Title

North Campus Open Space Restoration Project Annual Monitoring Report: Year 2 (2019)

Authors
Cheadle Center for Biodiversity and Ecological Restoration
Clark, Ryan D
Stratton, Lisa

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North Campus Open Space Restoration Project

Annual Monitoring Report: Year 2 (2019)

NORTH CAMPUS OPEN SPACE

CCBER CHEADLE CENTER FOR BIODIVERSITY & ECOLOGICAL RESTORATION

UC SANTA BARBARA

Restoration and associated monitoring for the North Campus Open Space Restoration Project are made possible with funding from the following agencies: USFWS, State Coastal Conservancy, Wildlife Conservation Board, California Department of Fish and Wildlife, Ocean Protection Council, Department of Water Resources Urban Streams Program, California Natural Resources Agency Urban Greening program, CalTrans, State Coastal Conservancy Wetlands Recovery project community grant program, Environmental Mitigation Program through CalTrans and California Department of Natural Resources with funding through California Climate Initiative, Proposition 1, Proposition 84. Additional funding has come from smaller contributions from SoCalGas, the UC Santa Barbara Associated Students' Coastal Fund, local foundations, and individual donors as well as funding from the County of Santa Barbara and the City of Santa Barbara which supported the planning and design process.

EXECUTIVE SUMMARY

Born out of a vision shared by the local community, students, faculty, researchers and state and federal agencies, the North Campus Open Space (NCOS) restoration project is recreating more than 40 acres of estuarine and palustrine wetlands that historically comprised the upper portion of Devereux Slough that was filled in the mid-1960s to create the Ocean Meadows golf course. Led by the UC Santa Barbara Cheadle Center for Biodiversity and Ecological Restoration (CCBER) in collaboration with other UCSB departments, faculty, student and local community groups, contractors and government agencies, the project is also restoring more than 60 acres of upland habitats that include native grassland, coastal sage scrub, riparian, oak chaparral woodland, vernal pools and patches of annual wildflowers in clay and sandy soils. In addition to wetland and upland habitat restoration, the goals of the NCOS project include flood reduction, support for threatened and endangered species, public access and the provision of educational opportunities. Ancillary benefits of the project include carbon sequestration, preservation of local genotypes, and protection of adjacent ecological values and infrastructure through a design that integrates sea level rise considerations.

Currently in its third year of implementation, the main planting phase of the project is approximately 90% complete, and the focus is now turning towards maintenance, continued monitoring, new research projects, and supplemental planting to add diversity, including special status species such as the Ventura marsh milk-vetch (*Astragalus pycnostachys* var*. lanosissimus*). This report describes the methods and results of monitoring for the first two years of the project, from vegetation and wildlife to wetland geomorphology, hydrology and water quality, carbon sequestration studies, community use and a detailed record of restoration efforts by type of worker, task and site location. This work documents the progress of the project and supports longer-term research and monitoring programs. Results from the second year of monitoring show substantial progress towards the project's restoration goals, with many being met or exceeded. Here follows a brief summary of the topics covered in this report.

Photo-Documentation Monitoring

Following an introduction with a summary and timeline of planting progress, the report begins with a set of photographs from the quarterly photo monitoring of the project site. These photographs provide a visual record of the transformation of the wetland portion of the site from a bare landscape at the end of 2017 to an almost completely established salt marsh and transitional habitat by the fall of 2019.

Vegetation

The second year of vegetation monitoring saw significant increases in absolute cover of native species and diversity in nearly all habitats, and significant declines in invasive species cover in most habitats. The establishment of native vegetation is on target relative to the year in which each habitat was first planted. For example, salt marsh was the first habitat to be planted beginning in late 2017, and as of the second year, it is exceeding three of the four main success criteria originally outlined in the Restoration Plan. Most of the drill seeding of *Stipa pulchra* in the native grassland habitat occurred in late 2018, and consequently, this habitat was still developing at the time that monitoring occurred in the summer of 2019. Nevertheless, the second-year goals for relative percent native cover and native species diversity for the grassland were exceeded. The vernal pool and riparian habitats are establishing steadily, but slowly. The coastal sage scrub mosaic was the last major vegetation community to be planted in the fall of 2019, and, therefore, the monitoring data collected in 2020 will be assessed against the “year 1” goals for this habitat. The total number of native species recorded across all habitats increased from 54 in the first year to 70 in the second year, and several special status plants such as the southern tarplant (*Centromadia parryi* var. *australis*) and *Anthrocemum subterminale* are well established on site.

Wildlife

The second year of wildlife monitoring at the NCOS project revealed some exciting results: two burrowing owls over-wintered in the hibernacula installed on the slopes of the Mesa; Western Snowy Plover were observed breeding for the second year in a row on the sand flat habitat specifically designed for them, and two pairs attempted to nest there in 2019; a Southwestern Pond Turtle was observed in the newly established pond habitat where Phelps Creek enters the site; and Tidewater Goby were found in the lower Devereux Slough for the first time in several years. Monthly bird surveys in year two showed increases in abundance by 30 % and diversity by 24 % over the first year, which might partly reflect the finding that aquatic invertebrates have recolonized the site in all aquatic habitats and even exceed the reference sites on Coal Oil Point Reserve both in number and diversity.

Wetland Geomorphology, Hydrology, and Water Quality

Several components of monitoring are focused on the hydrology and water quality of Devereux Slough and the tributaries that feed into the restored upper portion in the NCOS project. The results of this monitoring indicate that the estuary is performing as expected in terms of an increased water-holding capacity, reduced flood levels and an increased tidal prism. Dissolved oxygen and salinity tend to follow inverse patterns throughout the year with the deepest areas of the wetland channels becoming hypersaline and anoxic in the late summer and fall. Results of the first round of intensive sampling of nutrient and suspended solids concentrations in stormwater entering and leaving the restored upper slough are presented. More of this data is being collected in year 3 in order to capture the natural variability associated with precipitation. In 2019, three of the vernal pools on the Mesa held water for well over 100 days while the remaining five pools held water for close to 100 days, suggesting that the pools are functional in years with average to above-average rainfall. Groundwater monitoring indicates that, after grading, the water table is closer to the surface by two to three feet compared to pre-project data in areas of the western arm and along the east side of the wetland, and, as expected, salinity has increased where the greatest lowering of the ground surface occurred.

Community Use & Perception, and Education & Research

Surveys of the local community found broad support for the site’s values, particularly by people who visit NCOS and/or are well-informed about the project’s goals. Most dog owners now keep their dogs on leash when on-site, though this does require on-going education. As an ecological restoration training ground for UCSB and K-12 students, NCOS was visited by more than 1,200 K-12 students for focused educational trips in 2019, and over the first two years of the project, paid student workers logged more than 17,000 hours and volunteers contributed 6,000 hours to the restoration of the site. In addition, more than 30 students have participated in or are leading research projects at NCOS, ranging from soil carbon studies, wetland greenhouse gas fluxes, aquatic invertebrate and water quality studies and wildlife use of the habitat.

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1. INTRODUCTION

The North Campus Open Space (NCOS) restoration project comprises 100 acres of a 136-acre site located northwest of the main campus of the University of California Santa Barbara (UCSB). Bordered by Coal Oil Point Nature Reserve to the south and the City of Goleta's Ellwood Mesa/Sperling Preserve to the west, the NCOS site expands upon a contiguous block of open space and wildlife habitat, with residential neighborhoods to the north and east. The focal point of the project is the restoration of more than 40 acres of estuarine and palustrine wetlands that were historically part of Devereux Slough and were filled in the mid-1960s to create the Ocean Meadows golf course. Led by the UC Santa Barbara Cheadle Center for Biodiversity and Ecological Restoration (CCBER) in collaboration with other UCSB departments, faculty, student and local community groups, contractors and government agencies, the project is also restoring more than 60 acres of upland habitats that include native grassland, coastal sage scrub, riparian, oak chaparral woodland, vernal pools and patches of annual wildflowers in clay and sandy soils. Funded by federal, state and local agencies, the NCOS project's goals include flood reduction, wetland and upland habitat restoration, support for threatened and endangered species, public access and the provision of educational opportunities. Ancillary benefits of the project include carbon sequestration, preservation of local genotypes, and protection of adjacent ecological values and infrastructure through a design that integrates sea level rise considerations.

The formal, "on the ground" restoration of NCOS began in February 2017 with the removal of most of the exotic trees on the former Ocean Meadows golf course. The grading and movement of soil on the site occurred from April to October 2017. This was followed by the construction of a multi-use trail, two bridges, and a boardwalk and culvert crossing that were completed in June 2018. Descriptions of the target habitats to be restored and/or enhanced are provided in Section 3 of the Restoration Plan. The plan recognizes that changes or modifications in the locations and extents of habitats could occur depending on the post-grading conditions of the site. Changes that we have implemented include the replacement of the proposed back dune woodland scrub habitat with a complex of six vernal pools interspersed with grassland and vernal meadow species. Other habitat changes include the addition of pockets of oak woodland-chaparral within the coastal sage scrub habitat proposed along the northern slope of the Mesa. In response to plant establishment patterns and sub-surface hydrology, we adjusted planting to accommodate an expansion of salt marsh in the western arm by 4.3 acres and a reduction in transitional habitat as well as modest adjustments to the grassland and coastal sage scrub habitat acreage. A habitat referred to in this monitoring report that is not described in the Restoration Plan is the Peripheral Upland Mosaic, which comprises a mixture of primarily native grasses and scrub interspersed with bioswales and retained trees (mostly exotic). A map of the NCOS project in Figure 1 reflects the current extent of habitats being restored and enhanced, and includes the as-built elevation contour lines (one-foot interval) and the constructed trails, bridges and crossings.

Year 1 Planting Summary

During the first year of restoration (September 2017 – October 2018), more than 185,000 locally sourced native plants comprised of 45 species were installed across 40 acres, covering 75 percent of the Peripheral Upland Mosaic and Salt Marsh habitats. In December 2017, an inoculum containing seeds and dormant invertebrates from existing and adjacent vernal pools was spread in the eight vernal pools created on the Mesa area of NCOS. In addition, throughout the winter and spring of 2018, grasses such as *Hordeum brachyantherum* ssp. *brachyantherum* and *Stipa pulchra* were planted along the margins and between the vernal pools. Approximately 25 percent (3.9 acres) of the Native Perennial Grassland habitat (the eastern portion) was drill seeded with 4 lbs. per acre of *Stipa pulchra* seed in October 2017, and the remaining area (9.1 acres) was drill seeded with 6 lbs. per acre of seed in October 2018. More than 100 tree saplings comprised of six species were installed in the New Riparian habitat along the Whittier Channel in the northeastern area of NCOS, and while no planting occurred in the other target habitats, a small number of native plants sprouted in many areas of the project site.

Year 2 Planting Summary

The second year of restoration saw the addition of more than 100,000 plants and added 15 more species to the project site, bringing the overall total to nearly 290,000 individual seedlings of 60 species planted. The primary planting of the Salt Marsh and Transitional habitats as well as the Peripheral Uplands was completed. An additional 33 trees and more than 2,100 understory plants (20 species) were installed in the Riparian habitats along Phelps Creek and Whittier Channel, and 95 coast live oak (*Quercus agrifolia*) trees were planted in pockets along the north facing slopes of the Mesa (identified as Oak Woodland/Chaparral in the map in Figure 1), as well as in a few locations in the Peripheral Uplands near Phelps Creek. Planting of the Coastal Sage Scrub habitat along the Mesa slopes occurred late in the second year (in the fall of 2019), after monitoring for this report was completed.

Ongoing and Future Restoration Planting

Restoration planting in 2020 will include maintenance and diversification in all habitats as well as the following projects:

1. Herb and forb species are being added to the Mesa grassland and some species are being planted in experimental plots to examine the effects of herbivory and the pre-treatment of seeds.
2. A small population of the federally endangered Ventura Marsh Milk-vetch (*Astragalus pycnostachys var. lanosissimus*) has been planted in a sandy area at the foot of the eastern slope of the Mesa and will be monitored and assessed for future plantings in other areas of NCOS.
3. Through the Environmental Enhancement and Mitigation grant program, we are removing invasive species and restoring coastal sage scrub and chaparral in a 25-acre area west of the NCOS Mesa. With the inclusion of this and the adjacent South Parcel restoration site, NCOS will expand to a contiguous 136 acres of restored habitat.
4. We will also establish an interpretive trail and garden in association with the visitor plaza that will be constructed near the entrance to NCOS off Whittier Drive.
5. The peripheral upland portion along the north side of the western arm will be a focus during year three and the peripheral upland along the eastern arm will be established after the proposed new private housing development adjacent to that area is installed.

Report Structure and Content

This report describes the NCOS monitoring program, methods and protocols, and includes data from the first two years of monitoring (Year 1: September 2017 to October 2018, Year 2: November 2018 to November 2019) as well as discussion of the progress of restoration and monitoring through the second year. Most of the components of monitoring will continue through the year 2022.

The monitoring efforts described herein include:

- Photo-documentation monitoring
- Vegetation monitoring
- Wildlife monitoring
- Wetland geomorphology, hydrology and water quality
- Sediment accretion, carbon sequestration & related research
- Community use & perception
- Characterization of project effort

Data and related information about the project are posted on the EcoAtlas website, and monitoring reports and associated data will also be posted and available through the CCBER's eScholarship page and website.

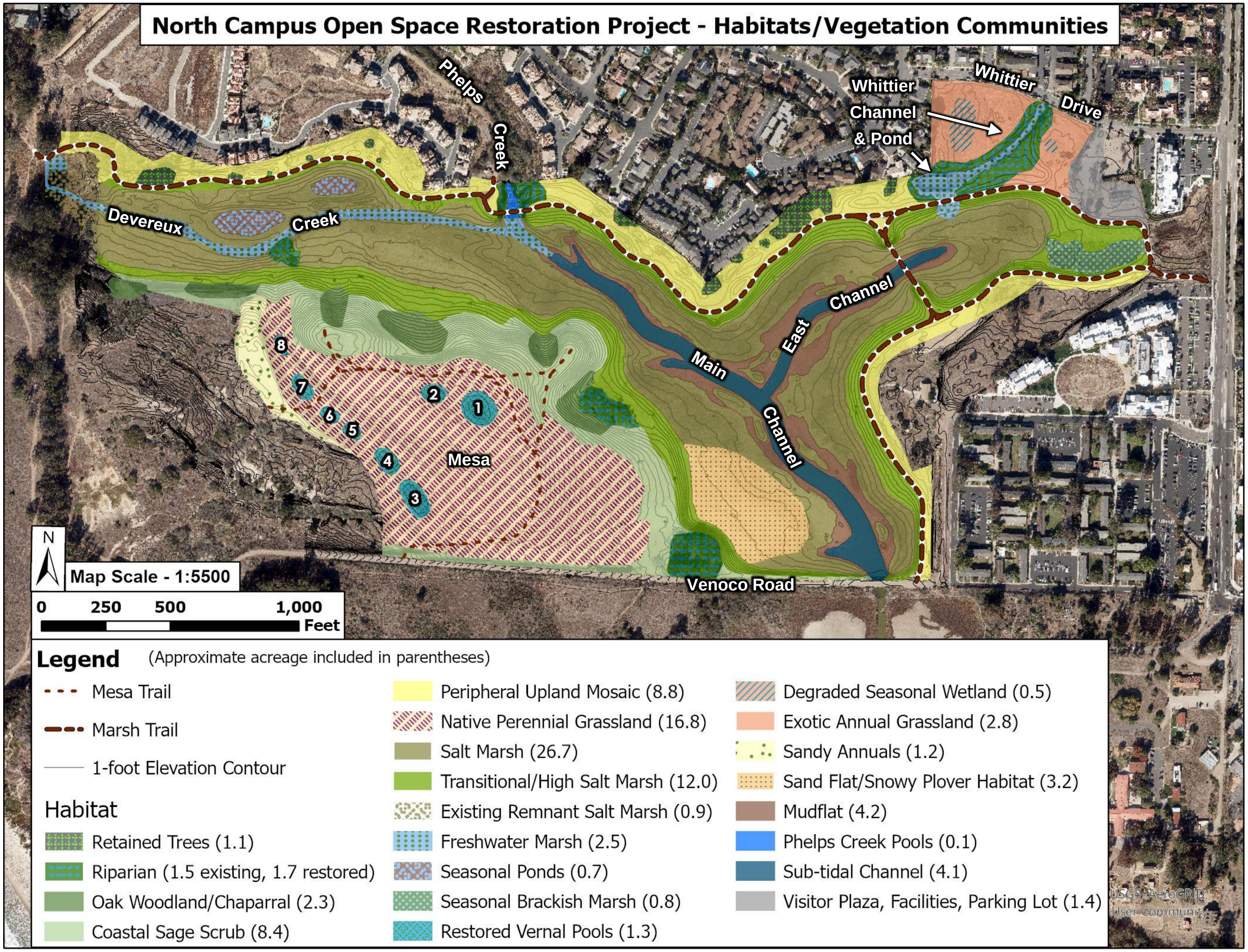


Figure 1. Map of the habitats/vegetation communities being restored at NCOS. The vernal pools on the Mesa are numbered.

2. PHOTO-DOCUMENTATION MONITORING

Photo-documentation was established in the NCOS Restoration Plan as one of the methods for monitoring the progress of the project, including the development of the wetland and changes in the size and cover of vegetation being restored across the different habitats. The locations of photo points were initially established, and the first set of photos were taken in December 2016, prior to the start of the project. These initial photos are included in Appendix A of the Restoration Plan. Subsequent photo-documentation monitoring is being conducted on a quarterly basis until the spring of 2020, after which the photos will be taken biannually until at least 2022.

At up to 46 points distributed across the site, one to seven photographs are taken depending on what is required to capture all aspects of the site that are visible from each point (see Figure 2 for a map of the photo monitoring points). Each photo is labeled with the photo point number, direction (N, SE, W, etc.), and the date the photo was taken (*e.g*. NCOS_08_N_20190417). Photo point numbers ending with the letters ‘a’ and ‘b’ are where photos are taken of the same general area but from different views or angles (*e.g*. 09a and 09b, 28a and 28b).

Through the early stages of the restoration project, a few minor revisions have been made in the number and location of photo points and the frequency of photos at some points. For example, points 05 and 13 were discontinued at an early stage because they were redundant (the photos from point 13 were subsequently relabeled as point 12), photos at what was originally point 09 ceased after the summer of 2017 and were then reinstated in the spring of 2019 and split into 09a and 09b. Documentation of the changes that have been made to the photo monitoring is available at this link.

Comparative photos from three points taken in October 2017, 2018 and 2019 are included below. The complete set of photos can be accessed from this interactive web map, or at this link.

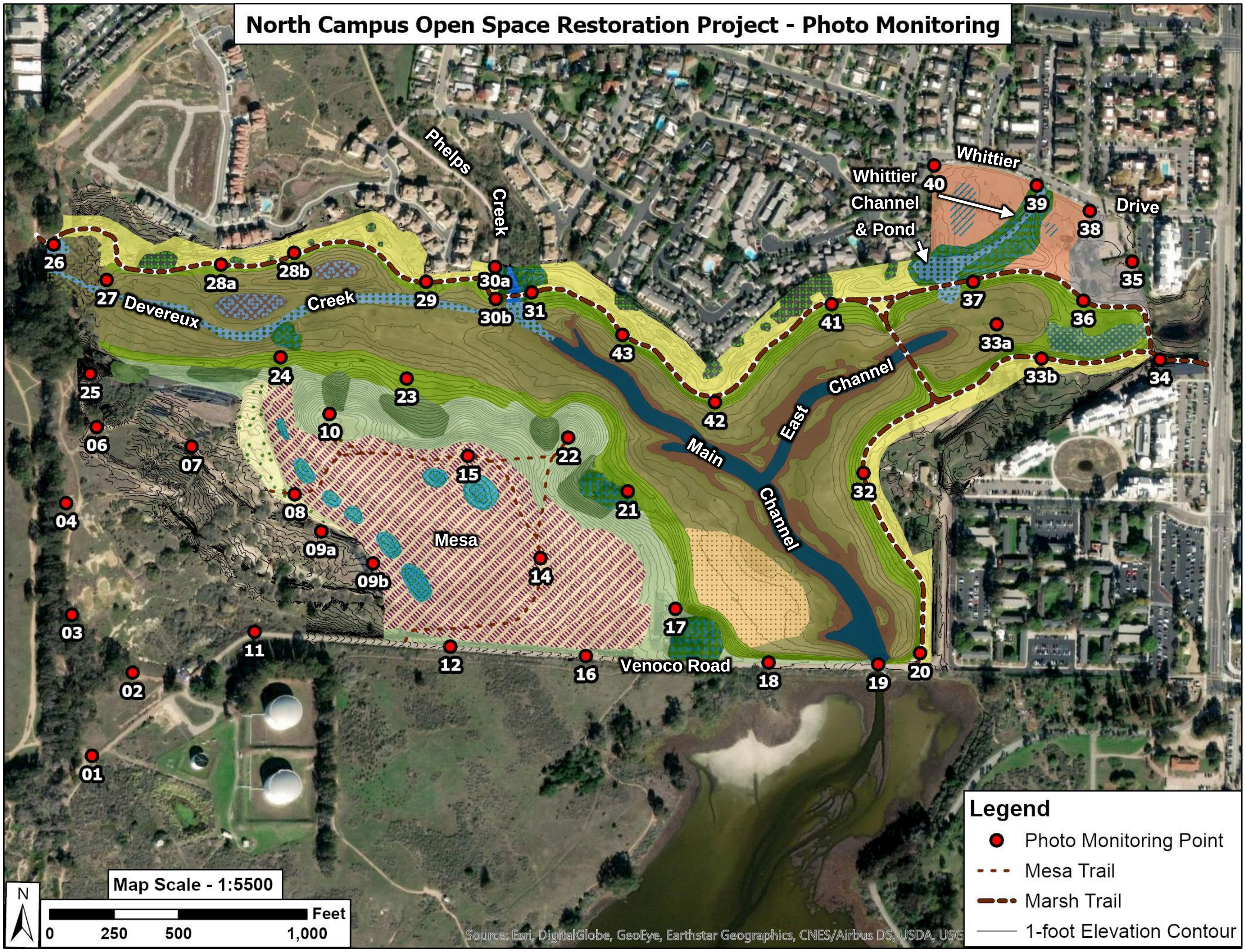


Figure 2. Map of the NCOS restoration project showing locations of photo monitoring points. See Figure 1 for a map and legend of the habitats/vegetation communities.

Photo point 20-NW – looking northwest from the southeast corner of the NCOS project site.

Baseline photo – post-grading, October 10, 2017.

Photo point 20-NW – looking northwest from the southeast corner of the NCOS project site.

Year 1 photo – October 16, 2018.

Photo point 20-NW – looking northwest from the southeast corner of the NCOS project site.

Year 2 photo – October 11, 2019.

Photo point 31-E – looking east from trail overlook on east side of Phelps Creek.

Baseline photo – post-grading, October 10, 2017.

Photo point 31-E – looking east from trail overlook on east side of Phelps Creek.

Year 1 photo – October 15, 2018.

Photo point 31-E – looking east from trail overlook on east side of Phelps Creek.

Year 2 photo – October 11, 2019.

Photo point 37-SW – looking southwest from trail at eastern end of Whittier Crossing.

Baseline photo – post-grading, October 10, 2017.

Photo point 37-SW – looking southwest from trail at eastern end of Whittier Crossing.

Year 1 photo – October 15, 2018.

Photo point 37-SW – looking southwest from trail at eastern end of Whittier Crossing.

Year 2 photo – October 11, 2019.

3. VEGETATION MONITORING

Vegetation Monitoring Methods

The establishment of native vegetation is usually the foundation and the most visible and commonly measured component of a restoration project. The initial vegetation monitoring plan and goals for the NCOS project are described in the Restoration Plan and allowed for modifications in order to adapt to potential post-grading changes in the location and extent of habitats. The modified monitoring plan and schedule is outlined in Table 1. The goal of this monitoring is to record changes in the absolute cover of native and non-native vegetation in each habitat by species, as well as the percent cover of thatch, bare ground and other cover such as mulch/woodchips or algae, all of which can provide habitat in one form or another for different organisms and thereby potentially increase the level of biodiversity across the site. Habitats comprised primarily of low growing vegetation, such as grasslands and wetlands, are monitored with quadrat transects (QT), and habitats with taller vegetation are monitored with point-intercept transects (PIT). Trees are monitored individually. Vegetation restoration success criteria are assessed at the end of this report section.

Quadrat Transects (QT)

In the eight habitats dominated by short or low-growing vegetation, permanent transects typically 30 meters long are monitored with a one-square-meter quadrat placed every three meters, alternating between the left and right side of the transect tape. The length of transects and number of quadrats across vernal pools and seasonal ponds depend on the overall shape and extent of these habitats. Daubenmire cover classes are used to estimate the cover of each species in the quadrat. Also recorded are the percent of the quadrat that contains only bare ground, thatch, or other cover types such as erosion control netting, black plastic for weed control, mulch and/or algae.

Point-Intercept Transects (PIT)

This method is used for vegetation communities with larger growth forms, such as Coastal Sage Scrub (CSS) Mosaic and Riparian. The species that cross a point at every meter along a 30-meter transect are recorded. Vegetation is grouped into two height classes: above two meters (canopy) and below two meters (sub-canopy). The point is represented by a two-meter tall, half-inch diameter wood dowel. A laser pointer is attached to the top of the dowel for extending the point through the canopy. When no vegetation crosses the point in the sub-canopy, other cover such as bare ground or thatch is recorded.

Trees

All trees planted at NCOS are monitored annually by measuring the height and diameter at breast height (DBH) in inches, and assessing tree vigor using a rating scale of 1 to 4, where 1 = high vigor with new growth; 2= medium vigor with some stunting, yellowing, or less vigorous growth; 3= poor, appearing nearly dead or dying; and 4 = dead.

Transect Locations & Data Collection Methods

Transect locations were established by generating a randomly placed starting point using GIS. Points were kept a minimum of 60 meters apart and 10 meters from the edge of the habitat/plant community. A 90-square-meter grid was used to divide the larger habitats (CSS Mosaic, Native Grassland, Peripheral Upland Mosaic, Salt Marsh, and the Sand Flat) into similarly sized sections, each separated by a 10-meter buffer, and the randomly-placed transect starting points were generated within these sections. This helped provide a more spatially balanced distribution of monitoring transects in these larger habitats/plant communities. In addition, we stratified the Salt Marsh and Transitional/High Elevation Salt Marsh each into two elevation bands (6-8 and 8-10 feet for Salt Marsh; 10-15 and 15-18 feet for Transitional/High Elevation Salt Marsh) in order to more closely assess the differences that may occur in species composition and coverage with changes in elevation. As part of the sea-level-rise adaptation design of the NCOS project, the elevation of the Salt Marsh habitat in the western arm extends up to 15 feet, particularly on the south side of Devereux Creek due to the higher elevation of the groundwater table (Figure 3).

Table 1. Vegetation monitoring plan for the habitats/vegetation communities at the North Campus Open Space restoration project. A map of the habitats is provided in Figure 1.

Habitat / Vegetation Community	Acres	Method	Survey Month	Number of Transects / Quadrats and/or Trees
Coastal Sage Scrub (CSS) Mosaic (incl. Chaparral / Oak Woodland)	10.7	PIT, Individual Trees	June/July	7 transects, ~ 130 trees
Native Grassland (Mesa)	16.8	QT	July	8 / 80
Peripheral Upland Mosaic (Grassland/Scrubland/Bioswale)	8.8	QT	June	7 / 70
Riparian – Existing	1.5	PIT	June/July	2
Riparian – New (Phelps Creek and Whittier Channel)	1.7	PIT, Individual Trees	June/July	2 transects, ~ 130 trees
Fresh-Brackish Wetland: Existing Brackish Marsh & New Seasonal Pond	1.5	QT	July/August	2 / 20
Vernal Pool Complex (8 pools)	1.3	QT	June	1 lengthwise transect with a minimum of 5 quadrats per pool, every other meter.
Salt Marsh - low (approx. 6-8 ft.) and mid (approx. 8-12 ft.) elevations, and Transitional/High Marsh at 10-15 and 15-18 feet in elevation	38.7	QT	August	21 / 210
Salt Marsh – Existing Remnant	0.9	QT	August	2 / 20
Sandy Dune Annuals	1.2	QT	June	1 /10
Sand Flat/Snowy Plover Habitat	3.2	QT	September (post-plover breeding season)	2 / 20

In the field, the locations of some of the transect starting points were adjusted slightly if they landed on irrigation infrastructure, a soil accretion or carbon sequestration monitoring plot, or other feature where disturbance should be avoided. The direction or bearing of transects was determined by a combination of factors: the distance of the starting point from the edge or boundary with adjacent habitats; the width of the habitat area around the point (if 30 meters or less, then the transect direction would be limited to run approximately parallel to the edges of the area); and if the transect would cross any features where disturbance should be avoided (*e.g*. sediment accretion or carbon sequestration monitoring plots). The start and end points of all transects are marked in the field with a labeled tag attached to a one-inch diameter PVC tube placed over rebar and protruding about one foot above-ground. A map of the vegetation monitoring transects is provided below in Figure 3.

At the start of each monitoring season, all surveyors are trained and calibrated on cover estimation and species identification as part of the QA/QC program. Transect and quadrat data are recorded using the ESRI Survey123 app on tablets, and photographs of each transect are taken from the starting point.

Vegetation Monitoring Data

Vegetation Cover Overview

The second year of monitoring showed increases in native vegetation cover in all habitats, a decrease in the amount of bare ground in most habitats, and variable yet mainly insignificant changes in the amount of non-native vegetation cover. In many habitats, the average percent of absolute native vegetation cover more than doubled since the first year, with the greatest increases observed in the Native Grassland, Peripheral Upland Mosaic, Salt Marsh and Transition/High Salt Marsh (Figure 4), as well as the Sandy Annuals (Figure 5) and the sub-canopy of the new Riparian habitat (Figure 6). This positive result also meant that these same habitats saw a significant reduction in the amount of bare ground between the first and second year of monitoring, particularly in the Salt Marsh habitat where the overall percent of bare ground decreased by more than half (Figure 4). The increase in vegetation cover and decrease in bare ground is also evident in a comparison of photos of transects from the first and second years of monitoring (Figure 7).

Species Diversity

A greater number of native species were recorded on most transects in year two, while the number of non-native species decreased in some habitats and increased in others. The total number of native species recorded across all habitats increased from 54 in the first year to 70 in the second year. A smaller increase was observed in non-native species diversity, from 61 to 73. Complete lists of all native and non-native species recorded during the second year (2019) of vegetation monitoring are provided in Appendix 1. Amongst the habitats, the greatest changes and highest levels in species diversity were observed in the Peripheral Uplands, where the number of native species increased from 16 to 40, and non-native species increased from 32 to 60 (Figure 4). These results are indicative of the variability of micro habitats (*e.g*. mounds and swales) developed throughout the Peripheral Uplands, and soil conditions that are generally less stressful (*e.g*. lower salinity) than elsewhere on the project site, both of which allow for the establishment of a greater diversity of the native plants in this area (relative to other habitats) yet also make it prone to a higher diversity of non-native species as well.

Coastal Sage Scrub Mosaic & Riparian

The point-intercept transect data for the Coastal Sage Scrub/Chaparral/Oak Woodland mosaic (CSS Mosaic) and the new and existing Riparian habitats is divided into two categories: canopy (above two meters) and sub-canopy. Most of the CSS Mosaic on the northern and eastern slopes of the Mesa were planted in the mid- to late fall of 2019, after the time when monitoring occurred. Consequently, there is very little vegetation cover recorded in the second year of monitoring data for the CSS Mosaic. However, one notable change in this habitat since the first year of monitoring is that the percent of non-native sub-canopy cover has decreased significantly, with an overall reduction from 30.1 down to 3.7 percent (Figure 6). In the first year of restoration (2018), more than 100 trees were planted in the new Riparian habitat (more details in the Tree Monitoring section). However, canopy cover from those trees had not yet established enough to be captured by the second year of monitoring. In the existing Riparian habitat, three native tree species dominate and there has been very little change in cover between 2018 and 2019 (Figure 6).

Vernal Pool Vegetation

While the second year of monitoring indicated that absolute native vegetation cover doubled in the vernal pools on the Mesa, the overall total remained relatively low at 10.7 percent, and despite this increase in cover, the amount of bare ground did not decrease (Figure 10). Pools one, two, four and eight have consistently held water for longer periods of time (see the Vernal Pool Hydrology section of this report), and these pools currently exhibit the greatest degree of successful plant establishment of all pools (vernal pool numbers are labeled in the map in Figure 1). All pools have native cover establishing slowly and we will continue to manage them as vernal pools to see how they evolve. In December of 2019, seeds of *Centromadia parryi* var. *australis*, a disturbance-dependent rare plant ranked 1B by California Native Plant Society, were added to the edges of all vernal pools where the intermittent flooding would potentially provide the type of regular disturbance that is favorable and could promote its long term establishment.

Salt Marsh & Transitional Vegetation

An examination of the salt marsh data separated by the four zones (low elevation - SML, mid-elevation - SMM, transition – SMT, and high elevation transition – SMTH) shows a consistent trend of increasing native cover and species diversity, and decreasing bare ground, with the exception of the SMTH zone where planting occurred late in 2019, after the time when monitoring occurred (Figure 11). Excluding SMTH, there is also a trend of overall species diversity (both native and non-native) increasing with the elevation of the salt marsh and transition zones. These trends should continue, and the amount of native cover and bare ground should reach levels similar to the existing salt marsh remnant (SMR) we are monitoring for comparison at the far western end of the wetland (see SMR data in Figure 11).

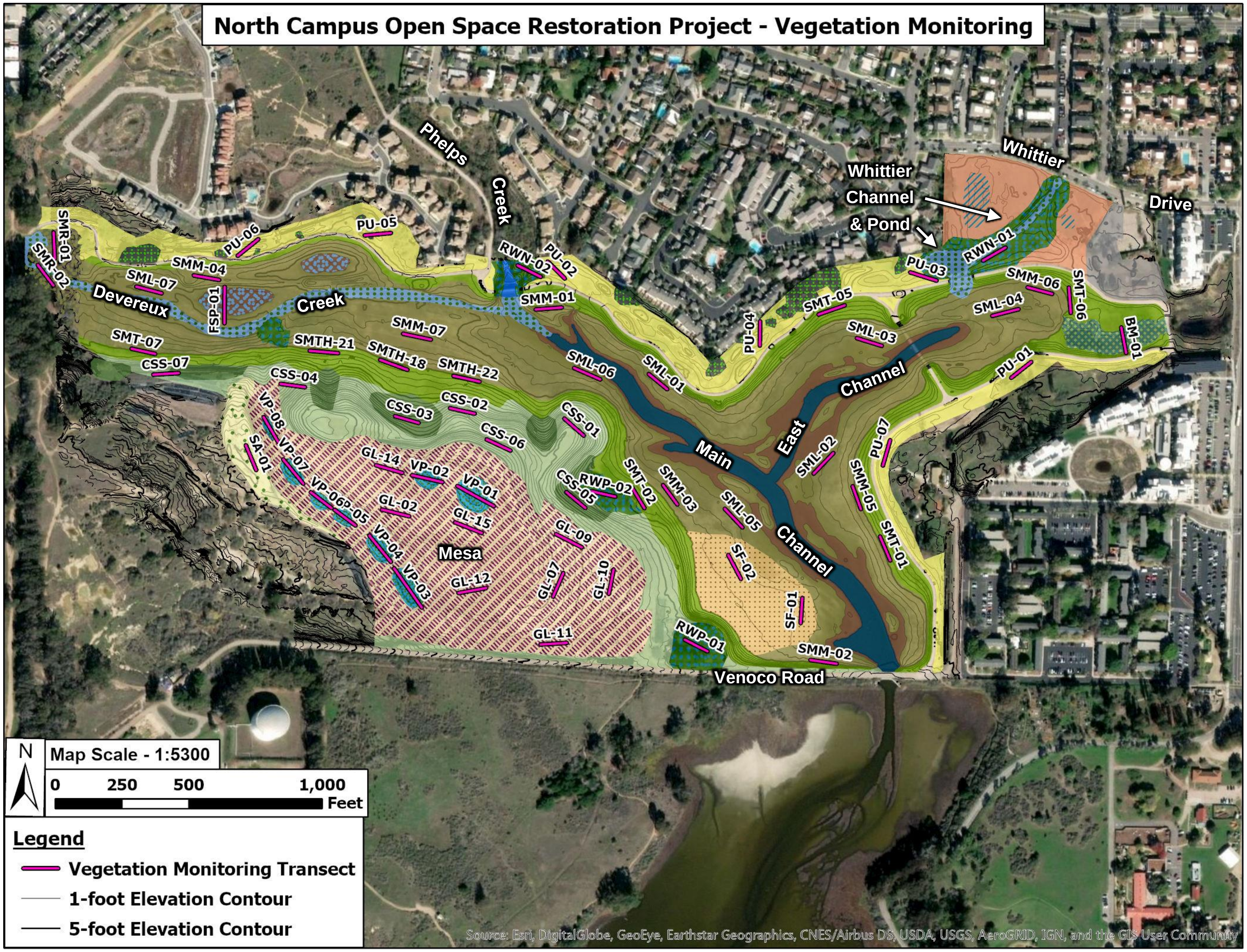


Figure 3. Map of the vegetation monitoring transects at NCOS, including the elevation bands for the Salt Marsh and Transitional/High Elevation Salt Marsh. See Figure 1 for a map and legend of the habitat/vegetation communities.

