Sediment Monitoring Report

For Water Year 2023

Morro Bay National Estuary Program
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List of Acronyms

Acronym	Definition
BMI	Benthic macroinvertebrate
BMP	Best management practices
Cal Poly	California Polytechnic State University, San Luis Obispo
CFS	Cubic feet per second (ft^3/s)
CSLRCD	Coastal San Luis Resource Conservation District
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Trichoptera
D50	Median gravel size diameter
ITRC	Irrigation Training and Research Center
MLLW	Mean lower low water
NMP	National Monitoring Program
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 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 ≤ 21%
Percent of Coarse Fines (all fines < 6.0 mm) in Spawning Gravels	Percent coarse fine ≤ 30%
Morro Bay Estuary	
Tidal Prism Volume	4,200 acre-ft

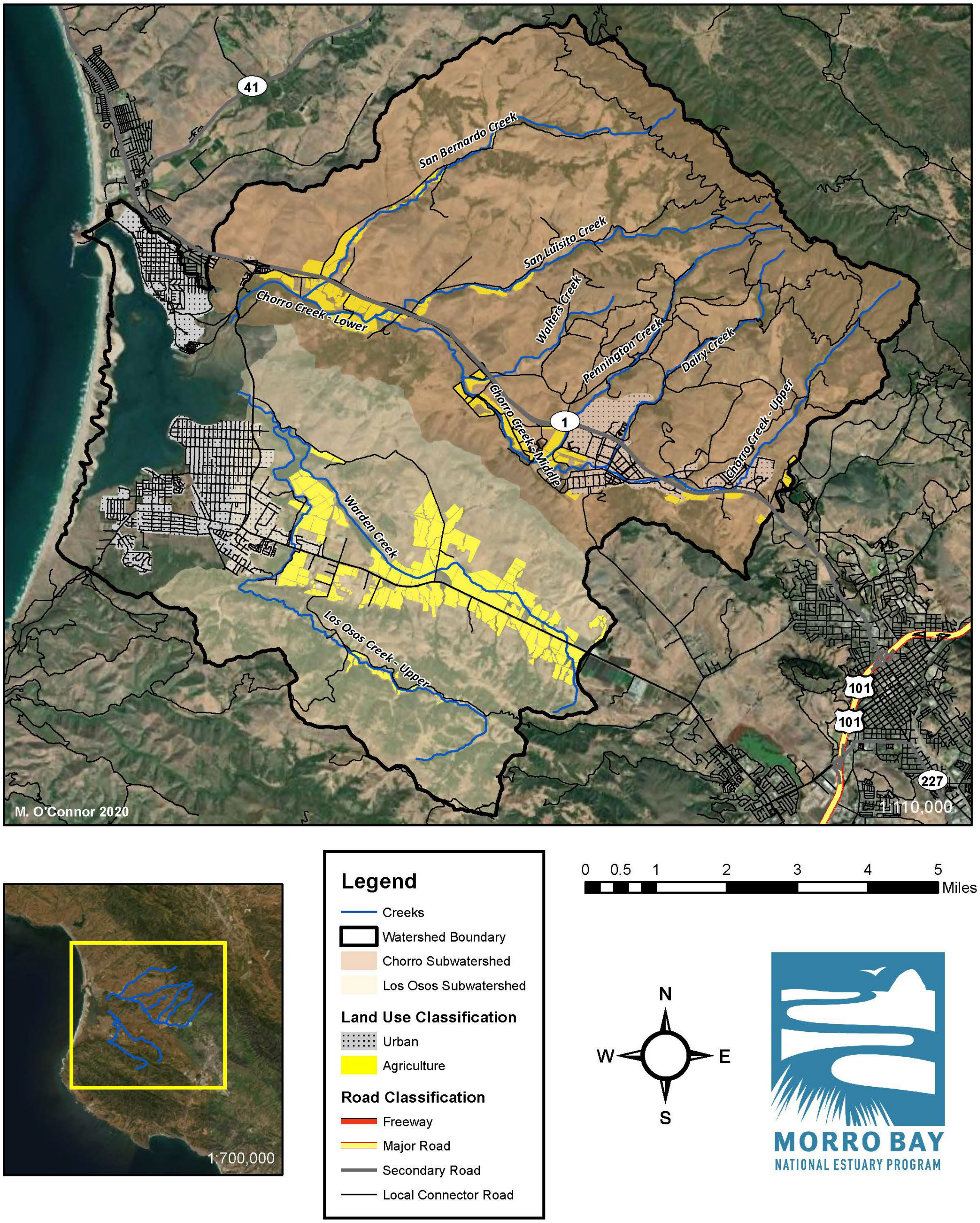
Numerous projects have occurred in the Morro Bay watershed to prevent sediment erosion and maximize sediment capture and retention within the watershed. The Estuary Program has worked with many local partners like the Coastal San Luis Resource Conservation District (CSLRCD), California Polytechnic University (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.



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.

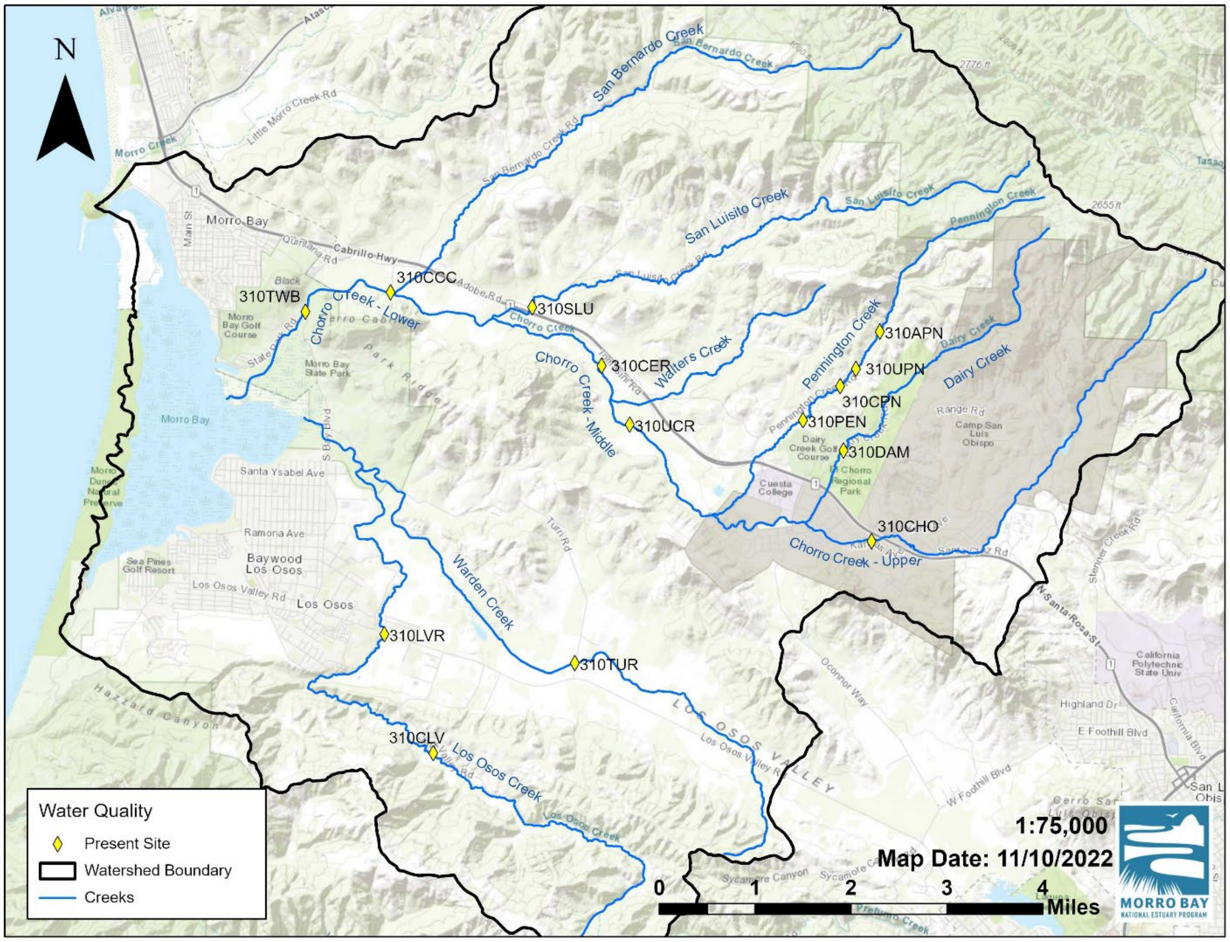


Figure 2. Map of the Estuary Program's ambient monitoring sites.

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 4,372 turbidity readings collected between 2002 and 2023, 2.4% 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.

