Boulder Creek and St. Vrain Creek Annual Water Quality Analysis for 2017

Prepared for
Keep It Clean Partnership

Prepared by
Wright Water Engineers, Inc.

Final Report
December 2018

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
Justin Elkins and Cameron Fowlkes, City of Louisville
Mick Forrester, City of Lafayette
Todd Fessenden and Wendi Palmer, Town of Erie
Judah 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

This page intentionally left blank.

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 fourth joint water quality analysis report resulting from the Monitoring Plan and provides a summary of flow and field conditions during 2017, 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 2017 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. Rock Creek is identified on Colorado's Monitoring and Evaluation List for elevated *E. coli*, but not formally designated as impaired. 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**: Instream total nitrogen standards do not yet apply in Boulder County; however, "interim values" for total nitrogen have been adopted by the Water Quality Control Commission. Above WWTP discharges, the streams in the watershed attain the "interim values" for total nitrogen. 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. Additional monitoring during 2017 suggests that this impairment may be limited to a limited portion of Segment 10.

- **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. The selenium monitoring frequency in these areas increased during 2017, confirming the impairment listing on Rock Creek. Recent monitoring results on Coal Creek indicate that it may now be attaining the selenium standard below Rock Creek. Continued characterization of selenium sources is needed to determine whether controllable sources of selenium loading are present or whether a site-specific standard should be proposed in the future.

- **Copper:** In the upper portion of the South Boulder Creek and Left Hand Creek watersheds, dissolved copper is elevated, largely due to historic mining operations in the watershed combined with very low hardness concentrations resulting in stringent stream standards. For the most part, copper has not been a stream impairment in the urbanized portion of the watershed, which is the focus of this KICP report. However, the 2018 303(d) List includes two stream segments within the KICP study area as impaired for the acute dissolved copper standard, including South Boulder Creek between Gross Reservoir and South Boulder Road and Left Hand Creek from Highway 36 to St. Vrain Creek.

- **Aquatic Life**: Based on biological monitoring results for 2017, significant improvement in aquatic life conditions has occurred in the watershed at most locations relative to post-flood conditions in 2013. Nonetheless, several streams in the KICP study area include segments that are identified as impaired for aquatic life on the 2018 303(d) List based on low multi-metric index (MMI) scores, including the main stem of Coal Creek from Highway 36 to the confluence with Boulder Creek (as well as the upper portion of Coal Creek) and the main stem of Boulder Creek from 107th Street to Coal Creek. The St. Vrain Creek and Left Hand Creek biological monitoring locations did not show impairment based on MMI scores in 2017, although two downstream sites on St. Vrain Creek had scores between impairment and attainment. Significant improvements in aquatic life conditions were measured at Left Hand Creek, possibly due to accumulated sediment flushing through the stream system. Revisions to Colorado's MMI calculation procedure under Policy 10-1 were completed in 2017 and may affect determination of aquatic life impairment designations for future evaluations.

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 2017, 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 measurable 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.	City of Longmont Watershed Monitoring Plan, 2017. 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 Lefthand 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. 2017 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
11-BC	Boulder Creek Gauge 06730500	Boulder Creek	BC-10	Erie
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
4a-RC	Brainard Drive (added 2017)	Rock Creek	BC-8	Superior
4b-RC	South 104th Street (added 2017)	Rock Creek	BC-8	Superior
4c-RC	W. Dillon Road near Ruth Roberts Park (added 2017)	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	M-8.9, St Vrain @ Golden Ponds	St. Vrain Creek	SV-3	Longmont
M8.4-SV	M-8.4, St Vrain @ Below Boston Ave	St. Vrain Creek	SV-3	Longmont
M8.2-SV	M-8.2, St Vrain @ Pratt Parkway	St. Vrain Creek	SV-3	Longmont
M8-SV	M-8, St Vrain @ Above Effluent	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	M-6, St Vrain @ County Line Rd	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 and 2017, 5-RC was monitoring separately by Lafayette (identified as "RCl") and Superior (identified as "RCs").

Plot ID	Instream Monitoring Location Description	Stream Name	Segment	Data Provider
M5.5-SV[4]	M-5.5, St Vrain @ Peschel	St. Vrain Creek	SV-3	Longmont
M4.8-SV[4]	M-4.8, St Vrain Below Spring Gulch #2	St. Vrain Creek	SV-3	Longmont
M4-SV	M-4, St Vrain @ Above Boulder Creek Confluence	St. Vrain Creek	SV-3	Longmont
LH-95	Lefthand Creek @ 95th	Left Hand Creek	SV-5	Longmont
T11-LH	T-11, Lefthand Creek @ St Vrain	Left Hand Creek	SV-5	Longmont
Sites Not Monitored during 2017				
10-BC	Boulder Creek below the North Erie WWTP discharge	Boulder Creek	BC-10	Erie
0-CC	Above urbanized area on Coal Creek	Coal Creek	BC-7a	Louisville

Noteworthy changes to the locations in Table 2 during 2017 include sites 0-CC and 10-CC are no longer being monitoring. Superior added sites 4a-RC, 4b-RC and 4c-RC primarily to support characterization of selenium and *E. coli* on Rock Creek. These sites were monitored beginning in August 2017. Longmont also provided data for two temporary monitoring sites downstream of County Line Road identified as M5.5-SV and M4.8-SV. These sites are being used to assess post-flood recovery and are not a permanent part of Longmont's long-term monitoring program. In 2017, Longmont also resumed monitoring M4-SV, which had been monitored in the 2008-2013 timeframe but temporarily discontinued following the 2013 flood. Also, a benthic macroinvertebrate site corresponding to M4-SV was resumed in 2017; however, this site is in a physically different location and is referred to as "SV-M4 Mod" in Section 5 of this report for consistency with the biological monitoring report prepared separately by Timberline Aquatics.

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.

[4] Temporary monitoring locations to assess post-flood recovery. These sites are not a permanent part of Longmont's monitoring program.

Table 3. WWTP Discharges

KICP ID	WWTP	Stream	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	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. 2017 KICP Monitoring Program Analytes

Parameter	Frequency	Method Detection Limit (MDL)
pH	monthly	1 SU
Dissolved Oxygen (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
Total Suspended Solids (TSS)	monthly	2 mg/L
Ammonia (NH3, as N)	monthly	50 µg/L
Nitrate/Nitrite (NO3+NO2, as N)	monthly	20 µg/L
Total Kjeldahl Nitrogen (TKN, as N)	monthly	100 µg/L
Total Nitrogen (TN, as N)	monthly	100 µg/L
Total Inorganic Nitrogen (TIN, as N)	monthly	NA
Total Phosphorus (TP, as P)	monthly	10 µg/L
Benthic monitoring*	twice per year, spring and fall	
Metals: (1) Arsenic, (2) Selenium, (3) Metals w/stream standards	TBD (min. quarterly)	varies

*Benthic monitoring results in this report are limited to those related to 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 2017, the Division monitored 15 locations in the watershed, with three locations within the KICP study area, as identified in Table 5.

- River Watch Program. River Watch volunteers have conducted monitoring in several areas of the watershed, primarily Gamble Gulch and the upper portion of the Left Hand Creek basin. Samples have also been collected on Coal Creek, Boulder Creek, St. Vrain Creek and South Boulder Creek in the past. During 2017, River Watch collected data at 17 sites in the watershed, with four sites of these sites within the KICP study area on Boulder Creek, Rock Creek, Coal Creek and St. Vrain Creek, as summarized in Table 5. The Lefthand 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, but it was not updated in 2018.

- 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 conducted by the cities of Lafayette, Louisville and Boulder. See the KICP 2016 Annual Report for a summary of the *E. coli* special study on Rock Creek and Coal Creek (WWE 2017).

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

A brief overview of a few specific monitoring programs conducted by others in 2017 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.

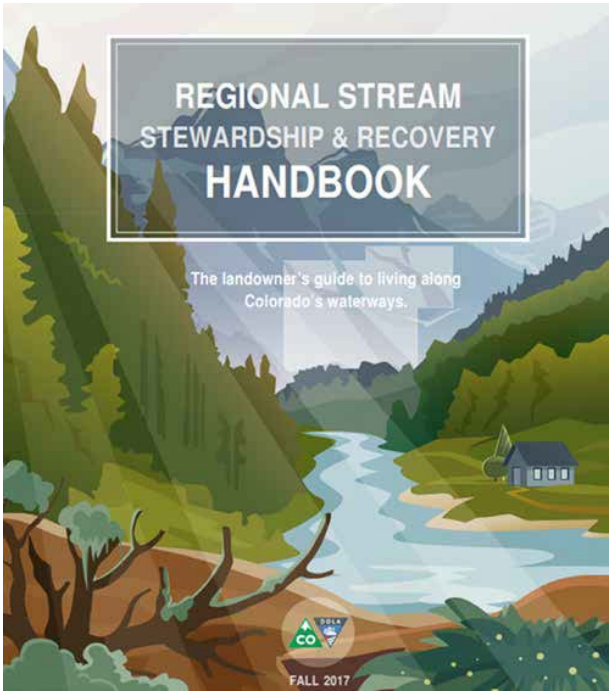
Table 5. CDPHE and River Watch Monitoring Locations within KICP Monitoring Area in 2017
(Source: https://www.waterqualitydata.us, accessed July 2018)

Location ID	Monitoring Station Name
21COL001_WQX-5588	S. BOULDER CREEK @ S. BOULDER RD
21COL001_WQX-5590	COAL CREEK @ 38 RD
21COL001_WQX-5594	COAL CK @ S. 120TH ST. (*upstream of Rock Creek*)
CORIVWCH_WQX-4	Trail Head (*on Coal Creek*)
CORIVWCH_WQX-4002	Rock Cr Farm (*on Rock Creek*)
CORIVWCH_WQX-423	75th St Br (*on St. Vrain*)
CORIVWCH_WQX-494	Oxbow (*on Boulder Creek*)

Lefthand Watershed Oversight Group 2017 Data Summary

The Lefthand Watershed Oversight Group (LWOG) is actively involved in monitoring water quality and stream restoration in the Left Hand creek watershed, particularly in the upper portion of the watershed. During 2017, LWOG continued its program of water quality monitoring that has been underway since 2006, mostly aimed at assessing the impact of acid mine runoff. Recent monitoring has focused on stream restoration. 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. Annual monitoring reports and special studies can be accessed on the LWOG website (www.lwog.org).

During 2017, LWOG implemented ten flood-related recovery river restoration projects, published a Regional Stream Stewardship Handbook, and developed a 5-year strategic plan. LWOG expanded monitoring services in collaboration with other entities interested in Left Hand Creek. LWOG worked with Trout Unlimited and the U.S. Forest Service to conduct an assessment of the decrease in lead contamination following restoration of an informal recreational shooting area on Lower Creek, a tributary to Left Hand Creek. Samples of stream water and bottom sediment were collected from Lower Creek and Left Hand Creek during snowmelt runoff, rainfall runoff, and low flow. The samples were analyzed for total lead and suspended sediment. Results showed a decline of about 75% in total lead concentrations in the samples of Lower Creek water collected after the completion of the restoration project (Patterson 2017).



In 2017, LWOG also continued River Watch sampling and photo monitoring of stream restoration sites. LWOG collaborated with the University of Colorado-Boulder graduate students in collecting data to help assess differences between restored and unrestored sites (https://lwog.org/wp-content/uploads/2018/03/2017-CU-Left-Hand-Creek-Field-Project-Report.pdf). The study found several statistically significant differences between reference and restored sites in biological measurements; however, most statistically-analyzed parameters were inconclusive. Multi-year data will be required to draw conclusions on the effectiveness of these restoration projects as they relate to ecosystem structure and functioning (Culler et al. 2017).

In January 2018, LWOG completed an updated annual report titled *Status of Watershed Science Activities for the Lefthand Watershed Oversight Group* (Patterson 2018). River Watch monitoring data for 2017 were not yet available; however, River Watch data in the watershed can be accessed through the National Water Quality Monitoring Council's website (https://www.waterqualitydata.us/).

Boulder County Open Space Agricultural Study 2017 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 to evaluate the effectiveness of various land management practices. During 2017, monitoring was conducted

for one sampling effort along Dry Creek south of Longmont and one sampling effort on Rock Creek south of Lafayette/Louisville. These monitoring efforts build on sampling conducted during 2015-2016. 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. A variety of water quality analytes were monitored such as nutrients, *E. coli*, total suspended solids and certain agricultural chemicals. For the sampling event conducted in July 2017, elevated *E. coli* was present in most samples, nitrate was below stream standards and TSS concentrations were relatively low. A report summarizing the program's findings is not yet available; however, data sharing between KICP and BCPOS is anticipated to be beneficial in the future.

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 (Personal Communication with Chase Dryden, BCPOS).

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 2017 were 21.3 inches and 15.7 inches, respectively. These data sets were used to determine whether significant storm events affected sampling conditions during 2017. Based on this review, several sample dates occurred in close proximity to a meaningful precipitation event, as discussed later in this report, particularly in the context of elevated total suspended solids concentrations. The largest storm event during 2017 occurred during May 18-19, totaling over 3 inches in Boulder and 2.8 inches in Longmont.

Figure 1. 2017 Monthly Precipitation Totals at Longmont and Boulder Rain Gauges

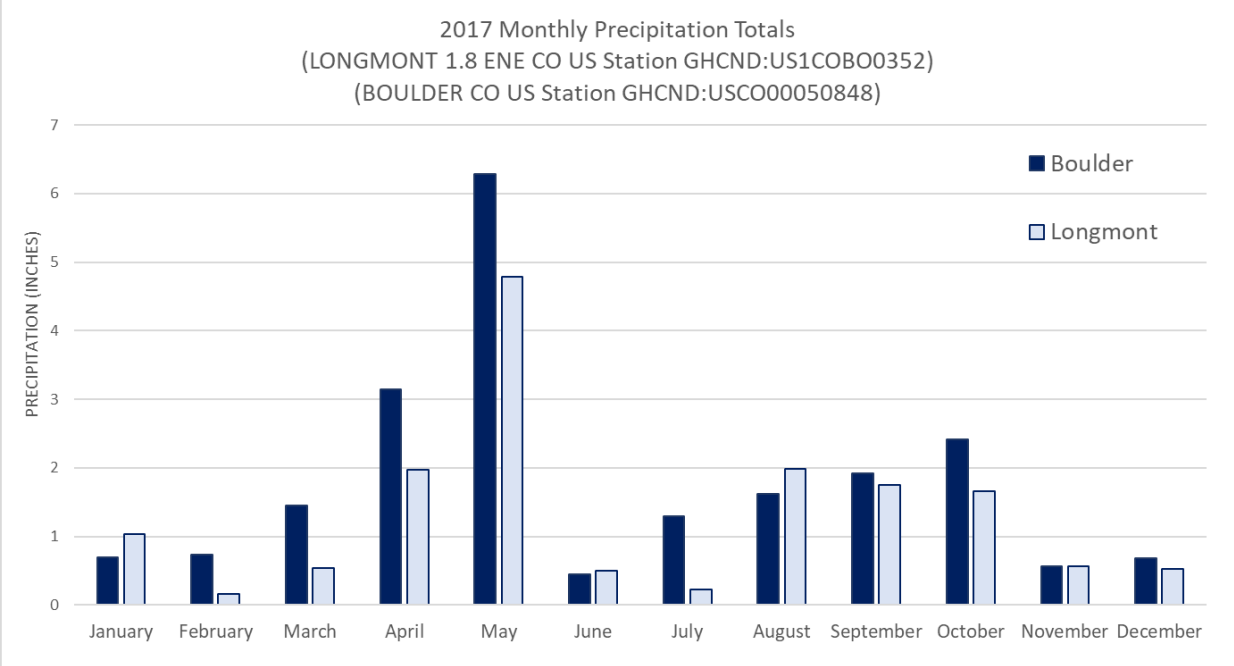


Figure 2. 2017 Daily Precipitation at Boulder Rain Gauge

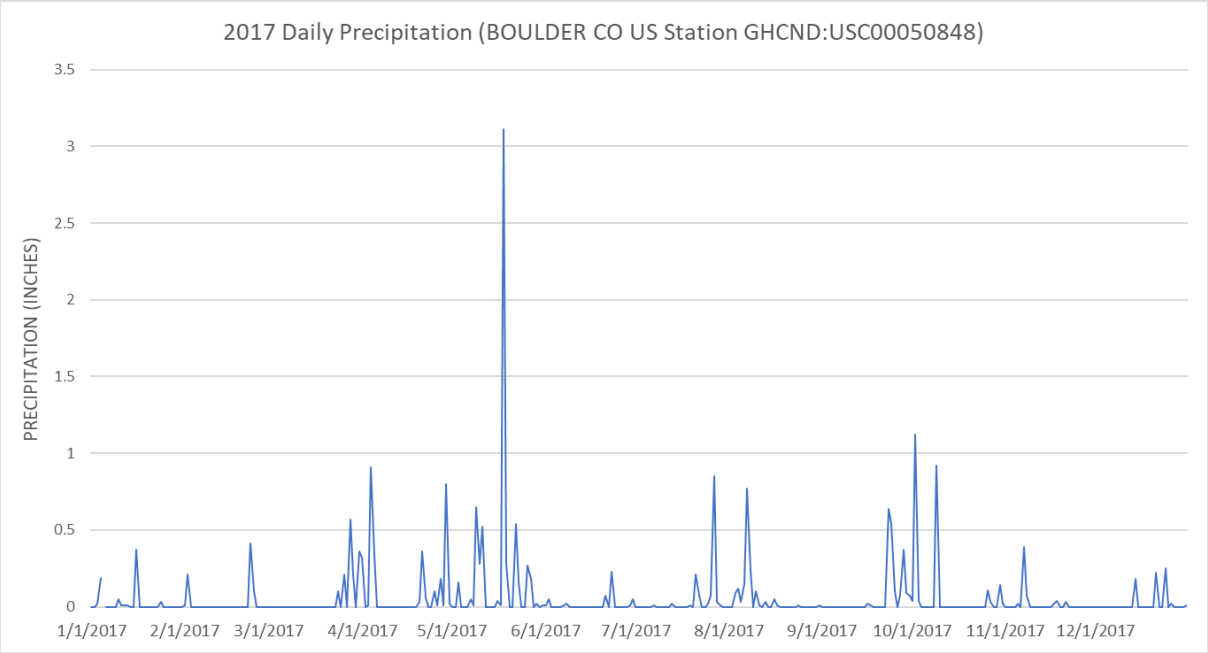
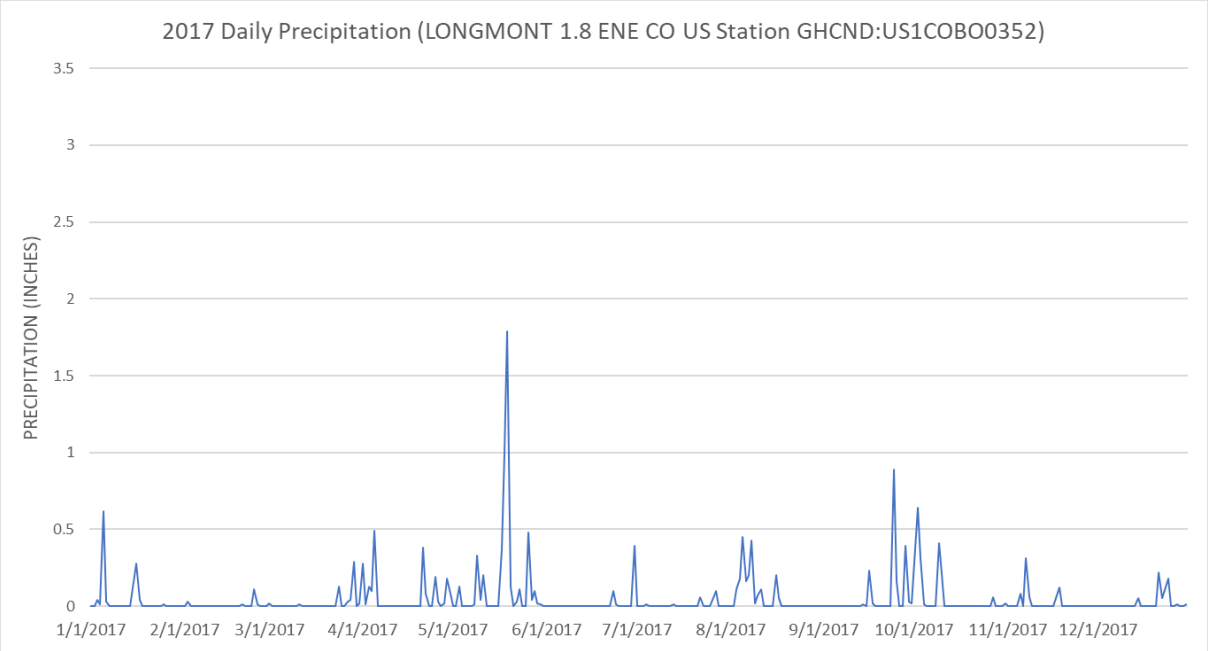


Figure 3. 2017 Daily Precipitation at Longmont Rain Gauge



During 2017, stream flow was measured at the gauge locations in Table 6. Figure 4 through Figure 12 provide the 2017 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 late May to mid-June for most streams in each basin.
- Streamflows during 2017 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 2017 data relative to this event include channel instability, denuded vegetation on banks and other long-term impacts from the September 2013 flood.

Table 6. Stream Gauges with 2017 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[5]
06730400	COALOUCO	COC-1 Louisville Gauge, no longer managed by USGS/DWR

[5] 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 stream gauge 06725450 is no longer included in this KICP report.
(Source: https://waterdata.usgs.gov/nwis/uv?06725450).

