



Sediment Monitoring Report

For Water Year 2024



Morro Bay National Estuary Program
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List of Acronyms

Acronym	Definition
BMI	Benthic macroinvertebrate
Cal Poly	California Polytechnic State University, San Luis Obispo
CDFW	California Department of Fish and Wildlife
CFS	Cubic feet per second (ft ³ /s)
CSLRCD	Coastal San Luis Resource Conservation District
DEM	Digital elevation model
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Trichoptera
D50	Median gravel size diameter
ITRC	Irrigation Training and Research Center
LiDAR	Light Detection And Ranging
MLLW	Mean lower low water
NTU	Nephelometric turbidity unit
SET	Surface elevation table
SNARL	Sierra Nevada Aquatic Research Laboratory
SSC	Suspended sediment concentration
SWAMP	Surface Water Ambient Monitoring Program
TMDL	Total maximum daily load
TSS	Total suspended solids
USF	University of San Francisco
USGS	United States Geological Survey
WY	Water year

Introduction

The Morro Bay estuary is impaired by accelerated sedimentation rates. The Morro Bay National Estuary Program (Estuary Program) compiles and analyzes data to assess sedimentation in the watershed and the bay.

In 1998, the Central Coast Regional Water Quality Control Board (Water Board) identified Chorro Creek, Los Osos Creek, and the Morro Bay estuary as impaired by sediment and listed the water bodies under Clean Water Act Section 303(d). The Total Maximum Daily Load (TMDL) identified accelerated sedimentation due to anthropogenic disturbance as the primary cause for the listing. TMDL documentation cited the 1998 Tetra Tech report estimates that the subwatersheds of Chorro and Los Osos Creeks deliver an average of approximately 70,000 tons per year of sediment into the Morro Bay estuary. The report indicated that the Chorro Creek watershed was estimated to contribute 86% of the total sediment delivered to Morro Bay, approximately 60,689 tons.

The *Morro Bay Total Maximum Daily Load for Sediment* was formally adopted by the Environmental Protection Agency (EPA) on December 3, 2003. The TMDL calls for a 50% reduction in the annual loading to Morro Bay. Sediment loads less than 34,885 tons per year would comply with the TMDL targets. This TMDL would be achieved by an average reduction of 607 tons per year over a 50-year time schedule, for compliance by 2052.

The TMDL identified five targets for monitoring and plans to track the progress of voluntary and required implementation actions (Table 1). Four numeric targets were established for the streams in the Morro Bay watershed: pool volume, median gravel size diameter (D50), percent fines in substrate, and percent of coarse fines in substrate. In the Morro Bay estuary, the TMDL identified tidal prism volume as the primary numeric target.

Table 1. Morro Bay Sediment TMDL numeric targets for Morro Bay, Chorro and Los Osos creeks, and tributaries.

Parameter	Numeric Target
Residual Pool Volume	$v^* = (a \text{ ratio})$
	Mean values ≤ 0.21 (mean of at least 6 pools per sampling reach)
	Max values ≤ 0.45
Median Diameter (D50) of sediment Particles in Spawning Gravels	D50 =
	Mean values ≥ 69 mm
	Minimum values ≥ 37 mm
Percent of Fine Fines (< 0.85 mm) in Spawning Gravels	Percent fine fines $\leq 21\%$
Percent of Coarse Fines (all fines < 6.0 mm) in Spawning Gravels	Percent coarse fine $\leq 30\%$
Morro Bay Estuary	
Tidal Prism Volume	4,200 acre-ft

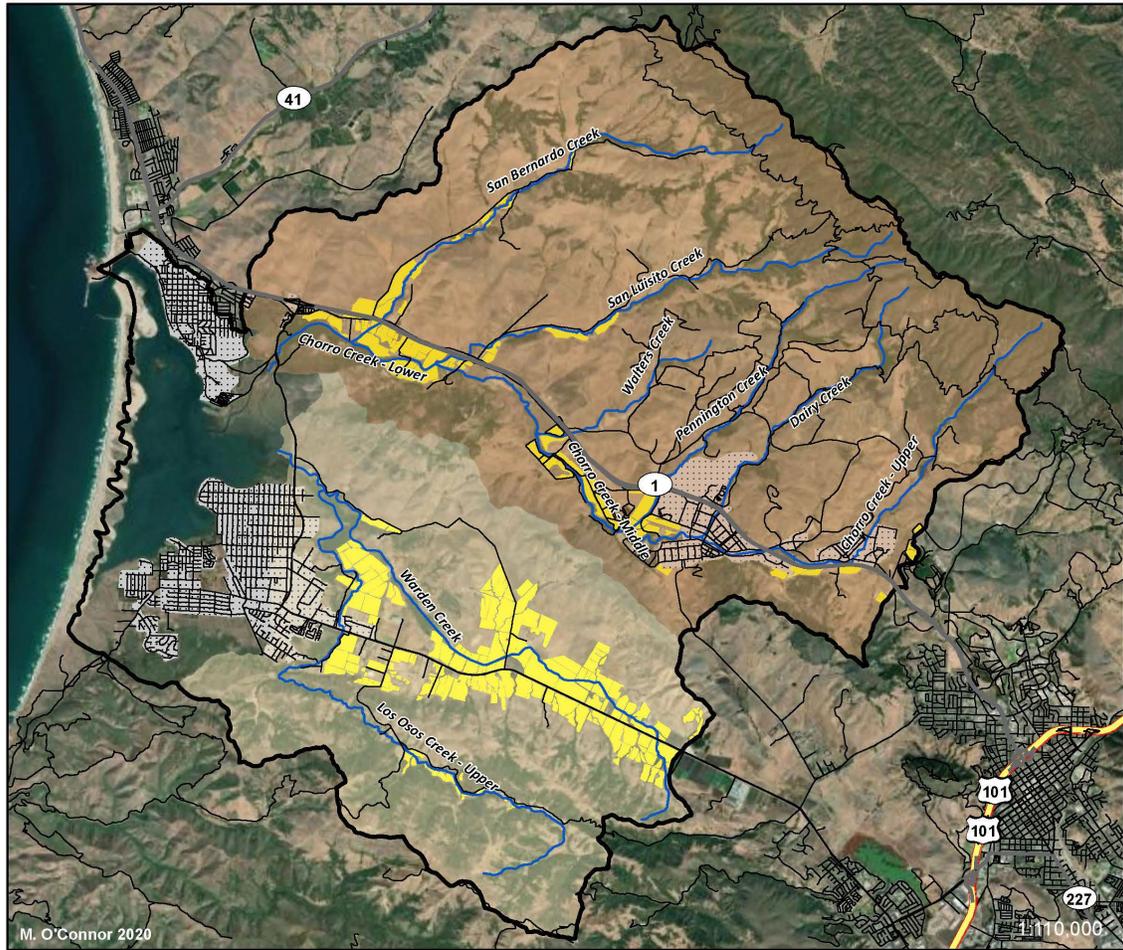
Numerous projects have occurred in the Morro Bay watershed to prevent sediment erosion and maximize sediment capture and retention within the watershed. The Estuary Program has worked with many local partners like the Coastal San Luis Resource Conservation District (CSLRCD), California Polytechnic University (Cal Poly), California Department of Fish and Wildlife (CDFW), and various other public and private landowners to implement projects to help meet TMDL goals.

Morro Bay Watershed

The Morro Bay watershed is located in San Luis Obispo County on California's Central Coast and encompasses a drainage area of approximately 75 square miles. The inland watershed drains west to the Morro Bay estuary and Pacific Ocean via two primary creeks, Chorro Creek and Los Osos Creek.

The Chorro Creek subwatershed encompasses a drainage area of 43.4 square miles. Land use in the subwatershed is primarily agricultural, with much of the area used as rangeland for beef cattle operations. Notable urban areas include the City of Morro Bay, Cuesta College, the California Men's Colony prison complex, and Army National Guard Base Camp San Luis Obispo (Camp SLO). Chorro Creek receives drainage from several tributaries: Dairy Creek, Pennington Creek, Walters Creek, San Luisito Creek, and San Bernardo Creek.

The Los Osos Creek subwatershed encompasses a drainage area of 23.1 square miles. Land use in the subwatershed is primarily agricultural and residential. In contrast to the Chorro Creek subwatershed, agriculture in the Los Osos subwatershed is characterized by plowed rotational fields generating a variety of forage and truck crops. Much of the intensive farming operations in the watershed occur in the Warden Creek drainage area.