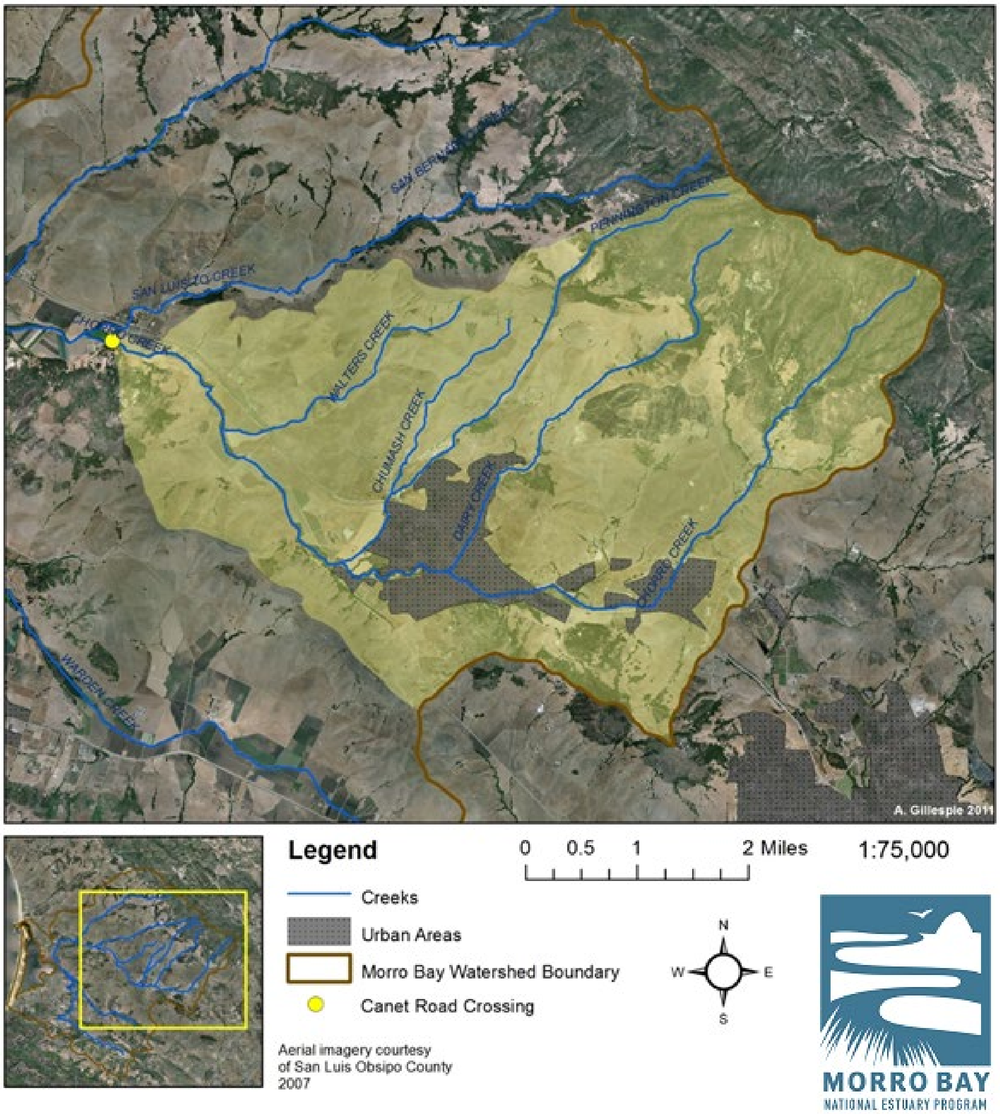


Figure 3. Map of watershed area that drains to Canet Road monitoring site.

Stage data from Station 753 provides critical information about water levels, flow conditions, and sediment transport potential within the Chorro Creek subwatershed. Collected at 15-minute intervals, the dataset captures both baseflow conditions and high-flow events that influence channel dynamics and sediment movement. Flows closer to the channel bottom (approximately 3.7 feet) indicate low sediment mobilization potential, while those nearing or exceeding the height of the bridge (approximately 12.1 feet) reflect conditions capable of transporting larger sediment loads. The hydrograph shown below illustrates stage height fluctuations at Station 753 during water year (WY) 2023 (October 1, 2022 to September 30, 2023) including multiple periods where flows exceeded 12.1 feet.

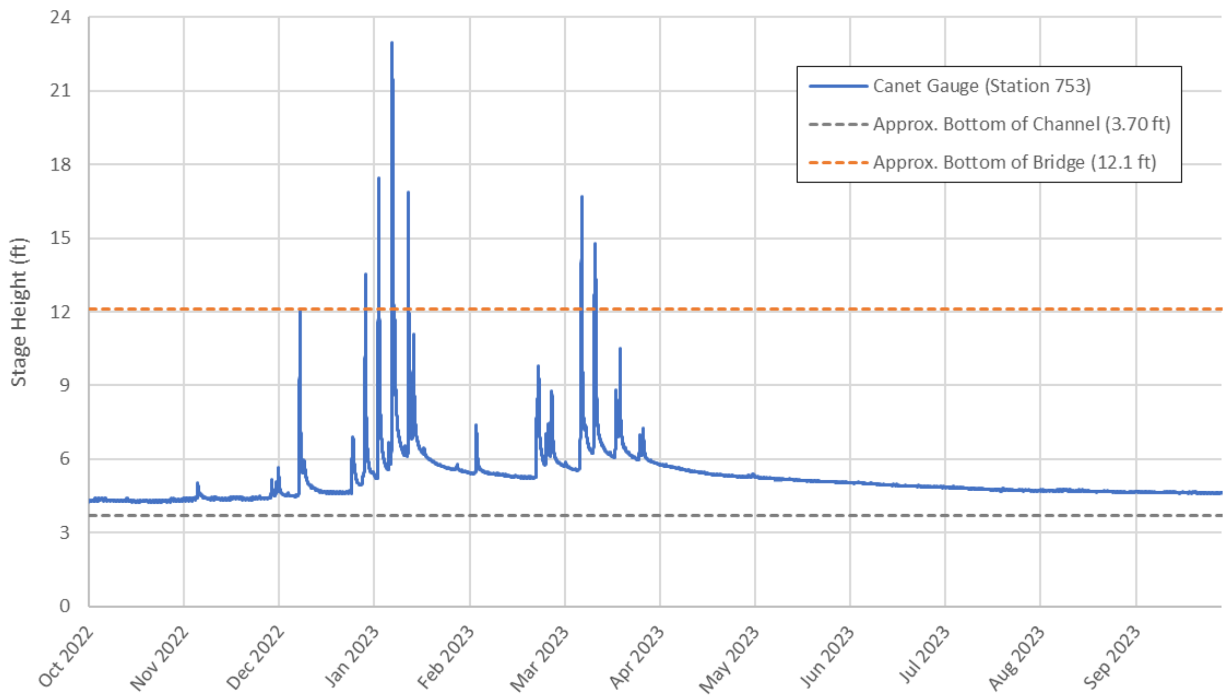


Figure 4. Stage height during WY2023 as recorded by SLO County Station 753 at Canet Road.

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, 2010).

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 feet[2]. The Creek Lands rating curve is 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.

[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.mbnep.org/wp-content/uploads/2024/09/MBNEP-Technical-Memo_CAN-Rating-Curve_2024.pdf.

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**.

It is important to note that the equations presented above 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. This limitation is particularly relevant for WY2023, during which stage heights exceeded 18.2 feet for an approximately 8-hour period on January 9, 2023. This timeframe represents some of the most extreme flow conditions ever recorded at the site, with a peak stage height of 22.95 feet. Because stage heights during WY2023 exceeded the upper limit of the rating curve, peak discharge and total annual discharge could not be calculated and are therefore not included in this report.

Precipitation Statistics

According to the San Luis Obispo County Department of Public Works precipitation contours (Appendix A), the Canet Road gauging station receives an average of 20 inches of rainfall per year. Table 2 summarizes the rainfall totals from Canet Road from WY2020 through WY2023.

Table 2. Rainfall statistics for WY2020 through WY2023.

Water Year	Total Annual Rainfall (in)	Percent of 20-inch Average Rainfall
2020	12.27	61.4%
2021	11.60	58.0%
2022	12.42	62.1%
2023	23.59	118%

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 WY2020 through WY2023, illustrating 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. WY2023 (in yellow) presents as a high rainfall year with a sharp increase in accumulated rainfall between January and February. Rainfall also continued later into the year than typical, with precipitation recorded as late as March and April.

