2016 and 2017, most of the monitoring effort related to restoration focused on establishing protocols and documenting pre-project conditions.

During 2016, LWOG also continued its program of water quality monitoring that has been underway since 2006, mostly aimed at assessing the impact of acid mine runoff. The 2017 report summarizes the monitoring undertaken by LWOG during 2016, including brief descriptions of the types of monitoring undertaken, locations of monitoring efforts, methods used, and, where available, results. To date, most of the monitoring for water quality has taken place in the mountain reaches of the watershed, as those reaches have been most impacted by mine drainage. Most of the monitoring for stream restoration, added during 2016, has taken place in the plains reaches, as most of the stream restoration projects under LWOG's direction are in these reaches. As part of the LWOG efforts, biological monitoring has also been conducted by Timberline Aquatics on Left Hand Creek, with results included in the 2017 LWOG report.

LWOG is developing a comprehensive monitoring plan to provide guidance on the monitoring activities described above, plus additional monitoring that will be added in the near future. The plan will include short-term activities such as using GPS to determine precise coordinates for all monitoring sites, and completing the Stream Visual Assessment Protocol, Version 2 implementation on remaining restoration reaches. The plan will also include addition of longer-term monitoring activities such as detailed vegetation monitoring for revegetated areas, a repeat study to determine metals loading to various reaches in the watershed, expansion of River Watch monitoring into the plains reaches, developing partnerships with local schools and with landowners for certain monitoring activities, and an annual overall watershed assessment to determine overall watershed condition and identify new priorities for stream restoration or protection that may arise.

Boulder County Open Space Agricultural Study 2016 Update

Boulder County owns and manages a significant portfolio of water resources for environmental and agricultural purposes. The water resources managed by Boulder County Parks and Open Space (BCPOS) allow farmers to successfully produce crops on the County's cropland. BCPOS is conducting monitoring of agricultural land and BMPs in several locations. During 2016, the segment of Dry Creek extending from 95th Street south of Longmont to County Line Road east of Longmont was selected for a second year of water monitoring, building upon data collected during the 2015 calendar year. BCPOS agricultural properties comprise the majority of lands adjacent to this stream segment, and the production types and irrigation systems used in these areas were of particular interest for analysis. Four creek sampling locations were chosen for monitoring in 2016, along with field inflow and tail water sampling points for four flood-irrigated crop fields. A total of 12 sampling locations were included in the program. A variety of water quality analytes were monitored such as *E. coli*, total suspended solids and certain agricultural chemicals.

BCPOS reported that additional data are required to support decision-making for additional BMP projects and practices for improved water quality within this stream segment of Dry Creek. Without several years of background information, no conclusions can definitively be drawn, nor informed decisions on management changes made. BCPOS reported that Dry Creek currently shows little negative impact from adjacent farming operations, and no significant single sources have been identified as negatively impacting the stream segment.

City of Lafayette *E. coli* and Selenium Special Study 2016 Interim Update

In 2016, the City of Lafayette conducted a special study related to *E. coli* and selenium on Rock Creek and Coal Creek. Findings of this study are within the physical boundaries of the KICP monitoring program, so these results have been integrated into this KICP report, where appropriate.

Lafayette focused on identifying *E. coli* sources of potential human origin by bracketing known stormwater outfalls on Coal Creek and Rock Creek and the area along Flagg Drive, where aging septic systems are present. Non-human hotspots such as livestock pastures, suspected wildlife concentrations, and open space were also bracketed by instream sampling.

Three separate reaches of river were addressed in this effort:

1) Coal Creek from near Lafayette's border with Louisville, at Centaur Village, to the confluence with Rock Creek, near Vista Business Park;

2) Rock Creek from just south of Dillon Road to the confluence;

3) Coal Creek from the confluence to just above the Water Reclamation Facility.

As part of the study, monitoring included 18 sites for *E. coli*, three sites for total selenium, and two sites for stream flow when conditions were safe. There were a few sites where all three parameters were being collected, and a few sites that are now inactive.

3.0 Summary of Annual Flow Data and Pertinent Field Conditions

Hydrologic conditions of interest include both precipitation and flow conditions. Annual precipitation amounts, magnitude of runoff during individual storm events, and timing of spring runoff are of particular interest.

As a general indicator of precipitation in the urbanized portion of the watershed, precipitation data at the National Oceanic and Atmospheric Administration/National Weather Service (NOAA/NWS) Cooperative Sites in Boulder and Longmont were obtained (Figure 1 through Figure 3). Precipitation totals measured at the Boulder and Longmont gauges during 2016 were 17.25 inches and 13 inches, respectively. These data sets were used to determine whether significant storm events affected sampling conditions during 2016. Based on this review, the primary sample date affected by rainfall included sample locations on Coal Creek, Rock Creek, and Boulder Creek (below Coal Creek) on June 1, when a 1.05-inch rainfall event was recorded in Boulder. *E. coli* at sample locations on Coal Creek and Rock Creek on this sample date exceeded the upper quantitation limit for *E. coli* of 2,420 MPN/100 mL. Sample locations on Boulder Creek below Coal Creek also showed elevated *E. coli* on this date.

Figure 1. 2016 Monthly Precipitation Totals at Longmont and Boulder Rain Gauges

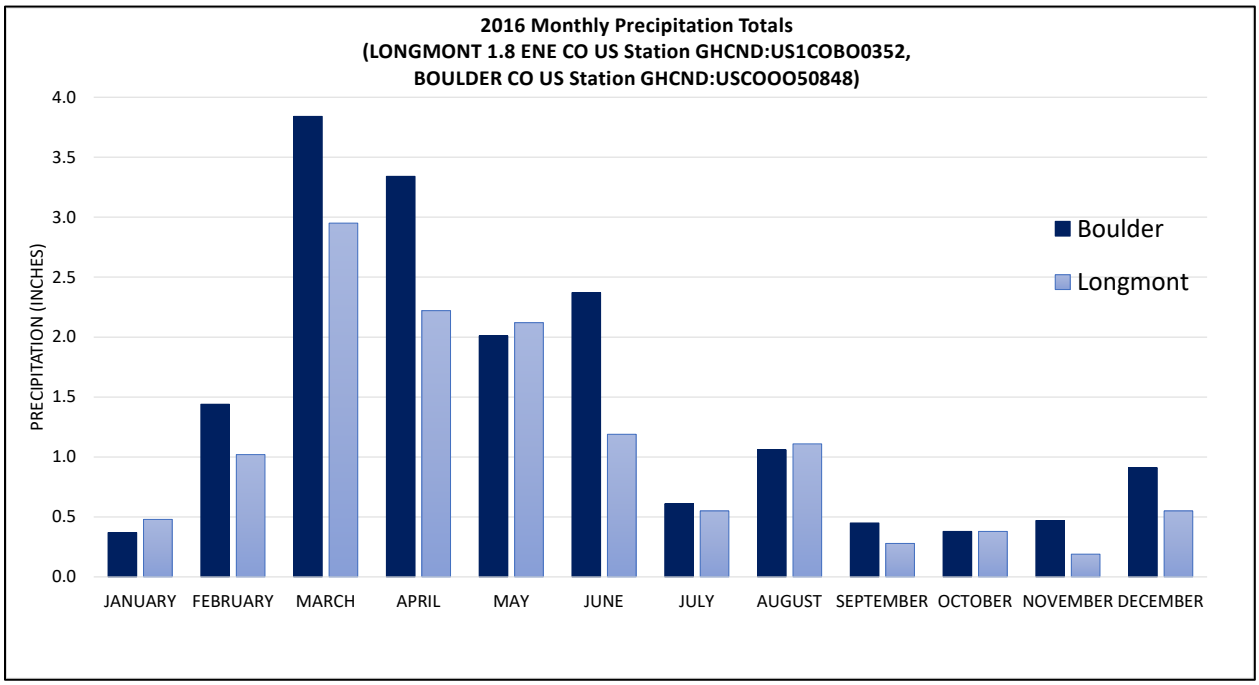


Figure 2. 2016 Daily Precipitation at Boulder Rain Gauge

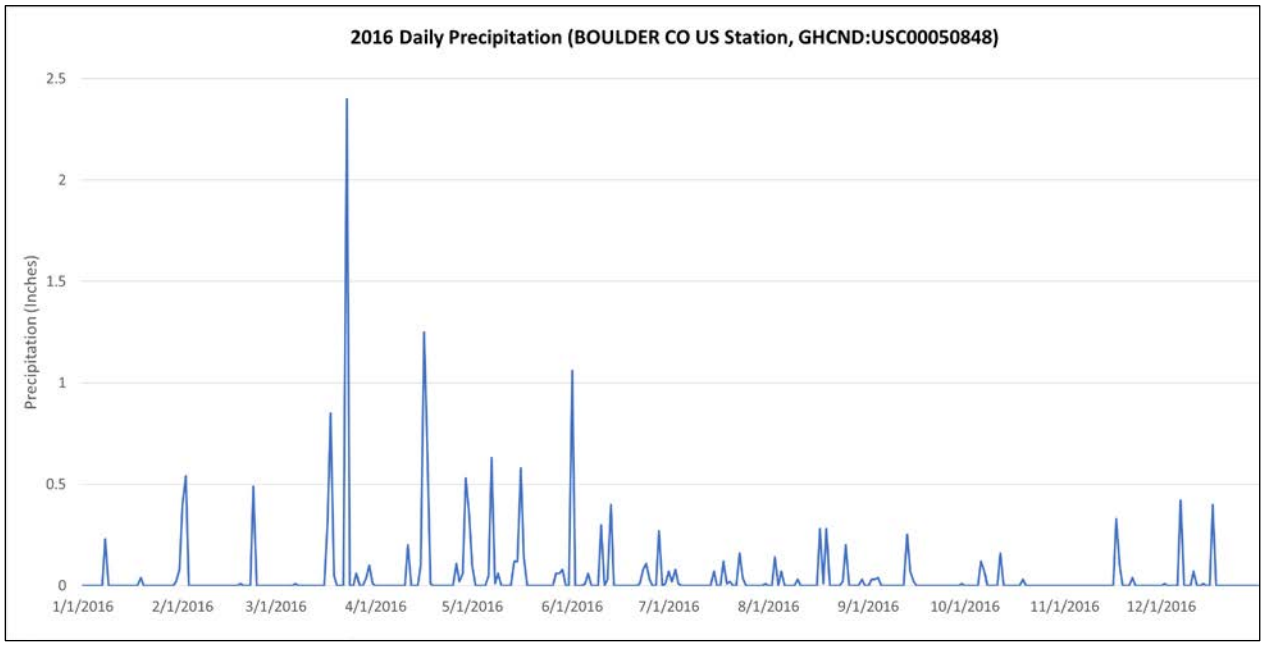
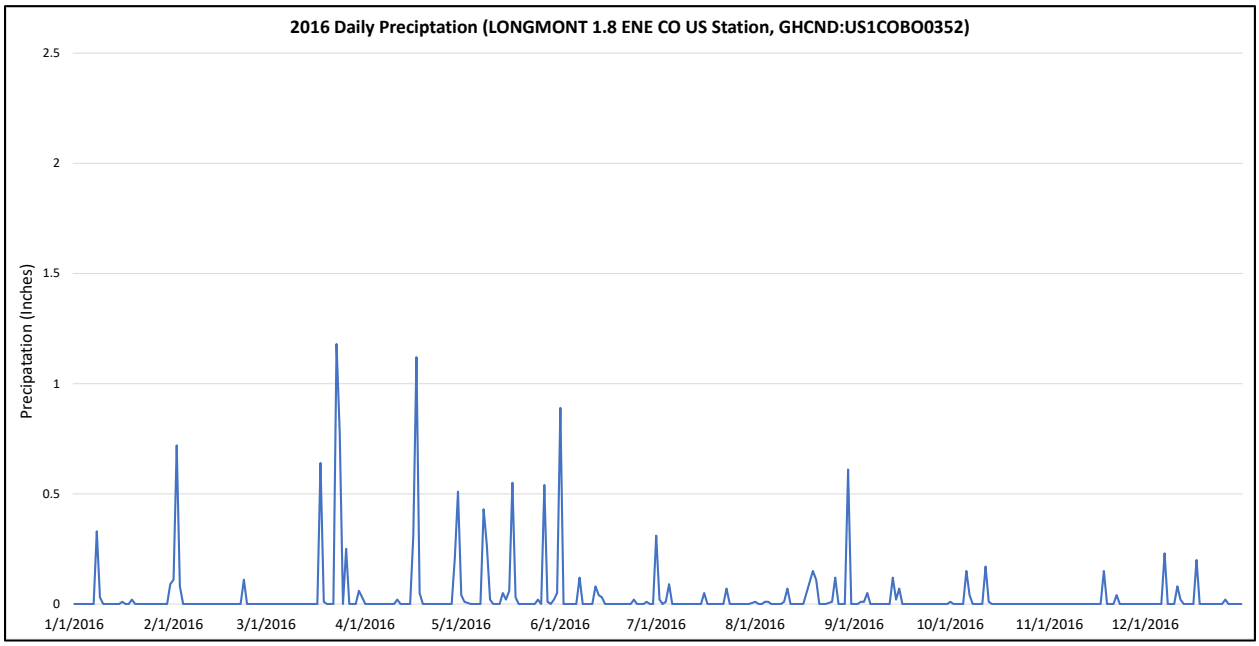


Figure 3. 2016 Daily Precipitation at Longmont Rain Gauge



During 2016, stream flow was measured at the gauge locations in Table 5. Figure 4 through Figure 12 provide the 2016 hydrographs at these locations, with the format differing slightly depending on whether the site is managed by the USGS, the DWR, or others. Varying periods of record are available for each gauge. A few observations from review of these hydrographs include:

- Spring runoff peaked in mid-June for most streams in each basin.
- Streamflows during 2016 were higher than the historic median during spring runoff for the majority of the basins with available data for comparison.

The most common use of flow data by watershed projects is pollutant load calculations, which are essential to TMDL development and implementation. Flow is an important variable to record along with water quality data because it has significant influence on pollutant loading to the stream and instream concentrations. Flow data helps to underscore the relative importance of various point and nonpoint sources by developing a relationship between water quality variables and discharge. Higher than normal flows can dilute wastewater contributions from WWTPs, but they can also impact the stability of the stream channel, the size and quantity of bed material, sediment transport rates, and pollutant transport rates from urban and agricultural land uses. Low flows can have significant impact on variables such as water temperature and fish habitat.

The Boulder Creek and St. Vrain Creek watersheds continue to recover from the flood that occurred in September 2013. Field conditions that may affect 2016 data relative to this event include channel instability, denuded vegetation on banks and other long-term impacts from the September 2013 flood.

Table 5. Stream Gauges with 2016 Data Retrieved

USGS ID	DWR or Other Name	Description
06727000	BOCOROCO	Boulder Creek Near Orodell
06730200	BOCNORCO	Boulder Creek at North 75th Street
06729500	BOCELSCO	South Boulder Creek Near Eldorado Springs
06730500	BOCLONCO	Boulder Creek at Mouth Near Longmont
06724970	LEFTHOCO	Left Hand Creek at Hover Road Near Longmont
N/A	SFCHGICO	St. Vrain Creek at Hygiene, CO
N/A	SVCLOPCO	St. Vrain Creek Below Ken Pratt Blvd. at Longmont, CO
06730525	SVCBBCCO	St. Vrain Creek Below Boulder Creek at HWY 119 Near Longmont[4]
06730400	COALOUCO	COC-1 Louisville Gauge, no longer managed by USGS/DWR

[4] The USGS stream gauge 06725450 St. Vrain Creek below Longmont (SVCBLOCO) was severely damaged by flood waters on September 12, 2013. A replacement gauge was set up downstream at Hwy 119, USGS Gauge 06730525. Although a calculated Mean Daily Discharge (06730525 - 0673050) was made available by the USGS after data at both sites had been verified, this calculation is no longer being completed by the USGS after September 30, 2016 so it is no longer included in this KICP report. (Source: https://waterdata.usgs.gov/nwis/uv?06725450).

Figure 4. Boulder Creek near Orodell 2016 Hydrograph

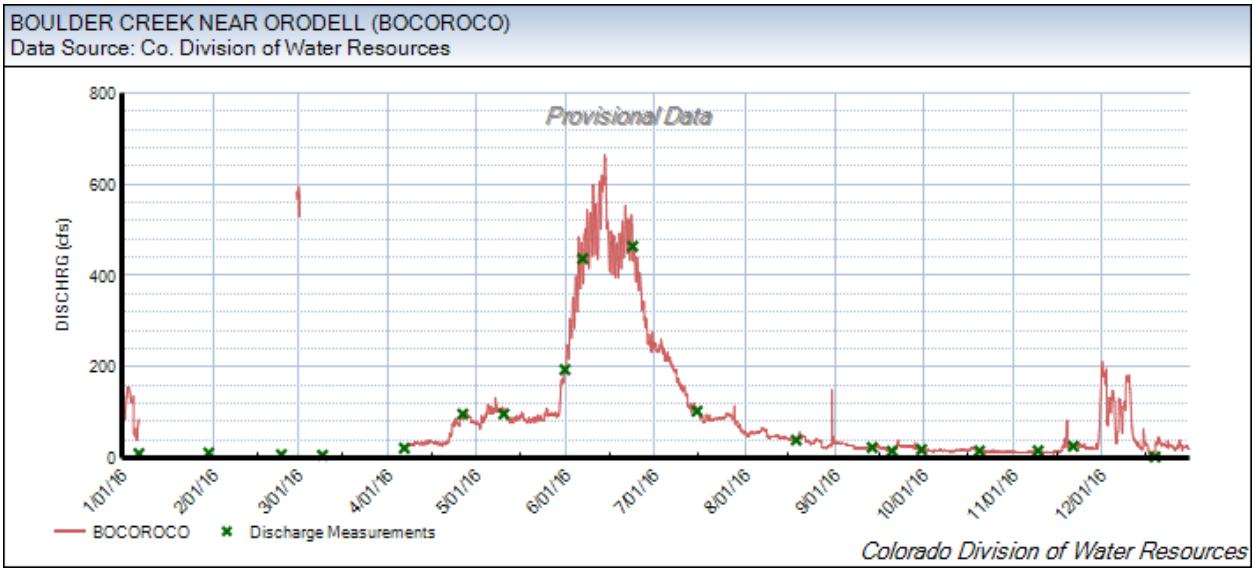


Figure 5. South Boulder Creek near Eldorado Springs 2016 Hydrograph

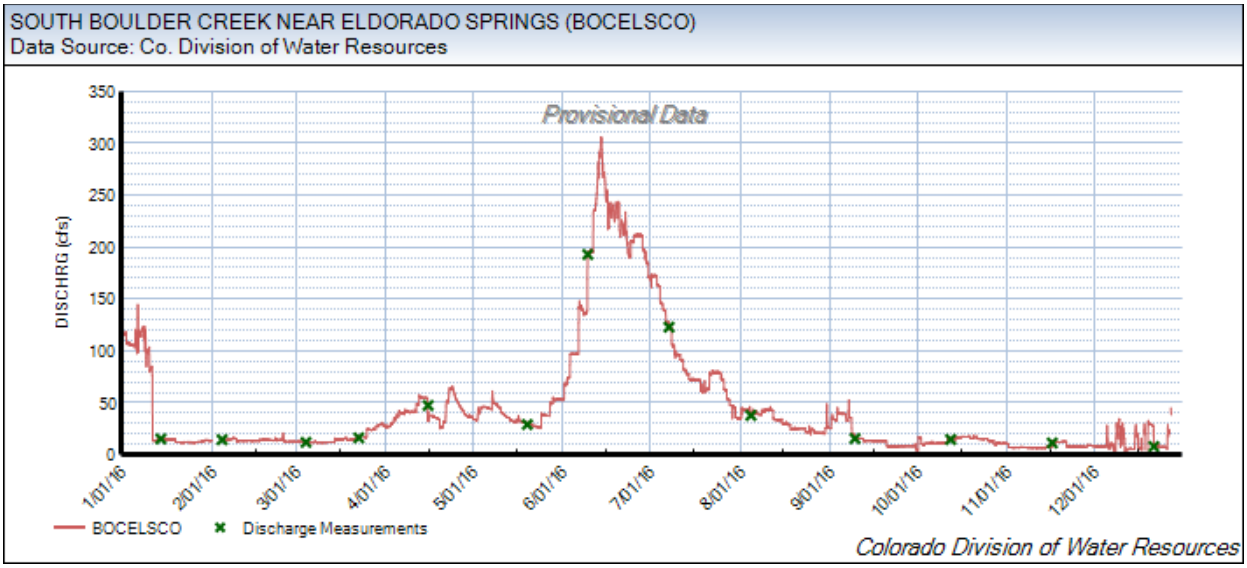


Figure 6. Boulder Creek at North 75th Street 2016 Hydrograph

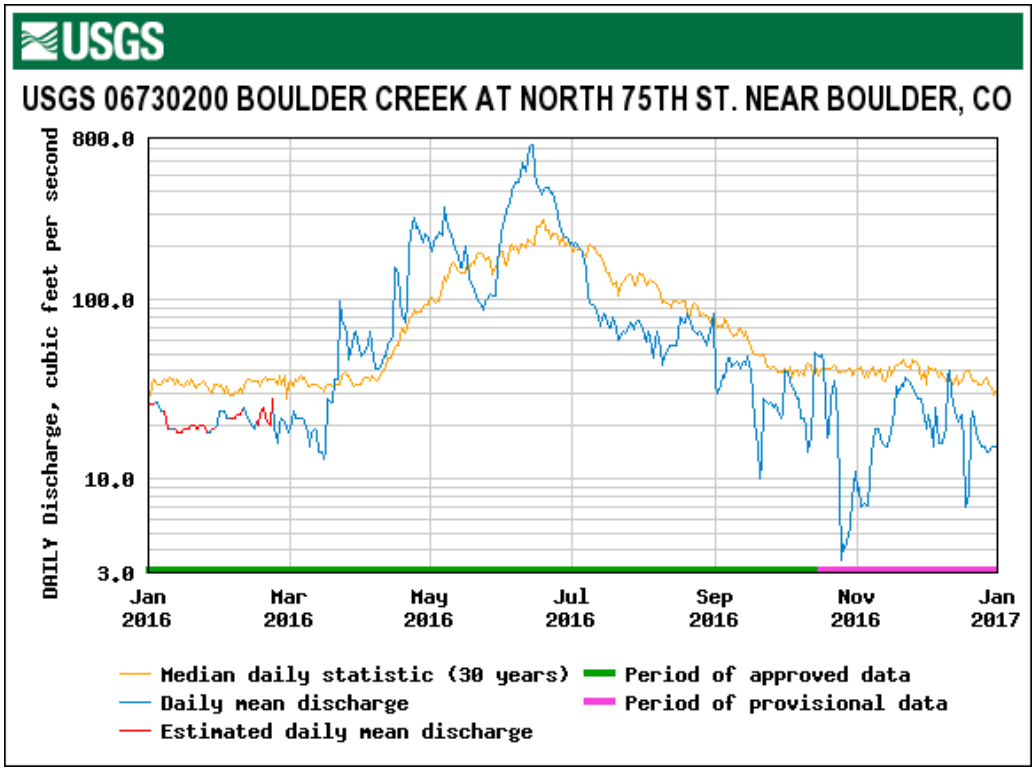


Figure 7. Boulder Creek at Mouth near Longmont 2016 Hydrograph

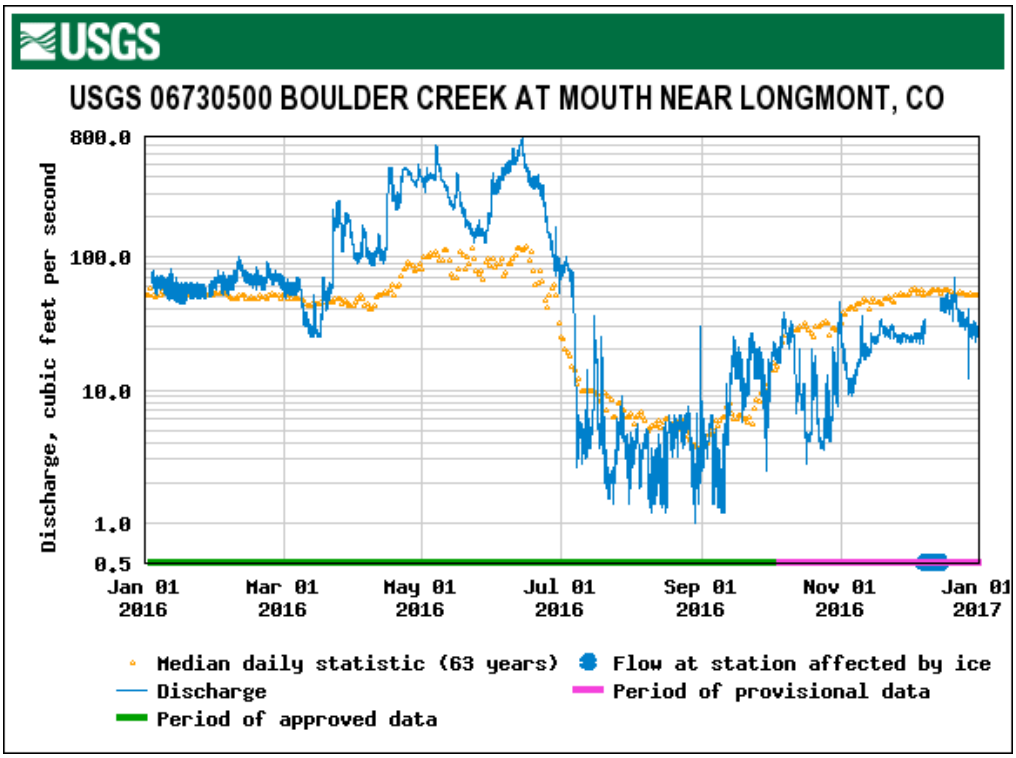


Figure 8. Left Hand Creek at Hover Road near Longmont 2016 Hydrograph

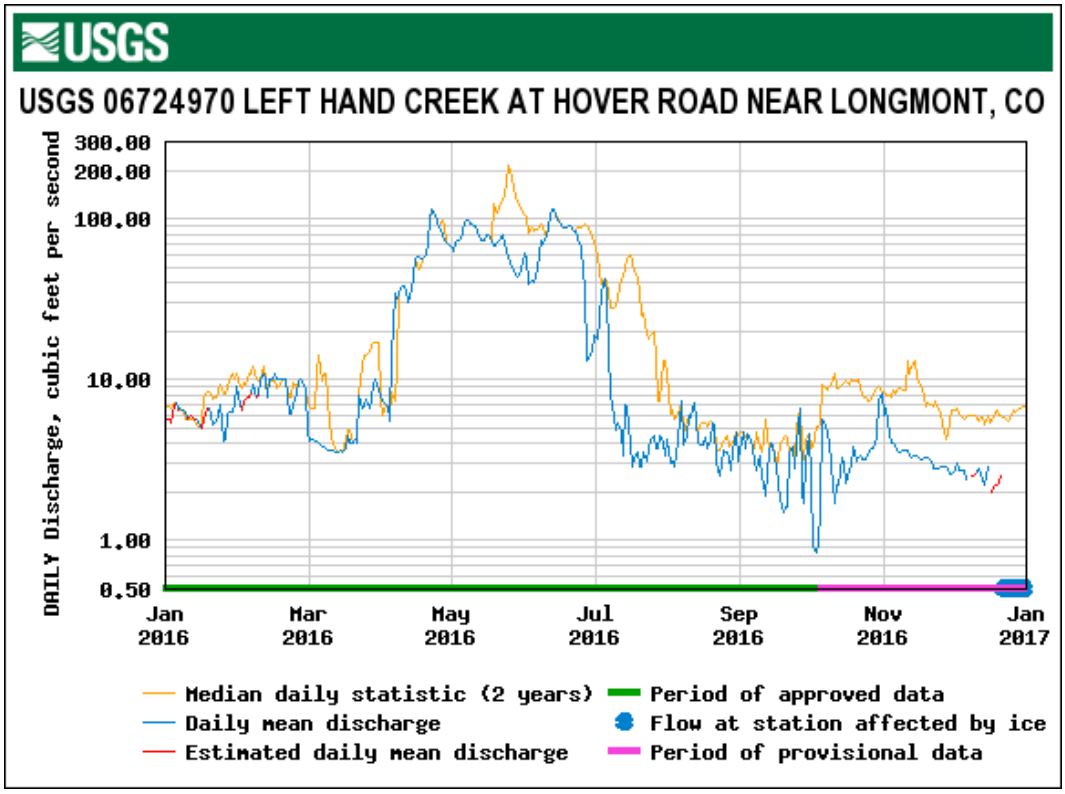


Figure 9. St. Vrain Creek at Hygiene, CO 2016 Hydrograph

Figure 10. St. Vrain Creek below Boulder Creek at Hwy 119 near Longmont 2016 Hydrograph

