Lindsay Creek Surface Water Quality Monitoring Report: 2018

State of Idaho
Department of Environmental Quality
November 2018

www.deq.idaho.gov

Acknowledgements

DEQ thanks Mark Dagelin of Odom Beverage, Brett Tuttle, Doug McIntosh, and Dan Mader for granting property access. DEQ also thanks Lynn Rasmussen of the NPSWCD and Joe Kauffman of the City of Lewiston for providing the METER sensor and data logger installed in Lindsay Creek. Jason Williams, Mark Sellet, and Sujata Connell conducted field sampling. Hawk Stone performed data validation. Brady Johnson reviewed project R code. Jason Williams prepared this report. Tyler Schade edited the report.

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Printed on recycled paper, DEQ November 2018, PID 5YST, CA code 22208. Costs associated with this publication are available from the State of Idaho Department of Environmental Quality in accordance with Section 60-202, Idaho Code.

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Abbreviations, Acronyms, and Symbols

§303(d)	Refers to section 303, subsection (d) of the Clean Water Act or to a list of impaired water bodies required by this section
°C	degrees Celsius
ASTM	American Society for Testing and Materials
BURP	Beneficial Use Reconnaissance Program
cfs	cubic feet per second
CTD-10	METER brand sensor used to measure stream water level, temperature, and conductivity
CWA	Clean Water Act
CWAL	cold water aquatic life
DEQ	Idaho Department of Environmental Quality
DO	dissolved oxygen
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
EXO-1	model name for water quality sonde used in project monitoring
FNU	formazin nephelometric unit
HDPE	high-density polyethylene
IDAPA	Numbering designation for all administrative rules in Idaho promulgated in accordance with the Idaho Administrative Procedure Act
IDFG	Idaho Department of Fish and Game
LC1	monitoring site at Odom Park, stream mile 0.2
LC2	monitoring site at the culvert at the bottom of Gun Club Creek
LC3	monitoring site on NF Lindsay Creek on Lapwai Road
LC4	monitoring site on SF Lindsay Creek on Lindsay Creek Road
LC5	monitoring site at the outflow of a culvert on Burrell Avenue
LC6	monitoring site at the headwaters west of Reservation Line Road

mg/L	milligrams per liter
mpn/100 mL	most probable number per 100 milliliters
MSL	mean sea level
NIST	National Institute of Standards and Technology
NO_3+NO_2-N	nitrate plus nitrite nitrogen
NO_3-N	nitrate nitrogen
NPSWCD	Nez Perce Soil and Water Conservation District
PQL	practical quantitation limit
RPD	relative percent difference
SCR	Secondary contact recreation
TMDL	total maximum daily load
TP	total phosphorus
QAPP	quality assurance project plan
YSI	Yellow Springs Instruments (brand name for water quality sonde used in project monitoring)

Executive Summary

Lindsay Creek is a tributary to the Clearwater River in Nez Perce County, Idaho. The Idaho Department of Environmental Quality (DEQ) previously identified Lindsay Creek as impaired by nitrate plus nitrite nitrogen (NO_3+NO_2-N), total suspended solids (TSS), and bacteria (*Escherichia coli [E. coli]*). DEQ previously developed the water quality improvement plan, *Lindsay Creek Watershed Assessment and Total Maximum Daily Loads* (Lindsay Creek TMDLs), to address these pollutants (DEQ 2007).

From March through September 2018, DEQ monitored Lindsay Creek water quality at six locations to evaluate progress towards meeting water quality goals defined in the Lindsay Creek TMDLs. This report documents monitoring methods and results and compares results to relevant targets established in the Lindsay Creek TMDLs and Idaho water quality standards.

The Lindsay Creek TMDLs established target concentrations for three pollutants: NO_3+NO_2-N (2 milligrams per liter [mg/L]), TSS (50 mg/L monthly average, 80 mg/L maximum), and *E. coli* (geometric mean of 126 most probable number per 100 milliliters, mpn/100 mL). In 2018, concentrations exceeded these targets for all three pollutants. NO_3+NO_2-N concentrations ranged from 0.75 to 14.3 mg/L and exceeded the NO_3+NO_2-N target at five out of six stream monitoring sites; the target was met only at the headwaters of Lindsay Creek near Mann Lake (0.75–1.7 mg/L). TSS concentrations exceeded both the monthly average target and maximum target near the mouth of Lindsay Creek, on North Fork Lindsay Creek, and on Gun Club Creek. *E. coli* concentrations exceeded the target at the mouth of Lindsay Creek and on North Fork Lindsay Creek.

DEQ also monitored three parameters not addressed in the Lindsay Creek TMDL: total phosphorus (TP), water column dissolved oxygen (DO), and stream temperature. TP concentrations ranged from 0.017 to 0.38 mg/L across six monitoring sites. At the Lindsay Creek mouth and Gun Club Creek, TP concentrations were positively related to TSS concentrations, suggesting TP loads at these sites result primarily from phosphorus bound to suspended solids. Water column DO concentrations and stream temperature were monitored at the Lindsay Creek mouth and on North Fork Lindsay Creek; these results were compared to Idaho water quality standards. DO concentrations and stream temperature met Idaho water quality standards for protection of cold water aquatic life at both locations.

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1 Introduction

1.1 Regulatory Background

The federal Clean Water Act (CWA) requires states and tribes to restore and maintain the chemical, physical, and biological integrity of the nation's waters. CWA §303 requires states and tribes to adopt water quality standards necessary to protect fish, shellfish, and wildlife while providing for recreation in and on the nation's waters whenever possible. In addition, CWA §303(d) requires states and tribes to identify and prioritize water bodies where water quality does not meet water quality standards. States and tribes must periodically publish a list (a "§303(d) list") of waters where standards are not met. For these waters, states and tribes must develop a water quality improvement plan called a total maximum daily load (TMDL). A TMDL defines maximum inputs of a pollutant from all sources that can occur while still meeting water quality standards. The United States Environmental Protection Agency (EPA) must review and approve TMDLs developed by states and tribes.

In 1978, The Idaho Department of Health and Welfare Division of Environmental Quality identified Lindsay Creek as not meeting water quality standards (IDHW 1978), and subsequently placed Lindsay Creek on Idaho's §303(d) list. In 2007, the Idaho Department of Environmental Quality (DEQ) developed TMDLs for three pollutants: nitrate plus nitrite nitrogen (NO_3+NO_2-N), sediment (total suspended solids [TSS]), and bacteria (*Escherichia coli* [*E. coli*]) (DEQ 2007). EPA approved the Lindsay Creek TMDLs in 2007.

Idaho Code §39-3611(7) requires DEQ to review approved TMDLs every 5 years to evaluate if assumptions, analyses, targets, and loads developed in TMDLs are still appropriate. In 2018, DEQ collected water quality data in Lindsay Creek to review the creek's TMDLs. This report documents monitoring methods and results and compares results to relevant thresholds defined in the Lindsay Creek TMDLs and Idaho water quality standards.

DEQ's review of the Lindsay Creek TMDLs will be described in a separate document and, as required by Idaho Code §39-3615, will be conducted in consultation with a watershed advisory group composed of local stakeholders affected by DEQ water quality management.

1.2 Watershed Description

Lindsay Creek is a tributary to the Clearwater River in Nez Perce County, Idaho (Figure 1). The Lindsay Creek watershed spans 22.4 square miles and includes a portion of Lewiston, Idaho (Figure 1). Lindsay Creek tributaries begin near residential development and farmland at approximately 1,800 feet above mean sea level (MSL). It flows through basalt canyons, farmland, ranchland, and residential areas as it descends 1,000 ft to its mouth (750 feet above MSL), where Lindsay Creek flows into a tunnel drain that is part of the levee system for the Lower Granite Dam and converges with the Clearwater River. The main stem of Lindsay Creek is a 3rd-order stream with typical flows of 1–4 cubic feet per second (cfs) in summer and 5–9 cfs in spring at the mouth. Several 1st- and 2nd-order tributary segments have lower flows and go dry during summer. Lindsay Creek receives ground water from springs located in landslide

deposits scattered throughout the watershed; ground water inputs appear to contribute to a large proportion of stream flow, especially during summer.

Land uses within the watershed include nonirrigated agriculture, small ranches and livestock operations, residential developments, and industrial businesses. Seventy-two percent of watershed area is nonirrigated agricultural land (USGS 2017). A 2002 farming practices survey indicated crops grown within the watershed included wheat, barley, legumes, alfalfa, and fallow fields (NPSWCD 2002). Approximately 18% of the watershed land area is developed, and 4% of the land surface is impervious material (USGS 2017). There are no point source discharges to surface water within the watershed permitted under the EPA National Pollution Discharge Elimination System program. However, the City of Lewiston stormwater system discharges into some Lindsay Creek tributaries. Those discharges may occur under a municipal separate storm sewer system permit in the future. A detailed description of the watershed is provided in the Lindsay Creek TMDL (2007).

1.3 Objectives

Objectives of this report are as follows:

- Document methods, data quality, and results associated with 2018 DEQ water quality monitoring in Lindsay Creek.
- Compare 2018 monitoring results to relevant TMDL targets and Idaho water quality standards.

