

Alaska Department of Environmental Conservation

Waterbody Field Report

2021 Kenai River Water Quality Monitoring



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Abstract

In 2021 the Alaska Department of Environmental Conservation initiated a two-year monitoring project on the Kenai River, Alaska. The Kenai River stretches 82 miles through the central Kenai Peninsula and supports a world class salmon fishery. The project was developed to address community concerns over dissolved metals, primarily zinc and copper, in the Kenai River mainstem. The secondary objective of this effort was to evaluate if stricter sampling protocols would improve data accuracy and precision. Over the 2021 field season, 16 sites were sampled (river mile 5 to 82.1) eight times (May through September). Water samples were analyzed for total metals (copper and zinc), dissolved metals (a suite of metals including copper and zinc), hardness (as CaCO₃), total dissolved solids, and dissolved organic carbon. In situ measurements were also collected at each sampling site and included: water temperature, pH, dissolved oxygen, salinity, and turbidity. Dissolved zinc was detected at levels above the practical quantitation limit in seven of the 107 samples analyzed for dissolved zinc. No dissolved zinc samples exceeded acute or chronic water quality criteria. Dissolved copper was detected at levels above the practical quantitation limit in six of the 107 samples analyzed for dissolved copper. No dissolved copper samples exceeded acute or chronic water quality criteria. Stricter sampling protocols appeared to reduce sample contamination but did not completely eradicate it, particularly for dissolved zinc and total dissolved solids, but the inclusion of additional sample metrics (i.e., field blanks, total metals, and additional duplicate samples) aided in identifying when sample contamination may have occurred. Incorporation of these additional sample metrics and the 'clean hands, dirty hands' techniques are recommended for future dissolved metals sampling efforts.

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Basic Waterbody Information

Table 1. Waterbody Information.

Assessment Unit Name	Lower Kenai River	Middle Kenai River
Assessment Unit ID	AK_R_2030218_002_001	AK_R_2030218_002_002
Location description	Mouth of Kenai River to Slikok Creek	Slikok Creek to outlet of Skilak Lake
Water Type	Freshwater, River	Freshwater, River
Area sampled	Downstream of Warren Ames Memorial Bridge (RM 5) to Slikok Creek (RM 19)	Upstream of Slikok Creek (RM 19.1) to Bing's Landing (RM 40)
Time of year sampled	May through September	May through September

Assessment Unit Name	Upper Kenai River	Kenai Lake
Assessment Unit ID	AK_R_2020214_007	AK_L_2030212_001
Location description	Inlet of Skilak Lake to Outlet of Kenai Lake	22-mile lake (13, 831 acres) near Cooper Landing, AK. Headwaters of the Kenai River.
Water Type	Freshwater, River	Freshwater, Lake
Area sampled	Jims' Landing (RM 70) to Resurrection Pass Trailhead (RM 76)	Upstream (RM 82.1) and downstream (RM 82) of the Cooper Landing bridge.
Time of year sampled	May through September 2021	Twice during a sample season, once in May and once in August/September.

Water Quality Evaluation

Background

The Kenai River is in the central Kenai Peninsula, Alaska, and stretches 82 river miles (RM) from the outlet of Kenai lake to its mouth at Cook Inlet. The upper (RM 70 – RM 82) and middle (RM 31 – 50) sections run through the Kenai Wildlife Refuge and small rural communities. The lower (RM 10.1 – 23) and estuary (downstream of RM 10.1) sections run through the cities of Soldotna and Kenai. All five species of Pacific Salmon spend part of their life stage in the Kenai River, and subsequently the river supports sport, commercial, and subsistence fishing activities.

A suite of metals, including zinc and copper, was evaluated against water quality criteria² for the Kenai River in the 2020 Integrated Report. The water quality evaluated had been collected on the Kenai River between 2017 and 2019 by multiple partner organizations. An initial review of the data indicated potential exceedances of acute and chronic aquatic life use criteria for dissolved zinc. No exceedances were observed for dissolved copper; however, copper had been noted as a potential contaminant of concern in past reports due to a potential positive trend in concentrations over time (KWF 2017).

The quality assurance (QA) check on the same data set submitted for the 2020 Integrated Report revealed that multiple parameters, including dissolved zinc and copper, failed the QA requirements outlined in the project's Quality Assurance Project Plan (QAPP) (KWF 2012 and 2020), specifically, eight of the 11 paired duplicates for dissolved zinc failed the 20% relative percent difference (RPD) threshold. A failure to meet RPD requirements was indicative of a precision issue with the data.³ In addition, no field blanks were collected and analyzed for this dataset. The data was not included in the 2020 Integrated Report due to failing to meet the project's precision requirements per the QAPP.

In 2021 DEC developed a monitoring project to 1) determine if zinc and copper exceeded water quality criteria on the Kenai River mainstem, and 2) to determine if accuracy issues could be mitigated by incorporating strict sample collection protocols developed for trace metals sampling (EPA 1996), specifically 'clean hands, dirty hands' sampling. These enhanced quality assurance measures were incorporated in DEC's QAPP (ADEC 2021) and project sample plan.

The DEC led Kenai River Metals monitoring project was initiated in May 2021 and will continue through September 2022. This field report summarizes the 2021 methods and results. In 2021 water samples were collected during ice-free months (May-August) at 15 locations along the Kenai River mainstem. A total of eight sampling events were scheduled for 2021, resulting in bi-weekly sampling. Sample sites included eight sites that had been historically sampled⁴, and seven sites selected specifically for this project (see Figure 1 and Appendix A: 2021 Sampling Locations).

² See 18 AAC 70 for State of Alaska Water Quality Standards

³ RPD review is available from DEC upon request.

⁴ Kenai River Multi-Agency Baseline Sampling organized by the Kenai Watershed Forum. This project has collected baseline data on the Kenai River bi-annually since 2001.

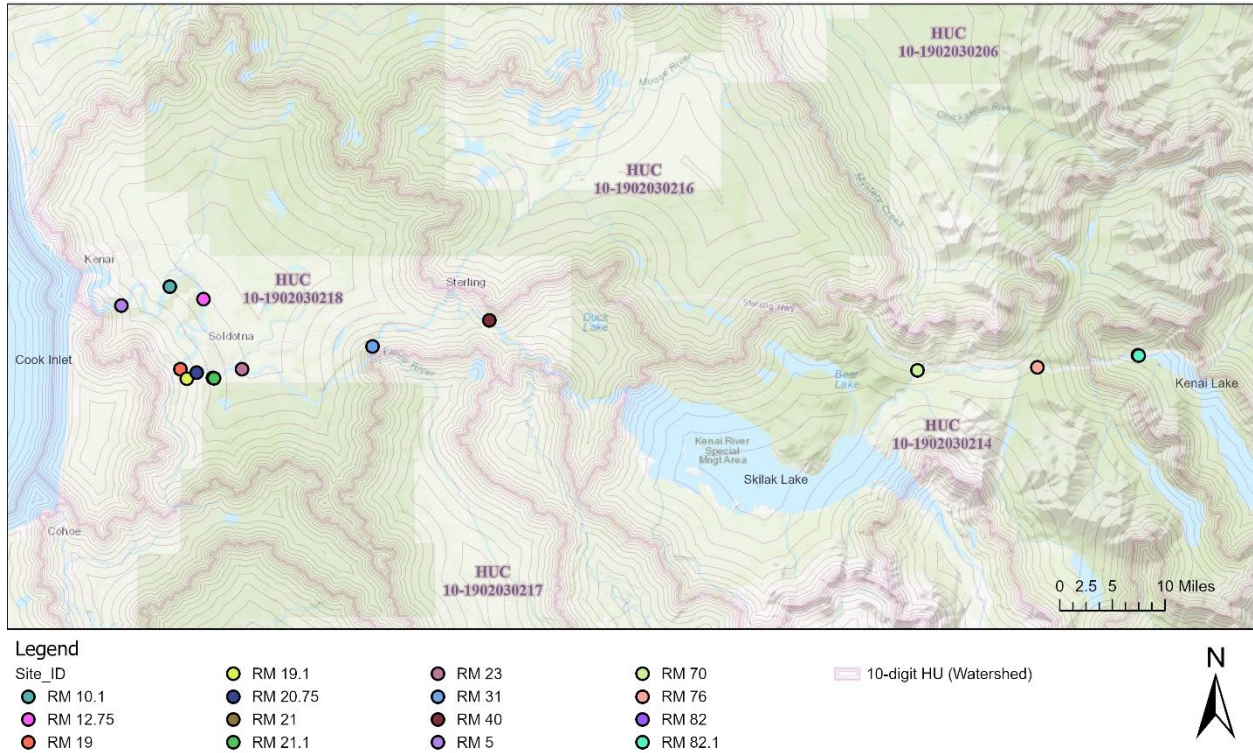


Figure 1. Map of 2021 monitoring locations and HUC-12 for the Kenai River, Alaska.

Objectives

The primary objective of this study was to determine if the Kenai River mainstem exceeded water quality criteria for copper and zinc.

A secondary objective was to determine effectiveness of modified sampling techniques.

Methods

All samples were collected at predetermined locations on a bi-weekly sample schedule. Sites were selected based on historic monitoring, accessibility, and proximity to areas of potential metals sources (e.g., downstream of stormwater outflows, bridges). In 2021, 15 sites were sampled across four assessment units (see Figure 1 and Appendix A: 2021 Sampling Locations).

Sample locations were accessed by foot or from a boat. Samples were collected upstream of the sample collector to avoid contamination from upturned sediment or the boat hull. All samples were collected using a plastic sample cup attached to an extendable pole (aka a 'dipper' or swing sampler). A 'clean hands, dirty hands' technique was used by the sampling team to collect all water samples (modified from EPA 1996, see Appendix F: Clean Hands, Dirty Hands, for more information). All staff wore powder free nitrile gloves for all sample collection and handling. Samples were stored in double layered clean plastic bags during transport.

In situ measurements were collected simultaneously using a handheld probe at all sample locations (In-Situ® Aqua TROLL 500 Multiparameter Sonde). Parameters included water temperature, specific conductivity, dissolved oxygen, pH, and turbidity.

