GEI Consultants

Consulting Engineers and Scientists

Substrate and Algae Assessment in the Colorado River and Fraser River Basins 2022

May 2023

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1. Introduction

At the request of Grand County's Learning by Doing (LBD), GEI Consultants, Inc. (GEI) conducted assessments of the substrate and algae at multiple sampling locations in the Colorado River and Fraser River basins in Grand County in the fall of 2022. A total of 18 sites were assessed in 2022. There were 17 sites sampled from September 21, 2022 through September 23, 2022, and one site sampled on November 2, 2022. Nine of the sites were located on the Colorado River, six of the sites were located on the Fraser River, and the remaining three were located on Ranch Creek, St. Louis Creek, and Willow Creek (one site per stream).

The sampling site on Ranch Creek and the downstream-most site on the Colorado River were not fully accessible for sampling efforts due to deep and/or fast water. Therefore, some individual transects at these two sites were assessed visually. Sixteen sites sampled by GEI for substrate and algae characteristics in 2022 were previously established by LBD at various locations throughout their Cooperative Effort Area (CEA). It should be noted that two of these sites (CR-24.9 and STC-0) had not been surveyed within the last four years. Two additional sites (CR-6.1 and WC-1) were established and sampled in 2022.

At 15 of the 18 sites, GEI performed pebble counts and measured percent fines, percent embeddedness, and algal cover. Riffle stability index was measured at ten of the sites, and volumetric sediment and suspended sediment samples were collected with a McNeil sampler at five sites. The data collected at each site location may be used to assess potential sediment transport issues in the basin and to address questions related to biological integrity such as the Sediment Tolerance Indicator Value (TIV_{SED}) for macroinvertebrates and suitability of salmonid spawning habitat.

2. Cooperative Effort Area

All of the sampling sites were located within LBD's CEA in Grand County (Figure 2–1; Table 2–1). The sampling area in 2022 includes nine sites on the Colorado River that extend from the town of Granby, CO to the town of Kremmling, CO. A new site, Site CR-6.1 was established on the Colorado River downstream of a restoration project led by the Irrigators Living in the Vicinity of Kremmling (ILVK). The purpose of this site is to monitor changes post-restoration. Site CR-6.1 replaces site CR-1.7 which was previously monitored as part of the ILVK restoration project. Site CR-1.7 was not a representative downstream project site and was difficult to monitor due to the area being dominated by fine substrate. A second site on the Colorado River (Site 24.9, located adjacent to Sheriff Ranch) was reestablished as part of this sampling effort. The purpose of monitor at this site is to gauge the effectiveness of the Connectivity Channel as well as track post-fire impacts from Drowsy Water Creek and Kinney Creek, which are upstream tributaries.

The six sites on the Fraser River extend from the vicinity of the Mary Jane Ski Area entrance upstream of the town of Winter Park to the town of Granby, CO. The one site on Ranch Creek is located in the town of Tabernash, CO, upstream from the confluence with the Fraser River (Figure 2–1). Monitoring was done on St. Louis Creek at Site STC-0, which is located a short distance upstream from the confluence with the Fraser River. The established monitoring frequency at this site once every 2-3 years, with the last monitoring event in 2018.

A new site on Willow Creek was monitored in 2022. The purpose of this monitoring is to establish baseline conditions for a planned restoration project on Willow Creek. The new site, Site WC-1, was located downstream of the planned restoration project and a short distance upstream from the confluence with the Colorado River (Figure 2–1).

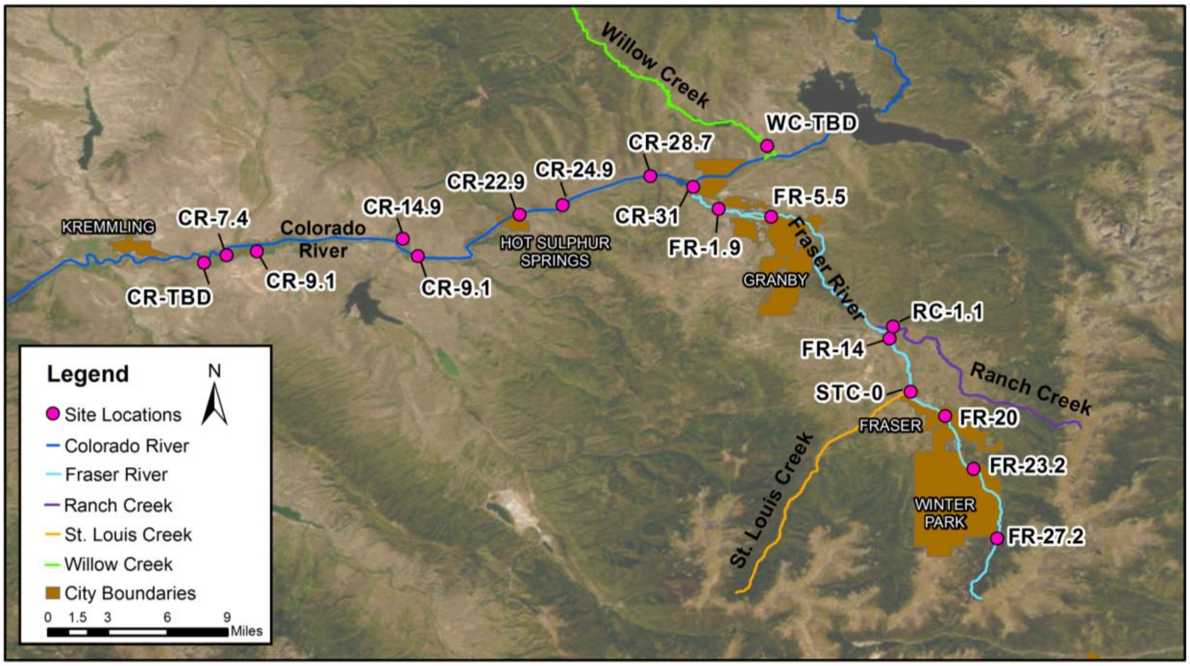


Figure 2-1: **All sites on the Colorado River, Fraser River, Ranch Creek, St. Louis Creek, and Willow Creek sampled in 2022.**

Table 2-1: **Names and locations for all 18 sites sampled in 2022. PC = pebble counts/algae/embeddedness, RSI = riffle stability index, MS = volumetric sediment samples with a McNeill Sampler**

Site Name	Station Description	Latitude/Longitude	PC	RSI	MS
CR-6.1	Colorado River downstream of IVLK	40.046 -106.328	X		
CR-7.4	Colorado River downstream of Troublesome Creek	40.051 -106.311	X	X	
CR-9.1	Colorado River at CR39 Bridge at KB Ditch	40.054 -106.289	X	X	X
CR-14.9	Colorado River downstream of Williams Fork	40.063 -106.183			X
CR-16.7	Colorado River upstream of Williams Fork	40.050 -106.173	X		
CR-22.9	Colorado River at Hot Sulphur Springs	40.080 -106.099	X		X
CR-24.9	Colorado River at Sheriff Ranch	40.087 -106.067	X		
CR-28.7	Colorado River just downstream of Windy Gap	40.108 -106.004	X	X	
CR-31	Colorado River upstream of Fraser and Windy Gap	40.101 -105.973	X		
FR-1.9	Fraser River upstream of Granby Sanitation District	40.085 -105.954		X	
FR-5.5	Fraser River at Granby Ranch	40.079 -105.916		X	X
FR-14	Fraser River upstream of Tabernash	39.992 -105.830	X	X	
FR-20	Fraser River at Rendezvous Bridge	39.935 -105.791	X		
FR-23.2	Fraser River upstream of Winter Park Sanitation	39.896 -105.769	X	X	
FR-27.2	Fraser River above Jim Creek	39.845 -105.752	X	X	
RC-1.1	Ranch Creek downstream of Meadow Creek	39.999 -105.828	X	X	X
STC-0	St. Louis Creek near mouth	39.952 -105.815	X	X	
WC-1	Willow Creek upstream of bridge/downstream of future restoration site	40.130 -105.919	X		

3. Methods

3.1 Pebble Counts and Embeddedness

At the 15 sites where pebble counts were performed, the Modified Wolman Pebble Count Method outlined by Colorado Water Quality Control Division (WQCD) Policy 98-1 (Colorado Department of Public Health and Environment [CDPHE] 2014) was utilized. Ten evenly spaced transects were established along a length of stream approximately twenty times the average bankfull width. At each of these ten transects, a 60 by 60-centimeter (cm) sampling frame was used to designate four substrate particles for measurement at ten evenly spaced points across the transect (Photos 3-1 and 3-2). This accounted for a total of 40 substrate particle measurements per transect, and a total of 400 measurements per sampling location. The 60 by 60 cm sampling frame consisted of 4 aluminum bars connected to form a square, with an inside width of 60 cm, and 4 elastic bands placed forming four cross sections with a width of 50 cm. The intermediate axis of each particle designated by the elastic band cross sections on the sampling frame was measured using a gravelometer (a ruler was used if the particle was too large to fit through the apertures in the gravelometer). Ocular estimates were used for substrate particles that could not be removed from the bed (i.e., due to size). The measurements of the individual particles were used to calculate the D_{50} and the D_{84} of the sample. The notation D represents the particle size in millimeters (mm), and the subscript denotes the percentile; the D_{50} and D_{84} are the diameters (in mm) that are larger than 50% and 84% of the particles in the sample, respectively. The percentage of fine substrate (i.e., < 8 mm) was also calculated to determine the availability of clean substrate and interstitial spaces (i.e., the spaces between gravel and cobble particles used by macroinvertebrates and juvenile fishes).

Photo 3-1: Substrate being measured with a gravelometer at Site CR-16.7 on the Colorado River.

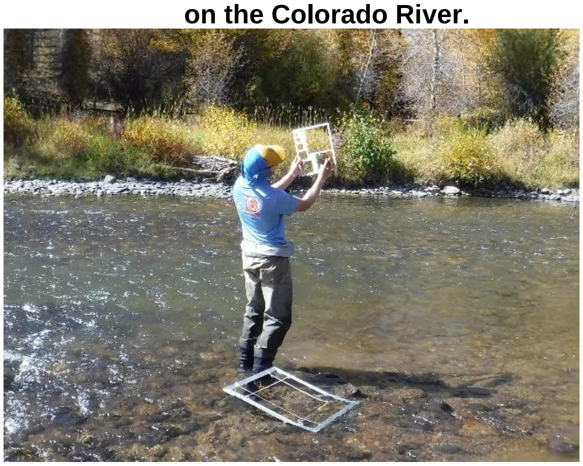
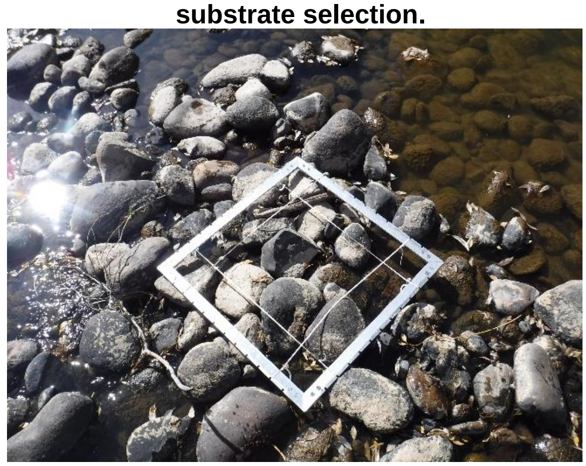


Photo 3-2: Sampling frame with four cross sections for randomized substrate selection.



A subset of the particles measured at each of the transects at each site were used to determine percent embeddedness, or the extent to which larger particles are surrounded by or buried in fine substrate (i.e., sand and silt). Five large gravel or cobble-sized particles at each transect were measured for percent embeddedness, for a total of 50 embeddedness measurements per sampling location. Embeddedness percentages were determined by measuring the height that each representative particle was buried and dividing by the total particle height. This method allowed for a quantitative estimate of the total percent embeddedness at each site.

A total of 10 transects were sampled at most sites. Site CR-6.1 was not wadeable at 5 of 10 transects due to the depth of the Colorado River at this site location. Site CR-7.4 was not wadeable in one portion of one transect and Site CR-16.7 was not wadeable in portions of 2 transects due to water depth. Site RC-1.1 on Ranch Creek was not wadeable at 7 of 10 transects due to the presence of multiple beaver dams and associated deep ponds. Inaccessible portions of sites were assessed visually when possible. For example, unwadeable transects on Ranch Creek were examined from a high point and by wading partway into the transect (if possible). In all cases, it was evident that the substrate was comprised of 100% fine sediment. If visual assessment of sediment particles, embeddedness, or algae cover was not possible, no data were collected.

Table 3-1: List of the 15 sites where 400-rock pebble counts, embeddedness estimates, and algae coverage estimates were planned. High water depth, fast water, and/or soft substrate prevented complete sampling at some sites.

Site Name	Station Description	Complete Transects	Notes
CR-6.1	Colorado River downstream of IVLK	5	80 rocks, 10 embeddedness, 6 algae. Largely not wadeable. Please see recommendations section on how to assess this site in the future
CR-7.4	Colorado River downstream of Troublesome Creek	9	383 rocks, 48/50 embeddedness, 27/30 algae
CR-9.1	Colorado River at CR39 Bridge at KB Ditch	10	
CR-16.7	Colorado River upstream of Williams Fork	8	400 rocks, 48/50 embeddedness 28/30 algae
CR-22.9	Colorado River at Hot Sulphur Springs	10	
CR-24.9	Colorado River at Sheriff Ranch	10	
CR-28.7	Colorado River just downstream of Windy Gap	10	
CR-31	Colorado River upstream of Fraser and Windy Gap	10	
FR-14	Fraser River upstream of Tabernash	10	
FR-20	Fraser River at Rendezvous Bridge	10	
FR-23.2	Fraser River upstream of Winter Park Sanitation	10	
FR-27.2	Fraser River above Jim Creek	10	
RC-1.1	Ranch Creek downstream of Meadow Creek	3	Seven assessed visually, but all estimated transects were in beaver ponds and 100% fines.
STC-0	St. Louis Creek near mouth	10	
WC-1	Willow Creek upstream of bridge/downstream of future restoration site	10	

3.2 Riffle Stability Index

The Riffle Stability Index (RSI) was determined at 10 sites using the methods outlined by Kappesser (2002). The RSI value indicates the percentage of mobile bed material in the riffle. A point bar, lateral bar, or similar depositional feature at each site was identified in close proximity to a riffle. A transect was established in a riffle across its bankfull width, and 200 substrate particles were selected. In smaller streams with insufficient width to allow selection of 200 particles, a second transect was established. The intermediate axis of each particle was measured. On the depositional feature, the intermediate axis of 10 to 30 of the largest recently deposited particles were measured, and the geometric mean of these particles was calculated. The geometric mean was then compared to the cumulative distribution of particle sizes from the 200-pebble count in the riffle. This determined the percentage of particles in the riffle that were smaller than the representative large mobile particles in the depositional feature at each site. The mobile fraction of the riffle can be estimated by comparing the relative abundance of various particle sizes present on the riffle with the dominant large particles on an adjacent bar (Kappesser 2002). A point bar, or the accumulation of gravel, cobble, and sand on the inside of a meander bend is a typical depositional feature in the CEA; depositional features at two sampling sites on the Fraser River are shown in Photos 3-3 and 3-4.

Photo 3-3: An example of a depositional point bar, from Site FR-27.2 on the Fraser River in 2022.

Photo 3-4: An example of a lateral depositional bar, from Site CR-16.1 on the Colorado River in 2022.

