



Coordinated Aquatic Monitoring Program

Sedimentation and Erosion Studies

Sedimentation and Water Quality Monitoring
Data Report
Upper Nelson River 2016

June 2017



COORDINATED AQUATIC MONITORING PROGRAM

SEDIMENTATION AND WATER QUALITY MONITORING DATA REPORT UPPER NELSON RIVER 2016

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EXECUTIVE SUMMARY

This document provides summary of the continuous and discrete sedimentation data (total suspended sediment, turbidity and particle size distribution data) and water quality data (temperature, conductivity, and dissolved oxygen) collected between June and October 2016 as a part of Coordinated Aquatic Monitoring Program (CAMP) along the upper Nelson River.

The physical environment monitoring was conducted at ten (10) different sites from the exit of Lake Winnipeg at Warren Landing and 2-Mile Channel to the entrance of Split Lake immediately downstream of the Kelsey Generating Station.

STUDY TEAM

Study Design, data review and reporting performed by Manitoba Hydro Water Resources Engineering Department

Data collection completed by Manitoba Hydro Hydraulic Operations Department

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1.0 Introduction

1.1 Scope

This document reports the 2016 monitoring data collected as a part of Coordinated Aquatic Monitoring Program (CAMP) sedimentation monitoring program along the upper Nelson River. Suspended sediment and water quality monitoring was performed at ten (10) different sites from the exit of Lake Winnipeg at Warren Landing and 2-Mile Channel to the entrance of Split Lake immediately downstream of the Kelsey Generating Station (Figure 1).

The report describes the monitoring program, review process and summary of the continuous and discrete sedimentation data (total suspended sediment, turbidity and particle size distribution data) and water quality data (temperature, conductivity, and dissolved oxygen) collected between June and October 2016.

2.0 Monitoring Program Description

The 2016 monitoring program included continuous monitoring and discrete TSS and water quality (turbidity, conductivity, dissolved oxygen and temperature) monitoring.

The monitoring was conducted at lake inlets and outlets to provide an understanding of the sediment transport entering and leaving the lakes. Discrete water samples were completed to verify the continuous data and to establish TSS – Turbidity relationships at the various locations. The water quality parameters were measured using an YSI EXO2 multi-parameter sonde.



Source: Hydraulic Operations Department, Manitoba Hydro

Photo 1: YSI EXO2 Sondes ready for deployment

Water samples were collected by lowering a hose to the desired depth and pumping the water sample to the surface into a sample bottle; duplicate water samples were collected. An YSI EXO2

sonde was used at the same time to collect and record the water quality data. Information such as sample time, GPS coordinates, site depth and sampling depth are also recorded at the time of collection.

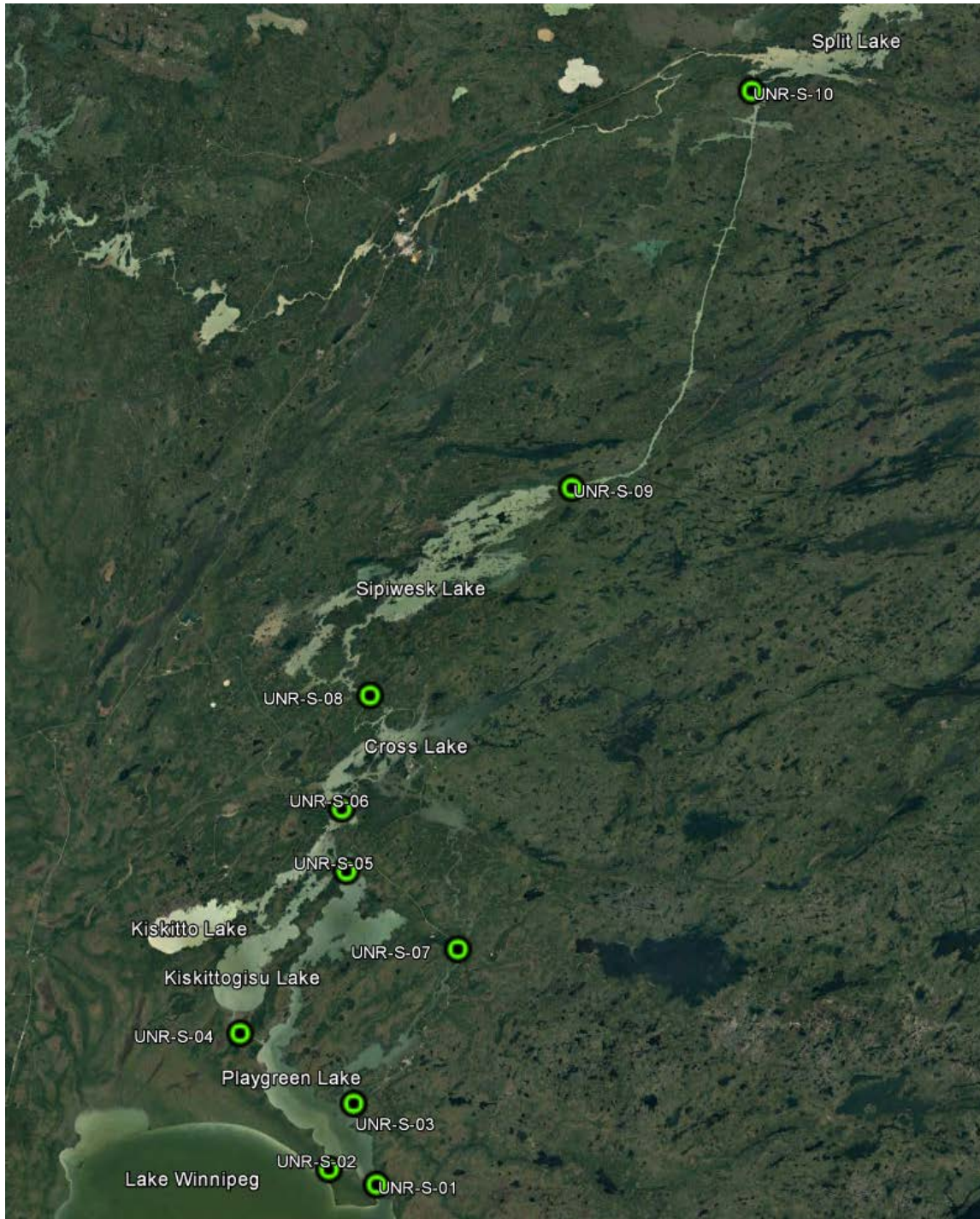
The continuous loggers are programmed to record turbidity, conductivity, dissolved oxygen and temperature data every 5 minutes. The sites were visited every 2 to 3 weeks to maintain and recover the data.

2.1 Location

General site locations for installation of continuous turbidity monitoring are shown in Figure 1 and a brief description of the purpose of the site included in Table 1. Specific field locations were established during a field trip at the start of the field season to ensure each had suitable conditions. The locations were selected to try and have well mixed conditions and having suitable conditions for installing moorings to mount equipment on.

The continuous data logging was done by installing an YSI EXO2 sonde at a depth of 2 metres near the centre of the channel. The site at which the sonde was installed is indicated in square brackets [Site ID] in the first column of Table 1.

At each site, discrete water samples were collected at 20% and 80% depths and at the continuous logger installed 2 m below the surface of the water. Additional discrete readings (turbidity, temperature, conductivity, and dissolved oxygen) were taken at approximately 1 metre depth intervals where conditions allowed (Figure 2). Additional vertical profiles were located across the river at each location verify the turbidity across the width and depth of the river section, these sites were assigned letter designations starting with the letter "a" on the left side looking downstream. The number of vertical profiles at each site was established based on the width of the river channel (Table 2).



Map 1: Upper Nelson River Monitoring Sites

Table 1: System Sediment Monitoring Sites in Upper Nelson Reach

Site ID [EXO2 site]	Northing (Zone 14)	Easting (Zone 14)	Site Description
UNR-S-01a-i [1c]	5955076	574704	Monitoring sediment from Lake Winnipeg to Playgreen Lake at Warren Landing
UNR-S-02a-e [2b]	5957865	562885	Monitoring sediment from Lake Winnipeg to Playgreen Lake through 2-Mile Channel
UNR-S-03a-g [3d]	5973681	568245	Monitoring sediment transport towards Norway House in east channel from Playgreen Lake/Lake Winnipeg
UNR-S-04a-e [4c]	5989319	540540	Monitoring sediment from Playgreen Lake to Kiskittogisu through 8-Mile Channel
UNR-S-05a-g [5b]	6028566	564562	Monitoring sediment from Playgreen Lake
UNR-S-06a-e [6c]	6043287	562999	Monitoring sediment passing through Jenpeg into Cross Lake
UNR-S-07a-e [7c]	6011323	591841	Monitoring sediment out of the east channel downstream of Norway House
UNR-S-08a-e [8c]	6070335	568711	Monitoring sediment from Cross Lake into Sipiwesk Lake
UNR-S-09a-e [9c]	6120918	613996	Monitoring sediment from Sipiwesk Lake into Nelson River
UNR-S -10a-e [10c]	6215957	653345	Monitoring sediment from Nelson River through Kelsey into Split Lake

Table 2: Number of Vertical Profiles

Channel Width (m)	Number of Verticals
<400	5
>400 <1000	7
>1000	9

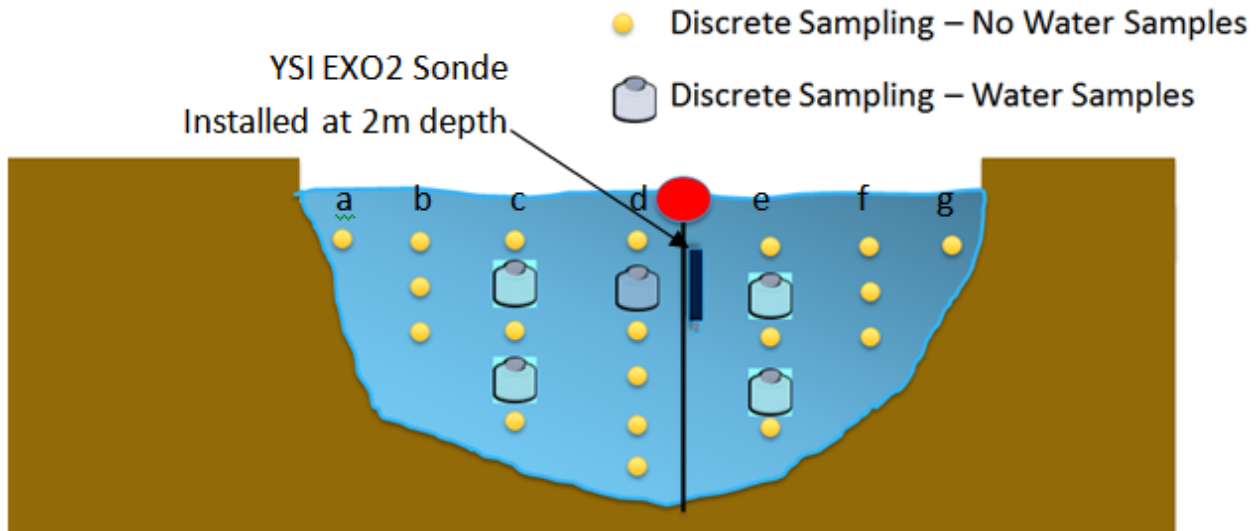


Figure 1: Example Sampling Locations at a River Section

2.2 Timing

The monitoring occurred from June into October (Table 3) with site visits occurring approximately every 2 to 3 weeks to collect discrete samples and maintain the continuous data loggers. Due to technical issues some sites do not have continuous data for the entire duration of the monitoring period.

Table 3: Monitoring Dates

		Site ID (UNR-S-#)									
		1	2	3	4	5	6	7	8	9	10
Monitoring Round	1				16/06/01	16/06/02	16/06/02		16/06/03		
	2	16/06/07	16/06/07	16/06/09	16/06/09	16/06/08	16/06/08	16/06/10	16/06/15	16/06/17	16/06/16
	3	16/06/23	16/06/22	16/06/22	16/06/22	16/06/21	16/06/21	16/06/20	16/06/27	16/06/24	16/06/29
	4	16/07/06	16/07/06	16/07/06	16/07/05	16/07/04	16/07/04	16/07/05			
	5	16/07/19	16/07/19	16/07/19	16/07/19	16/07/20	16/07/18	16/07/20	16/07/22	16/07/22	16/08/03
	6	16/08/10	16/08/10	16/08/10	16/08/10	16/08/09	16/08/09	16/08/09	16/08/16	16/08/16	
	7	16/08/30	16/08/30	16/08/22	16/08/31	16/08/23	16/08/23	16/08/24	16/08/26	16/08/26	16/09/07
	8	16/09/15	16/09/15	16/09/12	16/09/15	16/09/13	16/09/13	16/09/13	16/09/21	16/09/20	
	9	16/10/03	16/10/03	16/10/05	16/10/03	16/10/04	16/10/04	16/10/05	16/09/29	16/09/29	16/09/30

3.0 Data Management and Review Process

The water quality data collected during this program are recorded and stored in several databases. The discrete data is recorded in Manitoba Hydro's Physical Environment database and the continuous loggers' data files are stored in Manitoba Hydro's WISKI database.

3.1 Data Processing and Quality Control

The Quality Control process was completed by following the data review protocols developed for Manitoba Hydro's physical environment monitoring projects. The data review process includes ensuring all metadata are accurately recorded in the database and all field data screened for errors. The resulting good quality data was used to report on the key observations and to generate the summary tables and charts included in this report.

4.0 Sedimentation Data

The 2016 CAMP sedimentation monitoring program included collection of sedimentation data in the Upper Nelson River Reach. The following activities were conducted at the locations listed in Table 1, to understand the sediment transport processes in Upper Nelson River:

- Continuous collection of turbidity data at the monitoring locations
- Discrete collection of turbidity data along transects at the monitoring locations
- Collection of water samples along transects for Total Suspended Solids (TSS) and Particle Size Analysis (PSA)

The following sections contain the description, summary and graphical plots of the good quality data.

4.1 Discrete Sediment Data

The discrete sediment data (turbidity, TSS) is plotted in multiple ways to understand the spatial distribution of suspended sediment.

The discrete data plot presented in subsection 4.1.1 illustrates the variation of sediment parameters within the Upper Nelson River system.

The graphical representation of sediment data measured along the transect line at all monitoring locations can be found in subsection 4.1.2. These graphs provide valuable information about the extent of sediment mixing across the channel width.

A statistical summary of discrete sedimentation data is given in Table 4.

Table 4: Summary of Turbidity and TSS data collected in 2016

Site ID	Continuous			Discrete					
	Turbidity (FNU) 15 min avg.			Turbidity (FNU)			TSS (mg/L)		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
UNR-S-1	3	10	53	4	10	34	<2	10	36
UNR-S-2	4	19	204	5	21	83	3	22	74
UNR-S-3	6	12	32	5	13	51	6	14	54
UNR-S-4	8	24	141	13	23	41	13	23	37
UNR-S-5	9	15	33	8	15	23	9	16	22
UNR-S-6	12	17	28	7	17	26	9	15	24
UNR-S-7	10	13	26	9	13	26	9	15	29
UNR-S-8	15	19	26	10	19	27	4	19	41
UNR-S-9	14	19	29	13	17	23	7	12	20
UNR-S-10	15	17	19	15	21	30	8	16	26