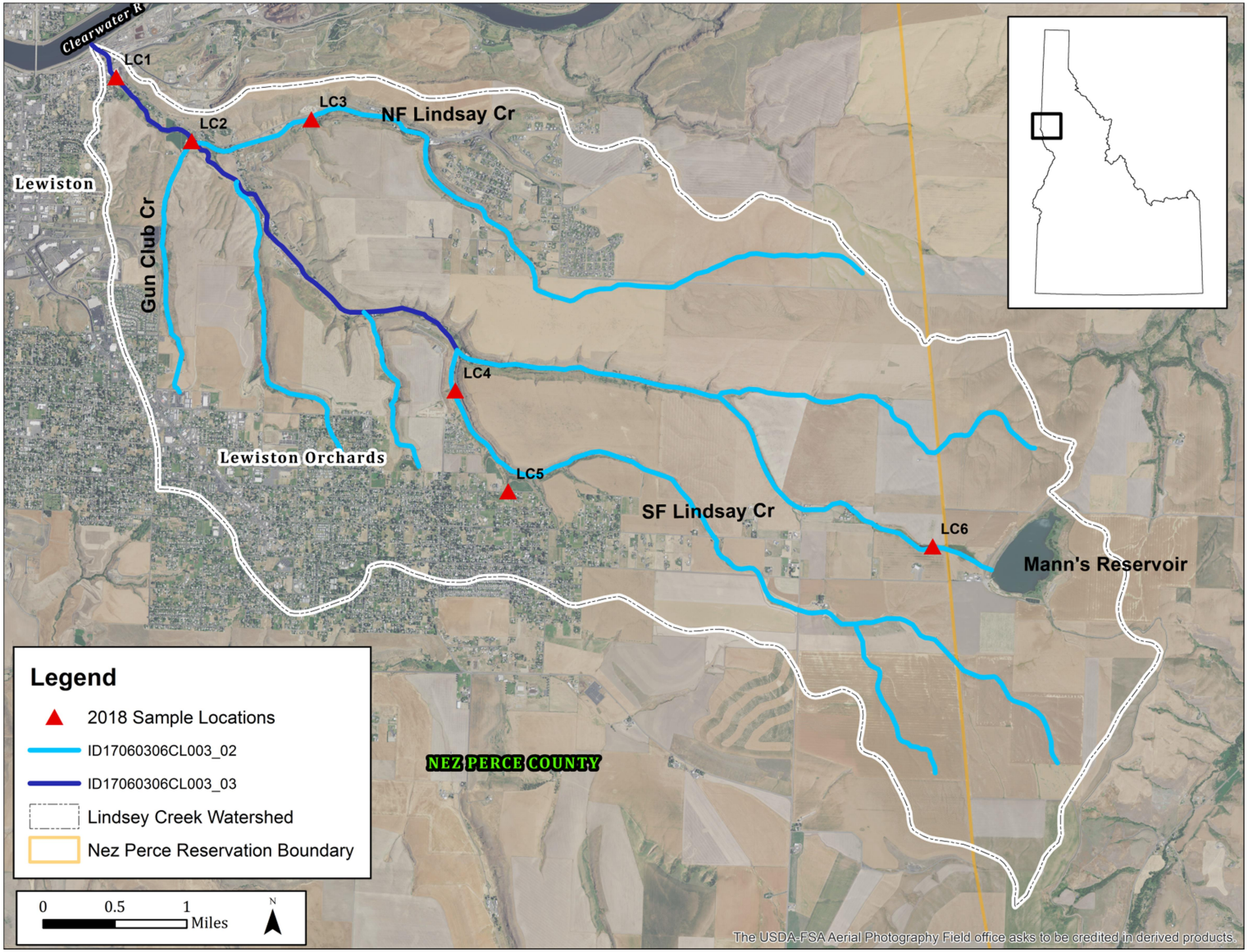

Figure 1. Lindsay Creek watershed and 2018 sample locations. See Table 1 for sample location descriptions.

Table 1. Lindsay Creek 2018 monitoring sites and parameters monitored.

Site ID	Description	Assessment Unit Number	Latitude/ Longitude[a]	Flow	Temp Logger	*E. coli*	NO_3+NO_2 (grab)	NO_3 (YSI)	TP (grab)	Turbidity (YSI)	TSS (grab)	DO
LC1	Stream mile 0.3 at Odum Park	ID17060306CL003_03	46.417177/ -116.988435	X	X	X	X	X	X	X	X	X
LC2	Outflow of culvert where Gun Club Creek enters Lindsay Creek	ID17060306CL003_02	46.41073/ -116.97723	X			X	X	X	X	X	
LC3	North Fork Lindsay Creek, along Lapwai Road	ID17060306CL003_02	46.413676/ -116.959751	X	X	X	X	X	X	X	X	X
LC4	South Fork Lindsay Creek along Lindsay Creek Road	ID17060306CL003_02	46.386895/ -116.937301	X			X	X	X	X	X	
LC5	Outflow of culvert on Burrell Avenue that drains the eastern Lewiston Orchards	ID17060306CL003_02	43.376935/ -116.929057	X			X	X	X	X	X	
LC6	West of Nez Perce Reservation boundary	ID17060306CL003_02	46.372957/ -116.866955	X			X	X	X	X	X	

a. Coordinates use the WGS 84 Datum

Notes: Dissolved oxygen (DO); total phosphorous (TP)

2 Methods

In 2018, DEQ measured stream flow, stream temperature, and concentrations of nutrients, dissolved oxygen (DO), TSS, and *E. coli* at multiple locations in the Lindsay Creek watershed (Figure 1, Table 1). Before sampling, DEQ developed a Quality Assurance Project Plan (QAPP) describing the planned field and laboratory methodology, quality assurance and quality control (QA/QC) procedures and data quality objectives (DEQ 2018). A summary of data QA/QC procedures and results is provided in Appendix A. All data collected for this project met data quality objectives specified in the QAPP and are considered adequate for use in the Lindsay Creek TMDL review (Appendix A).

2.1 Monitoring Sites

DEQ subdivides water bodies into assessment units (AUs) to assess and report if water quality standards are met. AUs are typically defined based on Strahler stream order, although additional factors such as land use, landscape physical characteristics, and local knowledge may also be considered. A detailed description of how DEQ subdivides state waters into AUs is provided in Idaho's most recent Integrated Report (DEQ 2017a). The Lindsay Creek watershed contains two AUs (Figure 1). AU ID17060306CL003_02 includes the Lindsay Creek tributaries (1st- and 2nd-order streams), and AU ID17060306CL003_03 includes the main stem of Lindsay Creek (3rd-order stream). Monitoring locations (Table 1, Figure 1) were selected to include sites within both AUs, facilitate comparison with previously collected data in DEQ's TMDL review, and evaluate the relative contribution of different stream segments to pollutant loads at the mouth while also considering property access and budget constraints.

2.2 Stream Flow

2.2.1 Instantaneous Flow Measurements

DEQ measured stream flow twice per month at each site (Table 1) from March 14, 2018, through September 10, 2018. At sites LC1, LC3, LC4, and LC6 (Figure 1), DEQ measured instantaneous stream flow using a portable electromagnetic velocity meter and the velocity area method. A stream transect was established perpendicular to stream flow. The transect was divided into equal-width cells and water depth and velocity were measured within each cell. Instantaneous stream flow was calculated by summing the product of velocity and area measurements calculated from each cell. At two culvert sites (LC2, LC5), flow was measured using a calibrated bucket and stopwatch.

2.2.2 Continuous Flow Measurements

In collaboration with the Nez Perce Soil and Water Conservation District (NPSWCD), DEQ installed a METER CTD-10 sensor and METER EM50G data logger near the mouth of Lindsay Creek at Odom Park (LC1). The CTD-10 sensor recorded stream water level, temperature, and conductivity at 15-minute intervals. NPSWCD previously installed and operated the METER

CTD-10 sensor and METER EM50G data logger in Lindsay Creek at Odom Park from 2013 to 2015 (NPSWCD 2016). DEQ relocated and reinstalled the equipment in 2018 (Figure 2).

DEQ measured instantaneous flow at LC1 twice per month and attempted to develop an equation relating measured flow to CTD-10 water level (a rating curve). However, DEQ could not develop a reliable rating curve because the water level sensor periodically malfunctioned, and occasional alterations to downstream water level control structures changed the relationship between water level and flow several times during the study period. Sensor water level measurements were used to track water level changes during deployment of a Yellow Springs Instruments (YSI) sonde (section 2.3.2) but were not used to calculate flow or develop a hydrograph.

Figure 2. METER CTD-10 sensor, data logger, and staff gauge setup in Lindsay Creek at Odum Park (LC1).

2.3 Water Chemistry

2.3.1 Grab Samples

Grab water samples were collected from the area within the stream channel that carries the greatest portion of flow (i.e., thalweg) by submerging a sample bottle below the stream surface. Water samples were analyzed at Anatek Labs in Moscow, Idaho. Analytical methods, preservatives, and holding times used are listed in Table 2. At least one field duplicate and one field blank sample were collected every 20 regular samples (Appendix A). Nutrient and sediment grab samples were collected twice per month concurrently with instantaneous flow measurements.

Idaho's *E. coli* water quality standard is based on the geometric mean of at least five samples collected every 3–7 days over a 30-day period. Five *E. coli* samples were collected over a 30-day period at two sites, one within each AU (Table 1), to quantify geometric mean concentrations and compare those concentrations to Idaho's water quality standard. *E. coli* samples were collected following procedures outlined in the QAPP (DEQ 2018) and DEQ's *E. coli* sampling standard operating procedure (DEQ 2017b).

Table 2. Analytical method, container, preservative, and holding time used and reporting limit for parameters analyzed by Anatek Labs.