M. O'Connor 2020

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1:700,000

Legend

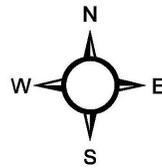
- Creeks
- Watershed Boundary
- Chorro Subwatershed
- Los Osos Subwatershed

Land Use Classification

- Urban
- Agriculture

Road Classification

- Freeway
- Major Road
- Secondary Road
- Local Connector Road



Data prepared by Land IQ, LLC and provided to the California Department of Water Resources (DWR) and other resource agencies. Major road data provided by ESRI, Tele Atlas North America. Local road data provided by County of San Luis Obispo. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1. Map of the Morro Bay watershed.

Water Quality and Hydrology

Since the adoption of the sediment TMDL in 2003, numerous monitoring efforts have been undertaken to quantify sediment transport and delivery to Morro Bay. From 2007 to 2019, the Estuary Program monitored suspended sediment concentration during storm events to quantify sediment loading. While this effort provided key understanding to sediment transport in the watershed, monitoring was put on hold indefinitely after 2019 due to the labor associated with storm-driven sampling and challenges with sample processing. The Estuary Program now compiles annual data related to sediment transport in the watershed including water quality data, discharge, and annual precipitation.

Ambient Water Quality

The Estuary Program's Monitoring Program has been conducting routine water quality monitoring throughout the estuary and watershed since 2002. Data is collected monthly by staff and trained volunteers per the program's Quality Assurance Project Plan (QAPP). Figure 2 illustrates a subset of ambient water quality monitoring sites located throughout the watershed. The sites shown are either perennial or semi-perennial and have long-running datasets.

Staff and volunteers measure a variety of water quality parameters including nephelometric turbidity and instantaneous flow volume. While this data is important for understanding long-term ambient trends across the watershed, it does not capture conditions during major winter storm events. Due to safety issues and monitoring constraints, data is only collected when streams are wadeable.

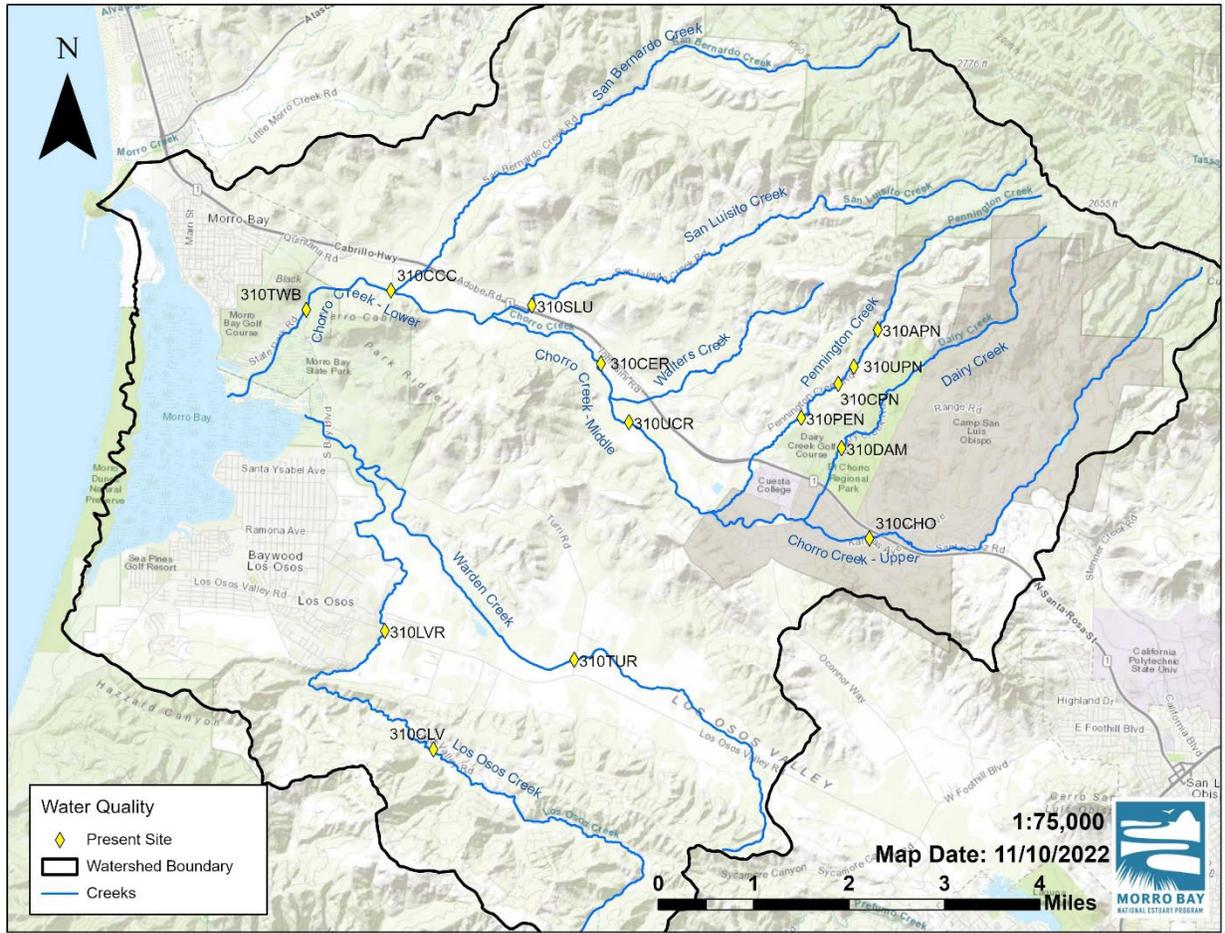


Figure 2. Map of the Estuary Program’s ambient water quality monitoring sites.

Outside of storm events, ambient turbidity levels rarely exceed the Central Coast Basin Plan levels of concern of 25 nephelometric turbidity units (NTU) for protection of aquatic life in cold water (beneficial use COLD) and 40 NTU in warm waters (beneficial use WARM). Of the 4,620 turbidity readings collected between 2002 and 2024, 2.3% exceeded 25 NTU and 1.3% exceeded 40 NTU.

Multiple studies have analyzed the accuracy of measuring turbidity as a surrogate for monitoring suspended sediment concentration (SSC) or total suspended solids (TSS). Turbidity monitoring is significantly faster and less expensive than monitoring SSC or TSS and has generally proven to be more accurate than other surrogate measures. However, there are limitations to its usefulness in quantifying suspended sediment load in surface waters (Ankcorn, 2003). This being the case, turbidity data collected by the Estuary Program is not used as a predictor of the total sediment load.

Stage and Discharge

To better understand the potential for sediment transport in the Morro Bay watershed, the Estuary Program compiles stage data from a San Luis Obispo County gauging station on Chorro Creek at Canet Road (Station 753)¹. This gauge has been collecting continuous data since 2003, making it a key dataset

¹ Data from San Luis Obispo County maintained gauges is available online at: <https://wr.slocountywater.org/>.

for analyzing hydrologic and sediment transport trends in the watershed. Prior analysis of stage height and SSC indicate a strong connection, with most sediment transport occurring during large-scale storm events.

The Station 753 gauge at Canet Road includes a drainage area of approximately 21.8 square miles of the 43-square-mile Chorro subwatershed. This area includes flows from the Pennington Creek, Dairy Creek, and Walters Creek tributaries, as shown in the map below.

