# QUARTERLY PROGRESS REPORT
# As of June 30, 2017 DRAFT

Date: July 26, 2017 Dates Covered by this Report: April 1, 2017 – June 30, 2017

Agreement No.: P1496011 00 Grant Term: March 1, 2020

Project Title: Initiation of Thin-Layer Sediment Augmentation on the Pacific Coast

Grantee: U.S. Fish and Wildlife Service, San Diego NWRC

## FISCAL REPORT

| Fund Source | Amount Awarded | Amount Expended as of June 30, 2017 | Total Amount Remaining |
|---|---|---|---|
| CDFW GGRF Grant Funds | $1,055,827 | $321,979 | $733,848 |
| Cost Share | $1,306,048 | $1,509,458* | -$203,410 |
| | | | |
| Agreement Totals | $2,361,875 | $1,831,437 | $530,438 |

* Includes in-kind staff time from USFWS (Refer to Attachment 1 for details.)

Invoice Submitted this Quarter: ☒ Yes (under separate cover) ☐ No

## PROGRAM/TECHNICAL REPORT

**Activities Performed from April 1 – June 30, 2017**:

- Monitoring: Researchers continued post-augmentation monitoring on the augmentation site and control site and/or conducted lab work to analyze data/samples obtained at the sites.

  USGS continued to conduct post-construction marsh surface elevation monitoring with deep rod Surface Elevation Tables (SETs) and adjacent feldspar plots. Monitoring of turbidity and sediment fluxes occurred at two YSIs and an ADCP in the deep channel site (control) and in the eelgrass site (adjacent to augmentation site). The monitored sites are illustrated in Figure 1.

- Site Observations: Samples taken by researchers from CSU Long Beach both at 6 months (Fall 2016) and 12 months (Spring 2017) post augmentation show an increase in the abundance of invertebrates with 21 out of 21 sites having invertebrates present in Spring 2017. Samples are still dominated by insects and insect larvae (early succession species), but there is an increased representation of oligochaetes and polychaetes from the Spring 2016 time point.

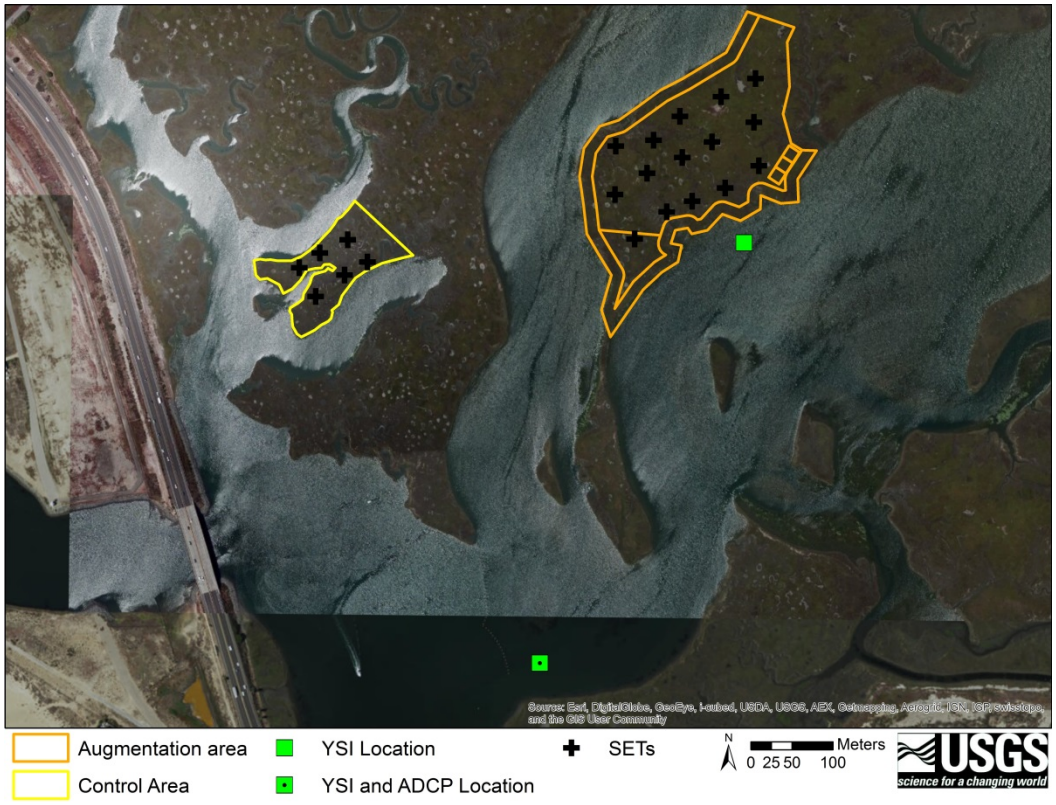


Figure 1. Site map of project area and USGS data collection locations.

The photographs presented in Attachment 2 were taken by USGS (May 1, 2017) and USFWS (May 9, 2017) during recent site visits. They document growth of pickleweed within the site and the movement of cordgrass back onto the site via rhizomes from adjacent cordgrass protected within the 50-foot buffer.

As described in USGS's annual report, dated June 22, 2017 (provided as Attachment 3), the SETs at the control area (see Figure 1) have had gains and losses of elevation since installation (Figure 2), but have a mean cumulative increase of 3.48 mm from the date of installation. The SETs in the augmentation site had a mean increase in elevation of 216 mm (8.50 in) with sediment application, but had a decrease in mean elevation of 75.59 mm (2.97 in) post sediment application (April 2016-May 2017). Elevation decreases were most rapid initially after the sediment application period (augmentation) and elevation loss has slowed over the course of monitoring. From the most recent measurements (January-May 2017), the augmentation SETs decreased in elevation again dropping 13.38 mm (0.53 in). This recent elevation decrease could be continued stabilization of the marsh surface and also the result of seasonal strong storms. Elevation loss was also measured at the control SETs (-35 mm, -0.01 in) during the same time period (USGS 2017).

