

# Napa River and Sonoma Creek Vineyard Waste Discharge Requirements

## Streambed Monitoring Final Report



### Prepared for:

San Francisco Bay Regional Water Quality Control Board

1515 Clay Street #1400

Oakland, CA 94612

### Prepared by:

Napa County Resource Conservation District



July 2024

## **Prepared By**

Napa County Resource Conservation District  
1303 Jefferson Street, Suite 500B  
Napa, California 94559  
[www.naparcd.org](http://www.naparcd.org)

Paul Blank  
Environmental Scientist  
(707) 690-3121  
[paul@naparcd.org](mailto:paul@naparcd.org)

K. Martin Perales, Ph.D.  
Environmental Scientist  
(707) 690-3118  
[martinp@naparcd.org](mailto:martinp@naparcd.org)

## **Acknowledgements**

Napa RCD would like to thank the Napa County Farm Bureau, the Sonoma County Farm Bureau, the participating Napa Valley and Sonoma Valley wine grape growers, Wine Institute, Sonoma RCD, Sonoma Ecology Center, San Francisco Bay Regional Water Quality Control Board staff and Watershed Stewards Program Corpsmembers, and the participating Napa River and Sonoma Creek streamside landowners for their assistance and support.

## Executive Summary

Order No. R2-2017-0033 was adopted by the California Regional Water Quality Control Board, San Francisco Bay Region, to implement the sediment Total Maximum Daily Loads (TMDLs) for the Napa River and Sonoma Creek watersheds in response to concerns about the negative effects of fine sediment on the habitat of steelhead trout, Chinook salmon, and other special status fish. One option for compliance by vineyard owners/operators subject to the order is by participation in the group water quality monitoring program organized by the Napa and Sonoma County Farm Bureaus and led by the Napa County Resource Conservation District (Napa RCD). The group program includes streambed monitoring, best management practices (BMP) effectiveness monitoring, data analysis, and reporting. This final report presents the results of streambed monitoring for Years 1 and 2 (2022 and 2023) of the program. The results of BMP effectiveness monitoring were reported separately.

Streambed monitoring involves identifying and assessing the condition, particularly the fine sediment content, of potential salmonid spawning gravels in the streambeds of the freshwater reaches of the mainstem Napa River and mainstem Sonoma Creek channels. The results will be used by the Water Board and community stakeholders to evaluate progress toward TMDL goals for sedimentation.

A total of 32 spawning gravel sites were selected for sampling in the Napa River monitoring reach along with 20 sites in Sonoma Creek, and bulk sediment samples from each site were collected, processed, and analyzed in 2022. Sampling was repeated in 2023. The water year preceding the 2022 sampling event was classified as average, though it was mostly dry with a single early season large streamflow event. The water year preceding the 2023 sampling was a wet year with multiple large streamflow events. Sampling sites were well distributed along the lengths of both stream mainstems. Analysis resulted in grain size distributions and statistics for each sample. Reach and subreach gravel statistics were also prepared. The following quality standards were selected from scientific literature and guidance documents to assess spawning gravel quality:

- The median particle diameter ( $d_{50}$ ) should be less than 40 millimeters (mm) to allow movement and excavation of gravels by all adult salmonids spawning in the system.
- The percentage of particles finer than 1 mm in potential spawning gravels should be less than 14% to allow for successful incubation of salmonid eggs (i.e., avoid asphyxiation).
- The percentage of particles finer than 5.6 mm in potential spawning gravels should be less than 30% to allow for successful emergence of salmonid fry (i.e., avoid entombment).

Analysis of Year 1 and Year 2 samples of spawning gravels collected from the Napa River and Sonoma Creek mainstem channels indicates that streambed conditions meet the quality standard for incubation of salmonid eggs but suggest a possible excess of fines in the coarse sand and fine gravel range that may decrease survival and emergence rates of salmonid fry. The cause of elevated levels of the coarse sand and fine gravel in this size range likely has to do with large-scale variations in the sediment budgets of these streams and is beyond the scope of this study to assess.

This monitoring effort was completed in accordance with the approved Monitoring Plan (Napa RCD 2020). It included a well-established method, collection of a large number of samples spread along the full lengths of the freshwater mainstems, and repeat sampling of the same sites in different water year types. As specified in the study design, we sampled streambed gravels at sites we believed to be viable spawning riffles, as opposed to randomly sampling a subset of all spawning riffles. This monitoring effort set out to characterize the quality of spawning habitat and did not quantify the total amount of spawning habitat available in the mainstem.

To maintain and improve streambed habitat, continued watershed-wide implementation of best management practices is recommended to reduce delivery of fine sediments to streams.

## Table of Contents

1	Introduction.....	1
2	Background.....	3
2.1	Project Timeline.....	3
2.2	Importance of Spawning Gravel Quality.....	3
2.3	Hydrologic Conditions.....	4
2.4	2017 and 2020 Wildfires.....	8
3	Methods.....	10
3.1	Monitoring Approach.....	10
3.2	Napa River Site Selection.....	10
3.3	Sonoma Creek Site Selection.....	12
3.4	Bulk Sediment Sample Collection.....	12
3.5	Data Analysis.....	13
4	Results.....	15
5	Discussion.....	26
5.1	Spawning Gravel Quality and Site Selection.....	26
5.2	Napa River Chinook Salmon Spawner Survey.....	27
5.3	Discontinuation of Streambed Slope Surveys.....	28
5.4	Recommendations.....	29
6	References.....	30

## Attachments

Attachment - Particle size distribution charts by size class

## **1 Introduction**

In 2017, the California Regional Water Quality Control Board, San Francisco Bay Region (Water Board) adopted Order No. R2-2017-0033 to implement the sediment Total Maximum Daily Loads (TMDLs) for the Napa River and Sonoma Creek watersheds in response to concerns about the negative effects of fine sediment on the habitat of steelhead trout, Chinook salmon, and other special status fish. This order, referred to as the Vineyard General Permit, seeks to reduce fine sediment inputs by implementing best management practices and applies to vineyard properties within the Napa River and Sonoma Creek watersheds (**Figure 1**). Vineyard owners/operators subject to the order can satisfy the monitoring requirements individually, on a property specific basis, or by participating in a group water quality monitoring program. One such group program was coordinated by the Napa and Sonoma County Farm Bureaus (Farm Bureaus).

At the request of the Farm Bureaus, the Napa County Resource Conservation District (Napa RCD) coordinated the actions required by the Vineyard General Permit for the group program, including preparation of a monitoring plan that provides a framework for streambed monitoring, best management practices (BMP) effectiveness monitoring, data analysis, and reporting. The Monitoring Plan (Napa RCD 2020) included contributions from Sonoma Resource Conservation District, Wine Institute, and the Farm Bureaus.

This final report presents the results of streambed monitoring for Years 1 and 2 of the program (2022 and 2023). The results of BMP effectiveness monitoring were reported separately.

Streambed monitoring involves identifying and assessing the condition, particularly the fine sediment content, of potential salmonid spawning gravels in the streambeds of the freshwater reaches of the mainstem Napa River and mainstem Sonoma Creek channels. The results will be used by the Water Board and community stakeholders to evaluate progress toward TMDL goals for sedimentation.

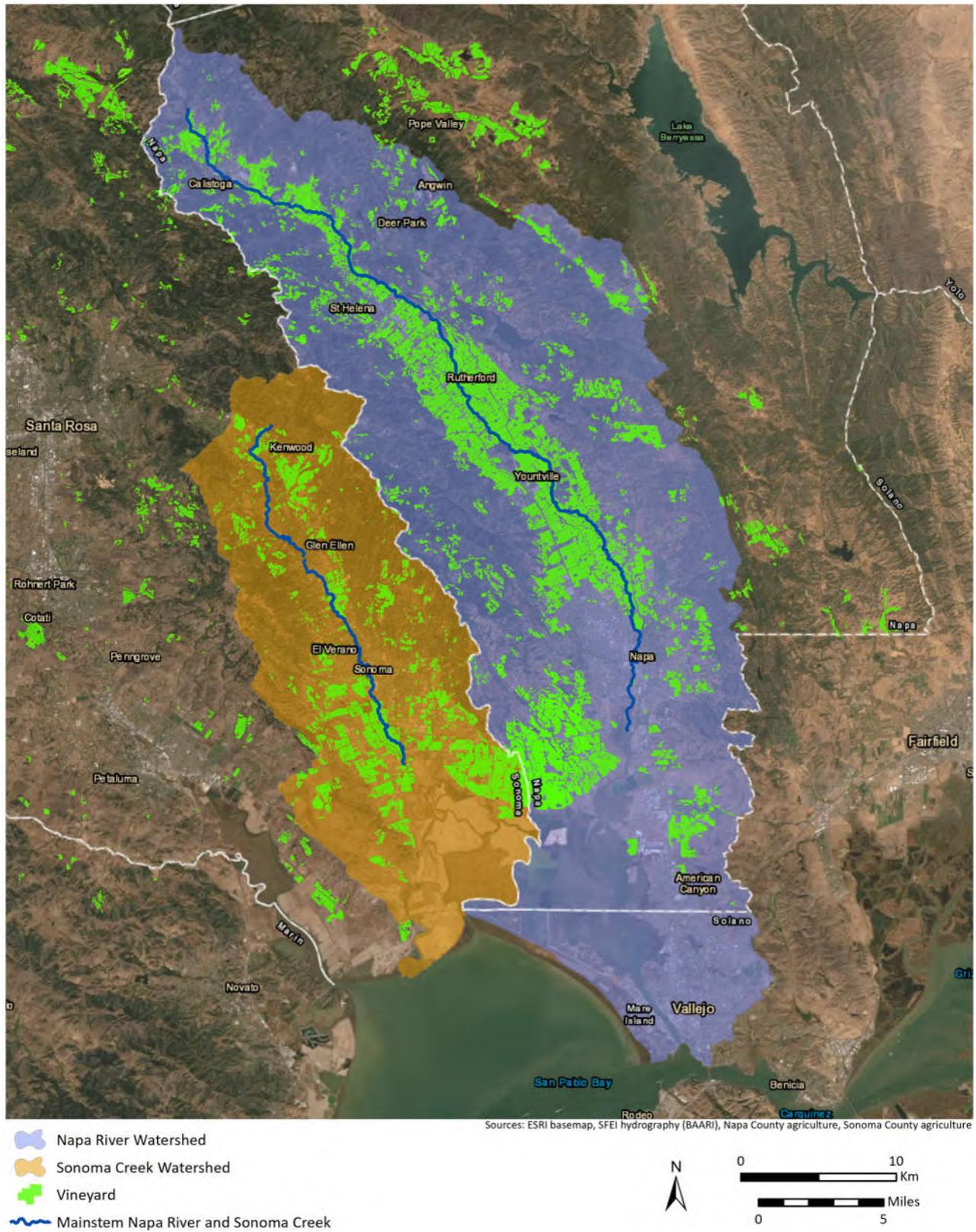


Figure 1. Vineyard properties within the Napa River and Sonoma Creek watersheds

## 2 Background

### 2.1 Project Timeline

The Monitoring Plan established a timeline for monitoring. Due to the Napa Valley wildfires of 2020, the Water Board granted a one-year delay to give vineyard operators affected by the fires time to recover. As a result, Year 1 of the monitoring program was pushed from 2021 to 2022, and all subsequent tasks were also delayed by one year (Table 1).

Following the two initial monitoring events of 2022 and 2023, reported herein, the Water Board will assess the need for additional monitoring under the Permit. If monitoring is desired by Water Board or community stakeholders, monitoring activities will be resumed after at least a four-year period to allow time for additional sediment supply reduction efforts to take effect, high-flow events to transport and sort sediments and approach equilibrium, and assessment and adjustment of the monitoring approaches and methods.

**Table 1.** Updated timeline for site selection, sampling field work, data analysis, and reporting. Solid blue areas indicate completed work and light blue areas indicate the timeline for possible future work.

Task	2022		2023		2024		2025		2026		2027		2028	
	Jan-Jun	July-Dec												
Site Selection														
Bulk Sediment Sampling Fieldwork														
Data Analysis & Reporting														

### 2.2 Importance of Spawning Gravel Quality

High-quality spawning gravels are required for reproductive success in salmonid (salmon and steelhead) and other native fish populations. These gravels provide suitable substrate for salmonid eggs, offering protection from predators while allowing for intra-gravel flow to oxygenate developing embryos. However, streambed gravels may be unsuitable as spawning gravel by being either too coarse or having excess fine sediment. In agricultural watersheds, the primary concern is often excess fine sediment inputs. In addition to numerous ecological impacts, this sedimentation poses a significant threat to fish populations as it can reduce

spawning habitat availability by smothering spawning gravels, reducing intra-gravel flow of oxygenated water, impairing incubation of eggs and preventing emergence of fry (newly hatched fish). This can lead to reduced survival and declines in salmonid and native fish populations. Therefore, prioritizing the preservation of high-quality spawning gravel and mitigating fine sediment inputs is essential for maintaining viable salmonid and other native fish populations and preserving the ecological integrity of river systems.

### 2.3 Hydrologic Conditions

Streambed data were collected in the summer months of 2022 and 2023 during the peak of the dry season. The particle size and fine sediment content of streambed gravels encountered in the summer months, and at the start of the flow season when salmon are spawning, are largely determined by recent large storm flows that have the capacity to mobilize a range of sediment sizes in the active bed. Flows of this magnitude typically occur several times per year in the Napa River, though there may be exceptions during dry or very dry water years. The hydrologic conditions of Water Years (WY) 2021-22 and 2022-23 are therefore important context for streambed monitoring results.

Water years (October 1 through September 30) in the Napa area are categorized as very dry, dry, average, wet, or very wet based on precipitation data collected at the Napa State Hospital rain gauge in the City of Napa from 1906 to 2012. A study by the County of Napa ([https://www.napawatersheds.org/managed\\_files/Document/6838/WaterYear\\_Methodology.pdf](https://www.napawatersheds.org/managed_files/Document/6838/WaterYear_Methodology.pdf)) has shown that this rain gauge adequately represents watershed-wide precipitation patterns. It is also presumed to adequately represent Sonoma Valley precipitation patterns for the purposes of interpretation of streambed monitoring results. Although unlikely to significantly affect the classifications of the water years in this study, it should be noted that the County's analysis omitted the period of 1981 through 1983 which included two of the wettest years on record. The period since 2012 has also included very wet and very dry years. An update of this analysis may measurably alter the water year classification boundaries. Cumulative monthly precipitation data from the Napa State Hospital rain gauge for WY 2021-22 and WY 2022-23 are shown on **Figure 2** which also includes 30-year mean data and water year classification thresholds.



**Figure 2.** Cumulative monthly precipitation and water year classification for WY 2021-22 and WY 2022-23. Data is from the Napa State Hospital rain gauge in the City of Napa. The series labeled “average” is the 30-year monthly mean data calculated from 1990 to 2020.

WY 2021-22 was characterized by unprecedented October rainfall. From October 20-25, 2021, 8.50 inches of rain were observed at the Napa State Hospital rain gauge including 5.35 inches on October 24. This wet period in addition to above-average December rainfall led to accumulation of 84% of the annual total by early January. Very little rainfall occurred during January through March, typically the wettest period of the year. The water year ended with the rainfall total slightly into the “average” year range.

WY 2022-23 was a “wet” year with 123% of mean annual rainfall measured at the Napa State Hospital rain gauge. The temporal distribution of the rainfall had a more typical pattern for the region, with the majority falling during the months of December through March.

Streamflow in the Napa River is measured at USGS Station 11458000, located at Oak Knoll Avenue bridge near the City of Napa. Streamflow in Sonoma Creek is measured at USGS Station 11458500, located at the Agua Caliente Road bridge near the City of Sonoma. Real-

time and historical stage and flow data for both stations are available at [waterdata.usgs.gov](https://waterdata.usgs.gov). Peak flow statistics are available at [streamstats.usgs.gov](https://streamstats.usgs.gov) and are summarized in **Table 2**.

**Table 2.** Peak flow statistics for Napa River and Sonoma Creek provided by USGS.

Recurrence Interval	USGS Station 11458000 Napa River near Napa CA (cfs)	USGS Station 11458500 Sonoma Creek at Agua Caliente CA (cfs)
2-Year	8,470	6,050
5-Year	15,300	8,540
10-Year	20,700	10,100
25-Year	28,100	12,000
50-Year	34,100	13,300
100-Year	40,400	14,500

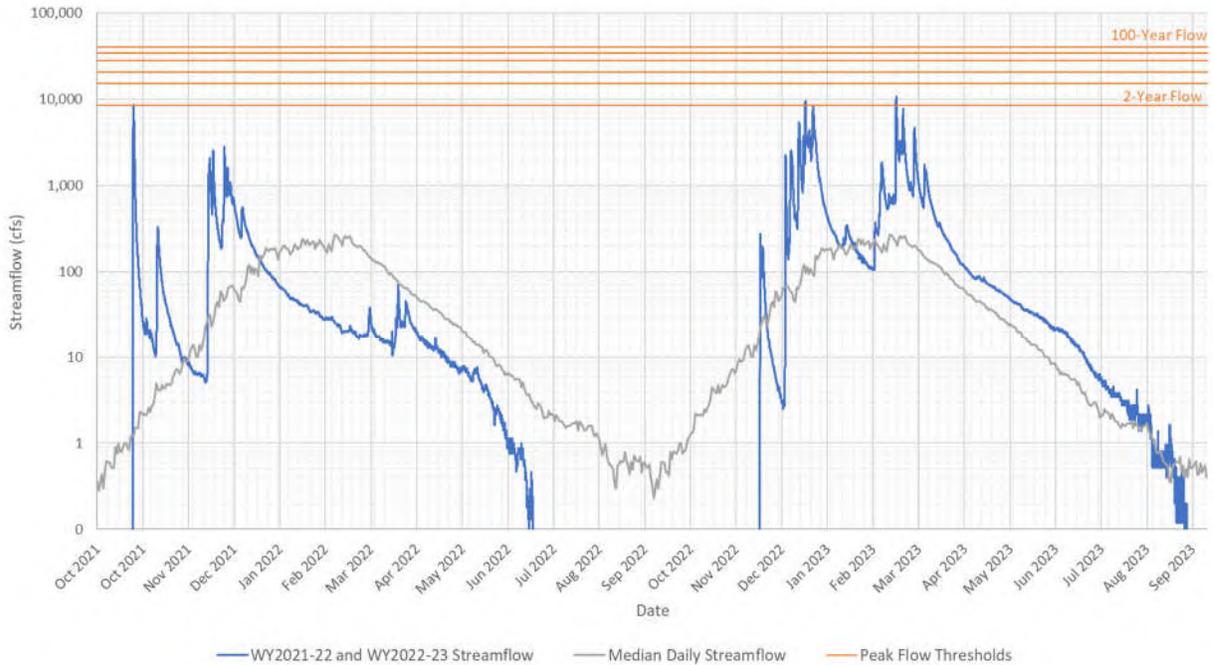
**Figure 3** shows two-year discharge hydrographs for the Napa River and Sonoma Creek, respectively, in relation to long-term median daily streamflow. For WY 2021-22, the plots depict the flow event resulting from extreme early season rainfall on October 24, 2021, which peaked at 8,570 cubic feet per second (cfs) in the Napa River and 7,140 cfs in Sonoma Creek. Comparison of these flows to peak flow statistics (**Table 2**) indicate occurrence of an approximate 2-year peak flow in the Napa River and an approximate 3-year peak flow in Sonoma Creek. Peak flows caused by this event would have been significantly larger had this storm fallen later in the season on saturated watersheds instead of on completely dry ground, resulting in increased change to the streambeds. This event was followed by a small number of minor stormflows through the first week of January 2022 beyond which discharge in both streams dropped and remained at below average levels for the rest of the water year due to a lack of ongoing rainfall.

For WY 2022-23, the hydrographs depict a late start in the Napa River with flow beginning on December 10, and a slow start in Sonoma Creek with flow remaining mostly below the long-term average until the start of a wet period from late December through mid-January. This wet period included peak flows on January 9, 2023, of 9,450 cfs in the Napa River and 7,780 cfs in Sonoma Creek. This was the peak flow of the year on Sonoma Creek and was equal to an approximate 3- to 4-year flood. A second wet period from late February through late March included peak flows on March 10, 2023, of 10,800 cfs in the Napa River and 6,060 cfs in Sonoma Creek. This was the peak flow of the year on the Napa River and was approximately equal to a 3-year flood.

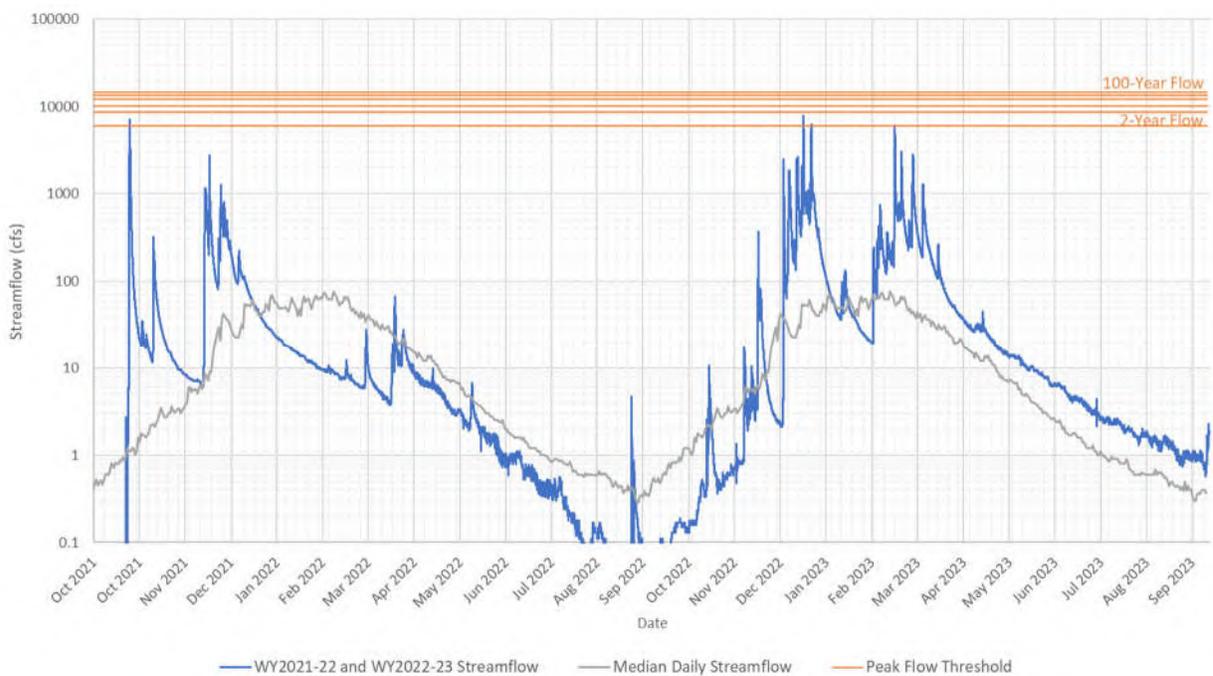
The differences in streamflow between the two years, including increased frequency and longer durations of large channel-forming flows in WY2022-23, can be expected to result in significant

changes to the streambeds, including particle sizes and fine sediment content of spawning gravels.

Napa River



Sonoma Creek



**Figure 3.** Two-year discharge hydrographs for WY 2021-22 and WY 2022-23 for the Napa River at USGS Station 11458000 and Sonoma Creek at USGS Station 11458500, including long-term median daily streamflow and peak flow thresholds.

### 2.4 2017 and 2020 Wildfires

Wildfire can increase storm runoff and surface erosion, which in turn can increase flood and debris flow hazard as well as inputs of ash, sediment, and woody debris to stream systems. Additional sediment inputs from burned areas have the potential to alter the grain size distribution of spawning gravels in the wake of wildfire as forested areas recover and sediments are transported through the watershed.

Multiple large wildfires burned expansive areas of the Napa River and Sonoma Creek watersheds in the 5-year period prior to the Year 1 bulk sediment sampling event (Table 3 and Figure 4).

Table 3. Recent wildfires in the Napa River and Sonoma Creek watersheds.