Water samples were analyzed by SGS Laboratory in Anchorage, Alaska. Filtering of dissolved metals samples was conducted by SGS staff to minimize potential contamination of samples in the field. Dissolved metals samples were filtered through 0.45 µm pore membrane filters. Total metals and hardness samples were acid preserved in the field (HNO₃). All samples were analyzed using approved EPA methods (Table 2).

Resulting data underwent a quality assurance review before further analysis. See the quality assurance section of this report for more detail.

Dissolved zinc and copper were evaluated against water quality criteria (18 AAC 70). Both the acute and chronic criteria for aquatic life are site specific and are calculated using hardness. The site-specific hardness criteria were calculated using analyte specific formulas listed in ADEC 2008.

Table 2. Grab sample analytical methods summary.

METHOD	DESCRIPTION	PARAMETERS
200.8 DISS	Dissolved metals in drinking water by ICP-MS	Aluminum; Cadmium; Calcium; Copper; Lead; Magnesium; Potassium; Selenium; Sodium; Zinc
200.8	Total metals in water by ICP-MS	Total calcium; Total copper; Total magnesium; Total zinc
SM 5310B	Dissolved Organic Carbon (DOC)	DOC
SM21 2540C	Total dissolved solids (TDS)	TDS
SM21 2340B	Hardness as CaCO ₃ by ICP-MS	CaCO ₃

Quality Assurance

All samples were collected under the protocols outlined in the approved project QAPP (DEC 2021). Staff received training in ‘clean hands, dirty hands’ techniques (see Appendix G: Clean Hands, Dirty Hands). Handling of sample bottles and sampling equipment was minimized. Any potential issues with sample bottles (e.g., lids not tight upon initial inspection) were noted in the project logbook.

The In-Situ® Aqua TROLL 500 multiparameter sonde was calibrated according to the equipment standard operating procedure (SOP) document before each sampling event (usually the Friday prior to sampling the following Monday). Sampling occurred over a two-to-three-day period (Monday through Wednesday). A full verification procedure was performed the morning before sampling. Post sampling validation was performed after the final sample collection of each week. All sonde calibration procedures, results, and discrepancies were documented in the project logbook. Sensors were replaced if needed (i.e., due to equipment malfunction or expiration).

A total of four duplicate samples were incorporated into each sampling event. Duplicate sites were selected using a random number generator. A total of six field blanks were also included.

Field notes and equipment logbooks were maintained throughout the field season. All log field notes and logbooks were scanned and saved in PDF form. Chain of Custody (COC) forms were filled out for

each set of samples before shipment to the lab in Anchorage. Sample bottles were packed with chemical ice and sealed before shipment.

All samples were analyzed by SGS labs in Anchorage. Method blanks and matrix spikes were performed by the lab. Lastly instrument sensitivities were within the range outlined in the project QAPP.

See Appendix F: QA Review Checklist for a completed QA checklist.

Relative Percent Difference (RPD)

A total of 31 paired samples were collected over the 2021 field season. Precision was measured using RPD between two paired measurements (measurements A and B). RPD was defined as follows:

$$RPD = \frac{(A - B)}{\left(\frac{A + B}{2}\right)} * 100$$

The precision goal for this project was an RPD of $\leq 10\%$ for all paired samples. Estimated values (detected at levels lower than the practical quantitation limit (PQL)⁵) were treated as non-detects for the purpose of this analysis. A set of paired samples was evaluated for RPD only if: one or both of the samples were above the PQL; and if one or both of the samples were at least two times the PQL. The pass rate for RPD ranged from 100% for cadmium, organic carbon, and selenium to 71% for aluminum. (Table 3). Pass rates for 20% RPD are also presented for comparison to historic projects.

Table 3. Relative percent difference comparison for dissolved metals and total dissolved solids (TDS). The precision goal for this project was an RPD of 10%. The 20% RPD summary data is provided to allow comparison to historic projects.

ANALYTE	# PAIRED SAMPLES	10% RPD FAIL	10% RPD PASS	20% RPD FAIL	20% RPD PASS
ALUMINUM	31	9	71%	5	84%
CADMIUM	31	0	100%	0	100%
CALCIUM	31	1	97%	1	97%
COPPER	31	1	97%	1	97%
LEAD	31	1	97%	1	97%
MAGNESIUM	31	1	97%	1	97%
ORGANIC CARBON	31	0	100%	0	100%
POTASSIUM	31	1	97%	1	97%
SELENIUM	31	0	100%	0	100%
SODIUM	31	1	97%	1	97%
TOTAL DISSOLVED SOLIDS	31	16	48%	8	74%
ZINC	31	2	94%	1	97%

⁵ SGS Laboratory, Anchorage reported limit of quantitation (LOQ) in the raw results. LOQ is equivalent to the practical quantitation limit (PQL).

Field Blanks

A total of 6 field blanks were collected during the 2021 season. Originally, two field blanks were planned for the entire 2021 season based on the requirements of the project QAPP (DEC 2021), but a decision was made starting after sampling event two to include a field blank for each sampling event. Dissolved zinc and total dissolved solids exhibited the highest frequency of detection (see Table 4), evidence of potential sample contamination.

Table 4. Field blank results. The qualifier 'U' indicates the analyte was not detected. The qualifier 'J' indicates the analyte was detected at a level lower than the practical quantitation limit (PQL), and therefore is an estimate.

		Field Blank Date of Collection							
		Analyte	6/21/21	7/7/21	7/19/21	8/3/21	8/16/21	8/31/21	Freq.
Total Metals	Calcium	250 U	250 U	250 U	250 U	250 U	250 U	18300	17%
	Copper	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.457 J	17%
	Magnesium	25.0 U	25.0 U	25.0 U	25.0 U	25.0 U	25.0 U	1130	17%
	Zinc	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	0%
Dissolved Metals	Aluminum	7.82 J	10.0 U	10.0 U	9.92 J	10.0 U	10.0 U	10.0 U	33%
	Cadmium	0.250 U	0.250 U	0.250 U	0.250 U	0.250 U	0.250 U	0.250 U	0%
	Calcium	250 U	250 U	250 U	250 U	250 U	250 U	250 U	0%
	Copper	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.500 U	0.364 J	17%
	Lead	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0%
	Magnesium	25.0 U	25.0 U	25.0 U	18.1 J	25.0 U	25.0 U	25.0 U	17%
	Potassium	250 U	250 U	250 U	250 U	250 U	250 U	250 U	0%
	Selenium	2.50 U	2.50 U	2.50 U	2.50 U	2.50 U	2.50 U	2.50 U	0%
	Sodium	250 U	250 U	250 U	198 J	250 U	250 U	250 U	17%
	Zinc	4.15 J	3.29 J	3.46 J	13.5	5.00 U	3.20 J	5.00 U	83%
TOC Average, Dissolved		0.500 U	0.500 U	0.500 U	0.551 J	0.500 U	0.500 U	0.500 U	17%
Hardness as CaCO ₃		5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	50.4	17%

Results

A total of 107 dissolved metals samples, 107 total metals, 31 duplicate samples, and 6 field blanks were collected over the 2021 sampling season. All sites were visited eight times, except for RM 23, which was visited seven times (see Appendix A). Samples for hardness, total organic carbon, and total dissolved solids were collected and evaluated during the 2021 season (107 each respectively). In situ measurements were collected at each sample site, during each sampling event apart from RM 19 on August 2nd.

Zinc (dissolved)

Dissolved zinc was undetectable, or detectable but under the practical quantitation limit (PQL, 10 µg/L), for 100 of the 107 samples analyzed for zinc (Figure 1). Observed zinc values ranged from not detected (multiple occurrences) to a maximum observed value of 13.6 µg/L (RM 12.75)⁶. No exceedances of the

⁶ See discussion on the outlier at RM 10.1 in the conclusion and Appendix B 2021 Dissolved Zinc (Zn) in this report.

acute or chronic criteria were observed (See Appendix B 2021 Dissolved Zinc (Zn) and Appendix D: Alaska Water Quality Criteria for Copper and Zinc, for a full summary of results from the 2021 field season). In total, two dissolved zinc values were rejected based on failing the 10% RPD criteria.

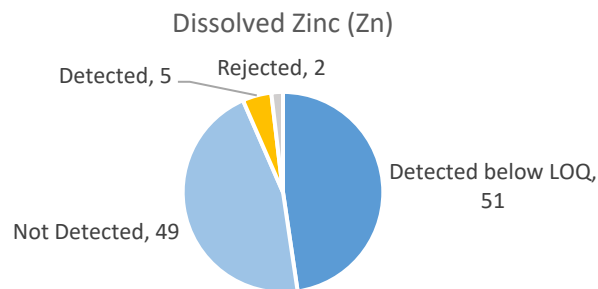


Figure 2. Detection condition of samples analyzed for dissolved zinc.

Copper (dissolved)

Dissolved copper was undetectable, or detectable but under the PQL (0.1 µg/L), for 101 of the 107 samples analyzed for copper (Figure 2). Observed copper values ranged from not detected (multiple occurrences) to a maximum observed value of 2.62 µg/L (RM 5). No exceedances of the acute or chronic criteria were observed (See Appendix C 2021 Dissolved Copper (Cu) and Appendix D: Alaska Water Quality Criteria for Copper and Zinc, for A full summary of results from the 2021 field season). In total, one dissolved copper value was rejected based on failing the 10% RPD criteria.

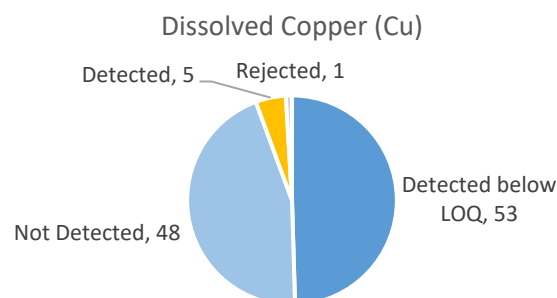


Figure 3. Detection condition of samples analyzed for dissolved copper.