Figure 4. Boulder Creek near Orodell 2017 Hydrograph

Figure 5. South Boulder Creek near Eldorado Springs 2017 Hydrograph

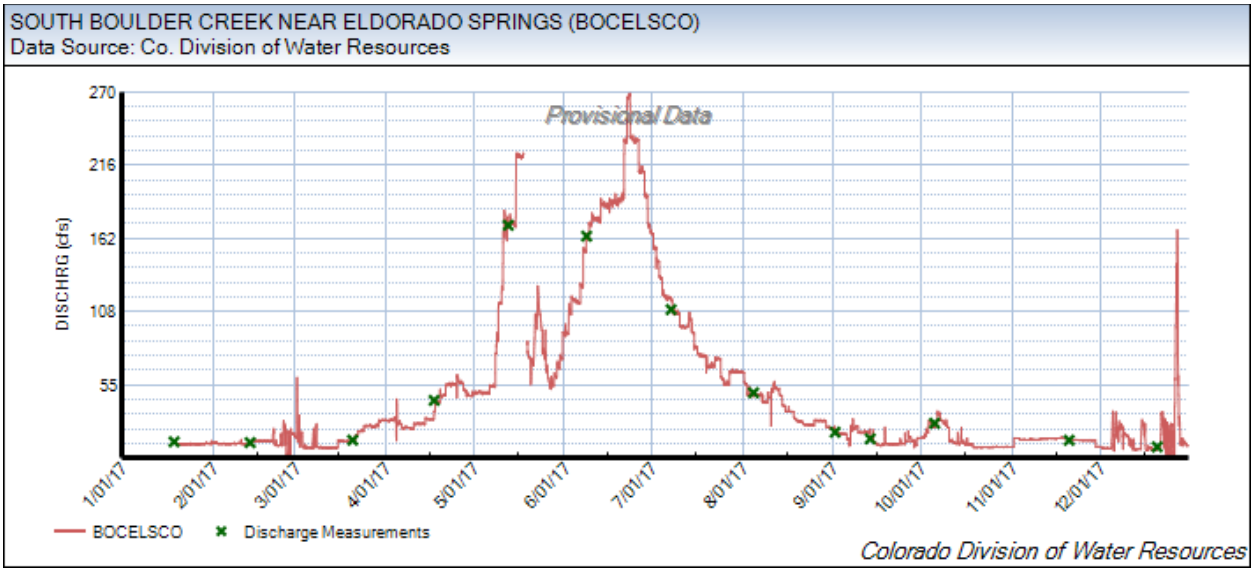


Figure 6. Boulder Creek at North 75th Street 2017 Hydrograph

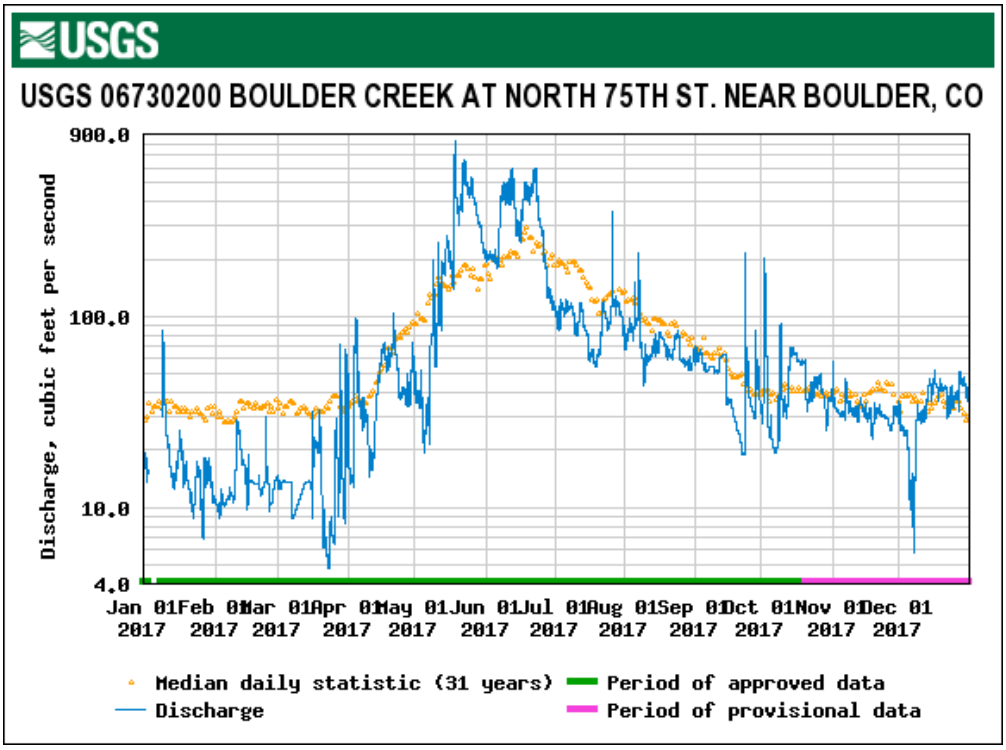


Figure 7. Boulder Creek at Mouth near Longmont 2017 Hydrograph

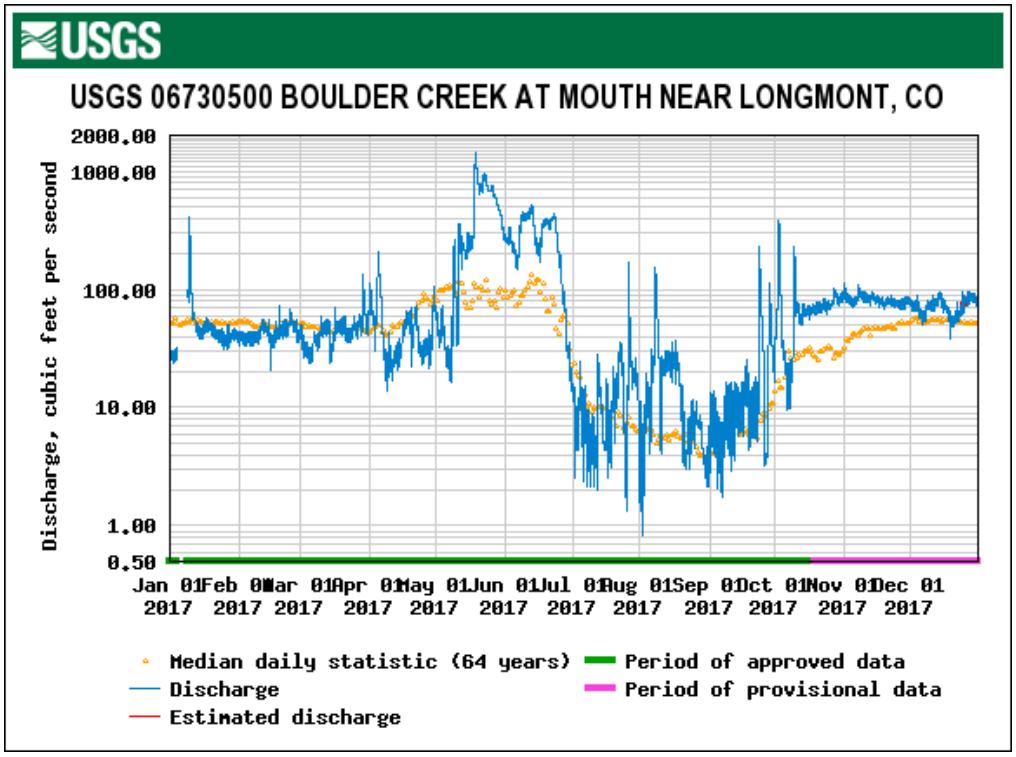


Figure 8. Left Hand Creek at Hover Road near Longmont 2017 Hydrograph

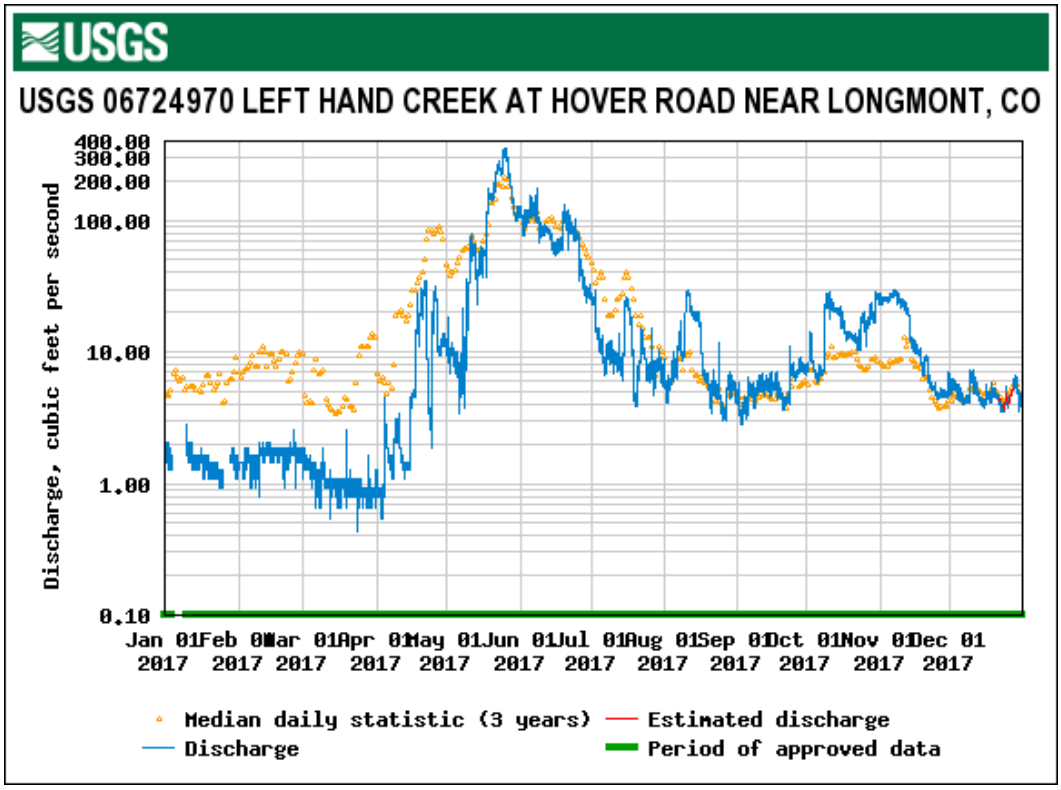


Figure 9. St. Vrain Creek at Hygiene, CO 2017 Hydrograph

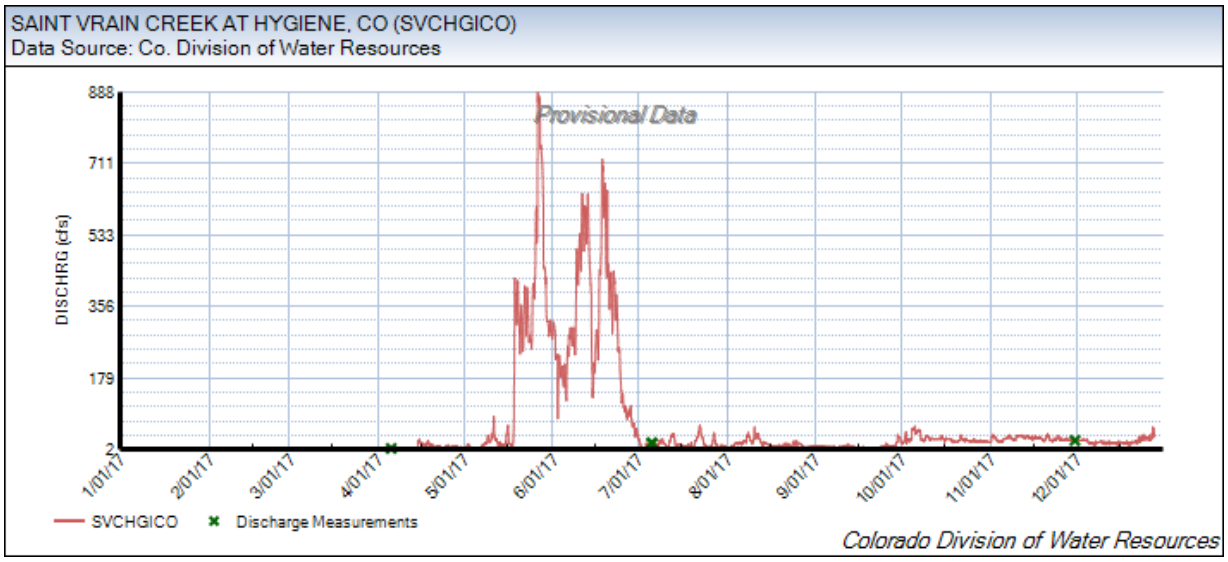


Figure 10. St. Vrain Creek below Boulder Creek at Hwy 119 near Longmont 2017 Hydrograph

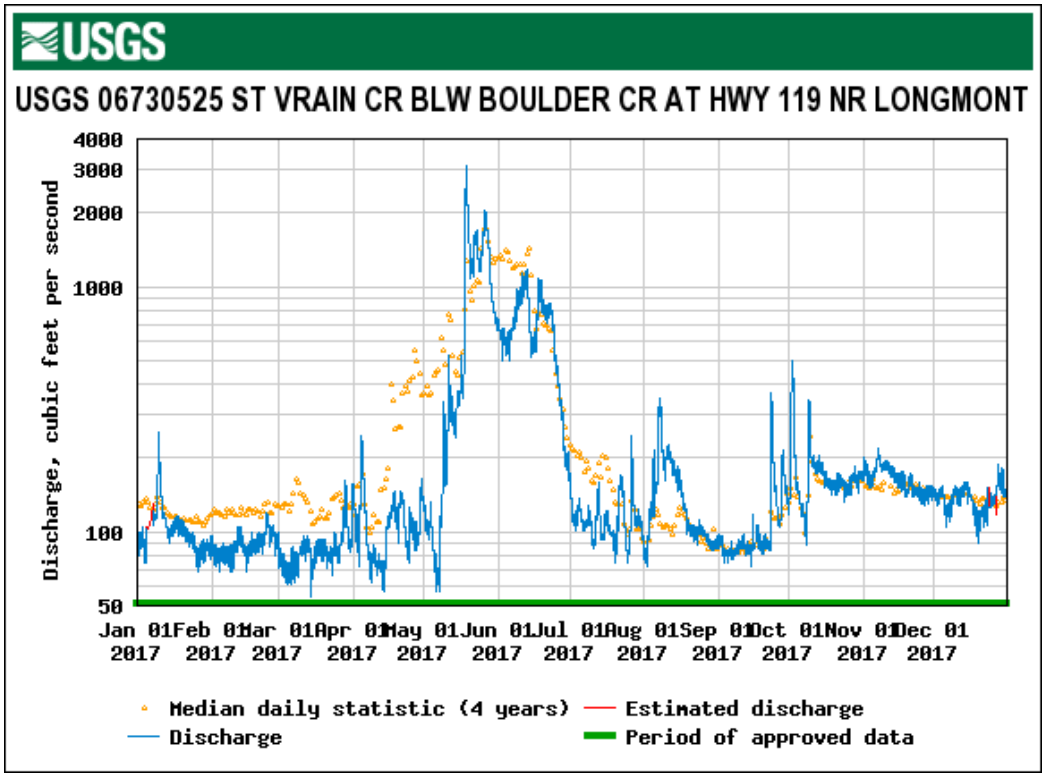


Figure 11. St. Vrain Creek below Ken Pratt Blvd at Longmont 2017 Hydrograph

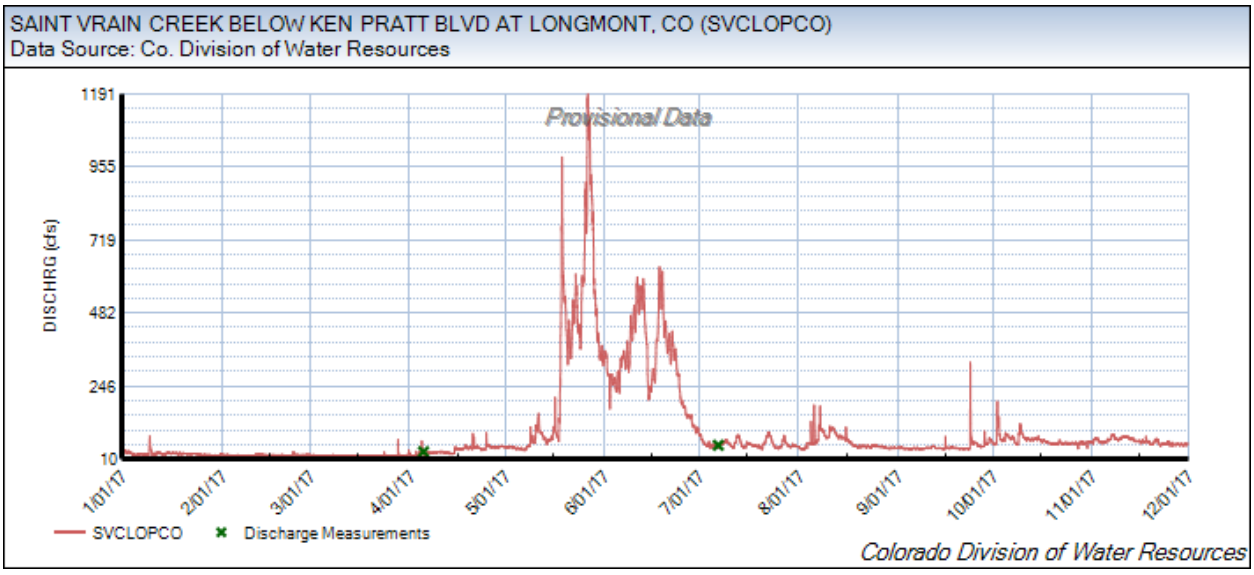
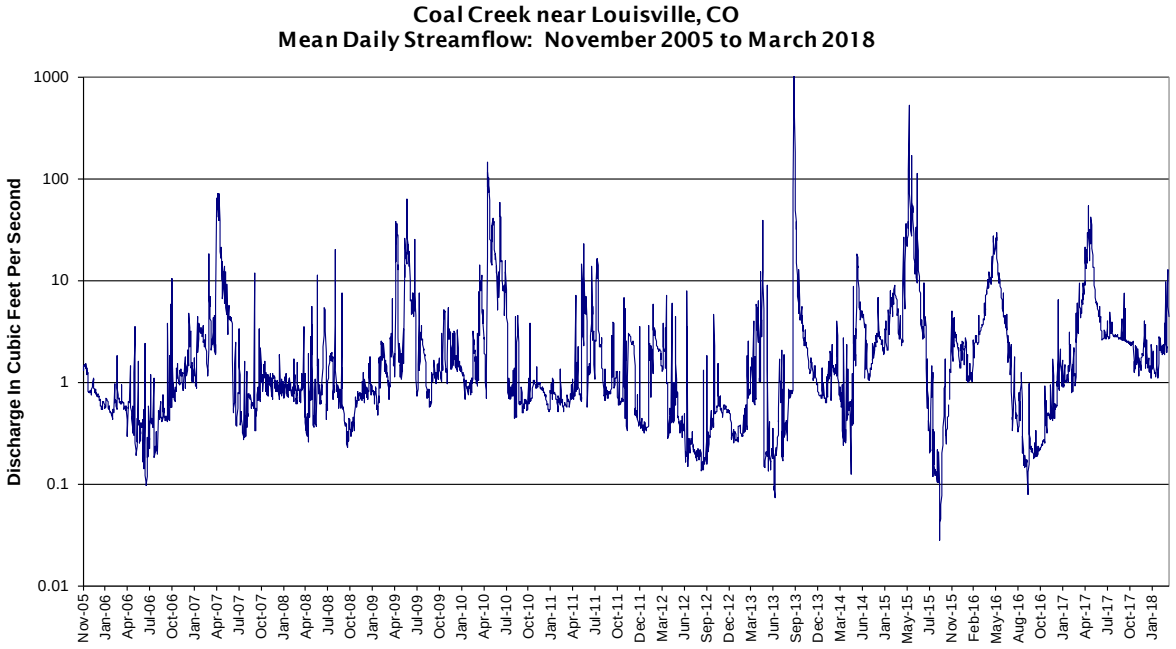


Figure 12. Coal Creek at Louisville (COC-1) November 2005-March 2018 Hydrograph



4.0 Water Quality Analysis

A brief overview of the statistical methods used in this analysis is provided, followed by an 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 7. 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). For the most part, this report focuses primarily on statistical characterization and does not include formal hypothesis testing and trend analysis, given that this is the fourth year of the KICP coordinated monitoring program. Some limited trend analysis for *E. coli* and nutrients is provided. For the 2019 analysis, the annual report is expected to support more hypothesis testing and trend analysis with the program reaching the 5-year milestone.

Table 7. Overview of Descriptive Statistics Provided in Appendices

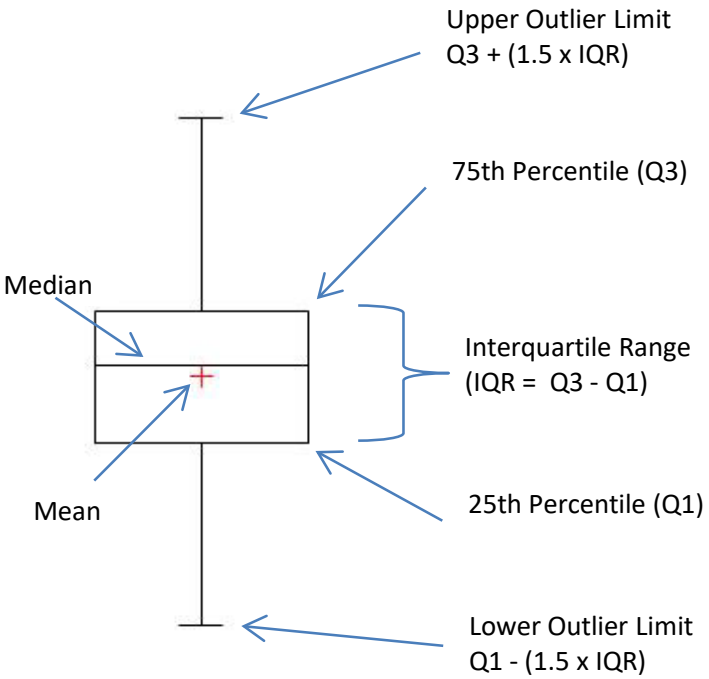
Parameter	Description
Number of observations	The number of values analyzed (n). Statistics based on few samples should be used with caution.
Minimum	The minimum of the series analyzed.
Maximum	The maximum of the series analyzed.
1st quartile	The first quartile (Q1) is defined as the value for which 25% 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 2017. 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 biennial 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 Monitoring and Evaluation 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 Monitoring and Evaluation 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 five data points within the 61-day "windows." If a minimum of one window with a sample size of five 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 in 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" for total phosphorus, total nitrogen and chlorophyll-*a*. Stream standards for total phosphorus and chlorophyll-*a* based on these values have been adopted for stream segments or portions of stream segments upstream of WWTPs for total phosphorus and chlorophyll-a, as summarized in Appendix E. Total nitrogen standards have not yet been adopted for streams in the watershed. Total phosphorus and total nitrogen standards are expected to apply to segments downstream of WWTPs in the future, following a rulemaking hearing scheduled for 2027 in accordance with Colorado's "10-Year Water Quality Roadmap." 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.)

SUMMARY OF 2018 303(D) LISTINGS

In December 2017, 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 2018 Monitoring and Evaluation List. Table 8 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). Tributaries to these segments or upstream portions of these segments may also be impaired as shown in Appendix F. The 303(d) List will be updated in 2020, with the regulatory process for the hearing beginning during the summer of 2019. For the streams in Table 8, no significant changes to the 303(d) List occurred in 2018 relative the 2016 list. For Coal Creek between Highway 93 and Highway 36 the macroinvertebrate listing status changed from the Monitoring and Evaluation List to the 303(d) List as "provisionally impaired" for macroinvertebrates. The area is currently slightly upstream of active monitoring in the KICP study area.

Table 8. 2018 303(d) and Monitoring Evaluation (M&E) List for Selected Stream Segments

WBID	Description	Portion	M&E	303(d)	Priority
Boulder Creek Segments in KICP Monitoring Area					
COSPBO02b	Boulder Creek, from below the confluence with North Boulder Creek to above the confluence with South Boulder Creek	COSPBO02b_B (13th St. to South Boulder Creek)	--	Arsenic (Total)	L
		COSPBO02b_C (North Boulder Creek to 13th St.)	--	Arsenic (Total)	L
COSPBO04b	Mainstem of South Boulder Creek, including all tributaries from the outlet of Gross Reservoir to South Boulder Road	COSPBO04b_B (All)	--	Copper (Dissolved) Arsenic (Total)	H/L
COSPBO07a	Mainstem of Coal Creek from Highway 93 to Highway 36	COSPBO07a_A (All)	--	Macro-invertebrates (Provisional)	L
COSPBO07b	Mainstem of Coal Creek from Highway 36 to Boulder Creek	COSPBO07b_A (Highway 36 to Rock Creek)	Macroinvertebrates	*E. coli*	H
		COSPBO07b_B (Rock Creek to Boulder Creek)	Macroinvertebrates	*E. coli* Selenium (Dissolved)	H/M
COSPBO08	All tribs to South Boulder Creek and all tribs to Coal Creek	COSPBO08_B (Rock Creek)	*E. coli*	Selenium (Dissolved)	L
COSPBO09	Mainstem of Boulder Creek, from South Boulder Creek to Coal Creek	COSPBO09_A (South Boulder Creek to 107th St.)	--	*E. coli* Arsenic (Total)	H/L
		COSPBO09_B (107th St. to Coal Creek)	--	Aquatic Life *E. coli* Arsenic (Total)	L/H/L
COSPBO10	Boulder Creek, Coal Creek to St. Vrain Creek	COSPBO10_A (All)	--	pH *E. coli* Arsenic (Total)	H/H/L

WBID	Description	Portion	M&E	303(d)	Priority
St. Vrain Segments in KICP Monitoring Area					
COSPSV03	St. Vrain Creek, Hygiene Rd. to S. Platte River	COSPSV03_B (Left Hand Creek to Boulder Creek)	--	*E. coli*	H
		COSPSV03_C (Hover Rd. to Left Hand Creek)	--	*E. coli*	H
		COSPSV03_D (Hygiene Rd. to Hover Rd. and Boulder Creek from I-25 to S. Platte River)	--	*E. coli*	H
		COSPSV03_E (Boulder Creek to I-25)	--	*E. coli*	H
COSPSV05	Mainstem of Left Hand Creek, including all tributaries and wetlands from Highway 36 to the confluence with St. Vrain Creek	COSPSV05_A[1] (Lefthand Feeder Canal to St. Vrain Creek)	--	Copper (Dissolved)	M

[1]"Lefthand Feeder Canal" is believed to be the "Boulder Feeder Canal." Additional impairments upstream of the canal (COSPSV05_B) are also on the 2018 303(d) List, but are not within the KICP monitoring area.