Year	Fire ID	Napa River Watershed			Sonoma Creek Watershed		
		Burn Area (ac)	Tributaries Affected	Drains To	Burn Area (ac)	Tributaries Affected	Drains To
2017	Tubbs	4,626 (1.7%)	Kimball, Blossom, Cyrus, Garnett	All subreaches	NA		
	Nuns	19,990 (7.4%)	Bale/Bear, Dry, Napa, Carneros, Huichica	Lower 3 subreaches	31,013 (29.2%)	Sonoma Cr, Pythian, Felton, Frey, Bear, Yulupa, Calabazas, Hooker, Agua Caliente.	All reaches of mainstem
	Atlas	27,905 (10.3%)	Conn, Chase, Soda, Milliken, Tulucay	Lower 2 subreaches	NA		
2020	Glass	31,789 (11.8%)	Garnett, Simmons, Selby, Bell, Diamond, Ritchey, Mill, York, Sulphur	All subreaches	5,255 (5.0%)	Sonoma Cr, Pythian, Felton, Frey, Bear.	All reaches of mainstem
	Hennessey	12,985 (4.8%)	Conn, Milliken	Lower 2 subreaches	NA		

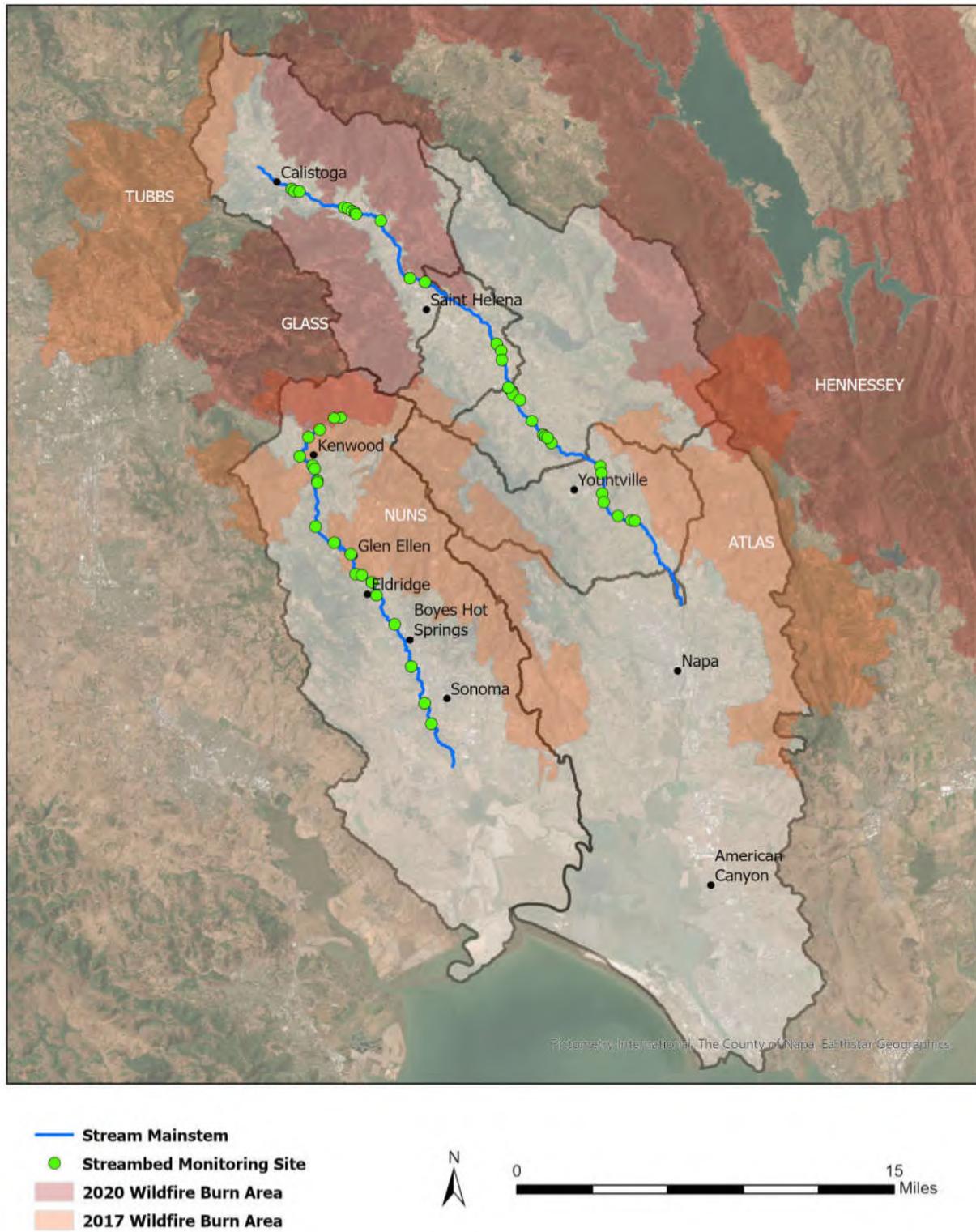


Figure 4. Recent wildfire burn areas in the Napa River and Sonoma Creek watersheds in relation to bulk sediment sampling monitoring reaches and sampling sites.

### **3 Methods**

#### **3.1 Monitoring Approach**

The composition of spawning gravel, particularly the proportion of fine sediment, is evaluated in spawning habitat assessment and monitoring projects to determine the quality of spawning habitat (Schuett-Hames et al 1996). For this monitoring effort, fine sediment concentrations were determined by collecting bulk sediment samples directly from streambed spawning areas at multiple locations throughout the monitoring reaches. Bulk sediment sampling allows preparation of full-range particle size distributions and calculation of size statistics and fine sediment content. This approach required careful identification of potential spawning gravel patches and, in Year 1, included streambed slope surveys to evaluate site quality. Field work included collection of 32 bulk sediment samples from the Napa River and 20 samples from Sonoma Creek each year. Collected material was dried and sorted in the field and subsamples of the finest material were sent to a laboratory for further processing and size, or grain size analysis. Monitoring activities were performed in accordance with the Monitoring Plan, as approved by the Water Board.

Napa RCD conducted field work in the Napa River, and subcontracted with Sonoma Ecology Center (SEC), who had local contacts and knowledge of Sonoma Creek, to assist with Sonoma Creek field work. Lab coordination, data processing, and reporting were completed by Napa RCD, with support from SEC.

#### **3.2 Napa River Site Selection**

Reconnaissance surveys of the Napa River were conducted to identify potential sampling sites. The purpose of the surveys was to generate a list of sites that: 1) included potential salmonid spawning gravels, 2) were accessible by vehicle or a short hike, and 3) had cooperative landowners who granted permission for access. The surveys were not intended to inventory all potential spawning habitat in the river. Napa RCD completed the surveys by kayak during May and June, 2022, under spring baseflow conditions when potential salmonid spawning habitat was mostly inundated. The surveys covered 22.6 miles (78%) of the 29-mile freshwater mainstem.

Spawning salmonids in the Napa River mainstem construct redds in a variety of locations, but the vast majority of redds are observed at riffle crests. Since riffle crests are easily identifiable in the field, they are the most reliable places to find potential spawning gravels. However, many riffle crests are unsuitable for spawning because they are composed of bedrock, riprap, tree

roots, sand, etc. Spawning riffles may also be temporarily unsuitable because they are too heavily vegetated, backwatered by downstream bed deposition or channel constriction, or covered or inundated by a beaver dam. Riffles can also have an extremely low slope with poor hydraulics for spawning. As a result, riffle crests alone are not an adequate proxy for potential spawning sites. A spatially and temporally extensive dataset of historical redd location data from spawner surveys was not available for the Napa River. Therefore, visual assessments of spawning conditions at each riffle crest were conducted to help ensure that samples would only be collected from potential spawning gravels, and not from other streambed sediments.

Napa RCD mapped each riffle crest and performed a visual assessment to evaluate its quality as a spawning site using a 3-point rating system. A riffle crest that scored a “1” did not appear to be a potential spawning site, “2” indicated a potential spawning site, and “3” was given to riffle crests that appeared to be high-quality spawning sites. Field crews used general guidelines to make the assessments (**Table 4**).

**Table 4.** Riffle crest spawning quality assessment rating guidelines, Napa River.

Rating	Guide
1	<ul style="list-style-type: none"> <li>• Non-gravel substrate (sand, cobble, bedrock, riprap, roots, or other)</li> <li>• Beaver dam, weir, or other structure present</li> <li>• Extremely low slope</li> </ul>
2	<ul style="list-style-type: none"> <li>• Gravel-bedded but coarse with high cobble content</li> <li>• Gravel-bedded but fine with high sand content</li> <li>• Heavily vegetated</li> <li>• Low slope</li> </ul>
3	<ul style="list-style-type: none"> <li>• At least one square meter of appropriately sized gravel</li> <li>• Sufficient slope/appropriate hydraulics</li> <li>• Low emergent vegetation and other impediments to sampling</li> <li>• Adjacent bar present if thalweg sampling not possible</li> </ul>

Reconnaissance surveys yielded an adequate number of sites from which 32 bulk sediment sampling sites could be selected. Sites were well distributed along the freshwater reach of the Napa River mainstem representing a favorable range of channel geometries (i.e., confined vs. unconfined), riparian buffer widths, and watershed areas (i.e., stream power).

The Monitoring Plan specifies that all sampled sites must have a minimum channel slope of 0.002 (0.2%) to avoid excessively sand-bedded conditions. In rivers and streams worldwide, there often is an abrupt transition from a gravel-bedded to a sand-bedded channel that is a function of a rapid reduction in shear stress (Lamb and Vendetti, 2016). Generally, where the channel slope is less than 0.001 the streambed would be expected to be sand-bedded (Parker, 2008). The average overall slope of the freshwater reach of the mainstem Napa River is

approximately 0.002, and therefore the Monitoring Plan specified that all sites must have a minimum local channel slope of 0.002 to ensure that sampling does not occur within a reach that could be naturally transitional between gravel- and sand-bedded. To determine if this criterion was met, longitudinal surveys of channel slope were conducted prior to sampling. Distance was measured along the approximate thalweg of the channel with a field tape and streambed elevations were measured along the tape using a survey-quality level and stadia rod. The surveys began at least one riffle crest upstream of the target sampling riffle and ended at least one riffle crest downstream. Channel slope was calculated by dividing the difference in elevation by the total surveyed distance. Sites with bed slopes above the minimum threshold were included for sampling.

In practice, streambed slope surveying began and ended at riffle crests, which were typically hundreds of feet upstream and downstream from the site and often separated by deep pools. Surveying using the chosen methods in these conditions for these distances was more labor intensive and time consuming than anticipated and we began to run up against time and budget constraints. As a result, we decreased the minimum slope threshold to 0.0018 to include three additional sites and meet the collection goal of 32 sampled sites.

### **3.3 Sonoma Creek Site Selection**

Site selection in Sonoma Creek was less complicated, as SEC staff were already familiar with many accessible spawning riffle locations where the targeted slope and gravel conditions could likely be found. With the goals of the Project in mind, SEC staff scouted locations at targeted sites in the Sonoma Creek mainstem and coordinated with private landowners where needed to designate an adequate number of potential sampling sites that were well distributed along the length of the monitoring reach. Streambed slope surveys were conducted in conjunction with staff from Napa RCD to ensure the targeted sites met that selection criterion according to the methods specified above. Ultimately, 20 spawning sites suitable for monitoring were selected.

### **3.4 Bulk Sediment Sample Collection**

At each selected sampling site, a suitable sampling location was identified with favorable substrate size and topography for salmonid spawning. Ideally, this sampling location would occur within or in immediate proximity to the channel thalweg but was shifted laterally if needed since sampling of finer streambed sediments could not be done under flowing conditions. For this reason, sampling of particular sites was delayed as long as possible into the dry season to allow streambeds to become dry. Every effort was made to ensure that the sampling location was on the active streambed where a salmonid could potentially spawn at

higher flows, and that the substrate composition appeared similar to that of the wetted portion of the channel.

Once each sampling location was selected, a single sample per site was collected to a depth of approximately 20 centimeters (cm) below the streambed surface using a shovel. The lateral dimensions of the sampled area were determined by the amount of sample needed, which was dependent on the size of the largest individual particle in the sample. A sufficient volume of sediment was collected to ensure that the largest particle represented less than five percent of the total sample mass. Largest particle mass percentages ranged from 0.2% to 4.8% and averaged 2.0%. Typically, an area of less than one square meter was excavated. Total sample weights ranged from 14.3 to 70.9 kilograms (kg).

Samples were carefully collected into 5-gallon buckets, taking care not to spill any material during transfer from shovel to bucket. Subsequently, material from the buckets was carefully spread out on plastic tarps and allowed to completely dry for one or more days before processing. In most cases this occurred at a level area onsite, but in some cases, samples were transported offsite for processing due to concerns about disruption or tampering. Care was taken to ensure that weather conditions (i.e., wind) would not influence the sample integrity. Once thoroughly dry, the entire sample was processed in place using a Gilson SS-35 Rocker sieve to sort the material into size fractions using the following screens: 63 millimeter (mm), 45 mm, 31.5 mm, 22.2 mm, 16 mm, 11.2 mm, and 8 mm. Each size class was weighed ( $\pm 0.02$  kg) using an Adam Equipment CPWplus-75 digital field scale. The smallest fraction of the sample passing through the final screen ( $<8$  mm) was subsampled by mounding the material into a circular pile, dividing it evenly, and collecting a 3 to 4 kg subsample. Actual subsample weights ranged from 2.4 to 4.9 kg. Subsamples were placed carefully into labelled plastic storage bags and sent to a specialized laboratory for fine grain sieving into the following size classes: 5.6 mm, 4 mm, 2.8 mm, 2 mm, 1.4 mm, 1 mm, 0.5 mm, and less than 0.5 mm. Year 1 analyses were performed by Delta Environmental Laboratories using ASTM Method E112. Year 2 analyses were performed by Brunsing Associates, Inc. using ASTM Method C136. Both methods determine particle size distributions.

### 3.5 Data Analysis

Laboratory results were compiled into particle size distributions. Grain size diameter statistics including the diameter at which 16% of the sample is finer ( $d_{16}$ ), median diameter ( $d_{50}$ ), diameter at which 84% of the sample is finer ( $d_{84}$ ), and geometric mean diameter ( $d_g$ ), as well as the percent of the sample finer than 1 mm, 2 mm, 5.6 mm, and 8 mm were calculated for each sample. Reach averages were calculated, and for the Napa River, the monitoring reach was divided into four subreaches:

- Calistoga (upstream end of mainstem) to Sulphur Creek
- Sulphur Creek to Bale Slough
- Bale Slough to Conn Creek
- Conn Creek to tidal boundary

The tributary creeks selected as the subreach boundaries are thought to play important roles in coarse sediment delivery to the mainstem. These lateral inputs may influence grain size and distribution of streambed gravels. The analysis method applied is based on Kondolf's literature review of laboratory and field studies (Kondolf 2000) and Water Board guidelines (Water Board 2006) and requires assessment of multiple gravel characteristics that affect salmonids at various life stages, specifically during redd construction by spawning adults, incubation of eggs, and emergence of fry.

Fine sediment content is of greatest interest because of its strong negative impacts on egg and larval salmonid survival rates, and its sensitivity to human activity in the watershed. Studies indicate that an excess of sediment finer than 1 mm can reduce intra-gravel flow to eggs, decreasing oxygen delivery and removal of metabolic wastes. For successful incubation, the percentage by weight of potential spawning gravel finer than 1 mm should be less than or equal to 14% (Water Board 2006 and Kondolf 2000).

An excess of sediments in the 1 to 10 mm size range in spawning gravel mixtures can block the movement of fry through intra-gravel pores and thus reduce the emergence rates of salmonid fry from redds. Unlike the threshold for incubation, the limit for emergence is more variable (Kondolf 2000). To assess gravel quality for emergence, the percentage by weight of the coarse sands and fine gravels in this size range can be compared to standards reported in scientific literature. The Water Board (2006) specifies that the fraction of fines less than 6.40 mm should be less than or equal to 30%. Since a 6.40 mm sieve was not used in this study, the nearest size class of less than 5.6 mm was selected to assess gravel quality for emergence. The selected standard for this study is that the fraction of redd gravel finer than 5.6 mm should be less than or equal to 30%.

Streambed material can be too coarse for adult salmonids to excavate during spawning. Coarseness was evaluated by comparison of the framework gravel sizes, represented by the  $d_{50}$  and  $d_{84}$  values, to established ranges reported in the scientific literature and by comparison to fish size. Studies show that adult salmonids can spawn in gravels with median diameters up to about 10% of their body length (Kondolf 2000). Unpublished data collected in the Napa River by Napa RCD between 2006 and 2018 from 80 spawned-out adult Chinook salmon carcasses indicate a body length range of 50 to 101 cm with a median length of 78 cm. Insufficient data are available to characterize the body length range of steelhead spawners in the Napa River;

however, mature steelhead are generally known to be 15% to 20% smaller than Chinook, therefore, a maximum  $d_{50}$  of 40 mm was selected as the standard for potential spawning gravels in the Napa River and Sonoma Creek to allow for successful gravel movement and excavation by all spawning salmonids. It should be noted that the  $d_{50}$  values presented in this study were calculated from bulk samples that include the full particle-size distribution of spawning gravels. In many other sampling efforts,  $d_{50}$  is calculated from pebble counts of the coarser surface layer of the streambed and are typically larger than values calculated from bulk samples. The results of the two methods cannot be directly compared.

In addition,  $d_{50}$  was plotted by river station to assess longitudinal trends in median grain size, and streambed slope was plotted against the percentage of particles finer than 2mm to evaluate the relationship between slope (as measured) and fine sediment content.

## 4 Results

A total of 304 riffle crests were mapped and assessed in the Napa River monitoring reach (Figure 5), 183 of which appeared to contain potential spawning gravels (rating of 2 or 3). Of these, 49 were targeted for potential sampling. Streambed slope was surveyed at 44 sites and 12 sites were discarded due to low slope. Another five sites were discarded due to lack of gravel, channel wetness, excessive coarseness/fineness of the substrate, or beaver activity (Table 5).

**Table 5.** Results of 2022 Napa River site selection surveys.

Spawning Quality Rating	Riffle Crest Count	Targeted for Potential Sampling	Discarded	Selected/ Sampled
1	121	0	0	0
2	133	28	7	21
3	50	21	10	11
<b>Total</b>	<b>304</b>	<b>49</b>	<b>17</b>	<b>32</b>

In Sonoma Creek, SEC identified 27 potential sampling sites and streambed slope was surveyed at 22 of these sites. Twenty-one sites met the slope criterion. Six sites were discarded due to channel wetness or visibly suboptimal streambed material (too coarse or too fine).

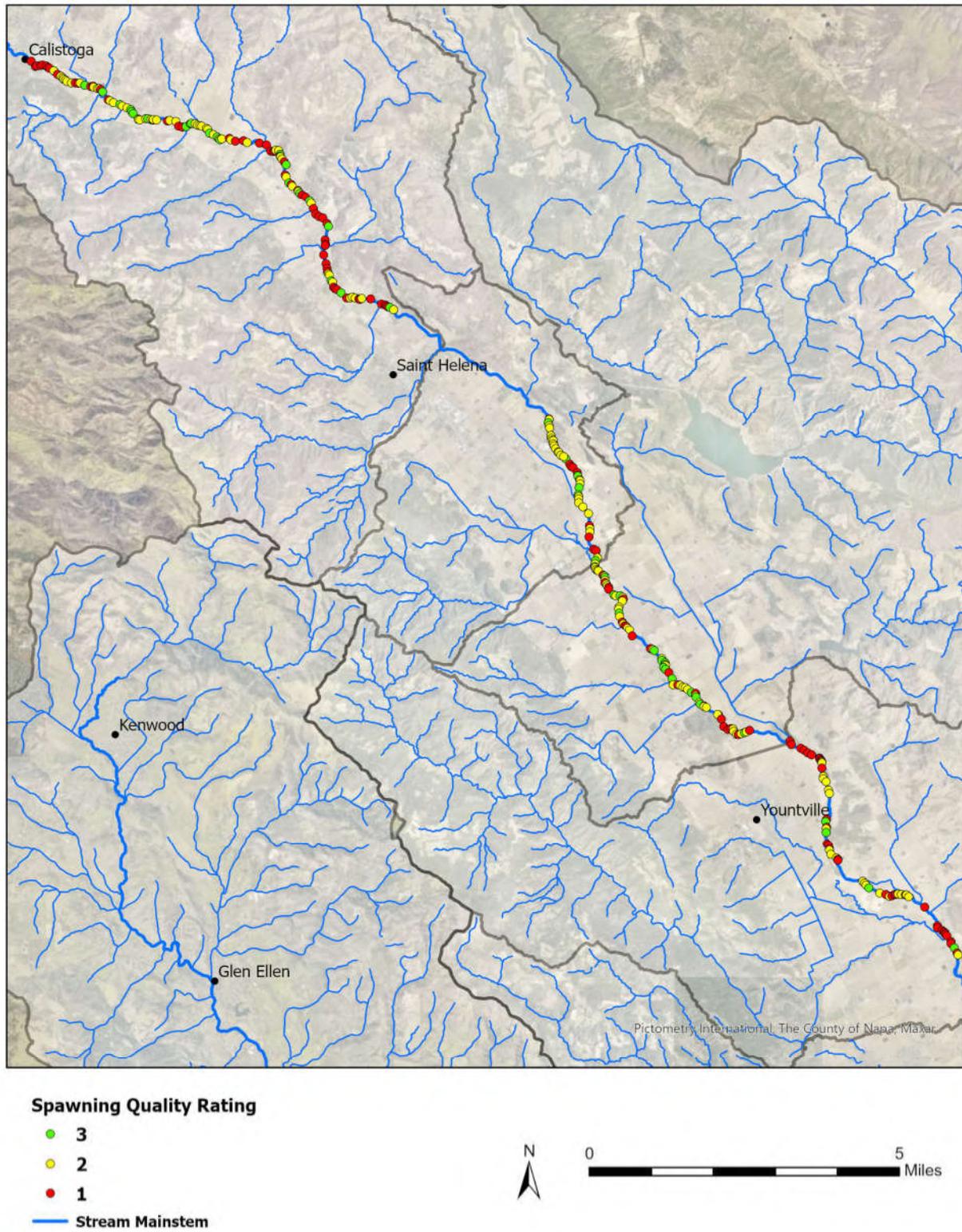


Figure 5. 2022 Napa River riffle crest locations (potential spawning sites) with spawning gravel quality ratings.

A total of 32 spawning gravel sites were selected for sampling in the Napa River monitoring reach along with 20 sites in Sonoma Creek (**Figure 6**), and bulk sediment samples from each site were collected, processed, and analyzed in each of the 2022 and 2023 collection years. Six sites in the Napa River monitoring reach (68300, 62000, 57220, 56670, 39620, and 23600) could not be reoccupied in 2023 because the riffle was no longer present at that location or had been inundated by a beaver pond. In each of these cases, samples were collected from a nearby accessible spawning riffle. Particle size statistics and fine sediment content were calculated from field and laboratory data (**Tables 6 and 7**).

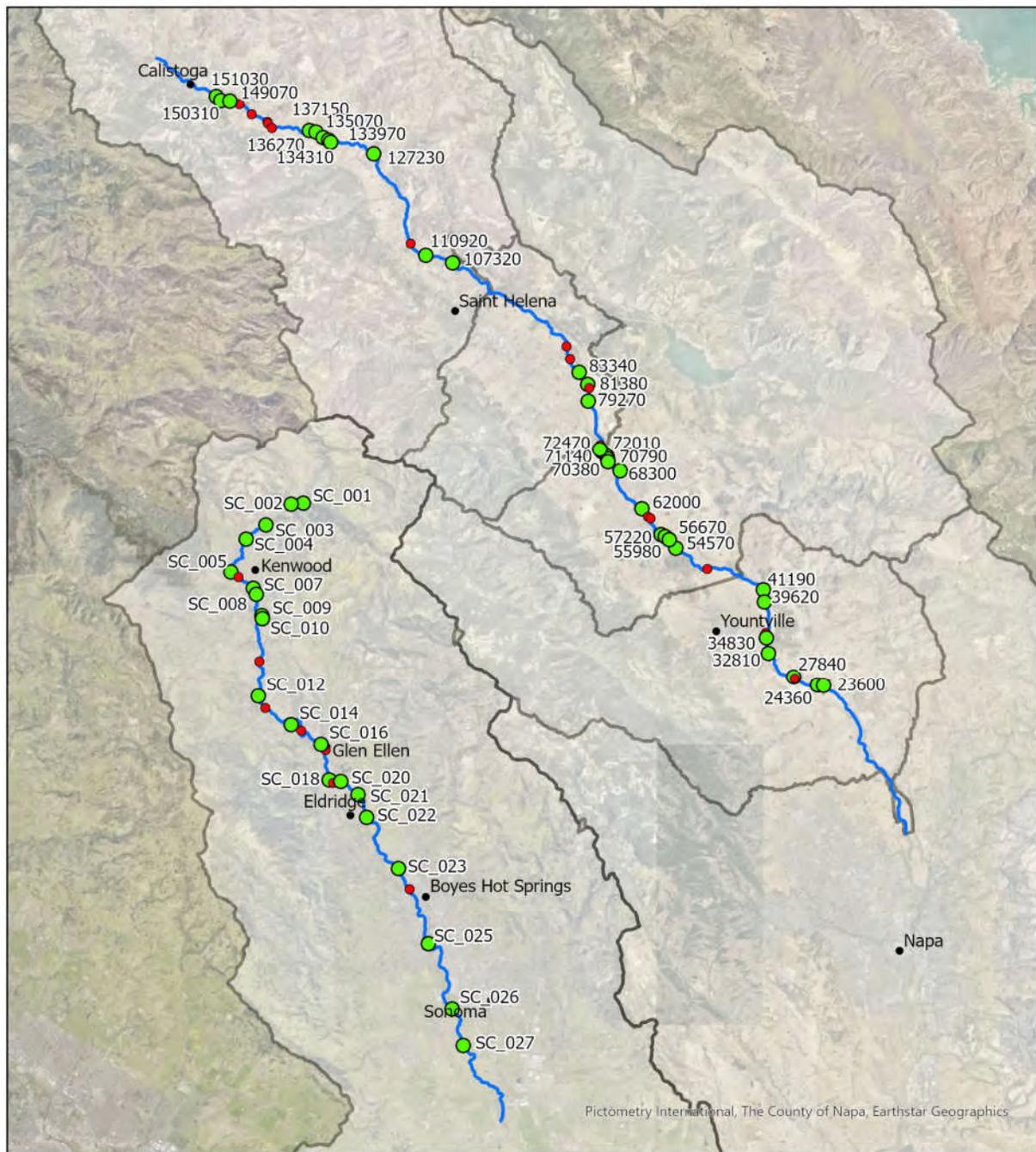
Particle size distributions for all uncorrected potential spawning gravel samples as a cumulative percentage of the sample are presented in **Figure 7**. Bulk sediment sampling results were also summarized by particle size classes according to Wentworth (1922). Charts showing particle size distributions by size class are provided in the **Attachment**. Copies of field data sheets, subsample laboratory analysis reports, and/or raw particle size distribution data are available upon request from Napa RCD.