In situ Field Measurements

In situ water quality measurements were collected at all sites, except for RM 19 on August 2nd, during each sampling event. Water temperature was consistent across sample sites, except for RM 19 (Slikok Creek), and water temperature increased as the sample season progressed. Dissolved oxygen remained consistent across sample sites and over the sampling season pH was more variable over space and over the sampling season than temperature. Salinity, turbidity, and total dissolved solids were elevated for RM 5 (Warren Ames Bridge, estuarine) RM 19 (Slikok Creek) and slightly elevated for sites upstream of

RM 70 (Jims' Landing to Cooper Landing Bridge) when compared to middle river sites. See Appendix D: 2021 In situ Environmental Parameter Summary.

Conclusion

No dissolved zinc or copper samples exceeded the acute or chronic water quality criteria (18 AAC 70). Dissolved zinc was detected at levels above the practical quantitation limit in seven of the 107 samples analyzed for dissolved zinc. Two observed dissolved zinc values were ultimately rejected after failing the 10% RPD and quality assurance check (see discussion below and Appendix B). Dissolved copper was detected at levels above the practical quantitation limit in six of the 107 samples analyzed for dissolved copper. One observed dissolved copper value was ultimately rejected because it failed the 10% RPD check and quality assurance check. This report only serves as an interim field report, and does not serve as a waterbody determination. A minimum of two years of data are required for a full waterbody evaluation in addition to a full analytical review.

Dissolved zinc and copper samples were collected at all targeted monitoring locations over eight sampling events except for RM 23 (Swiftwater Park). The original sampling location at RM 23 became inaccessible due to a habitat restoration project and was moved to a location approximately 150 ft downstream. Regular sampling resumed at this new site starting with event 3. Despite this, the completeness goal of 80% outlined for this project was met.

Clean hands, dirty hands

Additional sample collection procedures and equipment were successfully incorporated during the 2021 field season. Assigning 'clean hands, dirty hands' roles for crew, and then practicing these roles before actual field collection, greatly improved sample handling. Incorporating the dipper pole increased the distance (8 to 12 ft) between the sample collector and the sample bottle, thus reducing the likelihood of kicked up sediment or dust from the samplers' jacket or gear from contaminating the sample. It also improved staff safety while in the field. For example, it allowed a sample to be collected from fast moving, cold, and opaque glacial water while the sampler stood on shore. The open cup design was the only significant drawback. Airborne dust could freely enter the sample cup between the time of sample collection and sealing the water sample in a collection bottle. Windblown dust was hypothesized to be a potential source for some of the suspected contamination instances as wind gusts were noted during these sampling events. A modified container with a self-closing lid (e.g., a niskin bottle) may be a solution to this issue during the 2022 monitoring events.

Zinc

Some zinc contamination was still evident in the 2021 sampling results even with the incorporation of additional sample handling procedures. Zinc, especially dissolved zinc, is prevalent in the environment, and is notorious for contaminating water samples (Shiller and Boyle 1985, EPA 1996, Irwin et al. 1997). Since zinc contamination can be reduced but not eliminated, additional metrics were used to gage when and if sample contamination occurred. Field blanks, duplicates, and total metals were the additional metrics used in the 2021 sampling season. An example of these metrics in action was the water sample collected upstream of Beaver Creek (RM 10.1) on June 21st. The dissolved zinc value of 38.5 µg/L was significantly higher⁷ than observed elsewhere. Low levels of dissolved zinc were detected in the field

⁷ Defined here as being greater than two standard deviations away from the mean for the AU.

blank (4.15 µg/L), suggesting trace level contamination, but not enough to form a conclusion about the observed sample value. More telling was the duplicate for this sample. No dissolved zinc was detected in the duplicate. Lastly, total zinc was undetectable in the sample and the associated duplicate sample. Since dissolved zinc should be equal to or less than total zinc in a freshwater sample, was concluded that the observed value of 38.5 µg/L was a result of sample contamination and not reflective of actual water quality conditions. Comparing the original sample to its duplicate was key in deciphering the true nature of the sample result. However, it is not always practical or fiscally feasible to collect duplicate samples at every sampling event, so including additional metrics like total metals and field blanks are recommended for future monitoring efforts.

Total Dissolved Solids (TDS)

Two different methods were used to collect total dissolved solids (TDS) during the 2021 field season. The first method was as a grab sample that was collected and sent to the lab for filtering and analysis (APHA method 2540 C: Total Dissolved Solids Dried at 180°C). The second method was an in situ measurement with a multiparameter probe. The probe indirectly measured TDS by collecting in situ instantaneous measurements of conductivity and temperature, and then calculating TDS using these measurements. A routine quality assurance check of the grab sample TDS measurements indicated only 48% (16 out of 31) of the samples met the 10% RPD criteria goal set for this project (see Table 3). In contrast, TDS measurements collected with the multiparameter probe exhibited less variability over time and space (see Appendix E). The difference in reporting of TDS between the two methods was likely a product of the time scale each measurement method represented. The multiparameter probe calculated TDS every few seconds over a period of 5 minutes. The average TDS over 5 minutes was then calculated and reported. In contrast, the grab samples represented conditions over a single discrete (i.e., a few seconds) period. The practice of collecting an average measurement over 5 minutes with the multiparameter probe appears to have resulted in more consistent results in a dynamic river like the Kenai River. TDS grab sample collection is still planned for the 2022 monitoring season, however, the multiparameter probe method is recommended for future monitoring efforts requiring TDS measurements.

Recommended Next Steps

Sampling events are planned for 2022. A total of six (6) events are scheduled to occur between April and September 2022. These additional events are needed to meet the minimum data requirements for inclusion in the IR as listed in the Consolidated Assessment and Listing Methodology, namely that a dataset must include 1) a minimum of two years of data, and 2) a minimum of 10 sampling events for an Assessment Unit.

Considerations for 2022 sampling include:

- Sampling immediately after ice breakup on the lower Kenai River to evaluate potential impact of snow melt.
- Sampling immediately after rain events to evaluate potential impact of storm induced runoff.

Considerations for future water quality monitoring on the Kenai River for trace metals include:

- Trace metals monitoring projects should incorporate additional quality assurance protocols including, but not limited to field blanks, additional duplicate samples, 'clean hands, dirty hands' procedures, and lab filtering.
- Recommend use of a 'dipper cup' type device to increase distance between sampler and site of sample collection.
- Semi-annual review of project quality assurance goal(s), and address goals not being met. Consultation with DEC Quality Assurance Officer before the start of the field season and during the field season as needed.
- Review lab reports in season as they are received. Promptly discuss potential data quality issues with DEC Quality Assurance Officer. Document any required changes of sampling schedule or methods.
- Sediment sampling downstream of potential dissolved metals sources (e.g., downstream of traffic bridges, drainage pipes).
- Incorporating new technology to minimize potential contamination of samples (e.g., niskin bottles, peristaltic pumps) and technology to improve sampling crew safety (e.g., dipper pole, sUAV (i.e., drone) technology).
- Incorporate parameters⁸ required for EPA's biotic ligand model for copper (EPA 2016).

⁸ Parameters include pH, dissolved organic carbon, calcium, magnesium, sodium, sulfate, potassium, chlorine, alkalinity, and temperature.

References

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- Shiller, A.M., and E. Boyle. 1985. Dissolved zinc in rivers. *Nature* 317: 49-52.

Appendices

Appendix A: 2021 Sampling Locations

Table A. 1. Monitoring locations sampled as part of the Kenai River Water Quality monitoring effort. Monitoring locations occurred in four different assessment units and were designated by closest approximate river mile (RM). All sites except RM 19 occurred on the mainstem of the Kenai River. Historic sites were those sites sampled as part of the Kenai River Multi-Agency Baseline monitoring program.

Assessment Unit (AU)	RM	Latitude	Longitude	Type	Site Description	Historic Site	Access	Number of site visits in 2021
AK_R_2030218_002_001	5	60.52565	151.2088	Main	Warren Ames Memorial Bridge	No	Truck	8
	10.1	60.53928	-151.142	Main	Upstream of Beaver Creek	Yes	Boat	8
	12.5	60.53374	-151.099	Main	Upstream of Pillars Boat Launch	Yes	Boat	8
	19	60.48232	-151.127	Tributary	Slikok Creek	Yes	Boat	8
AK_R_2030218_002_002	19.1	60.47824	-151.122	Main	Upstream of Slikok Creek	No	Boat	8
	20.75	60.48173	-151.093	Main	Downstream of Centennial Park	No	Boat	8
	21	60.47663	-151.082	Main	Downstream of the Soldotna Bridge	Yes	Truck	8
	21.1	60.4764	-151.082	Main	Upstream of the Soldotna Bridge	No	Truck	8
	23	60.48034	-151.031	Main	Swiftwater Park	No	Truck	7
	31	60.49828	-150.863	Main	Morgan's Landing	Yes	Truck	8
	40	60.51544	-150.702	Main	Bings Landing	Yes	Truck	8
AK_R_2030214_007	70	60.48185	-150.114	Main	Jim's Landing	Yes	Truck	8
	75	60.48663	-150.001	Main	Sportsman's Landing	No	Truck	8
	76	60.48402	149.9513	Main	Resurrection Pass	No	Truck	8
AK_L_2030212_001	82	60.492	-149.811	Main	Cooper Landing Bridge downstream	Yes	Truck	2
	82.1	60.49189	-149.81	Main	Cooper Landing Bridge upstream	No	Truck	2



Figure A. 1. Kenai River from confluence with Cook Inlet to upstream of the Pillars Landing boat launch (RM 12.75).



Figure A. 2. Kenai River from downstream of Slikok Creek (RM 19) to upstream of Swiftwater Park (RM 23).



Figure A. 3. Kenai River from downstream of Morgan’s Landing (RM 31) to upstream of Resurrection Pass pullout (RM 76).



Figure A. 4. Confluence of the Kenai River and Kenai Lake at the Cooper Landing Bridge. Monitoring was conducted upstream (RM 82.1) and downstream (RM 82) of the Cooper Landing Bridge.