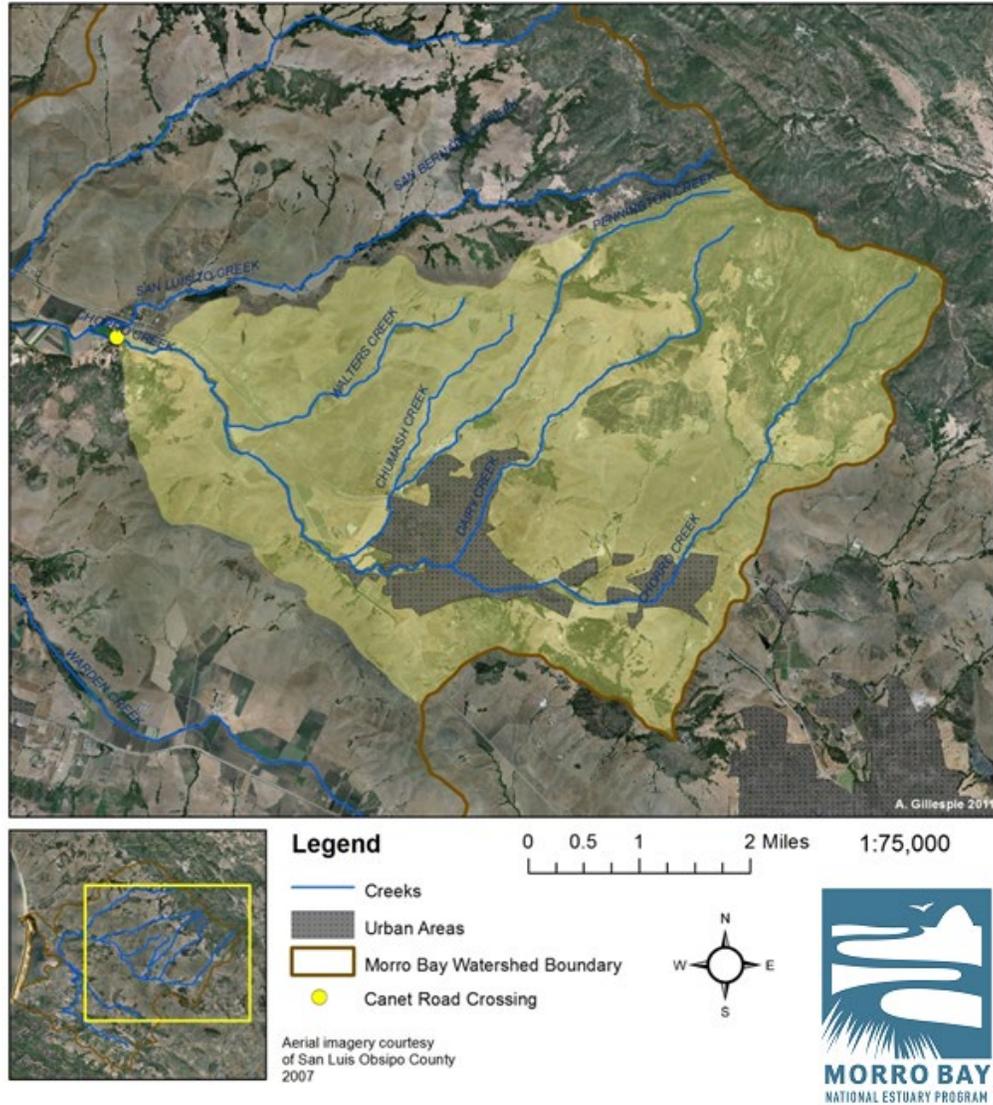


Figure 3. Map of watershed area that drains to Canet Road monitoring site.

While stage data provides valuable information about water levels, development and maintenance of a stage-discharge relationship is essential for estimating flow volume and stream discharge. Several rating curves have been developed for the Canet Road gauging station to estimate discharge. Cal Poly's Irrigation Training and Research Center (ITRC) developed a stage-discharge relationship in 2008, which was then refined in 2010 to better estimate peak flows. Their analysis indicated that three distinct equations were required to accurately approximate flow rates depending on stage height (MBNEP, 2011).

In 2015, the stage-discharge relationship was reevaluated to better approximate discharge for stage values less than 12.1 feet (MBNEP, 2015). While this revised equation was successful in estimating lower flows, it introduced a rating curve discontinuity when the stage value reached 12.1 feet.

In 2024, the Estuary Program contracted with Creek Lands Conservation to reassess the Canet rating curve and address the stage-discharge relationship discontinuity at 12.1 feet². The revised rating curve is a piecewise curve, intended to estimate discharge when stage values are between 3.75 and 18.2 feet. These limits reflect a range of stage heights that maintain discharge calculation confidence.

For each of the following equations, **Q (cfs)** is the estimated discharge of Chorro Creek at Canet Road, and **Y** is the stage value in feet as recorded by the SLO County stream gauge at Station 753. Please note that the equations cannot accurately predict discharge when stage values are less than 3.75 feet or greater than 18.2 feet, as those values are outside of the known stage-discharge relationship.

1. For stage values between 3.75 feet and 4.02 feet, discharge is assumed to be zero: **Q (cfs) = 0**.
2. For stage values greater than 4.02 feet and less than or equal to 11.2 feet, estimate discharge with the equation: **Q (cfs) = 20.907*(Y - 3.75)² - 5.8341*(Y - 3.75)**.
3. For stage values greater than 11.2 feet but less than 13.7 feet, use the linear interpolation: **Q (cfs) = 56.826*Y + 480.48**.
4. For stage readings greater than 13.7 feet and less than or equal to 18.2 feet, use the equation: **Q (cfs) = 1200 + 88.02*[(Y - 13.2) + 0.3259]²**.

The hydrograph below shows Chorro Creek discharge during water year³ 2024 (WY2024), using the equations presented above. The orange dotted line represents the point at which water levels have exceeded the bottom of the bridge at Station 753 (approximately 12.1 feet). Bridge-topping events reflect conditions capable of transporting larger sediment loads.

² For more information on the development of the 2024 rating curve, please see the Estuary Program's Stage-Discharge Technical Memo from August 2024: https://library.mbneep.org/wp-content/uploads/2024/09/MBNEP-Technical-Memo_CAN-Rating-Curve_2024.pdf.

³ Water years (WYs) are defined as October 1 to September 30 and named for the year in which it ends (e.g. WY2024 refers to October 1, 2023 to September 30, 2024).

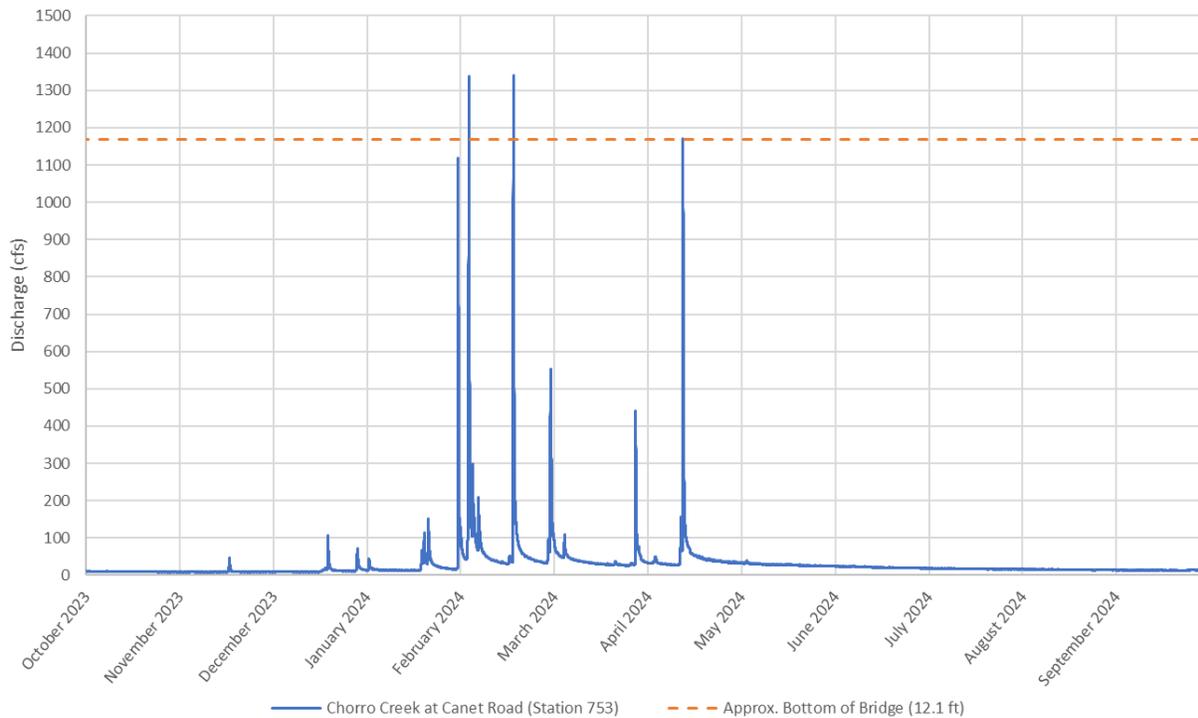


Figure 4. Chorro Creek hydrograph for WY2024 using rating curve equations for Station 753.

Precipitation Statistics

According to the San Luis Obispo County Department of Public Works precipitation contours, the Canet Road gauging station receives an average of 20 inches of rainfall per year (Appendix A). Table 2 summarizes the rainfall totals from Canet Road from WY2020 through WY2024.

Table 2. Rainfall statistics for WY2020 through WY2024.

Water Year	Total Annual Rainfall (in)	Percent of 20-inch Average Rainfall
2020	12.27	61%
2021	11.60	58%
2022	12.42	62%
2023	23.59	118%
2024	20.93	105%

While total annual rainfall provides insight into overall water input, the intensity and duration of precipitation events throughout the year play a key role in sediment transport. For example, high-intensity rainfall over short periods of time can lead to rapid increases in stream flow and runoff,

resulting in erosion and increased sediment loading. Low-intensity prolonged rainfall events allow water to infiltrate into soils, which reduces runoff and supports better groundwater recharge.