**Figure 7** shows reasonably tight groupings of cumulative particle size distributions for potential spawning gravels for each stream and each collection year, with a small number of outliers. The outliers may represent the variation in potential spawning gravels or reflect the error in site selection and the difficulty in identifying and/or sampling spawning gravels versus adjacent gravels in the streambed. These plots show that the median statistics from **Tables 6 and 7** appear to be reasonable measures of the central tendencies of these distributions. In either stream, removal of outliers has only a small effect on median values.

An exponential decrease in streambed particle size in the downstream direction, known as downstream fining, is a characteristic of many alluvial streams. While not the focus of this monitoring effort, evidence of possible downstream fining in our data would be an additional indication of streambed function and may provide context for interpreting the results. Plots of  $d_{50}$  by river station are included in **Figure 8**. This figure indicates possible trends toward downstream fining of the median grain size in both streams. Statistical analyses to determine significance were not performed. In the Napa River, a noticeable increase in  $d_{50}$  is observed downstream of the Conn Creek confluence in the 2022 dataset, possibly due to size-selective extraction of sediment at upstream reservoirs. For Sonoma Creek, the three upstream-most samples were omitted because they were collected in the confined upland channel where spawning, and therefore sampling, occurred in pockets of smaller gravels and do not likely represent the full range of grain sizes of the mobile bed.

To evaluate the effectiveness of streambed slope surveying in avoiding naturally fine-grained riffle crest substrate, and to support field observations that slope surveying was resulting in the

disqualification of high-quality spawning sites, a plot of the percentage of sediment finer than 2 mm versus bed slope was prepared for samples collected from the Napa River in 2022 (**Figure 9**). Upon visual assessment of the plot, there is not a clear or strong relationship between fine sediment content of potential spawning gravels and the local bed slope as measured in the field.



- Stream Mainstem
- Streambed Monitoring Site
- Discarded Site



**Figure 6.** Bulk sediment sampling reaches and sample locations, Napa River and Sonoma Creek mainstem channels. The contributing subreach drainage areas for the Napa River are included.

**Table 6a.** Results of bulk sediment sampling of spawning gravels, **Napa River, 2022**. Sites are presented in upstream to downstream order. Green indicates that the result is less than or equal to the standard. Red indicates that the result exceeds the standard.

Reach	Site	Visual Rating	Bed Slope	Sample Location	Potential Spawning Gravels								
					Particle Size (mm)				Percent Finer Than				
					d <sub>16</sub>	d <sub>50</sub>	d <sub>84</sub>	d <sub>g</sub>	1 mm	2 mm	5.6 mm	8 mm	
Calistoga to Sulphur Creek	151030	2	0.0034	bar	1.4	24.9	81.9 <sup>b</sup>	10.6	13.5%	19.3%	28.1%	31.2%	
	150310	2	0.0021	bar	1.7	12.2	37.3	7.9	8.9%	18.8%	34.6%	40.6%	
	149070	2	0.0023	bar	1.3	11.9	51.9	8.1	12.9%	22.8%	37.6%	42.9%	
	137150	3	0.0037	bar	0.9	13.6	42.5	6.1	18.0%	26.8%	36.3%	40.5%	
	136270	2	0.0023	bar	1.1	14.0	46.3	7.0	15.0%	24.5%	34.6%	38.7%	
	135070	3	0.0028	bar	1.1	12.5	44.2	7.1	14.2%	25.0%	37.3%	41.6%	
	134310	3	0.0022	thalweg	1.7	15.4	42.7	8.6	8.5%	18.2%	31.8%	37.3%	
	133970	3	0.0058	bar	2.4	15.3	36.8	9.3	7.0%	13.9%	26.2%	31.9%	
	127230	3	0.0034	bar	2.1	12.7	39.1	9.1	7.1%	15.3%	30.9%	38.0%	
	110920	2	0.0018 <sup>a</sup>	thalweg	1.1	7.7	66.4 <sup>b</sup>	8.5	14.1%	30.8%	46.7%	50.3%	
107320	3	0.0042	thalweg	1.1	16.4	52.3	7.7	14.2%	22.7%	31.8%	35.6%		
<b>median</b>					<b>1.3</b>	<b>13.6</b>	<b>44.2</b>	<b>8.1</b>	<b>13.5%</b>	<b>22.7%</b>	<b>34.6%</b>	<b>38.7%</b>	
Sulphur Creek to Bale Slough	83340	3	0.0022	bar	1.1	8.9	33.7	6.1	13.8%	27.1%	41.8%	47.4%	
	81380	3	0.0040	bar	1.5	8.4	30.8	6.8	10.6%	20.6%	38.5%	48.8%	
	79270	2	0.0039	thalweg	2.1	15.5	65.6 <sup>b</sup>	11.7	7.3%	15.5%	30.5%	37.8%	
<b>median</b>					<b>1.5</b>	<b>8.9</b>	<b>33.7</b>	<b>6.8</b>	<b>10.6%</b>	<b>20.6%</b>	<b>38.5%</b>	<b>47.4%</b>	
Bale Slough to Conn Creek	72470	3	0.0019 <sup>a</sup>	thalweg	2.8	14.4	34.6	9.8	7.2%	12.2%	26.3%	33.5%	
	72010	2	0.0047	bar	2.1	4.7	11.2	4.8	5.4%	14.7%	56.6%	68.4%	
	71140	2	0.0024	bar	2.0	9.7	29.2	7.6	8.2%	16.2%	36.6%	44.0%	
	70790	2	0.0049	bar	0.7	9.8	28.6	4.5	22.2%	29.5%	39.2%	45.6%	
	70380	2	0.0027	thalweg	1.7	9.5	32.6	7.3	8.9%	19.1%	37.5%	46.0%	
	68300	2	0.0037	thalweg	1.1	11.2	41.4	6.8	14.4%	24.8%	37.2%	42.5%	
	62000	2	0.0058	bar	1.2	5.4	18.5	4.7	12.7%	28.0%	51.0%	57.3%	
	57220	2	0.0050	thalweg	1.4	5.2	24.3	5.9	8.8%	25.1%	51.7%	62.0%	
	56670	2	0.0021	thalweg	1.6	8.0	23.3	6.1	8.8%	19.9%	40.3%	49.9%	
	55980	3	0.0021	thalweg	1.0	5.3	15.8	4.1	15.3%	28.7%	51.1%	59.9%	
54570	3	0.0021	bar	2.7	12.6	33.2	9.5	5.2%	11.9%	28.0%	37.0%		
<b>median</b>					<b>1.6</b>	<b>9.5</b>	<b>28.6</b>	<b>6.1</b>	<b>8.8%</b>	<b>19.9%</b>	<b>39.2%</b>	<b>46.0%</b>	
Conn Creek to Tidal Boundary	41190	2	0.0034	thalweg	1.1	13.9	57.4	7.9	15.0%	24.6%	35.6%	40.2%	
	39620	2	0.0036	bar	2.8	28.8	72.4 <sup>b</sup>	14.3	9.3%	14.0%	21.7%	26.1%	
	34830	2	0.0029	bar	2.8	16.7	47.7	11.6	8.1%	13.4%	23.4%	30.3%	
	32810	2	0.0030	thalweg	1.0	9.4	35.4	5.8	16.7%	27.2%	40.1%	46.2%	
	27840	2	0.0018 <sup>a</sup>	thalweg	1.6	14.0	38.6	7.8	10.7%	19.1%	33.0%	38.6%	
	24360	2	0.0028	bar	5.5	14.7	29.7	12.8	6.2%	8.7%	16.3%	24.0%	
23600	2	0.0023	bar	1.1	10.1	32.9	5.9	14.9%	27.2%	40.3%	44.4%		
<b>median</b>					<b>1.6</b>	<b>14.0</b>	<b>38.6</b>	<b>7.9</b>	<b>10.7%</b>	<b>19.1%</b>	<b>33.0%</b>	<b>38.6%</b>	
<b>Napa River Mainstem Overall</b>					<b>median</b>	<b>1.5</b>	<b>12.4</b>	<b>37.1</b>	<b>7.7</b>	<b>10.6%</b>	<b>20.2%</b>	<b>36.4%</b>	<b>41.1%</b>
					<b>min</b>	<b>0.7</b>	<b>4.7</b>	<b>11.2</b>	<b>4.1</b>	<b>5.2%</b>	<b>8.7%</b>	<b>16.3%</b>	<b>24.0%</b>
					<b>max</b>	<b>5.5</b>	<b>28.8</b>	<b>81.9</b>	<b>14.3</b>	<b>22.2%</b>	<b>30.8%</b>	<b>56.6%</b>	<b>68.4%</b>
<b>Gravel Quality Standard</b>					<b>&lt;40mm</b>				<b>&lt;14%</b>		<b>&lt;30%</b>		

d<sub>16</sub> = the grain size diameter at which 16% of the sample is finer

d<sub>50</sub> = the median grain size diameter, at which 50% of the sample is finer

d<sub>84</sub> = the grain size diameter at which 84% of the sample is finer

d<sub>g</sub> = geometric mean diameter,  $d_g = (d_{84} * d_{16})^{0.5}$

a = Although below the minimum bed slope of 0.002 specified in the Monitoring Plan, this sample was included to meet the collection goal of 32 total samples within available time and budget constraints.

b = The d<sub>84</sub> could not be properly calculated for this sample since it is greater than the largest sieve size. The value shown is an estimate based on an extrapolation of the particle size distribution.

**Table 6b.** Results of bulk sediment sampling of spawning gravels, **Napa River, 2023**. Sites are presented in upstream to downstream order. Green indicates that the result is less than or equal to the standard. Red indicates that the result exceeds the standard.

Reach	Site	Sample Location	Potential Spawning Gravels							
			Particle Size (mm)				Percent Finer Than			
			d <sub>16</sub>	d <sub>50</sub>	d <sub>84</sub>	d <sub>g</sub>	1 mm	2 mm	5.6 mm	8 mm
Calistoga to Sulphur Creek	151030	bar	1.6	14.4	59.1	9.8	10.2%	18.6%	32.1%	36.7%
	150310	bar	1.5	15.4	44.2	8.0	11.4%	19.7%	30.7%	35.3%
	149070	bar	1.1	16.2	56.0	8.0	14.0%	25.2%	36.6%	40.0%
	137150	bar	1.5	16.4	42.1	8.0	10.3%	19.5%	31.1%	36.5%
	136270	bar	0.9	9.7	27.9	5.0	17.6%	25.8%	37.9%	44.3%
	135070	bar	1.1	19.3	56.8	7.8	14.8%	27.5%	37.2%	39.5%
	134310	bar	1.2	15.7	42.3	7.0	13.9%	22.8%	33.0%	36.6%
	133970	bar	2.5	27.3	63.9 <sup>b</sup>	12.7	9.8%	14.1%	22.6%	25.2%
	127230	bar	2.5	22.9	69.0 <sup>b</sup>	13.2	8.4%	13.1%	25.4%	30.3%
	110920	bar	1.8	27.4	74.6 <sup>b</sup>	11.6	8.9%	17.3%	27.9%	30.9%
	107320	bar	1.2	8.7	31.5	6.2	13.1%	22.1%	39.1%	47.9%
		<b>median</b>	<b>1.5</b>	<b>16.2</b>	<b>56.0</b>	<b>8.0</b>	<b>11.4%</b>	<b>19.7%</b>	<b>32.1%</b>	<b>36.6%</b>
Sulphur Creek to Bale Slough	83340	bar	1.0	11.2	33.9	5.9	15.5%	25.0%	39.4%	43.7%
	81380	bar	1.0	11.6	40.3	6.5	15.5%	24.0%	37.5%	41.6%
	79270	bar	1.8	13.2	38.5	8.3	10.9%	17.3%	31.1%	36.5%
		<b>median</b>	<b>1.0</b>	<b>11.6</b>	<b>38.5</b>	<b>6.5</b>	<b>15.5%</b>	<b>24.0%</b>	<b>37.5%</b>	<b>41.6%</b>
Bale Slough to Conn Creek	72470	thalweg	2.2	15.7	32.3	8.4	9.9%	15.0%	26.3%	31.2%
	72010	thalweg	0.6	8.2	24.2	3.9	28.2%	36.7%	45.6%	49.5%
	71140	bar	0.6	5.3	19.7	3.4	25.4%	35.9%	50.9%	57.7%
	70790	bar	10.6	22.8	37.6	19.9	9.0%	9.8%	11.2%	12.3%
	70380	bar	1.1	9.5	27.4	5.5	14.5%	25.3%	39.4%	45.2%
	69180 <sup>c</sup>	bar	1.9	13.9	39.2	8.6	10.2%	16.5%	29.7%	35.4%
	65700 <sup>c</sup>	bar	1.4	10.4	28.7	6.3	10.5%	22.4%	37.0%	43.0%
	60240 <sup>c</sup>	bar	1.7	13.5	36.3	8.0	10.6%	17.5%	30.4%	35.7%
	58510 <sup>c</sup>	bar	2.3	10.0	25.9	7.7	5.6%	13.7%	32.3%	42.0%
	55980	bar	2.2	9.4	20.5	6.8	8.5%	14.7%	31.6%	42.7%
54570	bar	2.2	8.2	22.1	7.0	6.5%	14.3%	37.6%	49.2%	
		<b>median</b>	<b>1.9</b>	<b>10.0</b>	<b>27.4</b>	<b>7.0</b>	<b>10.2%</b>	<b>16.5%</b>	<b>32.3%</b>	<b>42.7%</b>
Conn Creek to Tidal Boundary	41190	bar	1.2	21.6	58.6	8.4	13.6%	22.0%	32.6%	36.2%
	39850 <sup>c</sup>	bar	1.4	6.8	33.7	6.8	10.2%	23.3%	46.0%	53.4%
	34830	bar	0.8	7.9	26.4	4.7	18.9%	29.4%	44.8%	50.2%
	32810	bar	0.6	6.1	21.7	3.7	24.2%	33.7%	48.1%	55.5%
	27840	bar	1.6	12.4	43.3	8.4	10.4%	18.6%	33.7%	39.7%
	24360	bar	6.8	17.6	35.4	15.6	6.3%	6.9%	12.9%	18.5%
	23320 <sup>c</sup>	bar	1.4	11.9	32.1	6.7	13.7%	19.3%	32.2%	38.6%
		<b>median</b>	<b>1.4</b>	<b>11.9</b>	<b>33.7</b>	<b>6.8</b>	<b>13.6%</b>	<b>22.0%</b>	<b>33.7%</b>	<b>39.7%</b>
<b>Mainstem Overall</b>		<b>median</b>	<b>1.5</b>	<b>12.8</b>	<b>35.9</b>	<b>7.8</b>	<b>10.8%</b>	<b>19.6%</b>	<b>32.8%</b>	<b>39.6%</b>
		<b>min</b>	<b>0.6</b>	<b>5.3</b>	<b>19.7</b>	<b>3.4</b>	<b>5.6%</b>	<b>6.9%</b>	<b>11.2%</b>	<b>12.3%</b>
		<b>max</b>	<b>10.6</b>	<b>27.4</b>	<b>74.6</b>	<b>19.9</b>	<b>28.2%</b>	<b>36.7%</b>	<b>50.9%</b>	<b>57.7%</b>
<b>Gravel Quality Standard</b>			<b>&lt;40mm</b>				<b>&lt;14%</b>		<b>&lt;30%</b>	

d<sub>16</sub> = the grain size diameter at which 16% of the sample is finer

d<sub>50</sub> = the median grain size diameter, at which 50% of the sample is finer

d<sub>84</sub> = the grain size diameter at which 84% of the sample is finer

d<sub>g</sub> = geometric mean diameter,  $d_g = (d_{84} * d_{16})^{0.5}$

b = The d<sub>84</sub> could not be properly calculated for this sample since it is greater than the largest sieve size. The value shown is an estimate based on an extrapolation of the particle size distribution.

c = 2022 sampling location could not be reoccupied. Sample was collected at nearest accessible and sampleable spawning site.

**Table 7a.** Results of bulk sediment sampling of spawning gravels, **Sonoma Creek, 2022**. Sites are presented in upstream to downstream order. Green indicates that the result is less than or equal to the standard. Red indicates that the result exceeds the standard.

Site ID	Site Location	Bed Slope	Sample Location	Potential Spawning Gravels							
				Particle Size (mm)				Percent Finer Than			
				d <sub>16</sub>	d <sub>50</sub>	d <sub>84</sub>	d <sub>g</sub>	1 mm	2 mm	5.6 mm	8 mm
SC_001	Sugarloaf boundary	0.0273	bar	1.6	7.2	17.2	5.2	9.6%	19.6%	41.1%	53.6%
SC_002	Pierson	0.0138	bar	2.3	7.6	16.4	6.2	5.1%	13.2%	37.0%	52.5%
SC_003	Fosters Crossing	0.0123	bar	1.6	7.9	26.3	6.6	9.1%	19.3%	38.5%	50.2%
SC_004	Rose Property	0.0078	bar	1.8	7.5	19.4	5.8	7.5%	18.2%	41.3%	51.7%
SC_005	Frey Confluence	0.0041	bar	1.7	12.4	37.9	8.1	8.6%	17.9%	32.6%	39.4%
SC_007	Tonelee	0.0038	bar	1.5	15.9	45.5	8.2	12.4%	19.5%	31.1%	35.6%
SC_008	Cypress	0.0032	bar	0.8	10.0	30.7	5.0	18.9%	28.2%	39.6%	45.6%
SC_009	above LWD	0.0030	bar	1.8	13.4	32.6	7.6	10.3%	17.3%	29.3%	37.1%
SC_010	below LWD	0.0099	bar	5.0	12.3	25.4	11.3	1.8%	3.6%	18.6%	30.8%
SC_012	Yulupa	0.0072	bar	1.3	8.5	34.7	6.7	12.2%	23.5%	41.0%	48.6%
SC_014	Dodwell	0.0089	bar	2.3	10.4	27.8	8.0	6.6%	13.8%	33.5%	41.8%
SC_016	Insley	0.0052	bar	1.7	18.9	59.0	9.9	12.0%	17.4%	28.2%	33.9%
SC_018	SDC upstream	0.0032	bar	3.4	7.4	14.0	6.9	5.5%	6.5%	36.4%	54.0%
SC_020	Station A	0.0057	bar	2.6	22.1	60.8	12.6	5.4%	13.0%	25.6%	31.4%
SC_021	SDC downstream	0.0035	bar	1.2	12.8	41.1	7.1	13.1%	23.4%	35.4%	40.7%
SC_022	Madrone	0.0200	bar	1.7	6.3	19.9	5.8	7.2%	19.3%	46.0%	57.9%
SC_023	Agua Caliente	0.0080	bar	1.6	3.3	7.0	3.3	4.4%	24.7%	77.0%	88.3%
SC_025	Maxwell	0.0046	bar	2.8	5.4	33.0	9.7	0.2%	3.9%	52.1%	66.6%
SC_026	Leveroni	0.0043	thalweg	2.6	23.3	52.4	11.6	6.1%	12.7%	26.6%	31.7%
SC_027	Watmaugh	0.0032	thalweg	3.0	14.1	45.2	11.7	5.2%	11.2%	24.6%	34.2%
<b>median</b>				<b>1.8</b>	<b>10.2</b>	<b>31.7</b>	<b>7.4</b>	<b>7.4%</b>	<b>17.6%</b>	<b>35.9%</b>	<b>43.7%</b>
<b>min</b>				0.8	3.3	7.0	3.3	0.2%	3.6%	18.6%	30.8%
<b>max</b>				5.0	23.3	60.8	12.6	18.9%	28.2%	77.0%	88.3%
<b>Gravel Quality Standard</b>				<b>&lt;40mm</b>		<b>&lt;14%</b>		<b>&lt;30%</b>			

d<sub>16</sub> = the grain size diameter at which 16% of the sample is finer  
d<sub>50</sub> = the median grain size diameter, at which 50% of the sample is finer  
d<sub>84</sub> = the grain size diameter at which 84% of the sample is finer  
d<sub>g</sub> = geometric mean diameter,  $d_g = (d_{84} * d_{16})^{0.5}$

**Table 7b.** Results of bulk sediment sampling of spawning gravels, **Sonoma Creek, 2023**. Sites are presented in upstream to downstream order. Green indicates that the result is less than or equal to the standard. Red indicates that the result exceeds the standard.

