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North Campus Open Space Restoration Project Year 3 Monitoring Report

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North Campus Open Space Restoration Project

Year 3 Monitoring Report

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, California State Parks, 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. 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. Led by UC Santa Barbara's Cheadle Center for Biodiversity and Ecological Restoration (CCBER), the NCOS project involves collaboration with other UCSB departments, faculty, student, and local community groups as well as contractors and government agencies. In addition to wetland and upland habitat restoration, project's goals include the reduction of flood levels, 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 fourth year of implementation and with planting of the project site more than 90% complete, project efforts are now focused primarily on maintenance, continued monitoring, new research projects, and supplemental planting to add diversity, including special status species such as the federally endangered Ventura marsh milk-vetch (*Astragalus pycnostachys* var. *lanosissimus*). This report describes the methods and results of monitoring for the first three years of the project, with a primary focus on the third year (fall 2019 – fall 2020). This work documents the progress of the project and supports longer-term research and monitoring programs. Results from the third 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

Comprehensive photographic documentation of the transition and development of the entire NCOS project site has been carried out on a quarterly basis since December of 2016. This section of the report describes the methods for capturing photos and includes a map of the photo point locations on the project site along with a set of representative photos in Appendix 1. These photographs provide a visual record of the transformation of the site from a bare landscape at the end of 2017 to almost completely established salt marsh and transitional habitats, and well-developed perennial grassland on the Mesa by the summer and fall of 2020. A link to the entire database of photos is also provided.

Vegetation

All habitats/plant communities met the year 3 success criteria for total vegetation cover and/or relative percent native cover despite being planted over a two-year time span. Minor exceptions where Year 3 criteria were not quite met included total vegetation cover in the brackish marsh and grassland habitats, and relative native cover in the peripheral uplands and sandy annual habitats. Total native species diversity increased to 73 locally sourced species and includes the largest population of the endangered Ventura marsh milk-vetch growing with no irrigation or protection from herbivory. In addition, multiple California Native Plant Society recognized special status species are establishing robust populations, including southern tarplant (*Centromadia parryi* var. *australis*) and Parish's glasswort (*Anthrocemum subterminale)*.

Wildlife

The third year of wildlife monitoring at the NCOS project revealed some exciting results: three Burrowing Owl over-wintered in the hibernacula installed on the slopes of the Mesa; for the third year in a row, Western Snowy Plover attempted to breed on the sand flat habitat and one pair produced a chick; and Belding's Savannah Sparrow were also seen on site for the third year in a row, with evidence of breeding activity. Monthly bird surveys in year three showed increases in abundance by 69 % and diversity by 24 % over the first year. These increases are driven primarily by waterfowl and a few insectivores and seed-eating species, which could reflect the greater extent of open water habitat that persisted throughout the winter of 2020 as well as the increased availability of vegetation cover providing food and shelter. Other wildlife monitoring in year three included quarterly acoustic surveys of bats, which detected up to eight species and showed a fair amount of seasonal, diurnal, and spatial variation in presence and/or activity. Preliminary surveys of small rodents and reptiles in the transitional salt marsh and grassland are also discussed.

Hydrology and Water Quality

Several components of our monitoring program are focused on the hydrology and water quality of Devereux Slough and the tributaries that feed into the restored estuary. Monitoring data collected in year three indicates that the estuary continues to perform as expected in terms of an increased water-holding capacity, reduced flood levels and an increased tidal prism. The hydrology of the 2020 water year was largely unlike any of the previous years that we have monitored. The unusual rainfall pattern resulted in a three-month stretch of high water levels in the slough through the winter, followed by a late breach in mid-March. A subsequent lack of late season rain led to the upper portion of the slough becoming almost completely dry by the end of September. These factors resulted in a long period of stratification of dissolved oxygen and salinity in the slough through the winter, and very high salinity levels late in the year. The unusual 2020 water year also affected the hydrology of the vernal pools on the Mesa, with all but two of the pools drying out following a seven-week dry spell in winter, then refilling briefly after rains in March. The three months of sustained high water in the slough raised groundwater levels and lowered salinity in monitoring wells near the wetland, while other wells exhibited patterns similar to previous years. We also include a detailed description of the methods and data from the intensive sampling of nutrient and suspended solids concentrations in storm water conducted in the 2020 water year.

Community Use Surveys, Education and Participation

Following safety protocols, we continued to conduct observational surveys of community use of the trails at NCOS during the coronavirus pandemic. A review of the data from all of the surveys carried out to date shows that dog walkers are increasingly keeping their dogs on leash, and the average number of users per hour during the pandemic was more than double the amount observed in the previous year. While the pandemic greatly restricted community volunteer and educational activities in 2020, a reduced number of UCSB students were able to work at the site and conduct field monitoring and research activities on an individual basis, contributing a total of 6,700 hours towards project efforts.

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1. INTRODUCTION AND PLANTING SUMMARY

The University of California, Santa Barbara (UCSB) North Campus Open Space (NCOS) is a 136-acre site located northwest of the main university campus. Bordered by the UC's 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. 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 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. 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. Led by UC Santa Barbara's Cheadle Center for Biodiversity and Ecological Restoration (CCBER), the NCOS project involves collaboration with other UCSB departments, faculty, student, and local community groups as well as contractors and government agencies.

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. Minor changes made in some of the vegetation communities are described in the year 2 monitoring report (escholarship.org/uc/item/5sj929vh). A map of the NCOS project in Figure 1 reflects the current extent of habitats being restored and enhanced along with the as-built elevation contour lines (one-foot interval), 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 voluntarily 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. 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 in the summer and fall.

Year 3 Planting Summary

Planting efforts in the third year of the project (2020) focused on continuing the development of Coastal Sage Scrub (CSS) communities around the site, particularly in the area to the west of the vernal pool swale on the Mesa. We refer to this part of NCOS as the EEM zone as its restoration is funded by a grant from the California Natural Resource Agency's Environmental Enhancement and Mitigation program. Nearly 7,000 plants comprised of 13 CSS-associated species and 1,200 *Stipa pulchra* were installed in this area. Other areas of focus included the Peripheral Uplands in the northwestern arm (5,300 plants from 14 species) and additions to sections of the transitional/high salt marsh (4,100 plants from 5 species). We also enhanced the grassland habitat on the Mesa by seeding and planting nearly 7,000 seedlings of five wildflower species, and we established the Discovery Trail and Visitor Plaza pollinator garden with more than 4,000 plants from 51 species (two additional species volunteered: *Datura wrightii* and *Lupinus succulentus*).

Twenty-nine coast live oak trees were planted in year three: twenty in a cluster on a slope in the EEM zone and nine in the pre-existing riparian woodland adjacent to Venoco road. This brought the total number of trees planted to 240, 166 of which are coast live oaks.

The successful establishment of the largest population (more than 400 individuals) of the federally endangered Ventura marsh milk-vetch (*Astragalus pycnostachys* var. *lanosissimus*) is an exciting achievement in third year of the NCOS project. Eight-five percent (404 of 495) of the originally planted seedlings survived to reproductive age and 75 seedlings from the 2020 cohort of offspring that successfully germinated in the spring were thriving in the fall. The success of this establishment prompted the collection of five cups of seeds in the fall that were dispersed in five other locations on NCOS that could potentially support the species. Recent monitoring in March of 2021 found more than 2,151 seedlings growing from the 2021 cohort, including 151 in the areas where seeds were dispersed in the fall of 2020. A detailed report on the establishment and monitoring of Ventura marsh milk-vetch at NCOS is available on the CCBER eScholarship webpage (escholarship.org/uc/item/91f243kg).

In total, we added more than 30,000 plants and 21 species in year three, bringing the overall total for the project so far to more than 320,000 plants comprised of 81 species.

Ongoing and Future Restoration Planting

Restoration planting in 2021 will include maintenance and enhancement in all habitats as well as the following projects:

1. Herb and forb species will continue to be added to the Mesa grassland.
2. Building on the successful establishment of Ventura marsh milk-vetch, we will monitor seedlings establishing in other potentially suitable habitat across the site.
3. The Duttenhaver Outdoor Classroom will be planted in late 2021 after minor grading.
4. Supplemental planting along the vernal pool swale, north facing slopes of the mesa and the eastern arm will continue in order to enhance these sites.
5. The peripheral upland portion along the north side of the western arm will continue to be a focus during year four and peripheral upland along the eastern arm will be established after the new private housing development adjacent to that area is constructed (2022).

Report Structure and Content

This report describes the NCOS monitoring program, methods and protocols, and includes data primarily from the third year of monitoring (October 2019 to October 2020) along with some data from Year 1 (September 2017 to October 2018) and Year 2 (October 2018 to October 2019) for comparison. We also discuss the progress of restoration and monitoring through the third year.

Monitoring and research efforts and data presented in previous reports that are not included in this Year 3 report include the development of the bathymetry of the wetland, and studies on sediment accretion, carbon sequestration, and greenhouse gas fluxes of the wetland. Some of these ongoing projects were put on hold in 2020 due to the onset of the coronavirus pandemic. We plan to re-measure the elevation cross-sections of the wetland again in 2021 or 2022, and extract the first set of cores from the sediment accretion monitoring plots in early 2023, which will be five years since the plots were set. Most of the components of monitoring described in this Year 3 report will continue through the year 2022.

The monitoring efforts described herein include:

- Photo-documentation
- Vegetation, including trees
- Wildlife, including bird surveys, special status species, and studies on aquatic arthropods, bats, small rodents, and reptiles
- Hydrology and water quality of Devereux Slough, the restored vernal pools on the Mesa, and groundwater at NCOS
- Community use surveys
- Characterization of project efforts

Key data and related information about the project are posted on the EcoAtlas website (www.ecoatlas.org/regions/ecoregion/statewide/projects/9462), and monitoring reports and associated data are also available through the eScholarship (escholarship.org/uc/ccber) and CCBER's website (www.ccber.ucsb.edu/ecosystem/management-areas/north-campus-open-space).

Figure 1. Map of the habitats/vegetation communities at the North Campus Open Space restoration project.

2. PHOTO-DOCUMENTATION

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 has been conducted on a quarterly basis.

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, we made a few minor revisions in the number and location of photo points and the frequency of photos at some points. In the past year, we added a point (number 44) and additional photos at points 36 and 38 to include better coverage of the development of the Visitor Plaza and Discovery Garden as well as forthcoming changes to the parking lot and area west of the ROOST building.

Comparative photos from four points taken in the month of October of each of the last four years are included in Appendix 1 of this report. The complete set of photos can be accessed from an interactive web map, and full details of the data set, including methodology, revisions, and urls for the web map and complete set of photos are available in a data description document on the CCBER eScholarship webpage (escholarship.org/uc/item/5zf6d6q3).

Figure 2. Map of photo monitoring points at the North Campus Open Space restoration project.

3. VEGETATION

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, which 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 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. The vegetation success criteria for the project 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 30-meters in length (except for Vernal Pools and the Fresh-Brackish Seasonal Pond) are monitored with a one-square-meter quadrat placed every three meters, alternating between the left and right side of the transect line. For the vernal pools, given their small extent relative to other habitats and plant communities, the quadrats are placed every two meters. The first quadrat is centered to the left of the starting point at each transect, which results in 11 quadrats for each 30-meter transect. The length of transects and number of quadrats across vernal pools and the seasonal pond depend on the overall shape and extent of these habitats. The quadrats are subdivided into 100 ten-centimeter squares and Daubenmire cover classes are used to estimate the cover of each species in the quadrat. We also record the percent of the quadrat that contains thatch (dead vegetation from the previous year's growth), and other cover types such as algae, moss, biocrust, mulch, erosion control netting, and black plastic for weed control. Bare ground is recorded only where there is no other cover in the quadrat.

Point-Intercept Transects (PIT)

This method is used for vegetation communities with larger growth forms, such as Coastal Sage Scrub (CSS) and Riparian. It records the presence of species in the canopy (above two meters) and sub-canopy (below two meters) at every meter along each 30-meter transect. Including the starting point, this results in a total of 31 points for each transect. The vertical "point" at each meter along the transect is represented by a two-meter tall, half-inch diameter wood dowel with a laser attached to the top for extending the point through the canopy. Each species that touches, or intersects the dowel in the sub-canopy is recorded once and each species that intersects the laser in the canopy is recorded once. Therefore, an individual tree or tall shrub is recorded present in both the canopy and sub-canopy if it intersects the point in both strata. When no vegetation crosses the point in the sub-canopy, other cover such as thatch or mulch is recorded or bare ground if there is no cover.

Table 1. Vegetation monitoring plan for the habitats/vegetation communities at the North Campus Open Space restoration project. Figure 3 contains a map of the habitats and monitoring transects.

Habitat / Vegetation Community	Acres	Method	Survey Month	Number of Transects / Quadrats and Trees
Grassland and Mosaic Habitats				
Perennial Grassland (Mesa)	16.8	QT	July	8 / 88
Peripheral Upland Mosaic (Grassland/Scrubland/Bioswale)	8.8	QT	June	7 / 77
Sandy Annuals	1.2	QT	June	1 /11
Wetlands				
Fresh-Brackish Wetlands: Remnant Brackish Marsh & New Seasonal Pond	1.5	QT	July/August	1 / 11 1 / 15
Vernal Pools (8 pools)	1.3	QT	June	1 lengthwise transect with a minimum of 5 quadrats per pool, every other meter.
Salt Marsh – Restored low (approx. 6-8 ft.) and mid (approx. 8-12 ft.) elevations, and Transitional/High Salt Marsh at 10-15 and 15-18 feet in elevation	38.7	QT	August	6-8 ft. 7 / 77 8–12 ft. 7 / 77 10-15 ft. 5 / 55 15-18 ft. 3 / 33
Salt Marsh – Pre-existing Remnant	0.9	QT	August	2 / 22
Shrublands and Woodlands				
Coastal Sage Scrub (CSS) Mosaic (incl. Chaparral / Oak Woodland)	10.7	PIT, Individual Trees	June/July	7 transects, ~ 105 trees
Riparian Woodland – Pre-existing	1.5	PIT	June/July	2 transects, 9 trees
Riparian Woodland – New (Phelps Creek and Whittier Channel)	1.7	PIT, Individual Trees	June/July	2 transects, ~ 130 trees
Open Ground / Sparsely Vegetated				
Sand Flat/Snowy Plover Habitat	3.2	QT	September (post-plover breeding season)	2 / 22

Transect Locations & Orientations

Figure 3 contains a map of monitoring transects and habitats/vegetation communities. 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, Perennial Grassland, Peripheral Upland Mosaic, Salt Marsh, Transition/High 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 into two bands based approximately on elevation, with some overlap. This could enable us to detect differences that may occur in species composition and coverage with changes in elevation. These transects are identified in the map in Figure 3 as follows: SML (low elevation salt marsh at 6-9 feet), SMM (mid-elevation salt marsh at 9-12 feet), SMT (transition/high salt marsh at 10-15 feet), and SMTH (transition/high salt marsh at 15-18 feet).

In the field, the locations of some of the transect starting points were initially 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.

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. We estimate the height of tall trees by reading a six-foot long pole marked with inches and feet that is held upright above a height of seven feet.

Data Collection & Management Methods

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, while the individual tree monitoring data is recorded in a Google Sheet. Photographs of each transect are taken from the starting point. Occasional plants that cannot be identified in the field are photographed and later identified as best as possible by staff with greater botanical knowledge. The data are reviewed as soon as possible after collection and any issues such as data entry errors, missing or duplicate quadrats are corrected through consultation with field staff. All data are collated, reviewed, managed, summarized and plotted using Microsoft Excel.

Figure 3. Map of the vegetation monitoring transects at the North Campus Open Space restoration project.

Vegetation Monitoring Data

Native Vegetation Summary

The mean percent of absolute and relative native vegetation cover increased significantly in most habitats, including more than double the amount of absolute cover recorded in year two for the Perennial Grassland, Seasonal Fresh/Brackish Pond, Vernal Pools, and Coastal Sage Scrub Mosaic, (Figures 4, 7, 9, and 13). Other habitats with notable increases in native vegetation cover include the Sandy Annuals, Transition/High Salt Marsh, New Riparian Woodlands, and Sand Flat (Figures 6, 12, 14, and 16). We recorded a small increase in native vegetation cover in all other monitored habitats/plant communities, except in the Remnant Brackish Marsh, which exhibited a small decrease in native vegetation cover compared with the year two monitoring data (Figure 8). All habitats/plant communities meet the year 3 success criteria for total vegetation cover and/or relative percent native cover despite being planted over a two-year time span (this is described further in the following section on vegetation success criteria).

The number of native species increased in most habitats, especially in the Seasonal Fresh/Brackish Pond, Coastal Sage Scrub Mosaic, New Riparian Woodlands, and Sand Flat (see numbers on top of bars in Figures 7, 13, 14, and 16). Though the increase in native cover was small in the Restored Salt Marsh, the number of native species doubled from 15 to 30 in the mid-elevation range and increased from 9 to 17 in the low-elevation range (Figure 10). Native species diversity decreased slightly in some habitats where native cover increased (*e.g*. Peripheral Uplands (Figure 5), Vernal Pools, and Sandy Annuals), while species diversity increased in the Remnant Brackish Marsh despite the decrease in native cover. Overall, the total number of native species increased from 70 in year two to 73 in year three, with the addition of nine species recorded for the first time. The saltmarsh aster, *Symphyotrichum subulatum*, was recorded more than any other species in 2020 (326 of 649 quadrats and 90 of 341 points). This species accounted for more than eight percent of all vegetation cover across the site, including a third of native vegetation coverage in the CSS Mosaic. Two salt marsh plants accounted for the most coverage of all native species and all vegetation: Pickleweed (*Salicornia pacifica*) at 20 percent of native species and 16 percent of all vegetation, and saltgrass (*Distichlis spicata*) at 15 percent of natives and 11.5 percent of all vegetation. Other native species with relatively high amounts of coverage included: *Eleocharis macrostachya, Stipa pulchra,* and *Frankenia salina*. Table A2.1 in Appendix 2 contains a list of all native species recorded in each habitat for each year of monitoring.

Non-Native Vegetation Summary

There was little to no change in the absolute and relative percent of non-native vegetation cover in year three. Nearly all habitats exhibited a slight increase in non-native vegetation cover, with the largest increases recorded in the Peripheral Uplands, Sandy Annuals, and Remnant Salt Marsh (Figures 5, 6, and 11). This reflects the impact of significantly reduced staffing during the spring stay-at-home order at the beginning of the COVID-19 pandemic, which affected our capacity to control non-native plants in a timely manner and forced us to rely on the use of string-trimming and mowing strategies rather than targeted hand removal. A slight decrease in non-native vegetation cover was recorded in the Seasonal Fresh/Brackish Pond and the Pre-existing Riparian Woodlands, the latter of which is where exotic pine trees were removed in late 2019 (Figures 7 and 15).

Unlike the percent cover of non-native vegetation, we did record a decrease in non-native species diversity in six habitats, most notably in the Sandy Annuals, Vernal Pools, and Restored Salt Marsh (Figures 6, 9, and 10). There were small increases in the number of non-native species in all other habitats, and the total number of non-native species increased from 73 in year two to 77 in year three.

In 2020, we recorded 30 non-native species that are ranked on the California Invasive Plant Council's (Cal-IPC) inventory. Only one species ranked as "High", *Cortaderia selloana*, was recorded on site, in one of the Pre-existing Riparian Woodlands (the location of transect RWP-02 in the map in Figure 3). The percent coverage of this species relative to total vegetation cover across both Pre-existing Riparian transects was 4.3 percent. The other species on the Cal-IPC inventory included 15 ranked as "Moderate", 12 as "Limited", and two listed as "Watch" species. Italian rye grass, *Festuca perennis* (ranked "Moderate" by Cal-IPC), was the most frequently recorded non-native species in 2020 (184 of 649 quadrats) and it accounted for 23 percent of all non-native and more than five percent of all vegetation coverage site-wide. Two other non-natives recorded in more than 100 quadrats and that each accounted for more than ten percent of non-natives and three percent of all vegetation coverage include a *Spergularia* species and *Plantago coronopus*. Table A2.2 in Appendix 2 contains a list of all non-native species recorded in each habitat for each year of monitoring, and the species with Cal-IPC ratings are indicated.

Bare Ground, Thatch, and Other Cover

With the significant increase in vegetation cover recorded in 2020, particularly native plants, the relative amount of bare ground decreased significantly to well below 50 percent in nearly all restored habitats, except the Sand Flat (76%) and Vernal Pools (52%). We recorded the greatest decrease in bare ground in the Coastal Sage Scrub Mosaic (26% less), New Riparian Woodlands (39% less), Peripheral Uplands (35% less), Sandy Annuals (52% less), and Vernal Pools (28% less). There was no change in the relative amount of bare ground in the Restored Salt Marsh (40%), and a slight increase in the Seasonal Fresh/Brackish Pond (from 37 to 40%). These habitats are expected to retain between 30% - 40% bare ground in the form of mud flats or salt flats, particularly in areas that are covered by deeper water for longer periods of time.

The relative cover of thatch, which we define as dead vegetation from the previous year's growth (some of which was mowed or trimmed), increased in most habitats in 2020. Some increase in thatch cover is expected as vegetation continues to develop and increase in cover across the site. The habitats where we observed the greatest increase in thatch cover in year three include: Peripheral Uplands (12% more), Sandy Annuals (16% more), and the New Riparian Woodlands (30% more). The Remnant Salt Marsh also exhibited a relatively large increase in thatch cover by 34% over year two, but this is likely because thatch cover was recorded inconsistently in this habitat in 2019 and 2018.

Other cover, which primarily consists of mulch, erosion control netting, and/or dried algae that occurs in seasonal ponds and wetlands, decreased in nearly all habitats. As with bare ground, this decrease is expected as vegetation continues to develop and increase in cover. In habitats such as the Seasonal Fresh/Brackish Pond, Remnant Brackish Marsh, and Restored Salt Marsh, we may see the amount of dried algae cover fluctuate each year, depending on the amount of rainfall and/or the rate that water in the ponds and wetlands evaporates. This type of cover, along with other dead plant matter, provides foraging habitat for invertebrates such as ephydrid flies, amphipods, and snails (as mentioned in the Restoration Plan).

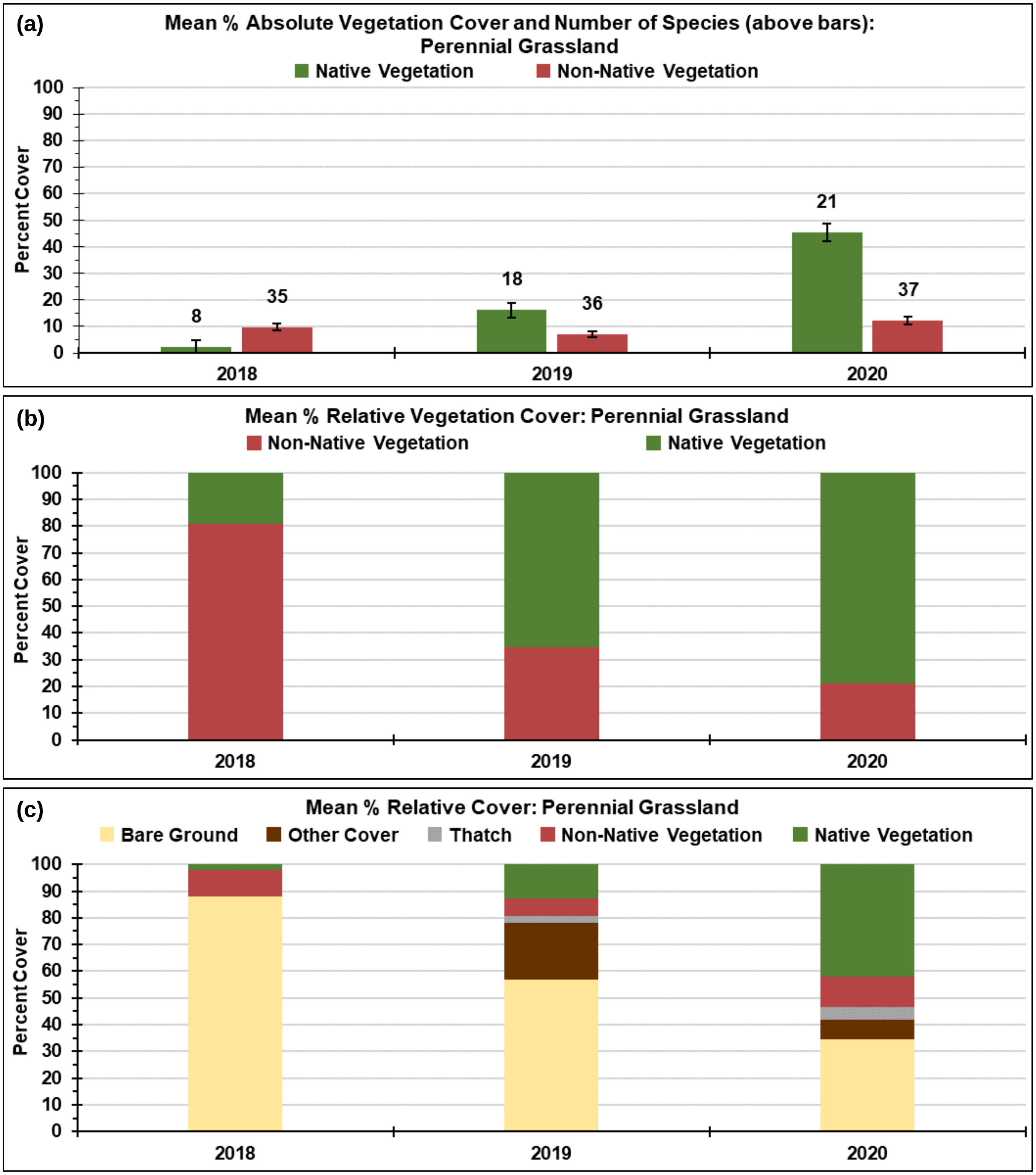

Figure 4. **Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Native Perennial Grassland habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.**

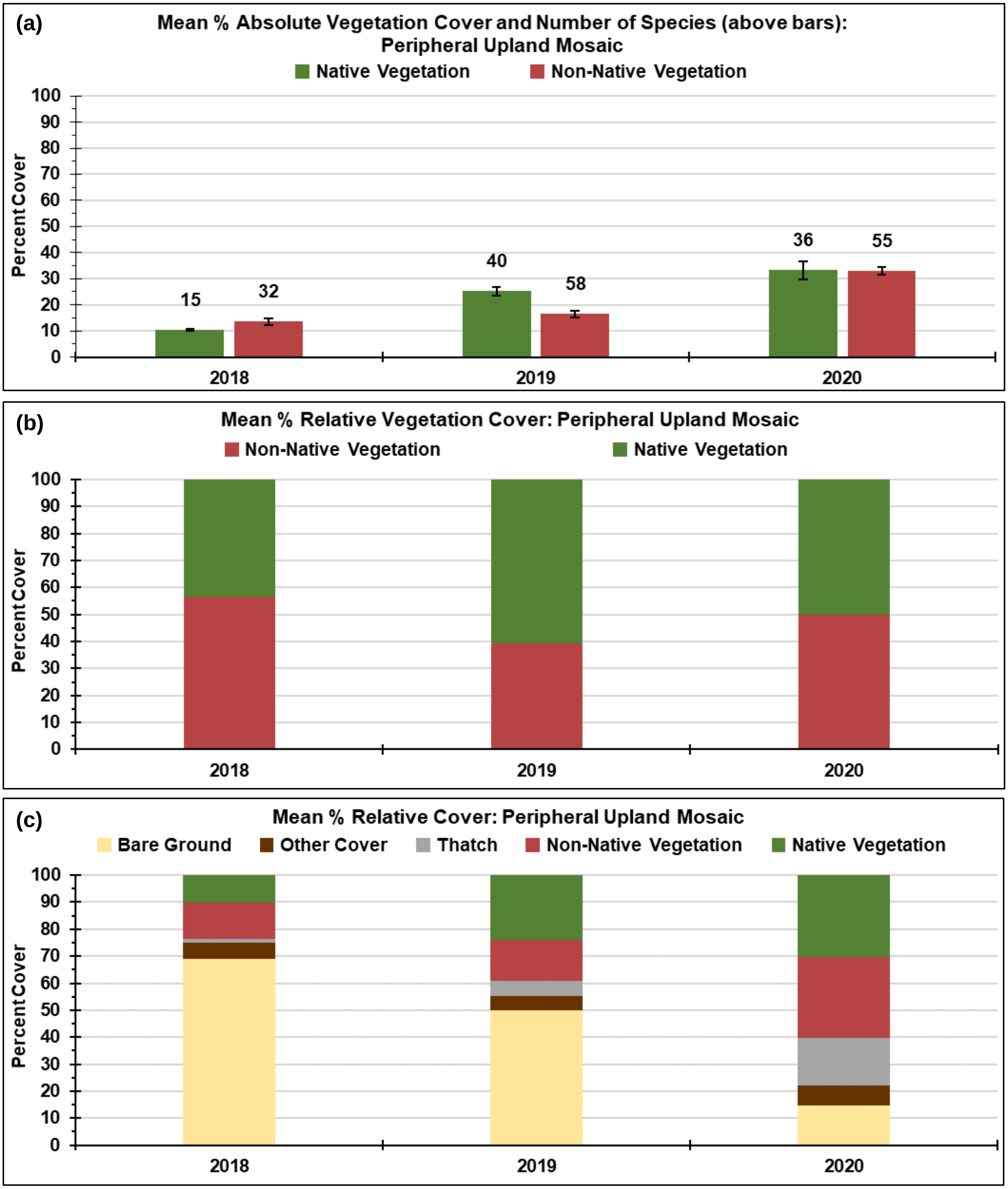

Figure 5. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Peripheral Upland Mosaic habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

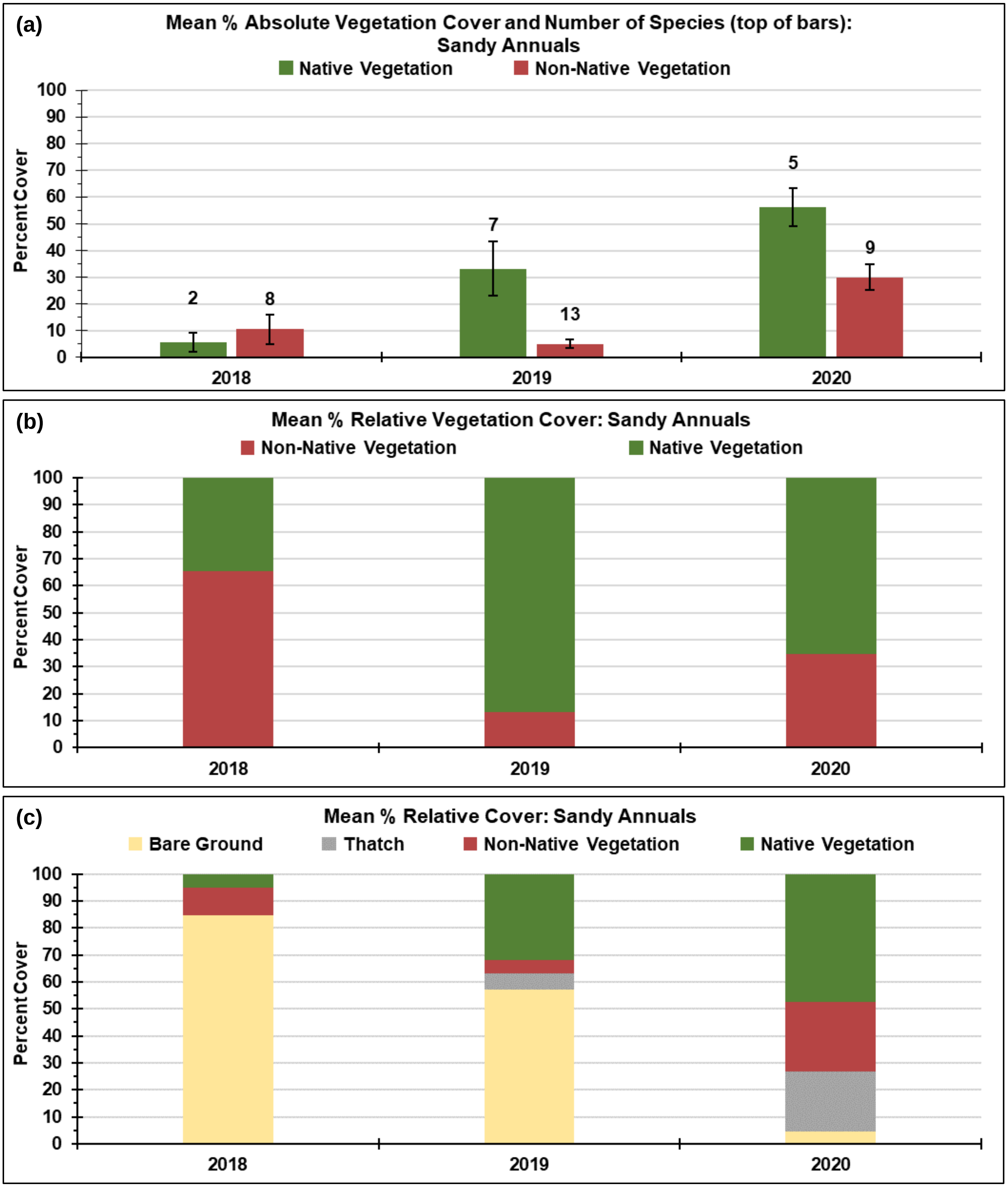

Figure 6. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Sandy Dune Annuals habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

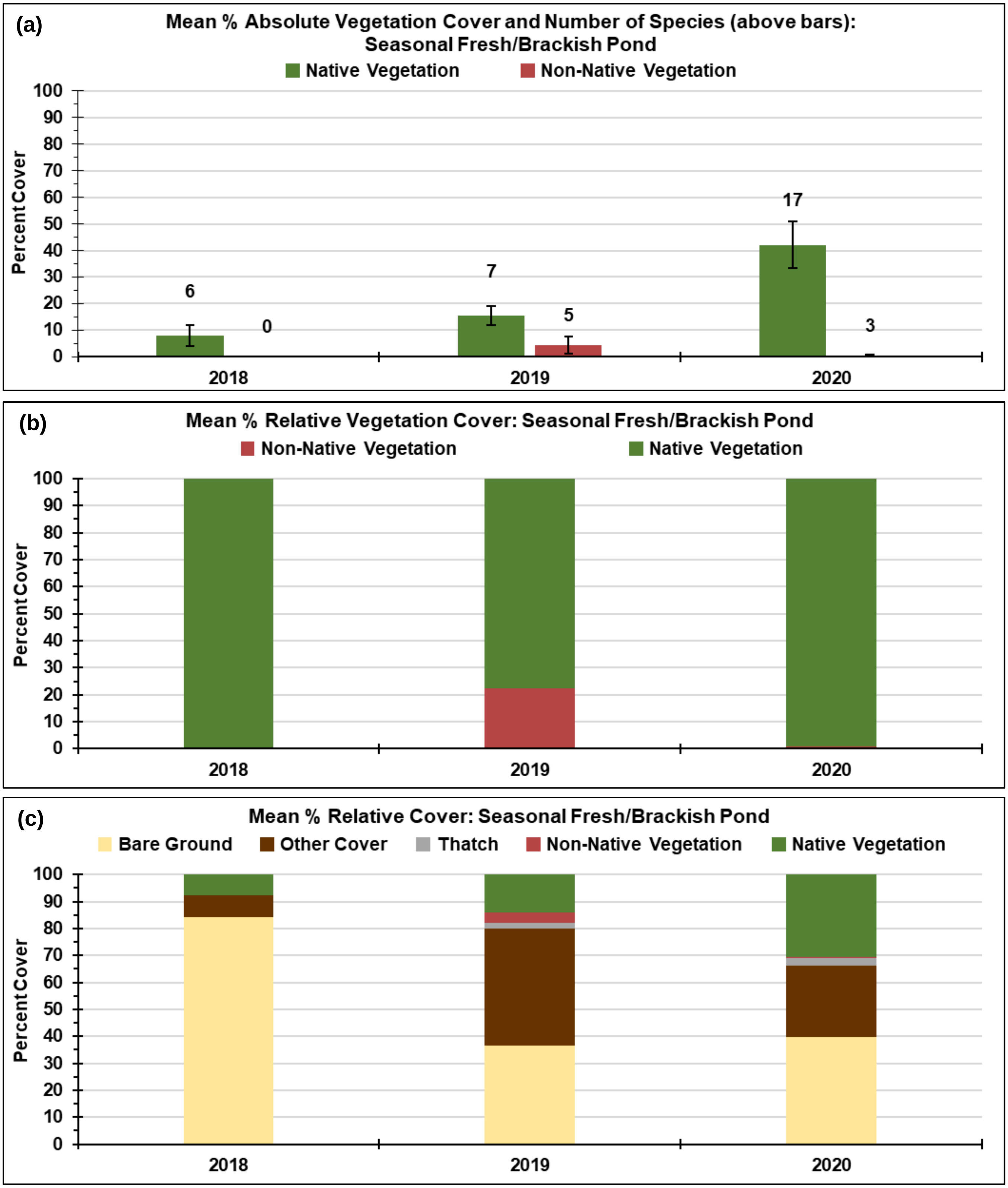

Figure 7. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Seasonal Fresh/Brackish Pond habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

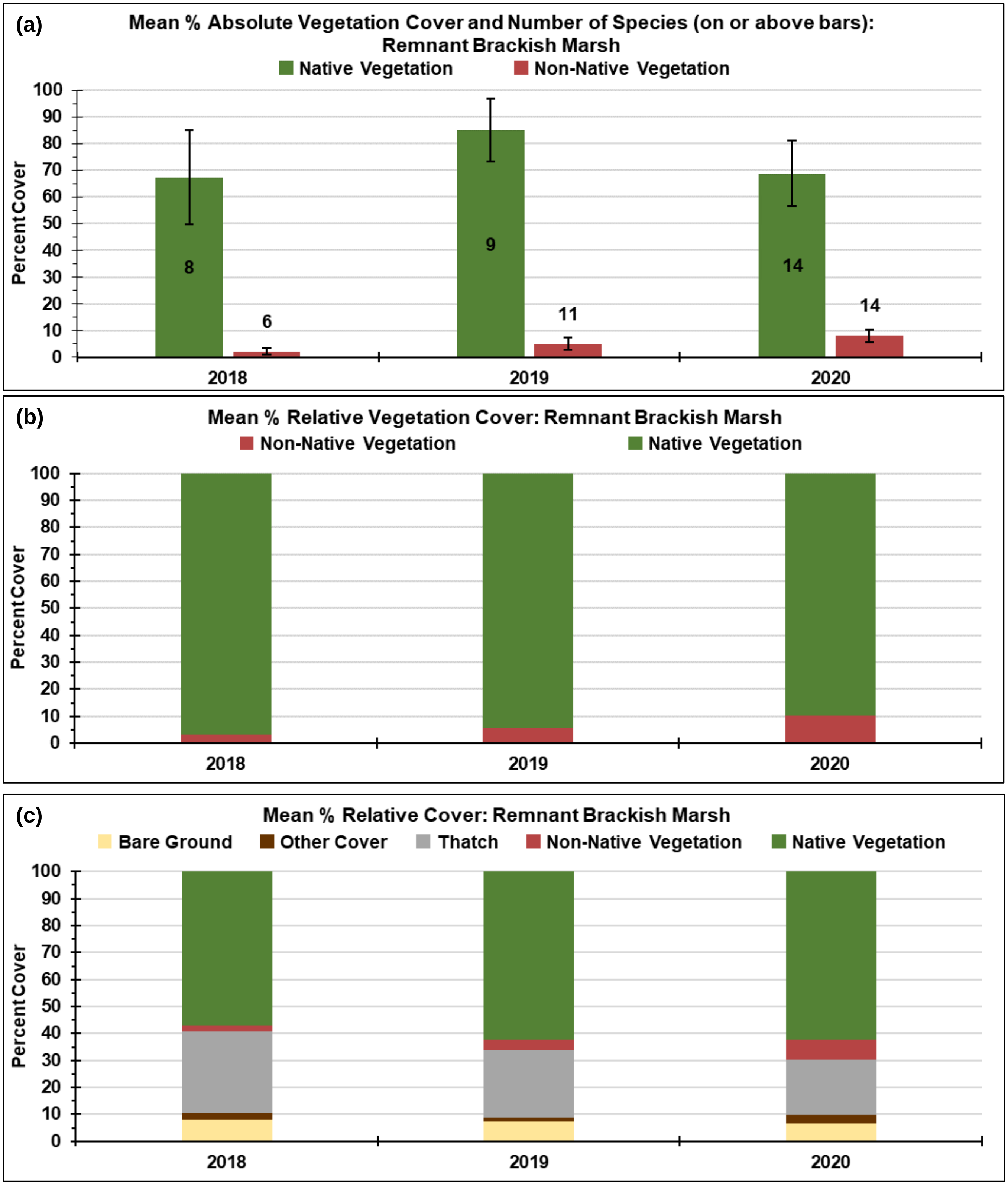

Figure 8. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Remnant Brackish Marsh habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

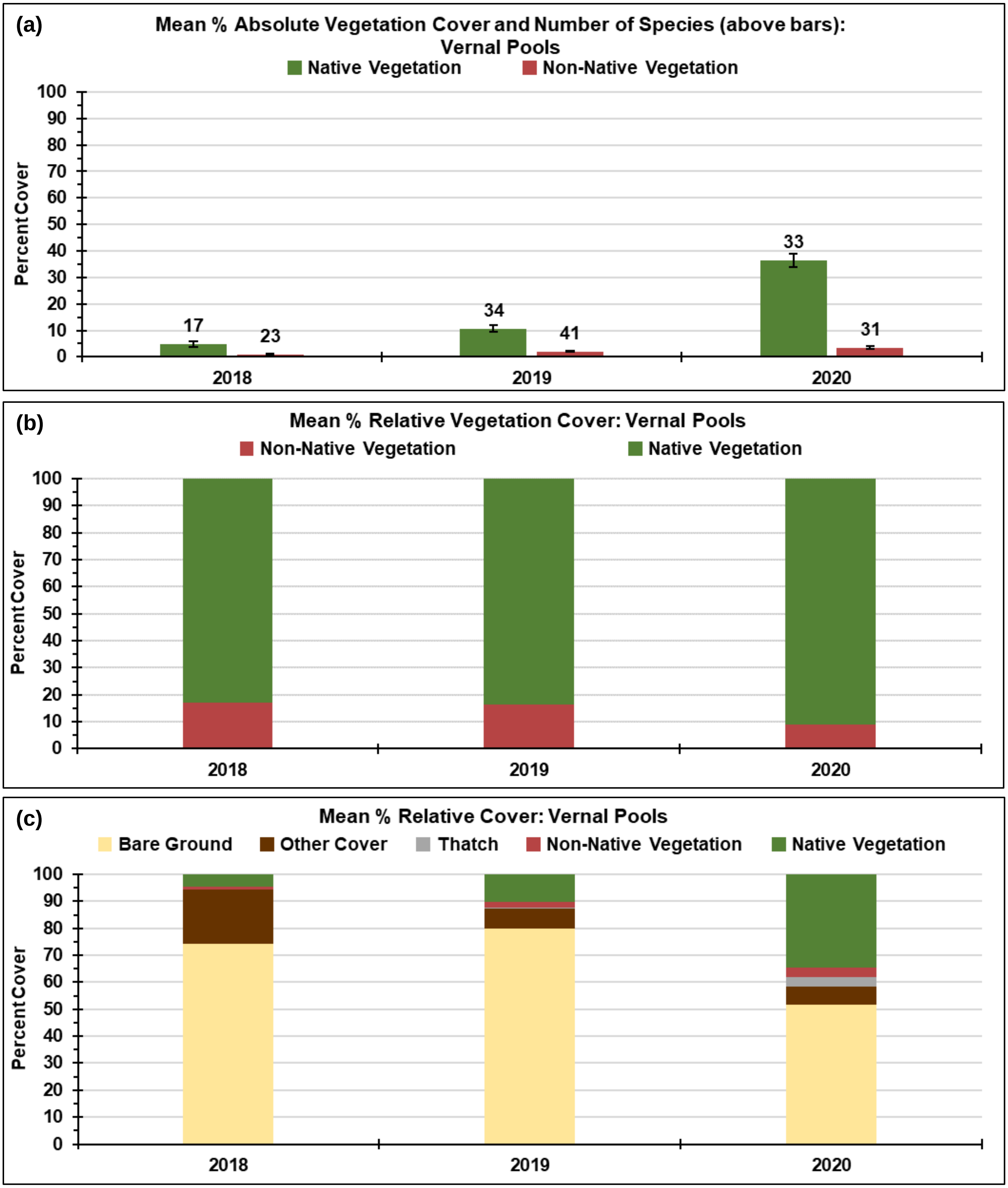

Figure 9. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the eight vernal pools on the mesa of the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

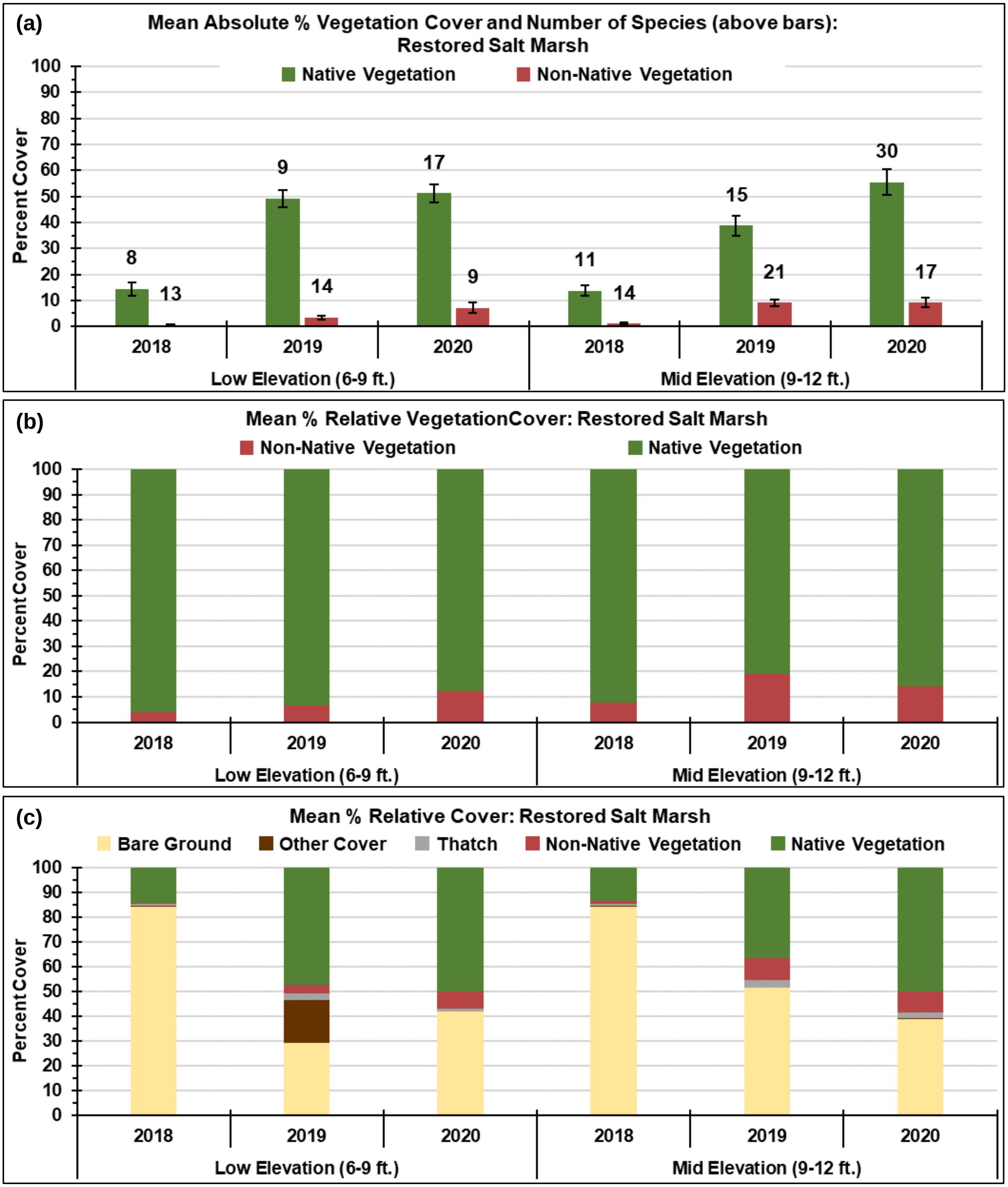

Figure 10. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Low and Mid Elevation Restored Salt Marsh habitats at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

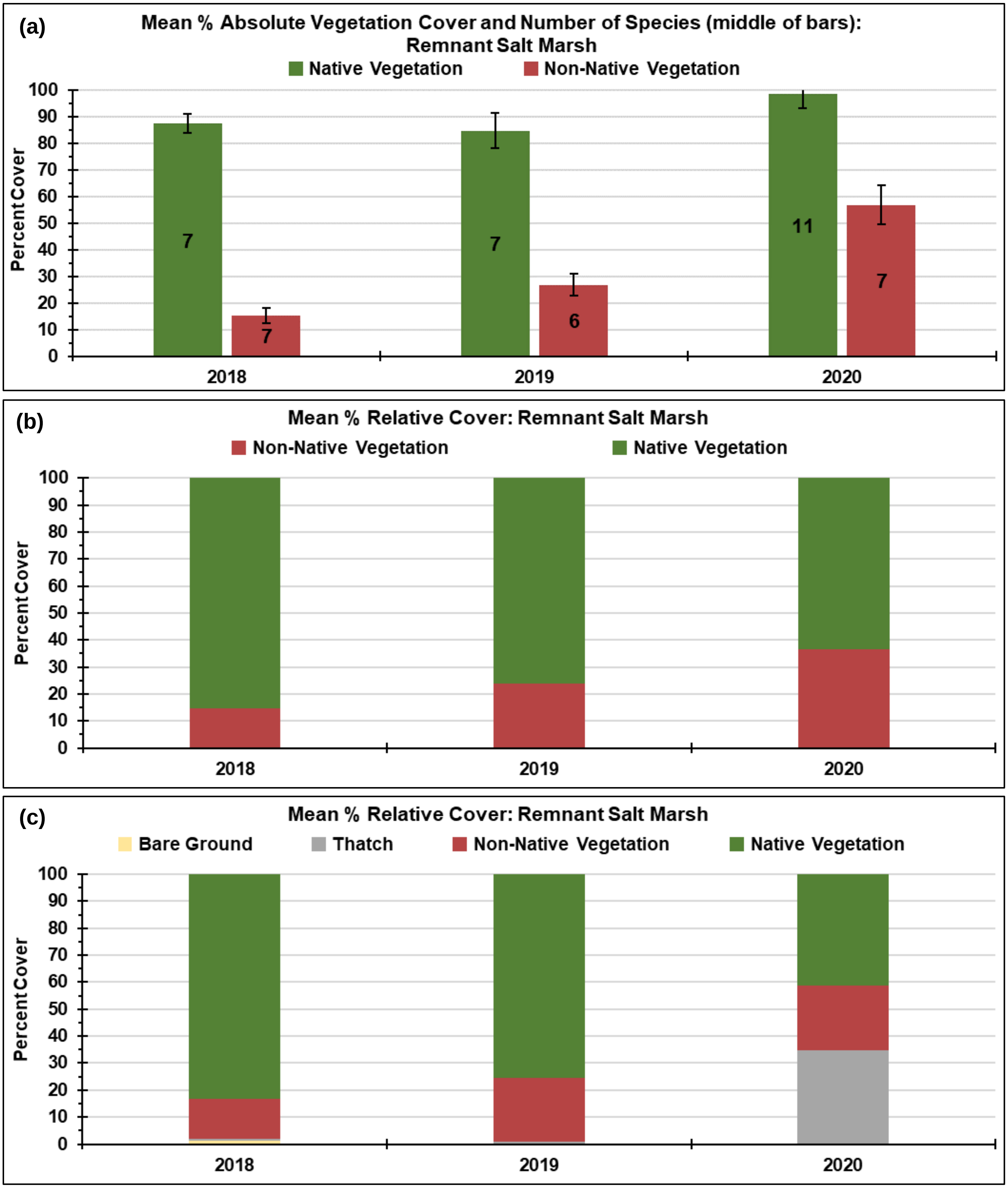

Figure 11. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Remnant Salt Marsh at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

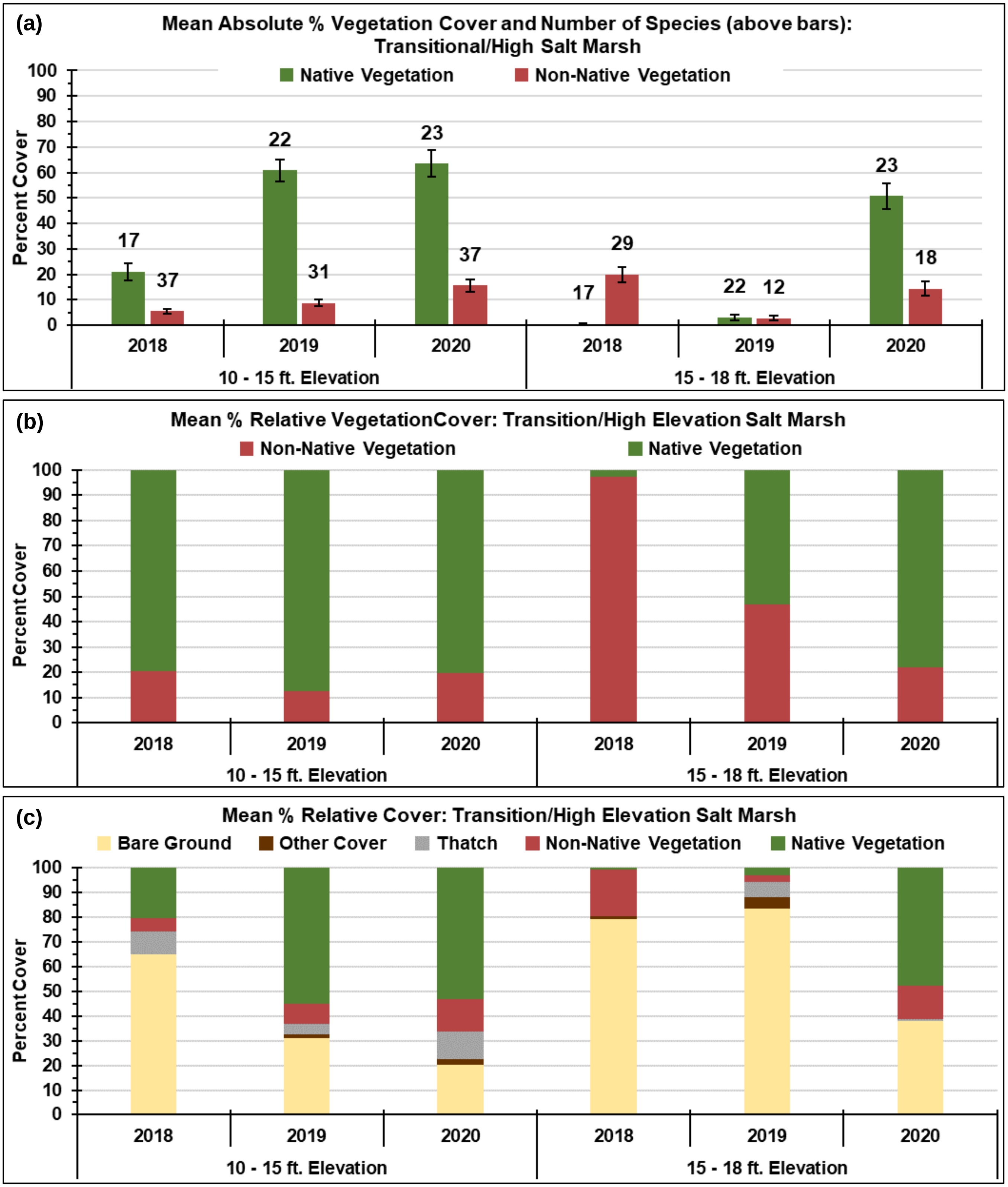

Figure 12. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the two elevation bands of Transition/ High Salt Marsh habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

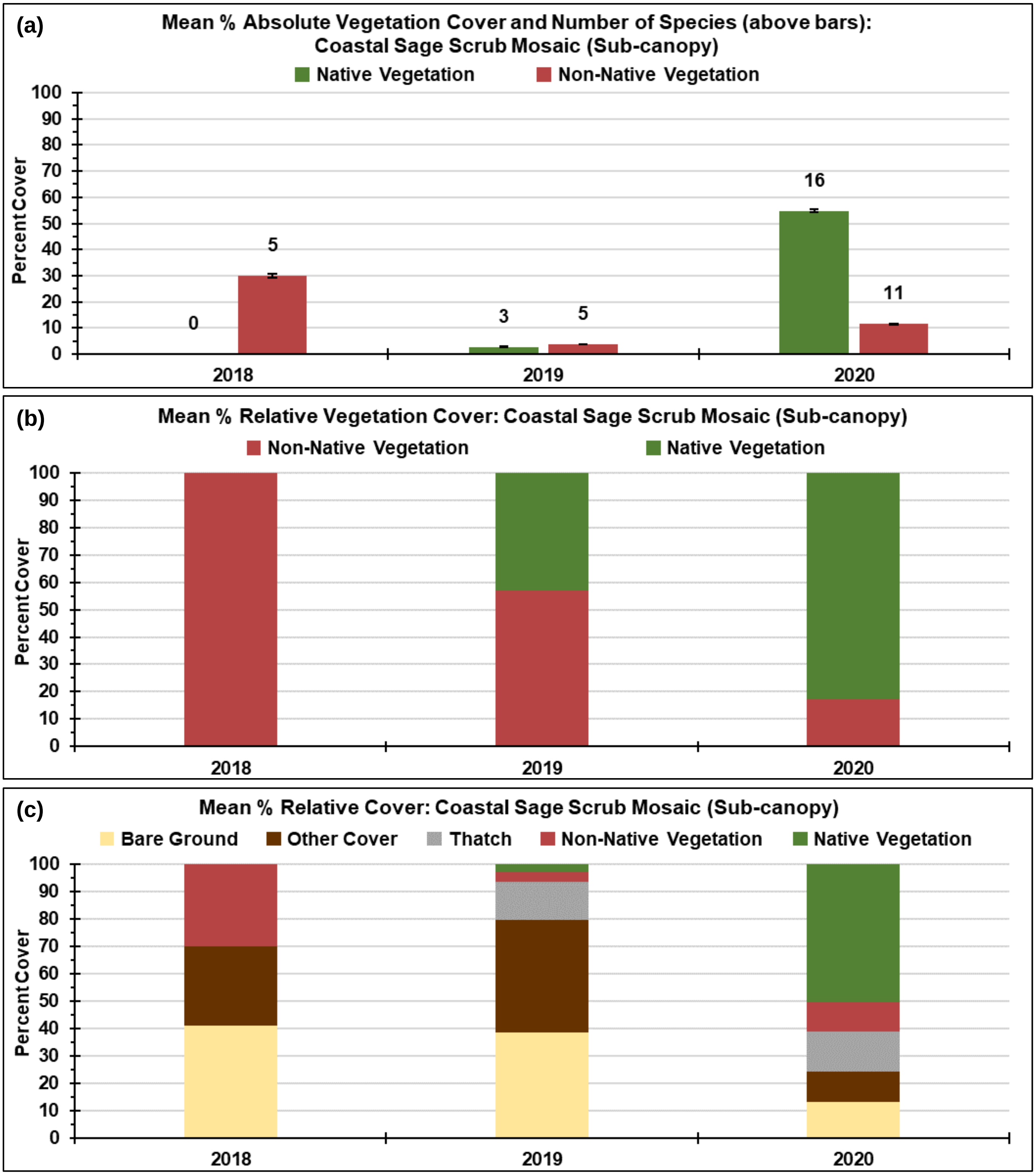

Figure 13. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the sub-canopy (below two meters in height) of the Coastal Sage Scrub Mosaic habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year. Canopy vegetation (above two meters in height) does not yet exist in this habitat.