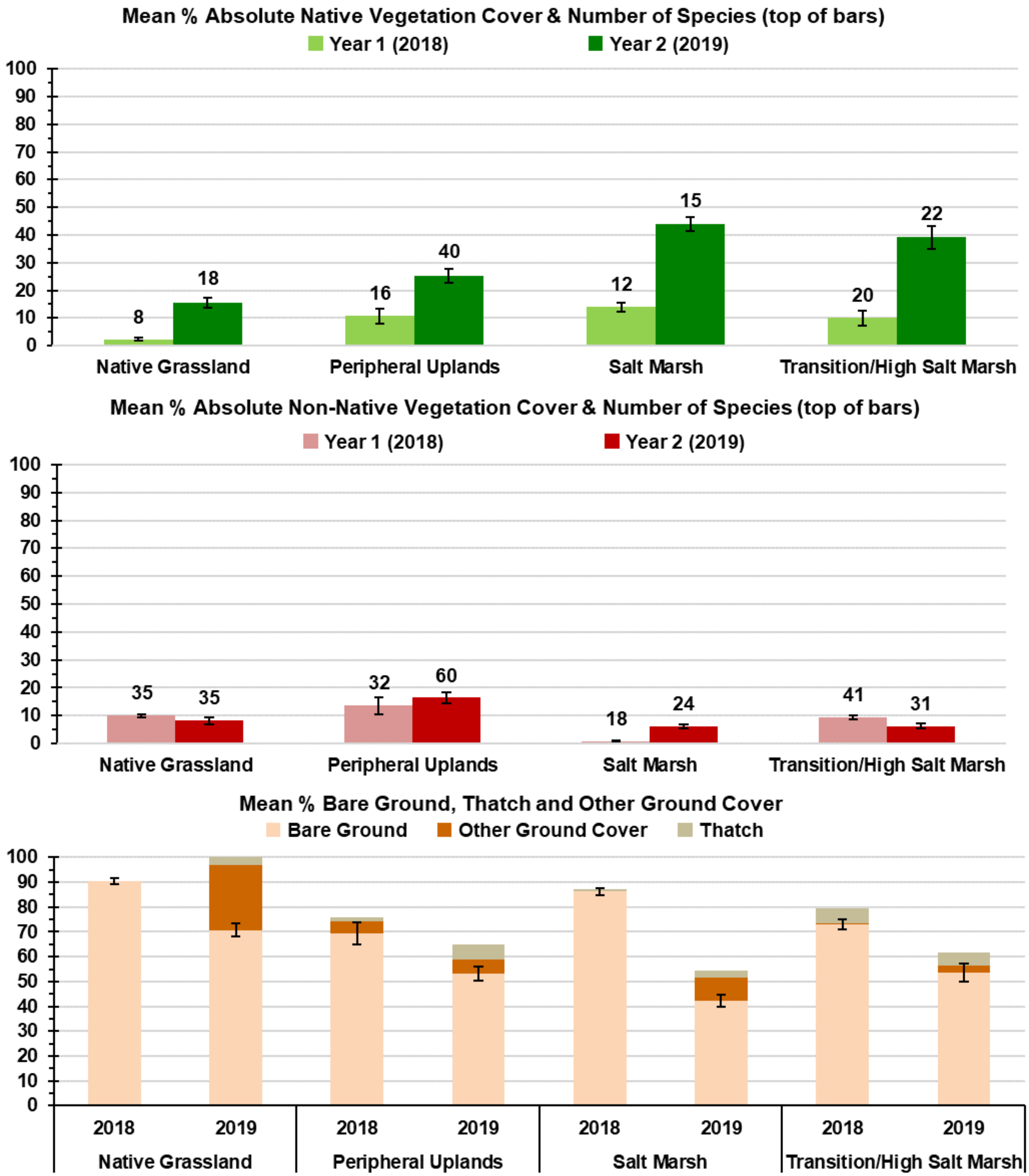


Figure 4. **Charts of the mean percent and standard error of absolute native (top) and non-native vegetation (middle) cover, and percent bare ground, thatch and other ground cover (primarily mulch/woodchips or dried algae) quantified from monitoring transects in the Native Grassland, Peripheral Upland and Salt Marsh and Transitional habitats at NCOS in year 1 (2018) and year 2 (2019). The number of native and non-native species recorded from the monitoring are on the top of the bars that represent percent cover.**

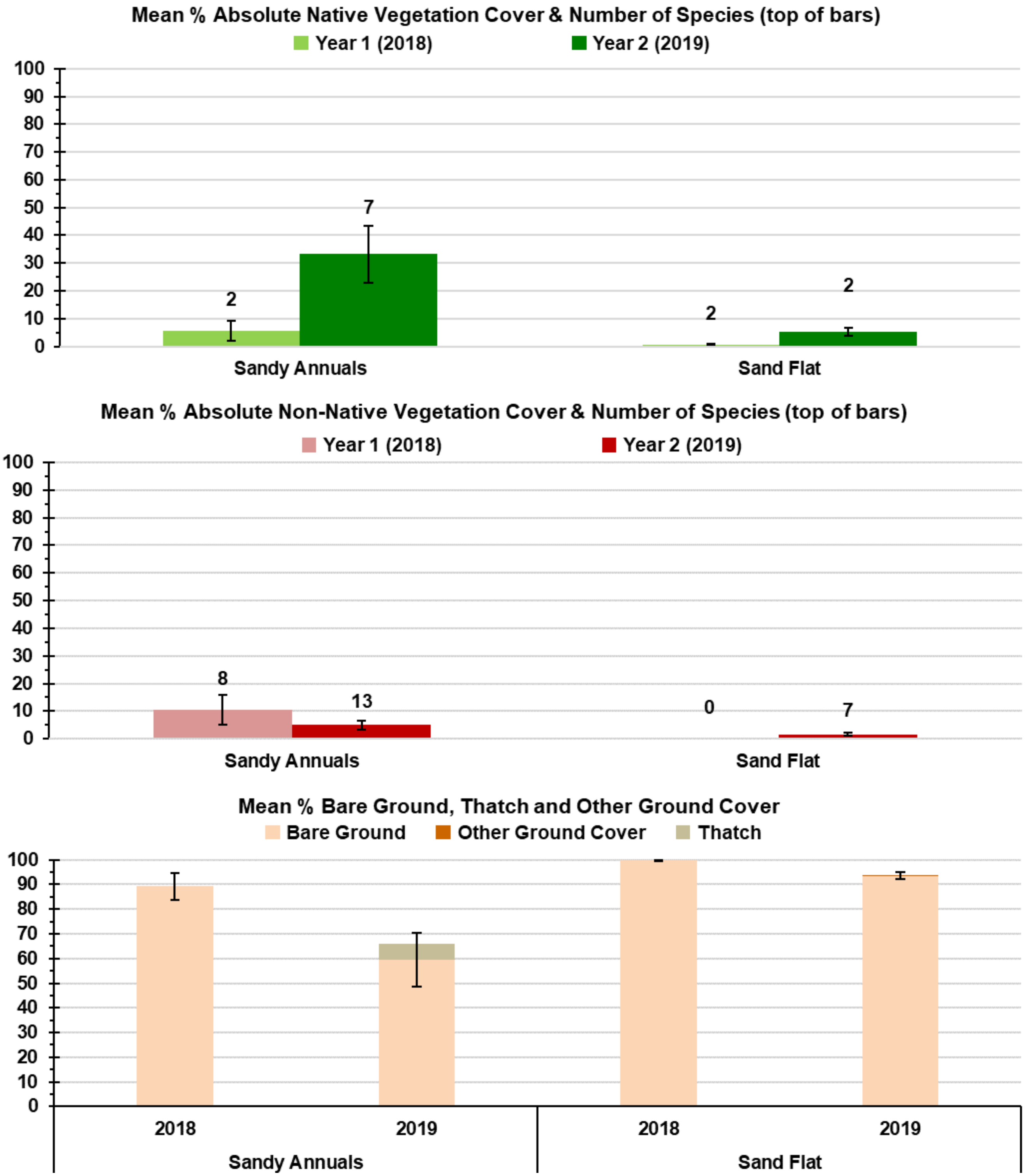


Figure 5. Charts of the mean percent and standard error of absolute native (top) and non-native vegetation (middle) cover, and percent bare ground, thatch and other ground cover (primarily mulch/woodchips or dried algae) quantified from monitoring transects in the Sandy Annuals and Sand Flat habitats at NCOS in year 1 (2018) and year 2 (2019). The number of native and non-native species recorded from the monitoring are on the top of the bars that represent percent cover.

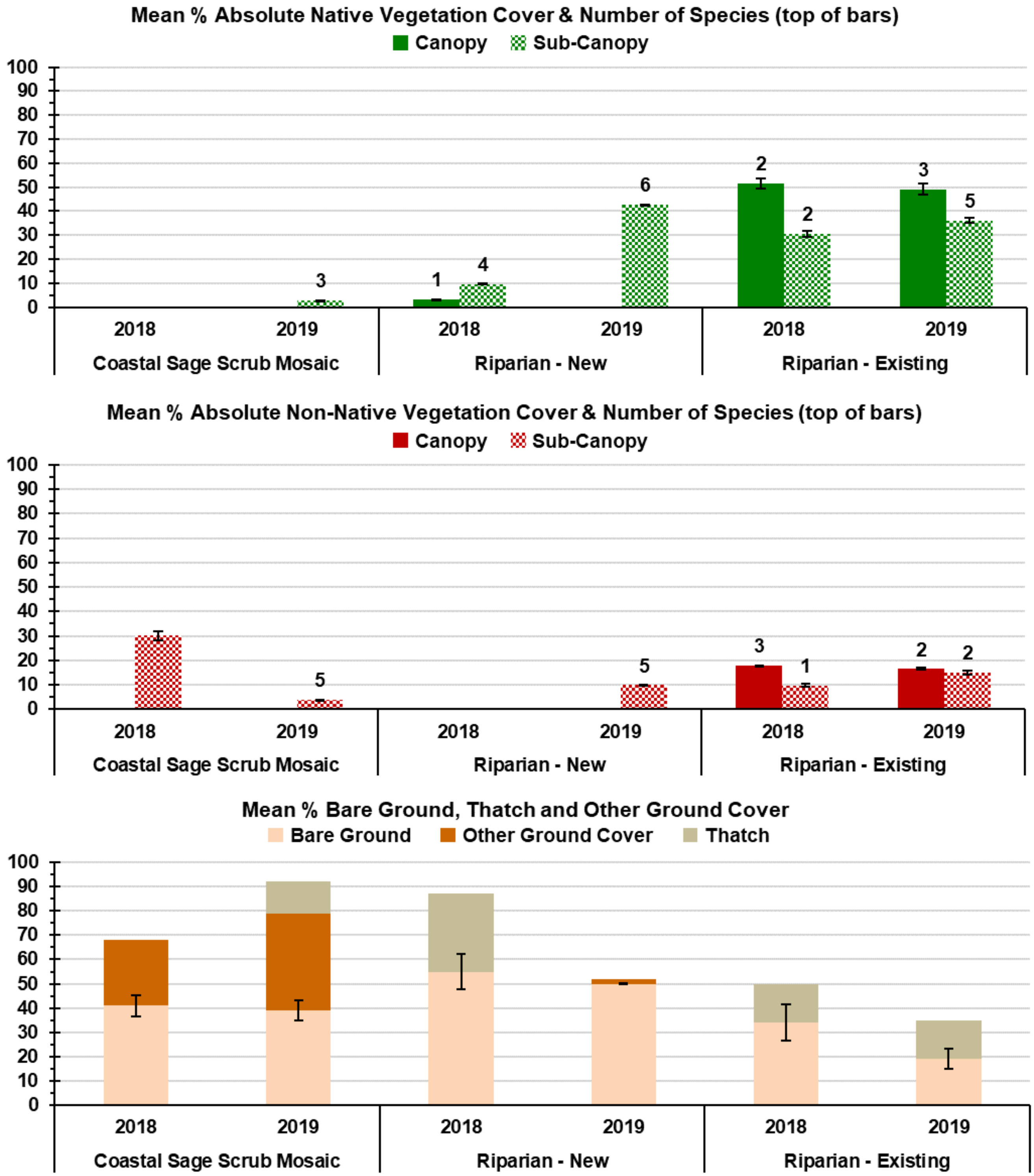


Figure 6. Charts of the mean percent and standard error of absolute canopy and sub-canopy cover of native (top) and non-native (middle) vegetation, and the percent of bare ground, thatch or other ground cover (mainly mulch/woodchips) recorded when there was no sub-canopy vegetation at point-intercept transects in the Coastal Sage Scrub (CSS) Mosaic, New and Existing Riparian habitats at NCOS in year 1 (2018) and year 2 (2019). The number of native and non-native species recorded from the monitoring are on top of the bars that represent percent cover.

Figure 7. Photographs of monitoring transect PU-04 in the Peripheral Uplands taken in year 1 (left image) and year 2 (right image).

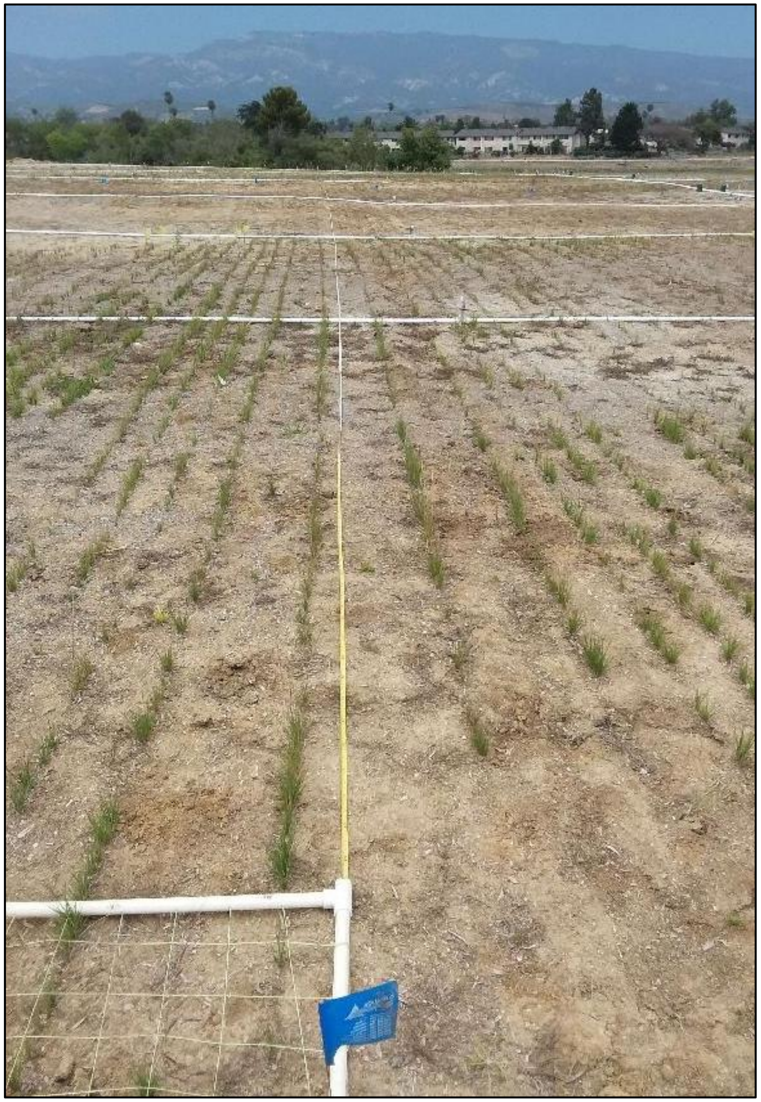
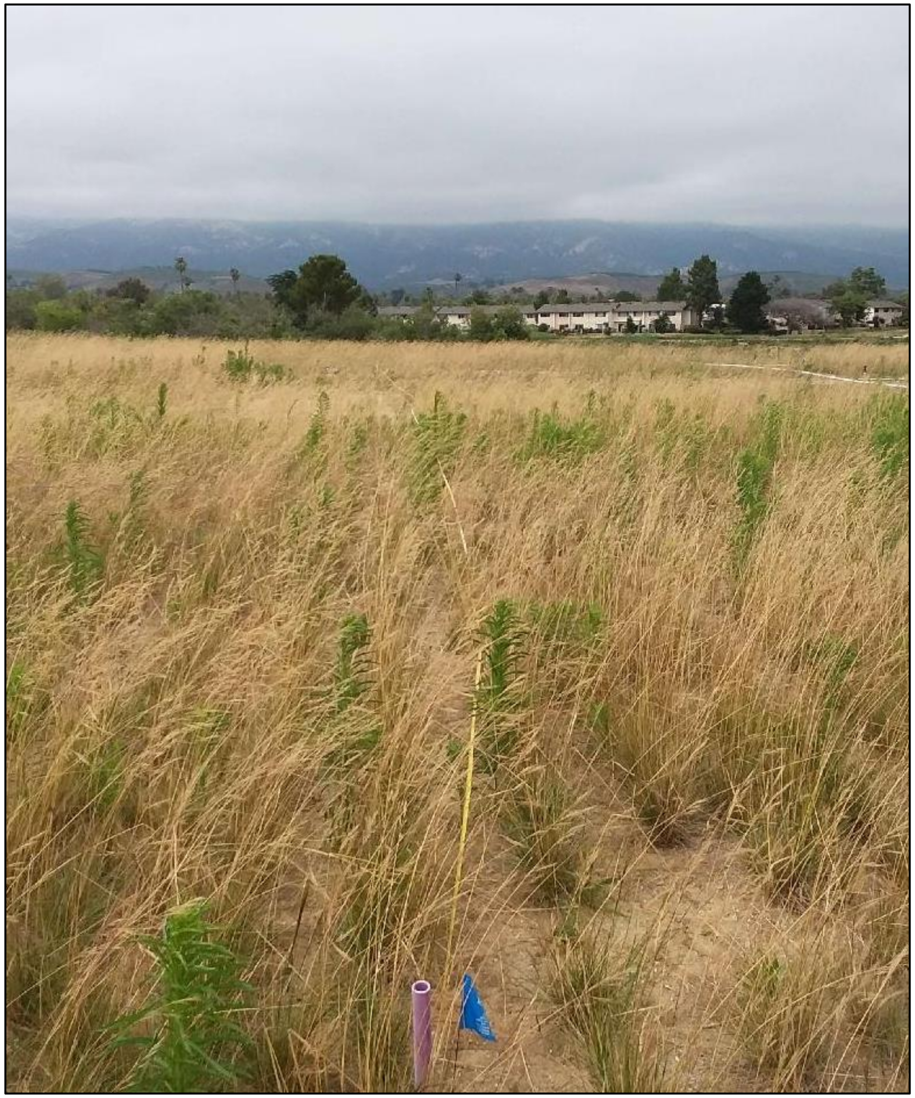



Figure 8. Photographs of monitoring transect GL-10 in the Native Grassland taken in year 1 (left image) and year 2 (right image).

Figure 9. Photographs of monitoring transect SML-05 in the Salt Marsh taken in year 1 (left image) and year 2 (right image).

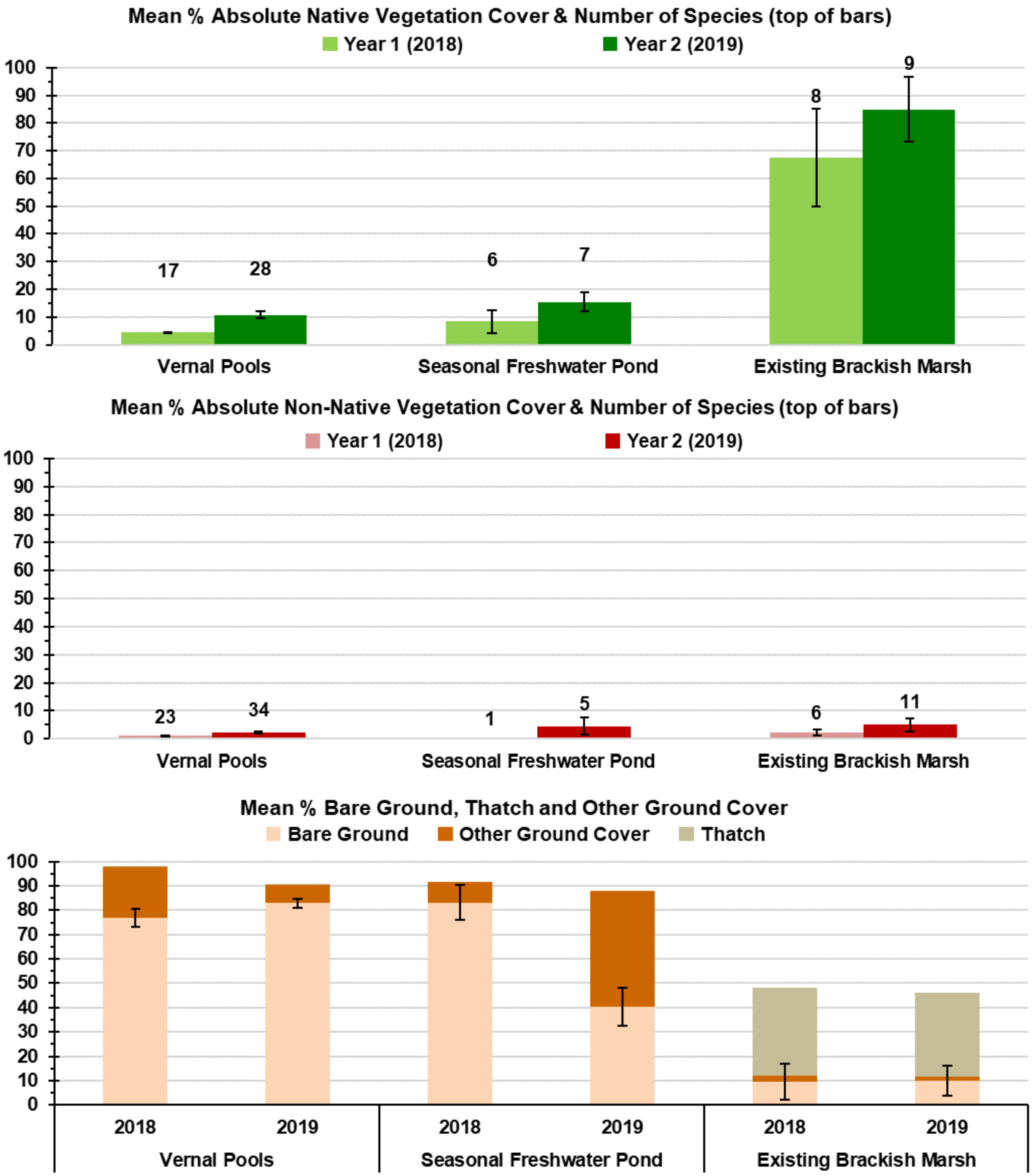


Figure 10. Charts of the mean percent and standard error of absolute native (top) and non-native vegetation cover (middle), and percent bare ground, thatch and other ground cover (primarily mulch/woodchips or dried algae) quantified from monitoring transects in the Vernal Pool, Seasonal Freshwater Pond and Brackish Marsh habitats at NCOS in year 1 (2018) and year 2 (2019). The number of native and non-native species recorded from the monitoring are on the top of the bars that represent percent cover.

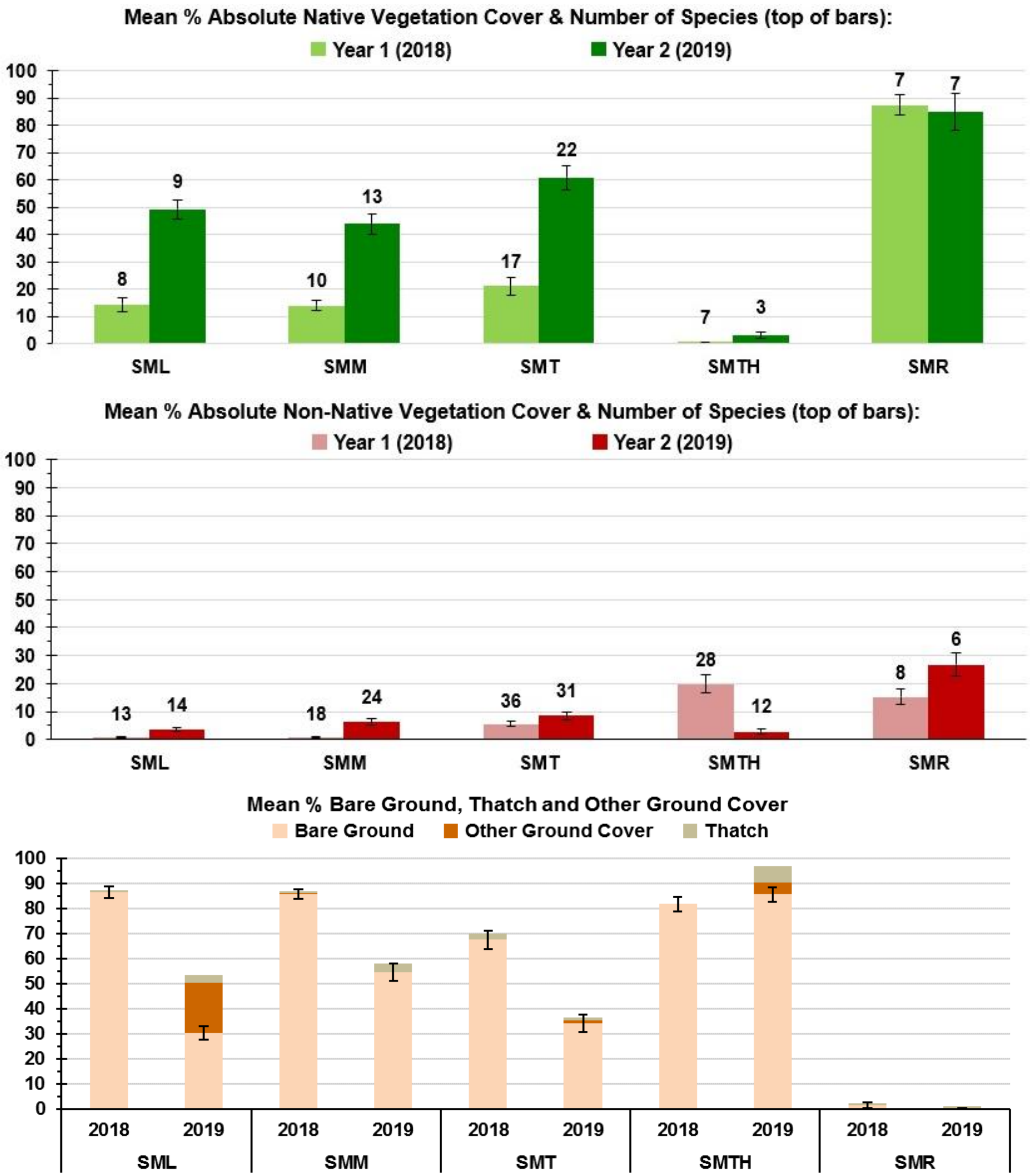


Figure 11. Charts of the mean percent and standard error of absolute native (top) and non-native vegetation cover (middle), and percent bare ground, thatch and other ground cover (primarily mulch/woodchips or dried algae) quantified from monitoring transects in the low and mid elevation Salt Marsh (SML, SMM), Transition and high elevation transition (SMT, SMTH) and the Remnant Salt Marsh (SMR) in year 1 (2018) and year 2 (2019). The number of native and non-native species recorded from the monitoring are on the top of the bars that represent percent cover.

Vegetation Success Criteria

The NCOS Restoration Plan includes a table of proposed vegetation success criteria, or objectives for the primary target habitats. The four criteria include the percent total vegetation cover, the relative percent of native and invasive vegetation cover, and the diversity of native species for each of the first five years of restoration planting. These criteria are reproduced and modified in Table 2 of this report in order to compare the vegetation monitoring data with the originally proposed criteria. The modifications to the table include the addition of the Peripheral Upland Mosaic habitat and the separation of the Riparian and Fresh-Brackish Marsh habitats (which were combined along with Back Dune Swale in the original table).

The establishment of native vegetation did not occur in all habitats at the same time. Therefore, the success criteria are assessed relative to the year in which each habitat was first planted. For example, Year 1 (2018) planting efforts were focused primarily in the Salt Marsh, Transition/High Marsh, and Peripheral Upland Mosaic as well as the Vernal Pools, about a third of the Grassland, and the Whittier Channel Riparian habitat where 100 trees were planted. Except for Riparian, all of these habitats exceeded the native species diversity goal for Year 1, and the Salt Marsh, Transition/High Marsh, Vernal Pools, and Riparian also met the Year 1 goal for relative percent native cover. However, since most habitats were partially planted during the first year of restoration and no planting occurred in the CSS Mosaic and upper-elevation Transition/High Salt Marsh, the original total cover goal for Year 1 could not be met in any habitat. In Year 2, the Salt Marsh, Transition/High Marsh, and Riparian habitats met the total cover target, and all habitats except the CSS Mosaic met the relative percent native cover and native species diversity goals for Year 2. The CSS Mosaic was the last major habitat to be planted in the fall of 2019, and though monitoring data has been collected in this habitat for the first two years of the project, the data collected in 2020 will be considered relevant to the “year 1” goals for this habitat.

In most habitats, the relative percent of invasive cover has been well above the proposed criterion of less than 5%, especially for Year 1. However, there was a significant decrease in invasive cover in Year 2 for many habitats, particularly the Native Grassland, Peripheral Upland Mosaic, Sandy Dune Annuals, and Coastal Sage Scrub Mosaic. With our continued efforts on weed control, we expect this downward trend in invasive cover to persist and will continue to aspire to the high bar of less than 5% relative non-native cover moving forward.

Table 2. Comparison of vegetation monitoring data with proposed minimum success criteria from the Restoration Plan for the North Campus Open Space project. The proposed minimum criteria are in italicized font in the five columns in the middle of the table and the monitoring data is in the columns on the right-hand side of the table. Table cells that are bold and green indicate monitoring data that meets or exceeds the corresponding criteria for each year.

	Proposed Minimum Criteria					**Monitoring Data**				
	Year 1	***Year 2***	***Year 3***	***Year 4***	***Year 5***	**2018**	**2019**	**2020**	**2021**	**2022**
Native Grassland										
% Total cover	*35*	*45*	*60*	*70*	*80*	12	24			
% Native Relative	*50*	***60***	*70*	*70*	*70*	19	**66**			
% Invasive Relative	*<5*	*<5*	*<5*	*<5*	*<5*	81	34			
Diversity (Native Species)	***3***	***4***	*6*	*7*	*7*	**8**	**18**			
Peripheral Upland Mosaic (Mixed Grassland/Shrubland)										
% Total cover	*35*	*45*	*60*	*70*	*80*	24	42			
% Native Relative	*50*	***60***	*70*	*70*	*70*	44	**61**			
% Invasive Relative	*<5*	*<5*	*<5*	*<5*	*<5*	56	39			
Diversity (Native Species)	***3***	***4***	*6*	*7*	*7*	**16**	**40**			
Salt Marsh and Transitional/High Salt Marsh										
% Total cover	*30*	***40***	*60*	*70*	*70*	19	**48**			
% Native Relative	***70***	***80***	*80*	*80*	*90*	**75**	**88**			
% Invasive Relative	*<5*	*<5*	*<5*	*<5*	*<5*	25	12			
Diversity (Native Species)	***4***	***6***	*7*	*7*	*8*	**24**	**28**			
Fresh/Brackish Marsh (Seasonal Pond)										
% Total cover	*50*	*50*	*60*	*70*	*80*	8	20			
% Native Relative	***70***	***70***	*70*	*80*	*80*	**99**	**78**			
% Invasive Relative	***<5***	*<5*	*<5*	*<5*	*<5*	**1**	22			
Diversity (Native Species)	*7*	***7***	*10*	*12*	*14*	6	**7**			
Vernal Pools										
% Total cover	*30*	*40*	*40*	*45*	*50*	5	13			
% Native Relative	***70***	***70***	*70*	*80*	*80*	**81**	**84**			
% Invasive Relative	*<5*	*<5*	*<5*	*<5*	*<5*	19	16			
Diversity (Native Species)	***7***	***7***	*10*	*12*	*15*	**17**	**28**			

	Proposed Minimum Criteria					Monitoring Data				
	Year 1	***Year 2***	***Year 3***	***Year 4***	***Year 5***	**2018**	**2019**	**2020**	**2021**	**2022**
Sandy Dune Annuals										
% Total cover (variable by season)	*20*	***25***	*30*	*35*	*40*	16	**38**			
% Native Relative	*50*	***60***	*70*	*70*	*80*	34	**87**			
% Invasive Relative	*<5*	*<5*	*<5*	*<5*	*<5*	66	13			
Diversity (Native Species)	*3*	***3***	*4*	*5*	*5*	2	**7**			
Coastal Sage Scrub Mosaic										
% Total cover	*30*	*40*	*50*	*60*	*65*	30	6			
% Native Relative	*50*	*60*	*65*	*70*	*80*	0	43			
% Invasive Relative	*<5*	*<5*	*<5*	*<5*	*<5*	100	57			
Diversity (Native Species)	*8*	*8*	*10*	*12*	*15*	0	3			
Riparian										
% Total cover	*50*	***50***	*60*	*70*	*80*	13	**52**			
% Native Relative	***70***	***70***	*70*	*80*	*80*	**100**	**81**			
% Invasive Relative	***<5***	*<5*	*<5*	*<5*	*<5*	**0**	19			
Diversity (Native Species)	*7*	*7*	*10*	*12*	*14*	5	6			

Tree Monitoring

In the first year of restoration planting, 101 saplings of six tree species were planted in the new riparian habitat along Whittier channel and pond (Figure 12). The height, DBH, and vigor rating of these trees were measured in November 2018 as part of the first year of monitoring. These trees were measured in August 2019 for the second year of monitoring, which showed a mean overall growth in height of 26.5 inches (33 %) and a doubling of mean overall DBH, with the greatest growth exhibited by white alder and California sycamore (Figure 13 and Figure 14). The mean vigor rating remained at 1 (high) in both years of monitoring for all species except black cottonwood, which improved from 2 (medium) in the first year to a rating of 1 this year.

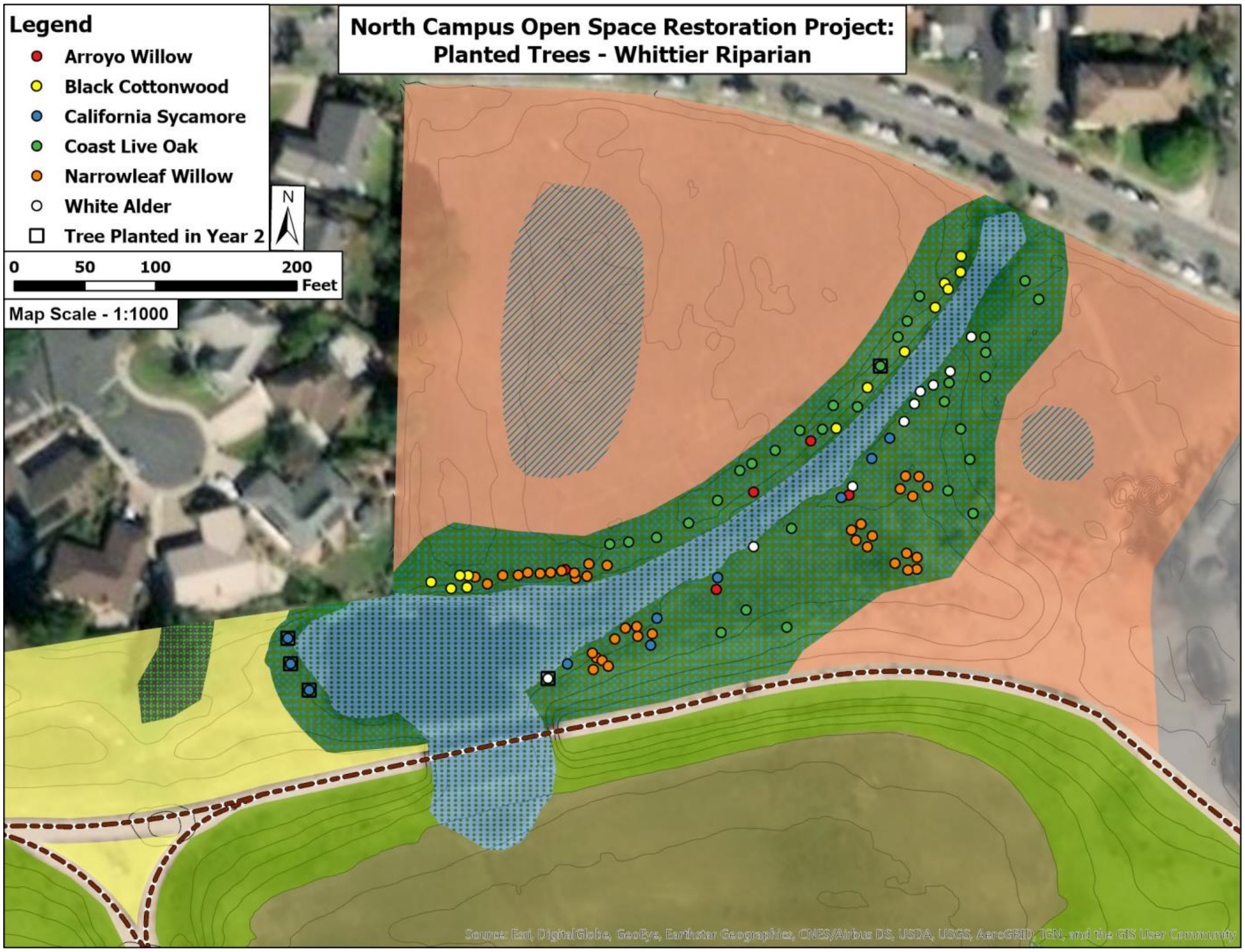


Figure 12. Map of the trees planted in the new riparian habitat surrounding the Whittier channel and pond at the North Campus Open Space restoration project. Points outlined by a box represent trees planted in the second year of restoration.