3.3 Algae Presence, Percent Cover, and Thickness

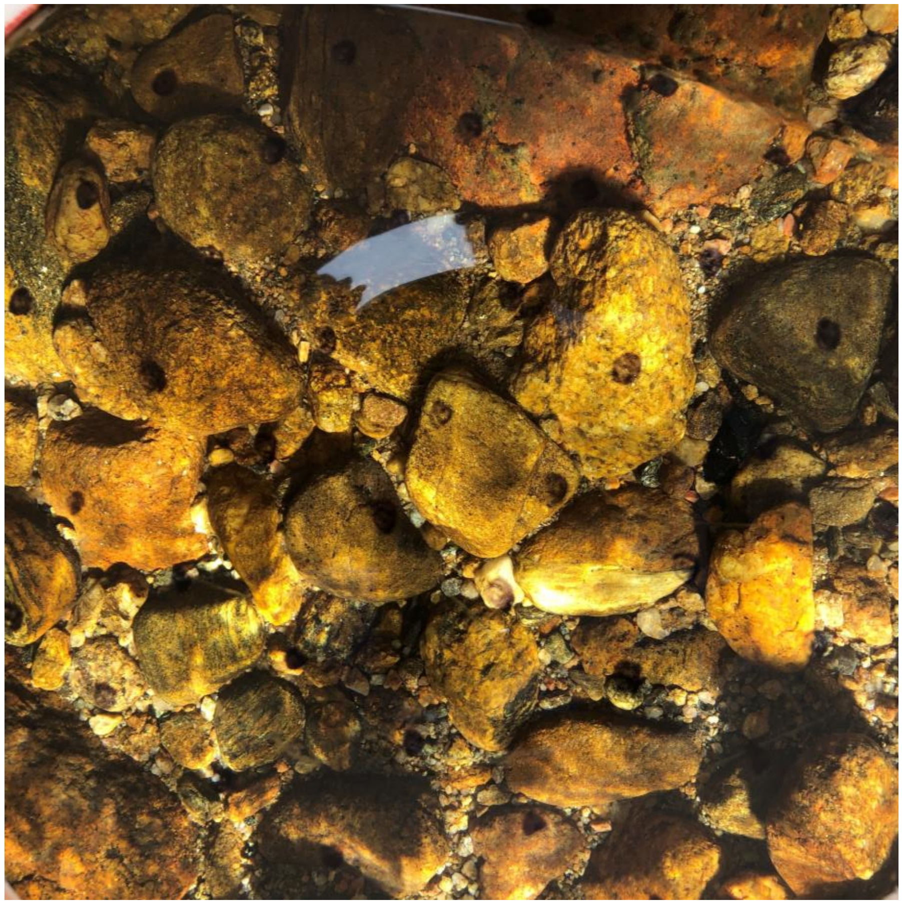
Algae presence (filamentous algae and diatoms), the percent filamentous algae cover, and diatom thickness data were recorded using a combined method that included protocols taken from the WQCD Standard Operating Procedures for the Collection of Stream Periphyton Samples (CDPHE, no year) combined with the grid-based pebble count method. Along each transect established for pebble counts, the presence of filamentous algae, the presence of diatoms, the percent filamentous algae cover, and diatom thickness were measured or visually estimated.

The algal communities were observed at three distances per transect: 25%, 50%, and 75% from the streambank, for a total of 30 points evaluated at each site. The algae viewing bucket consisted of a 5-gallon bucket with its bottom replaced with transparent plexiglass with 50 evenly spaced points marked with permanent marker (Photo 3–5). At each of the three transect positions, the presence of filamentous algae and/or diatoms was recorded. This metric provides information on whether algae and/or diatoms were found at most viewing locations or were patchy or rare in distribution at a site. Filamentous algae was defined as algae that was green in color and formed strands or filaments. Diatoms are microscopic algae and tend not to form tall-growing colonies, with one exception. *Didymosphenia geminata* (Didymo) sometimes forms dense, brown or gray blooms that can cover much of the stream substrate. Low-growing algae and the readily identifiable Didymo were considered diatoms. For filamentous algae cover data, the viewing bucket was used twice at each of the three locations along each transect, to allow viewing at a total of 100 evenly spaced points at each location. The total number of points where filamentous algae was growing was divided by 100 to calculate the percent filamentous algae cover at each of the three viewing locations per transect (see Appendix D for example photos of algal coverage). At each of the three distances the thickness of diatom growth was visually estimated in millimeters (mm) and categorized in accordance with Stevenson and Bahls 1999 (Table 3–1). Low light conditions during the survey effort prevented a large number of clear photographs of the substrate through the algae bucket at most sites. The available photos are presented in Appendix D. Alternatively, substrate was removed from the stream and photographed to provide representative examples of algal coverage – these are available upon request.

Table 3-2: Diatom thickness categories as defined by Stevenson and Bahls 1999.

Category	Categorical Description
0	Substrate rough with no visual evidence of microalgae
0.5	Substrate slimy, but no visual accumulation of microalgae evident
1	A thin layer of microalgae is visually evident
2	Accumulation of microalgal layer from 0.5 to 1 mm thick is evident
3	Accumulation of microalgal layer from 1 to 5 mm thick is evident
4	Accumulation of microalgal layer from 5mm to 2 cm thick is evident
5	Accumulation of microalgal layer greater than 2 cm thick is evident

Photo 3-5: View of the substrate through the algae viewing bucket (note black grid points in picture). The grid encompasses an area of roughly 100 in^2.



3.4 McNeil Substrate and Suspended Sediment

The amount of fine sediment and the composition of stream gravel were sampled using a McNeil sampler at three sites on the Colorado River (CR-22.9, CR-14.9, and CR-9.1), one site on the Fraser River (FR-5.5), and one site on Ranch Creek (RC-1.1). This sediment data can be used to assess the spawning success of salmonids and other gravel-dependent spawners (McNeil and Ahnell 1964), and channel characteristic data have been used to monitor changes in channel morphology that ultimately affect fish habitat quality over time (Olson-Rutz and Marlow 1992). Six replicate samples were taken from pool tails or low-gradient riffles at each of the sampled sites. Material was removed to the depth of the armor layer, or the layer of clean substrate that forms the top layer of stream substrate and would be moved by salmonids constructing redds, or nests. Substrate material was manually removed from the streambed using the McNeil sampler and brought to the GEI Ecological Laboratory for analyses.

Photo 3-6: Side-view and top-view of the McNeil sampler. Device was driven into the streambed up to the collar and substrate material was removed for analyses from the interior area of the narrow portion.

Each sample was dried before analysis by opening the sample bag and allowing the moisture to evaporate over a period of a few weeks. Dried samples were shaken through a series of sieves, and the amount of sample retained on each sieve was weighed. The weight of the sample retained on each sieve was divided by the total sample weight to obtain the percent of the sample weight belonging to each size class. The D_{50} and D_{84} were calculated for each of the McNeil core samples. The cumulative proportions of fine substrate with a diameter less than 0.85 mm, 2 mm, 3.35 mm, and 6.35 mm, was also calculated. The D_{50}, D_{84}, percent fines, and suspended solids values were compared between sample locations. Each sample was also compared to benchmarks established by Kondolf et al. (2008) to determine whether the grain size distribution could reduce the survival of salmonid eggs or the probability of successful emergence of salmonid fry from their redds.

The amount of suspended sediment was determined by using the American Society for Testing Materials (ASTM) method D3977-97 (ASTM 2019). The sediment core sample was removed from the inner portion of the sampler and placed in the collection chamber, which was full of water. The water was agitated, and a 470 milliliter (ml) sample was collected (after MacDonald and McDonald, 1987). The field samples were kept on ice below 4°C until analysis by the GEI Laboratory. A total of six replicate aliquots were taken from each sample, and the average of the six replicates was used to characterize the suspended solids at each sample location. The data from these samples are representative of the suspended sediment in the McNeil-Ahnell sampler, not necessarily what is being transported in suspension in the water column. The data from the analyses can be used to describe the potential of a site to produce suspended sediment as flows increase, or to describe the sediment volume that has settled from the water column during previous, higher flows. These suspended sediment data can be compared between sites and over time to help develop or corroborate hypotheses about sources of sediment and depositional characteristics in the watershed. However, actual characterization of suspended sediment in the CEA would require a more comprehensive sampling procedure that would involve data collection at multiple sites over targeted ranges of flow.

4. Results

4.1 Pebble Counts and Embeddedness

Pebble counts were performed at eight sites on the Colorado River, four sites on the Fraser River, and one site each on Ranch Creek, St. Louis Creek, and Willow Creek from September 21, 2022, through September 23, 2022.

Most sites on the Colorado River and Fraser River were dominated by substrate sizes categorized as gravel or cobble (Table 4–1). Fine substrate, particles with an intermediate width less than 2 mm, was abundant on the Colorado River at Site CR-24.9 and on Ranch Creek at Site RC-1.1 (Table 4–1).

Table 4-1: Percent average substrate size classes at all sites sampled in 2022.

Sites	Substrate Size Categories							
	Fines	Small Gravel	Gravel	Small Cobble	Cobble	Small Boulder	Boulder	Bedrock
	<2 mm	2-8 mm	8-64 mm	64-128 mm	128-256 mm	256-512 mm	>512mm	
CR-31	11.5	4.8	19.0	24.3	35.5	5.0	0	0
CR-28.7	25.4	0.7	14.9	31.5	22.5	4.6	0.2	0
CR-24.9	46.1	1.7	15.2	14.2	17.0	4.7	0	1.0
CR-22.9	15.4	0.5	38.8	31.6	7.0	3.2	1.5	2.0
CR-16.7	22.9	4.5	14.5	23.9	20.9	2.7	7.0	3.5
CR-9.1	16.1	9.4	23.2	22.9	21.9	6.3	0.3	0
CR-7.4	20.6	6.0	57.7	12.8	2.6	0.3	0	0
CR-TBD	21.3	8.8	38.8	17.5	12.5	1.3	0	0
FR-27.2	22.9	11.7	33.9	21.9	8.2	0.7	0.5	0
FR-23.2	8.0	7.5	29.3	25.3	17.3	6.3	6.5	0
FR-20	12.4	7.9	30.2	19.1	21.8	7.2	1.5	0
FR-14	12.4	8.8	30.6	19.7	23	4.5	0.9	0
RC-1.1	72.8	2.0	13.0	5.8	4.3	1.0	1.3	0
STC-0	9.3	8.0	21.8	21.5	29.0	9.3	1.3	0
WC-1	26.8	5.5	20.3	30.3	15.5	0.8	1.0	0

The percentage of substrate sizes observed in 2022 on the Colorado River varied between sites. Substrate between 2 mm and 512 mm was observed at all sites. There was little substrate greater than 256 mm at the two most downstream sites, Site CR-7.4, and Site CR-TBD. Site CR-7.4 had a noticeably greater percentage of small gravel and gravel substrate, between 2 mm and 64 mm, than all other Colorado River sites (Figure 4–1). The Colorado River sites exhibited a decrease in average substrate size from Site CR-31 downstream to Site CR-22.9, and then again from Site CR-16.7 downstream to Site CR-7.4 (Figure 4–1).

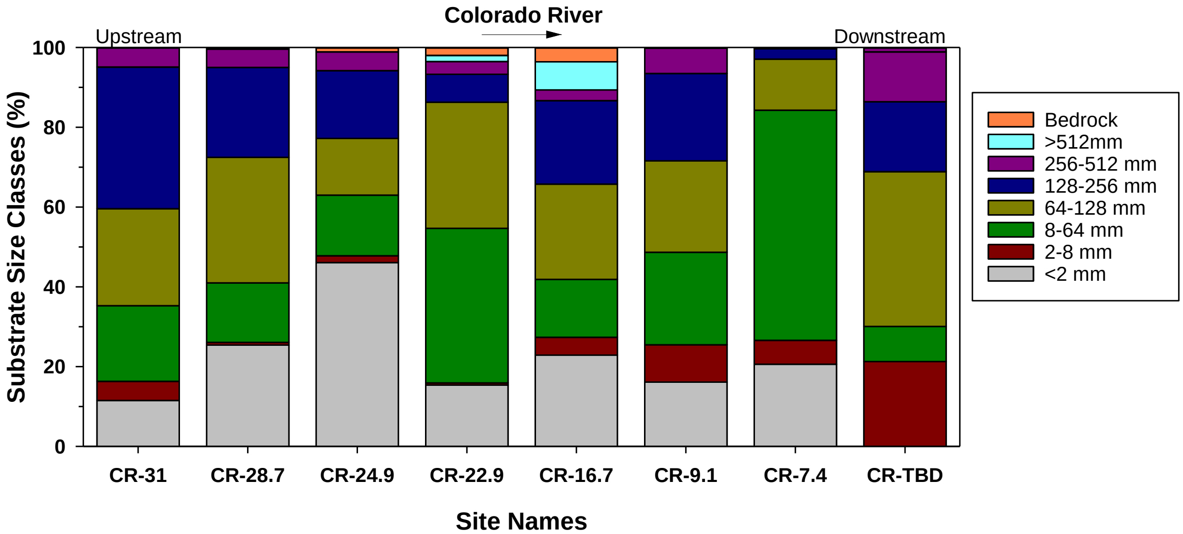


Figure 4-1: Percentage of substrate size classes for all sites on the Colorado River in 2022.

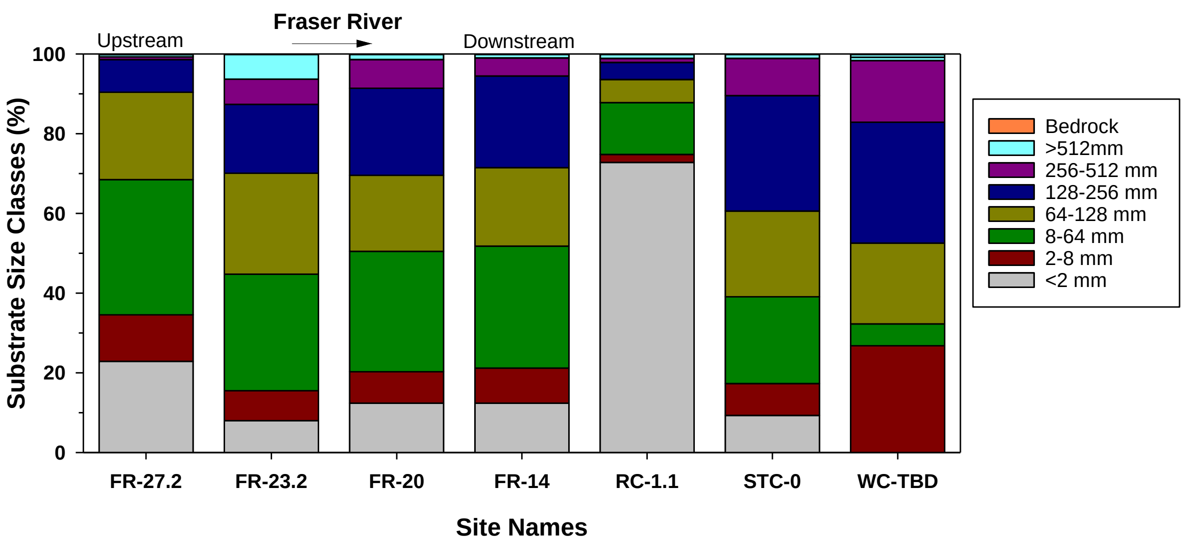


Figure 4-2: Percentage of substrate size classes for all sites on the Fraser River and Ranch Creek in 2022.

Substrate composition varied less between the Fraser River sites than the sites on the Colorado River (Figure 4–2). The proportions of gravel and small boulders decreased slightly in a downstream direction. The proportions of fine sediment increased in a downstream direction from Site FR-23.2 to Site FR-14, but overall proportions of all size classes were similar among the three most downstream sites on the Fraser River. There were small amounts of fine substrate at the three downstream sites, and these sites had greater proportions of larger substrate than the most upstream Fraser River site, Site FR-27.2 (Table 4–1 and Figure 4–2). This site was sampled by GEI for the first time in 2022 and was located farther upstream than previously established sites on the Fraser River.

Substrate types and proportions at Site RC-1.1 were dissimilar to those at all sites in the CEA, with a much greater percentage of fine substrate and small proportions of substrate other than fines or gravel (Figure 4–2). Site STC-0 on St. Louis Creek had a small proportion of fine substrate, and the majority of substrate was less than 128 mm. Site WC-1 on Willow Creek had a moderate amount of fine substrate and was dominated by substrate less than 128 mm.