The graph below shows accumulated rainfall for WY2022 through WY2024, illustrating precipitation timing and intensity variability from year to year. Vertical peaks on the graph indicate high-intensity rainfall over a short period of time, while flat horizontal lines represent dry periods. WY2022 (in green) shows early season rainfall with a low overall accumulated rainfall. WY2023 (in orange) presents as a high rainfall year with a sharp increase in accumulated rainfall between January and February. WY2024 (in yellow) represents a more average water year, with later moderate intensity storms. Both WY2023 and WY2024 had rains later in the year than is typical, with storms occurring as late as April.

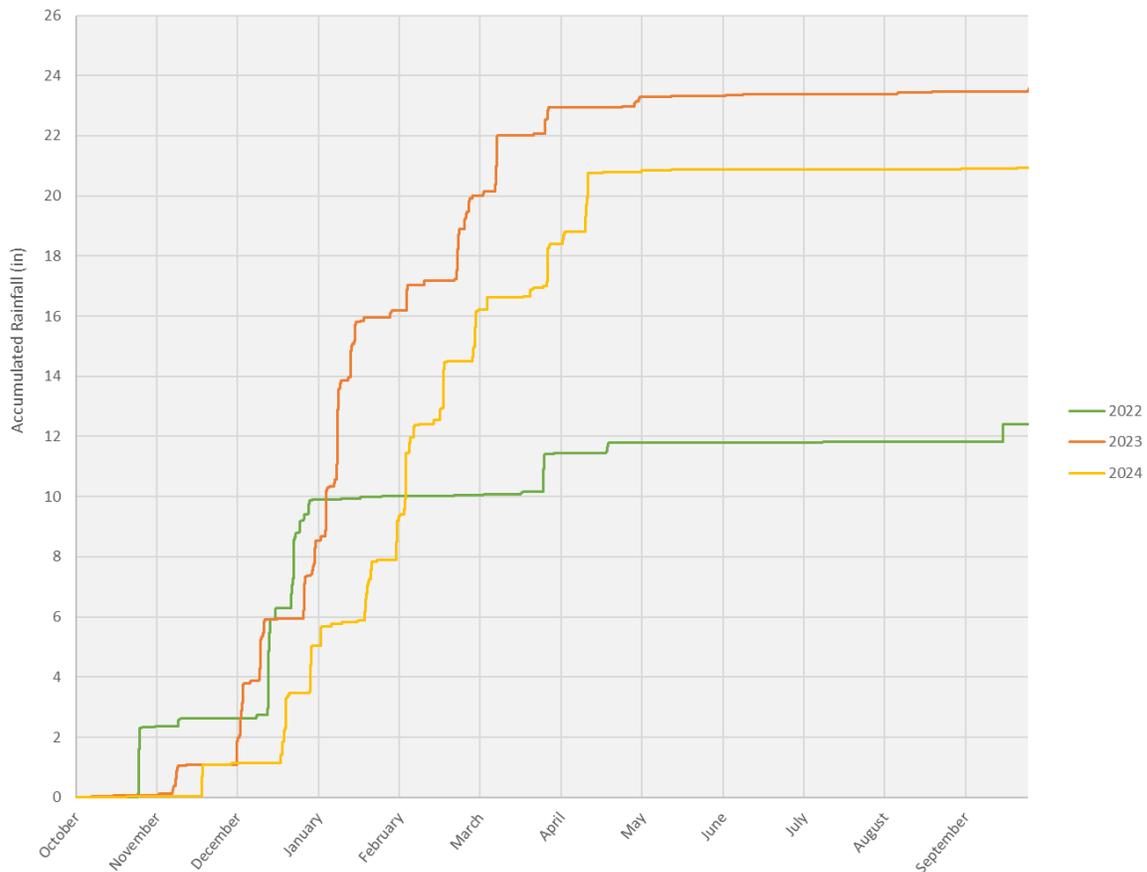


Figure 5. Accumulated annual rainfall for WY2020 to WY2024.

Discussion

While SSC was not modeled for this analysis, streamflow and precipitation data provide context for sediment transport potential. WY2024 represented near-average rainfall, and most storm events were low to moderate intensity, with the exception of three storms which topped the bridge at Canet Road (Figure 4). These storms represent the highest potential for sediment transport during the year. Because these bridge-topping events were brief, and overall flows remained moderate for much of the year, widespread substrate disturbance was likely minimal. However, following the flooding and extreme

hydrologic conditions of WY2023, peak flows could have contributed to further sediment mobilization particularly in areas with previously eroded banks or channel instability.

Chorro Creek Ecological Reserve Geomorphic Assessment

The Chorro Creek Ecological Reserve (CCER) is located near the center of the Chorro Creek sub-watershed, approximately one mile upstream of the Canet Road gauging station. In 2019, a restoration project was completed to promote fine sediment deposition, support floodplain reconnection, and enhance aquatic and riparian habitat. The project included construction of a secondary channel, installation of willow baffles and low-profile wood structures, and riparian vegetation plantings.

Large storm events in 2021 and 2023 caused significant changes across the project site, including channel migration, incision, and localized sediment deposition. In the winter of 2023, the primary flow path of Chorro Creek was altered, converting the former mainstem into a backwatered secondary channel, and the constructed secondary channel into the primary flow path. Although this was not the intended outcome of the project, this redistribution of flow likely helped reduce downstream sediment delivery to the estuary at peak flows.

In September 2024, the Estuary Program developed a detailed geomorphic assessment of the project area to evaluate restoration outcomes and inform ongoing adaptive management. The effort aimed to quantify sediment erosion and deposition patterns, assess changes in channel morphology, and evaluate implications for fish passage after the storms of 2021 and 2023.

Methodology

To assess erosion and deposition changes, a bare-earth digital elevation model (DEM) was developed using drone-based LiDAR. Surveys were completed using a Rock Robotic R2A LiDAR scanner mounted on a DJI M300 RTK drone. GNSS and Inertial Measurement Unit (IMU) were corrected using post-processed kinematic methods. An additional flight with a DJI P1 photogrammetric camera was completed for digital orthomosaic development in Agisoft Metashape photogrammetry software. Survey control was tied to ESA Control Point 103 and a nearby NGS benchmark (FV0393) for consistency with prior datasets.

Additional survey data were collected in areas where the LiDAR could not effectively scan, like below the water surface and areas with dense ground vegetation. A longitudinal profile and thirteen historic cross-sectional stream profiles were also resurveyed to address changes in channel morphology.

Analysis

The combined LiDAR and stream survey data revealed spatially variable patterns of sediment deposition and erosion. Figure 6 shows the elevation change at the CCER project site between 2021 and 2024 with negative elevation changes in shades of red and orange (erosion), positive elevation changes in shades of blue (deposition), and no elevation change in light blue.

In the upstream area of the project site (XS11 to XS8 in Figure 8), significant incision was identified with elevation losses of over three feet in some areas. Toward the middle of the site (XS7 to XS4), geomorphic patterns were more complex with some active erosion, sediment transfer, and localized deposition. The downstream region (XS3 to XS1) showed moderate erosion and some deposition toward the channel outlet. The former main channel, now functioning as side channel (XS12 and XS13), showed clear signs of deposition, reflecting its effectiveness at sediment capture and reducing downstream sediment transport.