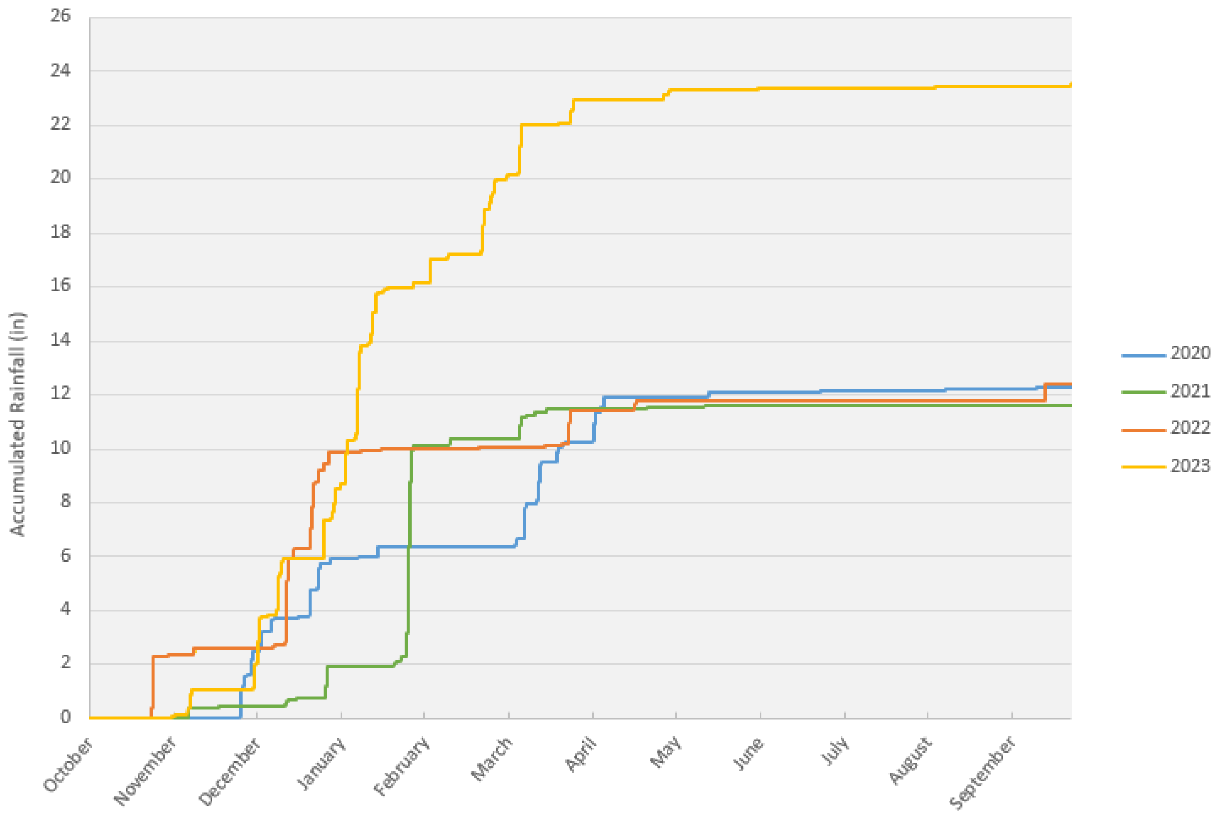


Figure 5. Accumulated annual rainfall for WY2020 to WY2023.

While SSC load was not modeled for this analysis, the high-intensity storm events and the extended wet season of WY2023 likely led to high rates of sediment mobilization and loading throughout the watershed. The consecutive dry years of WY2020 to WY2022 may have further increased sediment loading, as drought conditions can lead to soil compaction and reduced vegetation cover, making landscapes especially vulnerable during heavy rainfall (Bull & Kirkby, 2002). Erosion and bank failure were observed anecdotally on Pennington Creek and San Luisito Creek, suggesting that large volumes of sediment were likely pushed downstream to the mainstem of Chorro Creek.

Figure 6. Pennington Creek before and after a large scouring event in January 2023.

Cross Section Profiling

Creek cross sectional profiles provide detailed information about channel structure and morphology over time. In 1993, the Water Board established a series of cross-sectional profiling locations in the Chorro Creek sub-watershed as part of a long-term monitoring project implemented by the National Monitoring Program (NMP). The cross sections were located on upper Chorro Creek, Pennington Creek, Dairy Creek, and lower Chorro Creek. In 1997, CSLRCD established 21 additional cross sections on lower Chorro Creek after completion of the Chorro Flats Enhancement Project. Students from UC Berkeley attempted to locate and resurvey the CSLRCD cross sections in 2008 but were only able to locate two of the original sites. The students established five new cross sections within the Chorro Flats project area.

The Estuary Program has returned periodically to survey the NMP, CSLRCD, and UC Berkeley cross sections. In 2013, staff surveyed 19 NMP sites, one CSLRCD site, and four UC Berkeley sites. The remaining sites were unable to be located or surveyed. In 2019, the Estuary Program could only survey three of the NMP sites due to limited time and resources. During the most recent effort in calendar year 2023, the Estuary Program attempted to locate and survey as many existing sites as possible. Staff used a variety of historical data sources, maps, detailed site descriptions, high-accuracy GPS units, and metal detectors to search for the historic sites.

Monitoring Sites

Each cross-sectional profile relies on two stabilized rebar benchmarks on each bank to ensure consistency across surveys. During the 2023 survey effort, the Estuary Program visited 28 historic sites to locate left and right bank rebar benchmarks. Both historic rebar markers were found at ten sites, one of the two markers at nine sites, and no markers at the remaining nine sites. Sites with both benchmarks present that could be successfully surveyed were classified as active (shown in green in the map below); sites where access was limited or where only one benchmark was located were classified as temporarily inactive (shown in yellow); and sites where no benchmarks were found and determined to be permanently lost were classified as inactive (shown in red).

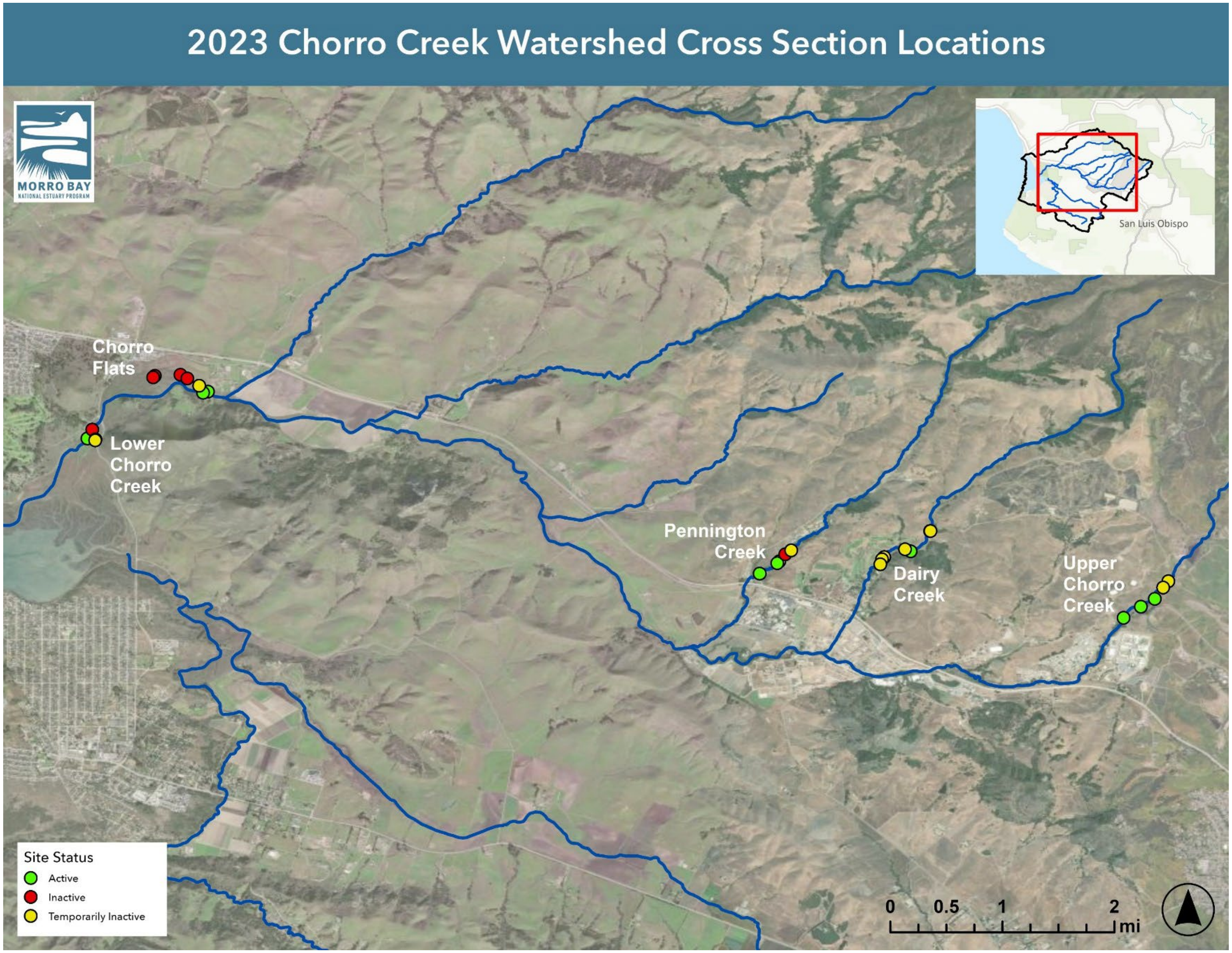


Figure 7. Cross section profile site status for the 28 locations assessed during 2023.

Results

The 2023 cross section results are summarized in the following maps and graphs. Years were selected for comparison based on the availability of high-quality data for each site. Data is not included for inactive or temporarily inactive sites.