Figure 14. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the new Riparian Woodland habitats at the North Campus Open Space restoration project. In plot (a), the numbers on the bars are the number of native and non-native species recorded each year. Canopy and sub-canopy vegetation are summed for the relative total vegetation cover in plots (b) and (c).

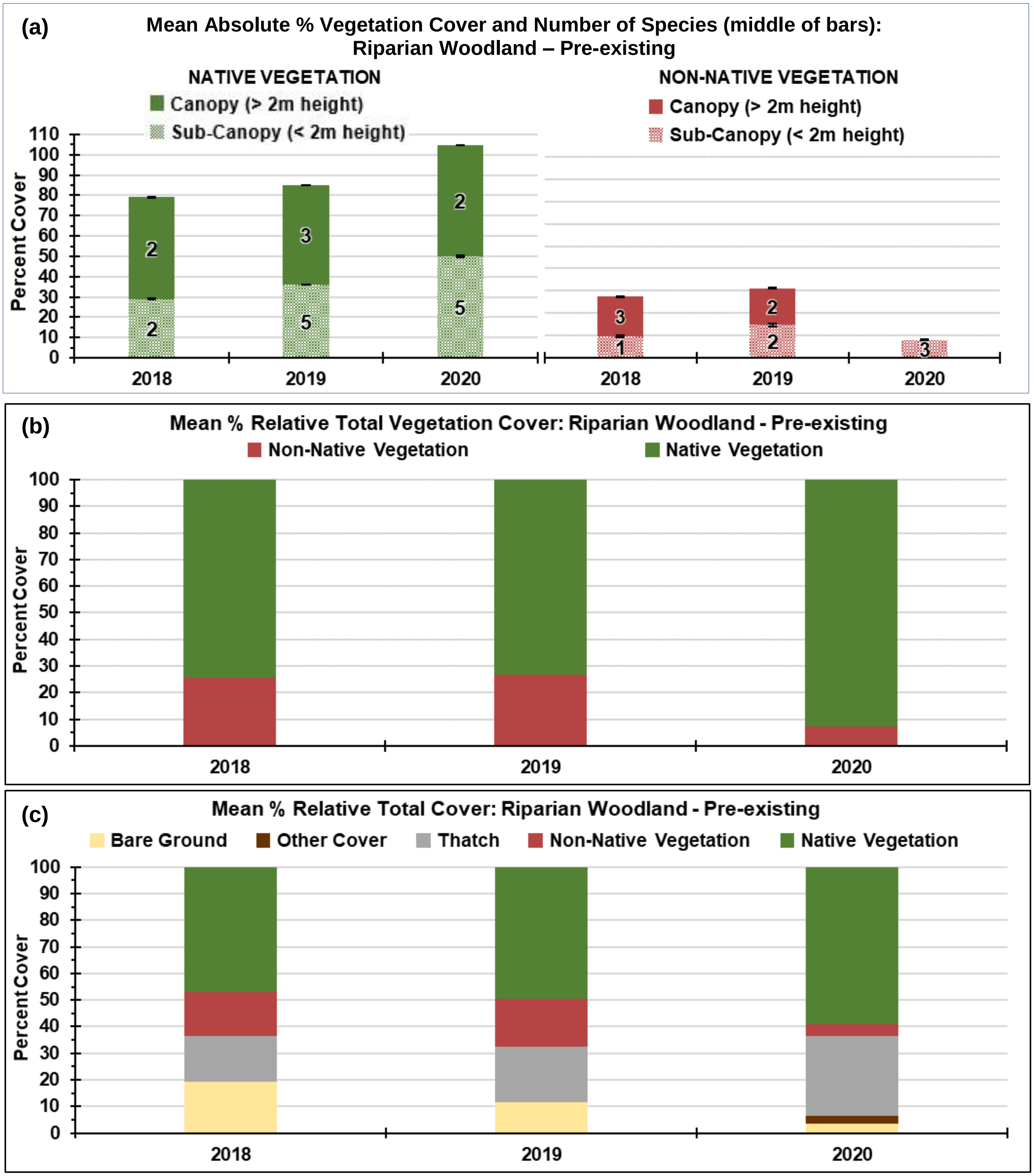

Figure 15. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the pre-existing Riparian Woodland habitats at the North Campus Open Space restoration project. In plot (a), the numbers on the bars are the number of native and non-native species recorded each year. Canopy and sub-canopy vegetation are summed for the relative total vegetation cover in plots (b) and (c).

Figure 16. Mean percent of (a) absolute cover of native and non-native vegetation, and (b) relative cover of vegetation, thatch, other cover types, and bare ground in the Sand Flat habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year. Since the mean percent relative cover of native and non-native vegetation is not important for the sand flat area, we have not included a separate chart for that metric.

Vegetation Success Criteria

The NCOS Restoration Plan identifies four vegetation success criteria, or objectives, for each of the first five years of restoration planting in the primary target habitats/plant communities:

- the percent of total vegetation cover,
- the relative percent of total vegetation cover by native species,
- the relative percent of total vegetation cover by invasive species rated as "High" by the California Invasive Plant Council (Cal-IPC), and
- the diversity of native species.

Table 2 lists the criteria values for each target habitat/plant community and contains the monitoring data associated with each criterion. The table includes the addition of the Peripheral Upland Mosaic habitat and the separation of the Riparian and Fresh-Brackish Marsh habitats, which were originally combined along with Back Dune Swale in the in the Restoration Plan.

Despite the variation in timing of native vegetation restoration and establishment in each plant community (*e.g*. planting of the Coastal Sage Scrub Mosaic began near the end of the second year of the project), the monitoring data collected in 2020 shows that all four success criteria were met in nearly all habitats for the third year of restoration. One of the exceptions was the total vegetation cover of the Native Perennial Grassland and Fresh/Brackish Marsh (Seasonal Pond), which were shy of the Year 3 goal by two percent and 17 percent, respectively. The other exception was the relative percent cover of native vegetation in the Peripheral Upland Mosaic and Sandy Dune Annuals. This goal was met by these habitats in year 2, but not in year 3, which may be due to our reduced ability to control non-native weeds during the spring of 2020 when safety restrictions for the coronavirus pandemic limited the number of staff that could work on site.

To date, our vegetation monitoring has recorded two instances of an invasive non-native species rated as "High" by Cal-IPC at NCOS. We recorded one individual seedling of *Tamarix ramosissima* in a vernal pool in 2019, and one small cluster of pampas grass (*Cortaderia selloana*) has been recorded each year in one of the pre-existing riparian woodlands near the center of the project site (see transect RWP-02 in the map in Figure 3). The coverage of this pampas grass relative to total vegetation cover estimated from the two pre-existing riparian transects was reduced to less than five percent in year three (2020), and we will work to completely remove it from the site. Since the success criteria apply only to newly restored habitats, the goal of less than five percent relative cover of invasive species has therefore been met in all habitats for the first three years of monitoring.

Table 2. Comparison of vegetation monitoring data with proposed minimum success criteria for target habitats/plant communities 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 Perennial Grassland										
% Total cover	*35*	*45*	*60*	*70*	*80*	12	24	58		
% Native Relative	*50*	***60***	***70***	*70*	*70*	19	**65**	**79**		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	***3***	***4***	***6***	*7*	*7*	**8**	**18**	**21**		
Peripheral Upland (Mixed Grassland/Shrubland)										
% Total cover	*35*	*45*	***60***	*70*	*80*	24	42	**66**		
% Native Relative	*50*	***60***	*70*	*70*	*70*	43	**61**	50		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	***3***	***4***	***6***	*7*	*7*	**15**	**40**	**36**		
Salt Marsh										
% Total cover	*30*	***40***	***60***	*70*	*70*	15	**50**	**62**		
% Native Relative	***70***	***80***	***80***	*80*	*90*	**94**	**88**	**87**		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	***4***	***6***	***7***	*7*	*8*	**11**	**15**	**30**		
Transitional/High Salt Marsh										
% Total cover	*30*	***40***	***50***	*60*	*65*	24	**46**	**74**		
% Native Relative	***50***	***60***	***65***	*70*	*80*	**55**	**86**	**79**		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	***8***	***8***	***10***	*12*	*15*	**20**	**22**	**28**		
Fresh/Brackish Marsh (Seasonal Pond)										
% Total cover	*50*	*50*	*60*	*70*	*80*	8	20	43		
% Native Relative	***70***	***70***	***70***	*80*	*80*	**99**	**78**	**99**		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	*7*	***7***	***10***	*12*	*14*	6	**7**	**17**		

	Proposed Minimum Criteria					Monitoring Data				
	Year 1	***Year 2***	***Year 3***	***Year 4***	***Year 5***	**2018**	**2019**	**2020**	**2021**	**2022**
Vernal Pools										
% Total cover	*30*	*40*	***40***	*45*	*50*	6	13	**40**		
% Native Relative	***70***	***70***	***70***	*80*	*80*	**83**	**84**	**91**		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	***7***	***7***	***10***	*12*	*15*	**17**	**28**	**33**		
Sandy Dune Annuals										
% Total cover (variable by season)	*20*	***25***	***30***	*35*	*40*	16	**38**	**86**		
% Native Relative	*50*	***60***	*70*	*70*	*80*	35	**87**	65		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	*3*	***3***	***4***	*5*	*5*	2	**7**	**5**		
Coastal Sage Scrub/Chaparral Mosaic										
% Total cover	*30*	*40*	***50***	*60*	*65*	30	7	**66**		
% Native Relative	*50*	*60*	***65***	*70*	*80*	0	43	**83**		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	*8*	*8*	***10***	*12*	*15*	0	3	**16**		
Riparian										
% Total cover	*50*	***50***	***60***	*70*	*80*	13	**53**	**90**		
% Native Relative	***70***	***70***	***70***	*80*	*80*	**100**	**81**	**88**		
% Invasive Relative	***<5***	***<5***	***<5***	*<5*	*<5*	**0**	**0**	**0**		
Diversity (Native Species)	*7*	*7*	***10***	*12*	*14*	4	6	**12**		

Tree Monitoring Data

In year three of the NCOS restoration project, the height, diameter at breast height (DBH), and vigor of 243 trees was monitored in August of 2020. This included 29 Coast Live Oaks (*Quercus agrifolia*) planted in late 2019 and early 2020: nine in one of the Pre-existing Riparian Woodlands (adjacent to Venoco Road), and 20 in a grove at the far western end of the north-facing slope of the mesa (see map in Figure 17). Excluded from this monitoring were fifteen Narrowleaf Willows (*Salix exigua*) originally planted in the first year of the project that were removed from a portion of the Whittier Riparian area that was graded for the creation of the Discovery Trail and Interpretive garden. Narrowleaf Willow has significantly expanded its extent in adjacent areas of the Whittier Channel where it was planted. In addition, three trees were found to be dead (vigor rating of 4) at the time of monitoring: two White Alders (*Alnus rhombifolia*) in the New Riparian Woodland adjacent to the Phelps Creek outlet and one Coast Live Oak on the mesa.

Overall, data from the third year of tree monitoring shows increased growth and improved vigor for all six species. A comparison of the year three and year two data for trees planted during the first two years of the project (211 out of 214, with three dead trees excluded) shows an increase in overall mean height by 14 inches (from 72 to 86), and an increase in mean DBH from 0.6 to 0.91 inches. The mean overall vigor rating improved from 1.2 to 1.1. The species that exhibited the greatest increases in mean height and DBH in year three include Arroyo Willow (*Salix lasiolepis*), California Sycamore (*Platanus racemosa*), and White Alder (Figure 18). The greatest improvement in vigor was exhibited by California Sycamore and Coast Live Oak trees, both of which improved from a mean of 1.4 in year two to 1.1 in year three.

Coast Live Oaks account for 64 percent of all trees planted in the first two years of the project (137 of 211), and the majority of these (85) were planted during the second year of the project in groves along the north-facing slopes of the mesa (see map in Figure 17). When comparing the year three and year two monitoring data, we separated the oaks planted on the mesa from those planted with other species in the Riparian Woodlands, most of which (31 of 52) were planted at least one year before the first oaks were planted on the mesa slopes. The mean height of both groups of oaks increased by about four inches in year three and mean DBH doubled in the riparian oaks while it increased from 0.1 to 0.41 in the mesa slope oaks (Figure 18). For the 29 Coast Live Oak trees planted in year three (not included in Figure 18), the mean height measured in August 2020 was 42.7 inches, mean DBH was 0.1 inches (only measureable for 3 trees that reached breast height), and mean vigor was 1.0.

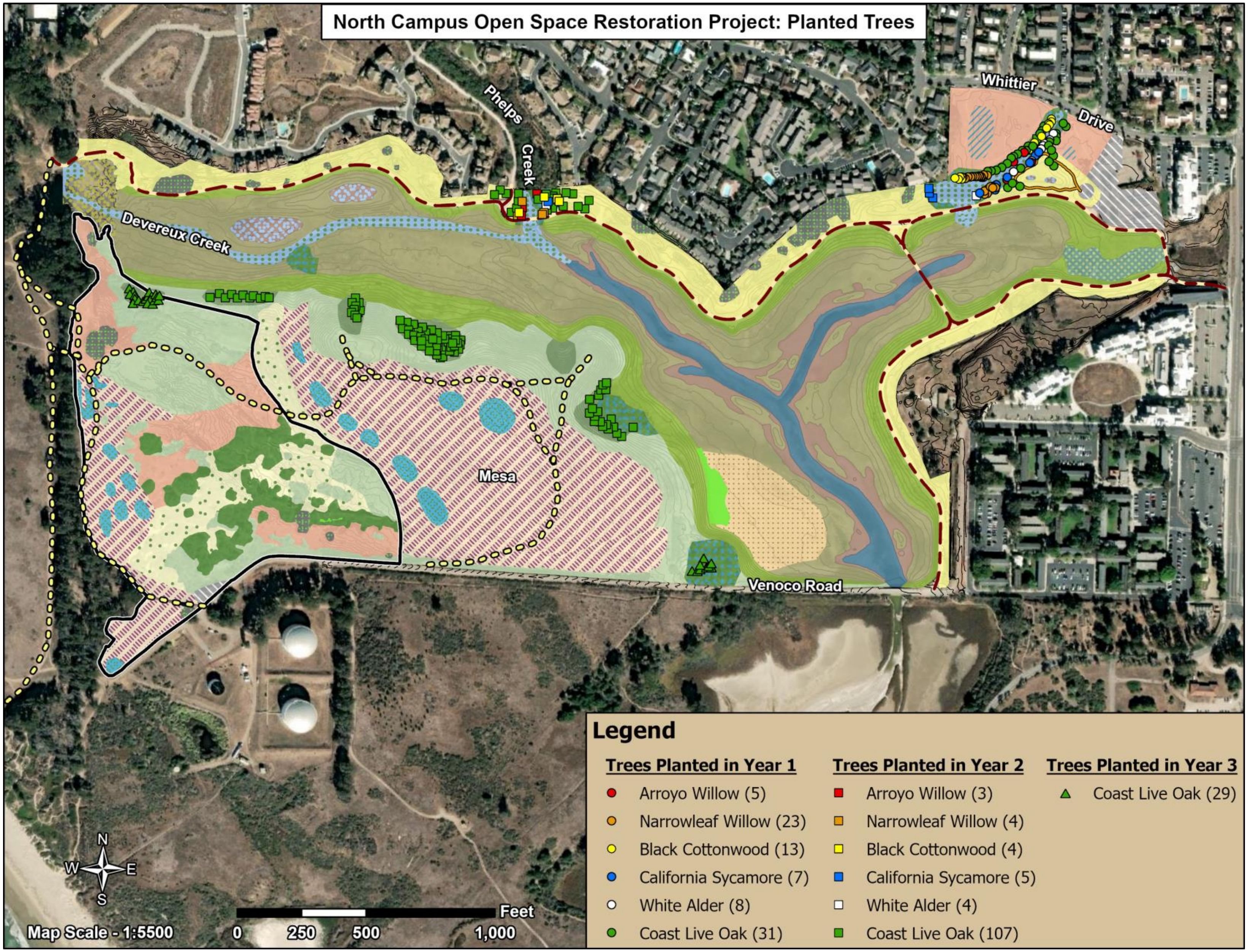

Figure 17. Map of trees planted during the first three years of the North Campus Open Space restoration project. See Figure 1 for a legend of the habitats/plant communities and trails.

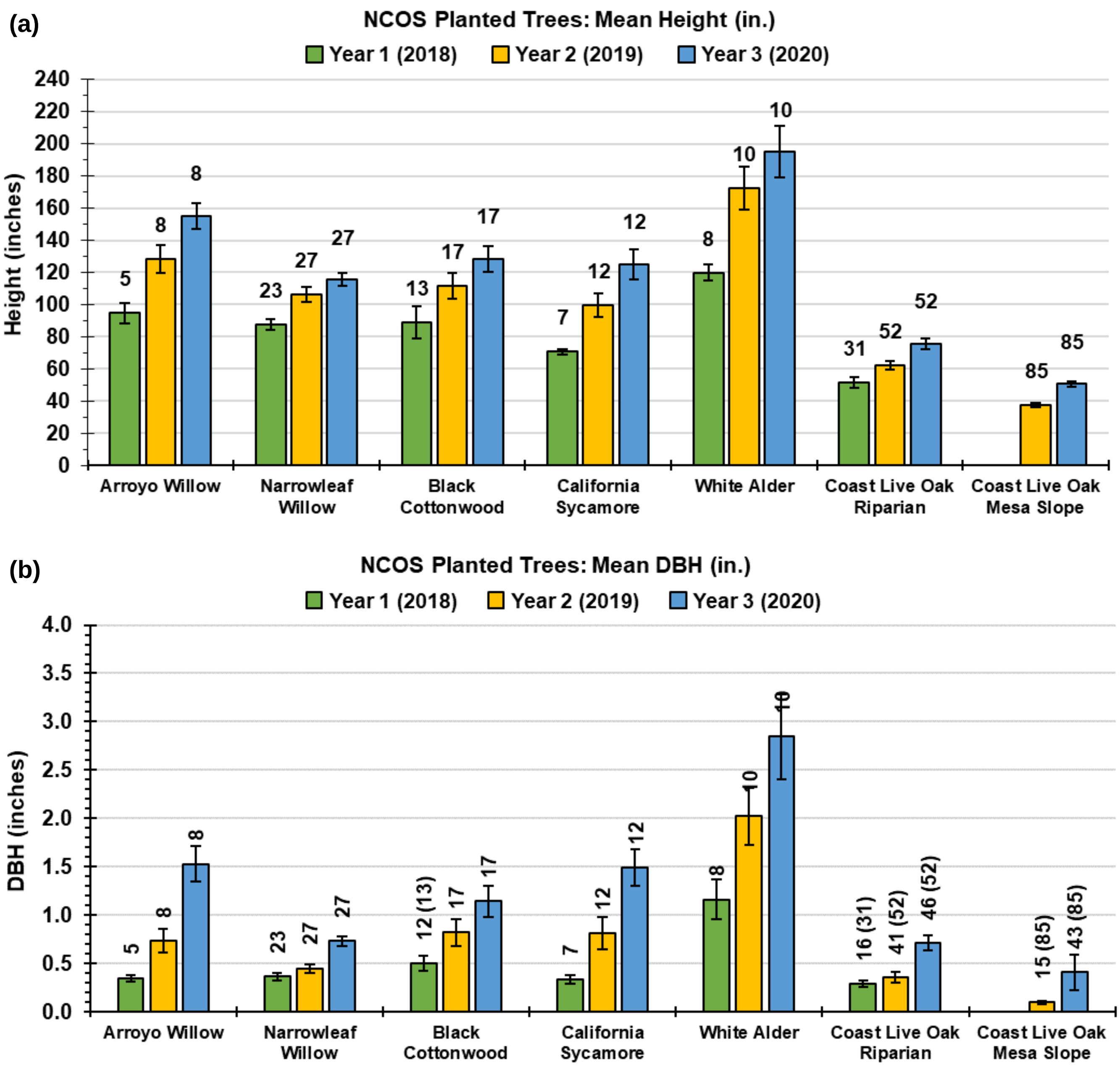

Figure 18. Bar charts of (a) the mean height (inches) and (b) mean diameter at breast height (inches) of six tree species planted during the first and second years of the North Campus Open Space restoration project. Coast live oak trees planted to create oak/chaparral groves on the slopes of the Mesa are shown separately from other oak trees planted in or adjacent to riparian zones. The cumulative number of trees planted and measured is indicated above the bars and is modified in (b) to indicate the number of trees (total planted in parentheses) that were tall enough for a DBH measurement. Error bars are +/- one standard error of the mean.

4. WILDLIFE

Wildlife monitoring efforts at NCOS are focused primarily on monthly bird surveys and targeted surveys for sensitive and special status species such as the federally endangered Tidewater Goby, the threatened Western Snowy Plover, and the California state endangered Belding's Savannah Sparrow. Certain aspects of NCOS are designed and managed specifically to support these and other special status species such as the Burrowing Owl. The status of these species at NCOS are described later in this section.

Additional studies and surveys that are examining and documenting the development of the greater food web at NCOS are focused on wildlife such as arthropods, bats, small rodents, and reptiles. These projects are briefly described at the end of this section.

Bird Survey Methods

CCBER has conducted monthly bird surveys at the project site since September 2017. The surveys are conducted in the morning, beginning within one hour of sunrise, and typically taking two to 2.5 hours to complete. 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). 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". Additional information that may be recorded includes 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. The elevation of the water in the slough (read from a staff gauge at Venoco bridge) and the weather conditions (temperature, wind speed and direction, cloud cover and precipitation) are recorded at the beginning and end of the survey. An example of a map of the observations and routes recorded using the ESRI Collector app for a typical survey is presented in Figure 19.

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. Lastly, the final, reviewed list and count of species observed for each survey, excluding repeat observations, is uploaded to the Cornell Lab of Ornithology's eBird repository.

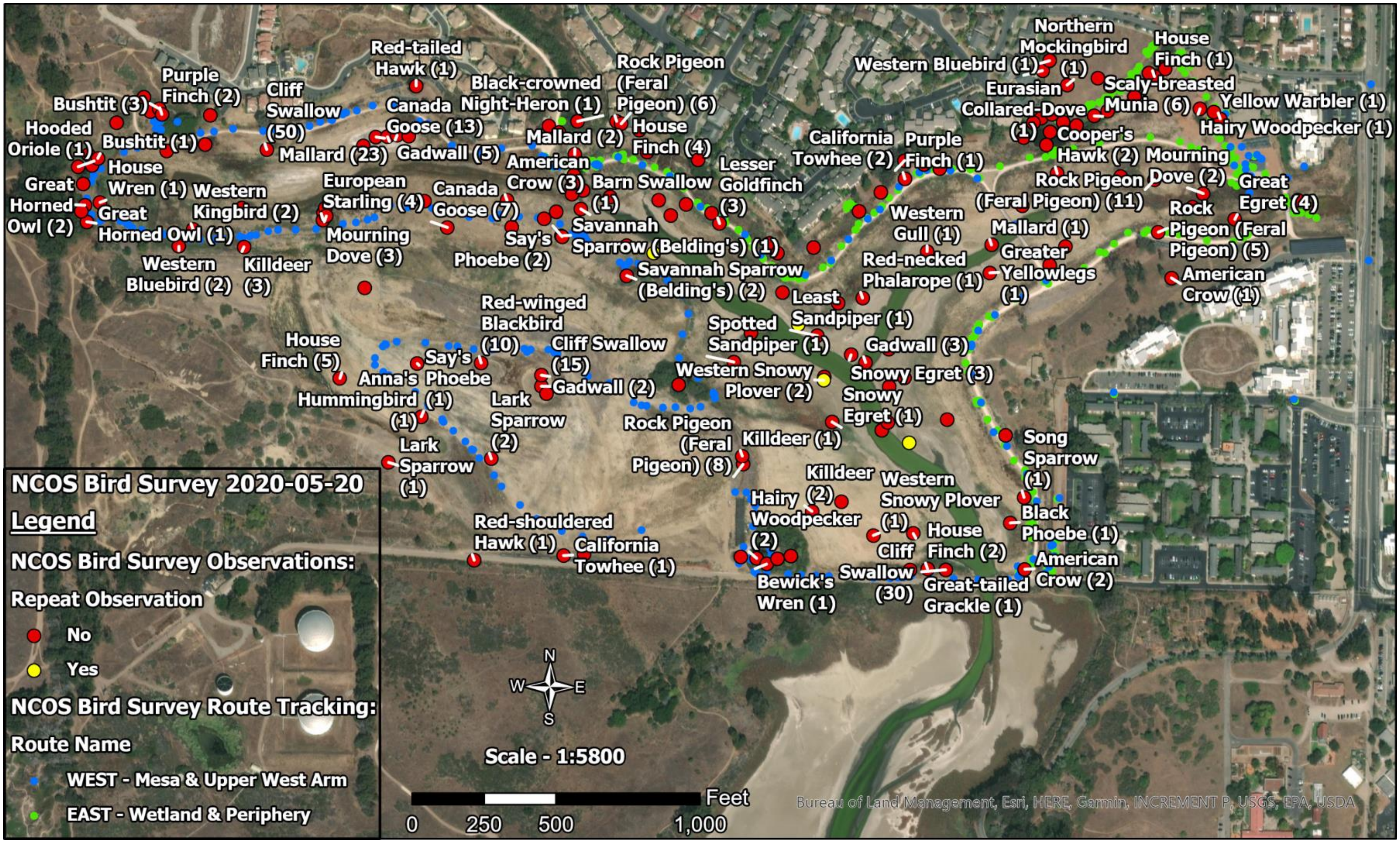

Figure 19. Map of observation data and routes from a bird survey of NCOS conducted on May 20, 2020. Using the ESRI ArcGIS Collector app on tablets, the observation data is manually entered by a member of each team and the route tracking is automatically recorded every 30 seconds. Many, but not all of the observation points from this survey are labeled in the map, including two locations where Savannah Sparrow (Belding's) and Western Snowy Plover were seen.

Bird Survey Data & Trends

Guilds and Data Metrics

To facilitate an efficient means of summarizing, analyzing, and interpreting the bird survey data, we categorized the species observed into 13 guilds based on their primary habitat and/or food source, or ecological niche. Beginning this year, we have split the large and diverse Insectivore guild into two, separating species that are predominately aerial insectivores (*e.g*. swallows and flycatchers) into an Insectivores – Aerial guild, and all others into an Insectivores – Terrestrial guild (e.g. blackbirds, sparrows, woodpeckers, and wrens).

In previous monitoring reports, we presented the cumulative total count of birds in each guild observed each year (September through August). The cumulative total count for a survey year is not a measure of the abundance of birds on NCOS. In this report, we present the data in terms of the mean and standard error of counts per monthly survey. These metrics represent the approximate abundance and variation of birds on the site throughout each year. In addition, we report the total number of species observed and the percent of total observations by guild for each of the three years of survey data collected from September 2017 through August 2020.

Comparison of Survey Years

Bar charts comparing the mean count per survey and the total number of species observed in each guild are presented in Figure 21. In Figure 22, pie charts show changes in the percent of total observations per guild in each year, and Appendix 3 contains a list of all species observed in each survey year grouped by our guilds and sub-classified into eBird Species Groups as defined by the "eBird Clements v2018 integrated checklist (August 2018)".

Since the first year (September 2017 – August 2018), the overall mean number of birds observed per survey has increased by 30 percent each year, from 400 in year one to 521 in year two, and then to 677 in year three (September 2019 – August 2020). This trend is primarily driven by large annual increases in the mean counts of the two Insectivore guilds and especially the Waterfowl & Allies guild (Figure 21). In fact, two Insectivore species (Cliff Swallow and White-crowned Sparrow) and three Waterfowl & Allies species (American Coot, Canada Goose, and Mallard) account for most of the increase in these two guilds, though the mean count of most other species in these guilds has also increased each year (see Appendix 3).

The Warblers guild also exhibited a large increase in the mean monthly count by nearly 200 % in year three (Figure 21). This was chiefly due to a very large increase in Yellow-rumped Warblers, particularly in October to December of 2019. While this warbler species feeds primarily on insects, during winter they will eat the fruits and seeds of many plants, including asters[1]. The aster *Symphyotrichum subulatum* was one of the most abundant species recorded in the 2019 vegetation monitoring data and may have attracted greater numbers of Yellow-rumped Warblers as well as other seed eaters such as White-crowned Sparrows.

[1] https://www.allaboutbirds.org/guide/Yellow-rumped_Warbler/lifehistory

There has been little change in the mean counts of birds in guilds such as Gulls & Terns, Hummingbirds, Omnivores, and Raptors, while the mean count of the Shorebirds guild has shown a decreasing trend since year one (Figure 21).

The total number of species observed increased from 104 in year one to 129 in year two, and 128 species were observed in year three. Though we did not observe an increase in the number of species in the third year of surveys, we did record several species not seen in previous years, such as American Avocet, Black-headed Grosbeak, Canvasback, Caspian Tern, Clark's Grebe, Northern Harrier, Red-breasted Nuthatch, and Virginia Rail. Collectively, 153 species have been recorded over the three years of surveys, which is 71 percent of the 216 species reported to the eBird repository since 2018 (ebird.org/hotspot/L820867?yr=all&m=). Trends in the total number of species and the percent of total observations per guild are similar to the mean monthly counts, though at a smaller degree of change between years (Figures 21 and 22).

Discussion of Slough Water Level Influence on Bird Trends

One factor that may have influenced the trends observed in the third year of surveys was the high level of water that remained in the slough through the winter months. The slough filled in late December and did not breach and empty into the ocean until the middle of March 2020. This resulted in a mean water surface elevation in the winter quarter (December – February) that was more than two feet greater than in previous years (Figure 23). This could explain the increase by nearly 100 percent in the mean monthly count of the Waterfowl & Allies guild, and potentially some of the decline in the mean count of Shorebirds as there would have been reduced mudflat and unvegetated shallow water habitat available. The extended period of a greater amount of open water habitat may have also attracted the nearly 50 percent increase in the number of Cliff Swallows compared to the previous year (see Appendix 3).

Comparison with Reference Site

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 at COPR are usually conducted within two days of the NCOS surveys. However, surveys were not conducted at COPR during most of 2020 due to restrictions associated with the COVID-19 pandemic. We have compared bird species abundance and diversity at the two sites for the first two years of surveys at NCOS. Excluding the beach habitat at COPR, the two years of survey data showed that the 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. This comparison of bird survey data from the two sites is described further in a short article on the CCBER website (www.ccber.ucsb.edu/news-events/2nd-annual-ncos-vs-copr-bird-survey-roundup).

(a)

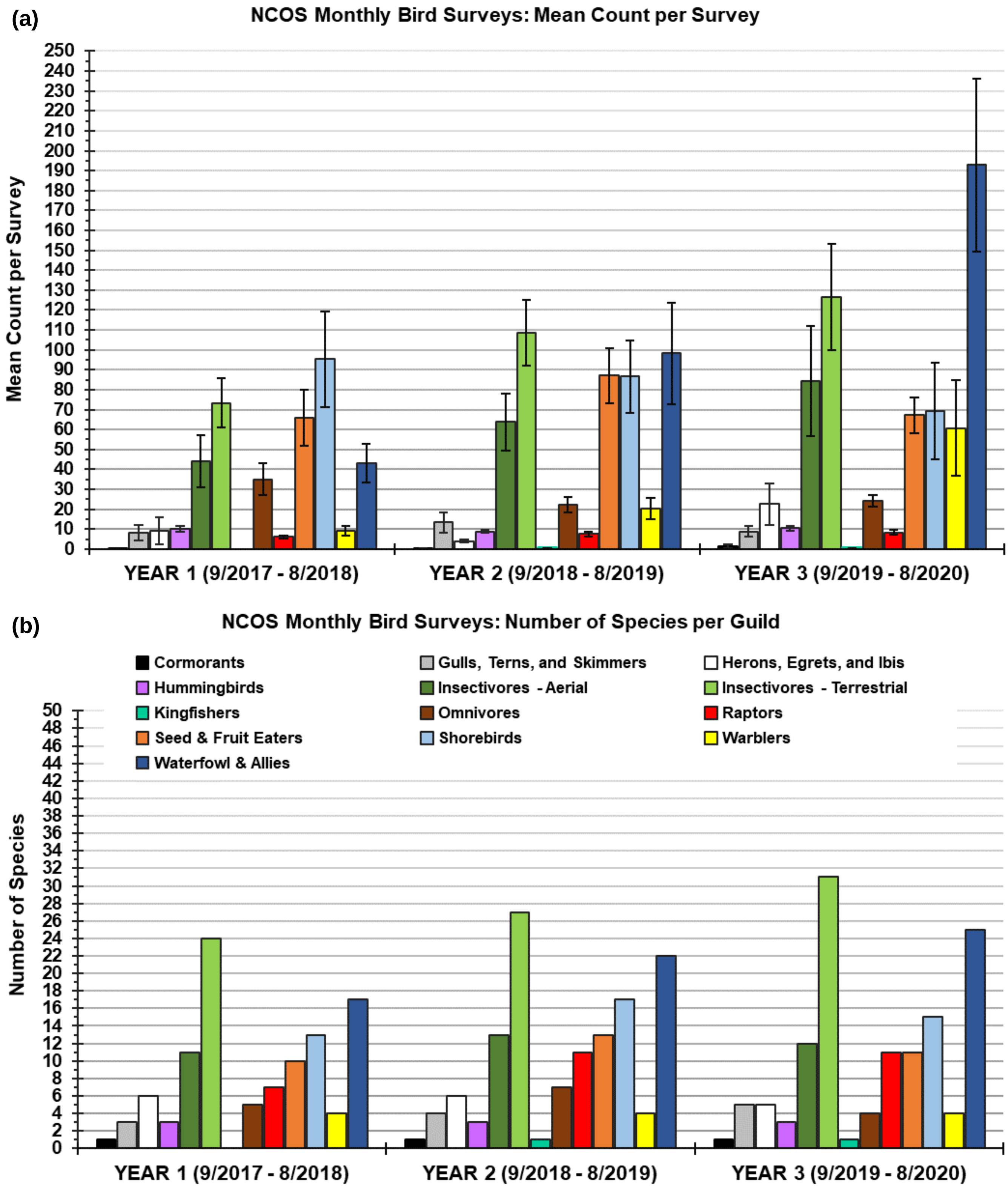

Figure 21. (a) Mean and standard error of counts per survey of birds in 13 guilds (legend in chart (b)) observed in each year (September through August) of monthly surveys at NCOS. (b) Total number of species observed in 13 guilds in each year of monthly bird surveys at NCOS.

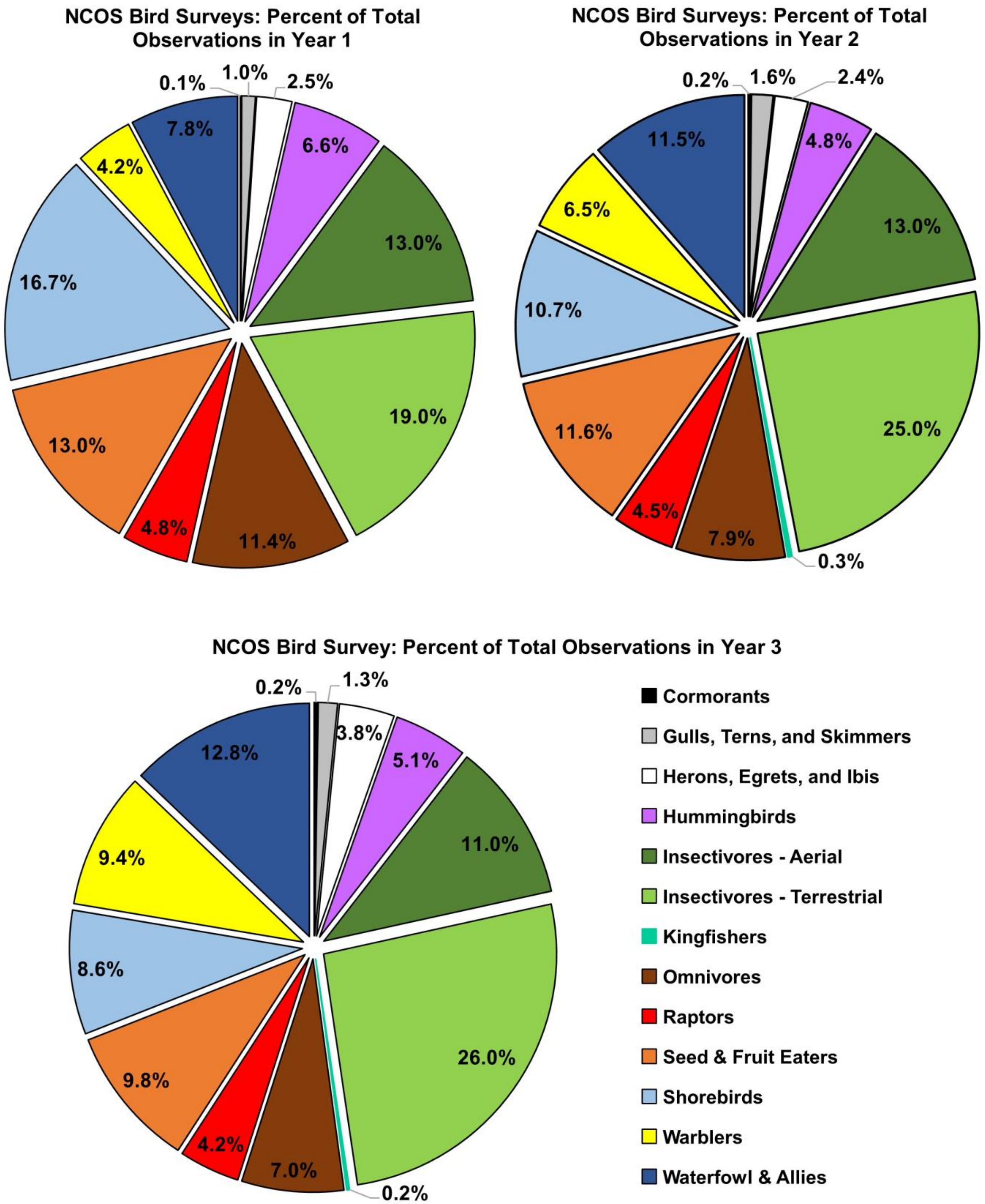

Figure 22. Pie charts of the percent of all observations by guild in each year (September through August) of monthly bird surveys at NCOS.

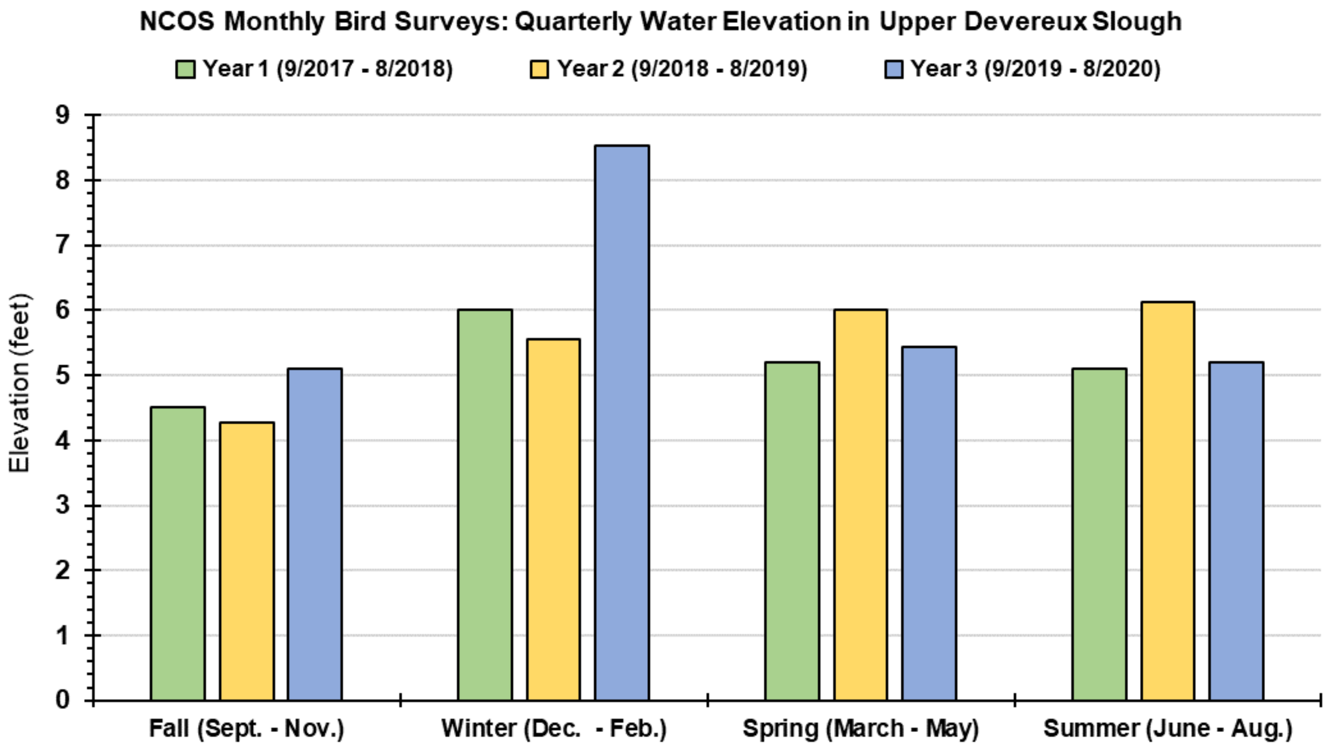

Figure 23. Bar chart comparing the mean quarterly water surface elevation (in feet) of the upper Devereux Slough for each year (September through August) of monthly bird surveys at NCOS.

Figure 24. Aerial photo of North Campus Open Space by Bill Dewey in January 2020 showing the high water level in Devereux Slough that persisted until a breach event in March.

Special Status Birds

Three bird species of particular interest at NCOS include the threatened Western Snowy Plover, the California state endangered Belding's Savannah Sparrow, and the Burrowing Owl, a species of conservation concern nationally and in California. Certain areas of NCOS are designed and managed with a focus on providing suitable and secure habitat for these species, such as the sand flat for the Western Snowy Plover and large areas of undisturbed salt marsh for the Belding's Savannah Sparrow.

Western Snowy Plover have been recorded on site in each survey year, with small increases in the number of observations and individuals seen year after year. During the breeding season, the Sand Flat habitat is monitored closely for signs of nesting activity, and any identified nests are carefully observed and protected when necessary. Breeding attempts have occurred in each of the last three years, with one unsuccessful nest in 2018, two in 2019 and one in 2020 that produced at least one fledgling, though it is uncertain whether it survived.

Belding's Savannah Sparrow have been recorded in each year of surveys, particularly in the spring and summer. There have been multiple observations with counts of more than one individual, with five being the highest count recorded to date. In the May 2020 survey, we recorded three separate observations of males singing, which is evidence of potential breeding activity on site.

Figure 25. Left image: Western Snowy Plover adult and chick on the sand flat at NCOS in June 2020 (photograph by Mark Bright). Right image: A Belding's Savannah Sparrow seen during a monthly bird survey at NCOS in November 2018.

On the top and slopes of the mesa, about 50 hibernacula were installed at the start of the project with Burrowing Owl in mind as well as to provide refuge for other species while vegetation became established. At least one overwintering Burrowing Owl has been recorded during surveys in the fall and winter months for the last two years. In October of 2020, we installed six artificial burrows specifically designed for Burrowing Owl on the mesa, and we have already recorded two owls using these features in recent surveys. Expert birders have also reported anecdotal observations of three Burrowing Owls on site during the most recent winter months.

Figure 26. Top image: One of three pairs of artificial burrows constructed on the mesa of NCOS in the summer of 2020. Bottom image: A Burrowing Owl at an artificial burrow entrance in November 2020.

Breeding Bird Observations

During the monthly surveys, an effort is made to record observations of breeding behavior such as gathering or carrying nest material, courtship/territorial displays or singing, copulation, and actual nests with eggs or chicks, or dependent fledglings with adults. With three years of data, we now have observations of breeding behavior recorded for 24 species, with an average of 13 species and 25 breeding behavior observations per year (Table A3.2 in Appendix 3).

Another source for records of breeding behavior at NCOS is the Santa Barbara Audubon Society's Breeding Bird Study database. The data extracted from this database for NCOS is similar to the monthly bird survey data, with a total of 26 species exhibiting breeding behavior at the site since 2018 at an average of 15 species and 30 observations per year. This database does include some of the records from our monthly bird surveys (Table A3.2 in Appendix 3).

Special Status Aquatic Species

To fulfill project grant and permit monitoring requirements, and for general interest, CCBER has conducted pre- and post-construction surveys for three sensitive and special status aquatic species: California Red-legged Frog, Tidewater Goby, and Southwestern Pond Turtle. These surveys have been led by a 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. A technical report about these surveys is included in the Year 1 NCOS Monitoring Report (escholarship.org/uc/item/0zc3n78c).

Additional surveys for Tidewater Goby have been conducted in October 2019 and July 2020. Details of the October 2019 survey, which recorded five Tidewater Goby in the lower slough, are described in a technical report included in the Year 2 NCOS Monitoring Report (escholarship.org/uc/item/5sj929vh). The survey conducted in July 2020 did not observe any Tidewater Goby, and, unlike prior surveys, did not include the lower portion of Devereux Slough that lies within Coal Oil Point Reserve due to restrictions associated with the COVID-19 pandemic. A Technical Memorandum about the results of the July 2020 survey is provided in Appendix 4 of this report.

Outside of the surveys described above, CCBER staff have observed a Southwestern Pond Turtle prior to construction in the area where Phelps Creek flows into NCOS, and periodically in the same area since the first post-construction sighting in November 2018. The last documented sighting of the species was in March of 2019.

Arthropod Surveys & Studies

Terrestrial Arthropod Surveys, Monitoring, and Collection

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 continuing to be 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. While the monthly bee sampling and related arthropod field work were suspended in March of 2020 due to the COVID-19 pandemic, the identification and quantification of samples in the collection has been able to continue. To date, classification of the specimens collected during the 2016 survey and the monthly bee sampling has identified 144 taxa (including subspecies and variants). This list is available on CCBER's Symbiota database.

Aquatic Arthropod Study

A study 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 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 a vernal pools on the mesa. These samples are compared with samples collected from up to 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 eScholarship (escholarship.org/uc/item/59c872mm).

The compilation, analysis, and summarization of data from the 2019 samples is in process, and sample collection was suspended for most of 2020 due to the pandemic. We anticipate this program to continue in 2021.

Bats, Small Rodents, and Reptiles

In 2020, CCBER performed a pilot study on conducting quarterly surveys of bats in four areas of NCOS using a Wildlife Acoustics sensor and app on a tablet. These surveys showed seasonal variation in the overall number of detections, a proxy for abundance and bat activity on site, as well as the number of species. Overall, up to eight bat species were detected, though the certainty of three of these species is low as they were detected only one to three times and are considered rare (Table 3). Details about this pilot study, including comparisons with a baseline survey of bats at NCOS in 2017, are further described in an article on the CCBER website. Through consultation with Paul Collins of the Santa Barbara Natural History Museum, we are planning to implement a different, more targeted approach to this monitoring in 2021.

Beginning in November 2019, CCBER initiated an education-focused program to assess and monitor the presence and abundance of small rodents and reptiles in the Salt Marsh and Native Grassland habitats on and adjacent to the NCOS mesa. One of these projects is a collaboration with the lab of USCB Ecology, Evolution and Marine Biology Associate Professor Hilary Young and conducted under approval of Institutional Animal Care and Use Committee (IACUC) protocol 908.1. The objective is to provide an educational experience in ecology for students while monitoring changes in the abundance and diversity of small rodents as the restoration progresses. The surveys are conducted by setting out three grids of 20 Sherman Live traps for four nights in a row in each habitat. The traps are baited and cotton balls are added to offer additional shelter and protection for captured animals through the night. All traps are checked early in the morning to avoid heat stress, and any animals captured are quickly identified, measured (length and weight) and marked with an ear tag or sharpee marker on the foot before they are released. We conducted four survey sessions from November 2019 to October 2020 that were focused primarily on establishing and fine-tuning the methods and procedures. Two common mouse species, *Peromyscus maniculatus* and *Reithrodontomys megalotis,* were captured during these first four surveys, with greater numbers of individuals captured in the Salt Marsh than in the grassland.

In October 2020, we established a student-led, long-term monitoring project that involves counting and identifying vertebrates and invertebrates under more than 40 coverboards distributed across the mesa and transition/high salt marsh zone along the southwestern half of NCOS. While this monitoring project is focused primarily on reptiles such as lizards and snakes, all other vertebrates and invertebrates encountered will be recorded and compared with data from pre-project coverboard surveys. Both of these small rodent and reptile monitoring projects are continuing in 2021 and we expect to have more data to report on next year.

Table 3. Number of bat calls per species recorded during dawn (AM) and dusk (PM) acoustic surveys conducted once per quarter at four regions of North Campus Open Space in 2020. The counts do not indicate the number of bats present. Bat calls are detected, recorded and initially identified with a Wildlife Acoustics Echo Meter Touch 2 Pro. Recordings and initial identifications are inspected and compared with keys using Wildlife Acoustics Kaliedoscope software to improve accuracy and confidence as much as possible. Confidence is low for the identification of the species preceded with an asterisk (*).

	WINTER 2020			SPRING 2020			SUMMER 2020			FALL 2020			GRAND
Common Name	**AM**	**PM**	**TOTAL**	**AM**	**PM**	**TOTAL**	**AM**	**PM**	**TOTAL**	**AM**	**PM**	**TOTAL**	**TOTAL**
MESA													
Big Brown Bat				4		*4*							**4**
Hoary Bat				1	5	*6*					19	*19*	**25**
Mexican Free-tailed Bat	3	35	*38*	3	32	*35*		2	*2*		42	*42*	**117**
Silver-haired Bat		3	*3*	1	4	*5*					1	*1*	**9**
NORTH													
Big Brown Bat								2	*2*		4	*4*	**6**
California Myotis		1	*1*										**1**
Hoary Bat	6	7	*13*	6	2	*8*					2	*2*	**23**
Mexican Free-tailed Bat	32	58	*90*	29	8	*37*				10	28	*38*	**165**
Silver-haired Bat		5	*5*	11	3	*14*					3	*3*	**22**
* Western Red Bat								1	*1*				**1**
* Yuma Myotis							2		*2*				**2**
NORTHEAST													
Big Brown Bat					2	*2*		1	*1*				**3**
California Myotis								1	*1*				**1**
Hoary Bat		5	*5*		5	*5*				4	15	*19*	**29**
Mexican Free-tailed Bat		43	*43*	5	79	*84*				50	49	*99*	**226**
Silver-haired Bat		6	*6*	1	25	*26*		2	*2*				**34**
* Western Red Bat										1		*1*	**1**
* Western Yellow Bat					1	*1*							**1**
SOUTH PARCEL													
Big Brown Bat	1		*1*		8	*8*		2	*2*				**11**
California Myotis				4		*4*		1	*1*				**5**
Hoary Bat	3	2	*5*		2	*2*					26	*26*	**33**
Mexican Free-tailed Bat	58	9	*67*	4	5	*9*					12	*12*	**88**
Pocketed Free-tailed Bat											1	*1*	**1**
Silver-haired Bat					2	*2*		1	*1*		1	*1*	**4**
* Yuma Myotis				1		*1*							**1**

5. HYDROLOGY AND WATER QUALITY

Hydrology and water quality monitoring at North Campus Open Space contributes to several objectives of the restoration project, such as: documenting the reduction of flood levels, monitoring the development and functionality of wetland habitats such as Devereux Slough and the newly created vernal pools, and developing long-term datasets that help improve knowledge and understanding of coastal ecosystems and how they may be affected by predicted future sea-level rise.