Parameter	Method	Units	Preservative	Container	Hold time	PQL/RL
TSS	EPA 160.2	mg/L	4ºC	1 L plastic	7 days	1
E. coli	SM 9223B	mpn/100 mL	Sodium thiosulfate, 4ºC	150 mL plastic	24 hours	1
NO_3+NO_2-N	EPA 353.2	mg N/L	H2SO4 to pH < 2, 4ºC	125 mL HDPE	28 days	0.1
TP	SM4500 PF	mg P/L	H2SO4 to pH < 2, 4ºC	125 mL HDPE	28 days	0.01

a. Holding time is 28 days if preserved with H_2SO_4, 48 hours if unpreserved.
Notes: Practical quantitation limit (PQL); reporting limit (RL)

2.3.2 YSI Sonde Measurements

2.3.2.1 Instantaneous Measurements

DEQ used an YSI EXO-1 multiparameter sonde to measure instantaneous stream nitrate (NO_3-N) and turbidity in the field when a grab water sample was collected. To evaluate sensor performance, DEQ calculated multiple performance statistics (bias, error, relative percent difference [RPD], r^2, and paired t-test). DEQ also qualitatively compared spatial and temporal patterns of sensor and laboratory values using graphs to describe sensor performance and evaluate the reliability of sensor measurements. Sensor performance analyses are described in Appendix B.

2.3.2.2 Deployment

From June 8 to 11, 2018, DEQ deployed the sonde at LC1 to monitor stream water quality patterns during a rain event. The sonde was deployed below the water surface within a polyvinyl chloride tube attached to the METER CTD-10 sensor setup (Figure 2). The sonde recorded NO_3-N, turbidity, DO, temperature, and conductivity every 15 minutes. NO_3-N, turbidity, and DO sensors were calibrated according to manufacturer specifications the day of deployment. NO_3+NO_2-N water samples were collected at the beginning and end of deployment and submitted to the laboratory for analysis to evaluate NO_3-N sensor performance. A TSS sample was also collected at the end of deployment to evaluate turbidity sensor performance. The CTD-10 sensor also recorded water level, temperature, and conductivity every 15 minutes. A detailed evaluation of sensor performance is in Appendix B. A DEQ weather station at Sunset Park in Lewiston recorded precipitation amount every 15 minutes using a Texas Electronics TR-525USW tipping bucket rain gauge.

2.4 Temperature

DEQ deployed Onset Water Temp Pro V2 (Onset) temperature loggers to measure stream water temperature at 15-minute intervals from March 14, 2018, through October 3, 2018. Temperature loggers were placed within each Lindsay Creek AU, at LC1 and LC3 (Table 1, Figure 1). A temperature calibration check was performed before and after deployment to verify temperature logger accuracy. Procedures followed standard DEQ protocols for temperature logger placement (DEQ 2013a) and deployment, retrieval, and data processing (DEQ 2013b). The METER CTD-10 sensor deployed at LC1 also recorded stream temperature at 15-minute intervals. The YSI

temperature sensor and Hach LDO 101 DO meter recorded temperature at 15-minute intervals (section 2.5) during deployments. Onset temperature logger data were used for comparison to water quality standards because the logger was subjected to the most rigorous QA/QC (pre- and post-deployment calibration checks).

2.5 Dissolved Oxygen

DEQ deployed a Hach LDO 101 DO Probe in the stream to measure water column DO every 30 minutes over a 24-hour period at sites LC1 and LC3. The Hach probe was deployed August 14–15, 2018, in LC1 and July 31–August 1, 2018, in LC3. The water column DO was measured at site LC1 using the YSI sonde DO sensor June 8–11, 2018 (section 2.2.2). Before deployment, both instruments were calibrated following the manufacturer's instructions.

2.6 Data Analysis

Data collected in 2018 were compared to relevant TMDL target concentrations and Idaho water quality standards intended to protect beneficial uses in Lindsay Creek (Table 3). Federal regulations for implementing the CWA (40 CFR 131.10) require states to specify the appropriate beneficial uses to be achieved and protected for their waters. Idaho water quality standards list beneficial uses and require that surface waters of the state be protected for those uses, wherever attainable (IDAPA 58.01.02.050.02). The Lindsay Creek TMDL (DEQ 2007) was developed to protect the designated cold water aquatic life (CWAL) and secondary contact recreation (SCR) beneficial uses of Lindsay Creek. Waters protected for CWAL are expected to maintain a viable aquatic life community for cold water species. Waters protected for SCR are expected to allow for recreational activities such as wading and fishing where water immersion and ingestion are unlikely. The Lindsay Creek TMDL defined targets for NO_3+NO_2-N and TSS intended to protect CWAL use, and defined targets for *E. coli* intended to protect SCR.

Monitoring results were compared to target concentrations established in the Lindsay Creek TMDL (DEQ 2007) for NO_3+NO_2-N, TSS, and *E. coli*. Stream temperature and DO data were compared to Idaho water quality standards (Table 3). During TMDL development, DEQ determined Lindsay Creek was not impaired by temperature or DO, so the TMDL did not define targets. Total phosphorous (TP) concentrations were compared to benchmark concentrations associated with algal community changes in Idaho streams (Tetra Tech 2017). Idaho water quality standards do not have numeric water quality criteria for nutrients, and the Lindsay Creek TMDL did not define a TP target. The TMDL addressed TSS, assuming TSS reductions would also yield TP reductions (DEQ 2007). The TP threshold used here is only a benchmark, not a water quality standard, and exceeding the benchmark does not mean a water quality standard is exceeded or a beneficial use is not supported.

Although Idaho water quality standards designate salmonid spawning as a beneficial use that must be protected in many tributaries of the Clearwater River, DEQ does not consider salmonid spawning a beneficial use in Lindsay Creek. The Army Corps of Engineers built a tunnel drain at the mouth of Lindsay Creek as part of the Lower Granite Dam project; the tunnel drain prevents salmonids in the Clearwater River from entering Lindsay Creek.

Table 3. For data analysis, concentrations water quality parameters were compared.

Parameter	Concentration(s)	Source
NO_3+NO_2-N	2 mg/L	Lindsay Creek TMDL (DEQ 2007)
TP	0.013 mg/L[a]	Tetra Tech 2017
TSS	50 mg/L TSS monthly average 80 mg/L TSS maximum daily average	Lindsay Creek TMDL (DEQ 2007)
E. coli	126 cfu/100 mL; geometric mean of at least five samples collected every 3–7 days over a 30-day period	Lindsay Creek TMDL (DEQ 2007), IDAPA 58.01.02.251.01
DO (water column)	6 mg/L	IDAPA 58.01.02.250.02a
Temperature	19ºC daily average, 22ºC daily maximum	IDAPA 58.01.02.250.02b

NOTE: *E. coli* units cfu/100 mL are considered equivalent to mpn/100 mL
[a]. TP threshold associated with algal changes in Idaho streams in the MF_N site class (mountains and foothills north of latitude 45.9)

DEQ used the R statistical software for data analyses and graphing in this report. R is free open-source software (*https://www.r-project.org*/). All R code was written by one person and reviewed as a QC check by a second person not involved in writing the code.

3 Results

3.1 Stream Flow

Instantaneous stream flow ranged from 4.1 to 6.8 cfs at LC1. Flows were ≤1 cfs at all tributary sites throughout the study period. Stream flow was greatest in May and slightly decreased through September (Figure 3).

3.2 NO_3+NO_2-N and NO_3-N

NO_3+NO_2-N ranged from 0.75 to 14.3 mg/L across sites and 7.93 to 9.92 mg/L at the LC1 site (Figure 3). NO_3+NO_2-N exceeded 7 mg/L at all sites except at the headwaters (LC6), where it ranged from 0.75 to 1.7 mg/L. NO_3+NO_2-N exceeded the TMDL target (2 mg/L) at all sites except LC6. NO_3+NO_2-N were consistently greatest in South Fork Lindsay Creek (LC4) and North Fork Lindsay Creek (LC3) (Figure 3). Except at the headwaters, tributary concentrations were consistently higher than at the mouth. At most sites, concentrations were highest in April and May, decreased in June, and then remained relatively constant through the monitoring period (Figure 3).

During the June 8–11, 2018 rain event, NO_3-N concentrations measured using the Sonde nitrate sensor ranged from 7.1 to 8.6 mg/L. NO_3-N generally decreased as the water level increased and had a similar pattern to specific conductivity (Figure 4). Both NO_3+NO_2-N and conductivity are elevated in shallow ground water within the Lindsay Creek watershed. The NO_3 pattern suggests water entering the stream was primarily “new” water that originated from precipitation and diluted the ground water NO_3+NO_2-N and conductivity signal.

Confirmation samples collected at the beginning and end of the deployment period and submitted to the lab for analysis had NO_3+NO_2-N concentrations of 8.48 and 7.93 mg/L, respectively, compared to corresponding sensor NO_3-N readings of 8.23 and 7.43 mg/L. Based on these confirmation samples and NO_3-N performance analyses (Appendix B), DEQ has confidence in the NO_3-N concentration trend pattern recorded during deployment (Figure 5). However, additional sensor deployments are needed to evaluate concentration trend patterns in different seasons and during different size rain events; the pattern observed during the June 2018 rain event may not be representative of other conditions.