All but two of the 15 sites surveyed with the 400-rock modified Wolman count had percentages of fine sediment (i.e., < 2 mm) less than 29.3%, which is the threshold set in CDPHE Policy 98-1 for the protection of macroinvertebrates for sites in the CEA. The surveys indicated that the substrate at sites CR-24.9 and RC-1.1 were heavily dominated by fine sediment.

Average percent embeddedness was equal to or greater than 39.0 at all sites on all streams, with the largest average percent embeddedness present at sites RC-1.1, CR-TBD, and WC--TBD (Table 4-2). Average percent embeddedness values on the Colorado River were similar among sites with the exception of notably greater values at sites CR-TBD and CR--28.7. Other than these two sites, average percent embeddedness on the Colorado River ranged from 40.4 to 64.0 percent. Average percent embeddedness values on the Fraser River were moderate to high for all sites, with values ranging from 37.7 to 56.7 percent (Table 4–2); embeddedness decreased between FR-27.2 and FR-23.2 then increased again between FR-23.2 and FR-14.

Average percent embeddedness at Site RC-1.1 on Ranch Creek was the greatest in the CEA at 84.8 percent and was the lowest at Site FR 23.2 on the Fraser River. Site WC-TBD on Willow Creek had a moderately high percent embeddedness with 65.1 percent.

Table 4-2: Average embeddedness at all sites sampled in 2022.

Sites	Waterbody	Average Percent Embeddedness
CR-31	Colorado River	40.4
CR-28.7	Colorado River	64.0
CR-24.9	Colorado River	53.7
CR-22.9	Colorado River	50.8
CR-16.7	Colorado River	51.3
CR-9.1	Colorado River	43.3
CR-7.4	Colorado River	49.0
CR-TBD	Colorado River	80.5
FR-27.2	Fraser River	56.7
FR-23.2	Fraser River	37.7
FR-20	Fraser River	40.2
FR-14	Fraser River	56.4
RC-1.1	Ranch Creek	84.8
STC-0	St. Louis Creek	39.0
WC-TBD	Willow Creek	65.1

4.2 Riffle Stability Index

According to protocol, a 200-riffle pebble count and a 15 to 30 pebble count on a nearby depositional feature were performed at 10 of the 18 sites in 2022. The RSI value indicates the cumulative percentage of riffle particles that are smaller than the dominant large particles on a depositional bar (Kappesser 2002). Values of the RSI range from 0 to 100, with higher numbers indicating sand and small gravel loading in the riffle. Reference, or unmanaged, streams in the Kappesser study (2002) had a median RSI value of 58, indicating that RSI values in the high 50s do not indicate an unexpected number of fines.

The minimum RSI value observed in 2022 occurred at Site CR-28.7 on the Colorado River and the maximum observed value was observed at Site FR-27.2 on the Fraser River. RSI values were also high at sites CR-9.1 and CR-7.4 on the Colorado River. In general, the RSI values were notably greater in the lower portion of the Colorado River compared to the upper portion in 2022. The RSI values on the Fraser River were similar among the four downstream sites, and the RSI at the most upstream site was substantially higher (Table 4–3).

Table 4-3: Average Riffle Stability Index (RSI) by site in 2022.

Sites	Waterbody	Riffle Stability Index
CR-28.7	Colorado River	34.6
CR-9.1	Colorado River	86.4
CR-7.4	Colorado River	88.1
FR-27.2	Fraser River	90.0
FR-23.2	Fraser River	40.4
FR-14	Fraser River	43.2
FR-5.5	Fraser River	54.0
FR-1.9	Fraser River	53.5
RC-1.1	Ranch Creek	56.4
STC-0	St. Louis Creek	62.6

4.3 Algae Presence, Percent Cover, and Thickness

The algae community was assessed at a total of 30 points within each site reach in conjunction with pebble count surveys from September 21, 2021 through September 23, 2021. The percent average presence of filamentous algae per site was generally 63 percent or greater among the sites surveyed in 2022. Notably, the most upstream sites on both the Colorado River and the Fraser River and the sites on St. Louis Creek and Willow Creek had much lower filamentous algae presence than the remaining sites in the CEA, with values ranging from 20 to 30 percent (Table 4–4).

The percent filamentous algae cover at each site varied widely and followed a similar trend to the percent average filamentous presence. Percent filamentous algae cover approached or exceeded 50 percent at nine of the fifteen sampled sites (Table 4–4).

Table 4-4: Filamentous algae and diatom data by site in 2022.

Sites	Waterbody	Percent Average Filamentous Presence	Percent Average Filamentous Algae Cover	Percent Average Diatom Presence	Average Categorical Diatom Thickness
CR-31	Colorado River	20.0	7.8	96.7	2.23
CR-28.7	Colorado River	100	78.7	3.7	0.04
CR-24.9	Colorado River	92.6	62.3	33.3	0.7
CR-22.9	Colorado River	100	70.7	12.5	0.1
CR-16.7	Colorado River	85.7	62.6	7.1	0.14
CR-9.1	Colorado River	66.7	43.2	33.3	0.38
CR-7.4	Colorado River	100	75.4	18.5	0.32
CR-6.1	Colorado River	90.0	49.8	16.7	0.08
FR-27.2	Fraser River	23.3	2.0	90.0	0.67
FR-23.2	Fraser River	73.3	9.5	23.3	1.0
FR-20	Fraser River	63.3	27.4	86.7	0.8
FR-14	Fraser River	100	72.1	29.2	0.3
RC-1.1	Ranch Creek	100	72.2	44.4	0.4
STC-0	St. Louis Creek	30.0	2.6	100	1.58
WC-1	Willow Creek	20	4.8	50.0	0.43

Diatoms were observed at each site sampled in the CEA in 2022. The percentage of diatom algae varied considerably on the Colorado River and Fraser River. The percentage of diatom presence ranged from 3.7 to 97 percent on the Colorado River and ranged from 23 to 90 percent on the Fraser River (Table 4–4). The percentage of diatom presence on Ranch Creek and Willow Creek was moderate with 44 and 50 percent, respectively, and highest on St. Louis Creek at 100 percent.

The diatom species *Didymosphenia geminata* (Didymo) is a stalked diatom that can form nuisance blooms in rivers in the western United States (Spaulding and Elwell 2007). On the Colorado River, Didymo was present in appreciable amounts at Site CR-31 and either absent or present in very small amounts at the remaining sites in 2022. Extensive and thick blooms of Didymo were present at Site CR-31, with thicknesses ranging from 0.5 mm to 2 cm at the site (Table 4–4; Table 3–1). Didymo was present at some sites on the Fraser River, but in small percentages and thicknesses. Diatom thickness on the Fraser River was lower than on the Colorado River with maximum thickness values of 1 mm to 5 mm present at only one site in a single transect. The remaining thickness values on the Fraser River ranged from being present but not visually evident to 1 mm thickness.

Diatom thickness was low at Site RC-1.1 on Ranch Creek and Site WC-TBD on Willow Creek, with maximum thickness values ranging from a thin layer being visually evident to 1 mm. More substantial amounts and thicknesses of diatoms were present at Site STC-0 on St. Louis Creek due to the intermittent presence of Didymo. At this site maximum diatom thickness was 1 mm to 5 mm in portions of five of the 10 transects at the site.

4.4 Volumetric Substrate and Suspended Sediment Analyses

Stream substrate was sampled with the McNeil sampler, and suspended sediment samples were collected at sites CR-9.1, CR-14.9, CR-22.9 on the Colorado River, Site FR-5.5 on the Fraser River, and at Site RC-1.1 on Ranch Creek. These samples provided data to help assess the quality of fish spawning and benthic macroinvertebrate habitat.

All sites on the three streams had low to moderate proportions of fine sediment, and similar average D_{50} and D_{84} substrate sizes (Table 4–5). Both the D_{50} and D_{84} for all sites were within the 8 mm to 64 mm range and categorized as gravel. The D_{50} at all sites sampled in the CEA fell within the range of 5.8 mm to 50 mm. This range of values was observed in redds constructed by Brown Trout (*Salmo trutta*) in a 1993 study by Kondolf and Wolman. Examination of the smaller sediment fractions also showed that the spawning areas surveyed in 2022 are conducive to successful trout reproduction. The mean maximum levels of different grain sizes that allow for 50 percent salmonid emergence are: <0.85 mm, 13.6 percent; <2.00 mm, 15 percent; <3.35 mm, 29.5 percent; and <6.35 mm, 30.3 percent (Kondolf et al. 2008). The mean proportions of fine substrate classes from the volumetric samples met these criteria for three of five sampled sites. At Site CR-14.9, the percentage of sediment < 2 mm was 19.7% percent. At Site FR-5.5, the percentage of sediment < 2 mm was 19.8%, and the percentage of sediment < 6.35 mm was 34.2%.

Table 4-5: Site-averaged McNeil-Ahnell sample data from 2022, showing median and 84th percentile grain sizes and multiple size classes of fine sediment. Standard deviation shown in parentheses for the D_{50} and D_{84}.

Sites	Waterbody	McNeil Samples		Fine Sediment			
		Average D_{50} (mm)	Average D_{84} (mm)	0.85 mm	2 mm	3.35 mm	6.35 mm
CR-22.9	Colorado River	14.6 (0.9)	39.8 (0.8)	7.4%	11.3%	15.7%	23.6%
CR-14.9	Colorado River	14.9 (3.5)	39.8 (3.1)	11.6%	**19.7%**	22.9%	26.2%
CR-9.1	Colorado River	17.6 (2.5)	42.2 (1.9)	8.4%	13.2%	15.0%	17.4%
FR-5.5	Fraser River	11.0 (3.9)	35.8 (4.6)	11.2%	**19.8%**	25.5%	**34.2%**
RC-1.1	Ranch Creek	12.9 (4.8)	37.5 (5.7)	6.6%	14.2%	20.0%	28.4%

Average suspended sediment varied among sampling sites, with lower concentrations present at CR-14.9 and CR-9.1 and higher concentrations present at CR-22.9, FR-5.5, and RC-1.1. Individual volumetric sediment samples collected from sites with high suspended sediment concentrations were highly variable, with ranges spanning an order of magnitude (Table 4–6). Values were notably higher at Site CR-22.9, which is downstream of fire-affected tributaries such as Drowsy Water Creek, and at Site FR-5.5, downstream of Fraser Canyon.

Table 4-6: Average, maximum, and minimum values of suspended sediment from the 2022 McNeil-Ahnell samples.

Sites	Waterbody	Suspended Sediment (mg/L)		
		Average	Minimum	Maximum
CR-22.9	Colorado River at Hot Sulphur Springs	21,217.5	5,232.3	49,590.0
CR-14.9	Colorado River downstream of Williams Fork	1,471.5	1,120.1	1,808.1
CR-9.1	Colorado River at CR39 Bridge at KB Ditch	4,156.5	1,813.1	7,142.4
FR-5.5	Fraser River at Granby Ranch	11,684.0	4,432.1	22,019.8
RC-1.1	Ranch Creek downstream of Meadow Creek	7,591.8	4,830.5	12,190.5

5. Discussion

The substrate, suspended sediment, and algae community data gathered in the fall of 2022 at multiple sites along representative stretches of the Colorado River, Fraser River, Ranch Creek, St. Louis Creek, and Willow Creek have enabled a basin-wide assessment of substrate size, substrate mobility, substrate deposition, and algae coverage data. This in turn allows inference about the effects of current substrate conditions on fish and macroinvertebrate habitat quality.

5.1 Pebble Counts and Embeddedness

5.1.1 Colorado River and Willow Creek

Observed changes between sites in 2022 included increases in fine sediment in a downstream direction on the Fraser River and longitudinal increases punctuated by decreases along the Colorado River. This suggests that sediment composition in the CEA is likely affected by large-scale factors such as reservoirs, tributary inputs, and magnitude of flow, and by local-scale factors such as hillslope erosion and stream diversion infrastructure. The major influences on sediment dynamics in the Colorado River are summarized briefly below.

Windy Gap Reservoir is located near the upstream end of the reach of the Colorado River that is located within the CEA; it is just below the Colorado River and Fraser River confluence and between Site CR-31 (the upstream-most Colorado River site in the CEA) and Site CR-28.7. The reservoir has been drawn down substantially over the last two years, and major changes are being made to the reservoir and the channel of the Colorado River. Fine substrate less than 2 mm was greatest at sites CR-28.7 and CR-24.9 on the Colorado River in 2022. The fine substrate at Site CR-28.7 may be related to activities at Windy Gap Reservoir, but the fine sediment at Site CR-24.9 almost certainly originated from Drowsy Water Creek and/or other nearby tributaries affected by the East Troublesome Fire. Mid-channel vegetated bars near this site suggest that this is a depositional area and that river processes will be slow to remove large accumulations of fine sediment. Among the studied sites in the CEA, the amount of fine sediment decreased substantially at two Colorado River locations in 2022: between Site 24.9 and Site CR-22.9, and between Site CR-16.7 and Site CR-9.1. Decreased fine sediment at Site CR-9.1 may be attributable to inputs of low-sediment flows from the Williams Fork River. As in previous years, sediment was probably introduced into Site CR-16.7 through Beaver and Little Muddy creeks and from hillslope inputs in Byers Canyon. The subsequent increase in the amount of fine sediment downstream of Site CR-9.1 is likely due to inputs from Troublesome Creek. Troublesome Creek is a potential source for large amounts of fine sediment and gravel, particularly after the East Troublesome Fire.

Due to higher sinuosity (i.e., degree of meandering), lower slope, reduced water velocity, and sediment inputs from Troublesome Creek and local bank erosion, the Colorado River downstream of Site CR-9.1 transitions from being dominated by cobble to being dominated by smaller substrate size classes.

Between 2019 and 2022, sediment dynamics changed at many of the monitoring sites on the Colorado River. This could be due to natural and anthropogenic changes that include fire effects on landscapes, variation in spring runoff and monsoon season moisture, stream restoration, and reservoir presence. Between 2019 and 2022, there was an increase in fine substrate less than 2 mm at almost all of the Colorado River sites surveyed in multiple years. Site CR-7.4, which is located within the IVLK restoration reach mentioned in Section 2.0, was the only Colorado River site that had a decrease in the proportion of fine substrate in 2022. The width-to-depth ratio of the channel at this site was decreased during stream rehabilitation activities in 2021; the change in the channel cross-section may have facilitated the transport of fine sediment through the site, even in a year when fine sediment loading was high throughout the system. Site CR-6.1 was sampled for the first time in 2022. Much of the site is unwadeable, and the site bears some resemblance to Site CR-1.7 in that it is characterized by long reaches dominated by fine sediment. However, unlike Site CR-1.7, Site CR-TBD contains natural riffles. We recommend that future sampling efforts focus on these riffles to collect data on sediment processes in the Colorado River. Most of the sampling sites experienced an increase in the proportion of fine sediment and/or gravels between 2020 and 2022, but not between 2019 and 2020. This appears to be the result of landscape-scale processes, such as runoff from fire-affected areas, input of materials from tributaries during the monsoon season, and deposition after a strong spring runoff in the Colorado River in 2022. Precipitation during the 2021 and 2022 monsoons introduced fines and gravels into the Colorado River, either through tributary inputs or via hillslope erosion. Increased sediment loading into streams, even in periods without significant rainfall, can produce exceptionally high rates of sediment transport (Ryan et al. 2011). Furthermore, flows from tributary floods can lead to rapid deposition of smaller substrate in the Colorado River (Wiele et al. 1996). Flows during spring runoff in 2022 were higher than the long-term median (1982-2022), which suggests that flushing flows occurred in 2022. However, large amounts of fine sediment may have been deposited on the descending limb of the spring runoff hydrograph (e.g., Knighton 1998) and during the monsoon.