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). The long-term South Boulder Creek monitoring location is named SBC-3.5, but an alternative location named SBC-4 was also monitored for several years 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 2017 include:

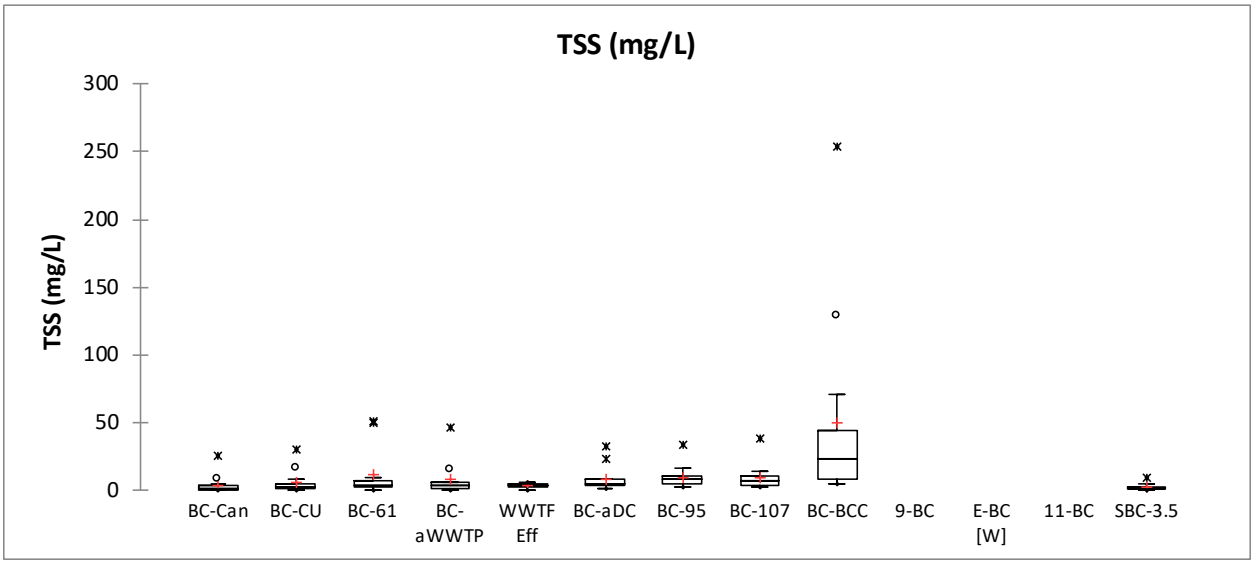
- For Boulder Creek, alkalinity, conductivity, hardness, pH and temperature generally increase from upstream to downstream, consistent with previous published analyses (e.g., Murphy 2006) and annual analysis by the City of Boulder (City of Boulder and WWE 2013 & 2015; Brown and Caldwell 2017). Temperature increases through the urbanized area in Boulder and gradually decreases in the downstream agricultural area. Concentrations of these parameters at the South Boulder Creek monitoring location (SBC-3.5) 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 mean TSS concentrations are notably higher below the confluence with Coal Creek (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 instream pH gradually increases through the urbanized area. The pH levels are typically slightly higher in the winter (City of Boulder and WWE 2015). Boulder Creek Segment 10 is listed on the 2018 303(d) List as impaired due to elevated pH. During 2017, all locations on Boulder Creek attained the pH standard except for one location below Coal Creek (9-BC) (Figure 15), with an 85th percentile value of 9.15. The 85th percentile value for Segment 10 (BC-bCC, 9-BC, 11-BC) during 2017 was 8.8. This suggests that it may be more appropriate for a limited portion of Boulder Creek below Coal Creek to be listed as impaired for pH rather than the entire segment. Continued instream pH monitoring by Erie at 9-BC and 11-BC will help to refine the understanding of the geographic extent of elevated pH in this reach. Long-term pH monitoring is not available at these two sites, but long-term pH monitoring at BC-bCC shown in Figure 16 suggests fewer exceedances of the upper pH limit in the last several years relative to the 2011-2013 timeframe.

Figure 14. 2017 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. 2017 Boulder Creek pH

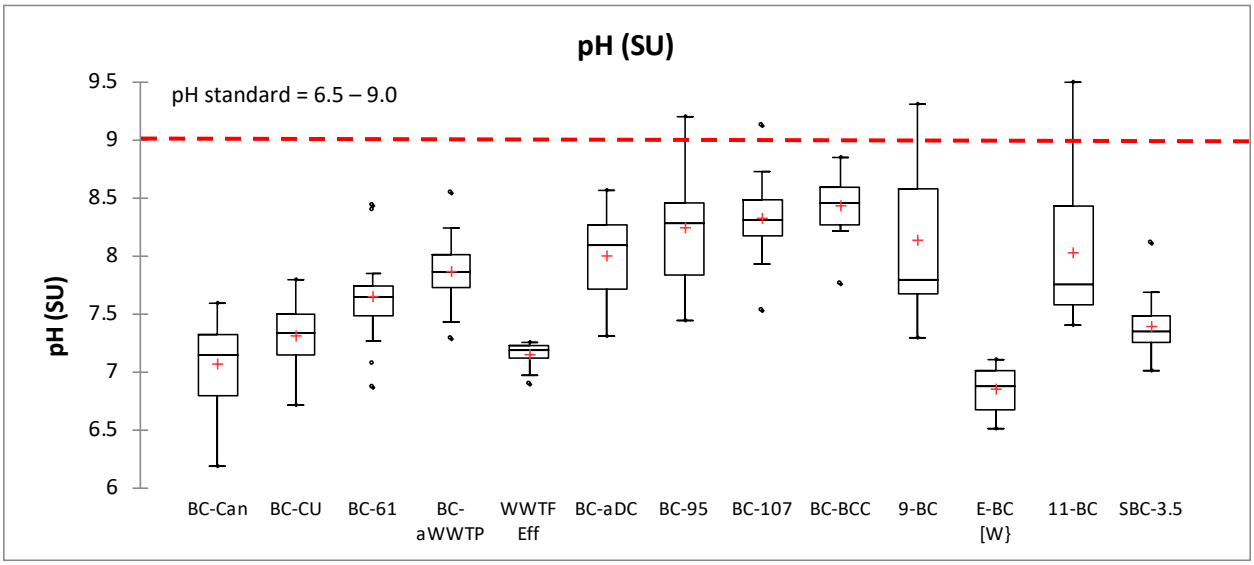
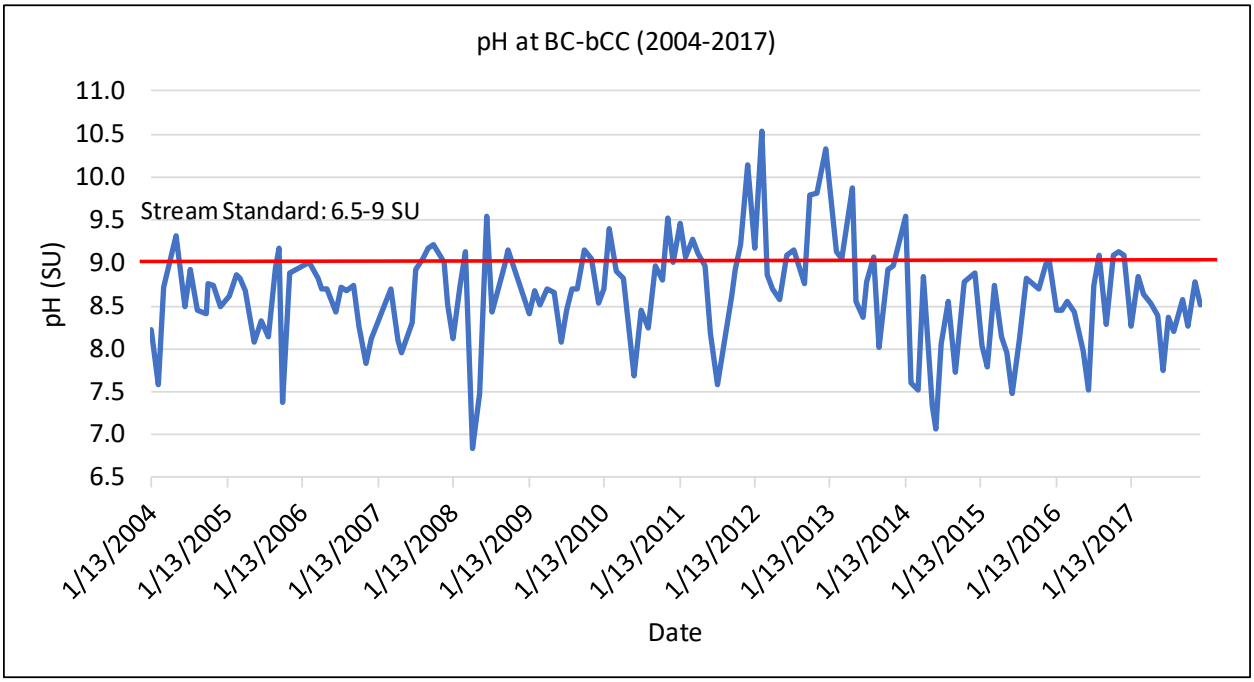


Figure 16. Long-term pH at Boulder Creek below Coal Creek



Coal Creek and Rock Creek

Coal Creek monitoring locations addressed in this report span from downstream of Highway 36 to Kenosha Road near the confluence with Boulder Creek. Rock Creek is monitored upstream of Highway 36 and 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 2017 relative to the previous three years of the monitoring program. During 2016-2017, both Lafayette and Superior monitored 5-RC on Rock Creek. For purposes of this report, the two data sets are kept separate, denoted by 5-RCl for 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 2017 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 both 8.2.

- Rock Creek and Coal Creek had relatively normal[6] alkalinity ranges on average with no apparent spatial trends observed.

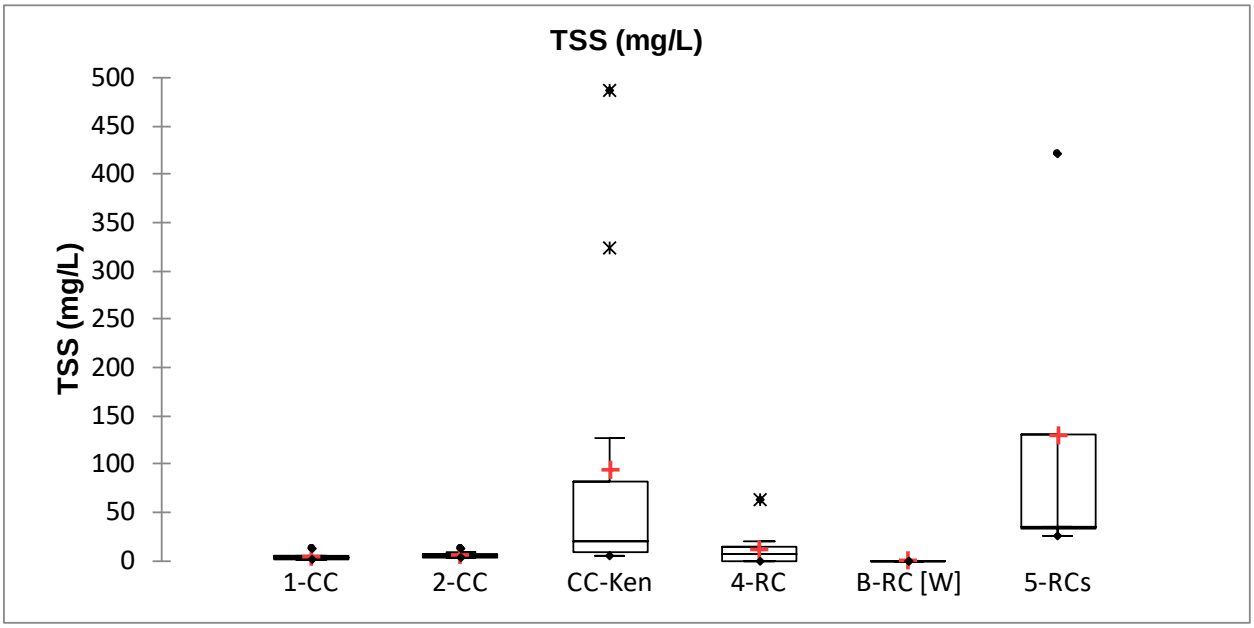
- Coal Creek and Rock Creek have relatively high hardness, with Coal Creek above Rock Creek averaging 204 mg/L, Rock Creek averaging 287 mg/L, and Coal Creek below the confluence averaging 248 mg/L. These relatively high hardness values result in less stringent hardness-based metals standards than those 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 was 1218 umhos/cm and the average conductivity for Coal Creek above the confluence with Rock Creek was 693 umhos/cm. The average conductivity for Coal Creek below the confluence with Rock Creek was 1175 umhos/com.

- TSS concentrations on Coal Creek and Rock Creek during 2017 were relatively low, with the exception of the furthest downstream monitoring location on Coal Creek (CC-Ken, just above the confluence with Boulder Creek), which averaged 93.6 mg/L. Two of the most elevated values at CC-Ken were influenced by approximately 1-inch precipitation events in August and October. Only four TSS samples were provided at 5-RC, with the mean concentration significantly influenced by an elevated sample of 422 mg/L in April following an early April snow storm. Figure 17 shows the range of TSS concentrations in Coal Creek and Rock Creek above the confluence with Boulder Creek.

[6] 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 17. 2017 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 the confluence with Boulder Creek (M4-SV). Left Hand Creek enters St. Vrain Creek below Longmont's WWTP discharge and was monitored at two locations during 2017: 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).

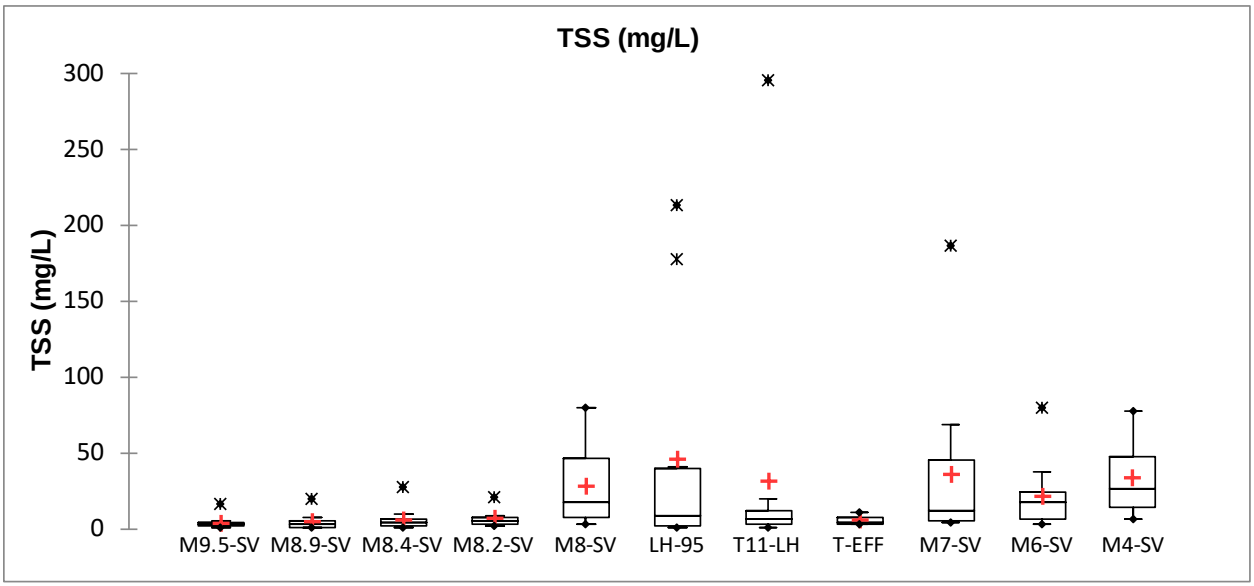
Key observations regarding general water chemistry for St. Vrain Creek and Left Hand Creek (above the confluence with St. Vrain Creek) during 2017 include:

- 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 for each stream segment; however, several unusually low pH values were measured at M9.5-SV resulting in a 15th percentile value of 6.4 during 2017. The 15th percentile value for 2013-2017 at M9.5-SV is 6.8, which attains the standard, consistent with the overall segment.

- TSS concentrations in St. Vrain Creek and Left Hand Creek were very low in the upper portion of the segment and moderately increase downstream of M8.2-SV (Figure 18). Left Hand Creek contributes to increases in TSS in St. Vrain Creek. For example, in May, most of the elevated TSS concentrations on the lower portion of St. Vrain Creek appear to have been influenced by Left Hand Creek, which had a TSS concentration of 296 mg/L at T11-LH. Observations during biological sampling in 2016 indicated that eroded sediment related to the 2013 flood 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). In 2017, this sediment appears to have been flushed further downstream with substrate conditions improving at T11-LH (Personal Communication with Dave Rees, Timberline Aquatics, August 2018).

Figure 18. 2017 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 or portions of segments as described further below. Additional nutrient standards for total nitrogen and total phosphorus, as well as chlorophyll-*a*, are expected to be added in the future in accordance with Regulation 31 and Colorado's 10-Year Water Quality Road Map. Technology-based WWTP effluent limits for total inorganic nitrogen (TIN) and total

phosphorus for WWTP discharges are being 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 9. Chlorophyll-*a* (as attached algae) is not part of the current Monitoring Plan,[7] 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 timeline for adoption for additional nutrient standards has been extended through 2027 and will be addressed in Colorado Water Quality Forum Nutrient Work Group efforts and future Commission hearings.

Table 9. "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 could potentially be applied downstream of WWTP discharges based on the outcome of a rulemaking hearing in 2027.
- As summarized in Table 9, total nitrogen "interim values" were adopted under Regulation 31. These values are not expected to be adopted to streams until 2027. (Total nitrogen

[7] The City of Boulder has conducted chlorophyll-*a* monitoring as attached algae, but it is not included in this report.

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 10 and 11 summarize the total nitrogen and total phosphorus data provided in support of this 2017 water quality analysis. Appendix I provides a fact sheet on nutrient conditions in the overall watershed.

Table 10. 2017 Total Phosphorus Data (mg/L)

Sample Location	No.	Min	Max	25%	Median	75%	Mean	Std. Dev.
BOULDER CREEK								
BC-Can	12	ND	ND	ND	ND	ND	ND	ND
BC-CU	12	ND	ND	ND	ND	ND	ND	ND
BC-61	12	ND	0.18	ND	ND	ND	0.02	0.05
BC-aWWTP	12	ND	0.14	ND	ND	ND	0.01	0.04
WWTF Eff **[W]**	12	0.79	5.26	2.59	3.26	3.58	3.08	1.15
BC-aDC	12	ND	2.06	0.41	1.28	1.59	1.07	0.69
BC-95	12	0.19	1.74	0.47	1.07	1.29	0.94	0.56
BC-107	12	ND	1.87	0.48	0.69	1.06	0.82	0.57
BC-bCC	12	0.23	1.53	0.48	0.65	1.28	0.82	0.47
9-BC	12	0.29	1.52	0.46	0.67	1.00	0.78	0.43
E-BC **[W]**	12	0.10	0.26	0.15	0.16	0.19	0.17	0.04
11-BC	12	0.24	1.31	0.36	0.63	0.93	0.67	0.36
SOUTH BOULDER CREEK								
SBC-3.5	12	ND	0.24	ND	ND	ND	0.02	0.07
COAL CREEK/ROCK CREEK								
1-CC	13	ND	0.12	ND	0.01	0.02	0.02	0.03
A-CC **[W]**	13	0.11	1.50	0.16	0.22	0.57	0.42	0.42
2-CC	13	0.04	0.77	0.08	0.12	0.30	0.22	0.22
3-CC	12	0.08	1.10	0.10	0.15	0.33	0.28	0.30
6-CC	12	0.13	0.59	0.21	0.31	0.46	0.33	0.16
C-CC **[W]**	12	2.00	3.50	2.55	3.05	3.33	2.90	0.54
7-CC	12	0.32	0.86	0.51	0.63	0.76	0.61	0.18
CC-Ken	12	0.25	2.48	0.80	1.00	1.10	1.00	0.56
4-RC	11	0.01	0.22	0.07	0.09	0.14	0.10	0.06
B-RC **[W]**	12	1.34	3.57	1.97	2.71	3.25	2.52	0.81
5-RCl	12	0.14	1.10	0.21	0.47	0.70	0.49	0.32
5-RCs	4	0.15	0.77	0.37	0.61	0.77	0.53	0.30
ST. VRAIN/LEFT HAND CREEK								
M9.5-SV	11	ND	0.05	0.01	0.01	0.01	0.01	0.01
M8.9-SV	11	0.01	0.04	0.01	0.01	0.02	0.01	0.01
M8.4-SV	11	0.01	0.04	0.01	0.02	0.02	0.02	0.01
M8.2-SV	11	0.01	0.05	0.01	0.02	0.03	0.02	0.01
M8-SV	12	0.01	0.12	0.02	0.04	0.05	0.04	0.03
LH-95	11	0.01	0.26	0.01	0.02	0.04	0.04	0.07
T11-LH	12	0.01	0.43	0.01	0.02	0.03	0.05	0.12
WWTP-LGMT **[W]**	12	0.83	5.42	2.09	3.24	4.30	3.17	1.37
T-EFF	12	0.95	4.48	2.01	2.81	3.84	2.82	1.24
M7-SV	12	0.09	1.27	0.46	0.75	0.98	0.71	0.35
M6-SV	11	0.17	1.28	0.49	0.72	1.01	0.73	0.39
M4-SV	11	0.16	0.96	0.28	0.52	0.73	0.54	0.28

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 11. 2017 Total Nitrogen Data (mg/L)

Sample Location	No.	Min	Max	25%	Median	75%	Mean	Std. Dev.
BOULDER CREEK								
BC-Can	12	0.13	0.80	0.17	0.31	0.47	0.35	0.22
BC-CU	12	0.17	1.18	0.31	0.43	0.67	0.50	0.29
BC-61	12	0.35	1.14	0.46	0.66	0.85	0.69	0.25
BC-aWWTP	12	0.28	0.96	0.45	0.49	0.57	0.52	0.17
WWTF Eff **[W]**	12	5.74	10.44	7.23	7.92	8.86	8.08	1.43
BC-aDC	12	0.45	5.36	2.30	3.84	4.43	3.41	1.54
BC-95	12	1.01	5.05	2.00	3.33	4.15	3.20	1.34
BC-107	12	0.81	6.23	2.04	2.77	3.62	3.01	1.66
BC-bCC	12	0.60	7.09	3.11	3.72	6.10	4.15	2.07
9-BC	12	1.86	6.79	1.88	3.31	4.35	3.56	1.80
E-BC **[W]**	12	9.26	14.06	9.80	10.44	11.68	10.85	1.41
11-BC	12	0.71	5.75	1.80	2.35	4.32	2.95	1.75
SOUTH BOULDER CREEK								
SBC-3.5	12	0.17	1.03	0.19	0.50	0.80	0.52	0.34
COAL CREEK/ROCK CREEK								
1-CC	12	0.20	1.80	0.30	0.37	0.51	0.52	0.44
A-CC **[W]**	12	1.71	15.00	4.00	4.50	6.38	5.83	3.57
2-CC	12	1.20	42.00	1.88	3.70	5.30	6.71	11.25
3-CC	12	0.52	9.60	2.51	3.38	4.03	3.51	2.30
6-CC	12	1.50	4.99	2.24	2.50	4.72	3.22	1.34
C-CC **[W]**	12	20.00	34.90	24.88	27.45	31.90	27.96	5.00
7-CC	12	2.60	8.41	4.92	6.85	7.96	6.35	1.82
CC-Ken	12	3.85	9.77	5.57	8.06	9.03	7.42	2.05
4-RC	11	1.19	3.21	1.37	1.78	2.80	2.06	0.78
B-RC **[W]**	12	12.31	24.23	15.12	17.51	18.71	17.49	3.19
5-RCl	12	0.69	9.20	1.47	4.00	6.75	4.37	3.14
5-RCs	4	0.80	6.17	2.91	4.89	6.17	4.19	2.56
ST. VRAIN/LEFT HAND CREEK								
M8-SV	12	0.14	1.38	0.28	0.49	0.79	0.58	0.41
T11-LH	12	0.23	2.39	0.51	0.82	1.09	0.93	0.62
WWTP-LGMT **[W]**	12	12.20	17.78	14.55	15.83	16.38	15.38	1.81
M7-SV	12	0.70	6.55	2.17	3.38	5.89	3.73	2.17

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 WWTP discharges from Louisville, Lafayette and Superior), 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 in Figures 19 through 22.