In this section, we describe the monitoring methods and data for the following:

- various aspects of the hydrology of Devereux Slough,
- the hydrology of the vernal pools created on the NCOS mesa,
- the hydrology and salinity of groundwater at the restoration site,
- dissolved oxygen and salinity levels at different locations and depths in the slough,
- and the concentrations of nutrients and suspended solids in storm water entering into and flowing out of Devereux Slough.

In general, nearly all aspects of the third year (2020 water year) of hydrology and water quality monitoring at NCOS and Devereux Slough reflected the rainfall pattern of the year. This included a seven-week dry spell with warm temperatures in January and February followed by a mid-March rain event that caused the mouth of the slough to breach. There was a sustained high water level of more than five feet deep in Devereux Slough for three months in the winter due to the precipitation pattern and a high beach berm elevation that prevented an early breach. The seven weeks of hot and dry conditions during January and February also affected the hydrologic patterns of the mesa vernal pools, causing all but two of them to dry out completely.

During the three months of high water in the slough, we observed a high degree of stratification of dissolved oxygen and salinity and our water quality sensor in the lower slough was beneath the halocline, recording very low DO levels and high salinity until the slough breached the berm at the mouth in mid-March. Following the slough breach, there were two week-long periods of tidal flow in and out of the slough in late March and early April. These were followed by three two-to-four day periods occurring about two to three weeks apart when seawater spilled over the regenerating beach berm during high tides. The lack of significant rain after the slough breach in March led to a very low water level and very high salinity in the slough by late summer and early fall. In fact, much of the upper portion of the slough became almost completely dry by the end of September.

Devereux Slough Hydrology

Monitoring the hydrology of Devereux Slough contributes to several of the North Campus Open Space restoration project's goals as well as research interests. One of the main goals of the restoration project is to restore the natural flood plain function of the wetland and, consequently, to lower flood levels that previously affected the developments adjacent to the tributaries of the wetland. The hydrology data is also important for documenting the increased water holding 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 that enter the slough in order to quantify the fluxes of nutrients and sediment entering the system, understand the erosional impacts of upstream development and associated imperviousness, and document storm intensity, which is predicted to increase with climate change. The surface water level and flow rate monitoring methods and data are described in the following two sections.

Surface Water Levels - Methods

Throughout the third year of the restoration project, surface water levels at NCOS were monitored using pressure transducer loggers deployed at seven locations:

- Devereux and Phelps Creeks,
- the storm drain outfall that flows into Whittier Channel and in Whittier Pond,
- the upper eastern arm of the restored slough where it is crossed by the long trail bridge,
- at Venoco Road bridge where the restored upper slough meets the extant lower slough,
- and in the lower slough at the pier.

The logger in the lower slough is a multi-parameter 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 North American Vertical Datum 1988, NAVD88) has been determined using either a Real Time Kinematic GPS unit, or by measuring the difference in elevation relative to the nearest reference point. Following an adjustment in August 2019, the elevation of the bottom of the EXO1 sonde was estimated to be 2.25 feet above sea level. The depth sensor on the sonde is 13.75 inches above the water quality sensors, which means the elevation of the depth sensor equates to approximately 3.4 feet elevation. Table 4 lists the locations and elevations of the loggers and Figure 27 contains a map of the locations of the loggers and other hydrology and water quality monitoring sites.

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 deployment locations are indicated in the map in Figure 27.

Deployment Location	Logger Elevation (ft. NAVD88)
Devereux Slough Pier (YSI EXO1 sonde)	Water quality sensors: 2.25, depth sensor: 3.4
East Arm Trail Bridge	3.96
Phelps Creek - Marymount Bridge	9.99
Venoco Bridge - north side	2.84
West Arm - Devereux Creek	8.41
Whittier Channel	10.41
Whittier Pond	5.04

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 contributes to the development of a long-term database that documents how the wetland functions under wet and dry conditions and improves 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 in sand berm elevation associated with sea level rise.

Surface Water Levels - Summary for Year 3 (2020 Water Year)

Prior to the NCOS restoration project, half of the wetland's potential water-holding capacity was supplanted by fill soil deposited to create the Ocean Meadows golf course. This led to flooding of the golf course and adjacent low-lying areas near homes where the incoming creeks entered the site. As we described in previous NCOS monitoring reports, our hydrology data shows that the amount of water level rise in Devereux and Phelps Creeks during storms has decreased from pre-project levels by at least a foot for comparable storm intensities. Peak water levels and elevations recorded during storms in the wet season of the 2020 water year (October 1, 2019 to September 30, 2020) were generally similar to what we observed in 2019 (compare Figures 28 and 29).

In addition to reducing flood levels, the project has also increased the water holding capacity of the slough, which was well demonstrated in the 2020 water year. The hydrology of Devereux Slough during the 2020 water year was largely unlike any of the previous years that we have monitored, and quite different from the 2019 water year (see Figures 30 through 32). The water level in the slough remained above 8.5 feet in elevation for nearly three months from late December until March 16, when a series of consecutive storms pushed the slough to breach the beach berm at the mouth (Figures 31 and 32). Two factors that likely contributed to the long period of high water were:

1. A low amount of rainfall that fell for two months between late December and early March, and
2. A higher beach berm elevation: the lowest elevation of the top of the beach berm measured on November 25, 2019 was 9.8 feet, which is half a foot higher than what was measured prior to the wet season of the previous year (9.3 feet on 12/03/2018).

Following the berm breach, there was tidal fluctuation in the slough for two separate periods of a week to ten days each in late March and following the last storm of the season in April. The slough received additional influxes of seawater during three high tide events. The largest influx occurred in early May and caused the water level in the slough to rise by one foot to an elevation of over six feet at Venoco bridge. Evaporation over the summer brought the water elevation at Venoco bridge down to less than 4.5 feet by the end of September, which is one of the lowest water levels we have recorded since the restoration began.

The Year 2 Monitoring Report (escholarship.org/uc/item/5sj929vh) includes further discussion of this component of the restoration project, including a modeled hypsometric curve for Devereux Slough. With continued monitoring of the hydrology of 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.

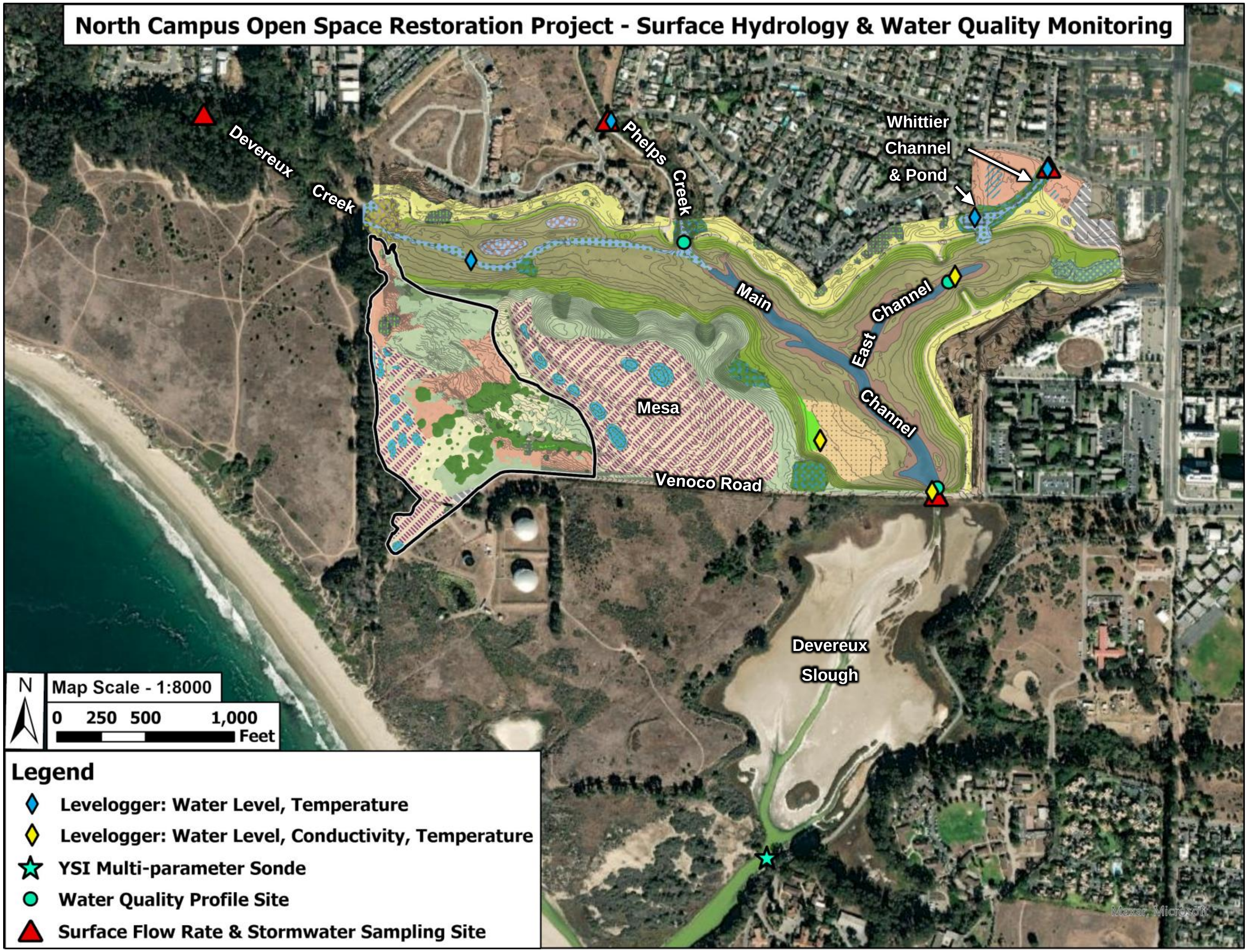

Figure 27. Map of the surface hydrology and water quality monitoring sites at North Campus Open Space and lower Devereux Slough. See Figure 1 for a legend of the habitats/vegetation communities.

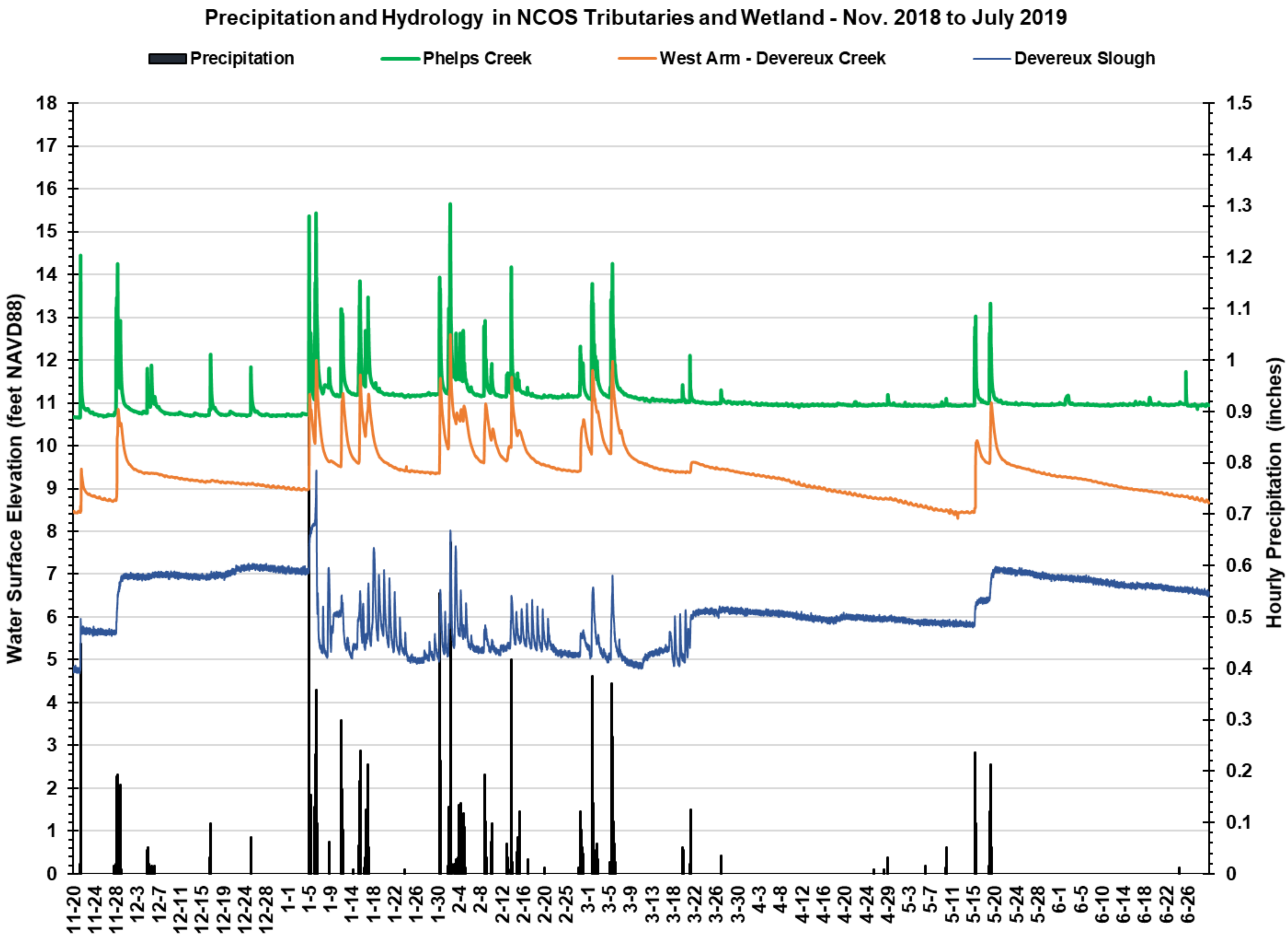

Figure 28. Water surface elevations in two NCOS tributaries and Devereux Slough, November 2018 to July 2019. Black bars represent weekly precipitation in inches recorded at a NOAA climate data station on Coal Oil Point Reserve.

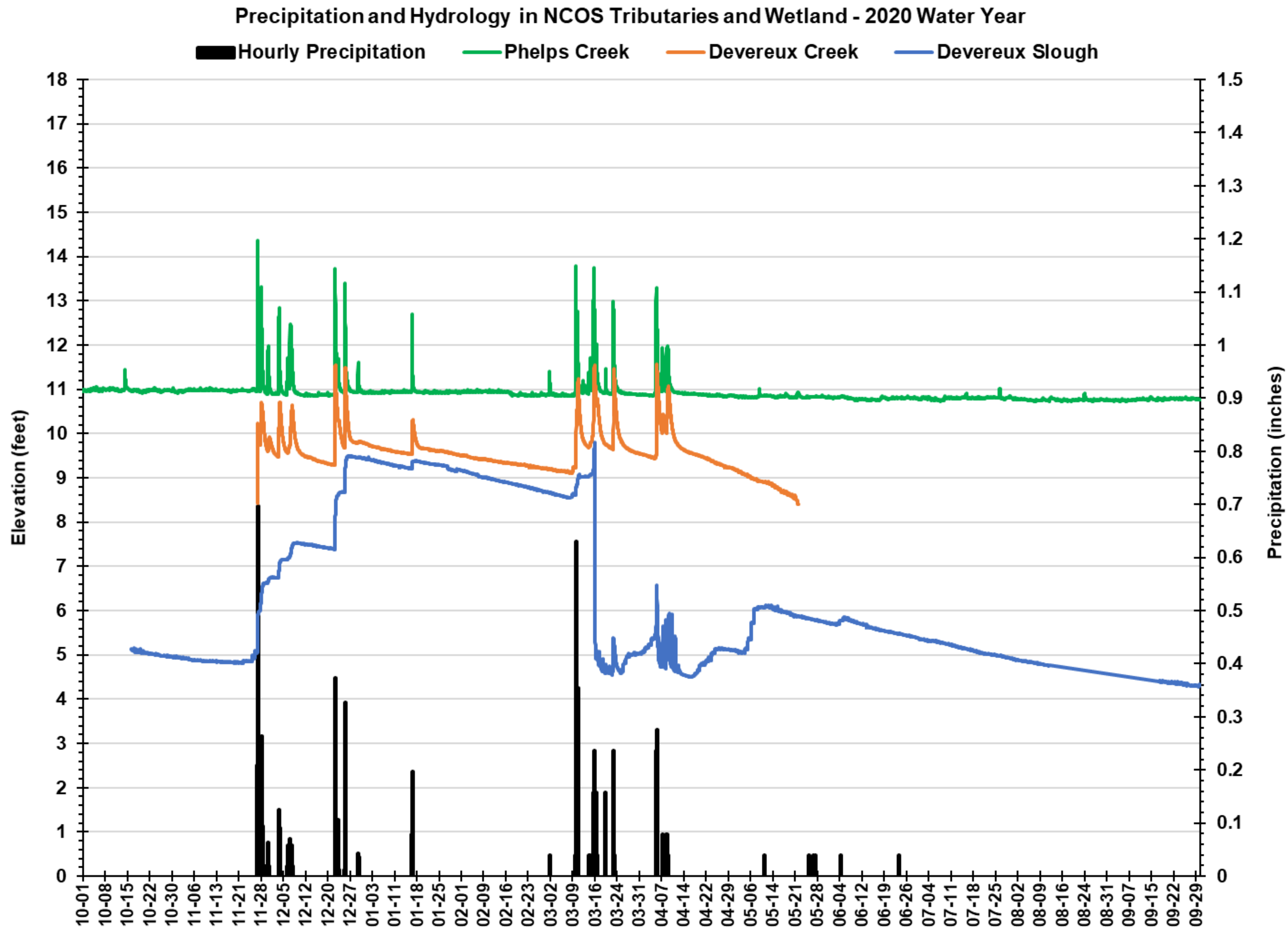

Figure 29. Water surface elevations (feet in NAVD88) of the two main tributaries of Devereux Slough (Phelps and Devereux Creeks), and in the slough at the Venoco access road bridge for the 2020 water year. Data was recorded every 15 minutes with Solinst Leveloggers. Black bars represent hourly precipitation recorded at a NOAA climate station on Coal Oil Point Reserve.

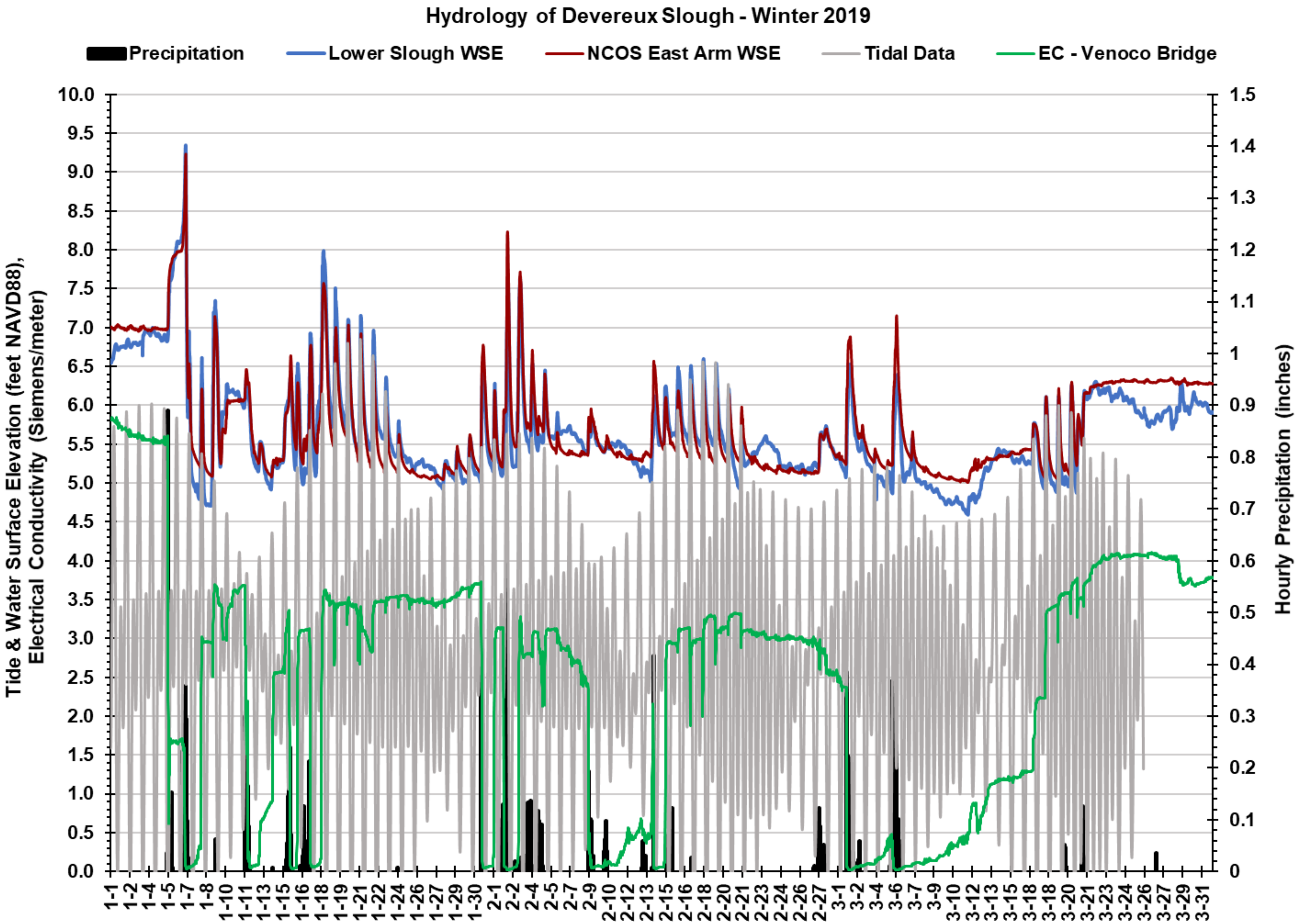

Figure 30. Water surface elevation (feet NAVD88) in the upper east arm and the lower half of Devereux Slough, with local tides in feet and hourly precipitation in inches (courtesy of NOAA), and electrical conductivity (Siemens per meter) of water in the upper east arm, January to April 2019.

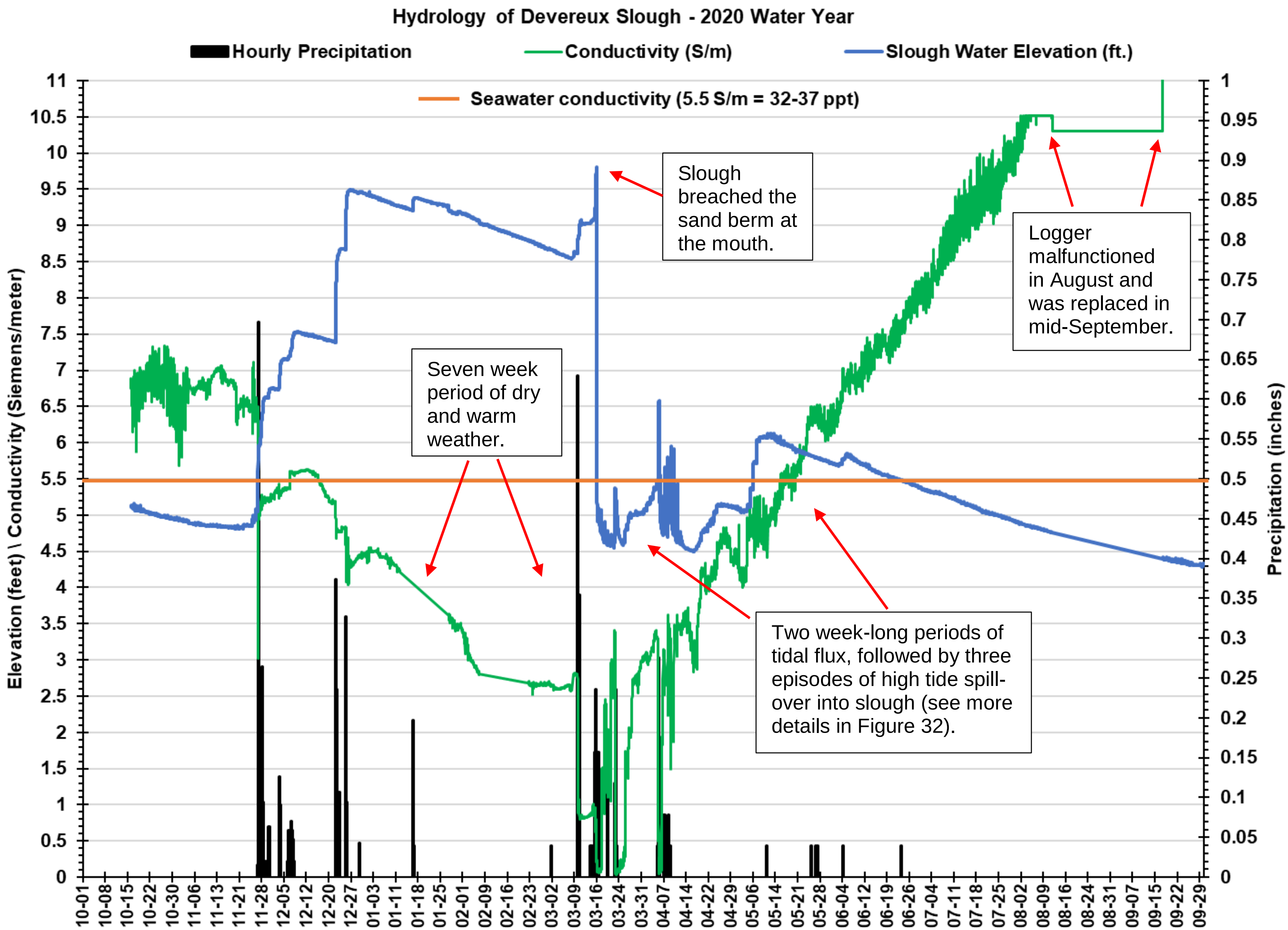

Figure 31. Water surface elevation (feet in NAVD88) and conductivity (Siemens/meter) of upper Devereux Slough during the 2020 water year. Data were recorded with a Solinst Levelogger deployed at the Venoco access road bridge. Black bars represent hourly precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

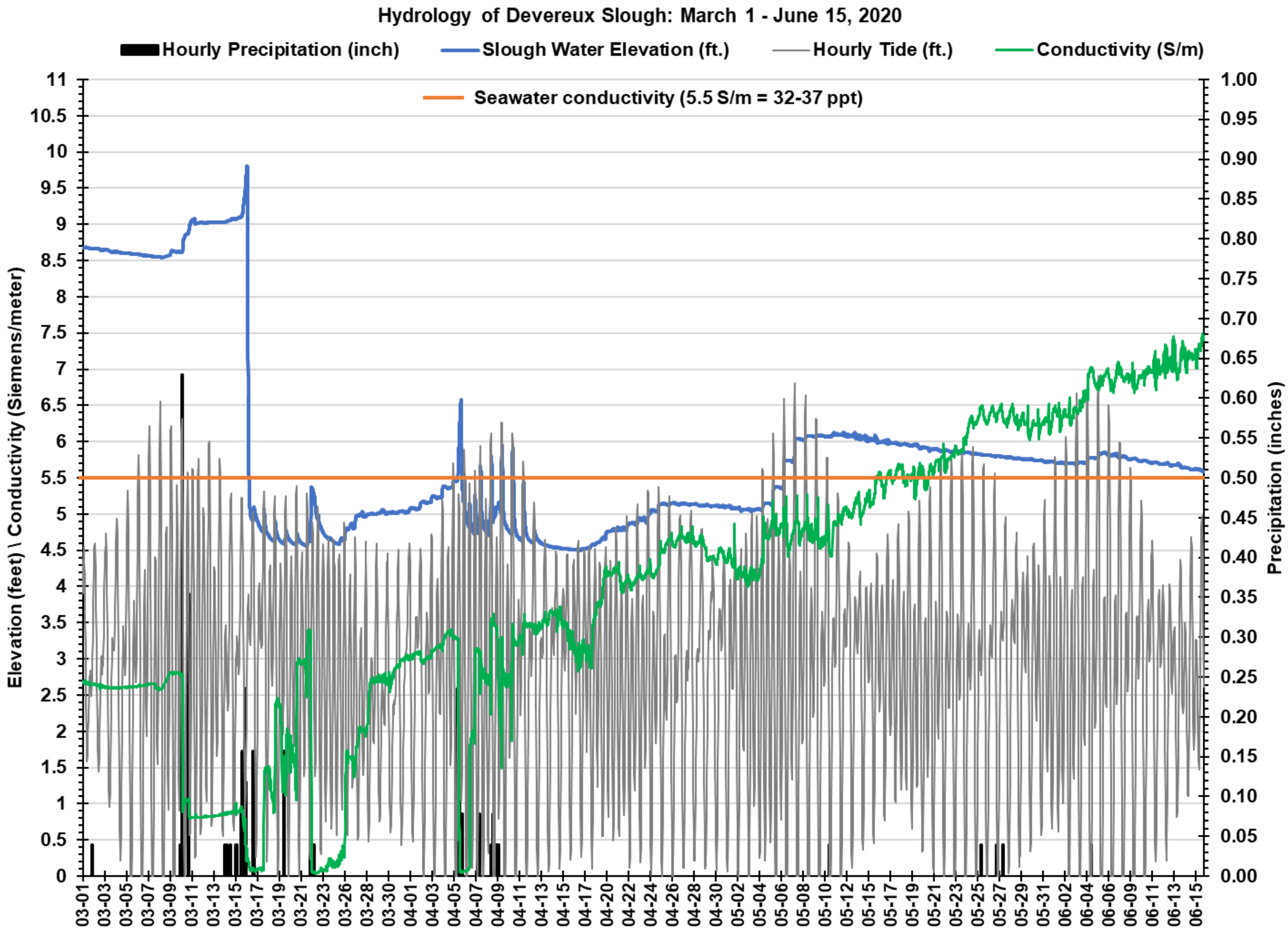

Figure 32. Water surface elevation (feet in NAVD88) and conductivity (Siemens/meter) of Devereux Slough during the

Surface Water Flow Rates

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 storm water flows and contribute 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 and/or cubic feet per second for the stream or storm drain. In order 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 to estimate the flow rate into the lower slough. In the winter of 2019-2020, during the third year of the restoration project, we measured flow at the Whittier Drive storm drain outfall and in Devereux and Phelps Creeks.

The red triangle icons in the map in Figure 27 correspond to the locations where flow measurements are 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 at conduit sites such as the Whittier Drive storm drain outfall. 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 flow rates measured in Phelps Creek, Devereux Creek and in the main wetland channel flowing into the lower Devereux Slough. This flow data is collected as part of the hydrology monitoring program at the North Campus Open Space restoration project.

Date	Time	Width of Stream (m)	Water Stage (cm)	Water Stage (ft)	Area of Flow (m^2)	Mean Velocity (m/s)	Overall Flow Rate (CMM)	Overall Flow Rate (CFS)	Comments
PHELPS CREEK, at Marymount Bridge									
03/07/2016	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.
01/09/2018		4.3	106	3.48	3.09	0.08	23.31	13.71	Segments were 2 ft wide. Uncertain of accuracy of this measurement.
02/13/2019	12:00 - 13:00	3.3	74	2.43	1.68	0.01	1.54	0.90	Segments were 50 cm wide.
02/14/2019	10:40 - 11:00	4.3	99	3.25	2.60	0.01	2.34	1.38	Segments were 50 cm wide.
03/17/2020		3.5	82	2.69	1.84	0.02	3.09	1.82	Segments were 50 cm wide.
DEVEREUX CREEK, near Colorado Drive									
03/21/2018	15:20 - 16:05	2.7	89	2.92	1.88	0.16	20.01	11.78	Segments were 30 cm wide.
03/16/2020	10:48 - 11:23	3.08	66	2.17	1.48	0.14	13.38	7.87	Segments were 50 cm wide.
DEVEREUX SLOUGH - MAIN CHANNEL (downstream of Venoco Bridge)									
02/14/2019	11:20 - 12:40	10.5	101	3.31	7.69	0.16	71.9	42.31	Segments were 50 cm wide.

Table 6. Surface water velocity and flow rates measured at the Whittier Drive storm drain outfall and at culverts that were in place before restoration for controlling the flow of Devereux Creek through the former golf course. This flow data is collected as part of the hydrology monitoring program at the North Campus Open Space restoration project.

WHITTIER DRIVE STORM DRAIN OUTFALL								
Date	**Time**	**Diameter (ft)**	**Level of water (ft)**	**Level / Diameter Ratio**	**Flow Unit Multiplier (K)**	**Mean Velocity (ft/sec)**	**Flow Rate (CFS)**	**Comments**
03/07/2016	14:30 - 15:00	3.64*	2.61	0.717	0.6054	0.1214	1.5065	Used 2-D method with 0.2, 0.4, and 0.8*depth velocity measurements along center line, half lines, and left corner. Right corner was only 0.4 * depth.
12/04/2019	12:00 - 12:35	3.64	1.62	0.45	0.3428	0.0713	0.5017	Used 2-D method, with velocity measurements at 7 depths along center line, 0.2, 0.4 and 0.8*depth along left and right half lines, and one 0.4*depth measurement in each corner.
PRE-PROJECT - DEVEREUX CREEK CULVERTS								
03/11/2016	14:00 - 14:15	1	1	1	0.7854	4.306	5.233	Upper Culvert
03/11/2016	14:00 - 14:15	1	1	1	0.7854	4.101	4.984	Lower Culvert
03/11/2016	15:45 – 16:00	1	1	1	0.7854	4.396	5.342	Culvert under sill that emptied into slough north of Venoco Bridge.

Vernal Pool Hydrology

Vernal pool hydrology monitoring consists of standardized recording of 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 mesa (see map in Figure 33) 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. Water levels in the pools are measured to the nearest quarter-inch by reading a ruler attached to a pvc pipe that is installed at the deepest area of each pool. This monitoring is conducted by CCBER staff and student interns.

The third year of vernal pool hydrology monitoring (water year 2020) began on December 6, 2019, one week after the first significant rainfall of the wet season. By the third week of monitoring, only pools 4 and 8 continued to hold water until the next significant storm in late December filled most pools. This was followed by a seven-week dry period, at the end of which only pools 1 and 2 still held water. A series of rainstorms in early to mid-March filled all pools again, however, subsequent monitoring was interrupted for four weeks in March and April due to safety precautions related to the COVID-19 pandemic. As a result, the amount of data collected was inadequate for determining the length of the water holding period of pools 3, 5, 6, and 7. The small amount of data recorded for these pools generally showed low and/or rapidly declining water levels. In contrast, pools 1, 2, 4 and 8 held water for longer periods, with pools 1 and 2 holding water for at least 21 weeks (Figure 34(b)). This is similar to what was observed during the 2019 water year (Figure 34(a)). Vernal pools are considered functional when they hold a minimum of a few inches of water for at least 100 days. Pools 1, 2, 4, and 8 met this criterion in the 2020 and 2019 water years.

Figure 33. Map of the mesa area of North Campus Open Space with the restored vernal pools labeled with their number. See Figure 1 for a legend of habitat features/plant communities.

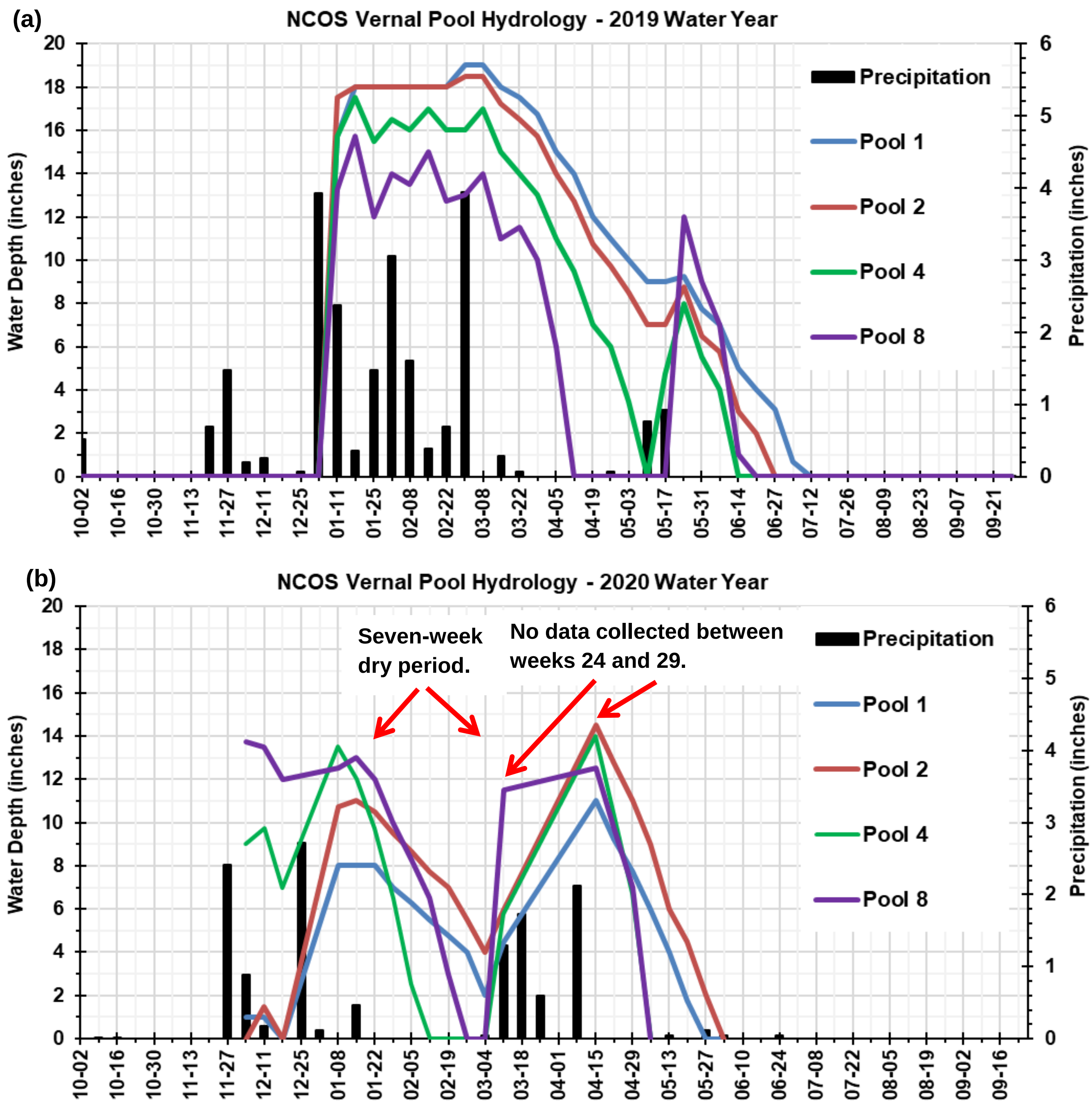

Figure 34. Hydrographs of weekly water depth (inches) in four of the restored vernal pools on the North Campus Open Space (NCOS) mesa in the (a) 2019 and (b) 2020 water years (October 1st to September 30th). The horizontal axis is the week of the water year with a date shown for every other week. Black bars represent weekly precipitation in inches recorded at a NOAA climate station on Coal Oil Point Reserve.

Groundwater Hydrology & Salinity

Monitoring of groundwater hydrology and salinity at the North Campus Open Space restoration site began in 2011, a few years before the project, to collect data that helped inform aspects of the restoration design and plan. After the soil movement and grading of the project site was completed, we resumed this monitoring in 2018 to continue building a long-term data set that informs our understanding of how groundwater hydrology and salinity may change following the restoration, may influence plant survivorship and growth, and may eventually change due to predicted sea level rise.

Groundwater Methods

Groundwater salinity and depth below surface are monitored in up to 12 piezometers, or monitoring wells, some of which have been installed across the greater project area since 2011. A map of the well locations and their elevations is provided in Figure 35. In February 2018, seven of the wells that had been removed for the grading of the project site in 2017 were reinstalled. Four of these wells were installed in the same locations as before the restoration project (wells 14, 15, 17 and 19). Groundwater salinity and depth below surface are typically monitored every two weeks throughout the year in six of the wells that surround the salt marsh (wells 13 through 19) and in well 7. Given its close proximity to the Western Snowy Plover habitat and the main Ventura marsh milk-vetch (VMMV) restoration site, well 12 is monitored using a Solinst Levelogger that records the water level and conductivity every 15 minutes. This enables the collection of high-resolution data that is helpful for planning and management of the VMMV site and significantly reduces the frequency of visits to the well, thereby minimizing disturbance of the Western Snowy Plover area. The other wells that are further away from the wetland and mainly at higher elevations (1, 3, 6, and 8) are typically monitored every two weeks once water is detected in the winter and continuing until they become dry.

To determine the depth to groundwater from the surface at each well (except well 12), a measuring tape with a line drawn with a wet erase marker is inserted to the bottom of the well and the distance (to 1/16 of an inch) where the marker line is washed off is recorded. This measurement is subtracted from the total depth of the well, excluding the height of the riser above ground, to obtain the depth of the groundwater table below the surface. The elevations of the wells (in feet NAVD88) have been recorded using a Real Time Kinematic (RTK) GPS, and this information is used to calculate changes in the approximate elevation of the groundwater at each well. Groundwater salinity (in parts per thousand, ppt) is measured by collecting a small sample in a vial attached to a weighted rope and applying the sample to a refractometer. This monitoring is conducted primarily by student interns and/or community volunteers.

Groundwater Hydrology Data & Trends

A comparison of the pre-restoration (2016 water year: October 1, 2015 to September 30, 2016) and post-grading data (2018 and subsequent water years) shows that, after grading, groundwater has risen closer to the surface by as much as 3.4 feet along the eastern and southern areas of the site that are adjacent to the wetland, and groundwater elevation rose by two to three feet in the western area of the site that is south of Devereux Creek (see data for wells 14, 15 and 19 in Table 7 and Figure 36).

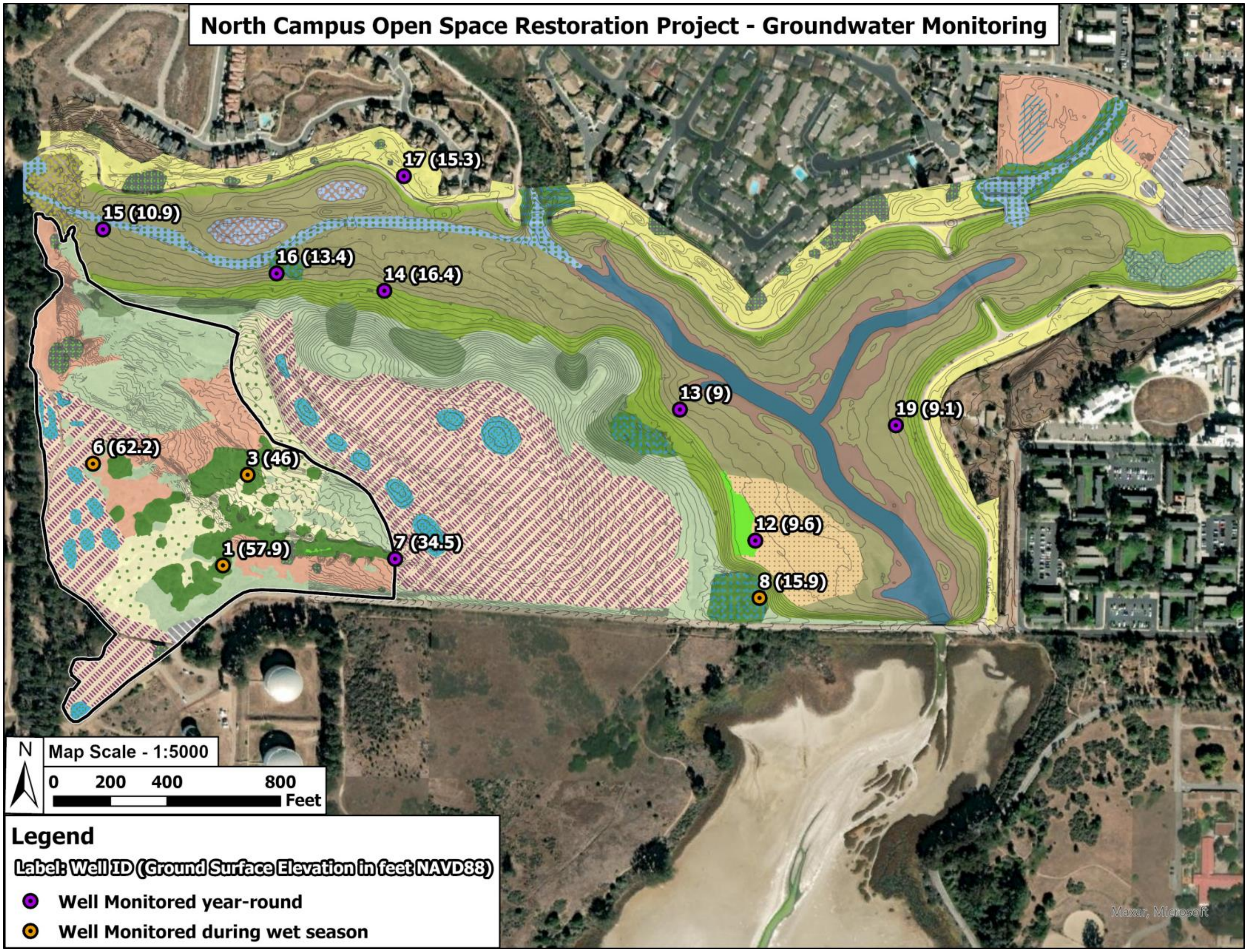

Figure 35. Map of the groundwater monitoring wells at North Campus Open Space, labeled with the well ID number and ground surface elevation in feet (NAVD88).

At the upper wells that have remained in place since installation in 2011, there has been a significant rise of groundwater closer to the surface at wells 3 and 7 following the deposition and grading of soil on the NCOS mesa. Groundwater was rarely detected in these wells prior to the restoration project and not at all for the entire 2016 water year. After grading of the site was completed and monitoring resumed, we began to detect groundwater in well 3 in June 2019 at four feet below the surface and continued to detect water at an average depth of five feet below the surface until September 2020 when no water was detected (Figure 37). Since March of 2018, groundwater has consistently been recorded in well 7 throughout the year at an average depth of 3 to 4 feet below the surface (Table 7 and Figures 37(b) and (c)). During the relatively wet 2019 water year, well 7 was completely submerged for 11 weeks (Figure 37(b)). This well is in a ditch that, prior to grading, ran down to the former sediment basin under the riparian woodland adjacent to Venoco road. The grading of the project site filled this ditch just east of well 7 for the creation of the mesa, which evidently blocked the flow of water past the well, therefore resulting in groundwater becoming perched much closer to the surface than before. This does not appear to have affected the groundwater level at well 8, which is in the former sediment basin that was previously the end of the drainage ditch in which well 7 lies. At well 8, groundwater rises close to or above the surface following heavy rain and then recedes quickly over a few weeks, and this pattern does not appear to have changed since the grading of the site (Figure 37). The groundwater level at well 1 tends to follow a similar pattern to well 8, rising rapidly after heavy rain and then quickly receding. While this trend has not been detected at well 1 prior to the 2020 water year, it may be that the timing of monitoring in previous years missed the brief periods when groundwater was within two to three feet of the surface.

In general, our monitoring data shows that groundwater tends to rise closer to the surface following rainfall in the winter and spring months, and then gradually recedes through the dry summer and fall months each year. The only exception we have observed is at well 6, where groundwater consistently remains at eight feet below the surface throughout each year (Figure 37). The primary factors that influence the amount of change in depth to groundwater throughout the year are the location of the monitoring well and how much rain falls during the winter and spring. The wells that are closest to the wetland (wells 13, 15, and 19) tend to show the greatest frequency of fluctuation in depth to groundwater, which may also be affected by periods of tidal activity in Devereux Slough. For example, the slough was tidal for most of the winter of the 2019 water year, and the depth to groundwater at well 19 along the eastern side of the wetland fluctuated by as much as two feet during this period (yellow line in Figure 36(b)). In contrast, groundwater at well 19 rose from a depth of 4 feet to near or at the surface for most of the winter of the 2020 water year, during which the slough retained a high level of water until breaching in mid-March (Figure 36(c)).

Groundwater Salinity Data & Trends

Since the grading of the site, groundwater salinity has gradually increased in the low-lying area of the western arm (well 15), remained at high levels along the eastern and southern margins of the salt marsh (well 19), and remained constant at brackish to near freshwater levels in all other areas (Table 7 and Figure 38). Salinity at all of the upper wells has consistently remained between 0 to 2 ppt on average.

Throughout the year, groundwater salinity generally decreases in the wells that are closest to the wetland during periods of rainfall in the winter and early spring months, sometimes by as much as 70 parts per thousand (ppt). During the 2020 water year, the salinity recorded at wells 13 and 19 dropped significantly following the first major rainfall of the season in late November and stayed relatively low until the summer (Figure 38(c)). Like the shallow depth to groundwater, this drop in salinity was also likely due to the long period of high water in the slough throughout the winter months. In contrast, during the extended period of tidal activity of the slough in the 2019 water year, the salinity at wells 13 and 19 fluctuated less and remained relatively high (Figure 38(b)), perhaps because there was less time for freshwater from rainfall to percolate through the soil than in the 2020 water year.

Groundwater Data at Well 12

Data recorded with the Levelogger at monitoring well 12 shows that groundwater in the area remains at a baseline depth of approximately 3 feet below the surface during the dry months of each year and quickly rises close to the surface during heavier periods of rainfall in the winter and spring (Figure 39). The sustained depth to groundwater during the winter months ranges from less than a foot down to two feet and may be influenced by the amount of surface water held by the slough, like at well 19 (compare the amount of fluctuation in depth to groundwater in the 2019 and 2020 water year plots in Figure 39). Despite its proximity to the wetland, groundwater salinity at well 12 (measured as electrical conductivity by the Levelogger) is consistently at or less than 1 ppt, which is the lowest of all wells.

Table 7. Pre-project and post-grading ground surface elevation and means of three parameters (groundwater table elevation, depth to water from surface, and salinity) monitored every two weeks (except for well 12, which is monitored with a Solinst Levelogger) at eight piezometers (monitoring wells) at North Campus Open Space. Pre-project data is from the 2016 water year (WY) and post-grading data is from three water years since grading of the project site (2018, 2019, and 2020). Water years (WY) run from October 1st to September 30th. Elevation data is measured in feet using the North American Vertical Datum of 1988 (NAVD88). NA (Not Applicable) is entered for wells that were in a different location pre-project and cannot be compared with data from their post-grading locations. "dry" is entered for pre-project data for well 7, where groundwater was not detected for WY2016. Figure 35 contains a map of NCOS with the locations of the wells labeled with the well number and ground surface elevation.