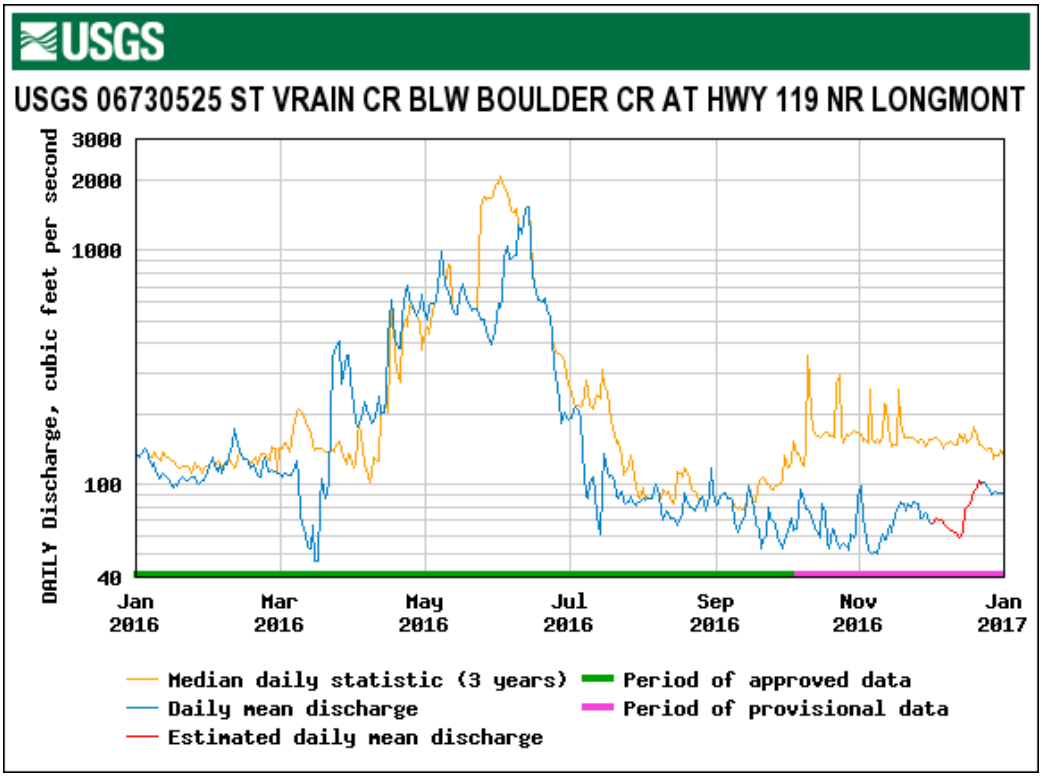


Figure 11. St. Vrain Creek below Ken Pratt Blvd at Longmont 2016 Hydrograph

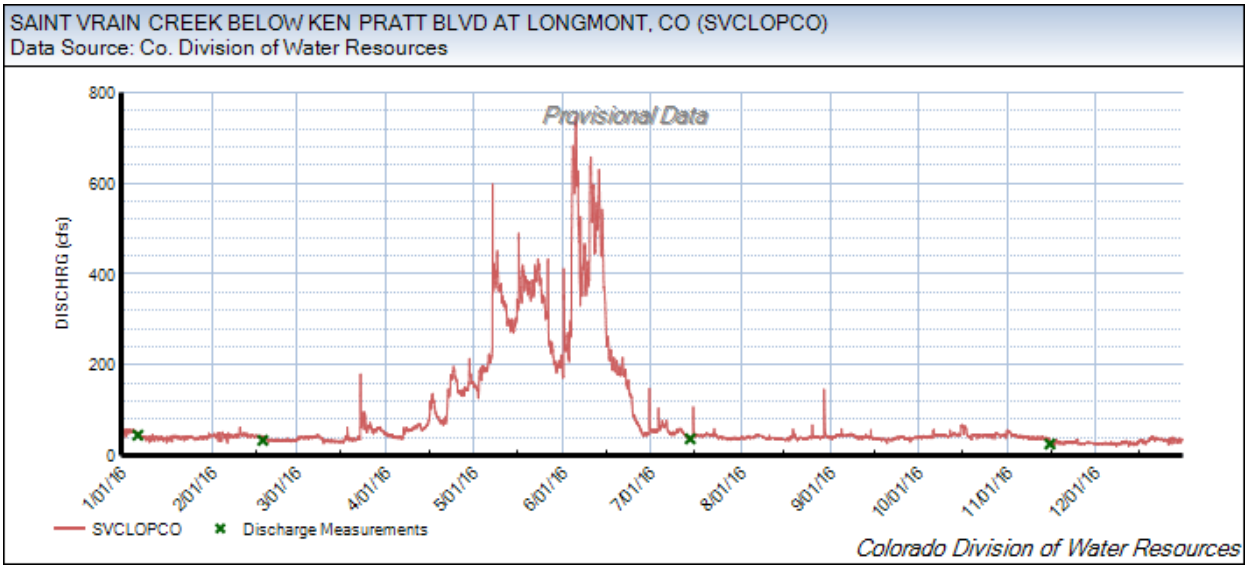
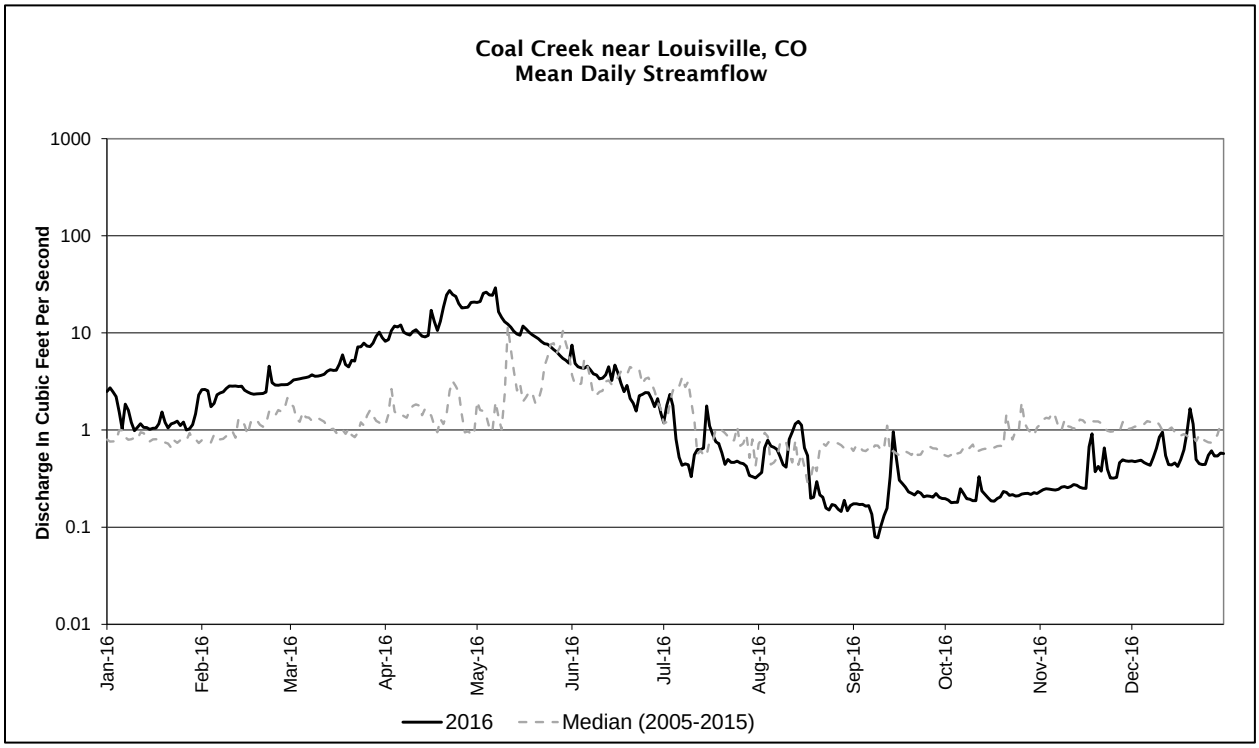


Figure 12. Coal Creek at Louisville (COC-1) 2016 Hydrograph



4.0 Water Quality Analysis

A brief overview of the statistical methods used in this analysis is provided, followed by a brief overview of selected stream standards assessment methodologies relevant to this report and a discussion of findings for general water chemistry, nutrients, *E. coli*, and selected metals for certain streams by basin. Appendices B through D provide statistical summaries and data plots.

STATISTICAL CHARACTERIZATION METHODS

Tabulations of basic summary statistics are provided in Appendix B, including measures of central tendency and range of the data, along with several other statistical parameters, as described in Table 6. For purposes of descriptive statistics and plots, zero was substituted for non-detects to be consistent with standards assessment procedures used by the Division. For *E. coli*, a value of 1 was substituted for non-detects to enable calculation of the geometric mean. In the event that more advanced trend analysis or hypothesis testing is conducted in future reports, an alternative substitution method may be considered (e.g., one-half of the detection limit, other advanced methods). This report is limited to statistical characterization and does not include formal hypothesis testing and trend analysis, given that this is only the third year of the KICP coordinated monitoring program.

Table 6. Overview of Descriptive Statistics Provided in Appendices

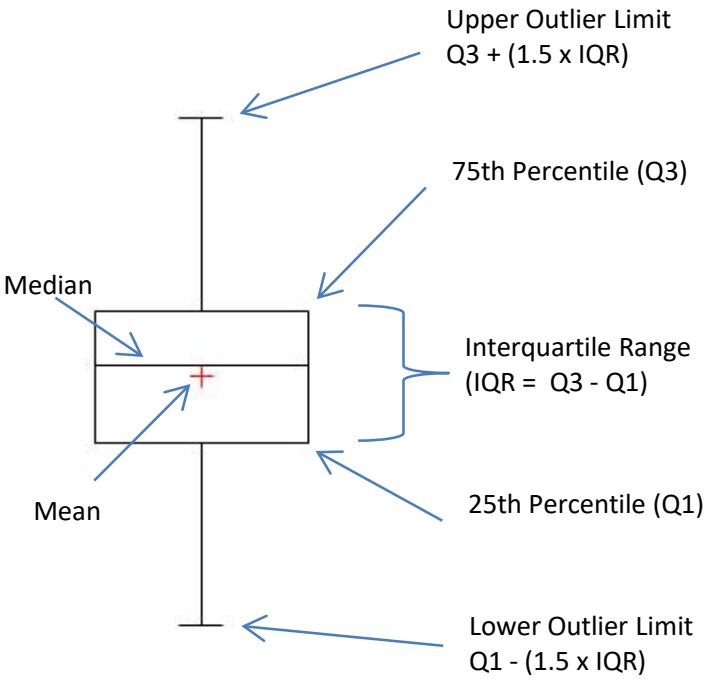
Parameter	Brief Description
Number of observations	The number of values analyzed (n). Statistics based on few samples should be used with caution.
Minimum	The minimum of the series analyzed.
Maximum	The maximum of the series analyzed.
1st quartile	The first quartile (Q1) is defined as the value for which 25% of the values are less. Corresponds to the "floor" of a boxplot.
Median	The median (Q2) is the 50^{th} percentile value for the data set that corresponds to the mid-line of a boxplot. This is a non-parametric estimate of central tendency that does not require the assumption of normally distributed data.
3rd quartile	The third quartile (Q3) is defined as the value for which 75% of the values are less. Corresponds to the "roof" of a boxplot.
Mean	The mean of the sample is the arithmetic average. This is a parametric estimate of central tendency that requires the assumption of normally distributed data.
Standard deviation	A measure of how widely values are dispersed from the average (mean) value.
Geometric mean	A type of average, defined as the n^{th} root of the product of n values. (Used for assessment of *E. coli* standard compliance.)

Graphical representations of water quality data are often useful for identifying potential spatial and temporal water quality trends. Appendices C and D provide boxplots and time series plots of the data provided in 2016. Descriptions of the plots include:

- **Boxplots**: The legend in Figure 13 provides a key for interpreting boxplots, which are useful for depicting both the central tendencies (e.g., mean and median) of data sets, as well as the range of concentrations observed. Each boxplot provides a graphical representation of the 1st quartile (Q1 or 25th percentile), median (50th percentile), and 3rd quartile (Q3 or 75th percentile) data values at a specific monitoring location displayed together as a box with a horizontal line at the median. Additionally, the mean is displayed with a red "+." Lastly, the plot includes the upper and lower limits (i.e., the ends of the "whiskers") beyond which values are considered anomalous. The ends of the whiskers represent the following: a) lower limit: = Q1 – 1.5 (Q3 – Q1) and 2) upper limit: Q3 + 1.5 (Q3 – Q1). Boxplots are provided in Appendix C for the KICP Monitoring Plan data set.

- **Time Series Plots**: Time series plots provide a graphical representation of data over time. The x-axis identifies sample dates and the y-axis provides quantitative values for those sample dates. Time series plots are particularly useful for identifying potential repeating seasonal patterns over time, or identifying whether multiple sample locations behave similarly or differently over time. Time series plots are provided in Appendix D for the KICP Monitoring Plan data set.

Figure 13. Boxplot Legend



OVERVIEW OF STREAM STANDARDS ASSESSMENT METHODOLOGY

Independent and proactive assessment of water quality data to determine whether streams attain Colorado water quality standards is an important aspect of the annual data review process. It provides an opportunity for local governments to identify potential water quality impairments and collect additional data prior to formal assessment by the Division for the 303(d) List of Impaired Waters. A complete assessment of water quality standards has not been completed for stream segments in this report because the analysis is limited to a subset of parameters on each stream segment. A full description of the Division's standards assessment methodology can be accessed in *Colorado Listing Methodology: 2018 303(d) List* (Division 2017). This methodology is typically reviewed and refined on a biennial basis, so it should be checked for changes prior to completing each annual report. A few key aspects of the assessment methodology for general reference for purposes of constituents discussed in this report for streams include:

- The most recent five years of data are typically used for purposes of standards assessment.
- For dissolved oxygen (DO), the 15th percentile value should not be less than the stream standard.
- For pH, the 15th percentile value should not be less than the lower pH range for the standard and the 85th percentile value should not be greater than the upper pH range.
- For assessment of chronic standards, the 85th percentile value for the data set is typically compared to the standard, with the exception of metals with standards in the total form. In those cases (e.g., iron, arsenic), the 50th percentile value is used.
- For assessment of acute standards, more than one exceedance of an acute standard over three years is considered an impairment.
- For *E. coli*, the geometric mean for sample results over a rolling 61-day interval is calculated. A sample size of five or more over the 61-day interval is required for an impairment determination. Locations with fewer samples may result in placement on the Monitoring and Evaluation (M&E) list. In 2017, the listing methodology changed substantially from past practice as further described in the call-out box. (Note: The routine sampling program in place in the watershed typically results in only two samples per assessment period, which does not meet the five-sample requirement for an impairment determination.)
- If evaluation of a data set for an entire segment does not indicate impairment, but specific location(s) within the segment consistently exceed acute or chronic standards, the specific portion of the segment may be listed as impaired.

- Water supply standards (e.g., nitrate, arsenic) are assessed along the entire segment for those segments where a water supply use has been adopted, regardless of whether or not there is a point of intake identified on the stream.

Revised *E. coli* 303(d) Listing Methodology Adopted for 2018 303(d) List

The *E. coli* standard of 126 MPN/100 mL is based on a two-month geometric mean. A new procedure has been adopted by the Water Quality Control Division to determine impairments, as described in the 2018 303(d) Listing Methodology. To evaluate this two-month criterion, the division calculates the geometric mean for *E. coli* data over rolling 61-day intervals, with each sample beginning a new interval for the entire period of record. Segments with site-specific standards are evaluated using the same method over the applicable period.

Waterbody segments with data intervals made up of two samples, after any bias correction, that indicate impairment of the *E. coli* standard will result in placement on the M&E List. Segments with *E. coli* data sets comprised of four samples where there is "overwhelming evidence" of non-attainment will be placed on the 303(d) List. If there are three or four samples with an indication of impairment but the evidence is not overwhelming, the segment will be placed on the M&E List. Data sets of five or more samples indicating any degree of non-attainment will be added to the 303(d) List.

Since the 2018 *E. coli* assessment methodology is a significant revision to the previous methodology, previous *E. coli* 303(d) listings should be reassessed where annual or seasonal geometric means were utilized in making the impairment decision. The new methodology should be applied to the older data used for the initial impairment determination. If the old data indicates attainment using the new method, the segment may be delisted due to a change in assessment methodology. Previously listed segments with no new data will only be delisted if there is a minimum of 5 data points within the 61 day 'windows'. If a minimum of one window with a sample size of 5 indicates attainment, and all other windows also indicate attainment with fewer samples, the division may delist the segment.

In order to delist a segment for *E. coli*, a minimum of five samples collected within the same months of the original exceedances that demonstrate attainment for a minimum of two consecutive years is required. For example, if the original listing was based on exceedances from May to October, a minimum of five samples would be required for 61-day intervals between May and October for two consecutive years. When examining data for a five year period of record, a segment may be considered attaining the *E. coli* standard if the first two or three years demonstrate exceedances but the most recent two years indicate attainment. Segments indicating attainment using the new methodology but lacking adequate sample size for delisting may be moved to a lower priority until a determination with adequate sampling can be made.

If evaluation of a data set for an entire segment does not indicate impairment, but specific location(s) within the segment consistently exceed acute or chronic standards, the specific portion of the segment may be listed.

- Temperature and ammonia standards evaluation require more complex assessment techniques, which are described in the 2018 303(d) Listing Methodology (Division 2017). Temperature has not been assessed in this KICP report. Ammonia standards have been calculated based on temperature and pH and have been evaluated for purposes of this report.

- For purposes of standards assessment, non-detects are replaced with zeros (or 1 for *E. coli*), per Division policy.

- If less than four samples are available, then the data set is not adequate to draw conclusions regarding impairment. In cases where less than four samples are available but impairment is indicated by available data, then the Division may list the segment on the Monitoring and Evaluation List until additional data can be collected.

- In 2012, Colorado adopted "interim nutrient values," which currently may be adopted as standards for stream segments upstream of WWTPs for total phosphorus and chlorophyll-a, but will also apply to segments downstream in the future (after May 31, 2022). For total nitrogen, interim values may be adopted after May 31, 2017 upstream of WWTPs and for other segments after May 31, 2022. For streams, total nitrogen, total phosphorus, and chlorophyll-*a* are evaluated based on comparison of annual median concentrations to the standard, which can be exceeded once every five years. (Additional assessment methods are in place for lakes and reservoirs.) In the June 2015 Rulemaking Hearing for Regulation 38, total phosphorus and chlorophyll-a standards were adopted for several stream segments in the watershed, including Boulder Creek Segment 2b, South Boulder Creek Segment 4b, Rock Creek (Boulder Creek Segment 8), Coal Creek (Boulder Creek Segment 7a) and Left Hand Creek (Saint Vrain Segment 5), as described further in Appendix E. The next Regulation 38 rulemaking hearing will be held in June 2020. Review of Colorado's nutrient regulations will occur in October 2017; however, based on the draft "Water Quality Roadmap" prepared by the Division, it is expected that additional implementation of the phased nutrient standards may be postponed until 2027.

SUMMARY OF 2016 303(D) LISTINGS

In December 2016, the Water Quality Control Commission (Commission) held a hearing to update Colorado's 303(d) List of impaired waters. Appendix F provides a summary of all of the stream segments in the Boulder Creek and St. Vrain watersheds that are identified as impaired or on the state's 2016 Monitoring and Evaluation List. Table 7 provides a summary of the subset of segments that are within the boundaries of this annual report (i.e., have monitoring stations included in this report). The 303(d) List will be updated in 2018, with the regulatory process for the hearing beginning during the summer of 2017.

Table 7. 2016 303(d) and Monitoring Evaluation (M&E) List for Selected Stream Segments

WBID	Description	Portion	M&E	303(d)	Priority
Boulder Creek Segments					
COSPBO02b	Boulder Creek, from below the confluence with North Boulder Creek to above the confluence with South Boulder Creek	all		As (*also TMDL for E. coli*)	L
COSPBO04b	Mainstem of South Boulder Creek, including all tributaries from the outlet of Gross Reservoir to South Boulder Road	all		Cu, As	H/L
COSPBO07a	Mainstem of Coal Creek from Highway 93 to Highway 36	all	Aquatic Life		H
COSPBO07b	Coal Creek, HWY 36 to Boulder Creek	all	Aquatic Life	*E. coli*	H
COSPBO07b	Coal Creek, HWY 36 to Boulder Creek	Below Confluence of Rock Creek		Se	M
COSPBO08	All tribs to South Boulder Creek and all tribs to Coal Creek	Rock Creek	*E. coli*	Se	L
COSPBO09	Mainstem of Boulder Creek, from South Boulder Creek to Coal Creek	all		As, *E. coli* (July to October)	L/H
COSPBO09	Mainstem of Boulder Creek, from South Boulder Creek to Coal Creek	From 107th Street to the confluence with Coal Creek		Aquatic Life (provisional)	L
COSPBO10	Boulder Creek, Coal Creek to St. Vrain Creek	all		*E. coli*, pH, As	H/H/L
St. Vrain Segments					
COSPSV03	St. Vrain Creek, Hygiene Rd. to S. Platte River	all		*E. coli*	H
COSPSV05	Mainstem of Left Hand Creek, including all tributaries and wetlands from Highway 36 to the confluence with St. Vrain Creek.	all		Cu	M

FINDINGS FOR GENERAL WATER QUALITY CONSTITUENTS BY BASIN

The Monitoring Plan includes several general water quality parameters that can be useful in trend analysis and/or that are also needed for calculating certain standards. These include pH, dissolved oxygen (DO), temperature, conductivity, hardness, alkalinity and total suspended solids (TSS). For example, pH and temperature are needed for calculating ammonia standards and hardness is needed to calculate table value standards for various metals. Tabular statistics, boxplots and time series plots for these general water quality constituents are provided in Appendices B through D. General observations from the review of these water quality data are provided by basin below, although formal hypothesis testing for trend analysis has not been conducted for purposes of this report.

Boulder Creek and South Boulder Creek

The Boulder Creek monitoring locations addressed in this report span from Canyon Road (BC-Can) to above the confluence with the St. Vrain (11-BC). The City of Boulder monitors the stream at various locations through the City of Boulder to below the confluence with Coal Creek. The Town of Erie monitors Boulder Creek in the lower portion of stream between Coal Creek and St. Vrain Creek. Boulder's 75th Street WWTP discharges to the stream in the vicinity of 75th Street and Erie's WWTP discharges to Boulder Creek downstream of Coal Creek. The City of Boulder also monitors South Boulder Creek in the open space area upstream of Highway 36 (SBC-3.5/4). The long-term South Boulder Creek monitoring location is named SBC-3.5, but an alternative location named SBC-4 has been monitored following the September 2013 flood. These two locations have been combined into one location representing open space for purposes of this report.

Key observations regarding general water chemistry for Boulder Creek during 2016 include:

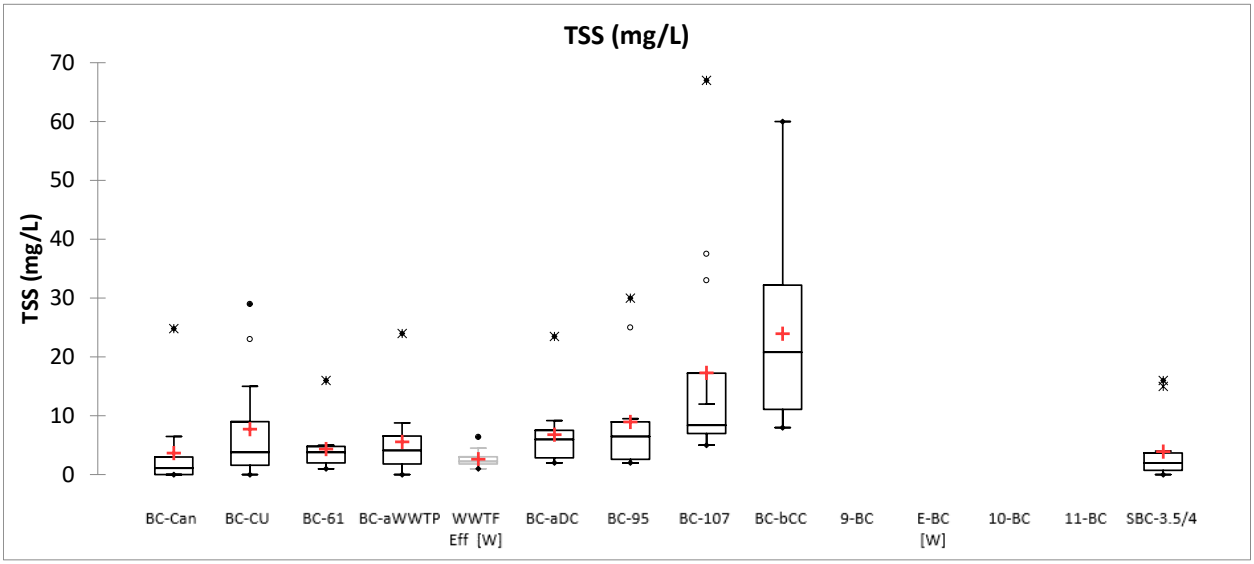
- For Boulder Creek, alkalinity, conductivity, hardness, pH and temperature generally increase from upstream to downstream, consistent with previous published analyses (e.g., Murphy 2006) and annual analysis by the City of Boulder (City of Boulder and WWE 2013 & 2015; Brown and Caldwell 2017). Concentrations of these parameters at the South Boulder Creek monitoring location (SBC3.5/4) are relatively similar to the upstream portion of Boulder Creek at site BC-Can.