4.1.1 Sedimentation Data variation along UNR Reach

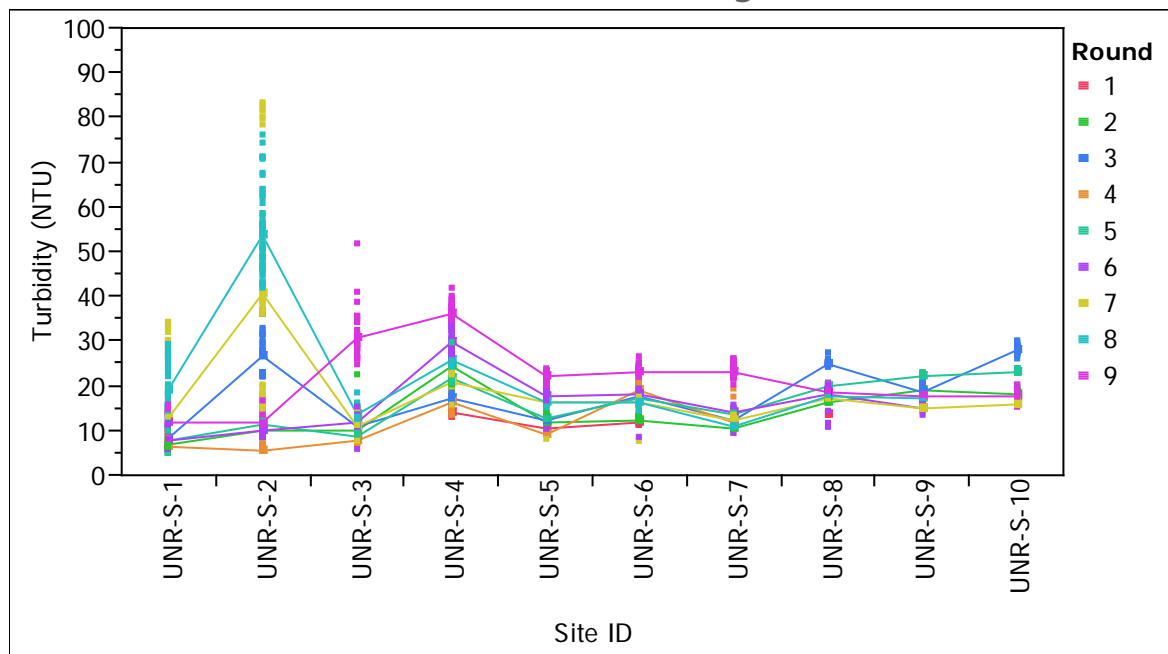


Figure 2: Turbidity (FNU) by Site

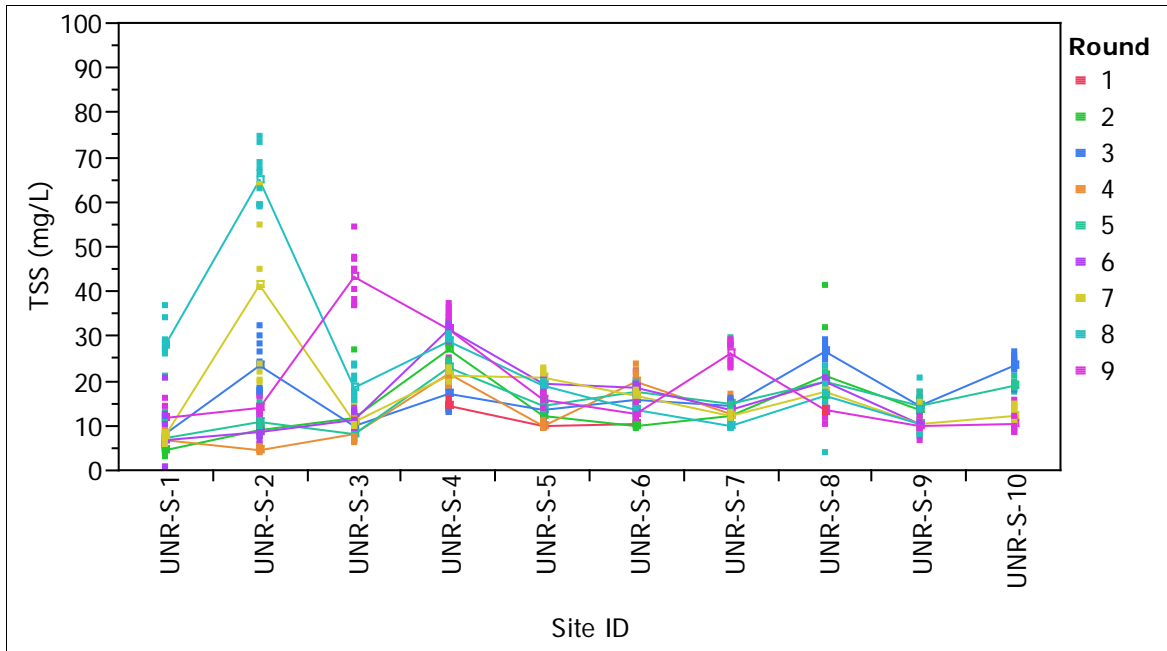


Figure 3: TSS (mg/L) Site

4.1.2 Sedimentation Data variation along Transect Lines

Turbidity at Site UNR-S-1

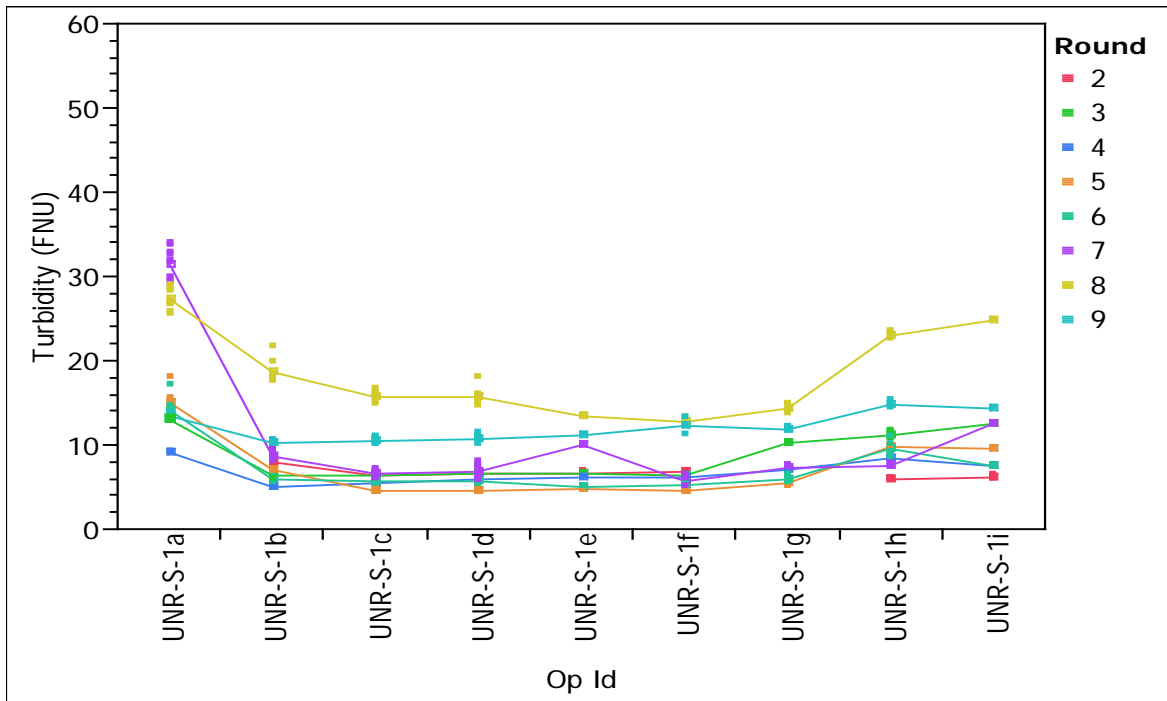


Figure 4: Turbidity at Site UNR-S-1

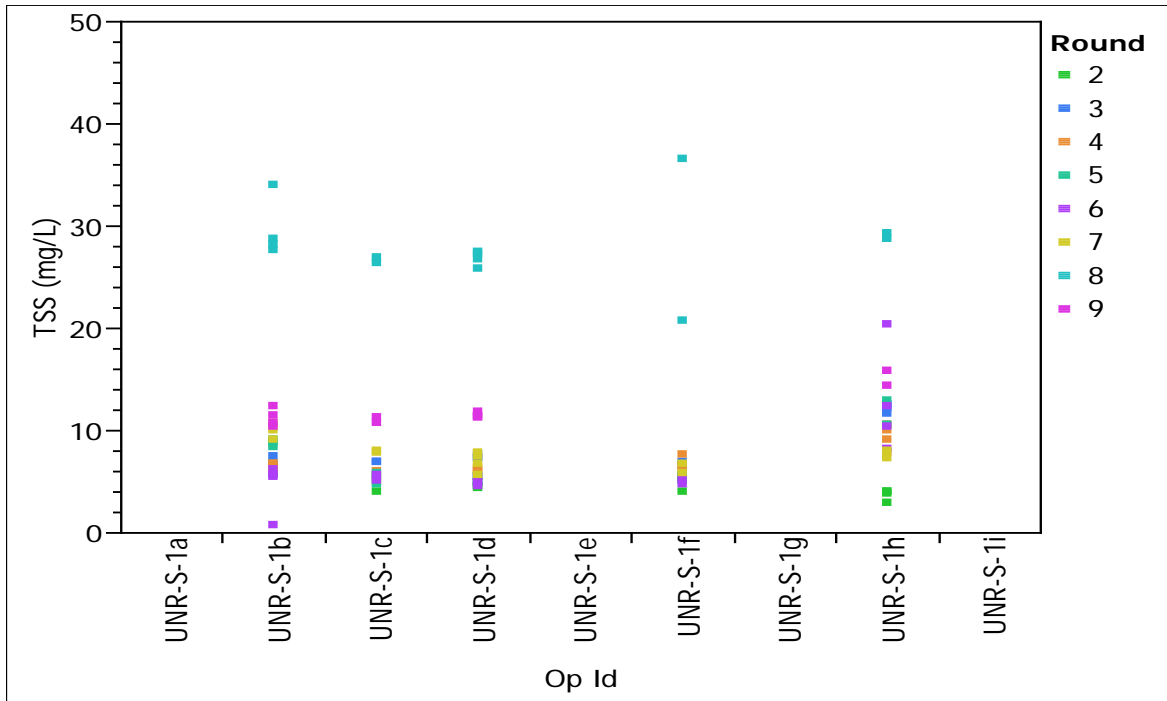


Figure 5: TSS at Site UNR-S-1

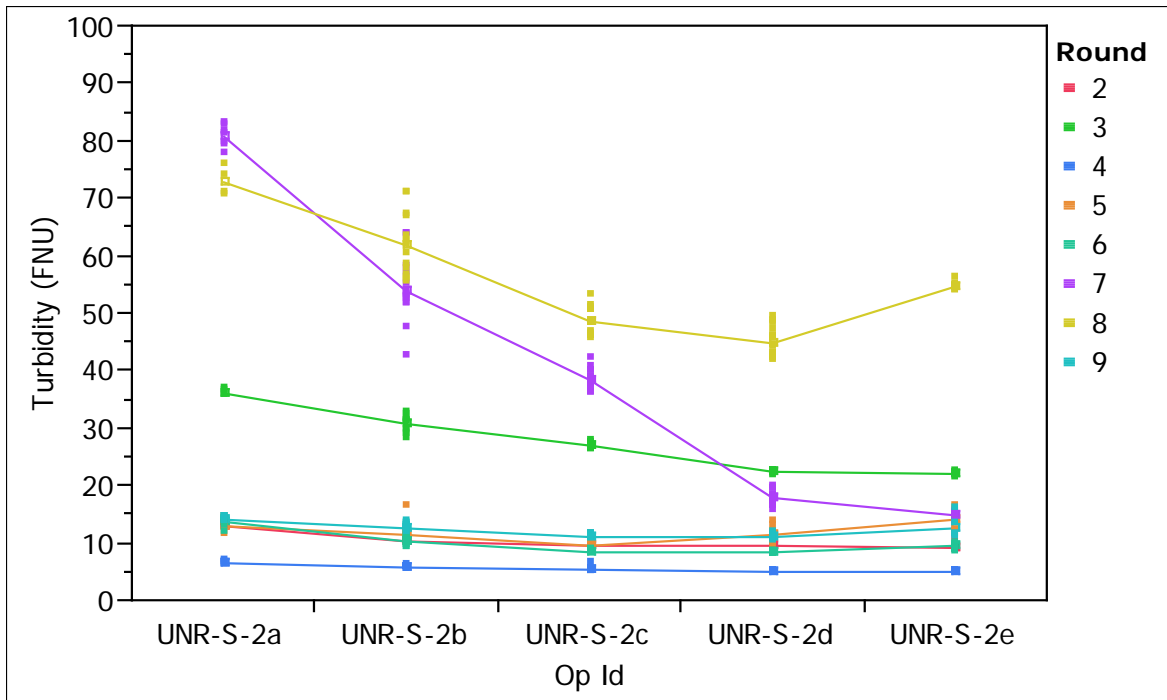


Figure 6: Turbidity at Site UNR-S-2

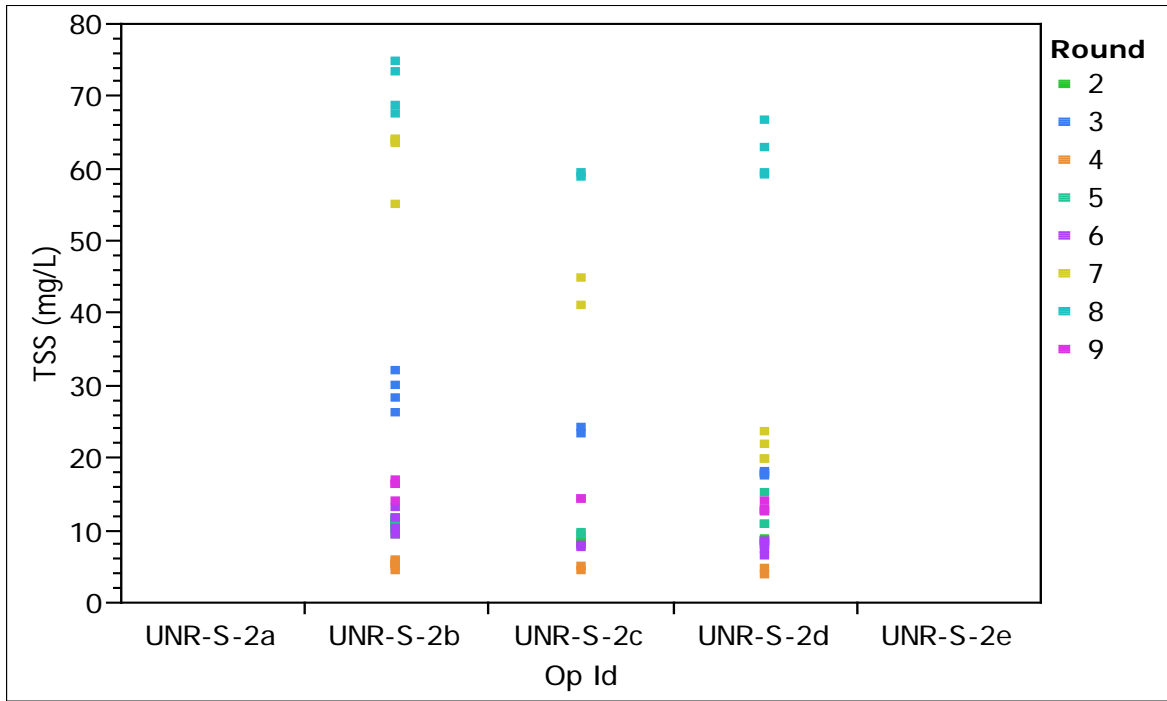


Figure 7: TSS at Site UNR-S-2

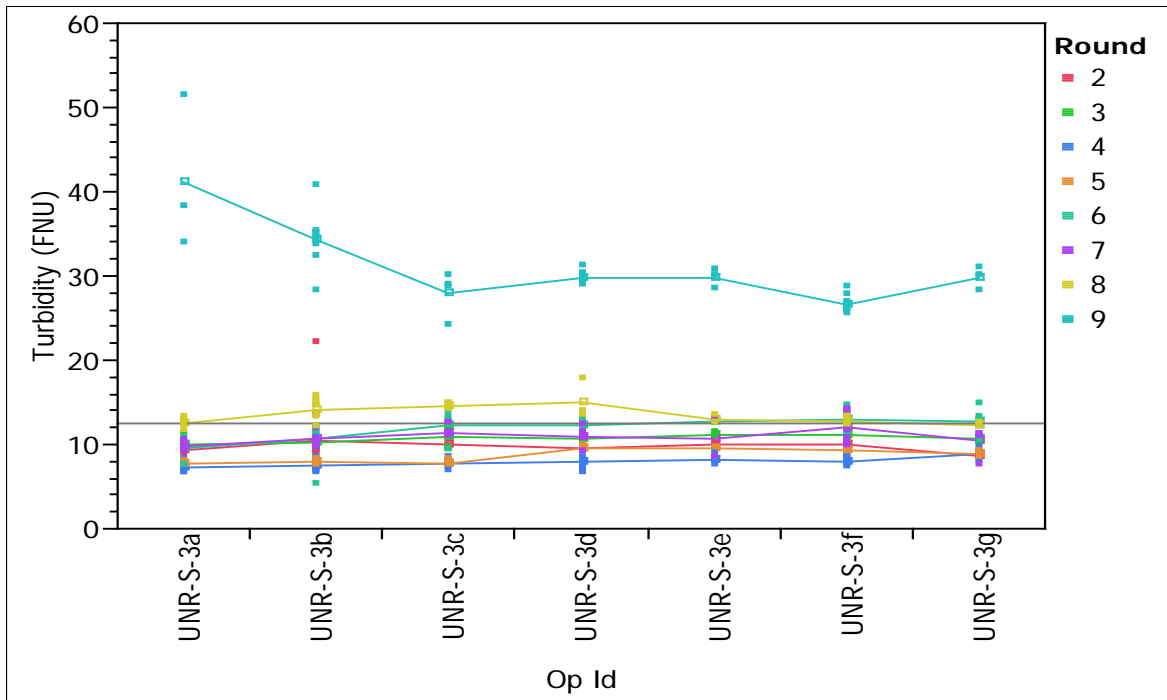


Figure 8: Turbidity at Site UNR-S-3

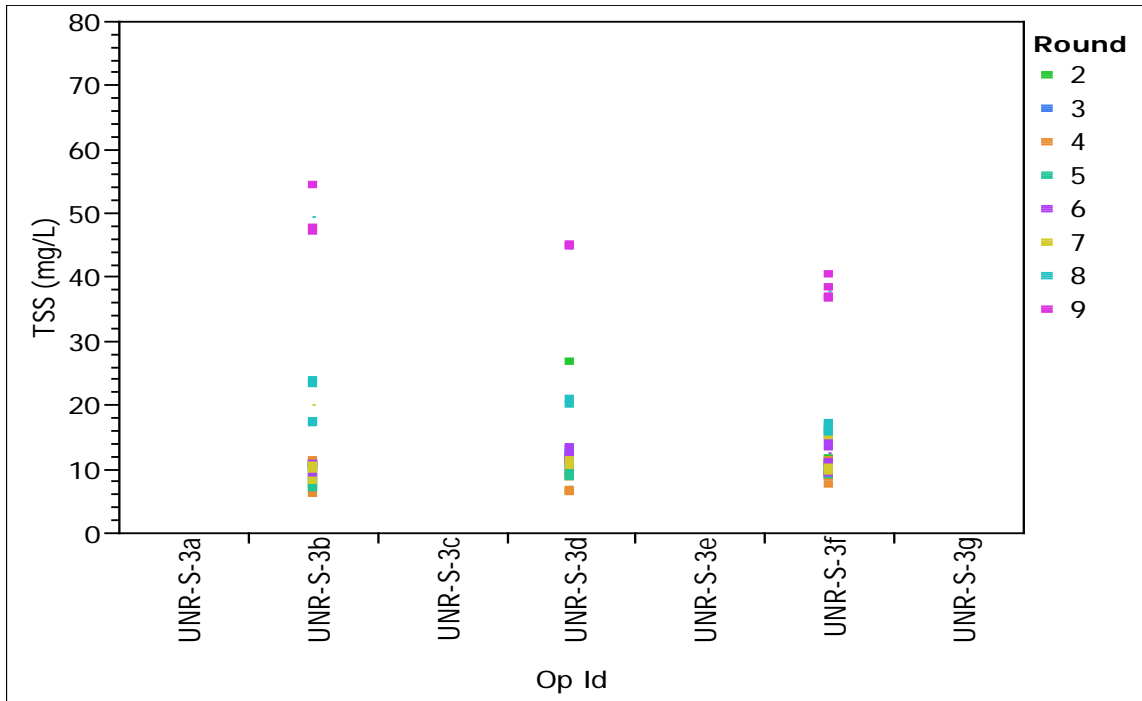


Figure 9: TSS at Site UNR-S-3

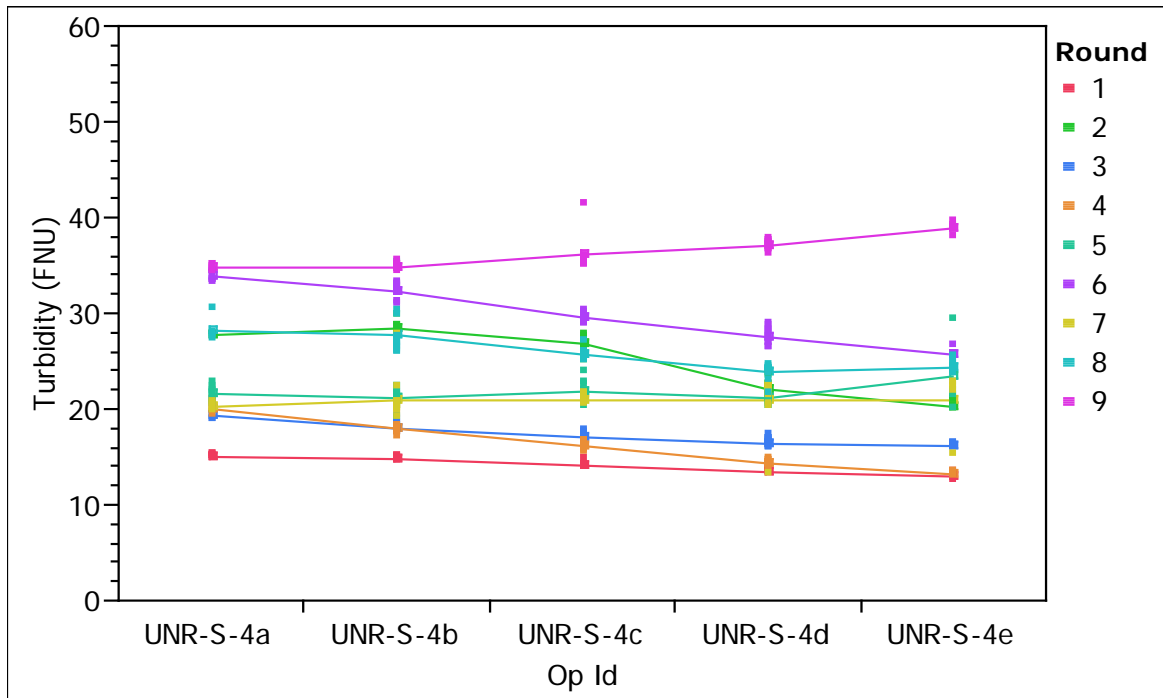


Figure 10: Turbidity at Site UNR-S-4

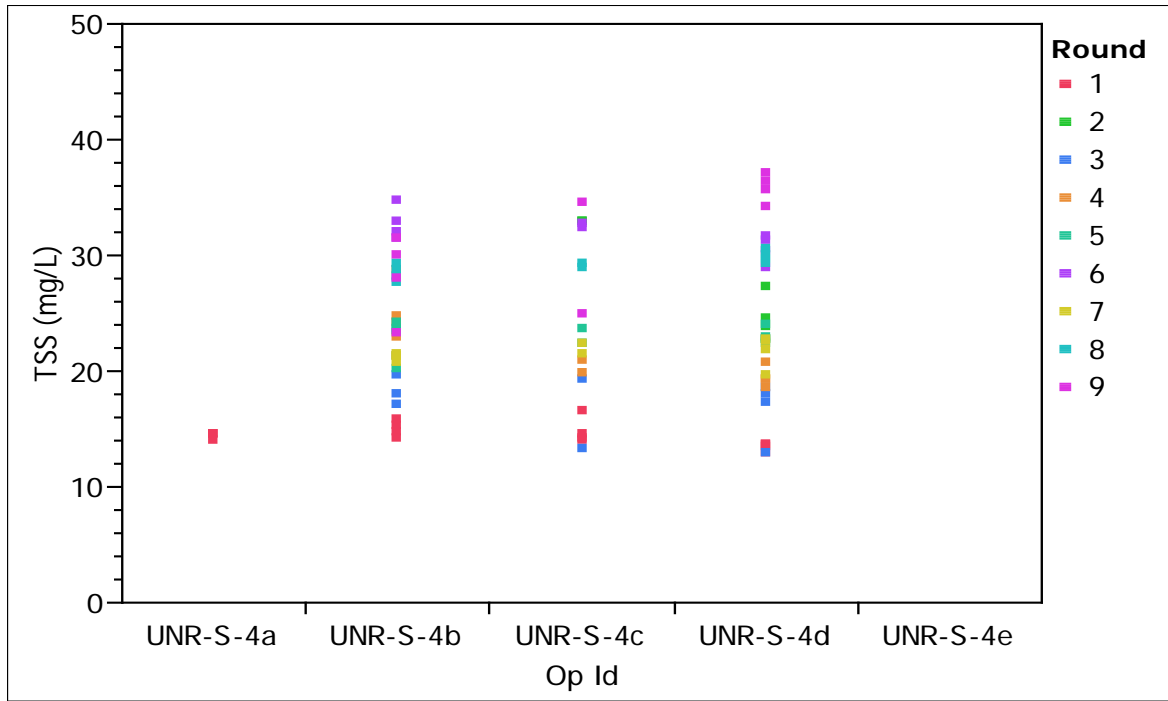


Figure 11: TSS at Site UNR-S-4

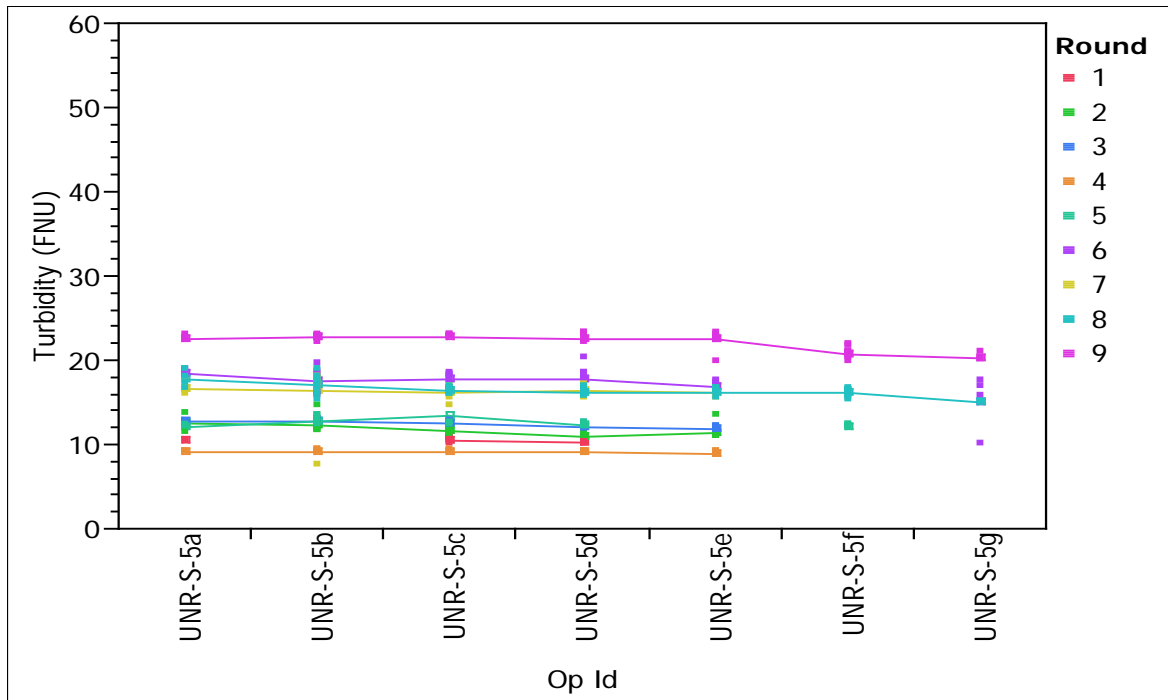


Figure 12: Turbidity at Site UNR-S-5

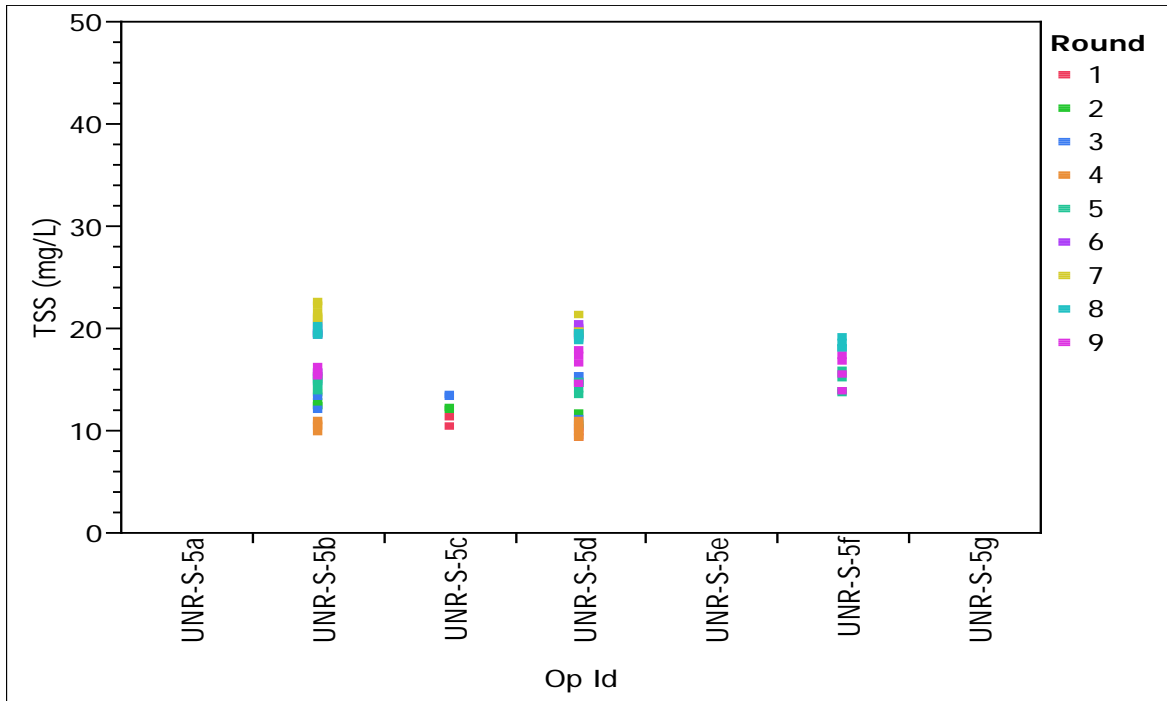


Figure 13: TSS at Site UNR-S-5