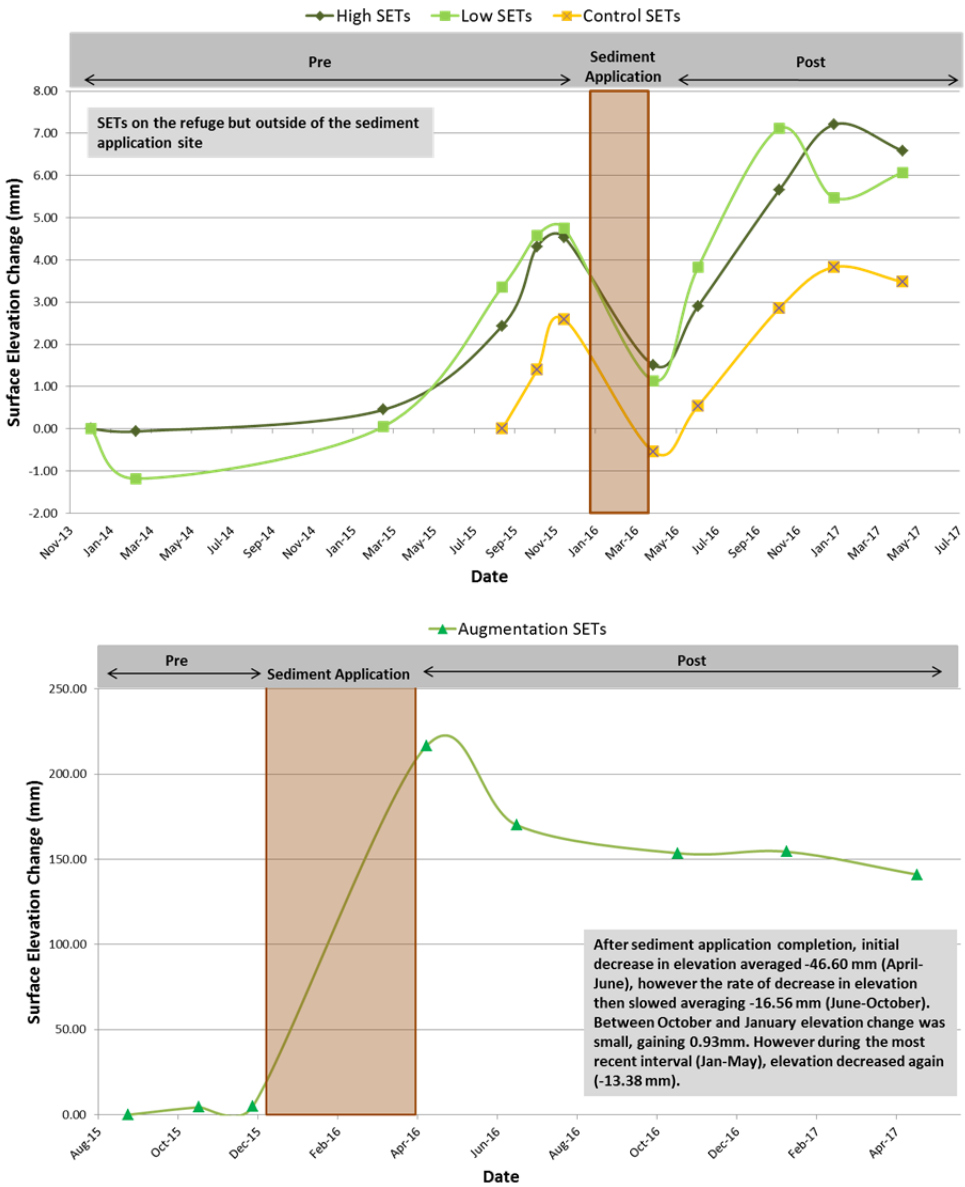


Figure 2. Mean surface elevation change at control site (above) and augmentation site (below). Brown box represented construction time frame (USGS 2017).

Elevated post-construction turbidity at the eelgrass site suggests that there may be lingering impacts from augmentation and heavy storm conditions during winter 2016 and early 2017. USGS speculates that this elevated turbidity, which is still low relative to other regional salt marsh sites during other periods, may be related to an increased sediment supply in the eelgrass bed from construction and/or continued, chronic export of sediment to the eelgrass site from tidal creeks in the augmentation site. However, the post-construction surface elevation and accretion gains from SETs suggest that erosion is not occurring from the marsh surface. This may mean that the increased turbidity levels observed at the eelgrass site during storms is not from runoff of the augmentation site, but possibly resuspension of sediment at the channel bottom and adjacent areas (USGS 2017).

With respect to gas fluxes, the results of this quarter's monitoring are similar to last quarter, as follows:

- Significant $CH_4$ fluxes were minimal, but there were occasional positive fluxes measured from *Spartina* (Pacific cordgrass) and pond communities at the control site. Low $CH_4$ fluxes are common from salt marsh soils.
- Positive $N_2O$ fluxes are rare. Low $N_2O$ fluxes are common in salt marsh soils without nitrogen pollution.
- $CO_2$ fluxes were generally lower from the control site pre-augmentation (possibly due to lower air temperatures during sampling) and were lowest from ponded communities. After the addition of sediment, the augmentation had very low $CO_2$ fluxes compared to pre-augmentation and the control site.

For the quarter ending June 30, 2017, no bird use on the augmentation site was observed during the monthly low and high tide bird surveys conducted in April and May, and during the low tide survey in June. Minimal bird use was observed during the June high tide survey, including the sighting of three black brant, one willet, and 20 short-billed dowitchers.

Unexpected bird activity occurred on the site in April, when a western snowy plover nest was discovered. Researchers from UCLA identified the nest on April 14, 2017. They immediately contacted the Refuge Manager, who determined that the nest and its three eggs would be lost to the higher high tides in the following week (April 25 – 28), because the site is typically fully inundated during the higher high tides. With assistance from Peter Knapp from the Bolsa Chica Conservancy, and with approval from the Carlsbad Fish and Wildlife Office, the eggs were collected on April 25, after waiting until the last possible high tide, and then transported to an incubator at Wetlands Wildlife Care Center in Huntington Beach. All three chicks hatched between May 12 and May 13, 2017 and were cared for with several other chicks at the Wetlands Wildlife Care Center until they were able to fly. The blue banded chicks in Figure 3 are the chicks rescued from the nest on the augmentation site. The chicks were banded and released on June 19, 2017. Their band numbers and color combos are: 2381-03143, YN:GG; 2381-03144, YN:RR; and 2381-03145, YN:WW.

Figure 3. Western snowy plover chicks hatched at the Wetlands Wildlife Care Center. (Photo: Ross Griswold)

Light-footed Ridgway's rail monitoring did not identify any use the nesting rafts located in the immediate proximity of the augmentation site. Rail activity was however observed on the rafts that were relocated prior to augmentation to the shore across the west channel from the augmentation site. Overall, the number of rails observed throughout the Refuge this year is similar to those documented last year. Final numbers will be available at the end of the nesting season.