Well Number	7	12	13	14	15	16	17	19
Pre-project Well Elevation (ft.)	34.5	NA	NA	15.7	13.8	NA	17.3	13.1
Post-grading Well Elevation (ft.)	34.5	9.6	9.0	16.4	10.9	13.4	15.3	9.1
Mean WY2016 Groundwater Table Elevation (ft.)	dry	NA	NA	10.1	6.7	NA	9.5	6.6
Mean WY2018 Groundwater Table Elevation (ft.)	30.0	7.4	7.6	12.8	8.2	10.1	9.1	5.2
Mean WY2019 Groundwater Table Elevation (ft.)	31.4	7.5	7.0	13.1	8.9	10.4	9.6	4.7
Mean WY2020 Groundwater Table Elevation (ft.)	30.8	7.5	6.4	13.8	7.6	10.1	9.3	7.0
Mean WY2016 Depth to Water from Surface (ft.)	dry	NA	NA	4.1	5.4	NA	6.4	5.0
Mean WY2018 Depth to Water from Surface (ft.)	4.5	2.2	1.4	3.6	2.6	3.3	6.3	3.9
Mean WY2019 Depth to Water from Surface (ft.)	3.1	2.1	1.9	3.1	2.0	3.0	5.5	4.2
Mean WY2020 Depth to Water from Surface (ft.)	3.8	2.1	2.7	2.5	3.3	3.3	6.0	2.2
Mean WY2016 Salinity (ppt)	dry	NA	NA	4	29	NA	8	78
Mean WY2018 Salinity (ppt)	0	1	61	2	33	6	6	93
Mean WY2019 Salinity (ppt)	1	<1	74	3	38	6	5	92
Mean WY2020 Salinity (ppt)	2	<1	64	4	41	7	7	50

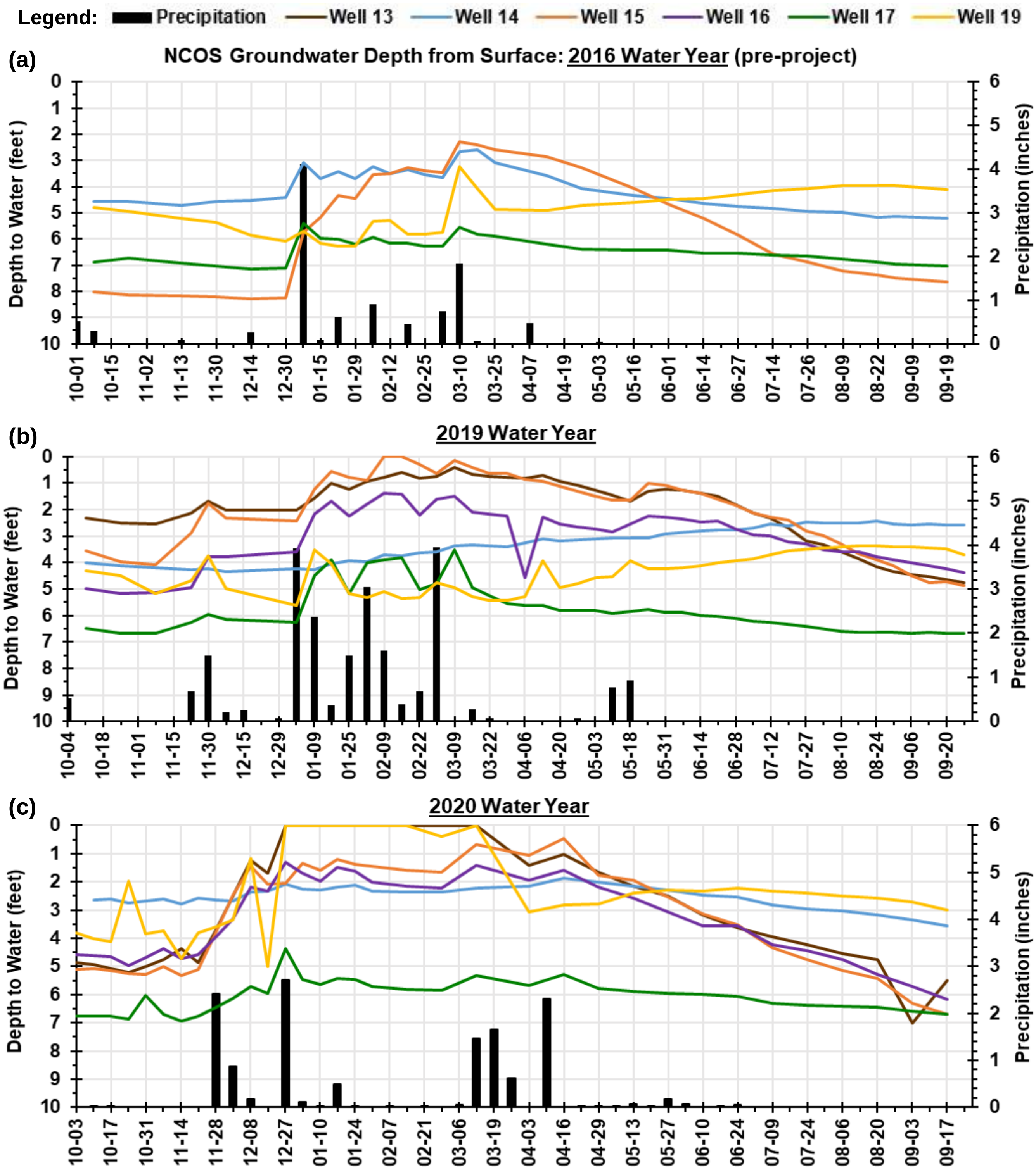

Figure 36. Plots of the depth to groundwater from surface (feet) measured every two weeks at six piezometers (monitoring wells) surrounding the North Campus Open Space wetland. Chart (a) is pre-project data collected in the 2016 water year at four wells installed in the same location after grading. Charts (b) and (c) are data collected in the post-grading water years of 2019 and 2020, respectively. The horizontal axis is the week of the water year with a date shown for every other week. Black bars represent weekly precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

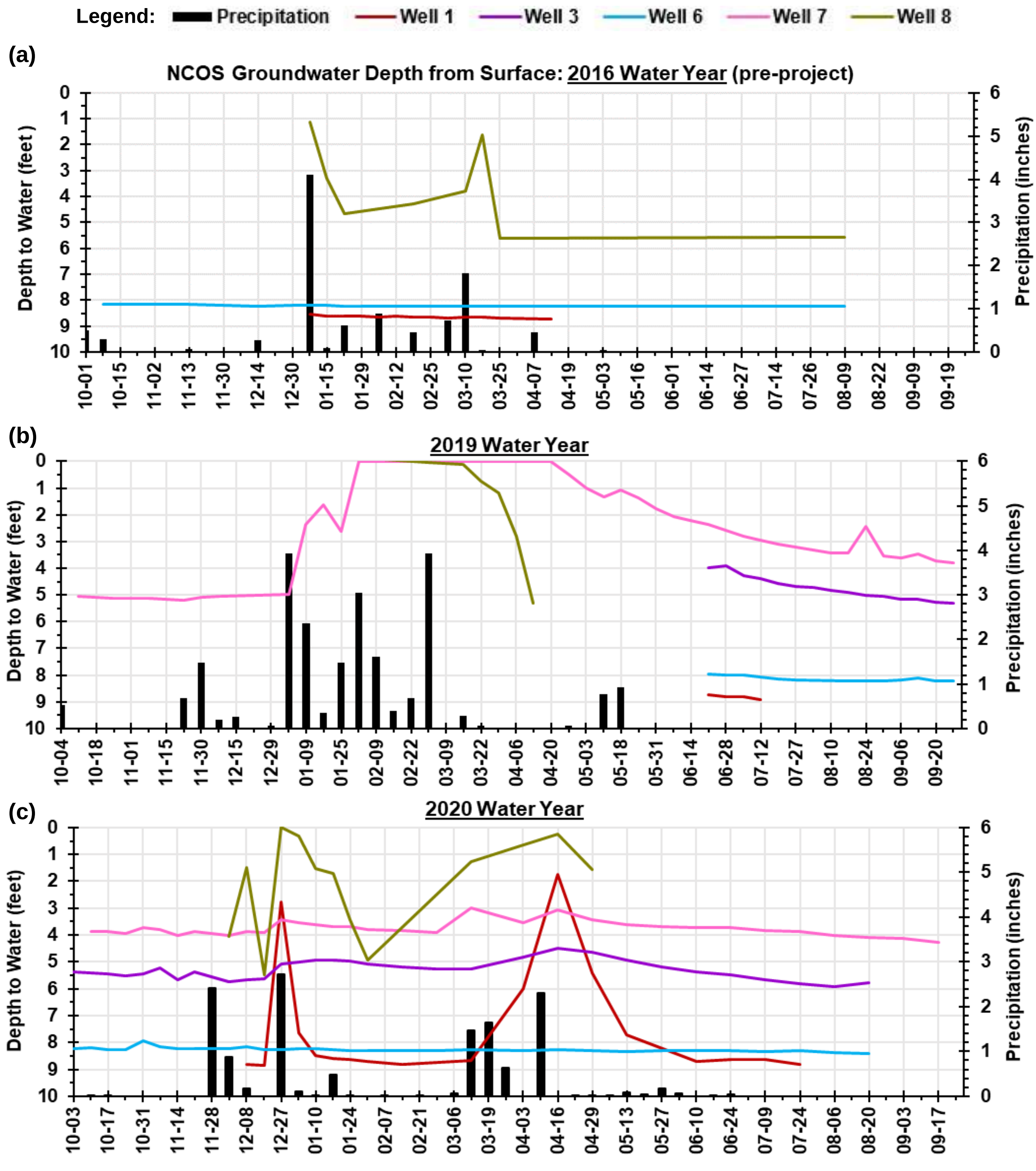

Figure 37. Plots of the depth to groundwater from surface (feet) measured periodically at five piezometers (monitoring wells) on the upper areas of North Campus Open Space. Chart (a) is pre-project data collected in the 2016 water year (no water detected in wells 3 and 7). Charts (b) and (c) are data collected in the post-grading water years of 2019 and 2020, respectively. The horizontal axis is the week of the water year with a date shown for every other week. Black bars represent weekly precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

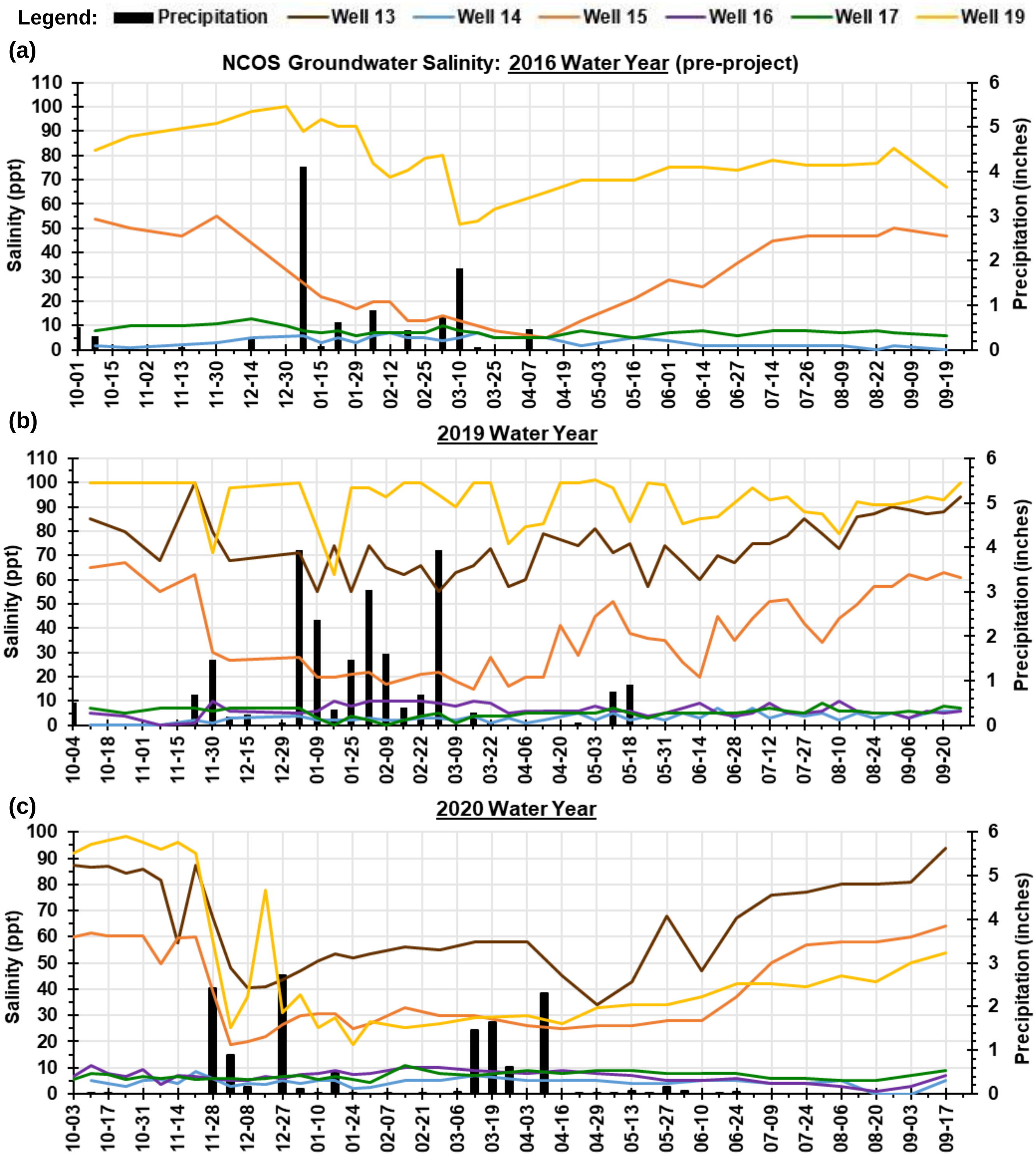

Figure 38. Plots of groundwater salinity (in parts per thousand, ppt) measured every two weeks at six piezometers (monitoring wells) surrounding the North Campus Open Space wetland. Chart (a) is pre-project data collected in the 2016 water year at four wells installed in the same location after grading. Charts (b) and (c) are data collected in the post-grading water years of 2019 and 2020, respectively. The horizontal axis is the week of the water year with a date shown for every other week. Black bars represent weekly precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

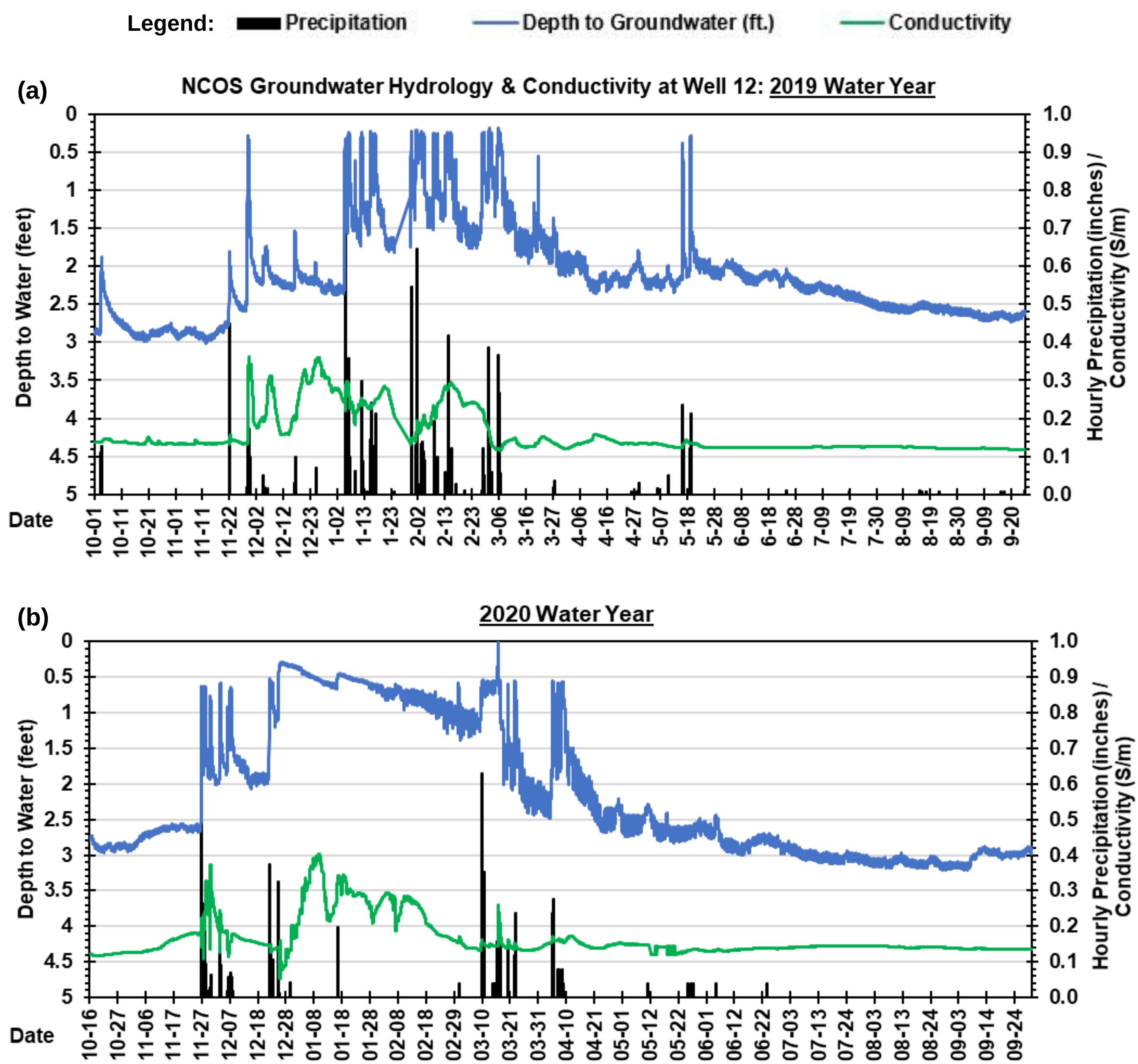

Figure 39. Plots of the depth to water from surface (feet) and conductivity (Siemens per meter, S/m) of groundwater recorded by a Solinst Levelogger every 15 minutes in piezometer monitoring well 12 in the (a) 2019 and (b) 2020 water years (October 1 to September 30) at North Campus Open Space (NCOS). The left vertical axis representing Depth from Surface (feet) is in ascending order with 0 at the top representing the ground surface. Black bars represent hourly precipitation in inches recorded at a NOAA climate data station on the adjacent Coal Oil Point Reserve. Figure 35 contains a map of the locations and elevations of groundwater monitoring wells.

Devereux Slough Water Quality

The enhancement of the ecological health and 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. This monitoring consists of three components:

1. Automated collection of data on dissolved oxygen, conductivity, salinity, temperature, and chlorophyll and blue-green algae concentrations as well as water level using a multi-parameter sonde at a fixed location in the lower section of the slough in Coal Oil Point Reserve.
2. Weekly collection of data on dissolved oxygen, conductivity, salinity, and temperature at one foot depth intervals at three locations in the restored upper arms of the slough at NCOS using a handheld water quality sensor.
3. Periodic collection and analysis of storm water samples for concentrations of nutrients and suspended solids as well as other inputs from urban runoff that enters the wetland.

Lower Slough Water Quality Data - Methods

CCBER initiated the automated collection of water quality data in the lower section of Devereux Slough in 2014, three years before restoration at NCOS began. The objective of this monitoring is to develop a long-term, high-resolution data set of water quality parameters for detecting potential changes in the slough before and after restoration at NCOS, and can serve as a reference for comparison with water quality data collected in the restored upper slough. The data is collected with a multi-parameter YSI EXO1 sonde deployed in the main channel of the lower Devereux Slough (see map in Figure 27). The sonde is housed in a perforated two-inch diameter pvc pipe attached to a pier pylon, and it is set at a fixed depth that ensures the water quality 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 psu), temperature (degrees Celsius), blue-green algae and chlorophyll (in relative fluorescence units or RFU and µg/L), and water depth (feet).

In this report, we present the daily average of the parameters recorded by the EXO1 sonde for the 2019 and 2020 water years, plotted in the two charts in Figure 40. These two water years differed noticeably in the amount and frequency of precipitation and the timing and duration of tidal connectivity of the slough (see Figures 30 through 32), and these differences had varied effects on the water quality data collected by the sonde.

Unfortunately, in both water years, the EXO1 sonde experienced a few malfunctions that resulted in periods of more than a month with missing data from one or all sensors. In June of 2019, we sent the sonde to YSI for repair, which resulted in two months of no data until we were able to redeploy the sonde at the end of August. At that time, we raised the fixed depth of sonde by approximately 2.25 feet in an effort to reduce the period of time that the sensors are below the halocline in the water profile, and to capture more of the variability in DO concentrations. This change in depth is reflected in the greater difference between the water surface elevation and the depth of water above the sensors that begins in the far right of the chart in Figure 40(a).

Lower Slough Water Quality Data – Dissolved Oxygen and Conductivity/Salinity

Since the sonde is deployed at a fixed depth and the water in Devereux Slough typically becomes stratified and hypersaline, particularly in the late summer and fall, there are periods when the sonde's sensors may sit below the halocline in a stratum where density and salinity are greater than at shallower depths and mixing seldom occurs. This at least partly explains the very low DO levels recorded by sonde during the first three months of the 2019 water year, and during the winter months of the 2020 water year, when the depth of water above the sensors was greatest and apparently none of the freshwater flowing in from winter storms reached the sonde (Figure 40).

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 conductivity and salinity, as well as frequent cycling or movement of water in the slough (Figure 40(a)), both of which tend to increase DO[2]. However, the DO concentrations during this time were abnormally high, indicating that there may have been a problem with the sensor. Late season rainfall in May of the 2019 water year led to a higher water level through summer that helped tamper the gradual increase in conductivity as water evaporated later in the year.

Conversely, in the 2020 water year, the water level in the slough remained at a high depth of more than five feet above the sensors for more than three months following the first major rains of the winter season. This appears to have kept the EXO1 sensors below the halocline in higher density and hypersaline water with no mixing during this entire period, as indicated by the very low DO concentrations and a static conductivity of about 60,000 µS/cm (or 6 S/m), which is above the average seawater conductivity of 55,000 µS/cm (5.5 S/m) (Figure 40(b)). As soon as the slough breached the berm at the mouth and briefly became tidal in late March, the DO concentration almost immediately increased and then fluctuated within a normal range of 4 to 11 mg/L for the rest of the year. This suggests that the change we made to the position of the sonde in August 2019 achieved our purpose of keeping the sensors above the halocline through the summer and into the fall.

Lower Slough Water Quality Data – Chlorophyll and Blue-green Algae

Concentrations of chlorophyll and blue-green algae recorded by the EXO1 sonde tend to follow similar patterns each year. The concentrations are usually greatest in late summer and early fall when there is no influx of new water and the existing water gradually evaporates and increases in density and salinity. The lowest concentrations occur primarily in the winter and spring, especially during and after periods of tidal fluctuation and filling of the slough with new water either from rainfall or from seawater brought in during tidal connectivity. There are usually brief spikes in concentrations following heavy rainfall, such as in mid-December and late March of the 2020 water year. Storms that produce a high amount of rainfall typically flush excess nutrients into the slough, which subsequently induces rapid growth of algae and phytoplankton. It is unclear what caused the high spikes in chlorophyll and blue-green algae in late November of the 2020 water year as this was not preceded by rain or any other influx of water. It did seem to coincide with a drop in temperature by an average of one degree Celsius as well as a brief drop in DO. These changes together suggest a shift or mixing of the layers or strata in the water column, possibly due to a large change in atmospheric pressure or a high wind event. The unusual spike in concentrations continued after all sensors were cleaned and calibrated on November 23rd, and only declined after the first major rains of the season fell at the end of November (see Figure 40(b)).

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[2] Fondriest Environmental, Inc. "Dissolved Oxygen." Fundamentals of Environmental Measurements. 19 Nov. 2013. Web. < https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/ >.

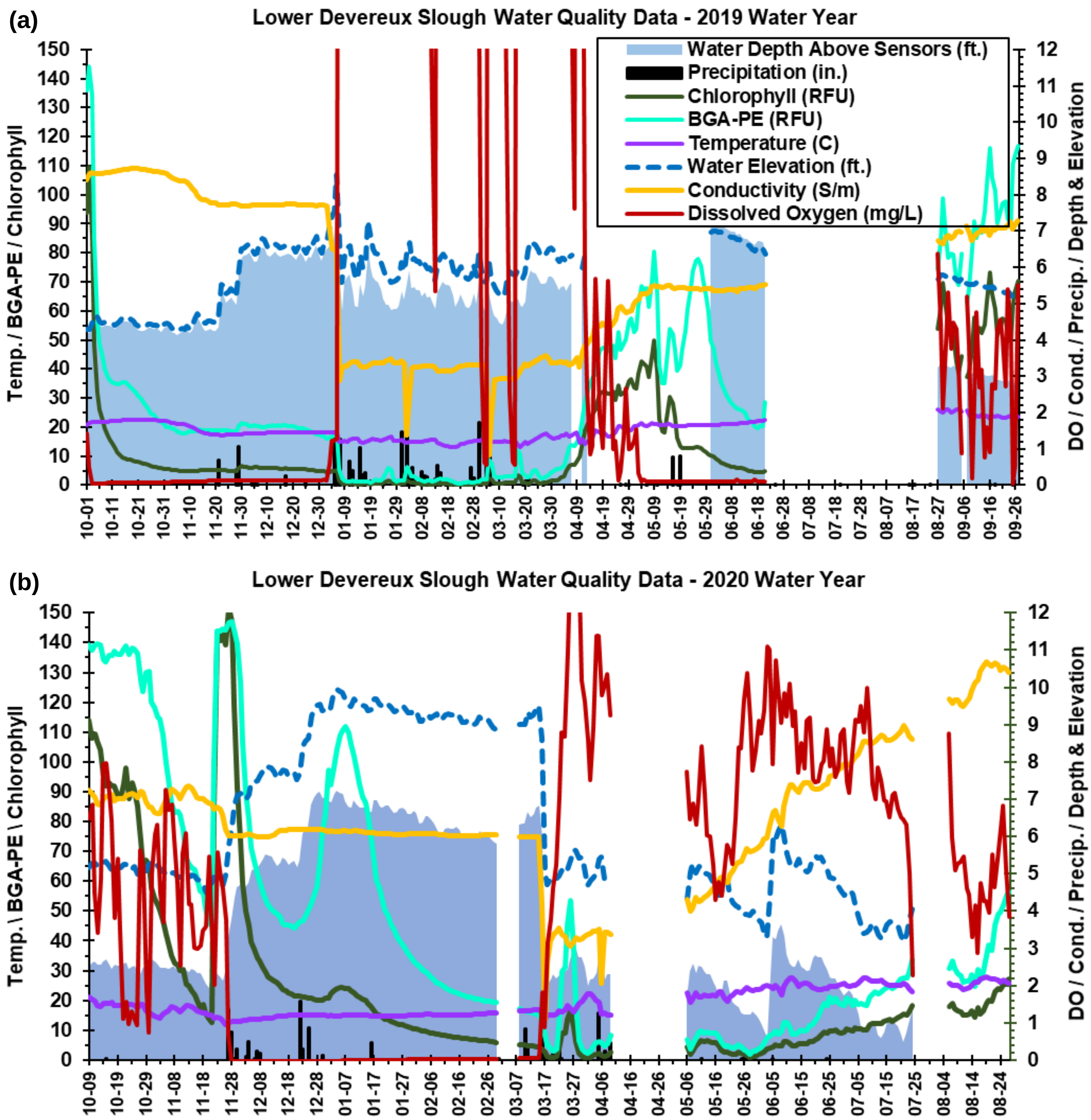


Figure 40. Daily average water quality and level data recorded in the (a) 2019 and (b) 2020 water years (October 1st to September 30th) with a YSI EXO1 sonde in the lower portion of Devereux Slough (see map in Figure 27). A dashed blue line indicates the water surface elevation in feet (NAVD 88), determined from comparing staff gauge measurements with the sonde's depth measurements. In August 2019, the fixed position of the sonde was raised by approximately 2.25 ft, which decreased the depth of water above the sensors. RFU stands for Relative Fluorescence Units. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. Precipitation data was recorded at a NOAA climate station on Coal Oil Point Reserve. Gaps in the data are periods when the sonde malfunctioned and/or was out for repairs.

Restored Upper Slough Water Quality Monitoring - Methods

In the restored upper arms of Devereux Slough, we are collecting dissolved oxygen, conductivity/salinity, and temperature data at three locations on a weekly basis. This data is primarily collected by student interns using a portable YSI Pro2030 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 27). From the bridges, the sensor is lowered to the water and data are recorded at the surface and at each foot of depth down to the bottom. The purpose of this monitoring is to detect and assess the stratification and variability of these water quality parameters at different locations in the wetland. This data provides environmental information for interpreting results from the monitoring of aquatic organisms such as arthropods and the tidewater goby, and it contributes to our understanding of the functionality of the wetland.

Restored Upper Slough Water Quality Monitoring – Data Summary & Main Observations

The dissolved oxygen (DO, in mg/L) and conductivity (Siemens per meter, S/m) data for the surface (top 1-foot of depth) and bottom of the water column along with the average temperature (Celsius) and water depth recorded weekly at the three sites in the 2019 and 2020 water years are presented in Figures 41 through 46. We present conductivity instead of salinity (in ppt) because in August and September of the 2020 water year, the salinity at the east channel and Venoco bridge sites exceeded the maximum limit that the YSI probe could calculate. This meant that the YSI could also only calculate DO concentrations in percent saturation, not mg/L. Therefore, we have left out the DO data for August and September of the 2020 water year at the east channel and Venoco bridge sites.

Our main observations from this monitoring are that there is vertical stratification of DO and conductivity/salinity at all locations in the wetland, but this varies in magnitude and duration depending on the depth of water and location. At the outlet of Phelps Creek into the upper western arm of the slough, the water depth is usually at or below two feet and there is little to no stratification throughout most of the year. One exception occurred for a few weeks in the winter of the 2020 water year when the water depth increased from two to five feet and the DO at the surface was greater than at the bottom of the water column by as much as 8 mg/L (Figure 41(b)). In contrast, surface DO tends to be greater than bottom DO by as much as 8 mg/L for most of the year in the main slough channel by Venoco bridge, where the water depth tends to remain well above two feet throughout the year (Figure 45).

Stratification in conductivity is also most prevalent in the main slough channel by Venoco Bridge, where the conductivity at the bottom of the water column can be greater than the surface by as much as 5 Siemens per meter (approximately 30 ppt) (Figure 45). Conductivity at the Phelps Creek outlet remains at freshwater levels for most of the year, with occasional brief increases likely caused by brackish water reaching the area when the slough is tidal (as in the winter of the 2019 water year), or during periods of high temperatures (Figure 42). The low conductivity/salinity that prevails at the Phelps Creek outlet also plays a role in limiting the stratification of DO since higher salinity reduces DO concentrations[3], which is apparent in the bottom of the water column of the main slough channel near Venoco Bridge. The high degree of stratification at the Venoco bridge site during the winter months of the 2020 water year

[3].Fondriest Environmental, Inc. “Dissolved Oxygen.” Fundamentals of Environmental Measurements. 19 Nov. 2013. Web. < https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/ >.

resulted in high conductivity and low DO levels at the bottom of the water column that were similar to what was recorded with the EXO1 sonde in the lower slough (compare Figure 45(b) with Figure 40(b)).

In the upper east arm of the restored slough, the degree of stratification sits roughly in-between the Phelps Creek and Venoco Bridge sites, while the conductivity/salinity levels are similar to the main slough channel (Figures 43 and 44).

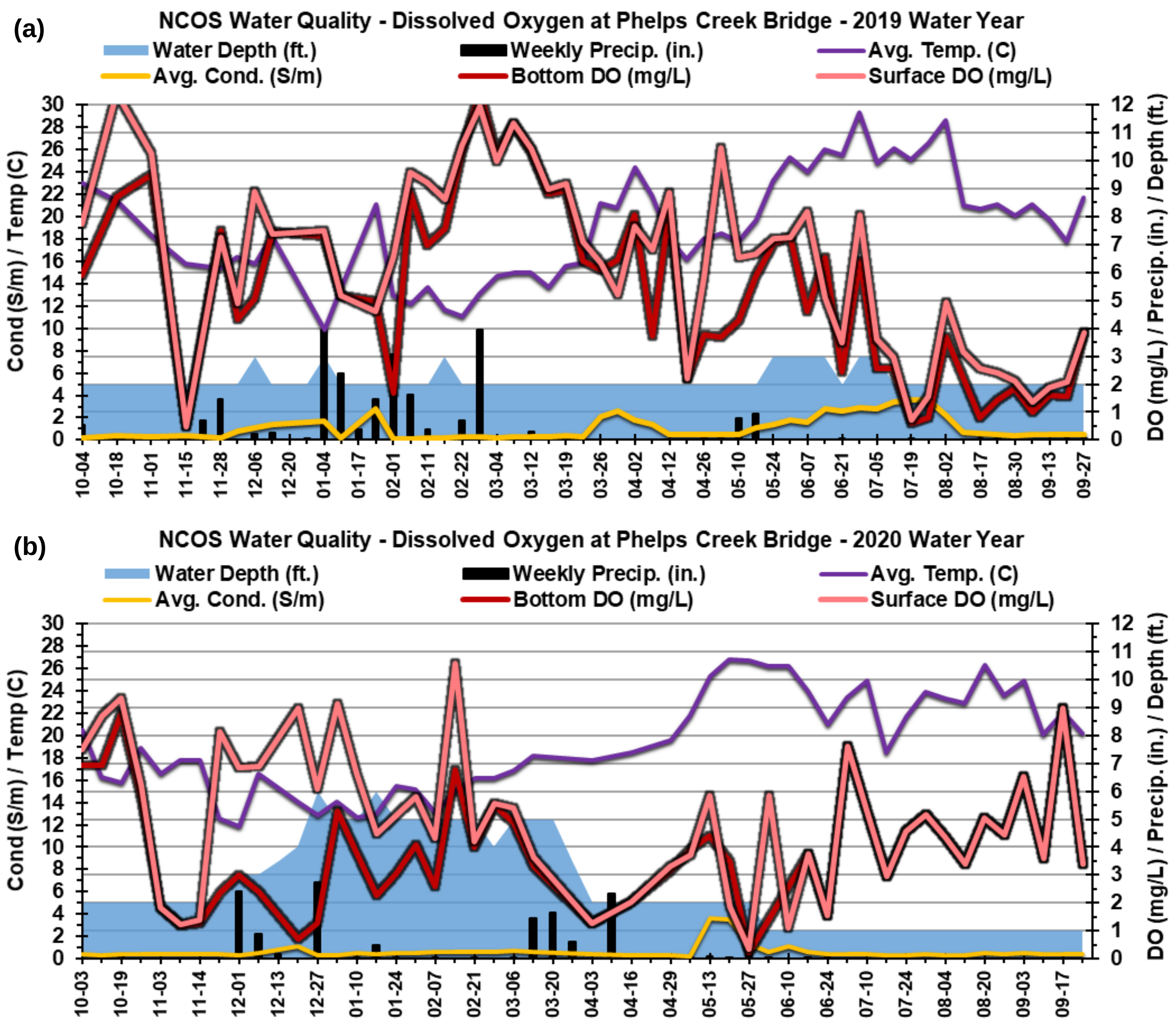
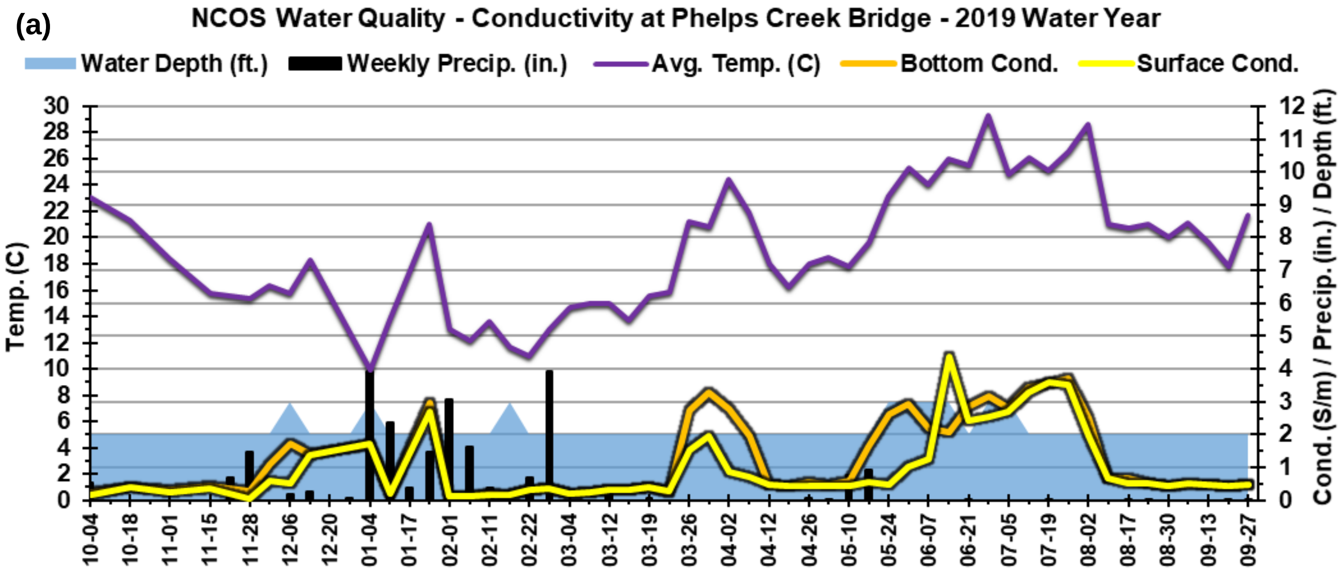


Figure 41. Dissolved oxygen (mg/L) at the surface (top 1-foot) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 at the Phelps Creek outlet into the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) and conductivity (Siemens/meter – yellow line) are averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. The sampling locations are represented by turquoise circles in the map in Figure 27.

(a)



(b)

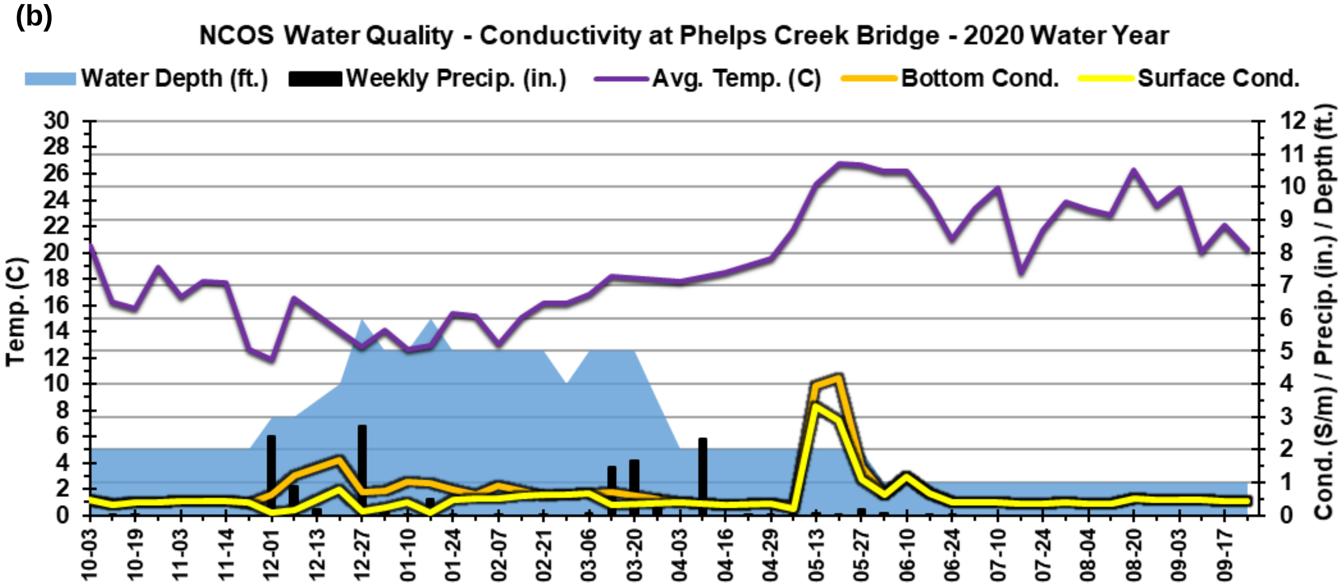
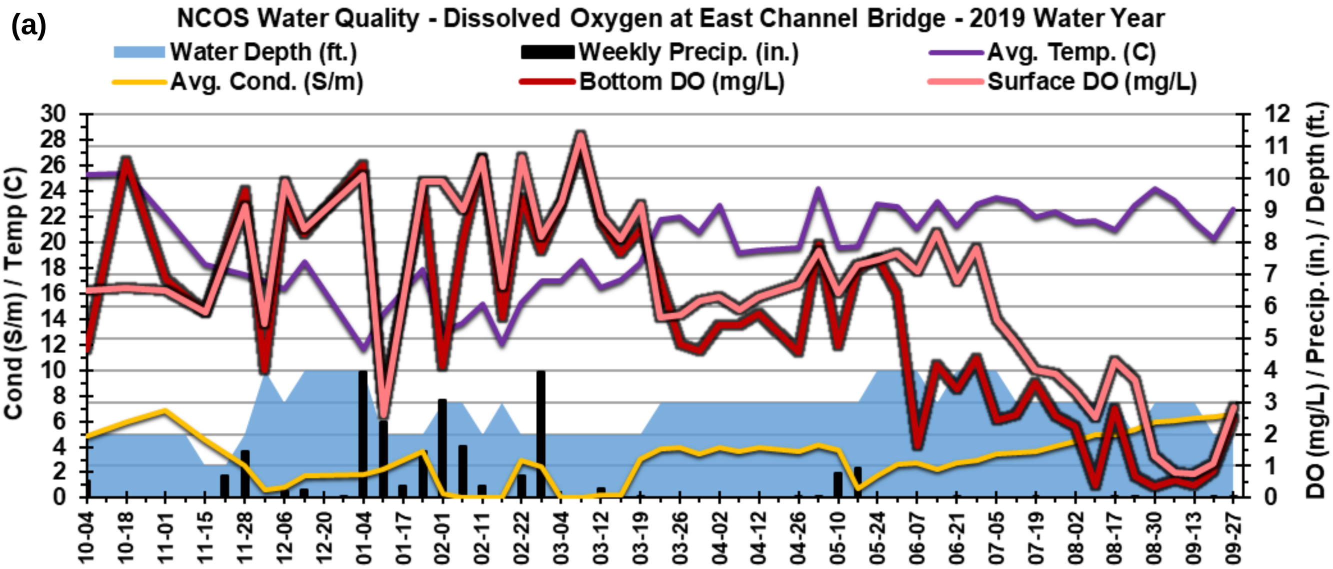


Figure 42. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 at the Phelps Creek outlet into the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) is averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27.



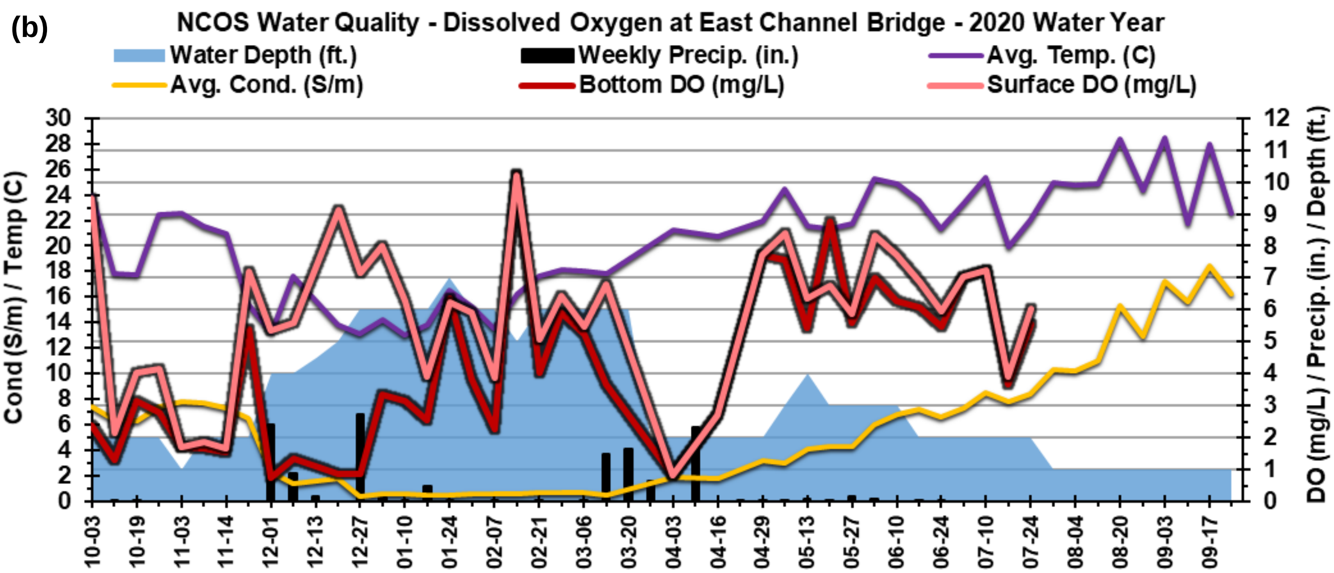


Figure 43. Dissolved oxygen (mg/L) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 in the east channel of the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) and conductivity (Siemens/meter – yellow line) are averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27. Note that in August and September of the 2020 water year the YSI was unable to calculate DO in mg/L because salinity was above its detection limit.

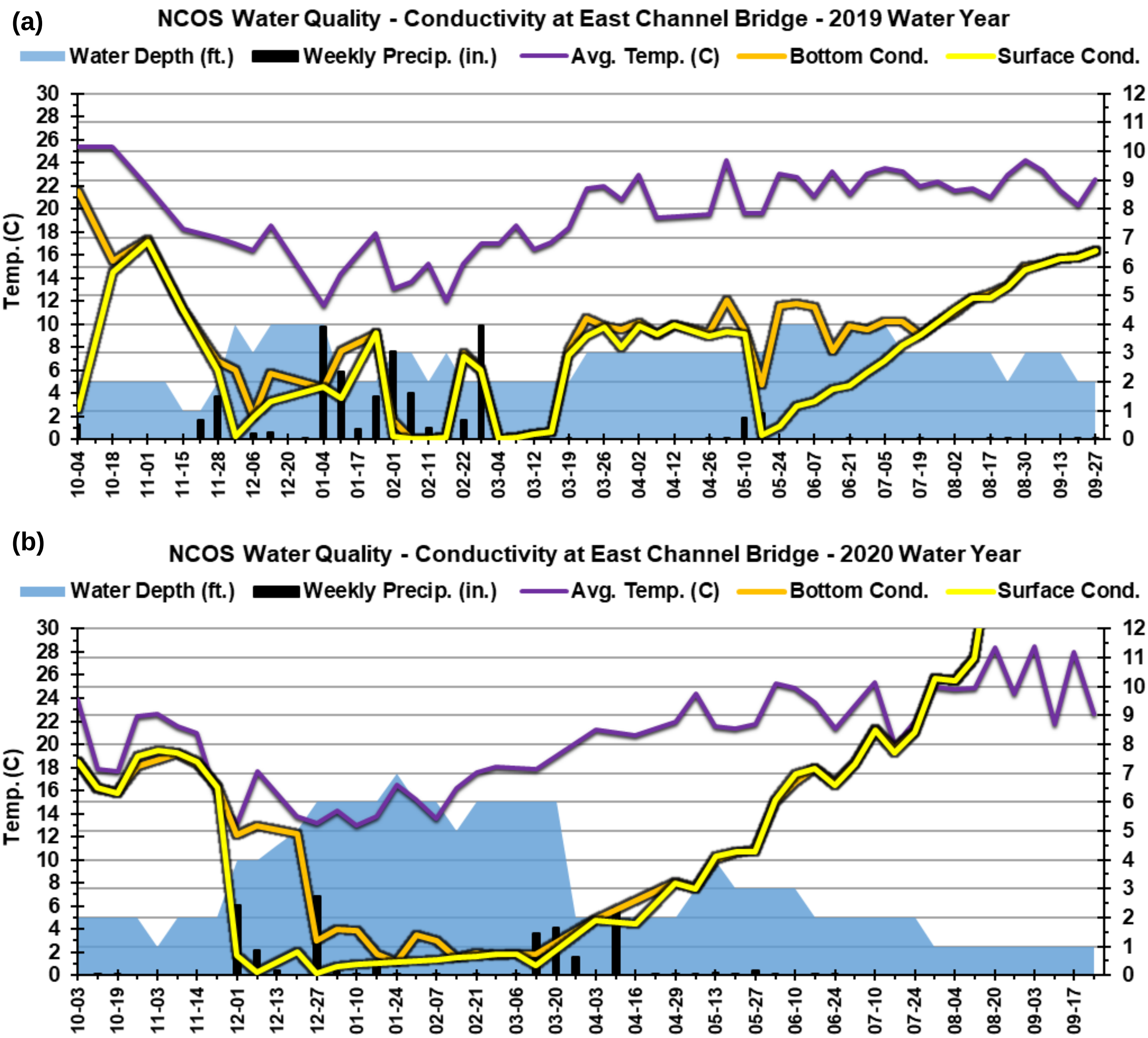
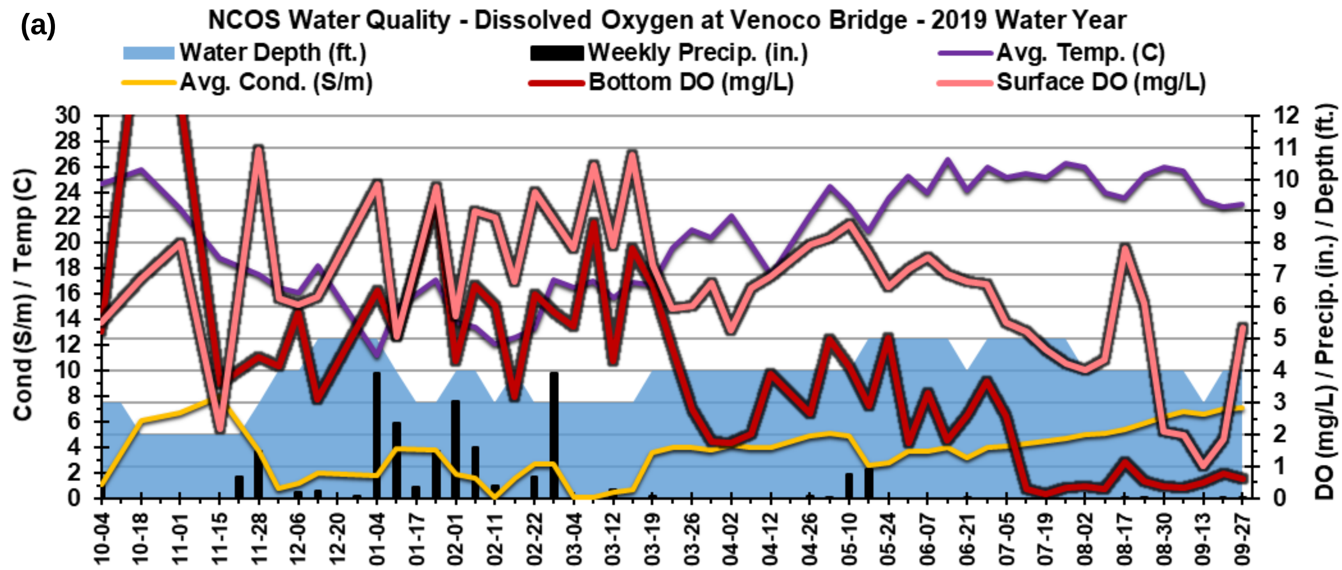


Figure 44. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 in the east channel of the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) is averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27.



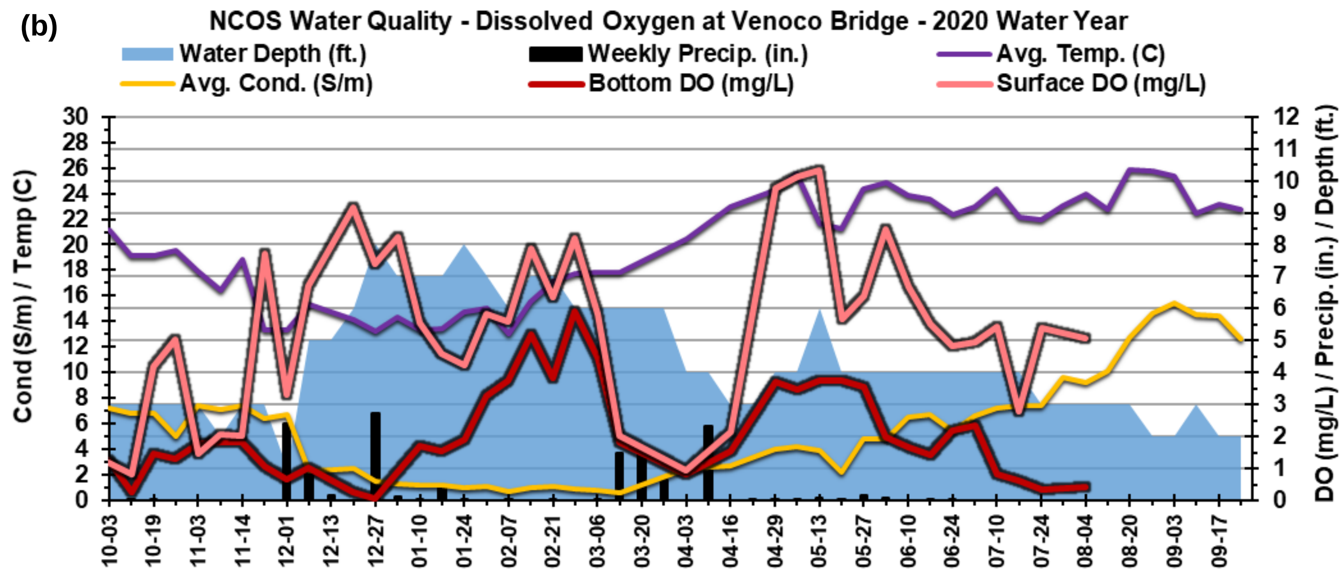


Figure 45. Dissolved oxygen (mg/L) recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 at the surface (top 1-foot of water column) and bottom of the water column in the main channel of the upper Devereux Slough at the Venoco access road bridge, North Campus Open Space. The temperature (Celsius – purple line) and conductivity (Siemens/meter – yellow line) are averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27. Note that in August and September of the 2020 water year the YSI was unable to calculate DO in mg/L because salinity was above its detection limit.

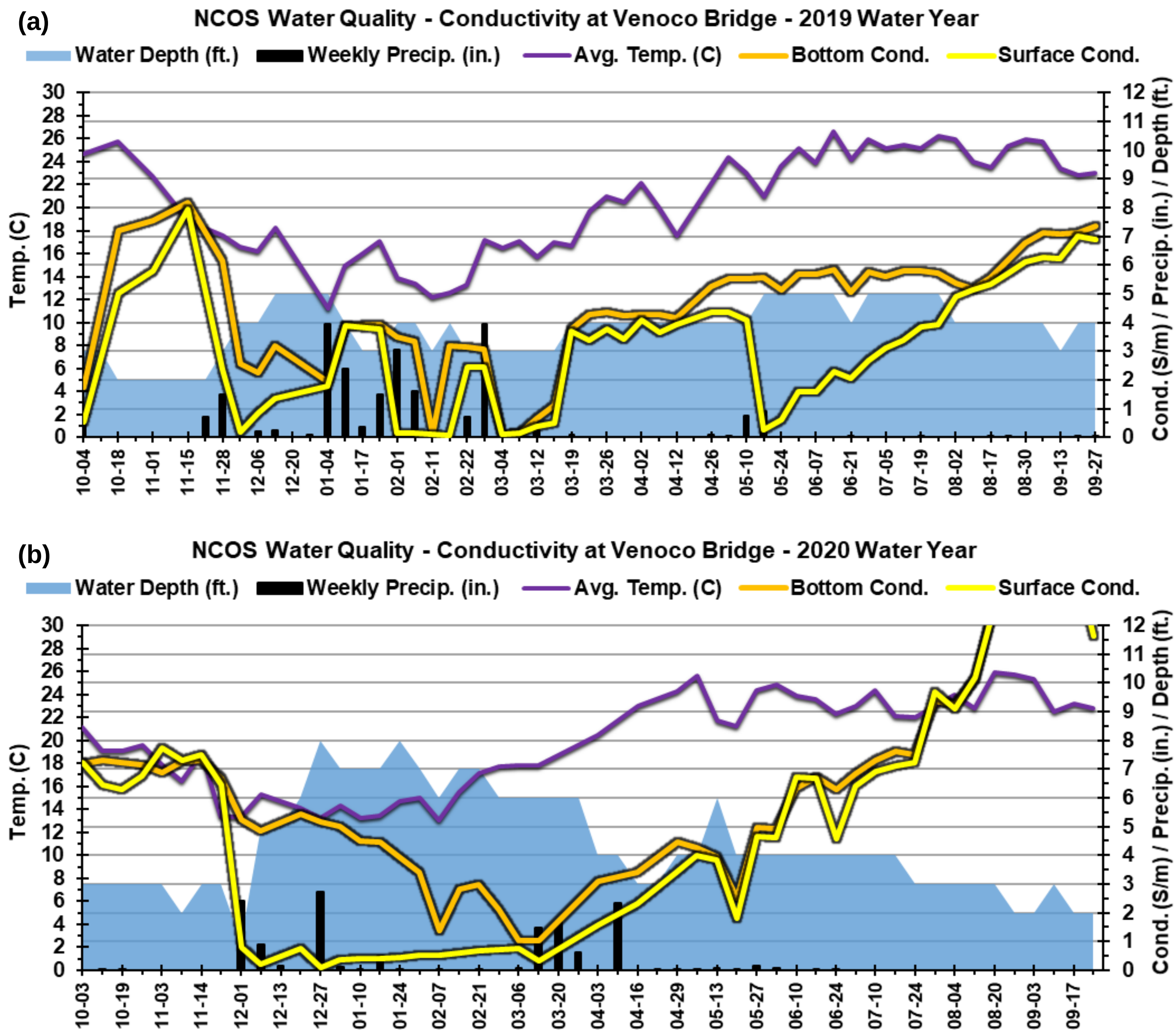


Figure 46. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 in the main channel of the upper Devereux Slough at the Venoco access road bridge, North Campus Open 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 obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27.

Overall, except for a few brief dips to low levels, DO concentrations at all three sites remain above the critical threshold of 2 mg/L throughout the year, particularly near the surface of the water column. This indicates that the wetland can functionally support aquatic wildlife year-round.

Sampling and Analysis of Constituents in Storm Water

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 storm water that enters the main tributaries of NCOS and the upper Devereux Slough.

Pre-Restoration Study

In 2016, grab samples of pre-project storm water and baseline flows were collected and analyzed for inorganic nutrients (Nitrite+Nitrate, Phosphate, and the ammonium portion of dissolved inorganic nitrogen, Ammonia(N)). 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 the report, "Water Quality of North Campus Open Space & Devereux Slough: Fall 2015 – Spring 2016", available on eScholarship (escholarship.org/uc/item/2923f039).