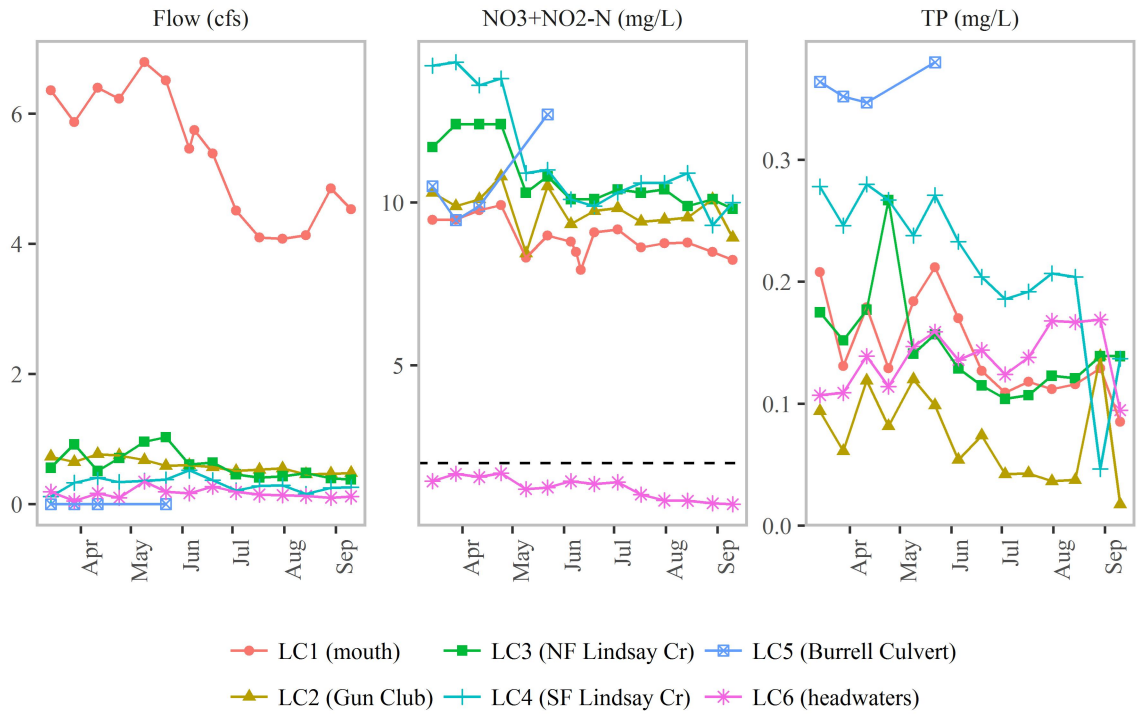

Figure 3. Lindsay Creek stream flow, NO_3+NO_2-N, and TP patterns during 2018 monitoring. The dashed horizontal line is the NO_3+NO_2-N defined in the TMDL.

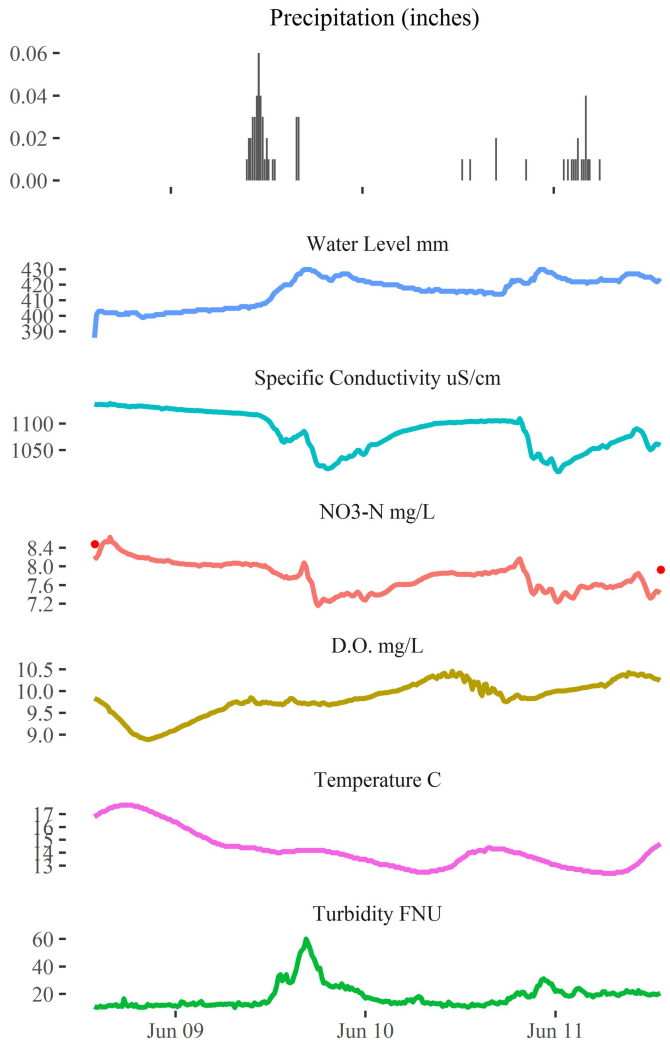

Figure 4. Precipitation, water level, and water chemistry patterns June 8–11, 2018, near the Lindsay Creek mouth at LC1. Red dots on the NO_3 plot indicate lab NO_3+NO_2-N from confirmation samples.

3.3 Total Phosphorus

TP concentrations ranged from 0.0177 to 0.38 mg/L across all sites. The greatest concentrations were observed in outflow of a culvert on Burrell Avenue (LC5, 0.35–0.38 mg/L), which only had water in spring. Otherwise, TP concentrations were generally highest at LC4 (Figure 3). TP concentrations did not show a strong seasonal pattern but followed a pattern similar to stream flow, generally decreasing from spring through summer. All TP sample results exceeded the 0.013 mg/L benchmark associated with algal changes in Idaho streams (Tetra Tech 2017).

At LC1 and LC2, TP concentrations were positively related to TSS concentrations (Figure 5). This relationship suggests TP loading at these sites comes primarily from phosphorus bound to suspended solids, and TSS reductions would be needed to reduce TP concentrations. In contrast, there was a weak relationship between TP and TSS at LC3-LC6, suggesting TSS reductions may not reduce TP. At these sites, addressing TP sources other than sediment may be needed to reduce TP.

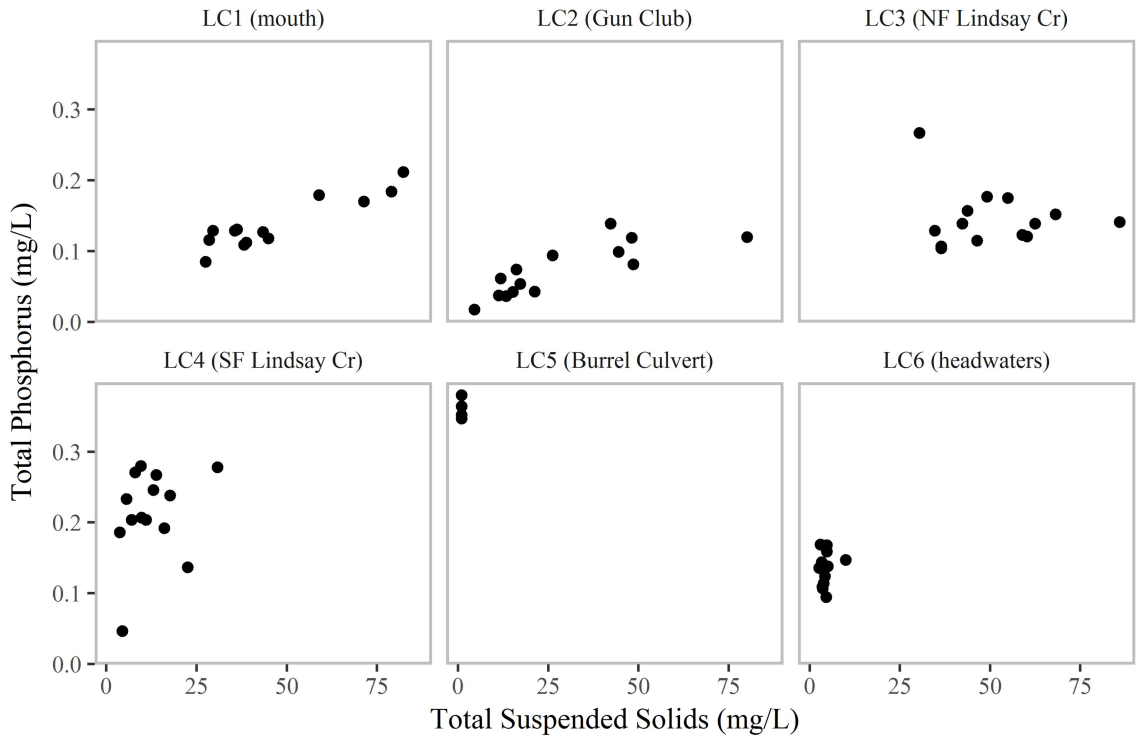

Figure 5. Relationship between TP and TSS at each stream monitoring site.

3.4 Sediment

TSS concentrations ranged from 1.0 to 85.9 mg/L across sites. Concentrations were consistently highest at LC1, LC2, and LC3 (Figure 6). TSS instantaneous loads (pounds per day) were also much greater at LC2 and LC3 than at other tributary sites. TSS was positively related to stream flow at the mouth (LC1) but not at other monitoring sites.

The Lindsay Creek TMDL established two TSS targets: a 50 mg/L monthly average and 80 mg/L maximum (DEQ 2007). TSS exceeded the 80 mg/L maximum target on May 9, 2018, at LC2 and LC2, and on May 22, 2018, at LC1. The 50 mg/L monthly average target was exceeded in May LC1 and LC2 and exceeded in March, May, August, and September at LC3.