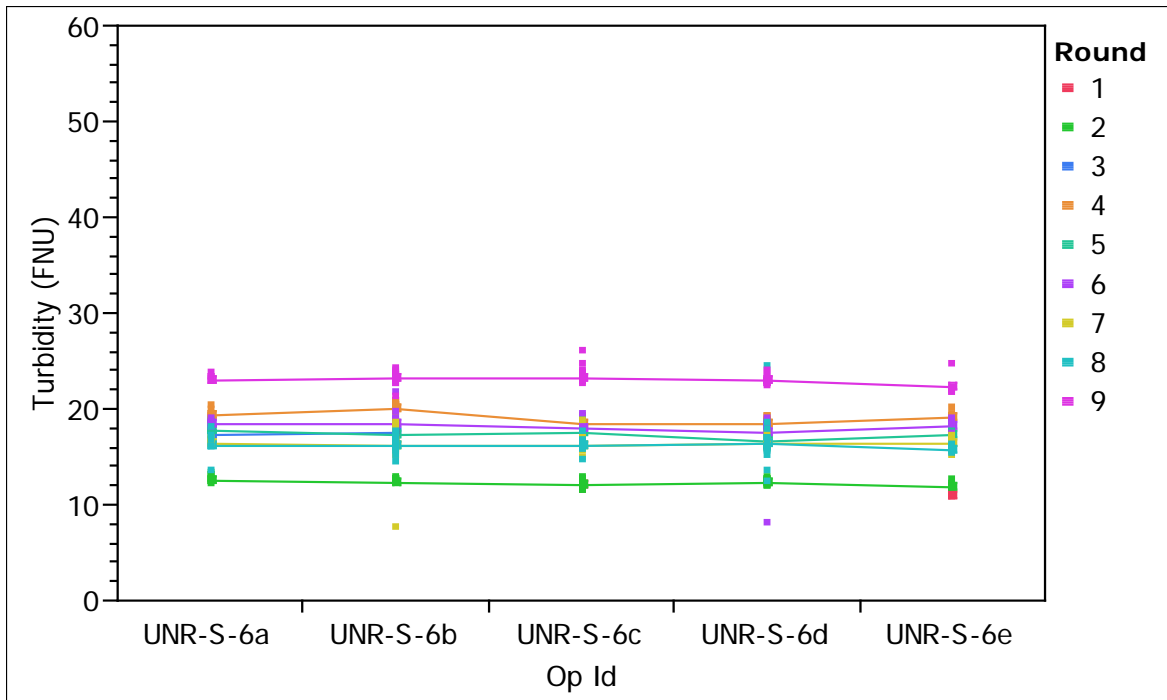


Figure 14: Turbidity at Site UNR-S-6

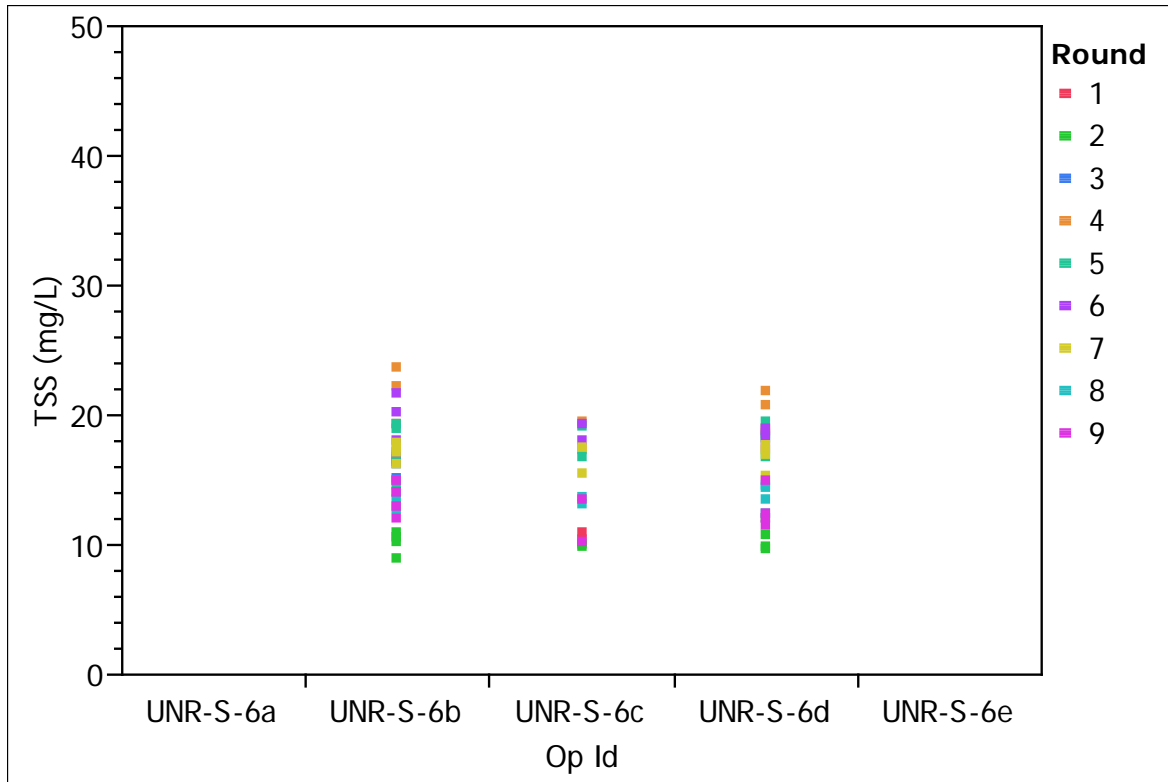


Figure 15: TSS at Site UNR-S-6

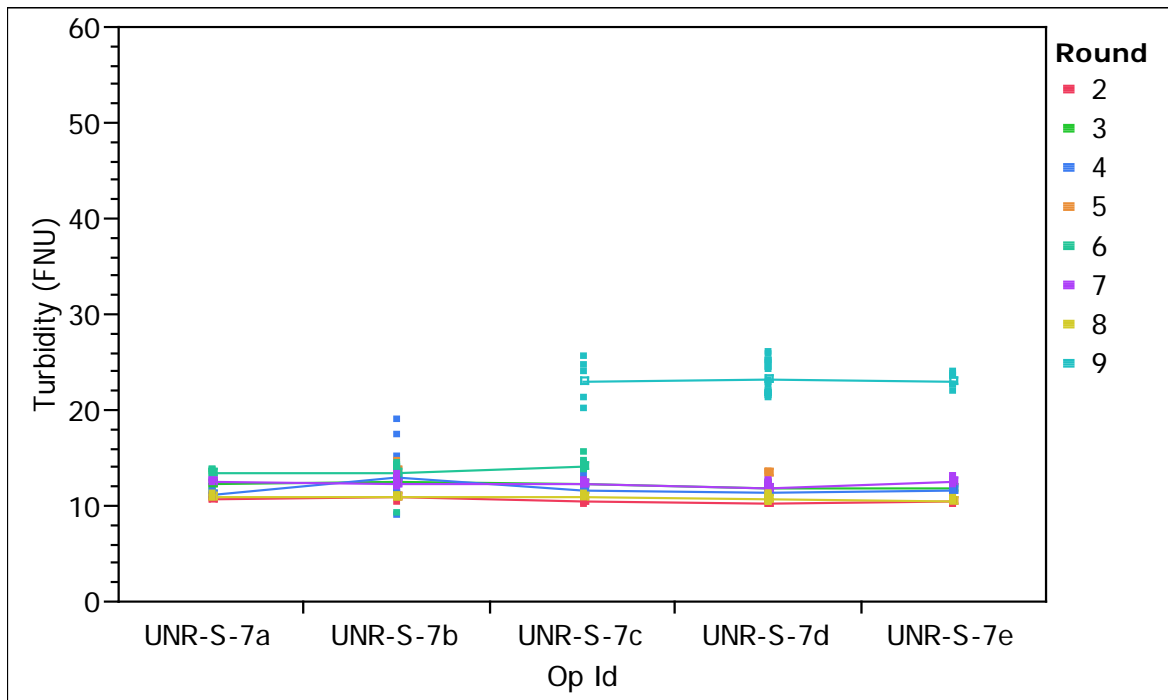


Figure 16: Turbidity at Site UNR-S-7

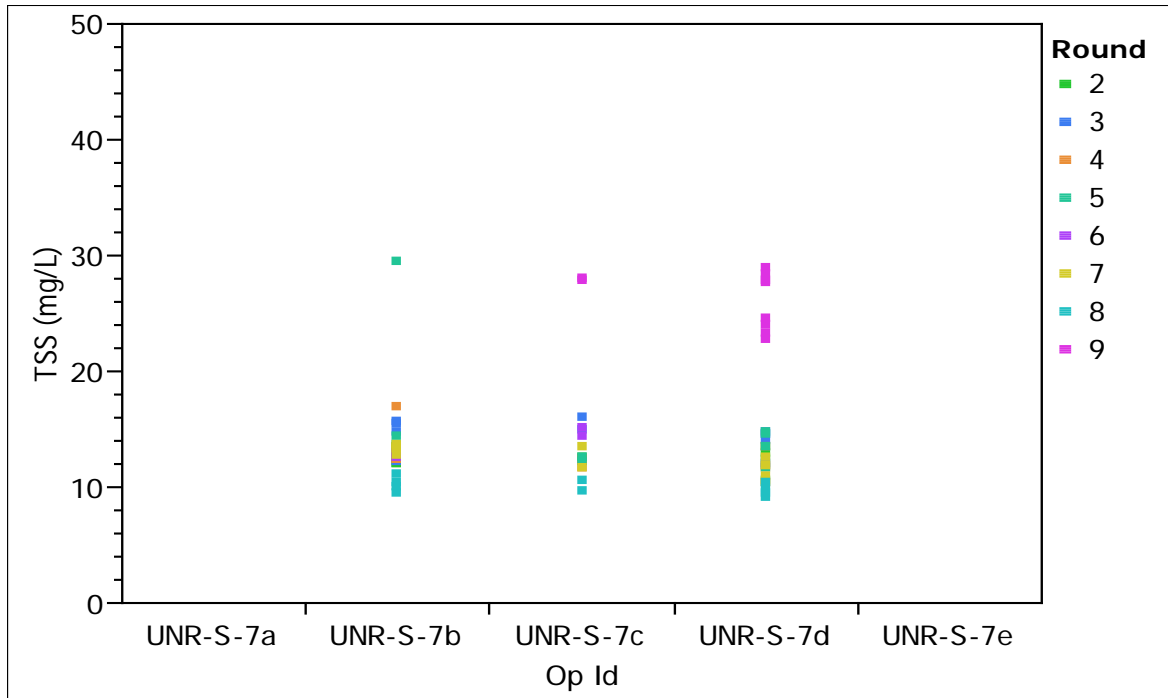


Figure 17: TSS at Site UNR-S-7

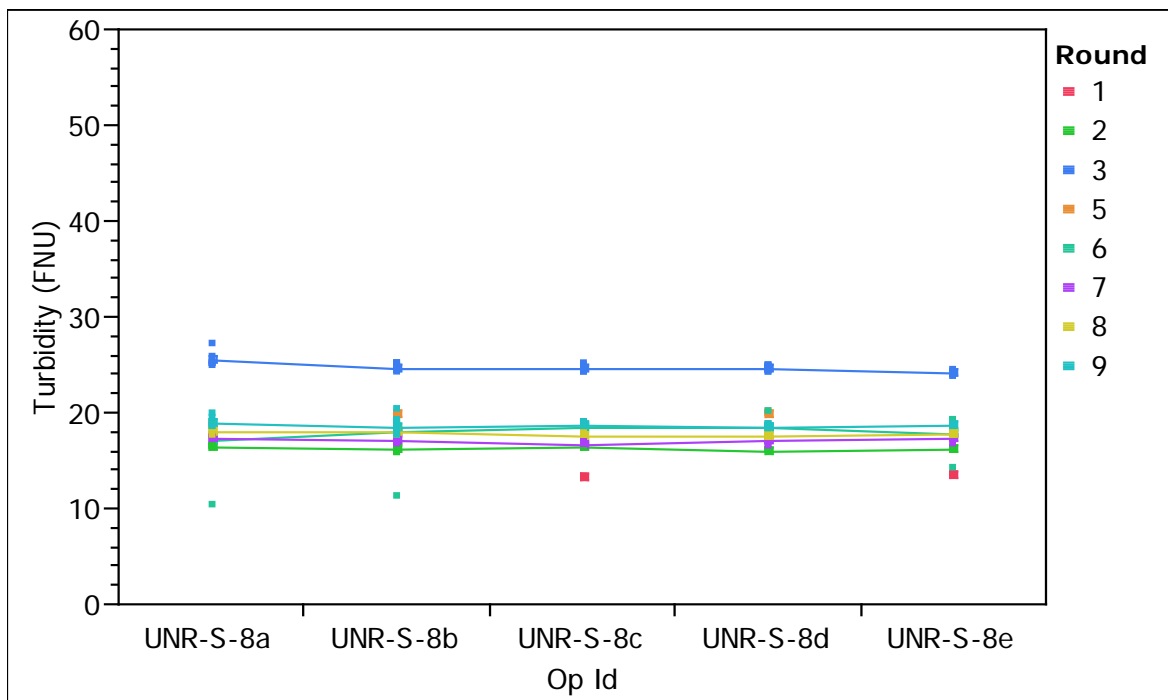


Figure 18: Turbidity at Site UNR-S-8

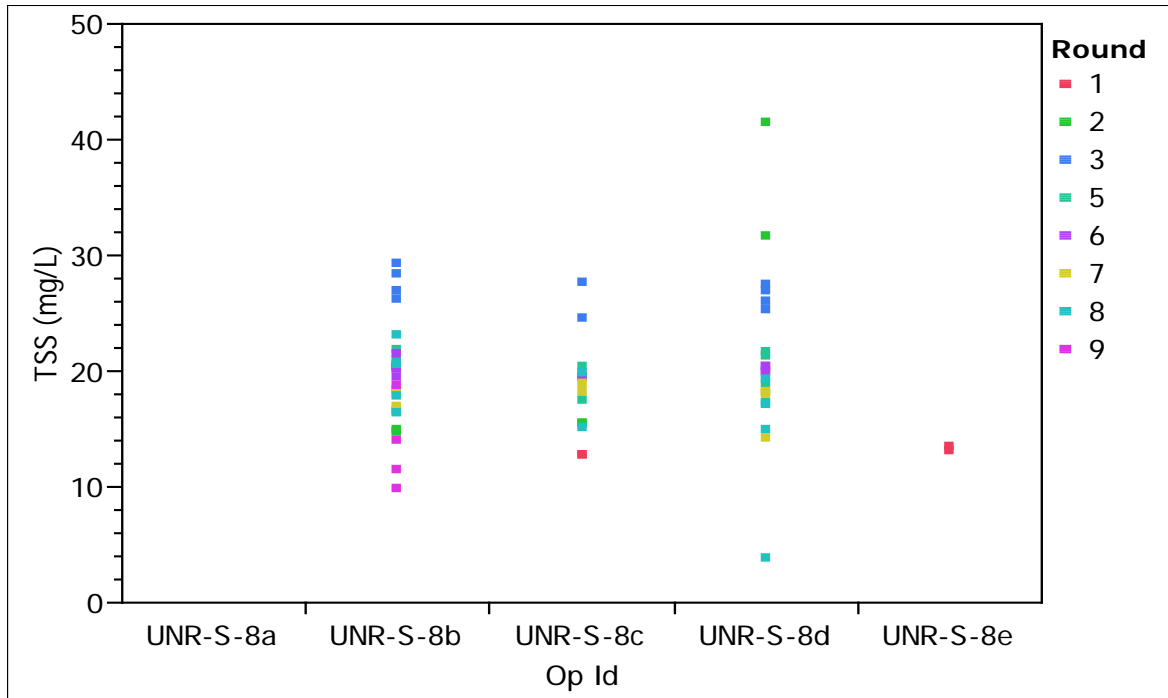


Figure 19: TSS at Site UNR-S-8

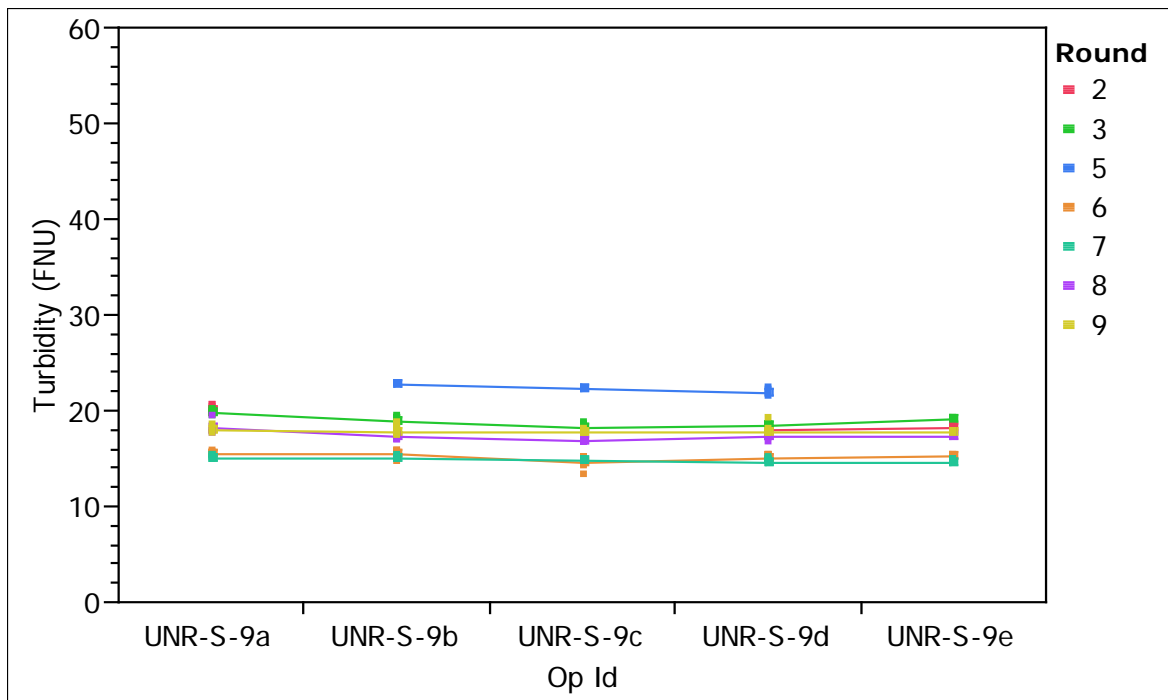


Figure 20: Turbidity at Site UNR-S-9

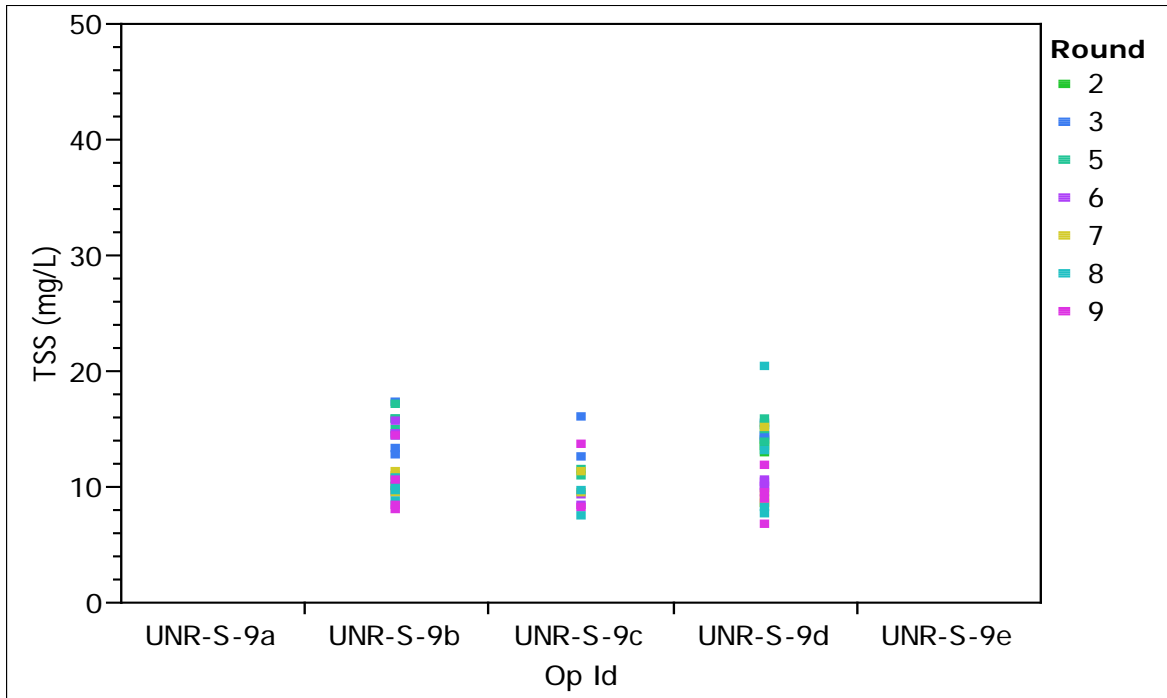


Figure 21: TSS at Site UNR-S-9

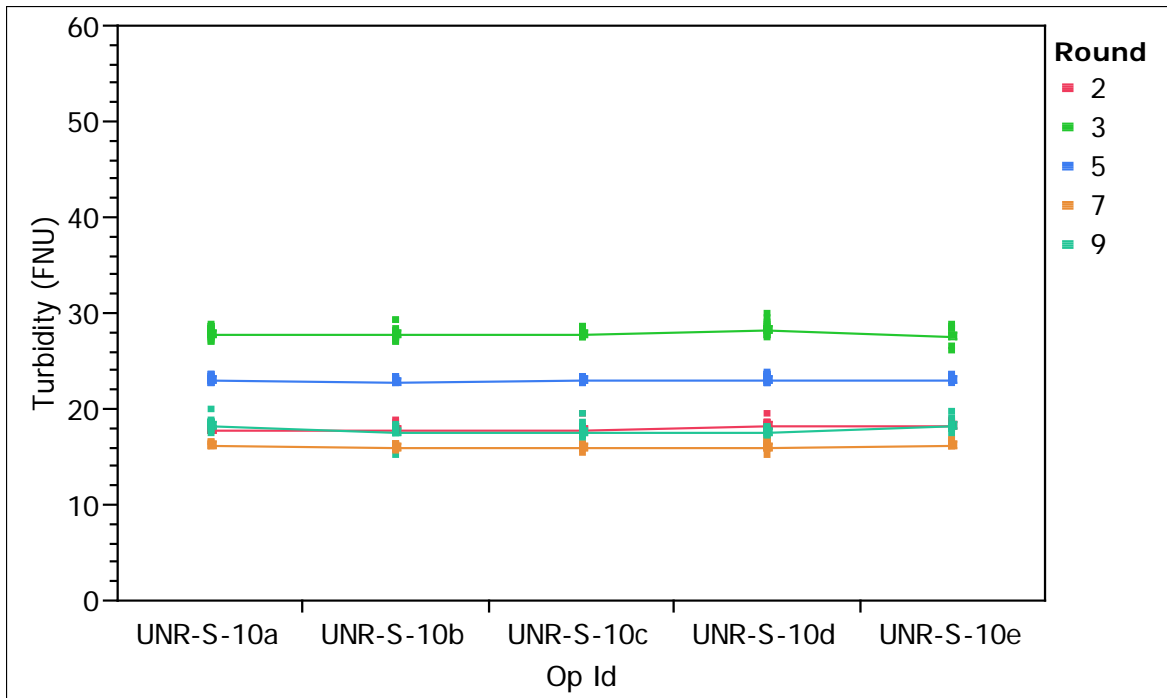


Figure 22: Turbidity at Site UNR-S-10

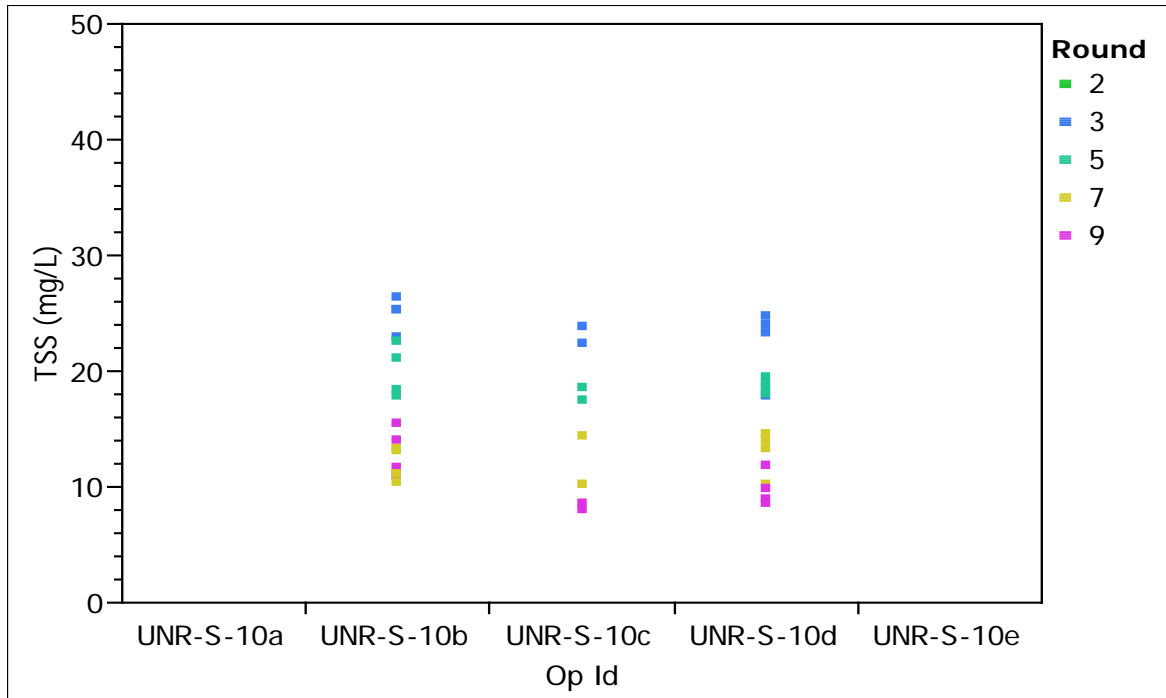


Figure 23: TSS at Site UNR-S-10

4.2 Continuous Sediment Data

The continuous turbidity data was recorded at all locations during the 2016 open water monitoring station. The plots of 15 minute moving average of good quality data for all monitoring locations can be found in subsection 4.2.1.