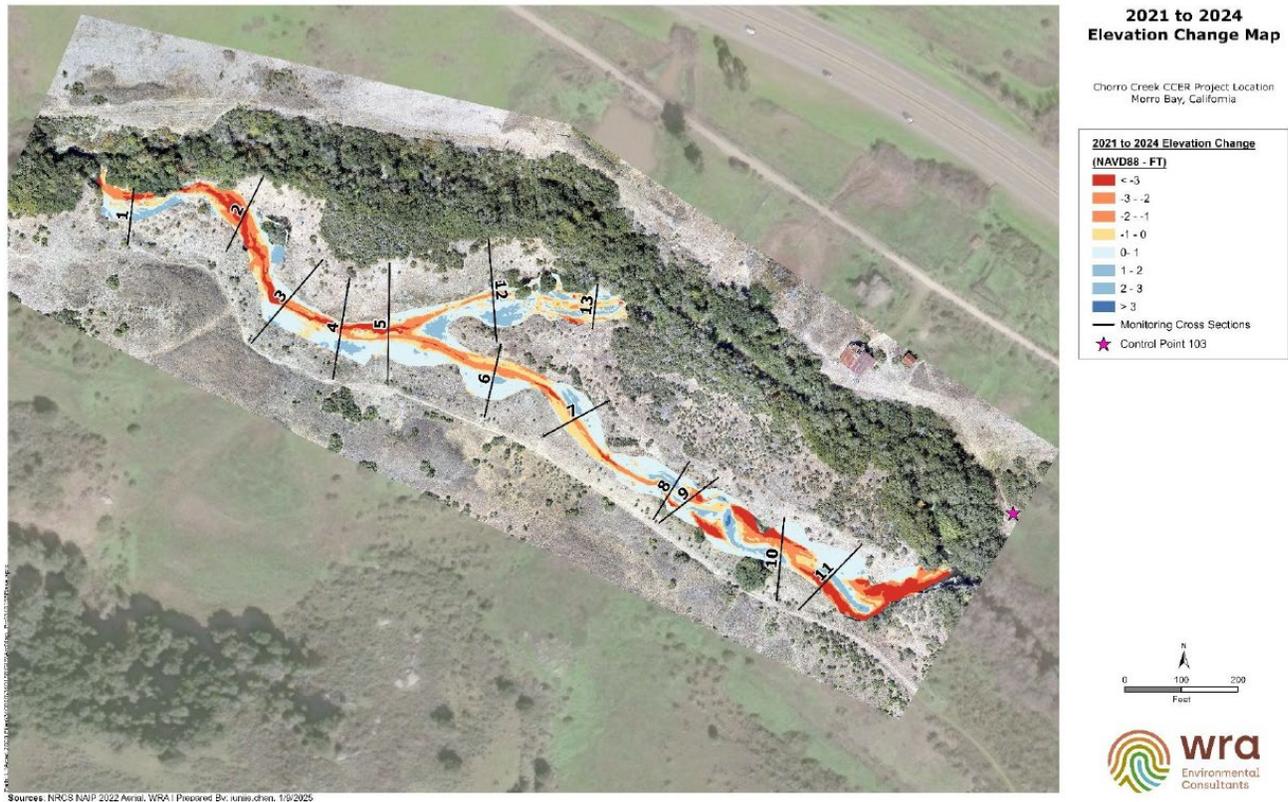


Figure 6. Elevation change at the Chorro Creek Ecological Reserve (CCER) between 2021 and 2024. Map courtesy of WRA Environmental Consultants.

The California Department of Fish and Wildlife’s Criteria for Fish Passage recommends that elevation drops exceeding one foot should have downstream jump pools with depths of at least two feet to support migratory fish passage (CDFW, 2002). To evaluate fish passage implications, the longitudinal profile results were analyzed with special attention for areas where the elevation dropped more than one foot. Water surface levels were also analyzed to assess jump pool depth. Several notable drops identified included a 3.89-foot drop near the downstream end of the project site (XS1), a 4.13-foot drop toward the middle of the site (between XS3 and XS4), and a 3.47-foot drop on the lower part of the upstream end (XS8). Water surface elevations measured at cross-sections suggested that some pools, such as those near the downstream end (0.69 feet at XS1; 0.95 feet at XS4), likely provide insufficient depths for fish passage.

Discussion

The CCER project site has undergone significant changes since 2019, particularly in response to the high-magnitude flow events of 2021 and 2023. The Estuary Program’s 2024 geomorphic assessment revealed channel incision, erosion, and localized deposition across the project reach. Cumulative sediment loss totaled roughly 59,777 to 64,498 cubic feet lost between 2021 and 2024, with mid-reach and downstream areas accounting for the largest volumetric losses. Although isolated zones such as along the new side channel (XS12 and XS13) were effective at retaining sediment, they were insufficient to offset the overall sediment deficit. This analysis also identified several areas where drops accompanied by shallow jump pool depths may block fish migration, especially during low-flow periods.

The Estuary Program plans to conduct further studies and implement adaptive management strategies to support key goals of the project like effective sediment retention, fish habitat development, and floodplain connectivity.

Streambed Sediment Impairment Indicators

Since 2002, the Estuary Program has conducted surveys each spring using the Surface Water Ambient Monitoring Program (SWAMP) bioassessment protocol. Data collected during these surveys generates physical and biological metrics that can be used to interpret the impacts of sediment. The Estuary Program utilizes the physical habitat data collected during bioassessment surveys to compare against proposed sediment indicators developed by the State Water Board and researchers at UC Davis.

While there are no numeric targets for sediment impairment and biological thresholds in the Morro Bay watershed, researchers from the Sierra Nevada Aquatic Research Laboratory (SNARL) have developed targets for the Central Coast and San Lorenzo River region (Herbst, 2011). To develop these targets, numerous indices were tested across a gradient of test sites. The outcome included 16 indicators of sediment impairment on aquatic habitat, including physical characteristics (sediment) and benthic macroinvertebrate community composition. Initial analysis shows that these physical and benthic indicator targets are likely relevant in the Morro Bay watershed.

The current SWAMP bioassessment monitoring protocol (Ode et. al, 2016) generates seven of the nine sediment indicators and six of the seven biological indicators used in the analysis. The indicators that are collected annually by the Estuary Program are bolded in the list below.

Sediment Indicators:

- 1. Percent of Fines (F) on transects**
- 2. Percent of Sand (S) on transects**
- 3. Percent of Fines (F) + Percent of Sands (S) on transects**
- 4. Percent of Fines, Sands and Gravels < 8mm on transects**
- 5. D50 Median particle size**
6. Percent patch-scale grid Fines and Sands
7. Log Relative Bed Stability
- 8. Percent of Fines (Steelhead)**
- 9. Percent Cover of Fines and Sands (BMI Limits)**

Biological Indicators

- 1. Total Richness**
- 2. EPT⁴ Richness**
- 3. Percent EPT**
- 4. Biotic Index**
- 5. Percent Tolerant**
- 6. Sensitive Number**

⁴ EPT refers to macroinvertebrate species orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). These three orders are considered biological indicators of favorable habitat and water quality conditions.

7. Crayfish Number and Size

For each indicator, there are three threshold criteria for comparison (Table 3). These criteria include targets that are recommended to support beneficial uses, targets that support preliminary low priority 303(d) listing, and targets that support high priority 303(d) listing.

Table 3. Sediment and biological indicator criteria.

	Recommended Numeric Targets To Support Beneficial Uses	Recommended Numeric Targets to Support Preliminary 303(d) Listing (lower priority)	Recommended Numeric Targets To Support 303(d) Listing (high priority)
Sediment Indicators		75/25	90/10
Percent Fines on transects	<8.5%	8.5 to 15.2%	>15.2%
Percent Sands on transects	<27.5%	27.5 to 35.3%	>35.3%
Percent Fines + Sands on transects	<35.5%	35.5 to 42.0%	>42.0%
Percent Fines, Sands, Gravel <8mm on transects	<40.0%	40.0 to 50.2%	>50.2%
D50 median particle size	>15 mm	7.7 to 15 mm	<7.7 mm
Percent Fines (steelhead)	<6%	6 to 10%	>10%
Percent cover of FS (BMI limits)	<30%	30 to 40%	>40%
Biological Indicators		75/25	90/10
Total Richness	>50.0	<50.0	<44.2
EPT Richness	>16.5	<16.5	<11.6
Biotic Index	<5.48	>5.48	>5.92
Percent Tolerant	<26.3%	>26.3%	>37.7
Sensitive Number	>9.5	<9.5	<5.8

Monitoring Sites

The Estuary Program monitors ten bioassessment sites each year based on program data needs, hydrologic conditions, and site accessibility. Sites are designated as “core” or “rotating.” Core sites are monitored every year, and rotating sites are monitored approximately every three years. The six core monitoring sites are included in this sediment analysis. Five of the six core monitoring sites are located in the Chorro subwatershed, and one is located in the Los Osos subwatershed (site code 310CLK). The sites within the Chorro subwatershed are Pennington Creek (310UPN), San Bernardo Creek (310MNO), San Luisito Creek (310LSL), Dairy Creek (310DAU), and lower Chorro Creek (310TWB).