Appendix B: 2021 Dissolved Zinc (Zn)

Table B. 1. Summary of detected dissolved zinc samples collected over the 2021 monitoring season. Total number of detected dissolved zinc samples are provided for each sample site. Summaries of averaged values of dissolved zinc over each assessment unit (AU) are also provided. Table excludes non-detect and rejected samples (n=2).

<i>Sample Site</i>	<i>Total # of Samples Collected</i>	<i>Zn Detected⁹</i>	<i>Zn Avg. (µg/l)</i>	<i>Max (µg/l)</i>	<i>Min (µg/l)¹⁰</i>	<i>St. Dev.</i>
KR RM 5	8	5	4.6	7.3	3.3	1.6
KR RM 10.1	8	4	6.3	10.5	4.8	2.8
KR RM 12.75	8	6	6.6	13.6	3.4	3.8
KR RM 19 SC	8	5	5.1	7.4	3.1	1.7
AK_R_2030218_002_001	32	20	7.9	16.7	3.7	5.7
KR RM 19.1	8	3	6.5	7.7	4.1	2.1
KR RM 20.75	8	3	9.6	12.5	3.8	5.0
KR RM 21	8	5	6.9	11.5	3.1	3.2
KR RM 21.1	8	3	6.4	10.8	4.1	3.8
KR RM 23	7	5	5.7	9.8	3.3	2.9
KR RM 31	8	5	5.1	8.3	3.5	1.9
KR RM 40	8	4	5.3	7.9	3.4	2.1
AK_R_2030218_002_002	55	28	6.5	9.8	3.6	3.0
KR RM 70	8	5	4.6	6.4	3.2	1.6
KR RM 76	8	4	6.7	9.1	4.0	2.3
AK_R_2030214_007	16	9	5.7	7.8	3.6	2.0
KR RM 82	2					
KR RM 82.1	2	1	6.4	6.4	6.4	-
AK_L_2030212_001	4	1	6.4	6.4	6.4	-
Grand Total	107	58	6.74			

⁹ Number includes estimated values (J) detected below the practical quantitation limit (PQL).

¹⁰ Minimum for samples where Zn was detected. Excludes non-detects.

Table B. 2. Dissolved zinc ($\mu\text{g/L}$) and corresponding hardness (mg/L) observed during the 2021 season. The acute freshwater criteria for zinc are also provided.

COLLECTION DATE	SAMPLE EVENT	RIVER MILE	HARDNESS (MG/L)	ZINC ($\mu\text{G/L}$) ¹¹	ACUTE(FRESH) CRITERIA	CONDITION
5/18/2021	1	10.1	30.6		43.0	Does not exceed
5/18/2021	1	12.75	29.9		42.1	Does not exceed
5/18/2021	1	19	35.2		48.4	Does not exceed
5/18/2021	1	19.1	28.3		40.2	Does not exceed
5/18/2021	1	20.75	30.4		42.7	Does not exceed
5/19/2021	1	31	34.0		47.0	Does not exceed
5/19/2021	1	40	29.5		41.7	Does not exceed
5/19/2021	1	70	40.0		53.9	Does not exceed
5/19/2021	1	76	38.6		52.3	Does not exceed
5/19/2021	1	82	38.9		52.7	Does not exceed
5/19/2021	1	82.1	43.2		57.5	Does not exceed
5/20/2021	1	5	108.0	3.58	125.1	Does not exceed
5/20/2021	1	21	28.9		40.9	Does not exceed
5/20/2021	1	21.1	28.8		40.8	Does not exceed
5/20/2021	1	23	31.5		44.0	Does not exceed
6/7/2021	2	10.1	37.3		50.8	Does not exceed
6/7/2021	2	12.75	37.2		50.7	Does not exceed
6/7/2021	2	19	53.6		69.1	Does not exceed
6/7/2021	2	19.1	36.6		50.0	Does not exceed
6/7/2021	2	20.75	36.8		50.2	Does not exceed
6/8/2021	2	5	45.9		60.6	Does not exceed
6/8/2021	2	21	36.9		50.3	Does not exceed
6/8/2021	2	21.1	36.9		50.3	Does not exceed
6/8/2021	2	31	38.0		51.6	Does not exceed

¹¹ Blank indicates analyte was not detected. When an analyte is not detected, a substitute value equal to one half of the practical quantitation limit (PQL) was used to evaluate against water quality criteria (see the DEC Consolidated Assessment and Listing Methodology).

COLLECTION DATE	SAMPLE EVENT	RIVER MILE	HARDNESS (MG/L)	ZINC (µG/L) ¹¹	ACUTE(FRESH) CRITERIA	CONDITION
6/8/2021	2	40	36.4		49.8	Does not exceed
6/8/2021	2	70	48.4		63.4	Does not exceed
6/8/2021	2	76	48.7		63.7	Does not exceed
6/21/2021	3	10.1	34.7	38.5	47.8	Does not exceed, Rejected ¹²
6/21/2021	3	12.75	35.8	5.49	49.1	Does not exceed
6/21/2021	3	19	59.7	4.03	75.7	Does not exceed
6/21/2021	3	19.1	35.6	7.71	48.8	Does not exceed
6/21/2021	3	20.75	36.0	3.82	49.3	Does not exceed
6/22/2021	3	5	40.3	7.32	54.3	Does not exceed
6/22/2021	3	21	34.6	8.24	47.7	Does not exceed
6/22/2021	3	21.1	35.0	4.06	48.1	Does not exceed
6/22/2021	3	23	36.1	3.65	49.4	Does not exceed
6/22/2021	3	31	36.4	3.75	49.8	Does not exceed
6/22/2021	3	40	33.9	3.44	46.9	Does not exceed
6/22/2021	3	70	46.0	3.32	60.7	Does not exceed
6/22/2021	3	76	48.1	8.08	63.0	Does not exceed
7/6/2021	4	10.1	37.8	7.71	51.4	Does not exceed
7/6/2021	4	12.75	37.2	5.52	50.7	Does not exceed
7/6/2021	4	19	75.7	7.4	92.6	Does not exceed
7/6/2021	4	19.1	39.0	7.7	52.8	Does not exceed
7/6/2021	4	20.75	36.9	12.5	50.3	Does not exceed, Rejected ¹³
7/7/2021	4	5	41.5	4.21	55.6	Does not exceed
7/7/2021	4	21	38.3	11.5	52.0	Does not exceed
7/7/2021	4	21.1	37.4	10.8	50.9	Does not exceed
7/7/2021	4	23	38.9	9.82	52.7	Does not exceed
7/7/2021	4	31	39.1	8.31	52.9	Does not exceed
7/7/2021	4	40	38.0	7.94	51.6	Does not exceed

¹² This sample and its paired duplicate sample failed the 10% and 20% RPD check (RPD=167%) indicating the observed value is likely a product of sample contamination.

¹³ This sample and its paired duplicate sample failed the 10%, but not the 20%, RPD check (RPD=10.97%).

COLLECTION DATE	SAMPLE EVENT	RIVER MILE	HARDNESS (MG/L)	ZINC (µG/L) ¹¹	ACUTE(FRESH) CRITERIA	CONDITION
7/7/2021	4	70	50.6	6.37	65.8	Does not exceed
7/7/2021	4	76	48.9	9.14	63.9	Does not exceed
7/19/2021	5	10.1	37.8		51.4	Does not exceed
7/19/2021	5	12.75	37.5	7.72	51.0	Does not exceed
7/19/2021	5	19	75.5	3.10	92.4	Does not exceed
7/19/2021	5	19.1	37.7		51.3	Does not exceed
7/19/2021	5	20.75	38.0		51.6	Does not exceed
7/20/2021	5	5	52.3	3.33	67.7	Does not exceed
7/20/2021	5	21	40.1		54.0	Does not exceed
7/20/2021	5	21.1	40.0		53.9	Does not exceed
7/20/2021	5	23	39.8	7.68	53.7	Does not exceed
7/20/2021	5	31	38.7	5.17	52.4	Does not exceed
7/20/2021	5	40	38.9	6.00	52.7	Does not exceed
7/20/2021	5	70	51.2	3.66	66.5	Does not exceed
7/20/2021	5	76	49.9		65.0	Does not exceed
8/2/2021	6	10.1	39.2	4.78	53.0	Does not exceed
8/2/2021	6	12.75	40.2	3.84	54.1	Does not exceed
8/2/2021	6	19	77.6	6.19	94.5	Does not exceed
8/2/2021	6	19.1	39.2	4.10	53.0	Does not exceed
8/2/2021	6	20.75	39.1	12.5	52.9	Does not exceed
8/3/2021	6	5	49.0	4.46	64.0	Does not exceed
8/3/2021	6	21	39.2	6.12	53.0	Does not exceed
8/3/2021	6	21.1	39.4	4.23	53.2	Does not exceed
8/3/2021	6	23	41.2	3.27	55.3	Does not exceed
8/3/2021	6	31	39.8	4.56	53.7	Does not exceed
8/3/2021	6	40	38.4	3.95	52.1	Does not exceed
8/3/2021	6	70	50.9	6.39	66.1	Does not exceed
8/3/2021	6	76	50.9	3.97	66.1	Does not exceed
8/16/2021	7	10.1	37.3	10.5	50.8	Does not exceed
8/16/2021	7	12.75	37.9	13.6	51.5	Does not exceed