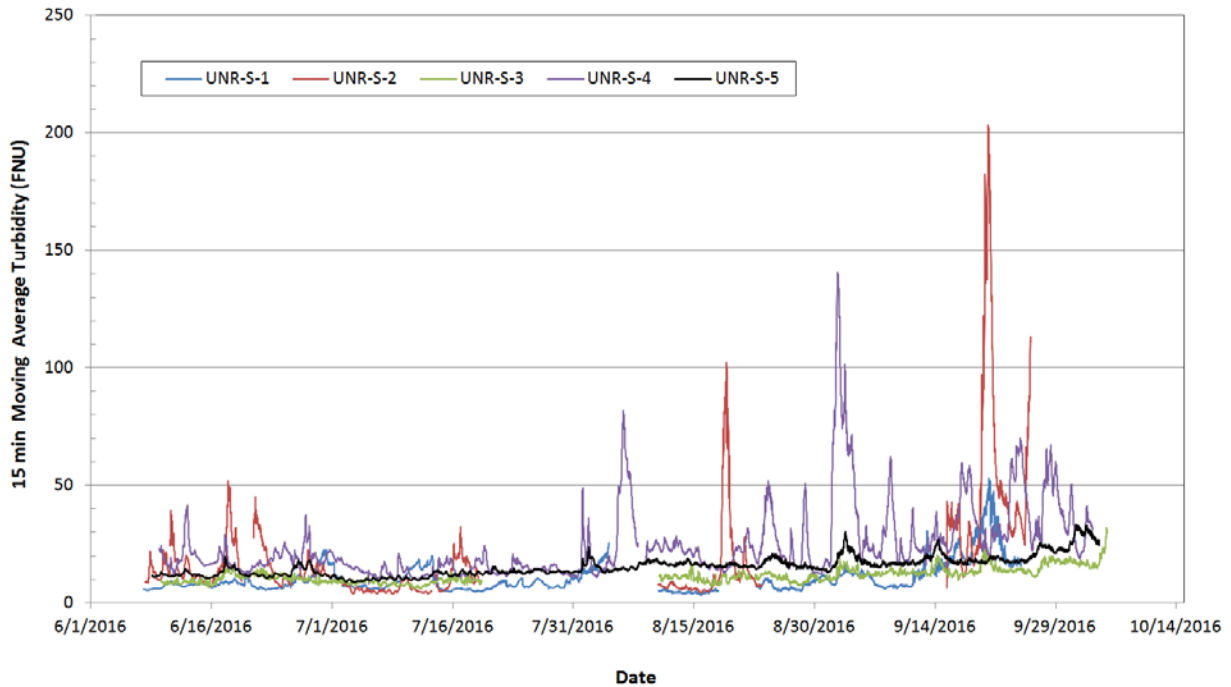
The turbidity plots do contain some gaps, and these gaps are attributed either to the omission of suspect/bad quality data during quality control process or to the absence of data.

In most cases the bad/suspect quality data resulted due to equipment malfunction (battery drain etc.) or due to hydraulic conditions. For example, the continuous logger at 2-mile channel (UNR-S-2) moved multiple times due to complex hydraulic conditions and resulted in suspect and bad quality data. Similarly, the suspect data generated at UNR-S-10 is attributed to the downstream hydraulics of the Kelsey GS.

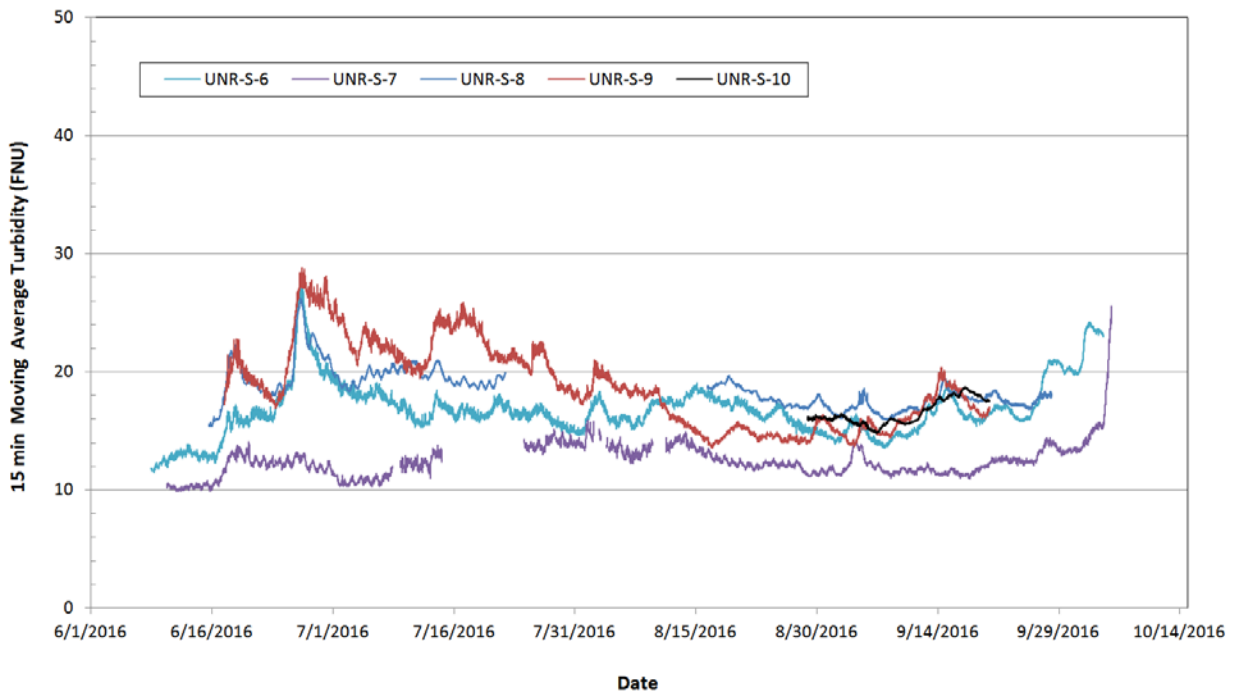
A few instances of no data between site visits resulted from equipment failure and operator error.

A summary of continuous turbidity data is provided in Table 4.

4.2.1 Continuous Water Turbidity Plots (15 min Average)



Continuous Water Turbidity (15 min average) at Locations (UNR-S-1 to UNR-S-5)



Continuous Water Turbidity (15 min average) at Locations (UNR-S-6 to UNR-S-10)

4.2.2 Particle Size Distribution

Water samples were collected at all monitoring locations during the field visits and sent to the laboratory to determine the TSS concentration and their grain size distribution. At each site, duplicate samples were collected at 0.2 and 0.8 depths following standard protocols.²

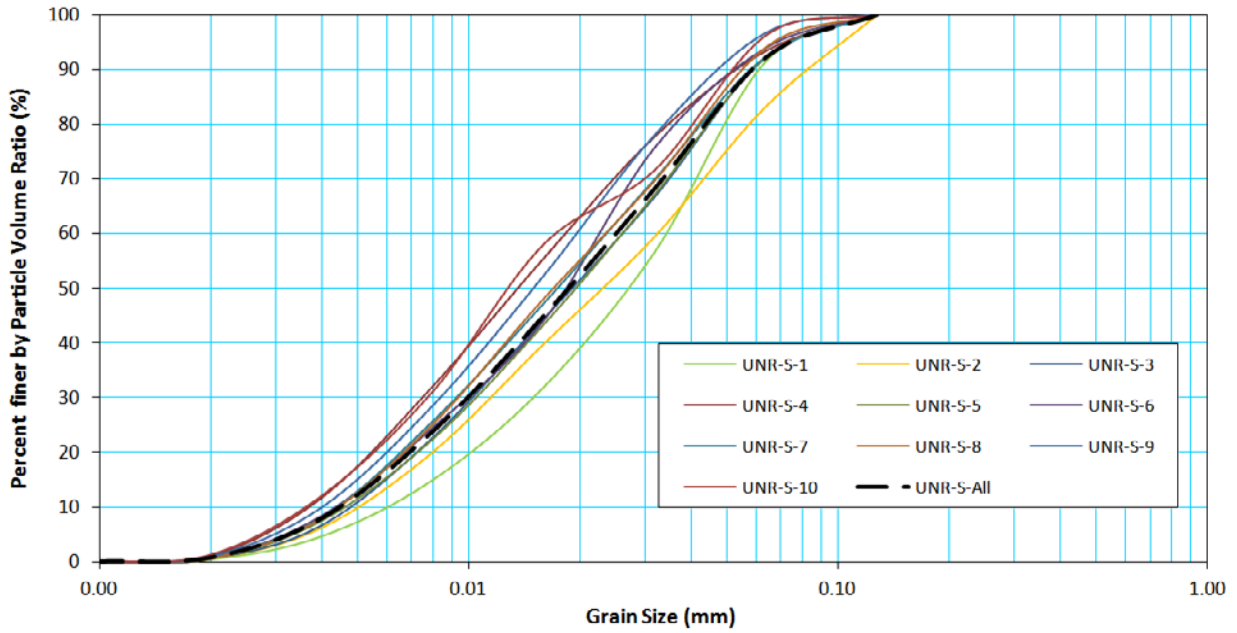
The average grain size distribution of suspended sediment for each site is provided in subsection 4.3.1, along with a plot of longitudinal variation of sediment fractions (Sand, silt and clay) within the upper Nelson River system.

A summary of the average grain size distributions by particle volume count is given in Table 5.

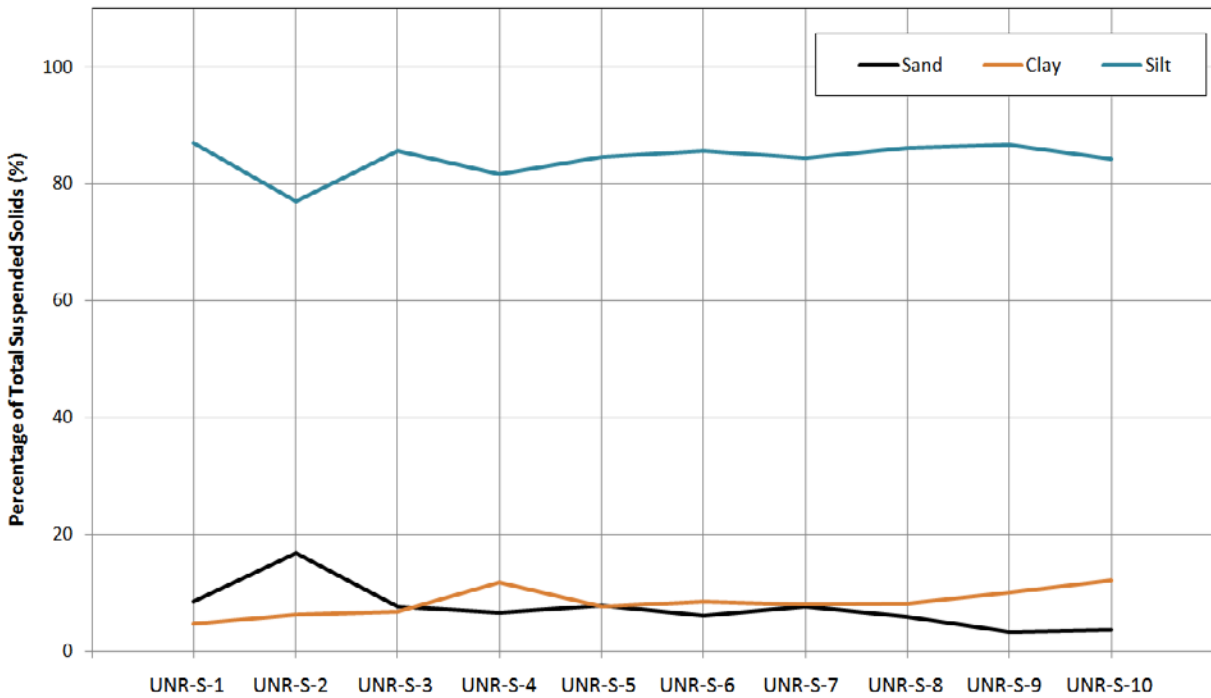
Table 5: Average Grain Size Distribution of Particle Size by Site

Grain Size (µm)	% Finer by Volume Ratio							
	128	0.064	0.032	0.016	0.008	0.004	0.002	0.001
Site ID								
UNR-S-01	100	91.5	56.7	31.9	14.9	4.6	0.4	0.0
UNR-S-02	100	83.3	59.5	39.9	20.1	6.3	0.6	0.0
UNR-S-03	100	92.4	66.8	44.4	22.7	6.7	0.6	0.0
UNR-S-04	100	93.4	77.8	55.5	32.1	11.8	1.1	0.0
UNR-S-05	100	92.2	67.2	43.4	22.5	7.6	0.6	0.0
UNR-S-06	100	94.0	75.8	44.2	24.5	8.4	0.7	0.0
UNR-S-07	100	92.4	70.0	47.2	25.6	8.0	0.7	0.0
UNR-S-08	100	94.1	69.8	48.2	25.2	8.0	0.7	0.0
UNR-S-09	100	96.7	78.1	52.3	28.6	10.0	1.0	0.0
UNR-S-10	100	96.3	71.7	58.1	31.1	12.1	1.3	0.0
UNR-S-All	100	92.2	68.3	45.0	23.8	7.9	0.7	0.0

4.2.3 Average Particle Size Distribution of Total Suspended Solids



Average Particle Size Distribution (by Particle Volume ratio) by Site



Longitudinal Distribution of TSS Fractions in Upper Nelson River Reach

5.0 Additional Water Quality Data

This section summarizes the water quality data collected in addition to the sedimentation data. The continuous data was collected at monitoring locations during the open water season, and the discrete data was collected along established transect locations during each filed visit.

A statistical summary of the collected continuous and discrete data is provided in Table-6 and Table-7 below.

Table 6: Summary of additional discrete data collected in 2016

Discrete Data Results									
Site ID	Temperature (°C)			Dissolved Oxygen (mg/L)			Conductivity (µS/m)		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
UNR-S-1	8.5	15.6	21.1	8.7	10.3	12.5	241	310	367
UNR-S-2	9.6	16.1	20.1	9.2	10.1	12.9	237	317	365
UNR-S-3	9.5	16.7	21.0	8.3	9.6	12.0	260	311	354
UNR-S-4	9.8	15.2	19.1	9.0	10.0	11.7	243	309	357
UNR-S-5	12.5	15.8	20.0	8.6	9.8	11.6	266	310	347
UNR-S-6	12.2	16.7	19.9	8.4	9.3	11.1	270	320	355
UNR-S-7	10.1	16.6	21.2	7.6	9.0	11.9	240	283	328
UNR-S-8	12.1	16.2	20.1	9.6	11.1	12.5	284	311	367
UNR-S-9	12.3	16.5	19.7	8.8	9.7	10.5	276	316	342
UNR-S-10	12.3	16.7	20.6	8.8	9.8	10.9	285	308	340

Table 7: Summary of additional continuous data collected in 2016

Continuous (15 min Average)									
Site ID	Temperature (°C)			Dissolved Oxygen (mg/L)			Conductivity (µS/m)		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
UNR-S-1	8.3	16.8	22.0	8.1	10.0	12.0	246	321	371
UNR-S-2	8.9	16.0	20.4	8.5	9.7	12.8	235	316	364
UNR-S-3	10.9	16.7	20.7	8.1	9.2	10.6	247	311	347
UNR-S-4	11.2	17.1	22.5	8.4	9.4	11.4	257	330	384
UNR-S-5	11.2	17.2	22.6	8.3	9.3	10.7	253	307	369
UNR-S-6	11.7	17.3	22.2	8.2	9.0	10.0	261	311	363
UNR-S-7	13.8	18.9	22.9	8.0	8.7	9.8	246	298	342
UNR-S-8	12.0	17.3	20.4	10.0	11.0	12.3	246	298	342
UNR-S-9	16.3	18.2	19.8	9.0	9.5	10.3	299	321	343
UNR-S-10	14.1	16.5	18.6	-	-	-	299	313	321

In the following sections, the collected data for each water quality indicator is plotted in multiple ways to illustrate the longitudinal variation of these parameters along the Upper Nelson River reach, spatial variation along transects, and temporal variation at the continuous monitoring locations during 2016 open water season.