- DO concentrations on Boulder Creek and South Boulder Creek attained the stream standards of 5 to 7 mg/L. The DO stream standard varies by segment, depending on location and spawning conditions.

- TSS concentrations on Boulder Creek were low (typically <30 mg/L), although a few elevated values were measured at stations BC-107 and BC-bCC. Higher concentrations typically occur during spring runoff and during storm events (City of Boulder and WWE 2015). Coal Creek has higher TSS concentrations than upstream locations on Boulder Creek and influences TSS concentrations in Boulder Creek below the confluence with Coal Creek (BC-bCC), as shown in Figure 14.

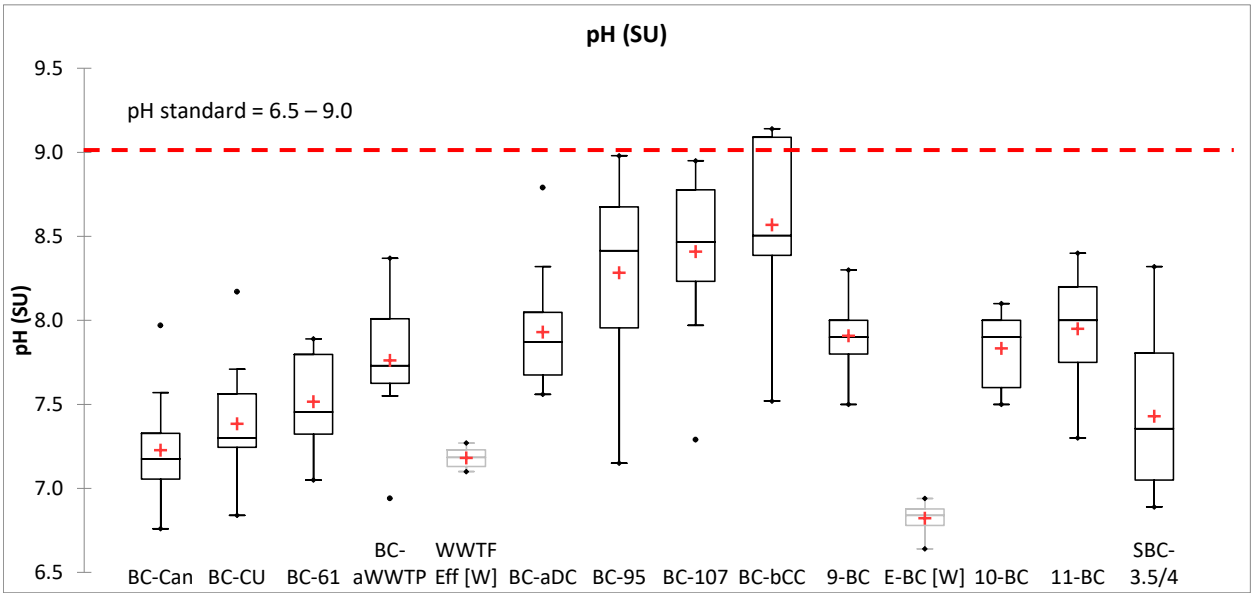
- The pH standard for Boulder Creek is based on an allowable range of 6.5 to 9.0. The pH levels are typically slightly higher in the winter (City of Boulder and WWE 2015). Boulder Creek Segment 10 is listed on the 2016 303(d) List as impaired due to elevated pH. During 2016, all locations on Boulder Creek attained the pH standard except for the location below Coal Creek (BC-bCC) (Figure 15) and the 85th percentile value for Segment 10 was 8.5. This suggests that it may be more appropriate for a portion of Boulder Creek to be listed as impaired for pH rather than the entire segment.

Figure 14. 2016 Boulder Creek Total Suspended Solids



Note: If no boxplot is shown for a site, then TSS data were not provided for that sampling location.

Figure 15. 2016 Boulder Creek pH



Coal Creek and Rock Creek

Coal Creek monitoring locations addressed in this report span from upstream of Highway 36 to Kenosha Road near the confluence with Boulder Creek. Rock Creek is also monitored above and below Superior's WWTP discharge. Rock Creek joins Coal Creek above Lafayette's WWTP. There are three municipal WWTPs actively discharging to these streams: Louisville and Lafayette discharge to Coal Creek and Superior discharges to Rock Creek. Historically, Erie's South WWTP also discharged to Coal Creek, but Erie is now utilizing its North WWTP, which discharges to Boulder Creek.

The coordinated instream monitoring program on Coal Creek and Rock Creek is relatively new. Water quality parameters were more consistently monitored during 2016 relative to the previous two years of the monitoring program. Site 0-CC at the upstream end of Coal Creek is new, so a complete data set was not yet available for that site. During 2016, both Lafayette and Superior monitoring 5-RC on Rock Creek. For purposes of this report, the two data sets are kept separate, denoted by 5-RCl Lafayette and 5-RCs for Superior. The results from the two efforts are not identical, but are reasonably comparable.

Key observations regarding general water chemistry for Coal Creek and Rock Creek during 2016 include:

- Coal Creek and Rock Creek attained the DO standard of 5 mg/L, as well as the pH standard. The 85th percentile pH values for Coal Creek and Rock Creek were 8.3 and 8.4, respectively.

- Rock Creek and Coal Creek had relatively normal[5] alkalinity ranges on average with no apparent spatial trends observed. Higher alkalinity concentrations were observed in the fall and winter, with lower alkalinity indicated during spring runoff.

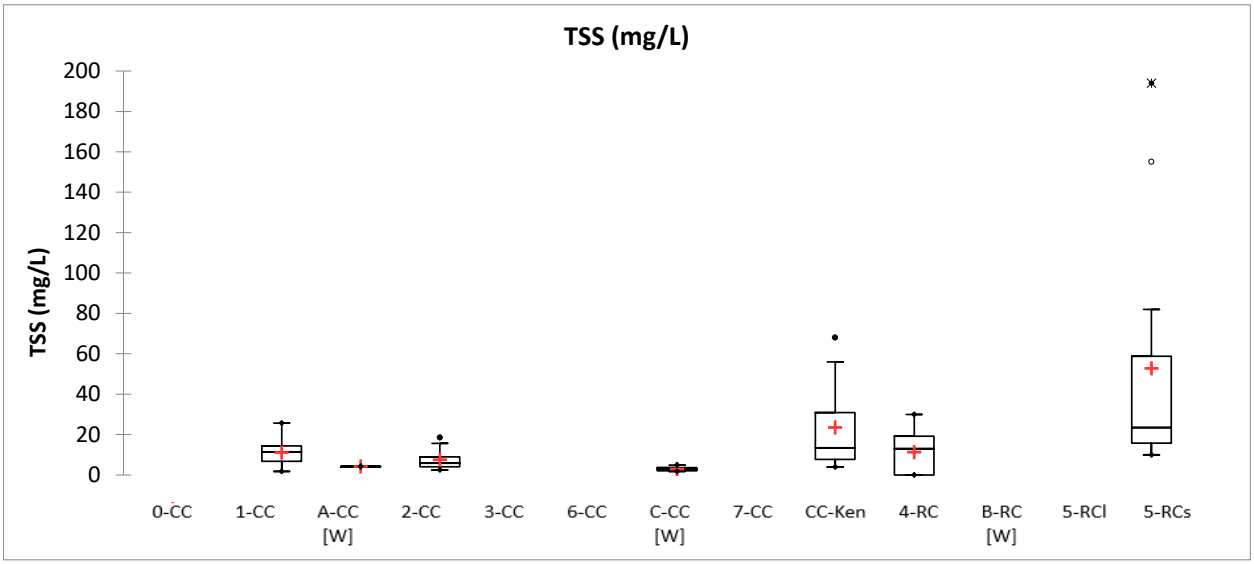
- Coal Creek and Rock Creek have relatively high hardness, with Coal Creek above Rock Creek averaging 234 mg/L, Rock Creek averaging 330 mg/L, and Coal Creek below the confluence averaging approximately 296 mg/L. These relatively high hardness values result in less stringent hardness-based metals standards than those calculated for Boulder Creek and South Boulder Creek.

- The conductivity of Coal Creek generally increases in an upstream to downstream direction and is influenced by high conductivity from Rock Creek. The average conductivity for Rock Creek above Coal Creek was 1685 umhos/cm and the average conductivity for Coal Creek above the confluence with Rock Creek was 818 umhos/cm. The average conductivity for Coal Creek above the confluence with Boulder Creek was 1006 umhos/com.

- TSS concentrations on Coal Creek during 2016 were relatively low, averaging less than 30 mg/L. The lower sampling location at RC-5 on Rock Creek averaged 53 mg/L TSS and had greater variability than the other sample locations, with the highest concentrations in the March to June timeframe. Figure 16 shows the range of TSS concentrations in Coal Creek and Rock Creek above the confluence with Boulder Creek.

[5] Alkalinity ranging between 100 and 250 mg/L is considered normal for surface waters. Levels greater than 250 mg/L are considered high. Levels between 25 and 400 mg/L are generally beneficial for aquatic life (Weiner 2008).

Figure 16. 2016 Coal Creek Total Suspended Solids



St. Vrain Creek and Left Hand Creek

St. Vrain Creek monitoring locations addressed in this report span from the western urbanized boundary of Longmont at North 75th Street to County Line Road (M6-SV) prior to the confluence with Boulder Creek. An additional monitoring location immediately above the confluence (M4-SV) has also been monitored by Longmont in the past, but has been discontinued following damage from the September 2013 flood. Left Hand Creek enters St. Vrain Creek below Longmont's WWTP discharge and was monitored at two locations during 2016: at 95th Street (LH-95) and above the confluence with St. Vrain Creek (T11-LH). Two locations monitored by Longmont are associated with Longmont's WWTP discharge: the effluent itself (identified as WWTP-LGMT) and a location that monitors the effluent comingled with a roadside ditch prior to discharge to the St. Vrain (identified as T-EFF).

In the data plots for St. Vrain Creek and Left Hand Creek, the two stations upstream of the urbanized area are plotted first (LH-95 and M9.5-SV), followed by the remainder of the St. Vrain monitoring locations from upstream to downstream with Left Hand Creek near the confluence (T11-LH) and the WWTP-related data (WWTP-LGMT and/or T-EFF) plotted where they enter St. Vrain Creek above M7-SV.

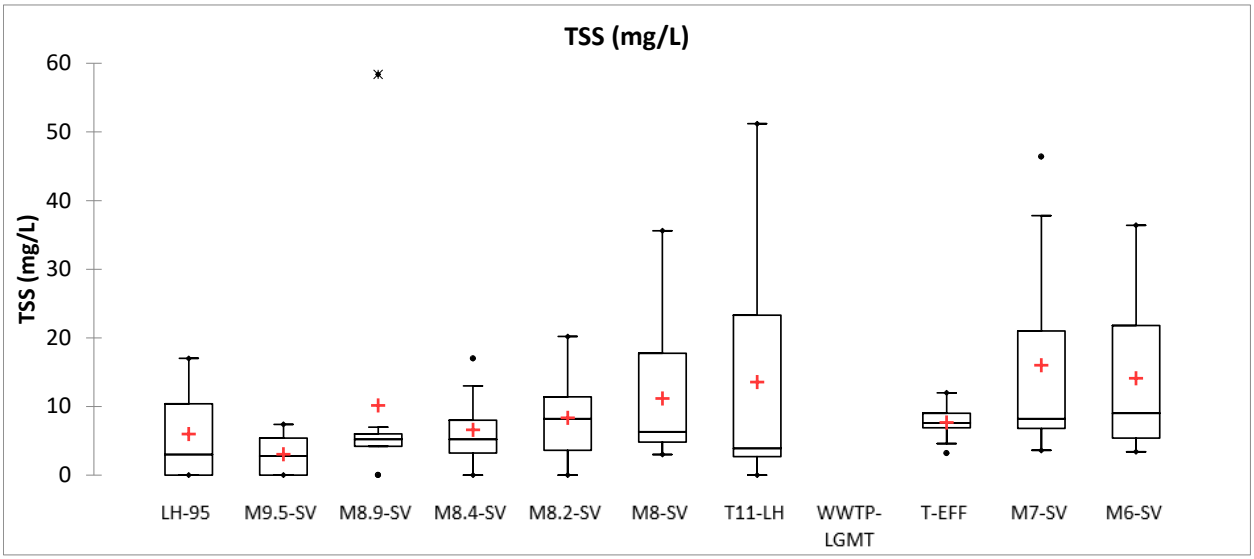
Key observations regarding general water chemistry for St. Vrain Creek and Left Hand Creek (above the confluence with St. Vrain Creek) during 2016 include:

- Alkalinity, conductivity, and hardness generally increase in an upstream to downstream direction; however, the Longmont WWTP discharge appears to "reset" the alkalinity and hardness concentrations by temporarily decreasing values after which the increasing trend for downstream sites begins again.

- Left Hand Creek and St. Vrain Creek attained the pH stream standard of 6.5 to 9.0. A few individual samples on St. Vrain Creek had low pH, but the 15th percentile still attained the standard at these locations.

- TSS concentrations in St. Vrain Creek and Left Hand Creek were relatively low (typically <30 mg/L) (Figure 17). Mean concentrations generally increase in a downstream direction, with Left Hand Creek contributing to increases in TSS in St. Vrain Creek. Mean TSS concentrations in Left Hand Creek have decreased since 2014, which may indicate that Left Hand Creek is becoming more stable following the 2013 flood. However, observations during biological sampling indicate that eroded sediment in the upper portion of Left Hand Creek has been flushed downstream, with substrate at T11-LH covered with about 2 feet of sediment (Personal Communication with Dave Rees, Timberline Aquatics, June 2017).

Figure 17. 2016 St. Vrain Creek and Left Hand Creek Total Suspended Solids



FINDINGS FOR SELECTED NUTRIENTS BY BASIN

Nutrients are of interest for each basin due to current and future water quality regulations and the communities' desire to maintain healthy aquatic life and aesthetically pleasing conditions in streams. Excessive nutrient concentrations can lead to undesirable algae and other vegetative growth, adversely affecting aquatic life and aesthetics.

Currently, stream standards for ammonia, nitrate and nitrite have been adopted for each stream segment in Regulation 38, and total phosphorus and chlorophyll-a standards have been adopted for certain segments as described further below. Additional nutrient "interim values" for total nitrogen and total phosphorus, as well as chlorophyll-*a*, are expected to be added in the future in accordance with Regulation 31. Technology-based WWTP effluent limits for total inorganic

nitrogen (TIN) and total phosphorus for WWTP discharges will be applied under Regulation 85, with most WWTPs receiving compliance schedules to allow time to implement treatment upgrades. The following nutrients are discussed in this section and will be of increasing interest to the municipalities:

- Phosphorus (total phosphorus)
- Nitrogen (total Kjeldahl nitrogen [TKN], nitrate, nitrite, ammonia, total nitrogen)

The "interim values" adopted in Regulation 31 for total nitrogen, total phosphorus and chlorophyll-*a* are summarized in Table 8. Chlorophyll-*a* (as attached algae) is not part of the current Monitoring Plan, so it is not discussed further in this report. Interim values vary for cold water and warm water streams, with more stringent values for cold water streams. Appendix E provides a summary of stream standards adopted for various stream segments in the basin, including various nutrient standards adopted in the June 2015 Regulation 38 Rulemaking Hearing. The exact timeline for adoption for additional nutrient standards is currently uncertain (e.g., may be extended to 2027) and will be addressed in upcoming Commission hearings.

Table 8. "Interim Values" for Total Nitrogen, Total Phosphorus and Chlorophyll-*a*

Analyte	Cold Water "Interim Value"	Warm Water "Interim Value"
Total Phosphorus	0.11 mg/L	0.17 mg/L
Total Nitrogen	1.25 mg/L	2.01 mg/L
Chlorophyll-*a*	150 mg/m^2	150 mg/m^2
Nutrients: Interim values for phosphorus and nitrogen in streams are assessed based on comparison of annual median to standard. Allowable exceedance frequency is once every five years. **Chlorophyll-*a*:** Chlorophyll-*a* is measured as maximum attached algae and is assessed during July 1-September 30 as a "not to exceed" value.		

As additional background on water quality standards for nutrients:

- The cold water total phosphorus standard of 0.11 mg/L now applies to the upper sites on Boulder Creek (Boulder Creek Segment 2b) and South Boulder Creek (Boulder Creek Segment 4b). The warm water phosphorus standard of 0.17 mg/L applies to Rock Creek above the Superior discharge (Boulder Creek Segment 8), Coal Creek above Highway 36 (Boulder Creek Segment 7a), and to Left Hand Creek (St. Vrain Creek Segment 5). Although these standards only apply above WWTP discharges, these standards will potentially be applied downstream of WWTP discharges after May 31, 2022.
- As summarized in Table 8, total nitrogen "interim values" were adopted under Regulation 31. These values could be applied no sooner than May 31, 2017 and may be applied after May 31, 2022. (Total nitrogen standards were not proposed for any of the stream segments in the June 2015 Regulation 38 hearing.) Total nitrogen is the sum of nitrate/nitrite and TKN.

- There is no standard for TKN, but it is an important component of total nitrogen. TKN represents organic nitrogen plus ammonia. To calculate total nitrogen, TKN is added to nitrate/nitrite.

- A nitrate standard of 10 mg/L is in place on streams with water supply use designations (Boulder Creek, South Boulder Creek, Coal Creek, Left Hand Creek). The Division adopted a new water supply use classification for Coal Creek in the June 2015 Regulation 38 hearing. For stream segments such as Rock Creek and St. Vrain Creek with agricultural use but no water supply designation, a standard of 100 mg/L applies.

- A nitrite standard of 0.05 mg/L for protection of aquatic life is also in place for the cold-water stream segments. For the warm water stream segments, the nitrite standard is ten times higher at 0.5 mg/L.

- Ammonia standards are adopted for protection of aquatic life and are calculated based on temperature and pH, in accordance with the aquatic life classification adopted for the segment in Regulation 38.

Tables 9 and 10 summarize the total nitrogen and total phosphorus data provided in support of this 2016 water quality analysis. Appendix I provides a fact sheet on nutrient conditions in the overall watershed.

Table 9. 2016 Total Phosphorus Data (mg/L)

Sample Location	No.	Min	Max	25%	Median	75%	Mean	Std. Dev.
BOULDER CREEK								
BC-Can	12	ND	0.79	ND	**ND**	ND	0.07	0.23
BC-CU	12	ND	0.17	ND	**ND**	ND	0.01	0.05
BC-61	12	ND	0.21	ND	**ND**	ND	0.02	0.06
BC-aWWTP	12	ND	0.12	ND	**ND**	ND	0.01	0.03
WWTF Eff **[W]**	12	2.32	3.90	2.83	**3.29**	3.64	3.21	0.52
BC-aDC	12	0.16	1.55	0.92	**1.18**	1.37	1.09	0.41
BC-95	12	0.18	1.16	0.58	**0.68**	0.97	0.73	0.31
BC-107	12	ND	1.35	0.38	**0.61**	1.03	0.69	0.45
BC-bCC	12	ND	1.29	0.48	**0.68**	0.89	0.71	0.40
9-BC	12	0.26	1.23	0.50	**0.66**	0.94	0.71	0.32
E-BC **[W]**	12	0.09	0.25	0.14	**0.15**	0.19	0.16	0.05
10-BC	12	0.25	1.05	0.48	**0.64**	0.86	0.66	0.27
11-BC	12	0.25	0.92	0.42	**0.51**	0.70	0.55	0.22
SOUTH BOULDER CREEK								
SBC-3.5/4	12	ND	ND	ND	**ND**	ND	ND	ND
COAL CREEK/ROCK CREEK								
0-CC	2	ND	ND	ND	**ND**	ND	ND	ND
1-CC	12	ND	0.28	ND	**ND**	0.03	0.03	0.08
A-CC **[W]**	12	0.13	2.70	0.28	**0.78**	1.75	1.09	1.00
2-CC	11	ND	1.50	0.09	**0.21**	0.56	0.44	0.53
3-CC	12	0.06	1.40	0.13	**0.17**	0.33	0.31	0.38
6-CC	12	0.13	0.85	0.20	**0.25**	0.39	0.33	0.21
C-CC **[W]**	12	1.50	8.50	2.50	**2.75**	3.13	3.19	1.78
7-CC	12	0.27	1.30	0.52	**0.73**	0.97	0.74	0.30
CC-Ken	12	ND	1.16	0.72	**0.91**	1.08	0.83	0.35
4-RC	12	ND	0.25	0.03	**0.10**	0.15	0.11	0.09
B-RC **[W]**	11	1.66	4.38	2.39	**2.49**	2.87	2.76	0.86
5-RCl	12	0.06	0.90	0.22	**0.36**	0.45	0.37	0.22
5-RCs	12	ND	1.31	0.20	**0.32**	0.71	0.44	0.38
ST. VRAIN/LEFT HAND CREEK								
LH-95	9	0.01	0.03	0.01	**0.02**	0.03	0.02	0.01
M9.5-SV	9	0.01	0.02	0.01	**0.01**	0.02	0.02	0.01
M8.9-SV	9	0.01	0.07	0.02	**0.02**	0.03	0.03	0.02
M8.4-SV	9	0.01	0.03	0.02	**0.02**	0.03	0.02	0.01
M8.2-SV	9	0.01	0.03	0.02	**0.03**	0.03	0.03	0.01
M8-SV	12	0.02	0.06	0.02	**0.03**	0.04	0.03	0.01
T11-LH	12	0.01	0.08	0.01	**0.02**	0.03	0.03	0.02
WWTP-LGMT **[W]**	12	0.25	4.53	1.23	**1.92**	2.95	2.15	1.31
T-EFF	12	0.24	4.09	0.94	**1.27**	2.62	1.86	1.33
M7-SV	12	0.03	1.52	0.17	**0.41**	0.56	0.46	0.41
M6-SV	9	0.04	1.47	0.12	**0.35**	0.49	0.42	0.44

Notes: Wastewater discharge sample locations are designated by [W]. T-EFF is the Longmont WWTP effluent channel combined with roadside ditch flow where it enters the St. Vrain. ND = non-detect.

Table 10. 2016 Total Nitrogen Data (mg/L)

Sample Location	No.	Min	Max	25%	Median	75%	Mean	Std. Dev.
BOULDER CREEK								
BC-Can	12	0.15	1.14	0.18	0.27	0.39	0.38	0.32
BC-CU	12	0.20	0.77	0.22	0.35	0.65	0.43	0.23
BC-61	12	0.25	1.20	0.36	0.72	0.78	0.64	0.31
BC-aWWTP	12	0.43	0.70	0.49	0.55	0.61	0.55	0.09
WWTF Eff **[W]**	12	9.01	16.56	10.04	11.30	11.77	11.36	1.92
BC-aDC	12	1.14	7.66	3.73	4.47	4.85	4.49	1.80
BC-95	12	0.79	5.30	2.27	3.41	4.13	3.31	1.34
BC-107	12	0.49	4.83	2.52	3.67	4.52	3.35	1.41
BC-bCC	12	1.38	7.60	3.91	5.23	6.58	5.10	1.82
9-BC	12	1.41	10.81	2.87	4.96	6.59	4.97	2.75
E-BC **[W]**	12	10.34	16.23	11.86	13.22	15.20	13.34	2.11
10-BC	12	1.40	6.97	3.23	5.31	6.08	4.60	1.92
11-BC	12	1.30	5.92	3.02	4.24	5.05	3.84	1.53
SOUTH BOULDER CREEK								
SBC-3.5/4	12	0.18	1.20	0.25	0.29	0.46	0.42	0.29
COAL CREEK/ROCK CREEK								
0-CC	1	ND	ND	ND	ND	ND	ND	--
1-CC	12	0.49	6.00	0.66	0.76	1.07	1.25	1.51
A-CC **[W]**	12	1.85	16.50	5.28	7.25	9.25	7.93	4.30
2-CC	11	0.56	6.30	1.92	3.90	5.25	3.55	2.00
3-CC	12	1.50	19.60	2.83	3.55	4.25	4.64	4.84
6-CC	12	1.80	9.70	2.60	3.60	4.15	3.95	2.19
C-CC **[W]**	12	18.40	32.70	22.05	25.55	29.95	25.88	4.66
7-CC	12	2.80	13.50	5.73	8.15	9.23	7.88	3.37
CC-Ken	12	3.97	10.93	6.54	8.80	9.47	7.88	2.55
4-RC	12	0.38	4.73	1.48	2.76	3.31	2.52	1.28
B-RC **[W]**	12	19.19	28.66	21.45	23.64	25.58	23.70	3.03
5-RCl	12	1.60	10.90	3.23	4.30	5.85	4.82	2.56
5-RCs	12	1.46	11.19	2.50	3.11	9.61	5.34	4.03
ST. VRAIN/LEFT HAND CREEK								
M8-SV	12	0.22	1.63	0.86	1.03	1.33	1.01	0.41
T11-LH	12	0.44	2.03	0.85	1.01	1.22	1.06	0.45
WWTP-LGMT **[W]**	12	12.65	20.30	14.00	15.95	17.06	15.90	2.38
M7-SV	12	0.50	6.26	2.39	5.01	5.83	4.06	2.21

Notes: Wastewater discharge sample locations are designated by [W]. T-EFF is the Longmont WWTP effluent channel combined with roadside ditch flow where it enters the St. Vrain. ND = non-detect.

Boulder Creek and South Boulder Creek

Boulder Creek monitoring data for nutrients included in this report extends from Canyon Road (BC-Can) to the USGS gauging station near the confluence with St. Vrain Creek (11-BC). This long stream reach includes Boulder's 75th Street WWTP discharge, Coal Creek flows (which are influenced by Louisville, Lafayette and Superior WWTP discharges), and Erie's North WWTP discharge shown as E-BC [W]. The first location on Boulder Creek below the confluence with Coal Creek is identified as BC-bCC. South Boulder Creek enters Boulder Creek above BC-61, but is shown at the downstream end of the graphs on the x-axis.

Key findings related to nutrients for Boulder Creek and South Boulder Creek include:

- As would be expected, nutrient concentrations for South Boulder Creek are very low and would attain the new total phosphorus standard (0.11 mg/L) adopted for this segment, the nitrate standard, and the potential future total nitrogen standard ("interim value").

- Upstream of Boulder's 75th Street WWTP, Boulder Creek also has low nutrient concentrations and would be expected to attain existing and potential future nutrient standards for total phosphorus and total nitrogen.