On a more local scale, reservoir operations and stream restoration activities could have affected sediment dynamics at individual sites. Windy Gap Reservoir was partially drained from 2020 through 2022 in preparation for the modification of the dam and construction of the connectivity channel in the Colorado River. Higher flows in spring of 2022 may have mobilized some of the remaining sediment in the reservoir and deposited it at Site CR-28.7.

Substantial restoration projects have occurred in the Williams Fork and Colorado rivers since 2018. In both cases, the work has resulted in a lower width-to-depth ratio of the stream cross section, which facilitates sediment transport. The proportions of gravel and smaller substrate classes at Site CR-9.1 (downstream of the Williams Fork) increased between 2019 and 2022. Site CR-9.1 also had greater proportions of fines, small gravel, and gravel substrate in 2020 and 2021, and greater proportions of gravel in 2022 than the next upstream site, Site CR-16.7. Although the restored reach of the Williams Fork River is below the Williams Fork Reservoir and potentially sediment-limited, the lower width-to-depth ratio of the river may have increased transport of locally available gravels into the Colorado River.

Based on sediment data from 2019 through 2022, Site CR-7.4 (on the main stem, within a restored reach) appears to receive a large amount of sediment annually. This sediment likely originates from unregulated tributaries (including those in fire-affected areas) with a small proportion of the sediment load resulting from bank erosion (GEI 2022, GEI 2021). However, the proportion of fine sediment decreased at this site between 2019 and 2022, despite introduction of large amounts of sediment into the Colorado River in 2021 and 2022 from adjacent fire affected areas. The decrease in fines could be due to the increased ability of the restored reach to transport sand and silt, as a result of restoration. There was a large increase in the proportion of gravel at Site CR-7.4 between 2019 and 2022 and a much smaller increase at the next upstream site location, Site CR-9.1. Troublesome Creek flows into the Colorado River between sites CR-9.1 and CR-7.4, and the increase in gravel at Site CR-7.4 is likely attributable to gravel inputs from Troublesome Creek.

Willow Creek was first sampled in 2022, with the establishment of Site WC-1 a short distance upstream of the confluence of Willow Creek and the Colorado River and downstream of Willow Creek Reservoir. The confluence is located upstream of Site CR-31. The Willow Creek Reservoir dam inhibits the natural movement of substrate through the downstream portion of Willow Creek. This site was dominated by small cobble substrate and the vast majority of substrate present was less than 128 mm. Site WC-1 is located in a low slope reach punctuated by beaver dams. The sediment dynamics in Willow Creek are affected by beaver dams and by the managed releases from Willow Creek Reservoir. Embeddedness at Site WC-1 was high and likely due to its location in an erodible watershed with dynamic beaver complexes.

Embeddedness values on the Colorado River in 2022 were similar among the majority of sites but notably greater at sites CR-28.7 and CR-TBD. Embeddedness was relatively low at the most upstream site (CR-31) and then increased notably at the next downstream site, Site CR-28.7. This greater embeddedness value at Site CR-28.7 may be related to its proximity to the Windy Gap Reservoir dam. Fines that were carried in suspension over the dam could have been deposited at this site on the descending limb of the spring hydrograph, or additional sediment may have moved into the site during the 2022 monsoon season. While significant construction is currently occurring in the area within and surrounding the reservoir, the effects of this activity are not known. However, any effects are expected to be temporary, and expected to result in an overall improvement in sediment transport in the Colorado River. Embeddedness values decreased between sites CR-28.7 and CR-22.9 and increased between sites CR-9.1 and CR-7.4. These changes likely mean that there were no notable additions of fine substrate from Site CR-22.9 downstream to Site CR-9.1 and that much of the fine sediment at sites CR-7.4 and CR-TBD originated in the Troublesome Creek Drainage.

Embeddedness at Site CR-6.1 was notably greater than at any other Colorado River site in 2022 with a value greater than 80 percent. This is due to the addition of substrate from tributaries, a notable decrease in the slope of the river, and an increase in sinuosity. These factors all decrease water velocity and facilitate deposition of fine substrate. The remaining differences in substrate composition and embeddedness between sites in 2021 and 2022 on the Colorado River are minor and probably due to a combination of natural variability and sampling variability.

5.1.2 Fraser River, Ranch Creek, and St. Louis Creek

As with the Colorado River, sediment composition on the Fraser River is affected by large-scale and local-scale factors. The primary large-scale factor is flow management, but local features such as unpaved roads, diversions, erodible hillslopes, beaver ponds, and man-made ponds appear to have a larger effect on the proportion of fine sediment at individual sites.

The Fraser River has four relatively large tributaries: Vasquez Creek, which enters the Fraser River between sites FR-23.2 and FR-20, Elk Creek and St. Louis Creek, both of which enter the Fraser River between sites FR-20 and FR-14, and Ranch Creek, which enters the Fraser River downstream of Site FR-14. Because these tributaries are also managed systems, they are not likely to provide substantial amounts of gravel to the Fraser River.

Site FR-27.2 is the most upstream site evaluated on the Fraser River and is located just upstream of the intersection of Mary Jane Road and Highway 40. The site is located in the upper portion of an open meadow and wetland-dominated reach. Downstream, the river quickly becomes confined by pine forest, the slope of the river increases, and sinuosity decreases. This site is also in close proximity to Highway 40 and upstream of the Denver Water diversion that is designed to trap traction sand that enters the river. The greater proportion of gravel, small gravel, and fine substrate at Site FR-27.2 than the other Fraser River sites in 2022 is probably attributable to the site’s proximity to abandoned beaver dams and Highway 40, as well as its location upstream of the sediment collection system. The large, active beaver dams between sites FR-27.2 and FR-23.2 also store large amounts of the fine sediment that would otherwise be transported downstream.

The three sites on the Fraser River downstream of Site FR-27.2 all had low amounts of fine substrate in 2022 and were dominated by gravel substrate. The proportions of substrate at sites FR-23.2, FR-20, and FR-15 changed little from 2021 to 2022. However, fine sediment decreased slightly at Site FR-23.2 and increased at Site FR-14. Spring runoff on the Fraser River upstream of Tabernash, Colorado in 2022 was notably higher than in 2021. This increased flow in 2022, in combination with increased tributary flows may have transported accumulated sediment from Site 23.2 downstream to Site FR-14. The stretch of the Fraser River between sites FR-20 and FR-14 increases in sinuosity and has reduced slope, which would enable more storage of smaller substrate. The lack of change in the substrate classes at Site FR-20 between 2021 and 2022 indicate that flow conditions at this site in 2022 allowed for continued transport of small substrate, as in previous years.

On Ranch Creek, the percentage of substrate <2 mm was high at Site RC-1.1 in 2022. The high proportion of fine sediment is due to a combination of multiple beaver dams upstream and within the site reach, and the high availability of sediment from unpaved roads and hillslopes in the watershed. Most of Site RC-1.1 was inundated by beaver ponds in 2022. Based on repeated field observations, the proportion of beaver ponds within Site RC-1.1 increased between 2020 and 2021 but remained stable between 2021 and 2022. The beaver complexes in the reach upstream of Site RC-1.1 are substantial and extend a long distance upstream of the site location. Site RC-1.1 on Ranch Creek was observed to have similar sinuosity, slope, and habitat types as the lower and middle sites on the Fraser River, suggesting that similarities in substrate characteristics in 2019 and 2020 when fewer beaver dams were present at this site could be attributable to similar stream morphologies at these sites.

St. Louis Creek was first sampled by GEI in 2022. Site STC-0 was located just upstream of the confluence of St. Louis Creek and the Fraser River but had to be moved slightly upstream of its original location due to construction. This site had a low proportion of fine substrate, and overall proportions of all substrate classes were comparable to values present at Site FR-23.2 on the Fraser River in 2022. These similarities are attributable to similar sinuosity and slope at the two sites. St. Louis Creek upstream of Site STC-0 flows through numerous beaver dam complexes. St. Louis Creek also contains multiple diversions. Both the beaver dams and the diversions have the potential to trap fine substrate and gravels. Regardless, Site STC-0 has low sinuosity and is partially confined by a road bank; this straightening increases stream slope and transport capacity, thus reducing the amount of fine substrate present at the site.

Embeddedness values were comparable between sites on the Fraser River in 2022 with only small changes between sites. Embeddedness increased in a downstream direction from Site FR-23.2 to Site FR-14 instead of decreasing like they did in 2021. Increased spring runoff in 2022 may have increased the transport of fine substrate from the upper section of the Fraser River, causing the slight longitudinal increase between Site FR-23.2 and Site FR-14. Additionally, the section of river between upstream of Site FR-14 was the focus of the Fraser Flats River Habitat Project, and the decrease in width-to-depth ratio has allowed this section of river to transport sediment successfully.

The largest changes in the Fraser River/Ranch Creek drainages from 2019 through 2022 involved the increase in fine substrate at Site FR-14, a small increase in gravel substrate at sites FR-23.2 and FR-20, and much greater proportions of fine sediment at Site RC-1.1 on Ranch Creek. In 2022, Site FR-23.2 on the Fraser River had the least change in substrate types from 2021 values. The proportion of fine sediment at Site RC-1.1 in 2021 and 2022 was much greater than observed in 2019 and 2020; this was due to the fact that much of the site has become inundated with beaver ponds, which have the capacity to store large amounts of sand and silt.

5.2 Riffle Stability Index

The mobile percentile of particles in a riffle, or RSI, is a useful estimate of the degree of increased sediment supply to riffles in mountain streams (Kappesser 2002). A stable stream reach in dynamic equilibrium has similar sediment size and sediment transport rates at the beginning of a reach compared to the end of a reach, so that there is no net gain or loss of sediment (Kappesser 2002). In the Kappesser (2002) study in north Idaho, reference streams had a median RSI value of 58 and managed watersheds had a median RSI value of 80. A higher RSI value shows that a higher proportion of the material in a riffle is smaller than the larger materials on depositional features. This indicates that a riffle is storing a higher proportion of fine materials such as sand.

The median RSI value was 86.4 for the sites on the Colorado River and 53.5 on the Fraser River in 2022. RSI sampling was only performed at three Colorado River sites in 2022, and two of these sites were in the downstream section of the river noted for its low slope and high degree of sinuosity. RSI values on Ranch Creek and St. Louis Creek were comparable to values seen on the lower portion of the Fraser River.

On the Colorado River, Site CR-28.7 had the lowest RSI value in 2022, suggesting that stream flows were sufficient to remove fine substrate from the riffles immediately downstream of Windy Gap Reservoir. Fine substrate, as measured by the pebble counts, was abundant at Site CR-28.7, but the low RSI value indicates that fines are being stored in slower-velocity areas such as pools or glides. RSI values were much higher and comparable at sites CR-9.1 and CR-7.4. The relatively high values, in combination with high proportions of fine sediment and embeddedness measured during the pebble counts, are indicative of increased sediment input. RSI values on the Fraser River in 2022 were high at Site FR-27.2 and low at the remaining four sites. This indicates that Site FR-27.2, which also had a higher proportion of fine sediment than the other Fraser River sites, is receiving high sediment input. This site is upstream of the sediment collector at the DW diversion on the Fraser River – it appears that this collection system, either singly or in combination with existing beaver ponds in the drainage, is effectively limiting the amount of traction sand that is delivered to downstream reaches. Thus, the remaining sites on the Fraser River may be sediment supply-limited.

The relatively low RSI value at Site RC-1.1 on Ranch Creek in 2022 is due to sediment storage by the beaver complexes upstream of the riffle habitat in 2022. The RSI value at Site STC-0 on St. Louis Creek was slightly greater than the value on Ranch Creek and the two most downstream Fraser River sites. This indicates increased storage of fine sediment in riffles at Site STC-0 in comparison to the other sites (see Section 6 for implications for aquatic life).

5.3 Algae Presence, Percent Cover, and Thickness

Green filamentous algae were present at every site sampled in 2022. There were extensive amounts of algae (i.e., > 50% average coverage) at almost all sites on the Colorado River in 2022, one site on the Fraser River, and the site on Ranch Creek. The most upstream sites on both the Colorado River and the Fraser River and each site on St. Louis Creek and Willow Creek had much lower percent average filamentous algae presence than the remaining sites in the CEA (see Section 6.0 for implications for aquatic life).

Low flow conditions throughout much of 2022 and nutrient inputs from sources such as agricultural run-off likely attributed to the extent of filamentous algae on the Colorado River and to a lesser extent on the Fraser River. Filamentous algae at Site WC-TBD may have been limited by the high turbidity at the site.

Diatoms were observed at all sites sampled in 2022 and in variable amounts on the Colorado River and Fraser River. Notable amounts of diatoms were present at the most upstream sites on the Colorado River and Fraser River in 2022. Didymo was present in the CEA and formed extensive blooms at sites CR-28.7 and in portions of Site STC-0. This species tends to create blooms in stable, low velocity flow regimes (Kirkwood et al. 2007; Miller at al. 2009). Sustained low flow periods in spring, summer, or fall can facilitate didymo blooms intermittently throughout the CEA, even in years with spring runoff flows that exceed the long-term median.

In 2022, there was little overall change in the amount of filamentous algae on the Colorado River and Fraser River except for a large decrease at Site CR-31 on the Colorado River. There was an increase in the amount of filamentous algae and diatoms on Ranch Creek in 2022, and some increases in diatoms at the sites on the lower portions of both the Colorado River and Fraser River (GEI 2021). The differences in the diatom and filamentous algae communities between 2021 and 2022 at each sampling location are likely attributable to a combination of human activity and natural variation. Blooms of diatoms and filamentous algae within each drainage are dependent on climatic conditions, flow regime, turbidity, and nutrient availability.

5.4 Volumetric Substrate and Suspended Sediment

Volumetric substrate data was collected using a McNeil sampler at three sites on the Colorado River, and at one site each on the Fraser River and Ranch Creek. Calculated values for the D_{50} and D_{84} were similar among all sites in the CEA. The D_{50} and D_{84} values at each site were generally lower than the corresponding values calculated from the pebble counts at each site. This is unsurprising and attributable to differences in sampling equipment and the areas targeted for data collection (i.e., spawning beds) between the two methods. The McNeil sample data show that the substrate composition in trout spawning habitat is comparable among the sampled sites.

An excess of fine sediment can be detrimental to trout reproduction. Incubating eggs and alevins must obtain oxygen and dispose of metabolic wastes while they inhabit the gravel, which requires that subsurface and surface water flow freely through the redd (Kondolf et al. 2008). Higher permeability of redds generally results in an increase in juvenile trout survival. Volumetric substrate sampling indicated that substrate sizes in spawning beds in the CEA are near the lower end of the range for spawning trout, slightly lower than the Brown Trout average. Fine substrate at sites CR-14.9 and FR-5.5 may inhibit trout emergence, as some of the cumulative percentages of fine sediment were slightly higher than the average values observed by Kondolf (2008).

Average concentrations of suspended sediment on the Colorado River increased between 2020 and 2021, but responses were variable between 2021 and 2022. Concentrations increased sharply between 2021 and 2022 at Site CR-22.9 but decreased at sites CR-14.9 and CR-9.1. Lower suspended sediment values at sites CR-14.9 and CR-9.1 could have been due to higher flows throughout 2022 compared to 2021 – these higher flows could have flushed some of the larger fractions of suspended sediment through the system. Locally high values at Site CR-22.9 were likely due to fine sediment inputs from Drowsy Water Creek. Turbidity was high throughout the CEA during the 2022 sampling effort, but the suspended sediment that contributes to turbidity is often “wash load”, or extremely small particles that are carried high in the water column. Wash load particles are small enough that wash load depends on supply, but not on a system’s transport capacity (Knighton 1998).

Suspended sediment concentrations also increased greatly at Site FR-5.5 between 2021 and 2022. This tends to support the hypothesis that fine sediment was transported down the Fraser River from Site FR-20 during higher flows in 2022. On the other hand, the suspended sediment values at Site RC-1.1 were surprisingly low. Low water velocities in the beaver ponds may have caused suspended sediment to fall out of the water column instead of being transported into downstream reaches.