5.1 Water Temperature

5.1.1 Water Temperature variations along UNR reach

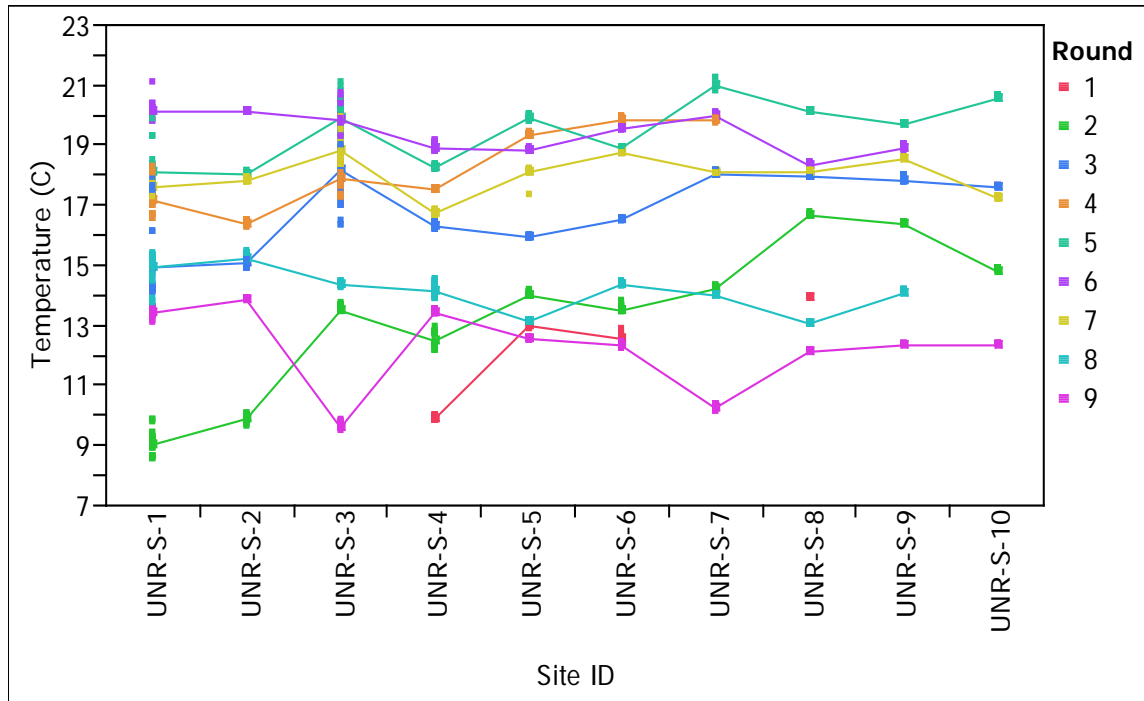


Figure 24: Temperature along UNR reach

5.1.2 Water Temperature variations along Transect Lines

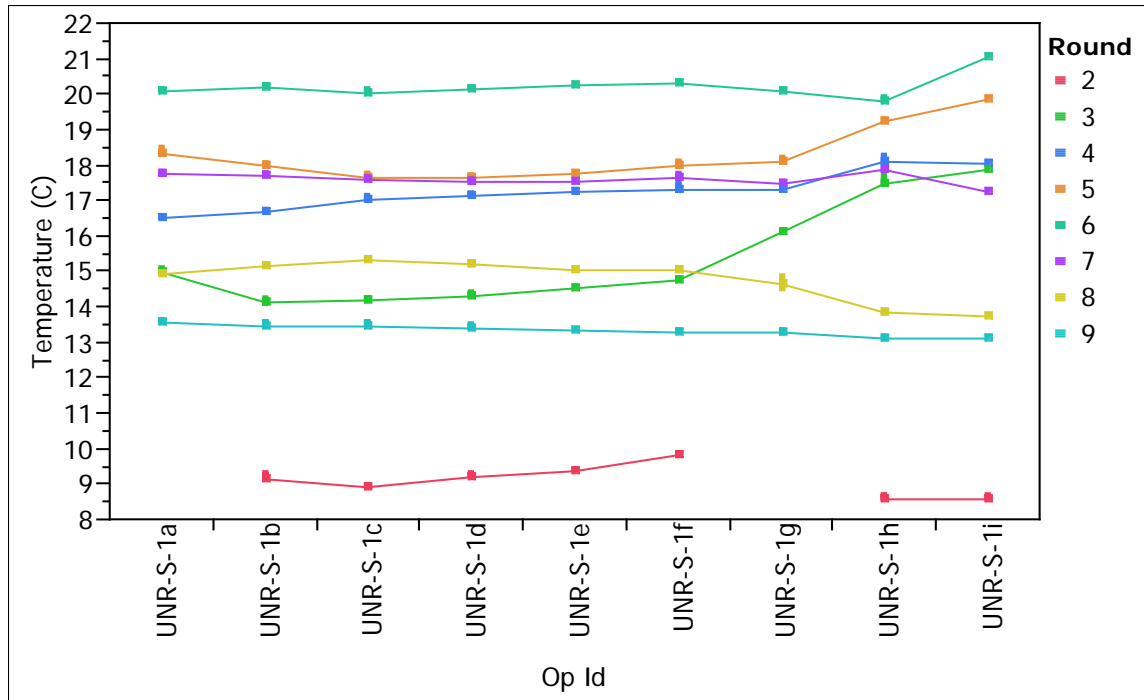


Figure 25: Temperature at Site UNR-S-1

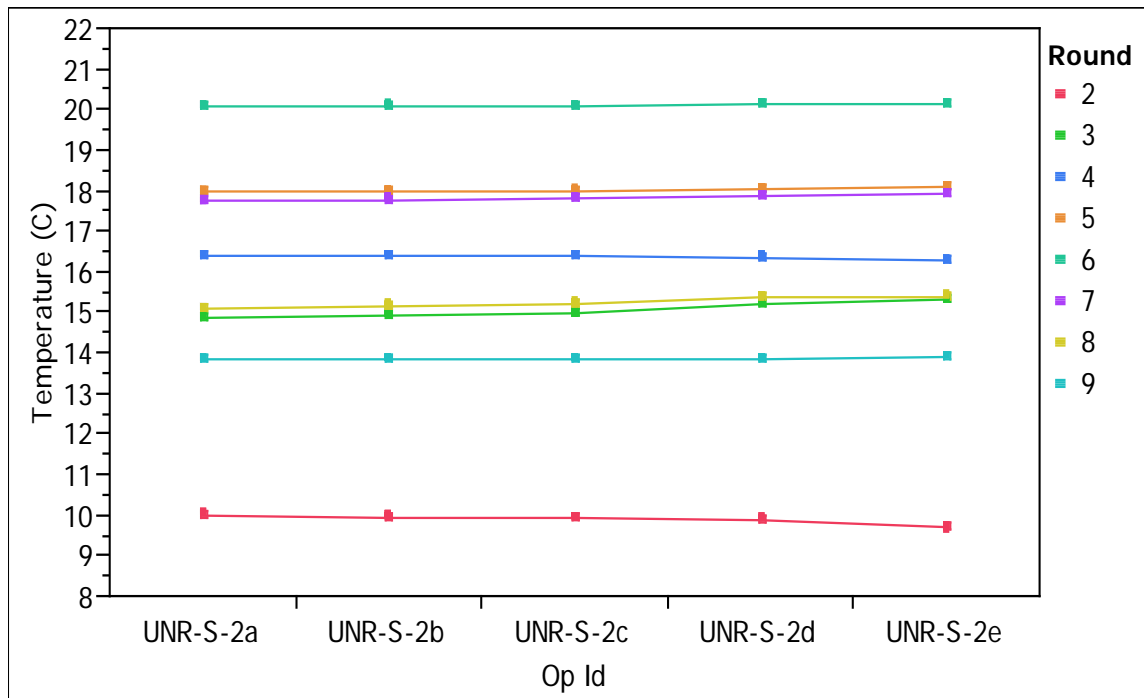


Figure 26: Temperature at Site UNR-S-2

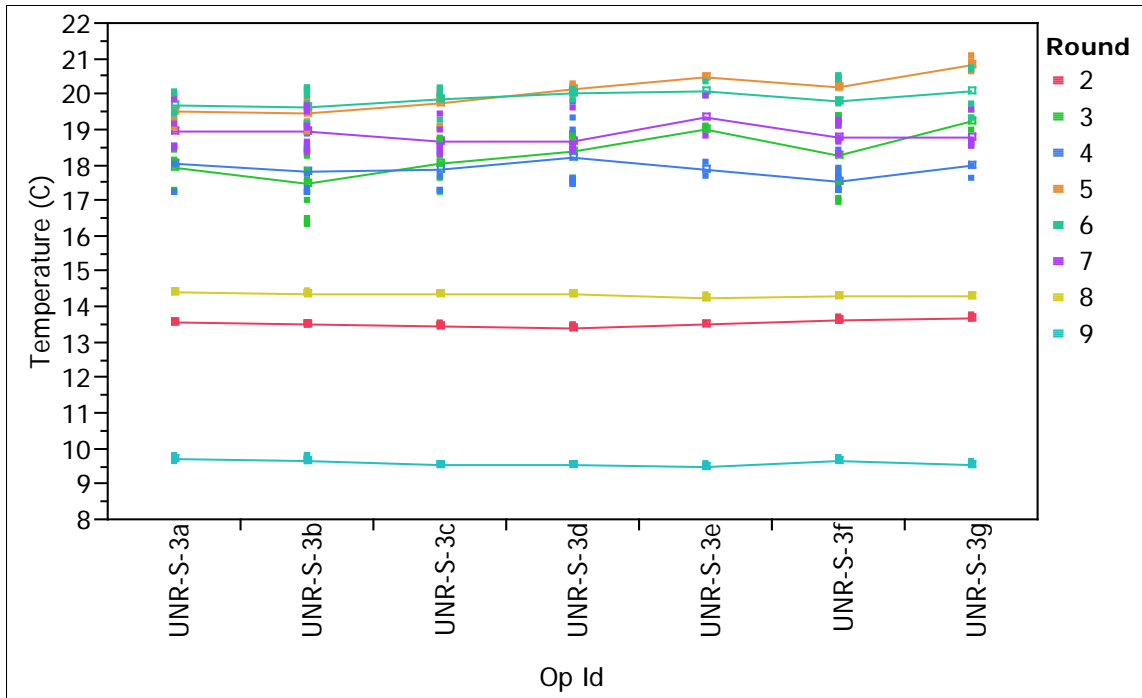


Figure 27: Temperature at Site UNR-S-3

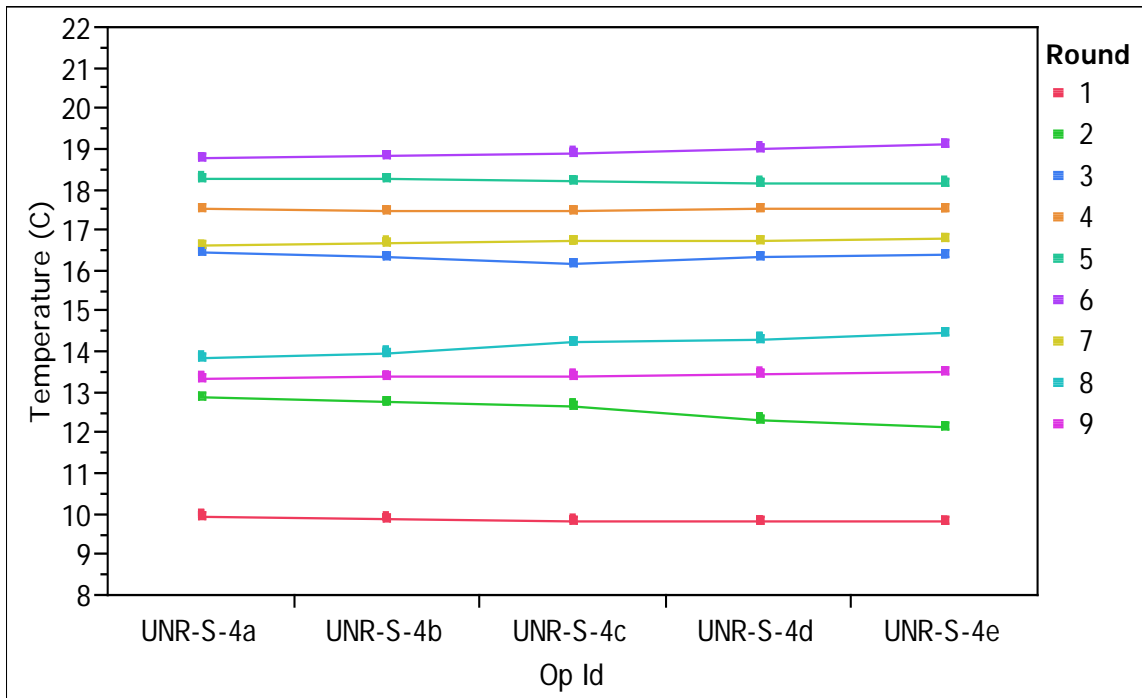


Figure 28: Temperature at Site UNR-S-4

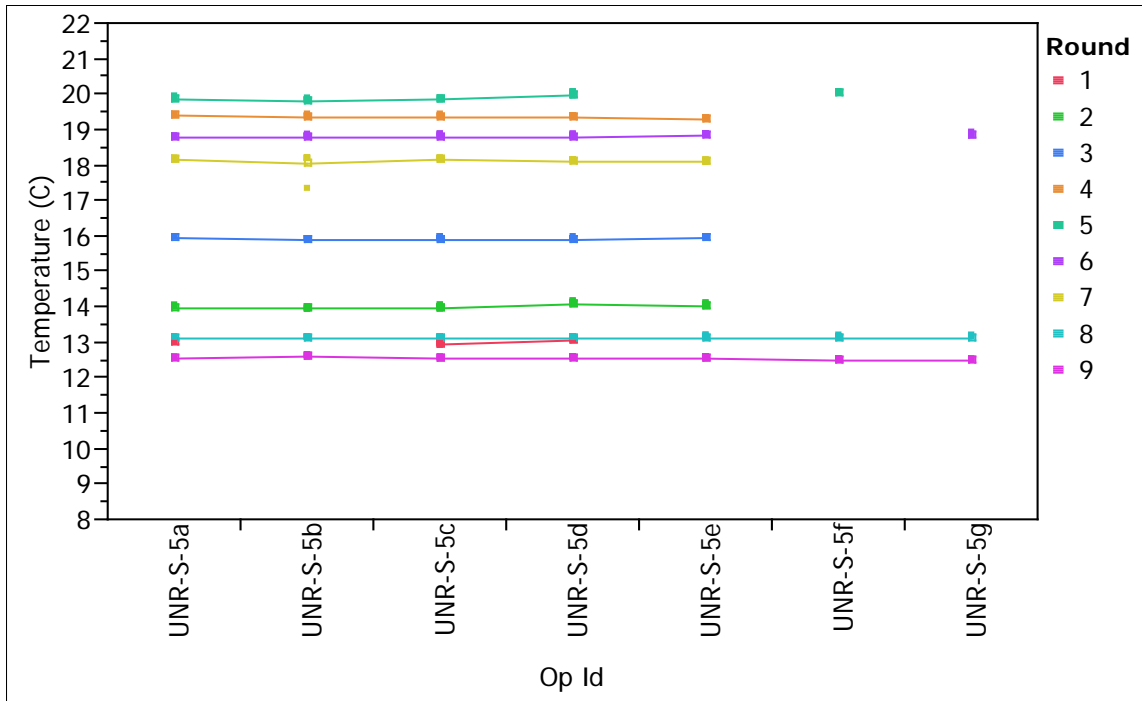


Figure 29: Temperature at Site UNR-S-5

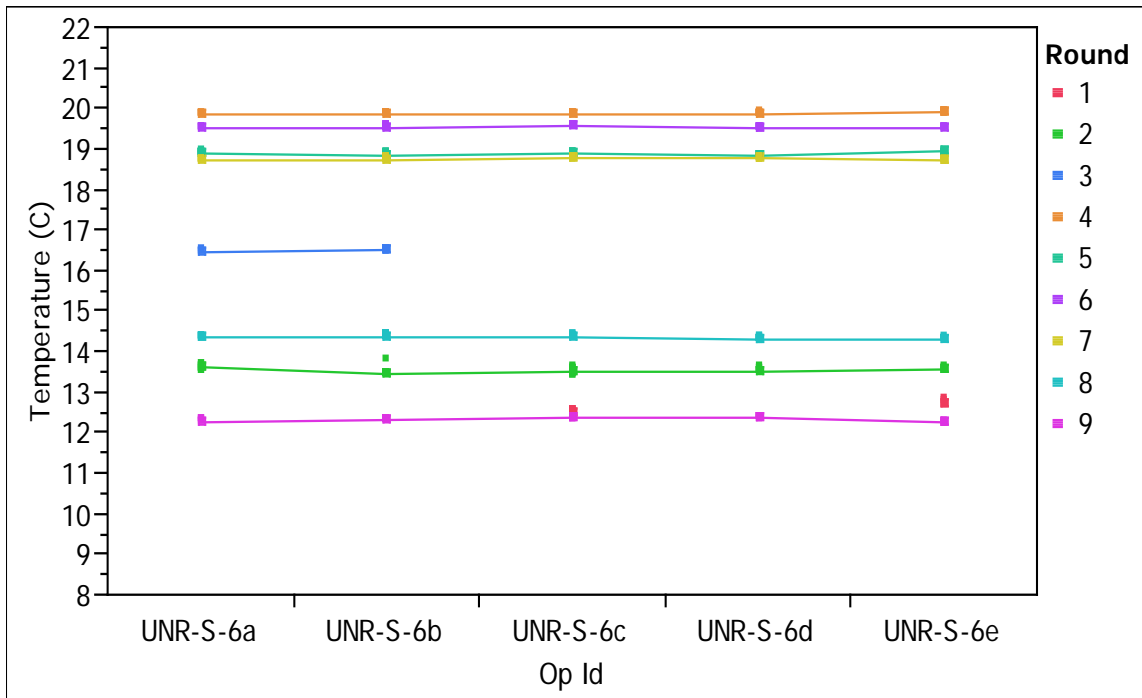


Figure 30: Temperature at Site UNR-S-6

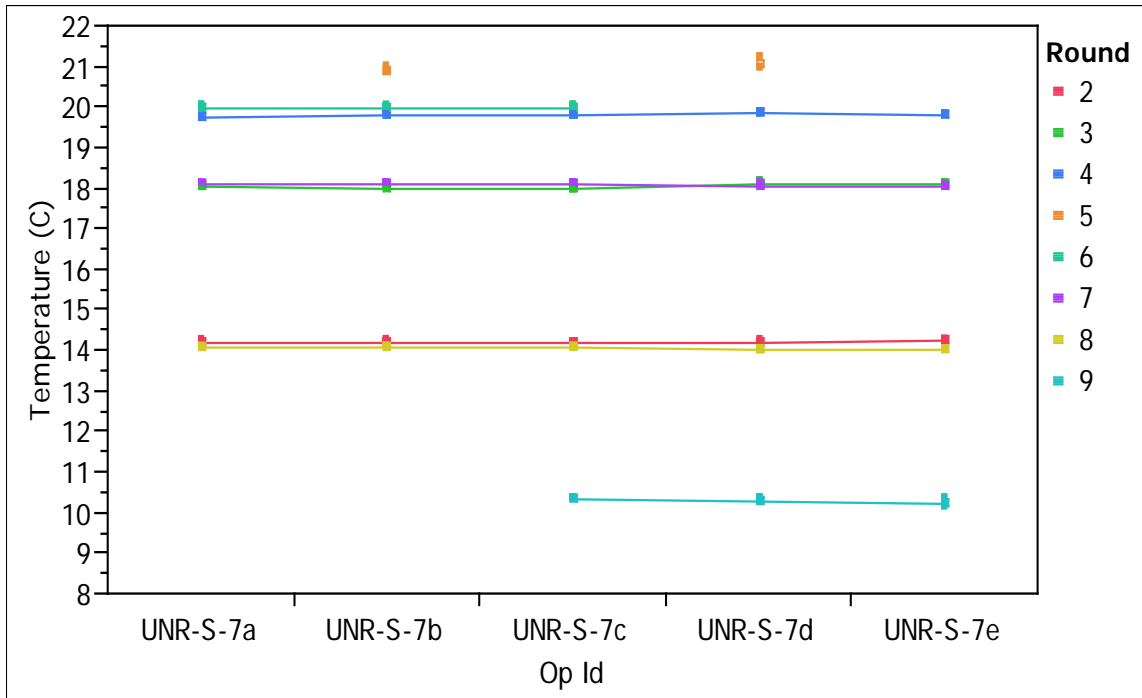


Figure 31: Temperature at Site UNR-S-7

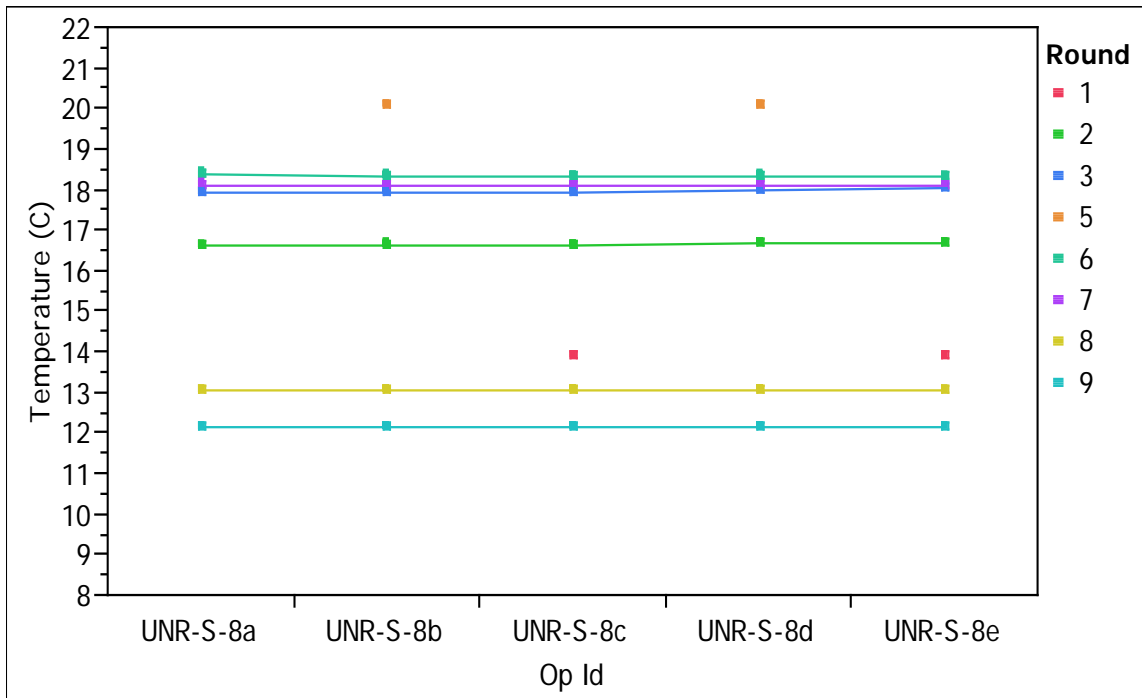


Figure 32: Temperature at Site UNR-S-8

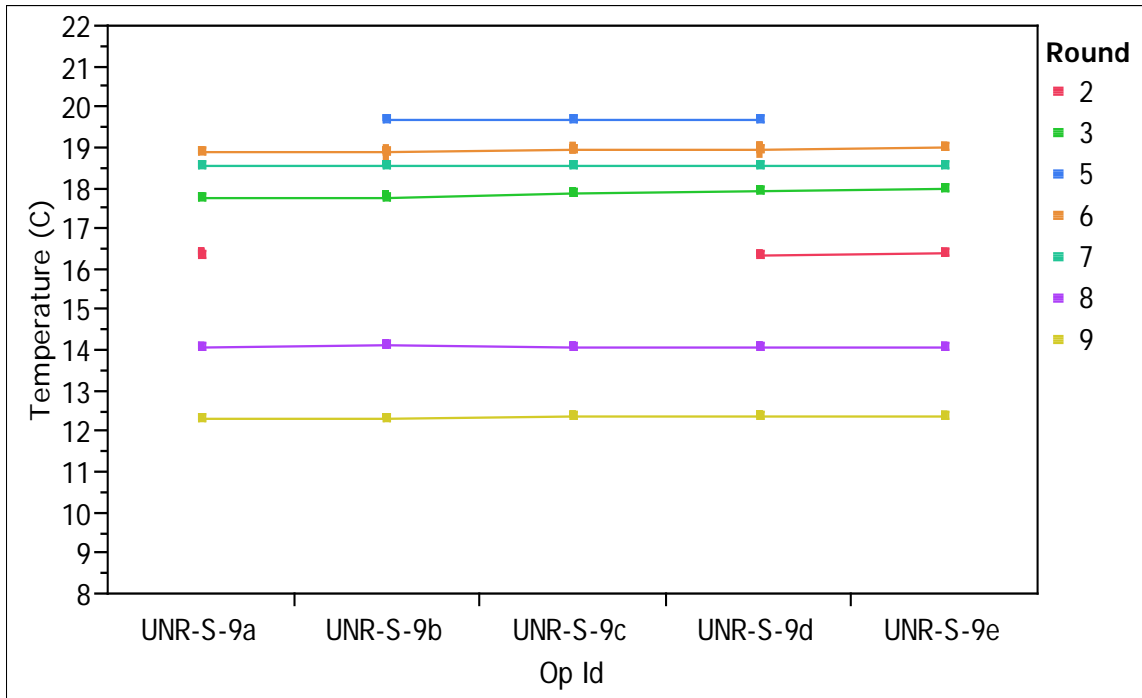


Figure 33: Temperature at Site UNR-S-9

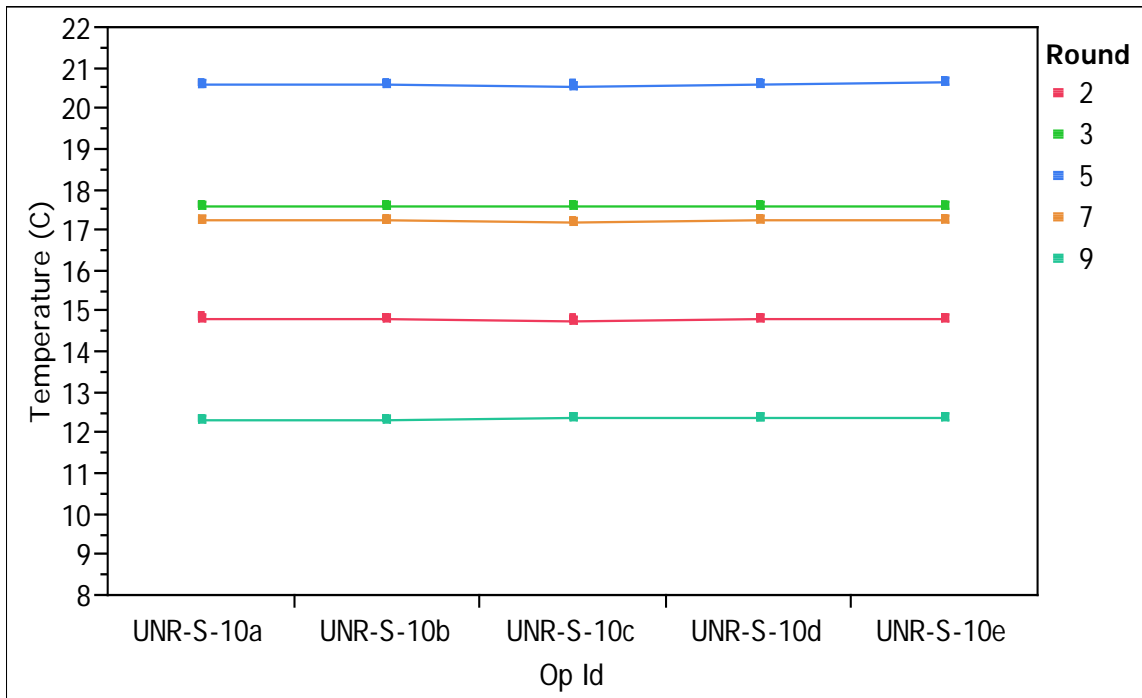


Figure 34: Temperature at Site UNR-S-10

5.1.3 Continuous Water Temperature Plots (15 min average)

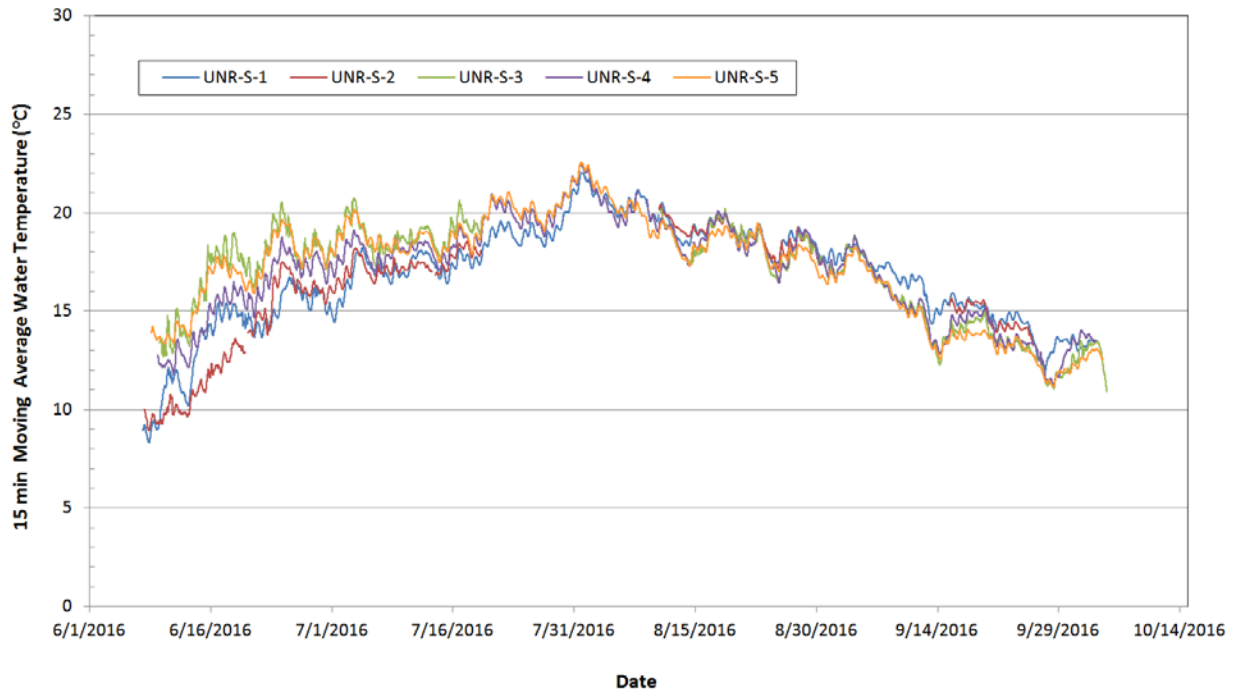


Figure 35: Continuous Water Temperature (15 min average) at Locations (UNR-S-1 to UNR-S-5)