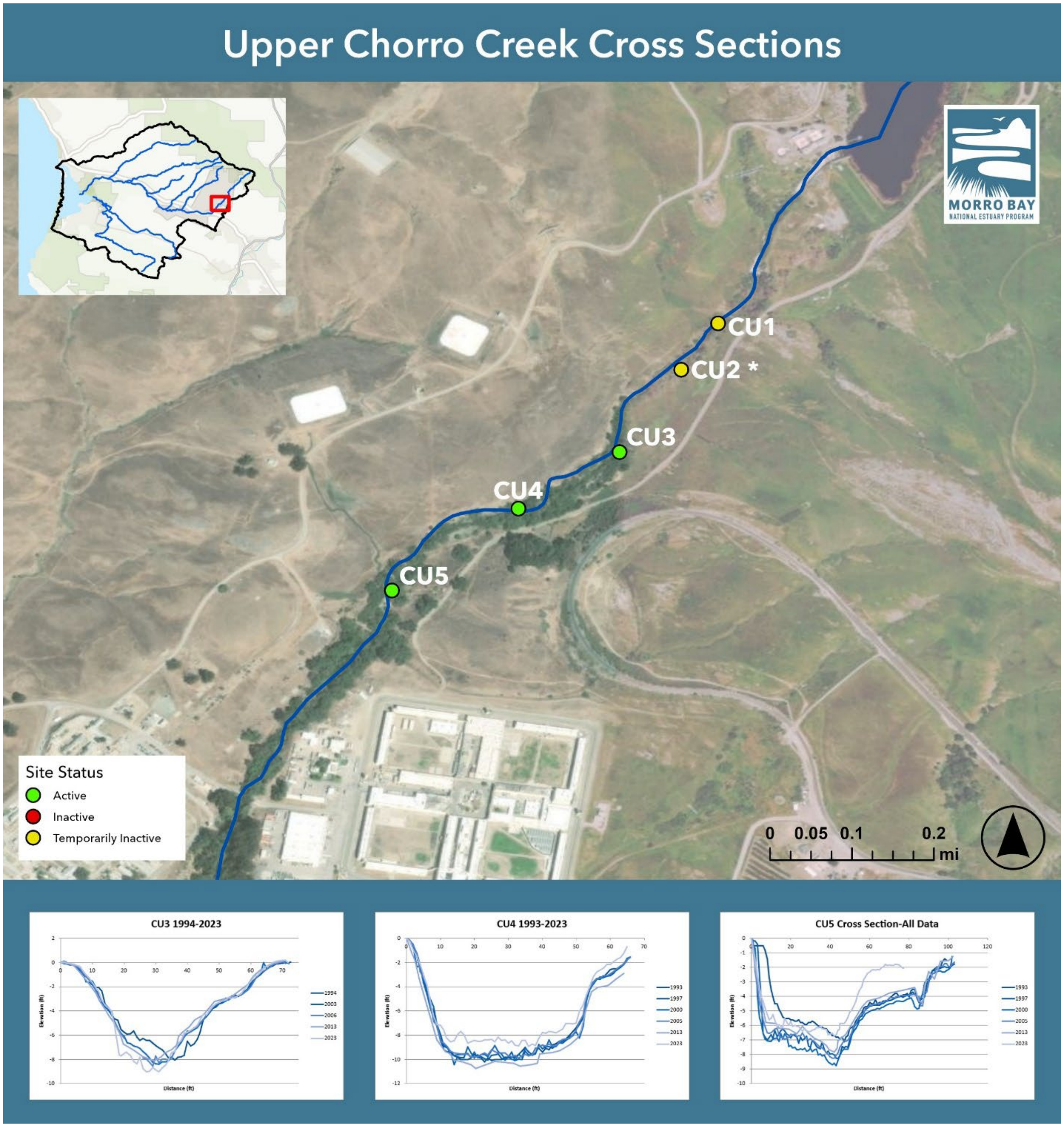


Figure 8. Upper Chorro Creek cross section profile results for 2023 (CU3, CU4, CU5).

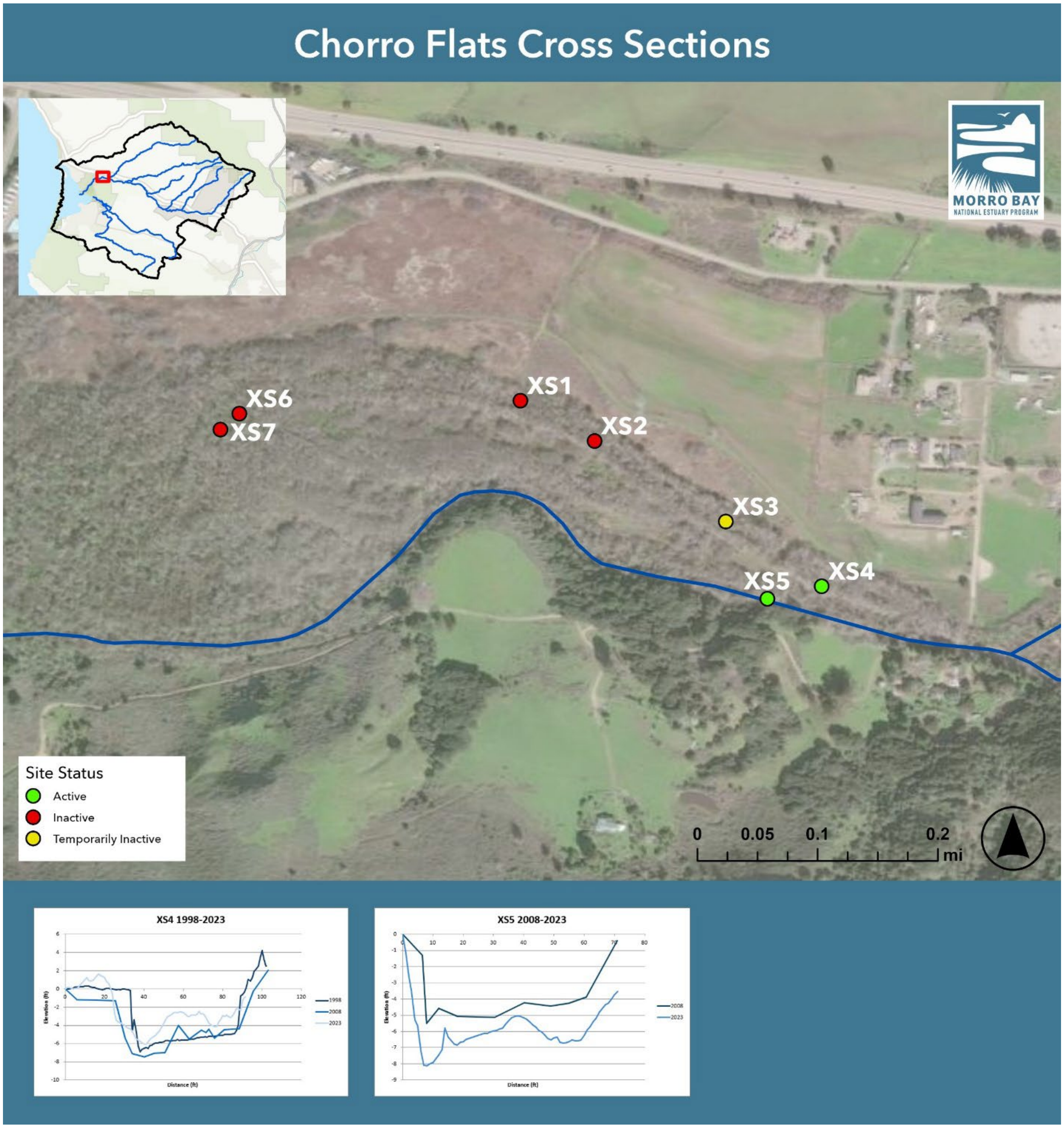


Figure 9. Lower Chorro Creek at Chorro Flats cross section profile results for 2023 (XS4, XS5).