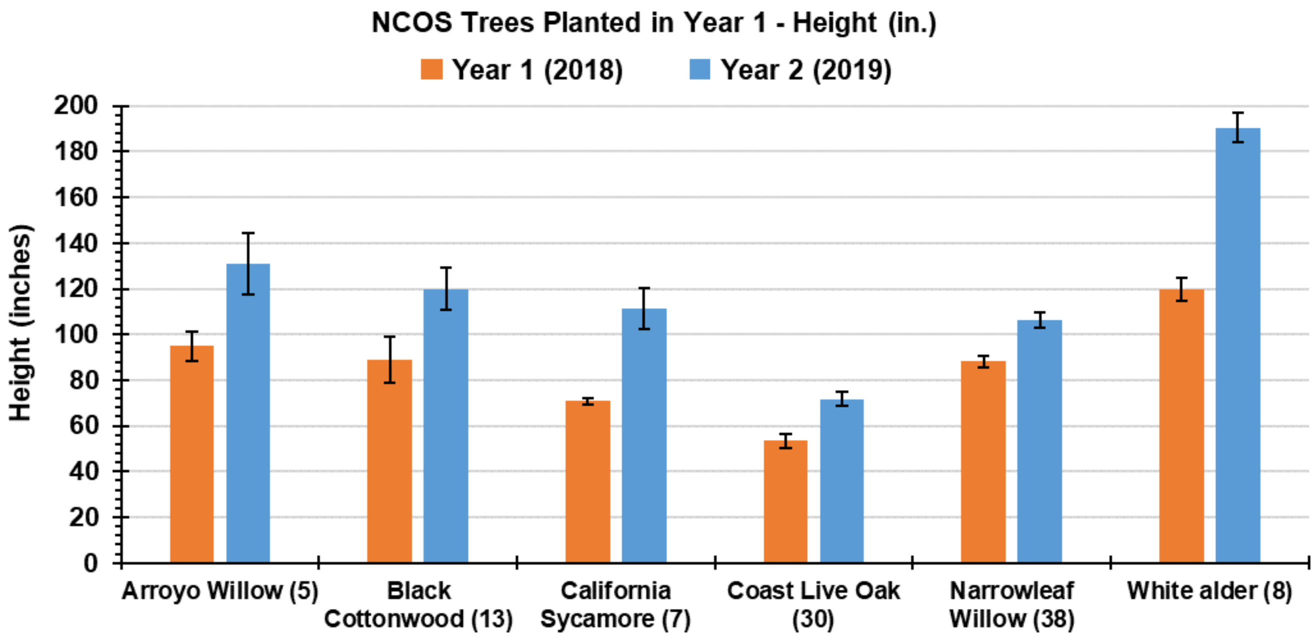


Figure 13. Bar chart of the mean height (inches) in year 1 (2018) and year 2 (2019) of six tree species planted in the first year of restoration at NCOS. The number of trees planted is in parentheses next to the name of each species. Error bars are +/- standard error of the mean.

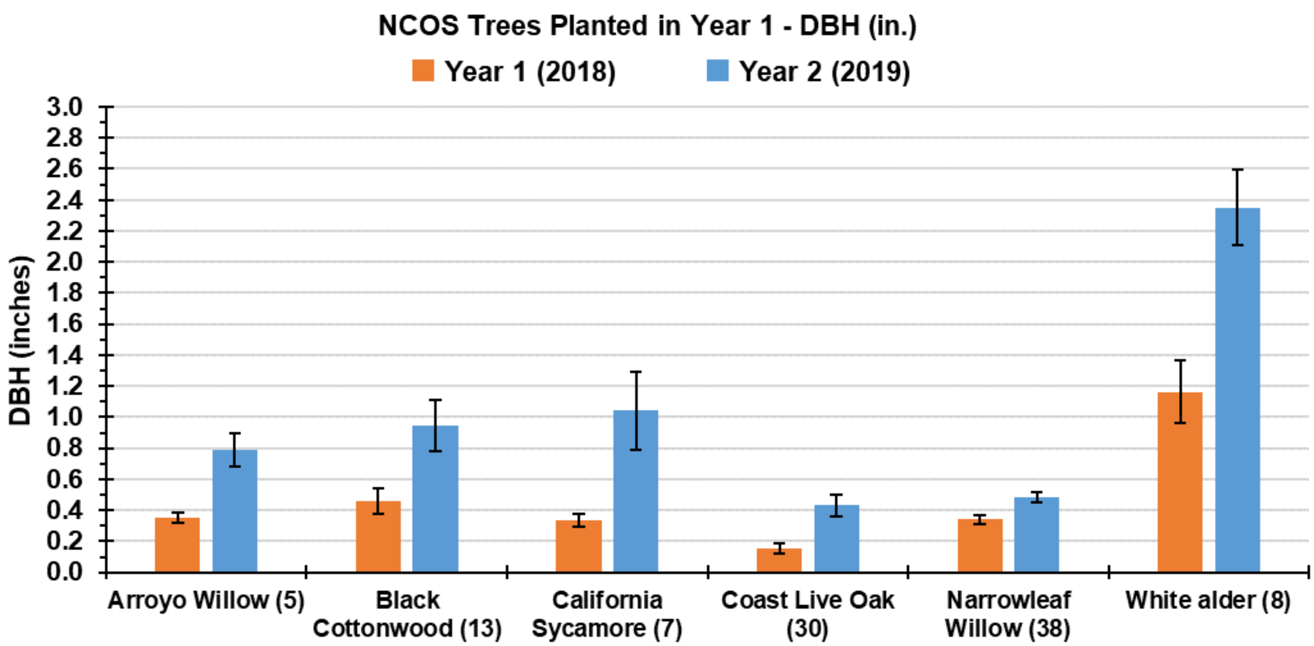


Figure 14. Bar chart of the mean diameter at breast height (inches) in year 1 (2018) and year 2 (2019) of six tree species planted in the first year of restoration at NCOS. The number of trees planted is in parentheses next to the name of each species. Error bars are +/- standard error of the mean.

In the latter half of 2018, the new riparian habitat surrounding Phelps Creek was planted with 28 saplings of the same six tree species, and in 2019 an additional five trees were added to the Whittier riparian habitat (boxed points in Figure 12). Also, in late 2018 and throughout 2019, a total of 95 coast live oak saplings were planted on the project site. The majority of these (86) were planted in patches on the slopes of the Mesa designated to be restored as oak woodlands, and nine were planted in the Peripheral Uplands habitat near the Phelps Creek trail bridge (Figure 15). The mean height and DBH of these trees were measured in August 2019 and are summarized in Figure 16 and Figure 17. Also measured in August 2019, the mean vigor rating for each species of these trees ranged from 1 to 1.5.

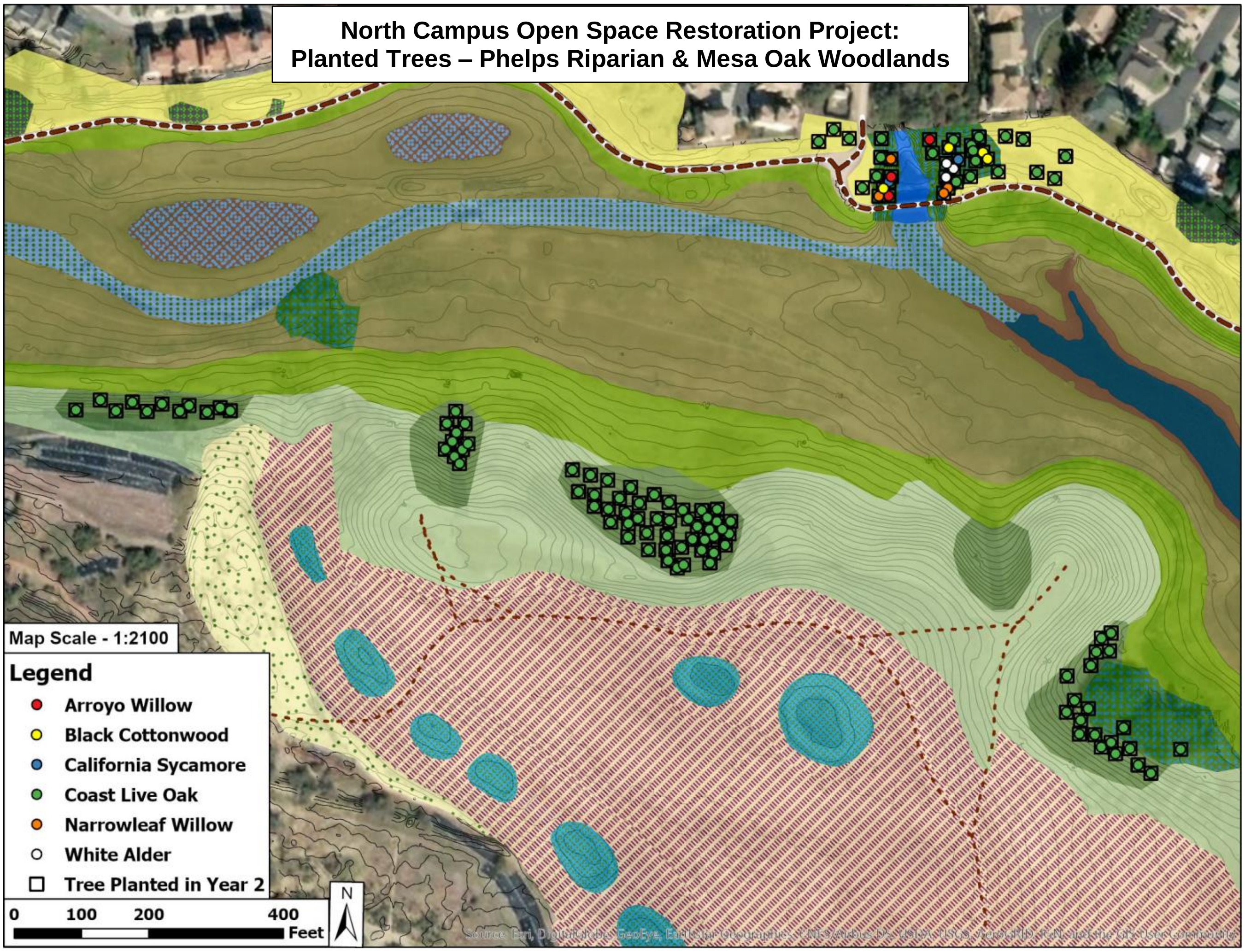


Figure 15. Map of locations of trees planted in the new riparian habitat surrounding Phelps Creek and ponds, and coast live oaks planted in the peripheral upland and oak woodland habitats at the North Campus Open Space restoration project. Points outlined by a box represent trees planted in the second year of restoration.

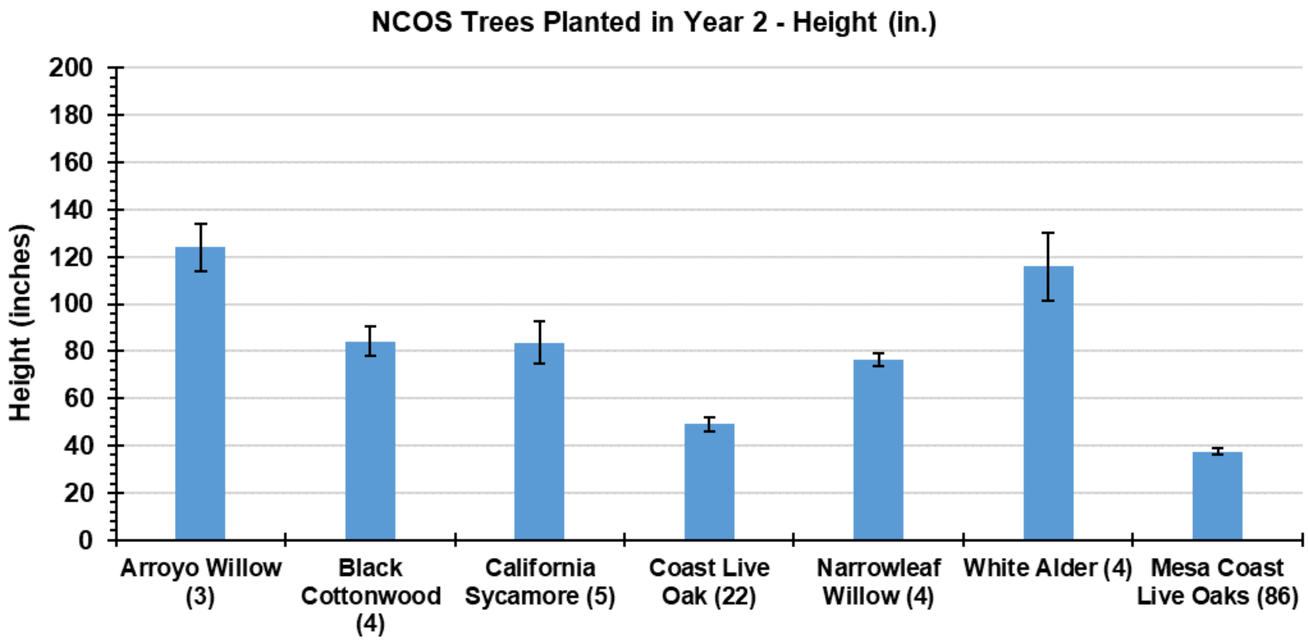


Figure 16. Bar chart of the mean height (inches) of six tree species planted in the second year of restoration at NCOS. Coast live oak trees planted to create oak woodlands on the slopes of the Mesa are shown separately from other oak trees. The number of trees planted is in parentheses next to the name of each species. Error bars are +/- standard error of the mean.

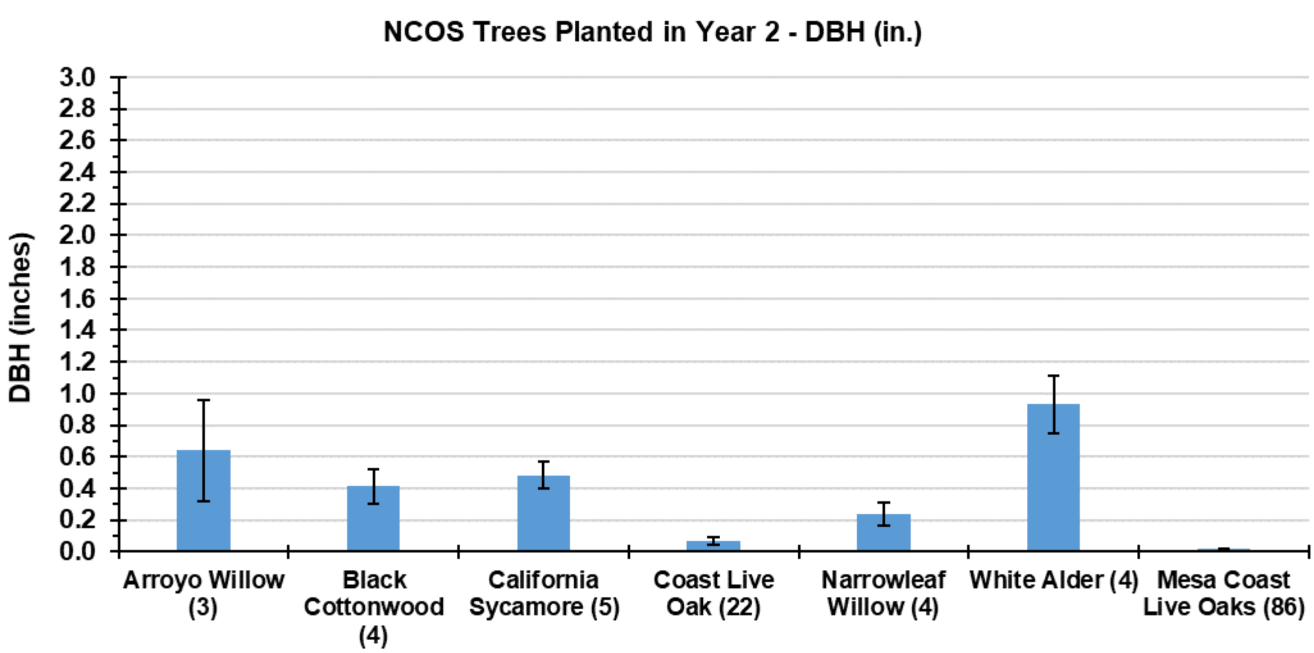


Figure 17. Bar chart of the mean diameter at breast height (inches) of six tree species planted in the second year of restoration at NCOS. Coast live oak trees planted to create oak woodlands on the slopes of the Mesa are shown separately from other oak trees. The number of trees planted is in parentheses next to the name of each species. Error bars are +/- standard error of the mean.

4. WILDLIFE MONITORING

Wildlife monitoring efforts at NCOS have been primarily focused on monthly bird surveys and targeted surveys for three sensitive and special status aquatic species: the Tidewater Goby (federally endangered), the California Red-legged Frog (federally threatened), and the Southwestern Pond Turtle (federal protection status under review; California State Species of Special Concern). During the breeding season, the Sand Flat habitat is monitored closely for signs of nesting activity by the threatened Western Snowy Plover and any identified nests are carefully observed and protected when necessary.

Additional wildlife monitoring includes:

- Various surveys and studies of terrestrial and aquatic arthropods, some of which are ongoing. These are further described later in this section.
- In late 2019, CCBER obtained permits for an education focused program to monitor small mammals and reptiles in the Salt Marsh and Native Grassland habitats that will begin in 2020.
- Also in 2020, CCBER has begun quarterly monitoring of bats using a Wildlife Acoustics sensor and app on a tablet. The bat identification data collected is reviewed by an expert who conducted baseline monitoring of bats at NCOS in 2017 using quarterly deployment of a bat sensor for a week at a time.

Bird Surveys

Monthly bird surveys at the project site began in September 2017. The surveys are conducted in the morning, beginning within one hour of sunrise, and are typically 2.5 hours in duration. Beginning at the Venoco access road bridge near the southeast corner of NCOS, two teams of observers walk eastern and western routes around the site, typically meeting at the end of the survey near the trail bridge over Phelps Creek, along the northern side of the site. At least one expert birder takes part in each survey, helping to verify species identification and counts. Using binoculars, spotting scopes and a GIS app (ESRI Collector) on a tablet, each team records every species of bird seen or heard on site, including birds flying between habitats or structures on or adjacent to the site. The ESRI Collector app also automatically records the route walked by each of the two teams. Each observation recorded in the app includes a minimum of the following information: the location and substrate/habitat of the observation, bird species (common name), and count (number of individuals of the species for the observation). Additional information that may be recorded for observations includes: the sex (male, female, or juvenile), evidence of breeding activity, and any other notes about the observation such as unusual or notable behavior and descriptions to help with uncertain identification of birds. Observations of birds seen previously during the survey in a different habitat, or that may have been observed by both teams are recorded as “Repeat Observations”. The weather conditions (temperature, wind speed and direction, cloud cover and precipitation) are recorded at the beginning and end of the survey. After the survey is completed, the total count of each species observed is reviewed and revised if needed by the expert birder and each team leader.

In the first year of surveys, a total of 4,787 birds from 104 species were counted. These numbers increased in the second year to a total of 6,256 individuals from 129 species. A few observations of birds that were not completely identified to species are not included in the totals. To assist in the analysis and interpretation of the data, we categorized the species observed into 12 guilds based on either their primary habitat or food source and/or ecological niche. The guild with the greatest abundance and diversity observed in both years were insectivores (terrestrial or aerial insectivores), which accounted for 2,068 individuals from 40 species in the second year. Despite the high diversity of the insectivore guild, three of the 40 species accounted for half of the total individuals observed: Cliff Swallow, White-crowned Sparrow and Song Sparrow. A guild that saw a notable increase in abundance and diversity was waterfowl (including grebes and rails), where the number of individuals observed in year two was more than double the total in year one. However, this was largely from one species, American Coot, which increased from 6 in the first year to 404 in year two. A bar chart comparing the total count and species for each guild is presented in Figure 18, and Appendix 2 contains a list of all species observed. An example of a map of the observations and routes recorded on the ESRI Collector app for each survey is presented in Figure 19.

Some of the notable increases in species diversity observed in year two include:

- Four raptors, including two Burrowing Owls that overwintered in some of the hibernacula created on the NCOS Mesa.
- A Belted Kingfisher, which increased the number of guilds from 11 to 12 in year two.
- Four Shorebirds, four Waterfowl (including two grebe species), and five insectivores, amongst a few others.
- Also, more Western Snowy Plovers were observed on site in 2019, including two pair that nested in the sand flat habitat. The nests were closely monitored, but it was uncertain whether they were successful and likely that the nests or chicks were predated by crows or skunks.

To the south of NCOS, and encompassing the majority of Devereux Slough, Coal Oil Point Reserve (COPR) is an important reference site for most of the bird species that we expect to see at NCOS as the restoration progresses. Monthly bird surveys are also being conducted at COPR within two days of the NCOS surveys, and we have been comparing avian abundance and diversity at the two sites. Excluding the beach habitat at COPR, the two sites are generally similar in overall diversity and abundance. In the second year of surveys, COPR had a greater abundance of Shorebirds, Herons/Egrets and Cormorants, while NCOS had more Insectivores and Seed/Fruit eaters. A short article about the comparison of bird survey data at NCOS and COPR is available on the CCBER website, and we are pursuing more detailed analyses of this data.

There are more species using NCOS than what has been observed in the monthly surveys. For example, some notable species that have not yet been observed during a survey include Peregrine Falcon, Yellow-crowned Night-Heron, and Lesser Nighthawk. The internet-based citizen science bird observation repository, eBird, currently lists 192 species for NCOS (considering only species recorded after restoration began). The observations from the second year of bird surveys, and the growing list of species on eBird collectively reflect growth in the availability and diversity of foraging and roosting habitat as well as food resources for birds at NCOS. In addition, it is exciting that some species are making use of habitat features, such as the hibernacula, that were created in part to support them.

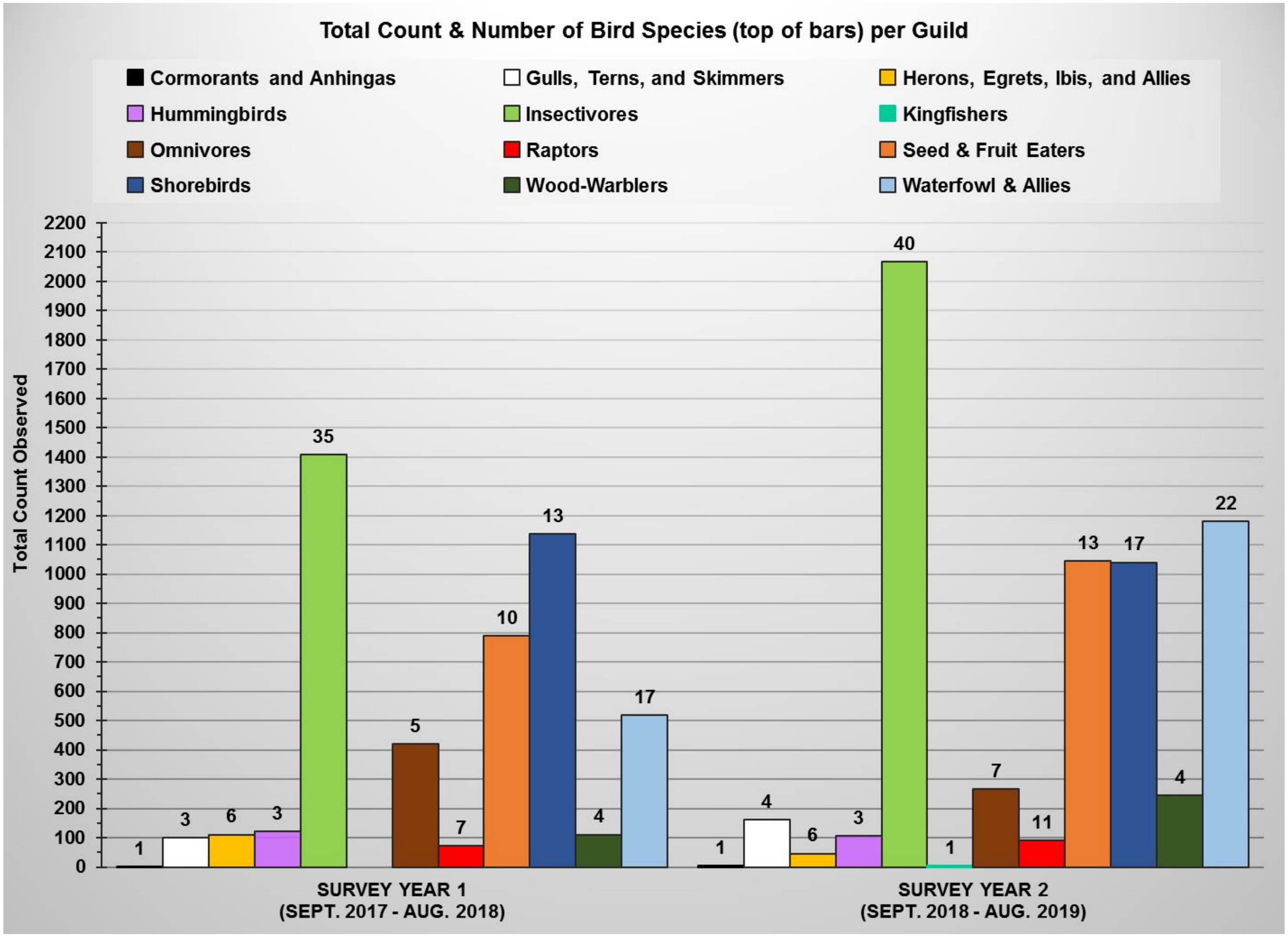


Figure 18. Bar chart comparing the total count and number of bird species (top of bars) grouped by guild observed during the first and second years of monthly surveys at North Campus Open Space. Appendix 2 contains a list of all species observed, grouped by guild.

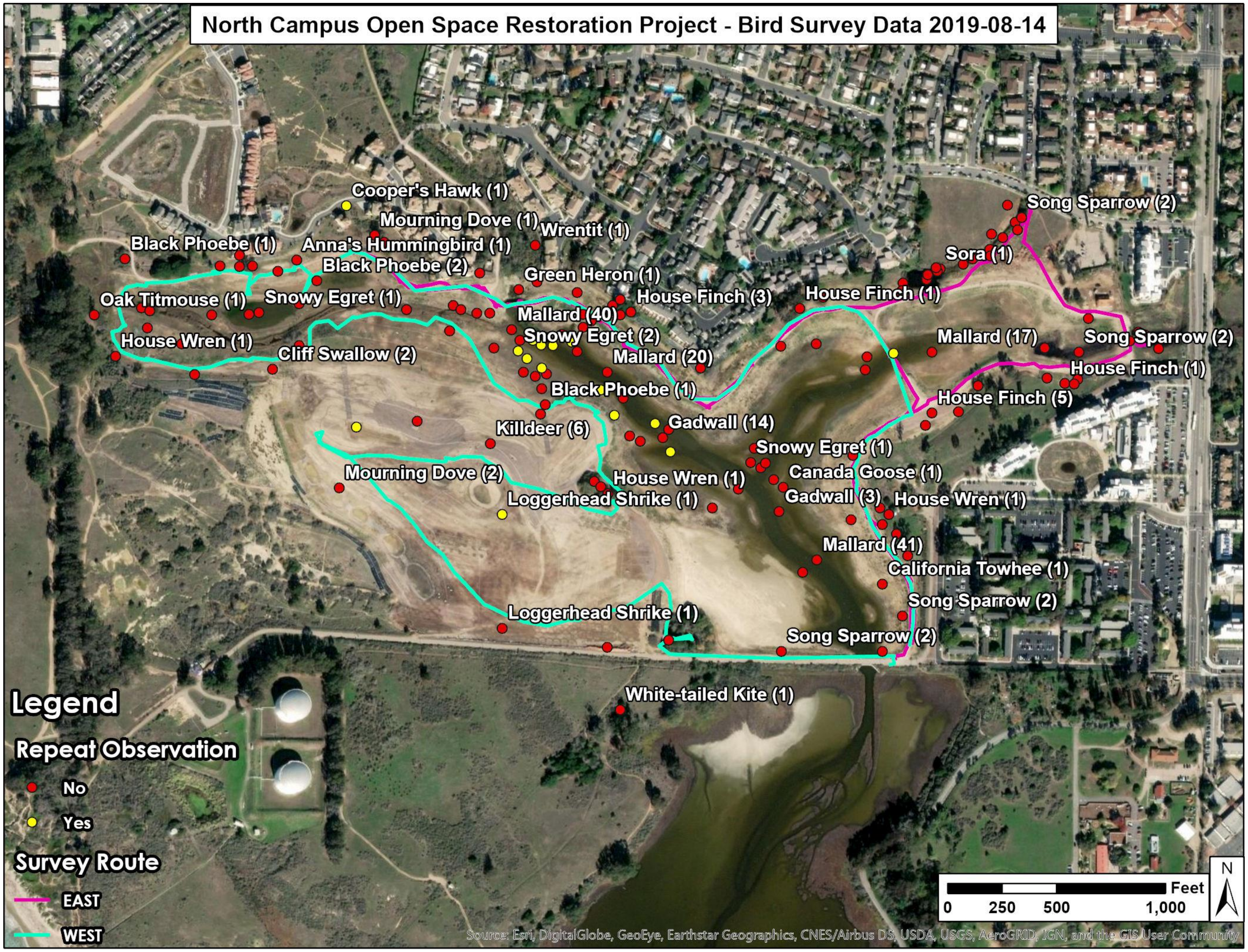


Figure 19. Map of observations and routes from a monthly bird survey at NCOS conducted on August 14, 2019. An interactive version of this map is available on the internet at this URL: http://arcg.is/1fTOKv

Special Status Aquatic Species Surveys

Surveys for the sensitive and special status species California Red-legged Frog, Tidewater Goby and Southwestern Pond Turtle have been conducted by permitted biologist, Rosemary Thompson (federal permit TE-815144-9, state permit SC-002731), with the assistance of CCBER staff. Pre-construction surveys conducted in 2016, and post-construction surveys conducted in the fall of 2017 and in August 2018 found no presence of the three species. Outside of these surveys, CCBER staff have observed a Southwestern Pond Turtle in Phelps Creek prior to construction, and periodically in the same area since the first post-construction sighting in November 2018 (Figure 20).

A third post-construction survey for Tidewater Goby conducted on October 17, 2019 found the presence of five individuals of the endangered fish in the lower most area of Devereux Slough (Figure 21). This was the first observation of the species in Devereux Slough in several years. The survey also found several individuals of three other native fish species, as well as hundreds of individuals of two non-native fish and a few non-native crayfish. The slough was connected to the ocean for several weeks in January and February of 2019, which may have allowed some Tidewater Goby to enter and remain in the slough. It is also possible that a small population has persisted in the slough for the past few years and not been captured in prior surveys. Tidewater Goby have been found in Phelps Creek in the past, and the results of this most recent survey are promising for the future presence of the species in the upper slough and tributaries of NCOS. A Technical Memorandum on the results of the October 2019 survey is provided in Appendix 3 of this report.

Figure 20. Photograph of a Southwestern Pond Turtle in the area where Phelps Creek enters NCOS, November 18, 2018.

Figure 21. Photograph of CCBER staff and permitted biologist, Rosemary Thompson, conducting a survey for Tidewater Goby in the upper Devereux Slough, October 2019.

Arthropod Surveys & Studies

A survey of primarily terrestrial arthropods, using four sampling methods, was conducted in the spring and summer of 2016 as a pre-restoration "snapshot" of arthropod diversity and abundance in the six dominant vegetation communities. The results of this project are being compiled and have led to multiple subsequent and ongoing undergraduate and graduate student research projects. A similar, post-restoration survey may be conducted after plant communities and habitats have become established across the site. In the meantime, monthly targeted sampling of bees using several grids of yellow, white and blue colored pan traps began in October 2018 at NCOS and other sites with varying levels of restoration or ecosystem management both on and off the UCSB campus. To date, classification of the specimens collected during the 2016 survey and the monthly bee sampling has identified 73 taxa (including subspecies and variants). This list is available on CCBER's Symbiota database.

A study that is comparing the aquatic arthropod fauna of the newly restored wetlands at NCOS with long established wetlands in the adjoining Coal Oil Point Nature Reserve (COPR) began in the spring of 2018 through a collaboration with the Santa Barbara Audubon Society and the COPR Nature Center. The ongoing project employs several undergraduate students in collecting, processing and analyzing samples of benthic and surface water arthropods that are collected on a quarterly basis along with water quality data (dissolved oxygen, temperature, and salinity) from up to five locations in the main wetland channels and creeks of NCOS as well as one of the seasonal ponds in the western arm and two of the vernal pools on the mesa (Figure 22). These samples are compared with samples collected from five sites in COPR (three in the lower Devereux Slough and two from seasonal freshwater ponds). The sampling conducted in 2018 found up to 13 taxa at NCOS dominated by four types overall (Copepoda, Corixidae, Ostracoda, and Cladocera), with an additional four taxa having relatively high abundance in benthic samples (Chironomidae, Ceratopogonidae, Ephydridae, and Nematoda). In comparison with COPR, the study has found that NCOS appears to have equivalent, if not slightly greater species richness and evenness. A detailed report on the analysis of aquatic invertebrates collected in 2018 is available on the CCBER eScholarship Repository.

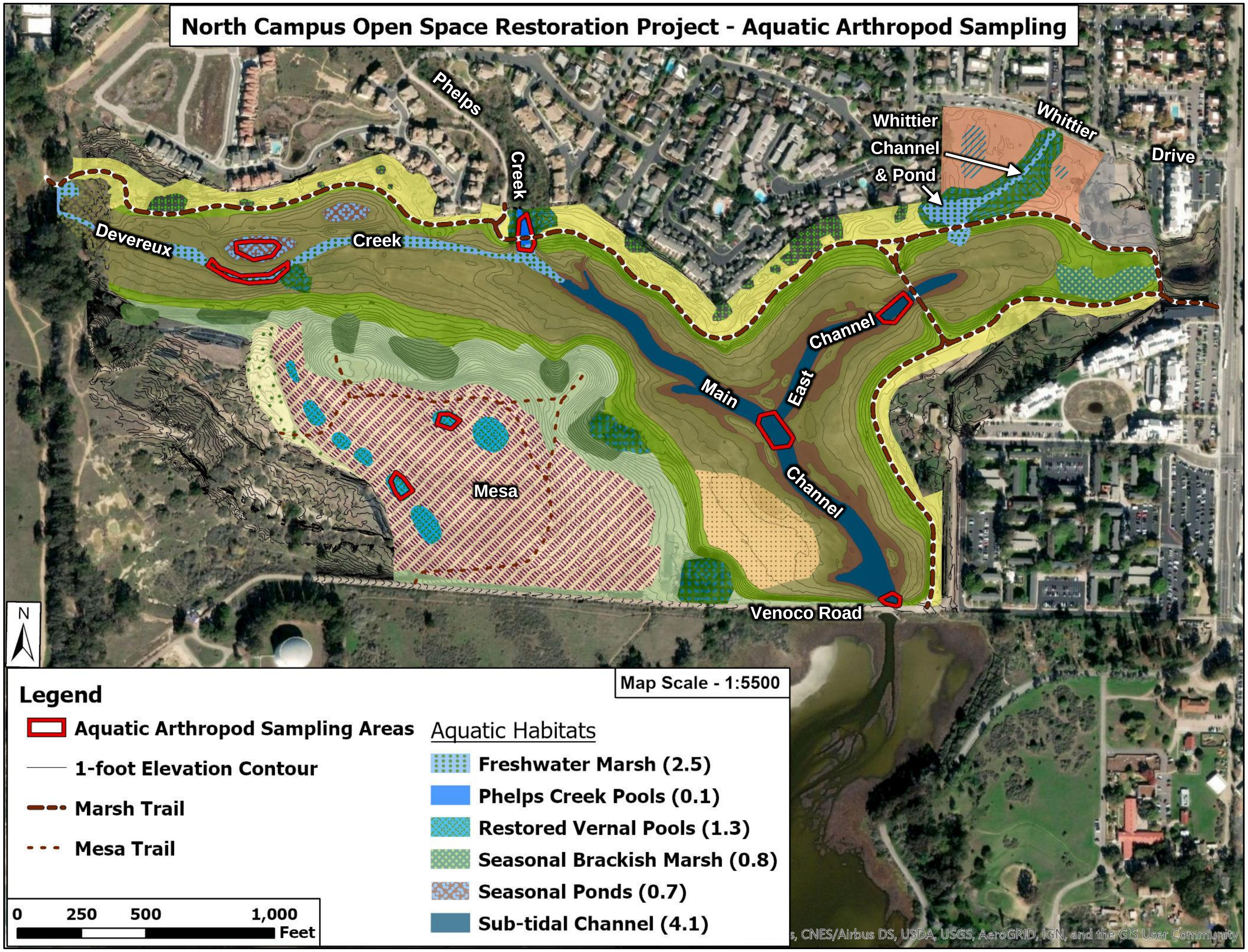


Figure 22. Map of the aquatic arthropod monitoring locations and aquatic habitats at NCOS. See Figure 1 for a map and legend of all habitats/vegetation communities.

5. WETLAND GEOMORPHOLOGY, HYDROLOGY AND WATER QUALITY

Wetland Geomorphology Monitoring

The primary objective of the wetland geomorphology monitoring at NCOS is to track the development of the main wetland channels and basin, and any significant changes from erosion of deposition that may warrant adaptive management. The elevation profiles obtained from this monitoring could also be used to generally assess accretion rates in the salt marsh in order to track how the wetland might adjust to local sea level rise.

Transects for measuring and monitoring changes to the geomorphology (hereafter bathymetry) of the restored wetland were established in November 2017, one month after the completion of grading. Fourteen transects in total were measured with a high-accuracy (within 5 centimeters (2 inches)), real-time kinematic (RTK) GPS unit. Seven transects are complete cross-sections with endpoints falling at the 10-foot elevation contour line on opposite sides of the wetland channels. Four of these transects span across the Main Channel (Main CS-1 through CS-4), one across the East Channel (East CS), one immediately downstream of the trail bridge over Phelps Creek (Phelps CS), and one immediately downstream of Venoco Bridge (VB South CS) (Figure 23). The other seven transects were measured across the width of the subtidal portion (below 5.5 feet in elevation) of the East and Main channels (three and four transects, respectively) (Figure 23). The elevation (in North American Vertical Datum 1988 - NAVD88) was measured at 6-foot intervals along each transect, except in the subtidal portion where elevation was measured at 3-foot intervals. The lowest elevation recorded in the seven subtidal transects and in the subtidal portions of the complete cross-sections are used collectively as a thalweg elevation measurement (Table 3). The subtidal elevations of these transects demonstrate that the wetland bathymetry was graded as per specifications in the plan.