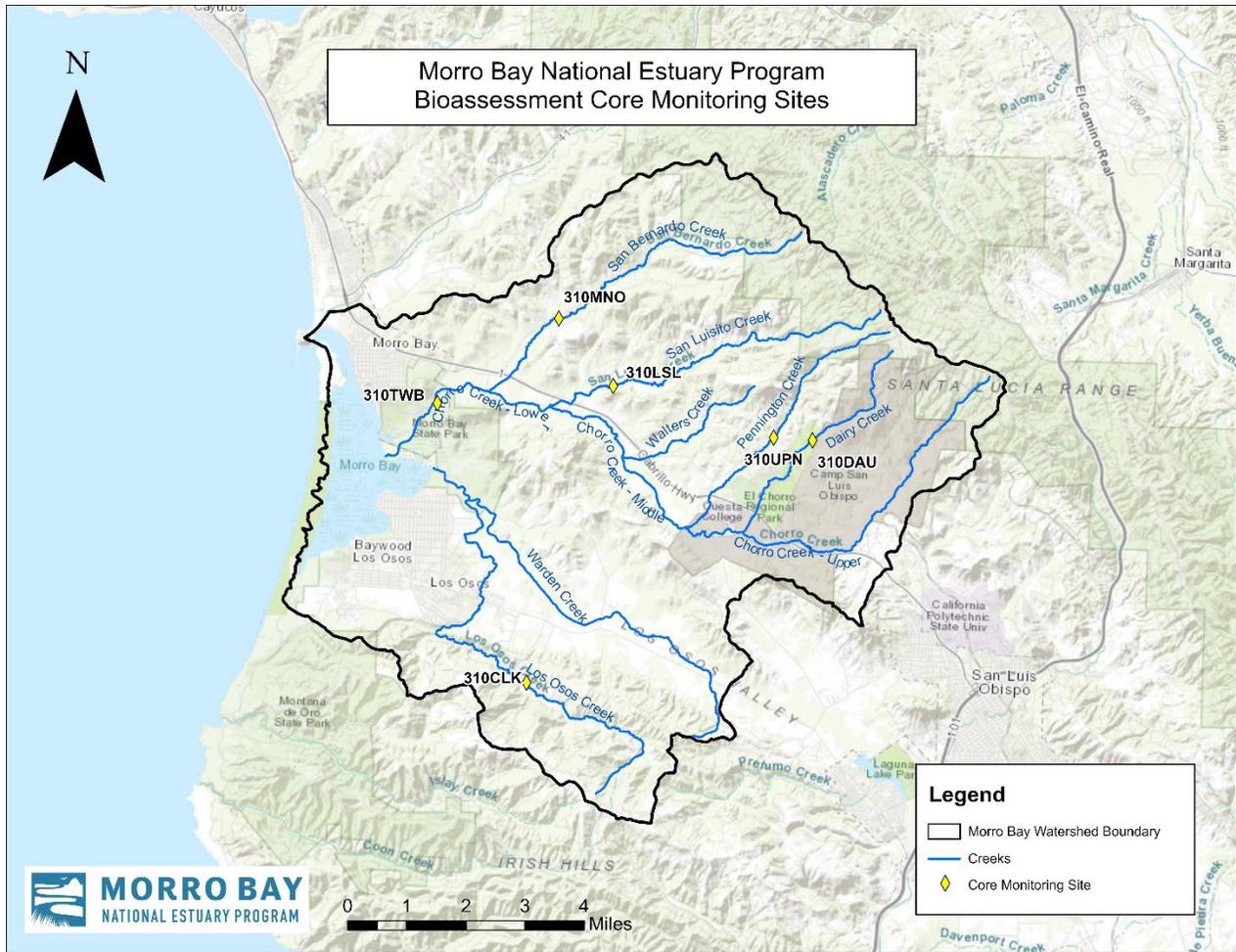


Figure 7. Core bioassessment monitoring sites in the Morro Bay watershed.

Results

Sediment impairment indicator scores were compiled from the six core monitoring sites from 2008 to 2024 (Table 4). The averaged scores from 2008 to 2024 are detailed in Table 5. Scores highlighted in green meet the target criteria for beneficial uses for the given site and year. Scores in yellow show some signs of impairment and would be low priority for 303(d) listing, and scores in red are more heavily impaired and strongly support the need for a 303(d) listing.

Table 4. Sediment indicators for core bioassessment monitoring sites from 2008 to 2023.

Site Code	Survey Date	Sediment Indicators							Biological Indicators					
		Percent Fines	Percent Sands	Percent <8mm	FS Sum Percent	D50 Median particle size	Percent Fines (steelhead)	Percent Cover of FS (BMI limits)	Total Richness	EPT Richness	Percent EPT	Biotic Index	Percent Tolerant	Sensitive Number
310MNO	2008	0.0	24.8	26.7	24.8	20.0	0.0	24.8	64.0	20.0	50.4	4.7	9.4	10.0
310MNO	2010	1.0	23.3	30.1	24.3	14.0	1.0	24.3	42.0	14.0	61.8	4.7	7.1	5.0
310MNO	2012	2.9	9.8	14.7	12.8	37.0	2.9	12.8	69.0	22.0	42.8	4.8	8.7	10.0
310MNO	2013	2.9	7.8	18.6	10.8	31.0	2.9	10.8	66.0	18.0	19.0	5.7	9.1	14.0
310MNO	2014	5.0	24.0	35.0	29.0	24.0	5.0	29.0	46.0	3.0	3.4	7.3	17.4	3.0
310MNO	2015	6.7	9.5	24.8	16.2	17.0	6.7	16.2	57.0	5.0	4.3	6.9	14.0	4.0
310MNO	2016	13.5	11.0	36.5	12.4	12.5	13.5	12.4	70.0	16.0	23.6	5.91	14.3	9.0
310MNO	2017	6.7	20.0	34.3	26.7	23.0	6.7	26.7	37.0	12.0	52.7	4.9	10.8	4.0
310MNO	2018	7.6	17.1	30.5	24.8	27.0	7.6	24.8	52.0	19.0	21.2	5.7	15.4	9.0
310MNO	2019	9.5	26.7	46.7	36.2	9.0	9.5	36.2	52.0	17.0	32.2	5.4	5.8	6.0
310MNO	2020	12.4	21.0	49.5	33.3	8.0	12.4	33.3	61.0	14.0	25.9	5.6	14.8	48.3
310MNO	2021	3.8	32.4	45.7	36.2	11.0	3.8	36.2	47.0	11.0	12.2	6.2	21.3	5.0
310MNO	2022	15.2	14.3	29.5	29.5	19.0	15.2	29.5	66.0	15.0	21.4	6.2	15.2	9.0
310MNO	2023	3.8	22.9	32.4	26.7	15.0	3.8	26.7	33.0	4.0	43.0	5.6	9.1	3.0
310MNO	2024	9.5	19.0	34.3	28.6	16.0	9.5	28.6	57.0	14.0	43.5	5.3	6.0	7.0
310LSL	2008	5.7	19.1	33.3	24.8	12.0	5.7	24.8	55.0	14.0	25.2	4.5	12.7	9.0
310LSL	2010	11.8	10.9	33.7	22.8	13.0	11.8	22.8	48.0	18.0	50.7	4.6	6.3	9.0
310LSL	2012	2.9	23.3	32.1	26.2	14.0	2.9	26.2	61.0	22.0	18.3	4.5	9.8	16.0
310LSL	2013	10.5	9.5	25.7	20.0	17.0	10.5	20.0	39.0	4.0	0.9	5.2	15.4	2.0
310LSL	2014	16.2	11.4	34.3	27.6	20.0	16.2	27.6	44.0	8.0	4.3	5.5	9.1	6.0
310LSL	2015	14.4	11.5	37.5	26.0	11.0	14.4	26.0	54.0	14.0	17.8	5.3	9.3	6.0
310LSL	2016	23.8	9.5	40.0	33.3	9.0	23.8	33.3	44.0	15.0	36.0	4.54	8.9	9.0
310LSL	2017	9.8	12.7	27.5	22.5	20.5	9.8	22.5	37.0	12.0	28.8	5.0	13.5	6.0
310LSL	2018	1.9	30.5	32.4	32.4	14.0	1.9	32.4	55.0	22.0	51.4	4.2	7.3	12.0
310LSL	2019	15.5	17.5	47.6	33.0	9.0	15.5	33.0	52.0	19.0	39.7	4.9	7.7	10.0
310LSL	2020	12.4	11.4	39.0	23.8	11.0	12.4	23.8	55.0	15.0	7.7	5.4	7.3	28.2
310LSL	2021	5.8	19.4	33.0	25.2	12.0	5.8	25.2	48.0	16.0	42.4	4.9	10.4	10.0
310LSL	2022	6.9	25.5	36.3	32.4	15.0	6.9	32.4	58.0	17.0	40.8	4.7	13.8	9.0
310LSL	2023	0.0	32.0	41.2	32.0	12.0	0.0	32.0	27.0	9.0	67.4	5.0	11.1	6.0
310LSL	2024	5.9	16.8	31.7	22.8	10.0	5.9	22.8	46.0	19.0	46.0	4.5	10.0	10.9
310UPN	2008	1.9	12.4	20.0	14.3	25.0	1.9	14.3	62.0	17.0	18.4	5.0	9.7	14.0
310UPN	2011	2.9	15.2	19.1	18.1	120.0	2.9	18.1	59.0	25.0	64.4	4.3	5.1	13.0
310UPN	2012	1.0	16.5	17.5	17.5	63.5	1.0	17.5	56.0	21.0	48.5	4.0	8.9	15.0
310UPN	2013	2.9	7.7	14.4	10.6	100.5	2.9	10.6	70.0	24.0	32.6	4.5	5.7	17.0
310UPN	2014	1.9	3.8	9.5	5.7	87.0	1.9	5.7	73.0	20.0	17.6	4.9	6.9	15.0
310UPN	2015	5.8	4.8	16.3	10.6	55.5	5.8	10.6	53.0	10.0	16.1	5.4	9.4	5.0
310UPN	2016	2.9	9.0	24.8	2.9	24.0	2.9	2.9	42.0	3.0	2.9	7.2	21.4	3.0
310UPN	2017	1.0	15.2	23.8	16.2	21.0	1.0	16.2	50.0	15.0	58.4	4.7	6.0	8.0
310UPN	2018	1.9	24.8	29.5	26.7	30.0	1.9	26.7	57.0	21.0	45.0	4.0	3.5	16.0
310UPN	2019	2.9	6.7	16.2	9.5	34.0	2.9	9.5	60.0	16.0	26.4	5.0	6.7	11.0
310UPN	2020	1.0	13.3	19.0	14.3	55.0	1.0	14.3	67.0	20.0	24.9	4.8	9.0	46.0
310UPN	2021	2.9	10.5	19.0	13.3	53.0	2.9	13.3	61.0	15.0	19.7	5.4	8.2	11.0
310UPN	2022	0.0	20.0	21.9	20.0	28.0	0.0	20.0	60.0	17.0	20.7	5.1	8.3	7.0
310UPN	2023	1.0	7.8	15.7	8.8	40.0	1.0	8.8	45.0	9.0	31.8	5.3	6.7	8.0
310UPN	2024	2.9	14.4	26.9	17.3	25.5	2.9	17.3	58.0	20.0	56.4	3.7	12.0	3.5
310TWB	2008	18.8	7.9	31.7	26.7	13.0	18.8	26.7	55.0	14.0	27.3	5.4	14.6	7.0
310TWB	2012	8.0	29.0	44.0	37.0	9.5	8.0	37.0	46.0	8.0	6.8	6.7	21.7	3.0
310TWB	2013	9.7	18.5	44.7	28.2	9.0	9.7	28.2	52.0	9.0	3.7	6.4	21.2	4.0
310TWB	2014	24.8	11.4	53.3	36.2	6.0	24.8	36.2	41.0	4.0	6.9	6.5	24.4	2.0
310TWB	2015	12.5	41.0	59.0	41.0	5.0	0.0	41.0	31.0	0.0	0.0	7.6	29.0	0.0
310TWB	2016	12.4	24.8	51.4	37.1	12.5	13.5	37.1	31.0	9.0	34.1	5.5	19.4	4.0
310TWB	2017	12.5	21.2	34.6	33.7	16.0	12.5	33.7	31.0	9.0	34.1	5.5	19.4	4.0
310TWB	2018	14.3	35.2	63.8	49.5	3.0	14.3	49.5	46.0	11.0	14.6	6.3	17.4	5.0
310TWB	2019	16.3	35.6	63.5	51.9	1.0	16.3	51.9	43.0	10.0	22.8	6.6	18.6	1.0
310TWB	2020	21.0	29.5	66.7	50.5	2.0	21.0	50.5	47.0	9.0	26.7	5.8	19.2	44.3
310TWB	2021	22.9	21.9	46.7	44.8	9.0	22.9	44.8	40.0	6.0	7.4	6.9	17.5	2.0
310TWB	2022	4.2	40.6	46.9	44.8	9.0	4.2	44.8	44.0	8.0	13.4	6.6	22.7	3.0
310TWB	2023	38.4	8.1	49.5	46.5	8.0	38.4	46.5	40.0	6.0	10.8	6.6	22.5	3.0
310TWB	2024	28.6	17.1	52.4	45.7	4.0	28.6	45.7	46.0	11.0	17.3	6.6	5.0	19.6
310CLK	2017	3.9	10.7	19.4	14.6	35.0	3.9	14.6	51.0	8.0	5.0	6.4	15.7	5.0
310CLK	2018	3.8	18.1	31.4	21.9	14.0	3.8	21.9	59.0	10.0	21.6	6.2	17.0	6.0
310CLK	2019	4.8	18.1	25.7	22.9	29.0	4.8	22.9	40.0	11.0	23.4	4.9	10.0	4.0
310CLK	2020	5.7	21.0	40.0	26.7	10.0	5.7	26.7	59.0	15.0	51.8	4.7	11.9	61.0
310CLK	2023	4.9	19.6	29.4	24.5	24.5	4.9	24.5	39.0	5.0	4.9	6.9	15.4	1.0
310CLK	2024	16.3	21.2	42.3	37.5	10.5	16.3	37.5	47.0	16.0	39.0	5.2	10.0	10.6
310DAU	2011	15.7	14.7	33.3	30.4	22.5	15.7	30.4	45.0	13.0	53.5	4.8	4.4	8.0
310DAU	2017	2.9	24.8	32.4	27.6	20.0	2.9	27.6	49.0	11.0	44.8	4.5	2.0	7.0
310DAU	2018	1.0	21.6	25.5	22.5	22.5	1.0	25.7	66.0	22.0	37.8	4.6	7.6	17.0
310DAU	2019	2.9	33.3	38.1	36.2	16.0	2.9	36.2	55.0	15.0	42.6	5.1	10.9	6.0
310DAU	2021	2.9	32.4	42.9	35.2	15.0	2.9	35.2	27.0	6.0	32.2	4.3	7.4	3.0
310DAU	2022	8.9	11.9	22.8	20.8	20.0	8.9	20.8	66.0	16.0	21.2	5.0	9.1	10.0
310DAU	2023	1.0	12.6	17.5	13.6	40.0	1.0	13.6	32.0	7.0	58.2	5.2	12.5	6.0
310DAU	2024	1.0	25.7	27.6	26.7	21.0	1.0	26.7	54.0	19.0	69.3	3.6	14.0	3.7