- Downstream of Boulder's 75th Street WWTP, a significant increase in total phosphorus is present (Figure 18) that would exceed interim values for total phosphorus. From BC-aDC to the confluence with the St. Vrain Creek, median total phosphorus concentrations remain elevated above the interim phosphorus value. Erie's WWTP discharge is comparable to the interim value for total phosphorus and an instream response from Erie's discharge is not apparent, based on review of Figure 18.

- Downstream of Boulder's 75th Street WWTP, a significant increase in total nitrogen and nitrate are present as shown on Figure 19a-b that would exceed interim values for total nitrogen, but attain the existing water supply standard for nitrate of 10 mg/L. Erie's WWTP discharge does not appear to significantly influence the instream total nitrogen and nitrate concentrations. Note that Erie's WWTP permitted discharge volume (1.5 million gallons per day [MGD]) is much smaller than Boulder's permitted capacity (25 MGD).

- Chronic and acute ammonia standards were calculated to assess attainment of ammonia standards based on calculations incorporating pH and temperature. All locations attained chronic and acute standards; however, an instream response to a decrease in the nitrification process at the Boulder WWTP is apparent for the April 12 sampling event. This malfunction did not cause a permit violation or exceedance of acute permit limits or stream standards; however, the locations below the WWTP discharge exceeded the chronic stream standard on that specific sampling date.

Figure 18. 2016 Boulder Creek and South Boulder Creek Total Phosphorus

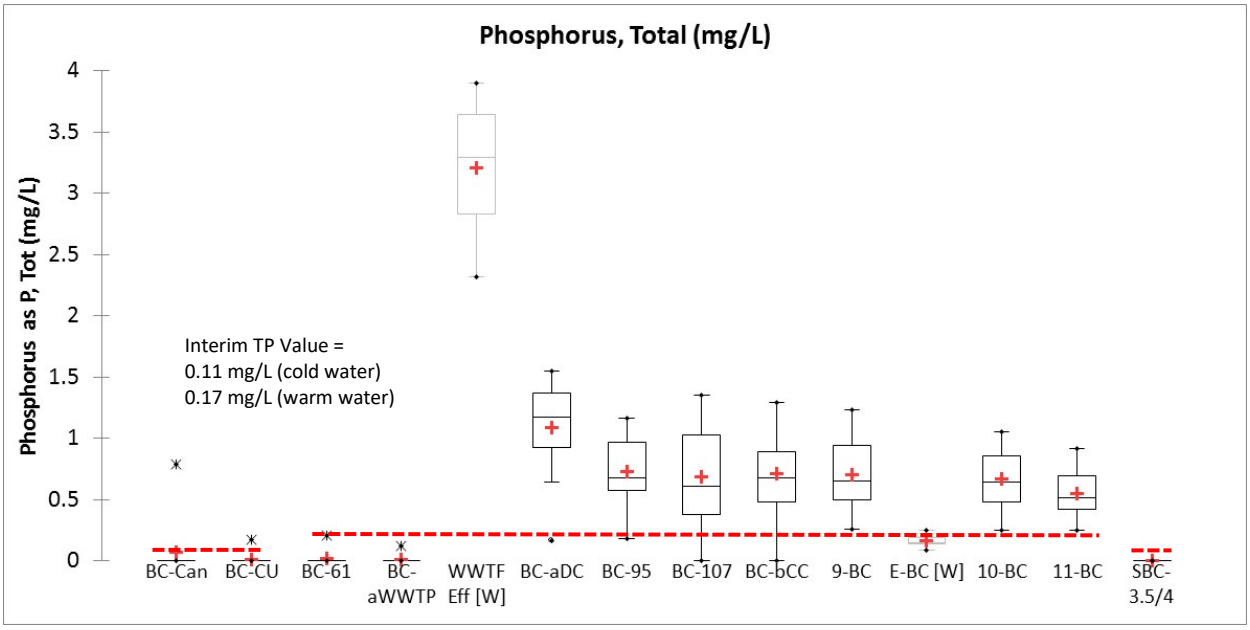
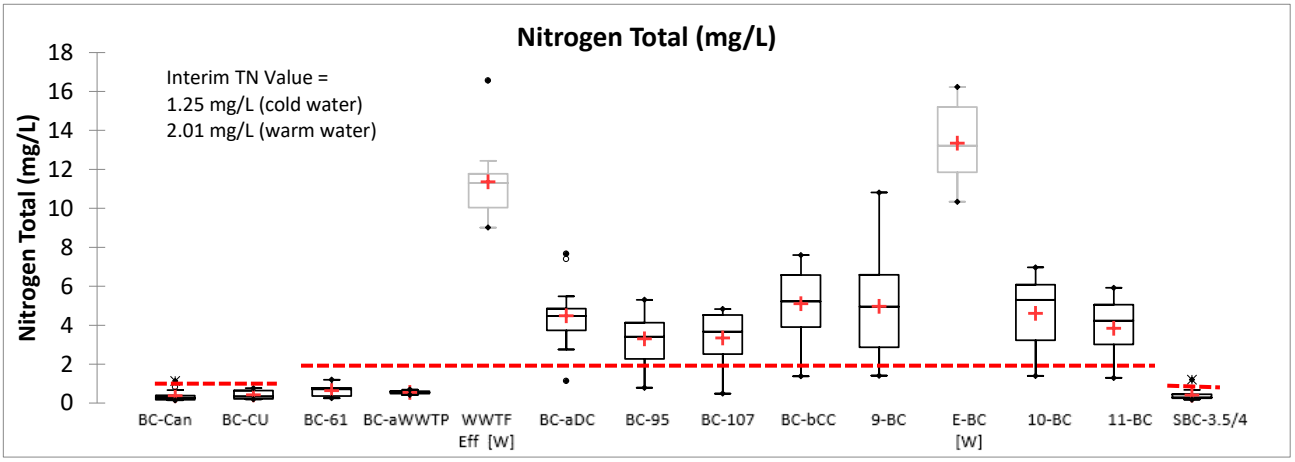
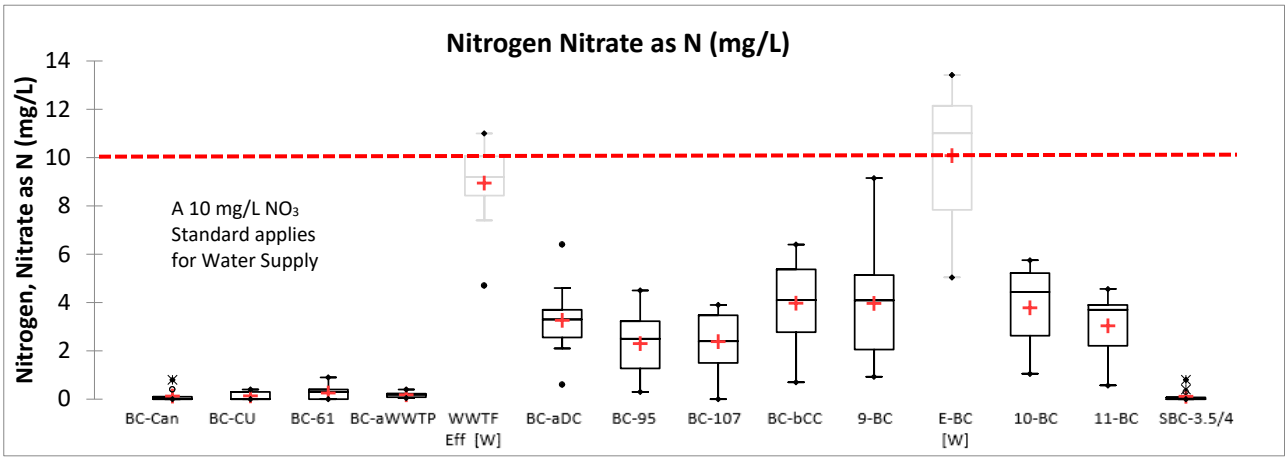
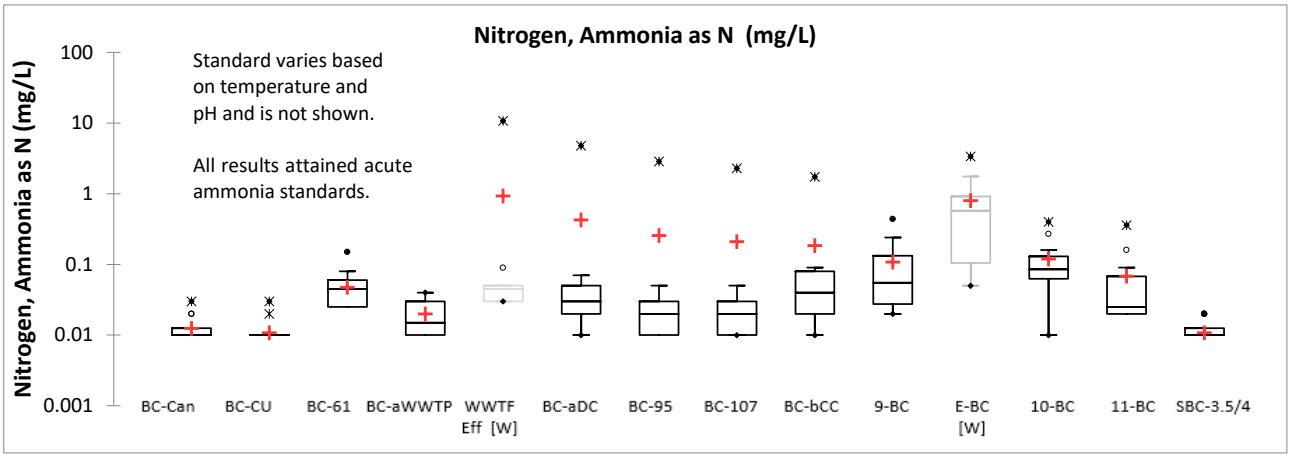


Figure 19 a-c. 2016 Boulder Creek and South Boulder Creek Nitrogen







Coal Creek and Rock Creek

Nutrient data are available for both Coal Creek and Rock Creek at various monitoring locations. Louisville (A-CC), Superior (B-RC), and Lafayette (C-CC) also provided WWTP effluent sample results for nutrients which are shown in light grey on Figure 20 and Figure 21a-c. Key findings related to nutrients for Rock Creek and Coal Creek include:

- As would be expected, instream concentrations of total phosphorus, total nitrogen, and nitrate increase below each WWTP discharge.

- A total phosphorus standard of 0.17 mg/L now applies to Rock Creek above the WWTP discharge and on Coal Creek above Highway 36. Phosphorus standards do not yet apply downstream of WWTP discharges, but data indicate that the stream would not meet the interim phosphorus value at any instream monitoring location below dischargers. Additionally, Rock Creek at 4-RC does not meet the total phosphorus standard above the WWTP discharge.

- As was the case for total phosphorus, an instream response to WWTP discharges is evident for total nitrogen and nitrate. The only locations on Coal Creek and Rock Creek that would be expected to attain a potential future total nitrogen standard of 2.01 mg/L is upstream of the Louisville discharge at 0-CC and 1-CC. It is also noteworthy that 4-RC, upstream of the Superior WWTP discharge, does not meet the interim value of 2.01 mg/L for total nitrogen. Annual median total nitrogen at 4-RC for 2014 through 2016 ranged from 2.30 to 2.76 mg/L.

- Chronic and acute ammonia standards were calculated to assess attainment of ammonia standards based on calculations incorporating pH and temperature. All locations attained chronic and acute standards. Table 10 and Figure 21c generally indicate ammonia concentrations are somewhat higher below the WWTP discharges.

Figure 20. 2016 Coal Creek and Rock Creek Total Phosphorus

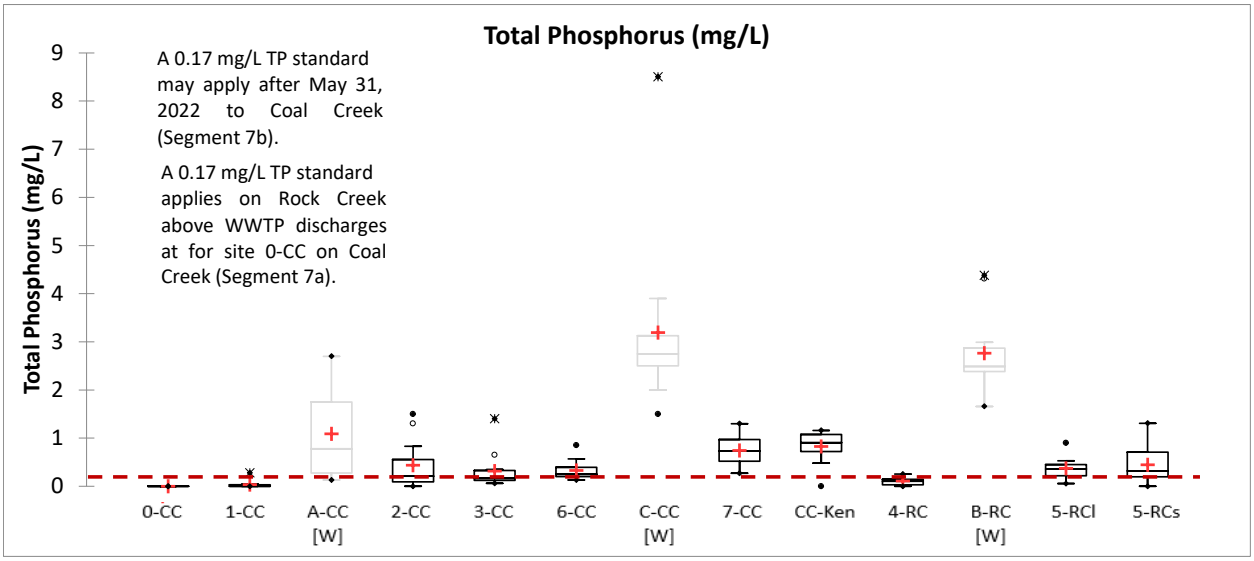
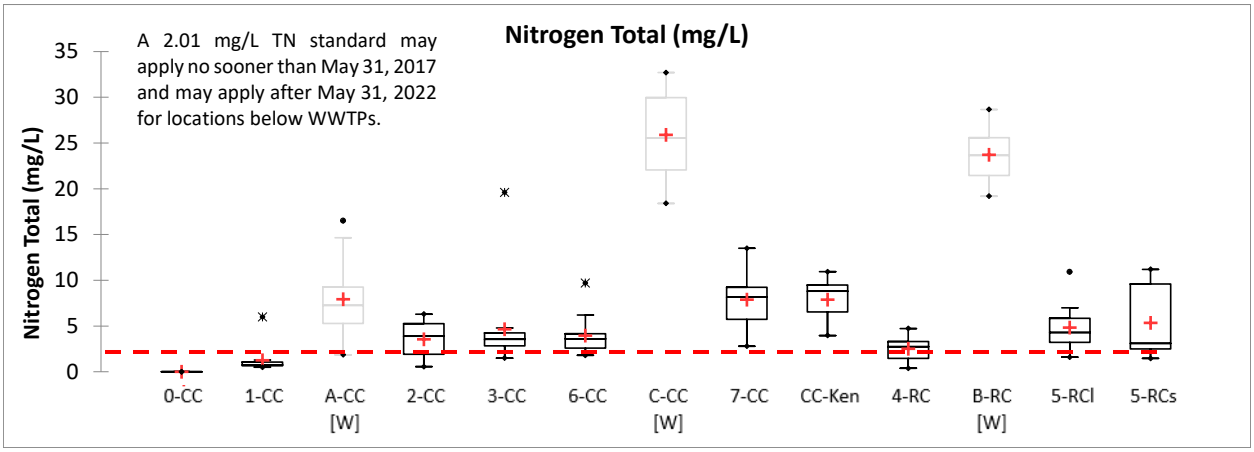
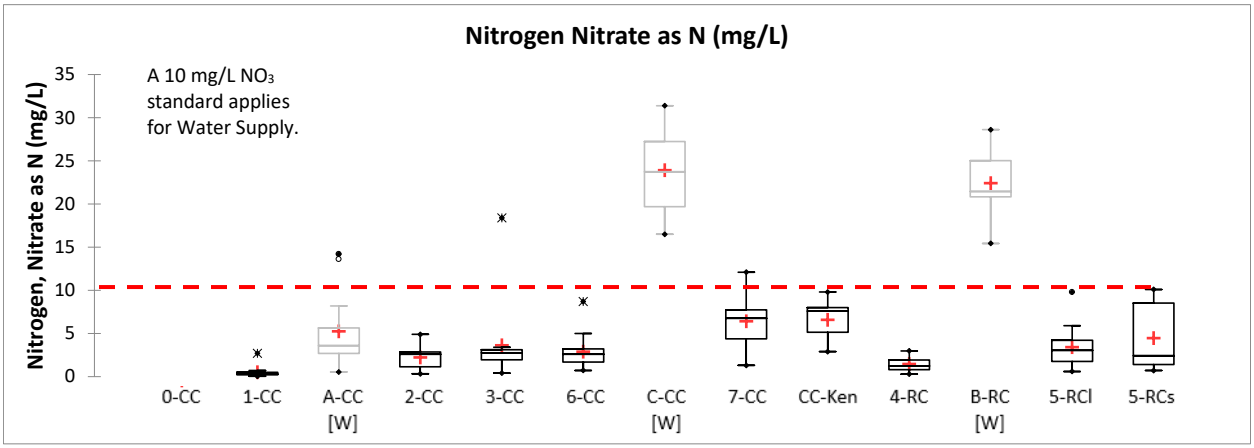
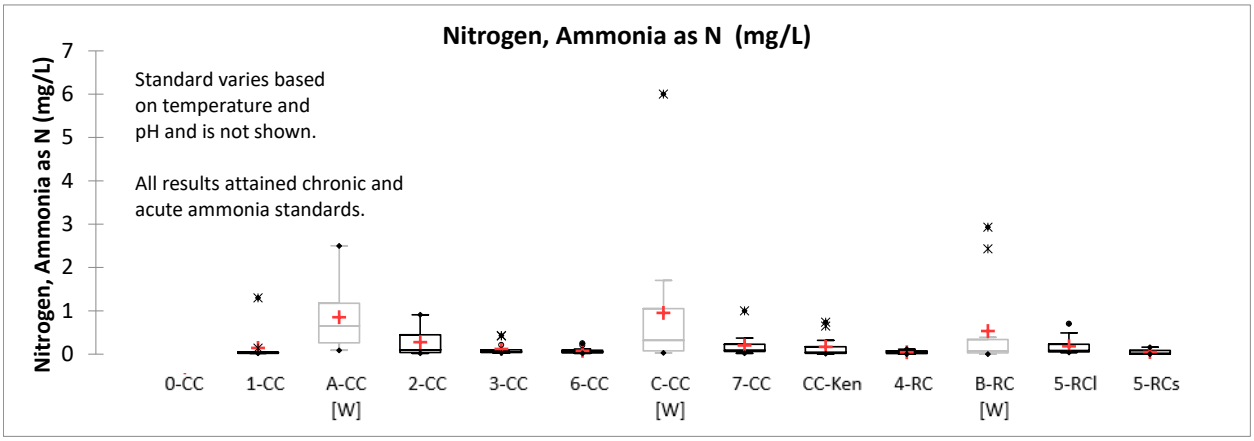


Figure 21 a-c. 2016 Coal Creek and Rock Creek Nitrogen





Note: For B-RC and 5-RCs, NO3/NO2 are shown because NO3 not reported.



St. Vrain Creek and Left Hand Creek

St. Vrain Creek and Left Hand Creek monitoring data for nutrients extend from the western boundary of Longmont's urbanized area to the confluence with Boulder Creek. Data are also provided for Left Hand Creek near the Hover Gage (LH-95) and its confluence with St. Vrain Creek (T11-LH) and for Longmont's WWTP discharge to St. Vrain Creek comingled with roadside ditch water (T-EFF) and the Longmont discharge (WWTP-LGMT). Key findings related to nutrients for St. Vrain Creek and the portion of Left Hand Creek near the confluence include:

- Upstream of Longmont's WWTP, St. Vrain Creek has low nutrient concentrations and would be expected to attain existing and future proposed standards for total phosphorus, total nitrogen and nitrate. In general, nutrient concentrations for Left Hand Creek are relatively comparable to nutrient concentrations in St. Vrain Creek above the WWTP discharge and would also meet nutrient standards.

- Downstream of Longmont's WWTP, a significant increase in total phosphorus is present as shown on Figure 22 that would exceed interim warm water values for total phosphorus of 0.17 mg/L. Similarly, a significant increase in total nitrogen and nitrate is present as shown downstream of Longmont's WWTP on Figure 23 a-c that would exceed the interim warm water value for total nitrogen (2.01 mg/L), but would attain the existing agricultural use standard for nitrate of 100 mg/L.

- Chronic and acute ammonia standards were calculated to assess attainment of ammonia standards based on calculations incorporating pH and temperature. All locations attained chronic and acute standards. Table 10 and Figure 23c generally indicate that instream concentrations of ammonia at M8-SV (above the Longmont WWTP discharge and the confluence with Left Hand Creek) are similar to concentrations below the WWTP discharge at M7-SV and M6-SV.

Figure 22. 2016 St. Vrain Creek and Left Hand Creek Total Phosphorus

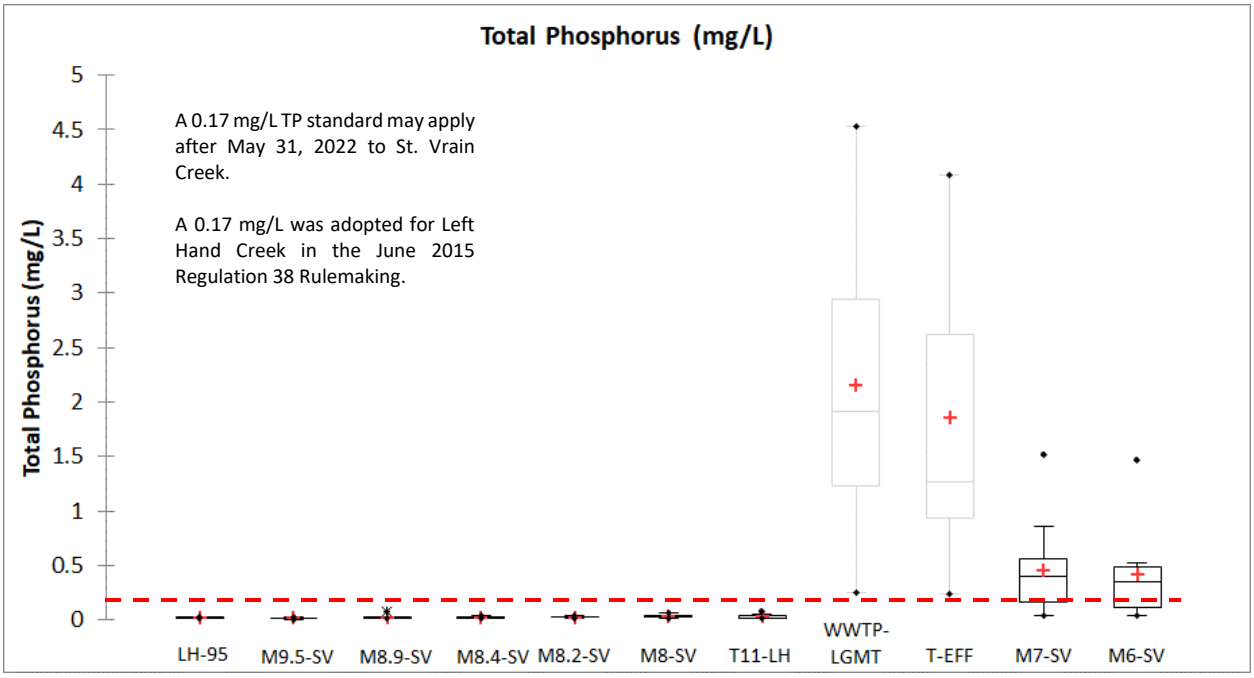
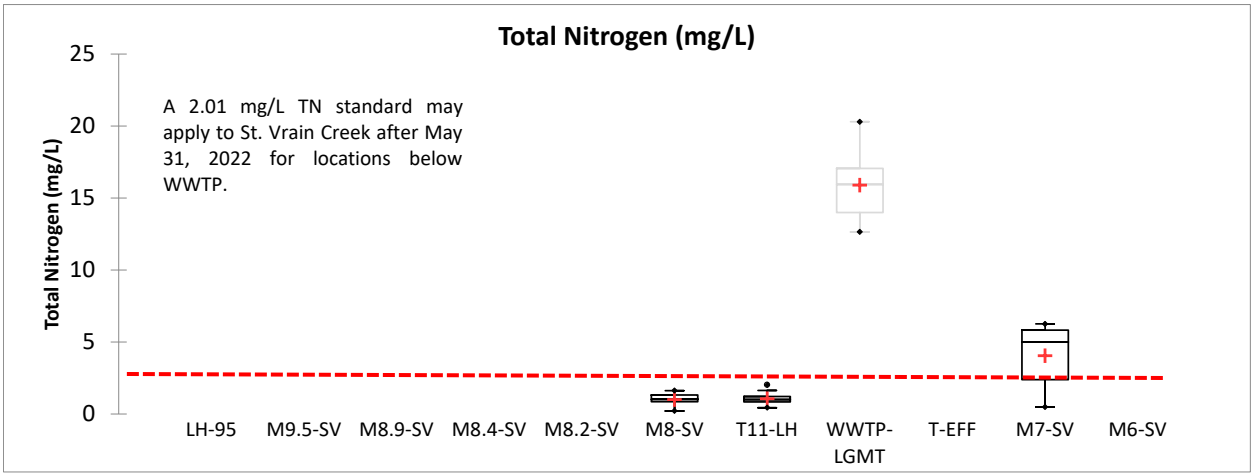
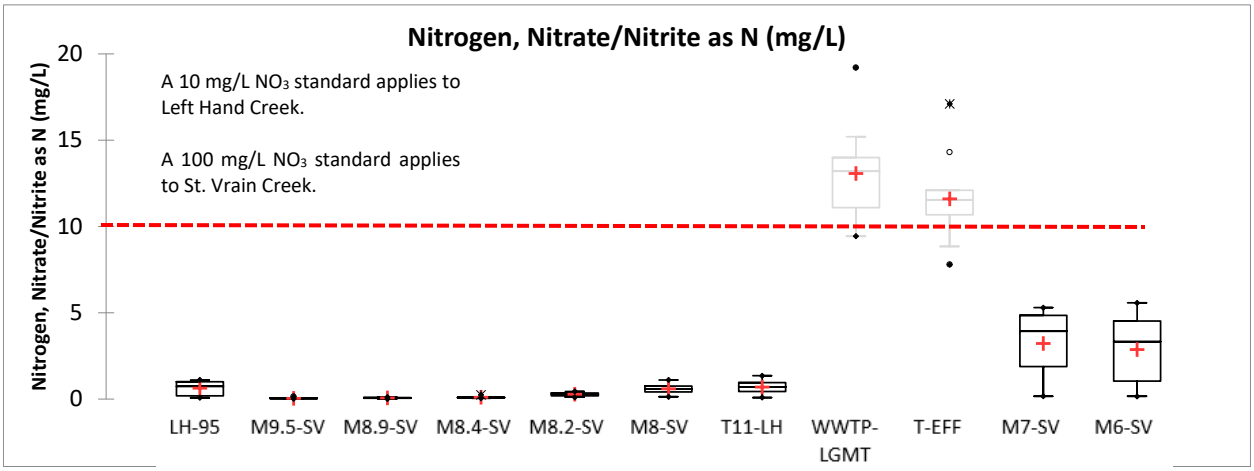
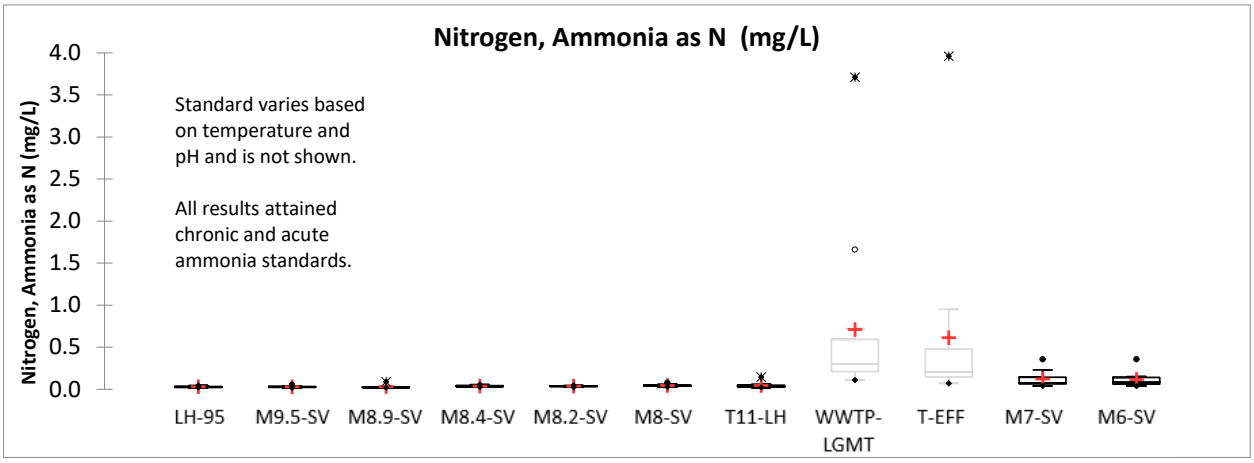


Figure 23 a-c. 2016 St. Vrain Creek and Left Hand Creek Nitrogen







FINDINGS FOR *E. COLI* BY BASIN

Portions of many urban streams in Colorado exceed primary contact recreational water quality criteria for *E. coli* during various times of the year, particularly during warm summer and fall months. Most modern WWTPs provide effective disinfection through ultraviolet (UV) disinfection or chlorination, so treated municipal effluent is not typically the cause of exceedances in urban areas (although leaking sanitary infrastructure may be a contributor in some areas).