6. Conclusion

The sediment and algae conditions in the CEA in the Colorado and Fraser River drainages are typical of managed systems, and a combination of natural and anthropogenic features influence stream sediment dynamics. The 2022 annual daily flows observed in Grand County, CO were higher than long-term medians at each gage location (Appendix B). On a local scale, ditches/dams and beaver ponds trap gravels, and unpaved roads, unregulated tributaries, and erodible hillslopes provide sources of sand and gravel. Although the proportion of sand and silt at all but two sites (CR-28.7 and RC-1.1) was low enough to meet CDPHE criteria for the protection of aquatic life, and the proportion of gravel increased modestly at several sampling sites, gravel was still limited throughout the CEA. Embeddedness was over 37 percent at every site on all five streams sampled, and the sediment was compacted at most of the sampling locations in the Colorado River, the Fraser River, and their tributaries. Aquatic life response to embeddedness is species-specific. While a limited number of studies suggest that embeddedness reduces diversity of aquatic life and/or fish body condition when values exceed 25 to 35% (Boillet et al. 2005, Hamid and Rawi 2011, McGinley et al. 2013), defining embeddedness goals for each site in the CEA would be difficult. The amount of fine sediment at a given site is a complex result of tributary inputs, transport from upstream areas, and inputs/storage on floodplains (Wohl et al. 2015).

Changes in substrate composition from 2020 through 2022 were largely consistent throughout the CEA. There was an overall increase in substrate less than 64 mm among almost all sites, and the proportion of fine sediments increased at many sites. The increase in gravel and fine substrate among most sites in the CEA was likely due to sediment deposition during abatement of spring runoff, sediment escapement from formerly impounded areas (e.g., beaver dams, reservoirs), sediment transport and deposition resulting from monsoonal rains, and snowmelt and precipitation over burned areas on the Colorado River.

Riffles with a lower RSI value (i.e., those with a lower proportion of fine material) provide more interstitial spaces, or small spaces between clean substrate particles. These interstitial spaces provide high-quality habitat for macroinvertebrates, some species of juvenile fishes, and benthic, or bottom-dwelling, fishes. Despite spring runoff being higher than the long-term median in 2022, many of the RSI values in the Colorado River were still indicative of working or managed rivers. However, RSI values in the Fraser River were more typical of reference streams. Thus, macroinvertebrate and fish habitat quality may currently be limited in portions of the Colorado River due to extensive sediment input in the wake of the East Troublesome Fire.

Didymo was present and extensive at Site CR-28.7 and Site STC-0, but generally absent or in low densities at the remaining sites in the CEA in 2022. Green filamentous algae was ubiquitous in the CEA, but algal coverage was variable, and nuisance blooms were generally absent. The sediment and algae conditions in the CEA have some implications for aquatic habitat quality, as discussed briefly below.

The substrate sizes present in the volumetric substrate samples are favorable for trout spawning and for certain benthic macroinvertebrate groups. This implies that trout can spawn successfully at the selected sampling sites. However, gravel is limited at some of the sampling sites, and substrate is compacted at many sites in the CEA. Limited substrate of appropriate size and compaction of that substrate (i.e., so trout have difficulty moving it) both inhibit spawning success. High RSI values in riffles in 2022 also indicate that sediment from fire-affected areas is limiting habitat quality for macroinvertebrates and for multiple species and life stages of fish in the Colorado River.

The availability of clean substrate and interstitial spaces is limited at many sites within the CEA due to high embeddedness by fine sediment. A low proportion of gravels and embeddedness of cobbles limit habitat for macroinvertebrates and small fishes (Waters 1995). A limited number of studies indicate that the effects of Didymo and green algae on macroinvertebrate communities are variable (Patrick 1983; Dodds and Gudder 1992; Ellsworth 2000; Spaulding and Elwell 2007; Tonkin et al. 2014), but reduction of sensitive taxa like mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) have been documented in some studies (Kilroy et al. 2009). Historic spring runoff flows in the CEA were greater in magnitude and duration than current spring runoff flows, multiple instream structures disrupt sediment transport, and natural processes and human land use have altered the nutrient dynamics of the Colorado and Fraser rivers. Unsurprisingly, aquatic habitat conditions in the CEA have characteristics that are typical of working rivers. However, it appears that some of the restoration projects in the basin may have facilitated some gravel transport in the Colorado River (downstream from the Williams Fork River and in the IVLK area) and in the Fraser River (downstream of Fraser Flats). Therefore, it is also possible that restoration efforts such as the Windy Gap Connectivity project will result in increased sediment continuity and the associated benefits to aquatic habitat. Finally, even though the effects of the East Troublesome Fire will be seen in the Colorado River for many years to come, the Colorado River may eventually benefit from the introduction of new gravel to the system.

7. References

American Society for Testing and Materials (ASTM). 2019. Standard Test Methods for Determining Sediment Concentration in Water Samples. D3977-97. Originally approved in 1997 and reapproved in 2019.

Boillet, V., A. Bardonnet, M. Jarry, J. C. Vignes, and P. Gaudin. 2005. Does embeddedness affect growth performance in juvenile salmonids? An experimental study in brown trout, Salmo trutta L. Ecology of Freshwater Fish 14(3):289-295.

Colorado Department of Public Health and Environment (CDPHE). 2014. Guidance for implementation of Colorado's narrative sediment standard. Regulation #31, Section 31.11(1)(a)(i).

Colorado Department of Public Health and Environment (CDPHE). No year. Standard operating procedures for the collection of streams periphyton samples. CDPHE Water Quality Control Division, Watershed Section. 10 pp.

Dodds, W.K. and D.A. Gudder. 1992. Review: The Ecology of *Cladophora*. Journal of Phycology 28: 415-427. Accessed at: https://www.k-state.edu/doddslab/journalarts/dodds%20and%20gudder%20j%20phycol%201992.pdf

Ellsworth, S.D. 2000. Influence of substrate size, *Cladophora*, and caddisfly pupal cases on colonization of macroinvertebrates in Sagehen Creek, California. *Western North American Naturalist* 60: 311-319.

GEI 2021. Sediment and Algae Assessment in the Colorado River and Fraser River Basins, 2020. Prepared for Grand County Learning by Doing, LLC.

GEI 2022. Sediment and Algae Assessment in the Colorado River and Fraser River Basins, 2021. Prepared for Grand County Learning by Doing, LLC.

Hamid, S. A. and C. S. Rawi. 2011. Influence of substrate embeddedness and canopy cover on the distribution of Ephemeroptera, Plecoptera and Trichoptera (EPT) in tropical rivers. Aquatic Insects 33(4):281-292.

Kappesser, G. B. 2002. A riffle stability index to evaluate sediment loading to streams. *Journal of the American Water Resources Association* 38(4):1069-1081.

Kondolf, G. M., J. Williams, T. Horner, D. Milan. 2008. Assessing Physical Quality of Spawning Habitat. *American Fisheries Society Symposium* 65:000-000.

Kondolf G. M., and M. Wolman. 1993. The Sizes of Salmonid Gravels. *Water Resources Research*. 29(7):2275-2285.

Kirkwood, A. E., T. Shea, L. J. Jackson, and E. McCauley. 2007. *Didymosphenia geminata* in two Alberta headwater rivers: an emerging invasive species that challenges conventional views on algal bloom development. *Canadian Journal of Fisheries and Aquatic Sciences* 64:1703-1709.

Kilroy, C., S. T. Larned, and B. J. F. Biggs. 2009. The non-indigenous diatom *Didymosphenia geminata* alters benthic communities in New Zealand rivers. *Freshwater Biology* 54:1990-2002.

Knighton, D. 1998. Fluvial Forms and Processes: a new perspective. Arnold Publishing, London, UK.

Macdonald, D. D. and L. E. McDonald. 1987. The influence of surface coal mining on potential salmonid spawning habitat in the Fording River, British Columbia. Water Pollution Research Journal of Canada 22(4):584-595.

McGinley, E. J., R. L. Raesly, and W. L. Seddon. 2013. The effects of embeddedness on the seasonal feeding of Mottled Sculpin. American Midland Naturalist 170:213-228.

McNeil, W. J. 1964. A Method of Measuring Mortality of Pink Salmon Eggs and Larvae. *U.S. Fish and Wildlife Service Fish Bulletin* 63:575-588.

Miller, M. P., D. M. McKnight, J. D. Cullis, A. Greene, K. Vietti, and D. Liptzin. 2009. Factors controlling streambed coverage of *Didymosphenia geminata* in two regulated streams in the Colorado Front Range. *Hydrobiologia* 630:207-218.

Olson-Rutz, K. M. and C. B. Marlow. 1992. Analysis and Interpretation of Stream Channel Cross-Sectional Data. *North American Journal of Fisheries Management* 12:55-61.

Patrick, R., C.F. Rhynme, R. W. Richardson, R. A. Larson, T. L. Bott, and K. Rogenmuser. 1983. *The Potential for Biological Controls of Cladophora glomerata.* United States Environmental Protection Agency. EPA-600/53-83-066. Duluth, MN.

Ryan, S.E., K.A. Dwire, and M. K. Dixon. 2011. Impacts of wildlife on runoff and sediment loads at Little Granite Creek, western Wyoming. *Geomorphology* 129: 113-130.

Spaulding, S. and L. Elwell. 2007. Increase in nuisance blooms and geographic expansion of the freshwater diatom Didymosphenia geminata: Recommendations for response. U.S. Environmental Protection Agency White Paper, 33 p.

Stevenson and Bahls 1999. Chapter 6. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Tonkin, J.D., R.G. Death, and J. Barquin. 2014. Periphyton control on stream invertebrate diversity: is periphyton architecture more important than biomass? *Marine and Freshwater Research* 65: 818-829.

Waters, T. F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society, Monograph 7, Bethesda, Maryland.

Wiele, S. M., J. B. Graf, and J. D. Smith. 1996. Sand deposition in the Colorado River in the Grand Canyon from flooding of the Little Colorado River. *Water Resources Research* 32 (12): 3570-359.

Wohl, E. E., B. P. Bledsoe, R. B. Jacobson, N. L. Poff, S. L. Rathburn, D. M. Walters, and A. C. Wilcox. The natural sediment regime in rivers: broadening the foundation for ecosystem management. Bioscience 65(4):358-371.

Appendix A 2022 Sediment and Algae Data

Site: CR-31
Date: 9/22/2022
Notes: Lots of loose uncompacted substrate. Landowner said river has been cloudy all summer. Very little didymo.

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	9	3	5	10	9	4		
2	7	1	12	11	7	2		
3		1	13	12	12	2		
4	4	3	8	7	15	3		
5	2	3	11	9	13	2		
6	3	1	4	9	22	1		
7	2	2	6	13	14	3		
8	3	2	6	10	17	2		
9	11	3	5	8	13			
10	5		6	8	20	1		
Total	46	19	76	97	142	20	0	0
% of Total	**11.5**	**4.8**	**19**	**24.3**	**35.5**	**5**	**0**	**0**

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	55	30	30	30	60
2	65	30	50	50	70
3	60	30	30	40	25
4	30	35	35	30	35
5	30	30	30	30	50
6	50	30	50	50	50
7	20	20	30	60	50
8	60	30	40	40	60
9	40	30	30	50	20
10	30	40	50	50	50

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	40	0.5	3	40	0.5	3	40	0.5	3
2	0	3	0	0	3	0	0	2	0
3	0	4	0	0	3	0	10	3	0.5
4	0	1	0	0	3	0	0	3	0
5	0	3	0	0	3	0	0	2	0
6	0	3	0	0	2	0	0	0.5	0
7	0	0.5	0	0	4	0	0	4	0
8	5	3	4	0	3	0	0	2	0
9	0	2	0	0	2	0	100	0	4
10	0	2	0	0	4	0	0	0.5	0
Average	4.5	2.2	0.7	4	2.8	0.3	15	1.8	0.8

Site: CR-28.7
Date: 9/21/2022
Notes: Lots of fines in interstitial spaces between larger particles in slower habitat.

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1			9	15	16			
2	9		5	12	12	2		
3	20		5	11	3	1		
4	10			13	14	3		
5	13		3	7	13	4		
6	8	1	8	13	9	5		
7	7	1	3	20	10	3	1	
8	13	1	13	10	3			
9	13		8	13	5	1		
10	11		7	15	7			
Total	104	3	61	129	92	19	1	0
% of Total	**25.4**	**0.7**	**14.9**	**31.5**	**22.5**	**4.6**	**0.2**	**0**

	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
200 Riffle Count	15	4	50	87	37	11	1	
% of Total	7.3	2	24.4	42.4	18	5.4	0.5	0
Cumulative %	7.3	9.3	33.7	76.1	94.1	99.5	100	100
	2	8	64	128	256	512	1024	

RSI	Geomean Particle Size*	Slope and Intercept for RSI	
34.551	34	b=	24.7
		m=	0.290

*no depositional feature present in 2022. 2021 depositional feature values used for particle size.

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	30	20	60	50	40
2	80	50	30	20	20
3	50	100	70	80	100
4	80	100	50	70	50
5	70	100	50	60	70
6	80	80	60	80	70
7	90	60	40	60	50
8	80	60	60	50	90
9	70	100	70	60	60
10	50	60	60	80	80

Site: CR-28.7
Date: 9/21/2022
Notes: Lots of fines in interstitial spaces between larger particles in slower habitat.

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	40	0	3	40	0	2	60	0	3
2	100	0	4	50	0	2	90	0	3
3	100	0	4	90	0	3	100	0	4
4		Too deep		80	0	3	60	0	3
5	100	0	2	60	0	3		Too deep/turbid	
6	100	0	3	90	0	3	90	0	3
7	50	0	2	50	0	3	50	0	3
8	80	0	3	90	0	3	100	1	3
9	100	0	4	100	0	4	90	0	3
10	70	0	3	90	0	3		Too deep/turbid	
Average	82.2	0	3.1	74	0	2.9	80	0.1	3.1

Site: CR-24.9
Date: 9/21/2022
Notes: River splits into two channels at transect 8, 5 throws were done on each side.

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	8		7	9	14	2		
2	8		7	6	16	3		
3	25		4	3	3	1		4
4	5		13	11	7	4		
5	34		4	1		1		
6	24		6	5	6			
7	18		8	7	6	1		
8	22	4	4	7	3			
9	25	3	4	3	4	1		
10	16		4	5	9	6		
Total	185	7	61	57	68	19	0	4
% of Total	**46.1**	**1.7**	**15.2**	**14.2**	**17**	**4.7**	**0**	**1**

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	10	10	5	10	10
2	35	10	10	10	10
3	15	45	50	40	60
4	20	60	50	50	15
5	90	100	90	100	100
6	100	90	80	95	100
7	90	80	90	75	60
8	60	60	30	100	*
9	60	50	40	50	50
10	100	30	30	*	*

*Not recorded

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	34	1	3	90	0	3	90	0	3
2	46	0	3	88	2	3	84	0	4
3	40	0	3		Too deep		16	0	3
4	36	0.5	4	42	0	3	34	0	3
5	0	0	0	0	0	0	40	0	3
6		Too deep		28	0	4	48	0	4
7	100	3	3	100	3	3	90	3	3
8	20	0	3	100	3	3	100	0	5
9	90	0	4	100	0	5	72	0	4
10	96	1	4		Too deep		96	1	4
Average	51.3	0.6	3	68.5	1	3	67	0.4	3.6

Site: CR-22.9
Date: 9/22/2022
Notes:

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	4		12	9	5	4	6	
2	1	1	12	14	4			8
3	2		21	14	1	2		
4	3	1	23	10	2	1		
5	8		11	12	7	2		
6	5		22	14	3			
7	5		12	20	2	1		
8	19		9	7	1	3		
9	13		14	11	1			
10	2		20	16	2			
Total	62	2	156	127	28	13	6	8
% of Total	**15.4**	**0.5**	**38.8**	**31.6**	**7**	**3.2**	**1.5**	**2**

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	45	50	50	50	20
2	60	50	60	50	0
3	40	50	20	30	70
4	60	50	50	45	30
5	40	30	30	60	70
6	50	60	60	60	60
7	50	50	30	50	40
8	40	50	70	70	100
9	100	60	50	50	60
10	50	60	60	*	*

*Not recorded

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	100	1	3	100	0	3		Too deep	
2	40	0	2		Too deep/turbid			Too fast	
3	40	0	3	100	0	3	100	0	3
4	50	0	3	50	1	2		Too deep/turbid	
5	100	0	4	50	0	2	100	0	3
6	50	0	2	50	0	2	70	0	4
7	70	0	3	50	0	3	80	1	3
8	100	0	3	70	0	3		Too deep/turbid	
9	100	0	4		Too deep/turbid		80	0	3
10	50	0	3	40	0	3	40	0	3
Average	70	0.1	3	63.8	0.1	2.6	78.3	0.2	3.2

Site: CR-16.7
Date: 9/21/2022
Notes: Water very turbid. Transect 3 just upstream of manmade rock structure. Recent fines deposition.