Initial Post-Restoration Study

Following the completion of the wetland grading, grab samples were collected at four locations (the red triangles in the map in Figure 27) during two major storms in 2018 for the analysis of dissolved inorganic nutrients, total suspended solids (used as an indicator of suspended sediment), 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(N) and Oil and Grease concentrations in the samples collected were below levels of concern. The concentration of Suspended solids ranged from the lowest amounts of 150 and 240 mg/L in Devereux Creek, increasing downstream to the highest levels of 700 and 1260 mg/L at Venoco Bridge.

High Frequency Automated Sampling

Beginning with the winter rain season of the 2019 water year, CCBER partnered with the lab of UCSB professor John Melack, who provided three portable Teledyne-ISCO samplers that were installed at the Phelps Creek, Whittier Channel (near the storm drain outflow) and Venoco Bridge sampling locations. These 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. Unlike grab samples, which are typically obtained from the water surface, ISCO samplers pump water through a hose line that is secured well below the water surface, usually within a few inches of the stream bed and as near as possible to the thalweg. At the Venoco Bridge site, the ISCO sampling line sits about two feet above the floor of the channel and a few inches off one side of the tunnel under the bridge. The sampling and analysis of storm water conducted in the 2019 water year are described in the second annual North Campus Open Space monitoring report (escholarship.org/uc/item/5sj929vh).

Summary of 2020 Water Year Efforts

Storm water monitoring efforts during the wet season of the 2020 water year included the deployment of ICSO auto samplers at the Phelps Creek, Whittier Storm drain Outfall, and Venoco Bridge sites supplemented with grab sampling at these sites as well as at the Devereux Creek site. We collected samples at all four sites during five storm events and collected “baseline” grab samples twice in-between storm events. A total of 64 grab samples were collected and analyzed for both nutrients and suspended solids. Of the ISCO samples collected, 100 were analyzed for nutrients and 131 were analyzed for suspended solids. Table A5.1 in Appendix 5 lists the number of each type of sample analyzed by site and date of sampling event.

We determined which ISCO samples to analyze by plotting sample collection times on hydrographs of water level data collected with Solinst Leveloggers deployed at the sampling sites. Samples were selected as consistently as possible for each storm event as follows: the first sample collected (usually just before the start of rainfall), samples collected at or nearest peak flows or highest water levels, at least one sample collected on the rising and falling slope of a peak flow, and one of the last samples collected an hour or more after rain stopped falling and water levels had receded. We selected additional samples for analysis based on balancing the amount of time and resources available and obtaining as comprehensive an assessment of each storm as possible.

Sample Processing and Analysis Methods

Samples selected to be analyzed for nutrients were filtered within 48 hours of collection. This consisted of pouring 10 to 15 mL of raw sample through a 47mm Pall-Gelman fiberglass filter installed on a vacuum into a 20 mL scintillation vial. These vials were then stored in a freezer until they could be analyzed by the UCSB Marine Science Institute’s Analytics Lab. The analysis of suspended solids concentration involved one of two methods depending on a visual assessment of the turbidity of a sample. Samples that appeared largely transparent with little to no visible particles were analyzed using the Total Suspended Solids (TSS) method, which involved pouring the entire volume of sample through a single 47-mm fiberglass filter and comparing the dried weight of the filter with its initial “clean” weight to obtain the milligrams of solids per liter (mg/L) of sample. The filters are dried in an oven at 105 degrees Celsius for a minimum of two hours and then cooled in a desiccator for 15 minutes before weighing. A loss correction factor that accounts for the average amount of mass naturally lost from a package of filters during use is applied to the calculation of mg/L of suspended solids. The method used for more turbid samples, called Suspended Solids Concentration (SSC), involves drying a portion of sample in a clean HDPE bottle and comparing the pre- and post-drying mass, excluding the mass of the bottle, to obtain the grams of solids per kilogram (g/kg) of sample. The HDPE bottles used for this analysis are dried in an oven, without caps, at 97 degrees Celsius for approximately 40 hours, followed by two hours at 105 degrees. For interpretation of the results, the SSC data are converted to mg/L to be plotted along with the TSS data.

Results and Initial Interpretation of 2020 Water Year Data

Appendix 5 contains several charts of the nutrient and suspended solids concentrations (SSC) of samples collected at each site and plotted by date and time along with water stage and hourly rainfall data. These charts are supplemented with box and whisker plots that compare all samples analyzed for each analyte at each site, with Grab and ISCO samples plotted separately. Water stage data was obtained from Solinst Leveloggers installed at or near each sampling site (for Devereux Creek the logger is approx. 1,800 feet downstream of the sampling site, in the western arm of NCOS, see map in Figure 27). The levelogger at the Venoco Bridge site also records conductivity, and this data is plotted with the SSC data to indicate when freshwater from storm flows reached the ISCO sample line.

Generally, the 2020 water year data suggest a greater flux of nutrients, particularly Nitrite+Nitrate, during the first major storm of the season, than in later storms, though there is variation between sites and storm events. This trend is consistent with the data collected in previous years. Box and whisker plots suggest that the concentration of Nitrite+Nitrate may be lower at Venoco Bridge than in the upstream inputs from Devereux Creek, Phelps Creek, and Whittier Storm drain, while it appears that the opposite trend may be occurring for Ammonia(N). There does not appear to be any difference in Phosphate concentration at each sampling site. The nutrients concentrations data are also summarized in Tables 8 and 9 below.

As detected in previous surveys, the mean suspended solids concentrations were greater at Venoco Bridge than at input sites, but may not be significantly greater (Table 10). The maximum concentrations in the samples we analyzed were up to 13 times greater than the maximum concentration of 540 mg/L observed by Warrick *et al*. (2015)[4] in the Devereux Creek watershed (collected near the Venoco Bridge site). However, only one of our samples was in the range of 5500 – 186000 mg/L recorded at other watersheds by the Warrick *et al*. study. A few of the samples collected at Venoco Bridge contained a high concentration of salts, such as the first two grab samples (both greater than 60,000 mg/L) collected during the first storm event on 11/27/2019 and two of the ISCO samples (one at 83,046 mg/L) from the second storm on 12/04/2019 (*e.g*. Figure 47). These samples likely contained hypersaline water collected before enough freshwater from rainfall had thoroughly mixed and/or flushed the hypersaline water downstream. We are excluding these samples from analyses.

[4] Warrick, J. A., Melack, J. M., Goodridge, B. M. 2015. Sediment yields from small, steep coastal watersheds of California. Journal of Hydrology: Regional Studies. 4, 516-534

Table 8. Number of samples analyzed and the mean, minimum, and maximum concentrations of Ammonia (mg/L) detected in baseline and storm water grab and ISCO samples collected during the rainy season of the 2020 water year at the three main tributaries of Devereux Slough and in the main slough channel where it passes under the Venoco access road bridge at North Campus Open Space. Samples of hypersaline water collected at the Venoco bridge site are excluded.

AMMONIA (mg/L)						
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**	**Standard Error**
GRAB - Baseline	**12**	**0.006**	**0.198**	**0.555**	**0.219**	**0.063**
Devereux Creek	2	0.010	0.033	0.057	0.033	0.023
Phelps Creek	4	0.116	0.438	0.555	0.215	0.107
Whittier Storm drain	3	0.060	0.109	0.172	0.057	0.033
Venoco Bridge	3	0.006	0.078	0.221	0.123	0.071
GRAB - Storm	**50**	**0.003**	**0.190**	**0.554**	**0.198**	**0.028**
Devereux Creek	13	0.003	0.114	0.293	0.114	0.032
Phelps Creek	14	0.011	0.153	0.545	0.152	0.041
Whittier Storm drain	10	0.009	0.062	0.171	0.051	0.016
Venoco Bridge	13	0.006	0.406	0.554	0.219	0.061
ISCO - Storm Only	**98**	**0.132**	**0.327**	**1.545**	**0.173**	**0.017**
Phelps Creek	38	0.001	0.047	0.673	0.141	0.023
Whittier Storm drain	35	0.003	0.176	2.558	0.464	0.078
Venoco Bridge	25	0.002	0.279	0.706	0.204	0.041
Grand Total	**160**	**0.001**	**0.168**	**2.558**	**0.279**	**0.022**

Table 9. Number of samples analyzed and the mean, minimum, and maximum concentrations of Phosphate and Nitrite+Nitrate (mg/L) detected in baseline and storm water grab and ISCO samples collected during the rainy season of the 2020 water year at the three main tributaries of Devereux Slough and in the main slough channel where it passes under the Venoco access road bridge at North Campus Open Space. Samples of hypersaline water collected at the Venoco bridge site are excluded.

PHOSPHATE (mg/L)						
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**	**Standard Error**
GRAB - Baseline	**12**	**0.056**	**0.366**	**0.646**	**0.208**	**0.060**
Devereux Creek	2	0.225	0.436	0.646	0.297	0.210
Phelps Creek	4	0.064	0.352	0.488	0.197	0.098
Whittier Storm drain	3	0.362	0.518	0.607	0.135	0.078
Venoco Bridge	3	0.056	0.184	0.374	0.168	0.097
GRAB - Storm	**50**	**0.046**	**0.292**	**0.663**	**0.110**	**0.016**
Devereux Creek	13	0.150	0.298	0.411	0.078	0.022
Phelps Creek	14	0.099	0.283	0.475	0.104	0.028
Whittier Storm drain	10	0.190	0.279	0.401	0.066	0.021
Venoco Bridge	13	0.046	0.307	0.663	0.167	0.046
ISCO - Storm Only	**98**	**0.132**	**0.327**	**1.545**	**0.173**	**0.017**
Phelps Creek	38	0.147	0.305	0.519	0.113	0.018
Whittier Storm drain	35	0.132	0.362	1.545	0.257	0.044
Venoco Bridge	25	0.243	0.313	0.490	0.072	0.014
Grand Total	**160**	**0.046**	**0.319**	**1.545**	**0.160**	**0.013**

NITRITE+NITRATE (mg/L)						
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**	**Standard Error**
GRAB - Baseline	**12**	**0.009**	**0.624**	**6.229**	**1.775**	**0.512**
Devereux Creek	2	0.009	0.015	0.022	0.009	0.006
Phelps Creek	4	0.012	1.732	6.229	3.013	1.507
Whittier Storm drain	3	0.130	0.158	0.213	0.048	0.028
Venoco Bridge	3	0.012	0.020	0.032	0.011	0.006
GRAB - Storm	**50**	**0.008**	**0.661**	**2.248**	**0.506**	**0.072**
Devereux Creek	13	0.008	0.768	1.362	0.324	0.090
Phelps Creek	14	0.018	0.823	2.248	0.605	0.162
Whittier Storm drain	10	0.038	0.409	0.966	0.281	0.089
Venoco Bridge	13	0.009	0.573	1.820	0.616	0.171
ISCO - Storm Only	**98**	**0.132**	**0.327**	**1.545**	**0.173**	**0.017**
Phelps Creek	38	0.005	0.818	1.607	0.386	0.063
Whittier Storm drain	35	0.139	0.633	2.272	0.479	0.081
Venoco Bridge	25	0.008	0.146	0.799	0.219	0.044
Grand Total	**160**	**0.005**	**0.609**	**6.229**	**0.658**	**0.052**

Table 10. Number of samples analyzed and the mean, minimum, and maximum concentrations of suspended solids (mg/L) detected in storm water samples collected during the rainy season of the 2020 water year at the three main tributaries of Devereux Slough and in the main slough channel where it passes under the Venoco access road bridge at North Campus Open Space. Samples of hypersaline water collected at the Venoco bridge site are excluded from this table.

SUSPENDED SOLIDS (mg/L)						
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**	**Standard Error**
GRAB - Baseline	**12**	**2.8**	**111.7**	**546.6**	**190.2**	**54.9**
Devereux Creek	2	12.2	154.2	296.2	200.8	142.0
Phelps Creek	4	2.8	9.2	14.8	5.0	2.5
Whittier Storm drain	3	16.6	321.1	546.6	273.7	158.0
Venoco Bridge	3	7.1	10.5	15.7	4.6	2.6
GRAB - Storm	**50**	**0**	**681.8**	**7080.0**	**1505.0**	**212.8**
Devereux Creek	13	18.8	211.3	975.4	248.0	68.8
Phelps Creek	14	7.8	601.7	4987.7	1298.5	347.0
Whittier Storm drain	10	0.0	98.1	628.3	193.9	61.3
Venoco Bridge	13	9.0	1687.7	7080.0	2388.7	662.5
ISCO - Storm Only	**126**	**0**	**246.0**	**3240.0**	**446.5**	**39.8**
Phelps Creek	47	0.0	236.0	900.0	254.6	37.1
Whittier Storm drain	41	0.0	127.7	1057.0	173.7	27.1
Venoco Bridge	38	7.1	386.1	3240.0	724.2	117.5
Grand Total	**188**	**0.0**	**353.3**	**7080.0**	**877.1**	**64.0**

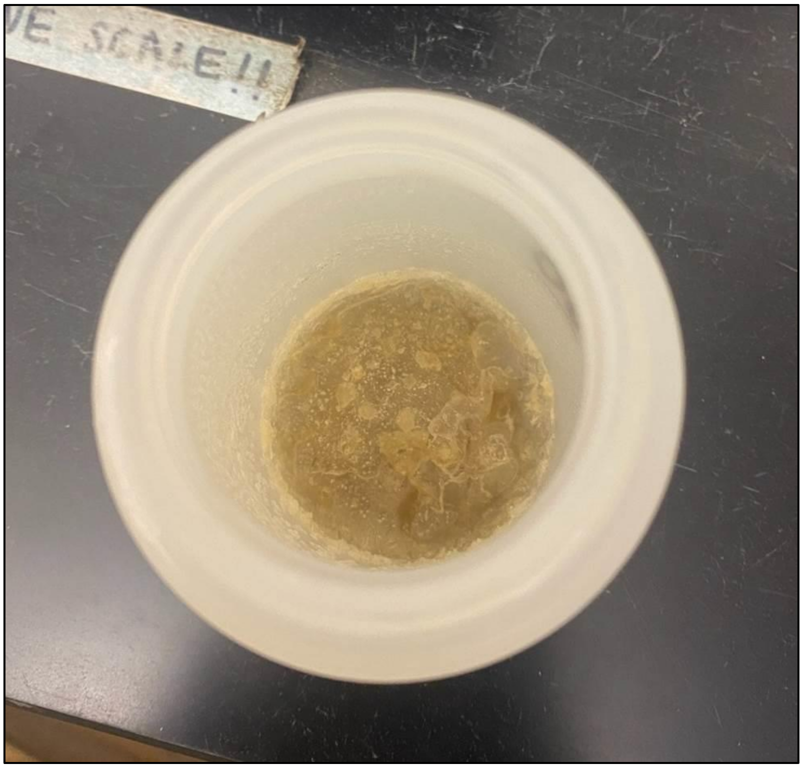


Figure 47. Photo of a suspended solids concentration sample after drying, with a high concentration of salts. The sample was collected at the Venoco Bridge site.

Future Storm water Plans

CCBER continued this regime of storm water sampling in the wet season of the 2021 water year, and we are working on more detailed analyses of this data as well as flow rate data collected at the sampling sites in order to calculate the approximate volume and mass of nutrients and suspended solids that are flowing into and through the restored slough. Our intention is to produce a separate report focused on the hydrology and water quality of Devereux Slough.

6. COMMUNITY USE SURVEYS

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).

Approximately twice per year, CCBER conducts an observational survey of community use of the trails at NCOS. The surveys are stratified across days of the week (including weekends) and periods of the day (morning, midday, and evening), and they are conducted over four to six weeks to ensure that at least three 30-minute surveys are conducted for each day/time combination at each of the main trailheads (West at Phelps Creek, Main at Whittier Entrance, and South at the “Slough” trailhead off of Venoco Road). The goal of the surveys is to characterize community use of NCOS in terms of activity (walking, dog-walking, exercising, commuting, and birding), number of users per hour, age groups, and the degree to which dogs are kept on leash. Data from the surveys is 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.

Since 2019, we have seen an increase in dogs-on-leash compliance from 80% to 95% (Figure 48). The increasingly high percentage of dog walkers observing the leash law enables visitors to enjoy observing undisturbed wildlife and will be important for enhancing opportunities to see Burrowing Owls and other grassland birds on the Mesa. The majority of trail users are either exercising or out for a stroll, with a smaller percentage walking dogs, commuting, or birdwatching (Figure 49). During the COVID-19 pandemic, community use of NCOS increased from a mean of 25 users per hour to more than 50 users per hour, with a peak average of 80 users per hour occurring during the evening in the spring of 2020 (Figure 50). The spring 2020 survey conducted during the pandemic also saw an increase in the number of children/minors and seniors using the trails (Figure 51). A reduced number of university students were recorded in the summer and during the pandemic, which reflects the lower student population in the area during those periods. Overall, the total number of users observed using consistent survey methodology has increased from 608 in the winter of 2019 to 1076 in the winter of 2021.

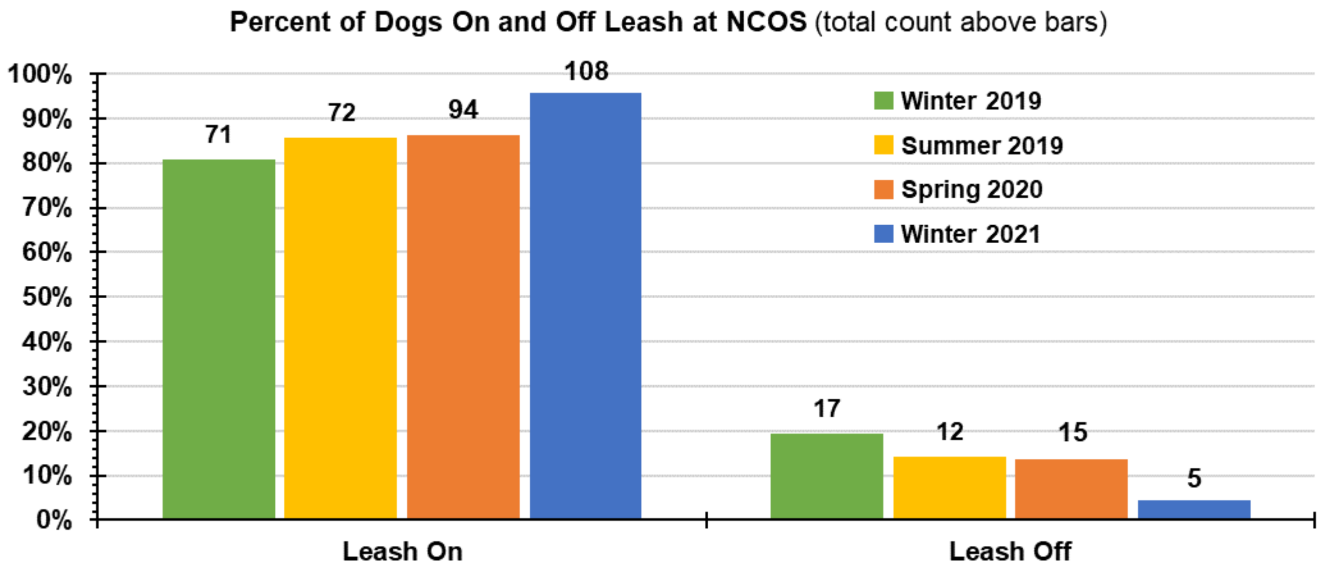


Figure 48. Bar chart of the percent of trail users observed with a dog on and off leash at North Campus Open Space during user surveys in 2019, 2020, and 2021.

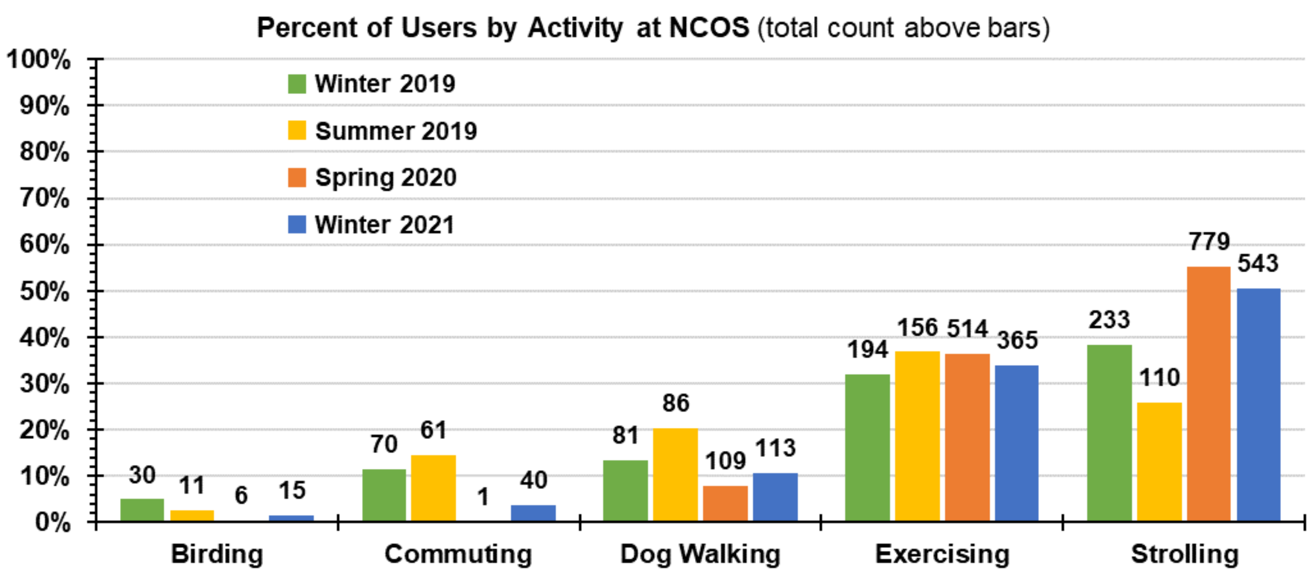


Figure 49. Bar chart of the percent of trail users grouped by activity observed at North Campus Open Space during user surveys in 2019, 2020, and 2021.

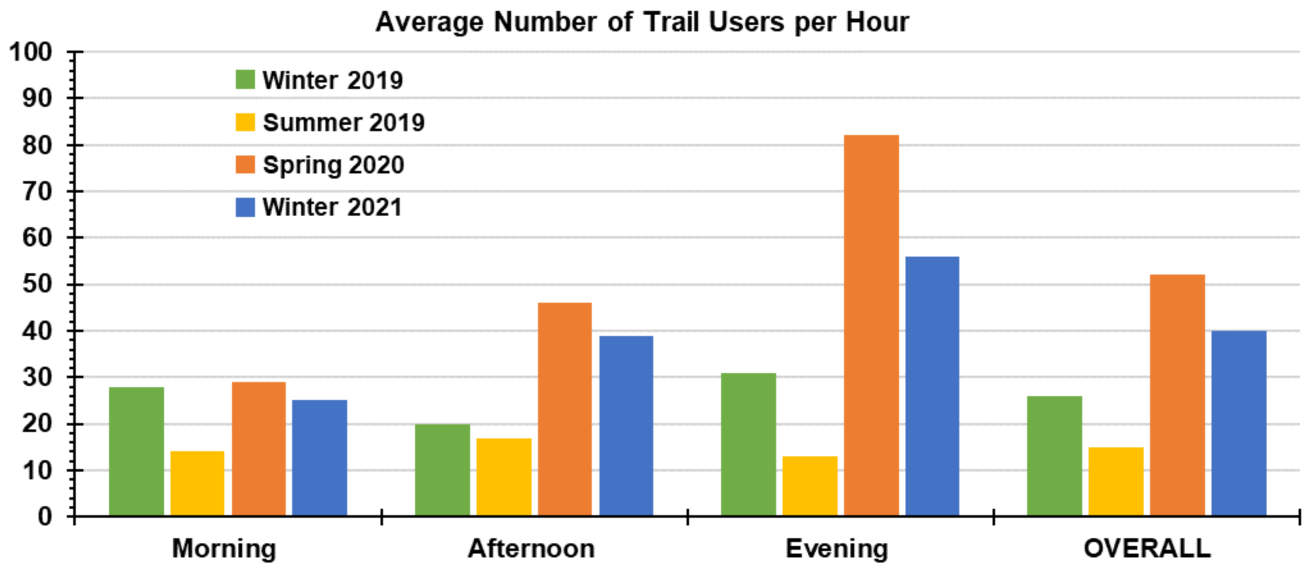


Figure 50. Bar chart of the average number of trail users per hour observed at North Campus Open Space during user surveys in 2019, 2020, and 2021.

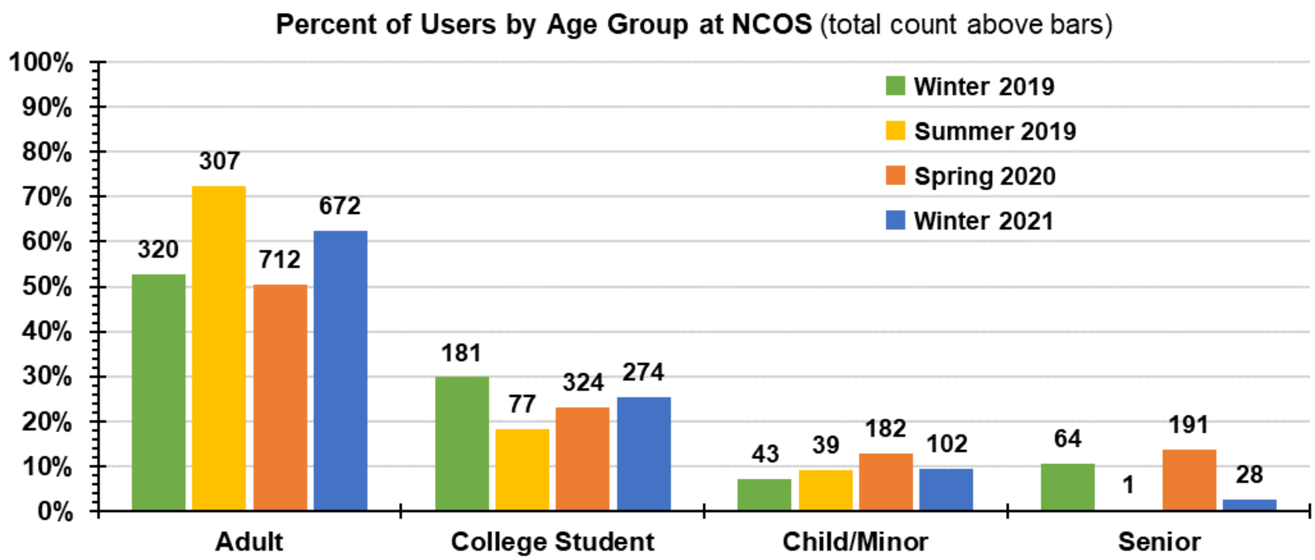


Figure 51. Bar chart of the percent of trail users by age group observed at North Campus Open Space during user surveys in 2019, 2020, and 2021.

7. CHARACTERIZATION OF PROJECT EFFORTS

When planting, maintenance, and monitoring began at the North Campus Open Space restoration project in the fall of 2017, we developed methods for workers to track the hours they spent on different tasks and at different zones of the project site using the 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 project effort data recorded for 2020, the third full year of the project, are summarized below and compared with the 2019 and 2018 data to show changes in the proportion of effort by worker type, general task, and zone.

In 2020, safety restrictions related to the COVID-19 pandemic reduced the overall total hours contributed by all worker types, especially volunteers (Figure 52). However, the proportion of project work attributed to student workers and full-time CCBER staff remained about the same as in 2019 and 2018.

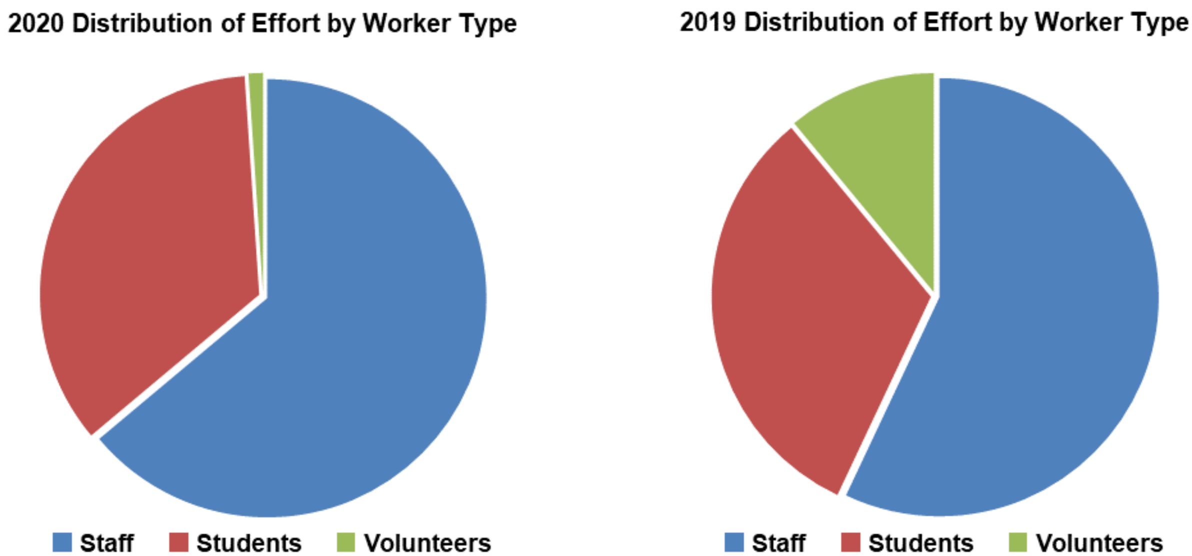


Figure 52. Pie charts of the proportion of effort (hours of work) at the North Campus Open Space restoration project by worker type in 2020 (left) and 2019 (right). The "Students" category includes paid workers and interns. Data for 2018 is not shown as it is nearly the same as 2019.

Looking at the distribution of work by task, we see that the proportion of effort allocated to planting has decreased by about 20 percent each year since 2018 while other tasks have remained about the same, apart from slight increases in Monitoring/Research and Management/Reporting efforts (Figure 53). These trends reflect the emphasis on planting in the first two years of the project and the growth and expansion of monitoring and research at NCOS as the site develops.

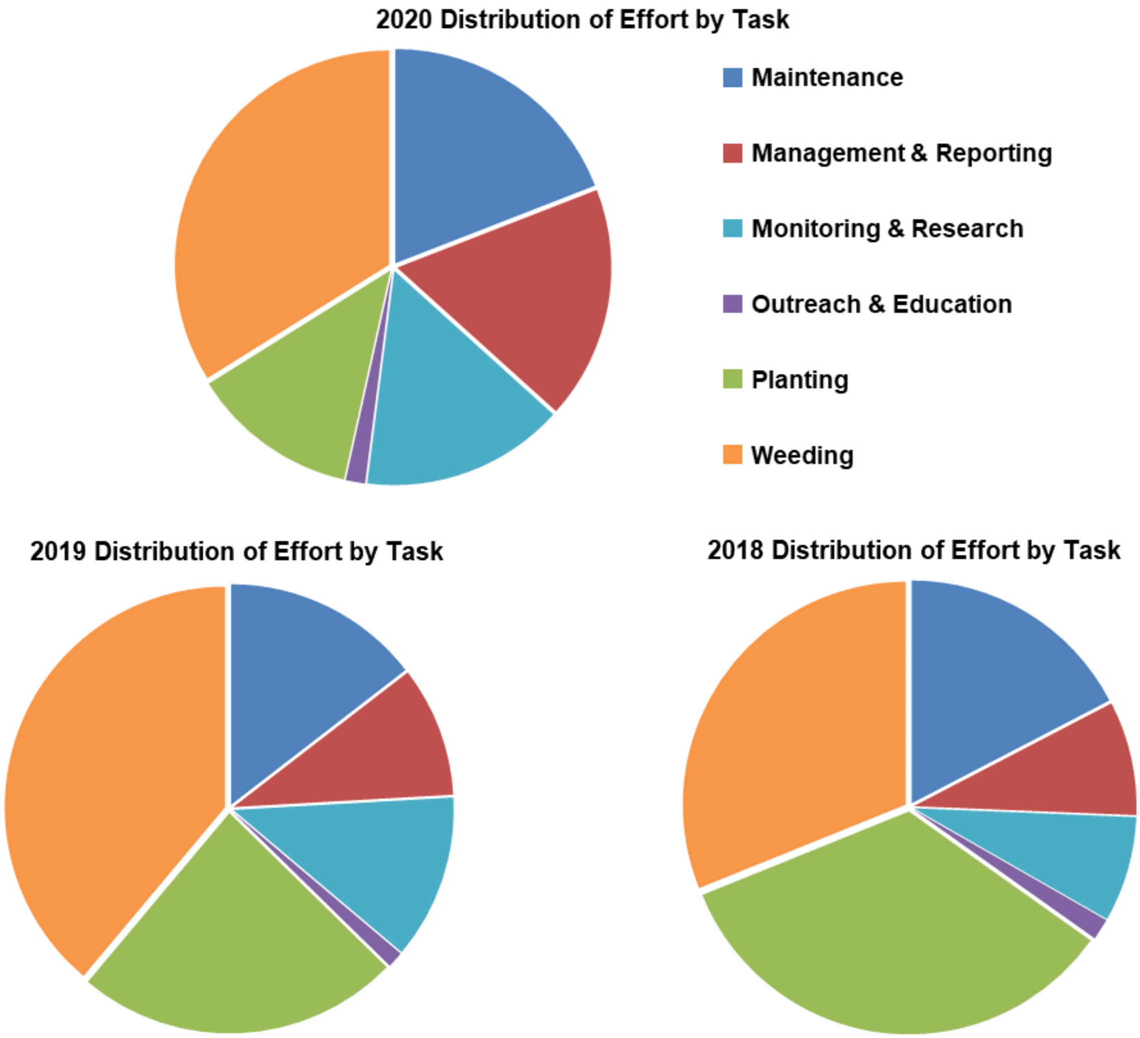


Figure 53. Pie charts of the proportion of effort (hours of work) at the North Campus Open Space restoration project by task in (a) 2020, (b) 2019, and (c) 2018.

Lastly, the distribution of effort (primarily planting and weeding) across the five main zones of the NCOS project has changed significantly each year (Figure 54). For example, half of all work in 2018 was allocated to the Salt Marsh and Transition zone, which is the largest zone of the site and where planting was primarily focused in the first year of the project. Planting and weeding were more heavily focused on the Mesa zone in 2019, and in efforts in 2020 focused more on maintenance and weeding of the Mesa and Peripheral Uplands than in other zones. The construction and establishment of the visitor plaza, pollinator garden, and discovery trail in the "Whittier" zone explains the increase in project efforts there in 2020, and the reduction of work in the Riparian zone reflects the well-established plantings that were carried out in the first two years of the project.

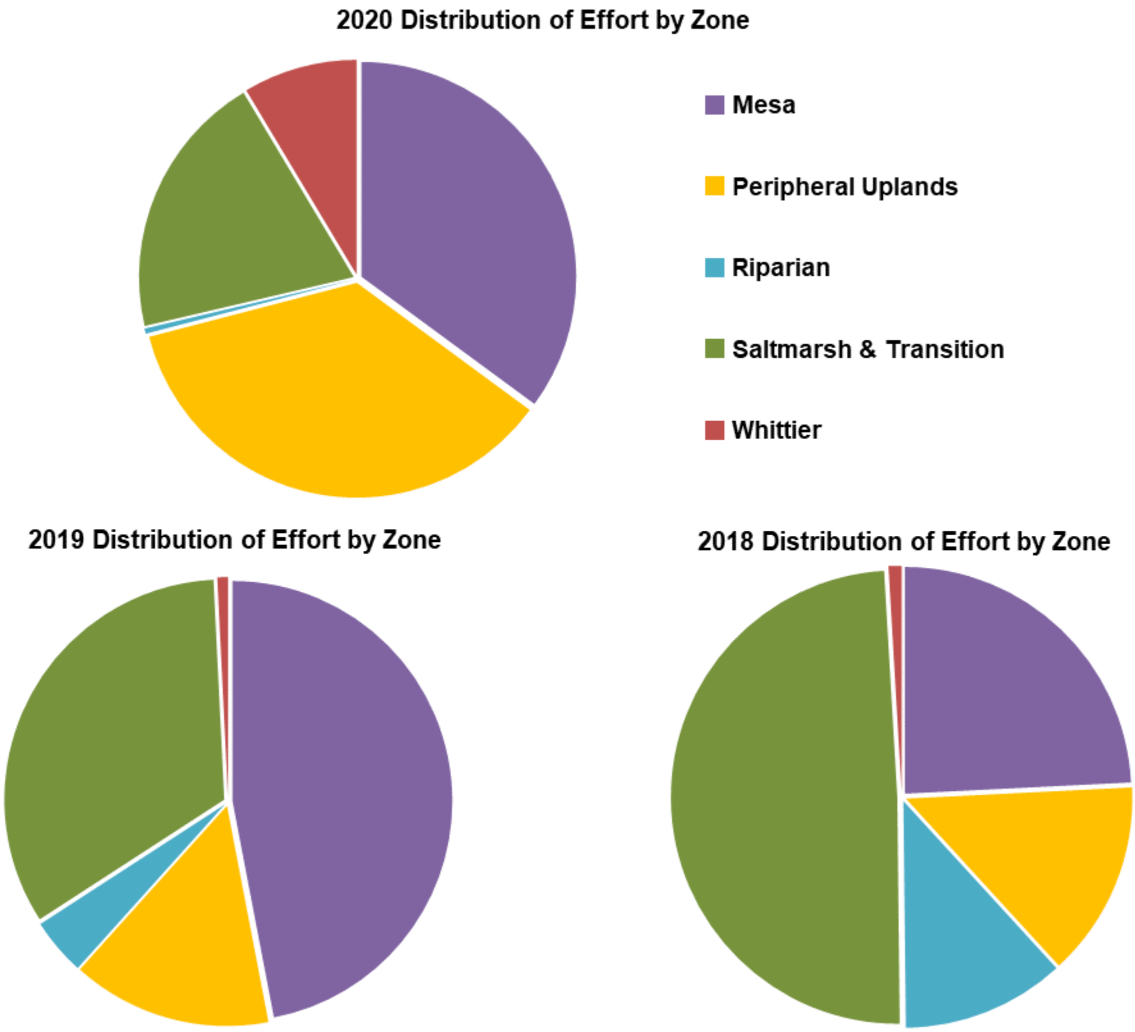


Figure 54. Pie charts of the proportion of effort (hours of work; primarily planting and weeding) at the North Campus Open Space restoration project by zone in (a) 2020, (b) 2019, and (c) 2018. Refer to the map in Figure 1 for the location and extent of each zone.

APPENDIX 1 – PHOTO-DOCUMENTATION SAMPLES

The following photographs are samples from the photo-documentation monitoring of the North Campus Open Space restoration project taken from the five points circled in turquoise in the map below (14, 20, 31, 33a, and 41).

Map of photo monitoring points at the NCOS restoration project. See Figure 2 for a larger map with legend.

Photo point 14 – looking northwest over the Mesa from the east leg of the Mesa trail

Year 1 – July 2018

Photo point 14 – looking northwest over the Mesa from the east leg of the Mesa trail

Year 2 – July 2019

Photo point 14 – looking northwest over the Mesa from the east leg of the Mesa trail

Year 3 – July 2020

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

Baseline (post-grading) - October 2017

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

Year 1 – October 2018

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

Year 2 – October 2019

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

Year 3 – October 2020

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

Baseline (post-grading) - October 2017

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

Year 1 – October 2018

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

Year 2 – October 2019

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

Year 3 – October 2020

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Baseline (post-grading) - October 2017

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Year 1 – October 2018

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Year 2 – October 2019

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Year 3 – October 2020

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Baseline (post-grading) - October 2017

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Year 1 – October 2018

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Year 2 – October 2019

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Year 3 – October 2020

APPENDIX 2 – VEGETATION MONITORING PLANT SPECIES LISTS

Table A2.1. Native plant species recorded during vegetation monitoring at the North Campus Open Space project. The numbers in each table cell represent the monitoring years in which each species was recorded in each habitat/plant community type (1 = 2018, 2 = 2019, 3 = 2020).

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Acmispon glaber								3					
Acmispon maritimus	2							3	2, 3				
Alnus rhombifolia											2		
Alopecurus saccatus								3					
Ambrosia psilostachya	2, 3	1, 2, 3			2	3	3	2				2, 3	
Anemopsis californica										1			
Artemisia californica		1, 2, 3							3				
Arthrocnemum subterminale				1, 2, 3	3		3						
Atriplex lentiformis		1, 2		3	1, 2, 3		3			1, 2, 3			
Baccharis glutinosa										2			
Baccharis pilularis	1, 2, 3	1, 2, 3		2, 3	1, 2, 3			1, 2, 3	3	3	3		
Bolboschoenus maritimus		3		2, 3	3	1, 2, 3	1, 2, 3	2, 3					3
Brickellia californica								2, 3					
Bromus carinatus		2, 3							3	3			
Centromadia parryi australis		2, 3		3				3					

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Cressa truxillensis	3	3	1, 2, 3	3	3								
Cyperus eragrostis	2, 3	2, 3		1, 3	1, 2, 3	2, 3		1, 2, 3					
Daucus pusillus		3											
Deinandra fasciculata	2, 3	2, 3		3	1, 2, 3	3		2, 3					
Distichlis littoralis			3	1, 2, 3	2, 3	3	1, 2, 3						
Distichlis spicata	2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 3			3			3
Eleocharis acicularis	3	2		3	3		3	1, 2, 3					3
Eleocharis macrostachya	2	1, 2, 3	2	3	3	1, 2, 3		1, 2, 3					
Elymus condensatus		1, 2, 3							3				
Elymus glaucus		2						2	2	3			
Elymus triticoides		1, 2, 3		1, 2, 3	1, 2, 3		3		3				
Encelia californica		1			1, 2				3				
Epilobium brachycarpum	2, 3	2, 3		3	1, 2, 3	1, 2, 3		1, 2, 3	3	3		2, 3	
Epilobium canum		1, 2, 3											
Epilobium ciliatum		2, 3										2	
Erigeron canadensis	1, 2, 3	2, 3		2, 3	1, 2, 3		3	1, 2, 3	3	2	2, 3	2, 3	3
Eriogonum parvifolium		2, 3											
Eriophyllum confertiflorum		3											
Eryngium vaseyi								1, 2, 3					
Euphorbia serpens		2, 3		3	2			2					

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Extriplex californica			3	1, 2, 3	1, 2, 3		3						3
Frankenia salina	1		1, 2, 3	1, 2, 3	1, 2, 3		3						3
Grindelia camporum								2, 3					
Heterotheca grandiflora	1, 2, 3	2, 3				3		1, 2, 3	3			1, 2, 3	
Hordeum brachyantherum			2	2, 3	3			2, 3					
Hordeum brachyantherum ssp. brachyantherum	2, 3	1, 2, 3	1, 3	1, 3	1, 3			1, 2, 3					
Isocoma menziesii	2	2, 3		3	2, 3								
Jaumea carnosa			3	1, 2, 3	3	3	1, 2, 3						3
Juncus bufonius	2, 3	1, 2, 3		3	2, 3		2	2, 3					
Juncus occidentalis		2, 3						3					
Juncus phaeocephalus	3	2, 3						3					
Laennecia coulteri	2, 3	2, 3		3	1, 2, 3			2, 3		3	3		
Limonium californicum				3									
Lonicera subspicata v. subsp.									3				
Lupinus bicolor												1, 2, 3	
Lupinus succulentus	1	2						1, 2, 3					
Mimulus aurantiacus									3				
Persicaria lapathafolia		2				2, 3							
Phalaris lemmonii								1, 2, 3					
Plagiobothrys undulatus								1, 2, 3					

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Plantago erecta	1, 3	2			1			2					
Platanus racemosa										1, 2			
Populus trichocarpa											1, 2, 3		
Pseudognaphalium californicum	3	1, 3											
Psilocarphus brevissimus	2	2						1, 2, 3					
Quercus agrifolia		3							2, 3		2		
Rosa californica										1			
Rubus ursinus										3			
Salicornia pacifica			1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3						1, 2, 3
Salix exigua										1, 2, 3			
Salix lasiolepis		2, 3	3	3	3			2, 3		3	1, 2, 3		1
Salvia leucophylla		2, 3							3				
Schoenoplectus californicus	3			2, 3	3		1, 2, 3	2, 3			1, 2		
Sisyrinchium bellum		2, 3						1, 2, 3					
Solanum douglasii		2, 3			1, 2			3				2	
Stebbinsoseris heterocarpa	1, 2, 3							2					
Stipa pulchra	1, 2, 3	2, 3						1, 2, 3	3				
Suaeda taxifolia			3	3	1, 2, 3	3	3						3
Symphyotrichum chilense					2					3			
Symphyotrichum subulatum	2, 3	1, 2, 3	3	1, 2, 3	1, 2, 3	1, 2, 3	2, 3	1, 2, 3	3	2, 3			2, 3

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Typha latifolia								1, 2, 3					
Vulpia microstachys	3												
Xanthium strumarium			1, 2	2	3	1, 2	3						

Table A2.2. Non-native plant species recorded during vegetation monitoring at the North Campus Open Space project. The numbers in each table cell represent the monitoring years in which each species was recorded in each habitat/plant community type (1 = 2018, 2 = 2019, 3 = 2020). The California Invasive Plant Council's rating for each species is indicated as follows: **(H)** – High, **(L)** – Limited, **(M)** – Moderate, and **(W)** – Watch.

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland - New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Aegilops cylindrical **(W)**	1, 2, 3	2, 3		2	2			3					
Aloe maculata		3											
Amaranthus albus				3	3								
Araujia sericifera **(W)**	2					3							
Atriplex prostrata		2		1, 2, 3	1, 2, 3	1, 2	2, 3						2, 3
Atriplex rosea					3								
Atriplex semibaccata **(M)**	1	1, 2, 3		2	1, 3								
Avena barbata **(M)**		3										3	
Avena fatua **(M)**	1, 2, 3	1, 2, 3			1, 2, 3			1, 2, 3	2, 3			2	
Bassia hyssopifolia **(L)**		2											
Beta vulgaris **(L)**	1												
Brachypodium distachyon **(M)**	1, 2, 3	2, 3			1, 2, 3			1, 2, 3	3			1, 2	
Brassica nigra **(M)**	1	3			1				1, 3			1	
Bromus catharticus	2, 3	1, 2, 3		1, 2, 3	1, 2, 3	3		2					
Bromus diandrus **(M)**	1, 2, 3	1, 2, 3			1, 2, 3	2		1, 2, 3	2, 3			1, 2, 3	
Bromus hordeaceus **(L)**	1, 2, 3	1, 2, 3			1, 2, 3			2, 3					

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland - New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Capsella bursa-pastoris		1, 2, 3		2									
Carduus pycnocephalus **(M)**	1, 3												
Centaurium sp.					3								
Centaurium tenuiflorum	2, 3	2, 3						1, 2, 3					
Chenopodium album		2				3							3
Chenopodium murale		3		1, 3			2						2
Convolvulus arvensis		2, 3		1				1, 3					
Cortaderia selloana **(H)**											1, 2, 3		
Cotula coronopifolia **(L)**				2, 3	3	2		2, 3		3			
Crypsis schoenoides				2, 3		1	2, 3	1, 2, 3					3
Cyclospermum sp.		3											
Cynodon dactylon **(M)**		1, 2, 3		1, 2, 3	1, 2, 3	1, 2, 3							
Dichondra micrantha	2, 3	2			1								
Dysphania ambrosioides		2											
Erharta erecta **(M)**		3											
Erigeron bonariensis	3	2, 3		2	2, 3					2, 3			
Erigeron sumatrensis		3											
Erodium botrys	1, 2	3	2		1			2				2	
Erodium cicutarium **(L)**	1, 2, 3	2			1				3			1, 2, 3	
Eucalyptus globulus **(L)**		2											

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland - New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Eucalyptus sp.		3											
Euphorbia maculata		3			3								
Festuca bromoides		1, 2, 3			3			2					
Festuca myuros **(M)**	1, 2, 3	1, 2, 3	1	1, 2	1, 2, 3			1, 2, 3				1, 2, 3	
Festuca perennis **(M)**	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	2, 3		1, 2, 3	1, 3	3		1, 3	
Foeniculum vulgare **(M)**	1				1, 3								
Geranium dissectum **(L)**	1, 2, 3	2, 3	3		3			1, 2, 3				2	
Helminthotheca echioides **(L)**	1, 2, 3	1, 2, 3	1, 2	2, 3	1, 2, 3	1, 2, 3		2, 3		2, 3			
Hirschfeldia incana **(M)**	2												
Hordeum marinum **(M)**	1, 3	1, 3		1, 2, 3	1, 2, 3	3		2					
Hordeum murinum **(M)**	2, 3	1, 2, 3		1, 2	1, 2, 3								
Hypochaeris glabra **(L)**	2							2, 3				2, 3	
Lactuca serriola	1, 3	1, 2, 3	3		1, 2, 3			1, 2					
Lepidium didymum	1	1, 2, 3		1	1								
Logfia gallica	3	2						3				2	
Lotus corniculatus					2								
Lysimachia arvensis	1, 2, 3	1, 2, 3		2	1, 2, 3			1, 2, 3			2, 3	2, 3	
Lythrum hyssopifolia **(M)**	2, 3	1, 2, 3			1, 3			1, 2, 3					
Malva parviflora	1, 2, 3	1, 2, 3			1, 2, 3			2	3				
Matricaria discoidea					1								

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland - New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Medicago lupulina	1, 3	2, 3						2, 3	3				
Medicago polymorpha **(L)**	1, 2, 3	1, 2, 3	1	1, 3	1, 2, 3			1, 2, 3	1, 2, 3	2		1, 2, 3	
Melilotus albus	1				3								2, 3
Melilotus indicus	1, 2, 3	1, 2, 3		1, 2, 3	1, 2, 3			1, 2, 3	1, 2, 3	2		2, 3	2
Oxalis pes-caprae **(M)**								2					
Parapholis incurva	1, 2, 3	1, 2, 3		1, 2, 3	1, 2, 3			2, 3					2
Paspalum dilatatum		1, 2, 3			1, 2								
Pennisetum clandestinum **(L)**		2		1	1, 2								
Phalaris aquatic **(M)**								1					
Pinus halepensis		3											
Pinus pinea		2									1, 2		
Pinus sp.											1		
Plantago coronopus	1, 2, 3	1, 2, 3		1, 2, 3	1, 2, 3	2, 3	2	2, 3					
Plantago lanceolata **(L)**	1, 2, 3	1, 2, 3			1, 2, 3			1, 2, 3				1	
Plantago major		2											
Poa annua		1, 2, 3			1, 3					3			
Polycarpon tetraphyllum		3									3		
Polygonum aviculare depressum	2, 3	1, 2, 3		1, 2, 3	1, 2, 3	2, 3		2, 3		2			2
Polypogon interruptus	3	3		3	3			1, 2, 3					
Polypogon monspeliensis **(L)**	1, 3	2, 3		2, 3	2, 3	2, 3		1, 2, 3					3

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland - New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Polypogon viridis					3			2					
Portulaca oleracea		3											
Pseudognaphalium luteoalbum	2, 3	2, 3			2, 3	2, 3		3					
Raphanus sativus **(L)**			1, 2, 3										
Rumex crispus **(L)**	2	1, 2, 3	2, 3		1, 3	1, 3		1, 2	2				
Salsola tragus **(L)**	2	1, 2		2	1								
Senecio vulgaris		2											
Silene gallica								2					
Sonchus asper	1, 2	1		1	1	3		1, 2					
Sonchus oleraceus	1, 2	1, 2, 3		1	1			2, 3		3			
Sonchus sp.	2, 3	2, 3		2	2, 3			2, 3	3				
Sorghum sp.								2					
Spergula arvensis				3	3			3					
Spergularia bocconi		2											
Spergularia rubra	1												
Spergularia sp.	2, 3	1, 2, 3	2, 3	1, 2, 3	1, 2, 3	1, 2, 3	2, 3	3		3			2, 3
Stipa miliacea		2						2					
Tamarix ramosissima **(H)**								2					
Taraxacum officinale		2, 3											
Trifolium hirtum **(L)**	3	2, 3		2	1, 2			1, 2					

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland - New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Trifolium repens		2											
Trifolium tomentosum	3												
Triticale	1, 2, 3			2	1				1				
Vicia sativa	1, 2	1, 2	1, 3		1			2				2	
Vicia sp.			1										
Vicia villosa	1							1					
Washingtonia robusta **(M)**		2											

APPENDIX 3 – BIRD SURVEY SPECIES LISTS

Table A3.1. List of all bird species and the total number of individuals of each species observed in each of the first three years of monthly bird surveys at the North Campus Open Space restoration project. Each "Survey Year" begins in September and ends in August. The species are grouped by general guild, with some more detailed categories as defined by the eBird Clements v2018 integrated checklist (August 2018).