Attainment of *E. coli* standards is sensitive to assessment methodology because of the highly variable nature of *E. coli*, which can span an order of magnitude or more between adjacent locations on the same sampling date, as well as between closely spaced sampling dates at the same location. For this reason, it is important to understand the current assessment procedure applied by the Division (Division 2017) in assessing recreational use attainment (see call-out box on p. 21).

Consistent with other voluntary instream monitoring programs along the Front Range, each municipality's *E. coli* data set typically includes one sample per month, which does not result in a sample size of five or more samples per 61-day rolling evaluation period. Because of the sample size limitations in the annual data set, two broad analysis subgroupings have been used for purposes of the analysis in this report. These groupings are identified as recreation season (May-October) and non-recreation season (November-April). Evaluation of a longer term data set is needed to draw statistically significant conclusions. This seasonal analysis approach is less stringent than the 61-day rolling assessment procedure used for standards assessment, so the findings in this section should not be interpreted as a regulatory evaluation.

The monthly sample collection frequency in 2016 would not result in movement of a stream segment onto or off of the 303(d) impaired waters list, but could result in addition of segments to the monitoring and evaluation list. A special *E. coli* study conducted by Lafayette on Coal Creek and Rock Creek in 2016, however, is conducted at an increased sample collection frequency, which can be used for standards assessment purposes related to impairment designations. Results from this special study are discussed further below. These findings confirm impairment of Rock Creek for *E. coli*.

Appendix I provides a fact sheet on *E. coli* conditions in the overall watershed and steps that citizens and local governments can take to help reduce *E. coli* loading to streams.

Boulder Creek and South Boulder Creek

An *E. coli* Total Maximum Daily Load (TMDL) was completed in 2011 for the portion of Boulder Creek Segment 2b from 13th Street to the confluence with South Boulder Creek, focusing on urban sources typically associated with the storm sewer system (Tetra Tech 2011a). (Note: this reach of stream includes monitoring location BC-CU.) Continued instream monitoring of *E. coli* is important to assess progress towards TMDL goals and to assess the effectiveness of measures identified in the TMDL Implementation Plan (Tetra Tech 2011b). Although the TMDL focuses on a portion of Segment 2b, other portions of the stream are also affected by elevated *E. coli* concentrations. Segments 9 and 10 of Boulder Creek are now listed on the 2016 303(d) List as impaired for *E. coli*. The impairment for Segment 9 is limited to July through October.

Table 11 provides seasonal geometric mean *E. coli* concentrations according to non-recreational (N-Rec, November-April) and recreational (Rec, May-October) seasons. Figure 24 and Figure 25 provide upstream to downstream *E. coli* plots according to non-recreational and recreational seasons during 2016.

During 2016, the recreation season geometric mean concentrations exceeded 126/100 mL at BC-CU, BC-bCC, 9-BC and 11-BC. BC-Can was the only instream site that did not exceed stream standards for any samples during 2016, and it is located upstream of the TMDL on Boulder Creek. *E. coli* concentrations in the Boulder WWTF and the Erie WWTF discharges are consistently well below stream standards.

One interesting observation is that South Boulder Creek had several elevated *E. coli* concentrations during the winter months, as was also the case during 2015. Results included an excceedance of the upper quantitation limit of 2,420 MPN/100 mL in March. It may be worthwhile to further characterize the cause of these exceedances to determine whether they are associated with grazing, wildlife or other sources.

Table 11. 2016 Boulder Creek and South Boulder Creek Seasonal *E. coli* Data

Station	Season	Nbr.	Geometric mean	Minimum	Maximum
BC-Can	N-Rec	6	6	1	22
BC-Can	Rec	6	26	19	41
BC-CU	N-Rec	6	110	36	1300
BC-CU	Rec	6	241	64	1300
BC-61	N-Rec	6	32	4	140
BC-61	Rec	6	41	15	210
BC-aWWTP	N-Rec	6	17	1	84
BC-aWWTP	Rec	6	38	7	461
WWTF Eff	N-Rec	6	11	4	18
WWTF Eff	Rec	6	14	5	38
BC-aDC	N-Rec	6	40	10	108
BC-aDC	Rec	6	119	68	308
BC-107	N-Rec	6	22	3	107
BC-107	Rec	6	83	43	548
BC-bCC	N-Rec	6	45	11	435
BC-bCC	Rec	6	138	47	435
9-BC	N-Rec	6	86	26	178
9-BC	Rec	6	169	46	980
E-BC [W]	N-Rec	6	2	1	3
E-BC [W]	Rec	6	1	1	1
10-BC	N-Rec	6	49	26	118
10-BC	Rec	6	107	63	727
11-BC	N-Rec	6	47	17	130
11-BC	Rec	6	176	64	613
SBC-3.5/4	Rec	6	43	23	108
SBC-3.5/4	N-Rec	6	89	7	2420

Notes: N-Rec = November to April; Rec = May to October. Assessment intervals used by the Division for regulatory purposes are 61-day rolling geometric means, not seasonal geometric means.

Figure 24. 2016 Boulder Creek and South Boulder Creek Non-Recreation Season *E. coli*

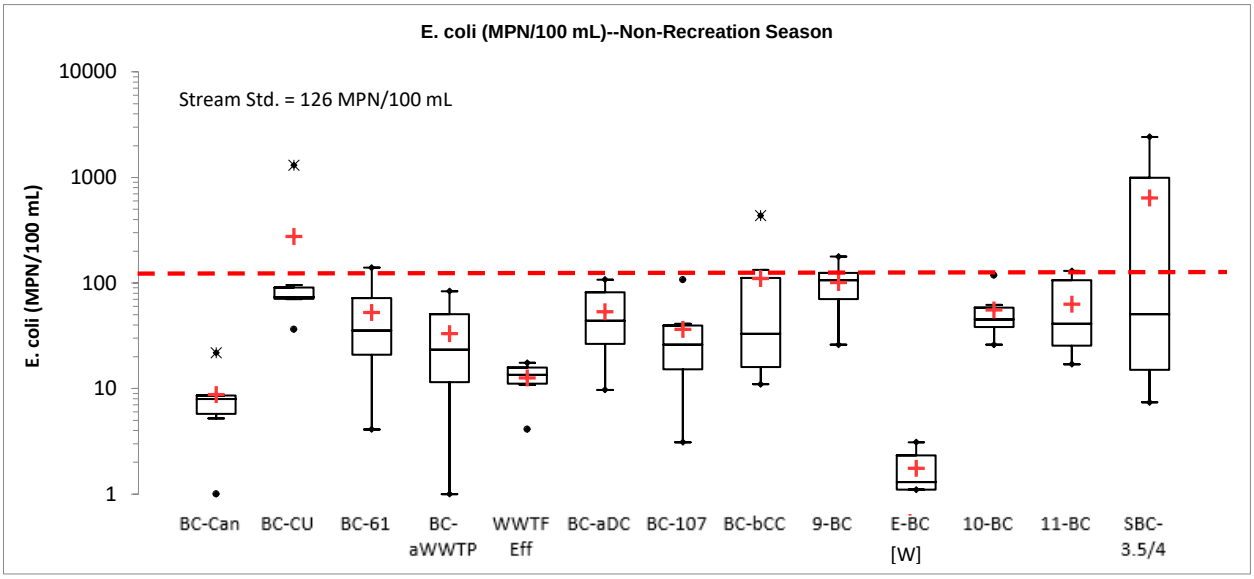
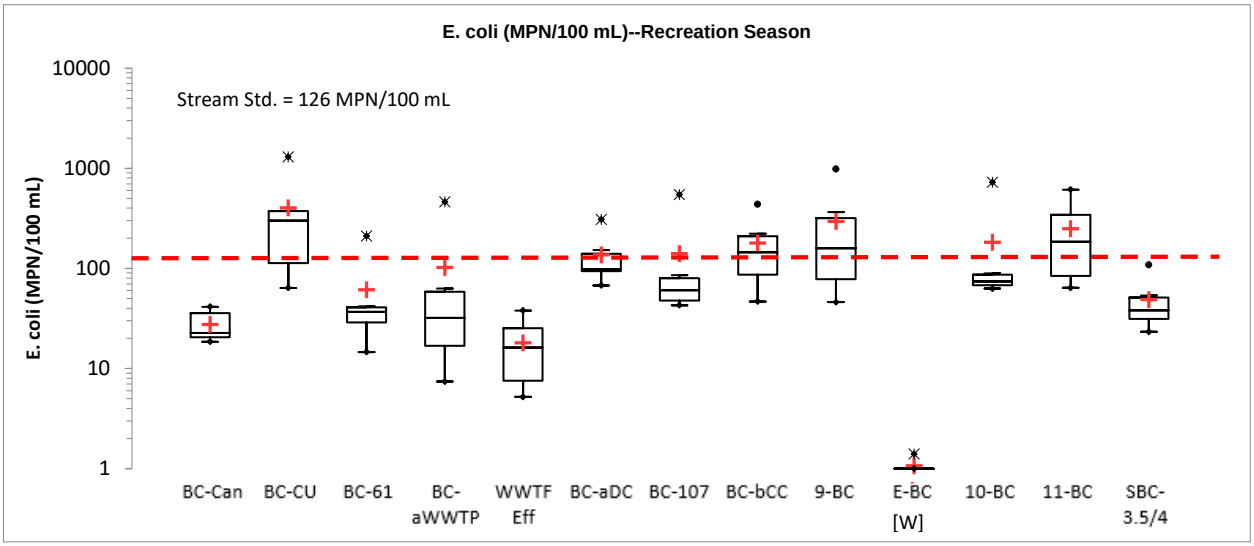


Figure 25. 2016 Boulder Creek and South Boulder Creek Recreation Season *E. coli*



Coal Creek and Rock Creek

Coal Creek is listed as impaired on the 2016 303(d) list and Rock Creek is identified in need of additional monitoring and evaluation to determine impairment for *E. coli*. Table 12 summarizes *E. coli* data available for Rock Creek and Coal Creek during 2016 and shows that most locations within Coal Creek exceeded water quality standards during the recreation season. Rock Creek also exceeded *E. coli* standards during the recreation season at 5-RC. Both streams included *E. coli* results exceeding the upper quantitation limit of 2,420 MPN/100 mL at various locations. E. coli results provided for the Louisville WWTP (A-CC) showed very low *E. coli*. Figure 26 and Figure 27 provide upstream to downstream *E. coli* plots according to non-recreational and recreational seasons during 2016.

Table 12. 2016 Coal Creek and Rock Creek Seasonal *E. coli* Data

Station	Season	Nbr.	Geometric Mean	Minimum	Maximum
0-CC	Rec	3	259	99	437
1-CC	N-Rec	6	42	6	115
1-CC	Rec	6	300	50	816
A-CC [W]	N-Rec	6	25	6	135
A-CC [W]	Rec	6	24	10	61
2-CC	N-Rec	4	45	14	152
2-CC	Rec	6	196	61	649
3-CC	N-Rec	6	98	26	411
3-CC	Rec	6	196	75	2420
6-CC	N-Rec	6	75	49	131
6-CC	Rec	12	348	102	2420
7-CC	N-Rec	6	68	23	107
7-CC	Rec	12	365	80	2420
CC-Ken	N-Rec	6	60	11	157
CC-Ken	Rec	6	233	101	1046
4-RC	N-Rec	6	45	1	582
4-RC	Rec	6	95	6	977
5-RCl	N-Rec	6	52	15	228
5-RCs	N-Rec	6	74	13	214
5-RCl	Rec	12	369	63	2420
5-RCs	Rec	6	265	56	1633

Figure 26. 2016 Coal Creek and Rock Creek Non-Recreation Season *E. coli*

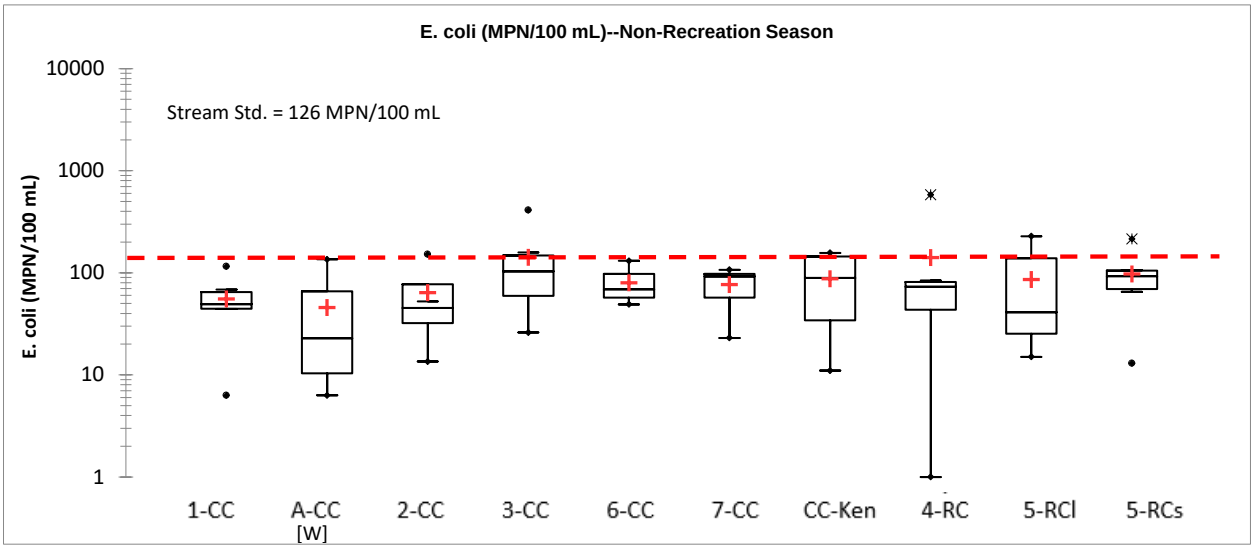
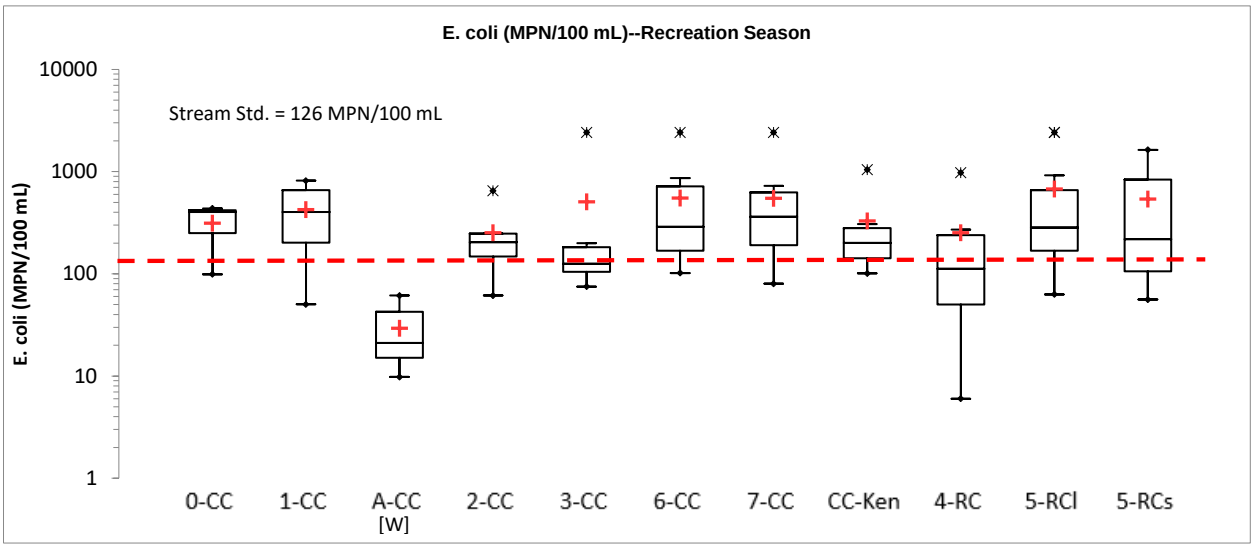


Figure 27. 2016 Coal Creek and Rock Creek Recreation Season *E. coli*



During 2016, Lafayette conducted a special *E. coli* study described in C*oal Creek and Rock Creek: 2016 Stream Monitoring, City of Lafayette Interim Report* (Lewand 2016). Samples were collected at the locations shown in Figure 28. The sample frequency was sufficient at most locations to conduct 61-day rolling geometric means, consistent with the Division's new assessment procedure for *E. coli*. These 61-day rolling geometric mean results for Rock Creek and Coal Creek are shown in Figure 29 and Figure 30, respectively. Table 13 shows that most locations on both streams exceed the primary contact recreation standard of 126 MPN/100 mL. As shown in the figures, the rolling geometric mean concentrations are highest in the summer months.

Figure 28. Lafayette *E. coli* Special Study Monitoring Locations

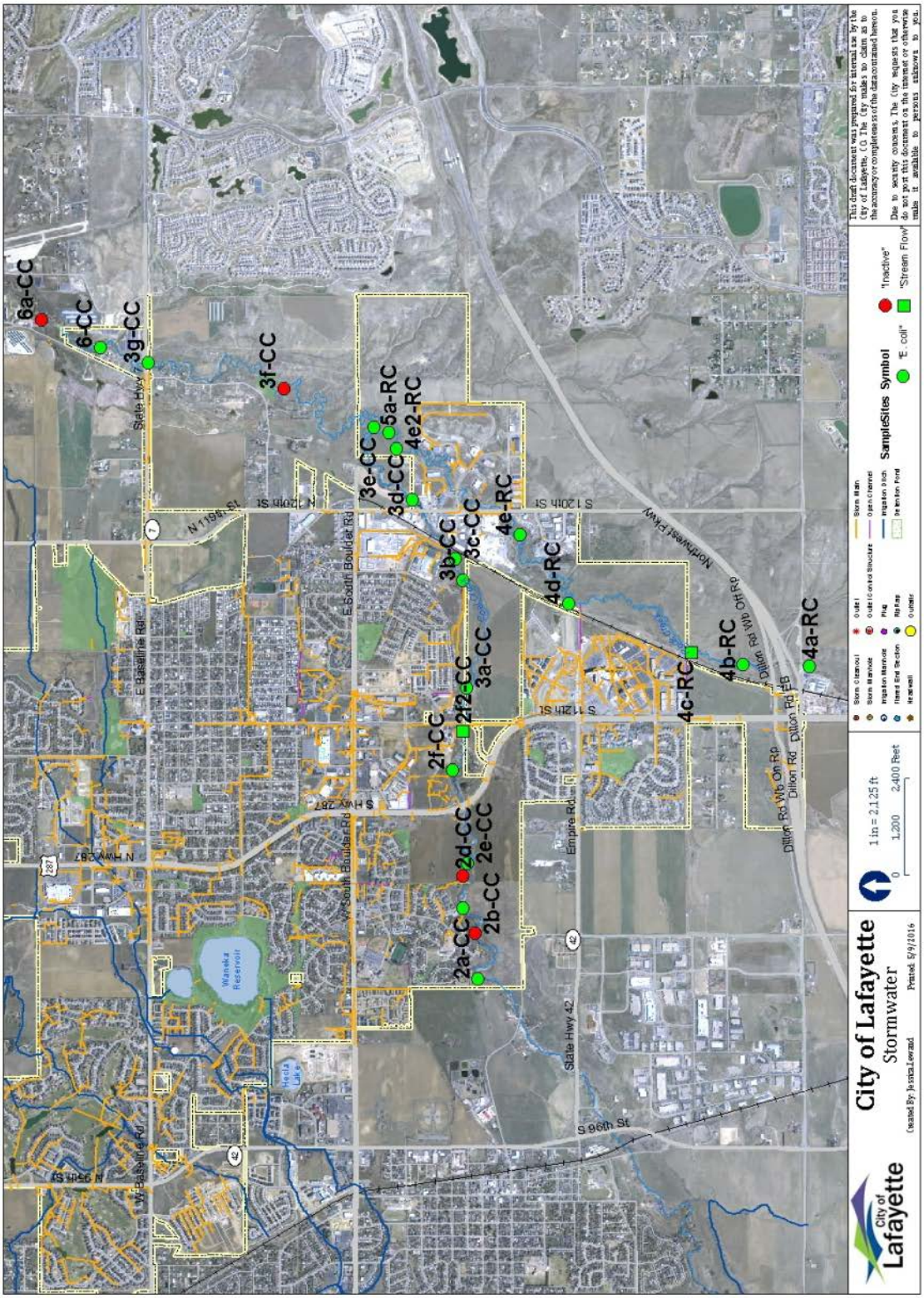


Figure 29. Lafayette *E. coli* Special Study Results for Rock Creek

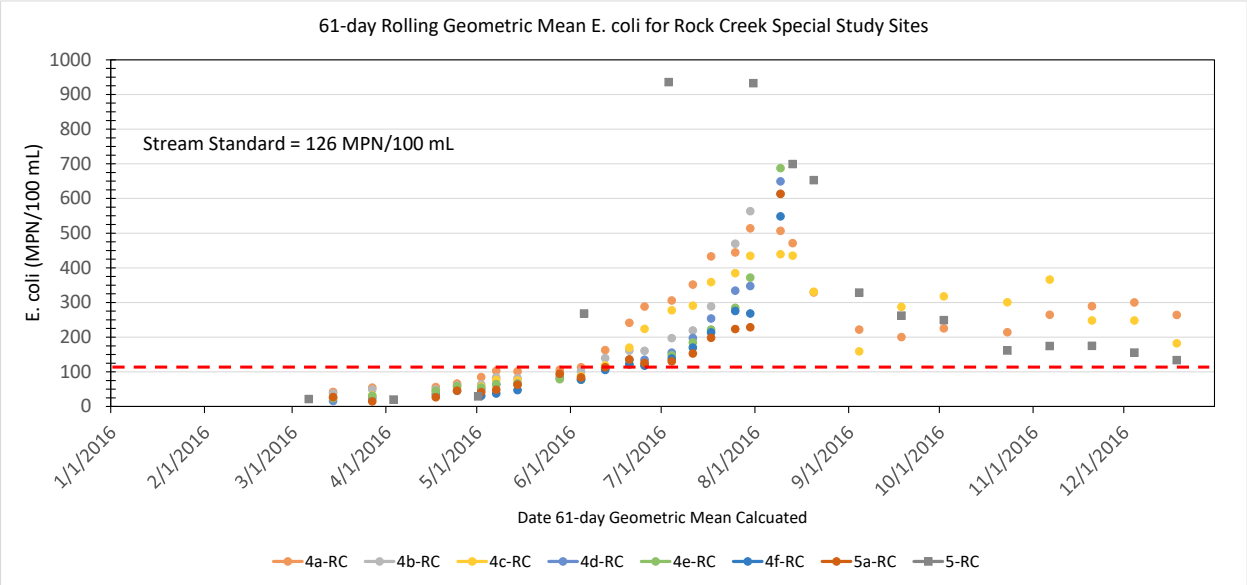


Figure 30. Lafayette *E. coli* Special Study Results for Coal Creek

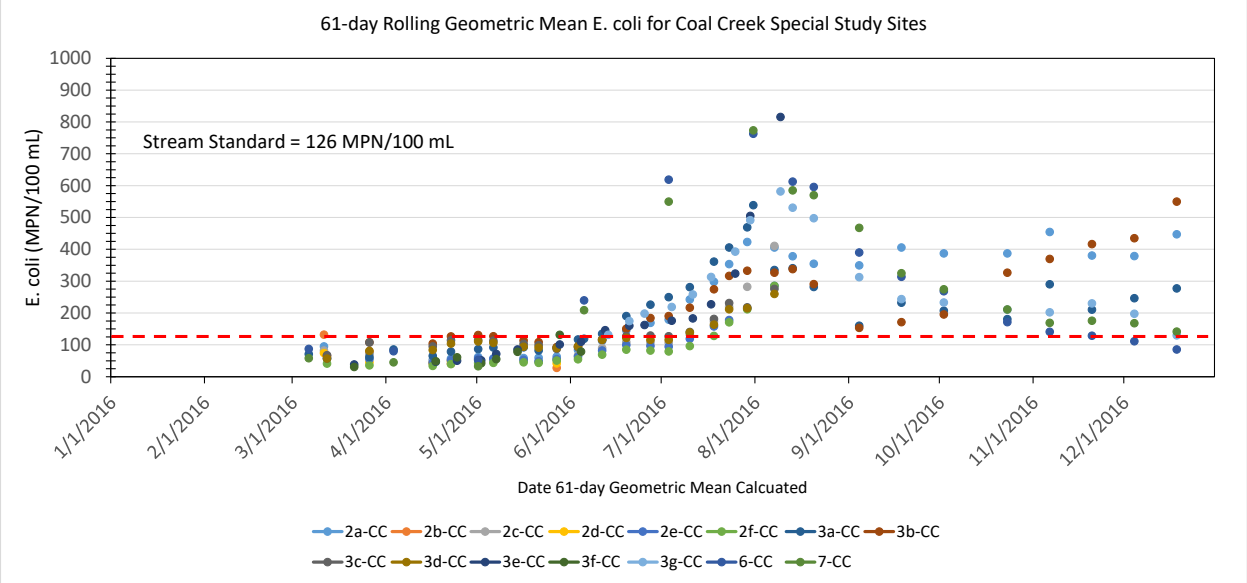


Table 13. Lafayette *E. coli* Special Study 61-day Rolling Geometric Means for Rock Creek and Coal Creek

Sample Location	E. coli Results (MPN/100 mL)			Number of 61-day Geometric Means			Impairment Characterization	
	Count	Min	Max	# of 61-day Rolling Geomeans >126/100 mL	# of 61-day Rolling Geomeans >4 Samples	# of 61-day Rolling Geomeans >126/100 mL AND >4 Samples	% 61-day Geometric Means with >4 Samples Exceeding Standard	Impaired?
2a-CC	29	53	454	18	22	11	50%	Yes
2b-CC	5	28	132	1	0	0	NA	NA
2c-CC	19	47	411	5	15	1	7%	Yes
2d-CC	5	42	74	0	0	0	NA	NA
2e-CC	19	44	285	4	15	0	0%	No
2f-CC	19	34	285	4	15	0	0%	No
3a-CC	33	57	539	20	26	13	50%	Yes
3b-CC	29	65	550	21	22	14	64%	Yes
3c-CC	19	67	276	8	15	4	27%	Yes
3d-CC	19	57	260	5	15	1	7%	Yes
3e-CC	17	38	816	9	13	5	38%	Yes
3f-CC	8	30	132	1	4	0	0%	No
3g-CC	19	130	582	19	12	12	100%	Yes
4a-RC	28	42	514	19	21	12	57%	Yes
4b-RC	18	37	613	9	14	5	36%	Yes
4c-RC	28	24	439	18	21	11	52%	Yes
4d-RC	18	16	649	8	14	4	29%	Yes
4e-RC	18	24	687	6	14	2	14%	Yes
4f-RC	13	31	548	6	9	2	22%	Yes
5a-RC	18	14	613	7	14	3	21%	Yes
5-RC	16	20	936	13	4	4	100%	Yes
6a-CC	6	14	21	0	2	0	0%	No
6-CC	16	52	763	11	4	4	100%	Yes
7-CC	16	33	774	13	4	4	100%	Yes

Lewand (2016) summarized the following findings from the special study:

- The most elevated *E. coli* was typically associated with large precipitation and runoff events.
- Summer concentrations are higher than winter concentrations.
- A potential "hot spot" for *E. coli* may be present in the reach between 3a-CC and 3d-CC surrounding the Warembourg Open Space when cattle are present. Conversely, when cattle are absent the results seem to follow the pattern of the surrounding sites.
- More data would be needed to determine if failing septic systems are impacting the stream below the confluence with Rock Creek.