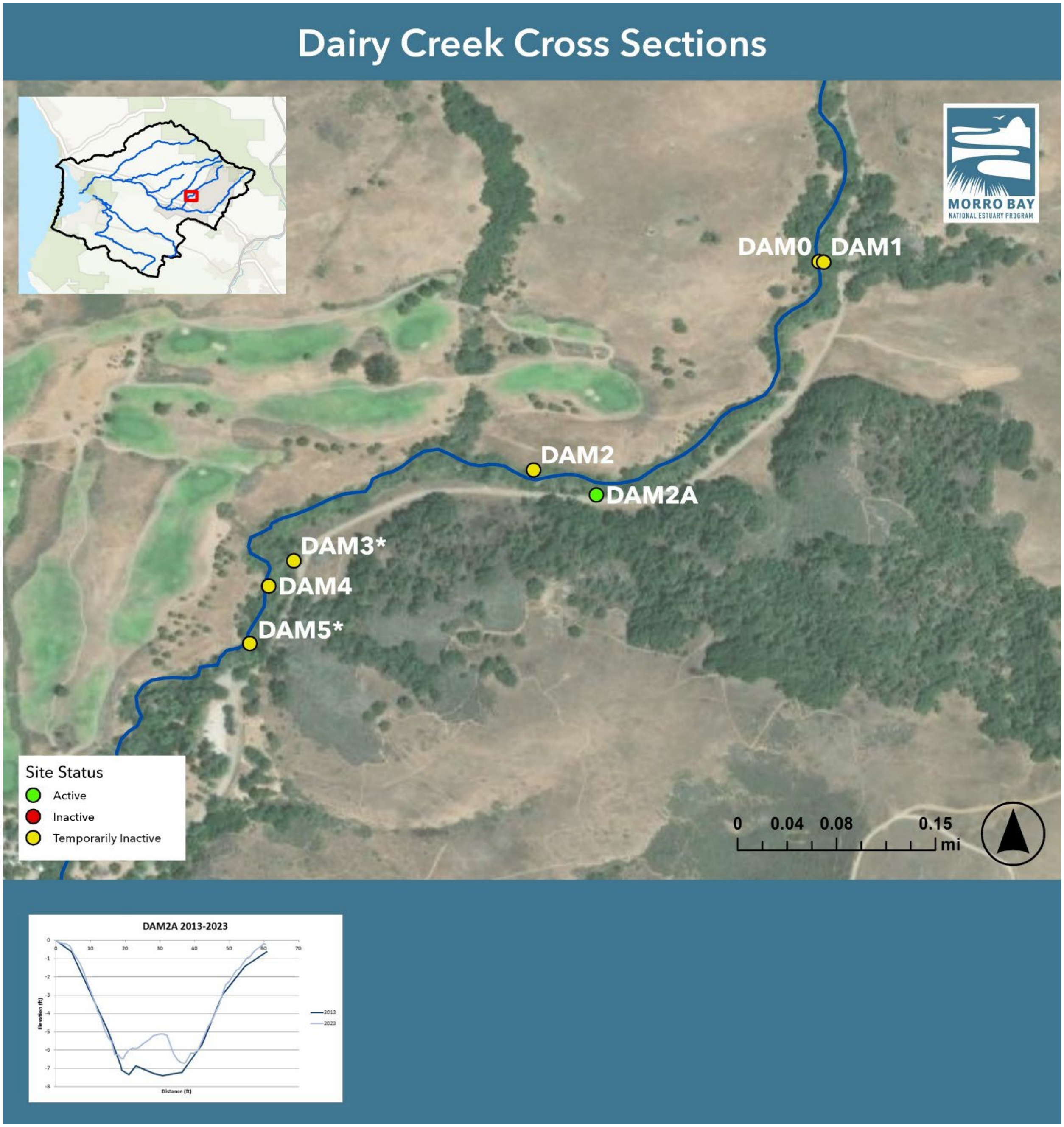


Figure 10. Dairy Creek cross section profile results for 2023 (DAM2A). Note that DAM3 and DAM5 could not be accessed due to extensive poison oak cover. These sites were listed as temporarily inactive but may be excluded from long-term monitoring if these conditions persist.

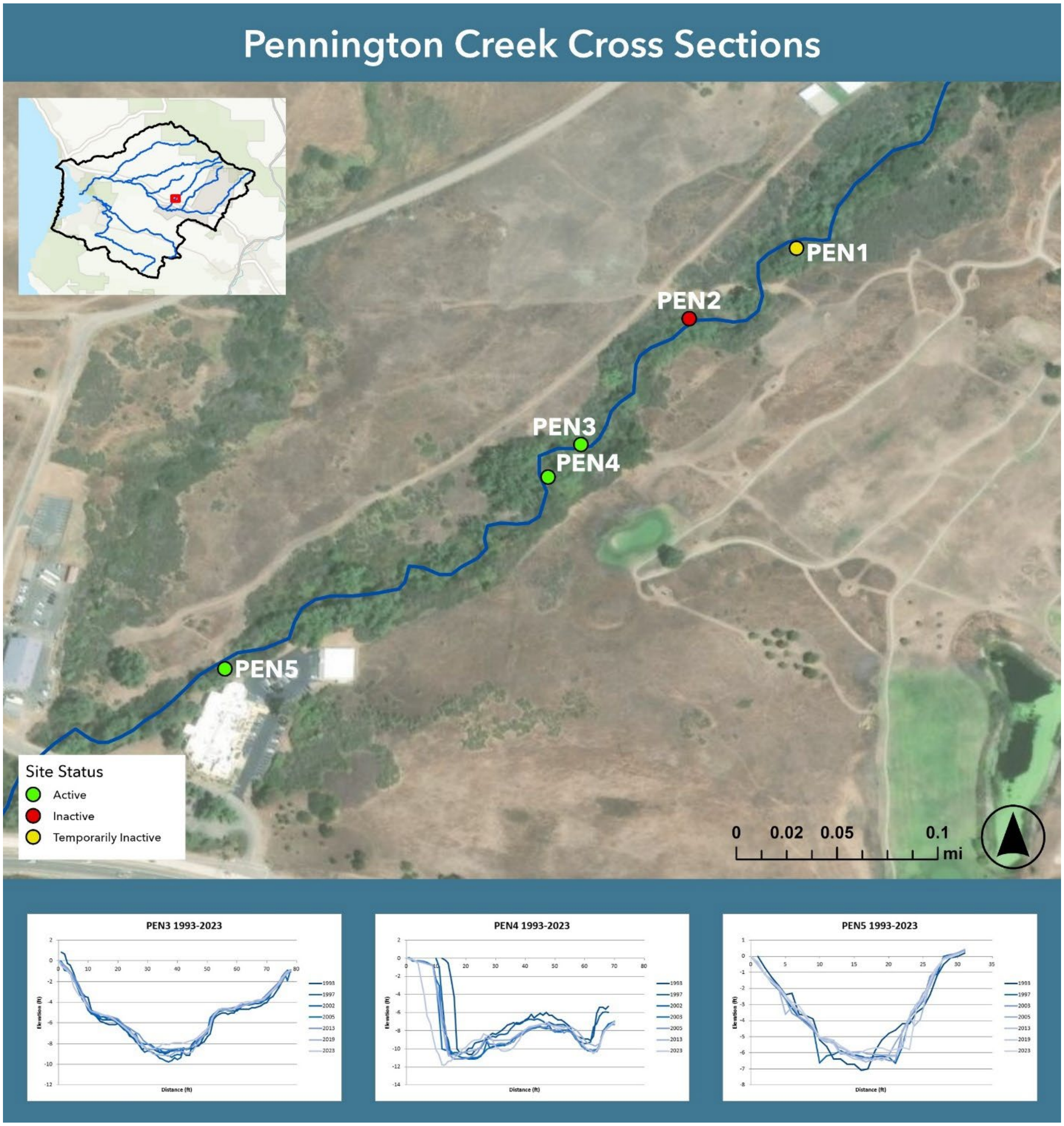


Figure 11. Pennington Creek cross section profile results for 2023 (PEN3, PEN4, PEN5).