	Year 1 (9/2017 – 8/2018)		Year 2 (9/2018 – 8/2019		Year 3 (9/2019 – 8/2020)	
Guild & Common Name	**Number of Observations**	**Avg. Count per Survey**	**Number of Observations**	**Avg. Count per Survey**	**Number of Observations**	**Avg. Count per Survey**
Cormorants and Anhingas	**1**	**0.08**	**3**	**0.33**	**5**	**1.33**
Double-crested Cormorant	1	0.08	3	0.33	5	1.33
Gulls, Terns, and Skimmers	**13**	**8.25**	**28**	**13.42**	**27**	**8.83**
California Gull	2	1.00	4	1.33	5	1.08
Caspian Tern		0.00		0.00	2	0.42
Mew Gull		0.00	3	1.83	1	1.33
Ring-billed Gull	3	3.00	6	1.33	4	1.08
Western Gull	8	4.25	15	8.92	15	4.92
Herons, Egrets, Ibis	**34**	**9.17**	**43**	**3.83**	**78**	**22.58**
Black-crowned Night-Heron	2	0.33	2	0.17	15	1.58
Great Blue Heron	14	1.33	5	0.42	17	2.25
Great Egret	6	3.58	13	1.08	20	7.17
Green Heron	7	0.58	3	0.25	2	0.17
Snowy Egret	4	3.25	19	1.83	24	11.42
White-faced Ibis	1	0.08	1	0.08		0.00
Hummingbirds	**88**	**10.17**	**84**	**8.83**	**104**	**10.42**
Allen's Hummingbird	5	0.58	5	0.42	9	0.92
Anna's Hummingbird	81	9.33	78	8.33	94	9.42
Black-chinned Hummingbird		0.00		0.00	1	0.08
Rufous Hummingbird	2	0.25	1	0.08		0.00

Guild & Common Name	Year 1 (9/2017 – 8/2018) Number of Observations	Year 1 (9/2017 – 8/2018) Avg. Count per Survey	Year 2 (9/2018 – 8/2019 Number of Observations	Year 2 (9/2018 – 8/2019 Avg. Count per Survey	Year 3 (9/2019 – 8/2020) Number of Observations	Year 3 (9/2019 – 8/2020) Avg. Count per Survey
Insectivores	**429**	**117.58**	**671**	**172.33**	**765**	**211.00**
Blackbirds	***37***	***21.42***	***50***	19.33	***35***	16.42
Bullock's Oriole	1	0.08		0.00	1	0.08
Great-tailed Grackle	1	0.17		0.00	3	0.25
Hooded Oriole	4	0.50	7	0.58	10	0.92
Red-winged Blackbird	12	2.67	22	9.17	7	1.50
Western Meadowlark	19	18.00	20	9.50	13	13.58
Yellow-headed Blackbird		0.00	1	0.08	1	0.08
Cardinals, Grosbeaks, and Allies		***0.00***	***2***	***0.17***		***0.00***
Western Tanager		0.00	2	0.17		0.00
Catbirds, Mockingbirds, and Thrashers	***2***	***0.17***		***0.00***	***3***	***0.25***
California Thrasher	2	0.17		0.00	3	0.25
Gnatcatchers	***8***	***0.75***	***25***	***2.42***	***48***	***5.75***
Blue-gray Gnatcatcher	8	0.75	25	2.42	48	5.75
Kinglets	***5***	***0.42***	***16***	***1.25***	***16***	***1.42***
Ruby-crowned Kinglet	5	0.42	16	1.25	16	1.42
Martins and Swallows	***46***	***32.42***	***39***	***44.58***	***40***	***66.17***
Barn Swallow	6	0.83	8	1.25	6	1.67
Cliff Swallow	26	28.92	25	40.92	27	60.08
Northern Rough-winged Swallow	10	1.75	3	0.50	2	1.83
Tree Swallow	4	0.92	2	1.25	4	2.42
Violet-green Swallow		0.00	1	0.67	1	0.17
New World Sparrows	***117***	***22.92***	***212***	***49.50***	***271***	***64.00***
Fox Sparrow	1	0.08		0.00		0.00
Golden-crowned Sparrow	1	0.17		0.00	1	0.08
Lincoln's Sparrow		0.00	5	0.42	9	0.83
Savannah Sparrow	1	0.25	10	2.08	17	4.42
Savannah Sparrow (Belding's)	8	1.17	8	1.50	5	0.58
Song Sparrow	69	8.67	121	15.42	154	18.00

Guild & Common Name	Year 1 (9/2017 – 8/2018) Number of Observations	Year 1 (9/2017 – 8/2018) Avg. Count per Survey	Year 2 (9/2018 – 8/2019 Number of Observations	Year 2 (9/2018 – 8/2019 Avg. Count per Survey	Year 3 (9/2019 – 8/2020) Number of Observations	Year 3 (9/2019 – 8/2020) Avg. Count per Survey
White-crowned Sparrow	37	12.58	68	30.08	85	40.08
Nuthatches		***0.00***	***3***	***0.25***	***8***	***0.75***
Red-breasted Nuthatch		0.00		0.00	8	0.75
White-breasted Nuthatch		0.00	3	0.25		0.00
Parrotbills, Wrentit, and Allies		***0.00***	***3***	***0.25***	***3***	***0.25***
Wrentit		0.00	3	0.25	3	0.25
Penduline-Tits and Long-tailed Tits	***9***	***5.00***	***21***	***10.67***	***31***	***15.25***
Bushtit	9	5.00	21	10.67	31	15.25
Starlings and Mynas	***6***	***1.67***	***11***	***4.67***	***14***	***6.17***
European Starling	6	1.67	11	4.67	14	6.17
Swifts	***1***	***0.17***	***1***	***1.08***		***0.00***
Vaux's Swift	1	0.17	1	1.08		0.00
Thrushes	***28***	***4.42***	***31***	***5.00***	***32***	***5.00***
Hermit Thrush		0.00	1	0.08	1	0.08
Western Bluebird	28	4.42	30	4.92	31	4.92
Tits, Chickadees, and Titmice		***0.00***	***5***	***0.42***	***4***	***0.42***
Oak Titmouse		0.00	5	0.42	4	0.42
Tyrant Flycatchers: Pewees, Kingbirds, and Allies	***121***	***11.58***	***193***	***18.25***	***184***	***18.08***
Ash-throated Flycatcher		0.00	3	0.25		0.00
Black Phoebe	65	6.00	112	10.42	89	8.08
Cassin's Kingbird	11	1.50	28	3.17	30	3.75
Pacific-slope Flycatcher	1	0.08	1	0.08	3	0.25
Say's Phoebe	42	3.83	47	4.17	51	4.67
Tropical Kingbird		0.00	1	0.08	3	0.33
Western Kingbird	1	0.08		0.00	7	0.92
Western Wood-Pewee	1	0.08	1	0.08		0.00
Willow Flycatcher		0.00		0.00	1	0.08

	Year 1 (9/2017 – 8/2018)		Year 2 (9/2018 – 8/2019		Year 3 (9/2019 – 8/2020)	
Guild & Common Name	**Number of Observations**	**Avg. Count per Survey**	**Number of Observations**	**Avg. Count per Survey**	**Number of Observations**	**Avg. Count per Survey**
Wagtails and Pipits	***24***	***14.33***	***19***	***10.67***	***8***	***5.00***
American Pipit	24	14.33	19	10.67	8	5.00
Woodpeckers	***6***	***0.67***	***11***	***0.92***	***15***	***1.33***
Acorn Woodpecker	2	0.33		0.00	1	0.08
Downy Woodpecker	2	0.17	2	0.17	6	0.50
Hairy Woodpecker	2	0.17		0.00	6	0.58
Northern Flicker		0.00	3	0.25	1	0.08
Nuttall's Woodpecker		0.00	6	0.50	1	0.08
Wrens	***19***	***1.67***	***29***	***2.92***	***53***	***4.75***
Bewick's Wren	13	1.17	14	1.67	17	1.58
House Wren	4	0.33	9	0.75	26	2.17
Marsh Wren		0.00	3	0.25	10	1.00
Rock Wren	2	0.17	3	0.25		0.00
Kingfishers		**0.00**	**5**	**0.42**	**4**	**0.33**
Belted Kingfisher		0.00	5	0.42	4	0.33
Omnivores	**152**	**35.08**	**140**	**22.17**	**144**	**24.25**
Blackbirds		***0.00***	***1***	***0.17***		***0.00***
Brewer's Blackbird		0.00	1	0.17		0.00
Catbirds, Mockingbirds, and Thrashers	***6***	***0.67***	***18***	***1.92***	***15***	***1.42***
Northern Mockingbird	6	0.67	18	1.92	15	1.42
Jays, Magpies, Crows, and Ravens	***53***	***20.92***	***47***	***9.58***	***72***	***14.92***
American Crow	53	20.92	46	9.50	72	14.92
California Scrub-Jay		0.00	1	0.08		0.00
New World Sparrows	***79***	***9.50***	***57***	***7.25***	***47***	***4.92***
California Towhee	78	9.42	56	7.17	47	4.92
Spotted Towhee	1	0.08	1	0.08		0.00
Old World Sparrows	***14***	***4.00***	***17***	***3.25***	***10***	***3.00***
House Sparrow	14	4.00	17	3.25	10	3.00

Guild & Common Name	Year 1 (9/2017 – 8/2018)		Year 2 (9/2018 – 8/2019		Year 3 (9/2019 – 8/2020)	
	Number of Observations	Avg. Count per Survey	Number of Observations	Avg. Count per Survey	Number of Observations	Avg. Count per Survey
Raptors	**64**	**6.00**	**79**	**7.50**	**86**	**8.33**
Falcons and Caracaras	***5***	***0.50***	***6***	***0.50***	***5***	***0.42***
American Kestrel	5	0.50	5	0.42	4	0.33
Merlin		0.00	1	0.08	1	0.08
Owls		***0.00***	***7***	***0.58***	***6***	***0.83***
Burrowing Owl		0.00	6	0.50	3	0.25
Great Horned Owl		0.00	1	0.08	3	0.58
Shrikes	***9***	***0.75***	***9***	***0.75***	***11***	***1.08***
Loggerhead Shrike	9	0.75	9	0.75	11	1.08
Vultures, Hawks, and Allies	***50***	***4.75***	***57***	***5.67***	***64***	***6.00***
Cooper's Hawk	11	0.92	16	1.42	19	1.83
Northern Harrier		0.00		0.00	2	0.17
Osprey		0.00	1	0.08		0.00
Red-shouldered Hawk	8	0.83	8	0.75	15	1.33
Red-tailed Hawk	17	1.50	19	1.92	15	1.42
Turkey Vulture	7	0.75	7	0.67	9	0.75
White-tailed Kite	7	0.75	6	0.83	4	0.50
Seed & Fruit Eaters	**174**	**65.83**	**205**	**87.08**	**201**	**67.17**
Blackbirds	***1***	***0.08***	***1***	***0.08***	***2***	***0.58***
Brown-headed Cowbird	1	0.08	1	0.08	2	0.58
Cardinals, Grosbeaks, and Allies	***1***	***0.08***	***1***	***0.08***	***1***	***0.17***
Black-headed Grosbeak		0.00		0.00	1	0.17
Blue Grosbeak	1	0.08	1	0.08		0.00
Estrildids	***23***	***11.50***	***33***	***20.92***	***28***	***14.17***
Scaly-breasted Munia	23	11.50	33	20.92	28	14.17
Finches, Euphonias, and Allies	***85***	***20.92***	***99***	***28.17***	***95***	***23.75***
House Finch	72	19.08	76	24.08	73	21.00
Lesser Goldfinch	13	1.83	22	4.00	20	2.50
Purple Finch		0.00	1	0.08	2	0.25

	Year 1 (9/2017 – 8/2018)		Year 2 (9/2018 – 8/2019		Year 3 (9/2019 – 8/2020)	
Guild & Common Name	**Number of Observations**	**Avg. Count per Survey**	**Number of Observations**	**Avg. Count per Survey**	**Number of Observations**	**Avg. Count per Survey**
Grouse, Quail, and Allies		***0.00***	***1***	***0.17***		***0.00***
California Quail		0.00	1	0.17		0.00
New World Sparrows	***3***	***0.75***	***16***	***2.33***	***20***	***2.42***
Chipping Sparrow		0.00	2	0.17	1	0.17
Clay-colored Sparrow		0.00	1	0.08		0.00
Dark-eyed Junco	1	0.08		0.00		0.00
Lark Sparrow	2	0.67	13	2.08	19	2.25
Pigeons and Doves	***61***	***32.50***	***54***	***35.33***	***55***	***26.08***
Eurasian Collared-Dove	9	1.17	2	0.33	5	0.58
Mourning Dove	23	7.83	19	4.25	18	2.33
Rock Pigeon (Feral Pigeon)	29	23.50	33	30.75	32	23.17
Shorebirds	**224**	**95.25**	**189**	**86.67**	**175**	**69.25**
American Avocet		0.00		0.00	2	0.17
Black-necked Stilt	5	0.83	11	1.50	23	3.17
Dunlin	1	0.08	1	0.08		0.00
Greater Yellowlegs	18	1.83	14	1.50	18	1.83
Killdeer	94	38.25	93	34.00	71	32.00
Least Sandpiper	45	14.08	30	23.33	17	6.92
Lesser Yellowlegs		0.00		0.00	1	0.17
Long-billed Curlew	2	0.17	3	0.83	2	0.25
Long-billed Dowitcher		0.00	2	0.42	5	1.83
Pectoral Sandpiper		0.00	1	0.08	1	0.17
Red-necked Phalarope	2	0.33	3	0.33	5	1.50
Sanderling		0.00	1	0.17		0.00
Semipalmated Plover	16	29.33	7	13.92	7	15.25
Solitary Sandpiper		0.00	1	0.08		0.00
Spotted Sandpiper	1	0.08	1	0.08	5	0.42
Western Sandpiper	36	9.67	17	9.58	11	4.00
Western Snowy Plover	1	0.08	2	0.50	4	1.00

Guild & Common Name	Year 1 (9/2017 – 8/2018) Number of Observations	Year 1 (9/2017 – 8/2018) Avg. Count per Survey	Year 2 (9/2018 – 8/2019 Number of Observations	Year 2 (9/2018 – 8/2019 Avg. Count per Survey	Year 3 (9/2019 – 8/2020) Number of Observations	Year 3 (9/2019 – 8/2020) Avg. Count per Survey
Whimbrel		0.00	1	0.17		0.00
Willet	1	0.08		0.00		0.00
Wilson's Snipe	2	0.42	1	0.08	3	0.58
Warblers	**56**	**9.17**	**114**	**20.42**	**193**	**60.75**
Common Yellowthroat	16	1.58	41	4.17	77	7.83
Orange-crowned Warbler	3	0.33	3	0.25	11	1.08
Yellow Warbler	1	0.08	4	0.58	4	0.42
Yellow-rumped Warbler	36	7.17	66	15.42	101	51.42
Waterfowl & ALLIES	**104**	**43.17**	**202**	**98.33**	**262**	**192.92**
Grebes	***2***	***0.25***	***10***	***1.25***	***21***	***2.42***
Clark's Grebe		0.00		0.00	5	0.42
Eared Grebe	2	0.25	6	0.83	4	0.67
Pied-billed Grebe		0.00	2	0.25	11	1.25
Western Grebe		0.00	2	0.17	1	0.08
Rails, Gallinules, and Allies	***7***	***0.67***	***59***	***34.92***	***48***	***42.58***
American Coot	5	0.50	45	33.67	39	41.75
Sora	2	0.17	14	1.25	7	0.58
Virginia Rail		0.00		0.00	2	0.25
Waterfowl	***95***	***42.25***	***133***	***62.17***	***193***	***147.92***
American Wigeon	3	0.58		0.00	8	2.67
Blue-winged Teal	1	0.08	2	0.25	2	0.25
Bufflehead	2	0.17	4	0.42	2	0.33
Cackling Goose (Aleutian)	5	1.25	1	0.08		0.00
Canada Goose	16	13.83	22	20.25	21	45.17
Canvasback		0.00		0.00	1	0.33
Cinnamon Teal	7	2.00	8	1.50	17	4.33
Cinnamon Teal x Northern Shoveler (hybrid)		0.00	1	0.08		0.00
Gadwall	7	1.58	10	3.50	21	8.58
Greater White-fronted Goose	7	4.67	2	0.33	4	0.83

	Year 1 (9/2017 – 8/2018)		Year 2 (9/2018 – 8/2019		Year 3 (9/2019 – 8/2020)	
Guild & Common Name	**Number of Observations**	**Avg. Count per Survey**	**Number of Observations**	**Avg. Count per Survey**	**Number of Observations**	**Avg. Count per Survey**
Green-winged Teal		0.00	3	1.17	5	1.08
Hooded Merganser	1	0.08	2	0.25	1	0.08
Mallard	35	16.08	53	27.42	62	52.83
Mute Swan		0.00	1	0.08		0.00
Northern Pintail	2	0.25		0.00	6	1.08
Northern Shoveler	3	0.75	14	4.08	17	17.67
Redhead	1	0.08	2	1.58	8	5.67
Ring-necked Duck		0.00		0.00	1	0.33
Ross's Goose		0.00	2	0.33	1	0.08
Ruddy Duck	5	0.83	4	0.50	15	6.42
Snow Goose		0.00	2	0.33	1	0.17
Grand Total	**1339**	**399.75**	**1763**	**521.42**	**2044**	**677.17**

Table A3.2. List of species and number of observations of breeding behavior recorded during monthly bird surveys at North Campus Open Space and reported to the Santa Barbara Audubon Society's Breeding Bird Study in 2018, 2019 and 2020. Note that some of the NCOS bird survey observations are also reported to the Breeding Bird Study.

	NCOS Monthly Bird Survey Observations			Breeding Bird Study Observations		
Species Common Name	**2018**	**2019**	**2020**	**2018**	**2019**	**2020**
American Crow			2			3
Anna's Hummingbird		1				
Barn Swallow						1
Bewick's Wren						1
Black Phoebe	3	2	1		1	3
Bushtit	1					
California Towhee	2		1	1		2
Canada Goose		2	2		1	1
Cassin's Kingbird					1	
Cliff Swallow	5	4	1	3	3	3
Cooper's Hawk	1		2			1
European Starling					1	1
Gadwall		2			3	1
Great Egret					1	
Great Horned Owl				1		1
House Finch	2	3	3	2	4	3
House Sparrow	2			2	1	
Killdeer	4	3	2	5	6	2
Lark Sparrow		2	1			1
Lesser Goldfinch		1	1		1	1
Mallard	1	2	2	2	2	2
Red-shouldered Hawk	1					1
Red-tailed Hawk		1				
Rock Pigeon (Feral Pigeon)	1			1		
Savannah Sparrow (Belding's)			3			4
Say's Phoebe				1	1	
Song Sparrow		2	1		7	1
Western Bluebird	1			1		
Western Sandpiper	1					
Western Snowy Plover			1	2	1	1
Wrentit			1			
Grand Total	**25**	**25**	**24**	**21**	**34**	**34**

APPENDIX 4 – JULY 2020 AQUATIC SPECIES SURVEY REPORT

Technical Memorandum

Date	August 14, 2020
To:	Lisa Stratton, UCSB; Chris Kofron, USFWS
From:	Rosemary Thompson
RE:	**Devereux Slough and UCSB North Campus Open Space July 2020 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 storm water 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 the Venoco Access Road. The weir has been removed, and grading has restored portions of the upper channels of Devereux Creek, allowing tidal influence upstream to near the Phelps Creek confluence and into 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, 2018, and 2019 found no tidewater gobies to be present in NCOS channels. The 2018 and 2019 surveys also found no southwestern pond turtles or California red-legged frogs. The 2019 post-construction tidewater goby survey conducted on 17 October by Rosemary Thompson found tidewater gobies in Devereux Slough downstream of Venoco Road.

A post-construction survey was conducted on 29 July 2020 in the restored channels upstream of Venoco Road and in Phelps Creek by Rosemary Thompson (federal permit TE-815144-9, state permit SC-002731) with assistance from Hannah Donaghe (Cardno biologist with a tidewater goby permit) and CCBER staff (Lisa Stratton, Beau Tindall, Darwin Richardson, and Hayden Hennigan). The methods used and results of the surveys are described below. No surveys were conducted in Devereux Slough downstream of Venoco Road due to lack of approval from Coal Oil Point Reserve.

2 Methods

<u>Tidewater goby and other fish</u>. Sampling sites were selected in the field based on access, water depth, density of *Ruppia* (an aquatic plant), and approximate location sampled in previous years (Figure 2). Three locations in the restored channels were seined, one near Venoco Road, one in the East Channel, and one in the West Arm between 10:00 AM and 12:15 PM. A minnow seine 3 meters (m) long by 1 m high with 3 mm mesh was used for the sampling. This was smaller than the

seine used in prior years due to the amount of *Ruppia* present that could entangle and damage fish. Seine hauls varied in length from about 8 to 10 m. The seine was pulled across the channel in NCOS 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 from upstream to the Phelps bridge near the confluence with the West Arm from 9:30 to 10:00 AM. Water depth ranged from 10 inches to 3 feet. Many sweeps were made wherever open water occurred with minimal obstructions. Organisms captured were identified and released.

Water quality. Water quality parameters (temperature in °C, 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, 3 native dragonfly nymphs were also captured.

Table 1 Fish and Crayfish Captured on 29 July 2020

Site	Common Name	Scientific Name	Number	Method
PC	Mosquitofish	*Gambusia affinis*	24	Dipnet
	Red swamp crayfish	*Procambarus clarkii*	12	
PC mouth	Mosquitofish	*Gambusia affinis*	125	Dipnet
	Red swamp crayfish	*Procambarus clarkii*	1	
	Mississippi silversides	*Menidia audens*	1	
MC-L	Mississippi silversides	*Menidia audens*	19	Seine (3 hauls)
	Mosquitofish	*Gambusia affinis*	20	
	Top smelt	*Atherinops affinis*	49	
	Longjaw mudsucker	*Gillichthys mirabilis*	1	
MC-WA	Mosquitofish	*Gambusia affinis*	25	Seine (3 hauls)
	Mississippi silversides	*Menidia audens*	43	
	California killifish	*Fundulus parvipinnis*	122	
EC	California killifish	*Fundulus parvipinnis*	2	Seine (3 hauls)
	Mosquitofish	*Gambusia affinis*	0	
	Mississippi silversides	*Menidia audens*	19	
	Longjaw mudsucker	*Gillichthys mirabilis*	1	

PC = Phelps Creek
MC-L = Main Channel just upstream of Venoco Road; MC-WA = West Arm; EC = East Channel

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, or in the NCOS channels. Tidewater gobies remaining upstream or those in Devereux Slough could expand into NCOS aquatic habitats in the future. Tidewater gobies generally only live one year (Swift et al.

1989, Moyle 2002).

The fish species collected in the restored estuarine channels on NCOS are similar to those found in Devereux Slough in 2019. 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 but slightly more than in 2019. Its spread into the restored channels will likely be limited by its intolerance of high salinity.

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	1.2-1.9	1.88-0	17.3-17.1
Phelps Bridge	34.421244	-119.878893	5.13-2.01	1.1-1.7	18.4-18.1
West Arm	34.420759	-119.878412	4.3-3.5	3414.1-14.8	21.5-22
East Channel	34.420628	-119.874310	3.2	61.6	21.4
Main Channel - lower	34.417846	-119.874249	2.6-5.18	69-69.7	21.7-22.3

4 References

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

Swift, C.C., J.L. Nelson, C. Maslow, and T. Stein. 1989. Biology and Distribution of the Tidewater Goby, *Eucyclogobius newberri* (Pisces: Gobiidae) of California. Natural History Museum of Los Angeles County, Contributions in Science, Number 404:1-19.

Figure 1 **Creeks and channels at NCOS.**

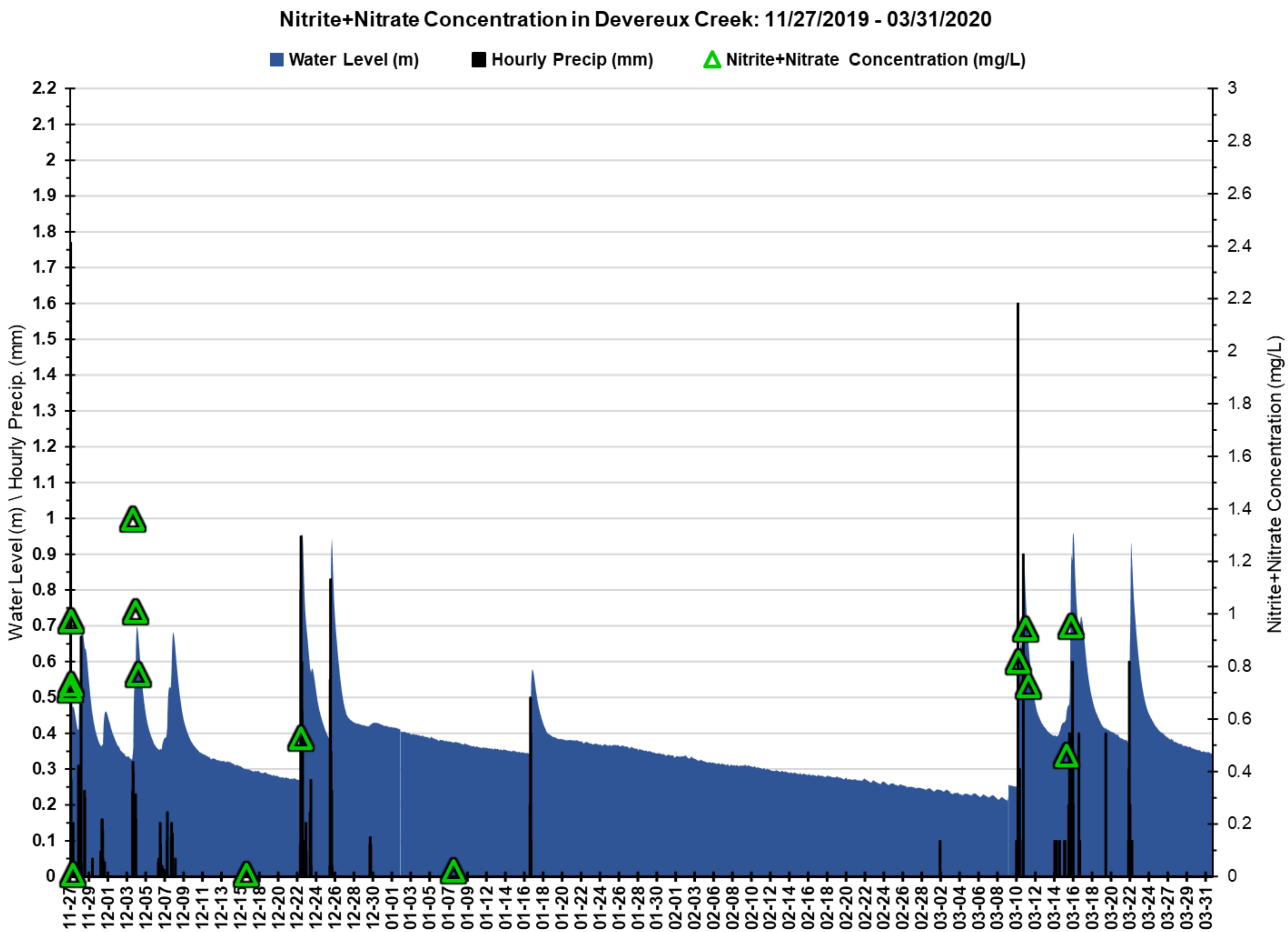
Figure 2 **Fish sampling and water quality locations (yellow-labeled points).**

APPENDIX 5 – 2020 WATER YEAR STORM WATER DATA

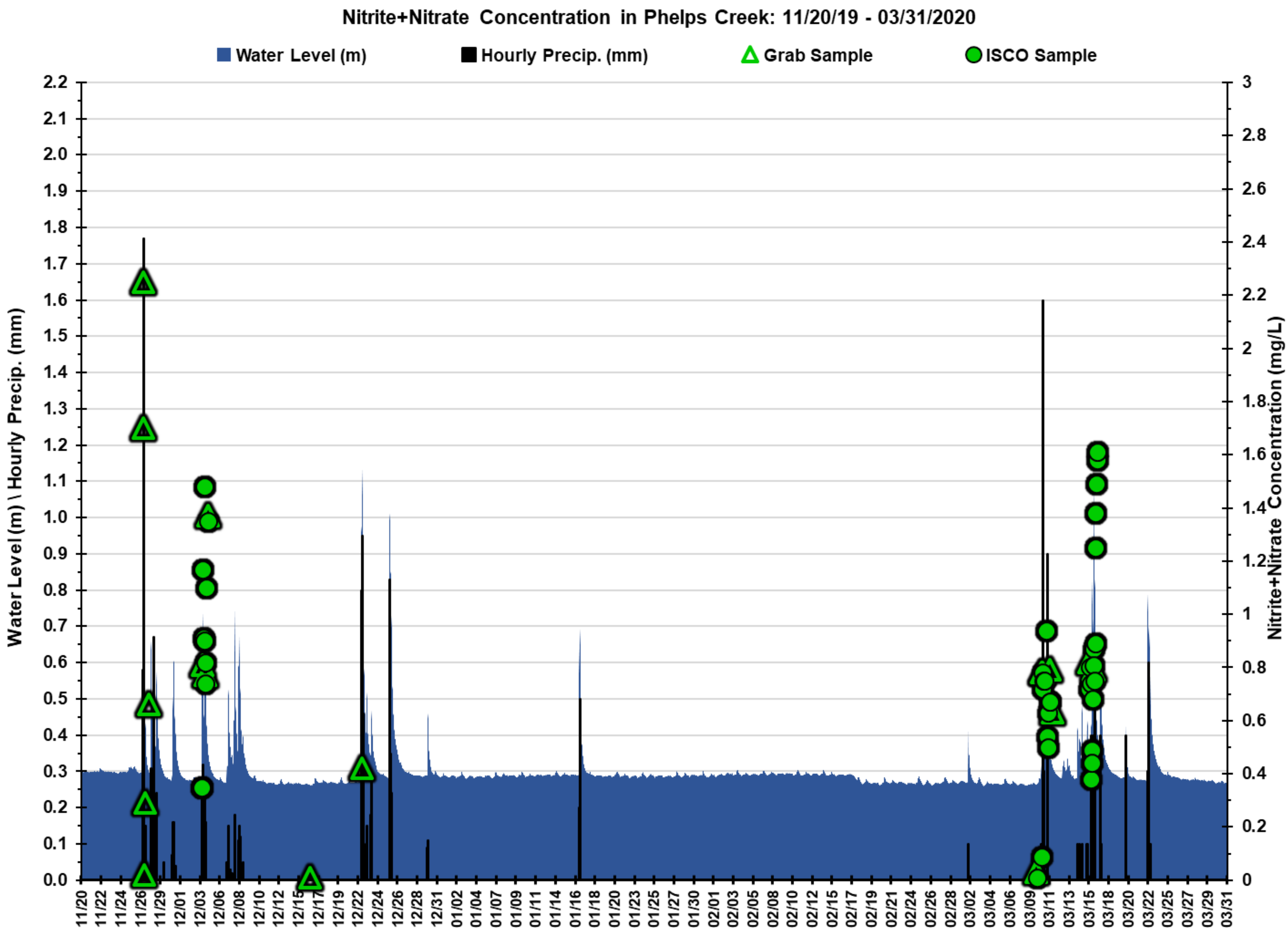
Table A5.1. Grab and ISCO samples analyzed for nutrients (N) and suspended solids concentrations (SSC) at each sampling site for each storm and baseline event in the 2020 Water Year (October 1, 2019 to September 30, 2020) at North Campus Open Space. At Devereux Creek, only Grab samples were collected and analyzed.

		Devereux Creek	Phelps Creek		Whittier Storm drain Outfall		Venoco Bridge	
Date	**Event Type**	**Grab**	**Grab**	**ISCO**	**Grab**	**ISCO**	**Grab**	**ISCO**
11/26-11/27/2019	Storm	4	5			7 (N) 8 (SSC)	5	
12/03-12/04/2019	Storm	3	3	10 (N) 11 (SSC)	3	2 (N) 2 (SSC)	3	7 (N) 7 (SSC)
12/16/2019	Baseline	1	1		1		1	
12/22/2019	Storm	1	1		1		1	
01/08/2020	Baseline	1	1		1		1	
03/09 – 03/11/2020	Storm	3	5	12 (N) 16 (SSC)	5	9 (N) 13 (SSC)	5	9 (N) 16 (SSC)
03/15 – 03/16/2020	Storm	2	2	16 (N) 20 (SSC)	2	17 (N) 18 (SSC)	2	11 (N) 17 (SSC)

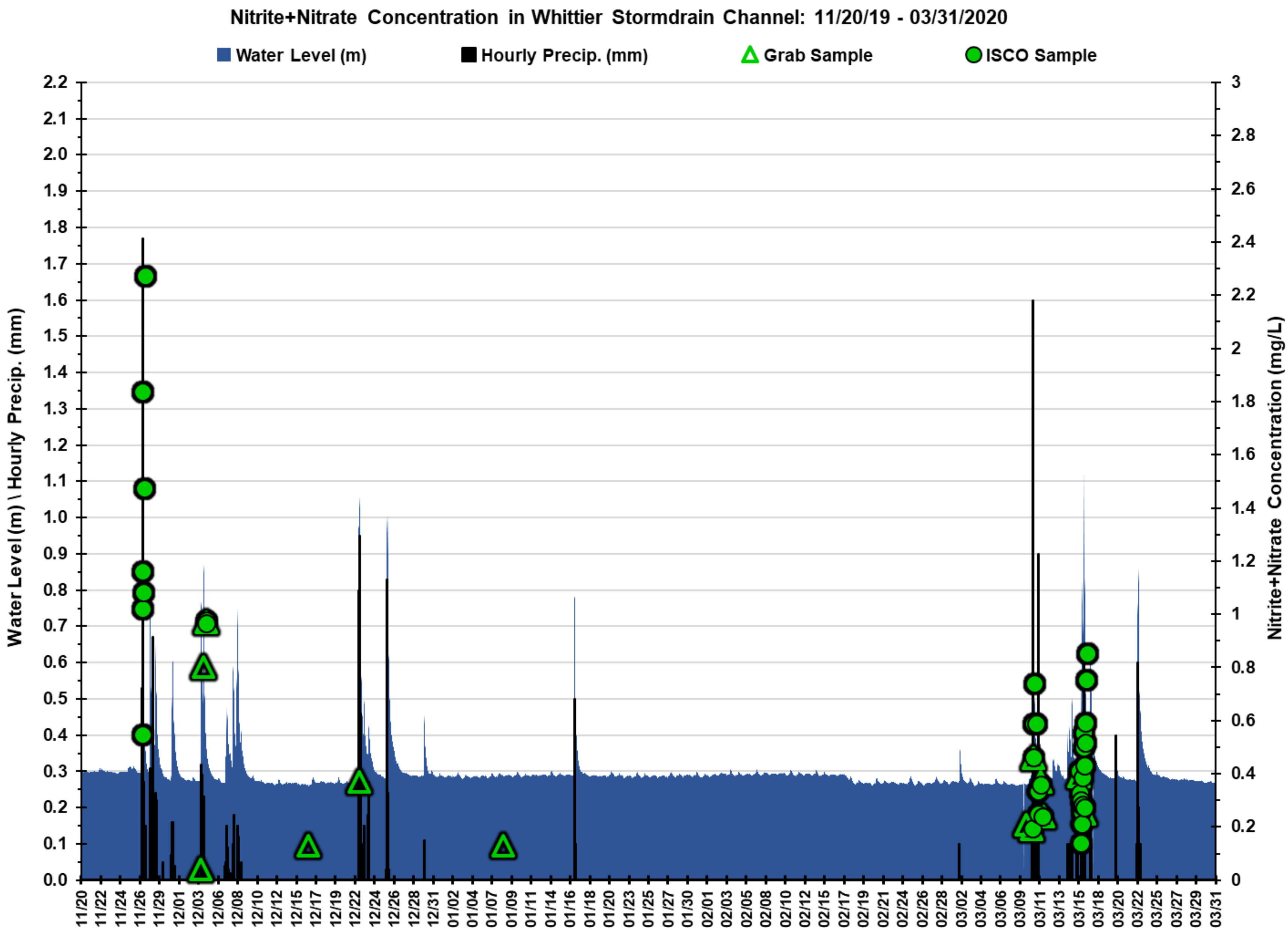
<u>NUTRIENT CONCENTRATIONS DATA: Nitrite+Nitrate – Site Comparisons</u>



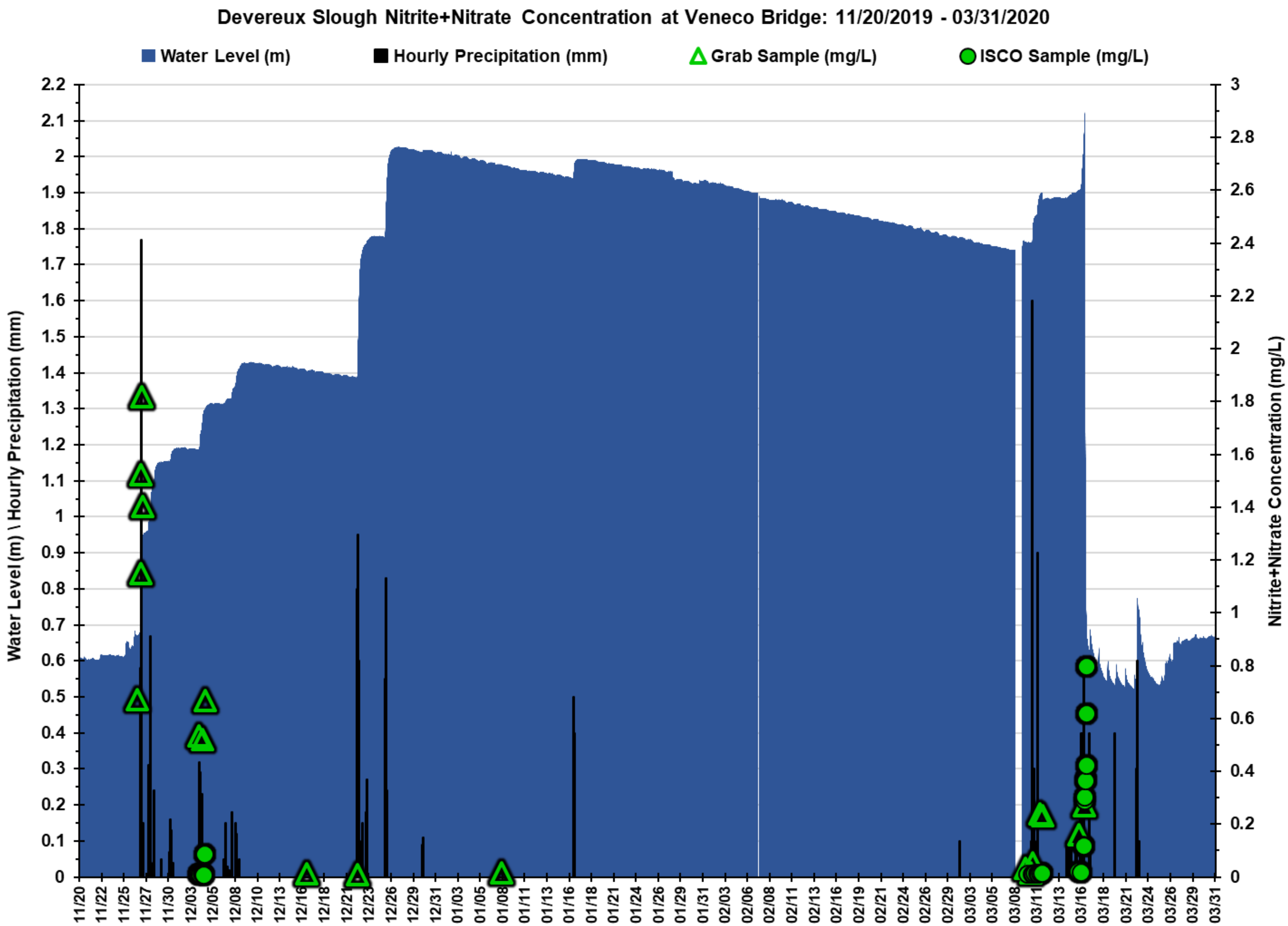
Nitrite+Nitrate Concentration in Devereux Creek: 11/27/2019 - 03/31/2020
Water Level (m)
Hourly Precip (mm)
Nitrite+Nitrate Concentration (mg/L)
Water Level (m) \ Hourly Precip. (mm)
Nitrite+Nitrate Concentration (mg/L)



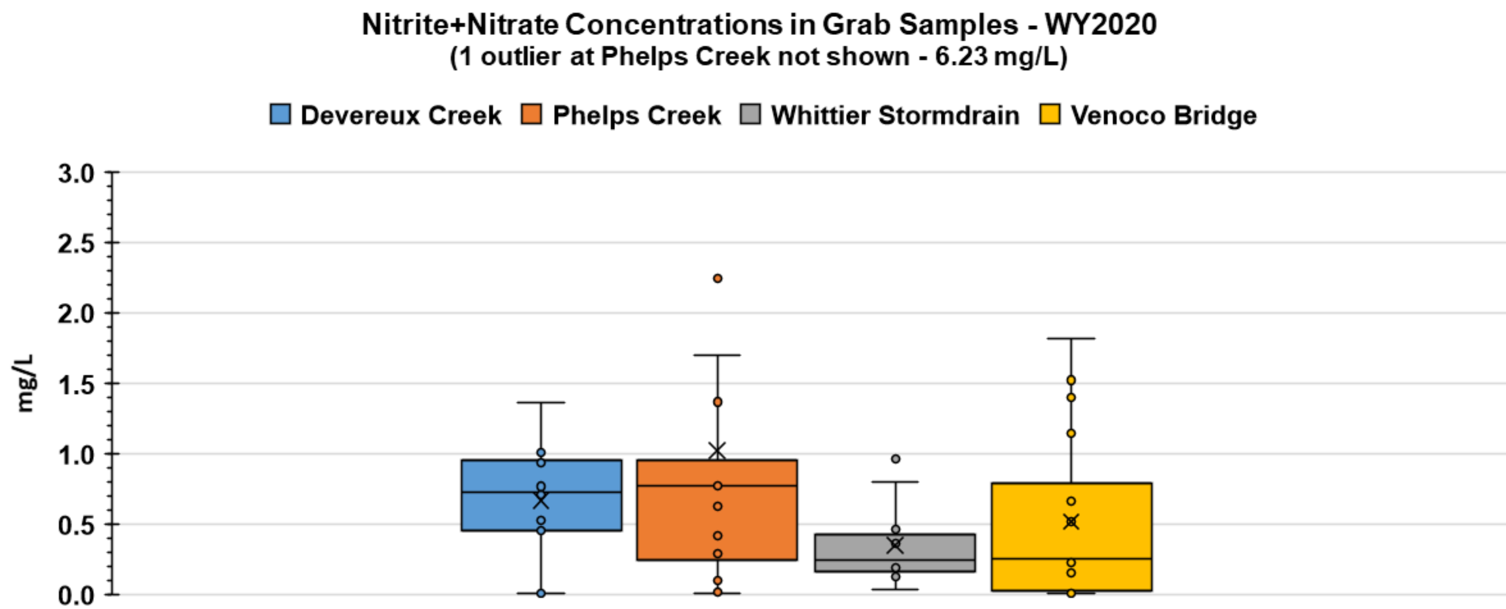
Nitrite+Nitrate Concentration in Phelps Creek: 11/20/19 - 03/31/2020
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Nitrite+Nitrate Concentration (mg/L)

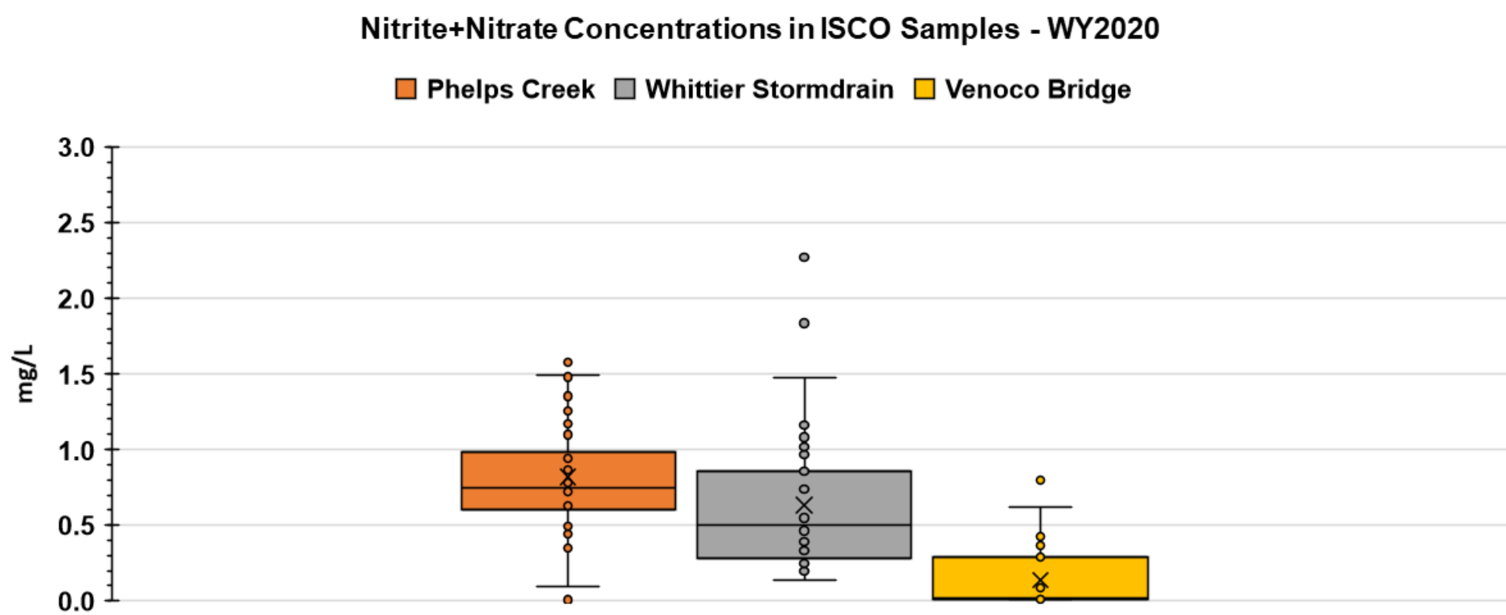


Nitrite+Nitrate Concentration in Whittier Stormdrain Channel: 11/20/19 - 03/31/2020
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Nitrite+Nitrate Concentration (mg/L)

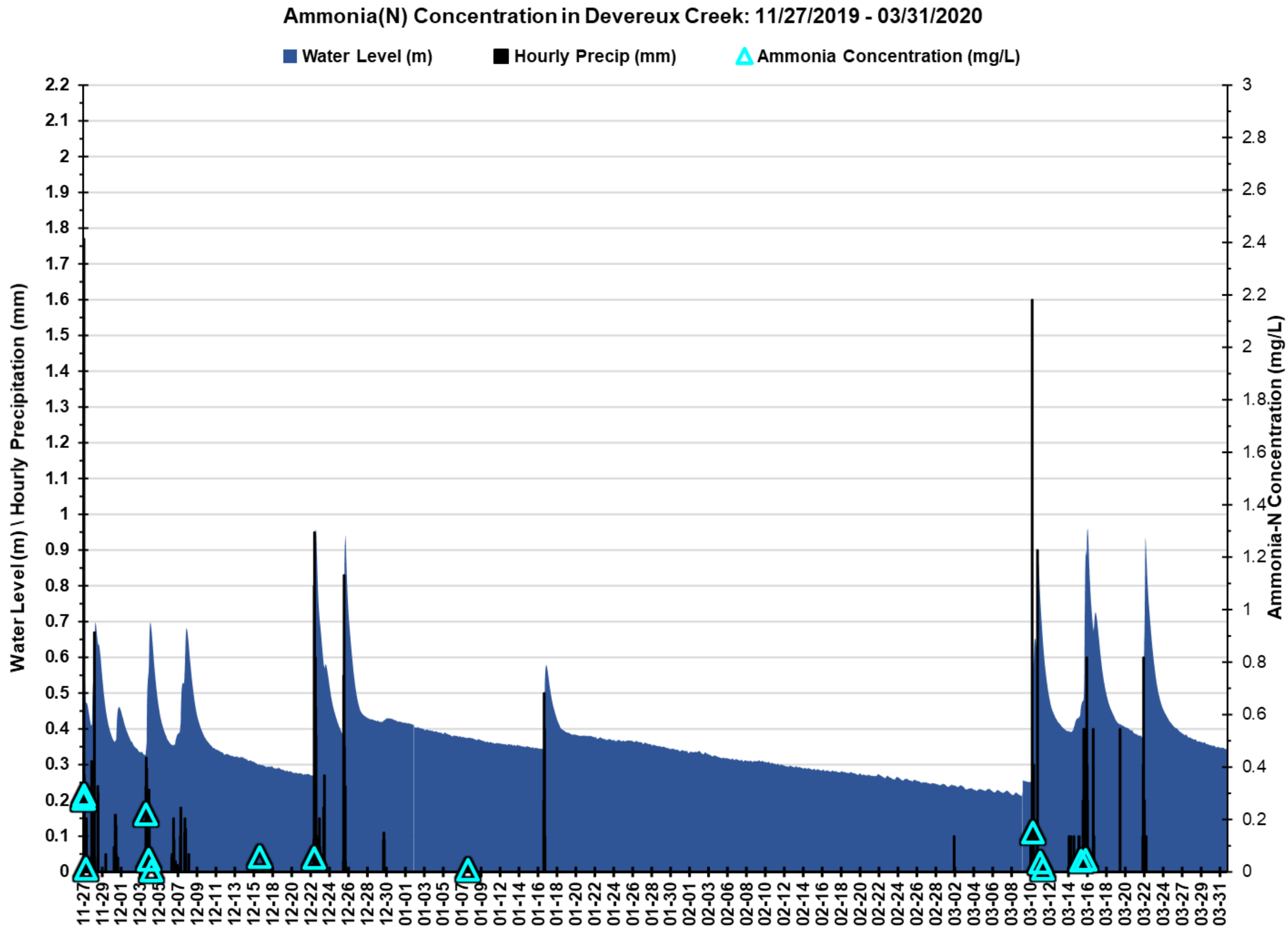


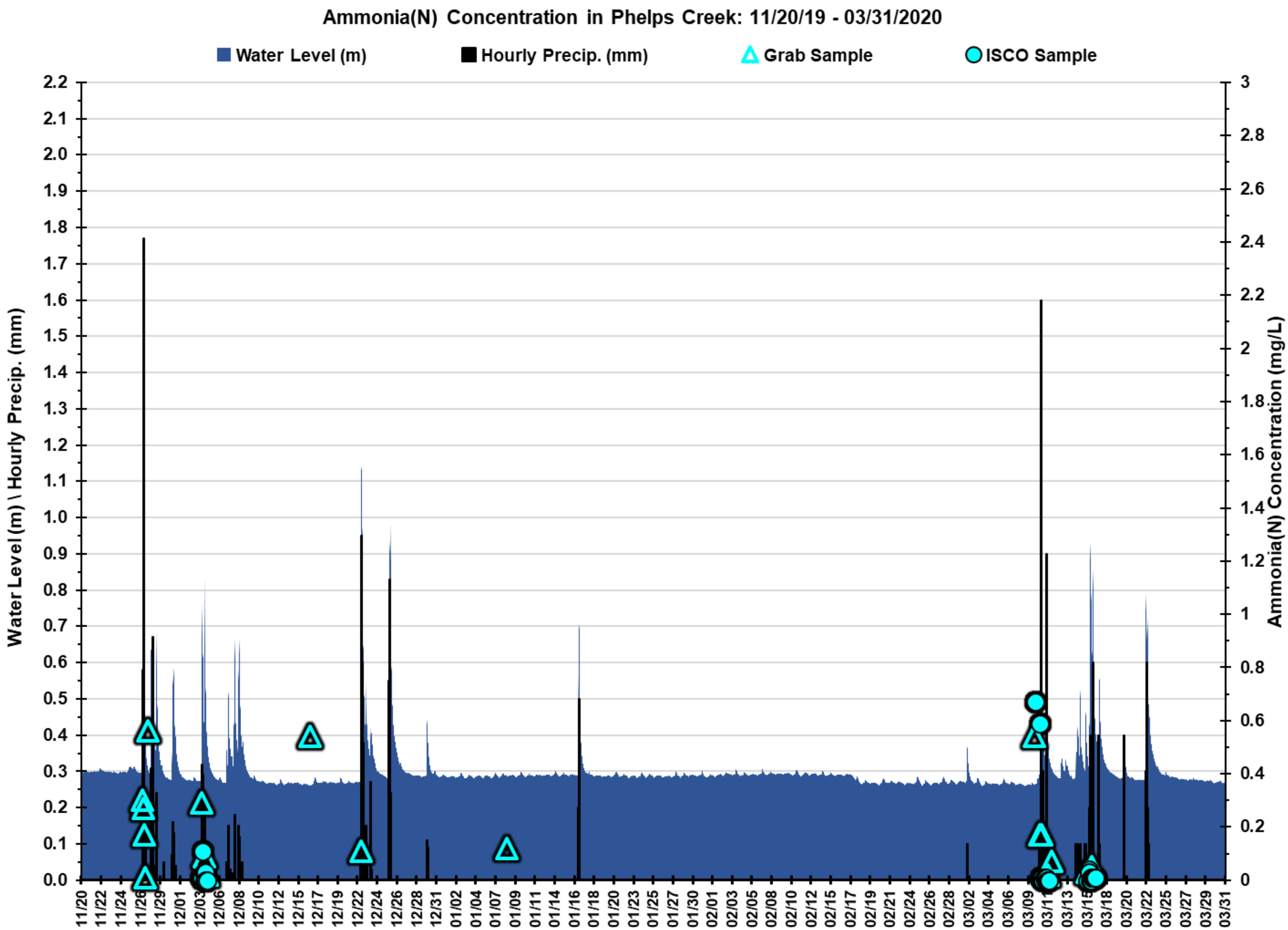
Devereux Slough Nitrite+Nitrate Concentration at Veneco Bridge: 11/20/2019 - 03/31/2020
Water Level (m)
Hourly Precipitation (mm)
Grab Sample (mg/L)
ISCO Sample (mg/L)
Water Level (m) \ Hourly Precipitation (mm)
Nitrite+Nitrate Concentration (mg/L)

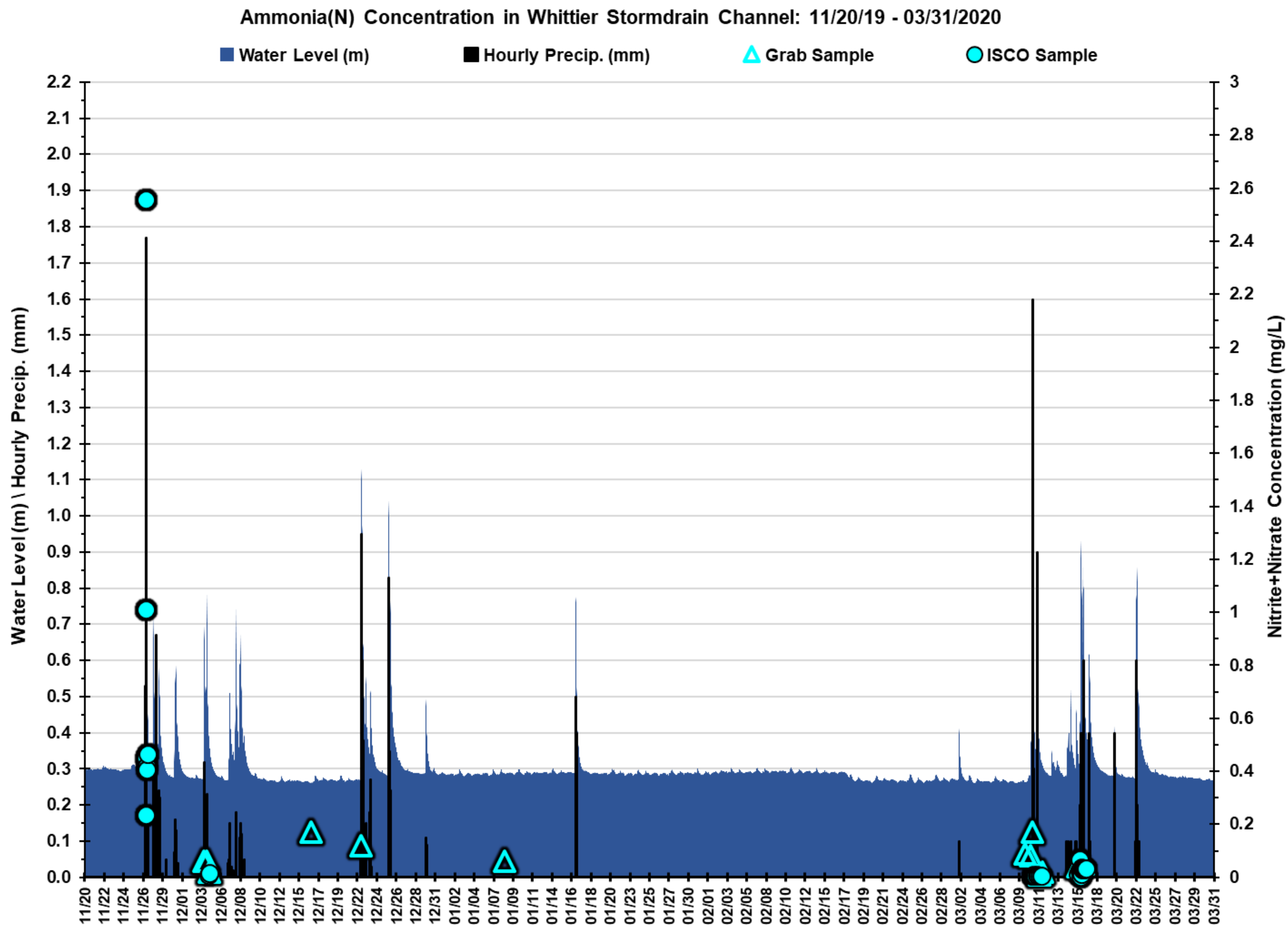

Nitrite+Nitrate Concentrations in Grab Samples - WY2020
(1 outlier at Phelps Creek not shown - 6.23 mg/L)
Devereux Creek
Phelps Creek
Whittier Stormdrain
Venoco Bridge
mg/L
3.0
2.5
2.0
1.5
1.0
0.5
0.0