COLLECTION DATE	SAMPLE EVENT	RIVER MILE	HARDNESS (MG/L)	ZINC (µG/L) ¹¹	ACUTE(FRESH) CRITERIA	CONDITION
8/16/2021	7	19	69.4		86.0	Does not exceed
8/16/2021	7	19.1	37.7		51.3	Does not exceed
8/16/2021	7	20.75	37.3		50.8	Does not exceed
8/17/2021	7	5	40.2		54.1	Does not exceed
8/17/2021	7	21	37.5	5.56	51.0	Does not exceed
8/17/2021	7	21.1	38.4		52.1	Does not exceed
8/17/2021	7	23	38.2	3.90	51.8	Does not exceed
8/17/2021	7	31	37.7		51.3	Does not exceed
8/17/2021	7	40	37.0		50.5	Does not exceed
8/17/2021	7	70	46.3		61.0	Does not exceed
8/17/2021	7	76	46.8		61.6	Does not exceed
8/30/2021	8	10.1	39.5		53.3	Does not exceed
8/30/2021	8	12.75	40.5	3.40	54.5	Does not exceed
8/30/2021	8	19	68.7	4.64	85.3	Does not exceed
8/30/2021	8	19.1	40.8		54.8	Does not exceed
8/30/2021	8	20.75	40.4		54.4	Does not exceed
8/31/2021	8	5	42.0		56.2	Does not exceed
8/31/2021	8	21	40.4	3.11	54.4	Does not exceed
8/31/2021	8	21.1	38.2		51.8	Does not exceed
8/31/2021	8	23	40.8		54.8	Does not exceed
8/31/2021	8	31	41.3	3.50	55.4	Does not exceed
8/31/2021	8	40	38.0		51.6	Does not exceed
8/31/2021	8	70	49.6	3.23	64.7	Does not exceed
8/31/2021	8	76	50.0	5.67	65.1	Does not exceed
8/31/2021	8	82	47.7		62.6	Does not exceed
8/31/2021	8	82.1	49.3	6.39	64.4	Does not exceed

Table B. 3. Averaged dissolved zinc and corresponding hardness by sampling event (4-day average). Corresponding chronic freshwater criteria is also provided. Analysis excludes rejected values (n=2).

SAMPLE EVENT	AVG. ZINC ($\mu\text{G/L}$)	AVG. HARDNESS (MG/L)	CHRONIC (FRESH) CRITERIA	CONDITION
AK_L_2030212_001				
1	5.00	41.05	57.3	Does not exceed criteria
8	5.70	48.50	65.9	Does not exceed criteria
AK_R_2020214_007				
1	5.00	39.30	55.3	Does not exceed criteria
2	5.00	48.55	65.9	Does not exceed criteria
3	5.70	47.05	64.2	Does not exceed criteria
4	7.76	49.75	67.3	Does not exceed criteria
5	4.33	50.55	68.2	Does not exceed criteria
6	5.18	50.90	68.6	Does not exceed criteria
7	5.00	46.55	63.7	Does not exceed criteria
8	4.45	49.80	67.4	Does not exceed criteria
AK_R_2030218_002_001				
1	4.65	50.93	68.6	Does not exceed criteria
2	5.00	43.50	60.2	Does not exceed criteria
3	5.61	42.63	59.2	Does not exceed criteria
4	6.21	48.05	65.4	Does not exceed criteria
5	4.79	50.78	68.5	Does not exceed criteria
6	4.82	51.50	69.3	Does not exceed criteria
7	8.53	46.20	63.3	Does not exceed criteria
8	4.51	47.68	64.9	Does not exceed criteria
AK_R_2030218_002_002				
1	5.00	30.20	44.4	Does not exceed criteria
2	5.00	36.93	52.5	Does not exceed criteria
3	4.95	35.37	50.7	Does not exceed criteria
4	9.80	38.23	54.0	Does not exceed criteria
5	5.55	39.03	55.0	Does not exceed criteria

SAMPLE EVENT	AVG. ZINC (μG/L)	AVG. HARDNESS (MG/L)	CHRONIC (FRESH) CRITERIA	CONDITION
6	5.53	39.47	55.5	Does not exceed criteria
7	4.92	37.69	53.4	Does not exceed criteria
8	4.52	39.99	56.1	Does not exceed criteria

Appendix C: 2021 Dissolved Copper (Cu)

Table 5. Summary of detected dissolved copper samples collected over the 2021 monitoring season. Total number of detected dissolved copper samples are provided for each sample site. Summaries of averaged values of detected dissolved copper over each assessment unit (AU) are also provided. Table excludes non-detects and rejected values (n=1).

Sample Site	Total # of Samples Collected	Cu Detected¹⁴	Cu Avg. (µg/l)	Cu Max (µg/l)	Cu Min. (µg/l)¹⁵	St. Dev.
KR RM 5	8	6	0.96	2.62	0.44	0.84
KR RM 10.1	8	6	0.50	0.67	0.36	0.13
KR RM 12.75	8	4	0.41	0.57	0.32	0.11
KR RM 19 SC	8	2	0.56	0.58	0.54	0.03
AK_R_2030218_002_001	32	18	0.77	1.51	0.41	0.45
KR RM 19.1	8	4	0.48	0.60	0.32	0.13
KR RM 20.75	8	4	0.71	1.36	0.38	0.46
KR RM 21	8	5	0.74	1.69	0.31	0.54
KR RM 21.1	8	4	0.53	0.66	0.36	0.14
KR RM 23	7	4	0.79	1.58	0.40	0.54
KR RM 31	8	3	0.54	0.64	0.41	0.12
KR RM 40	8	4	0.46	0.56	0.34	0.10
AK_R_2030218_002_002	55	28	0.60	1.01	0.36	0.29
KR RM 70	8	4	1.07	2.05	0.46	0.69
KR RM 76	8	5	0.49	0.55	0.39	0.07
AK_R_2030214_007	16	9	0.78	1.30	0.43	0.38
KR RM 82	2	2	0.42	0.43	0.40	0.02
KR RM 82.1	2	2	0.50	0.52	0.48	0.03
AK_L_2030212_001	4	4	0.46	0.47	0.44	0.02
Grand Total	107	59	0.61			

¹⁴ Number includes estimated values (J) detected below the practical quantitation limit (PQL).

¹⁵ Minimum for samples where Cu was detected. Excludes non-detects and rejected values.

Table C. 1. Dissolved copper ($\mu\text{g/L}$) and corresponding hardness (mg/L) observed during the 2021 season. The acute freshwater criteria for copper are also provided.

COLLECTION DATE	SAMPLE EVENT	RIVER MILE	HARDNESS (MG/L)	COPPER ($\mu\text{G/L}$) ¹⁶	ACUTE(FRESH) CRITERIA	CONDITION
5/18/2021	1	10.1	30.6	0.417	4.40	Does not exceed
5/18/2021	1	12.75	29.9	0.402	4.31	Does not exceed
5/18/2021	1	19	35.2		5.02	Does not exceed
5/18/2021	1	19.1	28.3	0.431	4.09	Does not exceed
5/18/2021	1	20.75	30.4	0.386	4.38	Does not exceed
5/19/2021	1	31	34.0	0.413	4.86	Does not exceed
5/19/2021	1	40	29.5	0.406	4.25	Does not exceed
5/19/2021	1	70	40.0	0.463	5.67	Does not exceed
5/19/2021	1	76	38.6	0.393	5.48	Does not exceed
5/19/2021	1	82	38.9	0.400	5.52	Does not exceed
5/19/2021	1	82.1	43.2	0.516	6.09	Does not exceed
5/20/2021	1	5	108.0	2.620	14.45	Does not exceed
5/20/2021	1	21	28.9	0.547	4.17	Does not exceed
5/20/2021	1	21.1	28.8	0.490	4.16	Does not exceed
5/20/2021	1	23	31.5	0.398	4.53	Does not exceed
6/7/2021	2	10.1	37.3	0.403	5.31	Does not exceed
6/7/2021	2	12.75	37.2		5.29	Does not exceed
6/7/2021	2	19	53.6		7.47	Does not exceed
6/7/2021	2	19.1	36.6		5.21	Does not exceed
6/7/2021	2	20.75	36.8		5.24	Does not exceed
6/8/2021	2	5	45.9	0.779	6.45	Does not exceed
6/8/2021	2	21	36.9	0.311	5.25	Does not exceed
6/8/2021	2	21.1	36.9		5.25	Does not exceed
6/8/2021	2	31	38.0		5.40	Does not exceed

¹⁶ Blank indicates analyte was not detected. When an analyte is not detected, a substitute value equal to one half of the PQL (1.0 $\mu\text{g/L}$) is used to evaluate against water quality criteria (see the DEC Consolidated Assessment and Listing Methodology).

COLLECTION DATE	SAMPLE EVENT	RIVER MILE	HARDNESS (MG/L)	COPPER (µG/L) ¹⁶	ACUTE(FRESH) CRITERIA	CONDITION
6/8/2021	2	40	36.4		5.19	Does not exceed
6/8/2021	2	70	48.4		6.78	Does not exceed
6/8/2021	2	76	48.7		6.82	Does not exceed
6/21/2021	3	10.1	34.7		4.96	Does not exceed
6/21/2021	3	12.75	35.8		5.11	Does not exceed
6/21/2021	3	19	59.7		8.27	Does not exceed
6/21/2021	3	19.1	35.6		5.08	Does not exceed
6/21/2021	3	20.75	36.0		5.13	Does not exceed
6/22/2021	3	5	40.3		5.71	Does not exceed
6/22/2021	3	21	34.6		4.94	Does not exceed
6/22/2021	3	21.1	35.0		5.00	Does not exceed
6/22/2021	3	23	36.1		5.15	Does not exceed
6/22/2021	3	31	36.4		5.19	Does not exceed
6/22/2021	3	40	33.9		4.85	Does not exceed
6/22/2021	3	70	46.0		6.47	Does not exceed
6/22/2021	3	76	48.1		6.74	Does not exceed
7/6/2021	4	10.1	37.8	0.356	5.37	Does not exceed
7/6/2021	4	12.75	37.2		5.29	Does not exceed
7/6/2021	4	19	75.7	0.543	10.34	Does not exceed
7/6/2021	4	19.1	39.0	0.323	5.53	Does not exceed
7/6/2021	4	20.75	36.9	0.381	5.25	Does not exceed
7/7/2021	4	5	41.5	0.438	5.87	Does not exceed
7/7/2021	4	21	38.3	1.690	5.44	Does not exceed
7/7/2021	4	21.1	37.4	0.356	5.32	Does not exceed
7/7/2021	4	23	38.9		5.52	Does not exceed
7/7/2021	4	31	39.1		5.55	Does not exceed
7/7/2021	4	40	38	0.342	5.40	Does not exceed
7/7/2021	4	70	50.6	2.050	7.07	Does not exceed, Rejected ¹⁷
7/7/2021	4	76	48.9	0.521	6.85	Does not exceed

¹⁷ This sample and its paired duplicate sample failed the 10% and 20% RPD check (RPD=135%).