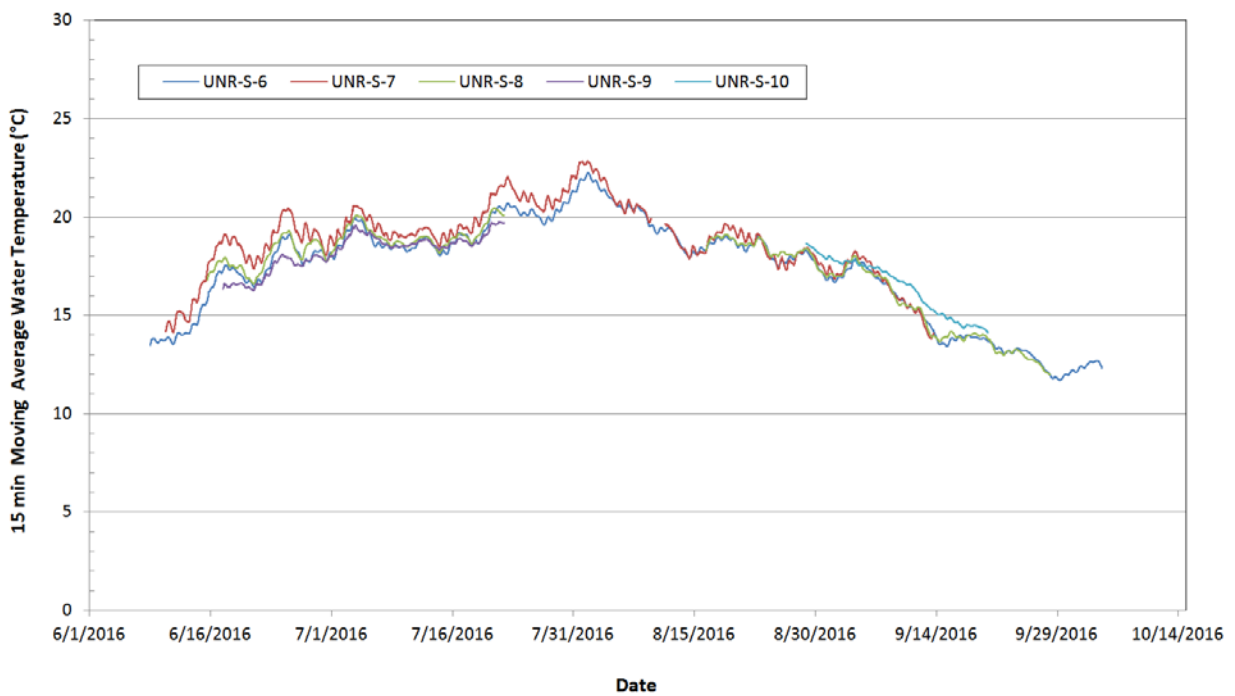


Figure 36: Continuous Water Temperature (15 min average) at Locations (UNR-S-6 to UNR-S-10)