Nitrite+Nitrate Concentrations in ISCO Samples - WY2020
Phelps Creek
Whittier Stormdrain
Venoco Bridge
mg/L
3.0
2.5
2.0
1.5
1.0
0.5
0.0

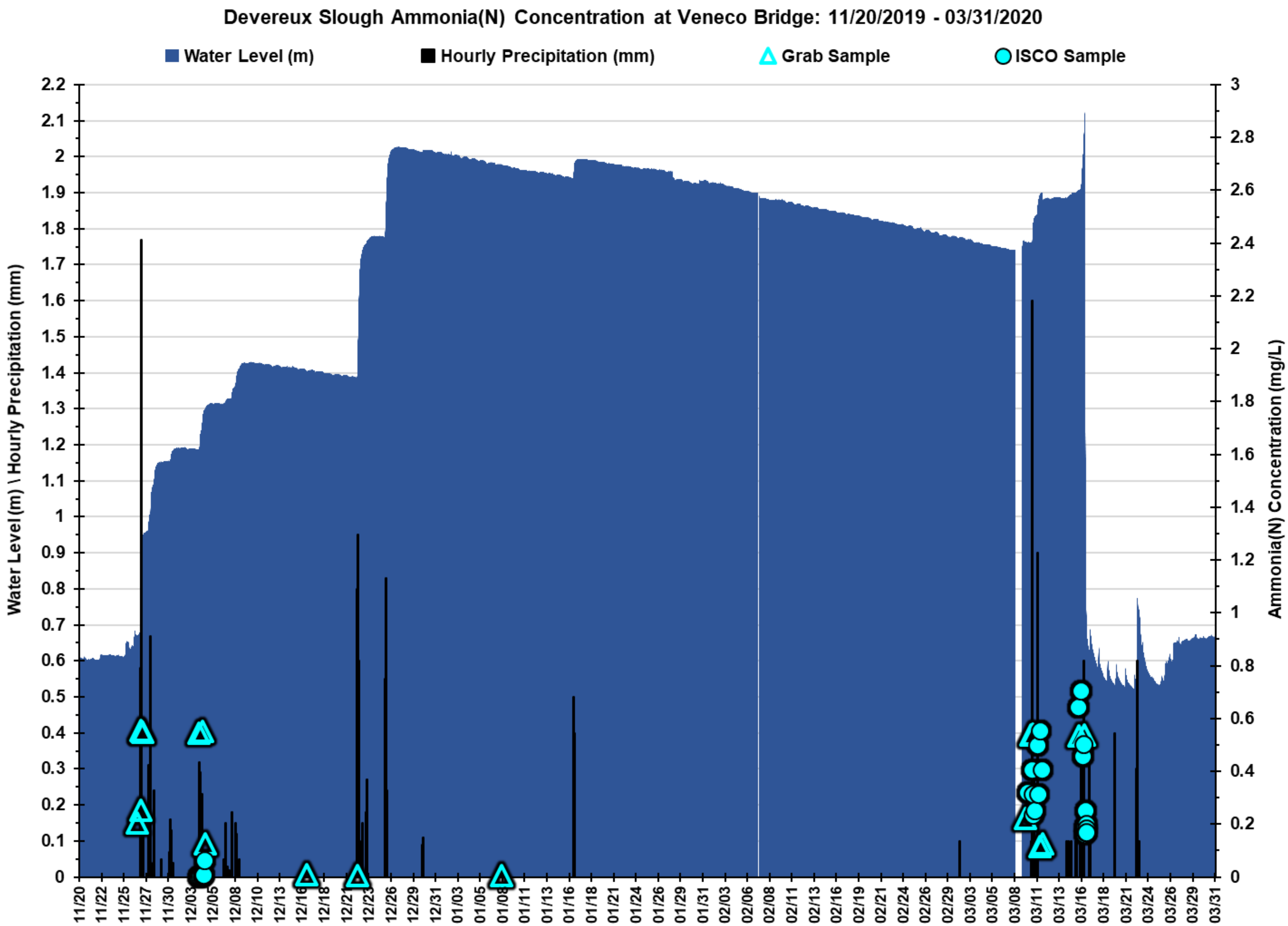
NUTRIENT CONCENTRATIONS DATA: Ammonia-N – Site Comparisons

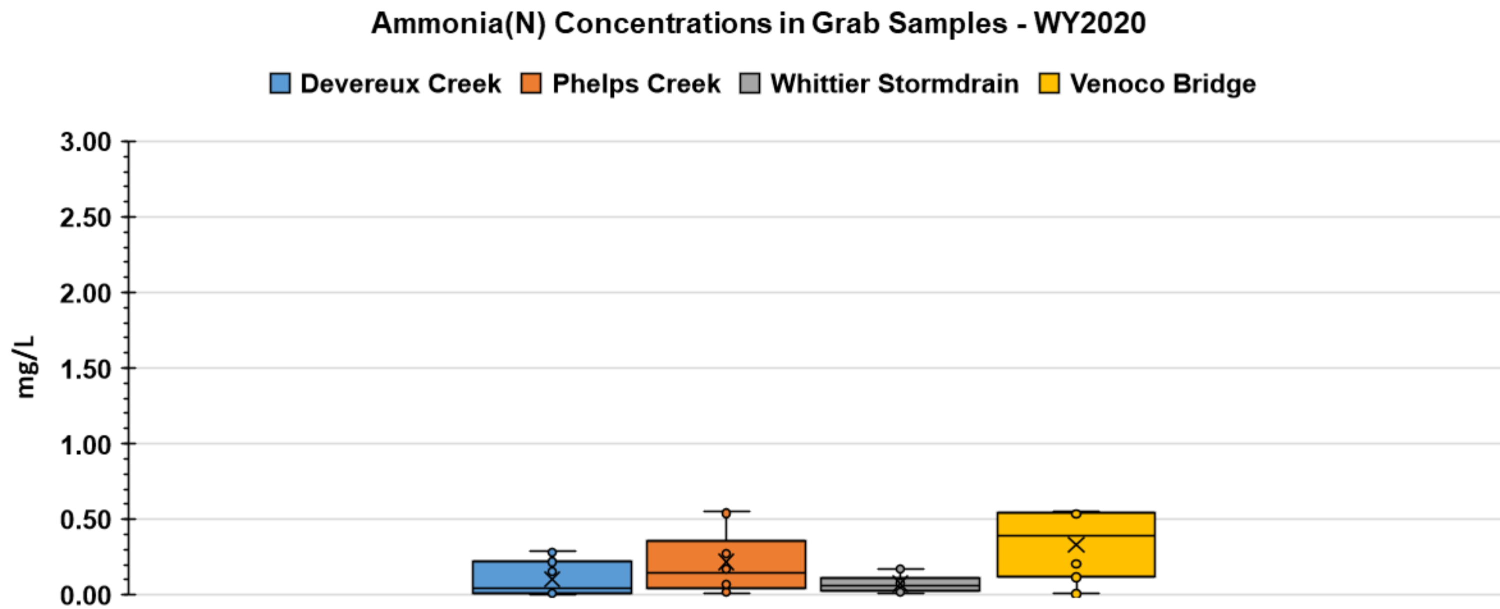

Ammonia(N) Concentration in Devereux Creek: 11/27/2019 - 03/31/2020
Water Level (m)
Hourly Precip (mm)
Ammonia Concentration (mg/L)
Water Level (m) \ Hourly Precipitation (mm)
Ammonia-N Concentration (mg/L)


Ammonia(N) Concentration in Phelps Creek: 11/20/19 - 03/31/2020
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Ammonia(N) Concentration (mg/L)

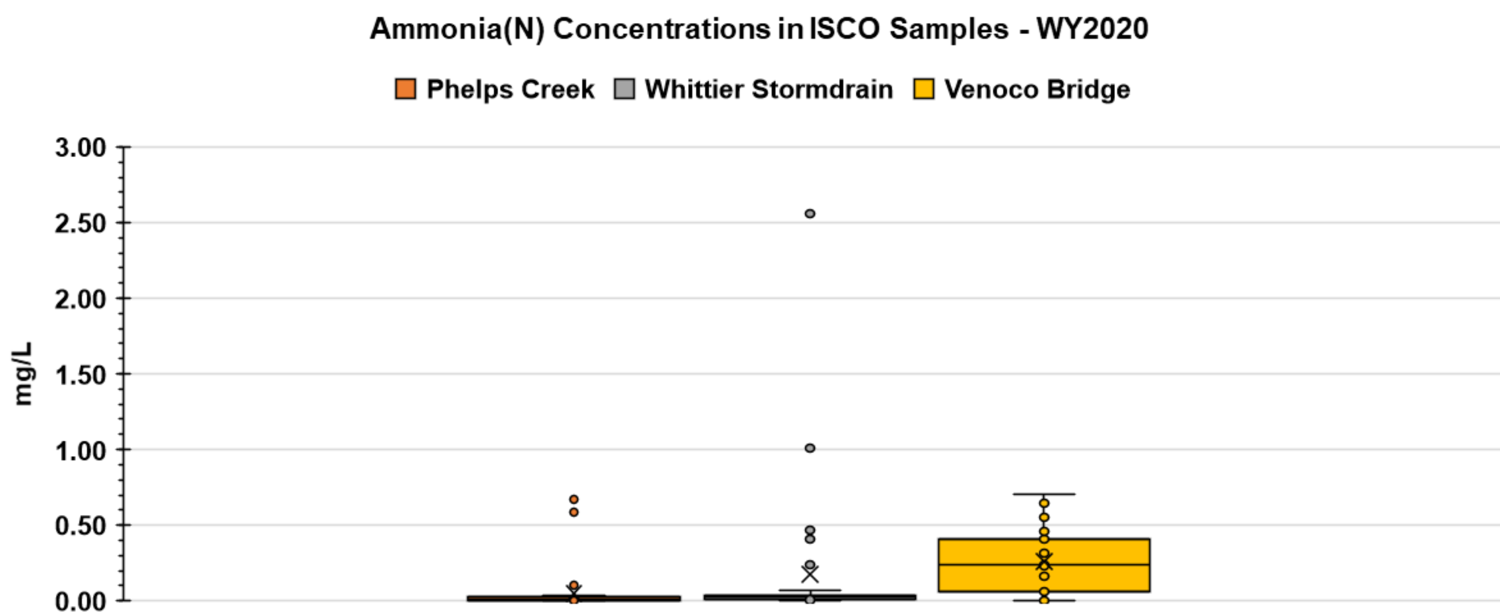


Ammonia(N) Concentration in Whittier Stormdrain Channel: 11/20/19 - 03/31/2020
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Nitrite+Nitrate Concentration (mg/L)


Devereux Slough Ammonia(N) Concentration at Veneco Bridge: 11/20/2019 - 03/31/2020
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precipitation (mm)
Ammonia(N) Concentration (mg/L)

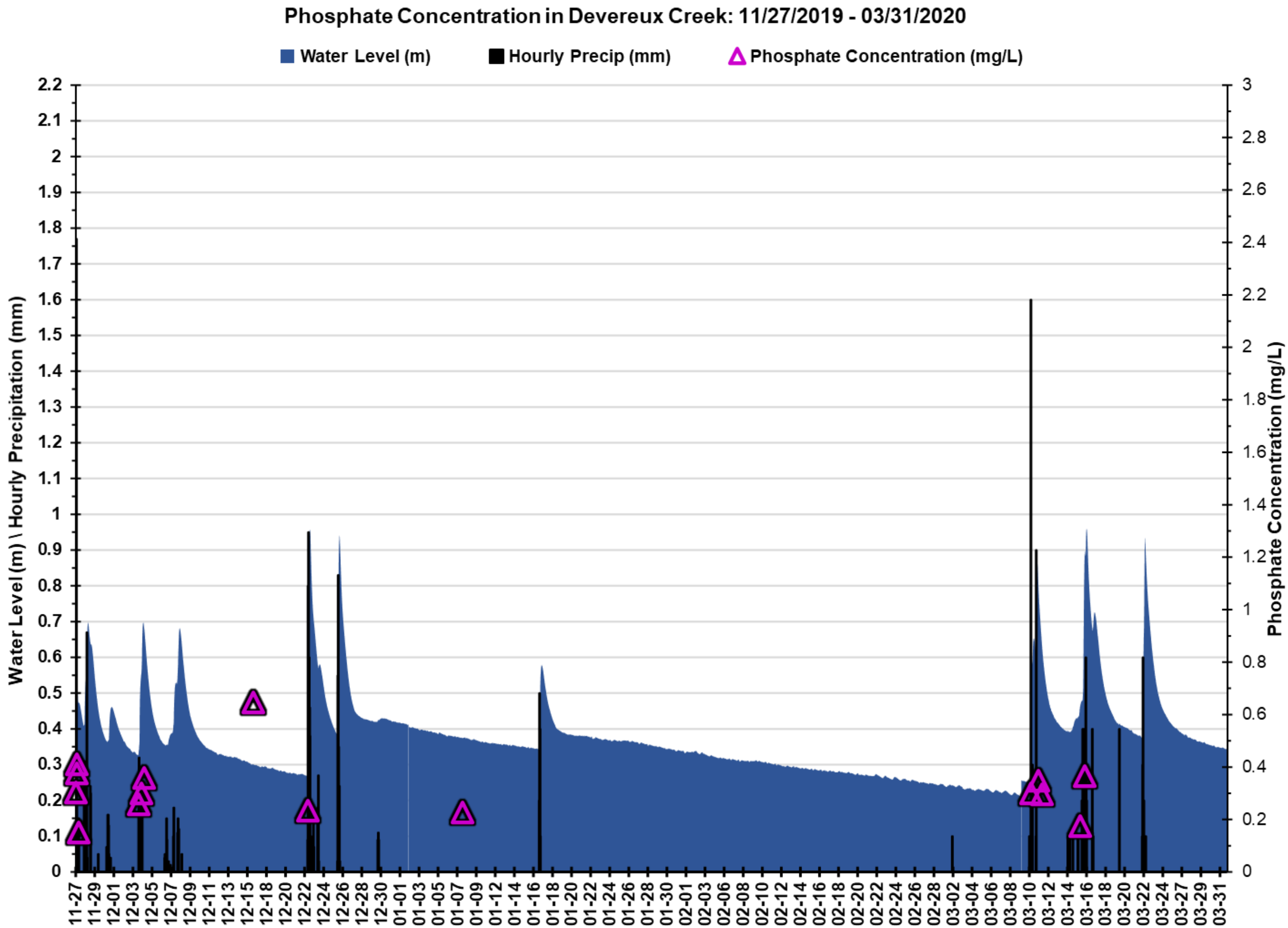


Ammonia(N) Concentrations in Grab Samples - WY2020
Devereux Creek
Phelps Creek
Whittier Stormdrain
Venoco Bridge
mg/L
3.00
2.50
2.00
1.50
1.00
0.50
0.00

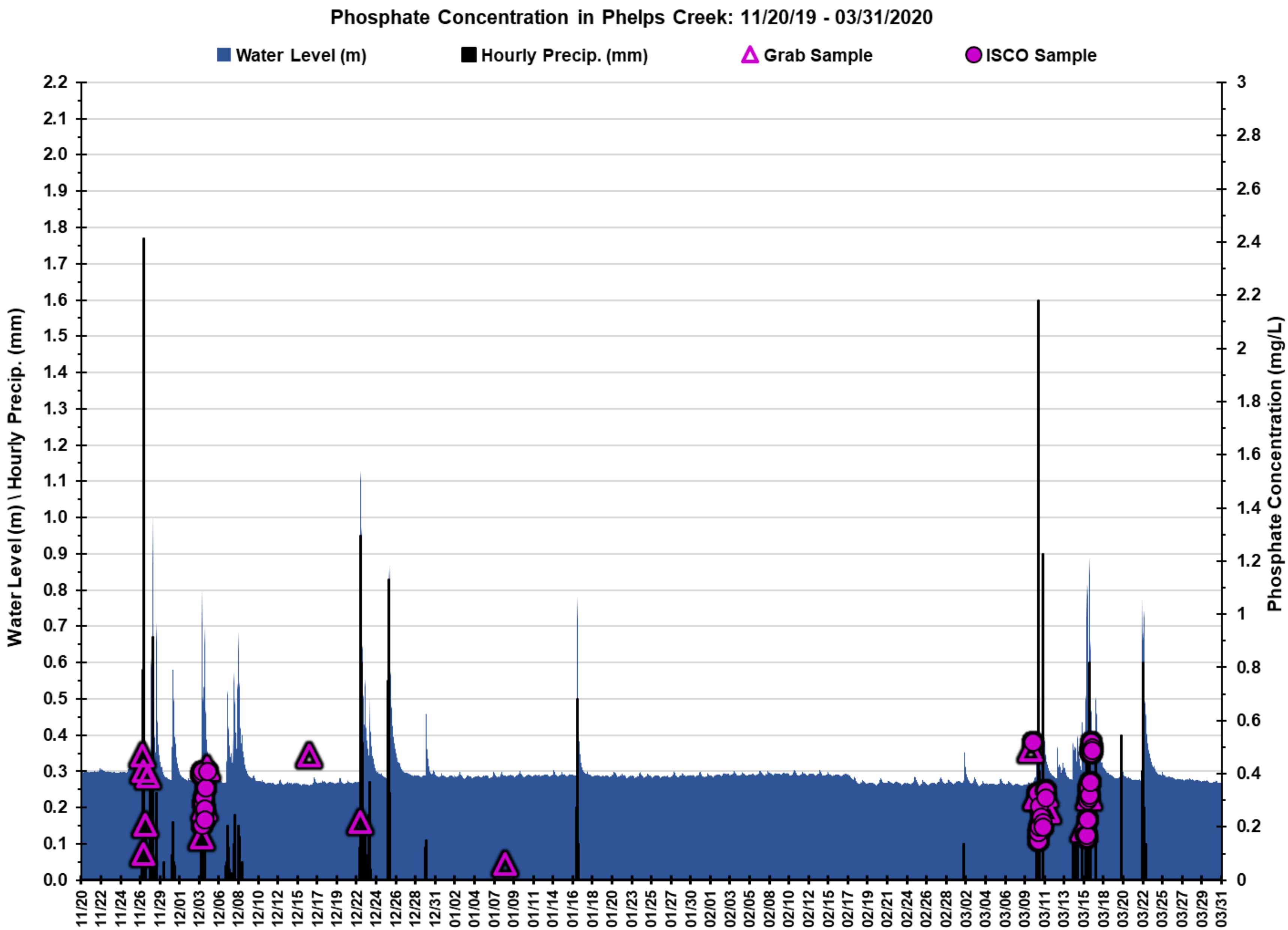


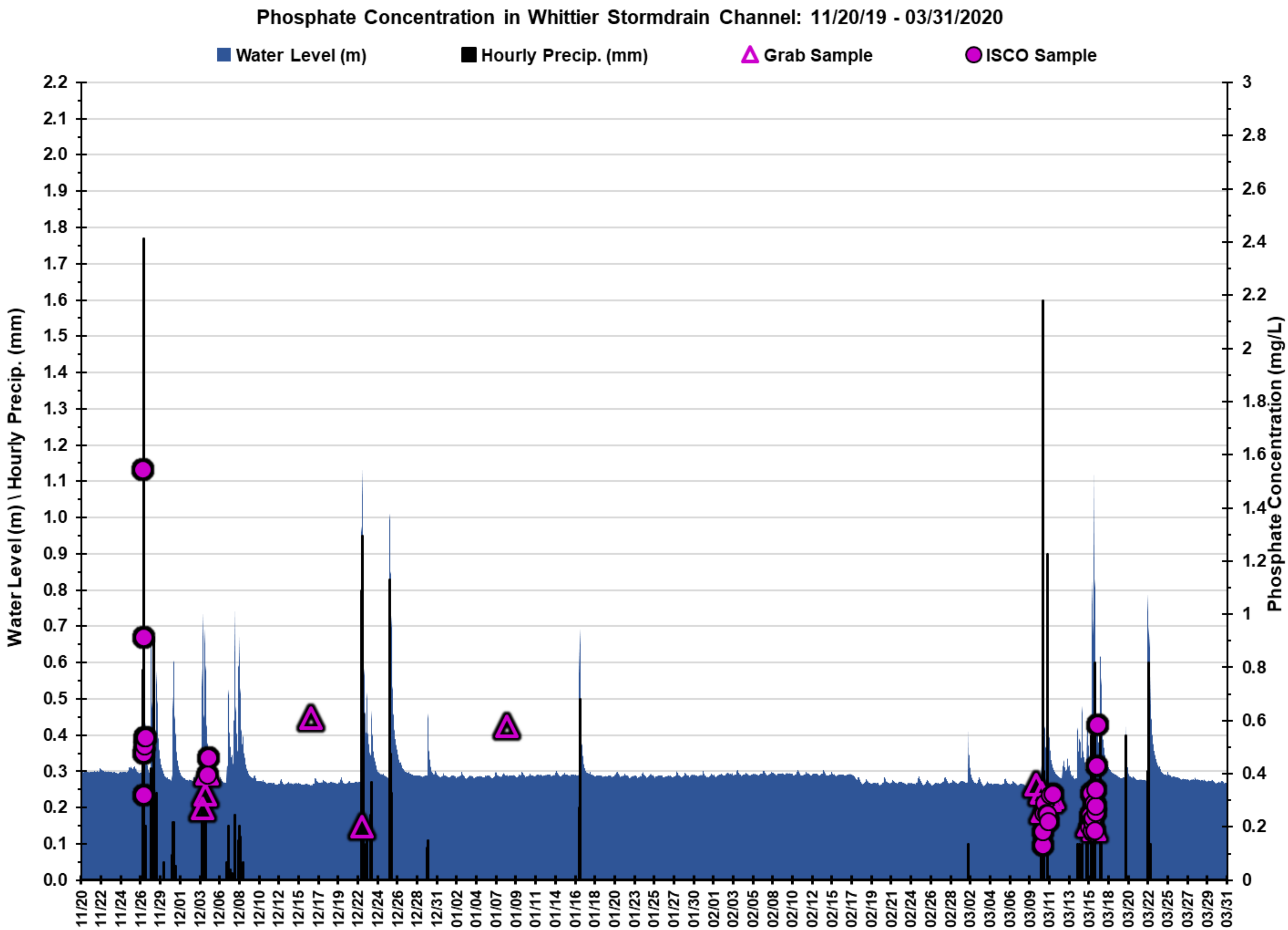
Ammonia(N) Concentrations in ISCO Samples - WY2020
Phelps Creek
Whittier Stormdrain
Venoco Bridge
mg/L
3.00
2.50
2.00
1.50
1.00
0.50
0.00

NUTRIENT CONCENTRATIONS DATA: Phosphate – Site Comparisons

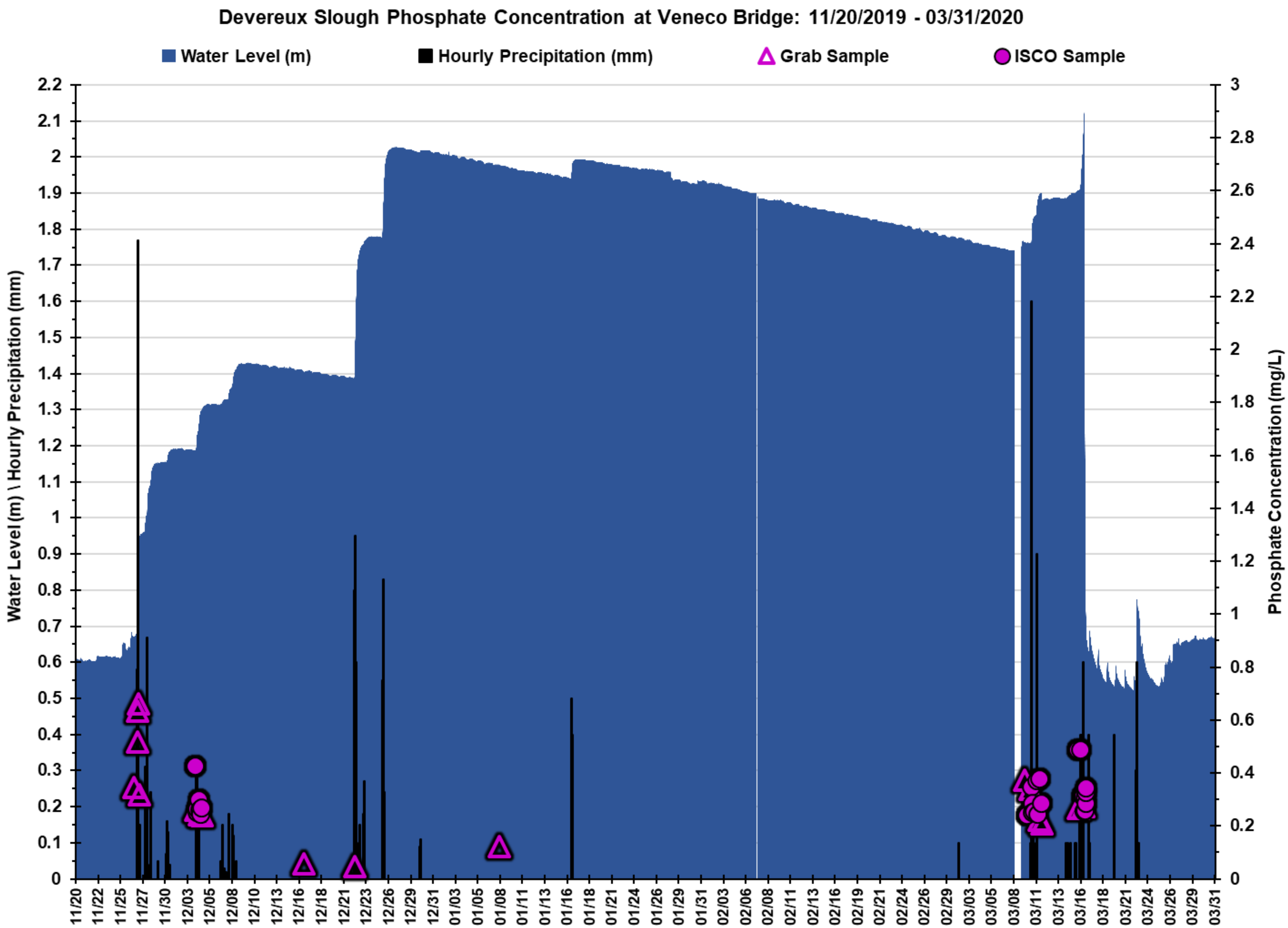


Phosphate Concentration in Devereux Creek: 11/27/2019 - 03/31/2020
Water Level (m)
Hourly Precip (mm)
Phosphate Concentration (mg/L)
Water Level (m) \ Hourly Precipitation (mm)
Phosphate Concentration (mg/L)

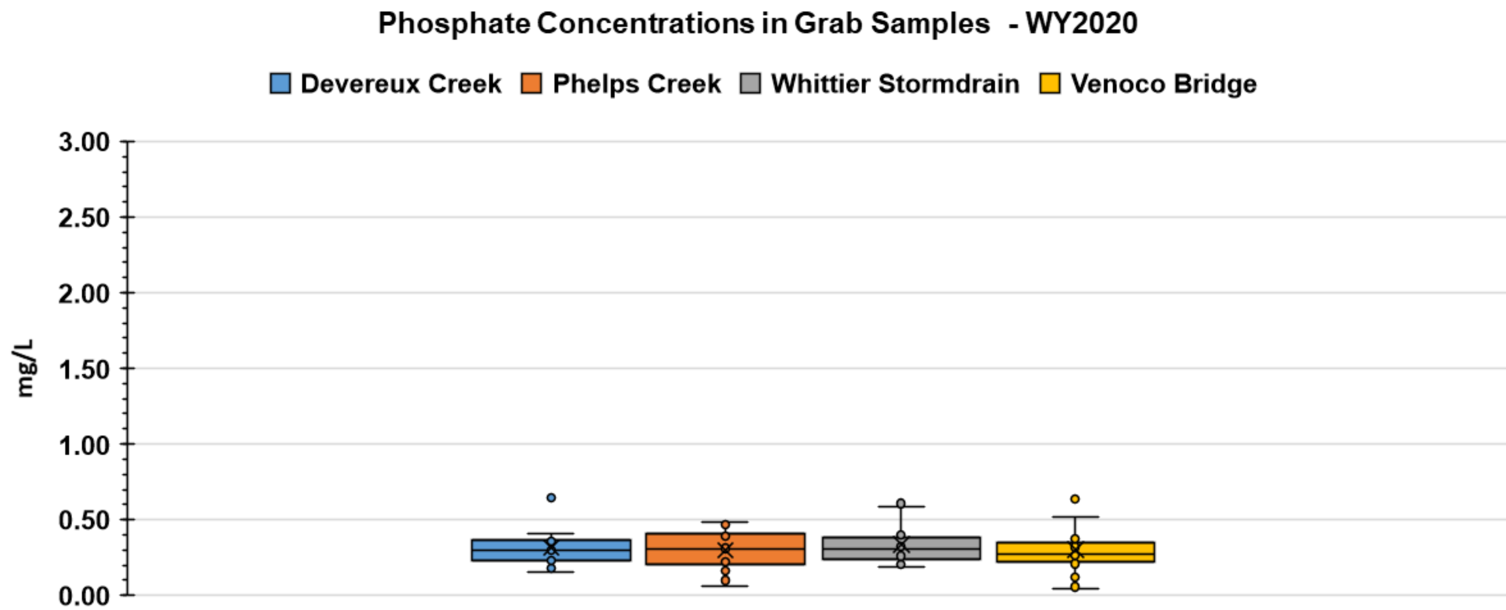

Phosphate Concentration in Phelps Creek: 11/20/19 - 03/31/2020
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Phosphate Concentration (mg/L)

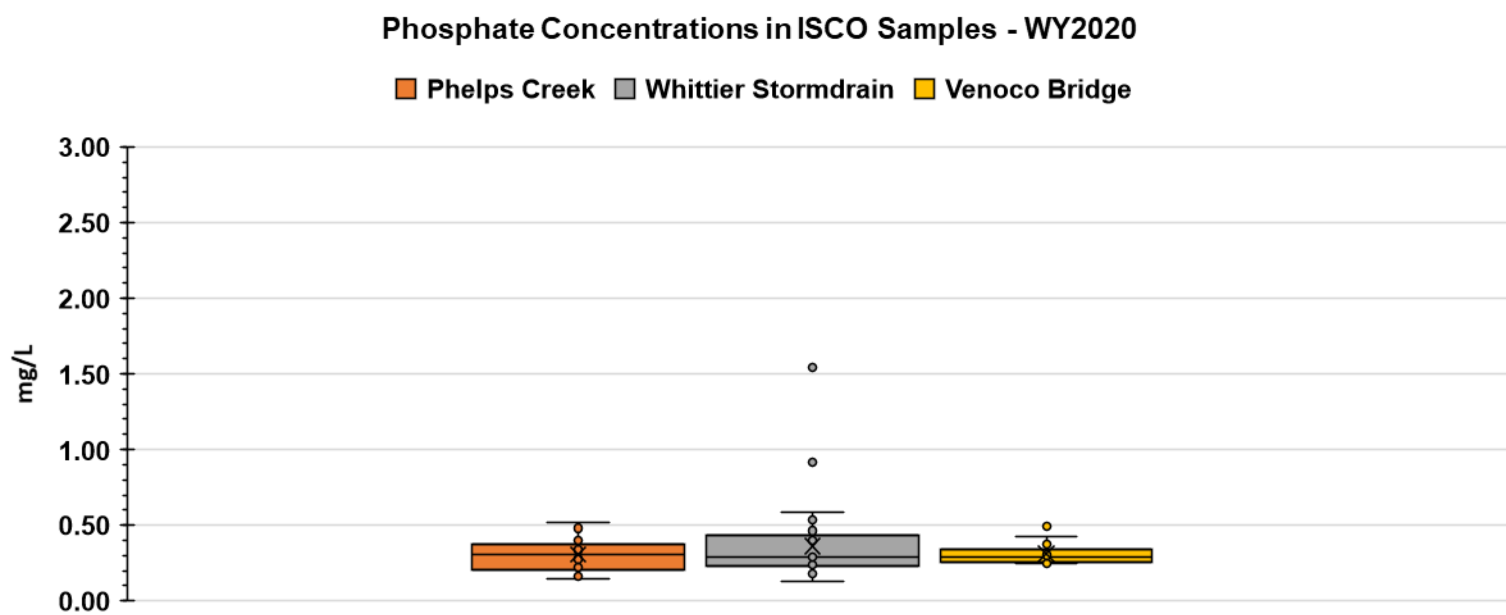


Phosphate Concentration in Whittier Stormdrain Channel: 11/20/19 - 03/31/2020
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Phosphate Concentration (mg/L)

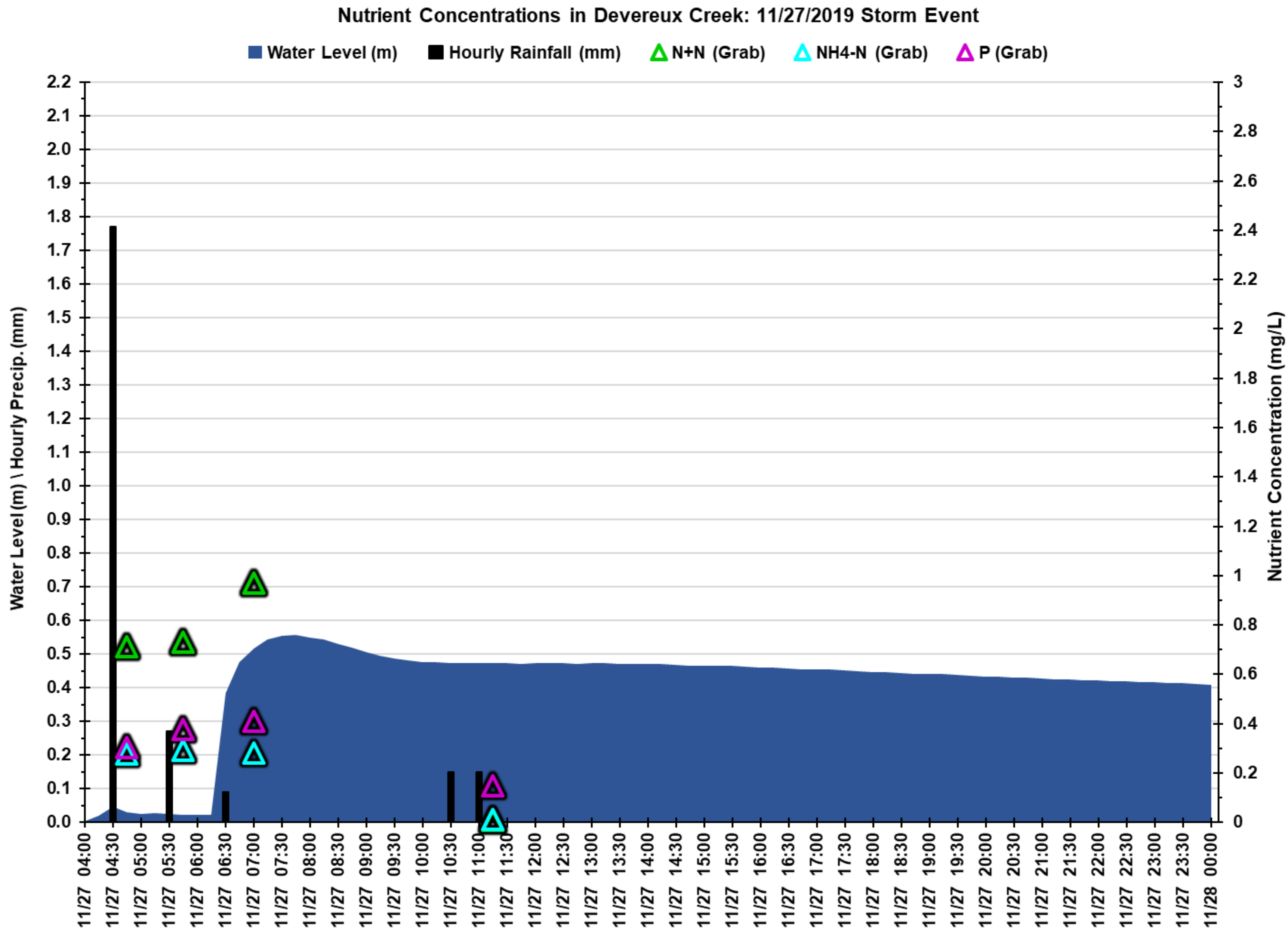


Devereux Slough Phosphate Concentration at Veneco Bridge: 11/20/2019 - 03/31/2020
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precipitation (mm)
Phosphate Concentration (mg/L)

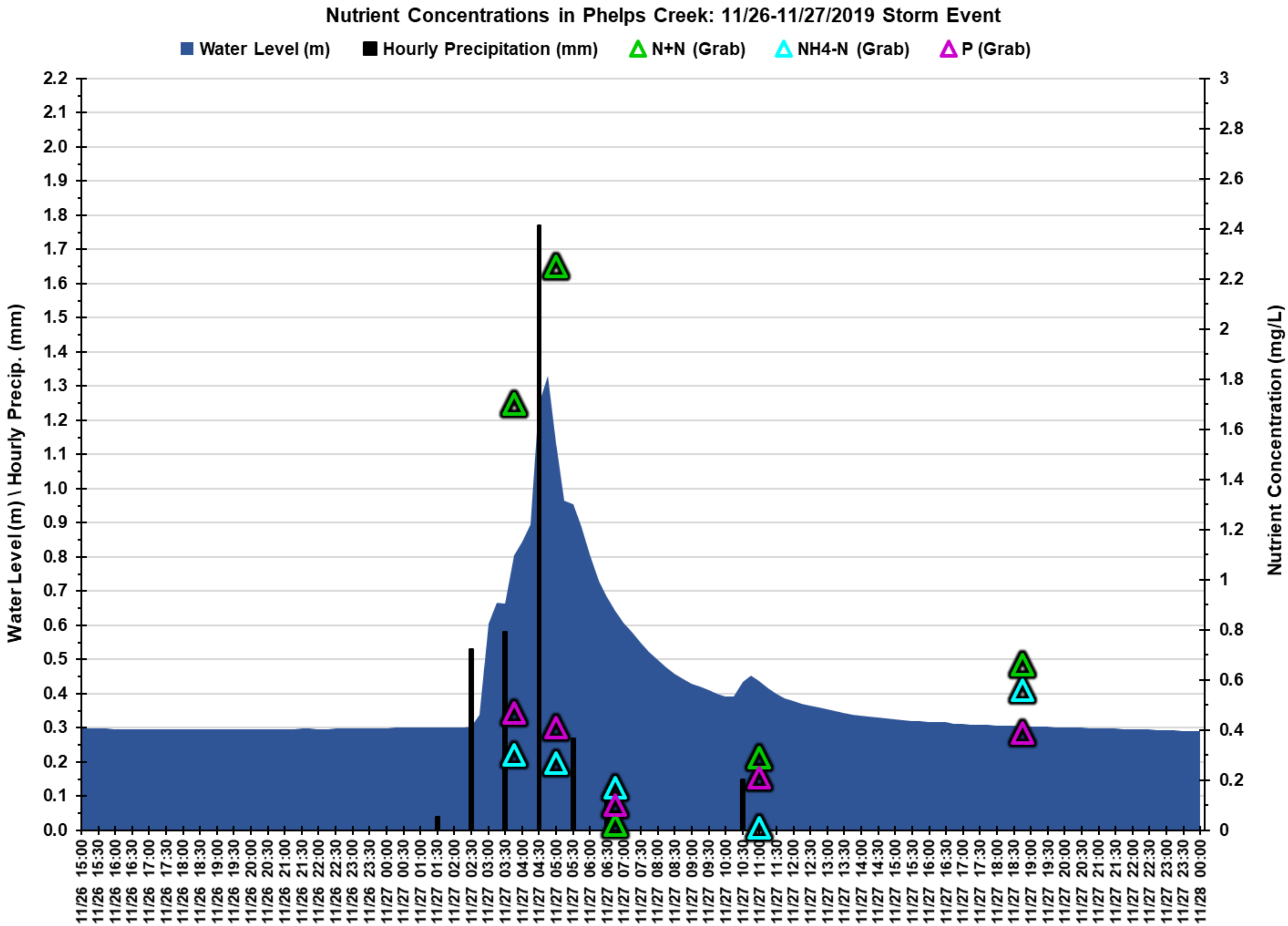

Phosphate Concentrations in Grab Samples - WY2020
Devereux Creek
Phelps Creek
Whittier Stormdrain
Venoco Bridge
mg/L
3.00
2.50
2.00
1.50
1.00
0.50
0.00


Phosphate Concentrations in ISCO Samples - WY2020
Phelps Creek
Whittier Stormdrain
Venoco Bridge
mg/L
3.00
2.50
2.00
1.50
1.00
0.50
0.00

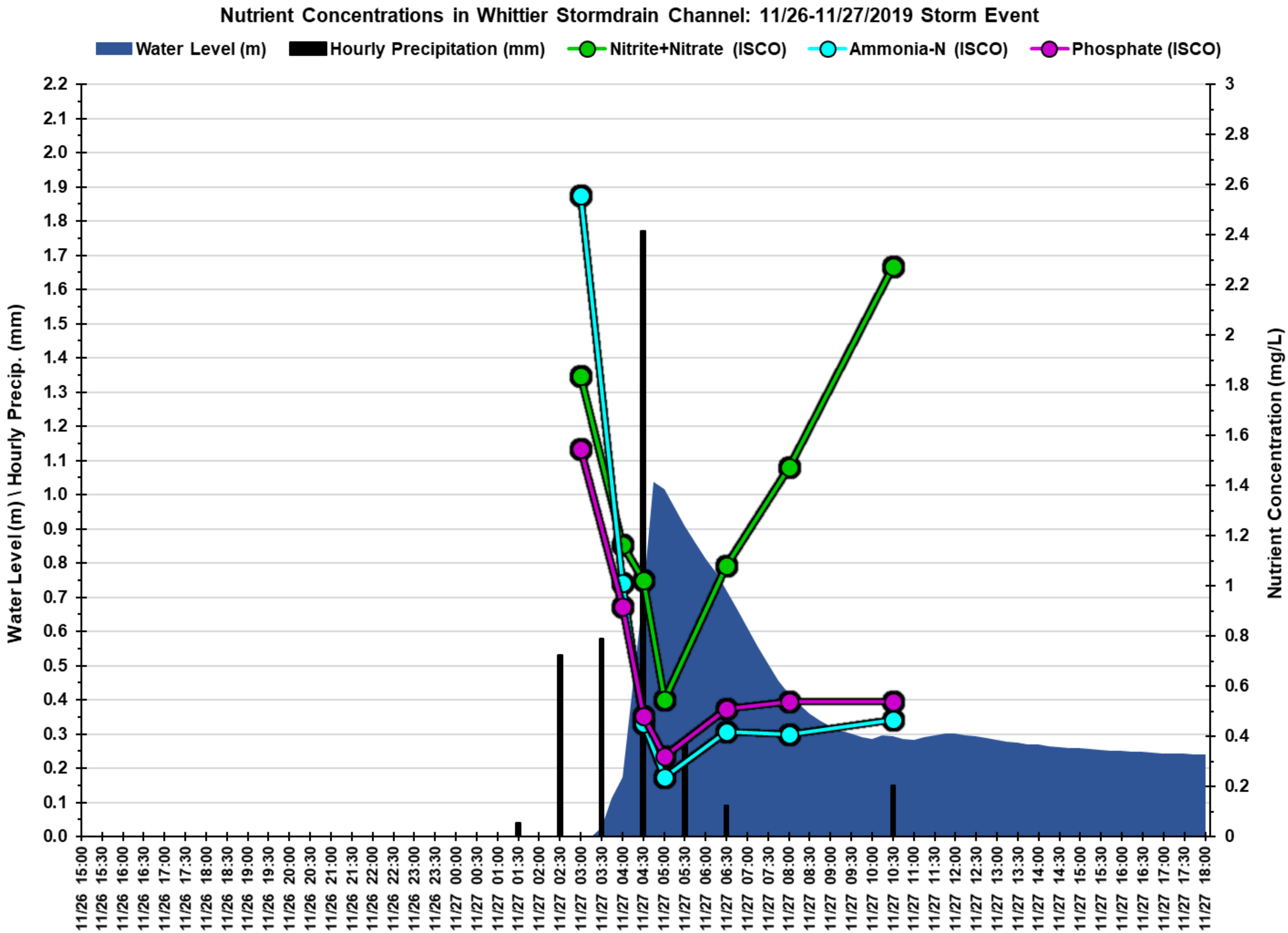
NUTRIENT CONCENTRATIONS DATA: Storm Charts for each Site



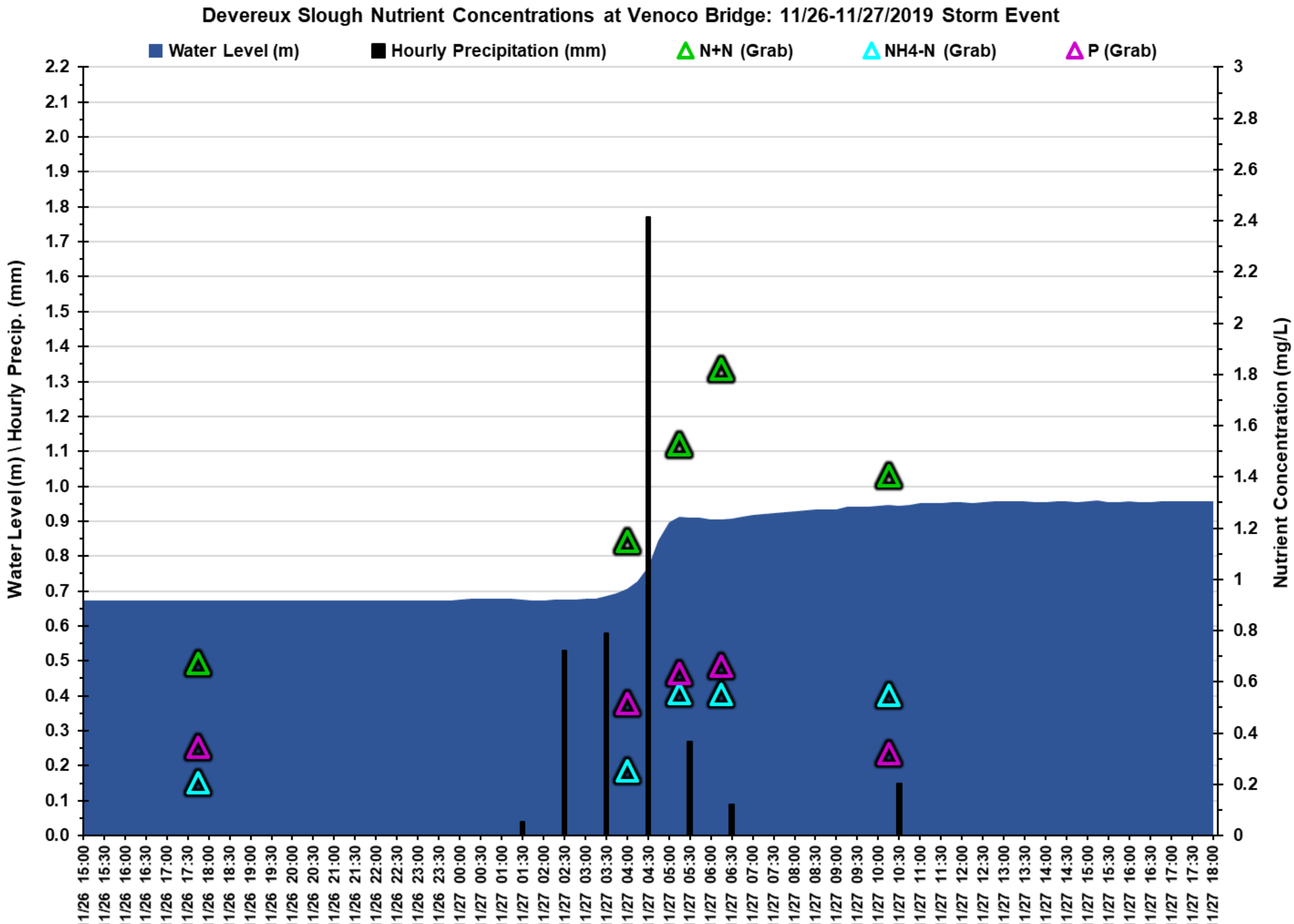
Nutrient Concentrations in Devereux Creek: 11/27/2019 Storm Event
Water Level (m)
Hourly Rainfall (mm)
N+N (Grab)
NH4-N (Grab)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)



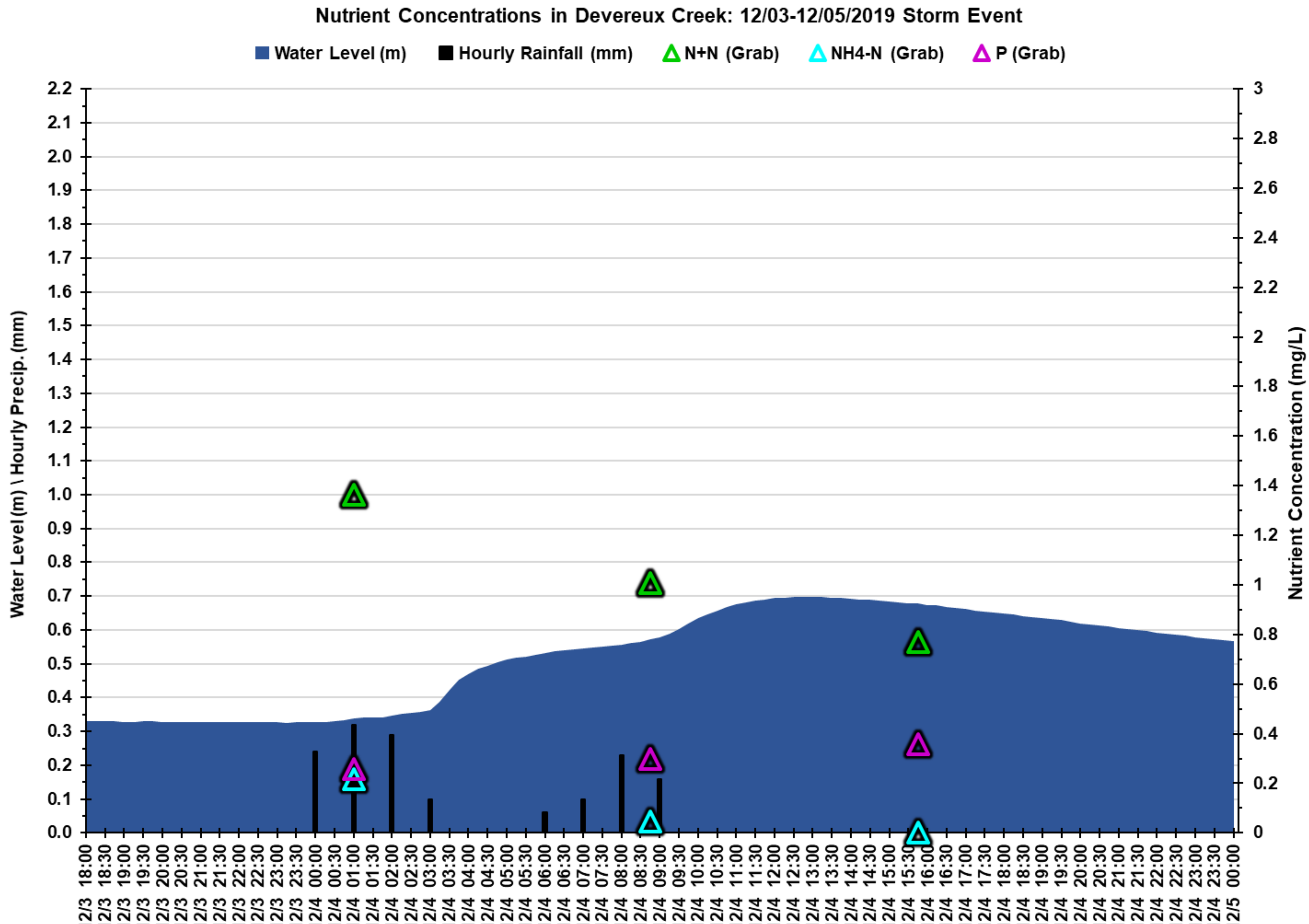
Nutrient Concentrations in Phelps Creek: 11/26-11/27/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (Grab)
NH4-N (Grab)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)



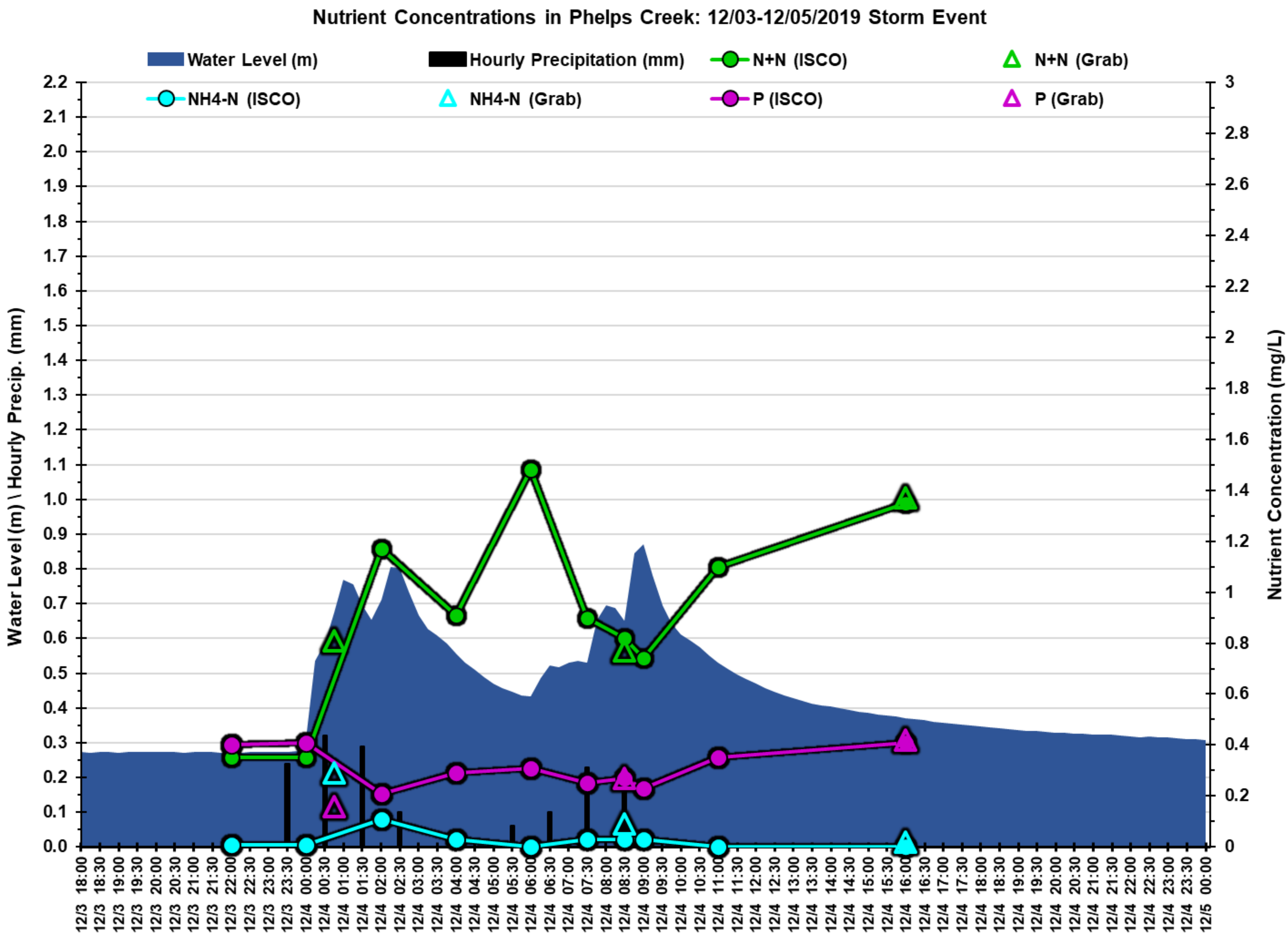
Nutrient Concentrations in Whittier Stormdrain Channel: 11/26-11/27/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Nitrite+Nitrate (ISCO)
Ammonia-N (ISCO)
Phosphate (ISCO)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