Other special studies for *E. coli* were also completed in the 2007-2014 timeframe by the City of Louisville, as summarized in Appendix G of the *KICP Annual Water Quality Analysis for 2014* (WWE 2015).

St. Vrain Creek and Left Hand Creek

St. Vrain Creek is listed on the 2016 303(d) List as impaired for *E. coli*. Table 13 summarizes *E. coli* data available for St. Vrain Creek and Left Hand Creek, and Figure 31 and Figure 32 provide upstream to downstream *E. coli* plots according to non-recreational and recreational seasons during 2016. The table and figures show that seasonal geometric mean *E. coli* concentrations for Left Hand Creek were below the stream standard for both seasons. For St. Vrain Creek, all locations met the *E. coli* standard during the non-recreation season except M6-SV. Several locations on St. Vain Creek experienced some exceedances during the recreation season, including M8.9-SV, M8-SV, M7-SV and M6-SV. Discharges from the Longmont WWTP, as represented by location T-Eff, which contains combined roadside ditch drainage and WWTP effluent, are typically low and well below the stream standard.

The pattern of exceedances of the *E. coli* standard for St. Vrain Creek and Left Hand Creek do not indicate a specific hot spot or upstream to downstream trend; therefore, identification of the causes of elevated *E. coli* would require additional monitoring at a finer spatial resolution and for a longer period of record to draw conclusions or form and evaluate hypotheses about sources.

Table 14. 2016 Left Hand Creek and St. Vrain Creek Seasonal *E. coli* Data

Station	Season	Nbr.	Geometric Mean	Minimum	Maximum
LH-95	N-Rec	3	29	16	46
LH-95	Rec	6	66	4	517
M9.5-SV	N-Rec	3	14	1	59
M9.5-SV	Rec	6	68	29	167
M8.9-SV	N-Rec	3	40	3	178
M8.9-SV	Rec	6	441	110	1990
M8.4-SV	N-Rec	3	125	57	201
M8.4-SV	Rec	6	50	11	236
M8.2-SV	N-Rec	3	81	31	135
M8.2-SV	Rec	6	103	18	1300
M8-SV	N-Rec	6	88	7	548
M8-SV	Rec	6	177	70	579
T11-LH	N-Rec	6	16	3	76
T11-LH	Rec	6	93	37	260
T-EFF	N-Rec	6	36	20	178
T-EFF	Rec	6	40	20	61
M7-SV	N-Rec	6	88	17	249
M7-SV	Rec	6	155	68	313
M6-SV	N-Rec	3	177	133	248
M6-SV	Rec	6	128	58	231

Figure 31. 2016 Left Hand Creek and St. Vrain Creek Non-Recreation Season *E. coli*

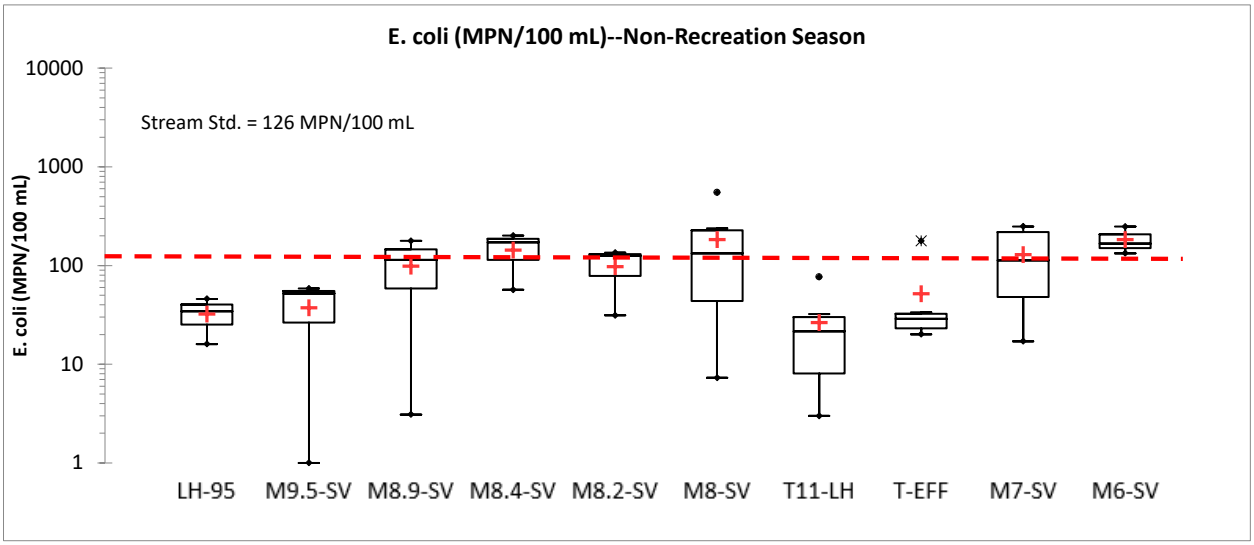
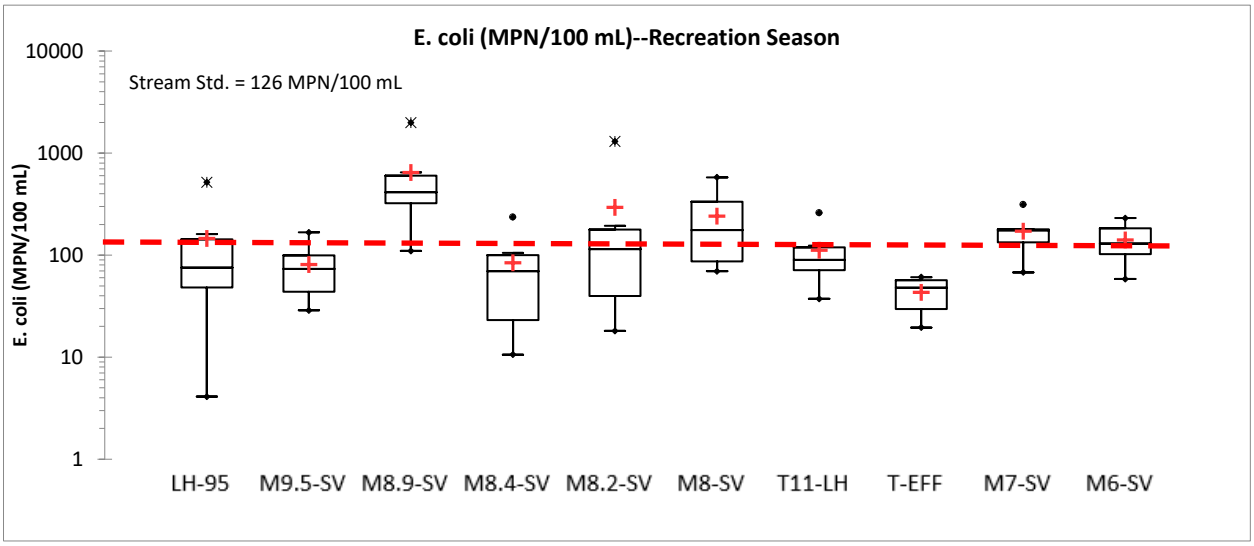


Figure 32. 2016 Left Hand Creek and St. Vrain Creek Recreation Season *E. coli*



Temporal Trends for *E. coli* 2014-2016

Three years of monitoring data for *E. coli* are now available as part of the KICP monitoring program, as summarized in Table 15 and Figure 33 through Figure 35 for the recreation season. No clear temporal trend over the three years is consistently identified.

Table 15. Geometric Mean Recreational Season *E. coli* Data (2014-2016)

Boulder Creek/S. Boulder Creek	2014	2015	2016
BC-Can	36	40	26
BC-CU	103	233	241
BC-61	145	79	41
BC-aWWTP	95	76	38
BC-aDC	135	166	119
BC-107	66	67	83
BC-bCC	206	131	138
9-BC		115	169
10-BC		111	107
11-BC		219	176
SBC-3.5/4	20	90	89
Coal Creek/Rock Creek	**2014**	**2015**	**2016**
1-CC		521	300
2-CC		273	196
3-CC	191	185	196
6-CC	371	618	348
7-CC	321	382	365
CC-Ken	289	258	233
4-RC		124	95
5-RC	276	411	317
St. Vrain/Left Hand Creek	**2014**	**2015**	**2016**
M9.5-SV	170	77	68
M8.9-SV	281	135	441
M8.4-SV	141	87	50
M8.2-SV	198	120	103
M8-SV	100	167	177
T11-LH	326	163	93
T-EFF	33	51	40
M7-SV	150	178	155
M6-SV	216	121	128

Note: locations without at least two years of data are not included in this table.

Figure 33. 2016 Boulder Creek and South Boulder Creek Recreation Season *E. coli* (2014-2016)

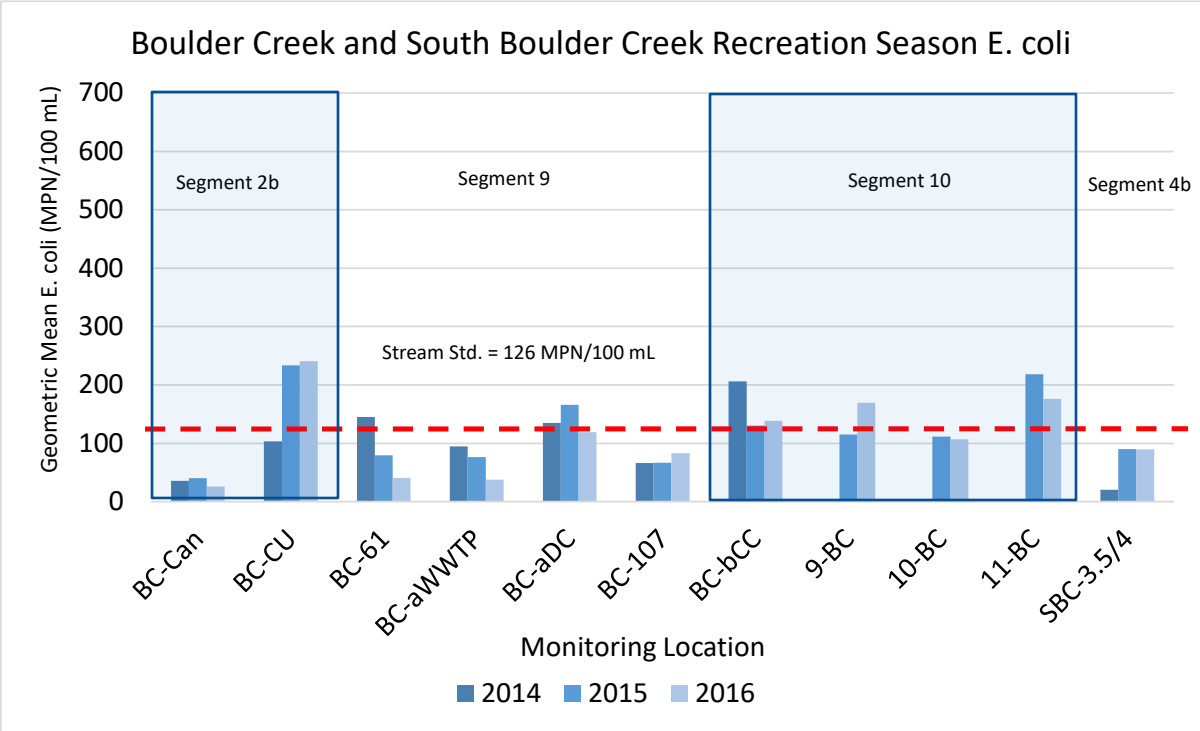


Figure 34. 2016 Coal Creek and Rock Creek Recreation Season *E. coli* (2014-2016)

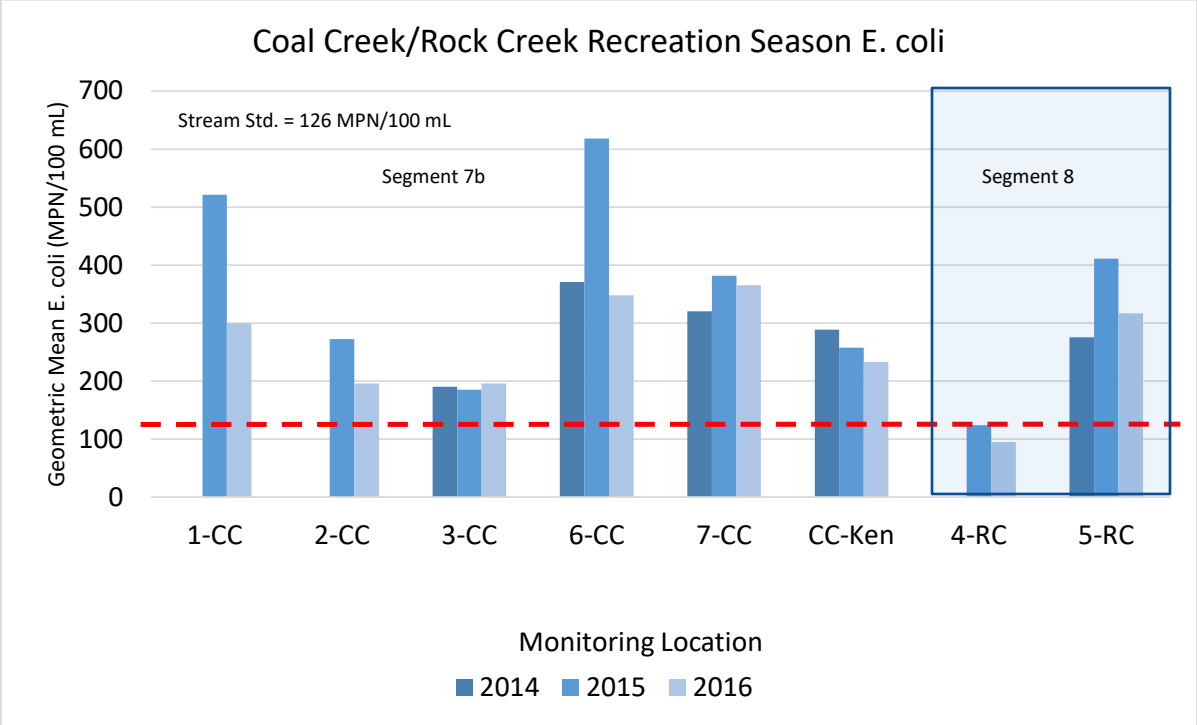
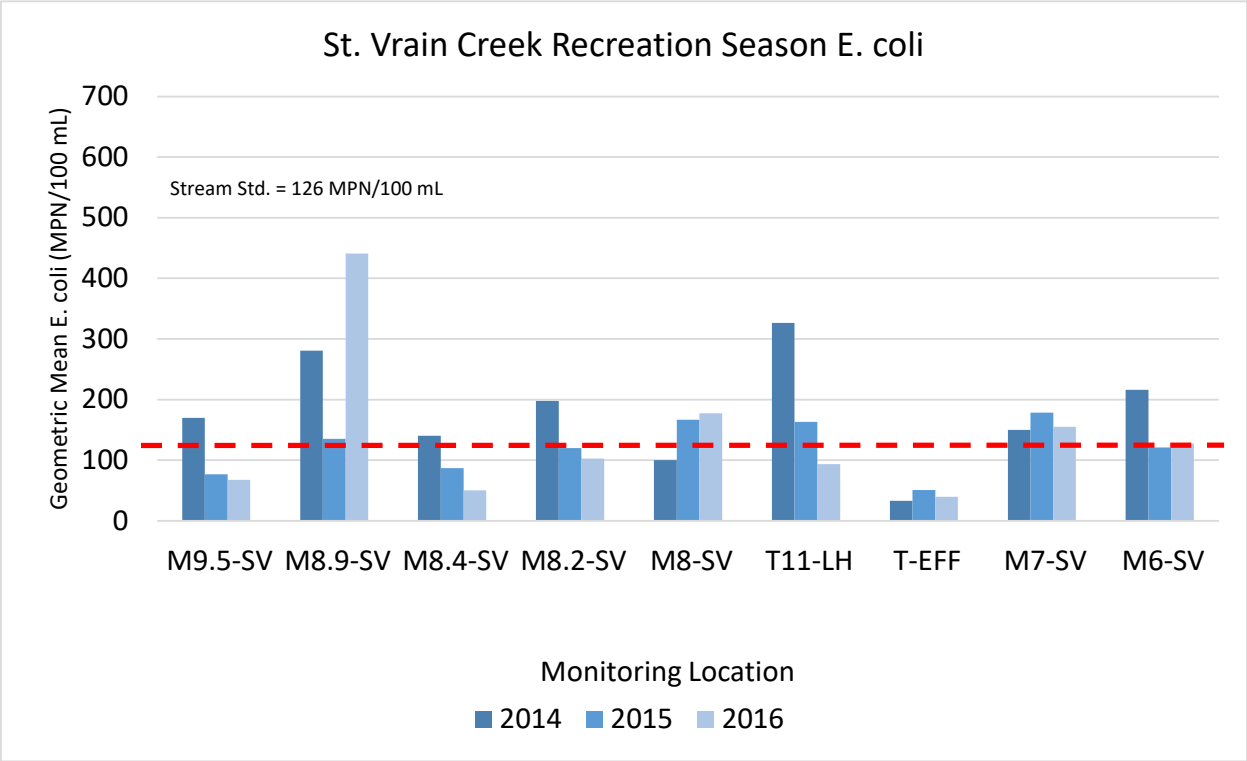


Figure 35. 2016 St. Vrain Creek and Left Hand Creek Recreation Season *E. coli* (2014-2016)



FINDINGS FOR SELECTED METALS

For the most part, metals are beyond the scope of the coordinated Monitoring Plan and this report; however, both the City of Boulder and City of Longmont monitor metals routinely so several metals of potential regulatory interest are discussed in this report for these data sets, including:

- Total recoverable arsenic for all stream segments with data.
- Dissolved selenium for Rock Creek and Coal Creek (based on River Watch data).
- Dissolved copper for South Boulder Creek and Left Hand Creek.

Arsenic

Figure 36 and Figure 37 provide results for total recoverable arsenic on Boulder Creek and St. Vrain Creek. Several different arsenic standards are in place in the basin, depending on the designated use of the stream. For example, the chronic total recoverable arsenic standards for each segment evaluated are:

- Boulder Creek and South Boulder Creek: 0.02 µg/L, with temporary modification at ambient condition through 12/31/2021.[6] This standard is based on "water + fish," where water supply and fish ingestion are designated uses.

- Coal Creek (Segment 7a, between Highway 36 and Highway 93): 0.02 µg/L, without a temporary modification. (For purposes of this report, only 0-CC is located in this segment and arsenic data are not collected at this location.)

- Coal Creek (Segment 7b): 0.02-10 µg/L, which is a hyphenated standard for water supply uses that allows permitted dischargers to meet a 10 µg/L limit and allows stream standard assessment against the 10 µg/L limit. This is a relatively new, more stringent standard for Coal Creek, as adopted by the Division in the June 2015 Regulation 38 rulemaking hearing.

- Rock Creek: 100 µg/L for protection of agricultural uses.

- St. Vrain Creek: 7.6 µg/L for fish ingestion.

- Left Hand Creek: 0.02-10 µg/L, which is a hyphenated standard for water supply uses that allows permitted dischargers to meet a 10 µg/L limit.

In the context of these stream standards, key findings regarding total recoverable arsenic concentrations in the basin include:

- Median arsenic concentrations at various monitoring locations on Boulder Creek ranged from 0.31 to 1.25 µg/L (Figure 36). The median South Boulder Creek concentration was 0.25 µg/L. Because of the temporary modification to the 0.02 µg/L standard, the stream is identified as a low priority for TMDL development. However, these results reiterate the importance of actively participating in the Regulation 31 Basic Standards work group process where this standard is being reevaluated.

- No results were provided for Coal Creek or Rock Creek.

- Arsenic concentrations on St. Vrain Creek generally increase in an upstream to downstream direction (Figure 37), and Left Hand Creek has higher total arsenic than St. Vrain Creek. Median arsenic concentrations at all locations are well below 7.6 µg/L on St. Vrain Creek.

[6] In Colorado, stream segments designated for water supply or "water + fish" have extremely low total arsenic standards of 0.02 µg/L. Because these standards are so low that they are not attainable in many parts of Colorado, the Commission has adopted temporary modifications to instream arsenic standards where "water + fish" criteria apply and when there is a discharge to the stream segment that cannot comply with corresponding effluent limits.

- Left Hand Creek arsenic concentrations range from 0.6 to 1.4 µg/L, with a median concentration of 0.8 µg/L, which exceeds the assigned standard of 0.02 µg/L, but is below the 10 µg/L threshold for designation as impaired.