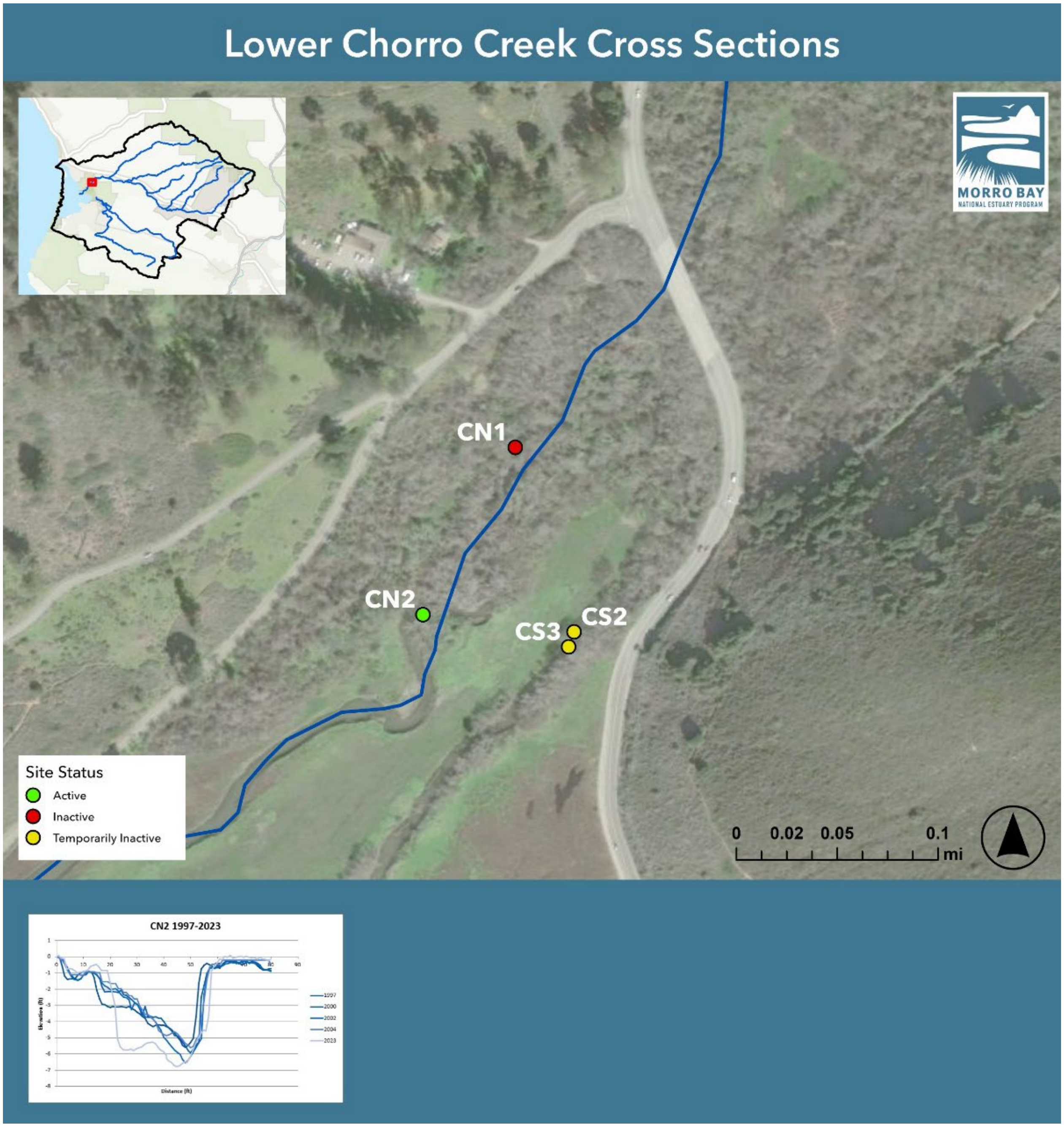


Figure 12. Lower Chorro Creek cross section profile results for 2023.

Analysis

Cross section area, mean depth, maximum depth, and width-depth ratios were calculated to quantify changes over time. These metrics were generated using the Reference Reach Spreadsheet (version 4.3L) developed by the Ohio Department of Natural Resources. Although the spreadsheet is designed to use bankfull elevation for calculations, this analysis used the lowest top of bank elevation instead, as bankfull was not consistently measured during past surveys.

The following tables show the percent relative change in each site's cross-sectional area, mean depth, maximum depth, and width-to-depth ratio. Table 3 compares 2023 results to the last year of data collected, while Table 4 compares 2023 results to the first year of available data. Cells highlighted in green indicate channel aggradation or deposition, and cells in pink indicate channel degradation or erosion.

Table 3. Percent relative change between last year of data collected and 2023.

Creek	Site	Timeframe	Cross-Section Area	Mean Depth	Max Depth	Width-Depth Ratio
Dairy Creek	DAM2A	2013 - 2023	-35.51%	-34.78%	-21.70%	+57.97%
Pennington Creek	PEN3	2013 - 2023	+0.11%	-2.63%	-1.52%	+5.08%
	PEN4	2013 - 2023	+31.07%	+26.67%	+30.26%	-20.31%
	PEN5	2013 - 2023	-4.48%	-5.13%	-7.15%	+8.11%
Upper Chorro Creek	CU3	2013 - 2023	+6.39%	+10.26%	+10.93%	-14.20%
Chorro Flats	XS4	2008 - 2003	-42.54%	-40.00%	-22.74%	+61.99%
	XS5	2008 - 2003	+183.67%	+127.27%	+132.99%	-44.72%
Lower Chorro Creek	CN2	2004 - 2023	+81.38%	+90.48%	+27.58%	-48.65%

Table 4. Percent relative change between first year of available data and 2023. Note that DAM4 was not monitored in 2023 but was included for comparison.

Creek	Site	Timeframe	Cross-Section Area	Mean Depth	Max Depth	Width-Depth Ratio
Dairy Creek	DAM2A	2013 - 2023	-35.51%	-34.78%	-21.70%	+57.97%
	DAM4	1993 – 2019*	+35.67%	+31.82%	+77.44%	-19.92%
Pennington Creek	PEN3	1993 - 2023	-10.02%	-11.90%	-9.72%	+13.41%
	PEN4	2001 - 2023	-1.48%	-5.00%	+16.80%	+8.13%
	PEN5	1993 - 2023	-1.63%	-2.63%	-14.08%	+5.26%
Upper Chorro Creek	CU3	1994 - 2023	+6.71%	+13.16%	+12.45%	-19.25%

Chorro Flats	XS4	1998 - 2023	-32.10%	-41.46%	-14.31%	+105.19%
	XS5	2008 - 2023	+183.67%	+127.27%	+132.99%	-44.72%
Lower Chorro Creek	CN2	1997 - 2023	+62.87%	+66.67%	+28.50%	-42.42%

The map below shows the mean depth status for sites monitored in 2023 as compared to the most recent year of data collected as presented in Table 3. While mean depth provides a useful summary of bed elevation changes over time, averaged conditions across the channel may not reflect localized scouring or channel fill.

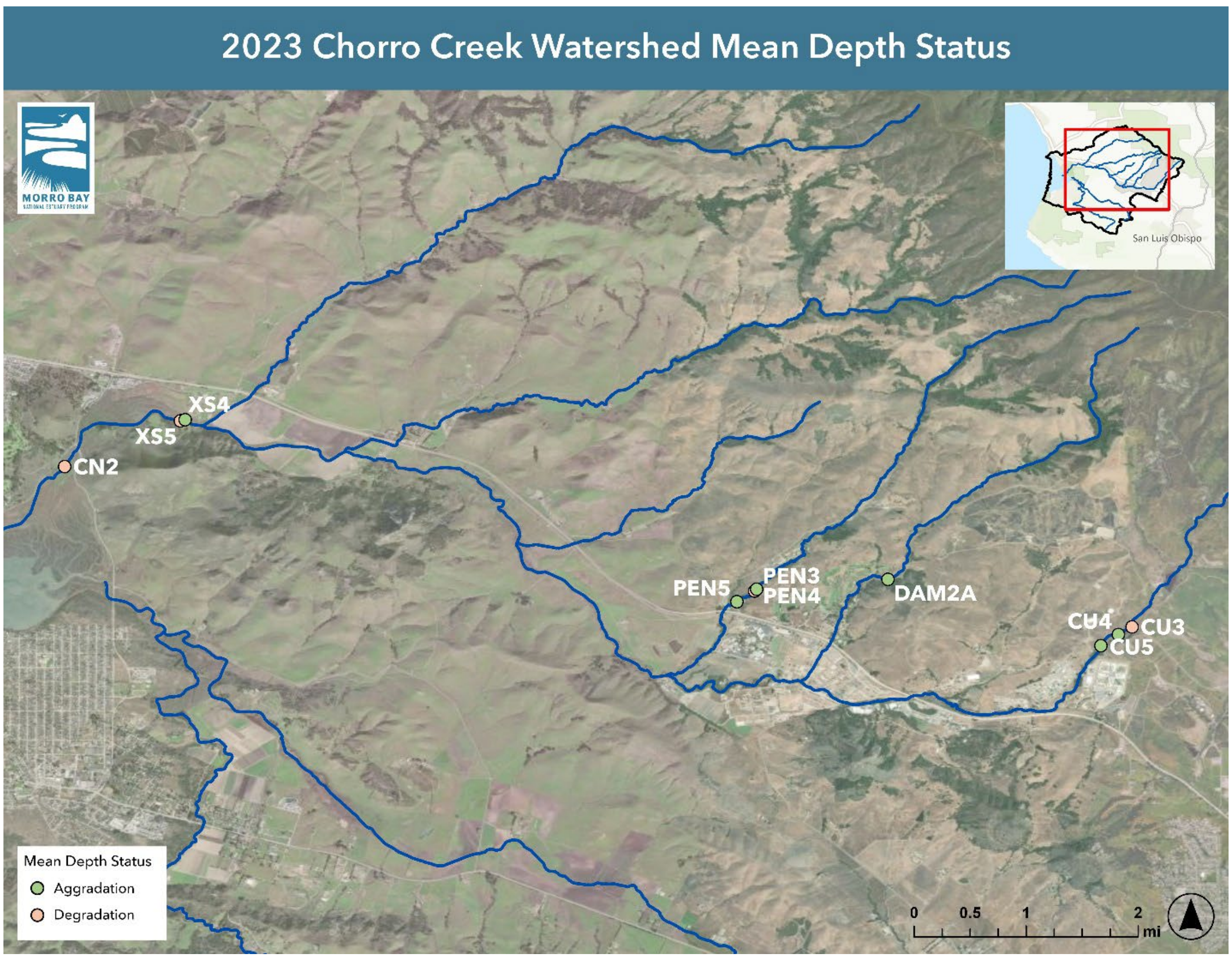


Figure 13. Mean depth status for cross section profiles monitored in 2023 as compared to most recent data collected..