Table 5. Averages for sediment indicators for core bioassessment monitoring sites. Note that the averages are calculated from the values in Table 4.

Site Code	Sediment Indicators							Biological Indicators					
	Percent Fines	Percent Sands	Percent <8mm	FS Sum Percent	D50 Median particle size	Percent Fines (steelhead)	Percent Cover of FS (BMI limits)	Total Richness	EPT Richness	Percent EPT	Biotic Index	Percent Tolerant	Sensitive Number
310MNO	6.7	18.9	32.6	24.8	18.9	6.7	24.8	54.6	13.6	30.5	5.7	11.9	9.8
310LSL	9.6	17.4	35.0	27.0	13.3	9.6	27.0	48.2	14.9	31.8	4.8	10.2	9.9
310UPN	2.2	12.1	19.6	13.7	50.8	2.2	13.7	58.2	16.9	32.3	4.9	8.5	12.8
310TWB	17.4	24.4	50.6	41.0	7.6	16.6	41.0	42.4	8.1	16.1	6.4	19.5	7.3
310CLK	6.6	18.1	31.4	24.7	20.5	6.6	24.7	49.2	10.8	24.3	5.7	13.3	14.6
310DAU	4.5	22.1	30.0	26.6	22.1	4.5	27.0	49.3	13.6	44.9	4.6	8.5	7.6

Recommended numeric targets to support beneficial uses
 Recommended numeric targets to support preliminary 303d Listing (low priority)
 Recommended numeric targets to support 303d listing (high priority)

Discussion

Sediment indicator results from 2024 suggest mostly unimpaired substrate conditions across the Morro Bay watershed. Five of the six core monitoring sites met most target criteria for sediment, indicating favorable streambed conditions and particle size distribution comparable to historical averages. As in previous years, Lower Chorro Creek (310TWB) continued to show evidence of sediment and biological impairment consistent with trends observed since 2008.

Biological indicators for 2024 showed significant improvement compared to 2023, where hydrologic conditions mobilized large amounts of sediment and displaced benthic macroinvertebrates. These conditions led to low biological indicator scores despite generally favorable substrate conditions. With more moderate hydrologic conditions in 2024, nearly all monitoring sites showed improvement in biological metrics, reflecting widespread macroinvertebrate community recovery in the watershed. The smaller tributaries of Dairy Creek (310DAU) and Pennington Creek (310UPN) exhibited the most dramatic improvement, particularly in EPT Richness, where 2024 results exceeded historical averages. Even consistently impaired sites like 310TWB showed some improvements in biological metrics compared to 2023.

While the sediment indicators for 2024 reflected generally intact conditions, Upper Los Osos Creek (310CLK), which has historically scored extremely well for sediment criteria, shifted into the 303(d) high priority category for Percent Fines and Percent Fines for steelhead. These results also increased 310CLK's historical average for Percent Fines for steelhead from 4.6% to 6.6%, placing it into the 303d low priority category. This site showed slightly slower biological recovery when compared to other tributary sites (MBNEP 2025), suggesting that fine sediment in Upper Los Osos Creek may have contributed to 310CLK's slower recovery timeline.

The sediment impairment criteria presented in this report differ from the monitoring criteria outlined in the approved sediment TMDL for Morro Bay. The Estuary Program submits all biotic and habitat data from bioassessment monitoring to SWAMP, where it is available to the CCRWQCB for TMDL and 303(d) assessments. The modified sediment impairment analysis discussed here is also shared with the CCRWQCB to support sediment impairment assessments in the Morro Bay watershed.