Site ID	Site Description	Sample Location	Potential Spawning Gravels							
			Particle Size (mm)				Percent Finer Than			
			d <sub>16</sub>	d <sub>50</sub>	d <sub>84</sub>	d <sub>g</sub>	1 mm	2 mm	5.6 mm	8 mm
SC-001	Sugarloaf Boundary	bar	2.1	10.3	30.3	7.9	8.5%	15.6%	33.4%	42.0%
SC-002	Pierson	bar	1.6	20.0	44.1	8.4	12.2%	17.8%	26.0%	28.5%
SC-003	Fosters Crossing	bar	1.8	9.6	18.6	5.7	12.4%	16.7%	29.7%	40.6%
SC-004	Rose Property	thalweg	1.5	17.5	57.7	9.2	11.0%	19.8%	30.0%	34.9%
SC-005	Frey Confluence	bar	1.2	10.0	31.4	6.0	14.0%	22.7%	37.2%	43.5%
SC-007	Tonelee	bar	0.9	10.8	37.0	5.8	16.7%	22.1%	37.0%	43.0%
SC-008	Cypress	bar	2.4	19.2	49.1	10.8	10.9%	14.7%	24.6%	30.9%
SC-009	Above LWD	bar	1.5	17.1	52.9	8.8	11.8%	19.5%	30.9%	36.3%
SC-010	Below LWD	bar	3.1	11.7	29.6	9.5	6.6%	10.2%	28.5%	37.2%
SC-012	Yulupa	bar	1.1	12.0	63.3 <sup>b</sup>	8.3	14.9%	23.2%	36.1%	42.6%
SC-014	Dodwell	bar	3.4	20.3	45.8	12.5	8.1%	11.0%	22.1%	26.3%
SC-016	Insley	bar	1.7	13.4	54.9	9.7	11.7%	17.4%	31.5%	38.7%
SC-018	SDC Upstream	bar	3.4	16.5	60.9	14.4	4.4%	8.3%	24.8%	32.9%
SC-020	Station A	thalweg	3.0	29.5	73.1 <sup>b</sup>	14.9	6.6%	12.7%	21.1%	25.7%
SC-021	SDC Downstream	bar	4.7	21.9	59.0	16.7	3.3%	6.1%	18.7%	25.4%
SC-022	Madrone	bar	1.7	8.2	63.0	10.3	4.9%	20.7%	45.1%	49.6%
SC-023	Agua Caliente	bar	3.5	13.6	29.5	10.2	7.4%	10.1%	23.0%	30.4%
SC-025	Maxwell	bar	2.1	17.9	44.9	9.6	9.3%	15.7%	26.5%	32.1%
SC-026	Leveroni	bar	1.0	10.9	37.0	6.1	15.8%	25.6%	38.0%	44.1%
SC-027	Watmaugh	bar	1.2	12.2	40.0	6.8	13.7%	24.4%	38.0%	41.5%
		<b>median</b>	<b>1.8</b>	<b>13.5</b>	<b>45.4</b>	<b>9.4</b>	<b>11.0%</b>	<b>17.1%</b>	<b>29.9%</b>	<b>36.8%</b>
		min	0.9	8.2	18.6	5.7	3.3%	6.1%	18.7%	25.4%
		max	4.7	29.5	73.1	16.7	16.7%	25.6%	45.1%	49.6%
<b>Gravel Quality Standard</b>			<b>&lt;40mm</b>				<b>&lt;14%</b>		<b>&lt;30%</b>	

d<sub>16</sub> = the grain size diameter at which 16% of the sample is finer

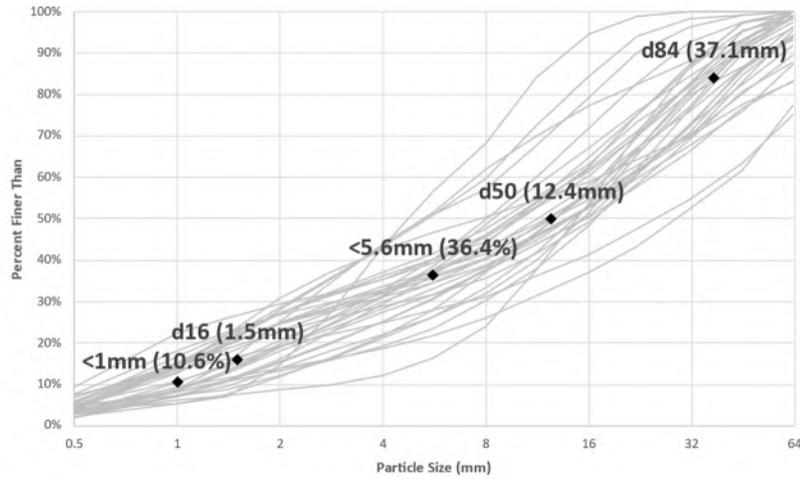
d<sub>50</sub> = the median grain size diameter, at which 50% of the sample is finer

d<sub>84</sub> = the grain size diameter at which 84% of the sample is finer

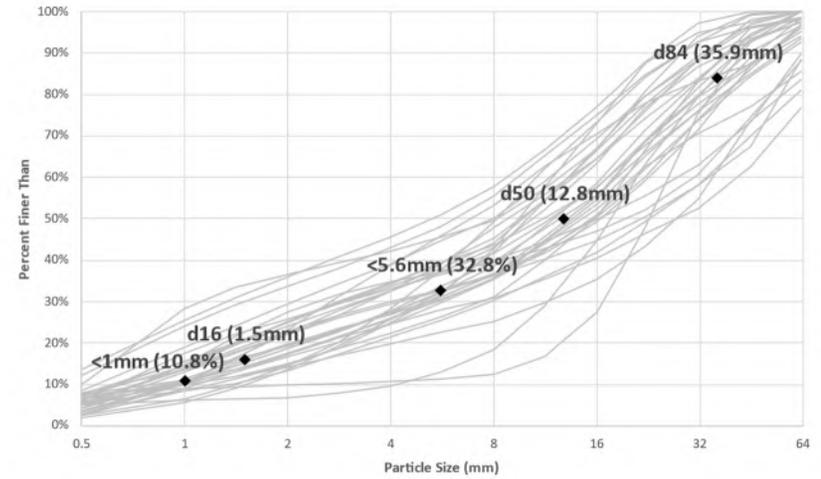
d<sub>g</sub> = geometric mean diameter,  $d_g = (d_{84} * d_{16})^{0.5}$

b = The d<sub>84</sub> could not be properly calculated for this sample since it is greater than the largest sieve size. The value shown is an estimate based on an extrapolation of the particle size distribution.

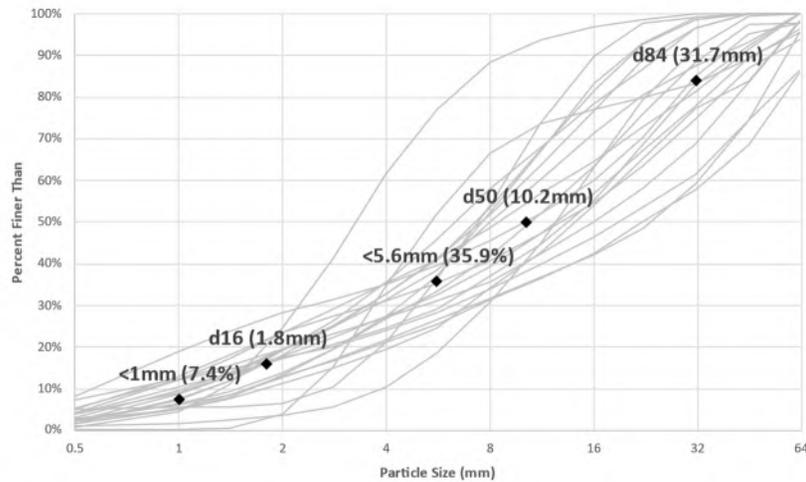
Napa River 2022



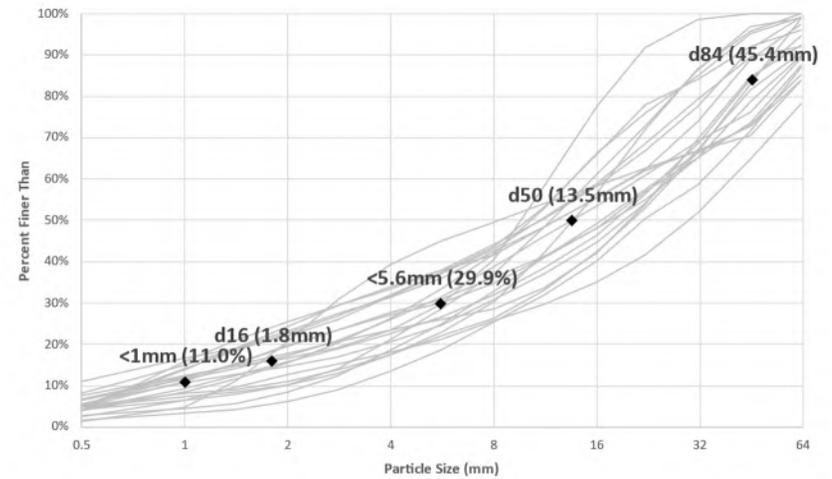
Napa River 2023



Sonoma Creek 2022

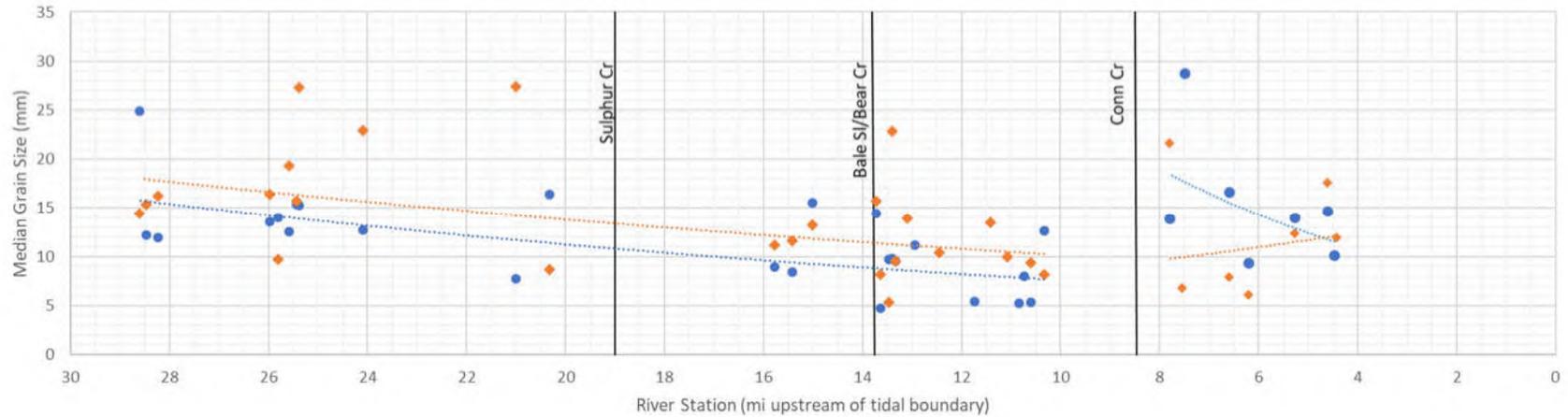


Sonoma Creek 2023

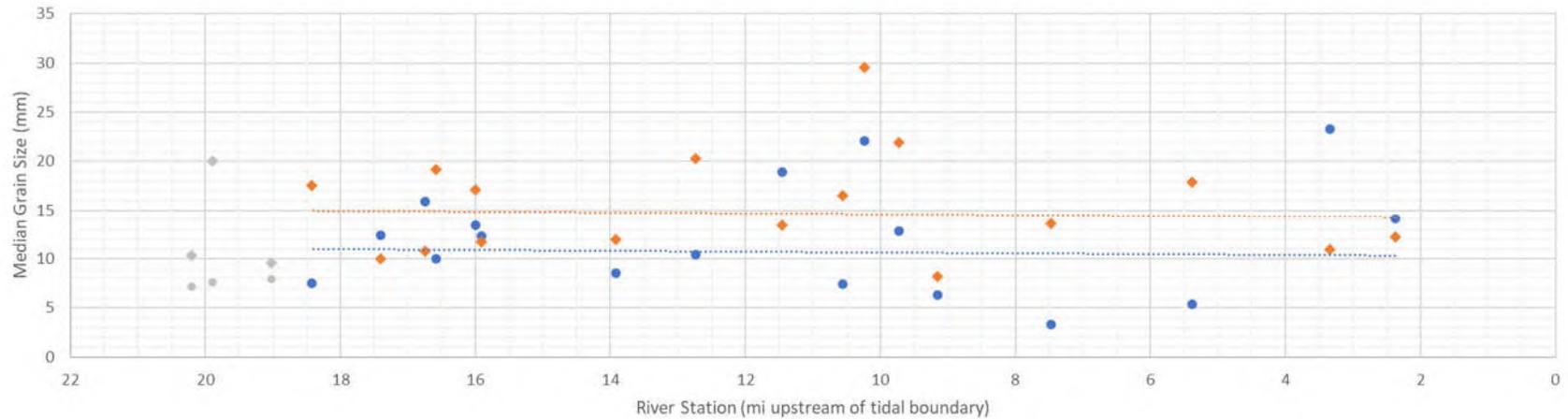


**Figure 7.** Cumulative particle size distributions of all samples of potential spawning gravels by collection year for Napa River and Sonoma Creek. Labeled points are median values of key statistics.

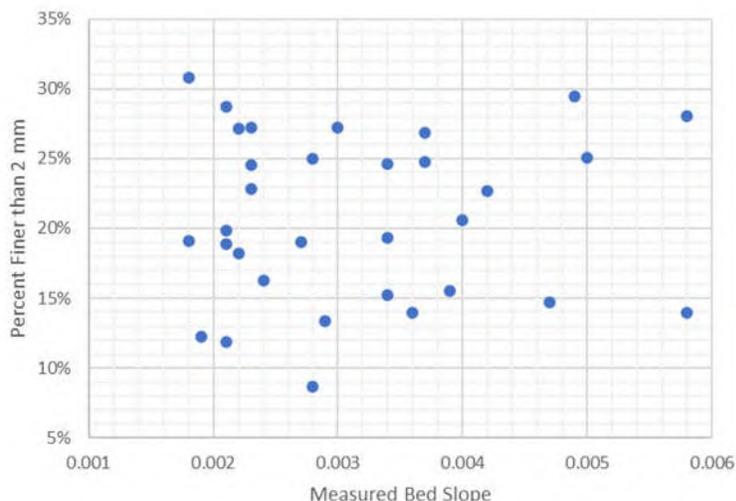
Napa River



Sonoma Creek



**Figure 8.** Median grain size diameter ( $d_{50}$ ) by river station for Napa River and Sonoma Creek. Exponential trendlines are included to show possible trends, but statistical analyses were not performed to determine significance. Blue circles represent 2022 data, orange diamonds represent 2023 data, and grey points represent confined upland channel sites that were omitted because spawning occurs in pocket gravels which do not likely represent the full range of grain sizes of the mobile bed.



**Figure 9.** Fine sediment content plotted against measured bed slope. Each point denotes a bulk sediment sample from the 2022 Napa River sampling effort.

## 5 Discussion

### 5.1 Spawning Gravel Quality and Site Selection

The results of two consecutive years of bulk sediment sampling in the freshwater reaches of the mainstem Napa River and mainstem Sonoma Creek indicated that median values of the percentage of particles finer than 1 mm are generally below the 14% standard and appear to meet desired conditions for incubation of salmonid eggs. In addition, at the time of redd construction, fine sediment content can be expected to decrease due to the winnowing effect of gravel movement by spawning fish. To be conservative, a correction factor to account for this effect was not applied because the relative improvement and persistence of the cleaning effect is difficult to quantify.

For the Napa River, median values of the percentage of particles finer than 5.6 mm are above the 30% standard for emergence of fry in all subreaches. In Sonoma Creek, this metric was above the standard in 2022, and slightly below in 2023. In both streams, median percentage of particles finer than 5.6 mm generally decreased from 2022 to 2023, suggesting an effect of streamflow conditions. Where the finer than 5.6 mm content was elevated, the results are near the desired condition of  $\leq 30\%$ . As with the assessment for incubation conditions, the finer than 5.6 mm content can be expected to decrease during redd building from conditions encountered during sampling although, to be conservative, a correction factor was not applied. It is unknown whether these results indicate degraded streambed conditions or are typical for these low-gradient streams. The cause of elevated levels of the coarse sand and fine gravel in

this size range likely has to do with large-scale variations in the sediment budgets of these streams and is beyond the scope of this study to assess.

The  $d_{50}$  and  $d_{84}$  sizes of potential spawning gravels in the Napa River and Sonoma Creek, are within the range of spawning gravel sizes reported elsewhere for steelhead and Chinook salmon (Kondolf & Wolman 1993) and well below the selected quality standard of less than 40 mm for the median particle diameter. This indicates that framework gravels are not overly coarse and are of an appropriate size that allows successful gravel movement and excavation by spawning salmonids.

Based on these results, fine sediments do not appear to be present in excess in potential spawning gravels to significantly impair incubation of salmonid eggs in the Napa River or Sonoma Creek. However, we found that the amount of material in the coarse sand and fine gravel range was great enough to potentially decrease survival and emergence rates of salmonid fry in both years of sampling in the Napa River and in one of two years of sampling in Sonoma Creek.

This monitoring effort was completed in accordance with the approved Monitoring Plan. It included a well-established method, collection of a large number of samples spread along the full lengths of the freshwater mainstems, and repeat sampling of the same sites in different water year types. As specified in the study design, we sampled streambed gravels at sites we believed to be viable spawning riffles, as opposed to randomly sampling a subset of all spawning riffles. This monitoring effort set out to characterize the quality of spawning habitat and did not quantify the total amount of spawning habitat available in the mainstem. Specifically, this study focused on evaluating whether potential spawning gravels were either too coarse or had too much fine sediment.

## **5.2 Napa River Chinook Salmon Spawner Survey**

An extensive Chinook salmon spawner survey completed in the Napa River in WY 2023-24 offers an opportunity for comparison of sampling sites, selected according to the study design, with sites used by Chinook salmon. The spawner survey, completed in early January 2024, had 16.5 miles of overlap with the 2022 reconnaissance survey of riffle crests. It should be noted that these surveys were separated by the wet 2022-23 water year which included multiple large storm flows that altered streambed conditions.

Comparison of the datasets indicates that 53 redds were observed in the common areas, 52 of which were located at riffle crests and one that was placed mid-riffle. Thirty of the redds were located at riffle crests mapped as potential spawning sites and seven were located at sites that

were deemed unsuitable. Five redds were located at sites that were beaver dams in the spring of 2022 and six redds were at riffle crests that were beneath beaver ponds in 2022. It is important to note that many beaver dams are seasonal in the Napa River. They tend to be at least partially destroyed during high flow events and reconstructed during the spring recession, often in different locations. Five redds were located at sites that were not mapped in 2022. While these unmapped sites may have been simply missed in error by the survey crew, they are more likely evidence of the dynamic nature of the streambed, where features are often moved, changed, backwatered, etc. The common areas of these surveys included 21 of 32 sampled sites, only four of which had spawning redds, although redds were located within 500 feet of nine additional sampled sites. Five redds were located at sites that were disqualified based on the streambed slope survey.

Observation of actual spawning behavior demonstrated that our definition of potential sampling sites may have been too conservative and highlights the difficulties of site selection in the Napa River. Assuming that spawning Chinook are selecting high-quality sites, this comparison suggests that our visual riffle crest assessments were meaningful but not highly accurate in differentiating spawning riffles from unsuitable riffles. In this effort, we attempted to only sample sites that fish would select for spawning; however, comparing our results to the spawner survey reveals that our qualitative assessments were too conservative and overlooked potentially viable spawning locations. Although this comparison shows that the accuracy of the study design has limitations, importantly, we are not aware of how our conservative selection of spawning sites may have biased our results in any specific direction.

Additionally, the comparison of actual spawning behavior to anticipated spawning behavior indicates that the spawning suitability of individual riffles varies from season to season at a relatively large percentage of sites, largely due to beaver activity but also likely due to high flow events altering the streambed. Finally, the comparison confirms that the streambed slope surveys were screening out valid spawning areas.

### **5.3 Discontinuation of Streambed Slope Surveys**

In accordance with the Monitoring Plan, streambed slope surveys were used in site selection in Year 1 to screen potential sampling sites for low-gradient and potentially excessively sand-bedded conditions. In the field, the slope surveys were more labor-intensive and time-consuming than anticipated, and based on the results, several sampling sites that appeared to contain high quality spawning gravels were disqualified from the study due to low slope. This caused us to reconsider the use of local bed slope, as we were measuring it, as a screening criterion. A plot of measured bed slopes versus 2022 spawning gravel fine sediment content for our Napa River sites (**Figure 9**) did not indicate a strong relationship. While a relationship

between these variables is presumed to exist, it is likely complex and influenced by numerous geomorphic processes. In addition, Chinook salmon redds were observed at five disqualified riffle crests during subsequent spawner surveying in the Napa River. Discontinuation of streambed slope surveys is recommended for any future efforts.

#### **5.4 Recommendations**

To maintain and improve streambed habitat, continued watershed-wide implementation of best management practices is recommended. Practices related to reducing sediment runoff and reducing concentration of flow from vineyards and rural roads reduce delivery of fine sediments to streams and prevent channel incision. Many land managers in the Napa River and Sonoma Creek watersheds have adopted best practices with the assistance of neighbors and organizations, and dedicated attention to stewardship will help protect biodiversity for future generations.

## **6 References**

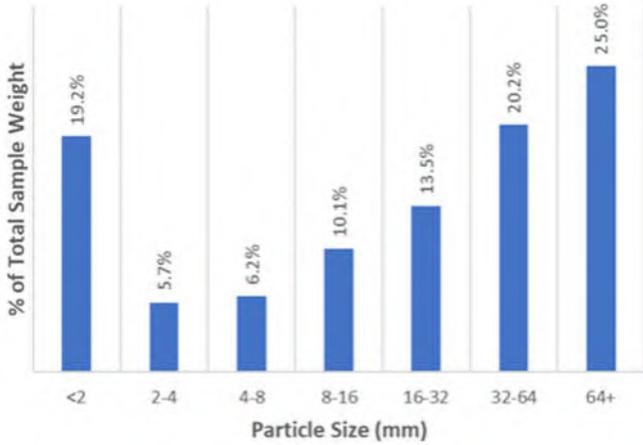
- Napa County Resource Conservation District (Napa RCD). 2020. Napa River and Sonoma Creek Vineyard General Permit Monitoring Plan. July 15, 2020.
- Schuett-Hames, D., B. Conrad, A. Pleus, and D. Smith. 1996. Field Comparison of the McNeil Sampler with Three Shovel-Based Methods Used to Sample Spawning Substrate Composition in Small Streams. Northwest Indian Fisheries Commission.
- Wentworth, C. 1922. A Scale of Grade and Class Terms for Clastic Sediments. *The Journal of Geology*, vol. 30, issue 5, pp. 377-392.
- Lamb, M. P., and J. G. Venditti. 2016. The grain size gap and abrupt gravel-sand transitions in rivers due to suspension fallout. *Geophysical Research Letters*, 43, doi:10.1002/2016GL068713. AGU Publications.
- Parker, G. 2008. Transport of gravel and sediment mixtures. Chapter 3. In: Garcia, M. (ed.), *Sedimentation engineering: Processes, measurements, modeling, and practice*. Am. Soc. Civil Engineers. Manual 110.
- Kondolf, G.M. 2000. Assessing Salmonid Spawning Gravel Quality. *Transactions of the American Fisheries Society* 129:262-281.
- State of California North Coast Regional Water Quality Control Board (Water Board). 2006. *Desired Salmonid Freshwater Habitat Conditions for Sediment-Related Indices*. July 28, 2006.
- Kondolf, G. M., and M. G. Wolman. 1993. The sizes of salmonid spawning gravels. *Water Resources Research* 29:2275–2285.