In the fall of 2019, all but two of the longer cross-section transects (Phelps CS and VB South CS) and one subtidal transect (Main Thal-4) were re-surveyed, and two additional cross-section transects were added west of Phelps Creek (West CS-1 and West CS-2 in Figure 23). Elevation profiles of each cross-section transect measured in 2017 and 2019 are plotted together in Figure 24, and the thalweg elevations from both surveys are listed in Table 3. These figures and the table show that, since 2017, a channel greater than 1-foot deep and up to 50-feet wide developed west of the confluence with Phelps Creek, particularly from the West CS-1 transect to past the Main CS-1 transect. It is also apparent that deposition of more than a half-foot occurred downstream around the area of the Main CS-2 transect. In the east arm and lower region of the main channel, there appears to have been little to no change in bathymetry between 2017 and 2019. The transects will be re-surveyed in 2021.

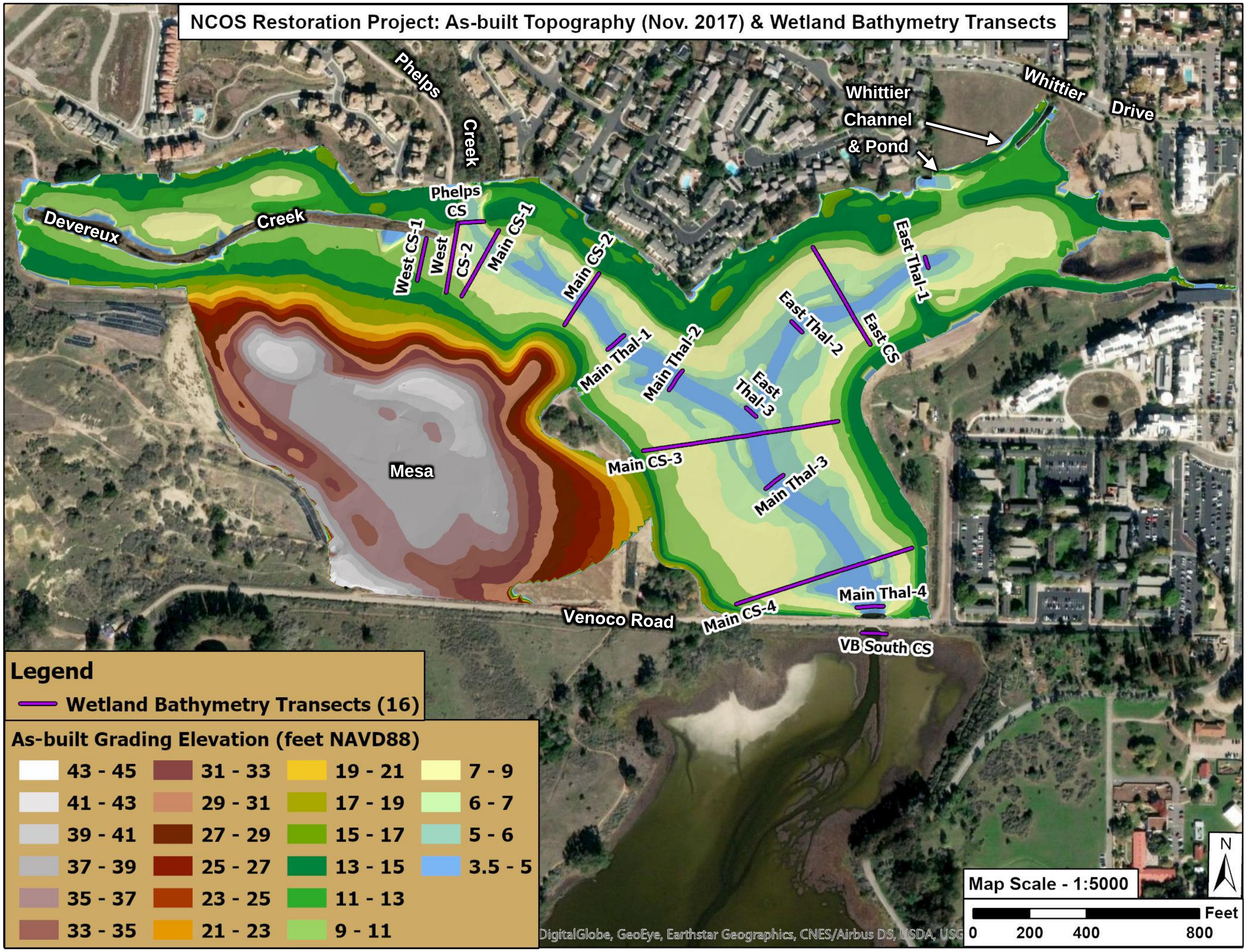
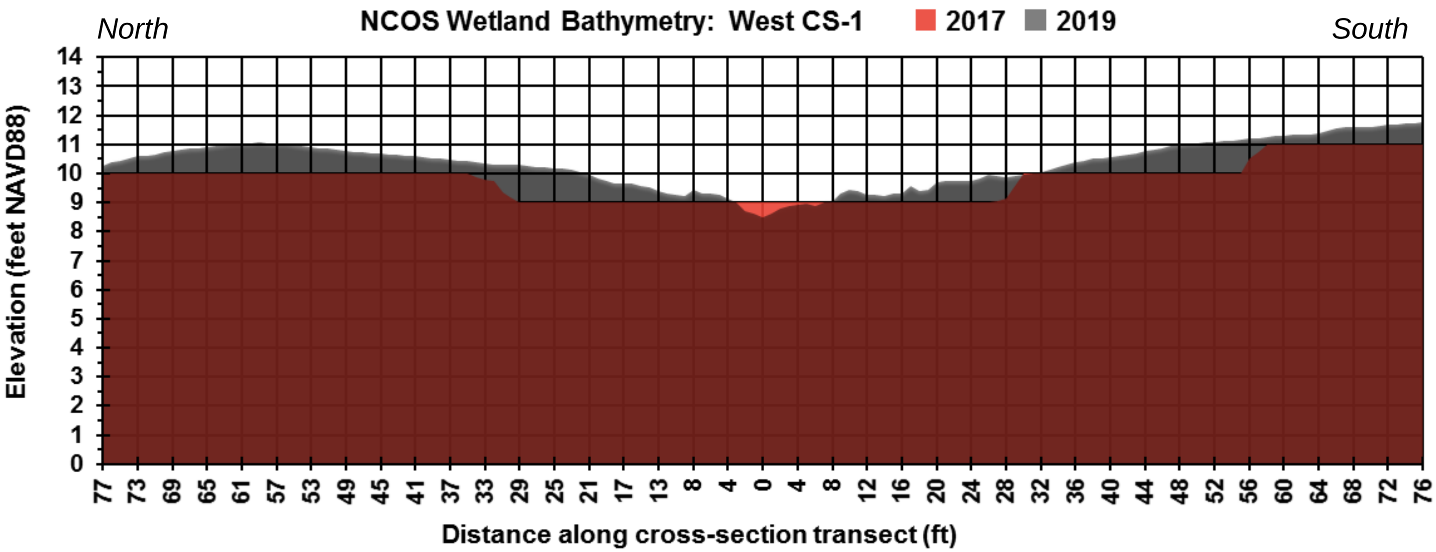


Figure 23. Map showing the 16 bathymetry cross-section (CS) and subtidal (Thal) transects across the restored wetland, overlaid on the as-built grading elevation of the NCOS Restoration Project. The two West CS transects were added in 2019.



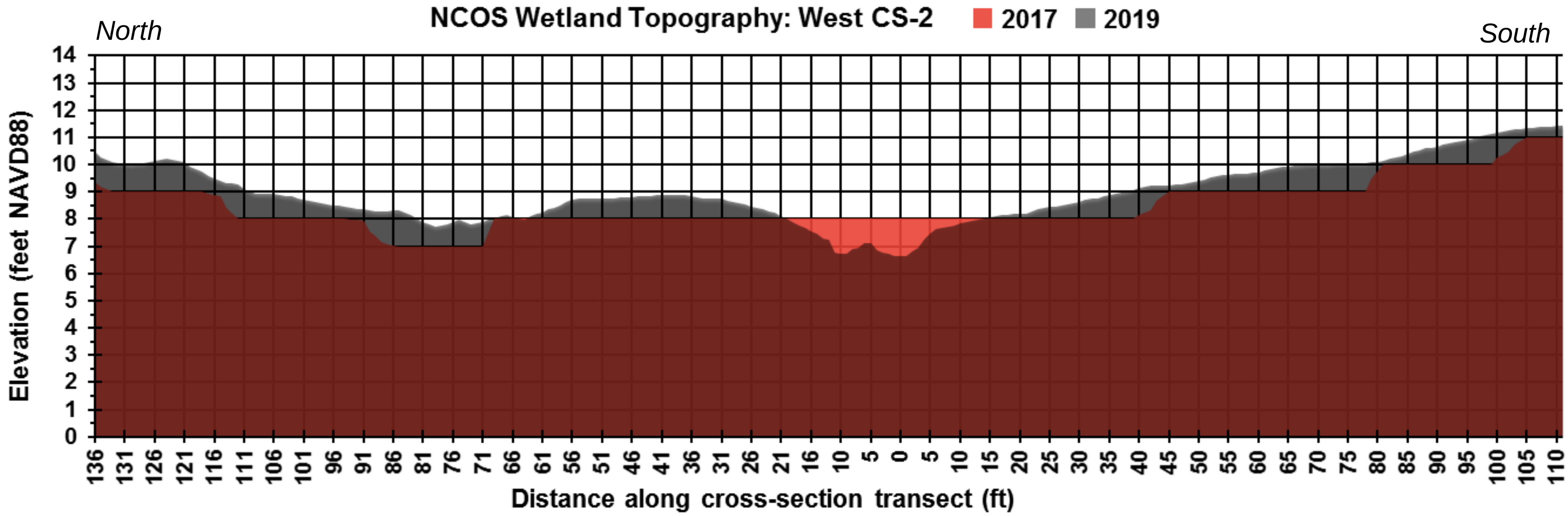
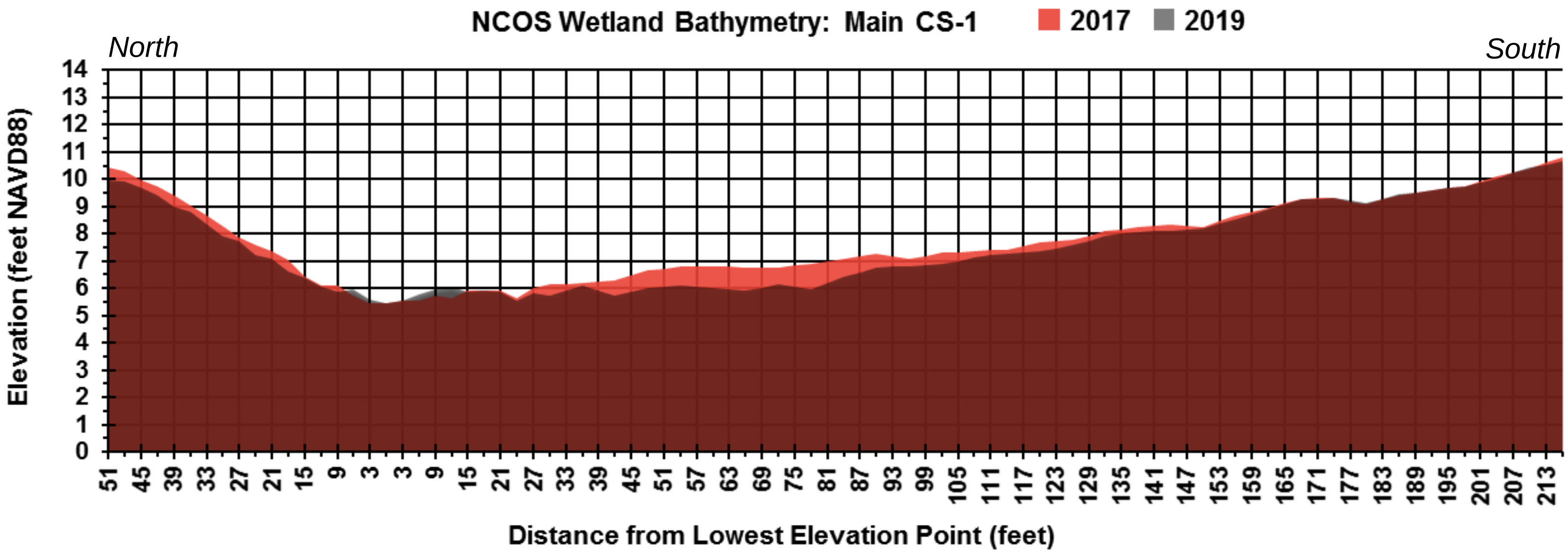


Figure 24. Profiles of the two NCOS wetland bathymetry cross-section transects west of the confluence with Phelps Creek that were added in 2019. The 2017 profiles for these transects are derived from a digital elevation model of the as-built grading, which explains the abrupt, step-wise change in elevation by 1-foot intervals. See Figure 23 for a map of the transects.



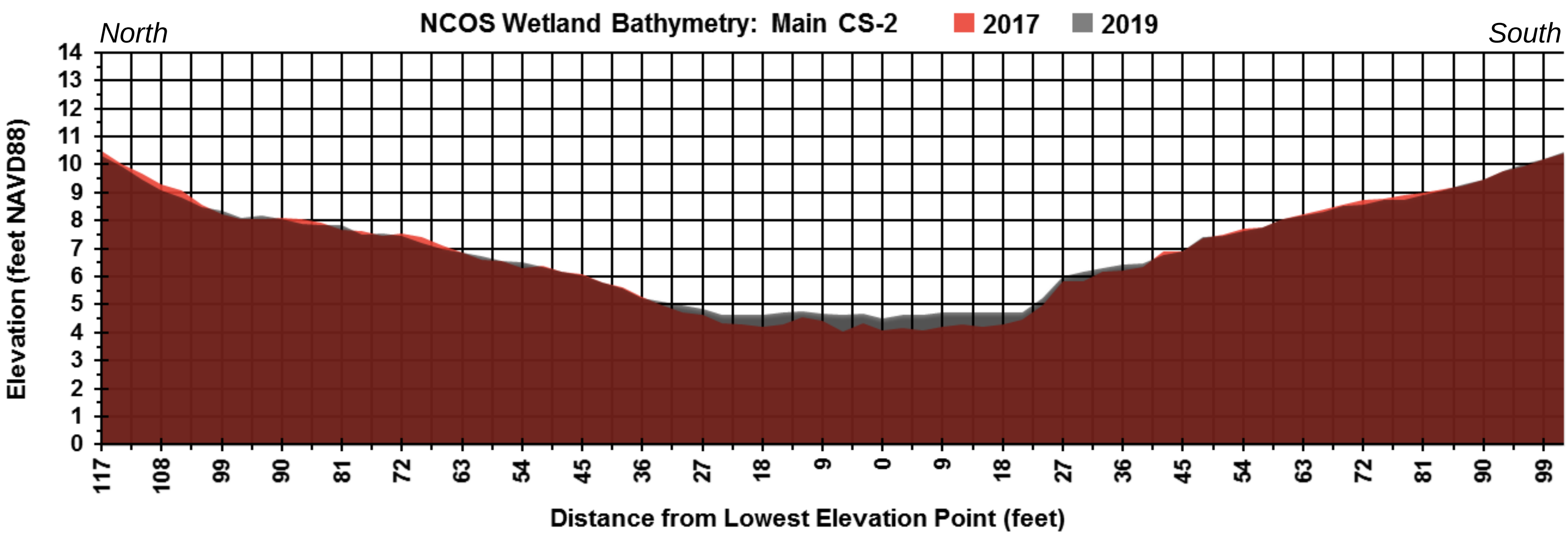
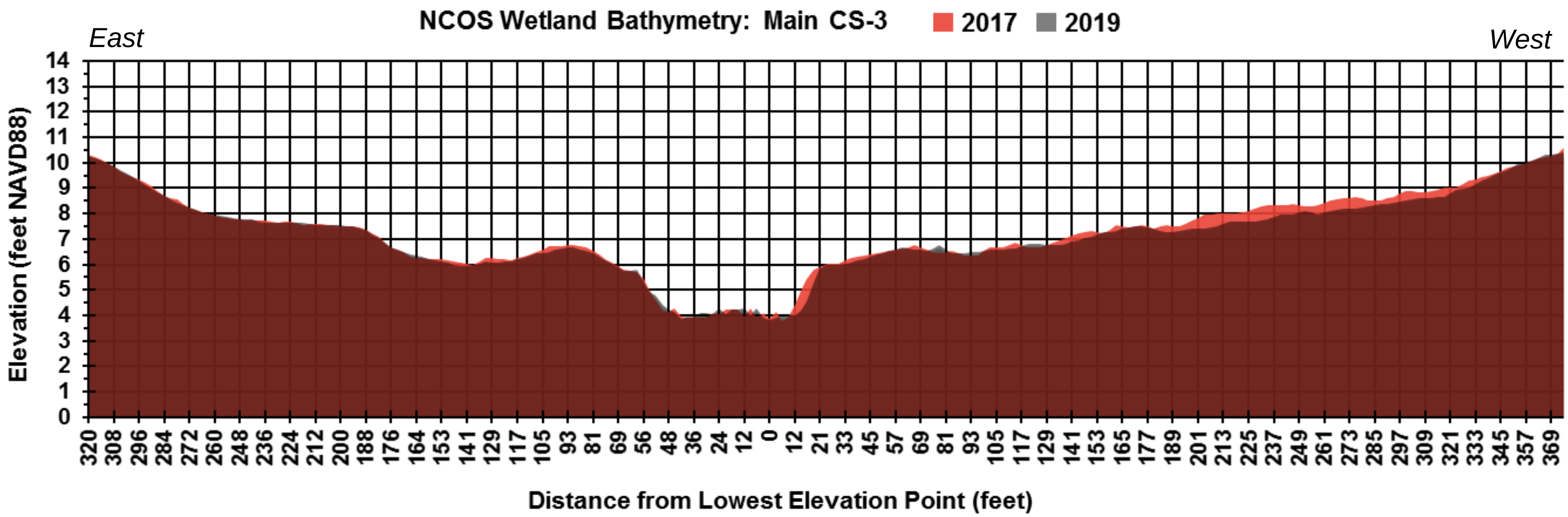


Figure 25. Profiles of the wetland bathymetry cross-section transects measured in 2017 (as-built) and 2019 in the upper portion of the Main Channel (Main CS) of NCOS. See <u>Figure 23</u> for a map of the transects.



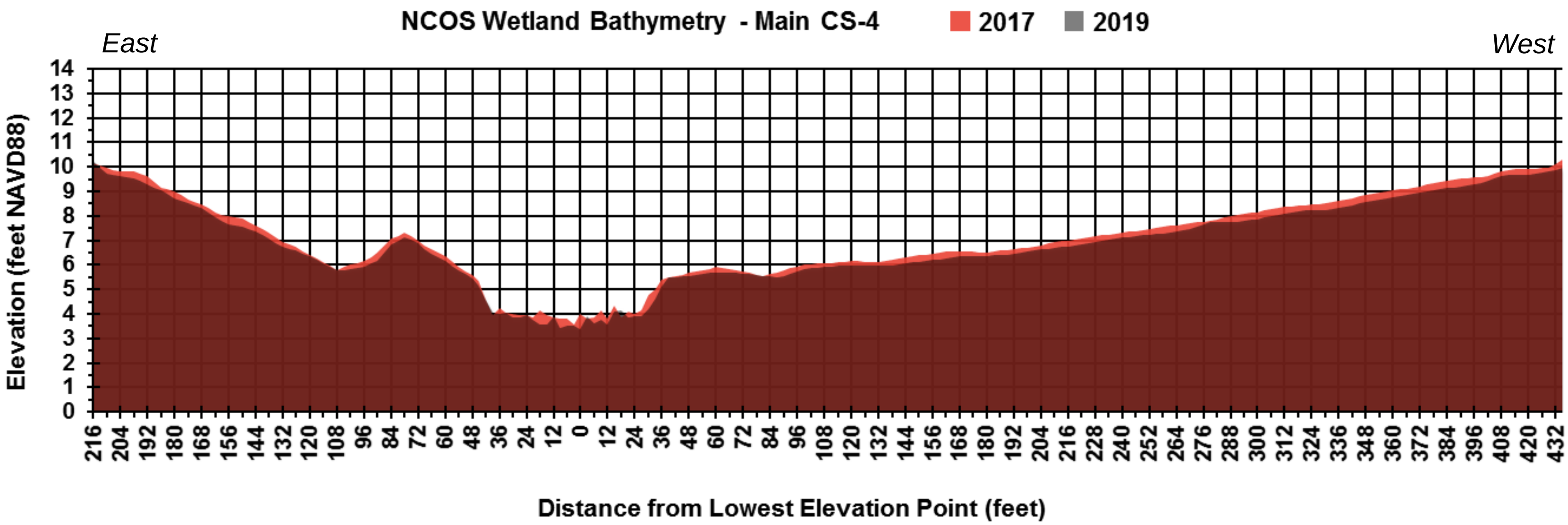


Figure 26. Profiles of the wetland bathymetry cross-section transects measured in 2017 (as-built) and 2019 in the lower portion of the Main Channel (Main CS) of NCOS. See <u>Figure 23</u> for a map of the transects.

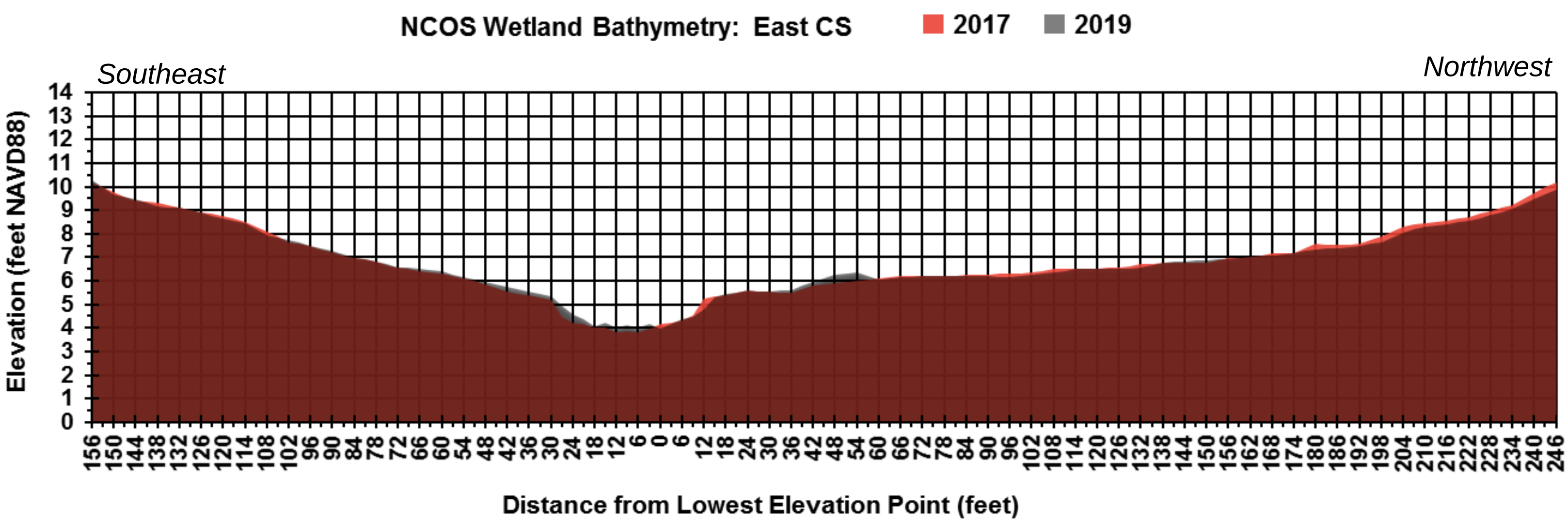


Figure 27. Profiles of the wetland bathymetry cross-section transect measured in 2017 (as-built) and 2019 in the East Channel (East CS) of NCOS. See Figure 23 for a map of the transects.

Table 3. Lowest elevations measured in the wetland bathymetry cross-section and subtidal transects in 2017 (as-built) and in 2019. Together, these provide a thalweg elevation of the wetland channels of the NCOS restoration project. See Figure 23 for a map with the locations of each transect.

Transect Label	2017 (as-built) lowest elevation (feet NAVD88)	2019 lowest elevation (feet NAVD88)
East Thal-1	3.87	3.73
East CS	3.82	3.97
East Thal-2	3.67	3.52
East Thal-3	3.39	3.43
West CS-1	9*	8.51
West CS-2	8*	6.66
Main CS-1	5.45	5.44
Main CS-2	4.04	4.51
Main Thal-1	3.71	3.99
Main Thal-2	3.78	3.66
Main CS-3	3.78	3.83
Main Thal-3	3.62	3.68
Main CS-4	3.56	3.38

Note: CS = Cross-section, Thal = subtidal transect for Thalweg measurement
** - the 2017 low elevations for the West CS transects are derived from the as-built digital elevation model.*

Wetland Hydrology Monitoring

Monitoring of the hydrology of the restored upper arms of Devereux Slough contributes to several of the NCOS restoration project's goals as well as research interests. First and foremost is the goal of lowering flood levels in the tributaries that drain into the wetland as well as the wetland itself. This is determined by monitoring water levels at multiple locations within the wetland and in the tributaries. The hydrology data is also important for understanding how the restoration project alters the water volume capacity of Devereux Slough, and the timing, frequency and duration of tidal flux. In addition to monitoring water levels, CCBER is collecting data on flow rates in the main tributaries of Devereux Slough. The water level and surface flow monitoring methods and data are described in the following two sections.

Water Level Monitoring

Surface water levels at NCOS are monitored using pressure transducer loggers deployed at eight locations: in the three primary tributaries that drain into the upper arms of Devereux Slough, at three locations in the slough, and at two of the larger ponds on NCOS. One of the loggers is an YSI EXO1 sonde and all others are Solinst Leveloggers. The Leveloggers are set at a fixed depth within a few inches of the bottom or floor of the channel or pond, and their approximate elevation (in feet NAVD88) has been determined using either an RTK GPS unit, or by measuring the difference in elevation relative to the nearest reference point. For all of 2018 and most of 2019, the depth of the EXO1 sonde equated to an approximate elevation of 1.2 feet above sea level, which was determined by hand measuring the depth of the sonde below the water surface elevation indicated by a staff gauge. Table 4 lists the locations and elevations of the loggers and Figure 28 contains a map of the locations of the loggers and other hydrology and water quality monitoring sites. All loggers record the water level every 15 minutes. The EXO1 sonde automatically compensates for barometric pressure while the data recorded on the Solinst loggers are compensated using barometric pressure data recorded with a “Barologger” deployed on site. Water level data is converted to water surface elevation (WSE) in feet NAVD88 using either the known elevations of the loggers (for Leveloggers) or regular readings of a WSE staff gauge (for the EXO1 sonde data). In addition, elevation profiles of the beach berm at the mouth of the slough are measured at least twice per year. This data helps to document the performance of the system under wet and dry conditions and improve our understanding of breaching and tidal patterns as well as evaporation and low flows. The data will also be valuable for documenting potential future changes associated with sea level rise.

Table 4. Deployment location and elevation (in feet NAVD88) of pressure transducer loggers (YSI EXO1 and Solinst Leveloggers) that record water levels every 15 minutes in Devereux Slough and the North Campus Open Space. The locations are indicated by the yellow diamonds in the map in Figure 28.

Deployment Location	Logger Elevation (ft. NAVD88)
Devereux Slough Pier (YSI)	1.18
East Channel Bridge	3.96
Phelps Creek - Marymount Bridge	9.99
Venoco Bridge - north side	2.84
West Arm - Devereux Creek	8.41
Western Seasonal Pond	6.20
Whittier Channel	10.41
Whittier Pond	5.04

Prior to the NCOS restoration project, half of the wetland’s potential water-holding capacity was supplanted by soil that was deposited to create the golf course. This caused water levels to rise rapidly to flood levels at the interface between the incoming creeks and the former wetland. Pre-project water levels recorded in Phelps and Devereux Creeks would rise by at least three feet immediately following rainfall amounts above 0.3 inches per hour, as was recorded in January 2017 (Figure 29). Following the excavation of the former golf course and grading of the wetland, the amount of water level rise during storms has decreased by at least a foot in both creeks, as seen in water level data from the month of March in 2018 (Figure 30), and during the wet season in 2019 (Figure 31).

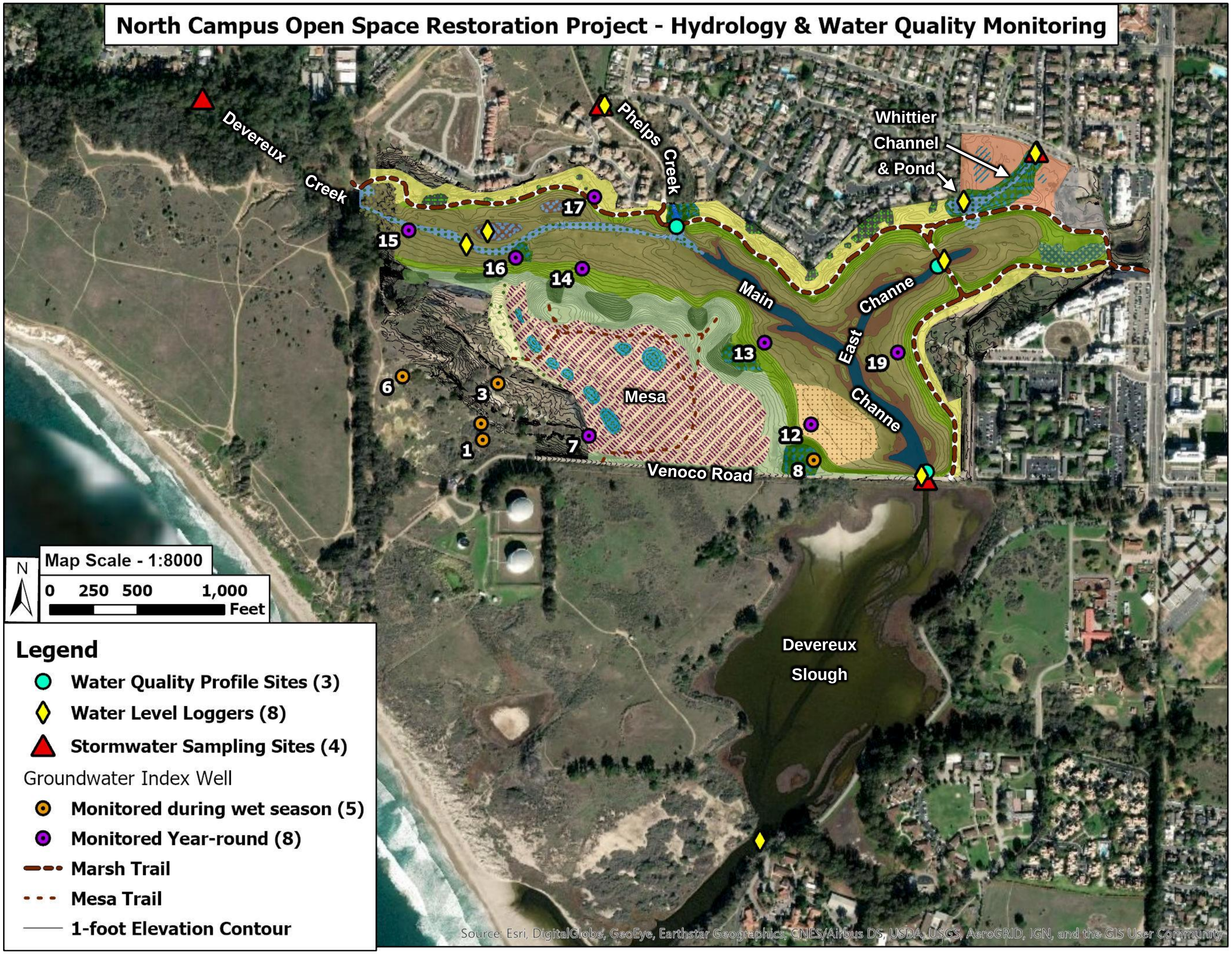


Figure 28. Map of NCOS showing hydrology and water quality monitoring sites, with groundwater index well numbers labeled. See Figure 1 for a legend of the habitat/vegetation communities.

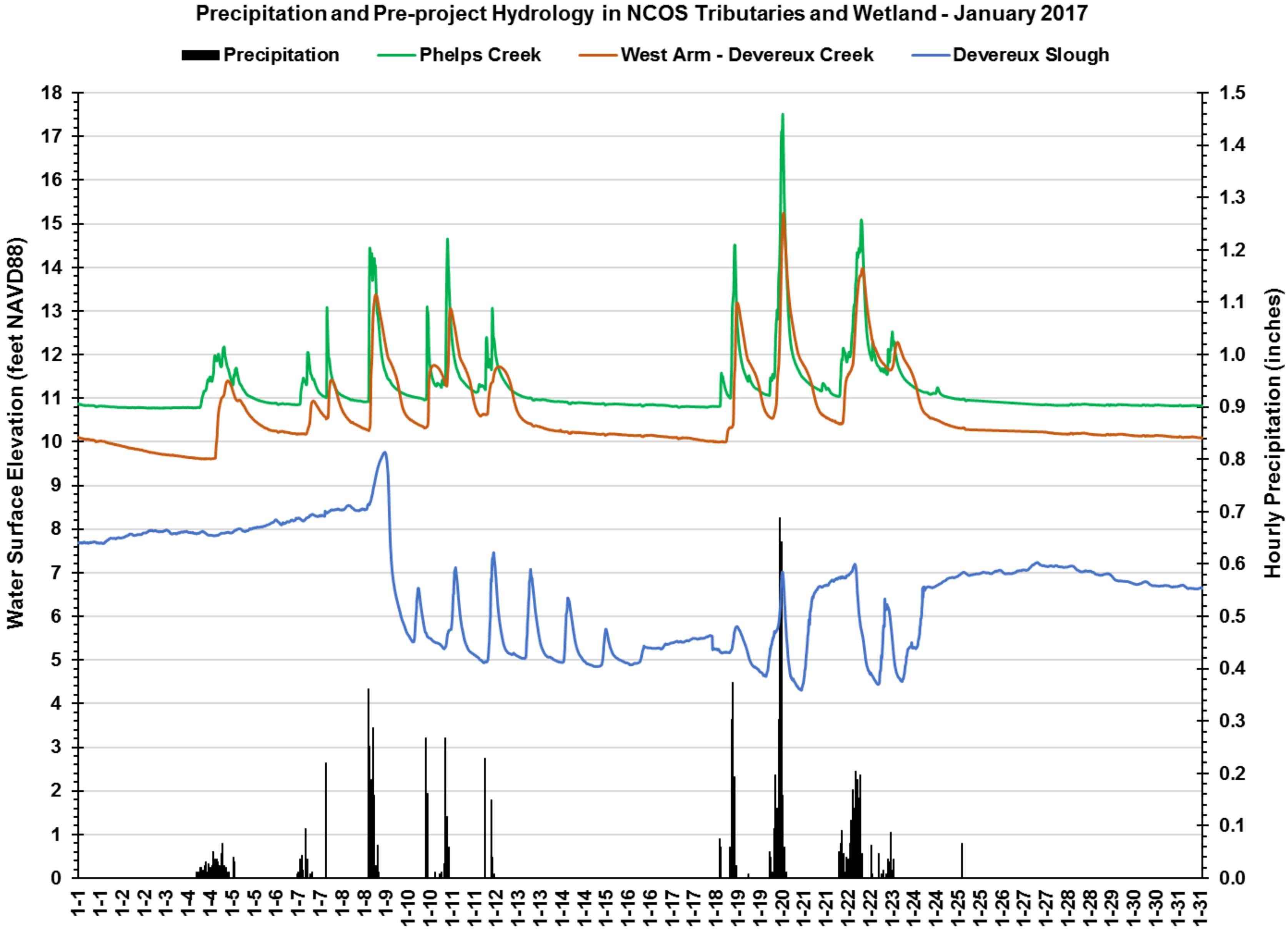


Figure 29. Pre-grading water surface elevations in two NCOS tributaries and Devereux Slough, January 2017. Black bars represent hourly precipitation in inches recorded at a nearby NOAA climate data station.