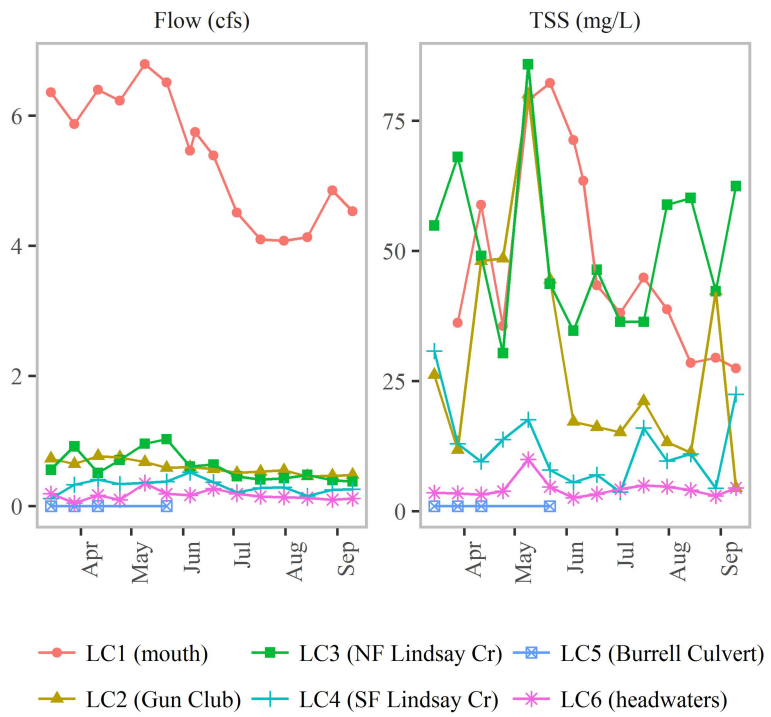

Figure 6. Lindsay Creek stream flow and TSS patterns (2018).

During a June 8–11 rain event, turbidity concentrations at LC1 ranged from 10.2 to 60 formazin nephelometric units (FNU). Turbidity spiked twice during the sensor monitoring period; each spike occurred shortly after a period of intense rainfall (Figure 4). A TSS sample collected at the end of the deployment period had a concentration of 63.5 mg/L. A regression analysis between paired turbidity and TSS measurements at LC1 gave an r^2 of 0.89 (Appendix B). Given the r^2 value and that seasonal turbidity patterns tracked relatively well with seasonal TSS patterns (Appendix B), DEQ has confidence in the TSS concentration trend pattern recorded during deployment (Figure 4).

3.5 *Escherichia coli*

E. coli concentrations exceeded Idaho's water quality standard of 126 mpn/mL geometric mean at LC1 and LC3 during summer (Table 4), exceeding the *E. coli* standard within both AUs (Figure 1). DEQ did not collect additional *E. coli* data because *E. coli* standard exceedances and spatial patterns in Lindsay Creek were documented in a previous report (DEQ 2016).

Table 4. *E. coli* load analysis based on 2017–2018 data.

Location	Monitoring Period	*E. coli* Geometric Mean (mpn/100 mL)
LC-1—Mouth (ID17060306CL003_03)	6/5/18 to 7/2/18	657.9
LC3—North Fork Lindsay Creek (ID17060306CL003_02)	6/5/18 to 7/2/18	456.6

3.6 Dissolved Oxygen

Water column DO concentrations at LC1 and LC3 met the Idaho water quality standard for protection of CWAL (6 mg/L) (Figure 4, Figure 7). Consistent with data collected while developing the 2007 TMDLs, the water column DO standard was met in both AUs.

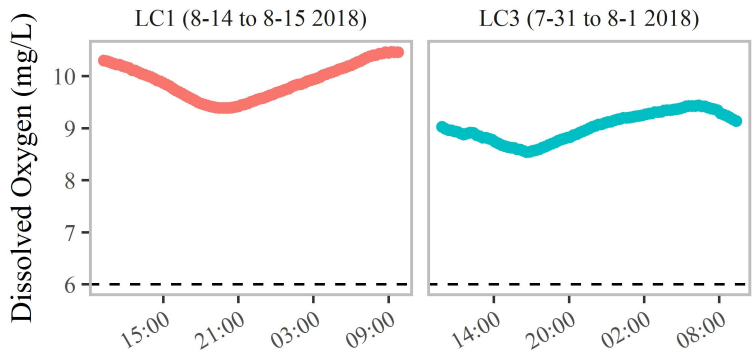

Figure 7. August 2018 DO monitoring results at LC1 and LC3. The dashed horizontal line indicated the Idaho water quality standard for protection of cold water aquatic life use (6 mg/L).

3.7 Temperature

Water temperature at LC1 and LC3 met the Idaho temperature water quality standards for protection of CWAL use (Figure 8). Consistent with data collected while developing the 2007 TMDLs, temperature standards were met within both AUs.

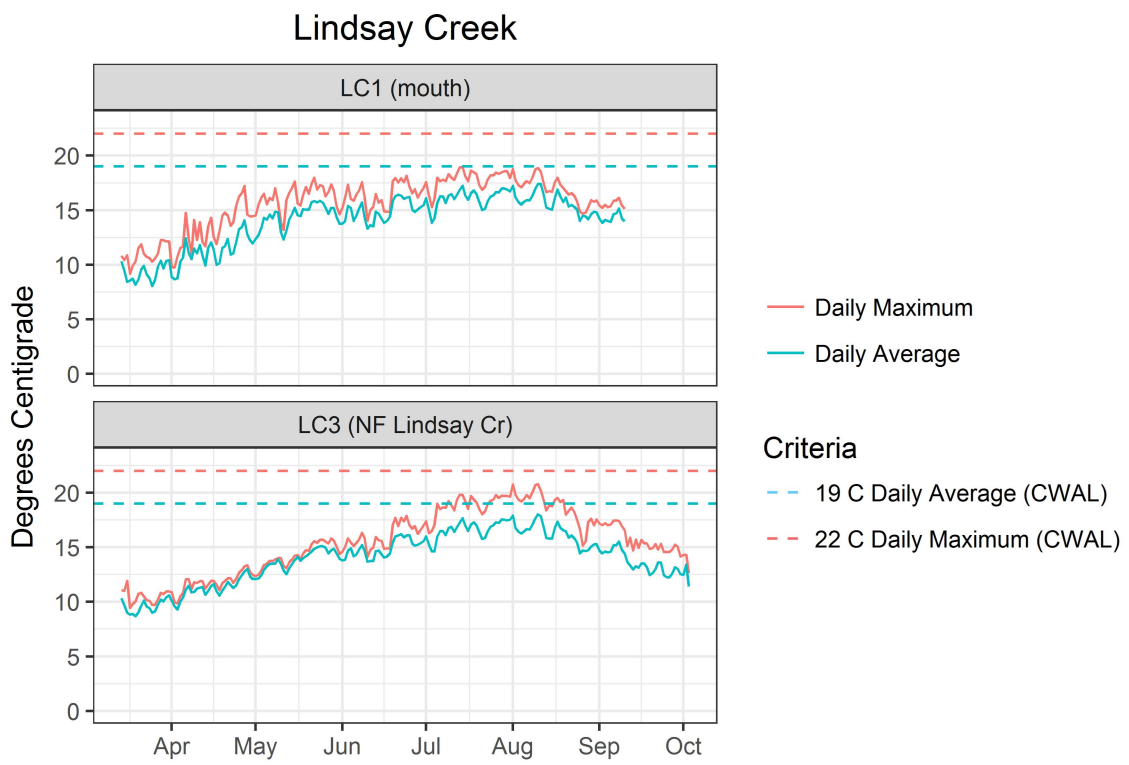

Figure 8. 2018 temperature logger results at Lindsay Creek mouth (LC1) and North Fork Lindsay Creek (LC3).

4 Conclusions

Table 5 summarizes the comparison of 2018 monitoring results to the relevant thresholds.

Table 5. Comparison of 2018 Lindsay Creek monitoring results to relevant thresholds.

Parameter	Threshold	Threshold Source	Result	
			ID17060306CL003_03	ID17060306CL003_02
NO_3+NO_2-N	2 mg/L	Lindsay Creek TMDL target (DEQ 2010)	7.9–9.9 mg/L threshold exceeded	0.75–14.3 mg/L threshold exceeded
TP	0.013 mg/L	Tetra Tech (2017)	0.09–0.2 mg/L threshold exceeded	0.017–0.38 mg/L threshold exceeded
E. coli	126 mpn/100 mL geometric mean	Lindsay Creek TMDL target (DEQ 2010), IDAPA 58.01.02.251.01	658 mpn/100 mL threshold exceeded	456 mpn/100 mL threshold exceeded
TSS	80 mg/L maximum	Lindsay Creek TMDL target (DEQ 2010)	27.5–82.3 mg/L threshold exceeded	1.0–85.9 mg/L threshold exceeded
TSS	50 mg/L monthly average	Lindsay Creek TMDL target (DEQ 2010)	27.5–80.7 mg/L threshold exceeded	1–64.8 mg/L threshold exceeded
DO	6 mg/L (minimum)	IDAPA 58.01.02.250.02a	9.3–10.4 mg/L not exceeded	8.5–9.4 mg/L not exceeded
Temperature	19°C daily average	IDAPA 58.01.02.250.02b	8.0–17.4°C not exceeded	8.7–18°C not exceeded
	22°C daily maximum	IDAPA 58.01.02.250.02b	9.6–19°C not exceeded	9.5–20.8°C not exceeded

5 Data Availability

Project data will be publically available through the Water Quality Portal (*http://www.waterqualitydata.us/*), which is a national data repository that houses publically available data. To access data, query for project ID 'LindsayCr', query data from organization ID 'IDEQ_WQX', or query data spatially. DEQ will also provide project data to interested parties in response to data requests. R code files used for analyses and graphing in this report are available on request.