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	2	1	9	14	13	1	1	
2	2	10	5	10	11	1	1	
3	24	2	4	7	3			
4	14		1	6	10	1	8	
5	12	1	5	4	4	1	8	5
6	4	1	9	6	8	2	1	9
7	1	1	8	20	9	1		
8	14		12	5	5	1	3	
9	6	2	5	15	10	2		
10	13			9	11	1	6	
Total	92	18	58	96	84	11	28	14
% of Total	**22.9**	**4.5**	**14.5**	**23.9**	**20.9**	**2.7**	**7**	**3.5**

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	5	20	60	60	40
2	60	30	40	10	40
3	20	20	100	100	100
4	80	60	60	100	100
5	90	70	60	0	0
6	20	50	50	40	0
7	40	10	5	5	5
8	100	100	60	70	70
9	40	40	60	40	30
10	100	100	100	*	*

*Not recorded

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	100	0	5	84	3	3	76	0	3
2	48	0	3	40	0	3	74	0	3
3	16	0	3	0	0	0	0	0	0
4	100	0	5	90	0	3		Too deep	
5	100	0	4	0	0	0	0	0	0
6	90	0	3	50	0	3	80	0	3
7	88	0	5	33	1	3	80	0	3
8	24	0	3		Too deep		82	0	3
9	88	0	3	100	0	3	96	0	3
10	44	0	3	86	0	3	92	0	3
Average	69.8	0	3.7	53.7	0.4	2.3	64.4	0	2.3

Site: CR-9.1
Date: 9/21/2022
Notes: Center of transects 4 and 7 were too deep to wade.

Transect Substrate Count

Transect	**Fines <2mm**	**Sm. Gravel 2-8mm**	**Gravel 8-64mm**	**Sm. Cobble 64-128mm**	**Cobble 128-256mm**	**Sm. Boulder 256-512mm**	**Boulder >512mm**	**Bedrock Bedrock**
1	6	4	6	10	12	2		
2	12	2	5	4	12	5		
3	5	1	12	7	12	3		
4	1	9	8	7	7	3	1	
5	7	4	10	7	9	3		
6	16	4	11	4	4	1		
7			6	11	9	2		
8	10	2	13	9	6			
9		5	8	17	8	2		
10	5	5	10	12	5	3		
Total	62	36	89	88	84	24	1	0
% of Total	**16.1**	**9.4**	**23.2**	**22.9**	**21.9**	**6.3**	**0.3**	**0**

	Fines <2mm	**Sm. Gravel 2-8mm**	**Gravel 8-64mm**	**Sm. Cobble 64-128mm**	**Cobble 128-256mm**	**Sm. Boulder 256-512mm**	**Boulder >512mm**	**Bedrock Bedrock**
200 Riffle Count	5	22	36	101	34	3		
% of Total	2.5	10.9	17.9	50.2	16.9	1.5	0	0
Cumulative %	2.5	13.4	31.3	81.5	98.4	99.9	99.9	99.9
	2	8	64	128	256	512	1024	

RSI	**Geomean Particle Size**	**Slope and Intercept for RSI**	
86.381	134	b=	-18.9
		m=	0.784

Embeddedness

Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**
1	50	30	40	15	20
2	35	30	30	70	70
3	35	30	40	30	20
4	30	40	60	30	60
5	30	20	20	40	50
6	70	90	80	70	40
7	50	20	40	Too deep	60
8	20	100	80	25	60
9	30	40	20	40	50
10	40	20	40	50	60

Site: CR-9.1
Date: 9/21/2022
Notes: Center of transects 4 and 7 were too deep to wade.

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	0	0	0	80	0	4	100	0	5
2	0	0	0	40	0	4	0	0	0
3	100	0	5	70	0	4	90	0	3
4	100	0	5	0	0.5	0	0	0.5	4
5	100	0	5	0	0.5	0	70	0.5	4
6	0	0	0	100	0	5	100	0.5	3
7	10	4	3	75	0	3	40	1	3
8	0	3	0	0	0	0	0	0.5	0
9	30	0	3	30	0	3	20	0	3
10	30	0.5	3	40	0	3	70	0	3
Average	37	0.8	2.4	43.5	0.1	2.6	49	0.3	2.8

Site: CR-7.4
Date: 9/21/2022
Notes: Redd on transect 4 near right bank, part of transect 9 too deep to wade

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	8	2	20	6	4			
2	3	6	21	9	1			
3	10	3	23	4				
4	5	2	22	6	4	1		
5	4	3	26	6	1			
6	4	1	32	3				
7	5	2	28	5				
8	19		16	5				
9	17		6					
10	4	4	27	5				
Total	79	23	221	49	10	1	0	0
% of Total	**20.6**	**6**	**57.7**	**12.8**	**2.6**	**0.3**	**0**	**0**

	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
200 Riffle Count	12	5	161	18	4			
% of Total	6	2.5	80.5	9	2	0	0	0
Cumulative %	6	8.5	89	98	100	100	100	100
	2	8	64	128	256	512	1024	

RSI	Geomean Particle Size	Slope and Intercept for RSI		
88.057	57	b=	80	y=mx+b, (y=RSI)
		m=	0.141	

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	40	50	40	30	30
2	20	10	40	40	20
3	100	60	50	70	60
4	40	40	40	30	100
5	100	60	30	40	40
6	50	50	30	50	50
7	50	50	40	40	50
8	50	50	40	30	60
9	100	60	60	Too deep	Too deep
10	50	50	60	50	50

Site: CR-7.4
Date: 9/21/2022
Notes: Redd on transect 4 near right bank, part of transect 9 too deep to wade

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	76	3	3	60	0	3		Too deep	
2	98	0	3	70	0	3	100	0	3
3	100	0	3	60	0	3	100	0	3
4	90	0	3		Too deep		80	0	3
5	100	0	3	60	0	3		Too deep	
6	50	0	3	50	0	3	30	0	3
7	90	3	3	74	0	3	100	0	2
8	50	0	3	70	0	4		Too deep	
9	100	0	3	100	0	5	80	2	3
10	80	0	3	60	--	--	40	0	3
Average	83.4	0.6	3	67.1	0	3.4	75.7	0.3	2.9

Site: CR-TBD

Date: 9/21/2022

Notes: Large portions of site were too deep to wade. Each transect started on right bank looking US except transect 5, which started on left bank, and extended into river until no longer wadeable.

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1			5	4	3			
2	4	1		4	3			
3	9		1	2				
4	4	3	4		4	1		
5		3	21	4				
6								
7								
8				Remainder of site too deep to wade				
9								
10								
Total	17	7	31	14	10	1	0	0
% of Total	**21.3**	**8.8**	**38.8**	**17.5**	**12.5**	**1.3**	**0**	**0**

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	10	--	--	--	--
2	30	30	--	--	--
3	100	30	--	--	--
4	60	60	--	--	--
5	--	--	20	20	40
6					
7					
8			Remainder of site too deep to wade		
9					
10					

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	97	0.5	4	--	--	--	--	--	--
2	0	0	0	--	--	--	--	--	--
3	0	0	0	--	--	--	--	--	--
4	100	0	4	--	--	--	--	--	--
5	--	--	--	100	0	4	0	0	0
6									
7									
8		Remainder of site too deep to wade			Remainder of site too deep to wade			Remainder of site too deep to wade	
9									
10									
Average	49.3	0.1	2	100	0	4	0	0	0

Site: FR-27.2
Date: 9/23/2022
Notes:

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	5	2	13	16	4			
2	2	3	17	13	5			
3	4	3	16	11	6			
4	6	4	15	9	6			
5	11	2	12	10	4	1		
6	12	6	12	8	2			
7	7	9	14	8	2			
8	2	7	20	8	3			
9	27	5	8	1				
10	16	6	9	4	1	2	2	
Total	92	47	136	88	33	3	2	0
% of Total	**22.9**	**11.7**	**33.9**	**21.9**	**8.2**	**0.7**	**0.5**	**0**

	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
200 Riffle Count	13	20	75	71	22			
% of Total	6.5	10	37.3	35.3	10.9	0	0	0
Cumulative %	6.5	16.5	53.8	89.1	100	100	100	100
	2	8	64	128	256	512	1024	

RSI	Geomean Particle Size	Slope and Intercept for RSI	
89.992	130	b=	18.5
		m=	0.552

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	50	60	30	40	30
2	30	20	30	50	70
3	80	70	35	50	40
4	60	20	50	35	50
5	100	70	50	50	20
6	40	60	50	70	100
7	70	50	60	70	50
8	60	70	30	25	50
9	100	70	70	100	100
10	50	70	80	50	100

Site: FR-27.2
Date: 9/23/2022
Notes:

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	0	0.5	0	0	0.5	0	0	0.5	0
2	0	0.5	0	0	0.5	0	8	0.5	2
3	0	0.5	0	0	0.5	0	0	0.5	0
4	0	0.5	0	0	0.5	0	0	0.5	0
5	0	0	0	0	0.5	0	0	0.5	0
6	2	0.5	3	0	0.5	0	2	0.5	3
7	40	1	3	0	0.5	0	2	0.5	3
8	0	0.5	0	0	0.5	0	2	0.5	3
9	0	0	0	0	2	0	0	0	0
10	5	3	2	0	2	0	0	1	0
Average	4.7	0.7	0.8	0	0.8	0	1.4	0.5	1.1

Site: FR-23.2
Date: 9/22/2022
Notes:

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	5	5	16	7	5	2		
2	3		12	8	8	5	4	
3	1	2	9	9	10	3	6	
4	1		19	7	7	4	2	
5	5	4	17	10	4			
6	1	5	11	10	6	4	3	
7	2	8	5	14	5	1	5	
8	7	1	10	10	7	1	4	
9	4	2	8	15	8	2	1	
10	3	3	10	11	9	3	1	
Total	32	30	117	101	69	25	26	0
% of Total	**8**	**7.5**	**29.3**	**25.3**	**17.3**	**6.3**	**6.5**	**0**

	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
200 Riffle Count	1	8	92	50	36	6	7	
% of Total	0.5	4	46	25	18	3	3.5	0
Cumulative %	0.5	4.5	50.5	75.5	93.5	96.5	100	100
	2	8	64	128	256	512	1024	

RSI	Geomean Particle Size	Slope and Intercept for RSI	
40.391	38	b=	25.5
		m=	0.391

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	50	15	50	50	50
2	40	40	15	50	20
3	30	30	20	50	30
4	30	25	40	60	30
5	40	50	40	30	30
6	70	40	30	25	15
7	30	30	40	40	30
8	20	60	40	40	80
9	40	50	30	20	30
10	30	40	40	50	50

Site: FR-23.2
Date: 9/22/2022
Notes:

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	0	1	0	0	1	0	0	0.5	0
2	0	0.5	0	0	1	0	0	2	0
3	0	0	0	0	2	0	0	0.5	0
4	0	2	0	0	2	0	0	1	0
5	0	0.5	0	0	1	0	0	2	0
6	0	0.5	0	0	2	0	0	2	0
7	0	0	0	0	1	0	40	1	3
8	0	1	0	0	2	0	80	0	4
9	0	0.5	0	15	0.5	4	40	0	4
10	0	0	0	60	0.5	5	50	1	4
Average	0	0.6	0	7.5	1.3	0.9	21	1	1.5

Site: FR-20
Date: 9/22/2022
Notes: Approximately six redds in reach.

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	5	1	12	9	12		1	
2	3	5	14	6	8	4		
3	2	4	15	6	9	4		
4		4	15	13	4	5		
5		4	12	11	8	3	3	
6		2	15	14	9			
7	26		3	3	5	3		
8	12	4	10	4	9	1	2	
9	1	5	15	4	10	5		
10	1	3	11	7	14	4		
Total	50	32	122	77	88	29	6	0
% of Total	**12.4**	**7.9**	**30.2**	**19.1**	**21.8**	**7.2**	**1.5**	**0**

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	20	40	20	40	60
2	20	20	40	40	10
3	60	40	40	20	20
4	20	20	40	10	10
5	40	10	40	40	60
6	20	30	20	40	40
7	100	60	80	80	80
8	70	80	60	50	70
9	20	40	20	30	40
10	60	40	20	20	60

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	0	1	0	0	1	0	0	1	0
2	26	1	3	16	1	3	12	1	2
3	0	1	0	16	1	3	0	1	0
4	0	2	0	0	2	0	0	1	0
5	6	1	3	0	1	0	6	1	3
6	32	1	2	60	1	0	32	1	2
7	0	0	0	0	0	0	50	1	0
8	100	0	3	38	0	3	70	1	3
9	30	0.5	3	80	0.5	3	66	0.5	3
10	32	0.5	1	60	0.5	1	90	0.5	1
Average	22.6	0.8	1.5	27	0.8	1.3	32.6	0.9	1.4

Site: FR-14
Date: 9/22/2022
Notes: First two transects too deep to wade, visually estimated. Threw out data from first two transects to maintain consistency with stretch previously evaluated.

Transect Substrate Count

Transect	**Fines <2mm**	**Sm. Gravel 2-8mm**	**Gravel 8-64mm**	**Sm. Cobble 64-128mm**	**Cobble 128-256mm**	**Sm. Boulder 256-512mm**	**Boulder >512mm**	**Bedrock Bedrock**
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	19		16	5				
4			16	12	12	4		
5	16	5	12	2	2	3		
6	4	17	4	8	9	2		
7		3	11	11	15	1		
8	2		16	7	14	1		
9		1	13	10	17			
10		3	13	10	7	4	3	
Total	41	29	101	65	76	15	3	0
% of Total	**12.4**	**8.8**	**30.6**	**19.7**	**23**	**4.5**	**0.9**	**0**

	Fines <2mm	**Sm. Gravel 2-8mm**	**Gravel 8-64mm**	**Sm. Cobble 64-128mm**	**Cobble 128-256mm**	**Sm. Boulder 256-512mm**	**Boulder >512mm**	**Bedrock Bedrock**
200 Riffle Count		9	80	36	67	14	1	
% of Total	0	4.3	38.6	17.4	32.4	6.8	0.5	0
Cumulative %	0	4.3	42.9	60.3	92.7	99.5	100	100
	2	8	64	128	256	512	1024	

RSI	**Geomean Particle Size**	**Slope and Intercept for RSI**	
43.203	64	b=	26.7
		m=	0.258

Embeddedness

Transect	**Emb. 1**	**Emb. 2**	**Emb. 3**	**Emb. 4**	**Emb. 5**	Avg.	
1	--	--	--	--	--	--	
2	--	--	--	--	--	--	
3	50	40	70	90	90	68.0	
4	40	50	50	50	100	58.0	
5	60	50	50	80	75	63.0	
6	90	90	80	80	90	86.0	
7	60	40	40	20	20	36.0	
8	50	50	60	60	40	52.0	
9	50	50	40	30	30	40.0	
10	40	50	50	50	50	48.0	
						56.4	**Total Avg.**

Site: FR-14

Date: 9/22/2022

Notes: First two transects too deep to wade, visually estimated. Threw out data from first two transects to maintain consistency with stretch previously evaluated.