Figure 36. 2016 Total Recoverable Arsenic for Boulder Creek and South Boulder Creek

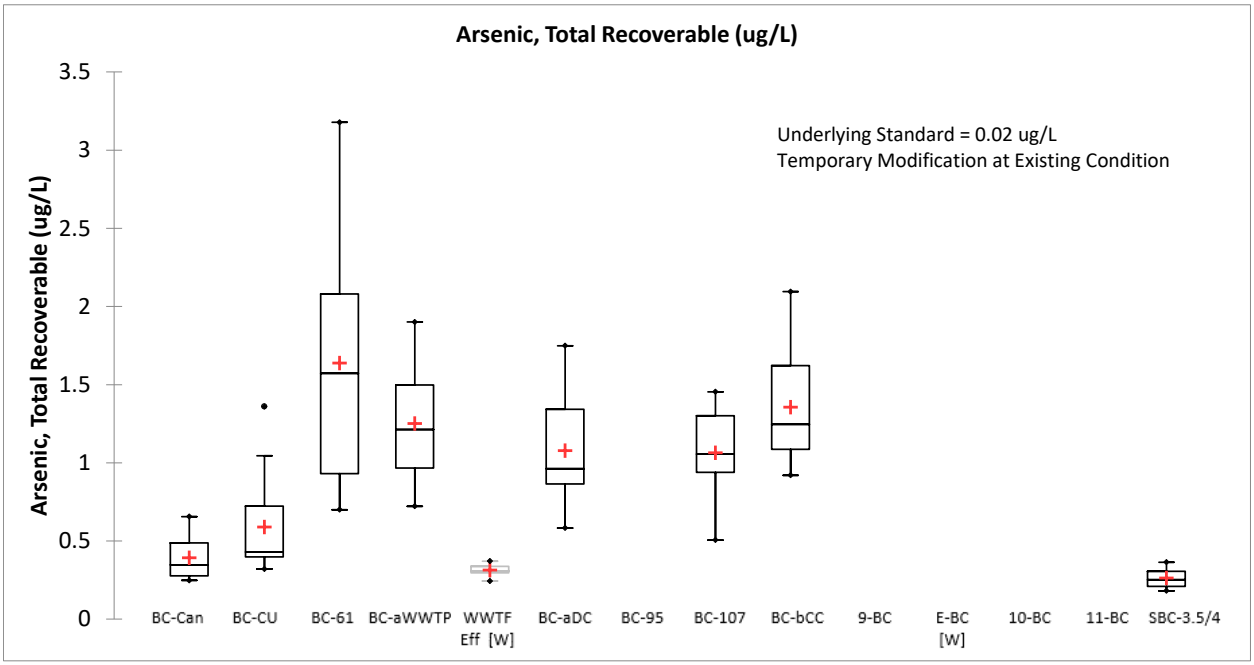
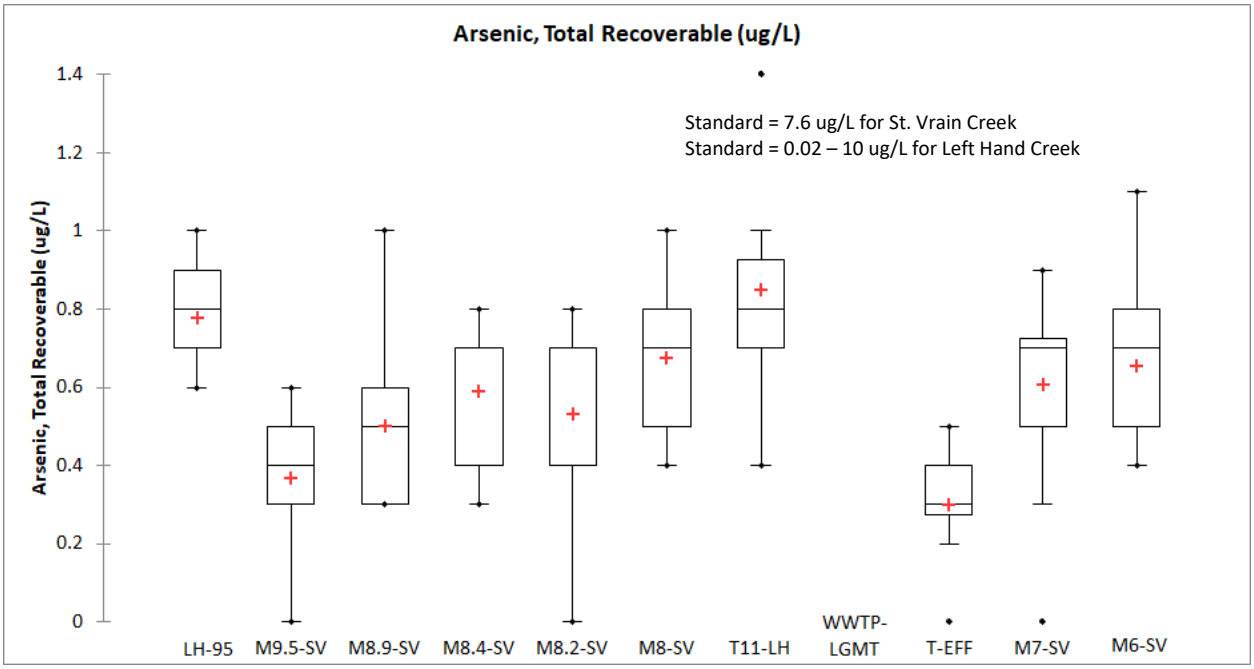


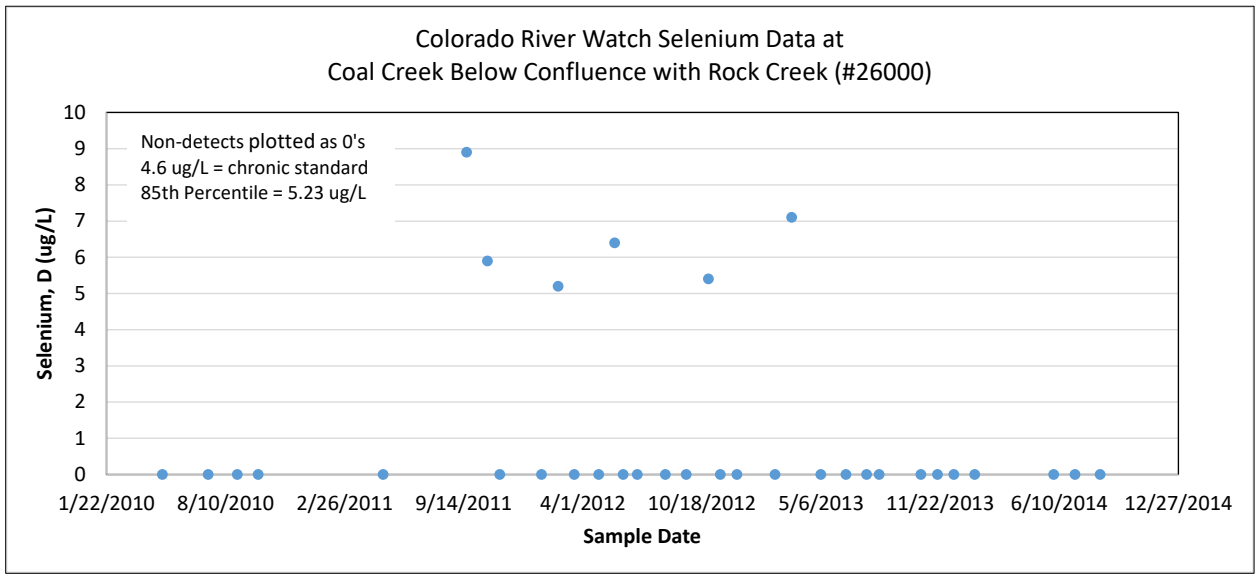
Figure 37. 2016 Total Recoverable Arsenic for St. Vrain Creek and Left Hand Creek



Selenium

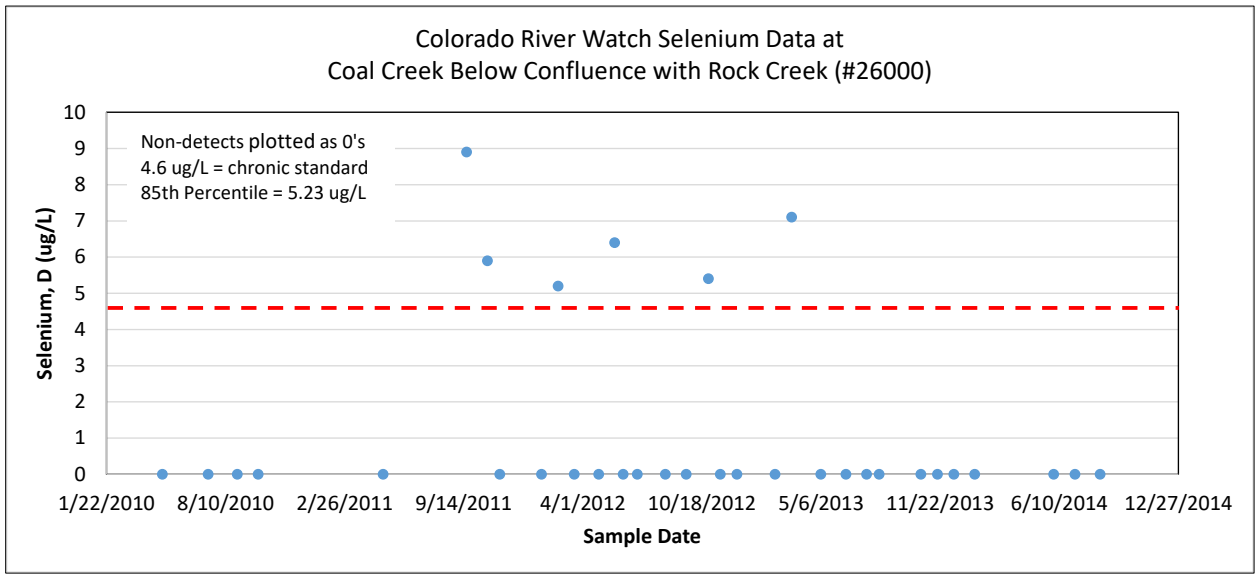
Rock Creek and Coal Creek below Rock Creek were placed on the 2016 303(d) List based on data collected by the River Watch program. The data forming the basis of these listings are shown in Figure 38 and Figure 39. The 85th percentile value for selenium at Coal Creek below Rock Creek for this data set is 5.24 µg/L (n = 33), including several additional samples collected during 2014 in STORET.[7] For Rock Creek, the 85th percentile value is 9.67 µg/L (n = 8). The underlying chronic standard is 4.6 µg/L. This segment has a temporary modification for selenium set at the current condition through December 31, 2020.

Figure 38. Selenium at Coal Creek below the Confluence with Rock Creek



[7] A data retrieval from STORET in June 2017 included several additional samples collected in 2014; however, the data set did not include an elevated selenium value previously reported for the spring of 2013. The basis of this discrepancy is unknown, but does not substantively change the impairment designation.

Figure 39. Selenium at Rock Creek at 120th Street



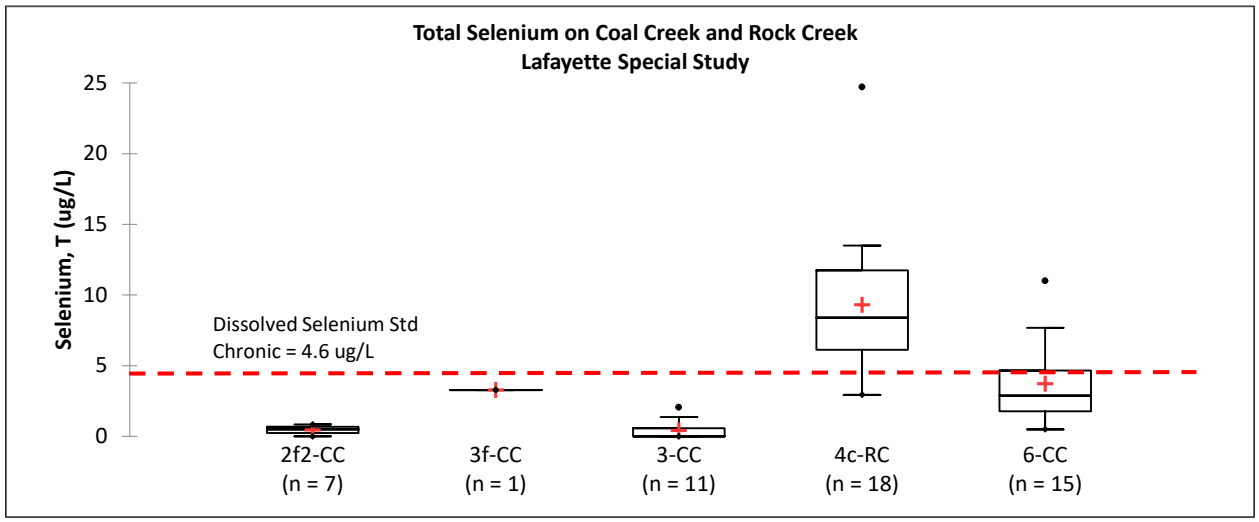
Additional monitoring conducted by KICP members included:

- During April through November 2016, Lafayette conducted supplemental monitoring for selenium at several locations on Coal Creek and Rock Creek, as shown in Figure 40. Although selenium was analyzed in the total form, the results general confirm that that Coal Creek above Rock Creek meets selenium standards, further supporting the current 303(d) listing that excludes Coal Creek above Rock Creek from the impairment designation. The results also show that Rock Creek contains elevated selenium and that an increase in selenium on Coal Creek is present below Coal Creek. (The total selenium data on Rock Creek and Coal Creek cannot be directly used for comparison against the dissolved standard.)

- Superior collected three selenium samples during the summer of 2016 at 0-CC and all three results were non-detect.

- The City of Boulder's monitoring results for selenium on Boulder Creek below Coal Creek show concentrations well below the chronic stream standard during 2016 (below 2.4 ug/L).

Figure 40. Lafayette Selenium Special Study Results



See Figure 28 for monitoring location map.

Copper

South Boulder Creek and Left Hand Creek are both listed as impaired for dissolved copper on the 2016 303(d) List. Both of these streams have mining-related impacts in their headwaters with TMDLs developed for the upstream segments for a variety of metals, as discussed in the Boulder Creek/St. Vrain Watershed-Based Plan (319 Plan) completed in 2015 (KICP and WWE 2015).

The South Boulder Creek listing is due to exceedances of the acute standard at two locations above Eldorado Springs. The chronic standard, calculated as 2.94 µg/L for the 2016 303(d) list, is attained; however, six exceedances of the acute standard occurred, with one exceedance in Eldorado Canyon, and five at the South Boulder Diversion Canal (as monitored by Denver Water).

For Left Hand Creek, the listing is also due to exceedances of the acute copper standard. The chronic standard of 5.23 µg/L is attained and the acute standard of 7.43 µg/L is exceeded for eight samples. The majority of these results were measured by River Watch at the Haldi Intake between 2009 and 2013.

For both South Boulder Creek and Left Hand Creek, the segment portions with copper impairment are upstream of the Monitoring Plan focus area for purposes of this report. Longmont monitors the lower portion of Left Hand Creek for total copper, but these results are not directly comparable to the dissolved standard. The City of Boulder monitors the lower portion of South Boulder Creek in the Open Space area (SBD-3.5/4). Dissolved copper results are very low at this location, with an 85th percentile value of 1.1 µg/L during 2016, and 9 out of 12 samples either being J-qualified or non-detect.

5.0 Biological Monitoring

On behalf of local governments in the watershed, Timberline Aquatics conducts biological monitoring of Boulder Creek and South Boulder Creek, Coal Creek and Rock Creek and St. Vrain Creek and Left Hand Creek. The monitoring is conducted using comparable methods for all of the streams, as described in the individual biological monitoring reports for each basin. Monitoring locations are shown in Appendix A. The summary below highlights key findings from the latest report for each stream, focusing primarily on comparison of the multi-metric index (MMI) scores to thresholds for various aquatic life biotypes defined in *Policy 10-1, Aquatic Life Use Attainment, Methodology to Determine Use Attainment for Rivers and Streams* (WQCD 2010). Policy 10-1 should be referenced for more detailed guidance on the interpretation of MMI scores.

As a brief overview of Policy 10-1, the location of macroinvertebrate sample sites results in assignment of one of three biotypes for the MMI assessments, as summarized in Table 16. Biotype site class is a function of three environmental variables: EPA Level IV ecoregion, site elevation, and stream slope (Policy 10-1, Appendix A). The thresholds that determine attainment or impairment are different for each biotype. Higher MMI scores are better than low scores. When an MMI score falls between the attainment and impairment thresholds identified in Table 14, additional evaluation using supplemental thresholds based on the Hilsenhoff Biotic Index (HBI) and the Shannon Diversity Index (SDI) (Table 17) are required for "Class 1" aquatic life, as described in Regulation 38 (see Appendix E). For the HBI, lower values are better. For the SDI, higher values are better. If a Class 1 site fails to meet the criteria shown in Table 17 for either auxiliary metric, the site will be considered impaired. Auxiliary metrics are not applicable to Class 2 waters (CDPHE 2010). The only Class 1 streams evaluated in this report are Boulder Creek, South Boulder Creek and St. Vrain Creek. (Auxiliary metrics do not apply to the segments of Coal Creek, Rock Creek and Left Hand Creek included in this report.)

Table 16. Policy 10-1 MMI Thresholds

Biotype	Description	Attainment Threshold	Impairment Threshold
1	Transition	>52	42
2	Mountains	>50	42
3	Plains & Xeric	>37	22

Table 17. Policy 10-1 Supplemental Evaluation Thresholds

Biotype	Description	Hilsenhoff Biotic Index	Shannon Diversity Index
1	Transition	<5.4	>2.4
2	Mountains	<5.1	>3.0
3	Plains & Xeric	<7.7	>2.5

All locations discussed in this report are located in either Biotype 1 or Biotype 3. Biotype 1 (Transition Zone) includes lower mountain areas of the Colorado Front Range downstream to the

lower boundary of the "Front Range Fans." Biotype 3 (Plains) ranges from the eastern border of the "Front Range Fans" to the eastern border of Colorado. Both ecoregion and stream elevation are used to determine which biotype is appropriate, with the elevation of 5085 feet serving as the dividing threshold between Biotype 1 and Biotype 3. The Division has acknowledged that where uncertainty exists regarding the transitional boundaries between biotypes, the MMI for the adjacent biotype may be used to help determine the status of the aquatic life use. This additional analysis may be conducted under two circumstances:

1. At sites in Level IV Ecoregion 21c where the biotype assignment along a waterbody varies between Biotypes 1 and 2 because the stream slope fluctuates above and below 0.04. This situation typically occurs when stream slopes are slightly greater than or less than 0.04 along the gradient of a waterbody resulting in varying site classifications or biotypes.

2. At sites that encompass the physical border between two different Level IV Ecoregions or elevation zone boundaries used in the biotype classification. This results in a predicted site classification in one biotype, but is narrowly adjacent to another biotype. In such cases, sites may be represented by characteristics shared by more than one biotype.

For these circumstances, the Division states that "MMIs for each of the adjacent biotypes shall be investigated and used in the assessment." This new procedure has not yet been applied to 303(d) listings to date, but may be a consideration for Boulder Creek above Coal Creek (BC-aCC) in the future, potentially resulting in this site being evaluated against Biotype 3 criteria.

For in-depth discussion of biological findings for each stream segment, the Timberline Aquatics annual reports for each basin should be reviewed. The remainder of this chapter provides MMI, HBI and SDI summaries, as well as EPT[8] scores, which are provided for general reference, but not discussed in this report.

BOULDER CREEK AND SOUTH BOULDER CREEK

For Boulder Creek and South Boulder Creek, sites were strategically established at specific locations to assist in the evaluation of aquatic conditions. Most of these sites correspond to water quality monitoring locations and include:

- BC-CAN: the furthest upstream site on Boulder Creek upstream of most urban development, serving as a reference site with relatively low anthropogenic influences.

- BC-28: within the City of Boulder, used to evaluate potential impacts of urban runoff.

[8] The EPT index is an index of water quality based on the abundance of three pollution-sensitive orders of macroinvertebrates relative to the abundance of a hardy species of macroinvertebrate. It is calculated as the sum of the number of *Ephemeroptera*, *Plecoptera*, and *Trichoptera* divided by the total number of midges (*Diptera: Chironomid*).

- BC-55: located further downstream on Boulder Creek and used to assess recovery that may occur downstream from the City of Boulder, but upstream of the 75th Street WWTP. This site is upstream of the confluence with South Boulder Creek.

- BC-aWWTP: located downstream of BC-55 and immediately upstream of Boulder's 75th Street WWTP to evaluate changes in habitat that have been observed at that location.

Four sites downstream of the WWTP provide information on the influence of WWTP effluent and potential recovery, including:

- BC-aDC: located on Boulder Creek 2.4 river miles (RM) (3.9 km) downstream of the WWTP.

- BC-95: located on Boulder Creek 3.2 RM (5.1 km) below the WWTP.

- BC-107: located on Boulder Creek approximately 4.7 RM (7.5 km) downstream of the WWTP.

- BC-aCC: established on Boulder Creek in 2012, farther downstream in a stream reach with possible impacts from nutrients.

South Boulder Creek monitoring is conducted for this location:

- SBC-OS: located on South Boulder Creek upstream of most urban development, serving as a reference site with relatively low anthropogenic influences. (South Boulder Creek flows into Boulder Creek between BC-55 and BC-aWWTP.)

Based on review of the biological metrics in Table 18 and Table 19, significant recovery of aquatic life following the 2013 flood impacts is evident at most of the sites. Based on MMI scores for the past three years, the only site identified as impaired would be Boulder Creek at the monitoring location above Coal Creek (BC-aCC). Boulder Creek from 107th Avenue to the confluence with Coal Creek was also identified as provisionally impaired for aquatic life on the 2016 303(d) List. Some questions remain regarding the appropriate biotype for this particular station and should be further considered prior to the 2018 303(d) List Hearing in December 2017.

For additional information on biological monitoring sponsored by the City of Boulder, see the most recent annual report by Timberline Aquatics and a recent analysis by the City of Boulder and CDM Smith (2017). The City of Boulder has monitored biological health for many years in both the spring and the fall. Only the fall data are referenced in this report because this is the sample season used for the MMI methodology in accordance with Policy 10-1.

Table 18. Boulder Creek and South Boulder Creek MMI Scores

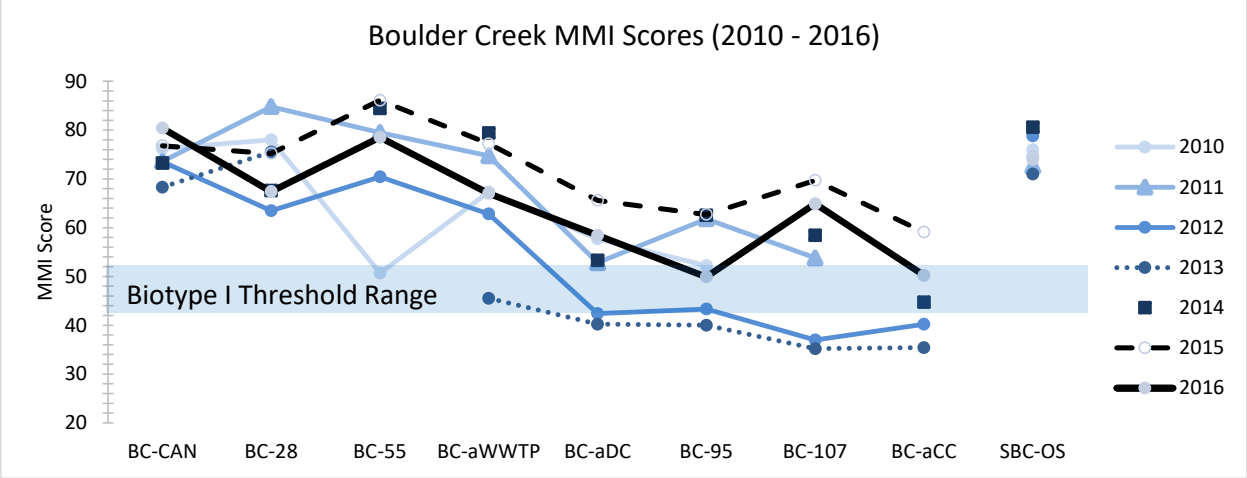
Date	BC-CAN	BC-28	BC-55	BC-aWWTP	BC-aDC	BC-95	BC-107	BC-aCC[2]	SBC-OS
23-Sep-10	76.2	78.0	**50.7**	67.3	57.7	52.2	NA	NA	76.0
29-Sep-11	73.6	84.8	79.5	74.7	52.8	61.8	53.8	NA	72.6
28-Sep-12	73.5	63.5	70.4	62.8	42.4	**43.3**	**37.0**	**40.2**	78.8
25-Oct-13	68.3	75.5	0[1]	**45.5**	**40.2**	**40.0**	**35.2**	**35.4**	71.0
26-Oct-14	73.2	67.6	84.4	79.4	53.3	62.5	58.4	**44** (Biotype 1) or 46.2 (Biotype 3)	80.6
24-Sep-15	76.8	75.2	86.1	77.2	65.6	62.7	69.7	59.1	74.6
22-Sep-16	80.4	67.4	78.5	67.0	58.4	49.9	64.9	**50.2** (Biotype 1) or 53.8 (Biotype 3)	74.0

Pink-shaded cells with bold font indicate impairments based on MMI score and SDI/HBI indices. Grey-shaded cells are MMI scores between attainment and impairment thresholds, but meeting the SDI and HBI indices.

[1]The substrate at BC-55 was completely covered with sand in October 2013, providing no colonizable substrate after the flood. No invertebrates were present at this site during 2013 sampling.

[2]BC-aCC may be more appropriately classified as Biotype 3 instead of Biotype 1. Timberline Aquatics recalculated the MMI score for this location as Biotype 3 for the 2014 and 2016 results, with resulting MMI scores that attain the Biotype 3 threshold (Personal Communication with Dave Rees, June 2017).

Figure 41. Boulder Creek and South Boulder Creek MMI Scores (2010-2016)



Note: graph does not show the "0" MMI score for BC-55 following the September 2013 flood.

Table 19. Boulder Creek and South Boulder Creek EPT, Diversity Index and HBI Scores

Date	BC-CAN*	BC-28	BC-55	BC-aWWTP*	BC-aDC*	BC-95*	BC-107*	BC-aCC	SBC-OS
EPT Scores									
23-Sep-10	23	14	12	14	10	10	NA	NA	22
29-Sep-11	17	19	14	13	8	8	6	NA	21
28-Sep-12	18	10	14	13	6	9	6	4	20
25-Oct-13	12	14	NA	8	6	5	7	7	18
26-Oct-14	18	-	18	19	17	8	10	8	8
24-Sep-15	18	-	24	18	17	12	13	12	29
22-Sep-16	22	24	20	14	10	11	12	9	-
Shannon Diversity Index Scores									
23-Sep-10	3.40	3.07	2.70	2.72	2.86	2.67	NA	NA	3.99
29-Sep-11	3.19	3.23	2.39	2.90	2.83	2.78	2.80	NA	3.01
28-Sep-12	2.80	3.15	3.46	2.50	3.12	2.82	2.35	2.52	3.77
25-Oct-13	2.61	2.96	NA	2.48	2.54	2.82	2.66	2.47	2.47
26-Oct-14	3.17	4.29	2.62	3.16	3.16	3.19	2.72	2.57	3.56
24-Sep-15	3.33	3.73	2.11	2.89	3.18	3.38	2.60	3.26	3.87
22-Sep-16	3.36	3.85	2.53	3.45	3.39	3.06	3.25	2.57	3.73
HBI Scores									
23-Sep-10	3.22	3.80	5.96	5.97	4.64	4.74	NA	NA	3.43
29-Sep-11	2.09	3.66	3.91	4.61	4.81	5.06	5.02	NA	4.60
28-Sep-12	3.60	4.22	5.22	6.01	4.93	5.64	7.41	6.51	2.69
25-Oct-13	3.56	3.64	NA	4.79	4.11	5.86	4.23	5.53	3.38
26-Oct-14	2.01	4.22	4.23	4.70	4.70	5.33	5.83	5.70	3.33
24-Sep-15	2.33	3.53	3.98	4.87	4.37	5.33	4.70	5.47	2.83
22-Sep-16	2.72	3.80	4.20	5.09	4.78	5.30	4.64	5.89	2.90

*Also an active water quality monitoring location.
Pink-shaded cells do not attain target thresholds for Biotype 1.

COAL CREEK AND ROCK CREEK

Coal Creek is included on the 2016 Monitoring and Evaluation List due to potential impairment of aquatic life uses. Five biological monitoring locations are included for Coal Creek and Rock Creek. These sites are located in Aquatic Life Class 2 segments and include these monitoring locations:

- CC-EMP: the "reference site" upstream of the effluent discharge from the WWTP for the City of Louisville.
- CC-OSB: 0.4 km downstream of site CC-EMP, intended to evaluate the potential influence of the Louisville WWTP.
- RC-120: on Rock Creek, approximately 1 km upstream of its confluence with Coal Creek, downstream of Superior WWTP.

- CC-AP: on Coal Creek: downstream of the confluence with Rock Creek, influenced by effluent from Lafayette WWTP and Rock Creek.

- CC-CLR: on Coal Creek, downstream of Erie South WWTP, influenced by effluent from all four municipalities (although Erie has been discharging from the North Erie WWTP to Boulder Creek instead of Coal Creek).