Discussion

Results from the 2023 cross sectional profiling effort indicate variability in channel conditions across the sites surveyed. Data from Dairy Creek (DAM2A) and Chorro Flats (XS4) suggested ongoing aggradation through reductions in cross-sectional area and channel depth, which may indicate increased sediment deposition or changes to flow patterns. Lower Chorro Creek (CN2), located at the lowest point in the watershed, showed significant increases in channel cross-section area and depth, indicating channel degradation.

The two sites monitored within Chorro Flats (XS4 and XS5) showed very different trends despite their proximity. The upstream site (XS4) experienced reductions in cross-sectional area and depth suggesting aggradation, while XS5 showed significant increases indicating degradation. This contrast suggests discontinuity between XS4 and XS5, potentially due to a change in dominant flow paths or vegetation. The Chorro Flats area is known to have braided channels and dense vegetation which likely contributes to variations in sediment deposition and flow.

Pennington Creek (PEN3, PEN4, PEN5) also exhibited varying sediment dynamics across the sites monitored. PEN3 remained relatively stable, while PEN4 showed moderate increases in cross-sectional area and depth, suggesting localized degradation. Farther downstream, PEN5 experienced minor declines in area and depth, indicating slight aggradation. Severe erosion observed in upper Pennington Creek (Figure 6) may be driving some of the channel dynamics observed at these sites.

While this effort provided valuable insights into site status and channel morphology, broader conclusions regarding watershed-scale hydrologic and geomorphic conditions are limited by the number of sites surveyed and the lack of supporting data on factors such as sediment transport, substrate composition, and vegetation cover. Future efforts may establish new monitoring locations or integrate other types of data, like bed substrate composition or vegetation to better understand sediment transport processes.

Streambed Sediment Impairment Indicators

Since 2002, the Estuary Program conducted bioassessment surveys each spring using the Surface Water Ambient Monitoring Program (SWAMP) protocols. The data collected during these surveys generates physical and biological metrics that can be used to interpret the impacts of sediment. The Estuary Programs 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.

<u>Sediment Indicators:</u>

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)**

<u>Biological Indicators</u>

1. **Total Richness**
2. **EPT[3] Richness**
3. **Percent EPT**
4. **Biotic Index**
5. **Percent Tolerant**
6. **Sensitive Number**
7. Crayfish Number and Size

For each indicator, there are three threshold criteria for comparison (Table 5). 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.

[3] 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.

Table 5. 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).

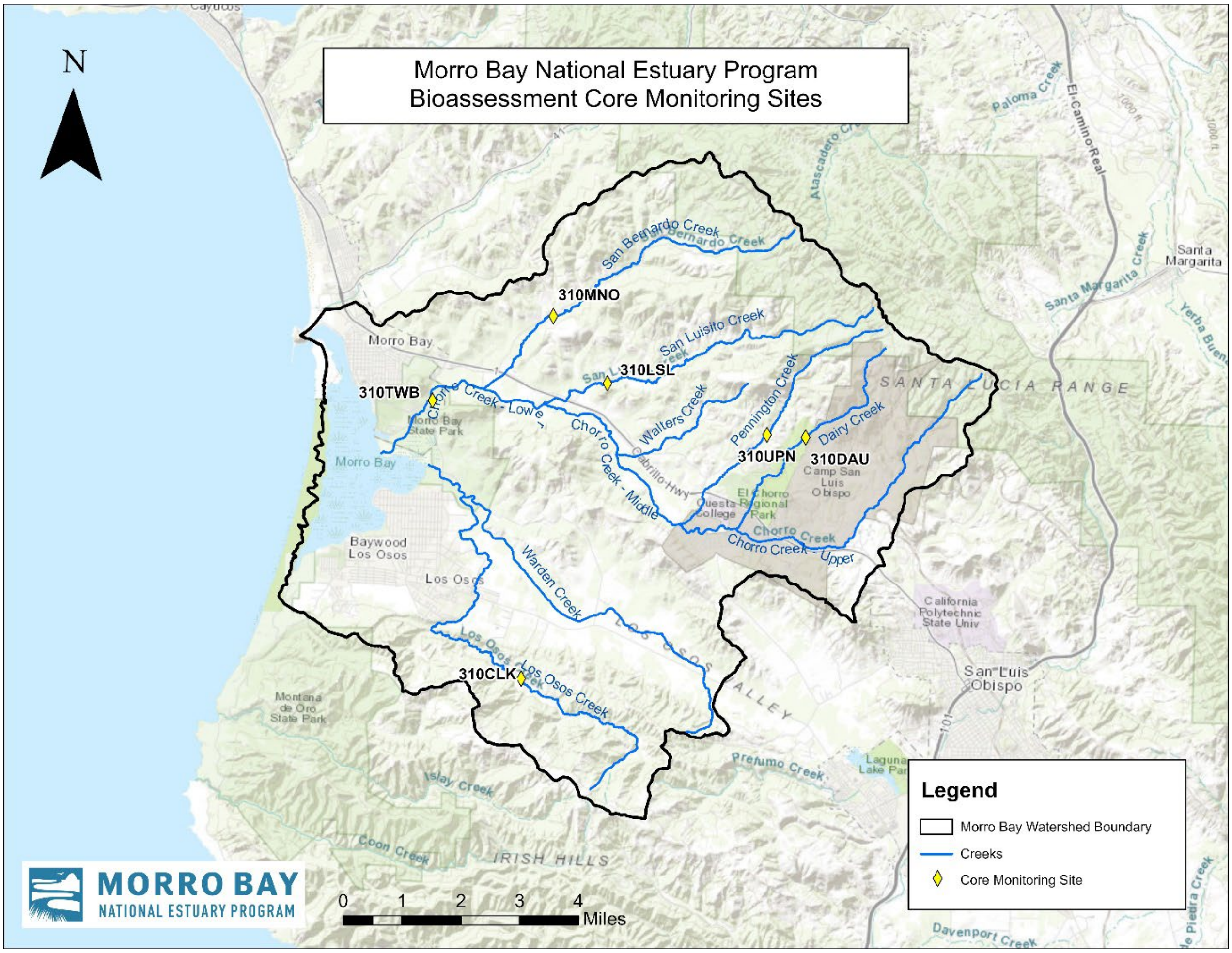


Figure 14. Core bioassessment monitoring sites in the Morro Bay watershed.

Results

Sediment impairment indicator scores were compiled from the six core monitoring sites from 2008 to 2023 (Table 6). The averaged scores from 2008 to 2023 are detailed in Table 7. 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 6. Sediment indicators for core bioassessment monitoring sites from 2008 to 2023.

Site Code	Year	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
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
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
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
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
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

Table 7. Averages for sediment indicators for core bioassessment monitoring sites. Note that the averages in Table 7 are calculated from the values in Table 6.

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	6.5	18.9	32.5	24.5	19.1	6.5	24.5	54.4	13.6	29.6	5.7	12.3	10.0
310LSL	9.8	17.4	35.3	27.3	13.5	9.8	27.3	48.4	14.6	30.8	4.9	10.2	9.9
310UPN	2.1	12.0	19.1	13.5	52.6	2.1	13.5	58.2	16.6	30.5	5.0	8.2	13.5
310TWB	16.6	25.0	50.4	40.6	7.9	15.7	40.6	42.1	7.9	16.0	6.3	20.6	6.3
310CLK	4.6	17.5	29.2	22.1	22.5	4.6	22.1	49.6	9.8	21.3	5.8	14.0	15.4
310DAU	5.0	21.6	30.3	26.6	22.3	5.0	27.1	48.6	12.9	41.5	4.8	7.7	8.1

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 2023 suggest mostly unimpaired substrate conditions across the Morro Bay watershed. Three of the six core monitoring sites met all target criteria for sediment (Dairy Creek, Pennington Creek, and Los Osos Creek), indicating favorable streambed conditions and particle size distribution. Only one of the six sites showed evidence of sediment impairment. This site, located on Lower Chorro Creek (310TWB), has had persistent sediment and biological impairment observed since 2008.

Despite these generally favorable substrate conditions, biological indicators for 2023 showed widespread impairment. All six core monitoring sites met high priority criteria for 303(d) listing for EPT Richness, and nearly sites met high priority criteria for Total Richness and Sensitive Number. This disconnect between sediment and biological indicator scores is likely associated with the extreme hydrologic conditions of WY2023 which mobilized large amounts of sediment throughout the watershed. While high flows can flush fine sediments, resulting in improved physical sediment metrics (e.g. increased D50 median particle size, reduced fines/sands), they can simultaneously displace benthic macroinvertebrates. Recovery timelines for these communities varies by species sensitivity and may have been further delayed by altered habitat, reduced food availability, or changes to water quality through mobilized sediment (Lake, 2000).

These findings suggest that physical sediment conditions may meet target thresholds even when macroinvertebrate communities remain impaired. This can be the case even several months after sediment-mobilizing storm events.

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, 2023). 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.