6 References

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Appendix A. Quality Assurance/Quality Control Summary

1 Background and Purpose

Before sampling, DEQ developed a QAPP for the Lindsay Creek TMDL review surface water sampling project (DEQ 2018). The QAPP described planned field and laboratory methodology, QA/QC procedures and data quality objectives. Data quality objectives and criteria were specified for data accuracy, precision, measurement range, representativeness, comparability, and completeness. This appendix reviews QA data collected during the project and evaluates if data quality objectives and criteria were met.

2 Precision

Precision is a measure of agreement between two measurements of the same parameter under prescribed conditions. Laboratory and field duplicates were used to evaluate precision for NO_3+NO_2-N, TP, TSS, and *E. coli*. Precision goals specified in the project QAPP were met.

2.1 NO_3+NO_2-N, TP, TSS, and *E. coli*

The RPD of laboratory replicates and field duplicates were used to assess data precision for parameters analyzed at Anatek. RPD was calculated as follows:

$$RPD = \frac{(C_1 - C_2)}{(C_1 + C_2)/2} \times 100$$

Where: C_1 = concentration in first sample
C_2 = concentration in the second/duplicate sample

Analytical methods used by Anatek to quantify NO_3+NO_2 (EPA 352.2) and TP (SM 4500PF) require analysis of laboratory duplicate samples. Anatek did not report results of laboratory replicates in result reports. If the RPD of laboratory duplicates exceeds RPD goals specified by the analytical method, Anatek notes this in laboratory results reports and may assign a laboratory qualifier to associated results. Anatek did not apply laboratory qualifiers to any results associated with this project. Therefore, DEQ assumed laboratory duplicate RPD requirements were met.

The QAPP required DEQ to collect one field duplicate sample for every 20 regular samples (5% field duplicates). This requirement was met for each of NO_3+NO_2, TSS, and TP.

The QAPP established a RPD goal of +/- 50% for low level concentrations (< 20 x laboratory practical quantitation limit) and 25% for high level concentrations (>20 x laboratory practical quantitation limit). RPD goals were met (Table A1).

Table A1. Field duplicate results.

Sample Date	Parameter	Location	Original Result	Duplicate Result	PQL	RPD (%)	Lab Report
4-11-18	NO_3+NO_2-N (mg/L)	LC1	9.76	10.1	1	-3.42	180412001_REG2
4-11-18	TP (mg/L)	LC1	0.179	0.186	0.01	-5.52	180412001_REG2
4-11-18	TSS (mg/L)	LC1	58.9	57.5	1	2.41	180412001_REG2
6-5-18	NO_3+NO_2-N (mg/L)	LC1	8.8	8.82	1	-0.23	180605056_REG2
6-5-18	TP (mg/L)	LC1	0.17	0.163	0.01	4.20	180605056_REG2
6-5-18	TSS (mg/L)	LC1	71.3	65.9	1	7.87	180605056_REG2
6-19-18	NO_3+NO_2-N (mg/L)	LC1	9.08	9.04	1	0.44	180620038_REG2
6-19-18	TP (mg/L)	LC1	0.127	0.137	0.01	-7.58	180620038_REG2
6-19-18	TSS (mg/L)	LC1	43.4	45.6	1	-4.94	180620038_REG2
7-2-18	*E. coli* (mpn/100 mL)	LC1	686.7	579.4	1	16.95	180703001_REG2
8-29-18	NO_3+NO_2-N (mg/L)	LC1	8.48	8.46	1	0.24	180830003_REG2
8-29-18	TP (mg/L)	LC1	0.129	0.136	0.01	-5.28	180830003_REG2
8-29-18	TSS (mg/L)	LC1	29.5	28.7	1	2.75	180830003_REG2

Notes: Practical quantitation limit (PQL)

2.1 Temperature Logger Precision

Duplicate Onset temperature loggers were deployed near the mouth at LC1; however, only one temperature logger was retrieved. The second temperature logger likely washed downstream after the tree branches the logger was tied to were trimmed or broke off.

3 Accuracy

Accuracy is a measure of agreement between a "true" or reference value and the associated measured value. Accuracy of parameters analyzed at Anatek was evaluated based on laboratory QC samples and field blanks. Temperature logger accuracy was evaluated by comparing temperature logger measurements to those from a thermometer with certified accuracy. Accuracy goals specified in the project QAPP were met, except for a TP detect in one field blank. No TP results were qualified or rejected based on the TP detect (section 3.1).

3.1 NO_3+NO_2-N, TP, TSS, and *E. coli*

Analytical methods used by Anatek to quantify NO_3+NO_2 (EPA 352.2) and TP (SM 4500PF) require analysis of laboratory control and laboratory-prepared matrix spike samples. Anatek did not provide results associated with laboratory control and laboratory-prepared matrix spike samples in their results reports. However, if results from these samples do not meet relevant data quality goals, Anatek notes this in laboratory results reports and assigns a laboratory qualifier to associated results. Anatek did not apply laboratory qualifiers to any results associated with this

project. Therefore, DEQ assumed laboratory control and matrix spike data quality objectives were met.

Field blanks were used to check for possible contamination of samples (analyte gain) during sample collection and processing for NO_3+NO_2, TSS, and TP. The QAPP required one field blank sample to be collected for every 20 regular samples (5% blanks). This requirement was met for NO_3+NO_2, TSS, and TP.

The QAPP required that field blank results are less than the laboratory practical quantitation limit (PQL). All NO_3+NO_2-N and TSS field blanks were less than the PQL (Table A2). One TP field blank collected on April 11, 2018, exceeded the PQL (Table A2). This TP field blank was collected using Cen-Med Enterprises Deionized Water compliant with American Society of Testing and Materials (ASTM) Type I water specifications. After Anatek reported the field blank result, DEQ collected and analyzed a bottle blank using this water source. The TP concentration in the bottle blank was below detection. The source of the TP present in the April 11, 2018, field blank is not known.

The QAPP stated "If field blanks yield results above the PQL, and field blank results are greater than 10% of associated regular sample results, the project manager will work with the project QA Officer (QAO) to determine if qualifying or rejecting regular sample results may is [sic] needed based on data validation requirements" (DEQ 2018). The April 11, 2018, field blank TP result was greater than 10% of TP concentrations observed in four out of six regular samples collected on that date. The DEQ project manager consulted with the project QAO. Because TP sample results were similar to those collected on other dates in 2018 and in previous years, and Anatek staff reported phosphorus detects have occurred with ASTM Type I water in the past on other projects (Eric Linskey, personal communication), DEQ decided to not qualify or reject TP results from samples collected on April 4, 2018. Anatek staff recommended using deionized water provided by Anatek for subsequent field blanks. DEQ used deionized water provided by Anatek for all subsequent project field blanks, which had results below detection (Table A2).

Table A2. Field blank results.

Sample Date	Parameter	Location	Field Blank Result	PQL	Lab Report
4-11-18	NO_3+NO_2-N (mg/L)	LC1	ND	0.1	180412001_REG2
4-11-18	TSS (mg/L)	LC1	<1	1	180412001_REG2
4-11-18	TP (mg/L)	LC1	0.0218	0.01	180412001_REG2
5-9-18	NO_3+NO_2-N (mg/L)	LC1	ND	0.1	180501002_REG2
5-9-18	TSS (mg/L)	LC1	<1	1	180501002_REG2
5-9-18	TP (mg/L)	LC1	ND	0.01	180501002_REG2
6-19-18	NO_3+NO_2-N (mg/L)	LC1	ND	0.1	180620038_REG2
6-19-18	TSS (mg/L)	LC1	<1	1	180620038_REG2
6-19-18	TP (mg/L)	LC1	ND	0.01	180620038_REG2
7-2-18	*E. coli* (mpn/100 mL)	LC1	<1	1	180703001_REG2
8-29-18	NO_3+NO_2-N (mg/L)	LC1	ND	0.1	180830003_REG2
8-29-18	TSS (mg/L)	LC1	<1	1	180830003_REG2
8-29-18	TP (mg/L)	LC1	ND	0.01	180830003_REG2
9-10-18	NO_3+NO_2-N (mg/L)	LC1	ND	0.1	180911049_REG2

Notes: Not detected (ND)

3.2 Temperature Logger Accuracy

The QAPP requires the accuracy of each temperature logger to be checked by comparing it to a National Institute of Standards and Technology (NIST) certified thermometer at two temperatures, both before and after deployment. Procedures described in the *Statewide Generic Quality Assurance Project Plan for Temperature Logger Deployment, Retrieval, and Data Processing* (DEQ 2013) were followed. Each of the three temperature loggers placed in Lindsay Creek for this project met QAPP specifications.

4 Sample Holding and Preservation Requirements

Project sample holding and preservation requirements are provided in Table 2. Sample holding and preservation requirements were met; Anatek did not note holding time or preservation concerns and did not qualify any lab results based on holding time or preservation issues.

5 Data Representativeness

Data representativeness is the degree to which the sample data accurately and precisely represent site conditions. The project QAPP did not provide specific representativeness criteria; however, it did provide guidelines for evaluating representativeness (DEQ 2018). Because field sampling and laboratory analysis followed standard procedures, procedures were consistent with those during previous sampling; samples were collected in both assessment units; laboratory accuracy and precision requirements were met; and there were no issues with laboratory QA review. All project data satisfy representativeness requirements.

6 Data Comparability

Comparability is the confidence with which one data set can be compared to another data set. The project QAPP provided did not provide specific comparability criteria; however, it did provide guidelines for ensuring data comparability (DEQ 2018). Because standard sampling and laboratory procedures were followed, procedures were consistent with those used for previous DEQ sampling, and no issues were identified during project data verification and validation. All project data satisfy representativeness requirements.