**ATTACHMENT**

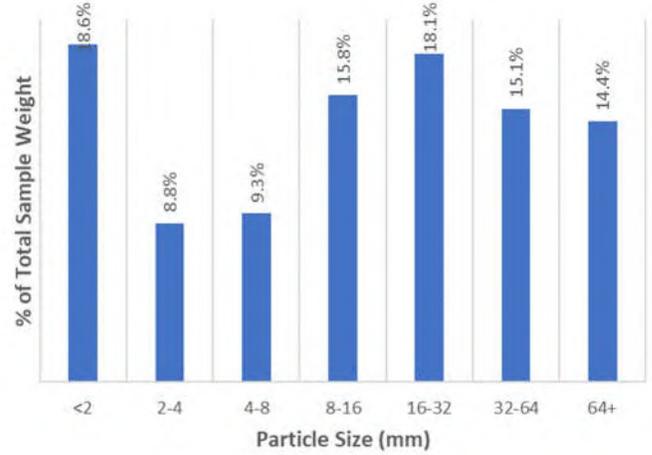
**PARTICLE SIZE DISTRIBUTION CHARTS BY SIZE CLASS**

# NAPA RIVER

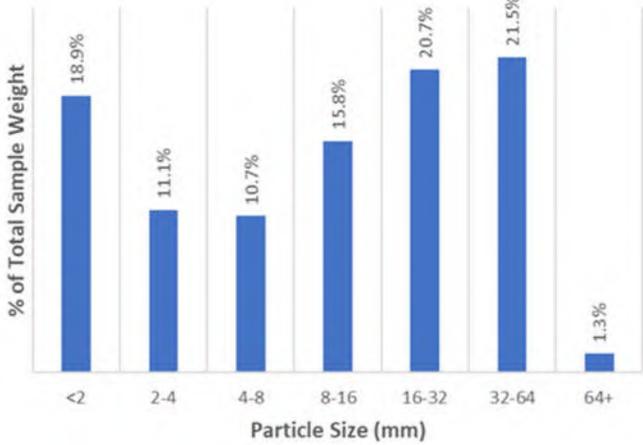
151030 2022



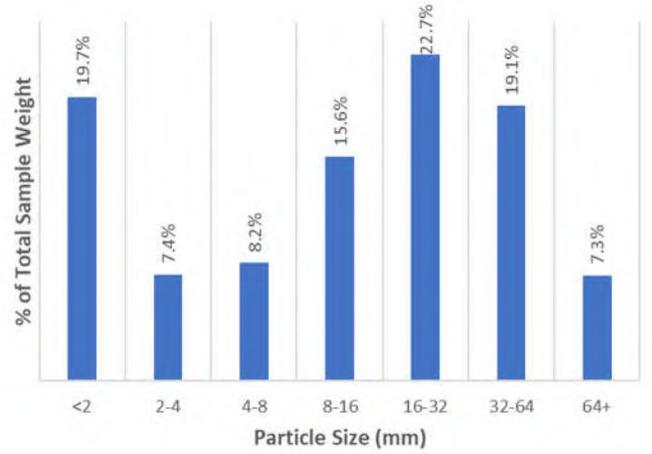
151030 2023



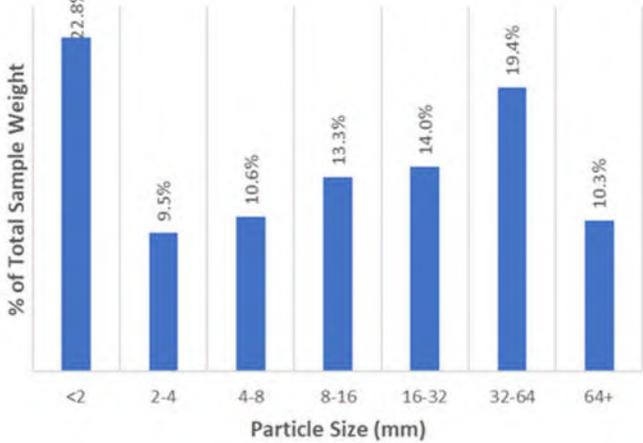
150310 2022



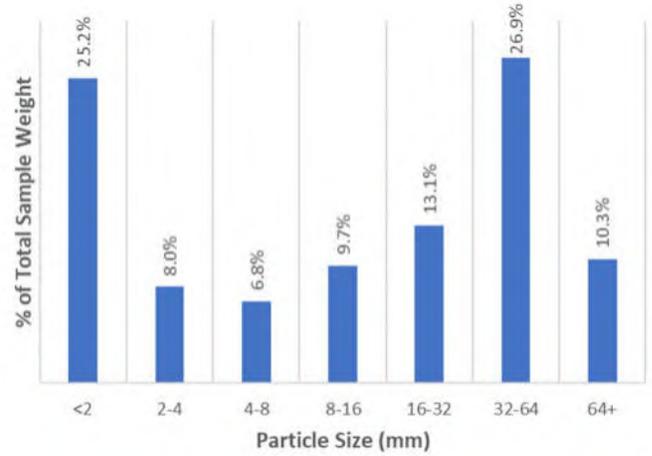
150310 2023



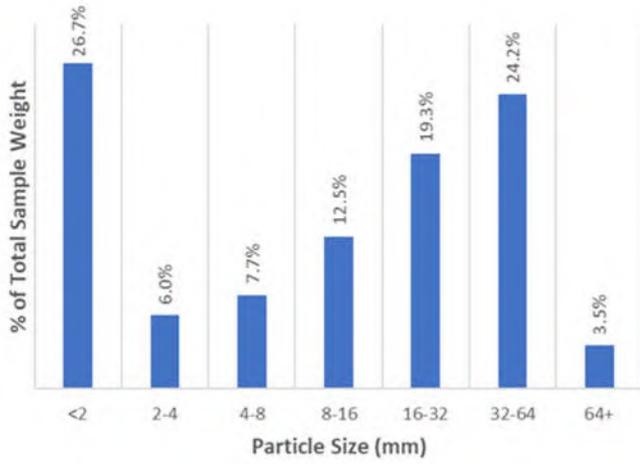
149070 2022



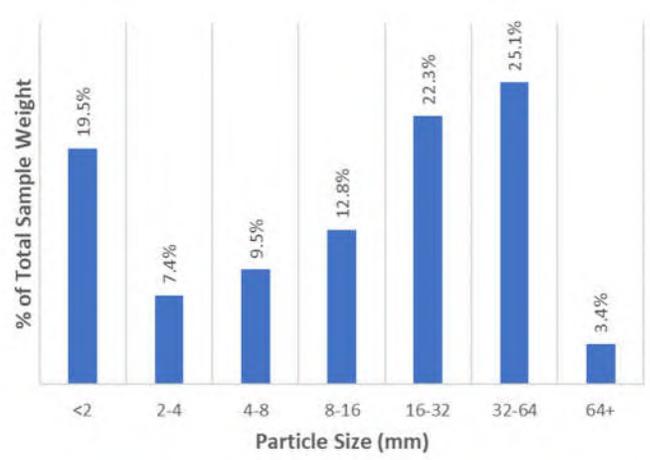
149070 2023



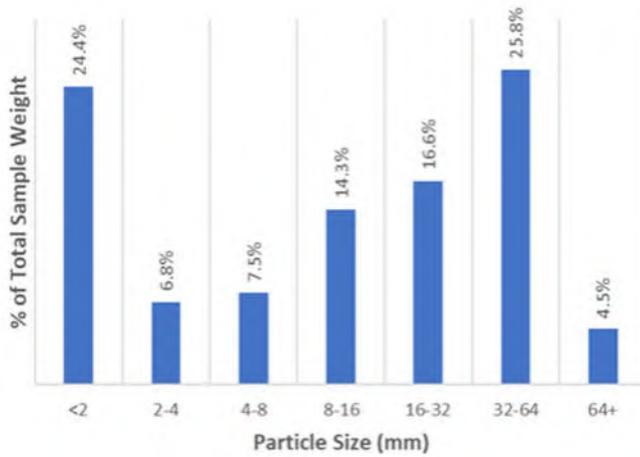
137150 2022



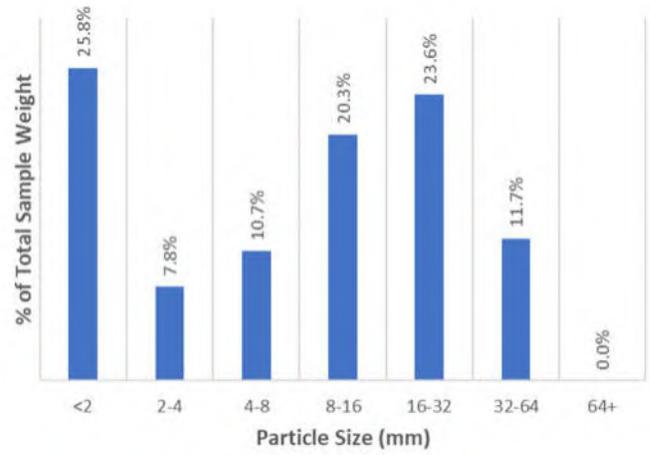
137150 2023



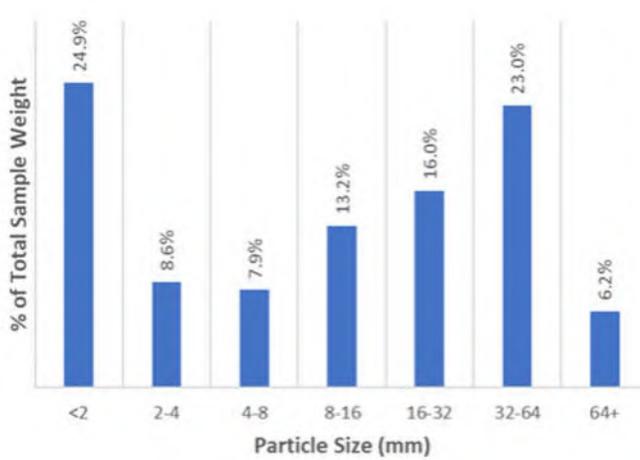
136270 2022



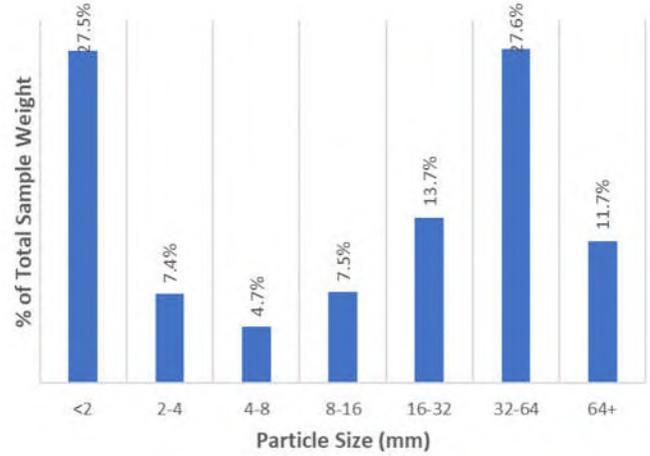
136270 2023



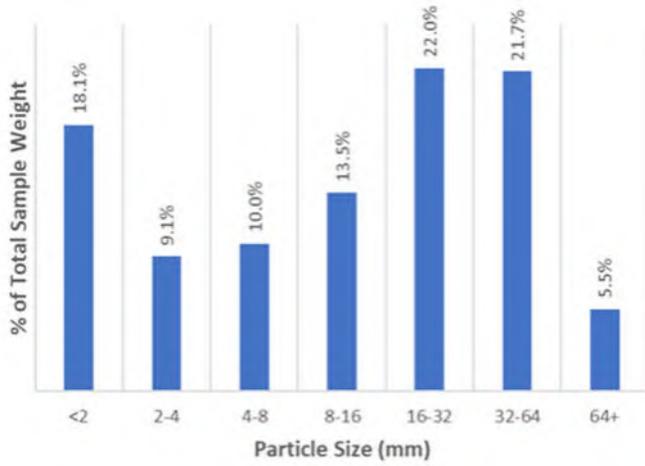
135070 2022



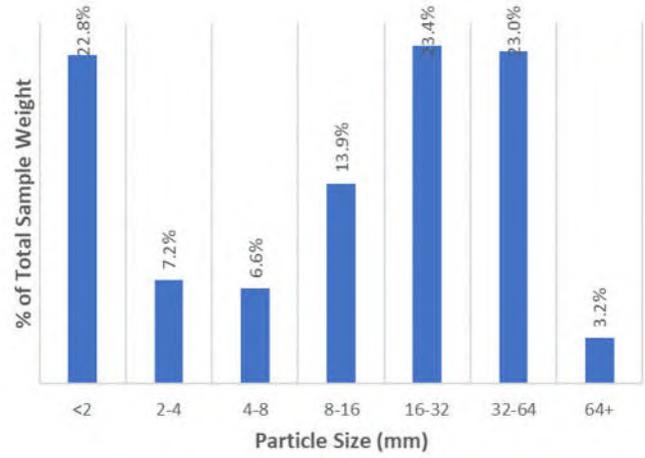
135070 2023



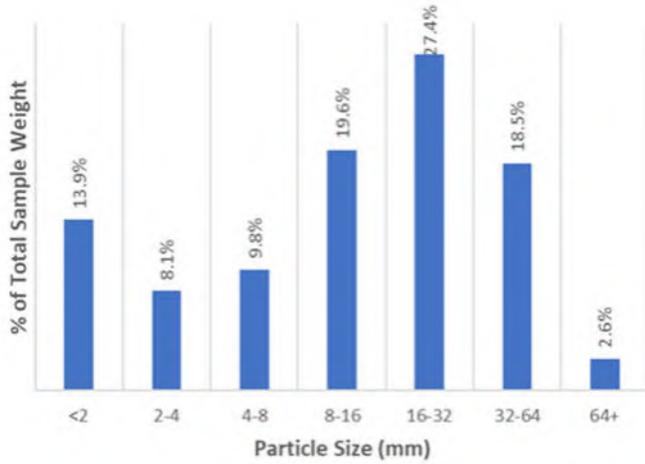
134310 2022



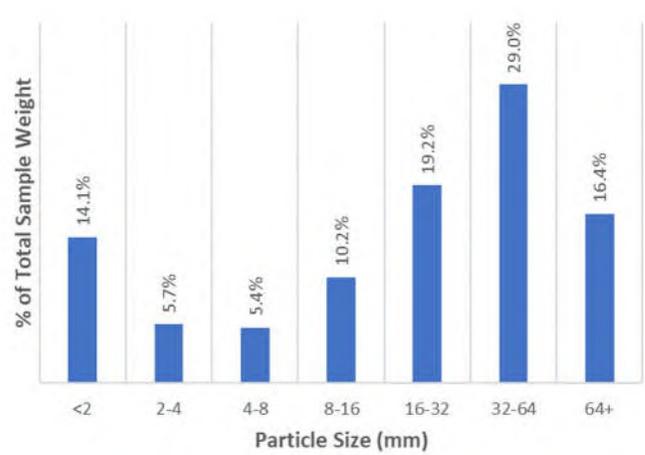
134310 2023



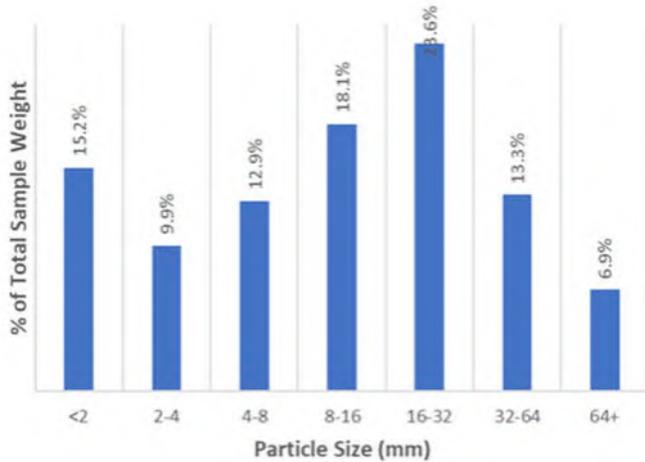
133970 2022



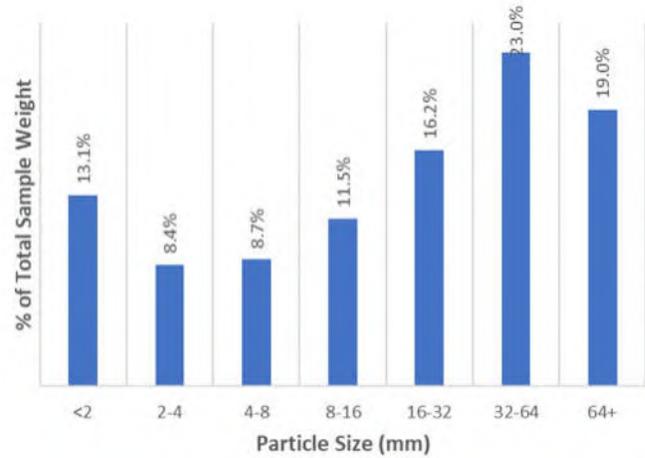
133970 2023



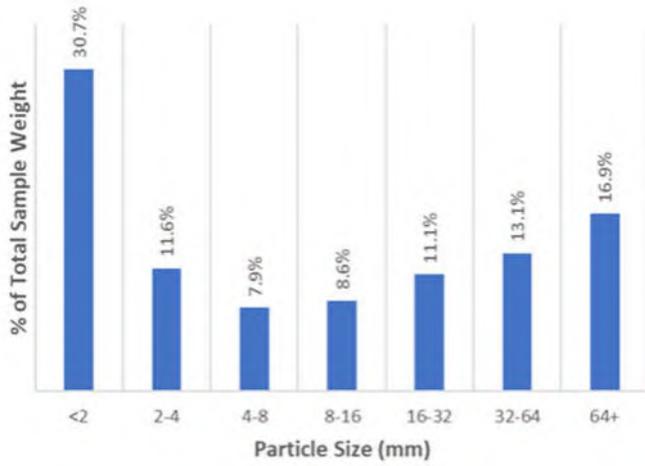
127230 2022



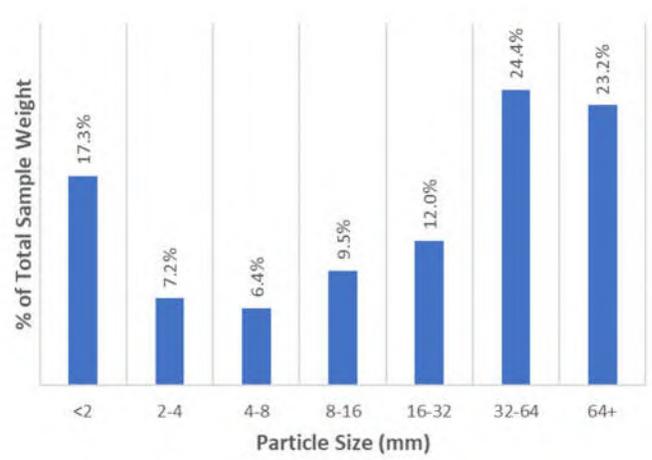
127230 2023



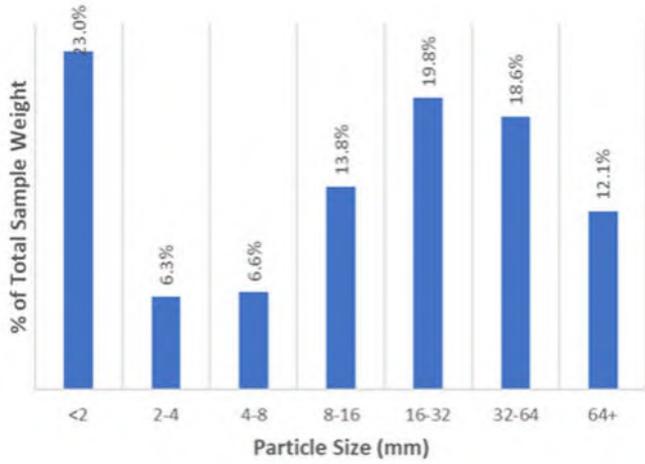
110920 2022



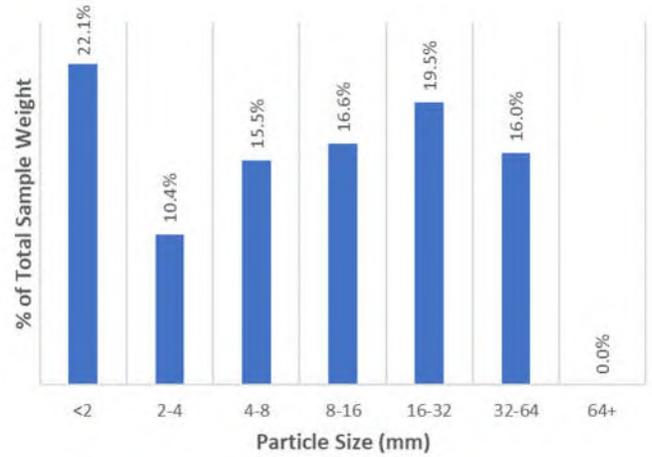
110920 2023



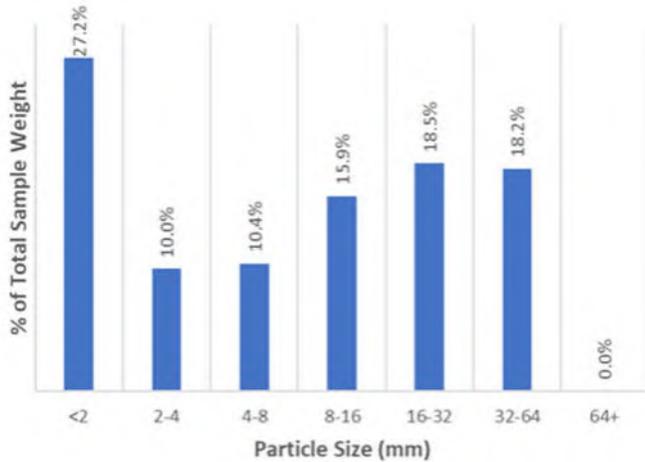
107320 2022



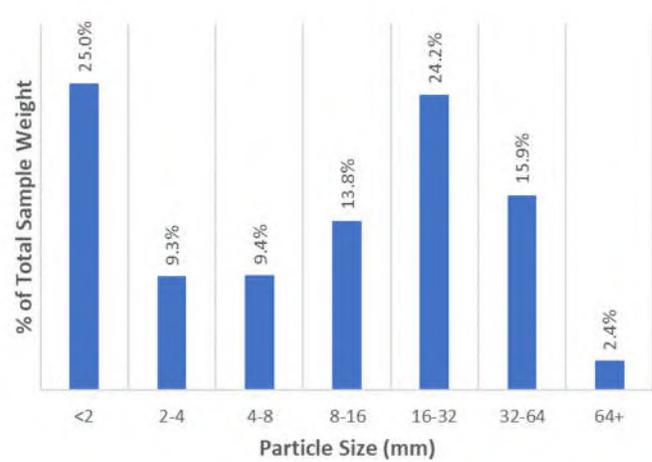
107320 2023



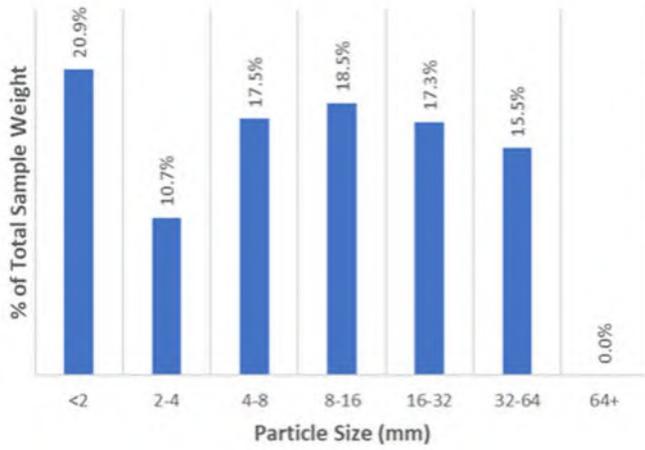
83340 2022



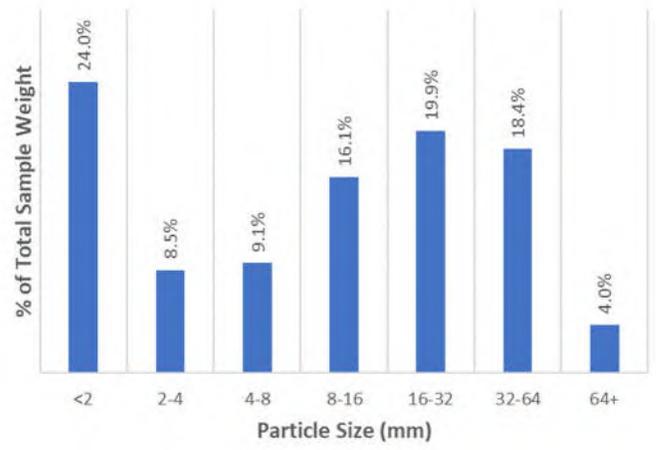