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1		--			--			--	
2		--			--			--	
3	80	1	5		Too deep		100	0	5
4	100	0	3	60	0	3	100	0	3
5	95	1	2	80	0	3	70	0	3
6	20	2	2	10	1	1		Too deep	
7	40	0	2	40	0	2	20	0	5
8	100	0	5	100	0	5	100	0	5
9	90	1	4	60	0	3	100	0	5
10	50	0	3	80	0	4	90	0	3
Average	71.9	0.6	3.3	61.4	0.1	3	82.9	0	4.1

Site: FR-5.5
Date: 9/22/2022
Notes:

	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
	<2mm	**2-8mm**	**8-64mm**	**64-128mm**	**128-256mm**	**256-512mm**	**>512mm**	**Bedrock**
200 Riffle Count	12	32	72	54	26	3		
% of Total	6	16.1	36.2	27.1	13.1	1.5	0	0
Cumulative %	6	22.1	58.3	85.4	98.5	100	100	100
	2	8	64	128	256	512	1024	

RSI	Geomean Particle Size	Slope and Intercept for RSI	
54.011	54	b=	31.2
		m=	0.423

Site: FR-1.9
Date: 11/2/2022
Notes:

	Fines	Sm. Gravel	Gravel	Sm. Cobble	Cobble	Sm. Boulder	Boulder	Bedrock
	<2mm	2-8mm	8-64mm	64-128mm	128-256mm	256-512mm	>512mm	Bedrock
200 Riffle Count	6	15	64	77	56	1		
% of Total	2.7	6.8	29.2	35.2	25.6	0.5	0	0
Cumulative %	2.7	9.5	38.7	73.9	99.5	100	100	100
	2	8	64	128	256	512	1024	

RSI	Geomean Particle Size	Slope and Intercept for RSI	
53.493	91	b=	3.5
		m=	0.550

Site: RC-1.1
Date: 9/22/2022
Notes: Beaver dam complex after first three transects, majority fines, landowner removed one beaver dam in spring, many fines in interstitial spaces

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	10		18	7	1	1	3	
2	1	5	12	12	7	3		
3		3	22	4	9		2	
4	40							
5	40							
6	40							
7	40			Too deep, visually estimated				
8	40							
9	40							
10	40							
Total	291	8	52	23	17	4	5	0
% of Total	**72.8**	**2**	**13**	**5.8**	**4.3**	**1**	**1.3**	**0**

	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
200 Riffle Count	10	28	106	54	5	2	1	
% of Total	4.9	13.6	51.5	26.2	2.4	1	0.5	0
Cumulative %	4.9	18.5	70	96.2	98.6	99.6	100.1	100.1
	2	8	64	128	256	512	1024	

RSI	Geomean Particle Size	Slope and Intercept for RSI	
56.387	31	b=	43.8
		m=	0.409

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	70	80	40	60	60
2	50	60	40	50	40
3	30	60	70	20	10
4*	100	100	100	100	100
5*	100	100	100	100	100
6*	100	100	100	100	100
7*	100	100	100	100	100
8*	100	100	100	100	100
9*	100	100	100	100	100
10*	100	100	100	100	100

*Too deep to wade, beaver dams, visually estimated

Site: RC-1.1
Date: 9/22/2022
Notes: Beaver dam complex after first three transects, majority fines, landowner removed one beaver dam in spring, many fines in interstitial spaces

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	100	0	3	100	0	5	100	0	5
2	32	1	5	52	1	5	48	0	3
3	82	1	3	100	0	5	36	1	3
4									
5									
6									
7		Too deep to wade			Too deep to wade			Too deep to wade	
8									
9									
10									
Average	71.3	0.7	3.7	84	0.3	5	61.3	0.3	3.7

Site: STC-0
Date: 9/22/2022
Notes: Site moved due to construction

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	5	1	3	5	18	8		
2	2	3	7	2	17	4	5	
3	6		8	6	13	7		
4	4	4	17	9	5	1		
5	5	1	9	13	9	3		
6	4	9	14	6	7			
7	3		8	13	13	3		
8	3	5	5	14	9	4		
9	3	4	10	9	12	2		
10	2	5	6	9	13	5		
Total	37	32	87	86	116	37	5	0
% of Total	**9.3**	**8**	**21.8**	**21.5**	**29**	**9.3**	**1.3**	**0**

	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
200 Riffle Count	6	19	70	55	44	6		
% of Total	3	9.5	35	27.5	22	3	0	0
Cumulative %	3	12.5	47.5	75	97	100	100	100
	2	8	64	128	256	512	1024	

RSI	Geomean Particle Size	Slope and Intercept for RSI	
62.634	106	b=	36.5
		m=	0.246

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	20	30	40	35	20
2	50	40	30	40	20
3	50	50	30	30	30
4	50	50	30	50	50
5	30	50	40	40	40
6	40	40	30	30	50
7	50	45	40	30	40
8	60	40	30	30	70
9	50	30	20	30	50
10	40	50	40	40	30

Algae Data

Site: STC-0
Date: 9/22/2022
Notes: Site moved due to construction

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	0	0.5	0	5	0.5	2	0	2	0
2	0	0.5	0	0	1	0	0	0.5	0
3	0	0.5	0	0	0.5	0	0	1	0
4	0	0.5	0	0	1	0	0	0.5	0
5	0	0.5	0	0	2	0	0	2	0
6	0	3	0	0	2	0	0	1	0
7	0	0.5	0	0	3	0	5	3	3
8	20	3	3	5	3	2	10	2	3
9	15	1	2	10	0.5	3	0	3	0
10	0	3	0	2	3	2	5	3	3
Average	3.5	1.3	0.5	2.2	1.7	0.9	2	1.8	0.9

Site: WC-TBD
Date: 9/22/2022
Notes: many bugs and macrophytes; compacted; signs of recent high flow/flood event; riffle, "long run" morphology

Transect Substrate Count

Transect	Fines <2mm	Sm. Gravel 2-8mm	Gravel 8-64mm	Sm. Cobble 64-128mm	Cobble 128-256mm	Sm. Boulder 256-512mm	Boulder >512mm	Bedrock Bedrock
1	6		16	13	5			
2	18	2	3	13	4			
3	1	1	14	15	9			
4	5	3	13	13	5	1		
5	15		6	14	5			
6	5	3	12	12	8			
7	18	2	2	9	7	2		
8	7	5	5	13	6		4	
9	19	2	3	9	7			
10	13	4	7	10	6			
Total	107	22	81	121	62	3	4	0
% of Total	**26.8**	**5.5**	**20.3**	**30.3**	**15.5**	**0.8**	**1**	**0**

Embeddedness

Transect	Emb. 1	Emb. 2	Emb. 3	Emb. 4	Emb. 5
1	30	60	65	60	50
2	100	90	65	40	30
3	30	30	20	30	40
4	50	70	70	50	50
5	95	80	70	40	50
6	20	50	30	40	30
7	100	90	90	80	90
8	80	80	90	80	80
9	100	90	90	90	70
10	80	70	90	80	100

Algae Data

Transect	25% Fil. Cover	25% Diatom Thickness	25% Fil. Thickness	50% Fil. Cover	50% Diatom Thickness	50% Fil. Thickness	75% Fil. Cover	75% Diatom Thickness	75% Fil. Thickness
1	5	0.5	3	0	1	0	40	0.5	4
2	0	0	0	0	0	0	0	2	0
3	0	0.5	0	0	0.5	0	0	1	0
4	0	0	0	0	0.5	0	0	2	0
5	0	0.5	0	10	0.5	3	0	2	0
6	20	0.5	3	0	0.5	0	60	0.5	4
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	10	0	2	0	0	0
Average	2.5	0.2	0.6	2	0.3	0.5	10	0.8	0.8

Appendix B Long-term Flow Data

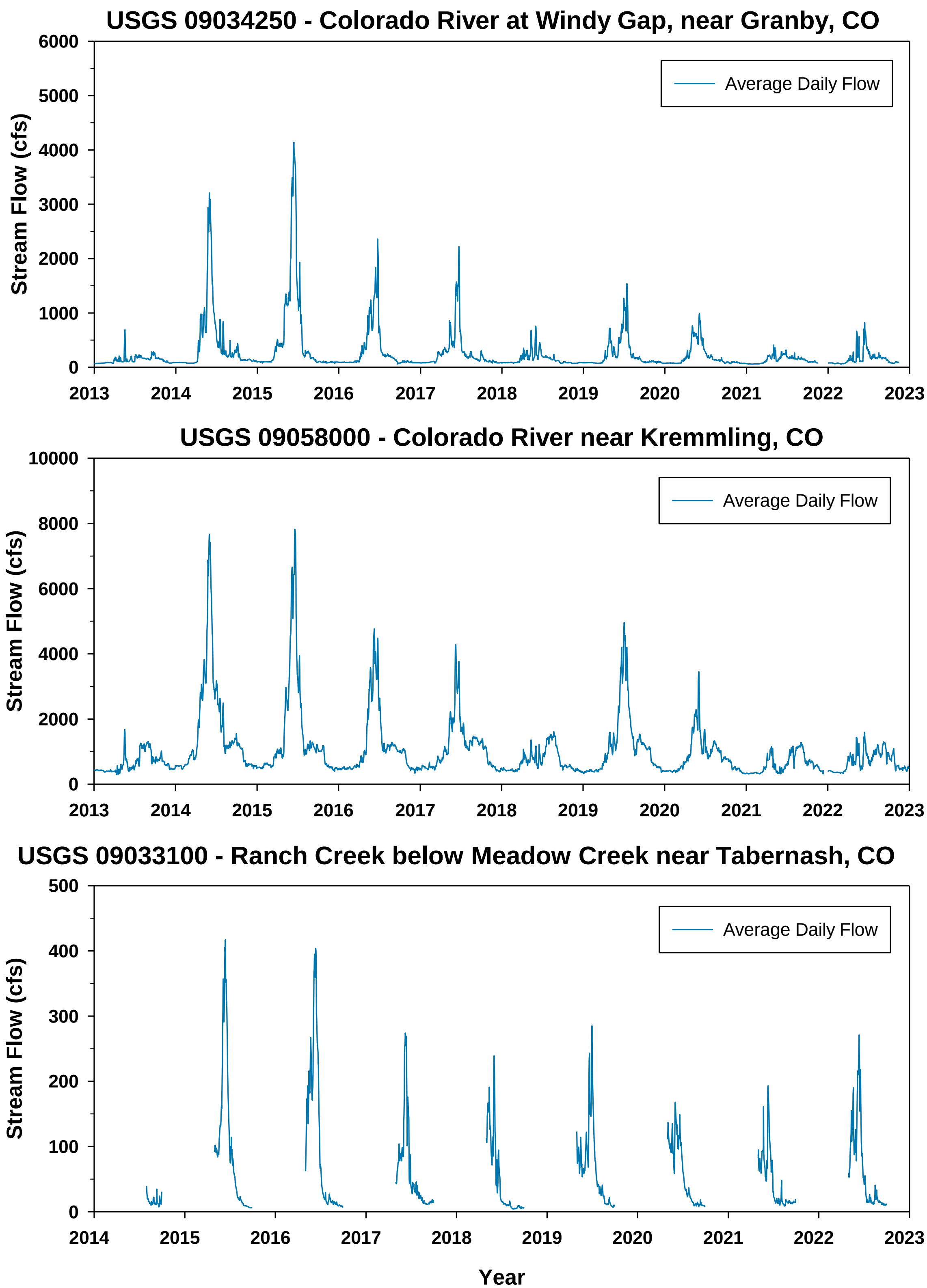


Figure B-1: Average daily flow data for USGS stream gages on the Colorado River and Ranch Creek in Grand County, CO.

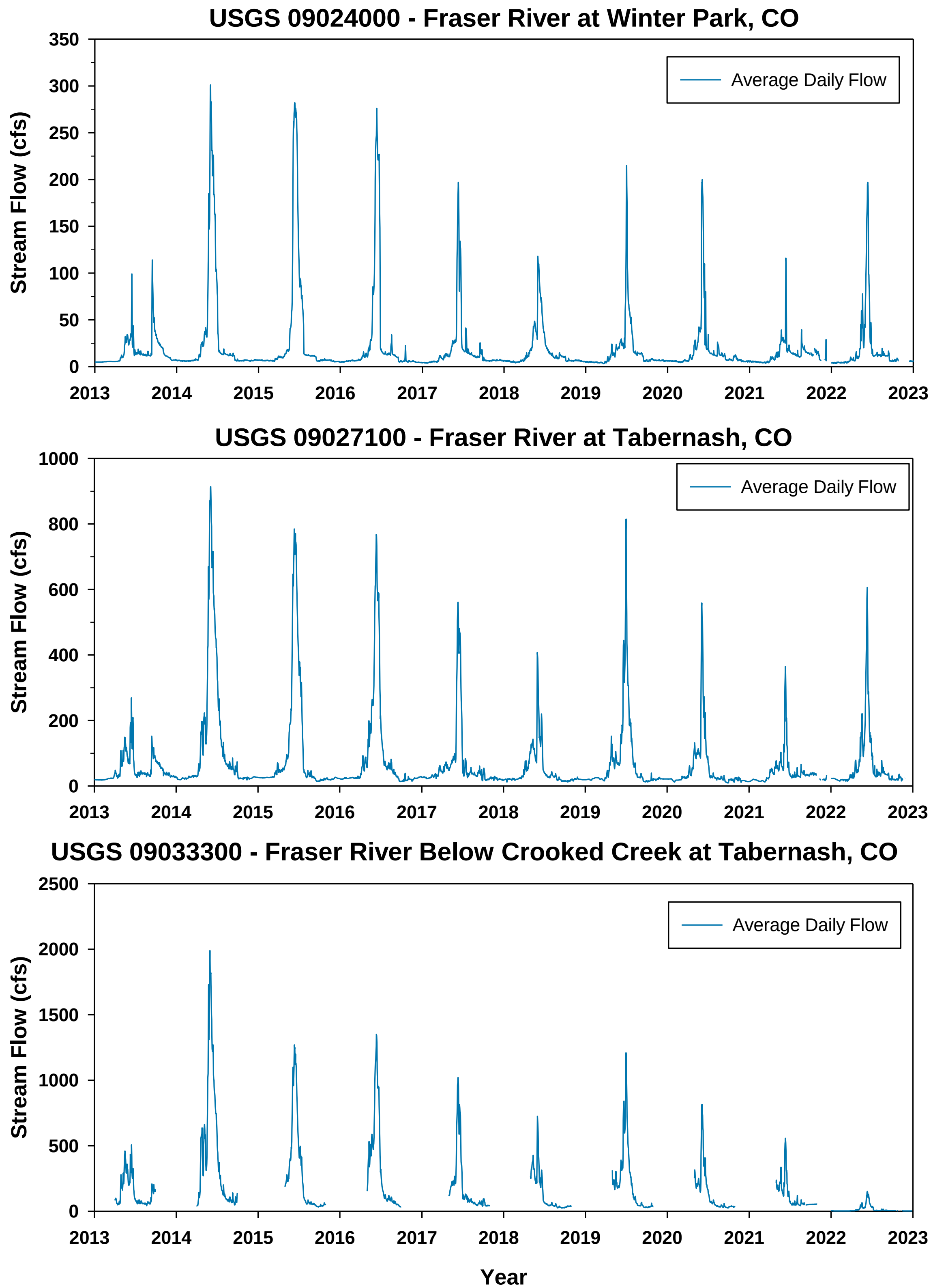


Figure B-2: Average daily flow data for USGS stream gages on the Fraser River in Grand County, CO.