## Project Coordination

- No team conference calls were held during this period, but Refuge staff coordinated with researchers on monitoring visits to the site and regarding quarterly and upcoming annual reports.
- Researchers and monitors provided summaries of activities completed during the quarter and when available, provided relevant interim results.

## Project Outreach/Information Dissemination

- The Refuge webpage (https://www.fws.gov/refuge/seal_beach/what_we_do/resource_management/Sediment_Pilot_Project.html) was updated to include new site photos.
- During her presentations at the Living Shorelines and Resilience in Southern California Workshop held in San Diego on June 20, 2017, Evyan Sloane, from the California State Coastal Conservancy, provided information about the thin-layer sediment augmentation pilot project at the Seal Beach NWR and the project's relevancy to future living shoreline projects in Southern California.
- Students of Dr. Keller presented a poster of their gas flux findings to date from the project site at the Southern California Academy of Sciences meeting on April 28, 2017. The poster was presented again at the Chapman University Student Research Expo in mid-May, and one of this student's gave an oral presentation on the results to Chapman faculty to fulfill his program honors requirements.
- Glenn Woerndle and Haley Miller of Chapman University also took part in an outreach program to help Orange County Girl Scout Troops achieve their woman in science and nature initiatives badges. They developed hands-on activities explaining how water quality (pH and salinity) impact wildlife and coastal ecology. Four troops of Girl Scouts and their families attended the event, which was hosted at the Seal Beach NWR.

## Status of Ongoing Research

**A. UCLA (SEDIMENT CORING)**: Researchers at UCLA under the direction of Dr. Glen MacDonald are finalizing their report on pre-augmentation net sediment accretion rates and average carbon accumulation rate (CAR) at Seal Beach NWR. Completion of the final report is now scheduled for September 2017, and the results will be included in the project's Annual Report to be provided in early October.

B. **UCLA (CHANGES IN MARSH PLAIN POST-AUGMENTATION):** Under the direction of Dr. Richard Ambrose, researchers continue to analyze data obtained at the project site and control site following completion of the augmentation process. Lab work includes analysis of bulk density, sediment height, grain size, feldspar cores, and tidal creek cross-sections. Preparation of UCLA's final report for pre-augmentation monitoring is underway.

C. **CSU LONG BEACH (PLANT AND INVERTEBRATE STUDIES):** Researchers from CSULB, under the direction of Dr. Christine Whitcraft, conducted one year post-augmentation field work (LiCor, invertebrate samples) between April 20 and 24, 2017. Laboratory analysis involving invertebrate sorting and identification for the top 2 cm of the augmented site and the control site has been completed for all samples collected to date. Belowground biomass cores have been completed, all data has been entered, and analysis of these data is currently in progress. Preparation of CSULB's final report for pre-augmentation monitoring is underway.

D. **CHAPMAN UNIVERSITY (GAS FLUX):** Dr. Jason Keller and his research team made trips to the augmentation and control sites on April 2-3, 2017 and June 12, 2017. On each sampling trip, gas samples were collected from both the control and augmentation sites. The samples were analyzed for carbon dioxide, methane, and nitrous oxide at Chapman University. In addition, surface porewater was collected to be analyzed for chemical properties. Dr. Keller has refined his sampling technique and is now able to collect porewater from both the control site, as well as the augmentation site, where collecting porewater has been more challenging.

   The potential for sulfide availability in the coarser materials applied to the site prompted concerns related to acificiation within the augmentation site. As a result, monitoring was expanded to measuring pH in surface water in the field and in porewater collected at both sites. This monitoring is continuing. Redox in surface water also continues to be measured.

   Methods necessary to measure porewater collected over the course of this project for sulfate and chloride have been finalized; this analysis is being conducted using ion chromatography. Also over the last quarter, the samples collected over the course of this project have been measured and the data is being analyzed to identify any patterns. Dr. Keller will continue to explore methods to quantify nitrate in porewater collected from the project site.

E. **USGS (SEDIMENT FLUX PATTERNS AND SETS):** Monitoring of post-construction marsh surface elevations with deep rod SETs and adjacent feldspar continued with site visits in early May. At the same time, monitoring of turbidity and sediment fluxes was done at two YSIs and an ADCP in the deep channel site (control) and in the eelgrass site (adjacent to augmentation site). An annual report was prepared that is provided as Attachment 3.

F. **BIRDS SURVEY RESULTS FOR THIS QUARTER:** Monthly high and low tide bird surveys continue to be conducted at the project site. In addition, the 2017 light-footed Ridgway's rail surveys are underway and will continue until the end of the nesting season.

## Percentage of Task Completed as of June 30, 2017:

| | |
|---|---|
| Task 1 – Project Management and Administration | 44% |
| Task 2 – Sediment Augmentation | 100% |
| Task 3 – Project Monitoring (overall) | 44**%** |
| 1) Carbon Storage/Sequestration Benefits | 95% |
| 2) Percent Total Plant Coverage | 20% |
| 3) Pacific Cordgrass Analysis | 20% |
| 4) Site Elevations | 30% |
| 5) Sediment Analysis (compaction, movement, bulk density) | 30% |
| 6) Turbidity Levels | 60% |
| 7) Eelgrass | 50% |
| Task 4 – Engineering Design/Environmental Documentation (overall) | 100% |
| 1) Engineering Plans for Sediment Augmentation Site | 100% |
| 2) Environmental Documentation* | 100% |
| *CEQA/NEPA has been completed by SCC/USFWS | |
| Task 5 – Public Participation/Presentations (overall) | 43% |
| 1) Oral/Poster Presentations | 50% |
| 2) Workshops and/or Webinars | 35% |
| **Overall Project** | **66%** |

## Deliverables Completed for Each Task:

Task 1 – Project Management and Administration

| | |
|---|---|
| 1) Quarterly Progress Report | 7 to date |
| 2) Monthly Invoices | 18 to date |
| 3) Subcontractor Selection | Orange County Parks & SWIA selected |
| 4) Data Management | preliminary data for monitoring locations |
| 5) Acknowledgement of Credit | ongoing |

Task 2 – Sediment Augmentation

| | |
|---|---|
| 1) Sediment Application | completed |
| 2) Adaptive Management | on going |
| 3) Reporting Results/Lessons Learned | in process |