Each of these locations is classified as Biotype 1. Coal Creek from Highway 36 to the confluence with Boulder Creek is listed on the 2016 Monitoring and Evaluation list. The most recent data suggest that non-attainment is limited to the upper portion of Coal Creek between Highway 36 and Rock Creek. The MMI scores for Rock Creek also indicate non-attainment for aquatic life. Most of the sites showed decreases in MMI scores following the September 2013 flood; however, the 2014 through 2016 MMI scores showed significant recovery of the aquatic life at most of these sites, with the exception of CC-OSB.

Timberline Aquatics (2013) noted that the relatively low MMI scores are likely influenced by the spring-fed nature of Coal Creek and Rock Creek which may have inadvertently influenced components of the MMI that are intended to represent responses to changes in water quality. The unique physical parameters (temperature, dissolved oxygen, etc.) that are typically found near the origin of spring-fed streams may contribute to the structure and function of macroinvertebrate communities in a way that negatively influences the MMI. These types of physical environmental changes may partially explain the relatively low MMI scores at the upstream sites (e.g., CC-EMP) on Coal Creek and gradual improvement in a downstream direction (Timberline Aquatics 2013).

The intermittent, spring-fed nature of these two effluent-dominated streams requires consideration when evaluating the status of aquatic life in Coal Creek and Rock Creek. The macroinvertebrate communities present in these streams depend on effluent discharged to provide stable aquatic habitat. The reference site in this study (CC-EMP) was selected because it was upstream of most potential perturbations and maintained enough groundwater to achieve permanent flow. At other locations, these streams rely on effluent discharge to maintain permanent flows through stream reaches that coincide with areas of urban development. Because of the intermittent nature of these streams, there is little opportunity for colonization from upstream macroinvertebrate populations in Coal Creek or Rock Creek. Aquatic life communities in these unique streams are substantially limited by the natural, intermittent, pre-existing conditions (Timberline Aquatics 2013).

Table 20. Coal Creek and Rock Creek MMI Scores

Date	CC-EMP	CC-OSB	RC-120	CC-AP	CC-CLR
22-Sep-10	**38.1**	42.2	**38.6**	44.1	50.1
28-Sep-11	**39.8**	**37.4**	**36.0**	51.4	49.7
27-Sep-12	43.7	**33.6**	**22.5**	42.2	53.6
26-Oct-13	**24.5**	**32.3**	**24.1**	**38.1**	**36.6**
28-Sep-14	47.8	**31.5**	**36.0**	51.3	53.4
23-Sep-15	48.2	**27.3**	44.6	54.4	58.9
24-Sep-16	**36.2**	**27.8**	**30.9**	53.0	45.9

Pink-shaded cells with bold font indicate impairments. Grey-shaded cells are MMI scores between attainment and impairment thresholds.

Figure 42. Coal Creek and Rock Creek MMI Scores (2010-2016)

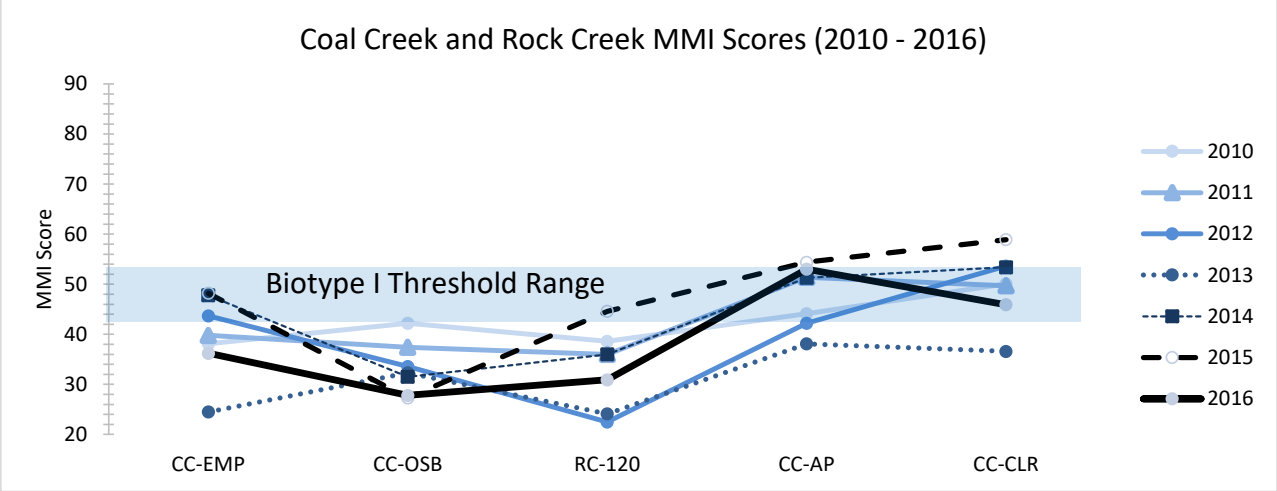


Table 21. Coal Creek and Rock Creek EPT, Diversity Index and HBI Scores

Date	CC-EMP	CC-OSB	RC-120	CC-AP	CC-CLR
EPT Scores					
22-Sep-10	6	7	8	9	8
28-Sep-11	6	4	8	9	8
27-Sep-12	6	2	6	6	10
26-Oct-13	4	6	4	7	10
28-Sep-14	9	5	7	10	9
23-Sep-15	10	6	8	10	10
24-Sep-16	8	3	7	10	10
Shannon Diversity Index Scores					
22-Sep-10	2.23	2.02	3.42	3.11	2.56
28-Sep-11	1.97	1.76	3.35	3.35	2.79
27-Sep-12	2.32	1.30	2.59	2.68	2.58
26-Oct-13	2.76	2.91	1.99	2.70	2.46
28-Sep-14	2.70	2.71	2.48	2.82	2.61
23-Sep-15	2.58	2.50	2.53	2.63	2.67
24-Sep-16	1.49	1.32	3.08	2.93	2.95
HBI Scores					
22-Sep-10	6.29	6.48	5.92	5.12	4.64
28-Sep-11	6.27	6.86	5.77	5.66	4.77
27-Sep-12	6.65	6.69	6.79	5.97	5.24
26-Oct-13	6.73	6.51	6.37	6.47	5.95
28-Sep-14	6.08	5.97	5.73	5.53	4.86
23-Sep-15	6.13	5.84	5.25	5.77	4.97
24-Sep-16	6.84	6.75	6.03	5.54	5.05

Note: Diversity and HBI scores are not required to be evaluated to assess aquatic life use attainment for Class 2 streams.

ST. VRAIN CREEK AND LEFT HAND CREEK

Biological monitoring is conducted at six monitoring locations on St. Vrain Creek, and Left Hand Creek.[9] These sites, which are all classified as Aquatic Life Class 1 segments, include:

- SVC-75: farthest upstream site was added in 2013 to serve as a new reference site on St. Vrain Creek upstream of urban influences.
- SVC-M9: upstream site on St. Vrain Creek is used to provide reference information upstream of urban influences.
- SVC-M8: site within the City of Longmont is used to assess potential impacts from urban runoff.

[9] A special study location on Spring Gulch (SG-2) is also monitored, but it is not included in this report since it is not part of the long-term monitoring program.

- SVC-M6: site is located on St. Vrain Creek downstream of the Longmont WWTP and is used to measure the influence of treated effluent in combination with urban runoff. This location is also located below the confluence with Left Hand Creek.
- SVC-M4: site is the farthest downstream site on St. Vrain Creek and was established to evaluate potential recovery downstream of the city. This site has been abandoned due to flood impacts.
- LH-95: new site on Left Hand Creek at 95th Street upstream of urbanized area.
- LHC-1: site on Left Hand Creek is located approximately 300 m upstream of its confluence with St. Vrain Creek and is used to evaluate the contributions and influence of Left Hand Creek on St. Vrain Creek.

During 2016, all MMI scores for St. Vrain Creek and Left Hand Creek attained the MMI threshold, except at LHC-1, which has been impacted by accumulation of fine sediment flushed from upstream following the 2013 flood (Personal Communication with Dave Rees, June 16, 2017). Most sites showed significant improvements in MMI scores relative to several previous years that showed impairment based on MMI scores such as following the 2013 flood. Although the St. Vrain Creek and Left Hand Creek sites are evaluated as Biotype 1, it is noteworthy that all of these sites are located in Biotype 3 elevation range (below 5085 feet) with the exception of SVC-75.

Table 22. St. Vrain and Left Hand Creek MMI Scores

Biological Site ID	SVC-75	SVC-M9	SVC-M8	SVC-M6	SVC-M4	LHC-95	LHC-1
WQ Cross-Ref ID	M9.5-SV	M8.9-SV	M8-SV	M6-SV	M4-SV	LH-95	T11-SV
22-Sep-10	-	62.5	58.2	**27.2**	**41.5**	-	**46.9**
28-Sep-11	-	62.3	59.1	46.2	44.0	-	43.8
27-Sep-12	-	63.2	44.5	**23.3**	**36.9**	-	**31.6**
28-Oct-13	-	51.0	51.4	**39.4**	**30.6**	-	**43.8**
2-Oct-14	82.9	47.1	51.4	43.9	54.9	-	46.6
28-Sep-15	82.9	81.5	52.5	53.0	-	58.2	57.4
23-Sep-16	77.0	81.4	61.0	57.2	-	57.2	34.7

Pink-shaded cells with bold font indicate impairments based on MMI score and SDI/HBI indices. Grey-shaded cells are MMI scores between attainment and impairment thresholds.
Note: all sites on St. Vrain and Left Hand Creek are below elevation 5085 ft with the exception of SVC-75.

Figure 43. St. Vrain and Left Hand Creek MMI Scores (2010-2016)

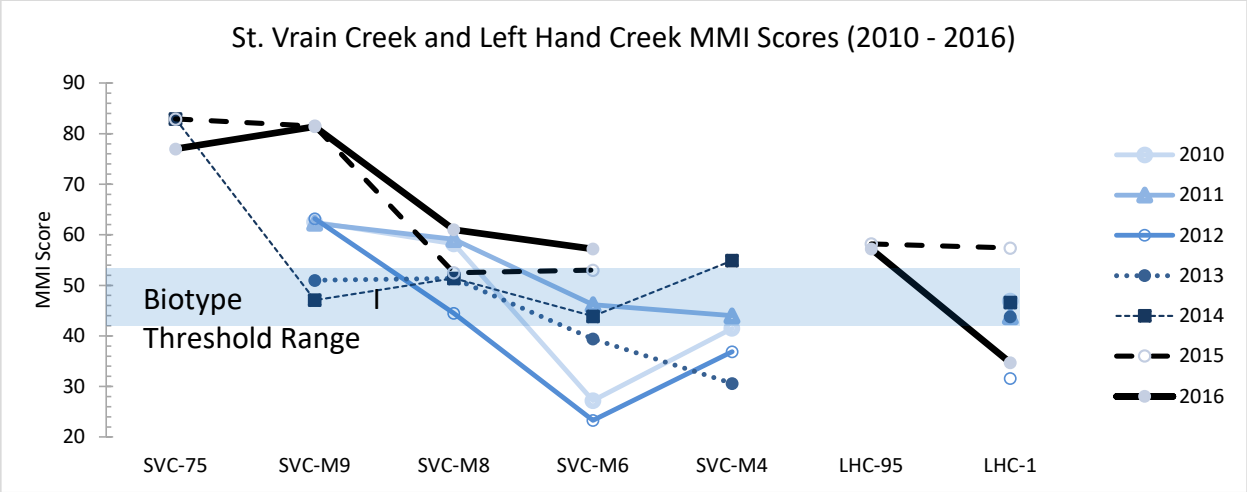


Table 23. St. Vrain and Left Hand Creek EPT, Diversity Index and HBI Scores

Date	SVC-75	SVC-M9	SVC-M8	SVC-M6	SVC-M4	LHC-95	LHC-1
	EPT Scores						
22-Sep-10	-	14	14	10	7	-	8
28-Sep-11	-	11	8	7	7	-	8
27-Sep-12	-	10	8	9	7	-	3
28-Oct-13	-	9	13	8	6	-	6
2-Oct-14	20	9	10	10	8	-	7
28-Sep-15	20	20	13	14	-	10	8
23-Sep-16	17	17	12	11	-	12	8
	Shannon Diversity Index Scores						
22-Sep-10	-	2.65	2.81	2.43	3.05		3.5
28-Sep-11	-	2.19	2.25	2.95	2.16		2.59
27-Sep-12	-	1.99	1.7	2.63	2.84		2.65
28-Oct-13	-	2.23	3.08	2.69	2		3.11
2-Oct-14	2.74	2.81	2.58	2.71	3.3		1.31
28-Sep-15	2.67	2.66	2.57	2.98	-	2.87	3.47
23-Sep-16	3.77	3.51	3.35	2.83	-	2.81	3.08
	HBI Scores						
22-Sep-10	-	3.9	5.15	5.49	5.12	-	6.49
28-Sep-11	-	4.9	4.73	4.37	4.95	-	6.83
27-Sep-12	-	5.36	6.56	5.93	5.68	-	7.41
28-Oct-13	-	4.58	5.42	4.96	4.13	-	5.11
2-Oct-14	3.67	4.41	5.72	4.19	4.88	-	3.54
28-Sep-15	3.96	3.8	6.06	4.51	-	4.81	4.62
23-Sep-16	4.70	4.42	5.32	4.75	-	4.51	4.98

Pink-shaded cells do not meet thresholds for SDI and HBI.

6.0 QA/QC Analysis

Field replicates and field blanks were recommended in the 2015 Monitoring Plan at the frequencies shown in Table 24. These frequencies have not yet been fully implemented by all of the participating communities (or may not have been included in the data submittal for purposes of this report). Therefore, the discussion below is limited to the available quality assurance data submitted during 2016 as summarized in Appendix G. Key observations include:

- Data provided by the City of Boulder included two sets of field replicates for total phosphorus. One pair had a calculated relative percent difference (RPD) of 14% and the other pair had a high RPD of 77%. It may be beneficial for laboratory staff to further review other replicate pairs if they are available to determine whether refinement of laboratory or field procedures are warranted for total phosphorus.
- Data provided by Lafayette included field blanks and replicates for *E. coli,* nitrate/nitrite, nitrate, nitrite, ammonia and TKN. All of the field blanks were either non-detect or J-qualified values. Lafayette also provided four sets of field replicates for the same pollutants (including some additional replicates for *E. coli*). The majority of these results had calculated RPDs less than 25 percent. Three of the four replicate pairs for nitrite had RPDs of 25 percent or higher. It may be beneficial for laboratory staff to further determine whether refinement of laboratory or field procedures are warranted for nitrite.
- Data provided by Longmont included 411 analytical results for field blanks with results for multiple analytes. The majority of these results were non-detect or below the method reporting limit (RL). For analytes included in this KICP report, the only remarkable results included three out of twelve TKN values reported at concentrations above the RL. Replicates were provided for 414 analyte pairs. Review of calculated RPD values did not result in identification of laboratory or field procedures warranting further review.

Table 24. Recommended Field Quality Control Samples

QC Sample	Data Quality Indicator	Collection Frequency (recommended)[1]	Acceptance Criteria	Corrective Action
Field Blank Sample	Bias Due to Sample Contamination	5% of samples (1 per 20 samples)	< Reporting Limit	Investigate and eliminate sources of contamination; flag suspect data (e.g., "B" qualifier)
Field Replicate Sample	Precision	5% of samples (1 per 20 samples)	For concentrations > Reporting Limit, <25% Relative Percent Difference	Investigate and eliminate cause (e.g., inconsistent field techniques and sample processing, lab error); request re-analysis of sample; flag suspect data

[1]If the recommended frequency is infeasible, it is highly recommended that, at a minimum, one set of field duplicates and one set of field blanks should be collected by each sampling program per year.

7.0 Conclusions Regarding Current and Future Regulatory Issues

Based on the analysis completed in this report and analyses conducted by others, current regulatory issues for the Boulder Creek and St. Vrain Creek basin include:

- *E. coli*: All segments evaluated in this report are identified as impaired for *E. coli* on the 2016 303(d) List with the exception of South Boulder Creek, Left Hand Creek, and Rock Creek (which is on the M&E List). The portion of Boulder Creek between 13th Street to the confluence with South Boulder Creek is included in an *E. coli* TMDL, which drives additional regulatory requirements under MS4 permits. TMDLs have not yet been developed for the other *E. coli*-impaired segments on the 2016 303(d) List of Impaired Waters. Data collected during 2016 continue to support these impairment designations. Additionally, data collected during 2016 as part of a special study by Lafayette confirm that Rock Creek is impaired for *E. coli*. Although South Boulder Creek and Left Hand Creek also showed some elevated results for *E. coli* during 2016, insufficient sample sizes are available to support a conclusive impairment designation utilizing the Division's new assessment methodology for *E. coli*.

- pH: Boulder Creek Segment 10 is identified as impaired for elevated pH on the 2016 303(d) List. During 2016, pH at monitoring locations in this segment attained standards with the exception of a site below the confluence with Coal Creek (BC-bCC) that has elevated pH.

- Selenium: Rock Creek and the portion of Coal Creek below Rock Creek are identified as impaired for elevated selenium based on River Watch data. During 2016, additional data collected by Lafayette and Louisville indicated that elevated selenium is present on Coal Creek below Rock Creek. It is recommended that additional monitoring continue to be conducted to better characterize selenium in these areas and that a site-specific standard potentially be proposed in the future. The dissolved fraction of selenium should be reported in these monitoring programs for comparison to the stream standard, which is in the dissolved form.

- Copper: The upper portion of South Boulder Creek and Left Hand Creek basins are identified as impaired for copper on the 2016 303(d) List. These impairments are located at sampling locations outside of the KICP Monitoring Plan area.

- Aquatic Life: Based on biological monitoring results for 2016, significant improvement in aquatic life conditions has occurred throughout the watershed at most locations relative to post-flood conditions in 2013. Based on 2016 results, one site on Boulder Creek (BC-aCC) may be considered impaired, depending on the biotype classification for this location. The two upper locations on Coal Creek qualifies as impaired, as does Rock Creek. Habitat conditions on Rock Creek and Coal Creek related to flow conditions may influence the low MMI scores and warrant further evaluation. The St. Vrain biological monitoring locations attain MMI thresholds, as does the upper monitoring location (LH-95) on Left

Hand Creek. Left Hand Creek near the confluence with St. Vrain Creek (LHC-1) had low MMI scores indicating impairment during 2016, which is believed to be due to sediment accumulation at this location. Revisions to the MMI calculation procedure under Policy 10-1 are anticipated in the next year and may affect determination of aquatic life impairment designations.

Future regulatory issues include:

- Total Phosphorus: Below WWTP discharges, no stream segments evaluated in this report would be expected to attain the "interim values" adopted in Regulation 31 in 2012.
- Total Nitrogen: Below WWTP discharges, no stream segments evaluated in this report would be expected to attain the "interim values" adopted in Regulation 31 in 2012. Additionally, Rock Creek above Superior's discharge does not attain the interim values for total nitrogen.
- Total Recoverable Arsenic: Although temporary modifications have been adopted for segments with "water + fish" standards for total recoverable arsenic through December 31, 2021, available data collected for Boulder Creek and South Boulder Creek indicate that the stringent 0.02 µg/L standard is not attainable at any monitoring location.
- Temperature: Based on a proposal from the City of Boulder, the Commission adopted a temporary modification for temperature during December to February on Segment 9 of Boulder Creek due to difficulty meeting the winter "shoulder season" standard for temperature. This temporary modification expires December 31, 2020.

Appendix I contains fact sheets on nutrient and *E. coli* conditions in the overall watershed that can be used to communicate with the public and local officials regarding these issues.

8.0 Recommendations

This annual water quality report continues to support efforts to coordinate monitoring and interpretation of water quality conditions in the overall St. Vrain Basin and to identify general water quality trends (at least spatially). This section provides recommendations for improvements to the Monitoring Plan, annual data compilation process, and general recommendations for water quality improvements and enhancements.

Recommended modifications to the Annual Report include:

- For the next Annual Report, trend analysis for selected parameters of interest to KICP should be incorporated into the report now that several years of consistently collected data sets are available for most stream segments. A table summarizing these trends should be incorporated into the Annual Report and included in the Executive Summary.

Recommended modifications to the Monitoring Plan include:

- In order to address controllable *E. coli* sources to the streams, a more refined monitoring program (both temporally and spatially) is needed for *E. coli*. Recommendations for monitoring to further refine understanding of sources of *E. coli* have been provided in the Boulder Creek/St. Vrain Watershed-Based Plan (KICP and WWE 2015).

- Lafayette and Superior both monitored 5-RC during 2016. Monitoring program costs can be reduced through enhanced coordination of monitoring at this site.

- For entities conducting special studies related to selenium, the dissolved form of selenium should be analyzed for consistency with the currently applicable water quality standard.

Recommendations for water quality enhancements and improvements:

- At this time, the recommendations of basin master plans in response to the September 2013 flood are considered highest priority, combined with gradual upgrades to WWTP treatment processes to reduce nutrients to meet Regulation 85 requirements. Appendix H provides a current summary of stream restoration progress and plans. There may be additional opportunities to coordinate with LWOG, particularly with regard to monitoring being conducted in the plains portion of the Left Hand watershed.

- Continued implementation of construction and post-construction stormwater quality BMPs following the recommendations of Volume 3 of the Urban Drainage and Flood Control District's *Urban Storm Drainage Criteria Manual* is generally recommended, particularly in MS4 permit covered areas. Inspection and maintenance are important MS4 permit requirements and are essential to proper functioning of stormwater BMPs. Because of the general nature of this water quality analysis, more detailed recommendations are not appropriate at this time. As a general recommendation for

bacteria, practices that provide runoff volume reduction through infiltration and/or filtration (e.g., sand filter, bioretention) are expected to be most beneficial for bacteria reduction. Although wet ponds with permanent pools may also help to reduce bacteria concentrations, water rights and space constraints often preclude their use for new developments and redevelopments in Colorado.

- Work with Boulder County Parks and Open Space to identify opportunities for implementation of agricultural BMPs. For agricultural areas, pollutant loading is affected by practices already in place on specific parcels. Some parcels may have significant opportunity for improvements, whereas others may already be implementing agricultural BMPs. An inventory of practices in place for various agricultural parcels has not been completed for purposes of this annual water quality report, but have been summarized in the Boulder Creek/St. Vrain Watershed-Based Plan (KICP and WWE 2015). KICP is also coordinating with Boulder County Parks and Open Space with regard to a water quality monitoring program that is being developed to assess the effectiveness of various practices implemented on County lands. Additionally, the City of Boulder Open Space and Mountain Parks has gone through a fairly detailed master planning process that addresses best practices on open space.

References

Brown and Caldwell. 2017. *Water Quality Monitoring Report: 2014/2015 Update*. January.

City of Boulder. 2014. Boulder Creek Monitoring Program, Prepared by the City of Boulder Department of Public Works Utilities Division, Water Quality and Environmental Services. May 2012. Updated 2016.

City of Boulder and CDM Smith. 2017. *City of Boulder - Boulder Creek Data Review Report.*

City of Boulder and Wright Water Engineers, Inc. 2013. *City of Boulder Water Quality Report: 2011 and Baseline.* August.

City of Boulder and Wright Water Engineers, Inc. 2015. *Boulder Creek and St. Vrain Creek Water Quality Analysis for 2012-2013.*

Colorado's Decision Support Systems website http://cdss.state.co.us/onlineTools/Pages/StreamflowStations.aspx, accessed June 2017.

Colorado Department of Public Health & Environment, Water Quality Control Commission. 2010. *Aquatic Life Use Attainment Methodology to Determine Use Attainment for Rivers and Streams*. Policy Statement 10-1. October 12, 2010.

Colorado Department of Public Health & Environment, Water Quality Control Division. 2017. *Section 303(d) Listing Methodology 2018 Listing Cycle*.

Colorado Department of Public Health and Environment, Colorado Water Quality Control Commission. 2015. Final Action Tables for Regulation 38 Stream Classifications and Water Quality Standards. June 30, 2015.

Colorado Department of Public Health and Environment, Water Quality Control Commission. 2016. *Regulation No. 31 - The Basic Standards and Methodologies for Surface Water. 5 CCR 1002-31.* Amended (amended 5/9/16, effective 6/30/16).

Colorado Department of Public Health and Environment, Water Quality Control Commission. 2016. 5 CCR 1002-93. *Regulation #93, Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List.*

Dryden, C. 2017. Agricultural Water Monitoring in Boulder County Open Space. Personal Communication, June 2017.

Keep It Clean Partnership and Wright Water Engineers, 2015. Boulder Creek and St. Vrain Creek Watershed-Based Plan. Prepared under 319 funding.

Left Hand Watershed Oversight Group (LWOG), 2016. Status Report on Water Quality Monitoring. February.

Lewand, J. 2016. Coal Creek and Rock Creek: 2016 Stream Monitoring, City of Lafayette Interim Report.

Murphy, S. 2006. State of the Watershed: Water Quality of Boulder Creek, Colorado. *U.S. Geological Survey Circular 1284*. Prepared in cooperation with the City of Boulder, Colorado.

NOAA Earth System Research Laboratory website http://www.esrl.noaa.gov/psd/data/, accessed June 2017.

Patterson, G., 2017. Status of Monitoring Activities for the Lefthand Watershed Oversight Group.

Tetra Tech. 2011a. *Boulder Creek, Colorado Segment 2b: From 13th Street to the Confluence with South Boulder Creek Total Maximum Daily Load Escherichia coli.* Prepared for City of Boulder, Colorado and State of Colorado Department of Public Health and Environment and U.S. Environmental Protection Agency, Region VIII. February 7.

Tetra Tech. 2011b. *Boulder Creek, Colorado Segment 2b: From 13th Street to the Confluence with South Boulder Creek Total Maximum Daily Load Escherichia coli Implementation Plan.* Prepared for City of Boulder, Colorado and State of Colorado Department of Public Health and Environment and U.S. Environmental Protection Agency, Region VIII.

Timberline Aquatics. 2013. *Summary Report, Benthic Macroinvertebrate Biomonitoring Program, Boulder Creek, Colorado 2012*. Prepared for City of Boulder Water Quality Services.

Timberline Aquatics. 2017. Personal communication with Dave Rees, transmittal of Excel spreadsheet summaries of MMI, EPT, HBI and SDI statistics calculated for Boulder Creek and St. Vrain Creek monitoring locations. June.

U.S. Geological Survey (USGS) Water Data for the Nation website: https://www2.usgs.gov/water/, accessed 2017.

Weiner, E. 2008. *Applications of Environmental Aquatic Chemistry*. Second Edition CRC Press.

Wright Water Engineers, Inc., 2014. *Boulder Creek and St. Vrain Creek Coordinated Watershed Monitoring Framework.* Prepared for Keep It Clean Partnership.

Wright Water Engineers, Inc., 2015. *Boulder Creek and St. Vrain Creek Annual Water Quality Analysis for 2014.* Prepared for Keep It Clean Partnership.

Wright Water Engineers, Inc., 2016. *Boulder Creek and St. Vrain Creek Annual Water Quality Analysis for 2015.* Prepared for Keep It Clean Partnership.