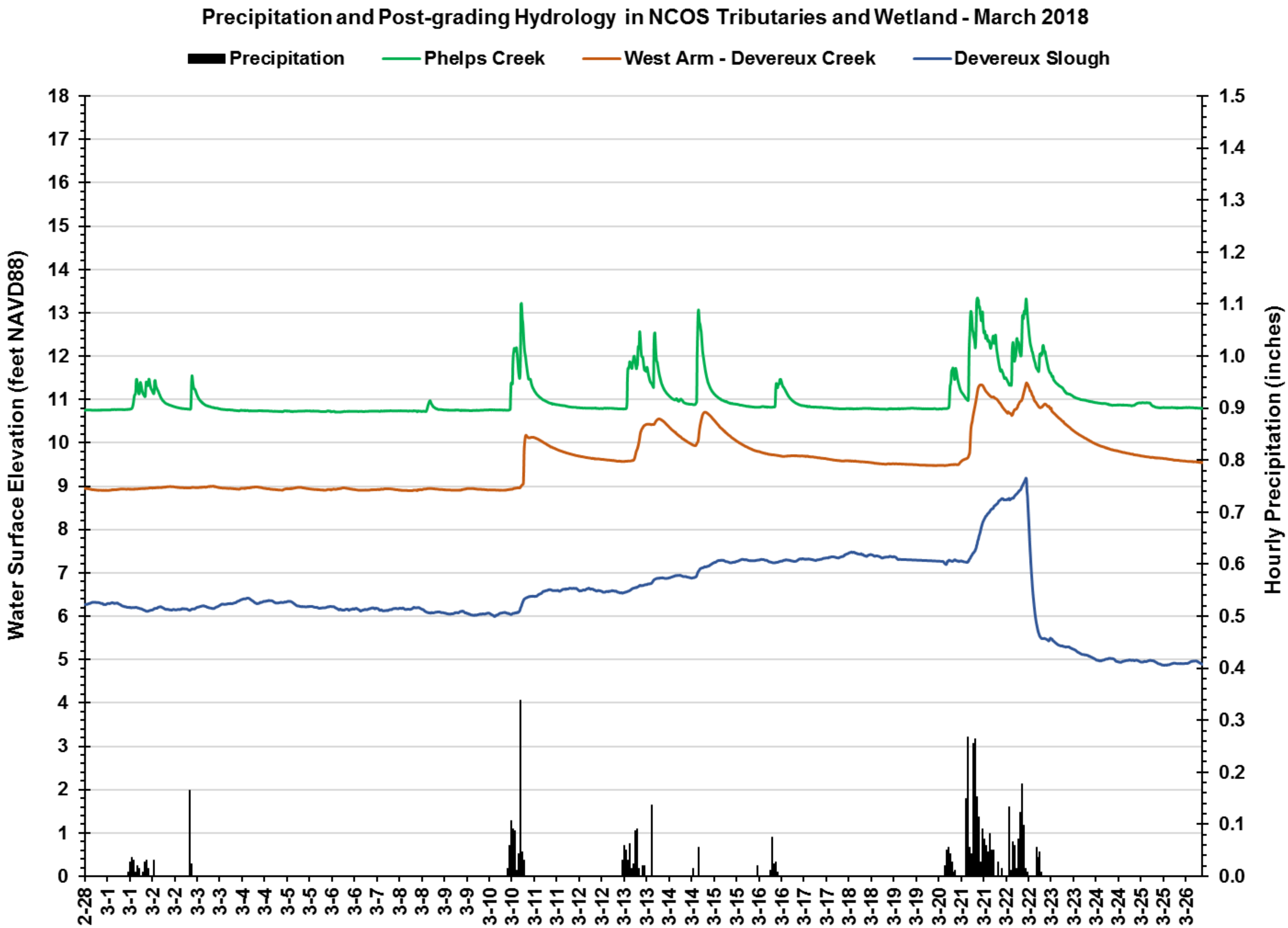


Figure 30. Post-grading water surface elevations in two NCOS tributaries and Devereux Slough, March 2018. Black bars represent weekly precipitation in inches recorded at a nearby NOAA climate data station.

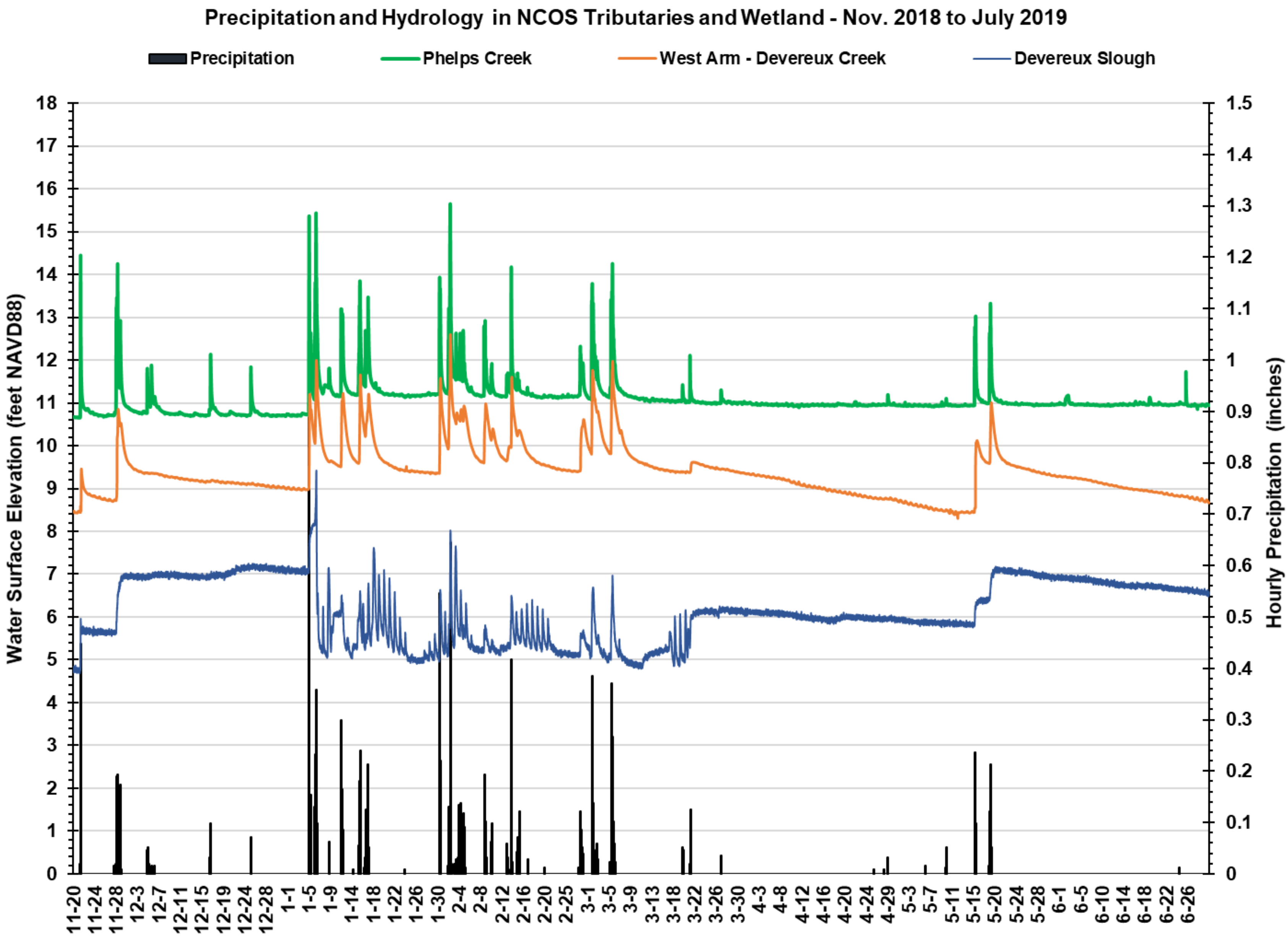


Figure 31. Water surface elevations in two NCOS tributaries and Devereux Slough, November 2018 to July 2019. Black bars represent weekly precipitation in inches recorded at a nearby NOAA climate data station.

In addition to reducing flood levels, the project also increased the water holding capacity of the slough, as reflected in the modeled hypsometric curve in Figure 32. On average, the sand berm at the mouth of the slough holds the water in the system up to an elevation of about 9.5 feet. The blue line in Figure 32 shows the capacity of the system before the project, when the mouth would breach after holding about 200 acre-feet of water. The orange line shows the post-project capacity of the system, indicating it will hold closer to 350 acre-feet before it breaches. Monitoring data collected so far shows that the system follows the modeled predictions, with some annual variability.

In the winter of 2016-17, prior to the commencement of restoration, the water surface elevation (WSE) in Devereux Slough rose to approximately 9.76 feet following a cumulative total of 7.2 inches of rain (since 10/01/2016) and breached the berm at the mouth on 1/9/17. The slough water level then fluctuated with the tides for seven days before waves deposited enough sand on the beach to temporarily seal off the mouth. Subsequent rains led to additional, shorter periods of tidal flux in January and February 2017 (Figure 33). The grading of the project site was completed in October 2017, and in the winter that followed, the slough did not breach the sand berm until 3/22/18 when the WSE reached 9.2 feet after an accumulation of 7.4 inches of rain, and there was virtually no subsequent tidal fluctuation (Figure 34). The lower WSE of this first post-grading breach was likely due to a lower minimum elevation of the sand berm, which was measured to be approximately 9.3 feet on 3/06/2018, two weeks before the breach. While the amount of rain preceding the 2018 breach was only slightly greater than in 2017, had the sand berm elevation been similar, it likely would have required at least another inch of rain to be breached. Furthermore, in August and September 2017, the Goleta Water District conducted a high power flushing of the water distribution system that resulted in the newly graded sub-tidal channel of the wetland filling up to a depth of one foot, which equates to runoff from approximately one inch of rain. The combination of this early runoff and that a greater amount of rainfall was required to breach a sand berm with a lower than average elevation reflect the greater water holding capacity of the restored wetland.

In the 2018-2019 winter, the slough breached the berm on 1/07/2019 when the WSE reached 9.4 feet after a cumulative total of 6.5 inches of rain. As with the 2018 breach, the elevation of the berm was lower than average, with a minimum elevation of 9.3 measured on 12/03/2018. Following the breach, an extended period of intermittent tidal fluctuation lasted for more than two months until 03/21/2019 (Figure 35). This long period of tidal connectivity with the ocean was the first time our loggers recorded sea water flowing into the restored upper arms of the slough. This can be seen in Figure 35 where the red line shows how the WSE in the upper east arm fluctuated with the tides and rainfall, and the green line shows variation in salinity (measured as electrical conductivity) in the upper east arm due to alternating freshwater flows from rain, and seawater influx during high tide. In addition, data from our Water Quality Profile Monitoring indicated that sea water flowed into the restored upper arms of the slough as far as the confluence with Phelps Creek. The extended period of tidal connectivity resulted in cyclical flushing of the wetland as well as an influx of nutrients, invertebrates (*e.g*. small crab on Levelogger in upper east arm, Figure 36) and fish, including potentially the tidewater goby that were found in the most recent survey.

With continued monitoring of the hydrology of Devereux Slough, including the elevation of the sand berm, we expect to gain a more robust understanding of the system and greater ability to estimate the potential effects of sea level rise.

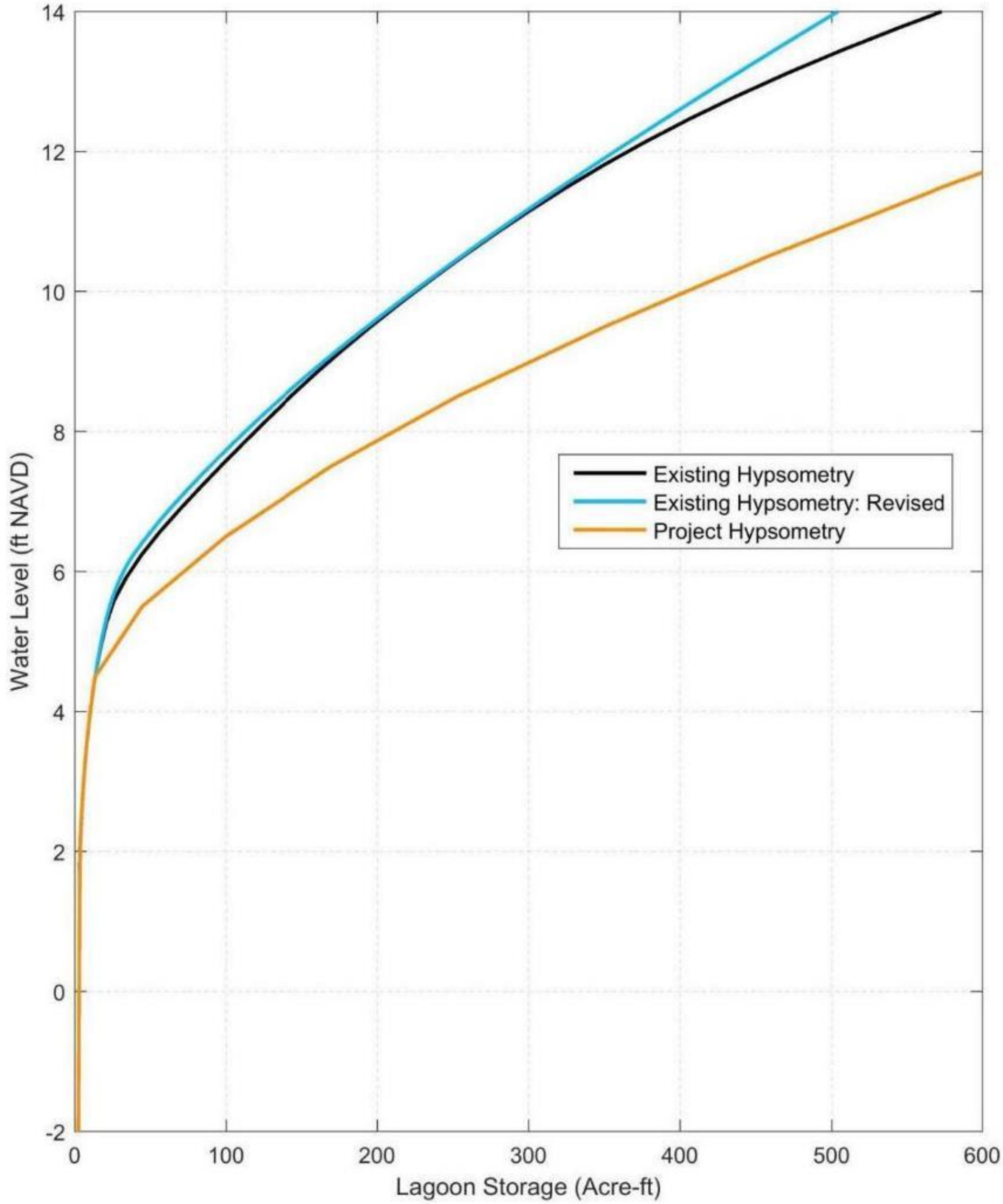


Figure 32. Comparison of modeled pre- and post-grading water stage-storage curves for Devereux Slough (Lagoon). Notice the lower post-project water levels at equivalent water storage levels (orange line). Pre-grading hypsometry is from Rich (2013). Revised pre-grading hypsometry is based on an ESA and Stantec survey. Post-grading hypsometry is based on the ESA grading plan for NCOS.

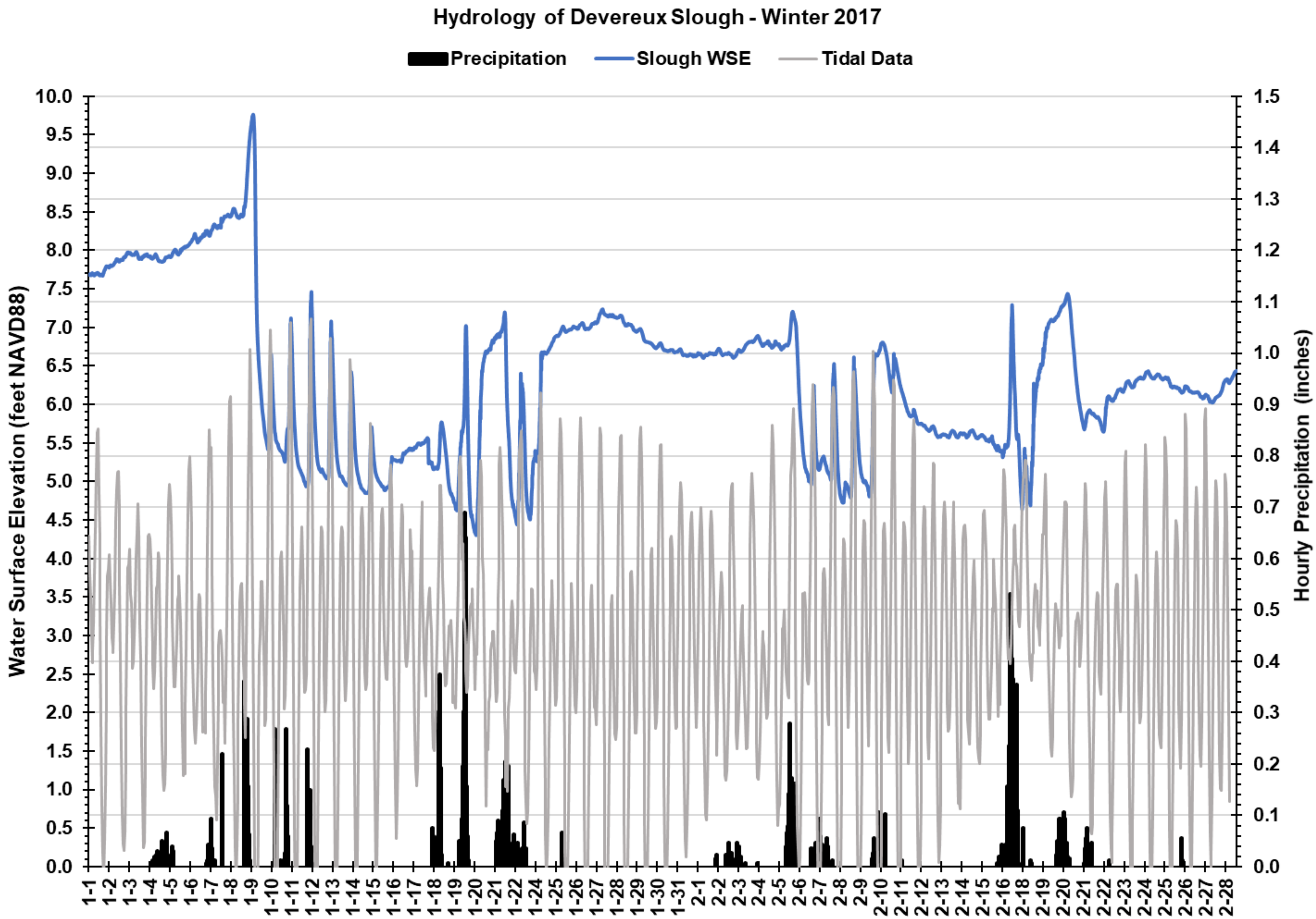


Figure 33. Water surface elevation (feet NAVD88) of Devereux Slough, with local tides in feet and hourly precipitation in inches (courtesy of NOAA), January to March 2017.

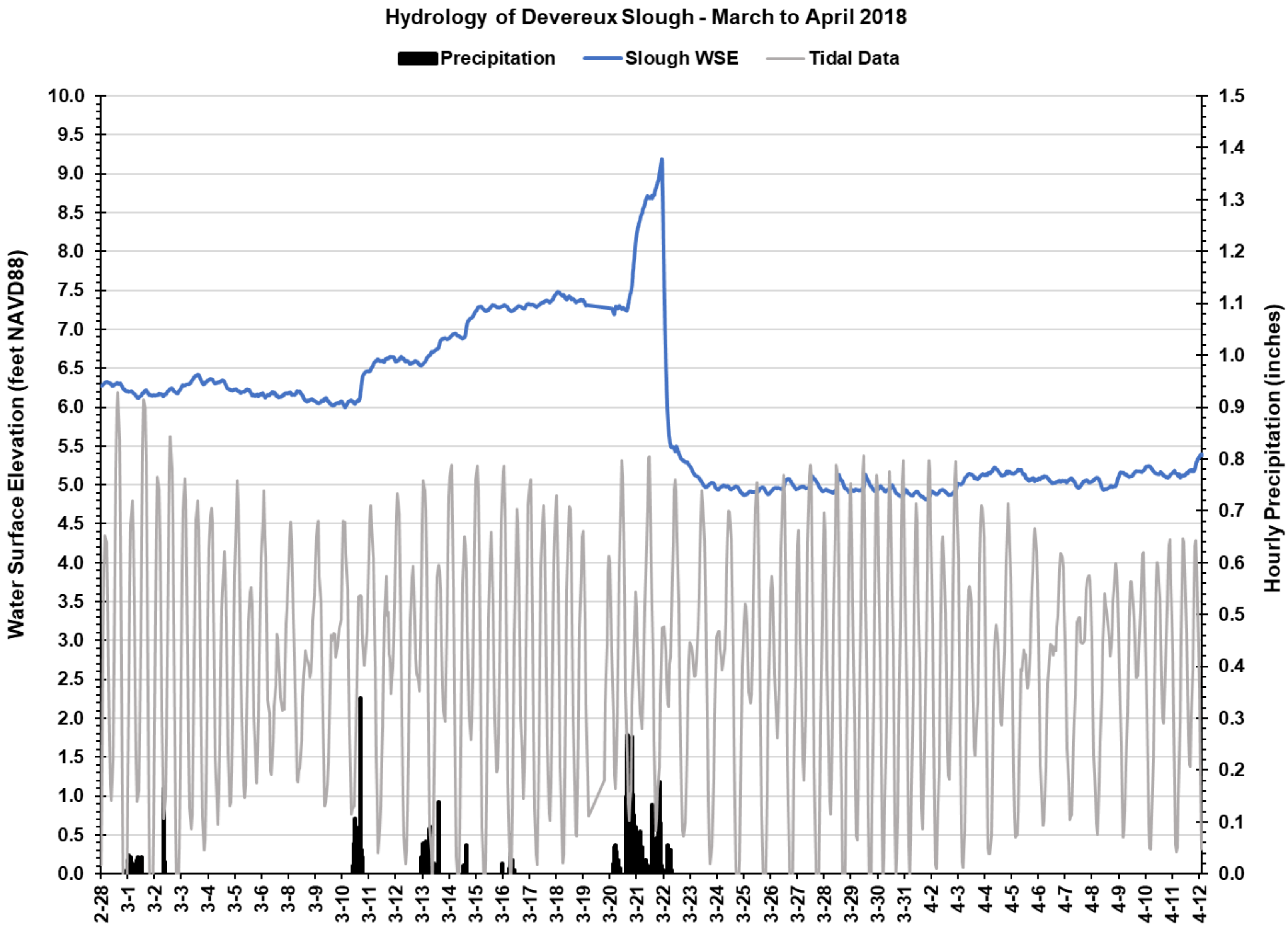


Figure 34. Water surface elevation (feet NAVD88) of Devereux Slough, with local tides in feet and hourly precipitation in inches (courtesy of NOAA), March to April 2018.

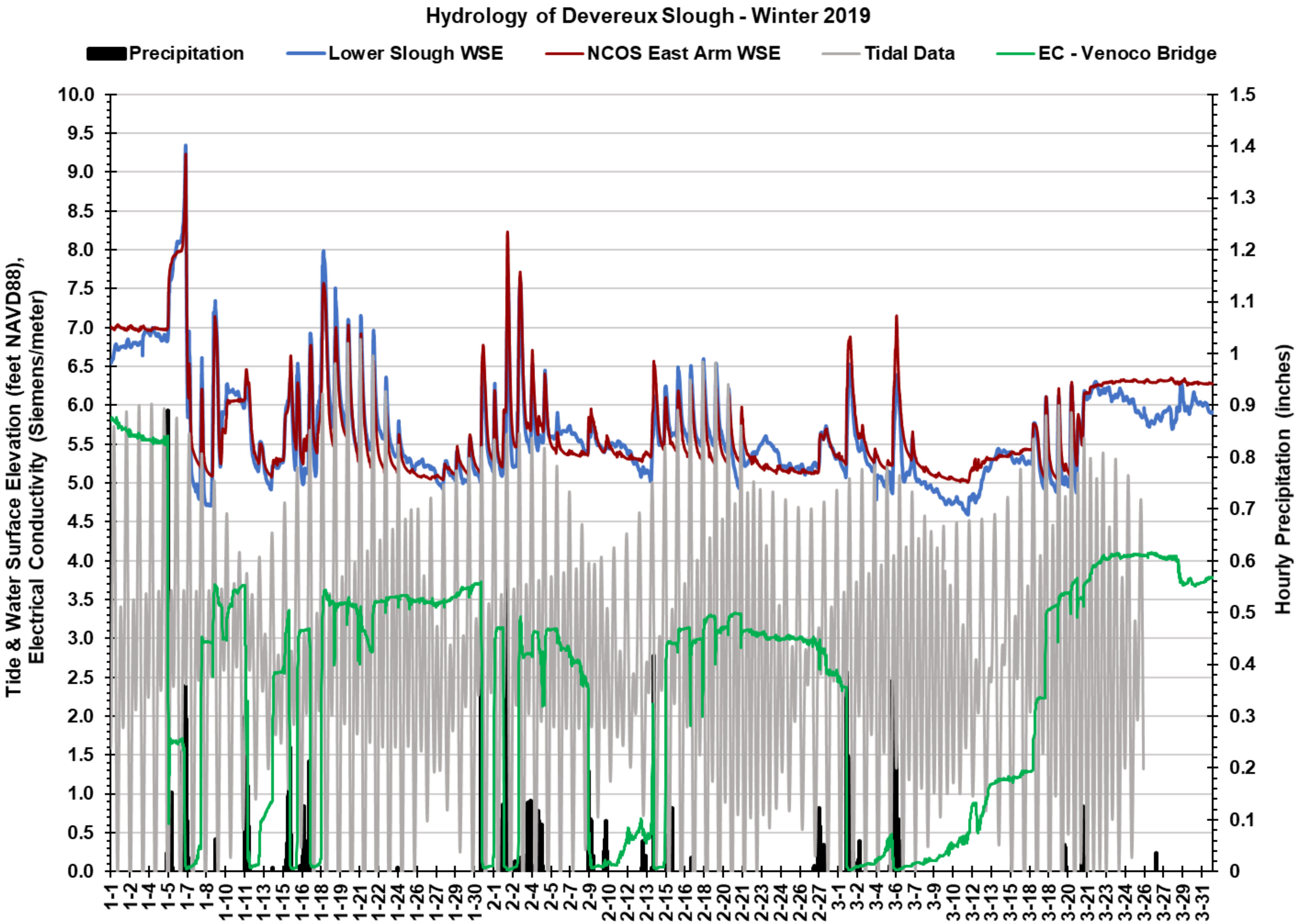


Figure 35. Water surface elevation (feet NAVD88) in the upper east arm and the lower half of Devereux Slough, with local tides in feet and hourly precipitation in inches (courtesy of NOAA), and electrical conductivity (Siemens per meter) of water in the upper east arm, January to April 2019.

Figure 36. A small crab found on a Solinst Levelogger in the restored upper east arm of Devereux Slough indicates that sea water infiltration during tidal connectivity likely deposited marine invertebrates.

Surface Flow Monitoring

Measurements of the flow rates of surface water in the two creeks (Devereux and Phelps) and the storm drains entering NCOS provides information for calculating the velocity and volume of water entering the system during storms or other runoff events. This information can be used along with water quality data for calculating nutrient and sediment fluxes during stormwater flows and contributes to analyses of the movement of water in the wetland as well as tidal dynamics.

Surface flow surveys at NCOS are usually conducted during or immediately after a rainfall event that produces measurable runoff. A Marsh-McBirney Model 2000 flow meter attached to a metric wading rod is used to record water velocity in meters or feet per second, which is measured at multiple depths in the middle of equal-sized segments (usually 50 cm) along a transect across the entire creek or channel. The number of velocity measurements depends on the shape or type of stream or conduit, whereas outfalls from circular culverts or storm drains are measured differently than “natural” or trapezoidal streams. The velocity measurements for each segment are averaged and multiplied by the segment area to obtain a rate of flow that is summed for all segments to obtain an overall flow rate (in cubic meters per minute or cubic feet per second) for the stream or storm drain. In an effort to calculate flow rate curves for use in hydrology and water quality analyses, we are endeavoring to collect velocity measurements during different flow rates or at different water stage levels. This monitoring is conducted by two CCBER staff, one standing in the stream with the wading rod and flow meter, while the other records the velocity measurements, depth and transect distance from the bank.

Pre-project surface flow was measured in 2016 in Phelps Creek, at the Whittier Drive storm drain outfall, at culverts that controlled the flow of Devereux Creek into the former golf course, and at the weir that separated Devereux Creek from the slough (water flowing over the top of the weir and through the culvert were both measured). Since the completion of the grading phase of the project, surface flow has been measured in Phelps Creek once in 2018 and twice in 2019, in Devereux Creek near Coronado Drive in 2018, and downstream of Venoco Bridge in 2019 in an effort to estimate the flow rate into the lower slough. The red triangle icons in the map in Figure 28 correspond to the locations where flow measurements are usually collected. Table 5 contains the parameters and flow rates measured at Devereux Creek, Phelps Creek and Venoco Bridge, while Table 6 contains the data collected in 2016 at Whittier storm drain and the Devereux Creek culverts. We will continue to collect flow measurements as opportunities arise in order to increase the robustness of flow rate curves and estimates of runoff velocity, volume and fluxes during different storm events.

Table 5. Surface water velocity and volume flow rates measured in Phelps Creek, Devereux Creek and in the main wetland channel flowing into the lower Devereux Slough.

Site	Date & Time	Width of Stream/Wet Area (m)	Water Stage (cm)	Water Stage (ft)	Area of Flow (m^2)	Mean Velocity (m/s)	Flow Rate (CMM)	Flow Rate (CFS)	Comments
Phelps Creek at Marymount Bridge	3/7/2016, 13:30 - 14:30	4.0	91	2.99	2.54	0.07	12.79	7.53	Segments were 1 meter wide. Uncertain of accuracy of this measurement.
Phelps Creek at Marymount Bridge	1/9/2018	4.3	106	3.48	3.09	0.08	23.31	13.71	Segments were 2 foot wide. Uncertain of accuracy of this measurement.
Phelps Creek at Marymount Bridge	2/13/2019, 12:00 - 13:00	3.3	74	2.43	1.68	0.01	1.54	0.90	Segments were 50 cm wide.
Phelps Creek at Marymount Bridge	2/14/2019, 10:40 - 11:00	4.3	99	3.25	2.60	0.01	2.34	1.38	Segments were 50 cm wide.
Devereux Slough Channel - South of Venoco Bridge	2/14/2019, 11:20 - 12:40	10.5	101	3.31	7.69	0.16	71.9	42.31	Segments were 50 cm wide.
Devereux Creek Overflow into Slough	03/11/2016, 15:00 - 15:45	12.0	58	1.90	4.17	0.23	47.9	28.20	
Devereux Creek ca. Coronado Drive	3/21/2018, 15:20 - 16:05	2.7	89	2.92	1.88	0.16	20.01	11.78	

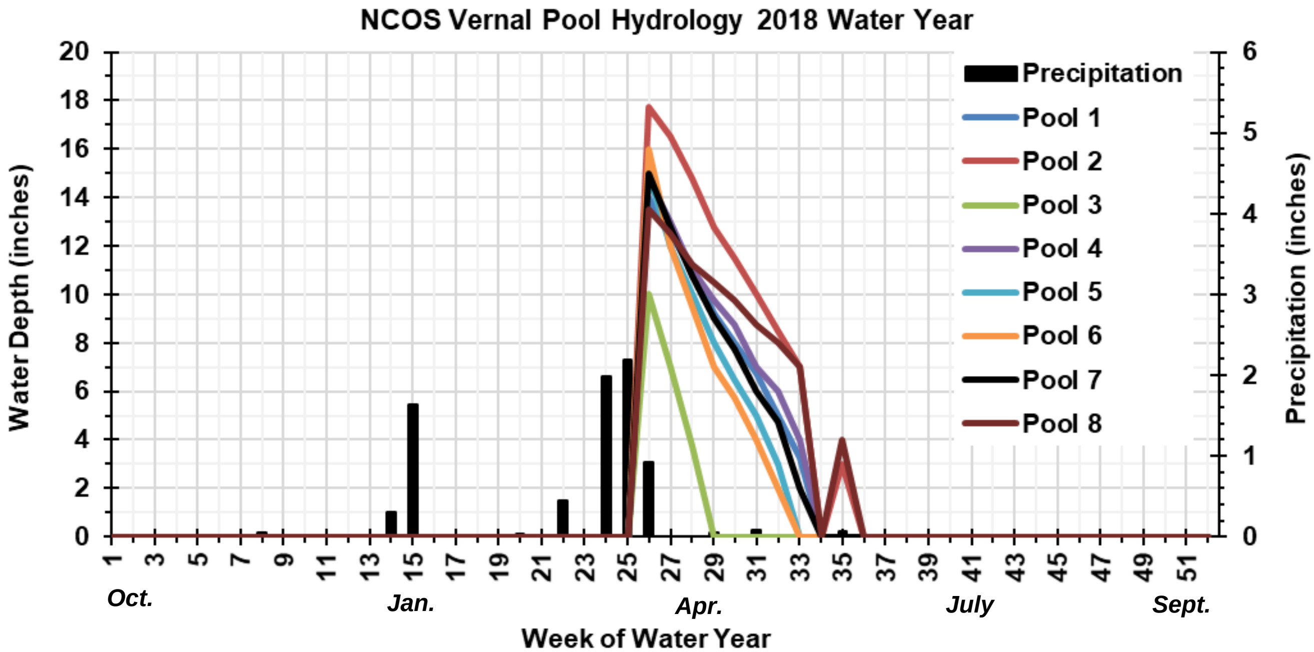
Table 6. Surface water velocity and volume flow rates measured in 2016 in the Whittier storm drain outflow and in culverts that controlled the flow of Devereux Creek into and out of the former golf course.

Site	Date & Time	Diameter (ft)	Level of water (ft)	Level/Diameter Ratio	Flow Unit Multiplier (K)	Mean Velocity (ft/sec)	Flow Rate (CFS)
Whittier Drive Storm drain Outflow	03/07/2016, 14:30 to 15:00	3.64	2.61	0.717	0.6054	0.1214	1.5065
West Devereux Creek Culverts – Upper	03/11/2016, 14:00 to 14:15	1	1	1	0.7854	4.306	5.233
West Devereux Creek Culverts – Lower	03/11/2016, 14:00 to 14:15	1	1	1	0.7854	4.101	4.984
Devereux Creek Culvert into Slough	03/11/2016, 15:45 to 16:00	1	1	1	0.7854	4.396	5.342

Vernal Pool Hydrology Monitoring

Vernal pool hydrology monitoring consists of standardized recording of the water levels in the restored pools created on the NCOS Mesa in order to assess their development and ecological functionality. Water levels in the eight vernal pools created on the NCOS Mesa are monitored on a weekly basis starting when the pools begin to hold water after the first rains of the wet season, and continuing until the pools become dry (see Figure 1 for the locations of the vernal pools). Water levels in the pools are measured to the nearest quarter-inch by reading an 18 to 24-inch metal ruler installed at the deepest area of each pool. This monitoring is conducted by CCBER staff and student interns.

The first year of hydrology monitoring of the vernal pools began in March of 2018 after only the second and last significant rainfall of the season filled the pools to a depth of 10 to 18 inches. Seven of the eight pools held water for eight to nine weeks, becoming dry by mid to late May (Figure 37 – top chart). In contrast, the second year of monitoring began in January 2019 and continued for 25 weeks until June 21st (Figure 37 – bottom chart). This was due to a much greater number of storms and overall rainfall than in 2018, including two late season events in mid-May. The 2019 data revealed variation in the length of the water holding period of the pools. The two pools on the upper Mesa (pools 1 and 2) held water for the entire length of the monitoring period, pool 4 had the second longest water holding period at 18 weeks, and the remaining pools held water for 12 to 13 weeks, with some pools holding water for 2 to 6 weeks after the late season rains in May. In both years of data, pool 3 appears to dry more rapidly than all other pools. Vernal pools are considered functional when they hold a minimum of a few inches of water for at least 100 days. Pools 1, 2 and 4 met this requirement in 2019, and the rest of the pools came very close.



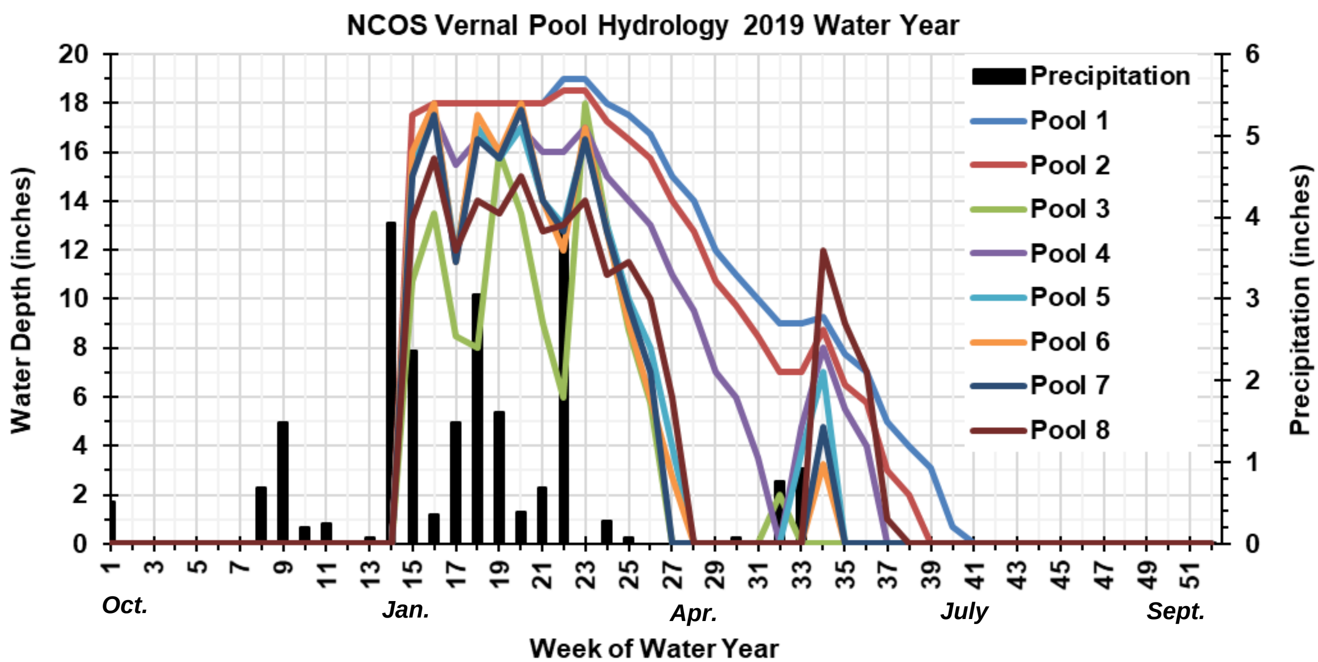


Figure 37. Hydrographs of weekly water depth (inches) in the eight restored vernal pools on the NCOS Mesa in the 2018 (top chart) and 2019 (bottom chart) water years (October 1st to September 30th). Black bars represent weekly precipitation in inches recorded at a nearby NOAA climate data station.