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

- 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 19) 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 19.

- Downstream of Boulder's 75th Street WWTP, a significant increase in total nitrogen and nitrate are present as shown on Figure 20 and Figure 21 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 based on pH and temperature to assess attainment of ammonia standards. All instream locations attained chronic and acute standards (Figure 22).

Figure 19. 2017 Boulder Creek and South Boulder Creek Total Phosphorus

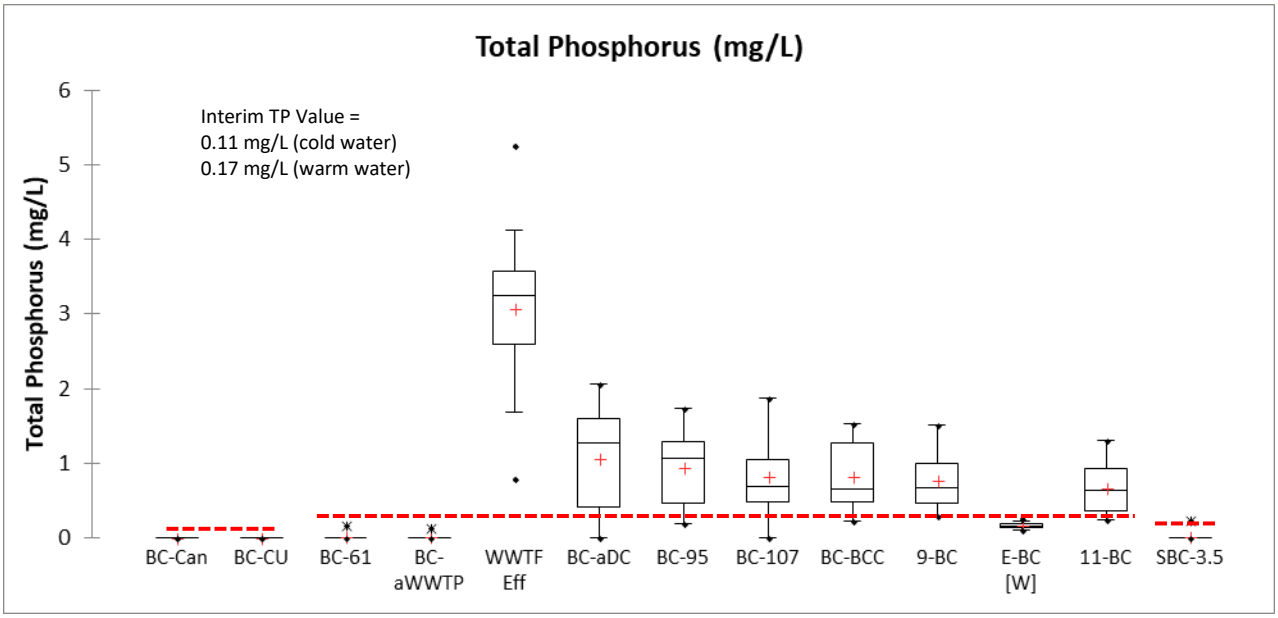


Figure 20. 2017 Boulder Creek and South Boulder Creek Nitrogen

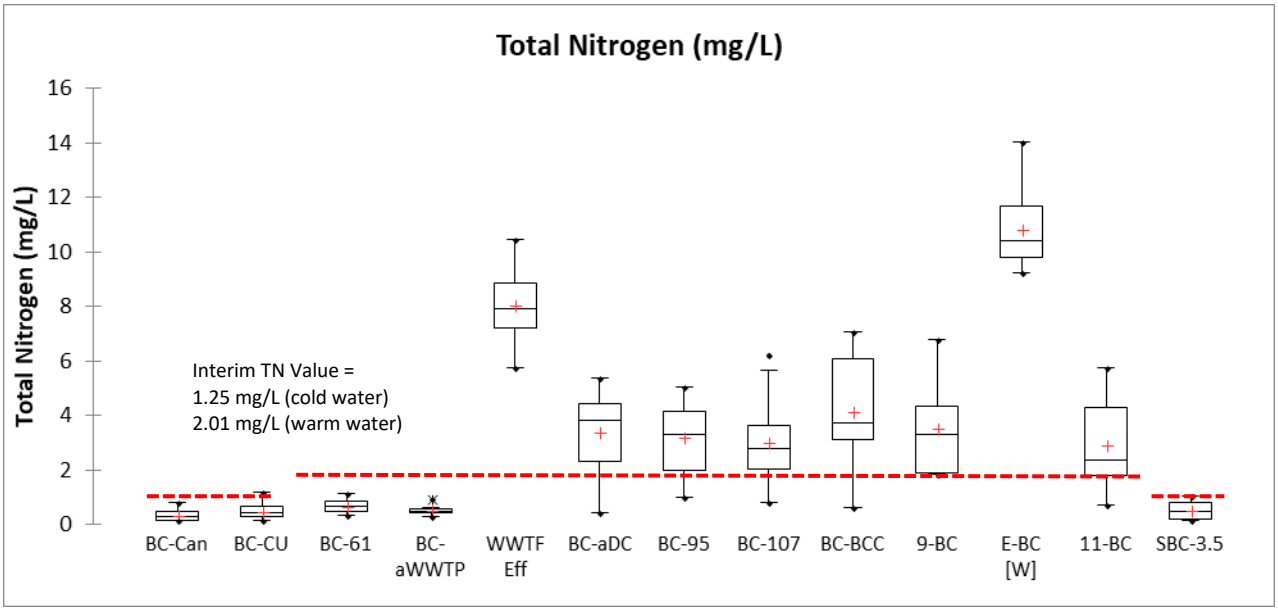


Figure 21. 2017 Boulder Creek and South Boulder Creek Nitrate

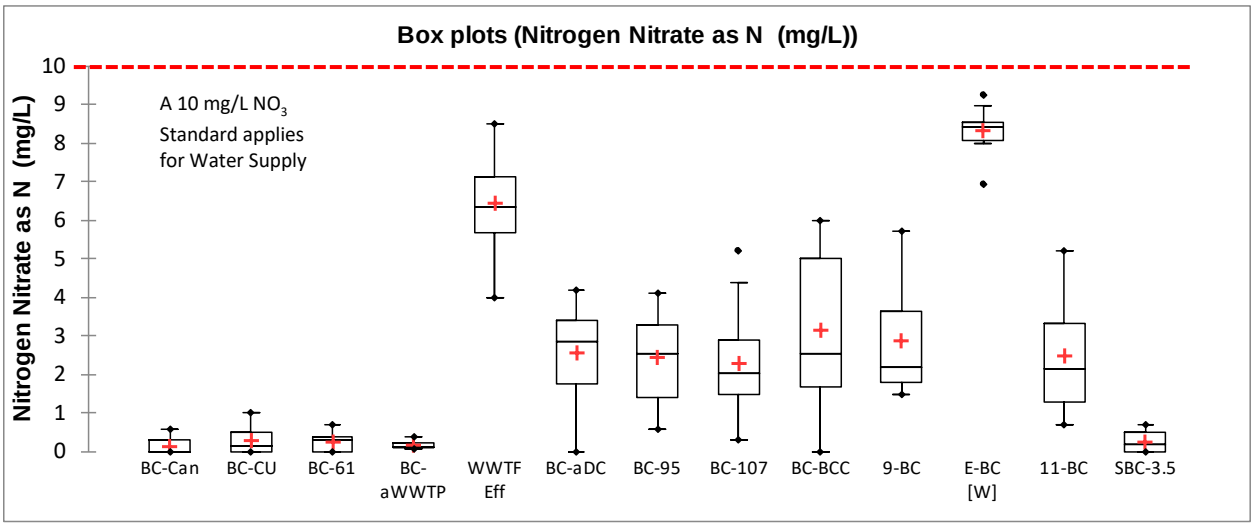
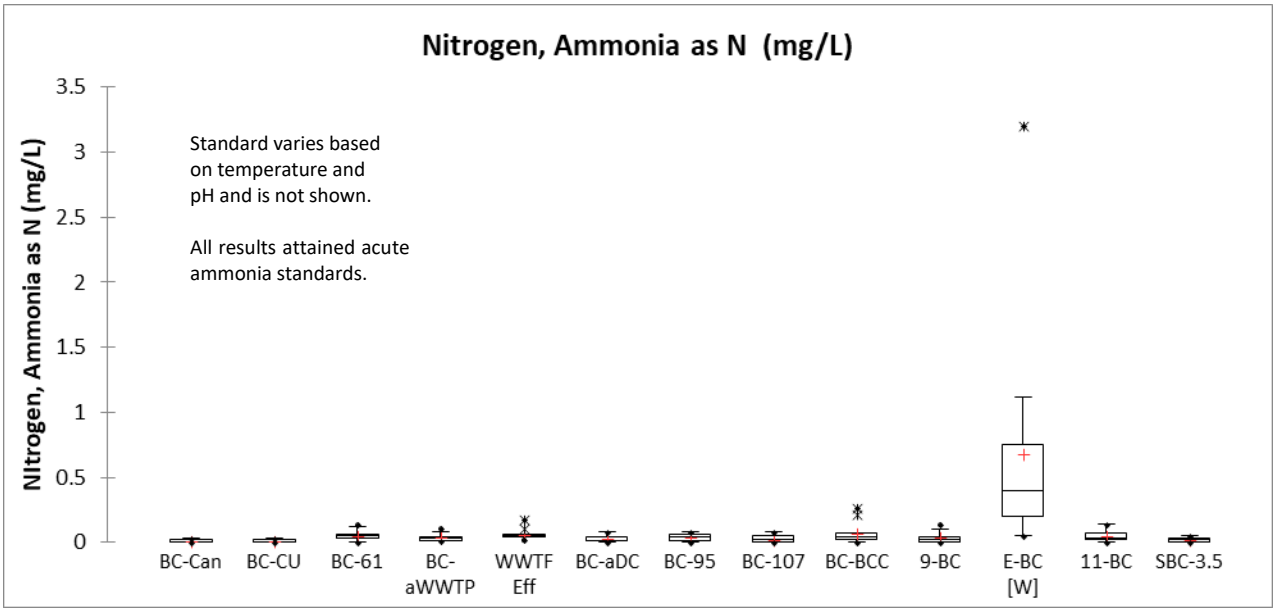


Figure 22. 2017 Boulder Creek and South Boulder Creek Ammonia



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. In Figures 23 through 26, Coal Creek results are shown to the left of Rock Creek data. Rock Creek enters Coal Creek between Coal Creek sites 3-CC and 6-CC. Rock Creek sites are represented by monitoring locations 4-RC through 5-RCs on the figures. 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 (this reach is no longer sampled or reported on by the KICP program). 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. Rock Creek at 4-RC meets 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 1-CC and upstream of the Superior discharge at 4-RC.
- Chronic and acute ammonia standards were calculated to assess attainment of instream ammonia standards. All instream locations attained chronic and acute standards.

Figure 23. 2017 Coal Creek and Rock Creek Total Phosphorus

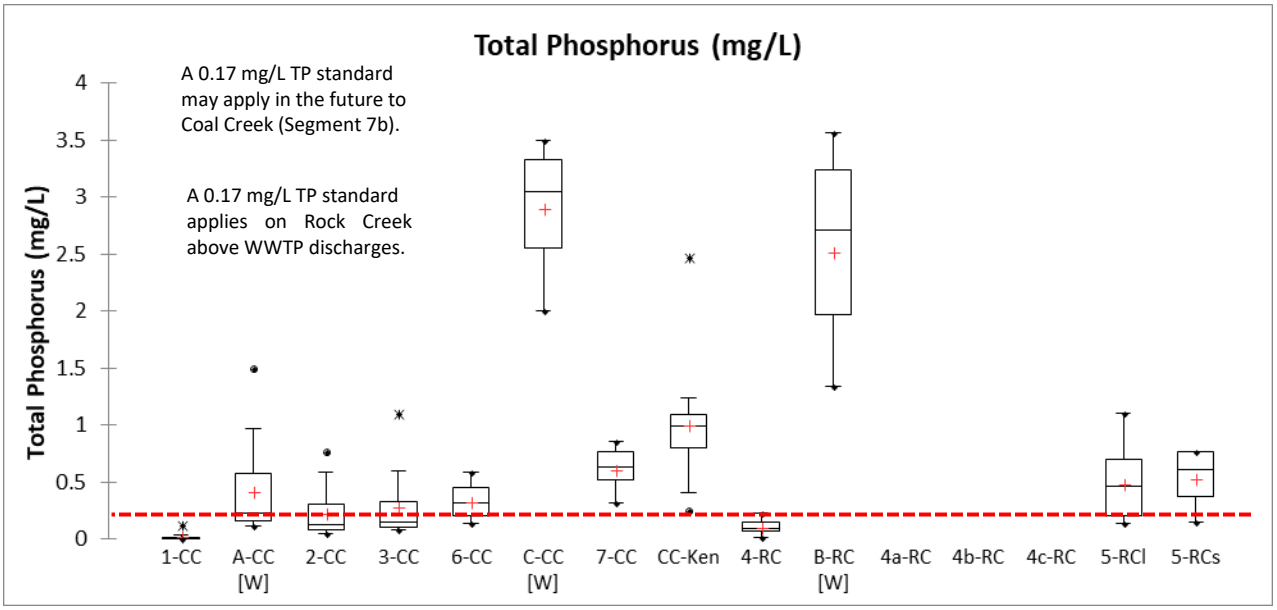


Figure 24. 2017 Coal Creek and Rock Creek Total Nitrogen

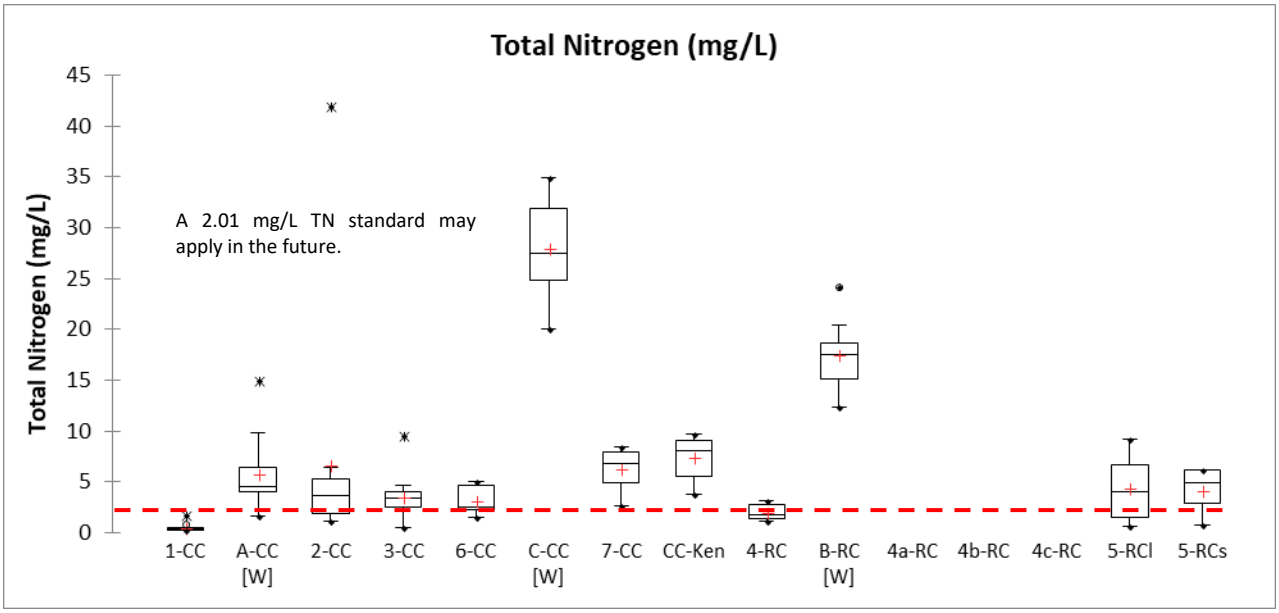
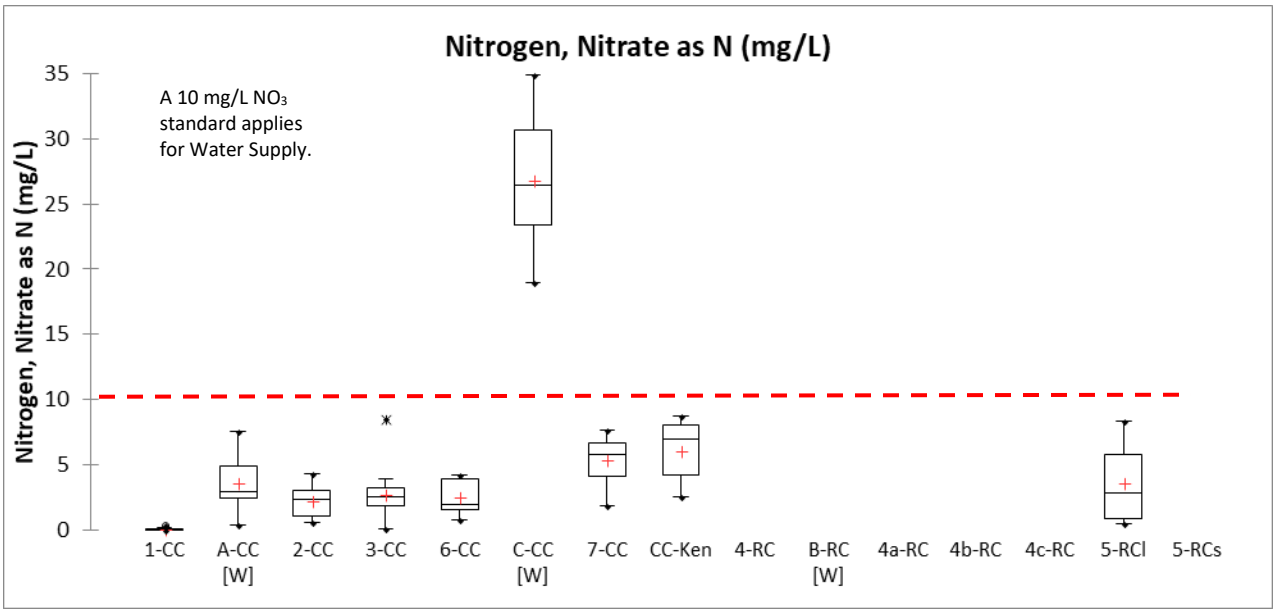
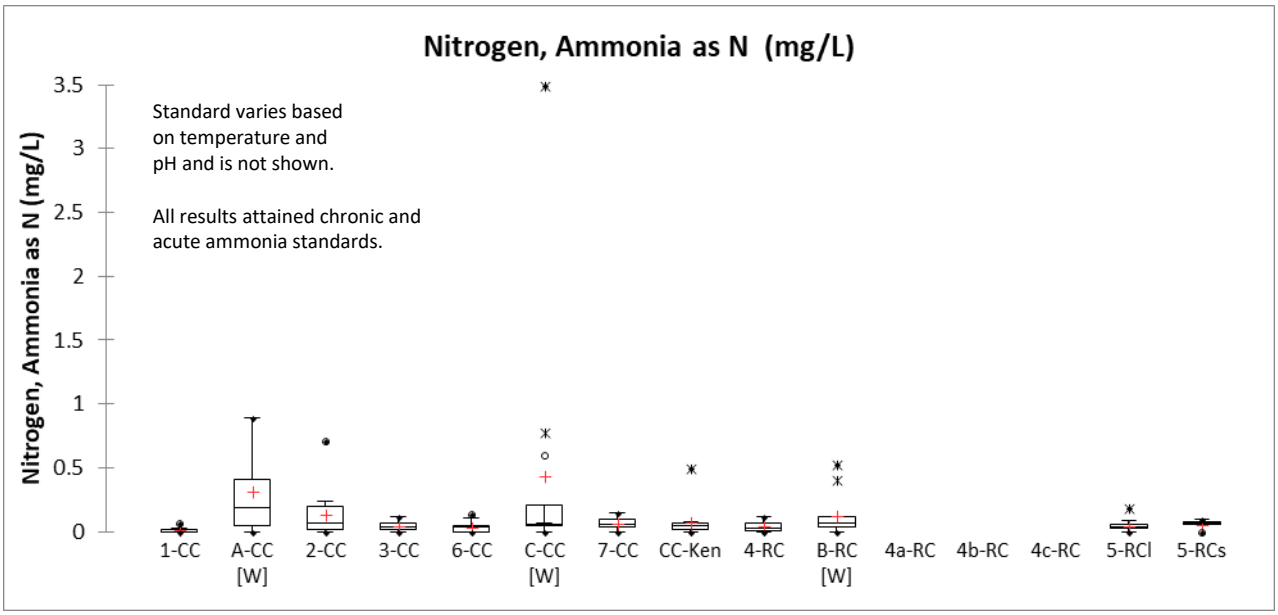


Figure 25. 2017 Coal Creek and Rock Creek Nitrate



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

Figure 26. 2017 Coal Creek and Rock Creek Ammonia



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 Gauge (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). These monitoring locations are shown on Figures 27 through 30 where these sources enter St. Vrain Creek downstream of M8-SV. 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 27 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 28 and Figure 29 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. All instream locations attained chronic and acute standards.