5.1 Dissolved Oxygen

5.1.1 Dissolved Oxygen variations along UNR reach

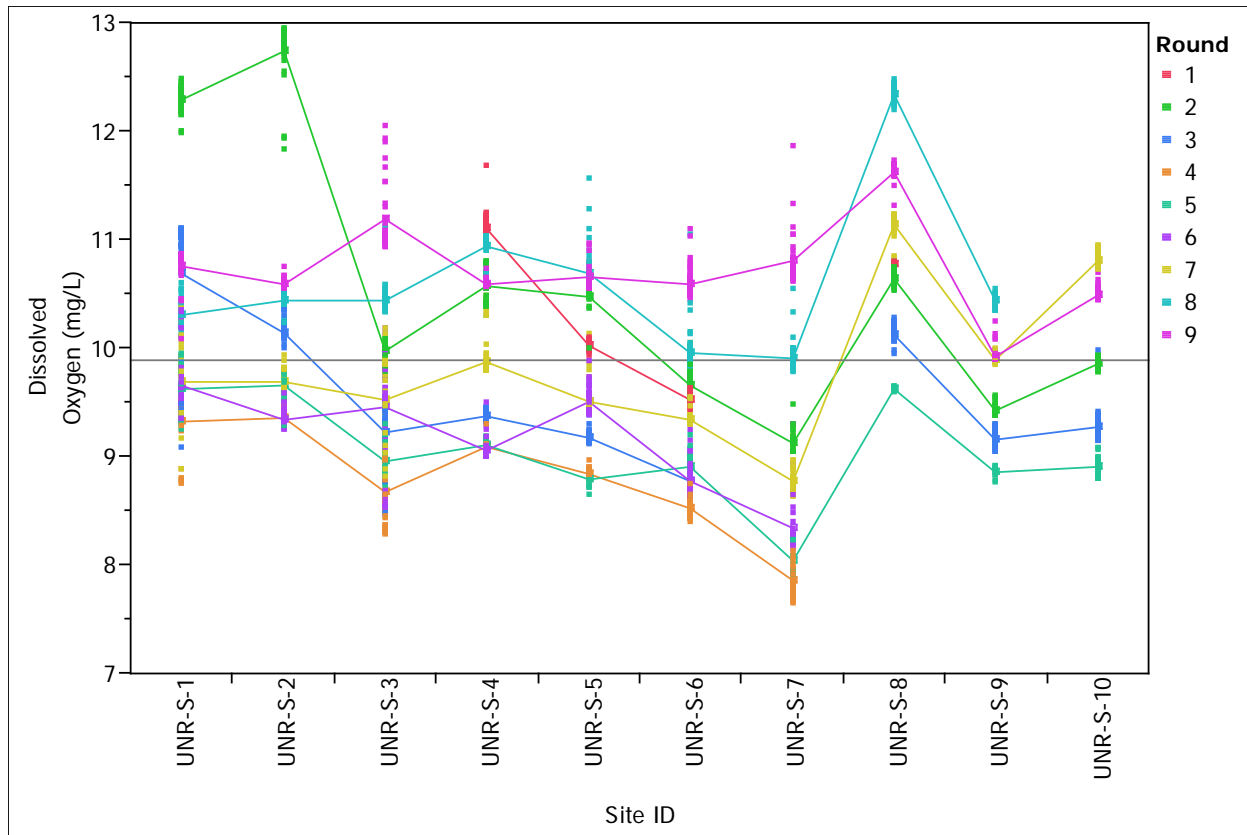


Figure 37: Dissolved Oxygen along UNR reach

5.1.2 Dissolved Oxygen variations along Transect Lines

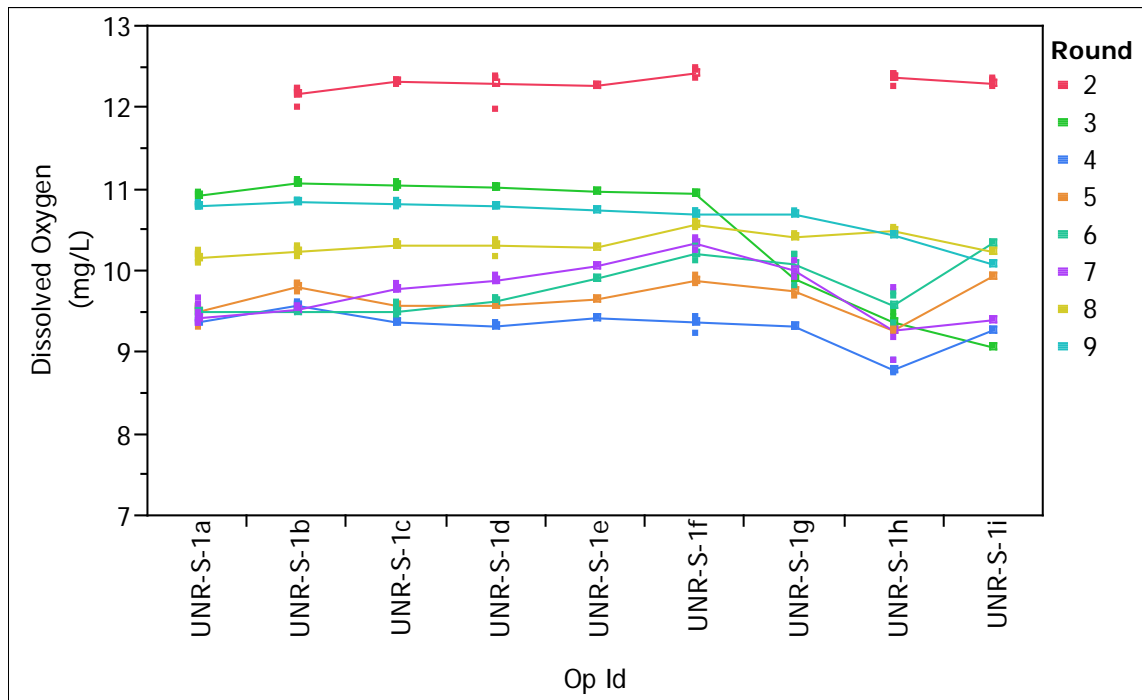


Figure 38: Dissolved Oxygen at Site UNR-S-1

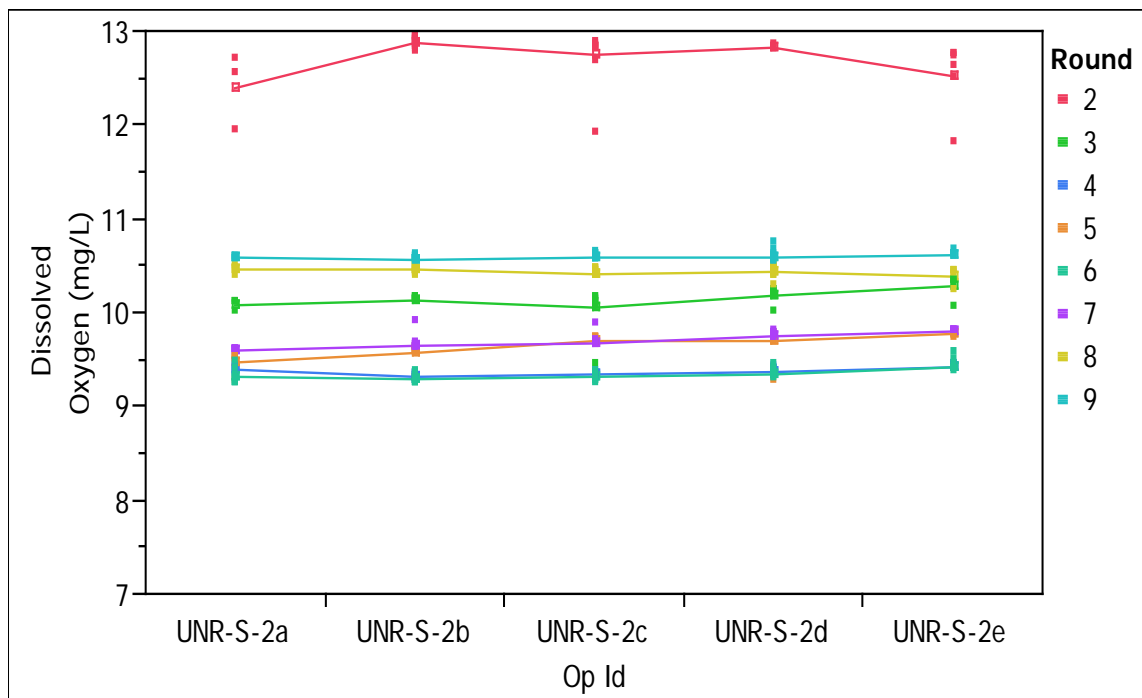


Figure 39: Dissolved Oxygen at Site UNR-S-2

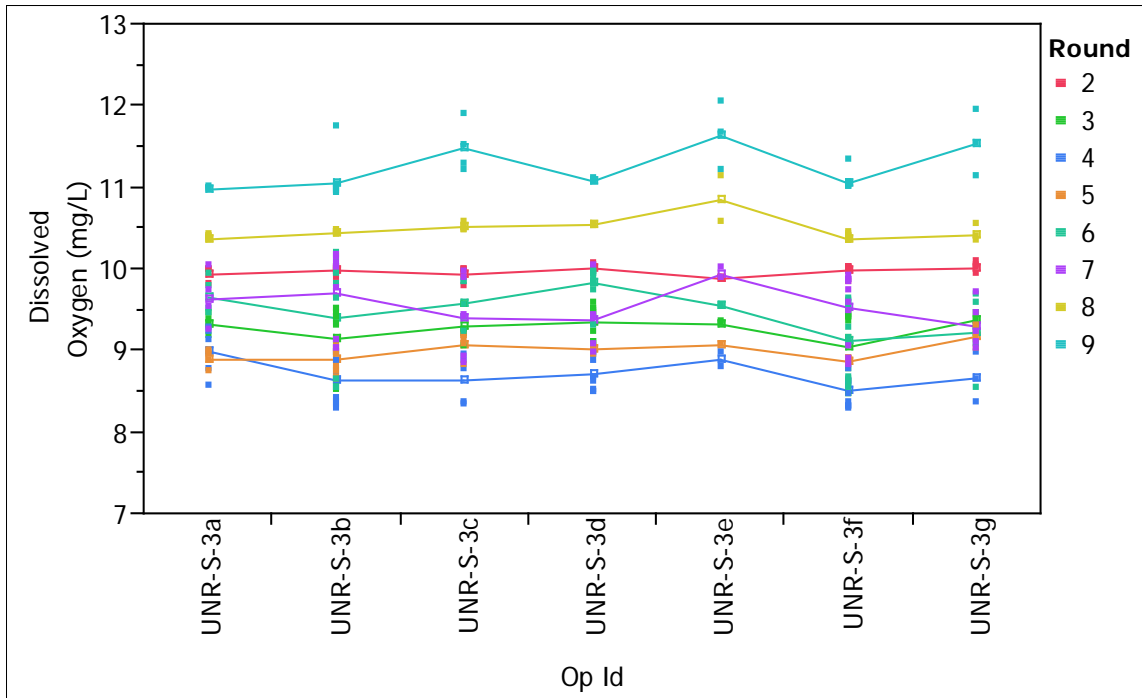


Figure 40: Dissolved Oxygen at Site UNR-S-3

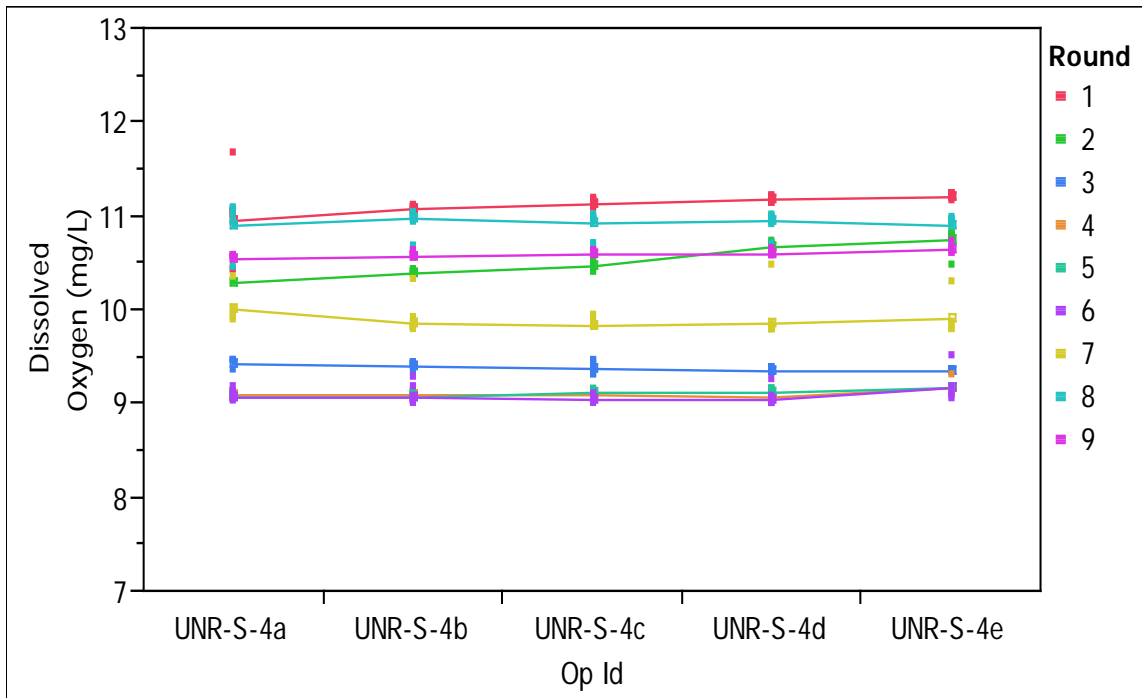


Figure 41: Dissolved Oxygen at Site UNR-S-4

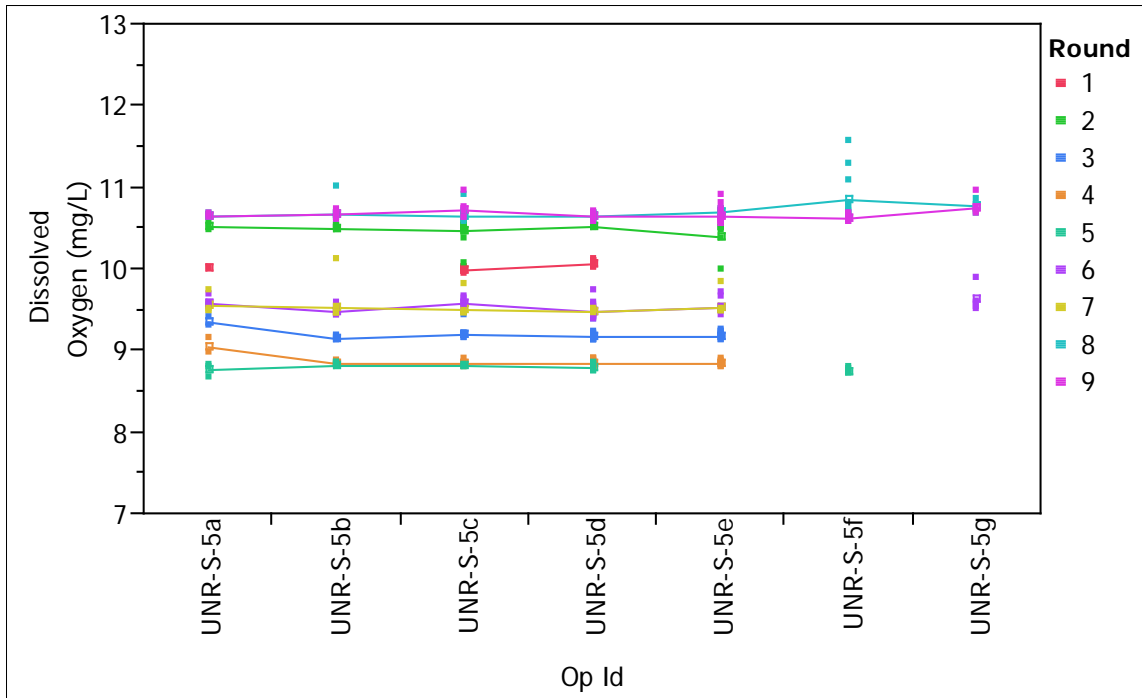


Figure 42: Dissolved Oxygen at Site UNR-S-5

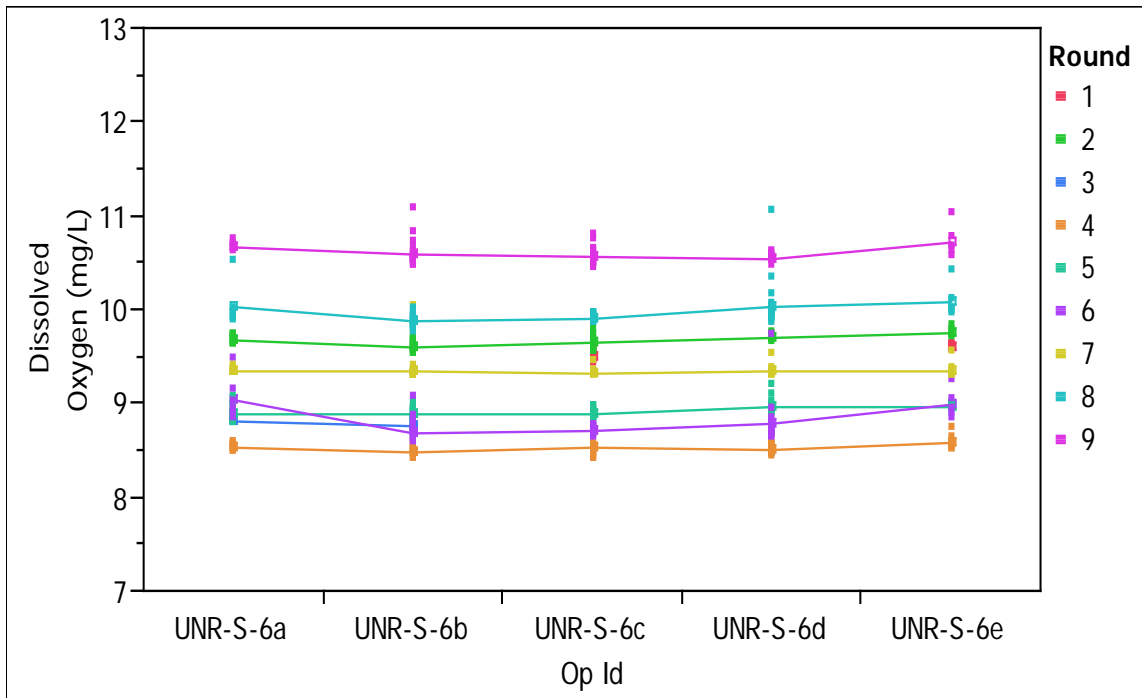


Figure 43: Dissolved Oxygen at Site UNR-S-6

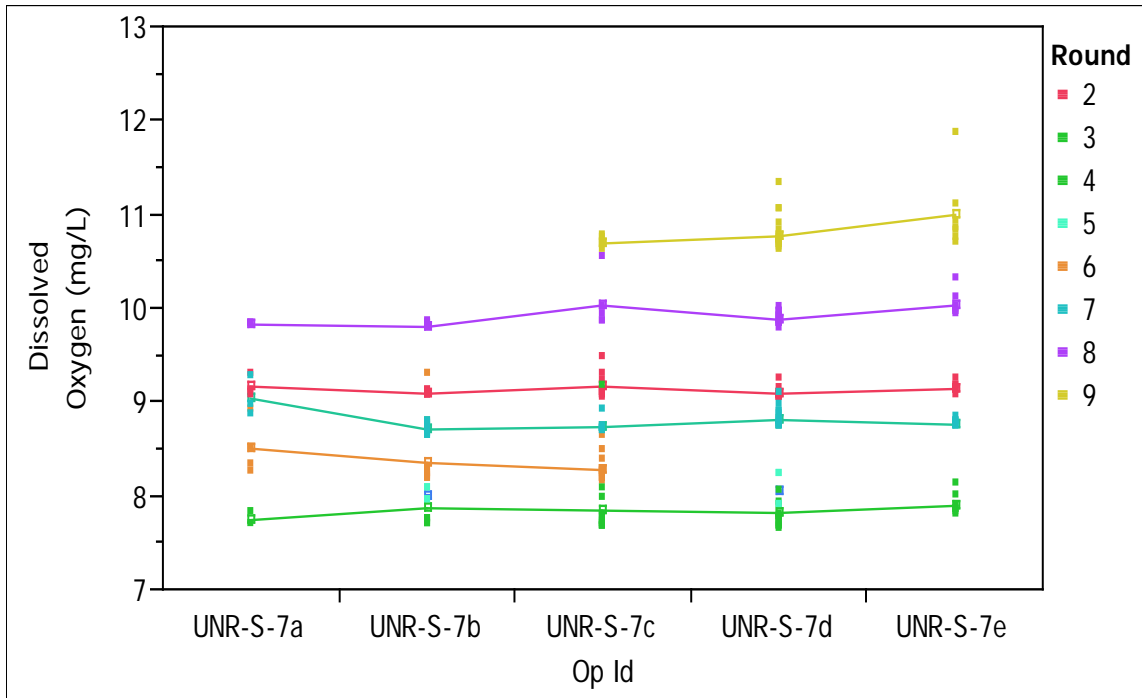


Figure 44: Dissolved Oxygen at Site UNR-S-7

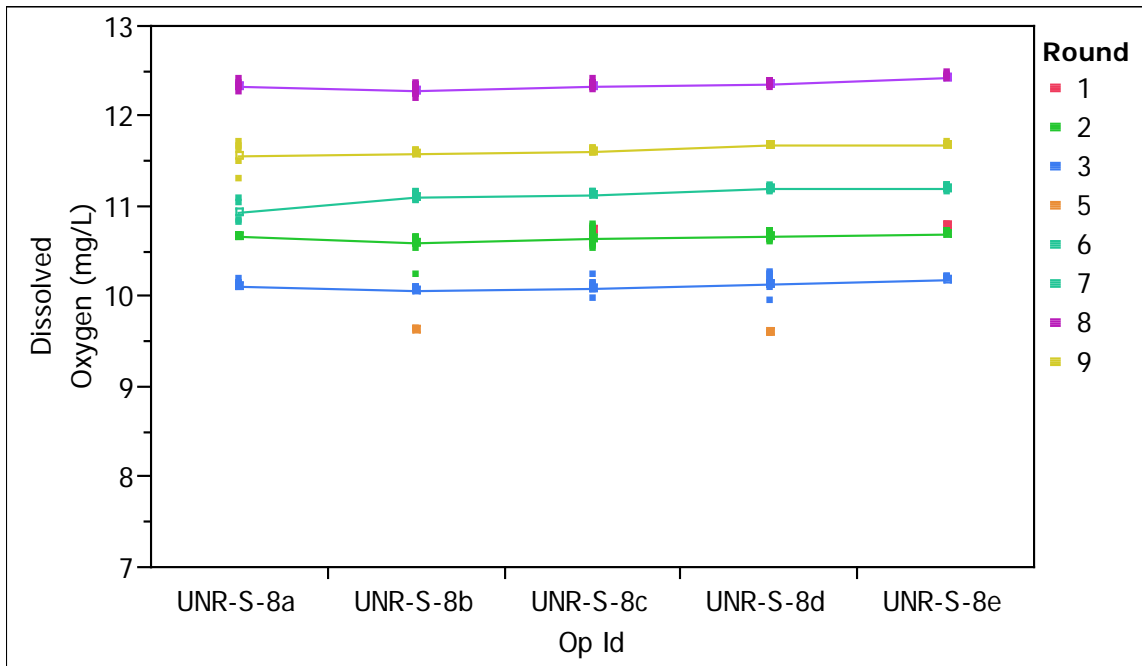


Figure 45: Dissolved Oxygen at Site UNR-S-8

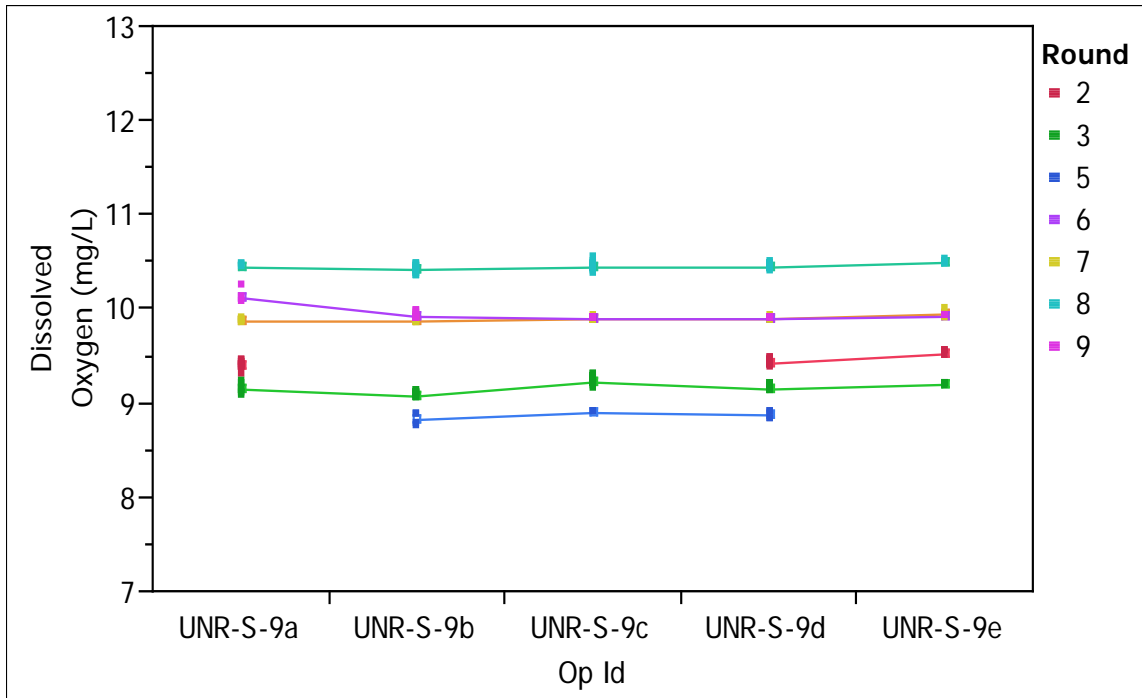


Figure 46: Dissolved Oxygen at Site UNR-S-9

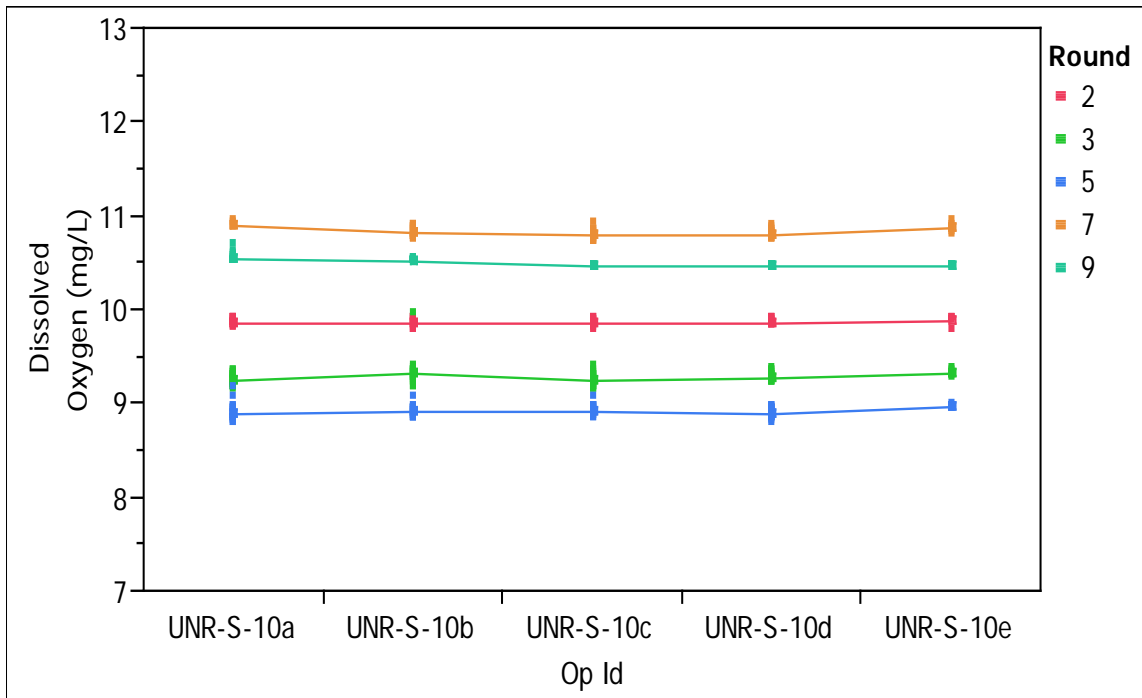


Figure 47: Dissolved Oxygen at Site UNR-S-10

5.1.3 Dissolved Oxygen Temperature Plots (15 min average)

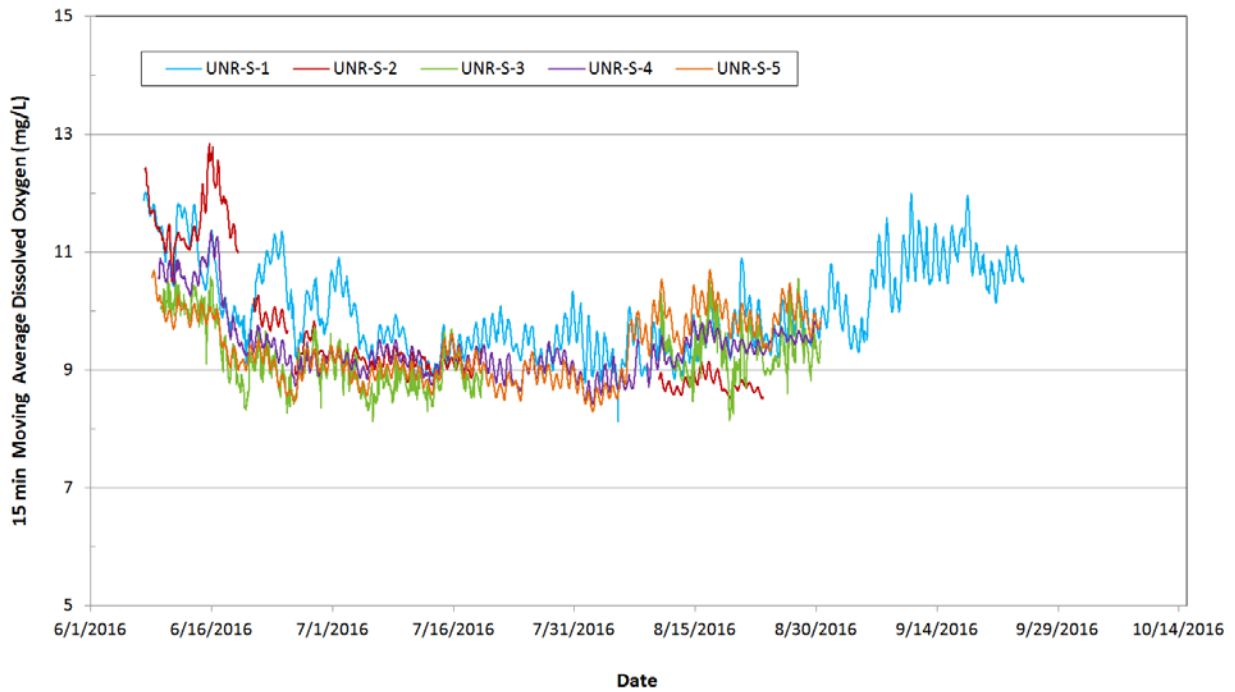


Figure 48: Continuous Dissolved Oxygen (15 min average) at Locations (UNR-S-1 to UNR-S-5)



Figure 49: Continuous Dissolved Oxygen (15 min average) at Locations (UNR-S-6 to UNR-S-10)