Task 3 – Project Monitoring

| | |
|---|---|
| 1) Carbon Storage/Sequestration Benefits | pre-augmentation site monitoring completed/core data processing underway |
| 2) Percent Total Plant Coverage | pre-augmentation work completed/post augmentation work underway |
| 3) Pacific Cordgrass Analysis | pre-augmentation work completed |

| | |
|---|---|
| 4) Site Elevations | pre-augmentation RTK survey and initial post-augmentation photogrammetry work completed; continuing data collection from SETs |
| 5) Sediment Analysis | initial core samples retrieved/data processing underway; more coring to occur |
| 6) Turbidity Levels | monitoring ongoing; prel. data available |
| 7) Eelgrass | pre-augmentation and initial post-augmentation work completed |

Task 4 – Engineering Design/Environmental Documentation

| | |
|---|---|
| 1) Engineering Plans for Augmentation Site | 100% engineering plans completed |
| 2) Environmental Documentation*<br>*for USFWS and Coastal Conservancy | CEQA/NEPA documents final; ND recorded |

Task 5 – Public Participation/Presentations

| | |
|---|---|
| 1) Oral/Poster Presentations | Presentations ongoing |
| 2) Workshops and/or Webinars | Participated in U.S. Army Corps webinar; Lessons learned/first-year post augmentation workshop/webinar fall 2017 |

**Problems/Delays Proposed Resolution:**

No delays have been identified for post-augmentation monitoring. We continue to monitor eelgrass recovery, which is occurring, adjacent to the site. Another eelgrass survey was conducted in the surrounding tidal channels in June 2017; we are awaiting the final results.

**Project Benefits and Results:**

It is too early in the project to address project benefits and results, but we have learned quite a bit about the thin-layer sediment augmentation process. Our project is being used by other agencies as an example of how such a project can be permitted and implemented. It has also been presented as a potential component of future living shoreline projects. Our “lessons learned” document will benefit those land managers contemplating the initiation of this process elsewhere on the Pacific Coast. The data being collected to better understand carbon sequestration rates at this site will also benefit other land managers along the southern California coast.

**Summarize Benefits to Disadvantaged Communities (if applicable):**

Not applicable to this project.

**List of Proposed Activities and Tasks for the Next Quarter:**

Task 1 – Project Management and Administration
Tasks include coordination of final pre-project monitoring reports and initiation of an annual report; preparation of a “lessons learned” document for the thin-layer sediment

augmentation process; assisting researchers with site access; preparing invoices and the next quarterly/annual report; providing other agencies with information about the project, and all other responsibilities needed to successfully complete the project.

Task 2 – Sediment Augmentation
The sediment augmentation process has been completed. Preparation of the "lessons learned" document is underway. The draft will be distributed to the project team for review and comment to ensure accuracy and completeness.

Task 3 – Project Monitoring
Refuge staff will continue photographing and recording the locations (GPS) of cordgrass regrowth within the augmentation site. We will attempt to determine how cordgrass reestablishment is occurring (e.g., extension of rhizomes from the adjacent buffer area, the result of seed distribution, regrowth from buried rhizomes). Photo documentation of changes on the augmentation site over time will also continue.

USGS will continue providing suspended sediment concentrations and flux data, along with elevation data from the SETs. There will also be an estimate of sediment depth from the pre and post sedimentation elevation data.

Dr. MacDonald and his team at UCLA will complete their core sample analyses and provide a final report.

Dr. Ambrose and his team at UCLA will compile data from field sampling (i.e., bulk density, sediment height, feldspar cores, tidal creek cross-sections) conducted at the augmentation site and control site in April 2017 and continue to analyze bulk density, grain size, and carbon content (loss on ignition [LOI]) for newly collected samples, as well as conduct data entry and analysis.

Dr. Whitcraft and her team will continue invertebrate community analysis in the laboratory on both the contract samples and continue processing the additional colonization experiment invertebrate samples. In addition, they will survey the site one or two times during the next quarter to determine how plants are recovering and if there are enough growth to facilitate additional photosynthetic measurements. Now that all belowground biomass cores are sorted, they will be conducting data analysis on those data and discussing the results with UCLA (as well as the rest of the research team).

Dr. Keller and his team will continue to measure greenhouse gas fluxes from the sites as more of the marsh begins to grow back following augmentation. Seasonal patterns in fluxes and their relationship to porewater chemistry will also be explored as their dataset expands.

MTS is currently completing the analysis of their eelgrass field survey. Upon completion, the results will be forwarded to NOAA and other interested parties.

Task 4 – Engineering Design/Environmental Documentation
This task has been completed.

Task 5 – Public Participation/Presentations
The projects lead researchers are working on a session focused on thin-layer sediment augmentation that will be presented at the fall 2017 Coastal and Estuarine Research Federation meeting.

The Refuge webpage will continue to be updated, and we will participate in conferences and webinars as opportunities arise. Once the "lessons learned" documentation is completed and we have some initial post-augmentation monitoring results, we will begin preparations for a workshop or webinar. In the meantime, information about the project continues to be disseminated through presentations from various team members at conferences, meetings, and agency-sponsored webinars. Upcoming conferences and other science-related meetings include:

- **Coastal & Estuarine Research Federation Meeting (Rhode Island, Nov. 2017)** Rich Ambrose, Evyan Sloane, Christine Whitcraft, Karen Thorne (USGS), and Kaelin McAtee will be presenting various aspects of this project at the meeting. More details will be provided in the next quarterly report.

**Description of Amendments and Modifications to Grant:**

No amendments or modifications were made this quarter. We previously made a minor modification to the existing grant by redirecting $4,950 of unallocated research funds to additional eelgrass survey work, which was approved by CDFW on June 10, 2016.