83340 2023



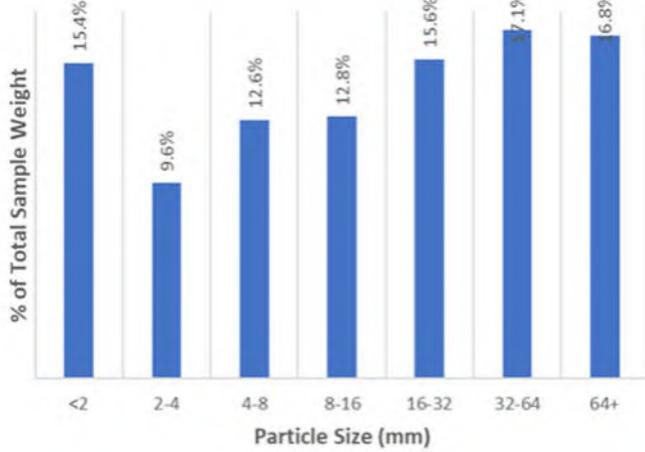
81380 2022



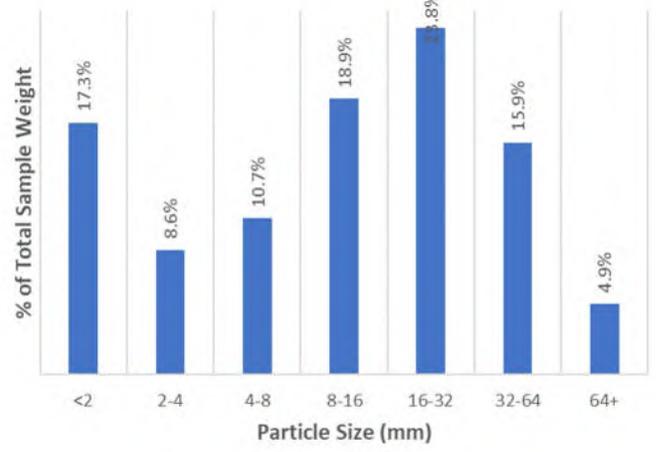
81380 2023



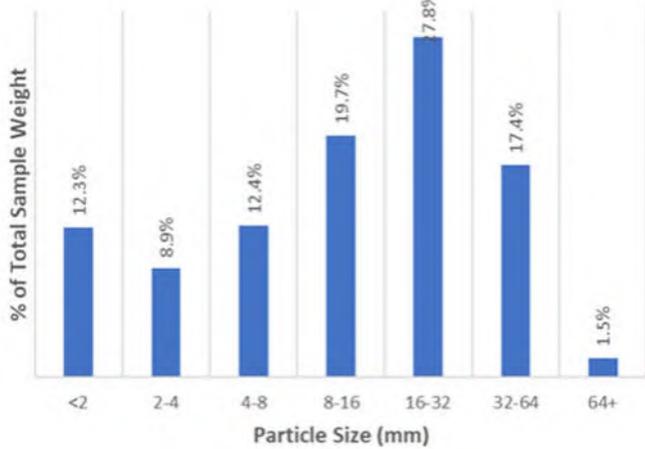
79270 2022



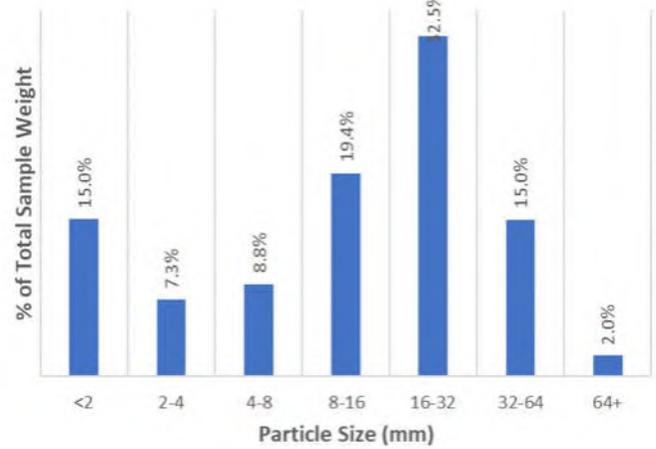
79270 2023



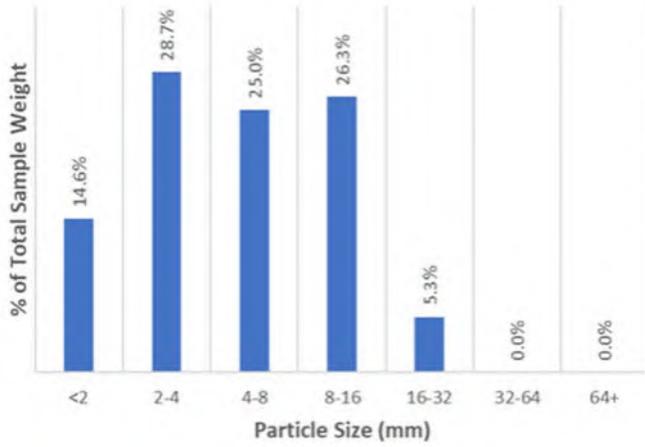
72470 2022



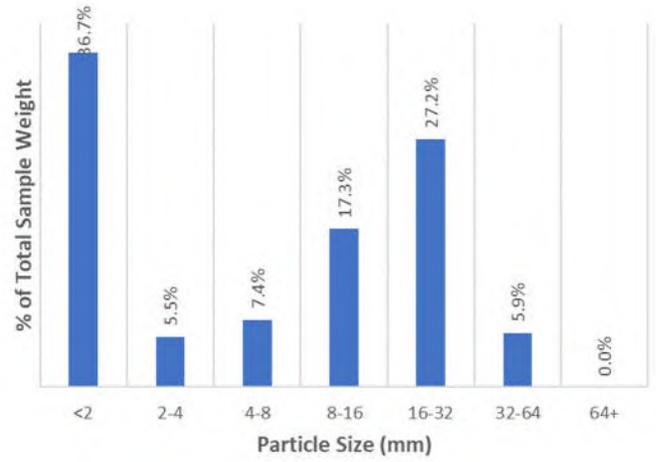
72470 2023



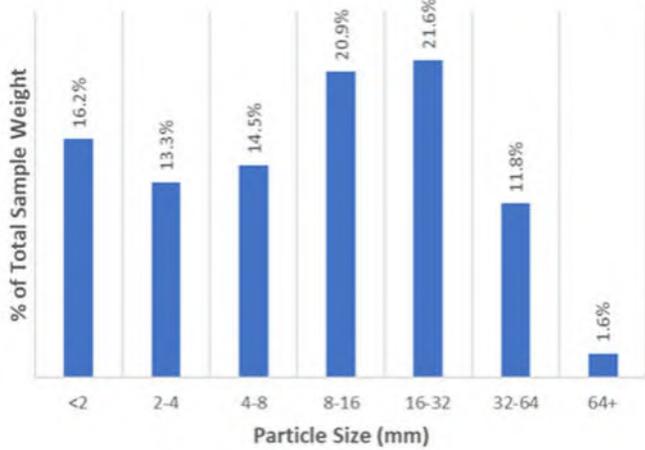
72010 2022



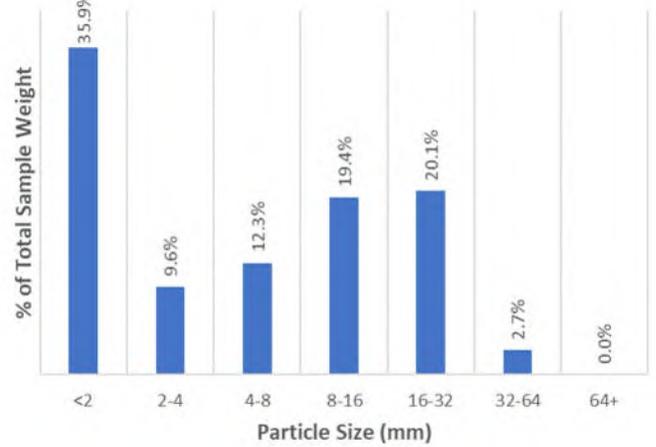
72010 2023



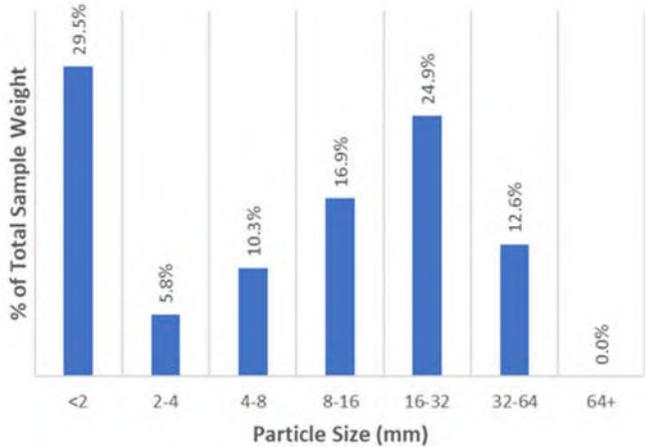
71140 2022



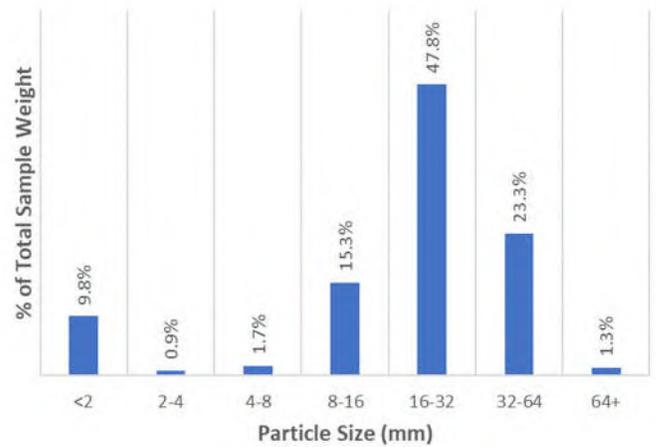
71140 2023



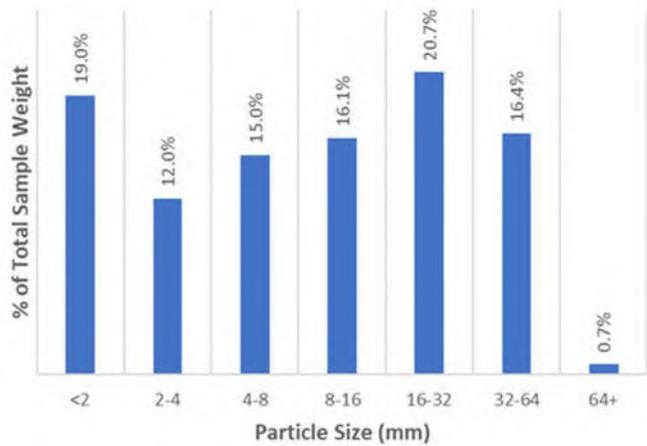
70790 2022



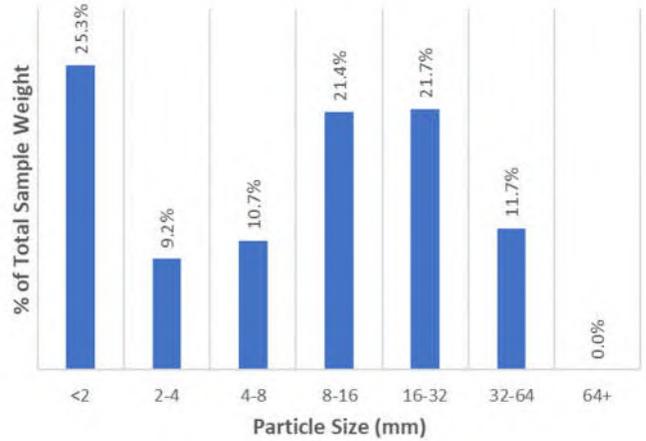
70790 2023



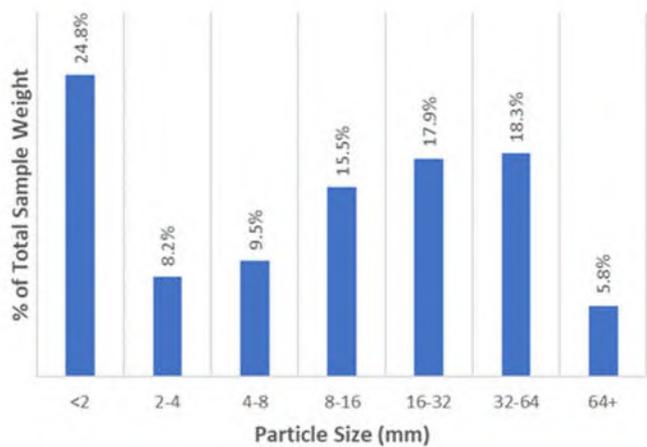
70380 2022



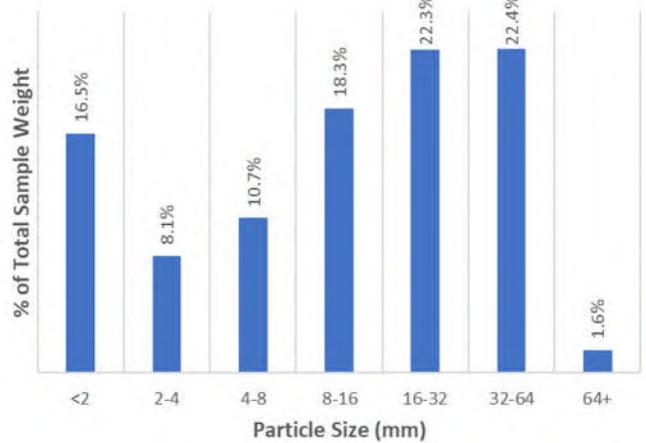
70380 2023



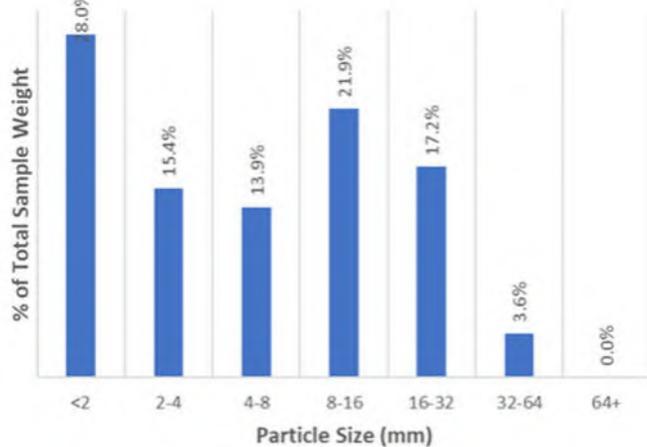
68300 2022



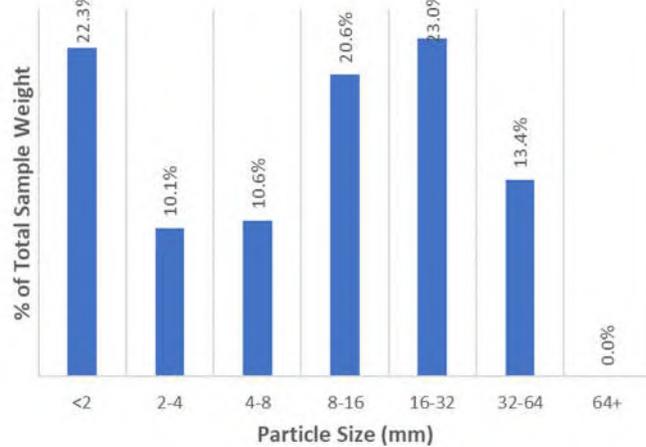
69180 2023



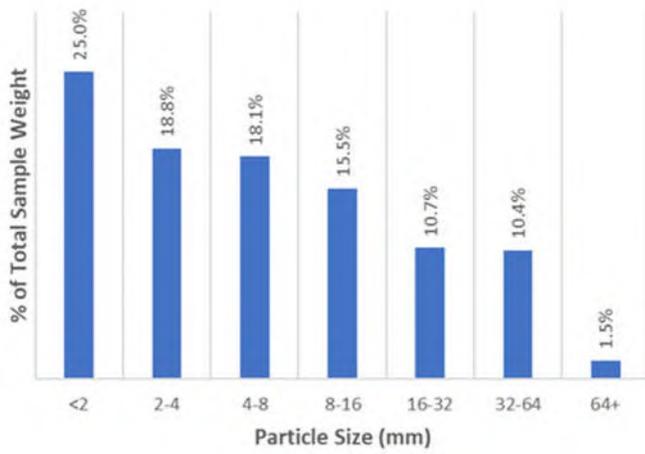
62000 2022



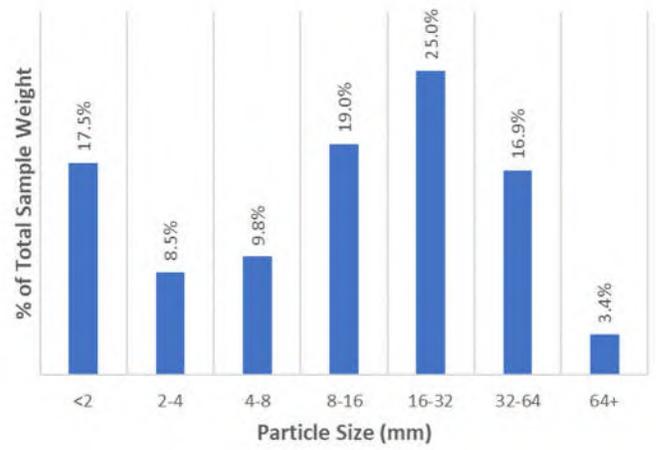
65700 2023



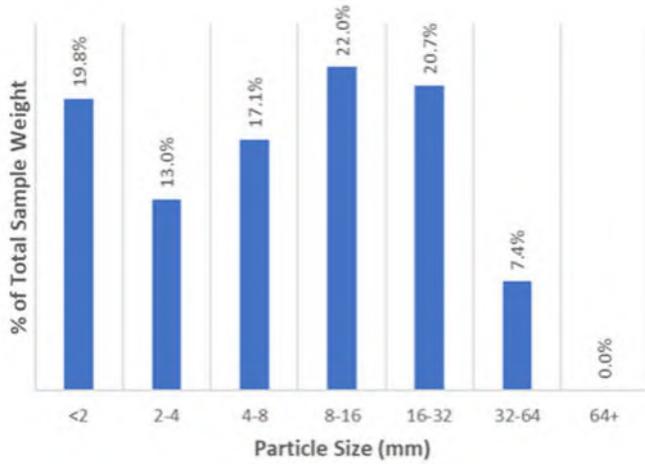
57220 2022



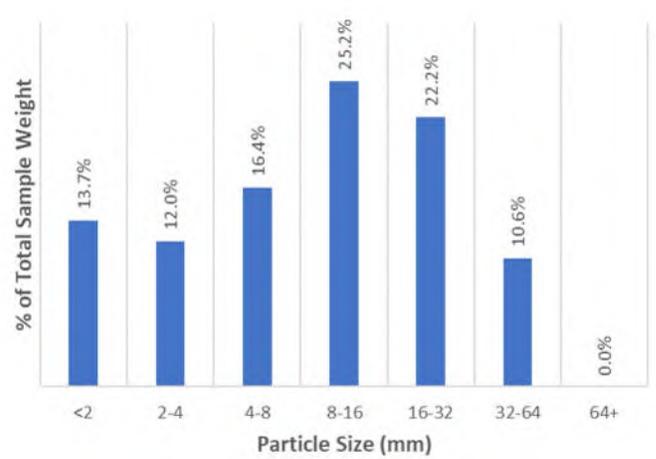
60240 2023



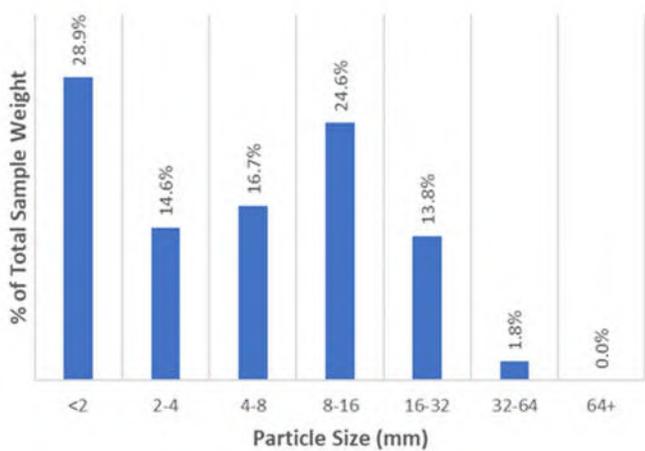
56670 2022



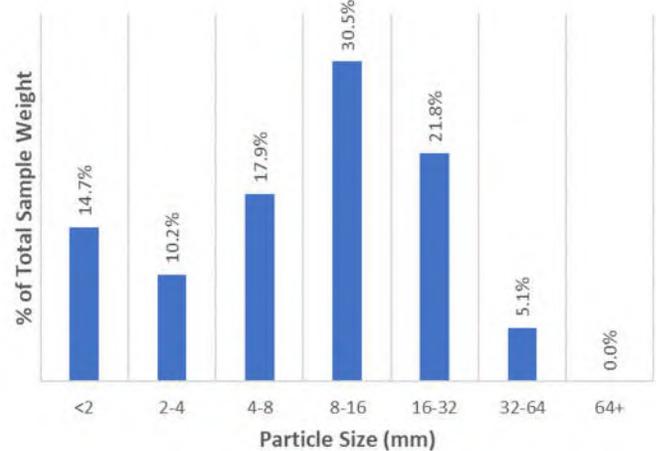
58510 2023



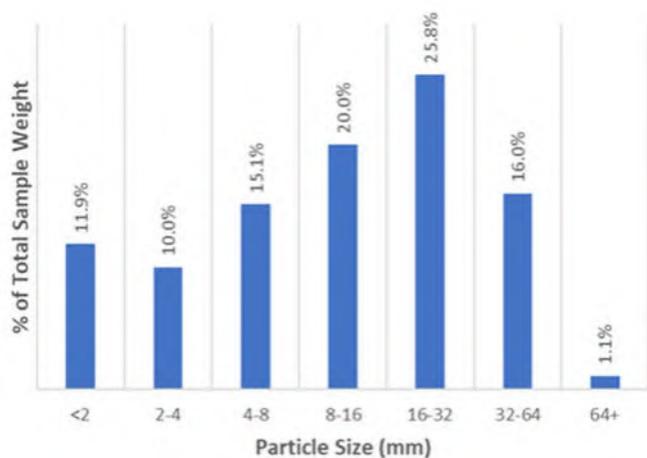
55980 2022



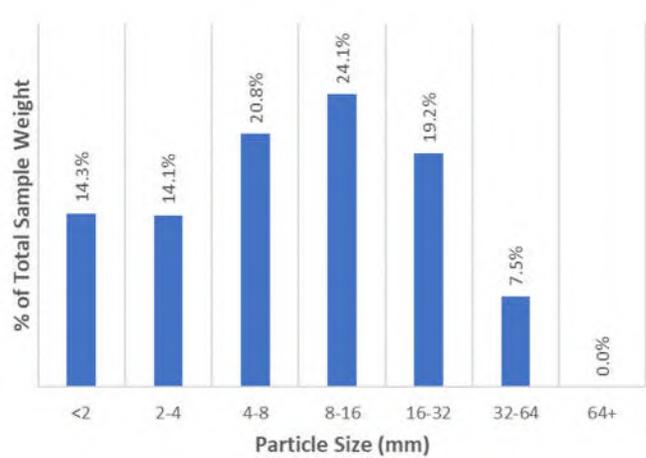
55980 2023



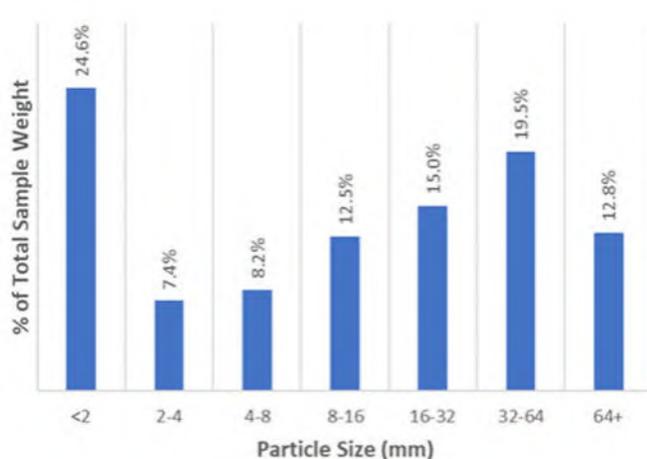
54570 2022



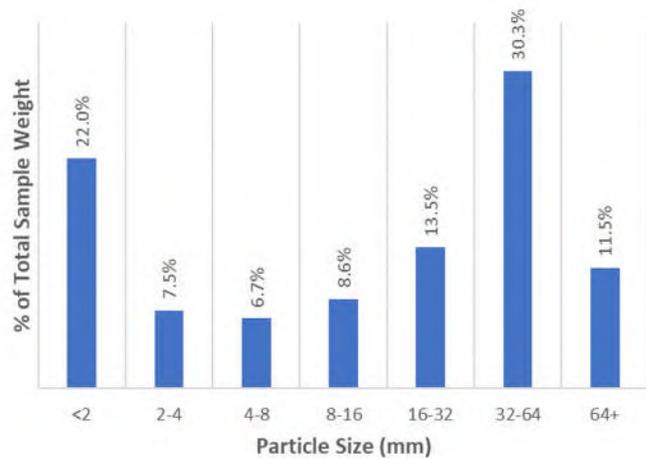
54570 2023