Figure 27. 2017 St. Vrain Creek and Left Hand Creek Total Phosphorus

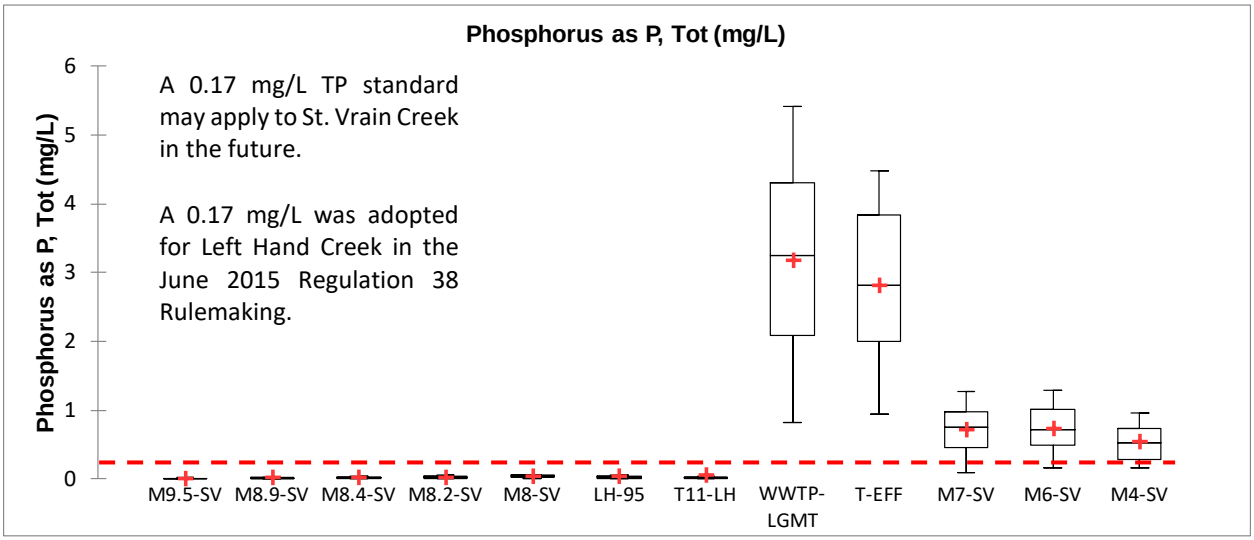


Figure 28. 2017 St. Vrain Creek and Left Hand Creek Nitrogen

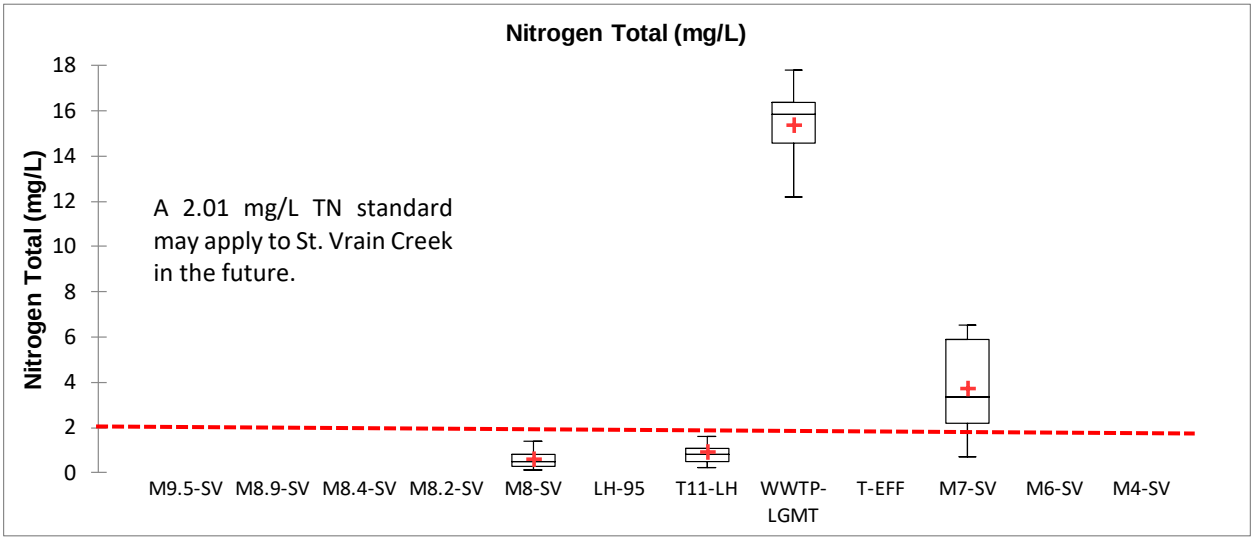


Figure 29. 2017 St. Vrain Creek and Left Hand Creek Nitrate/Nitrite

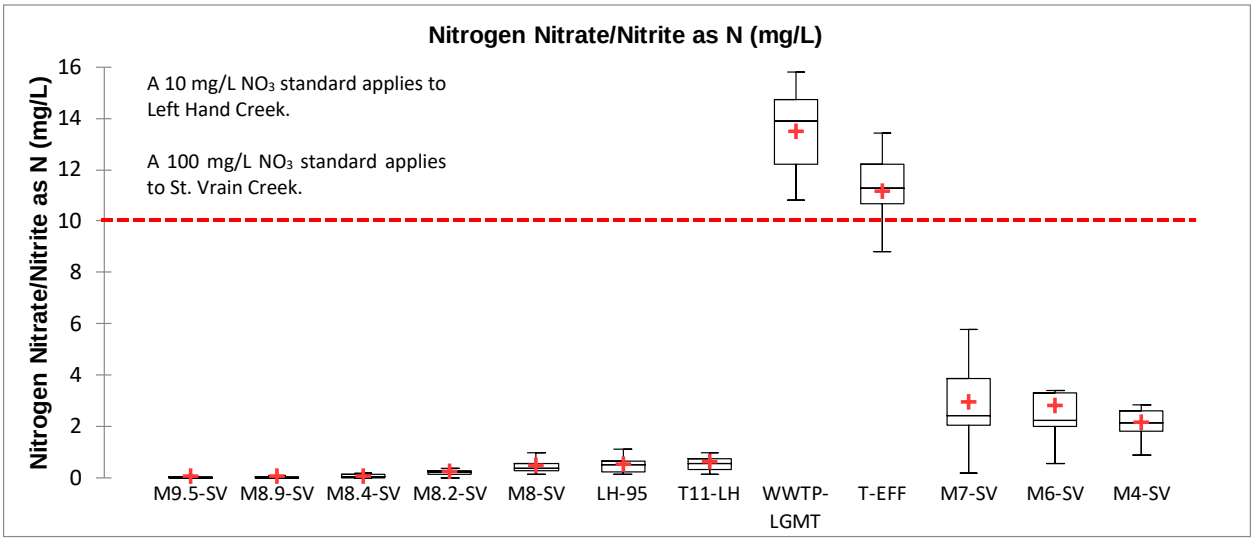
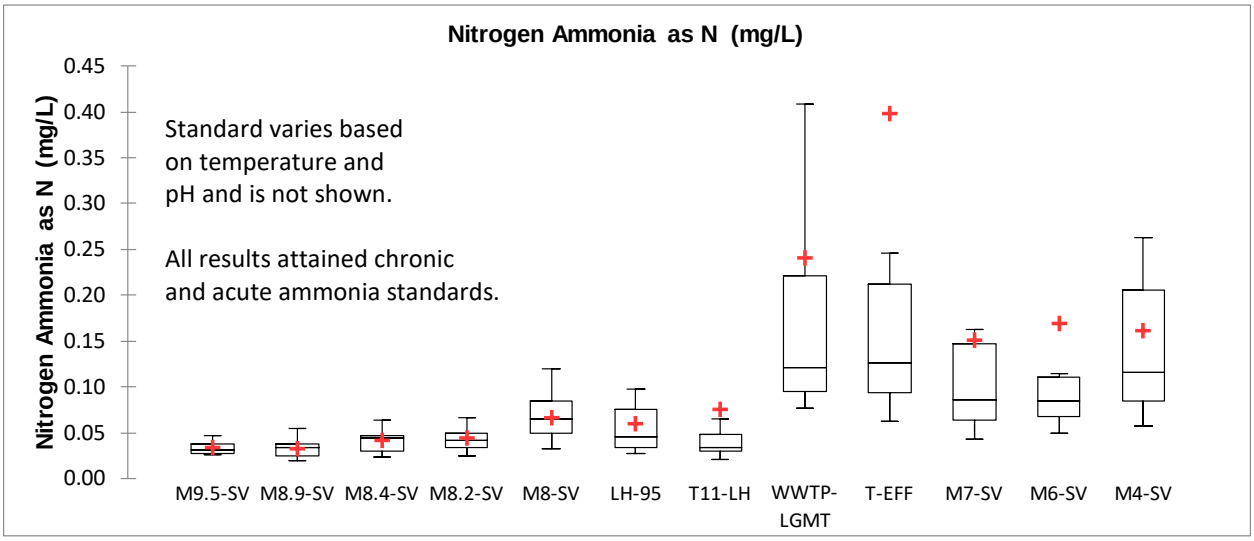


Figure 30. 2017 St. Vrain Creek and Left Hand Creek Ammonia



Total Phosphorus and Total Nitrogen Temporal Trends

As the coordinated sampling program continues, trends over time will become more meaningful to evaluate in statistically rigorous manner. Figures 31 through 36 provide annual median concentrations for the last four years of coordinated monitoring data for total phosphorus and total nitrogen. Visual observations from these figures include:

- Total phosphorus at Boulder Creek sites upstream of the WWTP are consistently low, with median concentrations below detection limits for most years. This is also true for South Boulder Creek, which is not shown on the figure. Year-to-year variability is present at most sites, although total phosphorus concentrations gradually increase over the four years at the site below the Boulder WWTP. Below Coal Creek, 2015 total phosphorus concentrations in Boulder Creek were generally higher than other years analyzed.

- Coal Creek and Rock Creek also display year-to-year variability for total phosphorus, with sites above the WWTPs on Coal Creek (1-CC) and Rock Creek (4-RC) being more constant and with lower total phosphorus concentrations. Site CC-Ken on Coal Creek above the confluence with Boulder Creek shows consistent annual increases in total phosphorus for the three years of available data.

- Total phosphorus concentrations on St. Vrain Creek are consistently low above the Longmont WWTP, with higher concentrations and year-to-year variability below the WWTP discharge that generally trends upward. Phosphorus concentrations on Left Hand Creek are generally low and appear to decrease relative to 2014 at T11-LH.

- Total nitrogen at Boulder Creek sites upstream of the WWTP are consistently low. This is also true for South Boulder Creek, which is not shown on the figure. Year-to-year variability is present at most sites, although total nitrogen concentrations generally appear to be trending downward.

- Coal Creek and Rock Creek also display year-to-year variability for total nitrogen. Sites on the upper portion of Coal Creek generally appear to be trending downward through site 6-CC, but are more variable further downstream. Total nitrogen concentrations at 5-RC are relatively constant year-to-year. Site 4-RC upstream of the WWTP discharge is close to the interim value for total nitrogen, with some years exceeding 2.01 mg/L and 2017 below 2.01 mg/L.

- Relatively few sites are monitored for total nitrogen on St. Vrain Creek and Left Hand Creek. Left Hand Creek and M8-SV upstream of Longmont's WWTP discharge are relatively low and consistent. Below the WWTP discharge, more year-to-year variability is present but with concentrations averaging approximately twice the total nitrogen interim value of 2.01 mg/L.

Figure 31. Annual Median Total Phosphorus for Boulder Creek

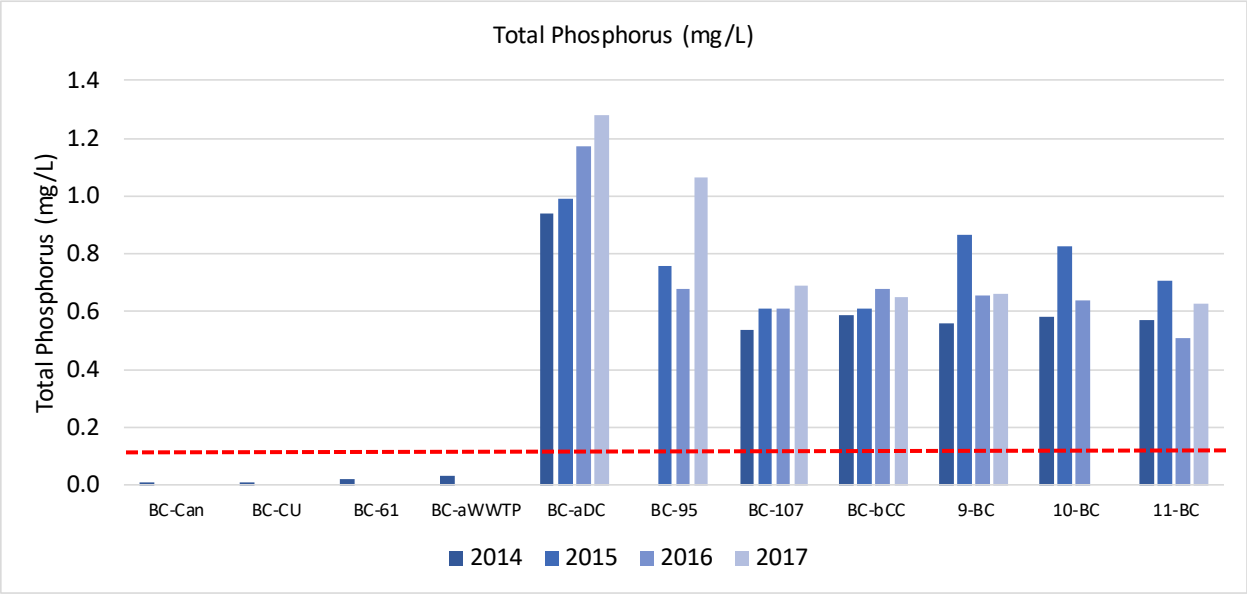


Figure 32. Annual Median Total Phosphorus for Coal Creek and Rock Creek

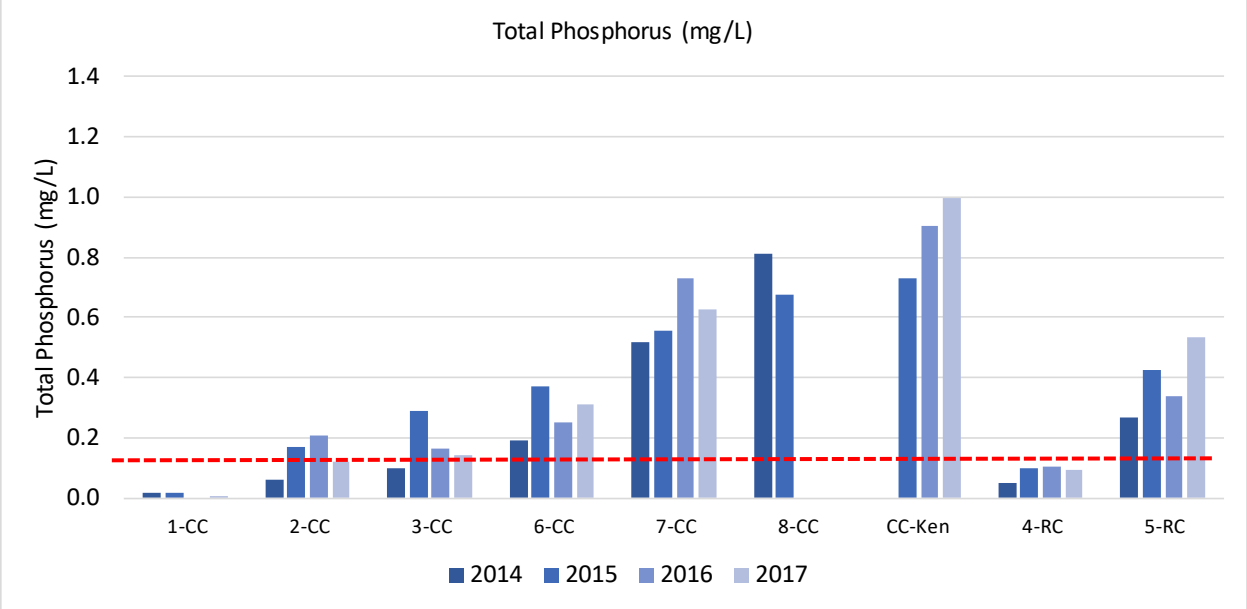


Figure 33. Annual Median Total Phosphorus for St. Vrain and Left Hand Creek

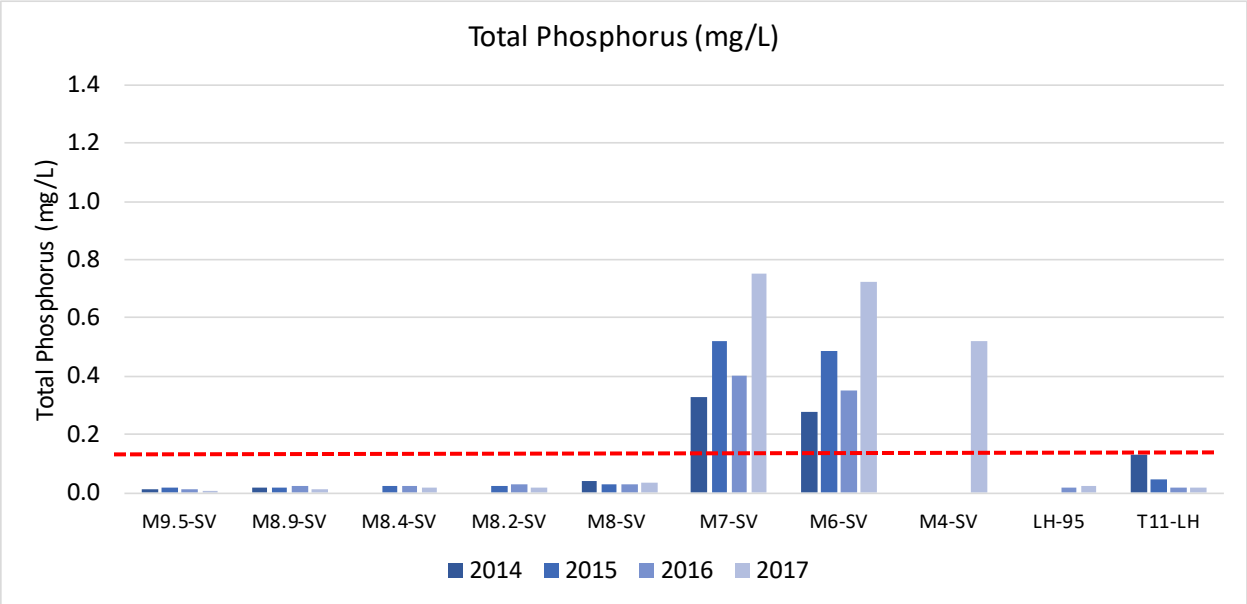


Figure 34. Annual Median Total Nitrogen for Boulder Creek

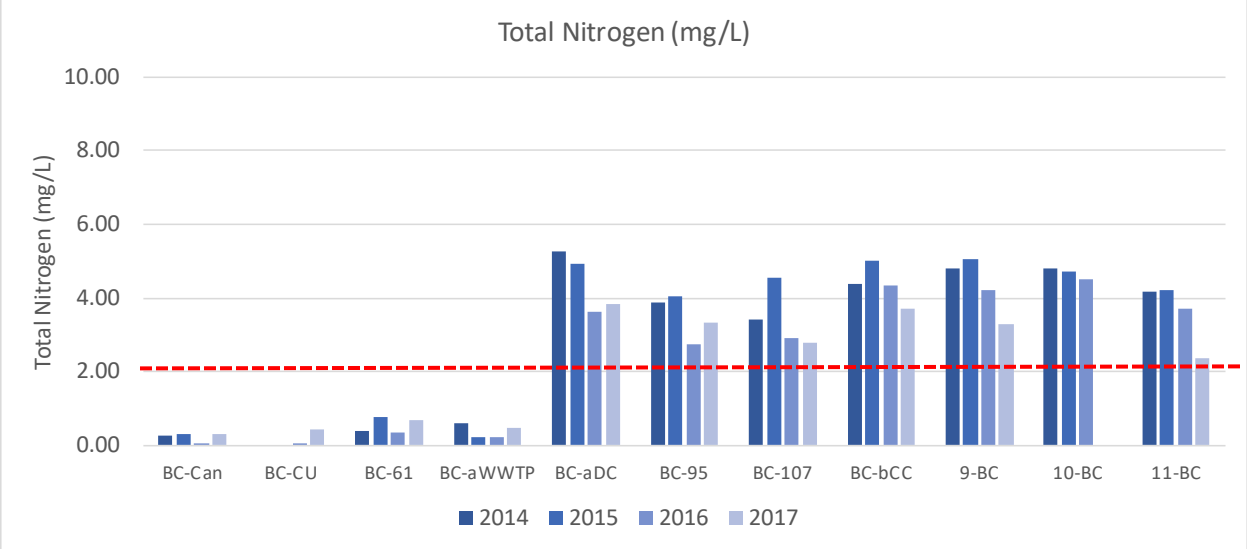


Figure 35. Annual Median Total Nitrogen for Coal Creek and Rock Creek

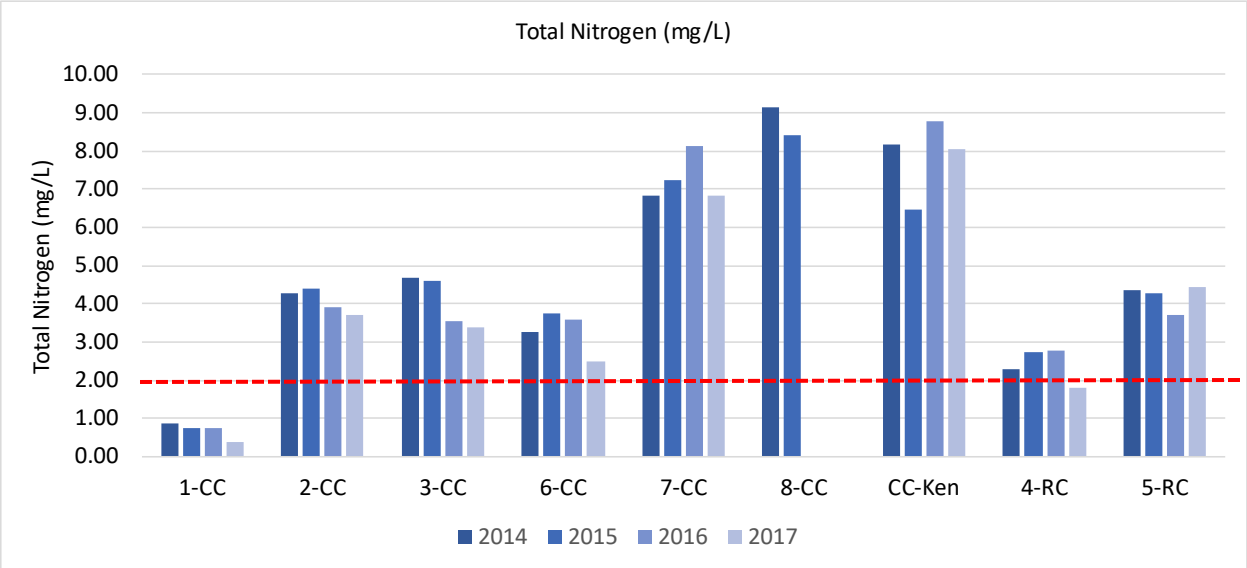
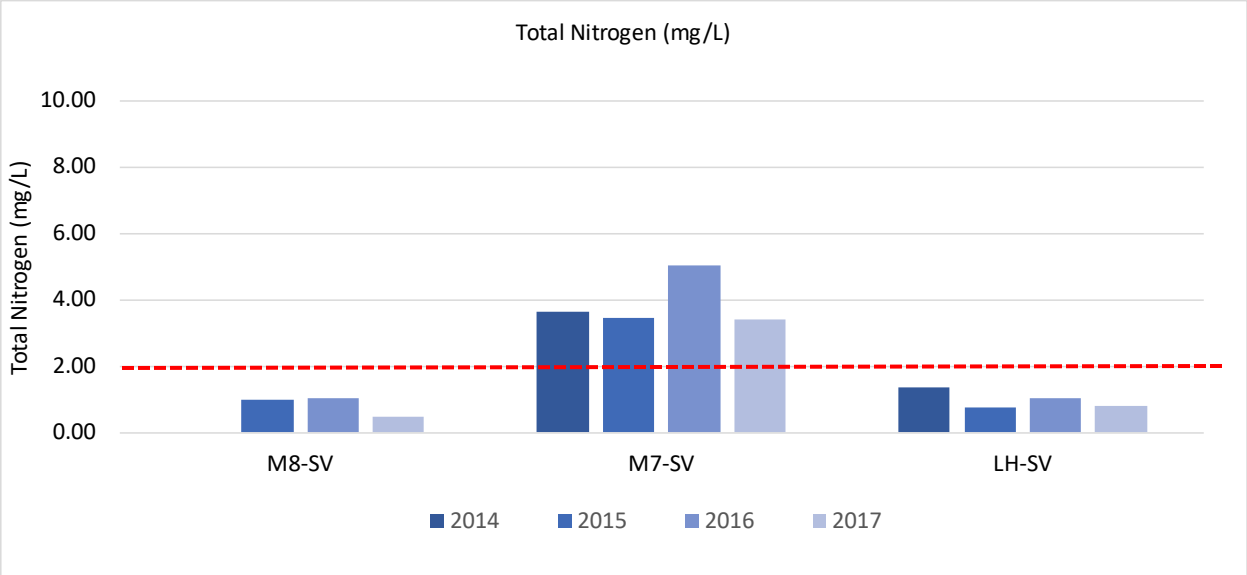


Figure 36. Annual Median Total Nitrogen for St. Vrain and Left Hand Creek



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 2017 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. However, Lafayette conduced a special *E. coli* study on Coal Creek and Rock Creek in 2016 at an increased sample collection frequency, which can be used for standards assessment purposes related to impairment designations. Results from this special study were discussed in the 2016 KICP Annual Report (WWE 2017) and are not repeated in this annual report. Lafayette's findings from 2016 monitoring confirmed impairment of Rock Creek for *E. coli,* showed higher summer concentrations, higher post-runoff concentrations and a potential "hot spot" in Warembourg Open Space when cattle are present (Lewand 2016). 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).

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 2018 303(d) List as impaired for *E. coli*.