**Attachments**

1. Itemized Cost Share Items and Activities
2. Photographs of the Project Site
3. Annual Report from USGS (June 2017)

# Attachment 1
# Itemized Cost Share Items and Activities

| Cost Share (June 1, 2015 to June 30, 2017) | | |
|---|---|---|
| Activity or Item[1] | Funding Source | Expenditure |
| Total Cost Share from June 1, 2015 to September 30, 2016 | | |
| Pre and Post-augmentation monitoring[1] | California State Coastal Conservancy | $170,776 |
| Purchase boat to access site | USFWS CRI Grant | $2,425 |
| RTK elevation survey | US Army Corps of Engineers | $50,252 |
| USFWS staff time[2] | USFWS CRI Grant | $137,592 |
| Sediment augmentation[3] | Orange County Parks | $670,500 |
| Sediment augmentation | USFWS CRI Grant | $350,000 |
| | **Subtotal** | **$1,381,545** |
| Total Cost Share from October 1, 2016 to December 31, 2016 | | |
| Post-augmentation monitoring | California State Coastal Conservancy | $45,179 |
| USFWS staff time[2] | USFWS CRI Grant | $10,575 |
| | **Subtotal** | **$55,754** |
| January 1 – January 31, 2017 | | |
| Post-augmentation monitoring | California State Coastal Conservancy | $7,222 |
| USFWS staff time[2] | USFWS CRI Grant and Station Funds | $1,071 |
| | **Subtotal** | **$8,293** |
| February 1 – February 28, 2017 | | |
| Post-augmentation monitoring | California State Coastal Conservancy | $384 |
| USFWS staff time[2] | USFWS CRI Grant and Station Funds | 0 |
| | **Subtotal** | **$384** |
| March 1 – March 31, 2017 | | |
| Post-augmentation monitoring | California State Coastal Conservancy | $30,396 |
| USFWS staff time[2] | USFWS CRI Grant and Station Funds | 0 |
| | **Subtotal** | **$30,396** |
| April 1 – April 30, 2017 | | |
| Post-augmentation monitoring | California State Coastal Conservancy | $3,216 |
| USFWS staff time[2] | USFWS CRI Grant and Station Funds | $2,551 |
| | **Subtotal** | **$5,767** |
| May 1 – May 31, 2017 | | |
| Post-augmentation monitoring | California State Coastal Conservancy | $15,449 |
| USFWS staff time[2] | USFWS CRI Grant and Station Funds | $3,050 |
| | **Subtotal** | **$18,499** |
| June 1 – June 30, 2017 | | |
| Post-augmentation monitoring | California State Coastal Conservancy | $5,220 |
| USFWS staff time[2] | USFWS CRI Grant and Station Funds | $3,600 |
| | **Subtotal** | **$8,820** |
| | **Total Cost Share to Date** | **$1,509,458** |

[1] Costs associated with bird surveys and light-footed Ridgway's rail monitoring are not included.

[2] This does not include staff time accounted for on monthly invoices.

[3] The bids for sediment augmentation came is much higher than estimated by the project engineer, therefore, some of the cost for sediment augmentation was covered by the Orange County Parks.

**Attachment 2**

Photographs taken on May 1, 2017 illustrating the reestablishment of pickleweed on the site (Photo: USGS).

Photographs taken on May 9, 2017 illustrating the growth of cordgrass into the site via rhizomes (Photo: USFWS/Nye).

# Annual Report: Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge

***Sediment flux and turbidity patterns***

***Surface Elevation Table (SET) monitoring***

June 22, 2017

*Pickleweed growing on the Seal Beach NWR augmentation area*

**Principle Contact**: Karen M. Thorne[1], 916-502-2996, kthorne@usgs.gov

**Team:** Neil K. Ganju[2], Chase Freeman[1], and Jordan A. Rosencranz[1]

*[1]USGS, Western Ecological Research Center, 505 Azuar Dr. Vallejo, CA, 94592*
*[2] USGS, Coastal and Marine Geology, 384 Woods Hole Road, Woods Hole, MA 02543-1598*

# Summary


- Pre-construction, construction period, and post-construction marsh surface elevation monitoring was done with deep rod Surface Elevation Tables (SETs) and adjacent feldspar throughout the year. Monitoring of turbidity and sediment fluxes was done at two YSIs and an ADCP in the deep channel site (control) and in the eelgrass site (adjacent to augmentation site) was conducted throughout the year.
- Mean sediment flux measured in the deep channel after augmentation construction demobilization was -0.01 g/m2/s, suggesting that little sediment flowed out of the marsh complex.
- Mean suspended sediment concentrations (SSC) at the deep site was 6 mg/L before and after construction, while post-construction mean SSC at the eelgrass site was 2.7 times greater than pre-construction levels.
- Control SETs have had gains and losses of elevation since installation, but have a mean cumulative increase of 3.48 mm from the date of installation.
- Augmentation SETs had a mean increase in elevation of 216 mm (8.50 in) with sediment application, but had a decrease in mean elevation of 75.59 mm (2.97 in) post sediment application (April 2016-May 2017). Elevation decreases were most rapid initially after the sediment application period (augmentation) and elevation loss has slowed over the course of monitoring.

# Objectives

Our research objectives were to: 1) detect changes in turbidity in the eelgrass bed (adjacent to augmentation site) due to effects of construction and sediment application; 2) detect changes in turbidity and sediment fluxes at the deep channel site (control) due to any effects of construction and sediment application; 3) monitor any post-construction impacts to in-channel turbidity at the eelgrass bed and deep channel site; and 4) assess changes in elevation, including accretion, erosion, compaction, and shallow subsidence before, during, and after construction at the sediment augmentation site, comparing our results to results at a control site.

# Methods

## Sediment fluxes and turbidity

Turbidity was measured with YSI multi-parameter sondes (sondes) at eelgrass bed and deep channel site (Figure 1). Prior to deployment, sondes were calibrated to a standard turbidity solution. During two deployments between January 2017 and March 2017, a poor turbidity standard was used due to a manufactured error, and turbidity data were corrected with new information. Sondes were recovered, cleaned, and deployed after approximately 1-2 months for continuous monitoring. Turbidity data were carefully scrutinized, so that periods characterized by biological fouling and short-term interference were omitted for further analysis. Data processing, time series analysis of turbidity data, and other summary statistics were completed in Matlab 2014a.

Following sonde deployment water samples were collected opportunistically from a boat with van dorn samplers. Samples were taken adjacent to sensors during a predicted turbidity measurement (i.e., every 15 minutes). Suspended sediment and loss on ignition data from each 1 L sample were analyzed at the U.S. Geological Survey California Water Science Center, Santa Cruz, California. Turbidity data were calibrated to suspended sediment via linear regression in Matlab 2014a.

Inundation and flow velocities were measured with Nortek aquadopp current profiler (ADCP). Combined with the instantaneous turbidity values, which were calibrated to collected suspended sediment data, the flow parameters were used to calculate sediment fluxes in Matlab 2014a.