Morro Bay Estuary

The Morro Bay estuary is comprised of approximately 2,300 acres of shallow, semi-enclosed intertidal and subtidal habitat. The estuary is bordered to the west by a four-mile vegetated natural sandspit that separates Morro Bay from the Pacific Ocean.

Habitats and beneficial uses within the estuary are protected through numerous regulatory frameworks. Morro Bay was established as California's first State Estuary in 1994 and was accepted into the National Estuary Program in 1995. Today, Morro Bay is one of the Environmental Protection Agency's 28 recognized National Estuaries. In 2007, the Morro Bay estuary was incorporated into the California Department of Fish and Wildlife's Marine Protected Areas. Through the Marine Protected Area designations, the intertidal and subtidal habitats within Morro Bay are protected as either a State Marine Recreational Management Area or a State Marine Reserve. All of these frameworks serve to protect important habitat for marine and migratory species.

Zostera marina (eelgrass) is an important component of coastal habitat and provides diverse benefits to coastal marine and migratory species as well as substantial ecosystem services. Eelgrass meadows are known to be highly sensitive to poor water clarity. Historic monitoring of eelgrass extent during the 1970s indicated that intertidal eelgrass beds in Morro Bay may have spanned up to 500 acres, supporting one of the largest eelgrass extents in Southern California (Bernstein, et. al. 2011). Between 2007 and 2016 however, eelgrass acreage declined by over 90%. A survey conducted in December 2017 estimated that just over 13 acres of eelgrass remained in the bay (MBNEP, 2019). This decline led to expanded monitoring, restoration, and research efforts. Since then, Morro Bay has seen encouraging signs of recovery, with approximately 500 acres of eelgrass mapped in 2021 (MBNEP, 2022), and the most recent mapping effort indicating nearly 750 acres of eelgrass (MBNEP, 2024). This improvement is likely the result of multiple factors, including changing water quality conditions, shifting bay elevations, and eelgrass restoration efforts. Mapping methods are not necessarily consistent from year-to-year, which also contributes to shifts in acreage numbers.

In addition to providing critical marine habitat, Morro Bay is also a popular destination for outdoor recreation, supporting kayaking, sailing, fishing, wildlife observing, and waterfowl hunting. Many of these uses are protected as designated "Beneficial Uses" within the Central Coast Regional Basin Plan administered by the Water Board.

Morro Bay is also an important center for commercial fishing and aquaculture operations. The bay is designated as a Harbor of Safe Refuge and is the only safe harbor between Santa Barbara and Monterey. Maintenance of the harbor so that it remains navigable necessitates frequent dredging of the main channel. The harbor entrance is dredged annually by the Army Corps of Engineers (ACOE) to maintain a channel depth of approximately 40 feet mean lower low water (MLLW). More information on annual dredging can be found in the Estuary Program's annual Eelgrass Reports.

Tidal Prism Volume

Tidal prism refers to the volume of water that flows in and out of an estuary with the tide. It affects how well an estuary is flushed out, influencing sediment transport, water quality, and habitat availability. Tidal prism volume is a primary numeric target in the Morro Bay TMDL, reflecting its importance as an indicator of long-term sedimentation.

Assessments for tidal prism volume are conducted infrequently due to the high cost and the time needed between surveys to obtain meaningful results. Consistent assessment methodology is also important to make comparisons between past and present data. The most recent survey, conducted in August 2019, collected acoustic depth measurements within the deeper channels while historic efforts measured depth along 500-foot interval profiles. Tetra Tech analysis of the 2019 survey results relative to past surveys indicated that Morro Bay's tidal prism volume had increased since 1999 rather than the expected decrease, although it is unclear whether these conclusions are due to factors such as differences in survey methodology or an inadequate tidal height data set.

In 2022, the Estuary Program contracted with NV5 to complete a baywide LiDAR survey to assess geomorphological changes and patterns of erosion and accretion within the estuary. Comparison of the 2022 LiDAR data with prior elevation surveys conducted in 2010 and 2019 indicated that sediment had deposited in areas where eelgrass had re-established. Because eelgrass plays an important role in stabilizing sediments, the results provide further context for understanding estuarine dynamics that will continue to influence tidal prism over time.

To improve the overall understanding of tidal prism in Morro Bay, the Estuary Program has worked with California Polytechnic University (Cal Poly) to analyze tide height and its potential future impacts on habitats in the bay. These projects are ongoing and will support future refinement of Morro Bay tidal prism calculations.

Salt Marsh Sediment Monitoring

For over a decade, the Estuary Program has collaborated with partners like the U.S. Geological Survey (USGS) and University of San Francisco (USF) to support sediment accumulation monitoring efforts in the Morro Bay salt marsh. These efforts not only provide critical insights into sedimentation dynamics across different marsh zones in Morro Bay but also contribute to a wider understanding of marsh elevation and accretion patterns across the West Coast.

To monitor long term sedimentation and elevation change in the salt marsh, USGS and USF utilize a combination of methods including surface elevation tables (SETs) and feldspar marker horizon plots. SETs are mechanical devices anchored to fixed monuments in the ground and used to precisely measure changes in marsh elevation. Feldspar marker horizons involve sprinkling a thin layer of feldspar clay on the surface of the plot and measuring the amount of sediment that naturally settles on it over time.



Figure 8. SET and feldspar locations in Morro Bay. Sites in orange represent monitoring locations established by USF in 2004, and sites in purple represent those established by USGS in 2013.

USF Monitoring

In 2004, Dr. John Callaway of USF established six SET and feldspar marker horizon monitoring locations in the Morro Bay salt marsh to measure sedimentation rates and establish baseline elevations. Additional sampling stations were established in the intertidal mudflats. Measurements were collected by USF on a variable frequency, with monitoring efforts occurring in calendar year 2004, 2007, 2010, and 2015. Since then, the Estuary Program and USGS have continued to monitor a subset of these sites on an approximately five-year basis. The USF SETs were last monitored in September 2024.

Between 2004 and 2024, USF SETs showed a cumulative elevation change of $21.69 \text{ mm} \pm 0.57 \text{ mm}$ in the high marsh, and $56.82 \text{ mm} \pm 2.87 \text{ mm}$ in the low marsh. The high SETs reflect a rate of 1.10 mm per year , and the low SETs reflect an elevation increase of 2.76 mm per year .

USGS Monitoring

In 2013, USGS established four additional SETs with feldspar marker horizons as part of a larger study of sedimentation rates on the West Coast. The monitoring sites included two interior marsh, or high marsh and, two edge marsh, or low marsh sites (Figure 8). Initially, the SETs were monitored annually during the dry season. In 2023, USGS and the Estuary Program expanded the monitoring to twice per year, including a winter and summer survey effort. The most recent surveys were completed in March and September

2024. Biannual monitoring is planned to continue until March 2025, after which annual monitoring will resume.

During 2024, the USGS sites located in the interior marsh, or high marsh, had an average cumulative elevation change of 19.79 ± 0.55 mm, while the sites in along the marsh edge, or low marsh, had an average cumulative elevation change of 23.85 ± 0.75 mm. The rate of change between 2013 and 2024 was 1.74 mm per year in the high marsh and 2.09 mm per year in the low marsh. Preliminary analysis suggests the measured accretion rates at the USF and USGS SET monitoring locations are keeping up with the 50-year rate of sea level rise and potentially outpacing sea level rise in lower marsh SETs.

Conclusions

While WY2023 represented an exceptionally wet year for the Morro Bay watershed, WY2024 reflected more average rainfall conditions coupled with several higher intensity storms. Although brief, these storms likely played an important role in sediment mobilization and redistribution. Streambed sediment indicator results suggested mostly unimpaired conditions throughout the watershed, especially compared to WY2023. The results indicate that macroinvertebrate communities are recovering, especially in smaller tributaries like Dairy Creek and Pennington Creek. While the Chorro Creek Ecological Reserve restoration project acted as designed during the winters of 2021 and 2023 to trap sediment and reduce flooding, the site was substantially altered by those large storms. Current site conditions have created potential fish passage barriers and require adaptive management to ensure the site can continue to operate as designed. In the estuary, long-term SET monitoring suggests that accretion in the salt marsh is keeping pace with current rates of rising sea levels, particularly in low marsh areas.

Sediment transport and deposition are complex processes influenced by precipitation patterns, discharge, channel morphology, sediment particle size, and a range of environmental and human factors. The Estuary Program continues to work closely with partners and landowners to improve overall understanding of sediment dynamics in the Morro Bay watershed and estuary and track TMDL metrics.

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Appendix A. San Luis Obispo County precipitation contours