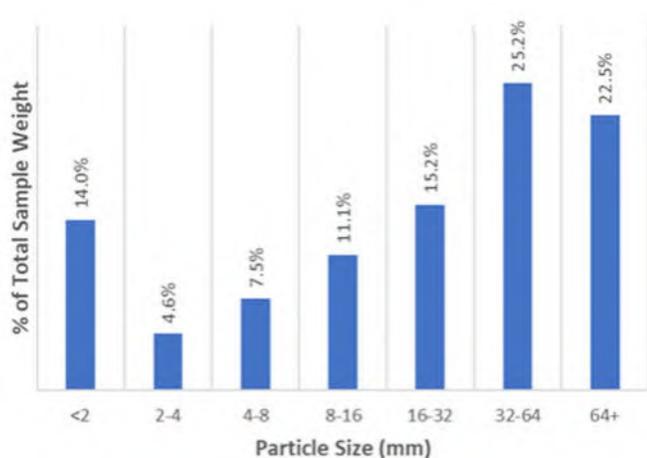
41190 2022



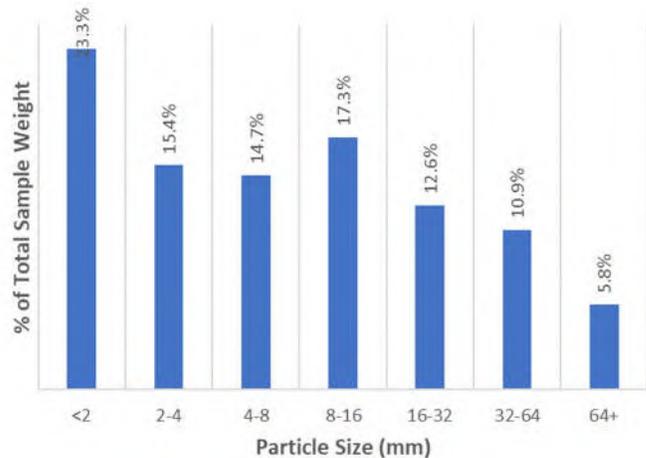
41190 2023



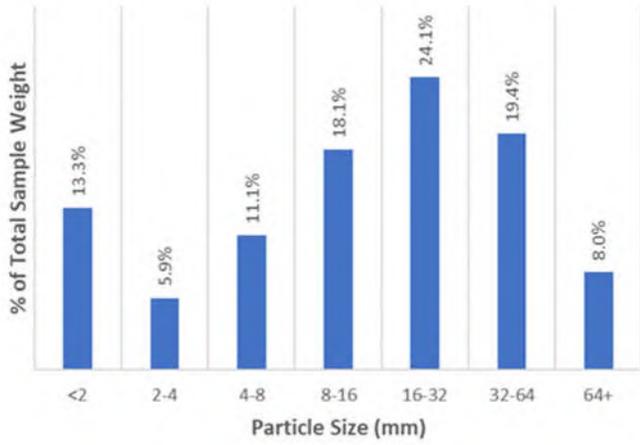
39620 2022



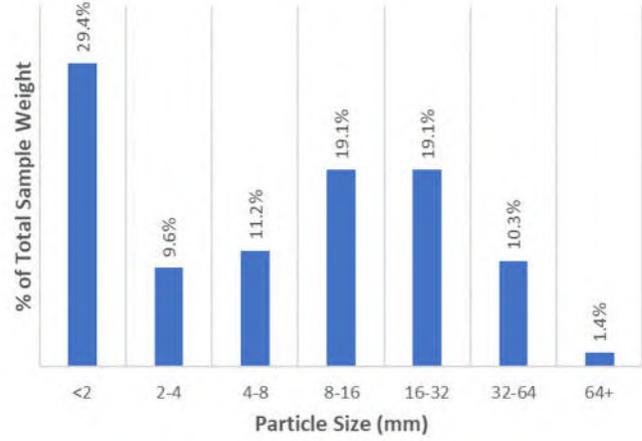
39850 2023



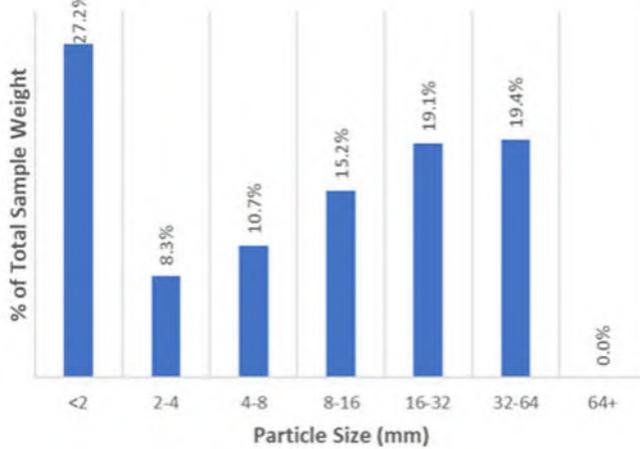
34830 2022



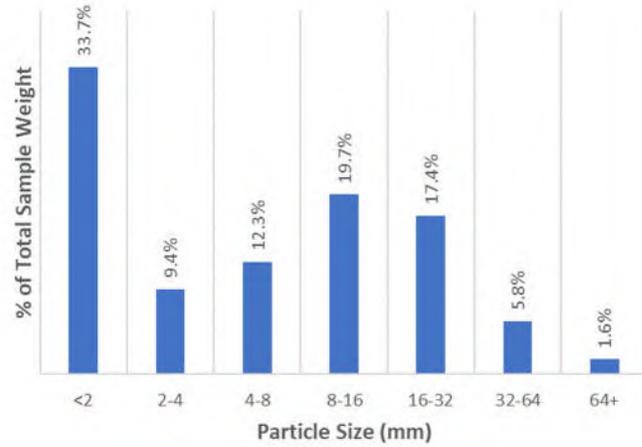
34830 2023



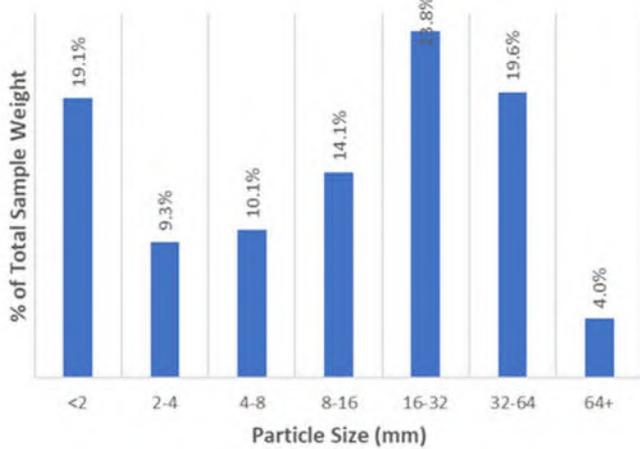
32810 2022



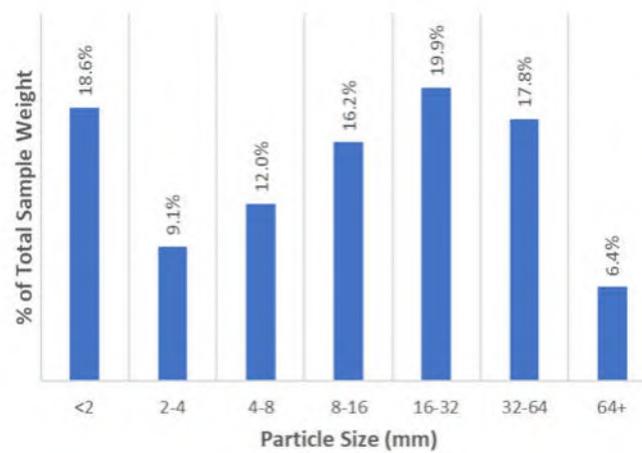
32810 2023



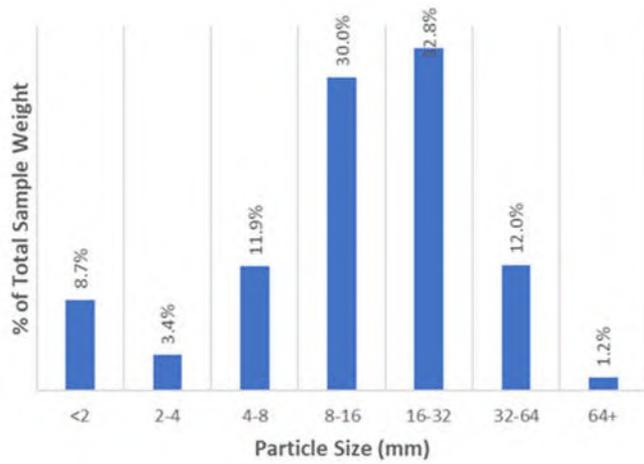
27840 2022



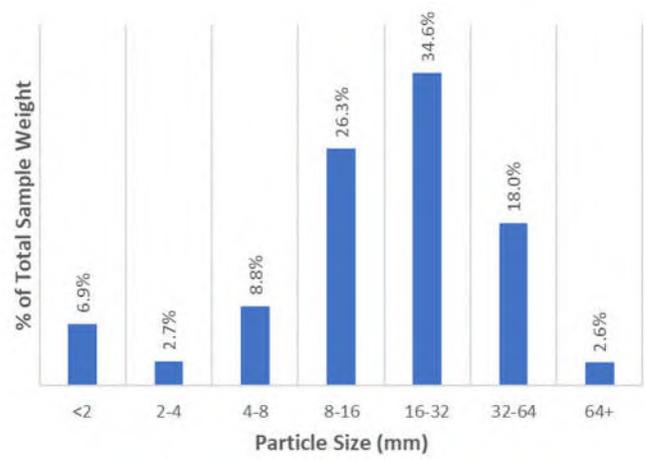
27840 2023



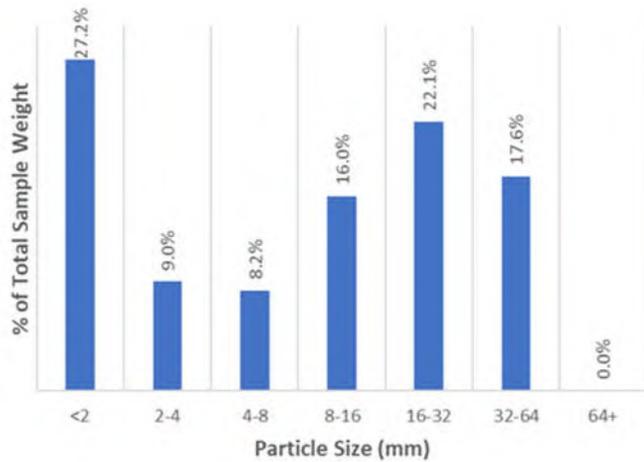
24360 2022



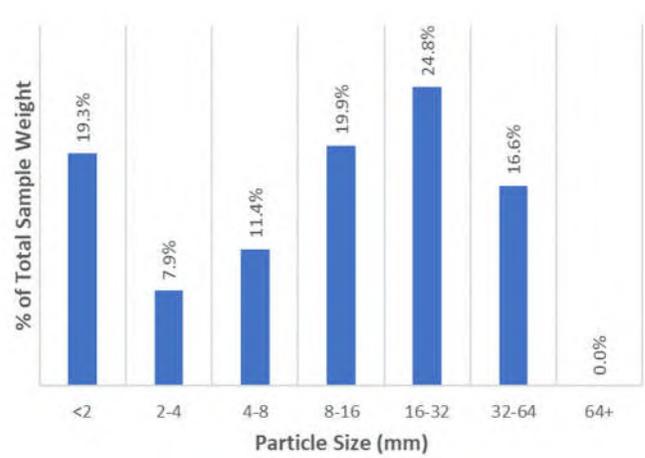
24360 2023



23600 2022

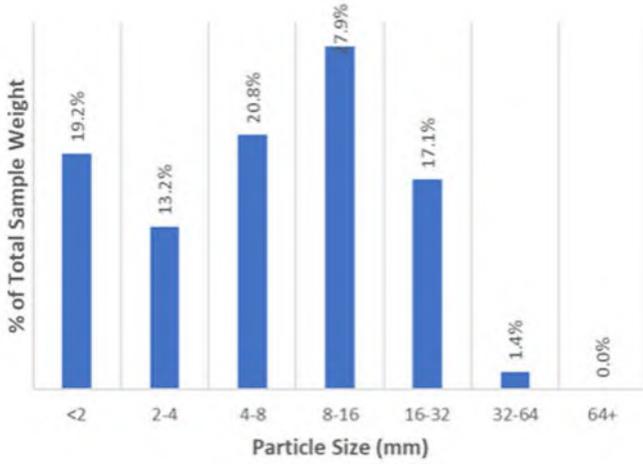


23320 2023

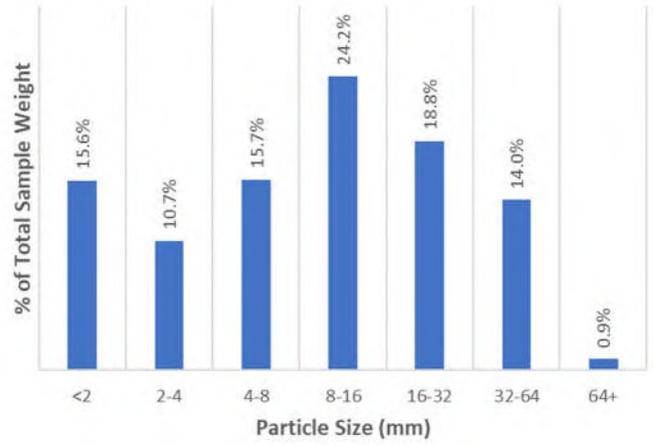


# SONOMA CREEK

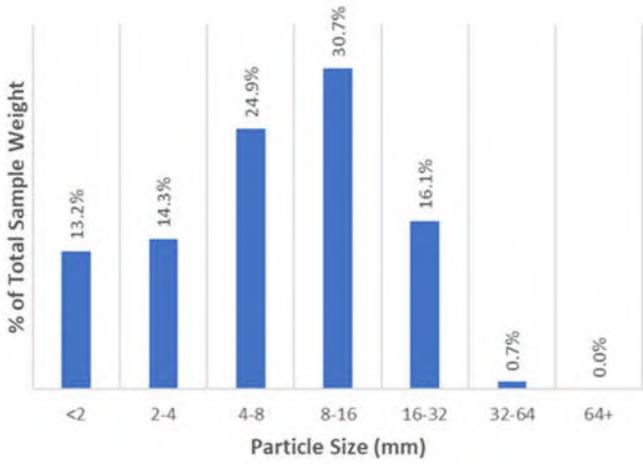
SC\_001 2022



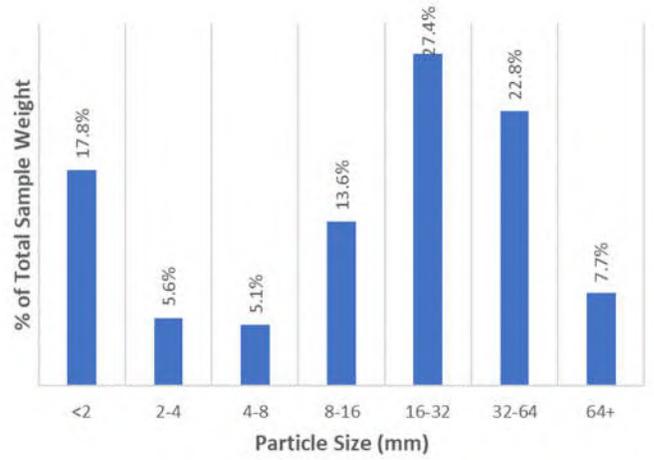
SC-001 2023



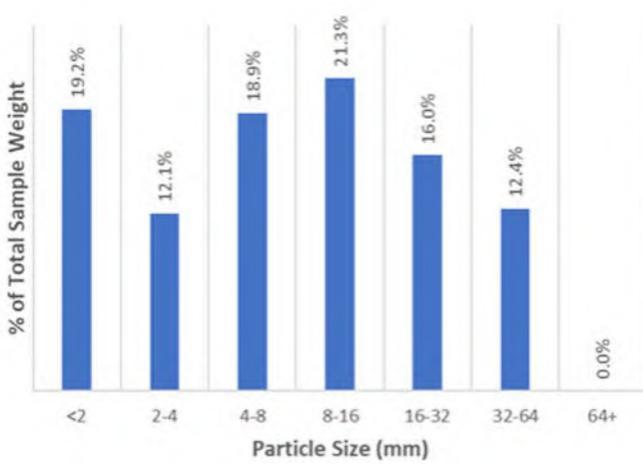
SC\_002 2022



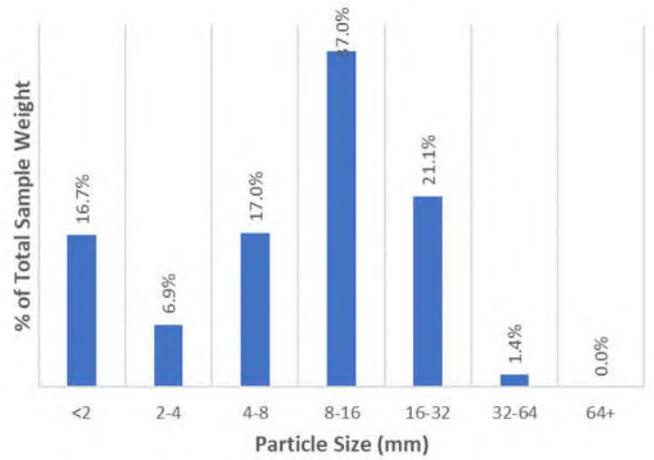
SC-002 2023



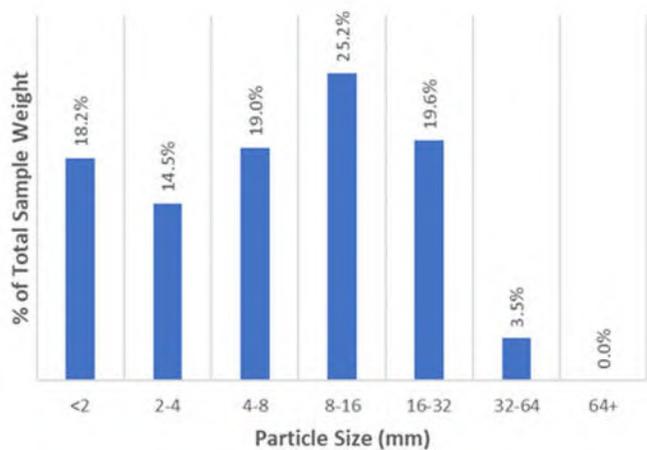
SC\_003 2022



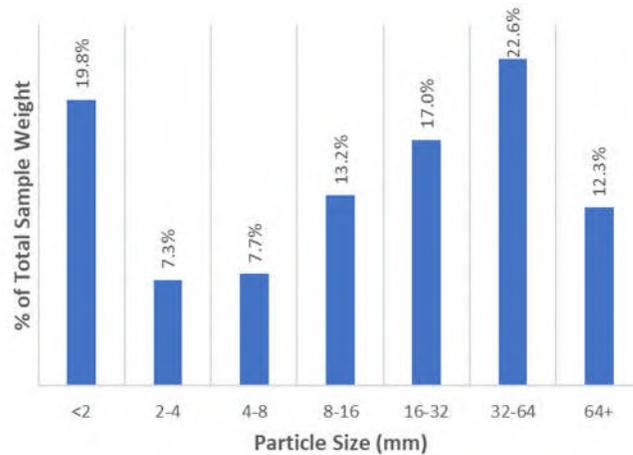
SC-003 2023



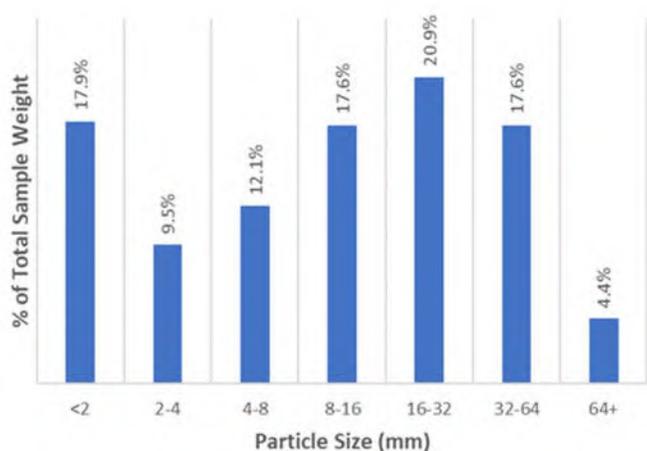
SC\_004 2022



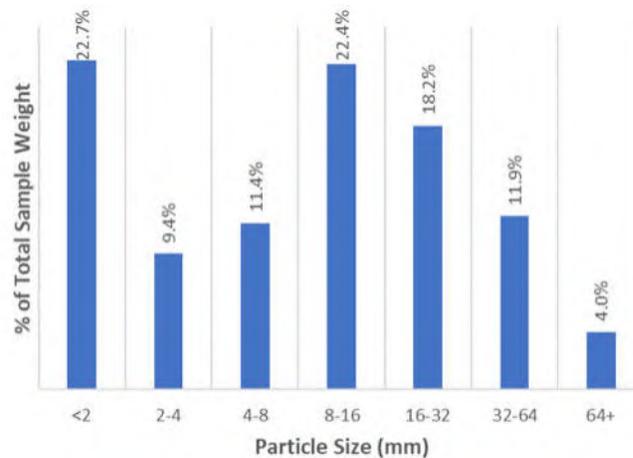
SC-004 2023



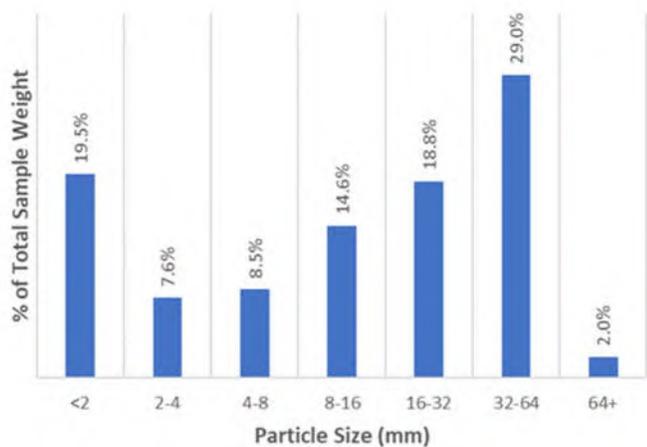
SC\_005 2022



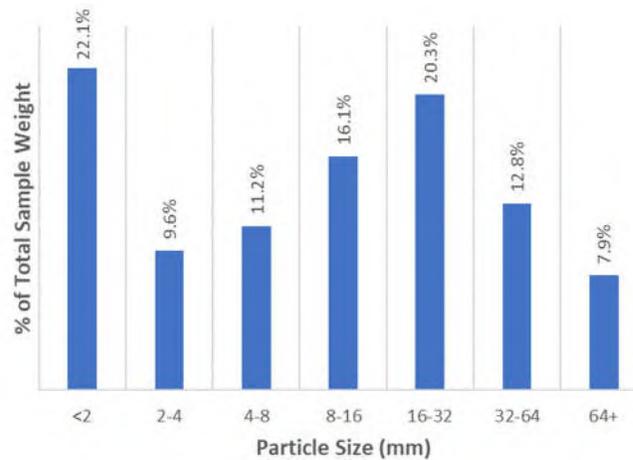
SC-005 2023



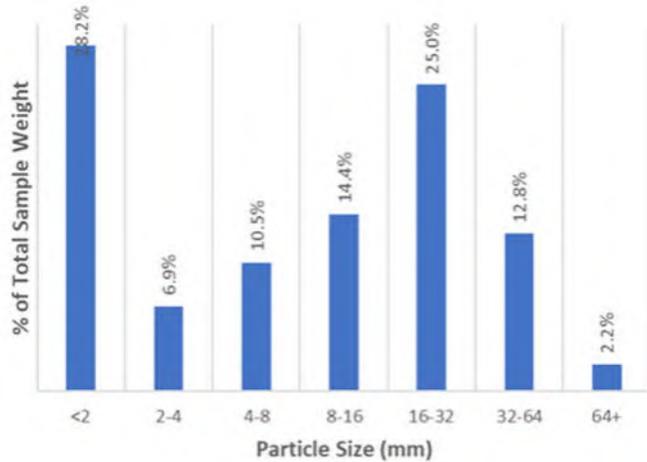
SC\_007 2022



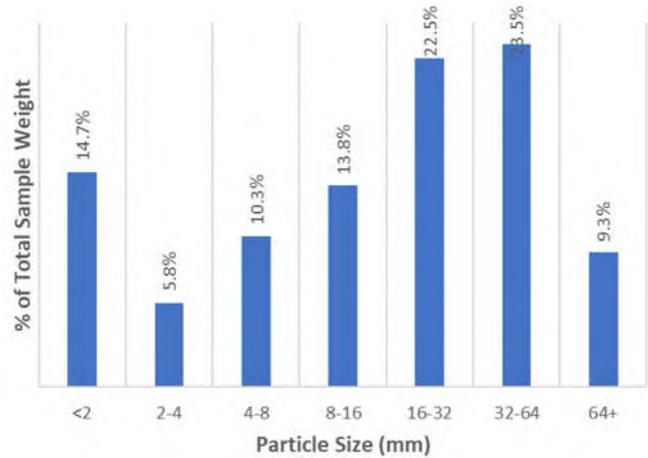
SC-007 2023