## Elevation and Accretion

Changes in elevation were assessed with deep rod Surface Elevation Tables (SET) and through the corresponding three feldspar marker horizons at each SET. There are 15 SETs at the augmentation site and 6 SETs at the control site (**Figure 1**). Prior to sediment application, accretion was measured at three feldspar proximal plots by cutting an approximately 3cm x 3cm x 6cm plug using a serrated knife. After sediment application occurred at the augmentation site, accretion was measured using a cryo coring method as well as a 1-m long Russian peat coring device.

# Results

## Water samples, turbidity, and sediment fluxes

Turbidity was calibrated to SSC (**Figure 2**) according to the following equation:

$$SSC = 2 * (NTU) - 0.42 \quad (1)$$

Mean flux measured in the deep channel after augmentation construction demobilization was -0.01 g/m2/s, suggesting that very little sediment was flowing out of the marsh complex after construction (**Figure 3** and **Table 1**). We measured no change in the mean SSC at the deep monitoring site (6 mg/L) before or after construction activities. While post-construction mean SSC at the eelgrass monitoring site which is adjacent to the sediment application area was 2.7 times greater than pre-construction levels. Storms, which can lead to elevated SSC and sediment fluxes, were common during the post-construction period and therefore probably increasing turbidity at the study sites. Mean SSC was greatest at both the eelgrass site (14 mg/L) and deep site (29 mg/L) during a storm on Jan 22, 2017, which yielded 9.3 cm (3.7 in) of rain (**Table 2**). During that extreme storm, the sediment import rate was 0.23 g/m2/s (**Table 2**).

## Surface elevation changes

Using Surface Elevation Tables (SETs) an initial surface elevation loss was documented at the Augmentation SETs between the end of construction application (4/15/2016) and the following measurements (6/24/2016 and 10/27/2016;

**Figure 4**), presumably from a combination of compaction of the marsh platform and sediment being re-suspended during high tides and leaving the marsh.

Control SETs have had gains and losses of elevation since installation, but have a mean cumulative increase of 4.08 mm from the date of installation (**Figure 4**). Augmentation SETs had a mean increase in elevation of 216 mm (8.5 in) with sediment application, but had a decrease in elevation of 63.16 mm (2.5 in) post sediment application (April-October). Then between October and January mean elevation increased 0.93 mm (0.04 in), showing that the marsh platform seemed to be stabilizing in elevation. However from the most recent measurements (January-May), the augmentation SETs decreased in elevation again dropping 13.38 mm (0.53 in). This recent elevation decrease could be continued stabilization of the marsh surface and also due to seasonal strong storms. We measured elevation loss at the control SETs (-0.35 mm, -0.01 in) during the same time period.

# Conclusions

Monitoring of the augmentation marsh surface with SETs showed that the area had initial elevation losses, but stabilized since construction was completed and elevation losses are small. Monitoring of turbidity and sediment fluxes during and after augmentation construction showed that suspended sediment impacts were localized and small, mostly at the adjacent eelgrass channel following demobilization of construction equipment. Elevated post-construction turbidity at the eelgrass site suggest that there may lingering impacts from augmentation, and associated with heavy storm conditions during the winter 2016 and early 2017. We

speculate that this elevated turbidity, which is still low relative to other regional salt marsh sites during other periods, may be related to an increased sediment supply in the eelgrass bed from construction and/or continued, chronic export of sediment to the eelgrass site from tidal creeks in the augmentation site. However, the post-construction surface elevation and accretion gains from SETs suggest that erosion is not occurring from the marsh surface. This may mean that increased turbidity levels at the eelgrass site during storms is not from runoff of the augmentation site, but possible resuspension of sediment at the channel bottom and adjacent areas.

# Tables

**Table 1.** Instantaneous SSC and sediment fluxes averaged across date range of activities. Spraying dredged sediment (12in pipe) and demobilization of equipment resulted in the highest SSC adjacent to the application site.

| Activity | Eel SSC (mg/L) | Deep SSC (mg/L) | Deep Flux (g/m2/s) |
|---|---|---|---|
| **Pre Construction** | 3 | 6 | -0.34 |
| **Hay Bale Install** | 11 | 6 | -0.25 |
| **Silt Fence Install** | 21 | 6 | -0.05 |
| **Spray Dredge 8 in** | 9 | 6 | -0.26 |
| **Spray Dredge 12 in** | 30 | 6 | 0.01 |
| **Dredge Clam Shell** | 18 | 6 | -0.12 |
| **Demobilization** | 35 | 5 | 0.24 |
| **Post Construction** | 8 | 6 | -0.01 |

*negative flux values indicate export

**Items are ordered in chronological order, but there is some overlap between construction events

**Table 2.** Instantaneous suspended sediment (SSC) and sediment fluxes averaged across date range of storms after demobilization.

| Date | Daily Precipitation (in) | Eel SSC (mg/L) | Deep SSC (mg/L) | Deep Flux (g/m2/s) |
|---|---|---|---|---|
| **Nov 21, 2016** | 0.6 | 2 | 5 | -0.31 |
| **Dec 16, 2016** | 0.6 | 5 | 7 | -0.98 |
| **Dec 21-23, 2016** | 0.6, 0.8, 1.1 | 1 | 6 | -0.30 |
| **Jan 5, 2017** | 0.5 | 1 | 2 | -0.08 |
| **Jan 9, 2017** | 0.6 | 2 | 3 | -0.27 |
| **Jan 12, 2017** | 0.7 | 5 | 5 | -0.63 |
| **Jan 19-20, 2017** | 0.7, 1.2 | 4 | 11 | -0.08 |
| **Jan 22, 2017** | 3.7 | 14 | 29 | 0.23 |
| **Feb 6, 2017** | 1.1 | 5 | 6 | -0.18 |
| **Feb 17, 2017** | 2.3 | 6 | 6 | 0.17 |