Groundwater Hydrology & Salinity Monitoring

The purpose of monitoring groundwater is to advance our understanding of the underlying hydrology and salinity and their relationship to plant survivorship and growth, and eventually to sea level rise. Groundwater table elevation and salinity are monitored regularly in up to 13 piezometers, or index wells, some of which have been installed across the greater project area since 2011 (see the purple and orange points in the map in Figure 28). In February 2018, seven of the wells that had been removed for the grading of the project site were reinstalled. Four of these wells were re-installed in the same locations as before the restoration project (wells 14, 15, 17 and 19). The elevation and salinity of groundwater is typically monitored on a weekly basis year-round in at least the seven wells surrounding the salt marsh (wells 12 through 19). Most of the other wells are monitored weekly in the winter and spring, and at a lower frequency in the summer and fall. The height of the water in the well is determined from the distance on a measuring tape (to 1/16 of an inch) where a wet-erase marker line is washed off by the groundwater. This measurement is then compared with the overall depth and the known elevation of the well in order to determine the elevation of the groundwater table (in feet NAVD88). The salinity (in parts per thousand [ppt]) is measured by collecting a small sample in a vial attached to a weighted string and applying the sample to a refractometer. This monitoring is conducted primarily by student interns and community volunteers.

A comparison of the pre-restoration (2016) and post-grading data (2018 and 2019) for wells 14, 15, 17 and 19 suggests that the groundwater elevation near the east side of NCOS may have lowered by about two feet and may have risen by two to three feet in the western area of the site that is south of Devereux Creek (see Table 7 and Figure 38). This could be due to changes in the ground surface elevation from the grading of the site. After the grading of the wetland, groundwater salinity has increased in the low-lying area of the western arm (well 15) and particularly along the eastern side of the salt marsh (well 19) (Figure 39).

Table 7. Top of well elevation (feet NAVD88), and mean elevation (feet NAVD88) and salinity (parts per thousand) of groundwater at four piezometers (index wells) at NCOS in the 2016 (pre-project) Water Year, and after wetland grading in the 2018 and 2019 Water Years. Water Years (WY) run from October 1st to September 30th each year. The locations of the wells are labeled in the map in Figure 28.

Well Number	14	15	17	19
Pre-project Well Elevation (ft.)	15.75	13.8	17.34	13.12
Post-grading Well Elevation (ft.)	17.43	11.71	16.47	10.11
Mean WY2016 Groundwater Table Elevation (ft.)	10.1	6.7	9.5	6.6
Mean WY2018 Groundwater Table Elevation (ft.)	12.8	8.2	9.1	5.2
Mean WY2019 Groundwater Table Elevation (ft.)	13.1	8.9	9.6	4.7
Mean WY2016 Salinity (ppt)	4	29	8	78
Mean WY2018 Salinity (ppt)	2	33	6	93
Mean WY2019 Salinity (ppt)	3	38	5	92

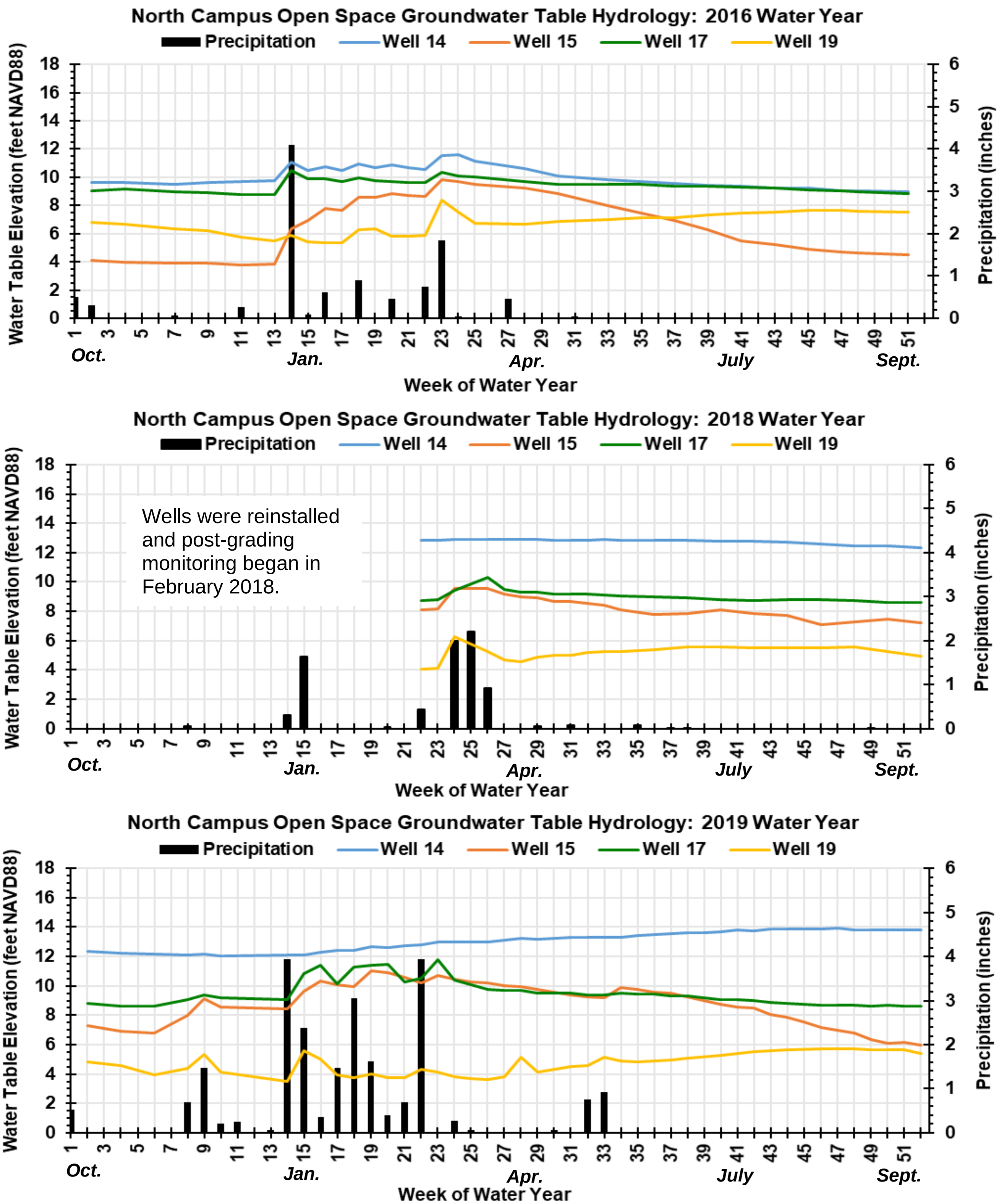


Figure 38. Charts of groundwater table elevation (in feet NAVD88) measured weekly in four piezometers (index wells) on North Campus Open Space in the pre-restoration water year (Oct. 1st to Sept. 30th) of 2016 (top chart), and in the post-wetland grading water years of 2018 (middle) and 2019 (bottom). Black bars represent weekly precipitation in inches recorded at a nearby NOAA climate data station.

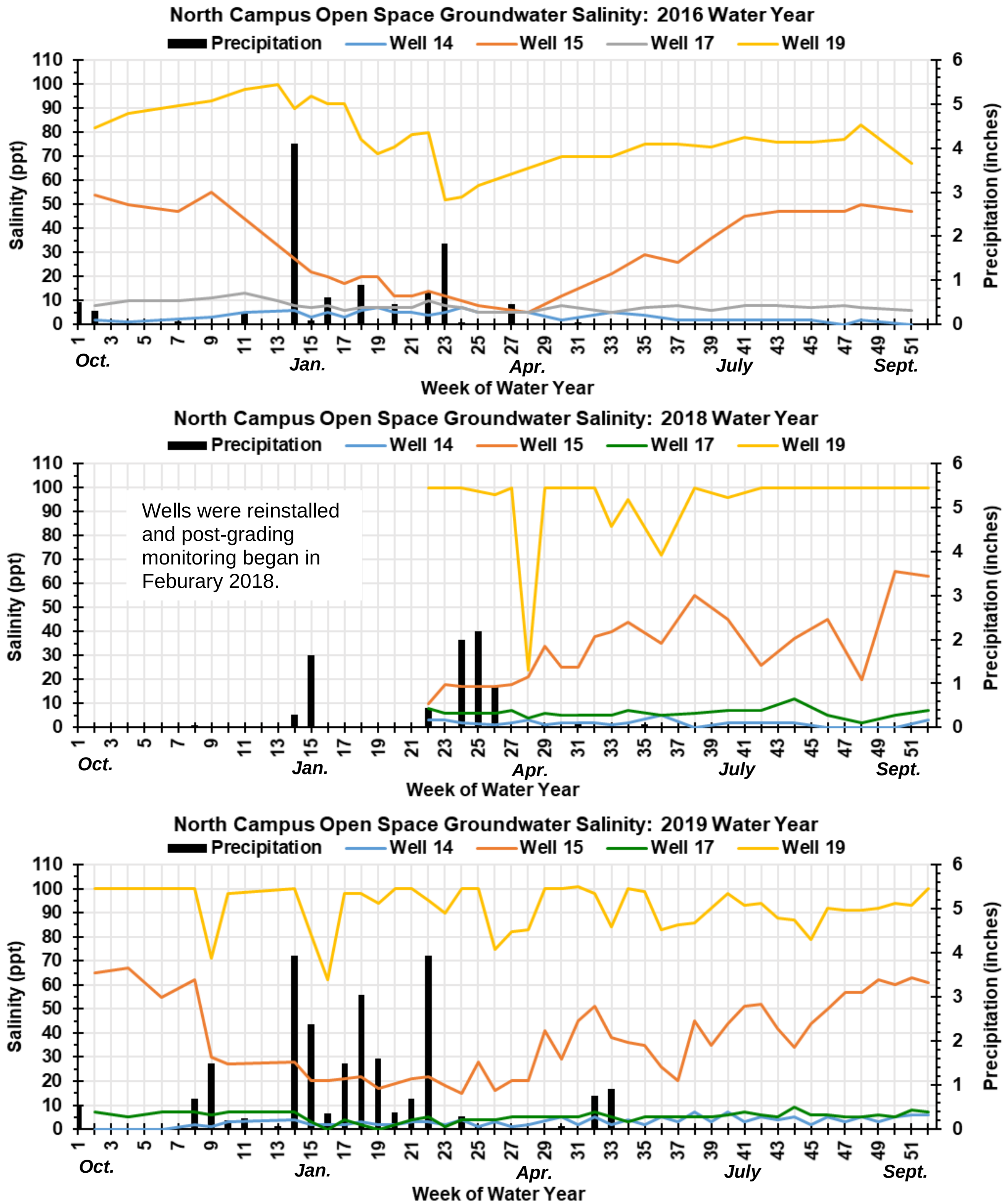
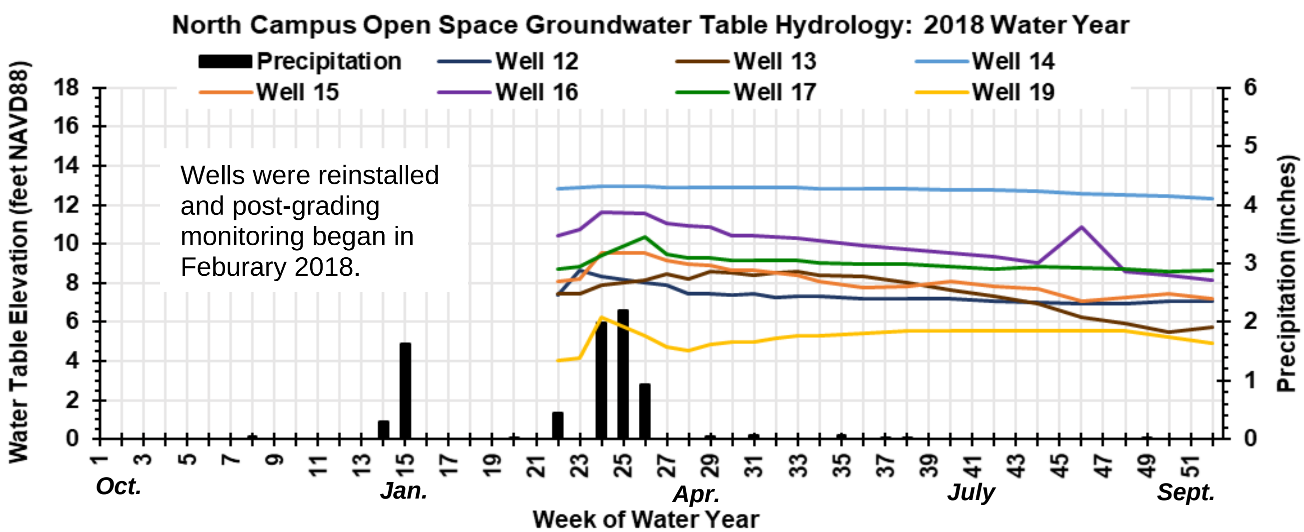


Figure 39. Charts of groundwater salinity (in parts per thousand, ppt) measured weekly in four piezometers (index wells) on North Campus Open Space in the pre-restoration water year (Oct. 1st to Sept. 30th) of 2016 (top chart), and in the post-wetland grading water years of 2018 (middle) and 2019 (bottom). Black bars represent weekly precipitation in inches recorded at a nearby NOAA climate data station.

Groundwater elevation and salinity data for seven of the regularly monitored wells collected in the 2018 and 2019 water years (October 1st to September 30th) are presented in Figure 40 and Figure 41. In late 2018, a Levelogger that records water level and conductivity every 15 minutes was installed in well 12 for detailed monitoring of the groundwater in the area where a population of Ventura marsh milk-vetch would be planted in 2019. The data recorded by the logger for the 2019 water year is presented in Figure 42. In addition, prior to the project, groundwater was only briefly detected in well 7 after extended periods of heavy rainfall. After the grading of the Mesa area was completed, monitoring data at well 7 shows that the elevation of the groundwater table has risen and tends to remain at a stable elevation (31 feet on average) throughout the year with a salinity near zero ppt. We will continue to monitor the wells and assess these trends further as the restoration of the site progresses.



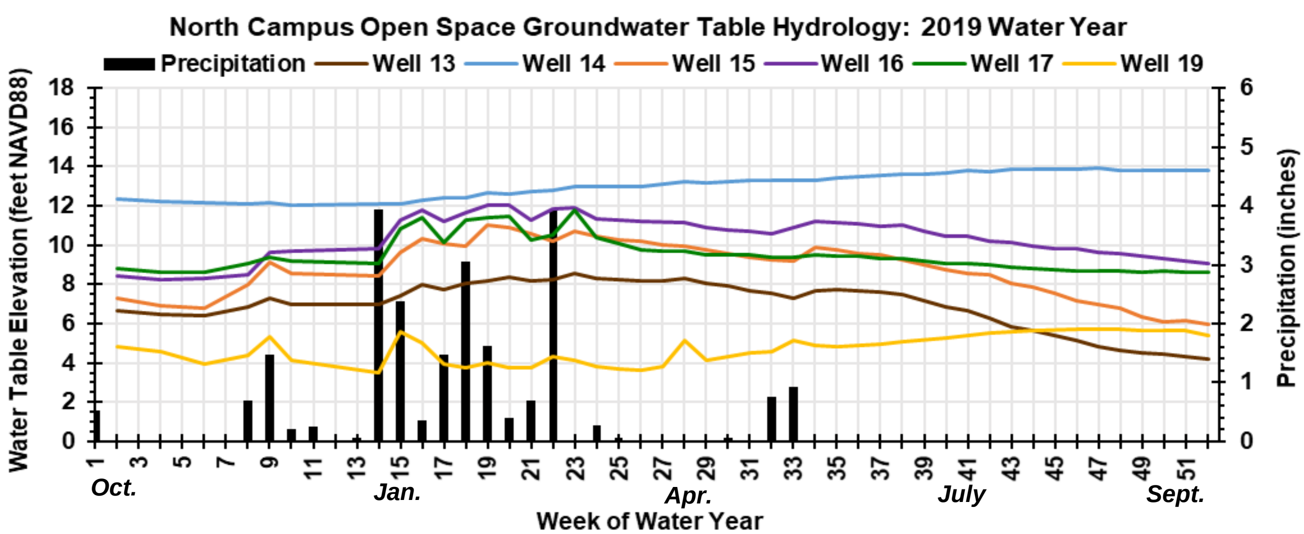
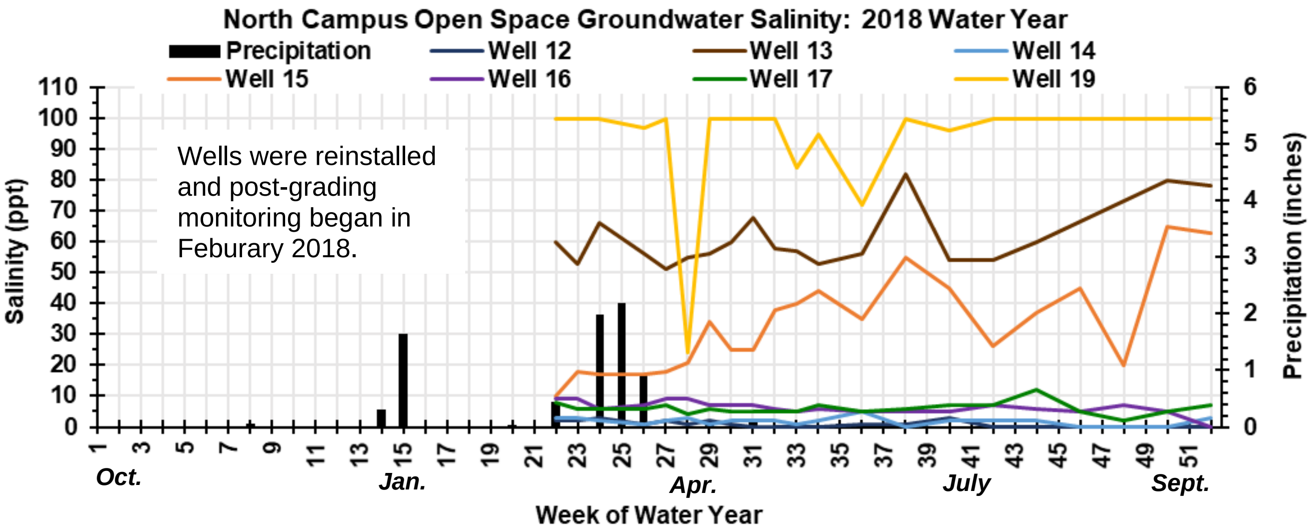


Figure 40. Charts of the groundwater table elevation (in feet NAVD88) measured weekly in seven piezometers (index wells) at North Campus Open Space in the post-grading water years of 2018 (top) and 2019 (bottom). Black bars represent weekly precipitation in inches recorded at a nearby NOAA climate data station. Post-grading installation and monitoring of the wells began in February of 2018. The locations of the wells are labeled in the map in Figure 28.



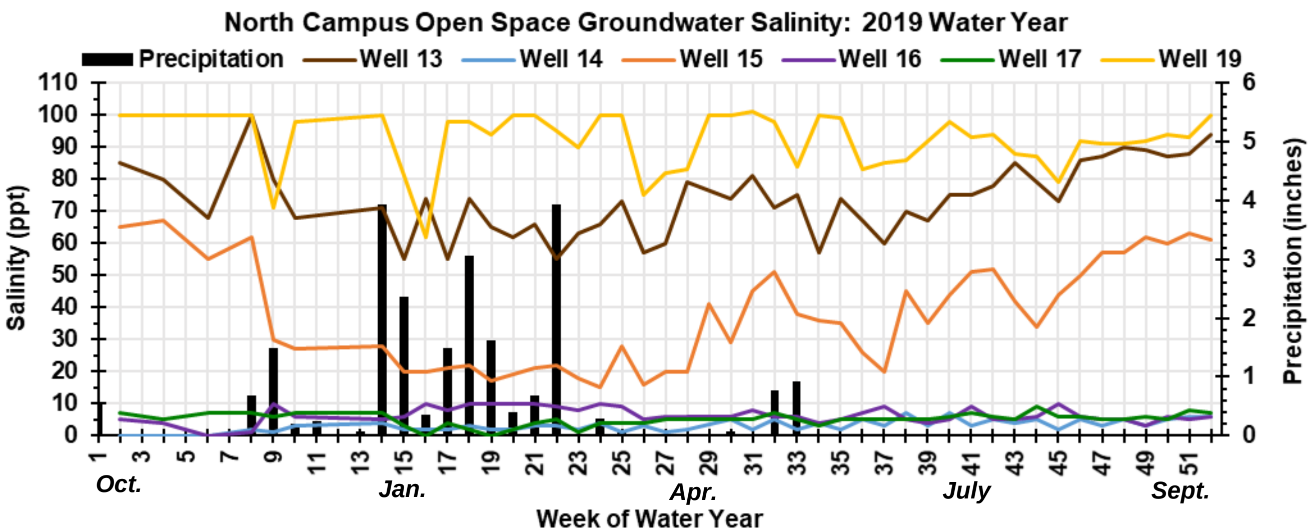


Figure 41. Charts of the groundwater salinity (in parts per thousand, ppt) measured weekly in seven piezometers (index wells) at North Campus Open Space in the post-grading water years of 2018 (top) and 2019 (bottom). Black bars represent weekly precipitation in inches recorded at a nearby NOAA climate data station. Post-grading installation and monitoring of the wells began in February of 2018. The locations of the wells are labeled in the map in Figure 28.

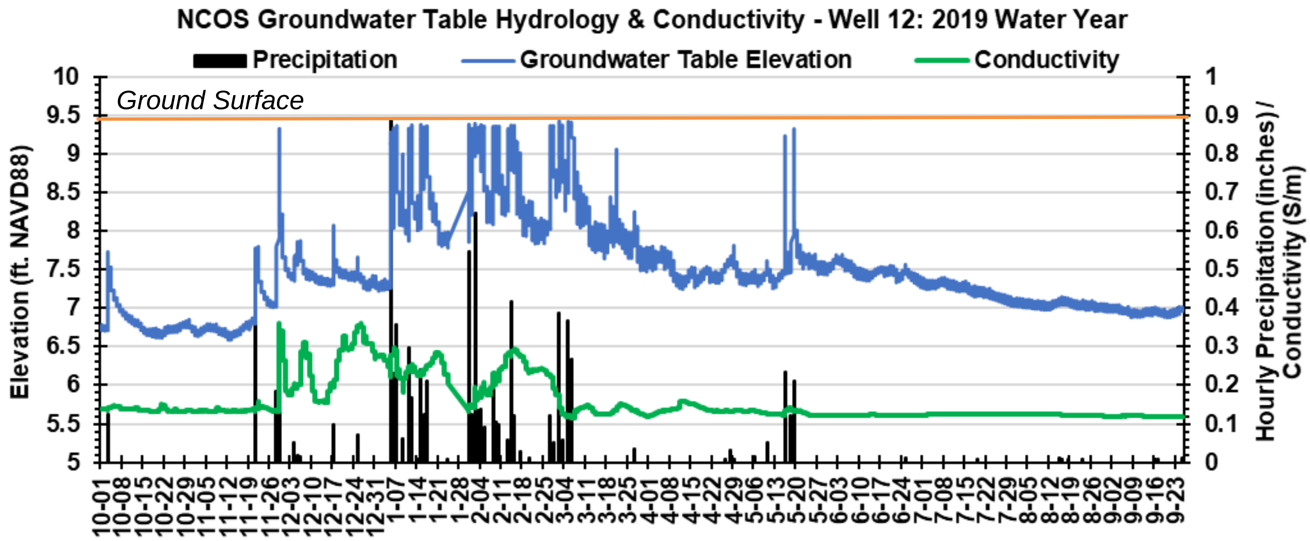


Figure 42. Elevation (feet NAVD88) and conductivity (Siemens per meter, S/m) of groundwater recorded during the 2019 water year with a Levelogger every 15 minutes in index well 12 at the North Campus Open Space project (see Figure 28 for a map including the locations of index wells). The orange line represents the ground surface elevation, thus reflecting that the groundwater frequently reached the surface during high rainfall events. Black bars represent hourly precipitation in inches recorded at a nearby NOAA climate data station.

Wetland Water Quality Monitoring

The enhancement of aquatic habitats and ecological function of Devereux Slough is a key goal of the NCOS restoration project. Monitoring aspects of the water quality of the wetland is one of the ways that CCBER is tracking the progress towards this goal, and this monitoring consists of two components: 1) automated and manual monitoring of dissolved oxygen, salinity, and temperature using various sensors in the restored upper arms and in the existing lower Devereux Slough, and 2) periodic collection and analysis of stormwater samples for concentrations of nutrients and suspended solids as well as other inputs from urban runoff that enters the wetland.

Automated Water Quality Sensor Monitoring

Two types of automated water quality sensors are deployed at three locations in the upper and lower slough. An YSI EXO1 sonde is deployed in the main channel of the lower Devereux Slough, attached to an old bridge structure and set at a fixed depth that ensures the sensors will remain submerged by at least 50 cm at low water levels. The sonde records the following data every 15 minutes: dissolved oxygen (DO, in mg/L and percent saturation), conductivity/salinity (in µS/cm and ppt), temperature (ºC), blue-green algae and chlorophyll (in µg/L), and water depth (feet). The other sensors are Solinst Leveloggers that record conductivity (µS/cm) and temperature along with water depth every 15 minutes. These loggers are deployed on the north side of Venoco Bridge and on the center support of the trail bridge across the restored upper eastern arm of the slough. The Leveloggers sit within a few inches of the bottom or floor of the wetland channel, and their approximate elevation (in feet NAVD88) has been determined from the difference in elevation relative to the nearest reference point (elevations are provided in Table 4). The locations of these sensors, as well as other loggers that record water depth and temperature, are indicated by the yellow diamonds in the map in Figure 28. Under current funding conditions, we will maintain and collect data from these sensors through 2024.

The weekly averages of all parameters recorded by the EXO1 sonde for the 2018 and 2019 water years are plotted in two charts in Figure 43. These two water years were very different in terms of the amount of precipitation (the 2019 water year had twice as much as 2018) and the duration of tidal connectivity of the slough (see Figure 34 and Figure 35), and this difference is reflected in the water quality data. In the 2019 water year, average DO concentrations were greatest from January until mid-April, which is when most of the winter rains fell and the slough was tidal for several weeks. These two factors resulted in a significant decrease in salinity and frequent cycling or movement of water in the slough, both of which tend to increase DO. Conversely, DO concentrations were near zero mg/L during most of the same period in the 2018 water year, and were greatest in December and from May to June, the latter of which followed a drop in salinity and a brief increase in blue-green algae that may have added oxygen to the system. Considering that the sonde is deployed at a fixed depth and that the water in Devereux Slough typically becomes stratified and hypersaline in the late summer and fall, the EXO1 sonde likely sits below the halocline for much of the year, where salinity and water density are greater. This could partly explain the near zero DO levels recorded from July through December 2018. Throughout 2018 and most of 2019, the depth of the sonde equated to an approximate elevation of 1.2 feet above sea level. In late August 2019, the sonde was raised by 2.5 feet in order to reduce the period that the sensors are below the halocline and capture more of the variability in DO. This change in depth is reflected in the greater difference between the water surface elevation and the depth of water above the sensors in the far right of the lower chart in Figure 43.

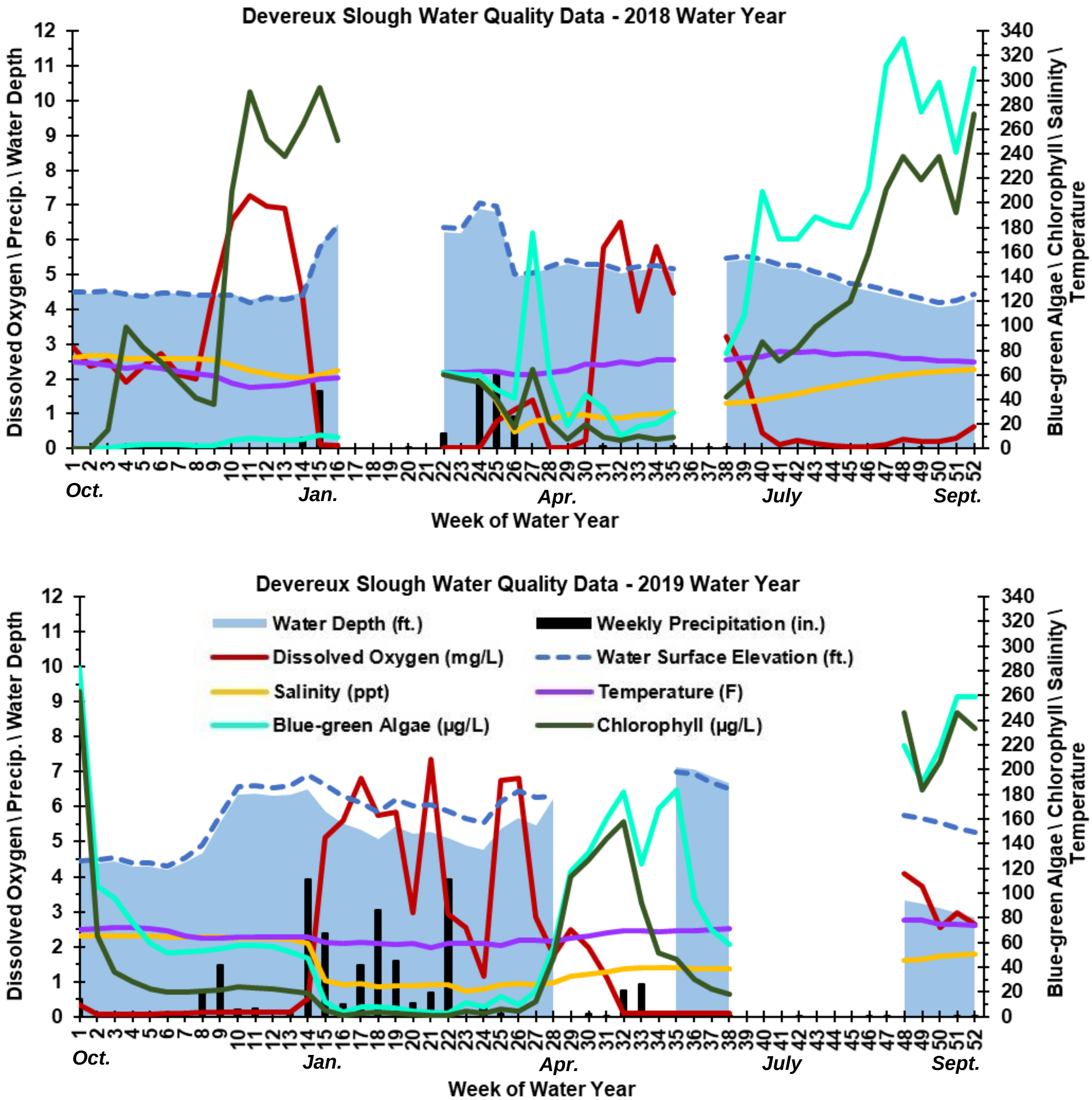


Figure 43. Weekly average water quality data recorded in the 2018 (top chart) and 2019 (bottom) water years (October to September) with a YSI EXO1 sonde in the lower section of Devereux Slough (see map in Figure 28). The sonde also records water depth, which is represented in the charts as the depth of water above the sensors. A dashed blue line indicates the water surface elevation in feet (NAVD 88), determined from comparing staff gauge measurements with the sonde's depth measurements. In August 2019, the fixed position of the sonde was raised by approximately 2.5 ft, which decreased the depth of water above the sensors. Gaps in the data are during periods when the sonde malfunctioned and/or was out for repair. Precipitation data was recorded at a nearby NOAA climate data station.

The Levelogger data from the Venoco Bridge and upper east channel deployment sites are very similar, and in this report, data from the east channel site are presented in Figure 35 as part of the wetland hydrology monitoring discussion.

Water Quality Profile Monitoring

In addition to the automated sensors, dissolved oxygen, salinity and temperature data are collected at three locations in the restored upper slough on a weekly basis. This data is primarily collected by student interns using a portable YSI Pro2030 sensor at the three bridges that cross the upper slough: the Marsh trail bridges over the Phelps Creek outlet and across the east channel, and the Venoco access road bridge (see the turquoise circles in the map in Figure 28). From the bridges, the sensor is lowered to the water and data are recorded at the surface and at each foot of depth. The purpose of this monitoring is to analyze the effects of depth, location and season on these parameters at different locations in the wetland and whether changes arise as the restored wetland develops.

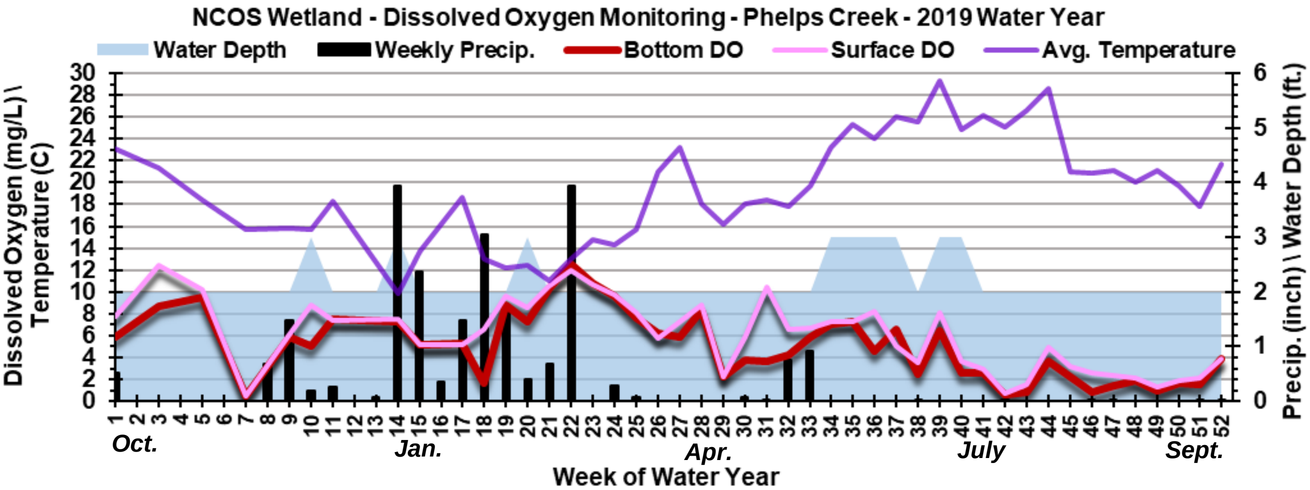
Dissolved oxygen (DO, in mg/L) and salinity (ppt) data for the surface (top 1-foot of depth) and bottom of the water column along with the average temperature (Celsius) at the three sites in the 2019 water year are presented in Figure 44. A few of the key points of interest in this data include:

(1) The fluctuation in DO and salinity that occurred during the 12-week period of frequent rainfall and tidal connectivity (January to April), particularly at the east channel (Figure 45) and Venoco bridge (Figure 46) sites (see also Figure 35).

(2) The two spikes in salinity on weeks 14 and 17 at the Phelps Creek site (Figure 44) suggest that was the first time that sea water infiltrated all the way up the restored upper arms of the slough.

(3) The difference between the surface and bottom DO and salinity is most pronounced at the Venoco bridge site where the water depth is greatest. This is particularly evident after late season rains in May (water year weeks 32 and 33), which caused surface salinity to quickly drop to near zero ppt while bottom salinity did not change.

Despite a couple of potential data entry or sensor errors, DO generally appears to decrease when salinity increases, particularly in the summer and fall when the water levels decline. Overall, DO concentrations remained above 2 mg/L throughout most of the 2019 water year, particularly near the surface, which means that the wetland can support aquatic wildlife year-round.



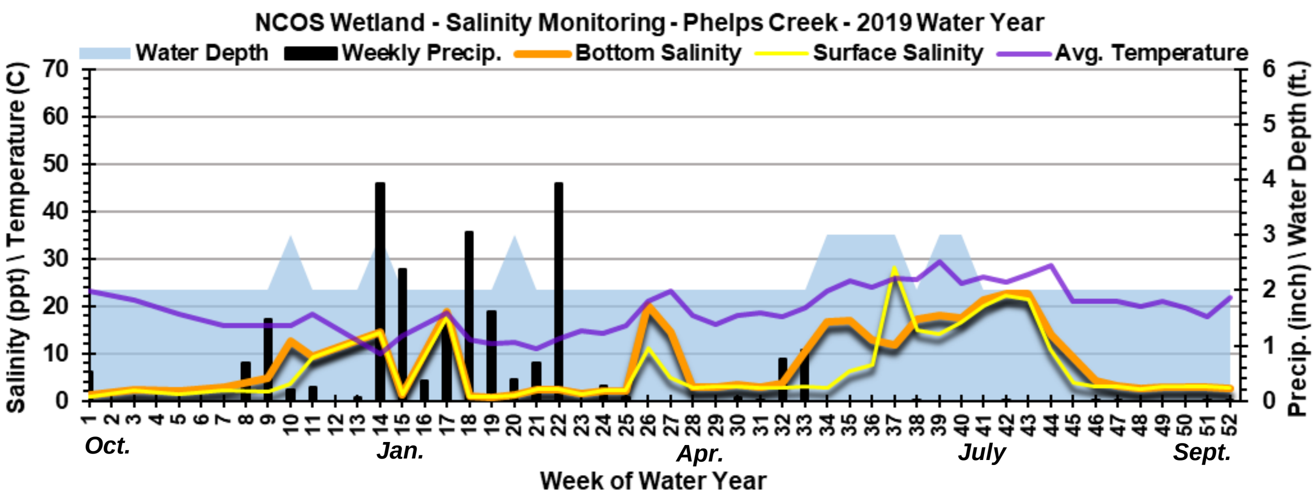
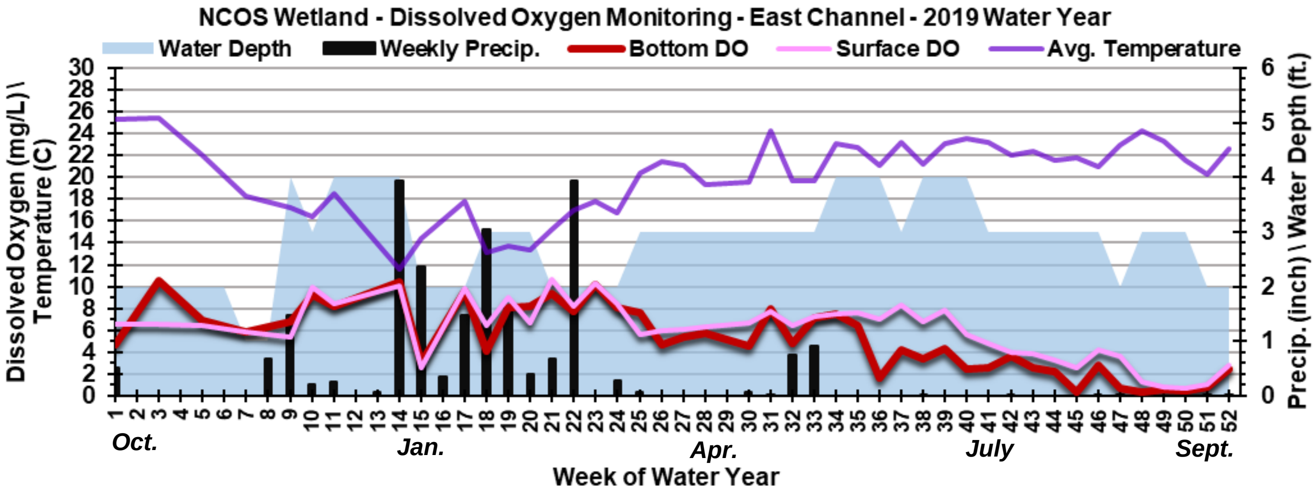


Figure 44. Top chart: Dissolved oxygen (mg/L), and bottom chart: Salinity (ppt) recorded weekly in the 2019 Water Year with a YSI Pro2030 at the surface (top 1-foot of water column) and bottom of the water column at the Phelps Creek outlet into the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) is averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was recorded at a nearby NOAA climate data station. The sampling locations are represented by turquoise circles in the map in <u>Figure 28</u>.