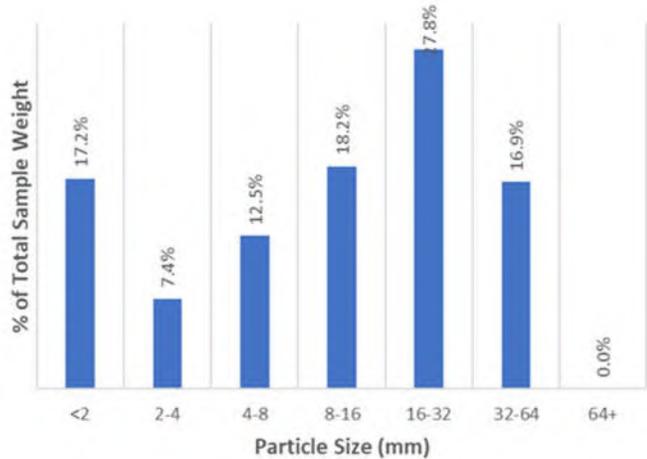
SC\_008 2022



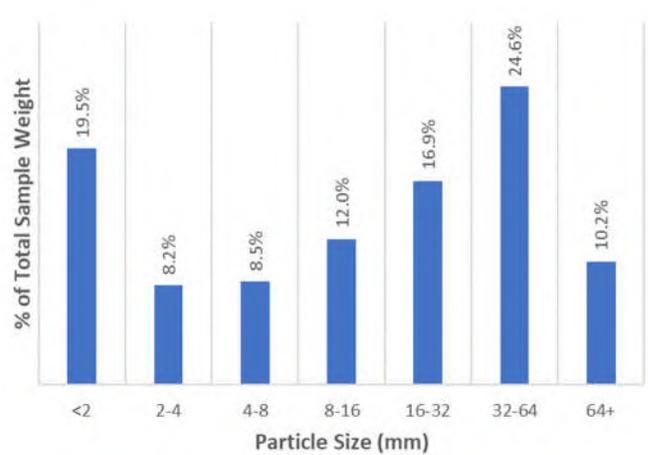
SC-008 2023



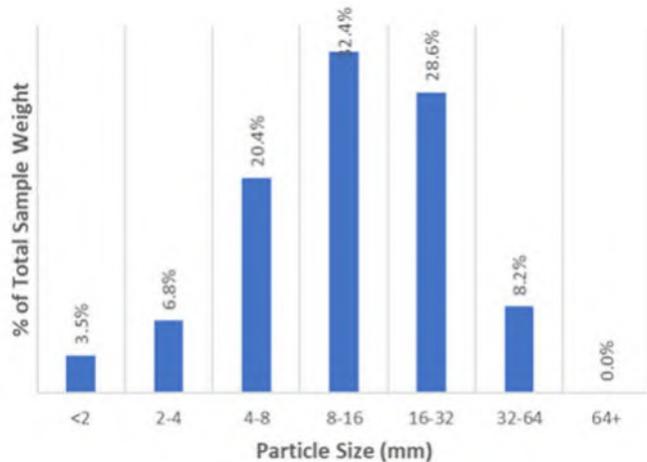
SC\_009 2022



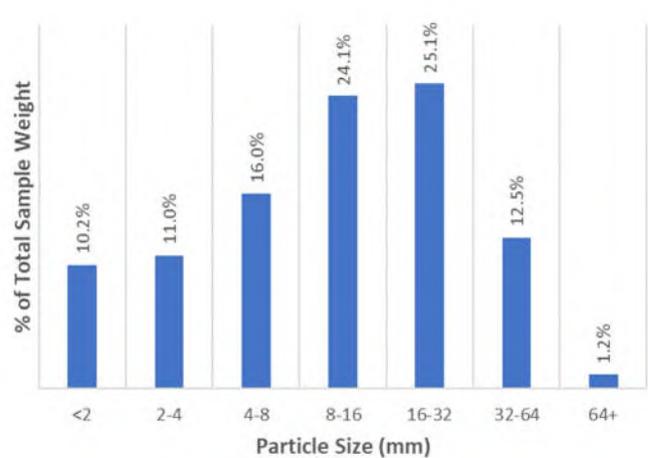
SC-009 2023



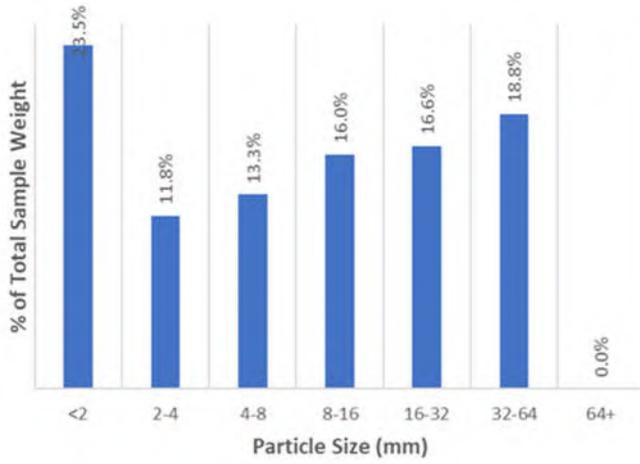
SC\_010 2022



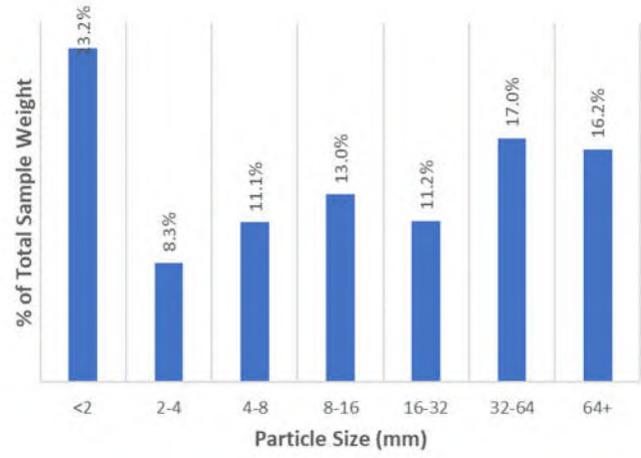
SC-010 2023



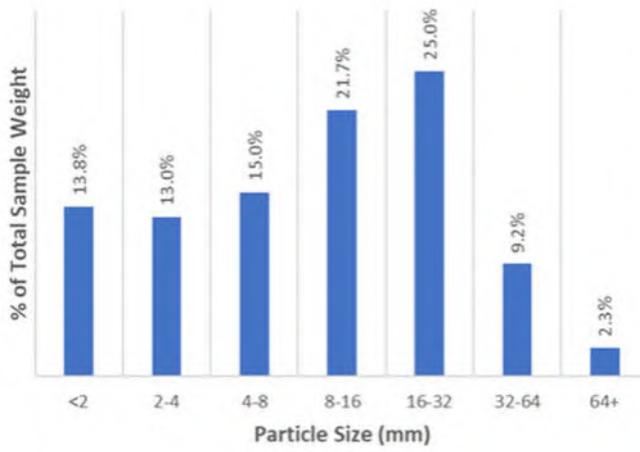
SC\_012 2022



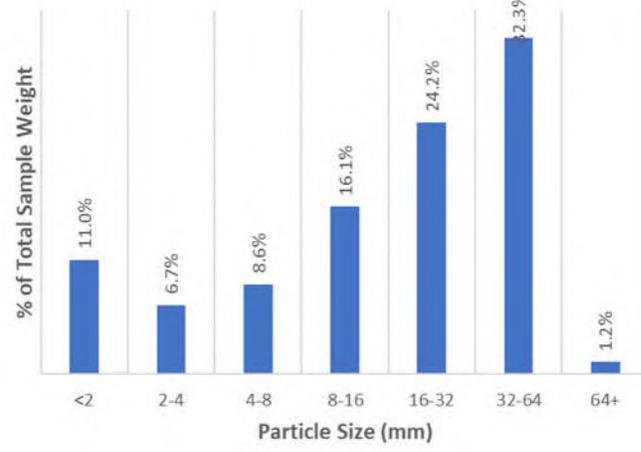
SC-012 2023



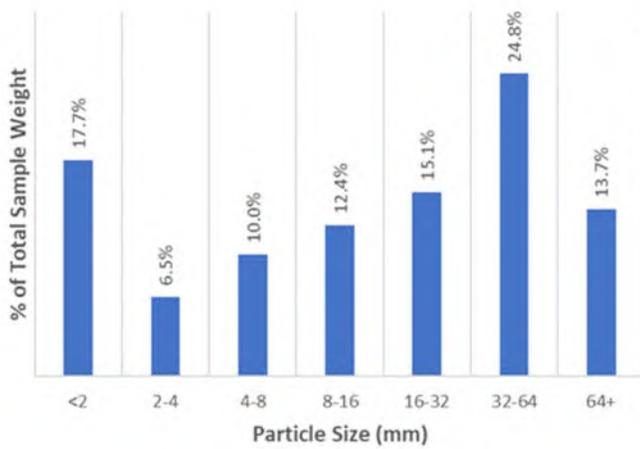
SC\_014 2022



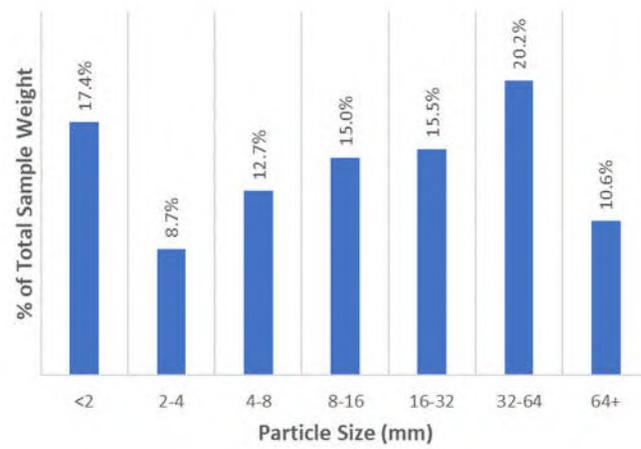
SC-014 2023



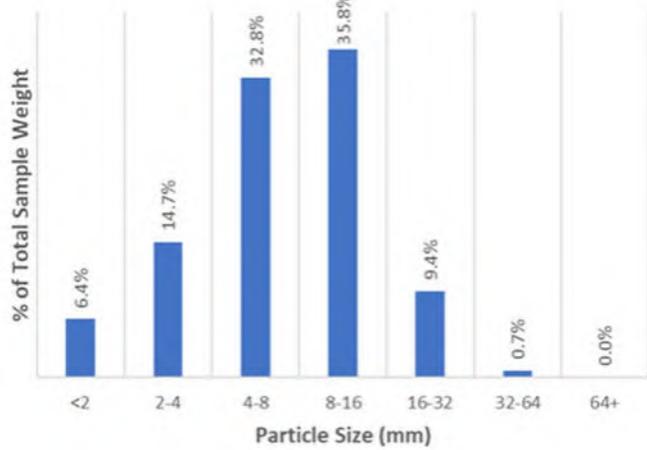
SC\_016 2022



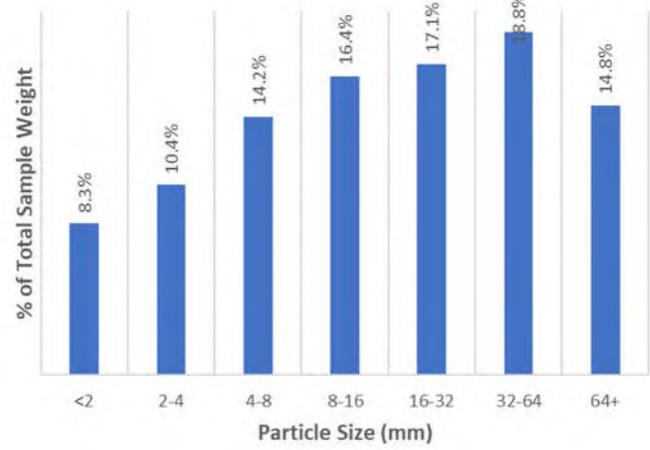
SC-016 2023



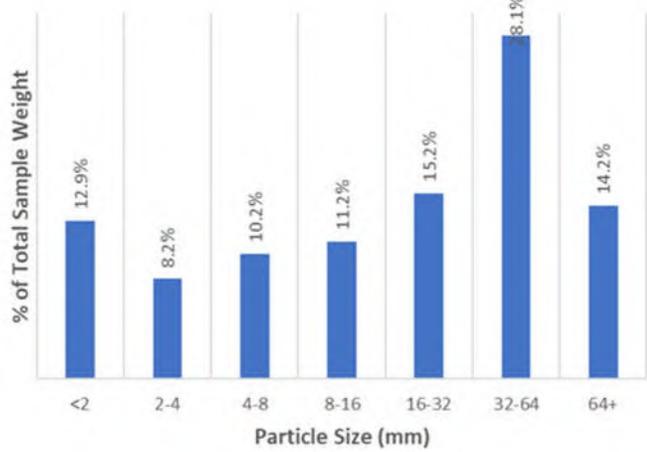
SC\_018 2022



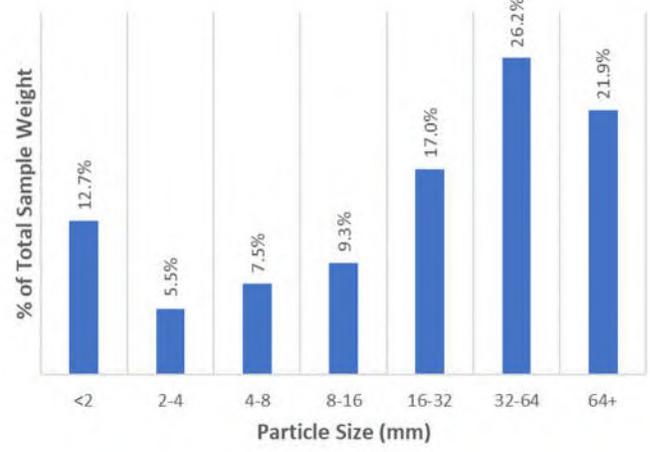
SC-018 2023



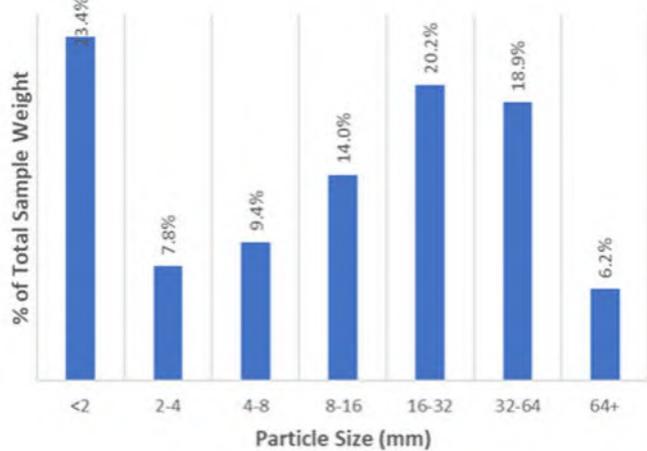
SC\_020 2022



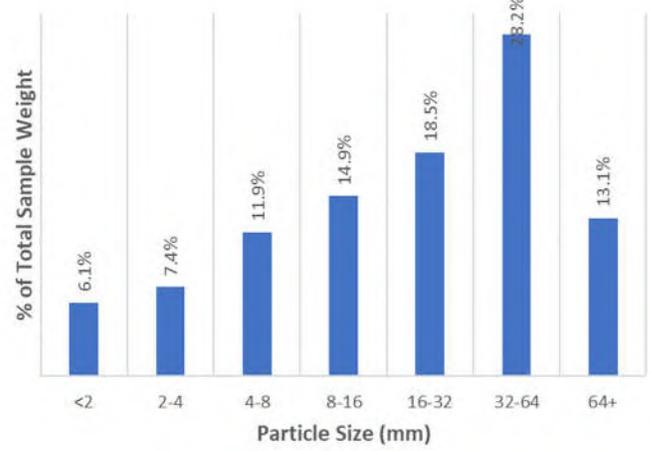
SC-020 2023



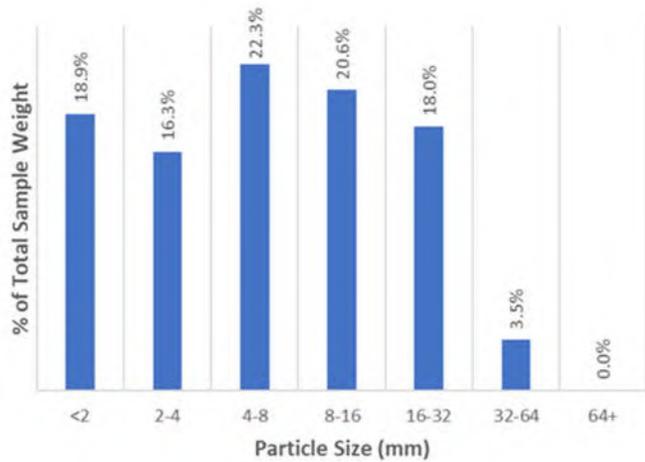
SC\_021 2022



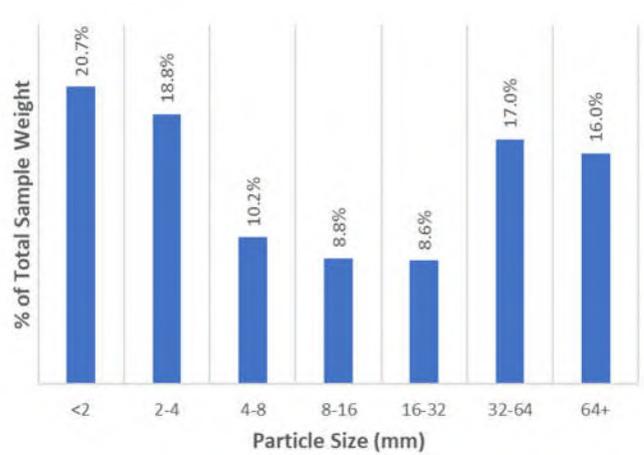
SC-021 2023



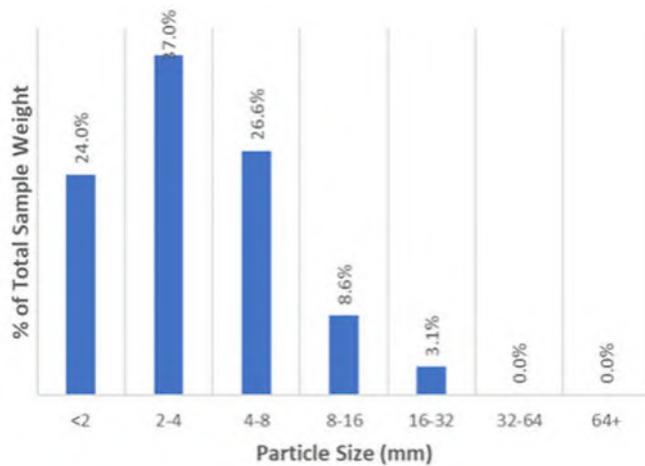
SC\_022 2022



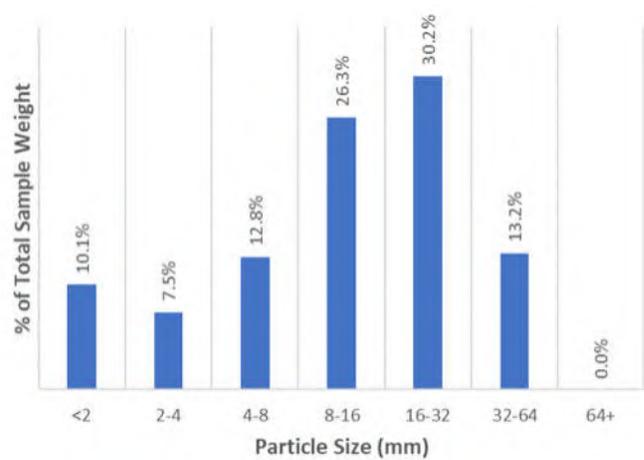
SC-022 2023



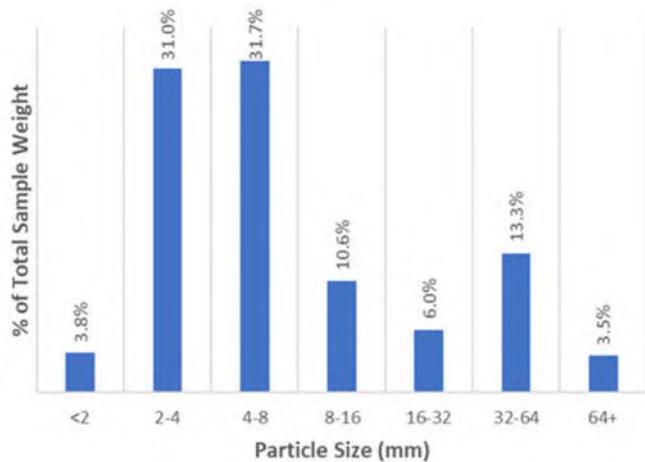
SC\_023 2022



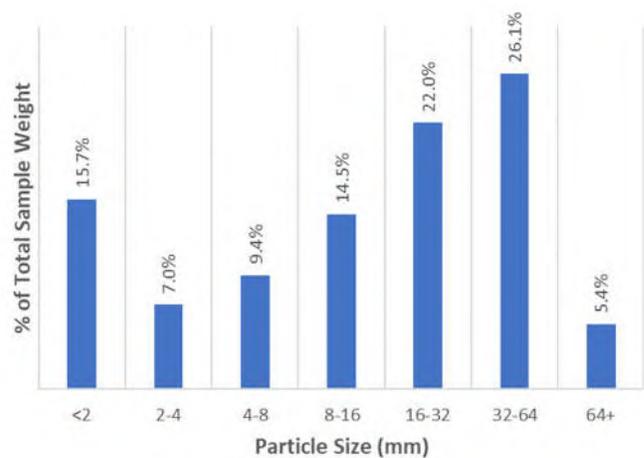
SC-023 2023



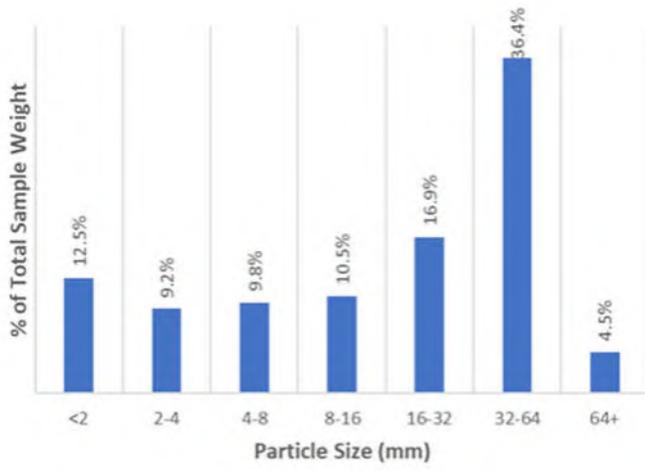
SC\_025 2022



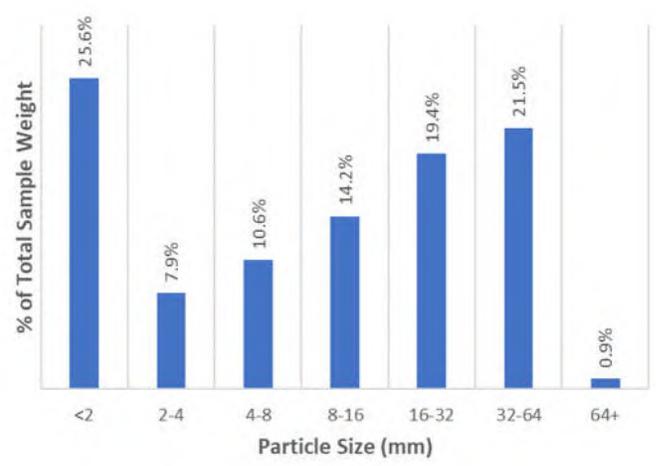
SC-025 2023



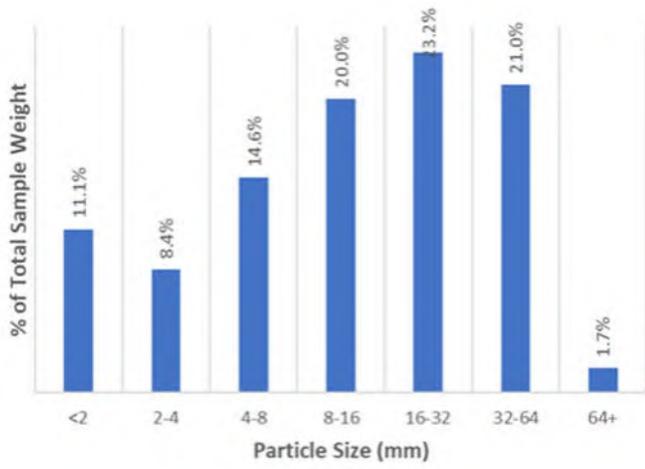
SC\_026 2022



SC-026 2023



SC\_027 2022



SC-027 2023