*negative flux values indicate export

**Storm was defined as one or more consecutive days of rain with at least 0.5in/day of precipitation

# Figures

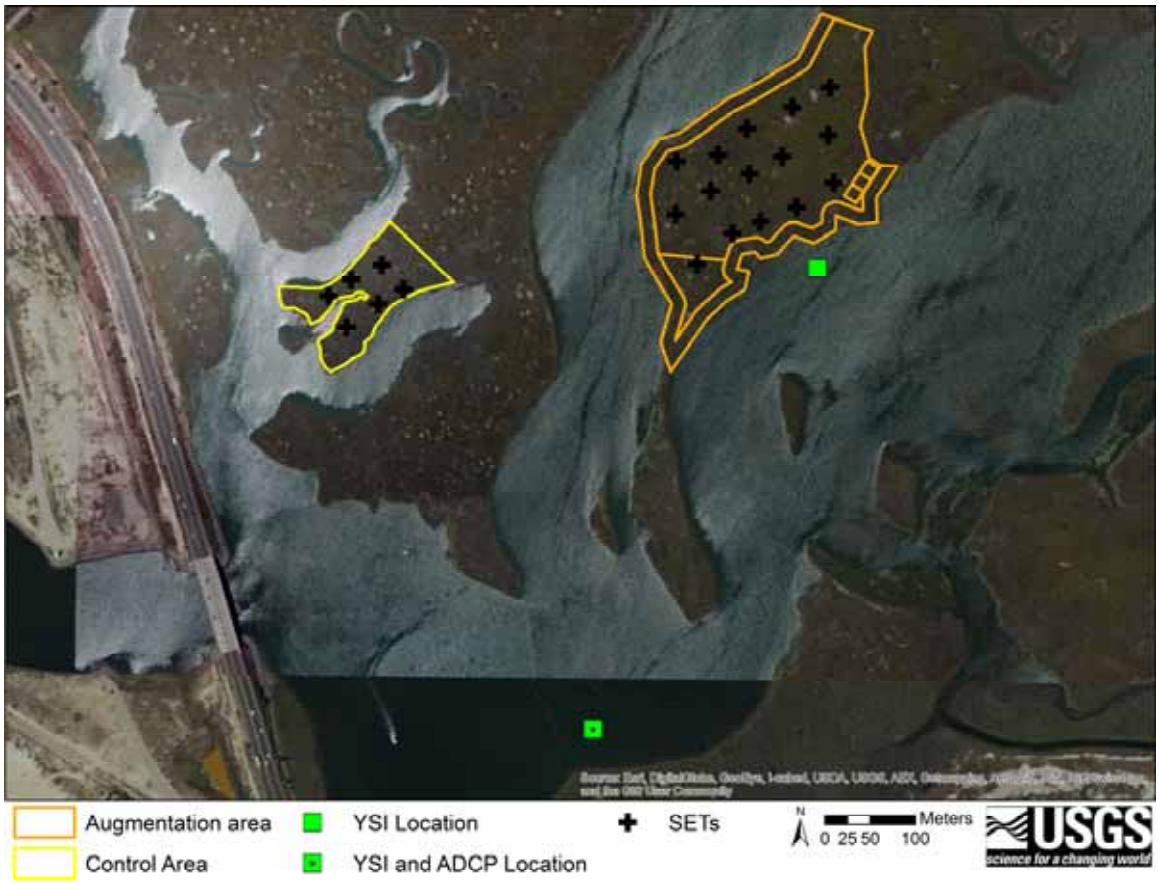


**Figure 1.** Site map of project area and data collection locations.

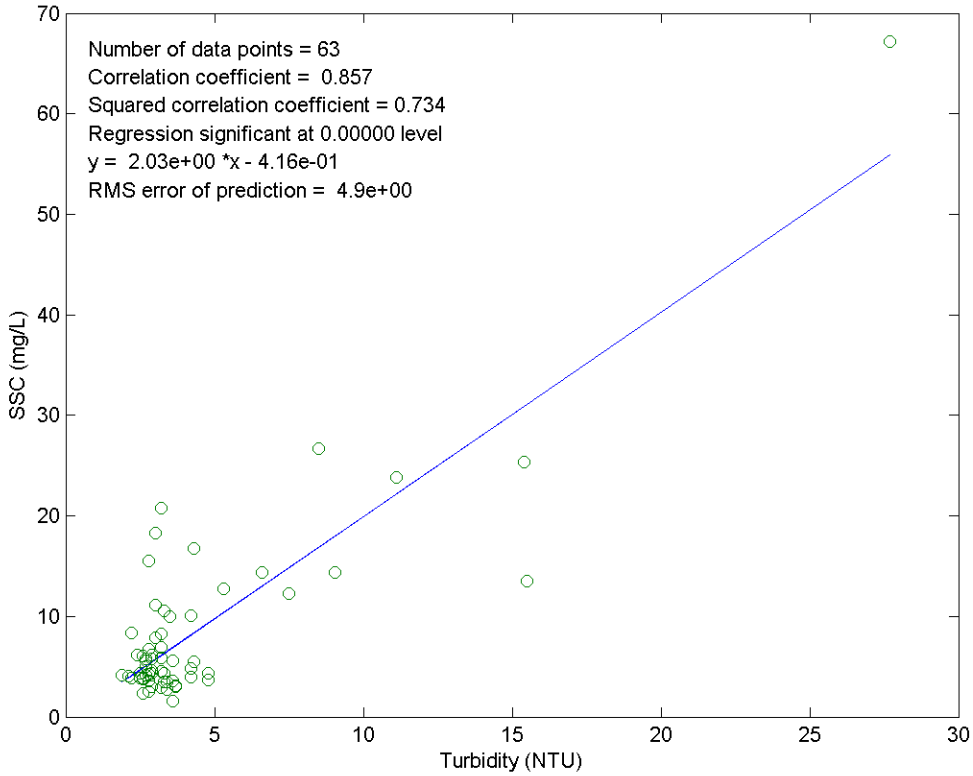


**Figure 2.** Relationship of suspended sediment concentration (SSC) measured by water samples to turbidity (NTU) from YSIs.