5.2 Water Conductivity

5.2.1 Water Conductivity variations along UNR reach

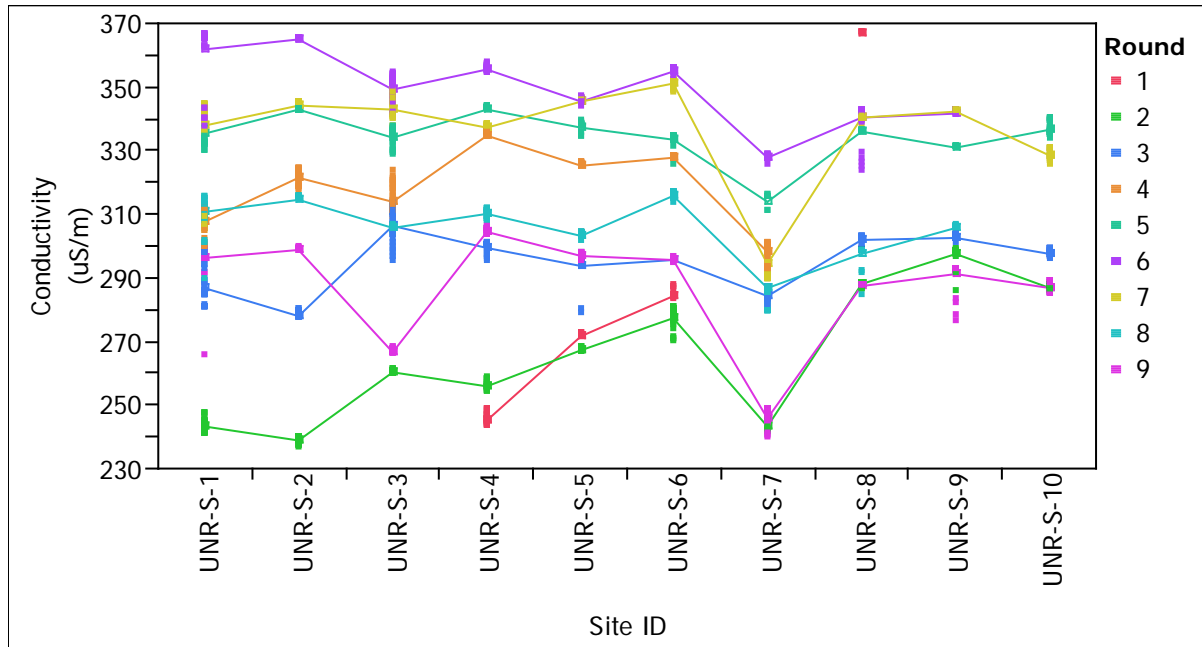


Figure 50: Water Conductivity along UNR reach

5.2.2 Water Conductivity variations along Transect Lines

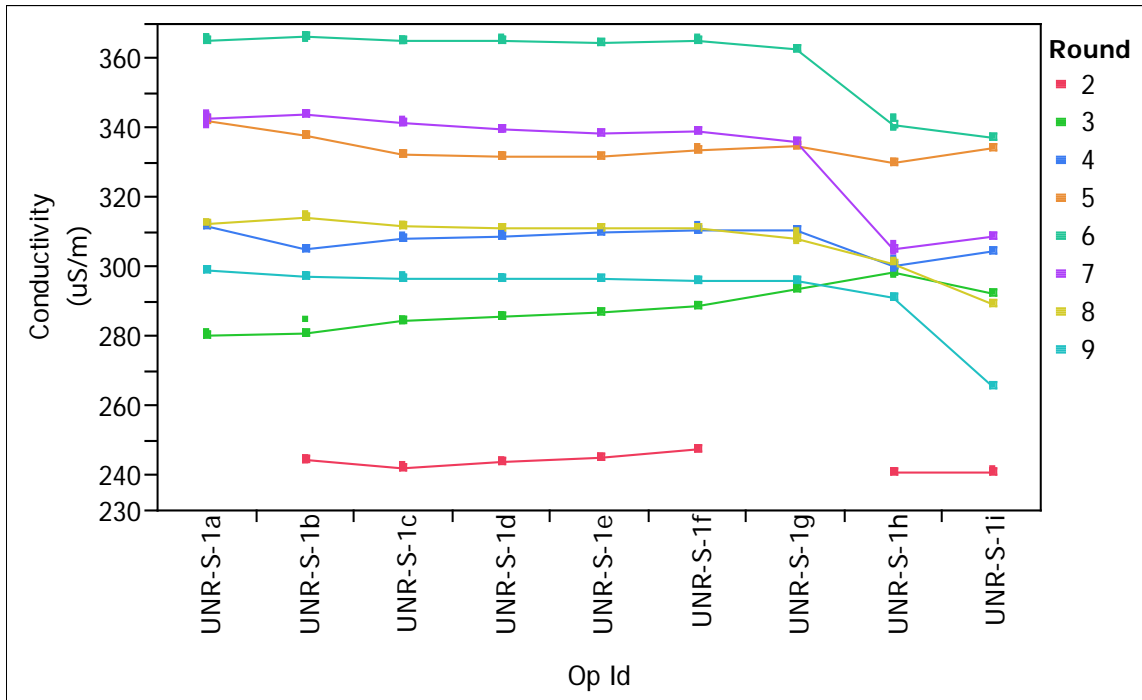


Figure 51: Water Conductivity at Site UNR-S-1

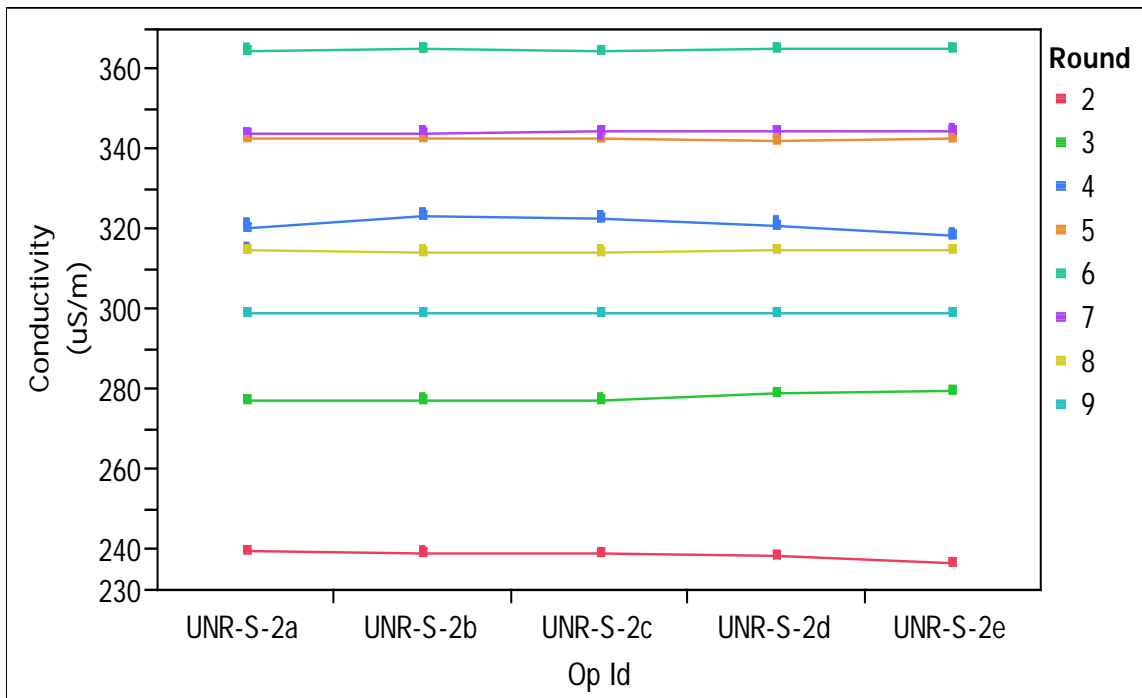


Figure 52: Water Conductivity at Site UNR-S-2

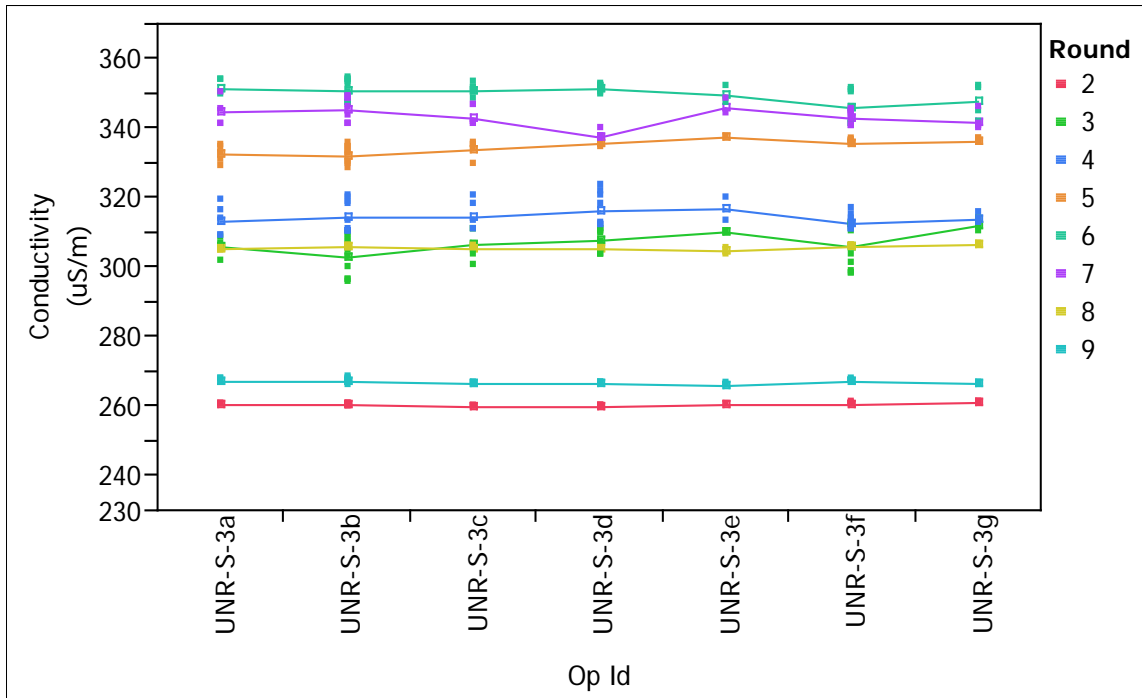


Figure 53: Water Conductivity at Site UNR-S-3

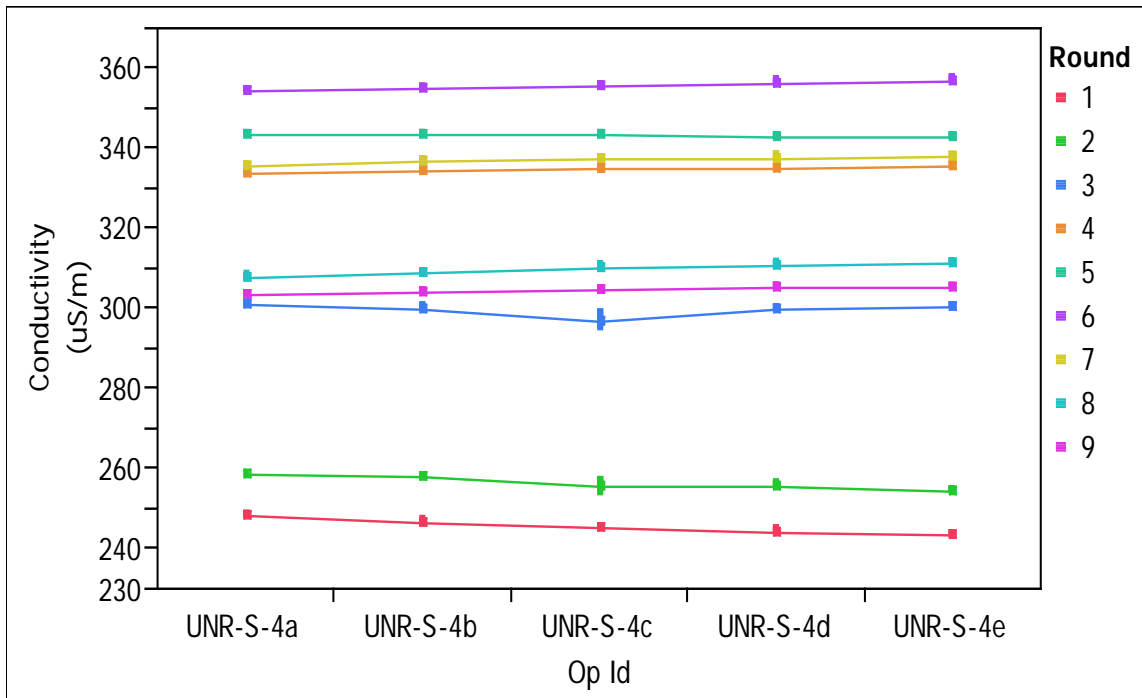


Figure 54: Water Conductivity at Site UNR-S-4

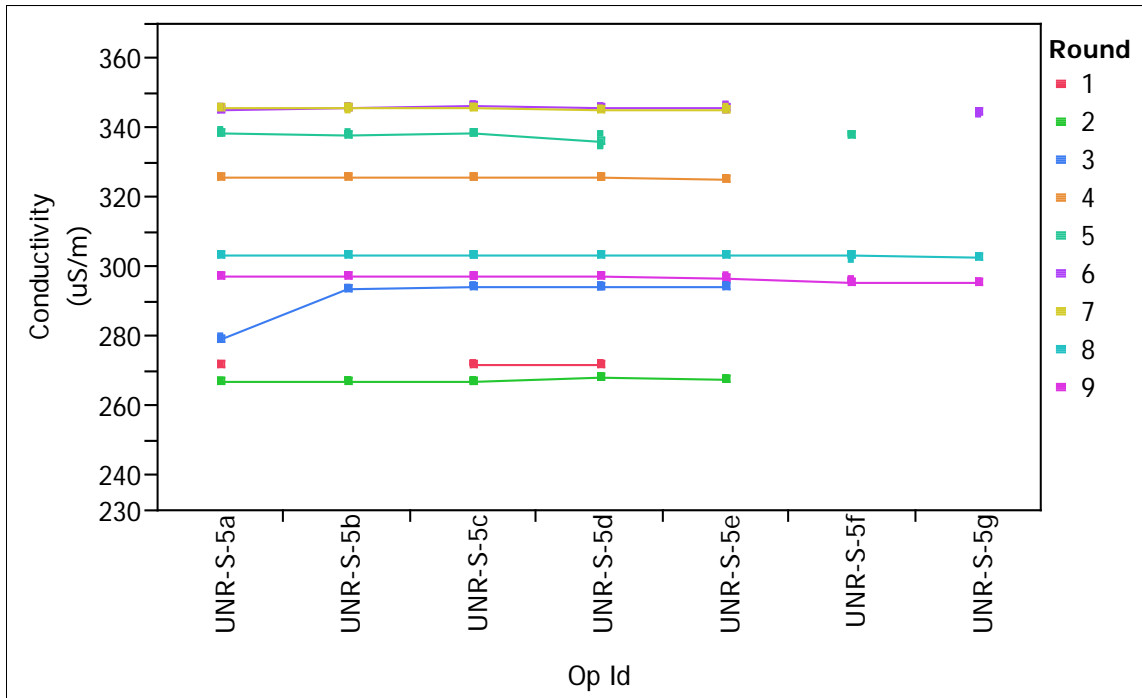


Figure 55: Water Conductivity at Site UNR-S-5

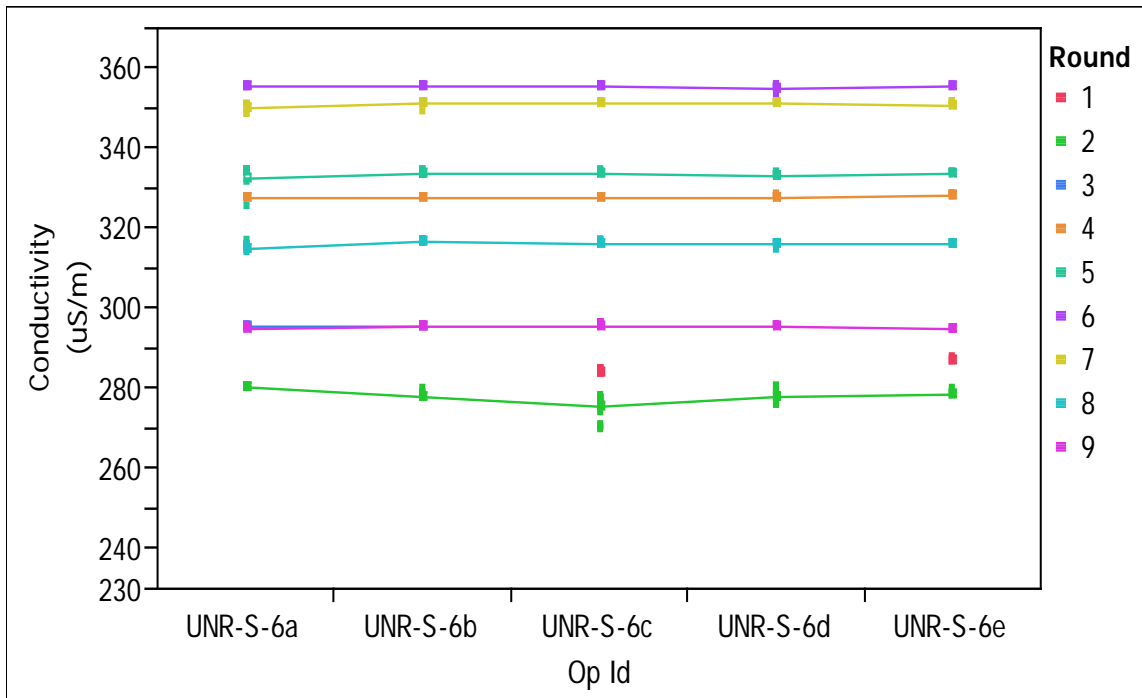


Figure 56: Water Conductivity at Site UNR-S-6

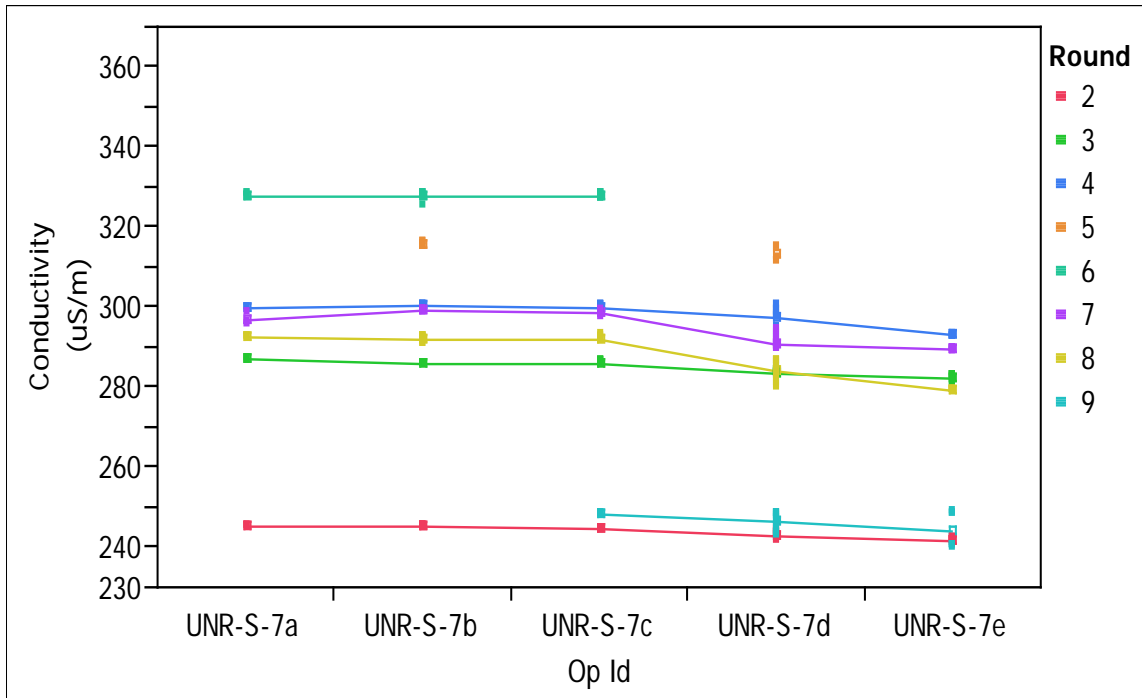


Figure 57: Water Conductivity at Site UNR-S-7

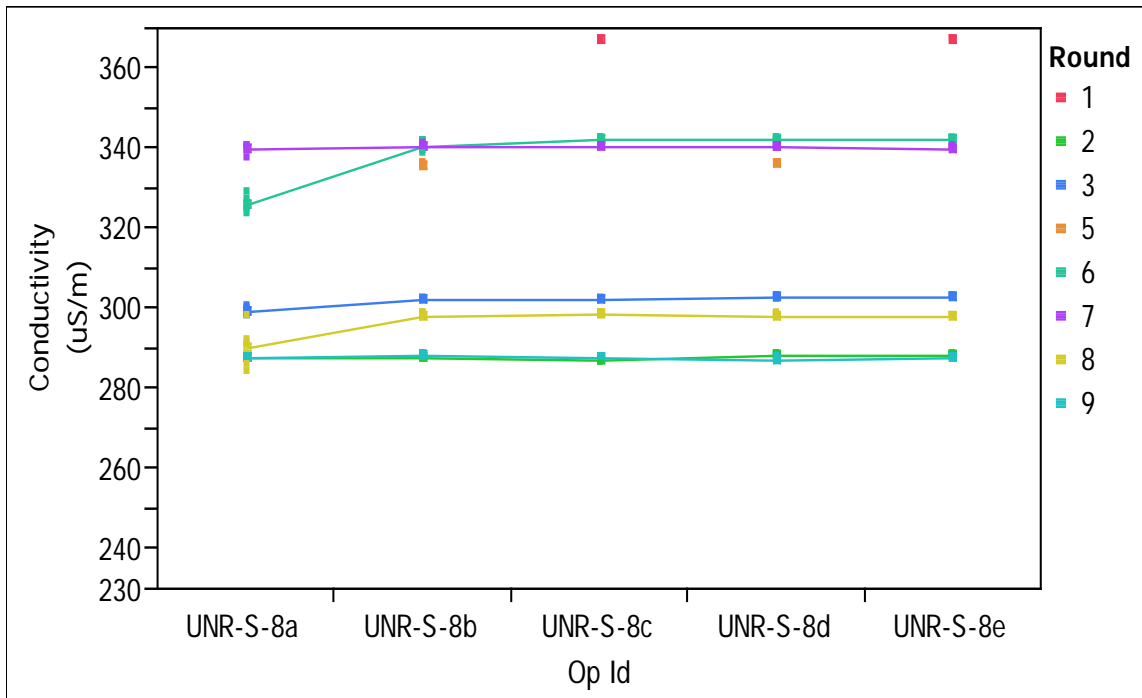


Figure 58: Water Conductivity at Site UNR-S-8

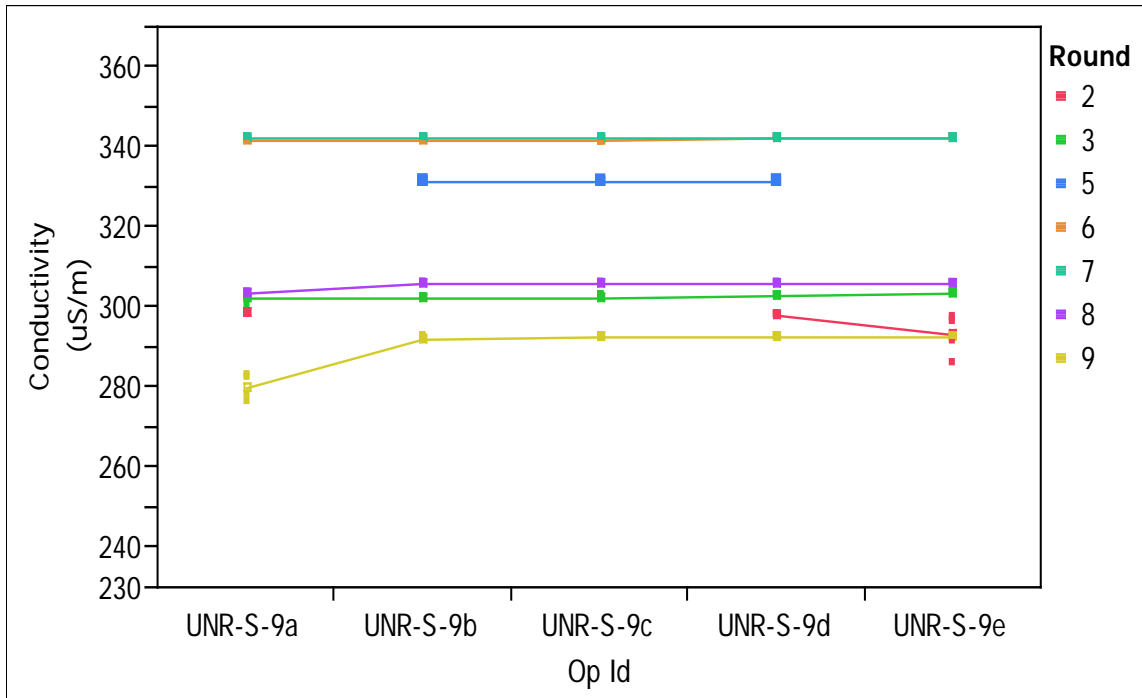


Figure 59: Water Conductivity at Site UNR-S-9

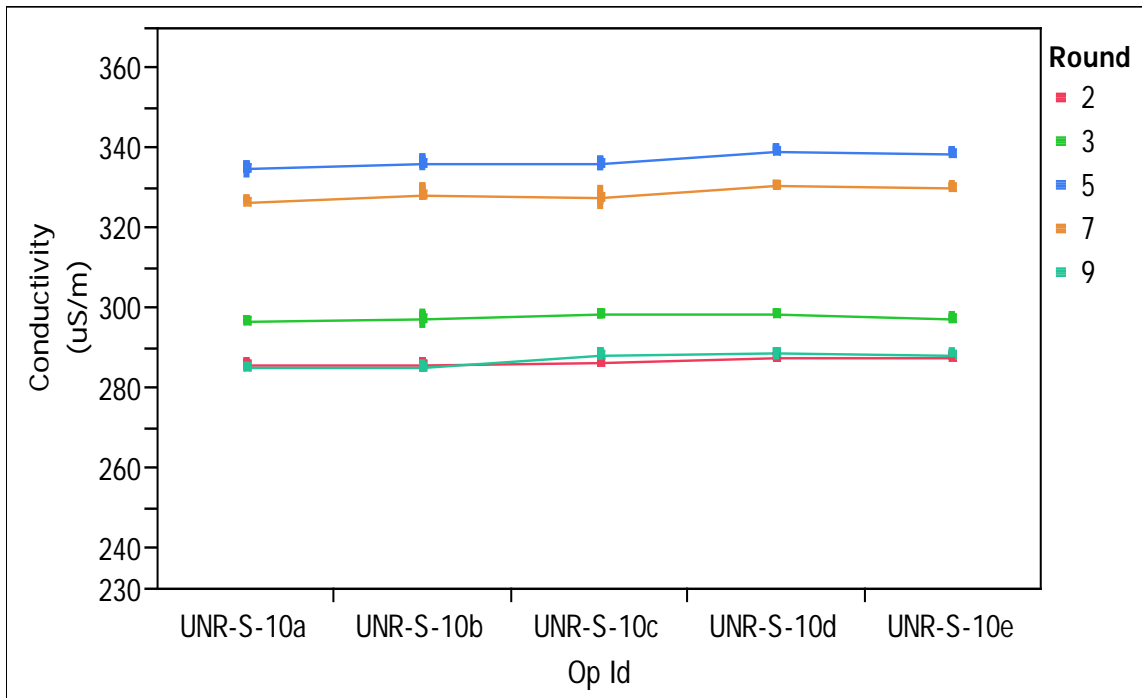


Figure 60: Water Conductivity at Site UNR-S-10

5.2.3 Continuous Water Conductivity Plots (15 min average)

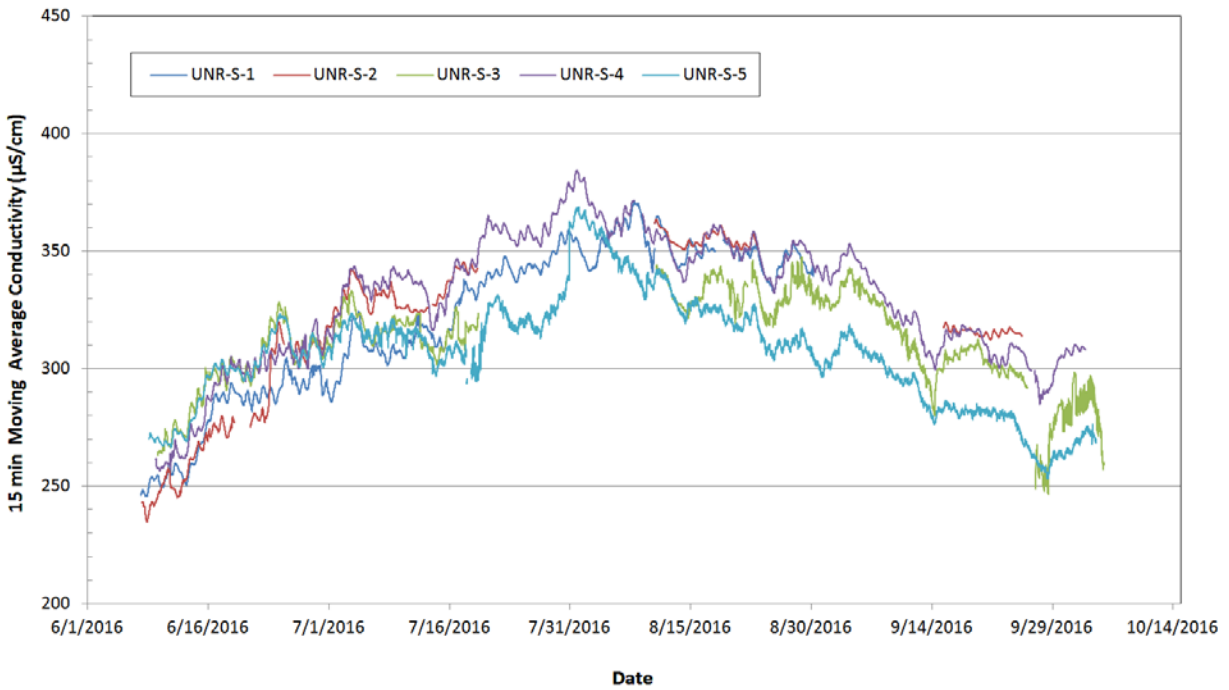


Figure 61: Continuous Water Conmductivity (15 min average) at Locations (UNR-S-1 to UNR-S-5)

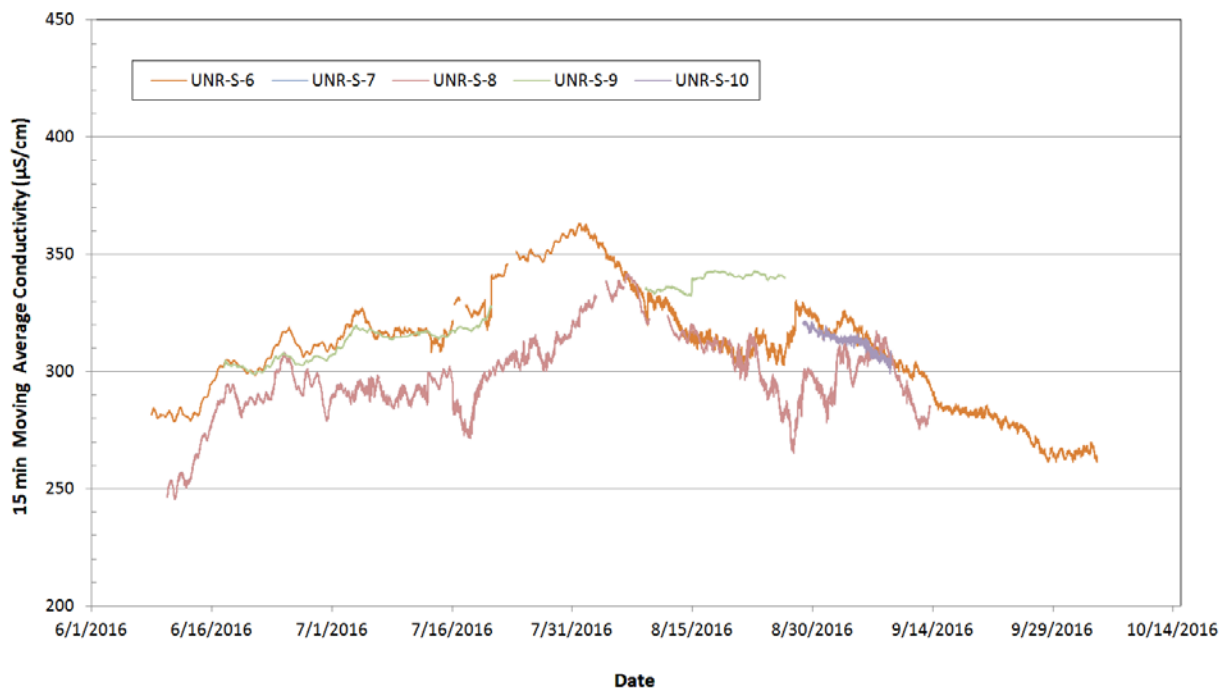


Figure 62: Continuous Water Conmductivity (15 min average) at Locations (UNR-S-6 to UNR-S-10)

6.0 Summary of Observations

Water quality and sediment data was collected in Upper Nelson River reach during 2016 open water season. The following is a summary of the main observations:

- The mean turbidity value along Upper Nelson River system ranged from 10 to 24 FNU at the 10 monitoring sites.
- 2-Mile channel (4 – 204 FNU) and 8-Mile channel (8 – 141 FNU) exhibited the widest variation in turbidity values.
- The mean discrete and mean continuous turbidity was generally within 2 FNU.
- Continuous data reported higher peak values at 7 of 10 sites, the greatest difference was at 2_Mile channel where the peak continuous measurement was 2.4 times higher than the peak discrete measurement.
- The mean TSS value in upper Nelson River system ranged from 10 to 23 mg/L at the 10 monitoring sites.
- The transect data suggests the periodic presence of unmixed sediment plumes in 2-mile channel triggered by wind events.
- The suspended sediment in Upper Nelson River is mainly composed of Silt fraction (>80%) and lesser amounts of clay and sand.
- The sand fraction of suspended sediment dropped considerably from Lake Winnipeg outlets to the downstream locations.



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