To improve the overall understanding of tidal prism in Morro Bay, the Estuary Program worked with Dr. Stefen Talke from California Polytechnic University (Cal Poly) and graduate student Kaden Caliendo to analyze tide height and its potential future impacts on eelgrass in the bay. Tidal gauges were installed at four locations in Morro Bay from March to August 2023. Tidal information, a digital elevation model (DEM), and sea level rise projections were used to estimate current and future tidal prism volumes and estimate shifts to eelgrass habitat (Caliendo, 2023). While the results show differences in the tidal prism depending on where tide gauges were located in the bay, the effects were the same order of magnitude as measurement uncertainty and thus not statistically significant. Additional projects are ongoing which may produce data to support 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 Francsico (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.

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 2004, 2007, 2010, and 2015. Since then, the Estuary Program and USGS have continued to monitor a subset of these sites opportunistically on an approximately five-year basis. While these sites were not monitored in 2023, they will be re-visited in 2024.

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 high marsh and two low marsh sites (Figure 15). 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 January and August 2023. Biannual monitoring is planned to continue until 2025, after which annual monitoring will resume.

Figure 15. USGS SET and feldspar locations in Morro Bay. High marsh locations are the interior marsh further from sediment sources, and low marsh locations are adjacent to channels on the edge of the marsh.

During 2023, the USGS sites located in the high marsh had an average cumulative elevation change of 6.51 ± 0.25 mm, and sites in the low marsh had an average cumulative elevation change of 13.47 ± 1.13 mm. The rate of elevation change over the course of the study period (2013 to 2023) was 0.85 mm per year in the high marsh and 1.15 mm per year in the low marsh.

When compared to 16 other marsh sites in the USGS study, Morro Bay had the lowest accretion rate at 1.38 mm per year (Thorne et al., 2023). Preliminary analysis suggests this accretion rate is keeping up with the current rate of sea level rise and potentially outpacing sea level rise in lower marsh SETs.

Short-Term Deposition Study

From January to September 2023, the Estuary Program partnered with USGS to monitor short-term sediment dynamics using feldspar marker horizons and sediment deposition pads. Sediment deposition pads consisted of pre-weighed glass filter pads attached to ceramic tiles. The tiles were deployed for three months in the winter and summer to assess seasonal deposition, including sediment that may be incorporated into soil or lost via erosion over time. Pads were exchanged twice per month in the winter and monthly in the summer, then dried and weighed for bulk density (dry mass) and furnaced to assess percent organic matter. The feldspar marker horizons were measured quarterly using a sharp knife to extract a soil plug and measure surface accretion with a ruler. Plugs were replaced into soil to allow repeat measurements over time.

The monitoring locations included three transects in the high tidal marsh, three transects in the low tidal marsh, and two transects in a fringing marsh near Sweet Springs Preserve (Figure 16). Within each transect, sediment pads were located 0.5 meters, 2 meters, 6 meters, 12 meters, and 24 meters from the channel. Feldspar marker horizon plots were located at 2 meters, 12 meters, and 24 meters from the channel.

Figure 16. Locations of sediment deposition pad and marker horizon plot transects.

Sediment deposition rates were highest at the high marsh monitoring locations (4.86 ± 0.80 g/m^2/day), compared to low marsh (2.91 ± 0.19 g/m^2/day) and fringing marsh (0.50 ± 0.06 g/m^2/day), due to an influx of sediment from high winter streamflow events. However, cumulative accretion since January 2023 was greater within low marsh environments (5.45 ± 1.02 mm/year) compared to high marsh (2.25 ± 0.41 mm/year) and fringing marsh (0.57 ± 0.18 mm/year) locations. These results suggest that while the high marsh may receive more sediment deposition during peak flow events, the low marsh is more effective at accreting sediment over time due to more frequent tidal inundation.

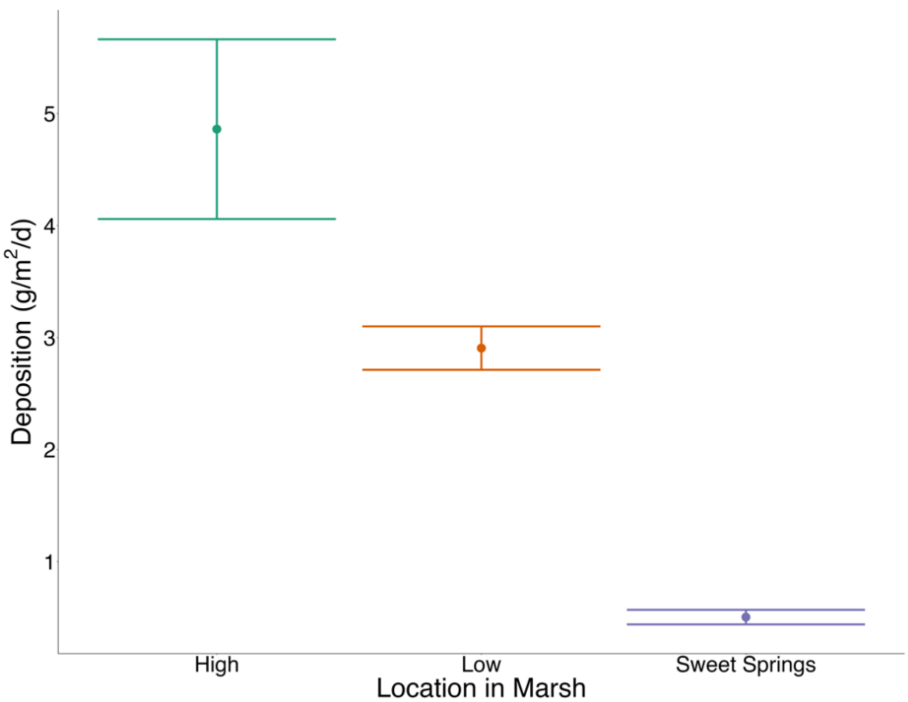


Figure 17. Average sediment deposition rates (± standard error) in grams per square meter per day on sediment traps within different tidal marsh locations in Morro Bay tidal marsh from January to September 2023.

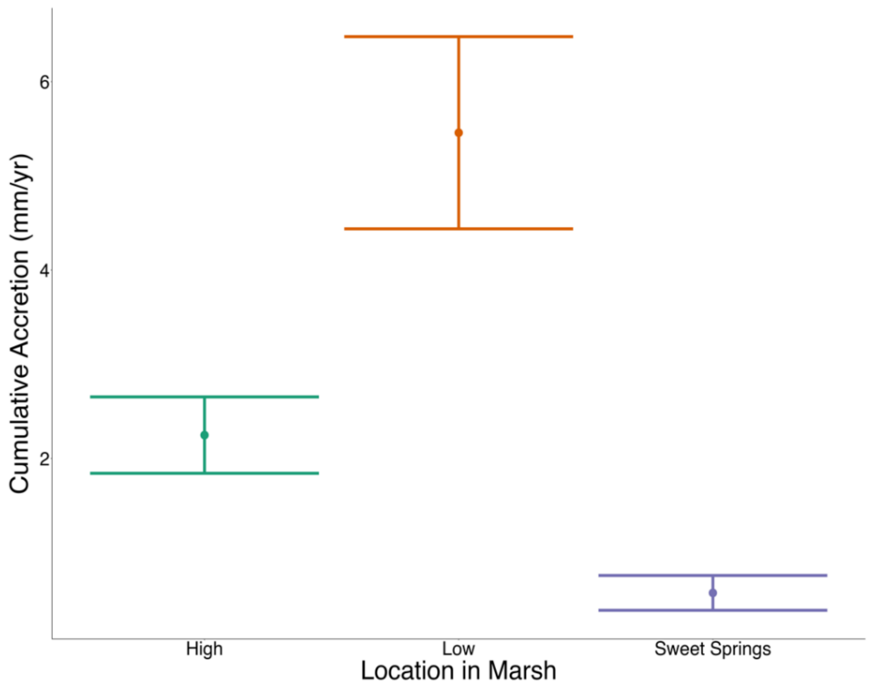


Figure 18. Cumulative average accretion (± standard error) in mm per year of sediment on marker horizon plots near sediment trap transects in Morro Bay tidal marsh from January to September 2023.

Conclusions

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.

WY2023 represented an exceptionally wet year for the Morro Bay watershed, receiving 118% of average annual precipitation. Although limitations with the stage-discharge relationship prevented an accurate calculation of peak and cumulative discharge, peak stage heights recorded at Station 753 were among the highest on record, suggesting some of the highest flows in decades.

These high flows led to widespread erosion and localized deposition throughout the watershed with variable implications. For cross section profiling sites, results showed aggradation in some areas and degradation in others, highlighting the need for additional monitoring particularly in areas with limited coverage like Dairy Creek and Lower Chorro Creek. Streambed impairment indicators from the Estuary Program's 2023 bioassessment effort showed sediment particle size distribution adequate for beneficial uses, while biological indicators reflected significant impairment. These results highlight how sediment-mobilizing storms may lead to favorable substrate distribution while simultaneously displacing benthic macroinvertebrate communities.

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. Results from short-term deposition monitoring also found that while high marsh areas receive more sediment during peak flow events, low marsh areas are more likely to accumulate sediment steadily due to more frequent tidal inundation.

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Appendix A. San Luis Obispo County precipitation contours