Table 12 provides seasonal geometric mean *E. coli* concentrations according to non-recreational (N-Rec, November-April) and recreational (Rec, May-October) seasons. Figure 37 and Figure 38 provide upstream to downstream *E. coli* plots according to non-recreational and recreational seasons during 2017. During the non-recreational winter months, the geometric mean at each site typically meets standards, although individual samples may exceed the standard.

During 2017, the recreation season geometric mean concentrations exceeded 126 MPN/100 mL at BC-CU, BC-61, BC-aWWTP, BC-aDC, BC-107, and BC-bCC. *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 and 2016. 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 12. 2017 Boulder Creek and South Boulder Creek Seasonal *E. coli* Data

Station	Season	Nbr.	Geometric mean	Minimum	Maximum
BC-Can	N-Rec	6	26	3	435
BC-Can	Rec	6	66	20	488
BC-CU	N-Rec	6	58	30	197
BC-CU	Rec	6	170	76	517
BC-61	N-Rec	6	22	1	1046
BC-61	Rec	6	199	70	1300
BC-aWWTP	N-Rec	6	15	2	387
BC-aWWTP	Rec	6	159	32	727
WWTF Eff	N-Rec	6	14	2	38
WWTF Eff	Rec	5	16	9	29
BC-aDC	N-Rec	6	61	20	326
BC-aDC	Rec	6	195	104	361
BC-107	N-Rec	6	37	8	225
BC-107	Rec	5	158	16	649
BC-bCC	N-Rec	6	44	17	365
BC-bCC	Rec	6	249	49	2420
9-BC	N-Rec	6	102	38	488
9-BC	Rec	6	97	38	866
E-BC [W]	N-Rec	6	2	1	4
E-BC [W]	Rec	6	2	1	7
11-BC	N-Rec	6	61	24	649
11-BC	Rec	6	86	20	435
SBC-3.5	N-Rec	6	65	3	2420
SBC-3.5	Rec	6	69	28	313

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 37. 2017 Boulder Creek and South Boulder Creek Non-Recreation Season *E. coli*

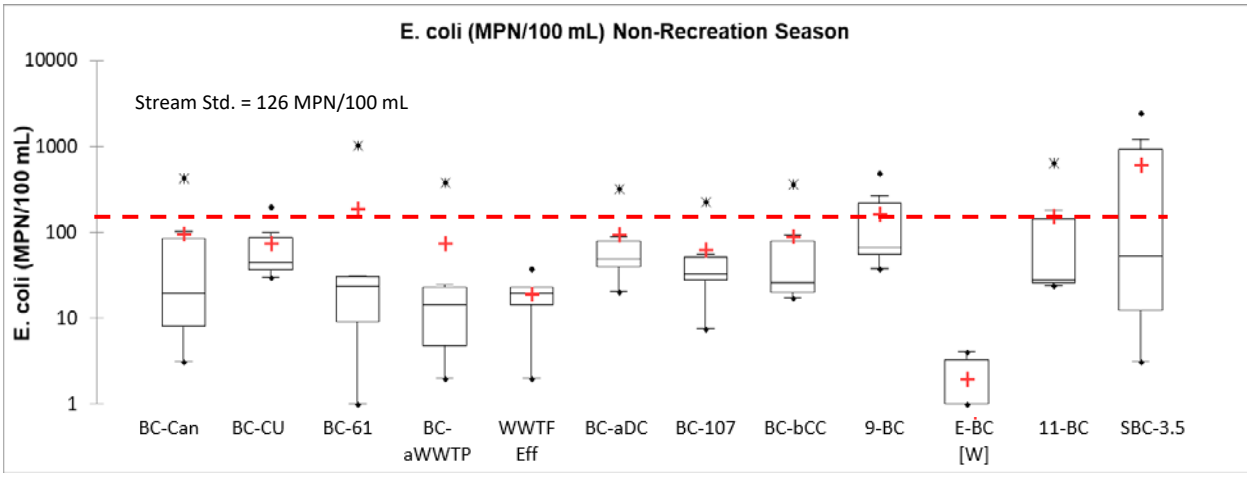
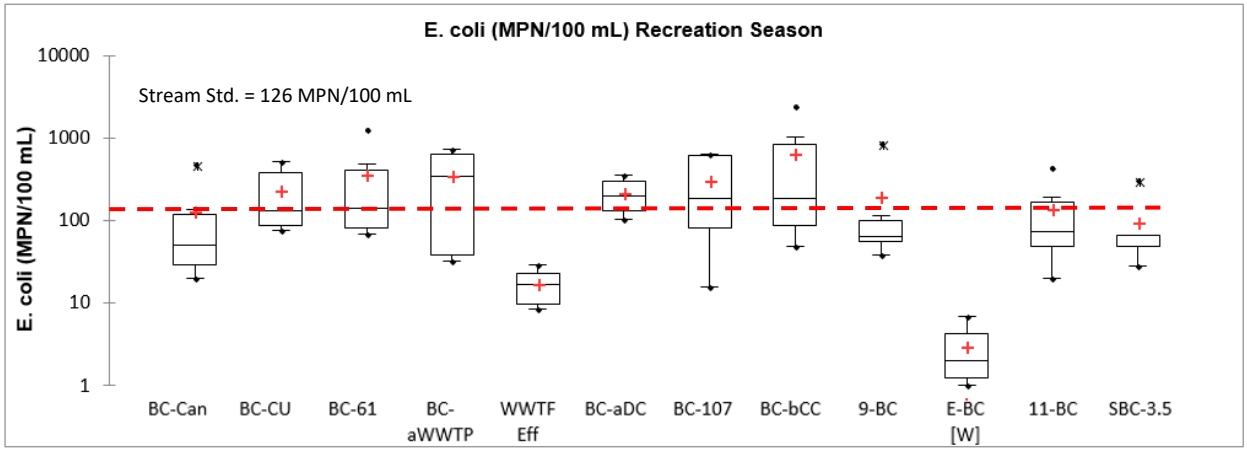


Figure 38. 2017 Boulder Creek and South Boulder Creek Recreation Season *E. coli*



Coal Creek and Rock Creek

Coal Creek is listed as impaired on the 2018 303(d) List and Rock Creek is identified in need of additional monitoring and evaluation to determine impairment for *E. coli*. Table 13 summarizes *E. coli* data available for Rock Creek and Coal Creek during 2017 and shows that all locations on Coal Creek and Rock Creek exceeded the *E. coli* standard during the recreation season, with the exception of 2-CC. Several of the Rock Creek monitoring locations only had a few samples collected, which may bias results high at these sites. The Louisville WWTP (A-CC) and Superior WWTPs (B-RC) sample results showed very low *E. coli*. Figure 39 and Figure 40 provide upstream to downstream *E. coli* plots according to non-recreational and recreational seasons during 2017.

Table 13. 2017 Coal Creek and Rock Creek Seasonal *E. coli* Data

Station	Season	Nbr.	Geometric Mean	Minimum	Maximum
1-CC	N-Rec	5	79	11	1120
1-CC	Rec	6	206	77	387
A-CC [W]	N-Rec	6	4	1	19
A-CC [W]	Rec	5	1	1	2
2-CC	N-Rec	5	124	50	345
2-CC	Rec	6	120	28	238
3-CC	N-Rec	8	76	12	517
3-CC	Rec	6	211	70	613
6-CC	N-Rec	8	73	27	613
6-CC	Rec	6	377	173	727
7-CC	N-Rec	8	89	27	727
7-CC	Rec	6	357	225	770
CC-Ken	N-Rec	6	111	27	1553
CC-Ken	Rec	6	493	91	2420
4-RC	N-Rec	5	111	17	224
4-RC	Rec	6	129	17	1373
B-RC [W]	N-Rec	6	1	1	1
B-RC [W]	Rec	6	1	1	1
4a-RC	N-Rec	2	125	79	198
4a-RC	Rec	3	201	63	690
4b-RC	N-Rec	2	204	164	255
4b-RC	Rec	3	634	476	731
4c-RC	N-Rec	2	123	108	141
4c-RC	Rec	3	779	115	3973
5-RCl	N-Rec	8	72	12	727
5-RCl	Rec	6	492	102	1553
5-RCs	N-Rec	1	208	208	208
5-RCs	Rec	3	101	96	111

Figure 39. 2017 Coal Creek and Rock Creek Non-Recreation Season *E. coli*

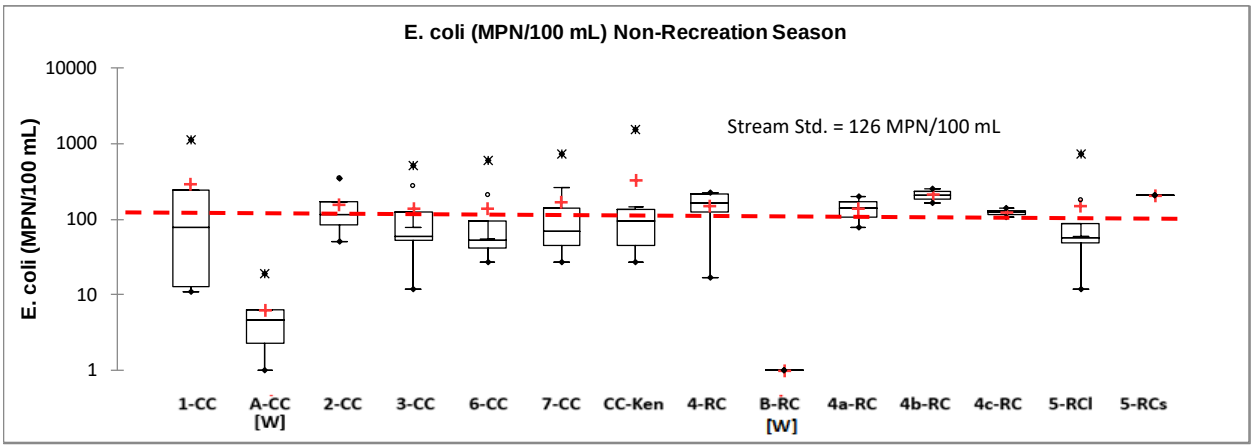
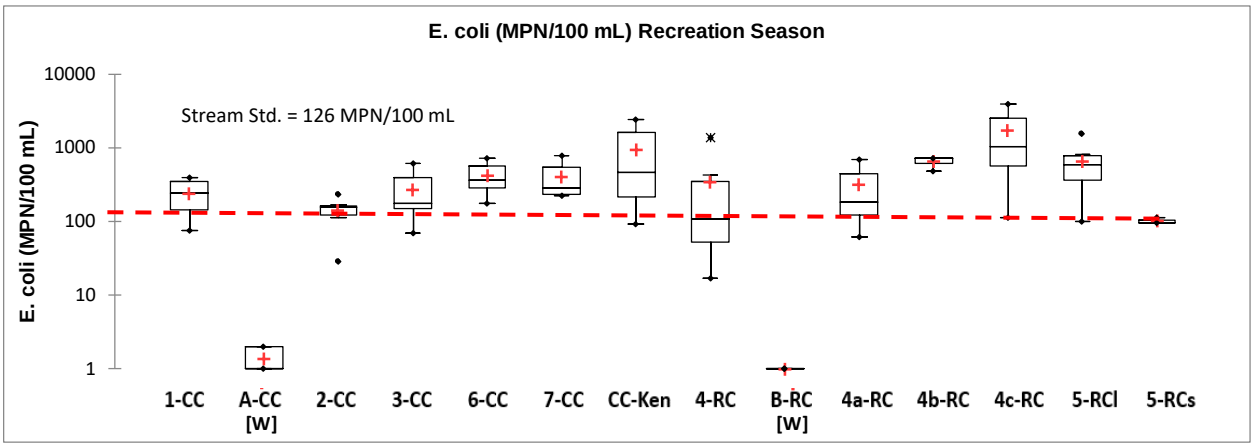


Figure 40. 2017 Coal Creek and Rock Creek Recreation Season *E. coli*



St. Vrain Creek and Left Hand Creek

St. Vrain Creek is listed on the 2018 303(d) List as impaired for *E. coli*. Table 14 summarizes *E. coli* data available for St. Vrain Creek and Left Hand Creek. Figure 41 and Figure 42 provide upstream to downstream *E. coli* plots according to non-recreational and recreational seasons during 2017. The table and figures show that seasonal geometric mean *E. coli* concentrations for Left Hand Creek at monitoring station T11-LH were above the stream standard for the recreation season. For St. Vrain Creek, all locations met the *E. coli* standard during the non-recreation season except M7-SV. Several locations on St. Vain Creek experienced some exceedances during the recreation season, including M8.9-SV, M8-SV, M7-SV, M6-SV, M5.5-SV, M4.8-SV, and M4-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. 2017 Left Hand Creek and St. Vrain Creek Seasonal *E. coli* Data

Station	Season	Nbr.	Geometric Mean	Minimum	Maximum
M9.5-SV	N-Rec	5	19	6	79
M9.5-SV	Rec	6	77	23	291
M8.9-SV	N-Rec	5	71	24	186
M8.9-SV	Rec	6	484	77	1550
M8.4-SV	N-Rec	5	46	25	109
M8.4-SV	Rec	6	66	25	291
M8.2-SV	N-Rec	5	79	45	150
M8.2-SV	Rec	6	73	21	285
M8-SV	N-Rec	6	97	31	866
M8-SV	Rec	6	209	54	1120
LH-95	N-Rec	5	26	6	70
LH-95	Rec	6	124	64	387
T11-LH	N-Rec	6	22	4	77
T11-LH	Rec	6	168	46	461
T-EFF	N-Rec	6	32	7	137
T-EFF	Rec	6	50	12	116
M7-SV	N-Rec	6	136	57	613
M7-SV	Rec	6	297	129	1050
M6-SV	N-Rec	5	84	65	115
M6-SV	Rec	6	245	84	921
M5.5-SV	N-Rec	6	112	58	387
M5.5-SV	Rec	6	148	44	687
M4.8-SV	N-Rec	6	61	5	579
M4.8-SV	Rec	6	223	51	921
M4-SV	N-Rec	6	118	53	397
M4-SV	Rec	6	260	91	816

Figure 41. 2017 Left Hand Creek and St. Vrain Creek Non-Recreation Season *E. coli*

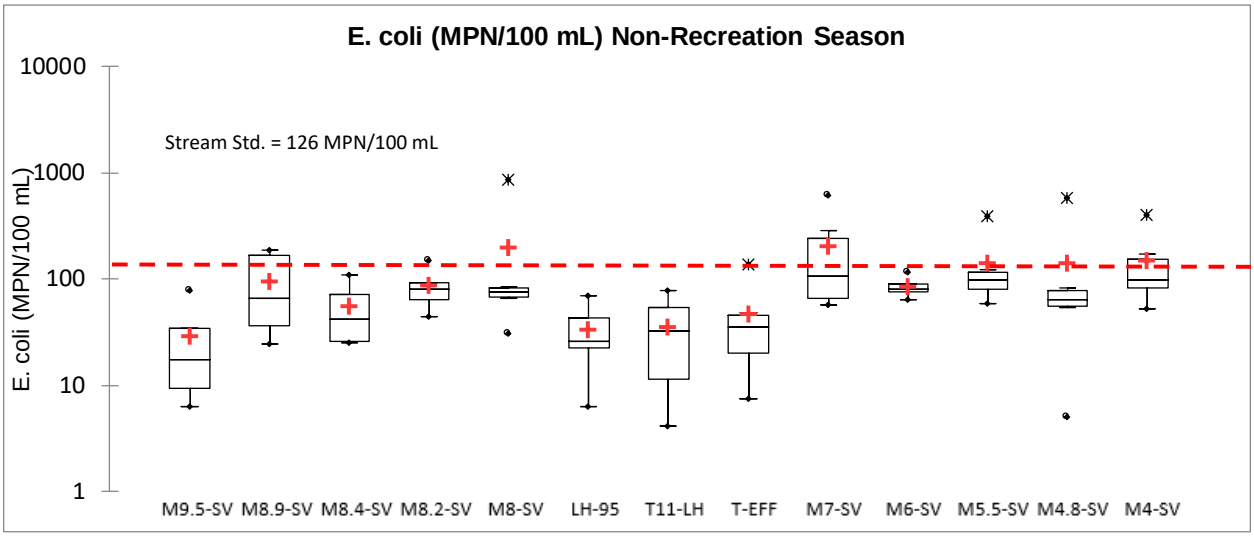
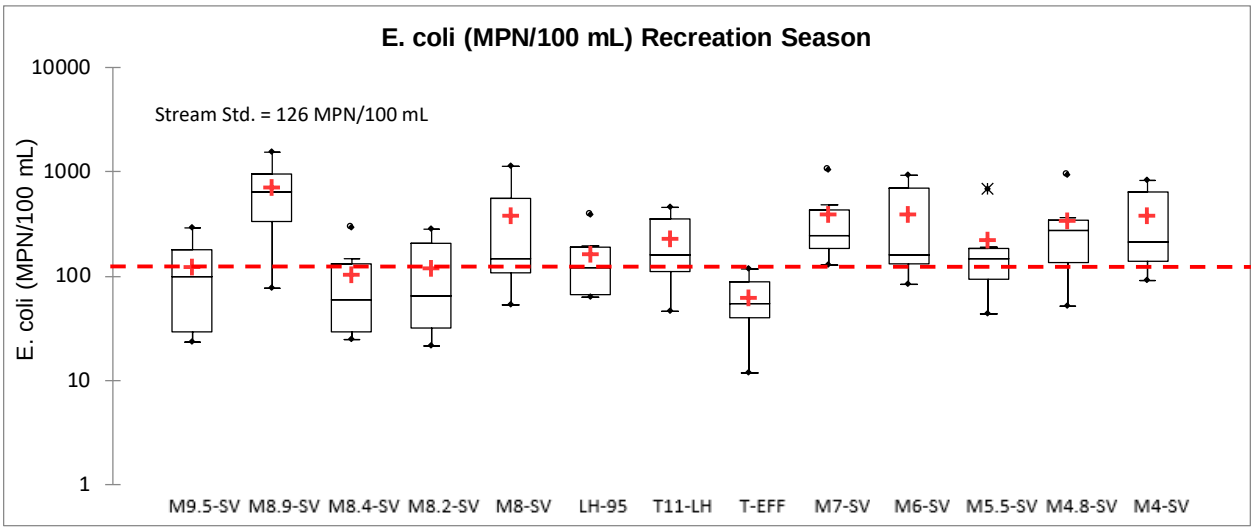


Figure 42. 2017 Left Hand Creek and St. Vrain Creek Recreation Season *E. coli*



Temporal Trends for *E. coli* 2014-2017

Four years of monitoring data for *E. coli* are now available as part of the KICP monitoring program, as summarized in Table 15 and Figure 43 through Figure 45 for the recreation season. No trends over the four years are consistently identified. For example, some site increase over time, others decrease and others increase and decrease over the time period.

Table 15. Geometric Mean Recreational Season *E. coli* Data (2014-2017)

Boulder Creek/S. Boulder Creek	2014	2015	2016	2017
BC-Can	36	40	26	66
BC-CU	103	233	241	170
BC-61	145	79	41	199
BC-aWWTP	95	76	38	159
BC-aDC	135	166	119	195
BC-107	66	67	83	158
BC-bCC	206	131	138	249
9-BC	NA	115	169	97
10-BC	NA	111	107	NA
11-BC	NA	219	176	86
SBC-3.5/4	20	90	89	69
Coal Creek/Rock Creek	**2014**	**2015**	**2016**	**2017**
1-CC	NA	521	300	206
2-CC	NA	273	196	120
3-CC	191	185	196	211
6-CC	371	618	348	377
7-CC	321	382	365	357
CC-Ken	289	258	233	493
4-RC	NA	124	95	129
5-RC*	276	411	317	492
St. Vrain/Left Hand Creek	**2014**	**2015**	**2016**	**2017**
M9.5-SV	170	77	68	77
M8.9-SV	281	135	441	484
M8.4-SV	141	87	50	66
M8.2-SV	198	120	103	73
M8-SV	100	167	177	209
LH-95			73	124
T11-LH	326	163	93	168
T-EFF	33	51	40	50
M7-SV	150	178	155	297
M6-SV**	216	121	128	245

Note: locations without at least two years of data are not included in this table.
*Used 5-RCI dataset because n=6.
**In 2017, site downstream of M4-SV ranged from 148-260 MPN/100 mL.

Figure 43. 2017 Boulder Creek and South Boulder Creek Recreation Season *E. coli* (2014-2017)

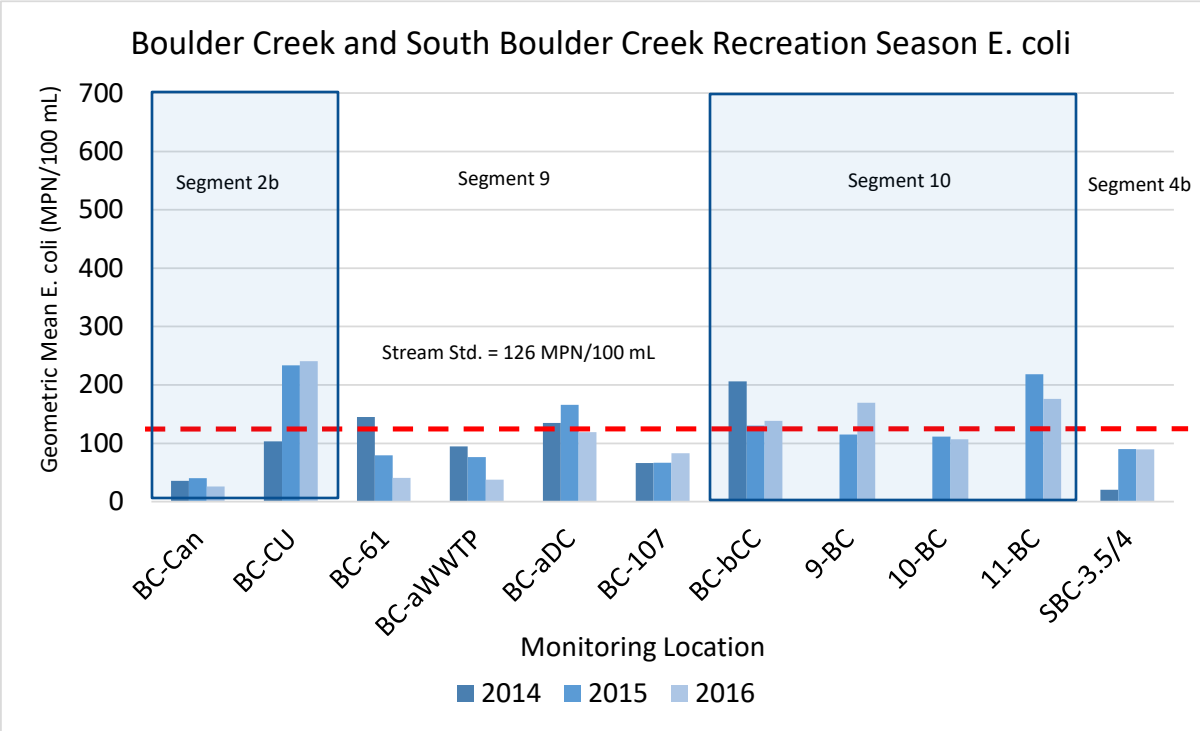


Figure 44. 2017 Coal Creek and Rock Creek Recreation Season *E. coli* (2014-2017)