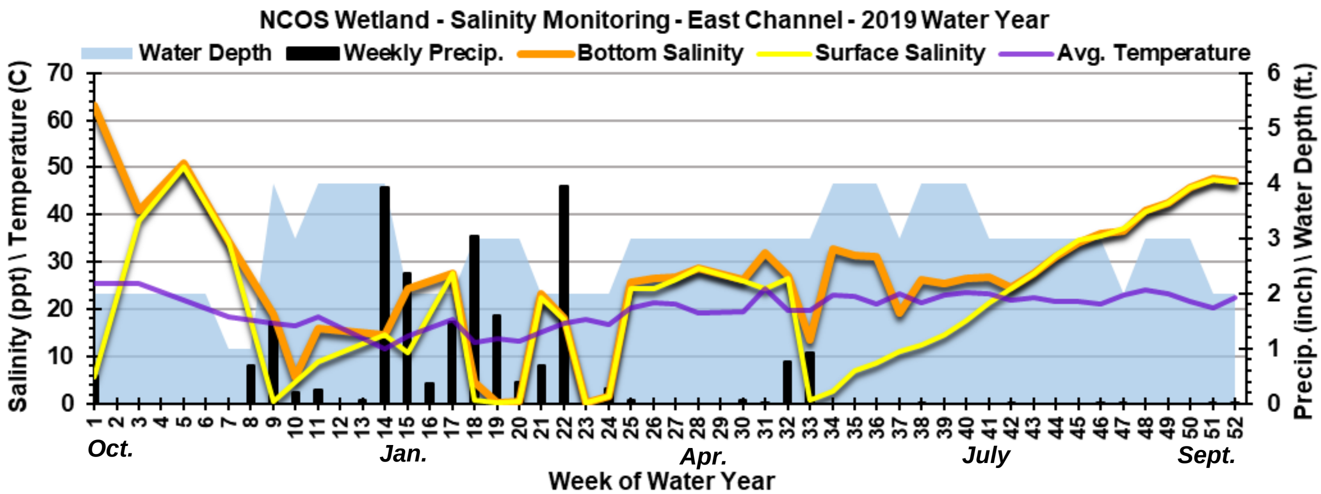


Figure 45. Top chart: Dissolved oxygen (mg/L), and bottom chart: Salinity (ppt) recorded weekly in the 2019 Water Year with a YSI Pro2030 at the surface (top 1-foot of water column) and bottom of the water column in the east channel of the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) is averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was recorded at a nearby NOAA climate data station. The sampling locations are represented by turquoise circles in the map in Figure 28.

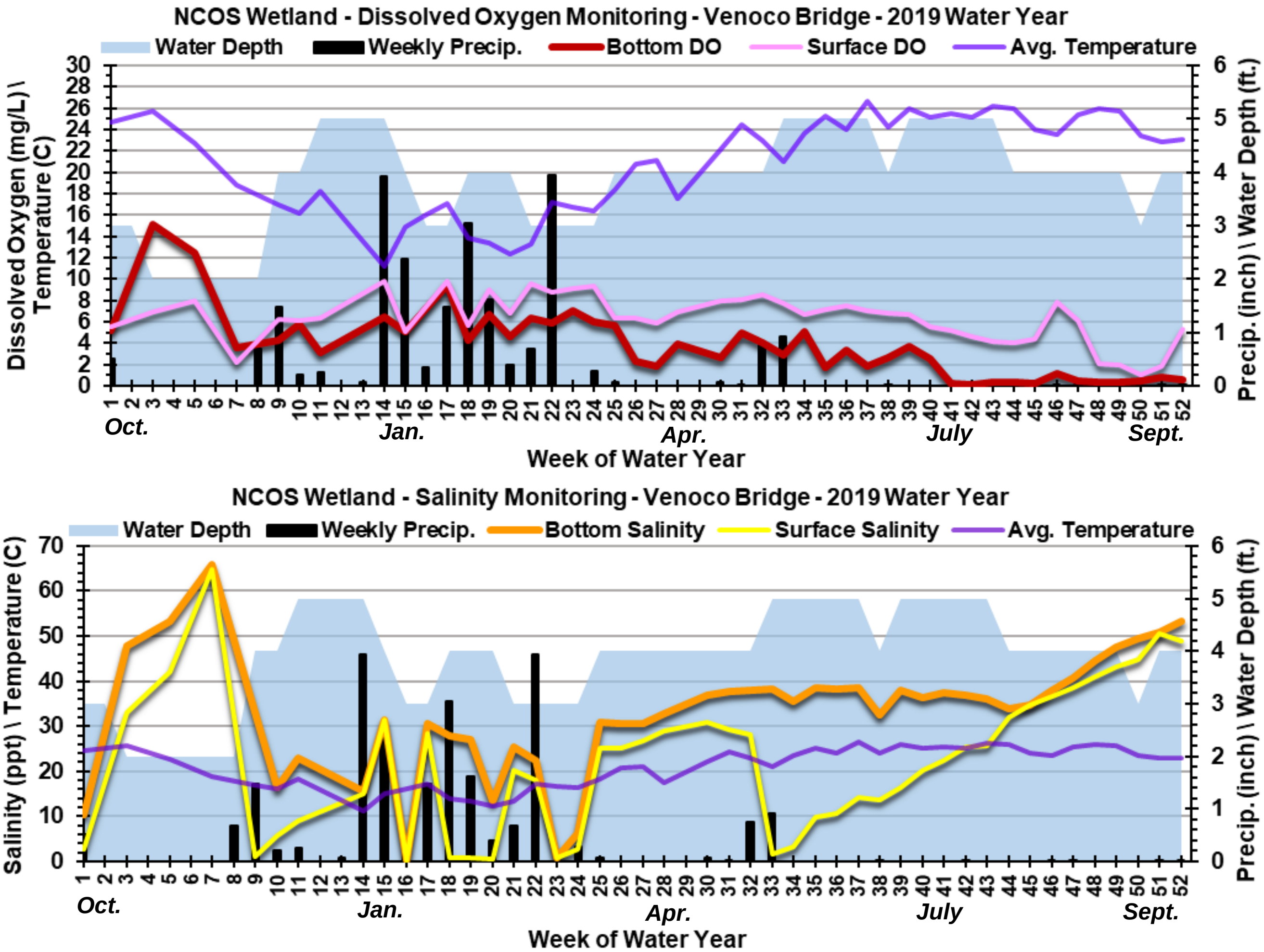


Figure 46. Top chart: Dissolved oxygen (mg/L), and bottom chart: Salinity (ppt) recorded weekly in the 2019 Water Year with a YSI Pro2030 at the surface (top 1-foot of water column) and bottom of the water column in the main channel of the upper Devereux Slough at the Venoco access road bridge, North Campus Open Space. The temperature (Celsius – purple line) is averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was recorded at a nearby NOAA climate data station. The sampling locations are represented by turquoise circles in the map in Figure 28.

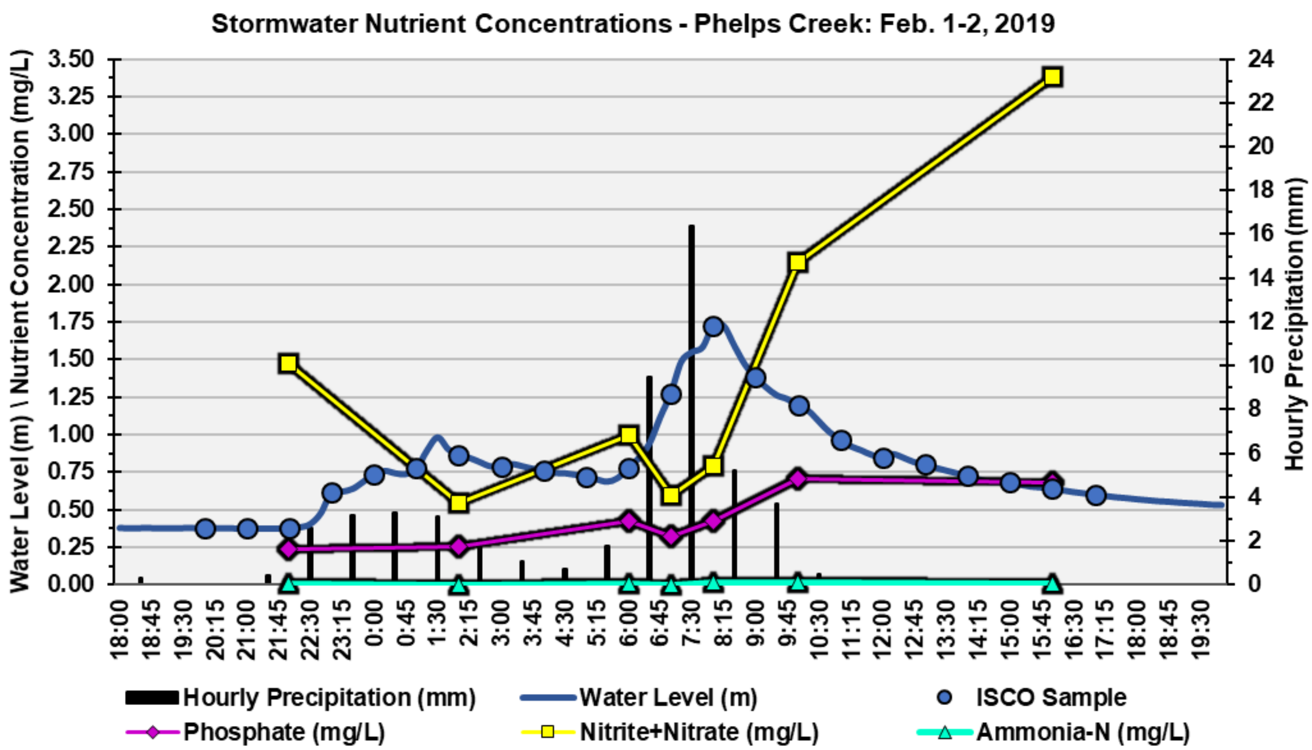
Sampling and Analysis of Constituents in Stormwater

In an effort to document and understand the nature and potential impacts of components in urban runoff, particularly nutrients and suspended solids, CCBER has conducted periodic sampling and analysis of stormwater that enters the main tributaries of NCOS and the upper Devereux Slough.

In 2016, grab samples of pre-project stormwater and baseline flows were collected and analyzed for inorganic nutrients (nitrate+nitrite, orthophosphate, and the ammonium portion of dissolved inorganic nitrogen). These samples demonstrated the likelihood of a flux of inorganic nutrients, particularly nitrogen and phosphate, in the tributaries that enter NCOS and Devereux Slough, especially during the first major storm of the season. This study along with other pre-project water quality data and analyses are discussed in detail in the report, "Water Quality of North Campus Open Space & Devereux Slough: Fall 2015 – Spring 2016", available on eScholarship.

Following the completion of the wetland grading, grab samples were collected at four locations (the red triangles in Figure 28) during two major storms in 2018 for the analysis of dissolved inorganic nutrients, total suspended solids, and oil and grease concentrations. Results of these analyses demonstrated trends for inorganic nutrients similar to the pre-project study in 2016. Concentrations of these nutrients tended to decrease downstream, as suggested by the lower concentrations detected at the Venoco Bridge sampling site. Ammonia and Oil and Grease concentrations in the samples collected were below levels of concern. The concentration of suspended solids increased downstream, with the greatest concentration detected at Venoco Bridge.

However, these were single grab samples from only two storms, which do not provide much information. Therefore, beginning with the winter rain season of 2019, ISCO samplers provided by a UCSB faculty member were installed at the Phelps Creek, Whittier Channel (near the storm drain outflow) and Venoco Bridge locations. The ISCO samplers are programmed to automatically collect samples at a set interval (*e.g*. once per hour) throughout a storm, which allows for more detailed analysis of the flux of nutrients and suspended solids that enter the wetland system during different storm events. We were able to run the ISCO samplers during three storms in 2019. Preliminary analysis of the samples collected showed an initial decrease in nutrient concentrations during a stormwater flow, followed by a noticeable increase, particularly for nitrogen. Concentrations of nitrogen appeared to be greatest in Phelps Creek, but did not decrease much downstream at Venoco Bridge. In Phelps Creek and the Whittier Channel, suspended solid concentrations were generally low at the start of a storm, then increased after the heaviest rainfall. This tended to be opposite at Venoco Bridge, where solids concentrations were often greatest before a storm, decreasing noticeably as stormwater runoff infiltrated and displaced the more saline water in the system (as indicated by quick, significant declines in conductivity). This inverse pattern in suspended solids in the middle of the slough may have been due to the suspension of sediments caused by significant tidal motion that occurred throughout the slough during much of the winter in 2019 (see Figure 35). Data collected during a storm on February 1st and 2nd are plotted in the charts in Figure 47. We will continue this study of stormwater using the ISCO samplers in 2020, and supplement with the analysis of grab samples of baseline flows.



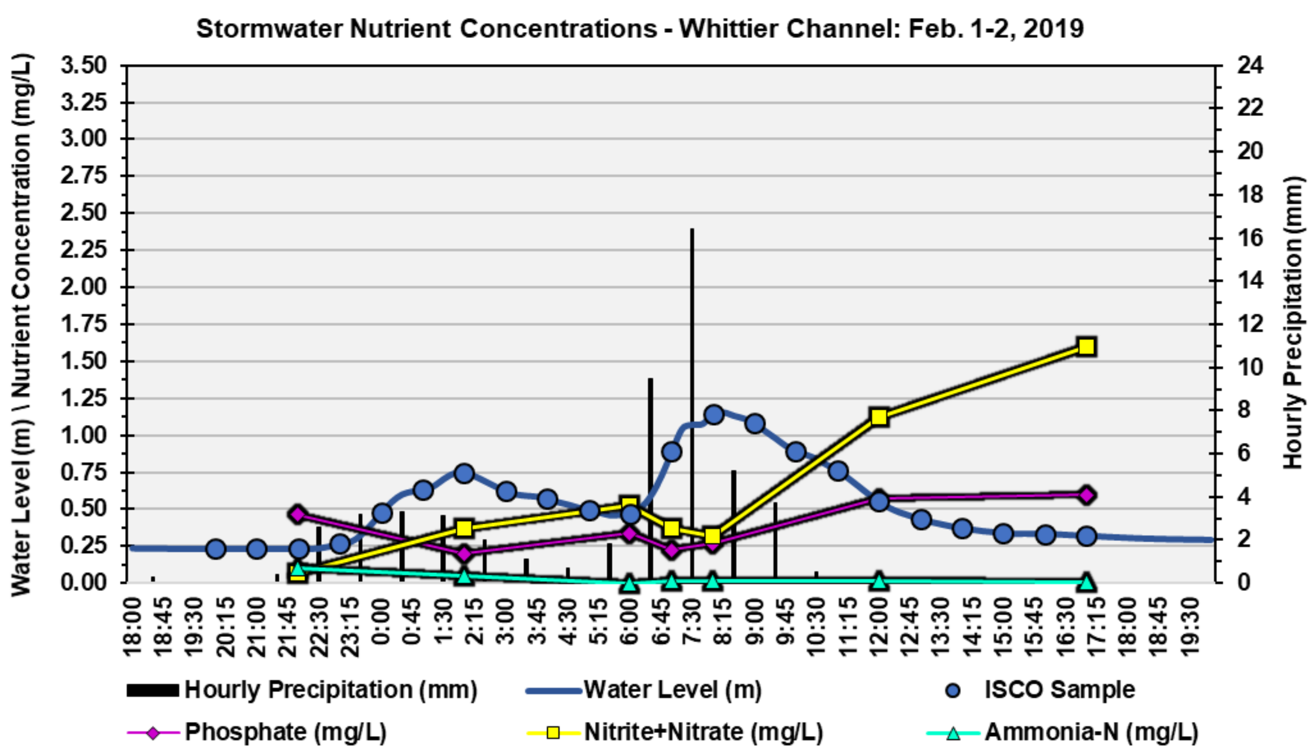
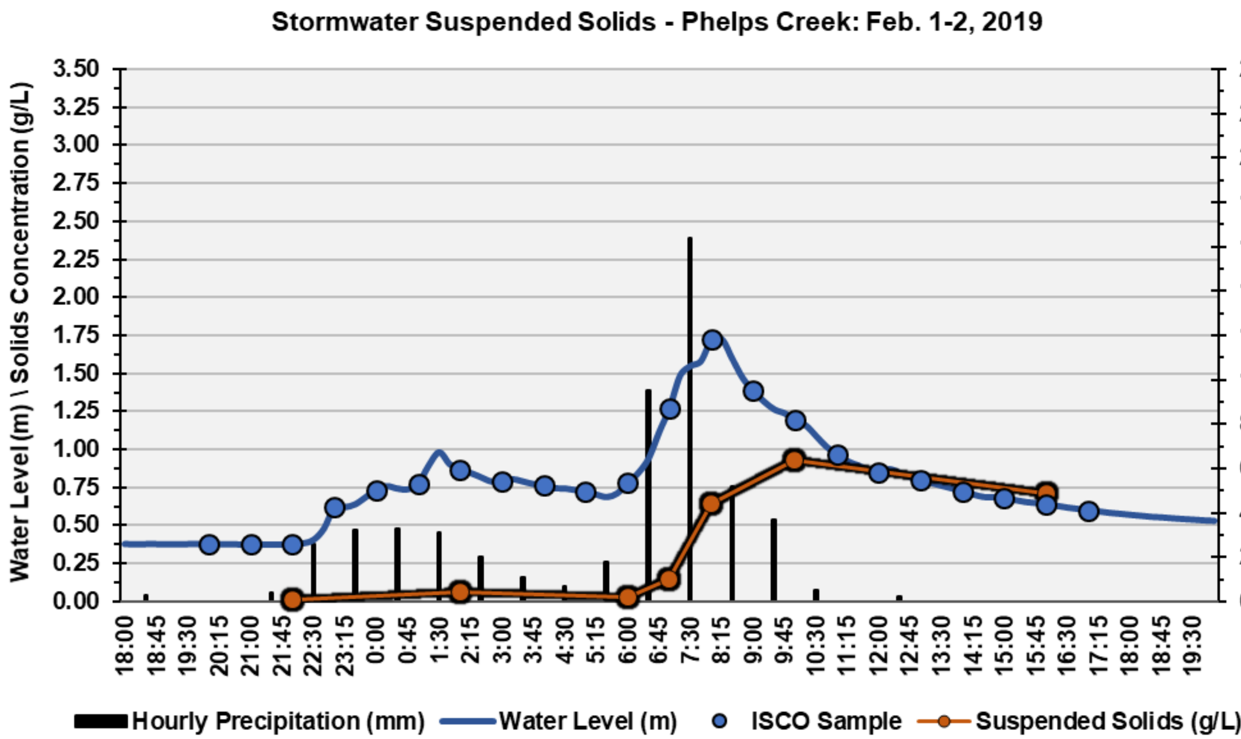


Figure 47. Concentration (mg/L) of inorganic nitrogen (nitrate+nitrite), phosphate, and ammonium (from nitrogen) in stormwater samples collected hourly (blue circles) with an ISCO auto-sampler during a storm on February 1st and 2nd, 2019 at Phelps Creek (top chart) and Whittier Channel (bottom chart) at North Campus Open Space. Note that selected samples were analyzed. Precipitation data was recorded at a nearby NOAA climate data station.



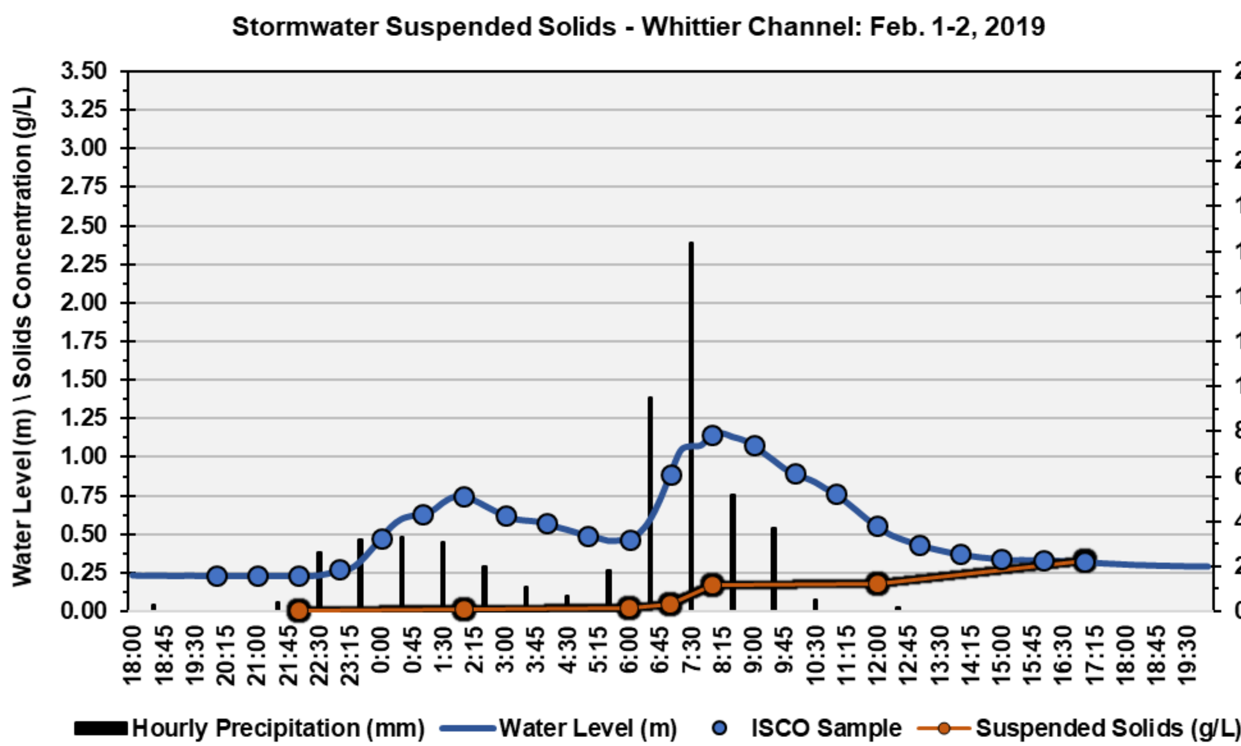
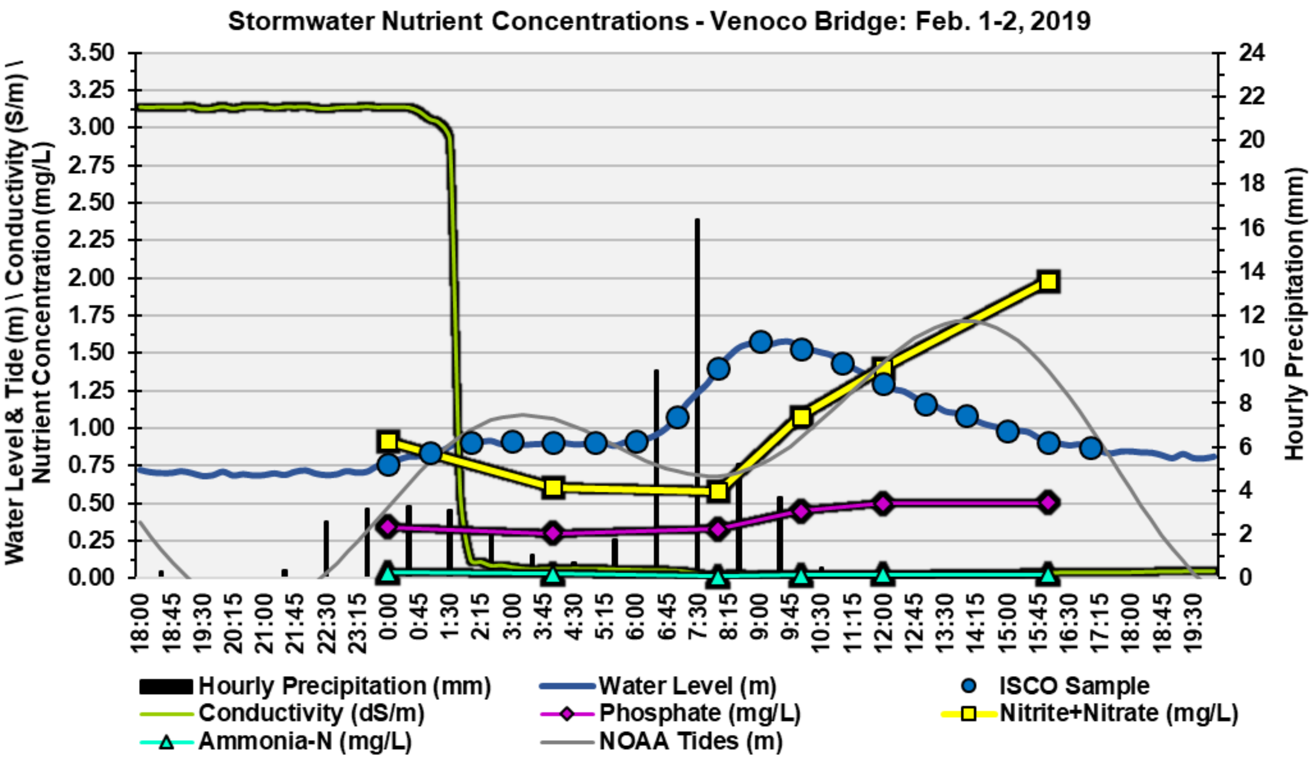


Figure 48. Suspended solids concentrations (g/L) in stormwater samples collected hourly (blue circles) with an ISCO auto-sampler during a storm on February 1st to 2nd, 2019 at Phelps Creek (top chart) and the Whittier Channel (bottom chart) at North Campus Open Space. Note that selected samples were analyzed. Precipitation data was recorded at a nearby NOAA climate data station.



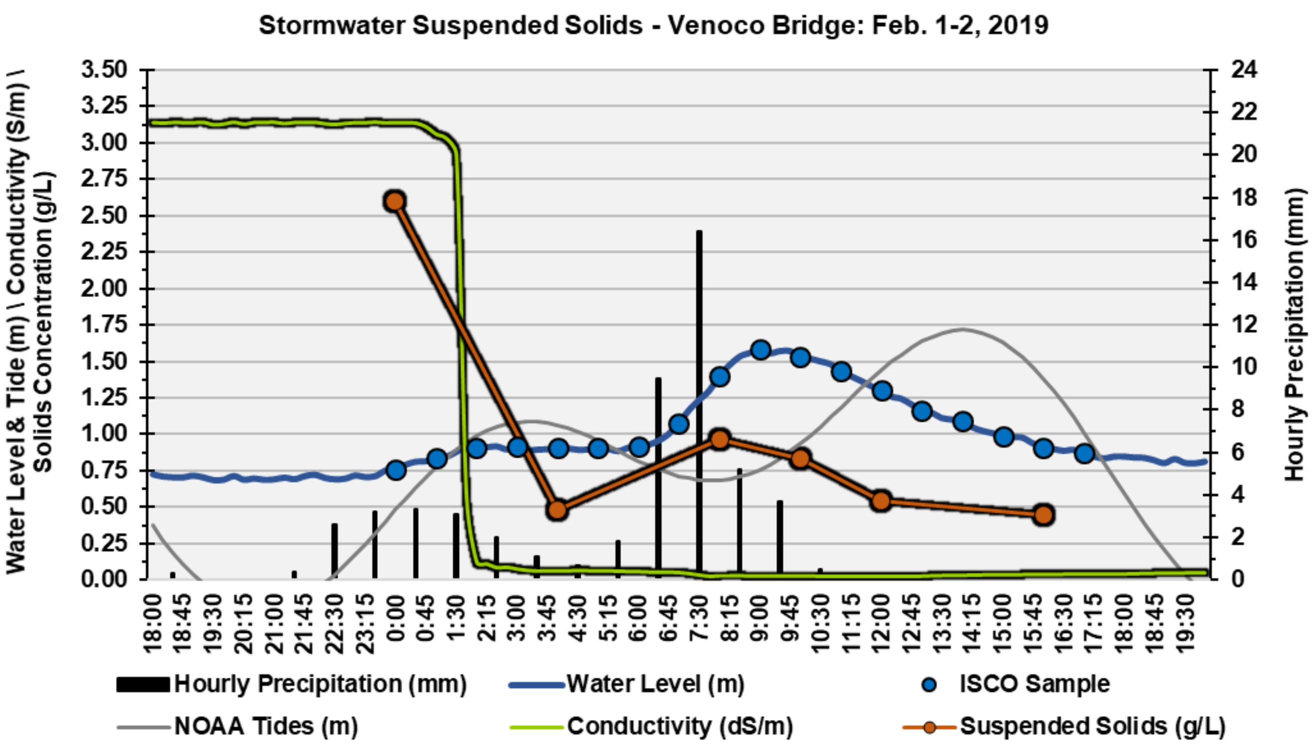


Figure 49. Top chart: inorganic nitrogen (nitrate+nitrite), phosphate, and ammonium (from nitrogen) concentrations (mg/L), and (bottom chart) suspended solids concentration (g/L) in stormwater samples collected hourly (blue circles) with an ISCO auto-sampler during a storm on February 1st to 2nd, 2019 at Venoco Bridge, North Campus Open Space. The conductivity (in Siemens/meter) indicates when freshwater from storm flows reached the sampler. Precipitation data was recorded at a nearby NOAA climate data station.

6. SEDIMENT ACCRETION, CARBON SEQUESTRATION & RELATED RESEARCH

Long-term monitoring and research projects related to the rates of sediment accretion and carbon sequestration in the restored salt marsh and perennial grassland were initiated in 2018 and are described below. In addition, an assessment of the contribution of the restoration project to carbon emissions was completed in 2018, and a study by a UCSB graduate student on the greenhouse gas fluxes of the restored salt marsh began in 2019.

To study sediment accretion rates in the restored salt marsh areas of NCOS and in the existing salt marsh of the lower Devereux Slough, we established fifty 2500 cm^2 (2.7 ft^2) plots with a 1-cm (0.4-inch) thick layer of feldspar stratified across four elevations (6.5, 7.0, 7.5, and 8.0 feet) at six locations in NCOS and five in the lower slough. In addition, three control plots were established in two areas of NCOS that were not disturbed as part of the restoration project (see map in Figure 50). Baseline soil cores/profiles were collected near each of the six sets of feldspar plots in NCOS. The feldspar plots in the lower slough were established near locations where soil cores were collected in 2015. These cores have been analyzed for the presence of Cesium-137 and Lead isotopes in 2-cm (0.8-inch) slices to a depth of 45-cm (1.5 feet) in order to determine the date and percent carbon of each slice and to integrate accretion rates with carbon sequestration rates. Soil cores will be extracted from the feldspar plots at five and ten years following project inception to assess sediment accretion rates based on the depth of soil above the white feldspar marker.

Soil carbon sequestration within the native perennial grassland is being assessed in three 50-by-200-foot experimental plots established on the upland mesa of NCOS where the soil excavated for the wetland was deposited (see map in Figure 50). These plots are divided into eight sub-plots with different combinations of biochar and compost incorporated into the top 18 inches of the soil in two layers (at the surface and below 12 inches). The growth of two grass species in each plot is being monitored, and the analysis of several baseline characteristics of the soil (*e.g.* percent moisture, salinity/electrical conductivity, carbon content) is in process. We anticipate the analysis of data collected from the first set of soil and grass samples to be completed by the end of 2020.

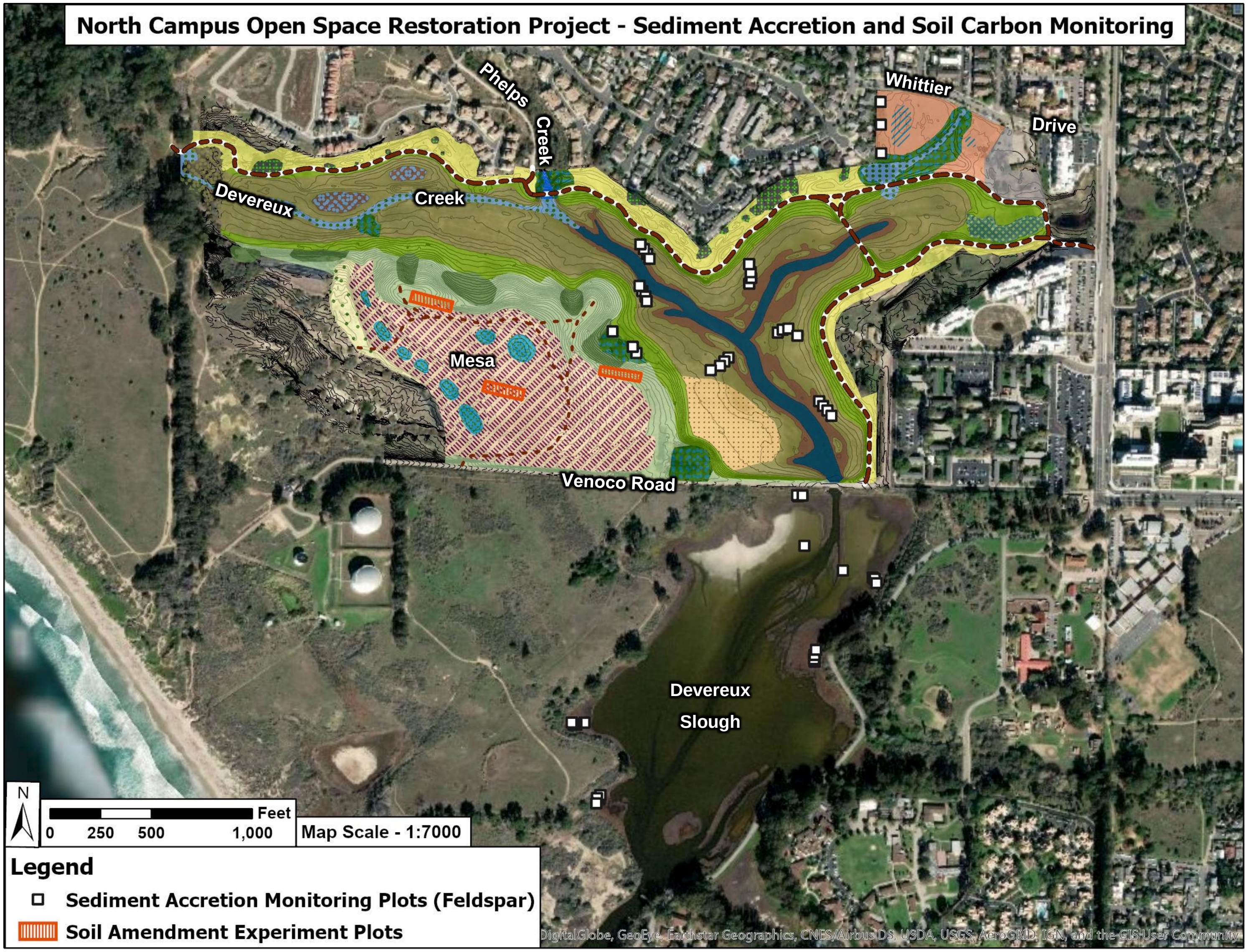


Figure 50. Map of the feldspar plots for monitoring sediment accretion in the salt marsh areas of NCOS and Devereux Slough, and the upland experimental carbon sequestration plots on the NCOS mesa. See Figure 1 for a map and legend of all habitats/vegetation communities.

7. COMMUNITY USE & PERCEPTION

An opportunity and a challenge with any restoration project in an open space area is to balance public use and educational benefits with impacts to plants and wildlife (*e.g.* arising from off-trail and off-leash dog use). CCBER is tracking the beneficial uses of NCOS for the local community by documenting activities by volunteers, undergraduate student restoration workers and research interns, community tours, and K-12 school visits to the site. In 2019, NCOS was visited by more than 1,200 K-12 students for focused educational trips, and since the start of the project more than 30 students have participated in or are leading research projects at NCOS, ranging from soil carbon studies, wetland greenhouse gas fluxes, aquatic invertebrate and water quality studies and wildlife use of the habitat. Details on the participation and contribution of volunteers and students to the restoration project are described in the following section of this report.

In 2019 two community use and one community perceptions survey were conducted at NCOS. The goal of this work was to characterize how the Marsh Trail is being used and how users perceive the project as it has progressed and become accessible. These data will be used to assess the potential impacts to ecological restoration goals and to determine if more education (*e.g*. signage or outreach programs), fencing or enforcement is required to preserve the natural functions of the site. For the community use surveys we specifically observed age group, purpose of use (exercise, transit, bird watching, other), and whether dogs were on-leash. The perceptions survey was designed to assess how well users understood the goals of the project, if they viewed the project positively or negatively, and whether they thought communication about the project was sufficient.