7 Data Completeness

Data completeness is the percentage of valid data relative to the total possible data points. The project QAPP defined a data completeness objective of 75% (DEQ 2018). Project data completeness is 100%.

8 Conclusion

DEQ requires several internal QA procedures. These include consultation with the DEQ quality assurance manager, registration of the project in a tracking spreadsheet, completion of three standardized quality assurance checklists, and review of all quality assurance data points. Project goals for data accuracy, precision, holding and preservation, representativeness, comparability, and completeness were met. DEQ therefore considers all project data adequate for use in the Lindsay Creek TMDL review.

Appendix B. Evaluation of YSI Nitrate and Turbidity Sensor Performance in the Lindsay Creek Watershed (2018)

1 Background and Objectives

DEQ used an YSI EXO-1 multiparameter sonde to measure stream NO_3-N and turbidity in the field concurrently with each NO_3+NO_2-N and TSS sample collected. NO_3-N was measured with an YSI nitrate ion sensitive electrode sensor. The manufacturer reported a measurement range of 0–200 mg/L from 0–30˚C and an accuracy of +/- 10% of reading or 2 mg/L, whichever is greater. Turbidity was measured with an YSI optical turbidity sensor. The manufacturer reported a measurement range of 0–4,000 FNU (equivalent to nephelometric turbidity unit) and 0.3 FNU or +/- 2% accuracy from 0 to 999 FNU. DEQ calibrated both sensors according to the manufacturer's specifications in the morning before each sample event. DEQ calibrated the nitrate sensor using 1 and 100 mg/L standards, and calibrated the turbidity sensor using 0 and 124 FNU standards. All calibration records and sensor results were saved electronically. This appendix describes the analyses DEQ conducted to evaluate the performance of YSI nitrate and turbidity sensors within the Lindsay Creek watershed.

2 NO_3-N Sensor Performance

To evaluate NO_3-N sensor performance, DEQ calculated multiple performance statistics to compare YSI NO_3-N readings and results of concurrently collected water samples analyzed at Anatek for NO_3+ NO_2-N (Table B1). Sensor bias averaged -0.3 mg/L and ranged from -3.2 to 5.2 mg/L (Table B2). A paired t-test indicated a statistically significant ($p < 0.05$) difference between sensor NO_3-N and lab NO_3+ NO_2-N values. Mean RPD_{YSI} (38.8 %) and $RPD_{predicted}$ (32.3 %) were much greater than the mean RPD of field duplicates analyzed at the laboratory (0.4%).

DEQ constructed simple linear regressions using paired sensor NO_3-N and lab NO_3+ NO_2-N measurements. Separate regressions were constructed using all data across sites and for individual sites. Regression r^2 values (Table B1, Figure B1) were calculated and compared to the target r^2 value specified in the QAPP. The QAPP stated regressions would be suitable for predicting lab results if the regression r^2 value is 0.9 or higher, and the regression was developed based on at least 15 paired measurements spanning a wide range of flow conditions (DEQ 2018). When all data were pooled across sites, the resulting regression had r^2 of 0.9 with 67 data points (Table B1). Site-specific regressions (Table B2) had much lower r^2 values because within-site variation in NO_3-N and NO_3+ NO_2-N was small and similar in magnitude to observed mean bias, mean error, and manufacturer's accuracy specifications; within sites, there was a "signal-to-noise" problem that yielded low r^2. For example, paired data at the mouth (LC1) yielded r^2 = 0.01.

DEQ also qualitatively compared spatial and temporal patterns in plots of sensor and lab values (Figure B2). Seasonal sensor NO_3-N patterns tracked relatively well with lab NO_3+NO_2-N patterns, although concentration differences >2 mg/L sometimes occurred (Figure B2).

Table B1. Performance statistics used to evaluate NO_3-N sensor performance.

Statistic	Description
Bias	YSI-lab
Error	| YSI – lab |
RPD (%) (lab samples)	(sample – field duplicate) / [sample + field duplicate)/2] x 100
RPD_{YSI} (%)	(YSI – lab) / [(YSI + lab)/2] x 100
$RPD_{predicted}$ (%)	(predicted – lab) / [(predicted + lab)/2] x 100, where predicted = lab value predicted based on a simple linear regression between YSI and lab values
Paired t-test	Test for a statistically significant (α = 0.05) difference between paired YSI sensor field readings and lab results from concurrently collected samples.
r^2	Indicates percentage of variation in lab values that can be explained by a simple linear regression model with YSI values as the predictor and lab values as the response. r^2 values range from 0–1 with 1 indicating 100% of variance is explained.

Table B2. Performance statistics for the YSI NO_3-N sensor.

Statistic	N	Minimum	Maximum	Mean	Median
Bias (mg/L)	67	-3.2	5.2	-0.3	-0.2
Error (mg/L)	67	0.01	5.2	1.2	1.0
RPD (%)	4	-3.4	0.4	1.1	-0.2
RPD_{YSI} (%)	67	-85	38.8	2.3	3.7
$RPD_{predicted}$ (%)	67	-116	32.3	-10	-0.2

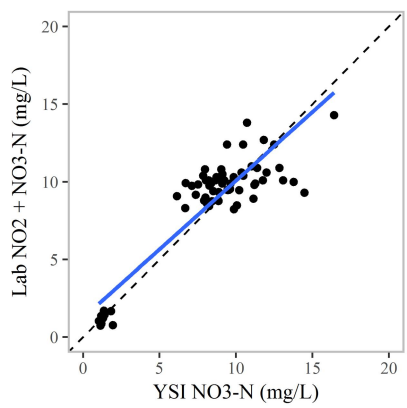

Figure B1. Relationship between YSI NO_3-N and lab NO_3+NO_2-N. The solid line is the regression line (r^2 = 0.9, y = 1.23538 + 0.88443x). The dashed line is a 1:1 line.

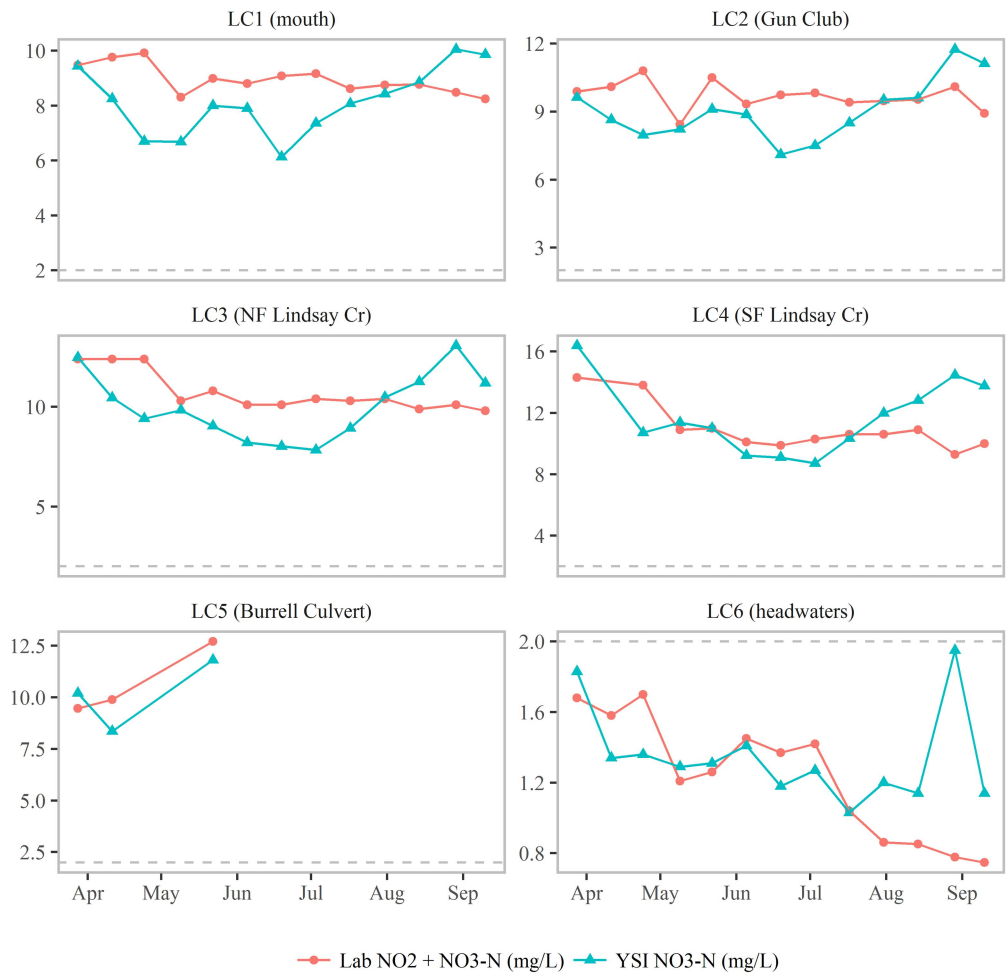

Figure B2. Comparison of YSI NO_3-N and lab NO_3+NO_2-N across sites and sample events in the Lindsay Creek watershed. The dashed horizontal line is the TMDL NO_3+NO_2-N target (2 mg/L).

3 Turbidity Sensor Performance

To evaluate turbidity sensor performance, DEQ constructed simple linear regressions using paired turbidity and TSS measurements. Separate regressions were constructed using all data across sites and for individual sites. Regression r^2 values were calculated and compared to target r^2 values specified in the QAPP. The QAPP stated "Linear regressions will be suitable for predicting TSS based on turbidity if the regression r^2 value is 0.9 or higher and the regression was developed based on at least 15 paired measurements spanning a wide range of flow conditions" (DEQ 2018).