COLLECTION DATE	SAMPLE EVENT	RIVER MILE	HARDNESS (MG/L)	COPPER ($\mu\text{G/L}$) ¹⁶	ACUTE(FRESH) CRITERIA	CONDITION
7/19/2021	5	10.1	37.8		5.37	Does not exceed
7/19/2021	5	12.75	37.5		5.33	Does not exceed
7/19/2021	5	19	75.5		10.31	Does not exceed
7/19/2021	5	19.1	37.7		5.36	Does not exceed
7/19/2021	5	20.75	38.0		5.40	Does not exceed
7/20/2021	5	5	52.3	0.533	7.30	Does not exceed
7/20/2021	5	21	40.1		5.68	Does not exceed
7/20/2021	5	21.1	40.0		5.67	Does not exceed
7/20/2021	5	23	39.8	1.580	5.64	Does not exceed
7/20/2021	5	31	38.7		5.49	Does not exceed
7/20/2021	5	40	38.9		5.52	Does not exceed
7/20/2021	5	70	51.2		7.15	Does not exceed
7/20/2021	5	76	49.9		6.98	Does not exceed
8/2/2021	6	10.1	39.2	0.623	5.56	Does not exceed
8/2/2021	6	12.75	40.2	0.572	5.69	Does not exceed
8/2/2021	6	19	77.6	0.579	10.58	Does not exceed
8/2/2021	6	19.1	39.2	0.602	5.56	Does not exceed
8/2/2021	6	20.75	39.1	1.360	5.55	Does not exceed
8/3/2021	6	5	49.0	0.953	6.86	Does not exceed
8/3/2021	6	21	39.2	0.552	5.56	Does not exceed
8/3/2021	6	21.1	39.4	0.627	5.59	Does not exceed
8/3/2021	6	23	41.2	0.592	5.83	Does not exceed
8/3/2021	6	31	39.8	0.644	5.64	Does not exceed
8/3/2021	6	40	38.4	0.515	5.45	Does not exceed
8/3/2021	6	70	50.9	0.766	7.11	Does not exceed
8/3/2021	6	76	50.9	0.554	7.11	Does not exceed
8/16/2021	7	10.1	37.3	0.537	5.31	Does not exceed
8/16/2021	7	12.75	37.9	0.356	5.39	Does not exceed
8/16/2021	7	19	69.4		9.53	Does not exceed
8/16/2021	7	19.1	37.7		5.36	Does not exceed

COLLECTION DATE	SAMPLE EVENT	RIVER MILE	HARDNESS (MG/L)	COPPER (µG/L)¹⁶	ACUTE(FRESH) CRITERIA	CONDITION
8/16/2021	7	20.75	37.3		5.31	Does not exceed
8/17/2021	7	5	40.2	0.424	5.69	Does not exceed
8/17/2021	7	21	37.5		5.33	Does not exceed
8/17/2021	7	21.1	38.4		5.45	Does not exceed
8/17/2021	7	23	38.2		5.43	Does not exceed
8/17/2021	7	31	37.7		5.36	Does not exceed
8/17/2021	7	40	37.0		5.27	Does not exceed
8/17/2021	7	70	46.3		6.51	Does not exceed
8/17/2021	7	76	46.8	0.530	6.57	Does not exceed
8/30/2021	8	10.1	39.5	0.666	5.60	Does not exceed
8/30/2021	8	12.75	40.5	0.322	5.73	Does not exceed
8/30/2021	8	19	68.7		9.44	Does not exceed
8/30/2021	8	19.1	40.8	0.554	5.77	Does not exceed
8/30/2021	8	20.75	40.4	0.702	5.72	Does not exceed
8/31/2021	8	5	42.0		5.93	Does not exceed
8/31/2021	8	21	40.4	0.590	5.72	Does not exceed
8/31/2021	8	21.1	38.2	0.655	5.43	Does not exceed
8/31/2021	8	23	40.8	0.581	5.77	Does not exceed
8/31/2021	8	31	41.3	0.555	5.84	Does not exceed
8/31/2021	8	40	38.0	0.557	5.40	Does not exceed
8/31/2021	8	70	49.6	1.000	6.94	Does not exceed
8/31/2021	8	76	50.0	0.427	6.99	Does not exceed
8/31/2021	8	82	47.7	0.430	6.69	Does not exceed
8/31/2021	8	82.1	49.3	0.477	6.90	Does not exceed

Table C. 2. Averaged dissolved copper and corresponding hardness by sampling event (4-day average). Corresponding chronic freshwater criteria is also provided. Analysis excludes rejected values (n=1).

SAMPLE EVENT	AVG. COPPER (µG/L)	AVG. HARDNESS (MG/L)	CHRONIC (FRESHWATER) CRITERIA	CONDITION
AK_L_2030212_001				
1	0.458	41.05	4.18	Does not exceed criteria
8	0.454	48.50	4.83	Does not exceed criteria
AK_R_2020214_007				
1	0.428	39.30	4.03	Does not exceed criteria
2	0.500	48.55	4.83	Does not exceed criteria
3	0.500	47.05	4.70	Does not exceed criteria
4	1.286	49.75	4.93	Does not exceed criteria
5	0.500	50.55	5.00	Does not exceed criteria
6	0.660	50.90	5.03	Does not exceed criteria
7	0.515	46.55	4.66	Does not exceed criteria
8	0.714	49.80	4.94	Does not exceed criteria
AK_R_2030218_002_001				
1	0.985	50.93	5.03	Does not exceed criteria
2	0.546	43.50	4.40	Does not exceed criteria
3	0.500	42.63	4.32	Does not exceed criteria
4	0.459	48.05	4.79	Does not exceed criteria
5	0.508	50.78	5.02	Does not exceed criteria
6	0.682	51.50	5.08	Does not exceed criteria
7	0.454	46.20	4.63	Does not exceed criteria
8	0.497	47.68	4.76	Does not exceed criteria
AK_R_2030218_002_002				
1	0.439	30.20	3.22	Does not exceed criteria
2	0.469	36.93	3.82	Does not exceed criteria
3	0.500	35.37	3.68	Does not exceed criteria
4	0.585	38.23	3.94	Does not exceed criteria
5	0.654	39.03	4.01	Does not exceed criteria

SAMPLE EVENT	AVG. COPPER (μG/L)	AVG. HARDNESS (MG/L)	CHRONIC (FRESHWATER) CRITERIA	CONDITION
6	0.699	39.47	4.05	Does not exceed criteria
7	0.500	37.69	3.89	Does not exceed criteria
8	0.599	39.99	4.09	Does not exceed criteria

Appendix D: Alaska Water Quality Criteria for Copper and Zinc

Table C. 3. Alaska water quality criteria for copper and zinc (DEC 2008).

POLLUTANT	CAS Number	Type of Pollutant	Drinking Water	Stock Water	Irrigation Water	ACUTE LIFE CRITERIA FOR FRESH WATER		AQUATIC LIFE FOR MARINE WATER		HUMAN CONSUMPTION OF:	
						Acute	Chronic	Acute	Chronic	Water and Aquatic Organisms	Aquatic Organisms Only
COPPER	7440508	Inorganic	-	-	200 µg/L	See equation for freshwater acute (1-hr avg) dissolved	See equation for freshwater chronic (4-day avg.) dissolved	4.8 µg/L See equation for marine acute (24-hr avg.) dissolved	3.1 µg/L See equation for marine chronic (4-day avg.) dissolved	1,300 µg/L	-
ZINC	7440666	Inorganic	-	-	2,000 µg/L	See equation for freshwater acute (1-hr avg) dissolved	See equation for freshwater chronic (4-day avg.) dissolved	90 µg/L See equation B (1-hr avg.) dissolved	81 µg/L See equation for marine chronic (4-day avg.) dissolved	9,100 µg/L	69,000 µg/L

Table C2. Formulas and parameters for calculating freshwater and marine dissolved metals hardness dependent criteria.

	m_a	b_a	m_c	b_c	CONVERSION FACTORS (CF)			
					Freshwater Acute CF	Freshwater Chronic CF	Marine Acute CF	Marine Chronic CF
COPPER	0.9422	-1.700	0.8545	-1.702	0.960	0.960	0.830	0.830
ZINC	0.8473	0.884	0.8473	0.884	0.978	0.986	0.946	0.946

HARDNESS-DEPENDENT CRITERIA MAY BE CALCULATED FROM THE FOLLOWING:

$$\text{Acute (dissolved)} = e^{\{m_a[\text{Ln(Hardness)}]+b_a\}} * \text{CF}$$

$$\text{Chronic (dissolved)} = e^{\{m_c[\text{Ln(Hardness)}]+b_c\}} * \text{CF}$$

Appendix E: 2021 In situ Field Measurements Summary

Summary of in situ field measurements collected over the 2021 sampling season.

Table D. 1. Average (Avg.) values for in situ parameters at each sample site.