Community use surveys were conducted in February and August, which are both periods of reduced use because of the typically inclement weather in February and the lack of students on campus in August. Over the course of 3 weeks, CCBER staff and student intern observers were stationed by the three primary entry areas to NCOS: Phelps Creek/Western arm, the Venoco access road entry at the southeast corner, and the Eastern Arm/Whittier Drive entry. We conducted 30-minute observation periods that were stratified across morning (7-10 am), midday (11-2pm) and afternoon (3-6pm) periods, and by weekday or weekend so that we had at least three observation periods per time frame and day type (weekend versus weekday).

We observed similar, consistent levels of use during the February and August surveys, and the level of use on weekends was not significantly different than on weekdays. Overall, we observed an average of 15-25 users per hour, and of the 424 people observed, 72% were adults, 18% college students and 1% were children. The majority of users were exercising (37%) or walking (25%), with an additional 20% walking their dogs. There were also birdwatchers (2%) and commuters (12%). A quarter of all users rode bikes. Of the dog walkers, 85% had their dog(s) on a leash during the August survey, which was a slight increase from 81% in the February survey. For the August survey, we sought to investigate the extent to which the site is serving community members of Hispanic or Latino descent. We found that this group accounted for 17% of users and had a greater proportion of children (5%) than the average of 1% observed for all users. As one would expect, more people used the site during sunny weather. In 2020, we will conduct one use survey in early May and/or mid-October to see if more favorable weather and a greater presence of students on campus results in a greater number of users and activity on the site.

The community perceptions survey was conducted in the spring of 2019 and included in-person interviews and an online survey. The interviews were conducted by going door-to-door in the neighborhoods adjacent to NCOS and with willing trail users. We interviewed 20 local residents/trail users and received more than 200 responses to the online survey. Overall, most respondents who expressed a positive attitude about the project or had developed a positive attitude over the course of the restoration did so because they understood the goals of the project. Respondents who were less informed tended to be less likely to have a positive attitude about the project (approximately 4% of survey respondents). We found that those who were most informed about the project had subscribed to our monthly NCOS email newsletter, which includes updates on the project and a range of photos of activities and wildlife. The newsletter usually includes an educational component to the stories regarding, for example, the importance of keeping dogs on leash or details about vector control, restoration activities and weed control strategies. We learned that we should endeavor to increase coverage of the project on the radio, local news blogs and the newspaper. We have reached out to some of those entities but have not been contacted for stories recently, and we have also not determined that there is a need at this time to purchase coverage such as a public service announcement.

8. CHARACTERIZATION OF PROJECT EFFORT

When restoration planting and maintenance began at the NCOS project in the fall of 2017, we developed methods for workers to track the hours they spent on different tasks and at different areas of the project site using the ESRI app, Survey123. This includes recording the number of students and volunteers and the total hours they worked on tasks such as planting or weeding. The data for 2018 and 2019 are summarized below by worker type, general task, and project site location or zone (a map of the zones is provided in Figure 54).

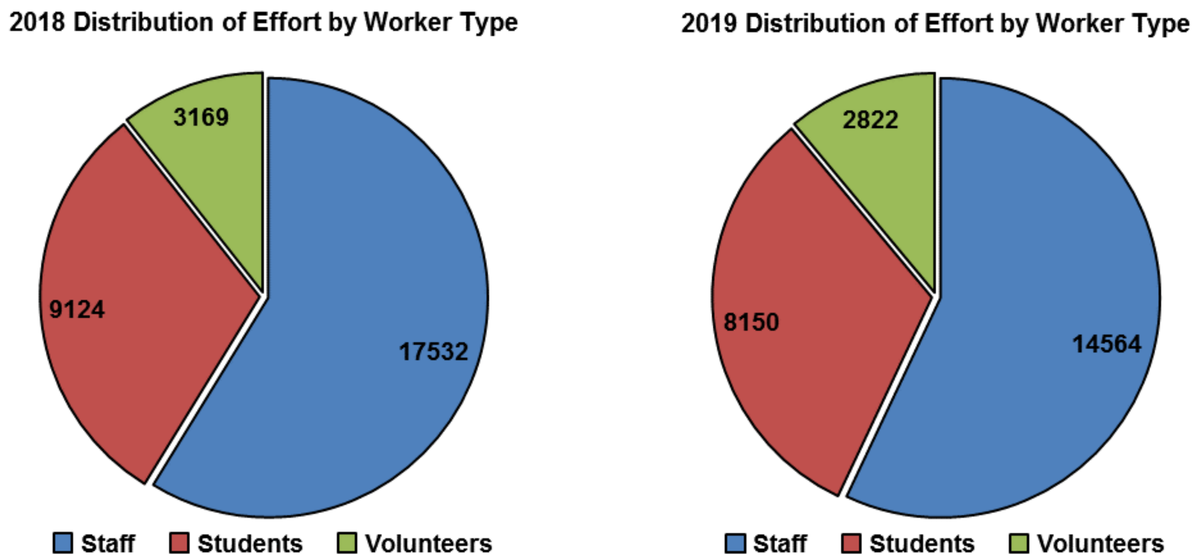


Figure 51. Pie charts of the distribution of effort (hours of work) for the NCOS project by worker type in 2018 and 2019. Students includes both paid workers and interns. The total number of hours for each group are displayed on the chart.

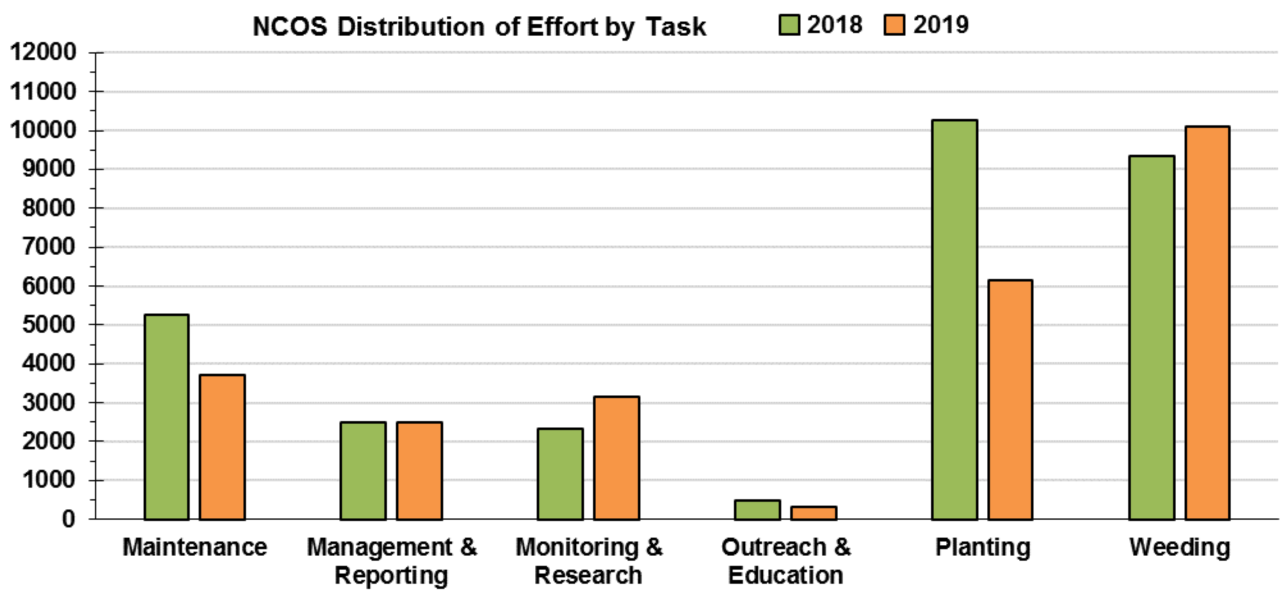


Figure 52. Chart of the distribution of effort (hours of work) for the NCOS project by task in 2018 and 2019.

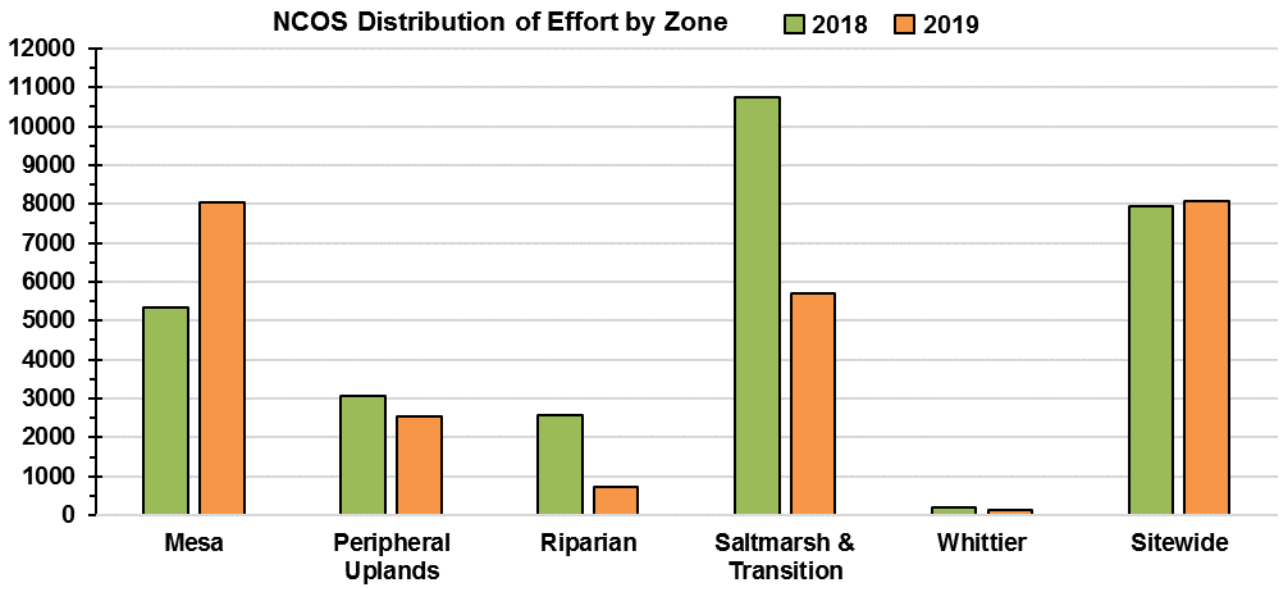


Figure 53. Chart of the distribution of effort (hours of work) for the NCOS project by site location or zone in 2018 and 2019. The Sitewide category contains most efforts in the Maintenance, Management & Reporting, Monitoring & Research and Outreach & Education task groups (plotted in Figure 52).

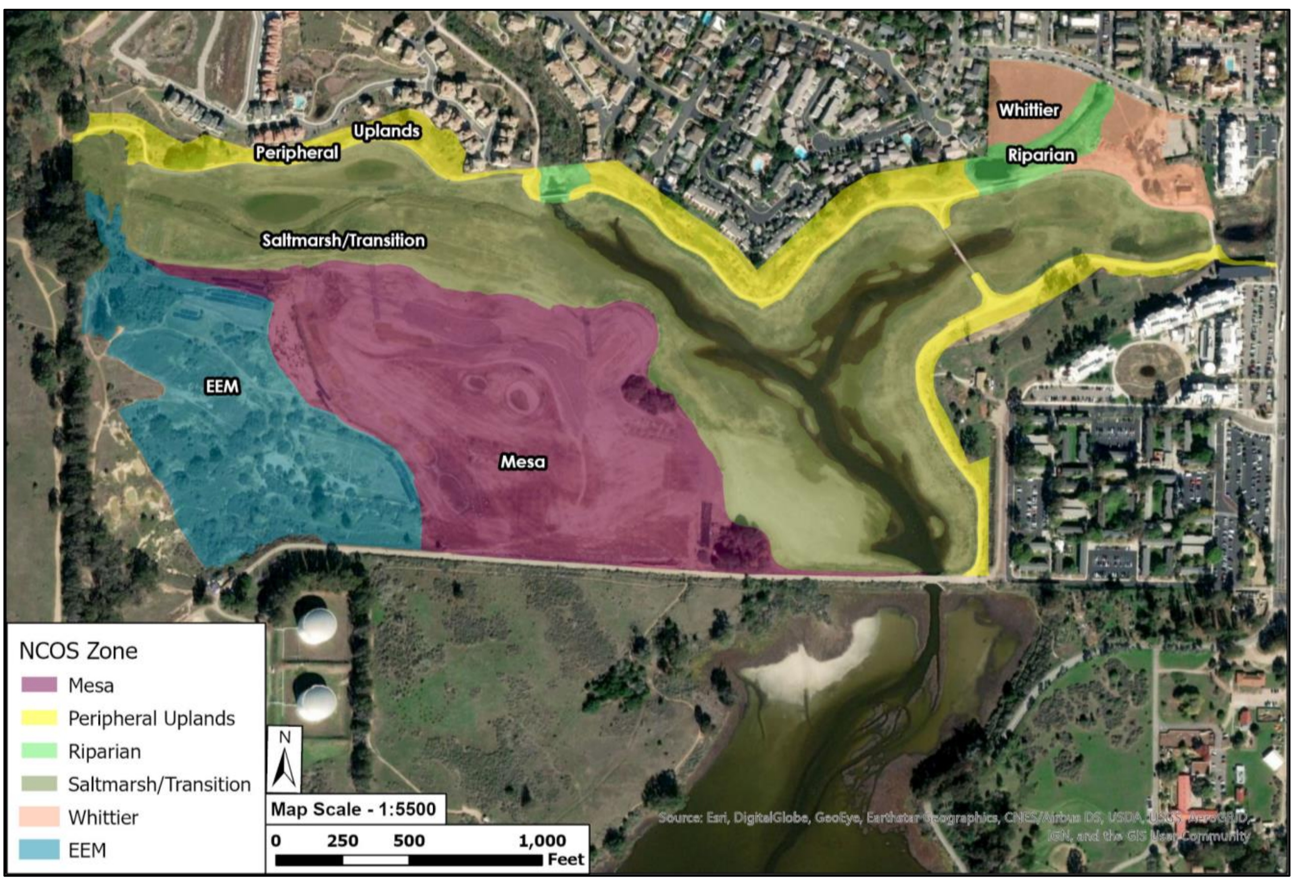


Figure 54. Map of the general zones at the North Campus Open Space (NCOS) restoration project. The EEM zone refers to the area being restored under the California Natural Resources Agency's Environmental Enhancement & Mitigation grant program.

APPENDIX 1 – VEGETATION MONITORING PLANT SPECIES LISTS

The native and non-native species recorded during the second year (2019) of vegetation monitoring at the North Campus Open Space project are listed in the tables below, beginning with the native species. For each species, an ‘x’ in a column corresponding to a habitat/plant community type indicates the species’ presence in that habitat.

Native Species	**Native Grassland**	**Peripheral Upland Mosaic**	**Sand Flat**	**Sandy Annuals**	**Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Salt Marsh**	**Seasonal Brackish Marsh**	**Seasonal Freshwater Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**New Riparian**	**Existing Riparian**
Acmispon maritimus	x										x		
Alnus rhombifolia													x
Ambrosia psilostachya	x	x		x		x							
Artemisia californica		x											
Arthrocnemum subterminale					x								
Atriplex lentiformis		x				x						x	
Baccharis glutinosa												x	
Baccharis pilularis	x	x			x	x				x			
Bolboschoenus maritimus					x			x	x	x			
Brickellia sp.										x			
Bromus carinatus		x											
Centromadia parryi australis		x											
Cressa truxillensis							x						
Cyperus eragrostis	x	x				x		x		x			
Datura wrightii		x											
Deinandra fasciculata	x	x				x				x			
Distichlis littoralis					x	x			x				
Distichlis spicata	x	x			x	x	x	x					
Eleocharis acicularis		x								x			
Eleocharis macrostachya	x	x					x	x		x			
Elymus condensatus		x											
Elymus glaucus		x									x		
Elymus triticoides		x			x	x							
Encelia californica						x							
Epilobium brachycarpum	x	x		x		x		x		x			

Native Species	Native Grassland	Peripheral Upland Mosaic	Sand Flat	Sandy Annuals	Salt Marsh	Transition/High Salt Marsh	Remnant Salt Marsh	Seasonal Brackish Marsh	Seasonal Freshwater Pond	Vernal Pools	Coastal Sage Scrub Mosaic	New Riparian	Existing Riparian
Epilobium canum		x											
Epilobium ciliatum		x		x									
Erigeron canadensis	x	x		x	x	x				x		x	x
Eriogonum parvifolium		x											
Eryngium vaseyi										x			
Euphorbia serpens		x				x				x			
Extriplex californica					x	x							
Frankenia salina					x	x	x						
Grindelia camporum										x			
Heterotheca grandiflora	x	x		x						x			
Hordeum brachyantherum					x		x			x			
Hordeum brachyantherum brachy.	x	x								x			
Isocoma menziesii	x	x				x							
Isolepis cernua		x											
Jaumea carnosa					x				x				
Juncus bufonius	x	x				x			x	x			
Juncus mexicanus										x			
Juncus occidentalis		x											
Juncus phaeocephalus		x											
Laennecia coulteri	x	x				x				x			
Lepidium nitidum		x											
Lupinus bicolor				x									
Lupinus succulentus		x								x			
Persicaria lapathafolia		x						x					
Phalaris lemmonii										x			
Plagiobothrys undulatus										x			
Plantago erecta		x											
Platanus racemosa												x	
Populus trichocarpa													x
Psilocarphus brevissimus	x	x								x			
Quercus agrifolia											x		x
Salicornia pacifica			x		x	x	x	x	x				

Native Species	Native Grassland	Peripheral Upland Mosaic	Sand Flat	Sandy Annuals	Salt Marsh	Transition/High Salt Marsh	Remnant Salt Marsh	Seasonal Brackish Marsh	Seasonal Freshwater Pond	Vernal Pools	Coastal Sage Scrub Mosaic	New Riparian	Existing Riparian
Salix exigua												x	
Salix lasiolepis		x								x			x
Salvia leucophylla		x											
Schoenoplectus californicus					x				x	x			x
Sisyrinchium bellum		x								x			
Solanum douglasii		x		x		x							
Stebbinsoseris heterocarpa	x												
Stipa pulchra	x	x								x			
Suaeda taxifolia						x							
Symphyotrichum chilense						x							
Symphyotrichum subulatum	x	x	x		x	x		x	x	x		x	
Typha latifolia										x			
Xanthium strumarium					x		x	x					

Non-Native Species	**Native Grassland**	**Peripheral Upland Mosaic**	**Sand Flat**	**Sandy Annuals**	**Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Salt Marsh**	**Seasonal Brackish Marsh**	**Seasonal Freshwater Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**New Riparian**	**Existing Riparian**
Aegilops cylindrica	x	x		x					x				
Araujia sericifera	x												
Atriplex prostrata		x		x	x		x	x	x				
Atriplex semibaccata		x		x									
Avena fatua	x	x				x			x	x	x		
Bassia hyssopifolia		x											
Brachypodium distachyon	x	x				x			x	x			
Bromus catharticus	x	x		x					x				
Bromus diandrus	x	x				x	x		x	x	x		
Bromus hordeaceus	x	x							x	x			
Capsella bursa-pastoris		x		x									
Centaurium erythraea										x			
Chenopodium album		x											
Chenopodium murale					x			x					
Convolvulus arvensis		x											
Cortaderia selloana													x
Cotula coronopifolia				x			x						
Crypsis schoenoides				x				x		x			
Cynodon dactylon		x		x			x		x				
Dichondra mycrantha	x	x											
Dysphania ambrosioides		x											
Erigeron bonariensis		x		x					x			x	
Erodium botrys	x		x			x				x			
Erodium cicutarium	x	x				x							
Eucalyptus globulus		x											
Festuca bromoides		x								x			
Festuca myuros	x	x		x		x			x	x			
Festuca perennis	x	x	x	x			x		x	x			
Geranium dissectum	x	x				x				x			
Helminthotheca echioides	x	x	x	x			x		x	x		x	
Hirschfeldia incana	x												
Hordeum marinum				x					x	x			

Non-Native Species	**Native Grassland**	**Peripheral Upland Mosaic**	**Sand Flat**	**Sandy Annuals**	**Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Salt Marsh**	**Seasonal Brackish Marsh**	**Seasonal Freshwater Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**New Riparian**	**Existing Riparian**
Hordeum murinum	x	x		x					x				
Hypochaeris glabra	x					x				x			
Lactuca serriola		x							x	x			
Lepidium didymum		x											
Logfia gallica		x				x							
Lotus corniculatus									x				
Lysimachia arvensis	x	x		x		x			x	x			x
Lythrum hyssopifolia	x	x								x			
Malva parviflora	x	x							x	x			
Medicago lupulina		x											
Medicago polymorpha	x	x				x			x	x	x	x	
Melilotus albus					x								
Melilotus indicus	x	x		x	x	x			x	x	x	x	
Parapholis incurva	x	x		x	x				x	x			
Paspalum dilatatum		x							x				
Pennisetum clandestinum		x							x				
Pinus pinea		x											x
Plantago coronopus	x	x		x			x	x	x	x			
Plantago lanceolata	x	x							x	x			
Plantago major		x											
Poa annua		x											
Polygonum aviculare depressum	x	x		x	x		x		x	x		x	
Polypogon interruptus										x			
Polypogon monspeliensis		x		x			x		x	x			
Polypogon viridis										x			
Pseudognaphalium luteoalbum	x	x					x		x				
Raphanus sativus			x										
Rumex crispus	x	x	x								x		
Salsola tragus	x	x		x									
Senecio vulgaris		x											
Sonchus asper	x									x			
Sonchus oleraceus	x	x								x			

Non-Native Species	**Native Grassland**	**Peripheral Upland Mosaic**	**Sand Flat**	**Sandy Annuals**	**Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Salt Marsh**	**Seasonal Brackish Marsh**	**Seasonal Freshwater Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**New Riparian**	**Existing Riparian**
Spergularia bocconi		x											
Stipa miliacea		x								x			
Tamarix ramosissima										x			
Taraxacum officinale		x											
Trifolium hirtum		x		x					x	x			
Trifolium repens		x											
Vicia sativa	x	x				x				x			
Washingtonia robusta		x											
Zeltnera muehlenbergii		x											

APPENDIX 2 – BIRD SURVEY SPECIES LIST

List of all bird species and the total number of individuals of each species observed in the first (September 2017 – August 2018) and second (September 2018 – August 2019) years of monthly bird surveys at the North Campus Open Space restoration project. The species are grouped by guild.

Guild & Common Name	Year 1 Total Count (Sept. 2017 - Aug. 2018)	Year 2 Total Count (Sept. 2018 - Aug. 2019)
CORMORANTS AND ANHINGAS	**1**	**4**
Double-crested Cormorant	1	4
GULLS, TERNS, AND SKIMMERS	**99**	**161**
California Gull	12	16
Mew Gull		22
Ring-billed Gull	36	16
Western Gull	51	107
HERONS, EGRETS, IBIS, AND ALLIES	**110**	**46**
Black-crowned Night-Heron	4	2
Great Blue Heron	16	5
Great Egret	43	13
Green Heron	7	3
Snowy Egret	39	22
White-faced Ibis	1	1
HUMMINGBIRDS	**122**	**106**
Allen's Hummingbird	7	5
Anna's Hummingbird	112	100
Rufous Hummingbird	3	1
INSECTIVORES	**1409**	**2068**
Blackbirds	***257***	***232***
Bullock's Oriole	1	
Great-tailed Grackle	2	
Hooded Oriole	6	7
Red-winged Blackbird	32	110
Western Meadowlark	216	114
Yellow-headed Blackbird		1
Cardinals, Grosbeaks, and Allies	***1***	***2***
Western Tanager		2
Western Wood-Pewee	1	
Catbirds, Mockingbirds, and Thrashers	***2***	
California Thrasher	2	
Gnatcatchers	***8***	***29***
Blue-gray Gnatcatcher	8	29
Kinglets	***5***	***15***
Ruby-crowned Kinglet	5	15

Guild & Common Name	Year 1 Total Count (Sept. 2017 - Aug. 2018)	Year 2 Total Count (Sept. 2018 - Aug. 2019)
Martins and Swallows	***389***	***535***
Barn Swallow	10	15
Cliff Swallow	347	491
Northern Rough-winged Swallow	21	6
Tree Swallow	11	15
Violet-green Swallow		8
New World Sparrows	***275***	***594***
Fox Sparrow	1	
Golden-crowned Sparrow	2	
Lincoln's Sparrow		5
Savannah Sparrow	3	25
Savannah Sparrow (Belding's)	14	18
Song Sparrow	104	185
White-crowned Sparrow	151	361
Nuthatches		***3***
White-breasted Nuthatch		3
Parrotbills, Wrentit, and Allies		***3***
Wrentit		3
Penduline-Tits and Long-tailed Tits	***60***	***128***
Bushtit	60	128
Starlings and Mynas	***20***	***56***
European Starling	20	56
Swifts	***2***	***13***
Vaux's Swift	2	13
Thrushes	***53***	***60***
Hermit Thrush		1
Western Bluebird	53	59
Tits, Chickadees, and Titmice		***5***
Oak Titmouse		5
Tyrant Flycatchers	***138***	***219***
Ash-throated Flycatcher		3
Black Phoebe	72	125
Cassin's Kingbird	18	38
Pacific-slope Flycatcher	1	1
Say's Phoebe	46	50
Tropical Kingbird		1
Western Kingbird	1	
Western Wood-Pewee		1
Wagtails and Pipits	***171***	***128***
American Pipit	171	128

Guild & Common Name	Year 1 Total Count (Sept. 2017 - Aug. 2018)	Year 2 Total Count (Sept. 2018 - Aug. 2019)
Woodpeckers	***8***	***11***
Acorn Woodpecker	4	
Downy Woodpecker	2	2
Hairy Woodpecker	2	
Northern Flicker		3
Nuttall's Woodpecker		6
Wrens	***20***	***35***
Bewick's Wren	14	20
House Wren	4	9
Marsh Wren		3
Rock Wren	2	3
KINGFISHERS	**0**	**5**
Belted Kingfisher		5
OMNIVORES	**420**	**266**
Blackbirds		***2***
Brewer's Blackbird		2
Catbirds, Mockingbirds, and Thrashers	***8***	***23***
Northern Mockingbird	8	23
Jays, Magpies, Crows, and Ravens	***251***	***115***
American Crow	251	114
California Scrub-Jay		1
New World Sparrows	***113***	***87***
California Towhee	112	86
Spotted Towhee	1	1
Old World Sparrows	***48***	***39***
House Sparrow	48	39
RAPTORS	**72**	**90**
Falcons and Caracaras	***6***	***6***
American Kestrel	6	5
Merlin		1
Owls		***7***
Burrowing Owl		6
Great Horned Owl		1
Shrikes	***9***	***9***
Loggerhead Shrike	9	9
Vultures, Hawks, and Allies	***57***	***68***
Cooper's Hawk	11	17
Osprey		1
Red-shouldered Hawk	10	9
Red-tailed Hawk	18	23

Guild & Common Name	Year 1 Total Count (Sept. 2017 - Aug. 2018)	Year 2 Total Count (Sept. 2018 - Aug. 2019)
Turkey Vulture	9	8
White-tailed Kite	9	10
SEED & FRUIT EATERS	**789**	**1045**
Blackbirds	***1***	***1***
Brown-headed Cowbird	1	1
Cardinals, Grosbeaks, and Allies	***1***	***1***
Blue Grosbeak	1	1
Estrildids	***138***	***251***
Scaly-breasted Munia	138	251
Finches, Euphonias, and Allies	***251***	***338***
House Finch	229	289
Lesser Goldfinch	22	48
Purple Finch		1
Grouse, Quail, and Allies		***2***
California Quail		2
New World Sparrows	***9***	***28***
Chipping Sparrow		2
Clay-colored Sparrow		1
Dark-eyed Junco	1	
Lark Sparrow	8	25
Pigeons and Doves	***389***	***424***
Eurasian Collared-Dove	13	4
Mourning Dove	94	51
Rock Pigeon (Feral Pigeon)	282	369
SHOREBIRDS	**1137**	**1040**
Black-necked Stilt	10	18
Dunlin	1	1
Greater Yellowlegs	21	18
Killdeer	454	408
Least Sandpiper	169	280
Long-billed Curlew	2	10
Long-billed Dowitcher		5
Pectoral Sandpiper		1
Red-necked Phalarope	4	4
Sanderling		2
Semipalmated Plover	352	167
Snowy Plover (Western)	1	6
Solitary Sandpiper		1
Spotted Sandpiper	1	1
Western Sandpiper	116	115

Guild & Common Name	Year 1 Total Count (Sept. 2017 - Aug. 2018)	Year 2 Total Count (Sept. 2018 - Aug. 2019)
Whimbrel		2
Willet	1	
Wilson's Snipe	5	1
WOOD-WARBLERS	**110**	**245**
Common Yellowthroat	19	50
Orange-crowned Warbler	4	3
Yellow Warbler	1	7
Yellow-rumped Warbler	86	185
WATERFOWL & ALLIES	**518**	**1180**
Grebes	***3***	***15***
Eared Grebe	3	10
Pied-billed Grebe		3
Western Grebe		2
Rails, Gallinules, and Allies	***8***	***419***
American Coot	6	404
Sora	2	15
Waterfowl	***507***	***746***
American Wigeon	7	
Blue-winged Teal	1	3
Bufflehead	2	5
Cackling Goose (Aleutian)	15	1
Canada Goose	166	243
Cinnamon Teal	24	18
Cinnamon Teal x Northern Shoveler (hybrid)		1
Gadwall	19	42
Greater White-fronted Goose	56	4
Green-winged Teal		14
Hooded Merganser	1	3
Mallard	193	329
Mute Swan		1
Northern Pintail	3	
Northern Shoveler	9	49
Redhead	1	19
Ross's Goose		4
Ruddy Duck	10	6
Snow Goose		4
GRAND TOTAL	**4787**	**6256**

APPENDIX 3 – DEVEREUX SLOUGH AND UCSB NORTH CAMPUS OPEN SPACE POST-CONSTRUCTION AQUATIC SPECIES SURVEY REPORT

Technical Memorandum

Date	November 1, 2019
To:	Lisa Stratton, UCSB; Chris Kofron, USFWS
From:	Rosemary Thompson
RE:	**Devereux Slough and UCSB North Campus Open Space Oct 2019 Post-Construction Aquatic Species Survey Report**

1 Introduction

The Cheadle Center for Biodiversity and Ecological Restoration (CCBER) at The University of California, Santa Barbara (UCSB) is in the process of restoring the former Ocean Meadows Golf Course to native upland and wetland/marsh habitats in Santa Barbara County. This area is called the North Campus Open Space (NCOS) and includes the downstream end of Devereux Creek from the west, Phelps Creek from the north, and stormwater inflows from the northeast via East Channel that converge and drain into Devereux Slough (Figure 1). Prior to restoration, Devereux Creek flowed into Devereux Slough at a weir on the north side of Venoco Access Road. The weir has been removed, and grading has restored portions of the upper channels of Devereux Slough, allowing tidal influence upstream to near the Phelps Creek confluence and the eastern channel. Preconstruction surveys of Devereux Creek and Phelps Creek by Rosemary Thompson and CCBER staff in 2016, and post-construction surveys in the Fall of 2017 and 2018 found no tidewater gobies to be present. The 2018 surveys also found no southwestern pond turtles or California red-legged frogs. A post-construction tidewater goby survey was conducted on 17 October 2019 by Rosemary Thompson (federal permit TE-815144-9, state permit SC-002731) in Devereux Slough, the restored channels, and lower Phelps Creek with assistance from CCBER staff (Lisa Stratton, Beau Tindall, Darwin Richardson, and Jeremiah Bender). The methods used and results of the surveys are described below.

2 Methods

<u>Tidewater goby and other fish</u>. Sampling sites were selected in the field based on access, water depth, and approximate location sampled in previous years (Figure 2). Three locations in Devereux Slough were seined plus four locations in the restored channels, one near Venoco Road, one in the East Channel, one in the Main Channel, and one in the West Arm between 9:00 AM and 2:00 PM. A minnow seine 18 feet long by 4 feet high with 3 mm mesh was used for the sampling. Seine hauls varied in length from about 40 to 50 feet. The seine was pulled across the channel in NCOS and parallel to shore in Devereux Slough and then swept into the shoreline, lifted, and placed on the shore. Fish captured were identified and counted. The fish were then returned to the water. Water depth was generally less than 2 feet. Phelps Creek was sampled using dip nets with 3 mm or smaller mesh. Many sweeps were made wherever open water occurred with minimal obstructions. Organisms captured were identified and released.

<u>Water quality</u>. Water quality parameters (dissolved oxygen in mg/l and salinity in ppt) were measured with a YSI Pro 2030 at each sampling location.

3 Results and Discussion

Table 1 summarizes the fish and crayfish captured. In Phelps Creek, 8 native dragonfly nymphs were captured.

Table 1 Fish and Crayfish Captured on 17 October 2019

Site	Common Name	Scientific Name	Number	Method
PC	Mosquitofish	*Gambusia affinis*	1	Dipnet
	Red swamp crayfish	*Procambarus clarkii*	3	
PC mouth	Mosquitofish	*Gambusia affinis*	168	Dipnet
	Mississippi silversides	*Menidia audens*	32	
DS-L	California killifish	*Fundulus parvipinnis*	69	Seine (3 hauls)
	Longjaw mudsucker	*Gillichthys mirabilis*	35	
	Mississippi silversides	*Menidia audens*	980	
	Topsmelt	*Atherinops affinis*	85	
	Tidewater goby	*Eucyclogobius newberryi*	5	
DS-M	California killifish	*Fundulus parvipinnis*	149	Seine (1 haul)
	Longjaw mudsucker	*Gillichthys mirabilis*	3	
	Mississippi silversides	*Menidia audens*	25	
	Topsmelt	*Atherinops affinis*	0	
DS-U	California killifish	*Fundulus parvipinnis*	11	Seine (1 haul)
	Longjaw mudsucker	*Gillichthys mirabilis*	5	
	Mosquitofish	*Gambusia affinis*	15	
	Topsmelt	*Atherinops affinis*	1	
	Mississippi silversides	*Menidia audens*	71	
MC-L	Mississippi silversides	*Menidia audens*	353	Seine (1 haul)
	Mosquitofish	*Gambusia affinis*	99	
	Longjaw mudsucker	*Gillichthys mirabilis*	2	
MC	Mosquitofish	*Gambusia affinis*	36	Seine (1 haul)
	Mississippi silversides	*Menidia audens*	600	
	California killifish	*Fundulus parvipinnis*	6	
MC-WA	Mosquitofish	*Gambusia affinis*	9	Seine (1 haul)
	Mississippi silversides	*Menidia audens*	343	
	California killifish	*Fundulus parvipinnis*	23	
EC	California killifish	*Fundulus parvipinnis*	2	Seine (1 haul)
	Mosquitofish	*Gambusia affinis*	38	
	Mississippi silversides	*Menidia audens*	827	

PC = Phelps Creek

DS = Devereux Slough; L= lower (near mouth), M = middle (near old pier), U = upper (just downstream of Venoco Road)

MC = Main Channel (central NCOS); L = lower (just upstream of Venoco Road); WA = West Arm; EC = East Channel

Water quality measured at the sample sites is presented in Table 2.

Table 2 Water Quality at Fish Sample Sites

Location	Lat	Long	DO (Mg/l)	Salinity (ppt)	Temperature (C)
Phelps Creek	34.422963	-110.879851	5.8	0	14.5
Phelps Bridge	34.421244	-119.878893	7.5	2.8	16.7
West Arm	34.420759	-119.878412	6	34	22
Central NCOS	34.420057	-119.876934	7	34	22
East Channel	34.420628	-119.874310	7.3	50.6	21.8
Main Channel - lower	34.417846	-119.874249	10.2	52	20.9
Devereux Slough - upper	34.416734	-119.874077	9.8	53	21.6
Devereux Slough - mid	34.412124	-119.876542	13.8	50.5	24
Devereux Slough - lower	34.409813	-119.879393	9	60	18

All fish captured are native to the area, except the silversides and mosquitofish, and can tolerate a wide range of salinities. The crayfish are also not native. No tidewater gobies were captured in Phelps Creek, although this species has been reported in that creek in the past. Tidewater gobies remaining upstream or those in Devereux Slough could expand into NCOS aquatic habitats in the future. Five tidewater gobies were captured in Devereux Slough, near the mouth. These were all about 25 mm in total length. The mouth of the Slough was open to the ocean from mid-February to mid-March 2019, which may have allowed colonization via the ocean from nearby populations. It is also possible that a few individuals were present in the Slough but not captured during the 2016- 2018 surveys and reproduced to maintain a small population. Tidewater gobies generally only live one year (Swift et al. 1989, Moyle 2002).

Salinity tolerance tests in the laboratory indicate that survival above approximately 40 ppt is limited to a few hours to days (Swift et al. 1989). Thus, the salinity measured in Devereux Slough (60 ppt) where the tidewater gobies were captured appears to be above their long-term tolerance based on that study. It is possible, however, that salinity tolerance in the wild, especially as salinity slowly increases, is higher than that measured in the lab. The high salinity may be stressful, but the fish appear to be surviving.

The fish species collected in Devereux Slough, except topsmelt and tidewater goby, are now present in the restored estuarine channels on NCOS. Removal of the weir at the Venoco Road crossing has allowed them access to upstream areas. Abundance of these species is expected to fluctuate over time in response to changes in habitat conditions and may stabilize as the restored area reaches a dynamic equilibrium.

The non-native red swamp crayfish continues to occur in Phelps Creek, although fewer were found than in 2018. Its spread into the restored channels will likely be limited by its intolerance of high salinity.

4 References

Moyle, P. B. 2002. Inland Fishes of California. University of California Press, Berkeley and Los Angeles. Pp 431- 434.

Swift, CC, J.L. Nelson, C. Maslow, and T. Stein. 1989. Natural History Museum of Los Angeles County, Contributions in Science, Number 404:1-19.

Figure 1 Creeks and channels at NCOS.

Figure 2 Fish sampling and water quality locations (yellow labeled points).