When all data were pooled across sites, the resulting regression had r^2 of 0.77 (Figure B3) and did not meet the target specified in the QAPP. When site-specific regressions were constructed, the regression line at the Lindsay Creek mouth (LC1), which also served as a control point in the TMDL (DEQ 2007), had an r^2 of 0.89 and 14 data points collected over a range of flow conditions (Figure B4).

DEQ calculated calculate $RPD_{predicted}$ (%) (Table B1) based on the all-sites regression and LC1 site regression. $RPD_{predicted}$ (%) was then compared to the mean RPD of field duplicates (RPD of two TSS samples collected at the same time and analyzed at the lab), and to the field duplicate RPD goal specified in the QAPP (+/- 25%) (DEQ 2018). $RPD_{predicted}$ (%) values from the all-sites regression were in some cases very large and exceeded the QAPP targets. $RPD_{predicted}$ (%) from the LC1 site regression ranged from -22% to 69% with a mean of 6.2%. The average RPD for TSS field duplicates was much smaller at 2%.

DEQ also qualitatively compared spatial and temporal patterns in plots of YSI and lab values (Figure B5). Turbidity patterns within and across sites were similar to TSS patterns (Figure B5).

Table B3. $RPD_{predicted}$ (%) for the YSI turbidity sensor.

Regression Type	N	Minimum	Maximum	Mean	Median
All sites	72	-165	234	-21	-6.8
LC1	14	-22	69	6.2	7.2

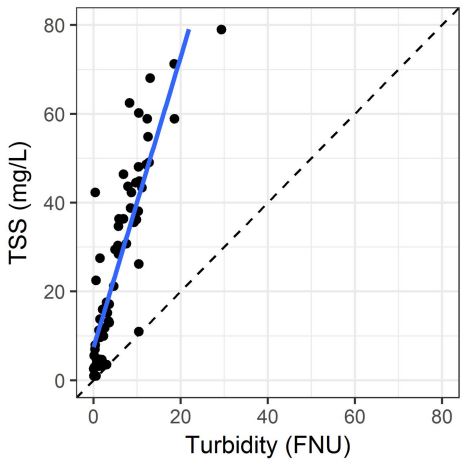

Figure B3. Relationship between YSI sensor turbidity and TSS across sites. The solid line is a linear regression line (y = 8.8040 + 3.0831x, r^2 = 0.77). The dashed line is a 1:1 line.

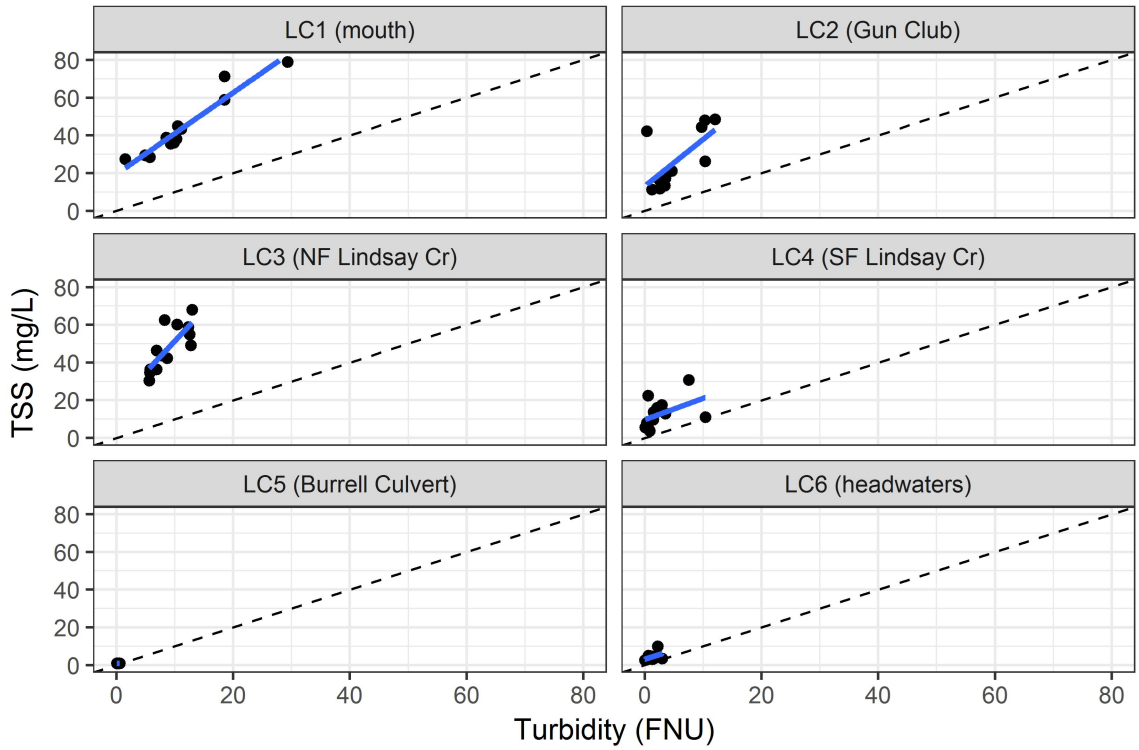

Figure B4. Site-specific relationships between YSI sensor turbidity and TSS. The solid line is a linear regression line. The dashed line is a 1:1 line. The linear regression line for LC1 is y = 18.1048 + 2.268x, r2 = 0.89 (n =14).

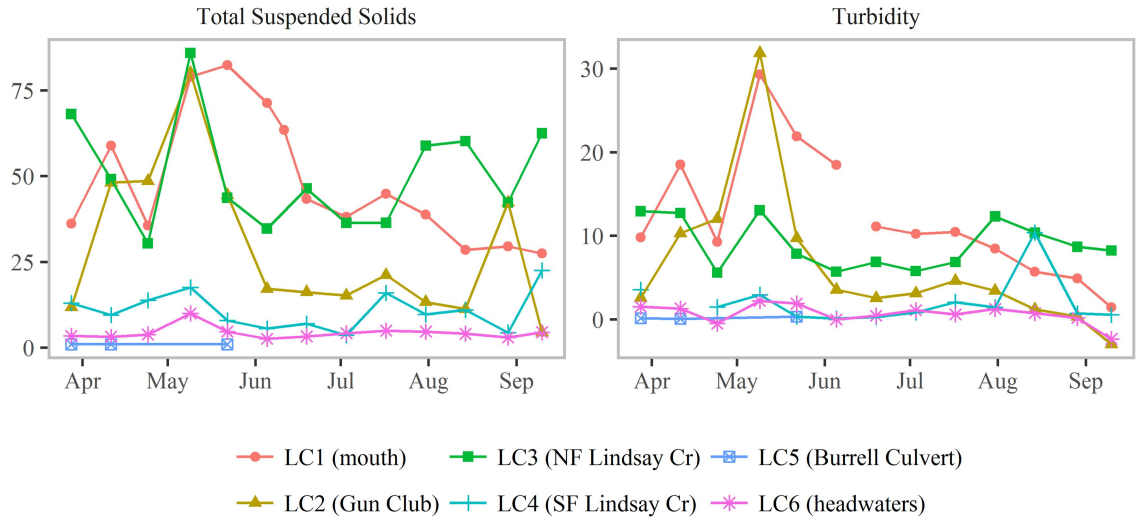

Figure B5. Comparison of TSS (mg/L) and turbidity (FNU) patterns by site.

4 Conclusions

NO_3-N Sensor

Because the YSI sensor measures NO_3-N and the laboratory measures NO_3+NO_2-N in lab samples, one should not expect sensor and lab results to be the same. The question addressed here was whether or not sensor NO_3-N is an adequate proxy for NO_3+NO_2-N lab results. Considering the poor r^2 values, nonsignificant t-test, and large RPD_{YSI} (%) and $RPD_{predicted}$ (%) values observed, DEQ concluded NO_3-N sensor results are not an adequate proxy for NO_3+NO_2-N lab results. However, several lines of evidence suggest the NO_3-N concentration trend pattern observed during the June deployment is reliable. NO_3-N sensor spatial and temporal patterns tracked relatively well with lab result patterns, and confirmation samples collected at the beginning and end of the June sonde deployment yielded relatively small bias (~0.5 mg/L).

Because stream conductivity patterns observed during deployment are consistent with available ground water and surface water conductivity and NO_3+NO_2-N information, DEQ has confidence in the NO_3-N concentration trend pattern observed during the June deployment. However, additional deployments would be needed to determine if the observed concentration trend pattern is consistent across seasons and differing size rain events. Combined with confirmation samples and adequate sensor performance information, future deployment of the NO_3-N sensor during rain events may yield reliable temporal concentration trend patterns to evaluate NO_3-N flow paths across different seasons and differing size rain events.

Turbidity Sensor

Using only data from site LC1, the YSI turbidity sensor nearly met QAPP requirements (r^2 = 0.89, 14 measurements versus requirement of r^2 = 0.9 and 15 measurements). Turbidity patterns at site LC1 also tracked well with TSS patterns (Figure B5). Sensor turbidity data therefore may be a reasonable surrogate for TSS at site LC1 using the regression equation specific to site LC1. However, additional turbidity and TSS data should be collected, especially during rain events to further verify turbidity sensor accuracy. At other Lindsay Creek monitoring sites, the turbidity sensor may be useful as a screening-level tool; for example, it may help monitor the relative TSS among different tributaries to help guide future TSS sampling efforts.