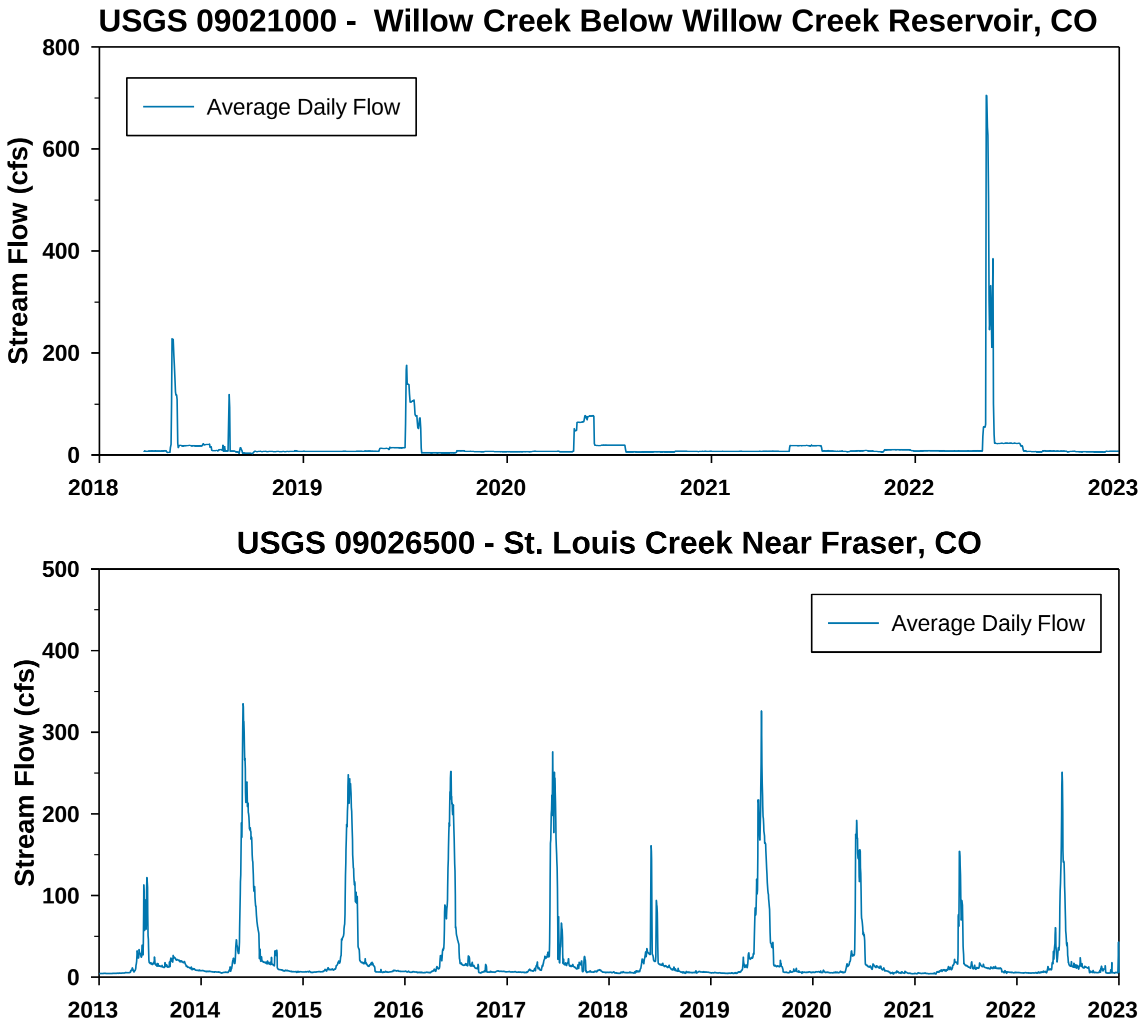


Figure B-3: **Average daily flow data for USGS stream gages on Willow Creek and St. Louis Creek in Grand County, CO.**

Appendix C 2019 to 2022 Pebble Count Data

Table C-1: Percent average substrate size classes at all sites sampled in 2019.

Sites	Substrate Size Categories							
	Fines	Small Gravel	Gravel	Small Cobble	Cobble	Small Boulder	Boulder	Bedrock
	<2 mm	2-8 mm	8-64 mm	64-128 mm	128-256 mm	256-512 mm	>512mm	
CR-31	5.5	3.3	18.8	32.0	29.0	11.5	0	0
CR-28.7	5.8	3.5	16.1	27.9	36.4	10.3	0	0
CR-22.9	4.1	2.7	15.2	20.7	46.0	10.6	0.7	0
CR-16.7	12.3	3.8	23.5	27.0	26.0	4.0	2	1.5
CR-9.1	12.0	1.7	17.7	27.2	38.7	2.7	0	0
CR-7.4	25.7	5.5	33.9	27.7	7.2	0	0	0
CR-1.7	65.8	13.8	6.5	5.8	7.0	1.3	0	0
FR-25.1	8.5	3.0	7.2	8.2	8.0	14.7	50.4	0
FR-23.2	4.7	2.5	24.6	35.2	28.3	3.5	1.2	0
FR-20	15.5	4.0	18.0	28.8	17.3	11.8	4.8	0
FR-15	13.4	2.5	21.3	24.3	22.3	13.6	2.5	0
FR-14	5.9	5.1	23.3	26.2	30.9	8.1	0.5	0
FR-1.9	8.8	3.8	22.8	35.8	22.3	6.5	0	0
RC-1.1	21.0	4.5	24.0	27.0	17.5	2.5	3.5	0

Table C-2: Percent average substrate size classes at all sites sampled in 2020.

Sites	Substrate Size Categories							
	Fines	Small Gravel	Gravel	Small Cobble	Cobble	Small Boulder	Boulder	Bedrock
	<2 mm	2-8 mm	8-64 mm	64-128 mm	128-256 mm	256-512 mm	>512mm	
CR-31	6.8	2.5	11	18.8	47.9	13	0	0
CR-28.7	7.8	3.5	18	12	46.8	12	0	0
CR-22.9	5.2	6	18.5	20.4	36.2	12.7	1	0
CR-16.7	11.2	5.7	12	19	32.9	15.5	3.5	0.2
CR-9.1	8.5	4	28	35.3	19.8	4.3	0.3	0
CR-7.4	22.9	9	49.9	15	3	0.2	0	0
FR-25.1	10.3	3	6.5	5.3	10	22.3	42.8	0
FR-23.2	12.8	10.3	15	16.3	23.3	12.8	9.8	0
FR-20	8.3	3	15.4	25	28	18.7	1.5	0
FR-15	7.8	6	15	21.8	33.3	15.5	0.5	0
FR-14	3.8	7.5	11.5	20.3	34.3	22.5	0.3	0
FR-12.4	8.8	10.3	18.5	26.5	24.5	11.3	0.3	0
FR-5.5	5	9	20	37	27	2	0	0
RC-1.1	13	8.5	25.3	27.5	19.3	2.8	3.8	0
FRC-2	5	32.7	45.5	13.9	3	0	0	0

Table C-3: Percent average substrate size classes at all sites sampled in 2021.

Sites	Substrate Size Categories							
	Fines	Small Gravel	Gravel	Small Cobble	Cobble	Small Boulder	Boulder	Bedrock
	<2 mm	2-8 mm	8-64 mm	64-128 mm	128-256 mm	256-512 mm	>512mm	
CR-31	6.5	6.3	32.8	21.5	22.5	10	0.5	0
CR-28.7	13	1.2	19	20.7	36.2	6.7	3.2	0
CR-22.9	10.4	10.6	37.4	18.6	16.3	4.5	2.2	0
CR-16.7	18.8	3.3	19.5	17	31	7.8	2.8	0
CR-9.1	24	14	34	18.3	8.5	1	0.3	0
CR-7.4	9.8	8.8	59.3	17.5	4.5	0.3	0	0
CR-1.7	86	4.8	4.8	2.5	0	1.3	0.8	0
FR-25.1	5	14.3	17.5	5	12.3	6	40	0
FR-23.2	22.5	6.3	29	10.3	20.8	5.5	5.8	0
FR-20	13.3	7.3	29.8	14.5	22	9.5	3.8	0
FR-15	7.6	7.1	44.1	17.2	15.9	7.1	1	0
FR-14	5	15.3	34.2	17.1	19.3	7.2	2	0
FR-1.9	6.3	11.3	33.8	22.3	24.8	1.8	0	0
RC-1.1	63.8	3.3	18.3	4	6.8	1.8	2.3	0

Table C-4: Percent average substrate size classes at all sites sampled in 2022.

Sites	Substrate Size Categories							
	Fines	Small Gravel	Gravel	Small Cobble	Cobble	Small Boulder	Boulder	Bedrock
	<2 mm	2-8 mm	8-64 mm	64-128 mm	128-256 mm	256-512 mm	>512mm	
CR-31	11.5	4.8	19.0	24.3	35.5	5.0	0	0
CR-28.7	25.4	0.7	14.9	31.5	22.5	4.6	0.2	0
CR-24.9	46.1	1.7	15.2	14.2	17.0	4.7	0	1.0
CR-22.9	15.4	0.5	38.8	31.6	7.0	3.2	1.5	2.0
CR-16.7	22.9	4.5	14.5	23.9	20.9	2.7	7.0	3.5
CR-9.1	16.1	9.4	23.2	22.9	21.9	6.3	0.3	0
CR-7.4	20.6	6.0	57.7	12.8	2.6	0.3	0	0
CR-TBD	21.3	8.8	38.8	17.5	12.5	1.3	0	0
FR-27.2	22.9	11.7	33.9	21.9	8.2	0.7	0.5	0
FR-23.2	8.0	7.5	29.3	25.3	17.3	6.3	6.5	0
FR-20	12.4	7.9	30.2	19.1	21.8	7.2	1.5	0
FR-14	12.4	8.8	30.6	19.7	23.0	4.5	0.9	0
RC-1.1	72.8	2.0	13.0	5.8	4.3	1.0	1.3	0
STC-0	9.3	8.0	21.8	21.5	29.0	9.3	1.3	0
WC-TBD	26.8	5.5	20.3	30.3	15.5	0.8	1.0	0

Appendix D Algae Cover Photos

Photo D-1: Examples of approximately 25 percent (left) and 50 percent (right) algae cover.

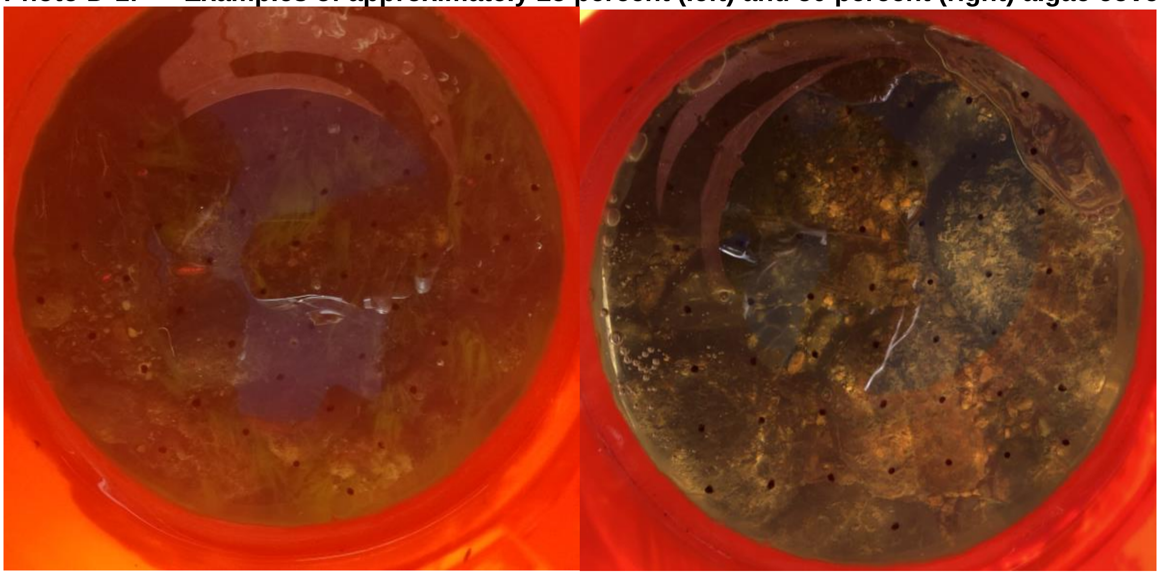
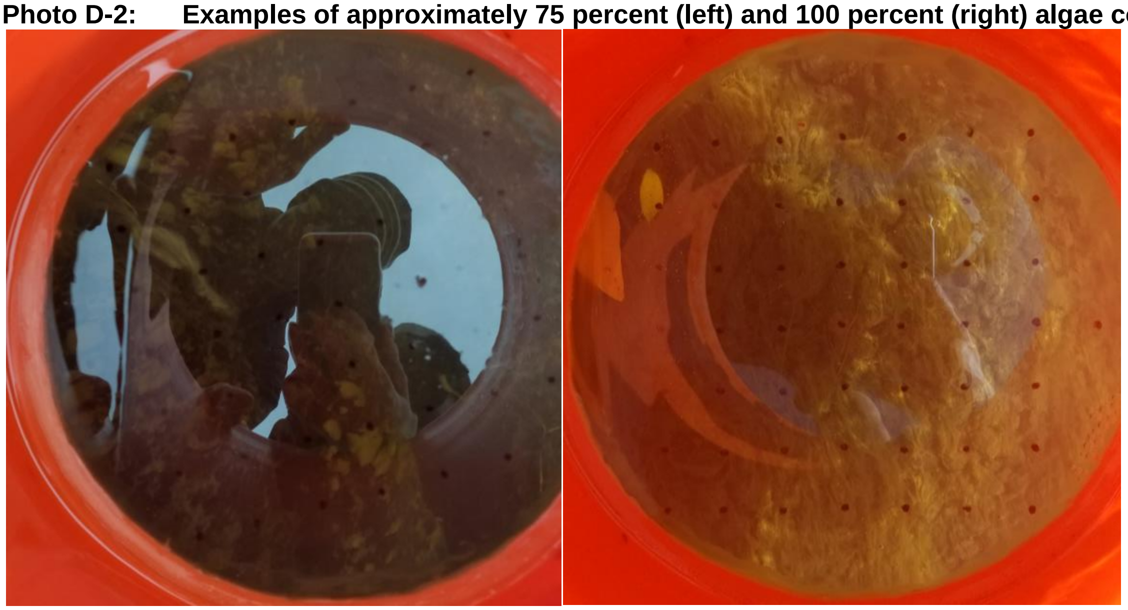


Photo D-2: Examples of approximately 75 percent (left) and 100 percent (right) algae cover.



Appendix E Long-term Embeddedness Data

Table E-1: Long-term embeddedness data from 2019 - 2022. NS = Not Sampled.

Sites	Waterbody	Average Percent Embeddedness			
		2019	2020	2021	2022
CR-31	Colorado River	44.8	22.6	49.4	40.4
CR-28.7	Colorado River	48.8	48.7	64.3	64.0
CR-24.9	Colorado River	NS	NS	NS	53.7
CR-22.9	Colorado River	43.7	39.8	47.8	50.8
CR-16.7	Colorado River	49.0	31.5	51.9	51.3
CR-9.1	Colorado River	42.3	40.5	62.0	43.3
CR-7.4	Colorado River	55.5	54.3	44.3	49.0
CR-TBD	Colorado River	NS	NS	NS	80.5
CR-1.7	Colorado River	65.5	NS	90.1	NS
FR-27.2	Fraser River	NS	NS	NS	56.7
FR-25.1	Fraser River	51.8	37.3	59.4	NS
FR-23.2	Fraser River	39.4	34.7	57.7	37.7
FR-20	Fraser River	37.4	37.9	50.3	40.2
FR-15	Fraser River	46.9	35.4	48.0	NS
FR-14	Fraser River	40.5	38.1	44.9	56.4
FR-12.4	Fraser River	NS	35.9	NS	NS
FR-1.9	Fraser River	40.0	NS	44.5	NS
RC-1.1	Ranch Creek	51.4	45.4	81.6	84.8
STC-0	St. Louis Creek	NS	NS	NS	39.0
WC-TBD	Willow Creek	NS	NS	NS	65.1