RIVER MILE	AVG. WATER TEMP (DEG C)	AVG. DISSOLVED OXYGEN (DO) (MG/L)	AVG. PH	AVG. TURBIDITY (NTU)	AVG. SALINITY (PSU)	AVG. SPECIFIC CONDUCTIVITY (US/CM)	AVG. TOTAL DISSOLVED SOLIDS (PPT)
5	11.9	11.1	7.83	269.3	0.049	105.5	0.069
10.1	10.4	11.8	7.86	65.7	0.035	75.4	0.049
12.75	10.4	11.8	7.84	33.2	0.035	75.5	0.049
19	11.3	11.3	7.76	3.8	0.061	130.7	0.085
19.1	10.6	12.1	7.97	26.0	0.034	74.8	0.049
20.75	10.7	12.0	8.03	116.1	0.033	72.8	0.047
21	10.6	11.8	7.92	21.6	0.033	71.6	0.047
21.2	10.6	11.8	7.90	18.1	0.032	71.1	0.046
23	11.2	11.7	8.04	19.2	0.034	73.4	0.048
31	10.6	11.8	8.01	14.7	0.034	73.5	0.048
40	10.3	12.0	7.95	17.1	0.032	70.8	0.046
70	9.6	11.9	7.88	2.3	0.043	92.3	0.060
76	9.3	12.1	7.80	2.3	0.042	91.7	0.060
82	7.9	12.6	7.47	74.7	0.038	83.4	0.054
82.1	7.7	12.3	7.52	8.4	0.050	109.3	0.071
OVERALL AVG.	10.5	11.8	7.90	47.3	0.038	83.2	0.054

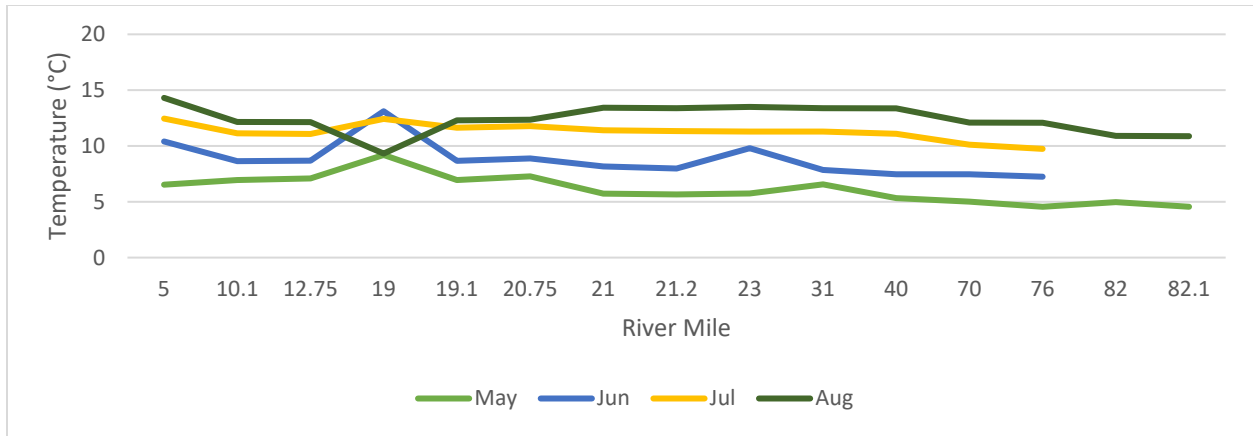


Figure D. 1. Average temperature (°C) observed over the 2021 monitoring season.

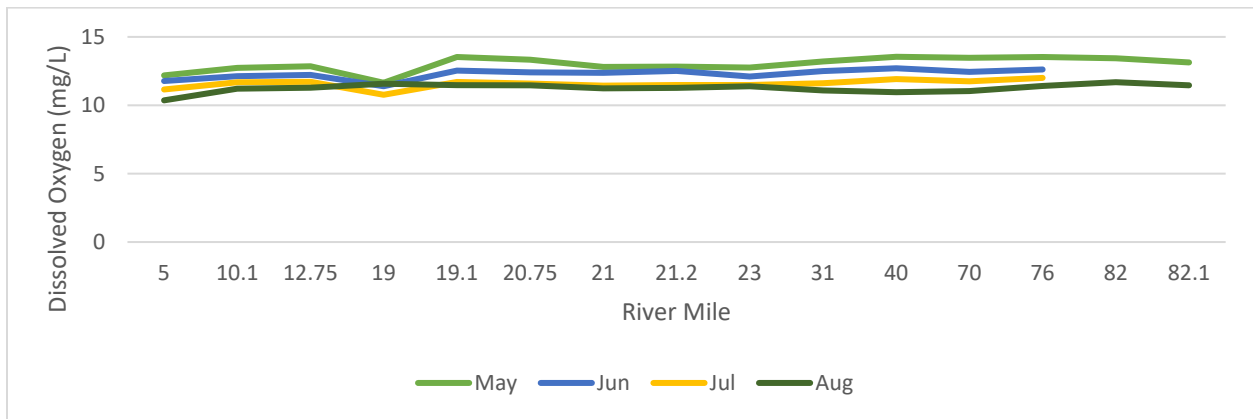


Figure D. 2. Average dissolved oxygen (mg/L) observed over the 2021 monitoring season.

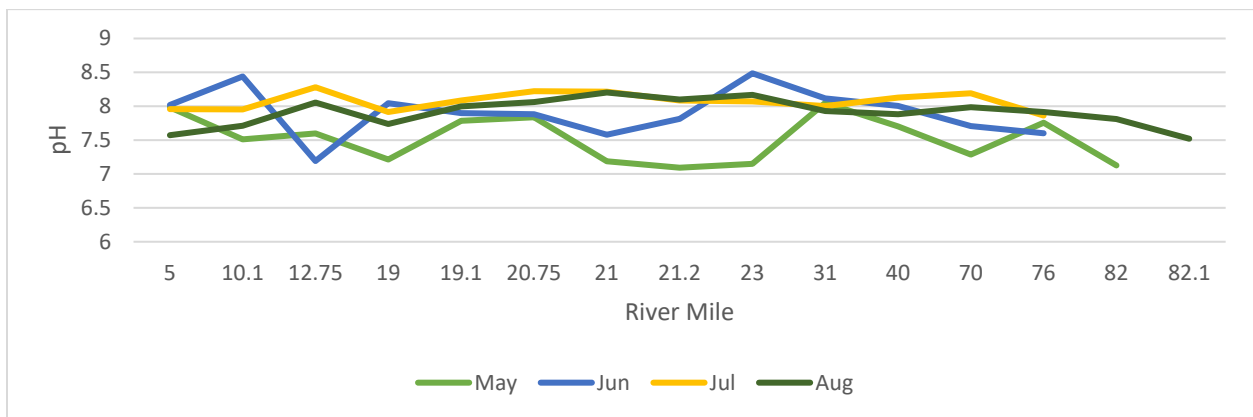


Figure D. 3. Average pH observed over the 2021 monitoring season.

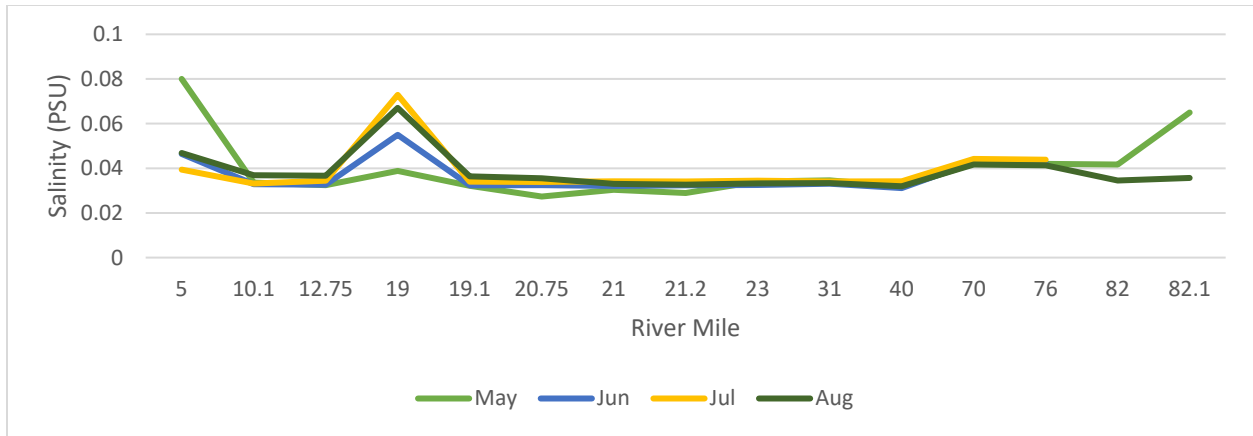


Figure D. 4. Average salinity (PSU) observed over the 2021 monitoring season.

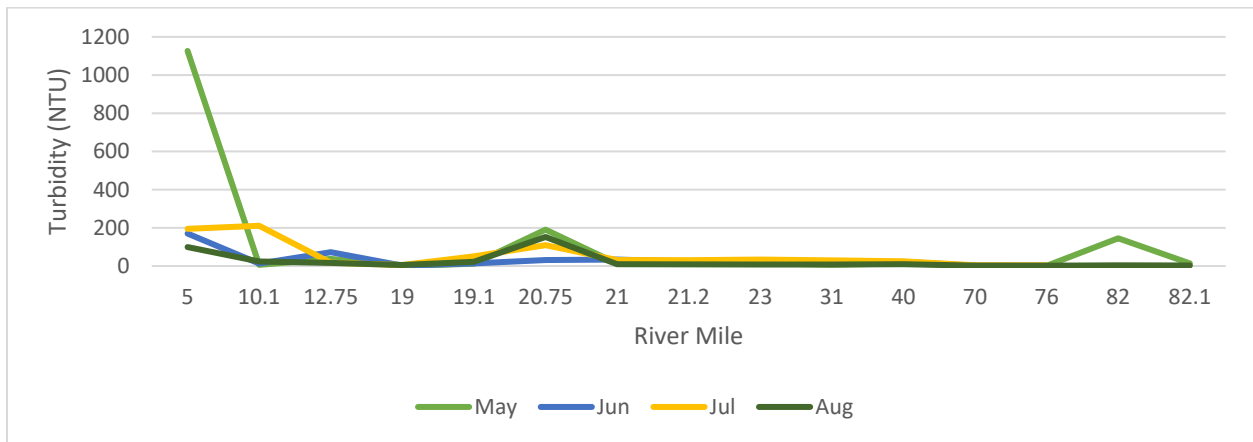


Figure D. 5. Average turbidity (NTU) observed over the 2021 monitoring season.