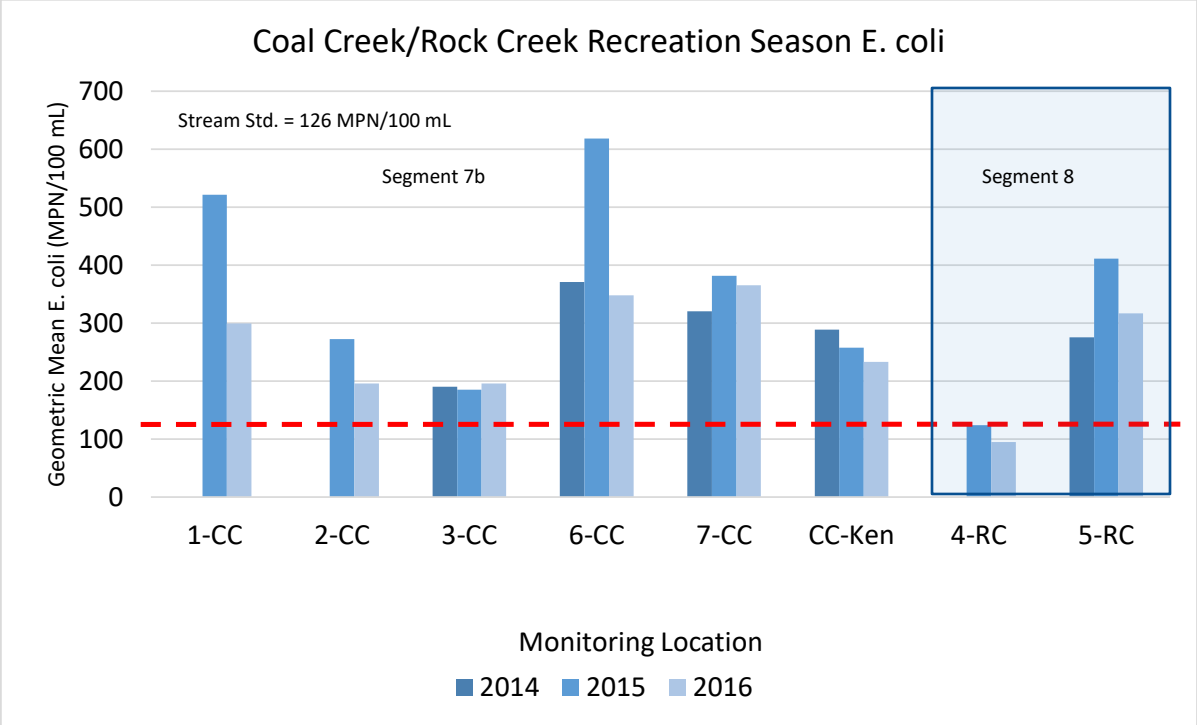
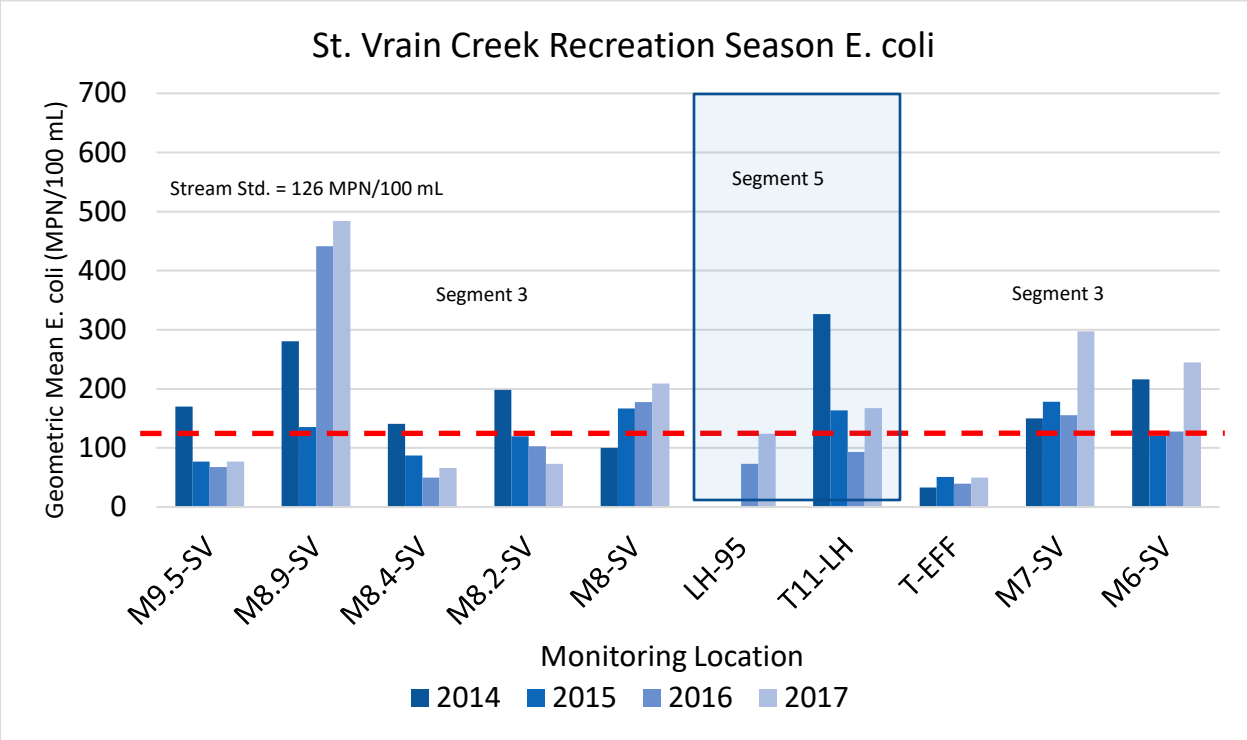


Figure 45. 2017 St. Vrain Creek and Left Hand Creek Recreation Season *E. coli* (2014-2017)



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 and Lafayette has been monitoring selenium, so several metals of potential regulatory interest are discussed in this report for these data sets. Additionally, both the Division and River Watch conducted monitoring for metals during 2017. The metals addressed in this report include:

- Total recoverable arsenic for all stream segments with data.
- Dissolved selenium for Rock Creek and Coal Creek.
- Dissolved copper for South Boulder Creek and Left Hand Creek.

Arsenic

Figure 46 through Figure 48 provide results for total recoverable arsenic on Boulder Creek, Coal Creek, Rock 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.[8] This standard is based on "water + fish," where water supply and fish ingestion are designated uses.

- 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 0.38 to 1.34 µg/L (Figure 46). The median South Boulder Creek concentration was 0.21 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 as part of Colorado 10-year Water Quality Roadmap, with a rulemaking hearing scheduled for 2021.

- Median arsenic concentrations for the two monitored locations on Coal Creek were 0.56 and 0.86 µg/L, respectively, and the median concentration for the one monitored location on Rock Creek was 1.28 µg/L.

- Arsenic concentrations on St. Vrain Creek generally increase in an upstream to downstream direction (Figure 48), 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.

[8]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 median arsenic concentrations are 0.8 µg/L at T11-LH and 1.1 µg/L at LH-95, which exceed the assigned standard of 0.02 µg/L, but is below the 10 µg/L threshold for designation as impaired.

Figure 46. 2017 Total Recoverable Arsenic for Boulder Creek and South Boulder Creek

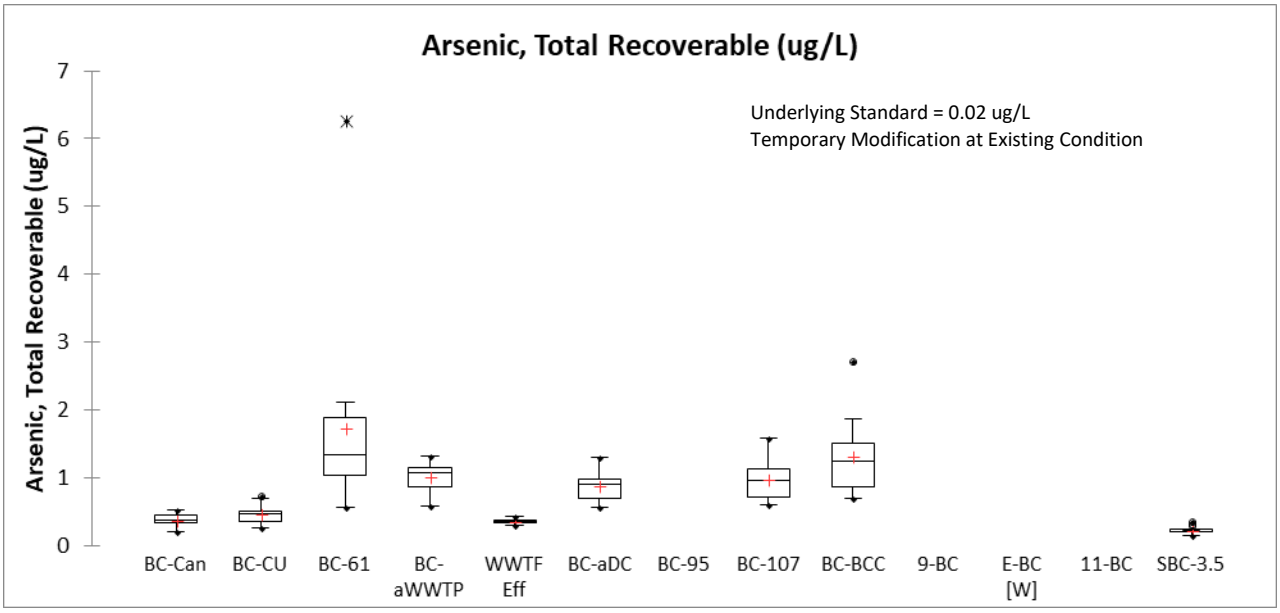


Figure 47. 2017 Total Recoverable Arsenic for Coal Creek and Rock Creek

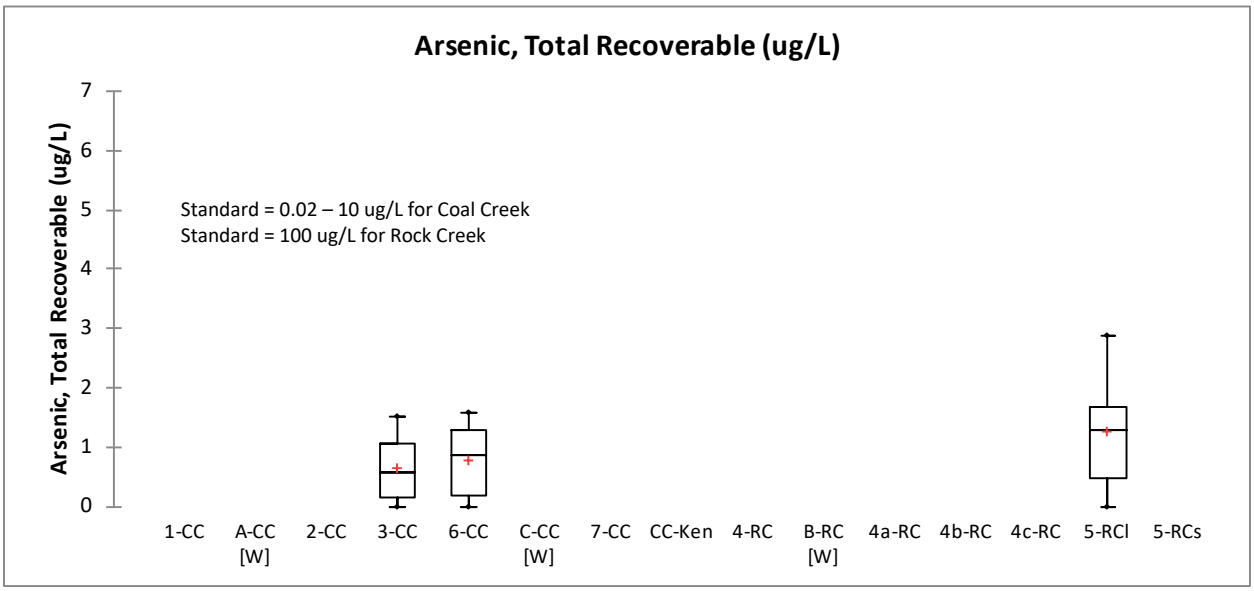
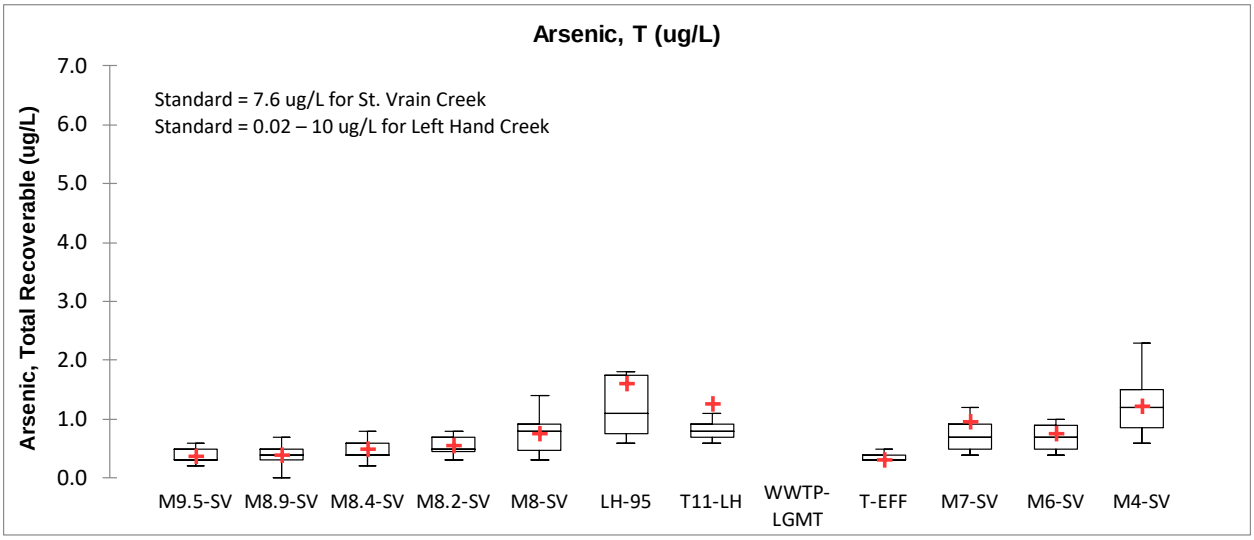


Figure 48. 2017 Total Recoverable Arsenic for St. Vrain Creek and Left Hand Creek



Selenium

During 2017, selenium data collected for all streams in the KICP monitoring program met the selenium standard with the exception of Rock Creek. 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 and remained on the 303(d) List in 2018. For Rock Creek, the underlying chronic standard for selenium is 4.6 µg/L; however, this segment has a temporary modification for selenium set at the current condition through December 31, 2020. Coal Creek does not have a temporary modification for the selenium standard.

During 2017, most of the samples in the KICP monitoring program were collected at 5-RC (Figure 49). The 85th percentile value for dissolved selenium at 5-RC was 9.15 ug/L for 2017 for 21 samples, continuing to demonstrate impairment of Rock Creek. The Division monitored Rock Creek at 120th Street between 2009 and 2013, with an 85th percentile value of 9.67 ug/L for 8 samples (Figure 50). Neither data set had exceedances of the acute selenium standard.

For Coal Creek, Figure 51 provides recent data collected under the KICP program, which does not indicate selenium impairment, even below Rock Creek. Recent Division data collected in 2017-2018 also shows attainment of the selenium standard on Coal Creek. Earlier data collected in the 2011-2013 timeframe show elevated selenium for Coal Creek at a site below the confluence with Rock Creek. Figure 52 provides the cumulative data set for the Division and River Watch from 2008 through 2018. Based on the available data, it is unclear whether Coal Creek below Rock Creek is impaired. Continued monitoring by KICP is recommended to develop a better understanding of selenium in Coal Creek. Based on available data, the portion of Coal Creek below Rock Creek continues to be of primary interest for Coal Creek.

Figure 49. Dissolved Selenium for Rock Creek Monitoring Sites in the KICP Program

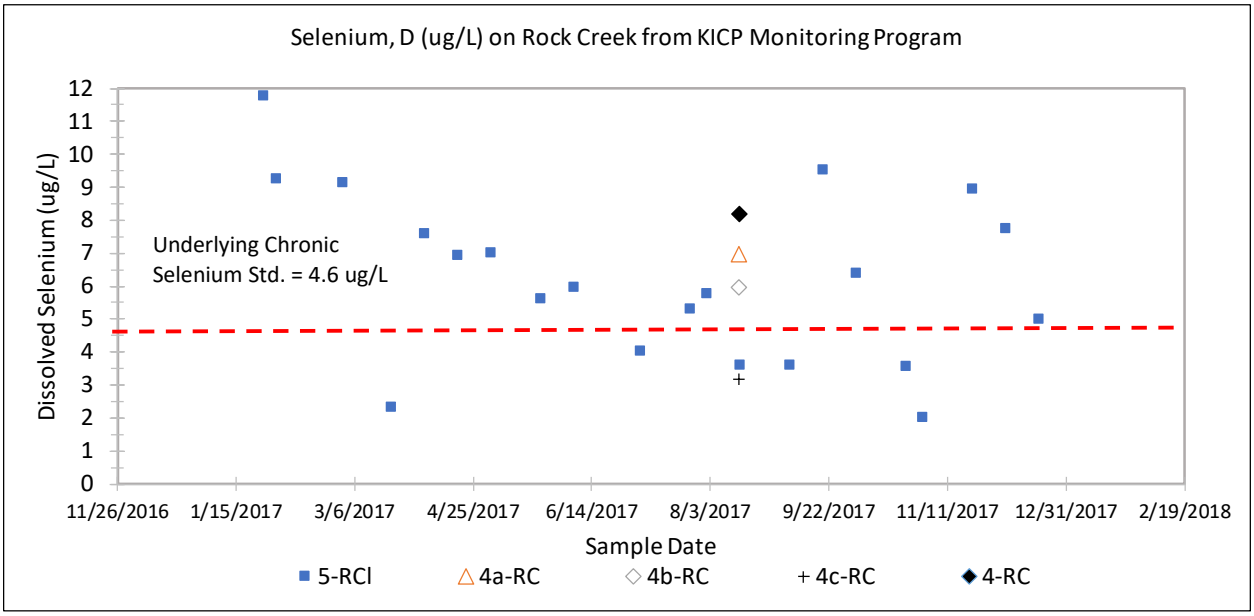


Figure 50. Dissolved Selenium for Division's Rock Creek Monitoring Site at 120th St.

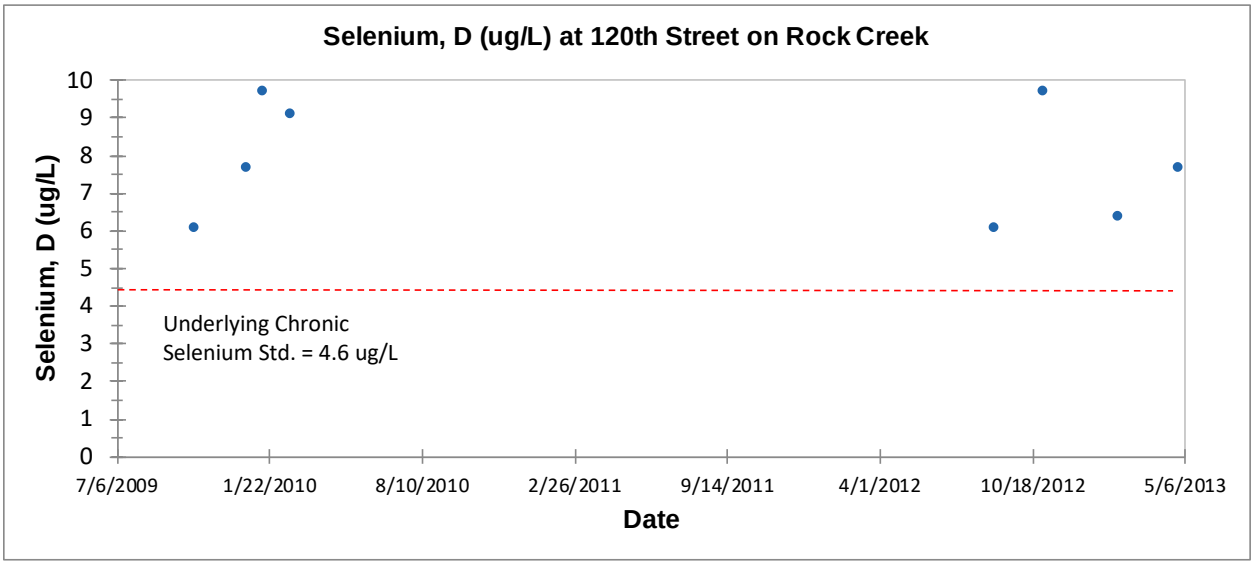


Figure 51. Dissolved Selenium for KICP's Monitoring Sites on Coal Creek

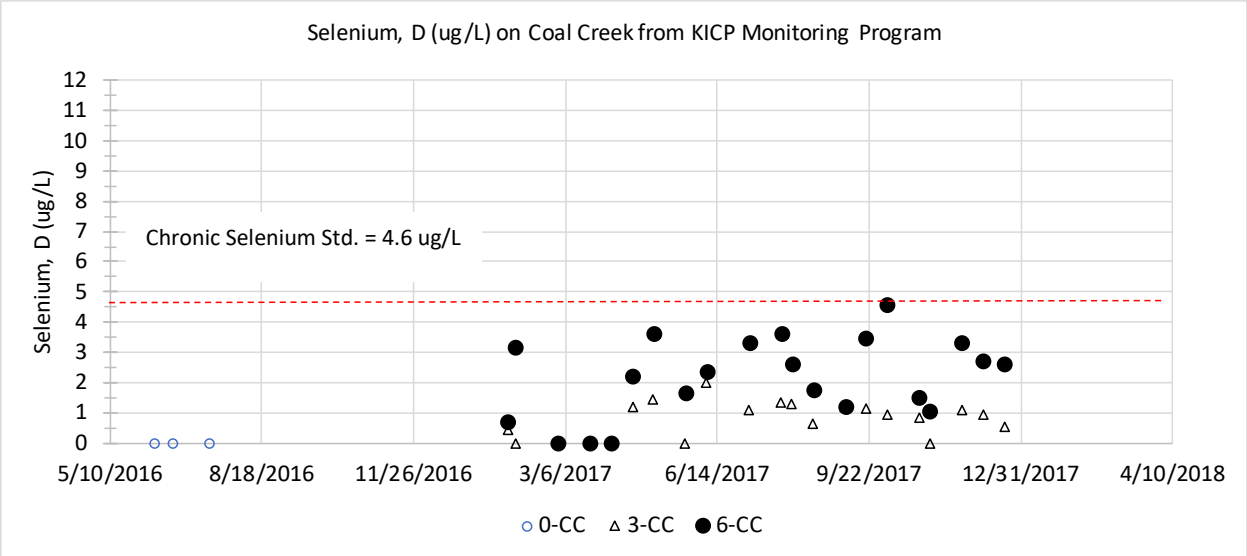
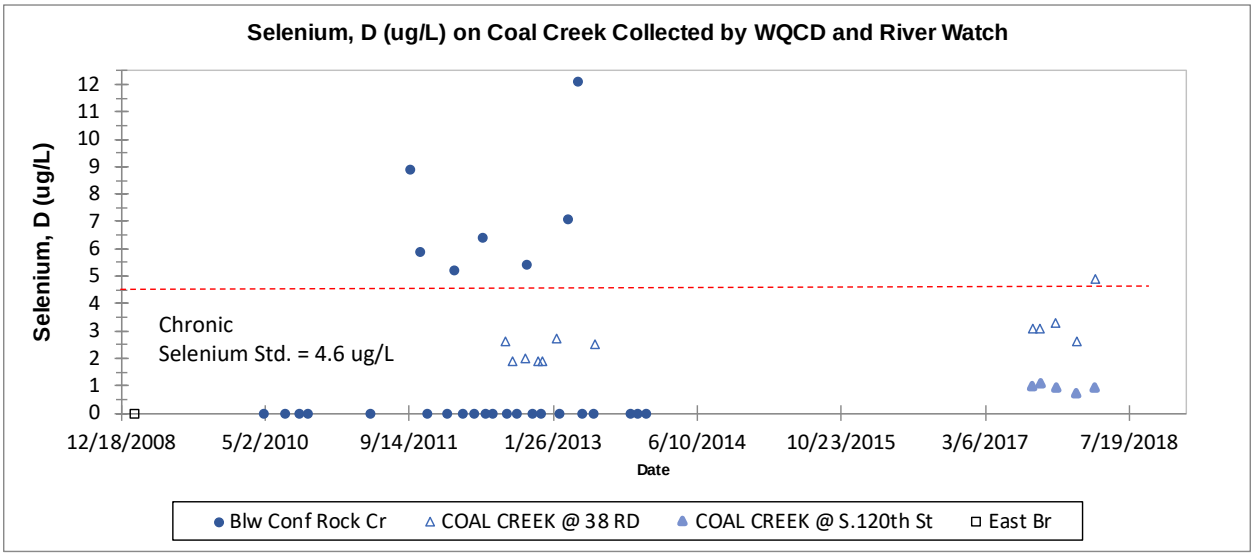


Figure 52. Dissolved Selenium for Division's and River Watch's Sites on Coal Creek



Copper

South Boulder Creek and Left Hand Creek are both listed as impaired for dissolved copper on the 2018 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).