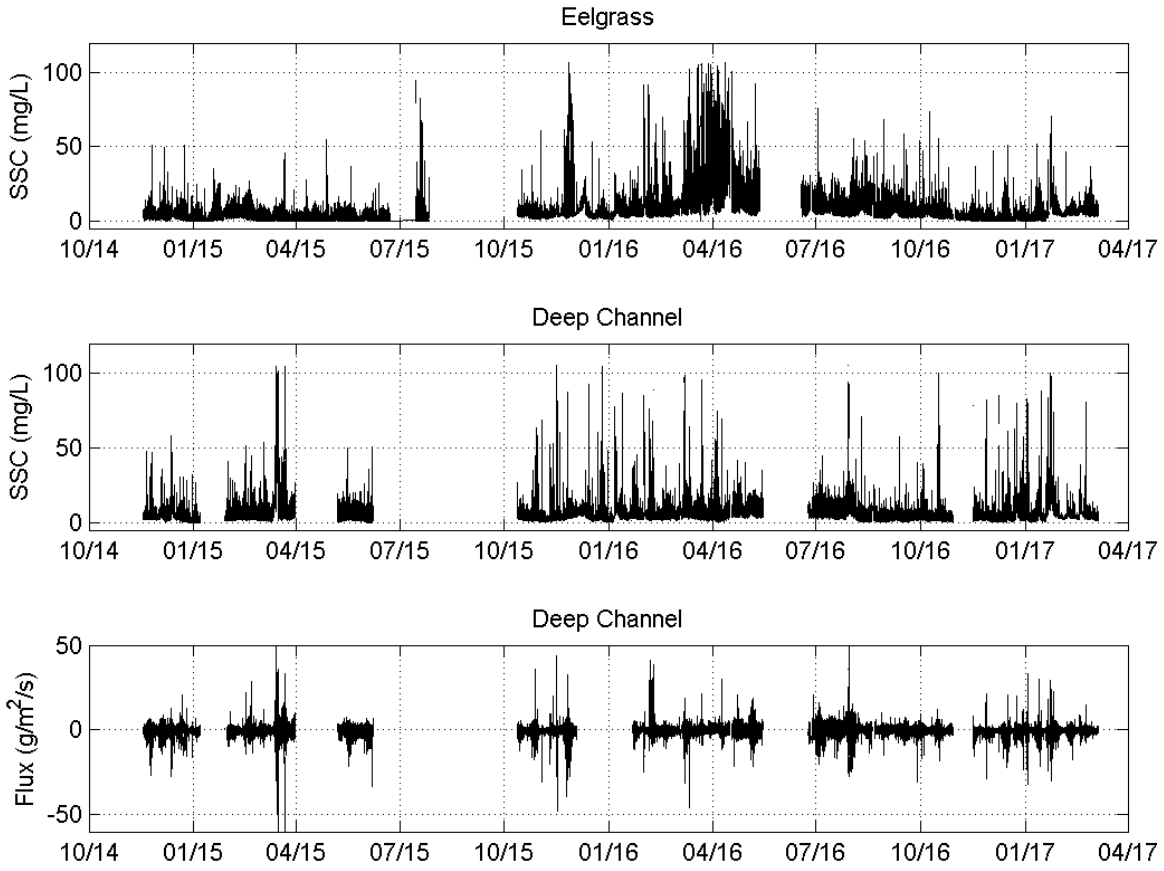


**Figure 3**. Time series of suspended sediment concentrations (SSC) and flux per unit area of the creek cross-section at deep channel site over the November 11, 2014-March, 2017 monitoring period during and after augmentation construction activities. Anything after April 4th, 2016 was considered post sediment application moniting.

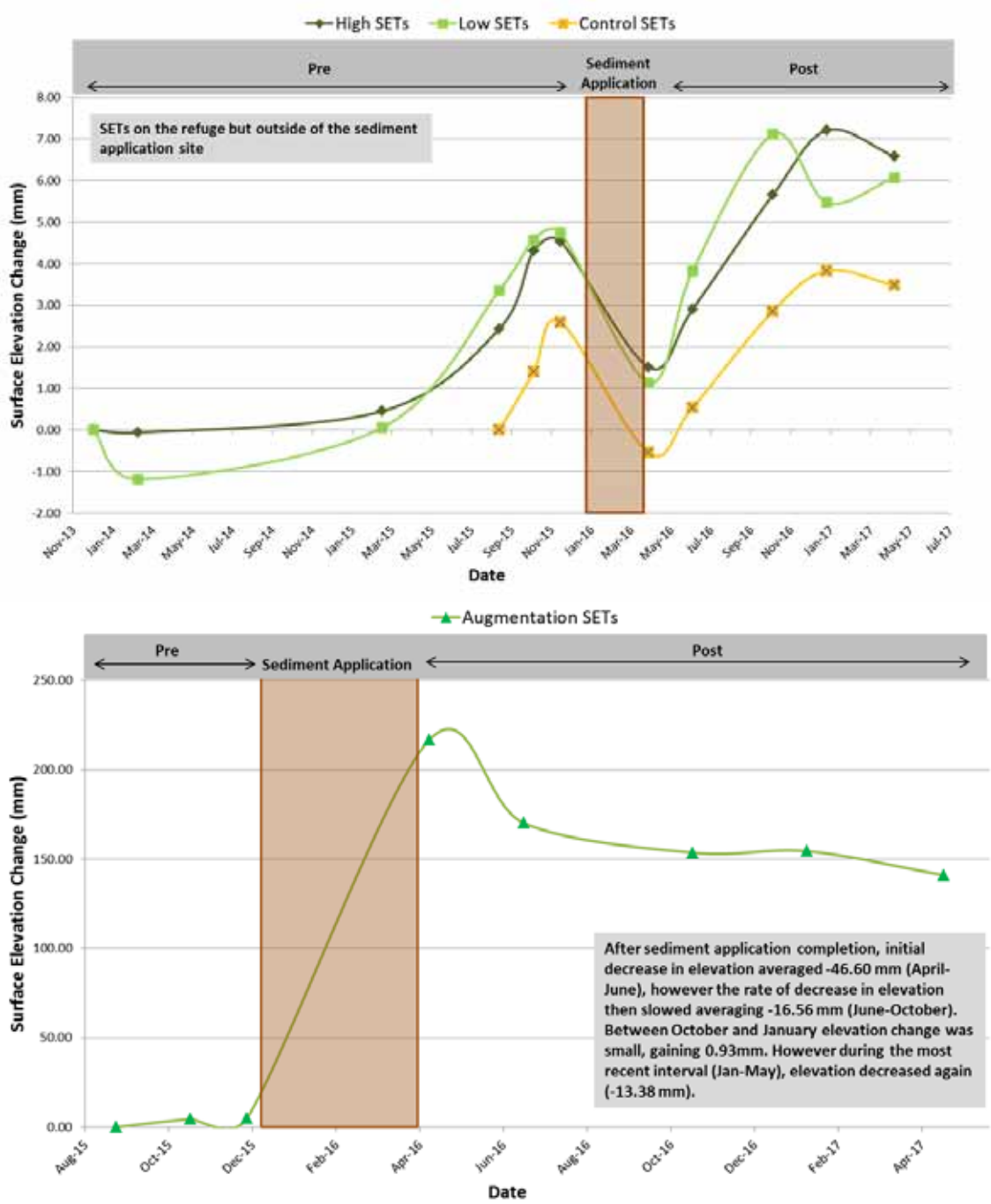


**Figure 4.** Mean surface elevation change at control site (above) and augmentation site (below). Brown box represented construction time frame.