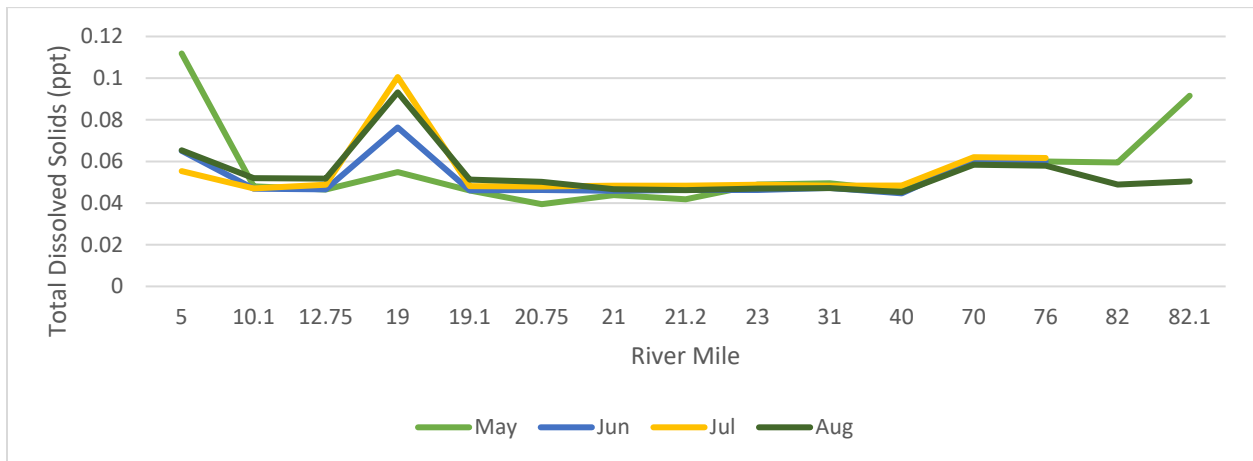


Figure D. 6. Average total dissolved solids (ppt) observed over the 2021 monitoring season.

Total Dissolved Solids (TDS) Method Comparison

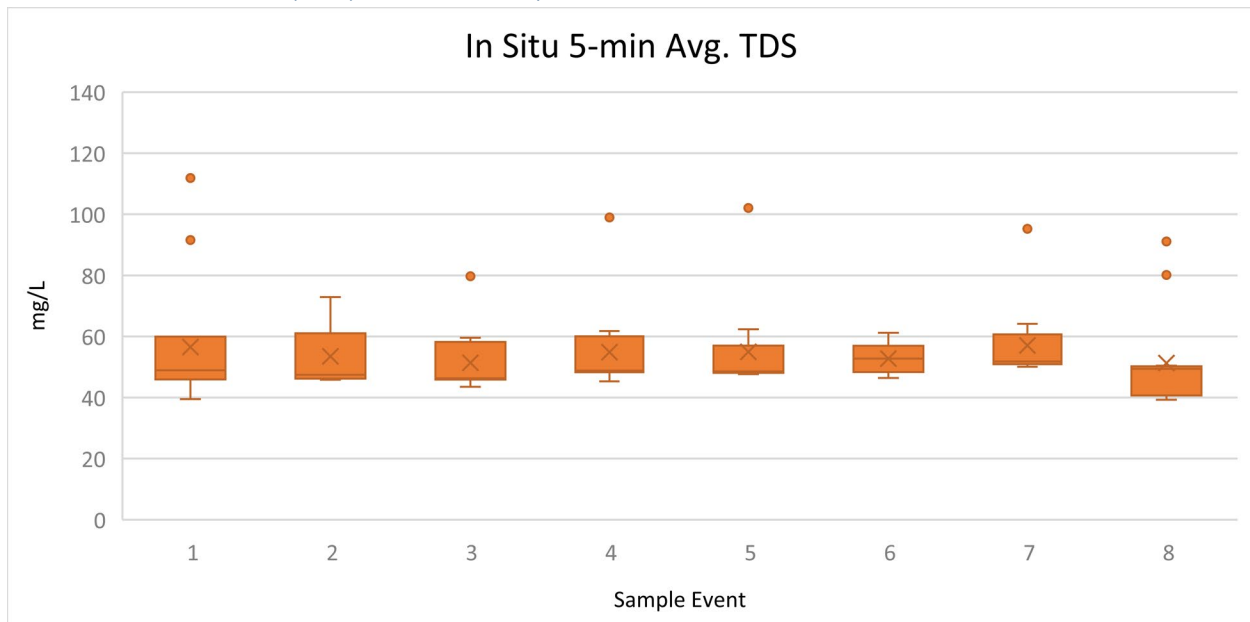


Figure D. 7. Box plots of TDS in situ measurements by 2021 season sampling event. TDS was measured instantaneously, approximately every seven seconds, and then averaged over a five-minute period. In situ TDS measurements were reported in parts per thousand (ppt) and converted to mg/L to allow for direct comparison with grab sample TDS measurements.

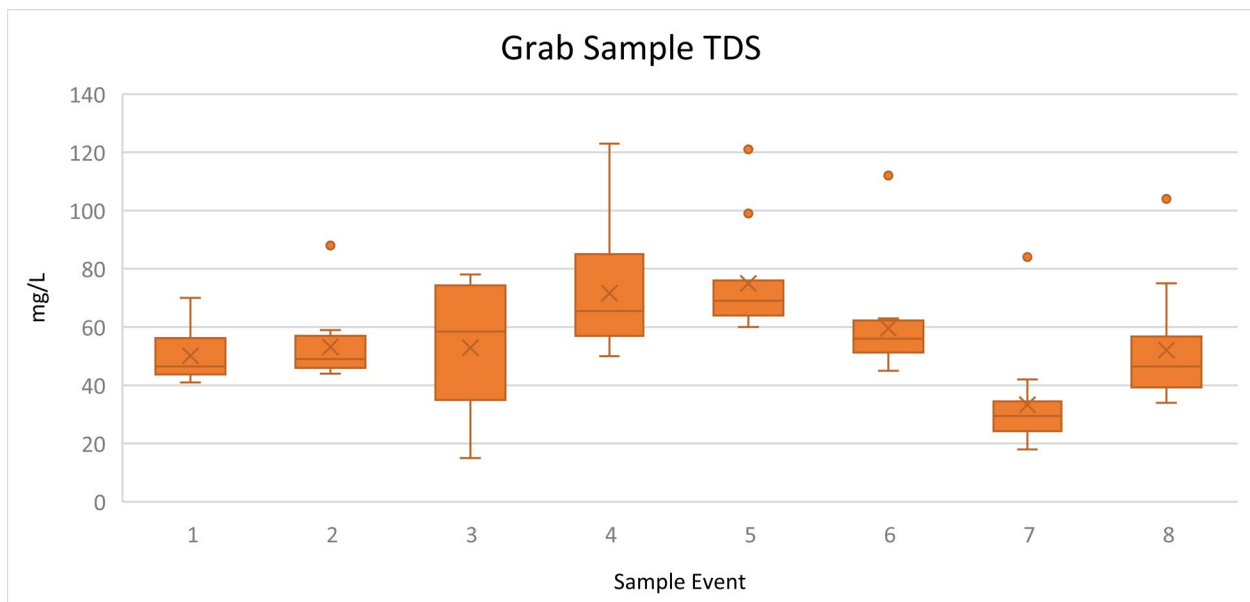


Figure D. 8. Box plots of TDS grab sample results by 2021 season sampling event. Grab samples were collected in the field and sent to a lab for analysis. Grab samples were reported in mg/L.

Appendix F: Clean Hands, Dirty Hands

What is 'Clean Hands, Dirty Hands' (CHDH)?

The Clean Hands Dirty Hands sampling technique of EPA-1669 was developed for low level mercury testing but is often applied to trace metals sampling. This method minimizes potential sample contamination by designating one person to be 'clean hands' (CH) and another as 'Dirty Hands' (DH). DH handles all sampling equipment and CH handles all sample bottles.

Field Application

Clean Hands – The person designated as Clean Hands (CH) will handle the actual sample bottles. CH will fill and label the bottles. CH is responsible for keeping hands clean during sampling events, and changing gloves if contamination occurs. CH is responsible for communicating with other crew members to open coolers, handle sampling equipment, etc., as CH should not be handling any sampling items except for the sample bottles themselves.

Field Sampling Crew – The field sampling crew will be Dirty Hands (DH). DH will open/close the cooler, handle the sealed (in Ziplock) bag of sample bottles, handle the dipper (water collector), and record data.

Boat Crew – The boat operator will be in contact with motor oil, galvanized metals, etc. and therefore should not be handling the actual sample bottles. The boat operator will be responsible for maintaining the boat in position for sampling and safely transporting the crew from one site to the next. The boat operator may help with data recording and other tasks as needed that do not involve directly handling sample bottles.

Required Preparation

- Practice makes perfect – The field sampling team will practice sample collection using the CHDH technique. At least one practice sample collection will be conducted on land, and the other during the boat scouting day.
- Pre-sampling preparation – Bottles will be carefully handled with gloved hands, labeled, and placed into double layer Ziplock bags. DO NOT open bottles before actual sample collection.
- Supplies – The Project Manager will make sure that the field team has enough nitrile gloves, Ziplock's and other tools required to complete field work.

Sunscreen, jewelry, and galvanized metals

- Many cosmetic products including sunscreen contain zinc. It's important to protect you skin against UV, however if you wear sunscreen DO NOT touch your face during active sampling. If you do, change gloves, and start over. Alternatively, wear physical sun protection such as a sun hat, face mask/gaiter, long sleeved shirt, etc.
- Avoid wearing jewelry on your hands and/or wrists. Earrings and necklaces are fine, just avoid touching them during active sampling. If you touch metal jewelry, even if it's not zinc based, change your gloves immediately.
- Galvanized metals are metals coated in zinc oxides. No one actively collecting samples should touch galvanized surfaces during active sample collection. If samplers accidentally touch galvanized metal they should stop, remove the contaminated gloves, and replace contaminated gloves with clean gloves.