For the most part, copper has not been a stream impairment in the urbanized portion of the watershed, which is the focus of this KICP report. The 2018 303(d) List includes two stream segments within the KICP study area that are identified as impaired for the acute dissolved copper standard, including South Boulder Creek between Gross Reservoir and South Boulder Road and Left Hand Creek from Highway 36 to St. Vrain Creek. Analysis of data collected by the City of Boulder suggests that the impairment on South Boulder Creek is likely limited to the upper portion of the segment in the South Boulder Diversion Canal and Eldorado Canyon area, given that Boulder's monitoring locations in the Open Space attain the copper standard. 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 2018 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).

The Left Hand Creek acute exceedances appear to be located primarily at the Haldi intake area, upstream of urbanized area. 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. On Left Hand Creek, only total copper data are available for the Left Hand Creek sites monitored by Longmont. A comparison of total copper data to the dissolved copper standard suggests that infrequent exceedences of the acute copper standard could potentially be occurring in the lower portion of Left Hand Creek. Monitoring for dissolved copper would be necessary to determine whether copper impairment extends into the urban area on Left Hand Creek.

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 Colorado's 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 was updated on August 7, 2017 (CWQCC 2017) and included a recalibration of the MMI (Jessup and Stribling 2017). This recalibration resulted in a different algorithm used in the Division's Ecological Data Application System (EDAS) to calculate the MMI, as well as different attainment and impairment thresholds for determining attainment and impairment. For continuity with scores calculated for KICP's long-term data set, the new methodology was **not** applied to the 2017 data set for purposes of this report. The **2010** version of Policy 10-1 should be referenced for more detailed guidance on the interpretation of MMI scores in this report.

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 16, additional evaluation using supplemental thresholds based on the Hilsenhoff Biotic Index (HBI) and the Shannon Diversity Index (SDI) () 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 16 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 (2010 Methodoloy)

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 procedure 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. As of the 2018 303(d) List, the segment of Boulder Creek where BC-aCC is located is identified as provisionally impaired for macroinvertebrates.

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[9] scores, which are provided for general reference, but not discussed in this report.

[9] 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*).

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.
- 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.)

The main stem of Boulder Creek from 107th Street to Coal Creek is identified as provisionally impaired for macroinvertebrates on the 2018 303(d) List. 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; however, 2017 MMI scores were generally lower at all sites relative to 2016 scores except for BC-28 and the South Boulder Creek site (SBC-OS). Based on MMI scores for 2017, the only site identified as impaired would be Boulder Creek at a monitoring location below the WWTP (BC-95). This site attained Biotype 1 thresholds in 2014 and 2015, but has had notably lower MMI scores in both 2016 and 2017. A cause for these changes

has not been identified and may simply represent the normal range of year-to-year variation (Personal Communication with Dave Rees, August 2018).

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

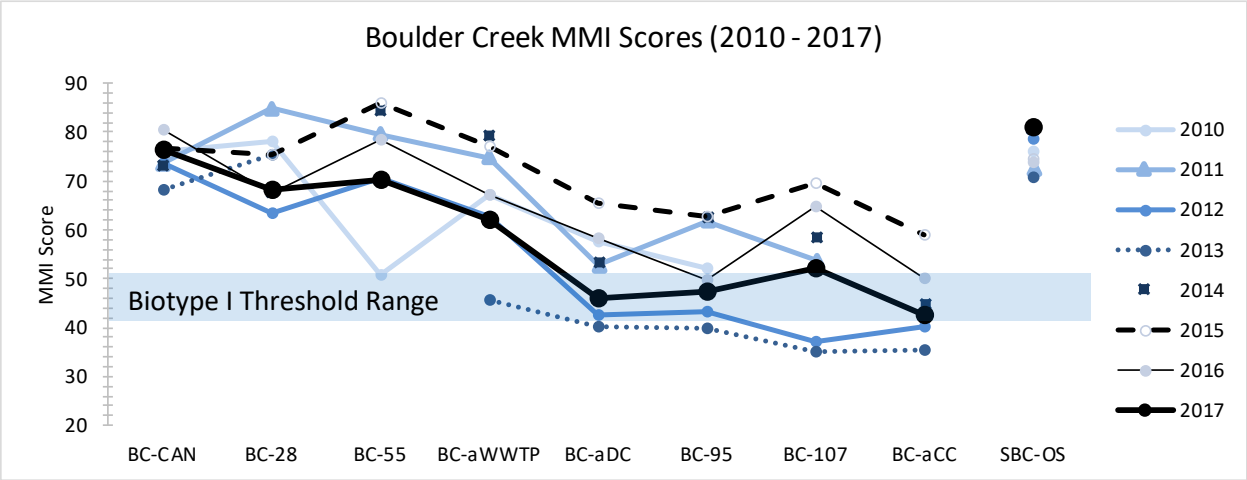
Date	BC-CAN	BC-28	BC-55	BC-aWWTP	BC-aDC	BC-95	BC-107	BC-aCC[2]	SBC-OS
23-Sep-10	76.2	78.0	**50.7**	67.3	57.7	52.2	NA	NA	76.0
29-Sep-11	73.6	84.8	79.5	74.7	52.8	61.8	53.8	NA	72.6
28-Sep-12	73.5	63.5	70.4	62.8	42.4	**43.3**	**37.0**	**40.2**	78.8
25-Oct-13	68.3	75.5	0[1]	**45.5**	**40.2**	**40.0**	**35.2**	**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
28-Sep-17	76.4	68.1	70.2	62.1	46.1	**47.2**	52.3	42.7	81.2

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 53. Boulder Creek and South Boulder Creek MMI Scores (2010-2017)



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	-
28-Sep-17	22		20	14	15	10	12	7	25
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
28-Sep-17	3.53	3.58	3.30	3.21	2.77	2.37	3.13	2.78	3.55
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
28-Sep-17	1.82	4.07	4.76	5.31	5.04	6.15	6.60	5.05	3.51

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

COAL CREEK AND ROCK CREEK

The main stem of Coal Creek from Highway 36 to the confluence with Boulder Creek is included on the 2018 Monitoring and Evaluation List due to potential impairment of aquatic life uses based on macroinvertebrate data. Upstream of this reach, the mainstem of Coal Creek from Highway 93 to Highway 36 was also identified as provisionally impaired for macroinvertebrates on the 2018 303(d) List, but is upstream of the KICP study area. Five biological monitoring locations are included for Coal Creek and Rock Creek between Highway 36 to the confluence with Boulder Creek. Each of these locations is classified as Biotype 1 on Aquatic Life Class 2 stream segments and include these sites:

- 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.
- 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).
- RC-120: on Rock Creek, approximately 1 km upstream of its confluence with Coal Creek, downstream of Superior WWTP.

Several monitoring locations on Coal Creek are considered impaired based on 2017 MMI scores, whereas Rock Creek's MMI score falls between impairment and attainment. Most of the sites showed decreases in MMI scores following the September 2013 flood; however, the 2014 through 2017 MMI scores showed significant recovery of the aquatic life at most of these sites, with the exception of CC-OSB. In 2017, the only site with an MMI score in the attainment range on Coal Creek was site CC-CLR; however, most scores improved relative to 2016 other than CC-AP.

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	CC-AP	CC-CLR	RC-120
22-Sep-10	**38.1**	42.2	44.1	50.1	**38.6**
28-Sep-11	**39.8**	**37.4**	51.4	49.7	**36.0**
27-Sep-12	43.7	**33.6**	42.2	53.6	**22.5**
26-Oct-13	**24.5**	**32.3**	**38.1**	**36.6**	**24.1**
28-Sep-14	47.8	**31.5**	51.3	53.4	**36.0**
23-Sep-15	48.2	**27.3**	54.4	58.9	44.6
24-Sep-16	**36.2**	**27.8**	53.0	45.9	**30.9**
22-Sep-17	**41.4**	**32.9**	48.2	53.7	43.3

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

Figure 54. Coal Creek and Rock Creek MMI Scores (2010-2017)

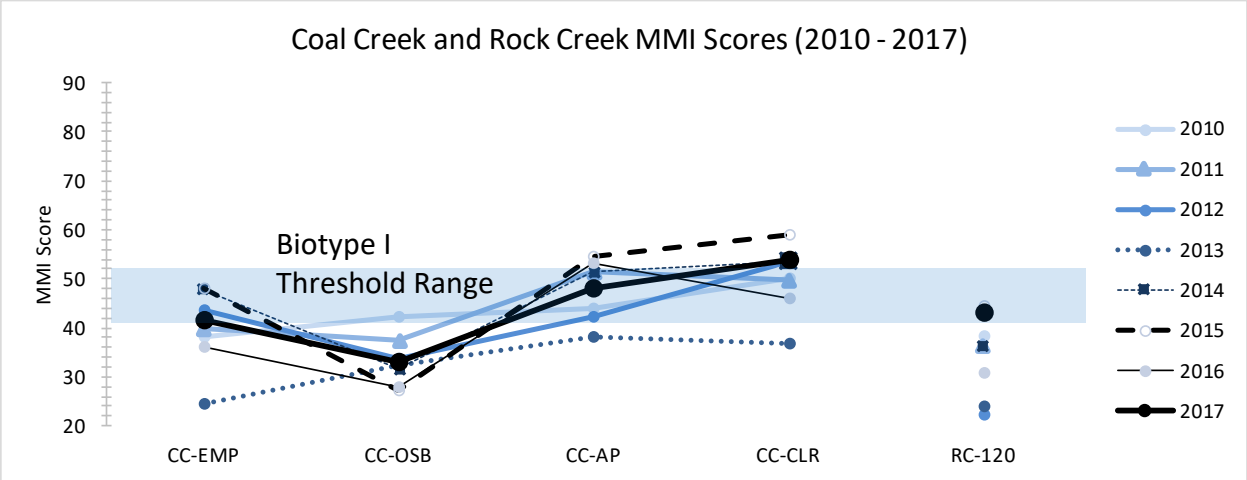


Table 21. Coal Creek and Rock Creek EPT, Diversity Index and HBI Scores

Date	CC-EMP	CC-OSB	CC-AP	CC-CLR	RC-120
EPT Scores					
22-Sep-10	6	7	9	8	8
28-Sep-11	6	4	9	8	8
27-Sep-12	6	2	6	10	6
26-Oct-13	4	6	7	10	4
28-Sep-14	9	5	10	9	7
23-Sep-15	10	6	10	10	8
24-Sep-16	8	3	10	10	7
21-Sep-17	8	4	9	10	8
Shannon Diversity Index Scores					
22-Sep-10	2.23	2.02	3.11	2.56	3.42
28-Sep-11	1.97	1.76	3.35	2.79	3.35
27-Sep-12	2.32	1.30	2.68	2.58	2.59
26-Oct-13	2.76	2.91	2.70	2.46	1.99
28-Sep-14	2.70	2.71	2.82	2.61	2.48
23-Sep-15	2.58	2.50	2.63	2.67	2.53
24-Sep-16	1.49	1.32	2.93	2.95	3.08
21-Sep-17	2.18	1.76	2.78	2.72	3.07
HBI Scores					
22-Sep-10	6.29	6.48	5.12	4.64	5.92
28-Sep-11	6.27	6.86	5.66	4.77	5.77
27-Sep-12	6.65	6.69	5.97	5.24	6.79
26-Oct-13	6.73	6.51	6.47	5.95	6.37
28-Sep-14	6.08	5.97	5.53	4.86	5.73
23-Sep-15	6.13	5.84	5.77	4.97	5.25
24-Sep-16	6.84	6.75	5.54	5.05	6.03
21-Sep-17	6.25	6.20	5.30	4.79	5.14

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.[10] Monitored sites on St. Vrain Creek are classified as Aquatic Life Warm Class 1 segments and sites on Left Hand Creek are classified as Aquatic Life Warm Class 2 segments. Monitored sites 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.

[10] 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-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.

- 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-M4.8: new site located on St. Vrain Creek below Spring Gulch #2.

- 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 and a new site is being monitored in its place, beginning with the 2017 data set.

- SVC-M4 mod: After the flood in 2013, there were many changes in this reach of St. Vrain Creek. A new channel was created during the flood and the old location for M4 has been dry for the last 5 years. Also, Boulder Creek now enters St. Vrain Creek more than 0.5 miles upstream from the previous confluence. St. Vrain creek also flows through a small lentic habitat upstream from SVC-M4 mod. The old site (SVC-M4) and new site (SVC-M4 mod) are not really directly comparable, other than the new site (SVC-M4 mod) continues to monitor aquatic life in the lower portion of the study area (without influence from Boulder Creek).

- LH-95: 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 2017, all MMI scores for St. Vrain Creek and Left Hand Creek met the MMI attainment threshold, except SVC-M6 and SVC-M4.8, which had scores between the impairment and attainment thresholds for Biotype I. Due to stream restoration activities repairing damage from the 2013 flood, there may be temporary stream improvement-related disruptions occurring that lead to variability in MMI scores on St. Vrain Creek, which shown some decrease in 2017 MMI scores relative to 2016. For Left Hand Creek, observations during biological sampling in 2016 indicated that eroded sediment in the upper portion of Left Hand Creek has been flushed downstream, with substrate at LHC-1 covered with about 2 feet of sediment. Field observations in 2017 indicated that most of the fine sediment that had accumulated at LHC-1 has been flushed out of Left Hand Creek during runoff. Observations during the fall of 2017 indicated that the substrate at site LHC-1 was much improved and the macroinvertebrate community was healthier

than it had been in years (Personal Communication with Dave Rees). The MMI score at LHC-1 increased over 30 points between 2016 and 2017.

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-M4.8	SVC-M4	LHC-95	LHC-1
WQ Cross-Ref ID	M9.5-SV	M8.9-SV	M8-SV	M6-SV	M4.8-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**
22-Sep-17	74.5	69.2	53.0	49.1	42.3	54.4*	61.4	67.8

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.
*Modified site relative to previous monitoring years.

Figure 55. St. Vrain and Left Hand Creek MMI Scores (2010-2017)

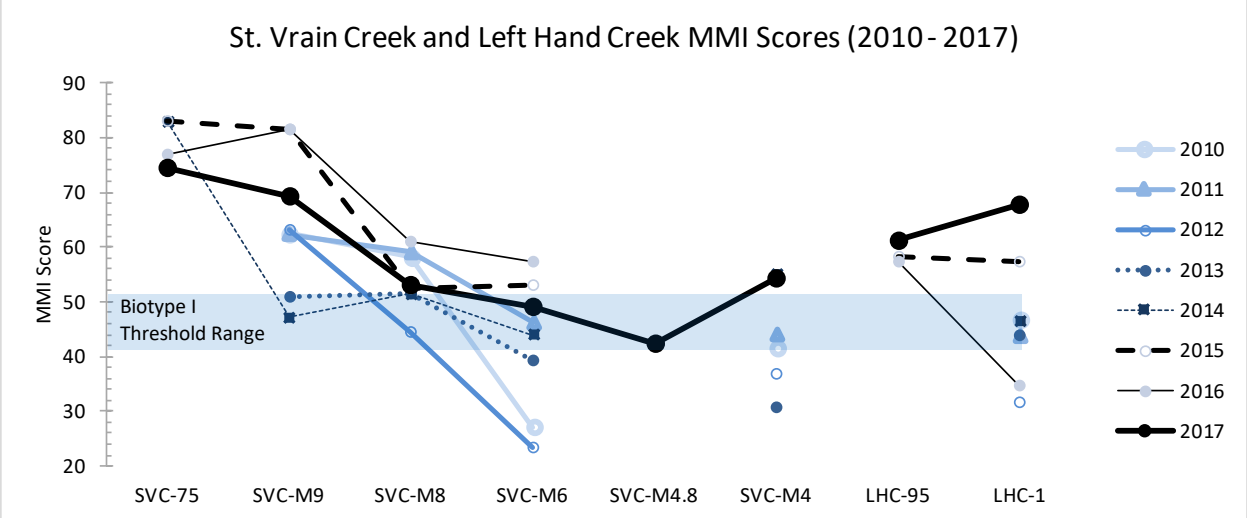


Table 23. St. Vrain and Left Hand Creek EPT, Diversity Index and HBI Scores

Date	SVC-75	SVC-M9	SVC-M8	SVC-M6	SVC-M4.8	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
22-Sep-17	16	15	10	10	8	11*	14	13
		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
22-Sep-17	3.24	2.85	2.78	2.66	2.87	3.46*	3.27	2.83
		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
22-Sep-17	4.31	4.50	5.28	5.06	4.97	5.04*	4.80	5.15

Pink-shaded cells do not meet thresholds for SDI and/or HBI.
*Modified site relative to previous monitoring years.

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). Field replicate pairs for Lafayette and Longmont are provided in Appendix G and were reviewed to identify potential quality control concerns for analytes of interest to this KICP report. Overall, results were within reasonable ranges for parameters of interest to this report. See Appendix G for results and relevant comments.

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***: Most stream segments evaluated in this report are identified as impaired for *E. coli*, except South Boulder Creek and Left Hand Creek. Rock Creek is identified on Colorado's Monitoring and Evaluation List for elevated *E. coli*, but not formally designated as impaired. 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**: Instream total nitrogen standards do not yet apply in Boulder County; however, "interim values" for total nitrogen have been adopted by the Water Quality Control Commission. Above WWTP discharges, the streams in the watershed attain the "interim values" for total nitrogen. 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. Additional monitoring during 2017 suggests that this impairment may be limited to a portion of Segment 10.

- **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. Selenium monitoring in these areas increased during 2017, confirming the impairment listing on Rock Creek. Recent monitoring results on Coal Creek indicate that it may now be attaining the selenium standard below Rock Creek. Continued characterization of selenium sources is needed to determine whether

controllable sources of selenium loading are present or whether a site-specific standard should be proposed in the future.

- **Copper:** In the South Boulder Creek and Left Hand Creek watersheds, dissolved copper is elevated, largely due to historic mining operations in the watershed combined with very low hardness concentrations resulting in stringent stream standards. For the most part, copper has not been a stream impairment in the urbanized portion of the watershed, which is the focus of this KICP report. However, the 2018 303(d) List includes two stream segments within the KICP study area as impaired for the acute dissolved copper standard, including South Boulder Creek between Gross Reservoir and South Boulder Road and Left Hand Creek from Highway 36 to St. Vrain Creek. Analysis of data collected by the City of Boulder suggests that the impairment on South Boulder Creek is likely limited to the upper portion of the segment in the South Boulder Diversion Canal and Eldorado Canyon area, given that monitoring locations in the Open Space attain the copper standard. The Left Hand Creek acute exceedances appear to be located primarily at the Haldi intake area, upstream of urbanized area. On Left Hand Creek, only total copper data are available for the Left Hand Creek sites monitored by Longmont. A comparison of total copper data to the dissolved copper standard suggests that infrequent exceedences of the acute copper standard could potentially be occurring in the lower portion of Left Hand Creek. Monitoring for dissolved copper would be necessary to fully evaluate the extent to which copper impairment extends into the urban area on Left Hand Creek.
- **Aquatic Life:** Based on biological monitoring results (i.e., MMI scores) for 2017, significant improvement in aquatic life conditions have occurred throughout the watershed at most locations relative to post-flood conditions in 2013. However, during 2017, macroinvertebrate scores declined on Boulder Creek, with one site at 95th Street (BC-95) considered impaired. Several locations on Coal Creek also scored as impaired. Both South Boulder Creek and Rock Creek met MMI attainment thresholds. Habitat conditions on Coal Creek related to flow conditions may influence the low MMI scores and warrant further evaluation. The St. Vrain Creek and Left Hand Creek biological monitoring locations did not show impairment based on MMI scores in 2017, although two downstream sites on St. Vrain Creek had scores between impairment and attainment. Significant improvements in aquatic life conditions were measured at Left Hand Creek, possibly due to accumulated sediment being flushed downstream. Revisions to Colorado's MMI calculation procedure under Policy 10-1 were completed in 2017 and may affect determination of aquatic life impairment designations for future evaluations.

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.

- **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.
- Other regulatory issues may become apparent as a result of stream standard changes occurring as part of Colorado's "10-year Water Quality Road Map." For more information on these changes or to participate in Colorado Water Quality Forum work groups, see https://www.colorado.gov/pacific/cdphe/WQ-10-Year-Roadmap. Topics addressed include nutrients (total nitrogen, total phosphorus, and chlorophyll a), ammonia, cadmium, arsenic, selenium and temperature.

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. 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 continue to be incorporated into the report now that several years of consistently collected data sets are available for most stream segments.

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 both 2016 and 2017. 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.

- Longmont should consider monitoring the dissolved form of metals which have dissolved stream standards such as copper. Dissolved copper data on Left Hand Creek could potentially limit the portion of Left Hand Creek impaired for copper.

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.

- At the October 2017 CWQCC Rulemaking Hearing related to nutrients, phased adoption of instream TN and TP standards was extended from 2022 to 2027. As part of this decision, a new CWQCC policy, Policy 17-1 Voluntary Incentive Program for Early Nutrient Reductions, was adopted. Among other provisions, the Incentive Program will allow a WWTP to accrue time under a post-2027 compliance schedule through trading or

watershed nutrient reductions as part of its nutrient reduction plan. There may be opportunities to implement watershed projects that could benefit WWTPs in the watershed under this program. For example, stream restoration projects that stabilize banks and reduce sediment loading may also reduce phosphorus loads.

- 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*. Prepared for the City of Boulder. 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 Commission. 2017. *Aquatic Life Use Attainment Methodology to Determine Use Attainment for Rivers and Streams*. Policy Statement 10-1. August 7, 2017. https://www.colorado.gov/pacific/sites/default/files/Policy%2010-1_Appendices.pdf

Colorado Department of Public Health & Environment, Colorado Water Quality Control Commission, 2017. Water Quality Control Commission Policy 17-1, a Voluntary Incentive Program for Early Nutrient Reductions. Regulation #85 – Section 85.5(1.5) Approved: November 13, 2017. Expires: December 31, 2020.

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.*

Colorado Department of Public Health & Environment, Water Quality Control Division. 2017. *Section 303(d) Listing Methodology 2018 Listing Cycle*. https://www.colorado.gov/pacific/sites/default/files/303d_LM_2018.pdf

Culler, E., Matthew Jones, M. and Isabel Schroeter, I., 2017. Lefthand Creek Field Project Report. December 17, 2017. https://lwog.org/wp-content/uploads/2018/03/2017-CU-Left-Hand-Creek-Field-Project-Report.pdf

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

Dryden, C. 2018. Agricultural Water Monitoring in Boulder County Open Space. Personal Communication, July, 2018.

Jessup, B.K. and J.B. Stribling 2017. Recalibration of the Macroinvertebrate Multi-Metric Index for Colorado. Prepared for: Colorado Department of Public Health and Environment, Denver, CO. Prepared by: Tetra Tech, Inc., Center for Ecological Sciences, Owings Mills, Maryland.

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

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

Lefthand Watershed Oversight Group (LWOG), 2017. Annual Report. https://lwog.org/wp-content/uploads/2018/04/2017-Annual-Report-Final-Web-version.pdf

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 2018.

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

Patterson, G. 2017b. Post-Project Monitoring Lower Creek and Left Hand Creek Final Project Report. Prepared for Lefthand Watershed Oversight Group. https://lwog.org/wp-content/uploads/2018/01/FINAL-report-to-TU-and-USFS-12-30-2017.pdf

Patterson, G., 2018. Status of Watershed Science Activities for the Lefthand Watershed Oversight Group. Prepared 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.

Timberline Aquatics. 2018. 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. August.

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.

Wright Water Engineers, Inc., 2017. *Boulder Creek and St. Vrain Creek Annual Water Quality Analysis for 2015.* Prepared for Keep It Clean Partnership.