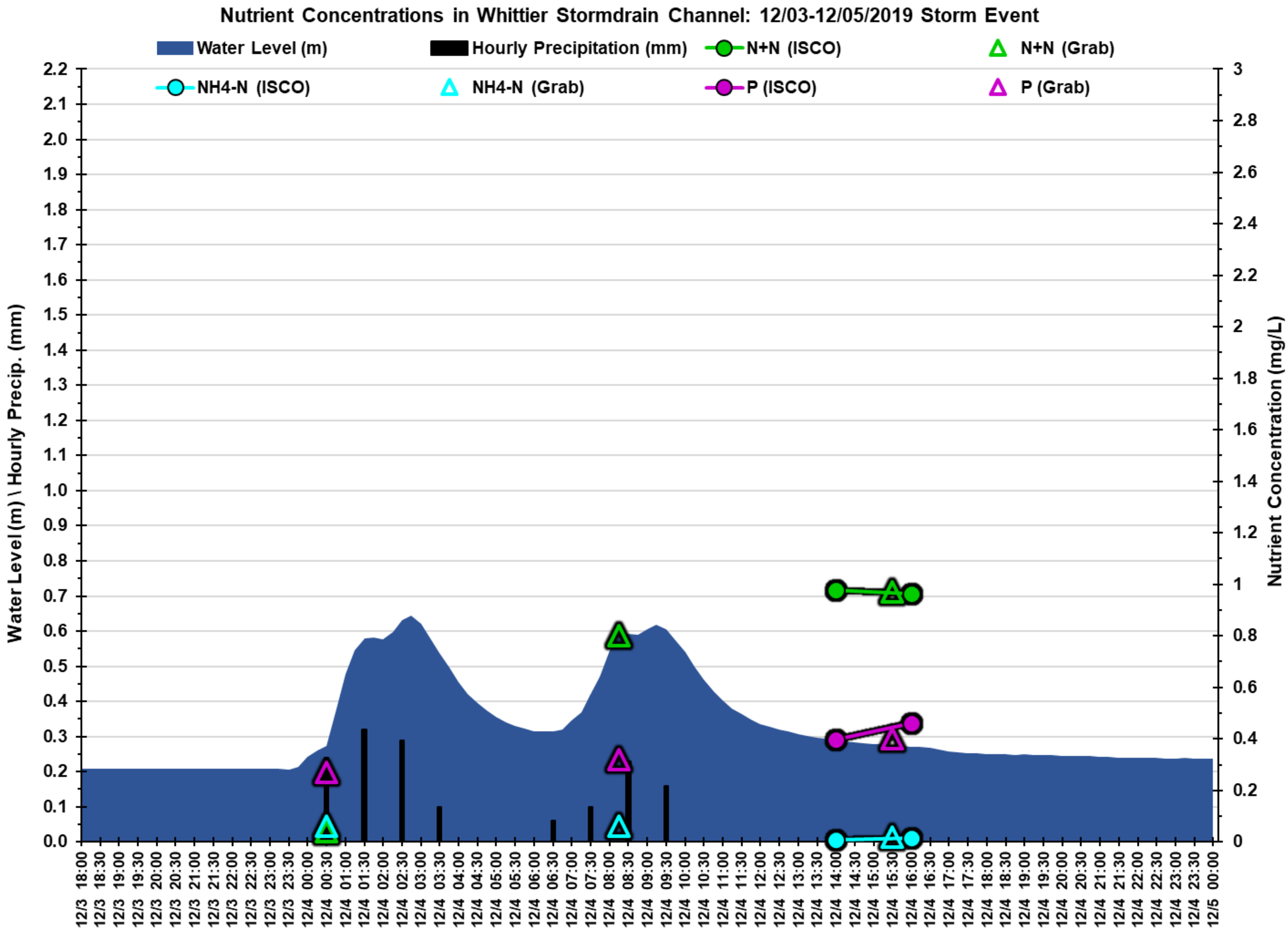


Devereux Slough Nutrient Concentrations at Venoco Bridge: 11/26-11/27/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (Grab)
NH4-N (Grab)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

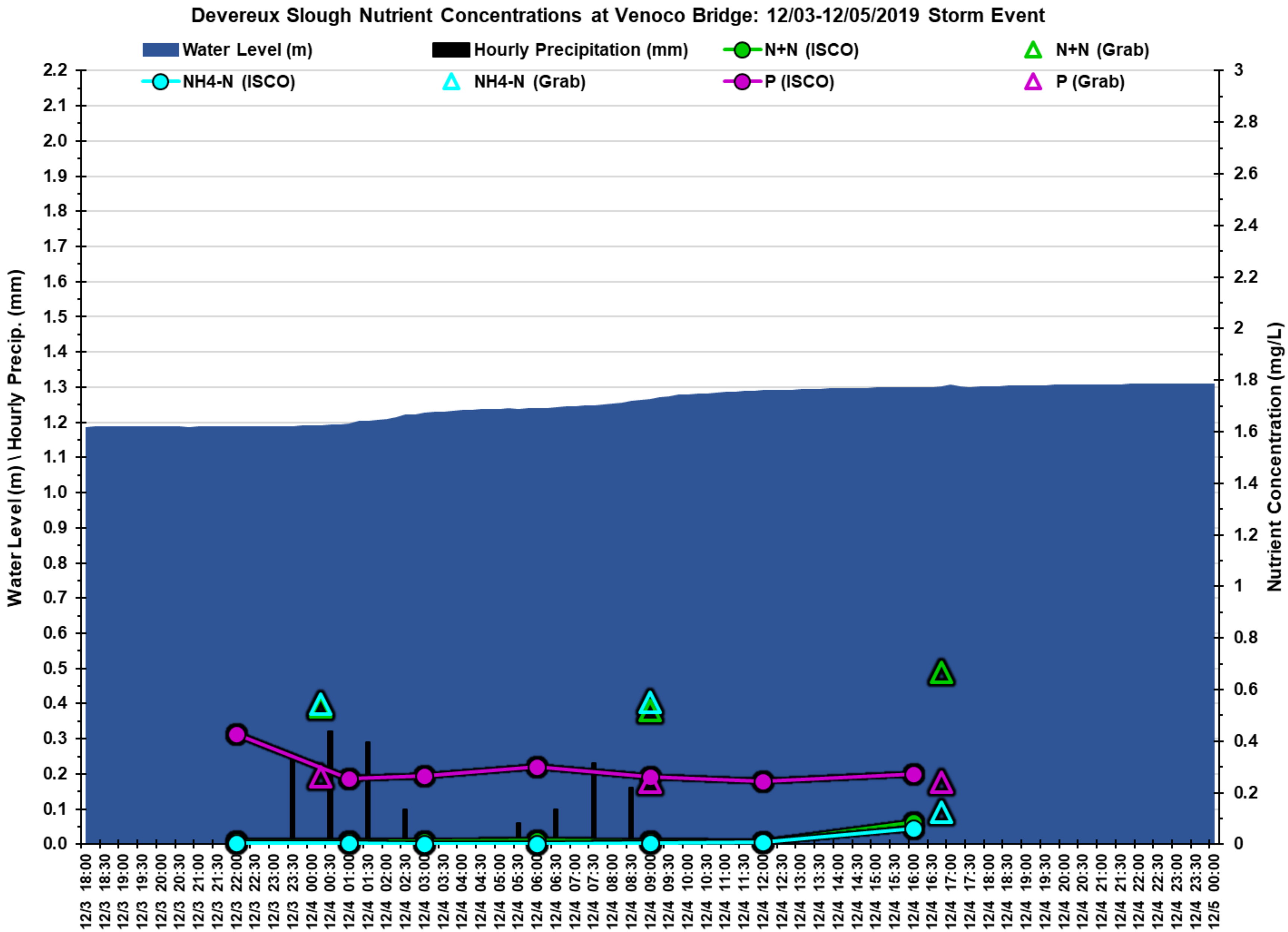


Nutrient Concentrations in Devereux Creek: 12/03-12/05/2019 Storm Event
Water Level (m)
Hourly Rainfall (mm)
N+N (Grab)
NH4-N (Grab)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

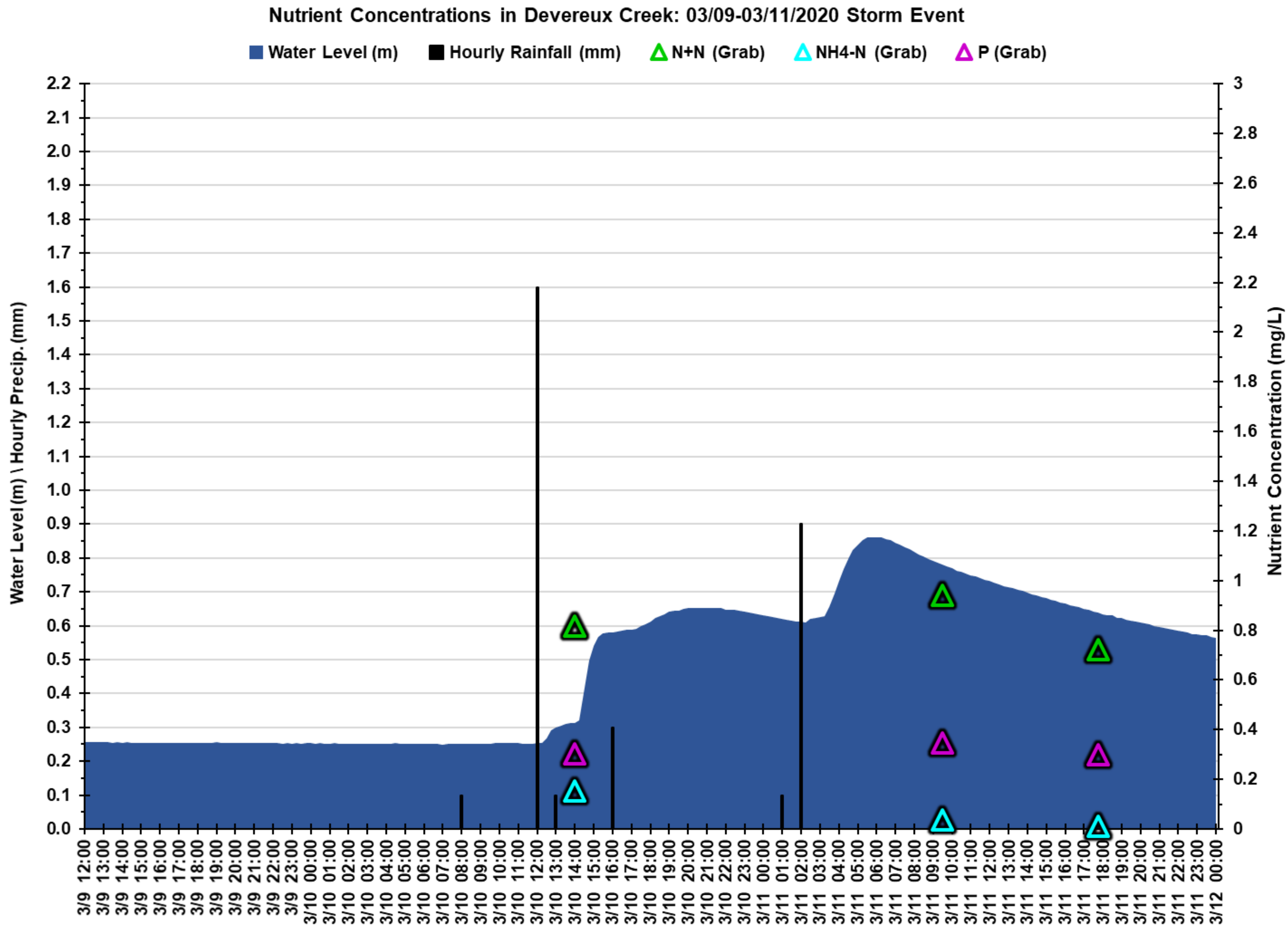

Nutrient Concentrations in Phelps Creek: 12/03-12/05/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

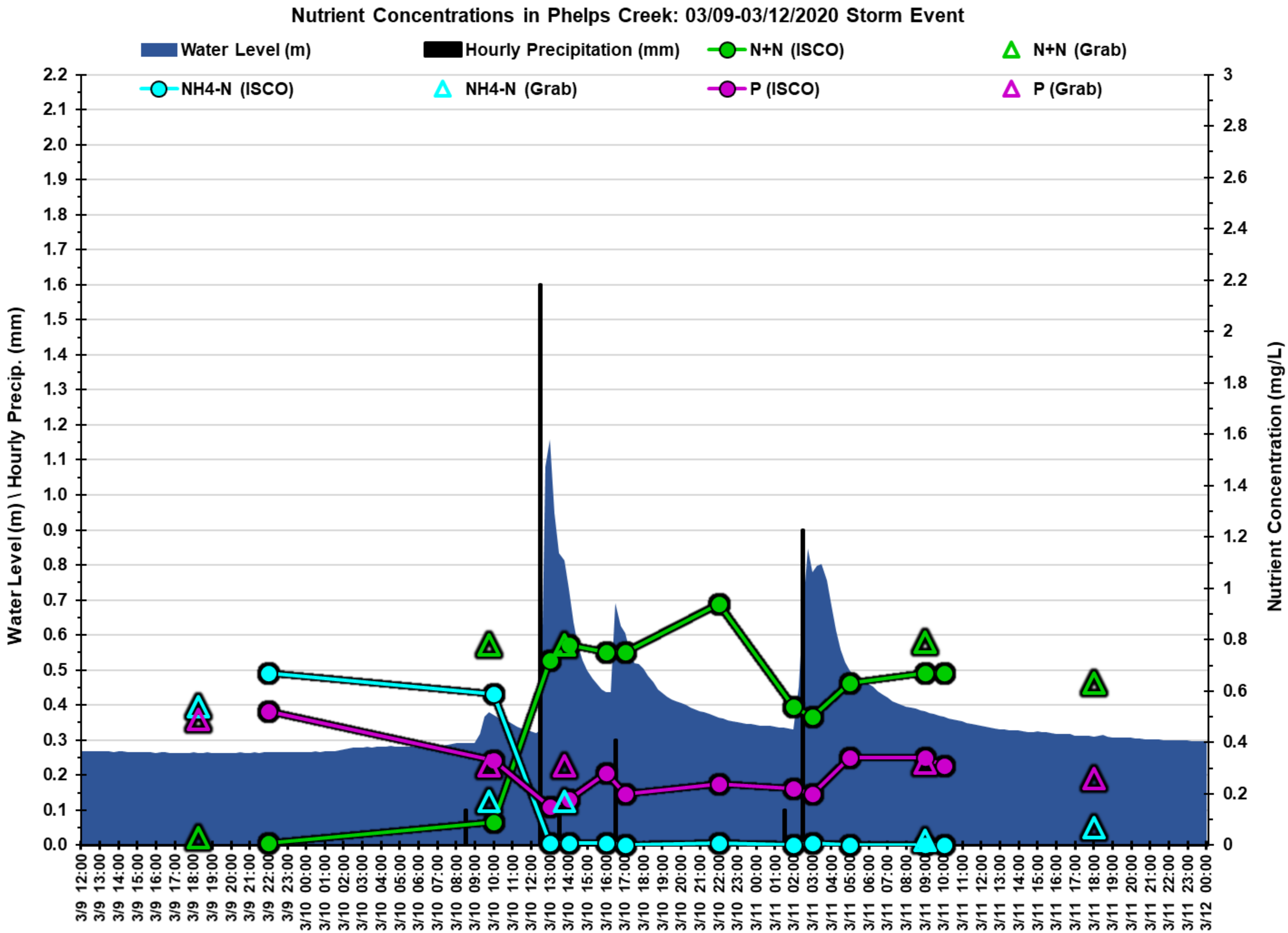


Nutrient Concentrations in Whittier Stormdrain Channel: 12/03-12/05/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

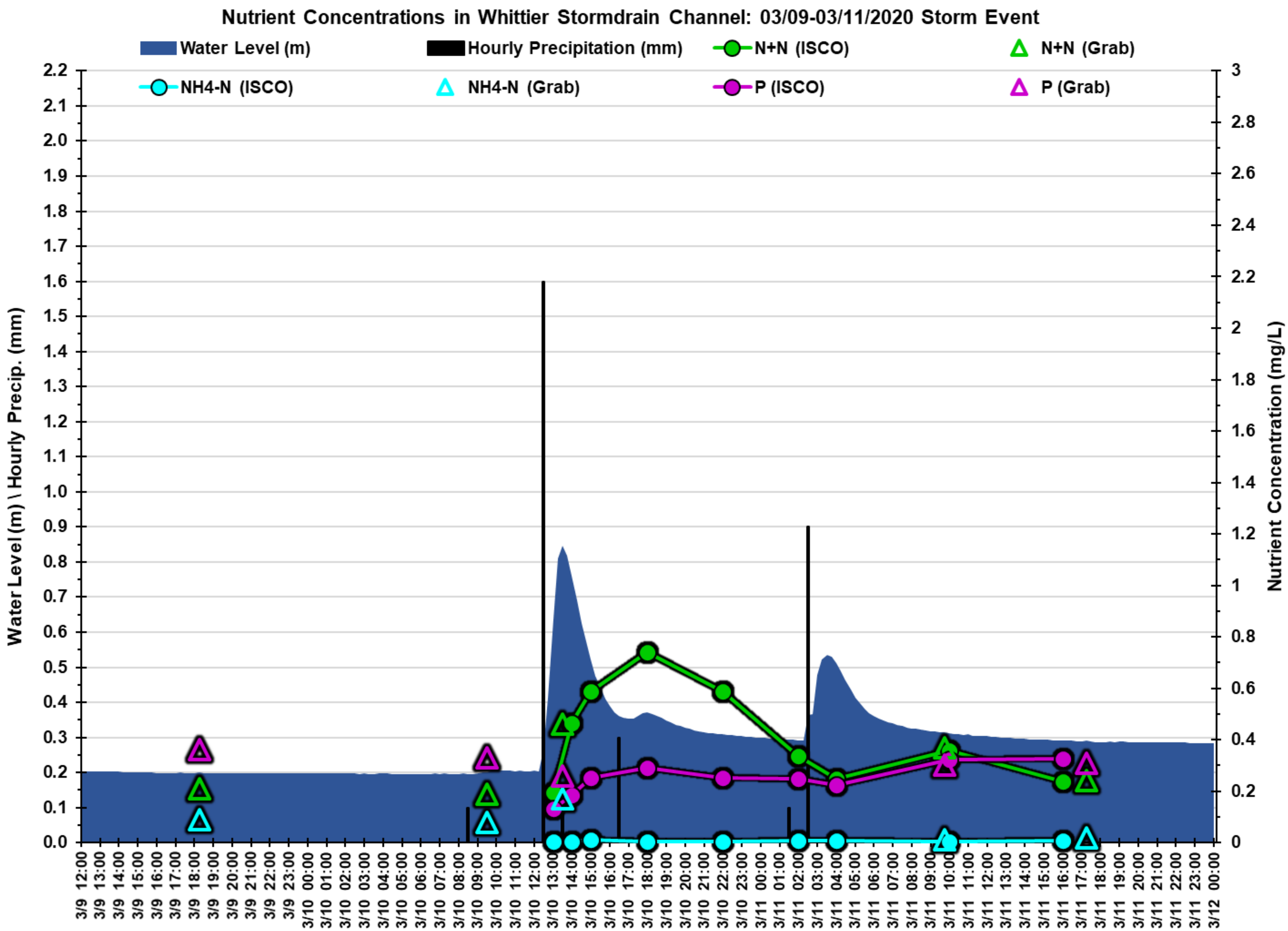


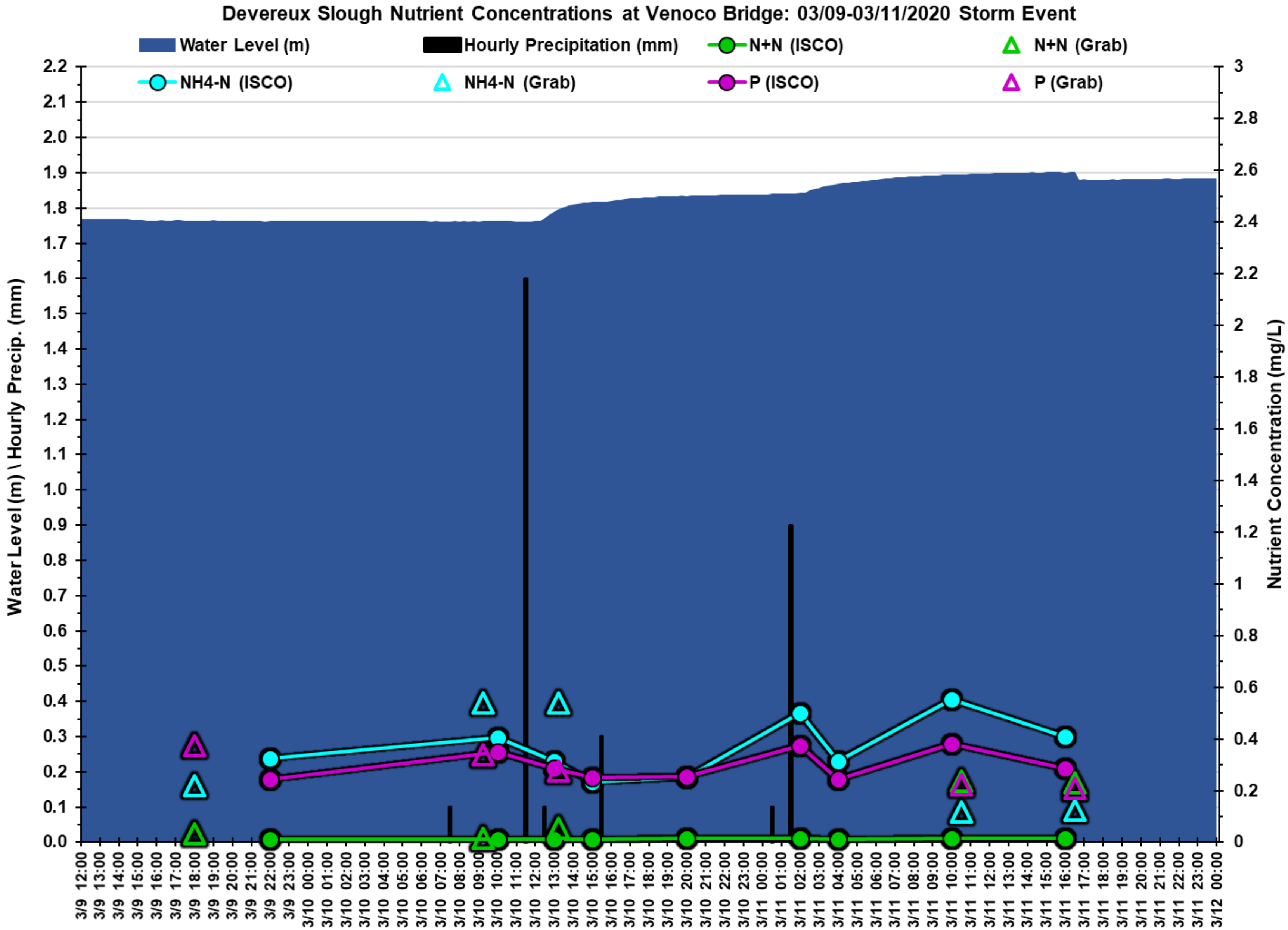
Devereux Slough Nutrient Concentrations at Venoco Bridge: 12/03-12/05/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)


Nutrient Concentrations in Devereux Creek: 03/09-03/11/2020 Storm Event
Water Level (m)
Hourly Rainfall (mm)
N+N (Grab)
NH4-N (Grab)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

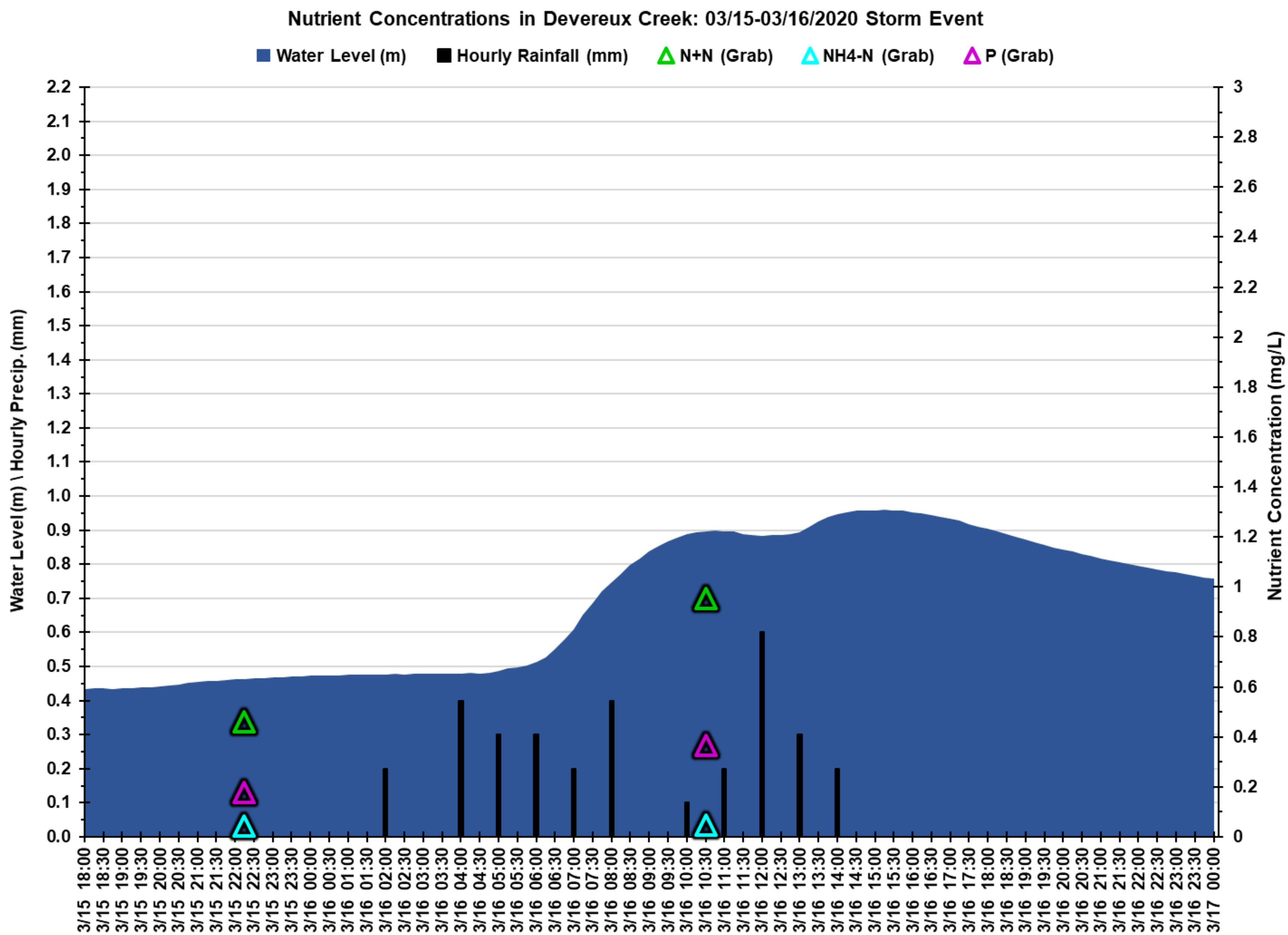


Nutrient Concentrations in Phelps Creek: 03/09-03/12/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

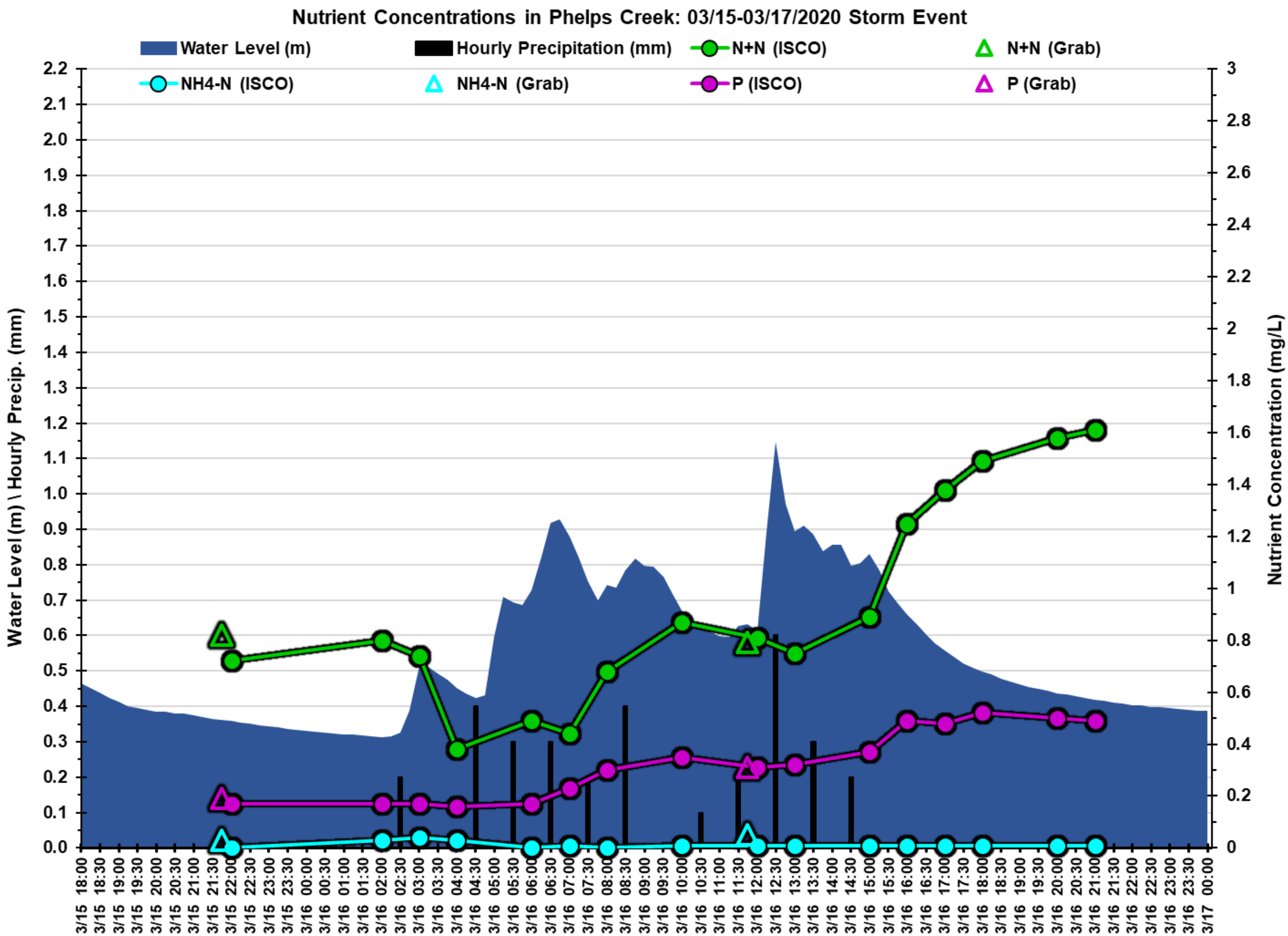

Nutrient Concentrations in Whittier Stormdrain Channel: 03/09-03/11/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

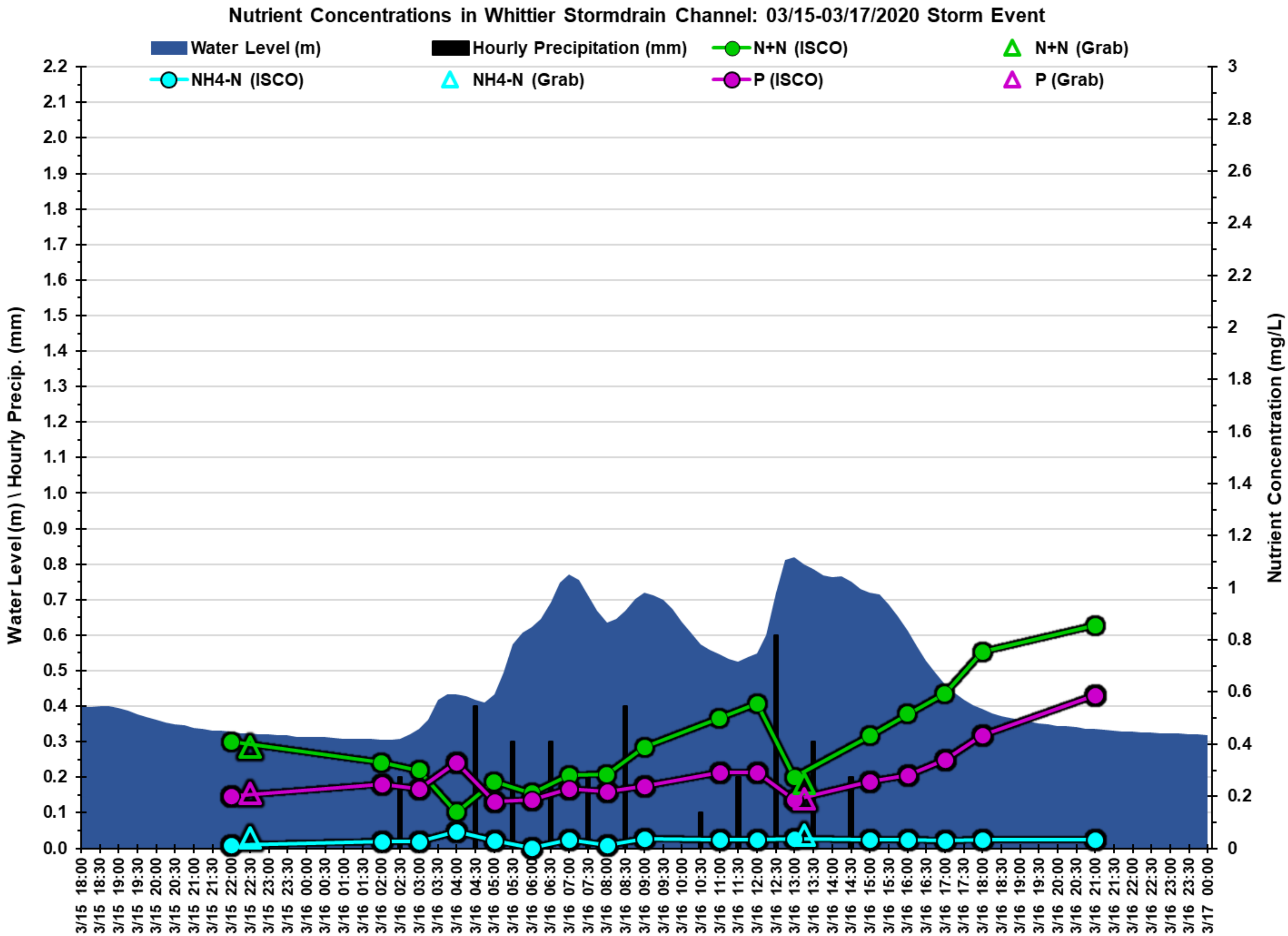


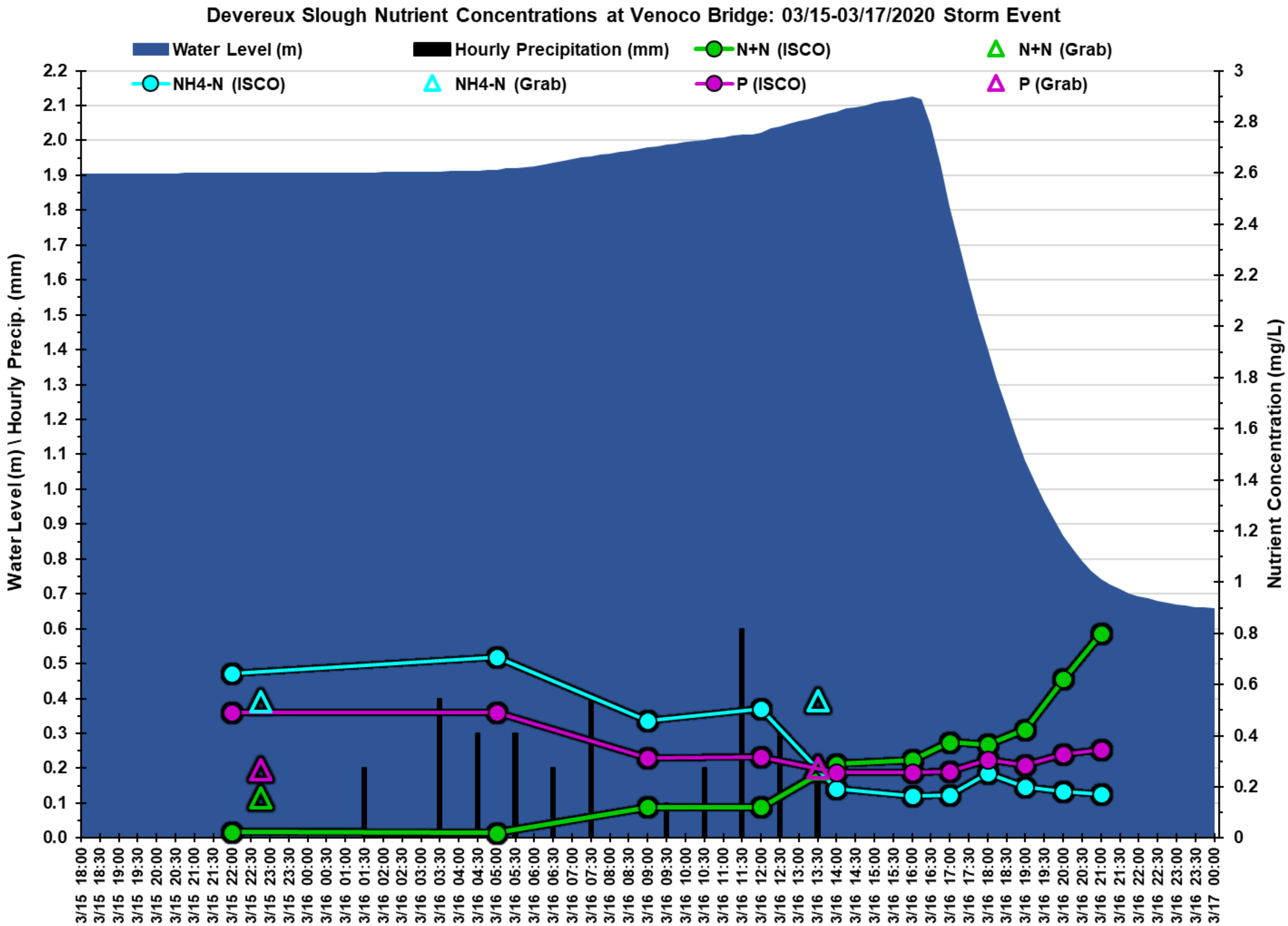
Devereux Slough Nutrient Concentrations at Venoco Bridge: 03/09-03/11/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)



Nutrient Concentrations in Devereux Creek: 03/15-03/16/2020 Storm Event
Water Level (m)
Hourly Rainfall (mm)
N+N (Grab)
NH4-N (Grab)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

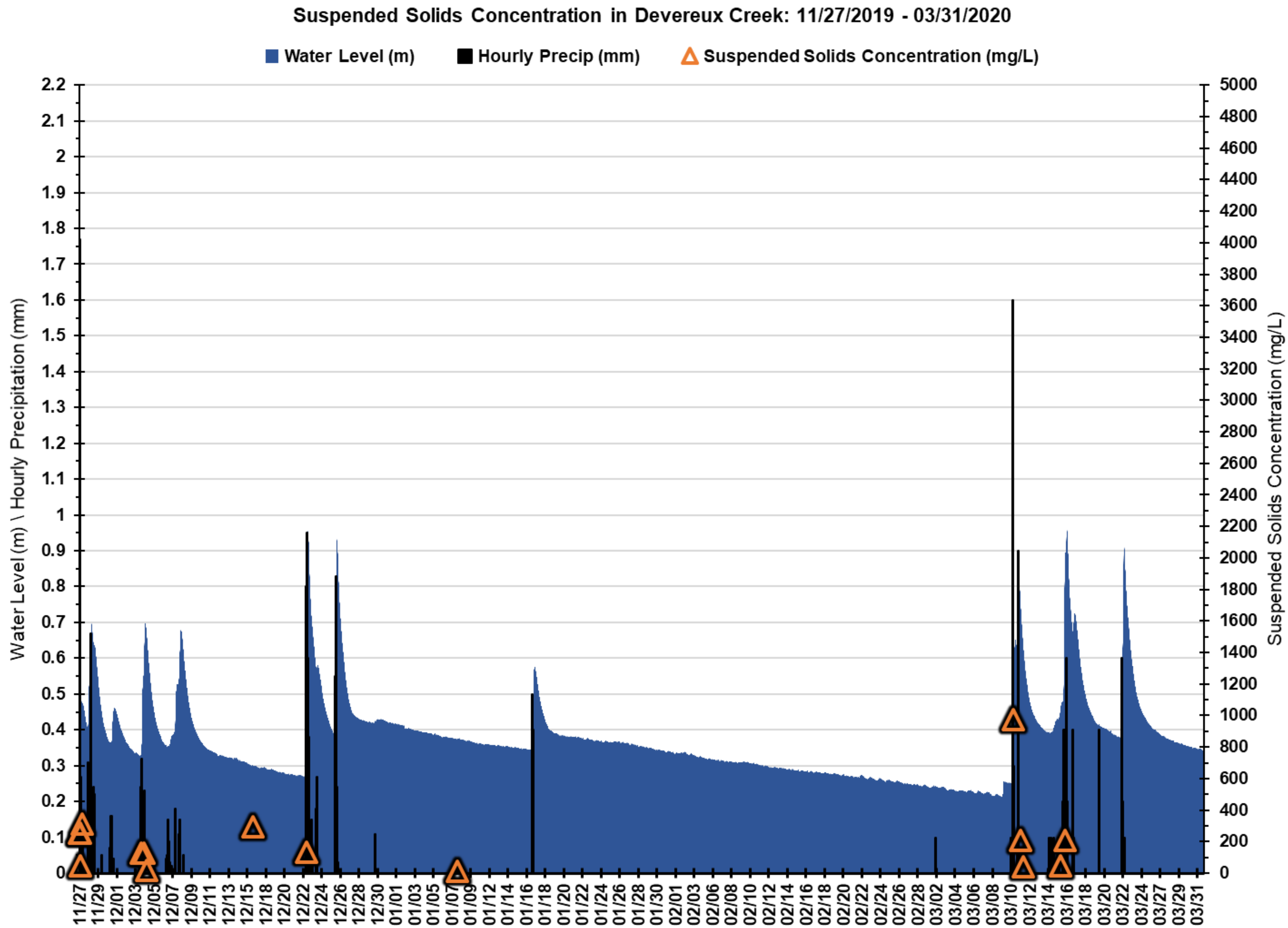

Nutrient Concentrations in Phelps Creek: 03/15-03/17/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)


Nutrient Concentrations in Whittier Stormdrain Channel: 03/15-03/17/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

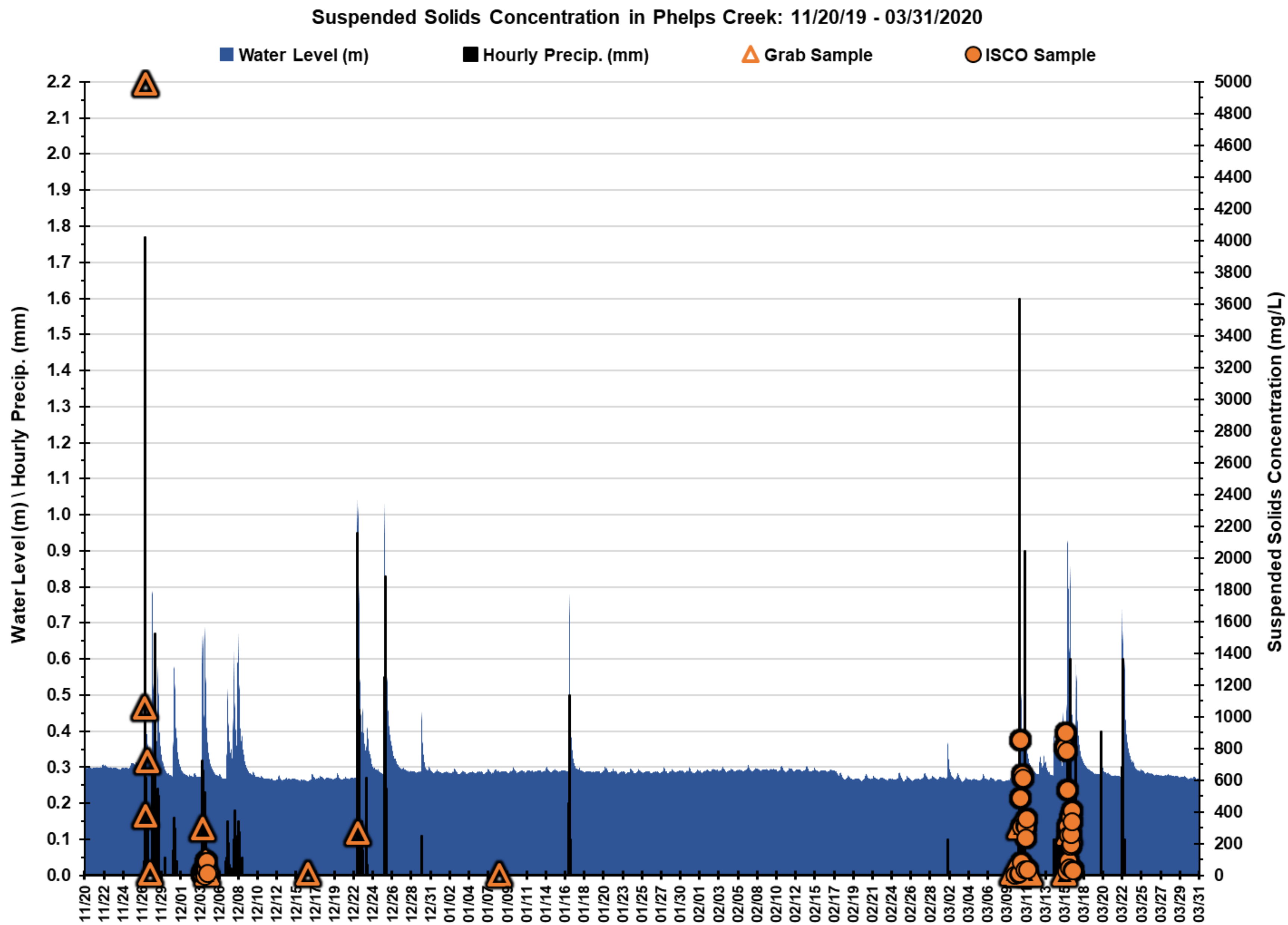


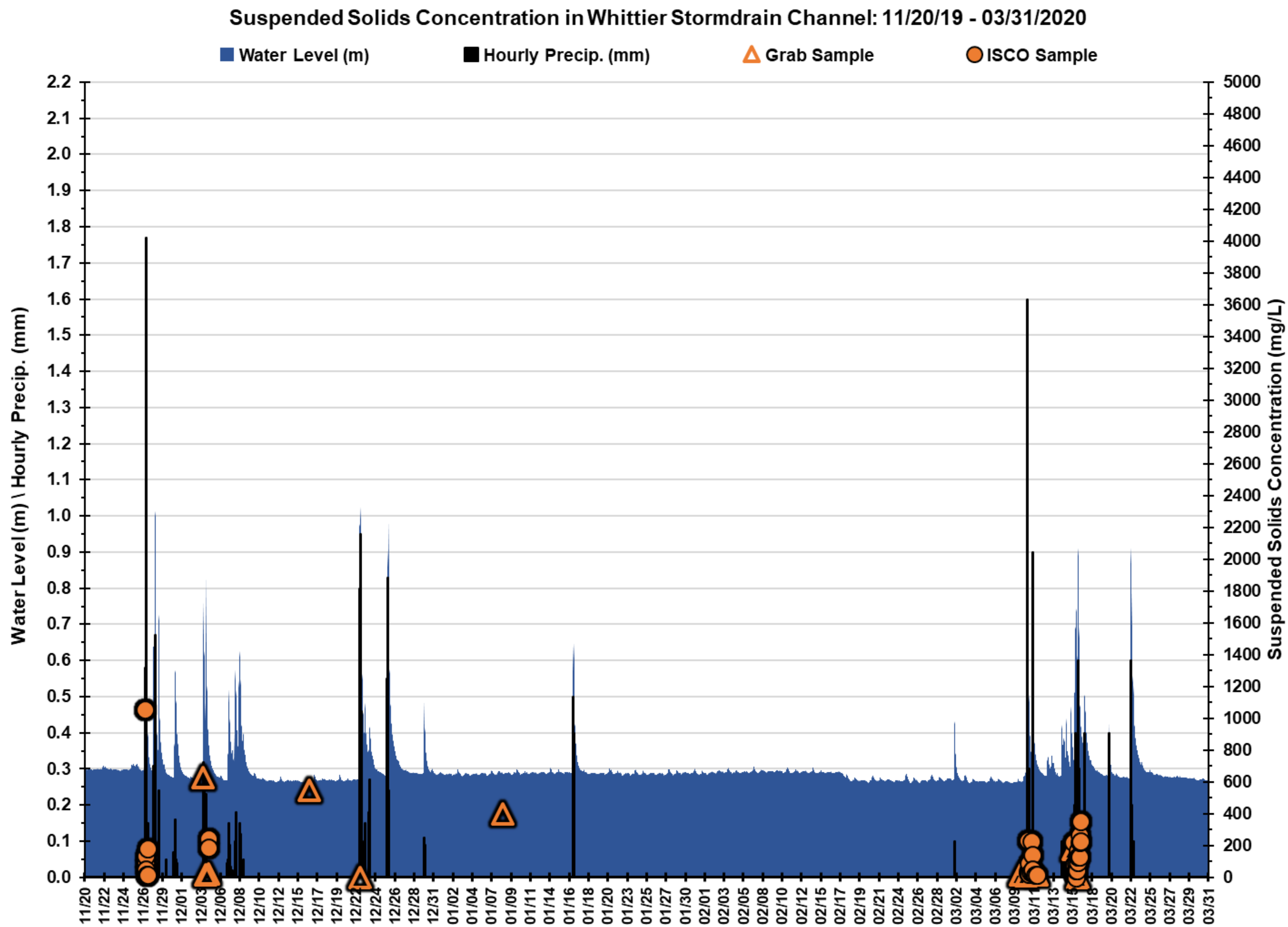
Devereux Slough Nutrient Concentrations at Venoco Bridge: 03/15-03/17/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
N+N (ISCO)
N+N (Grab)
NH4-N (ISCO)
NH4-N (Grab)
P (ISCO)
P (Grab)
Water Level (m) \ Hourly Precip. (mm)
Nutrient Concentration (mg/L)

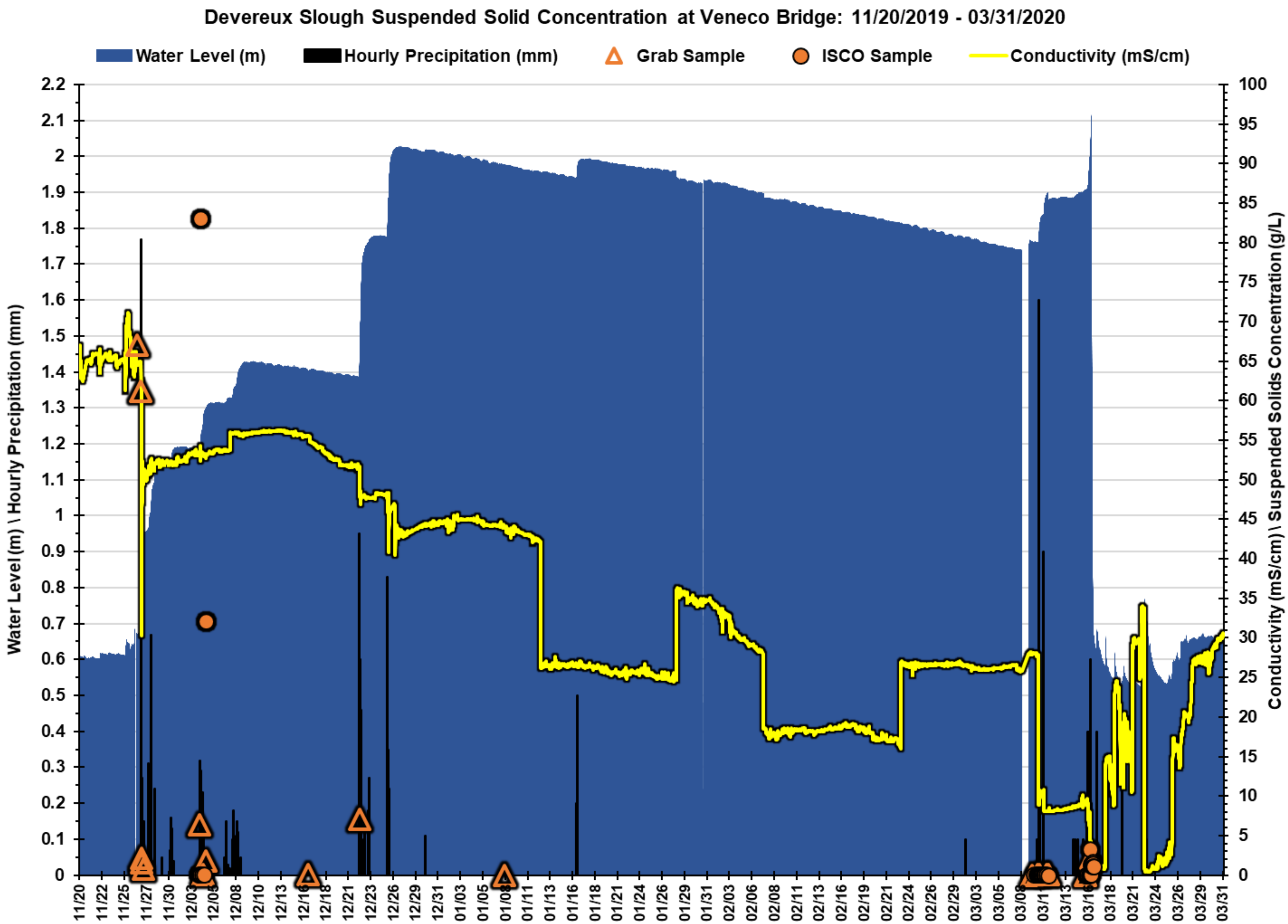
SUSPENDED SOLIDS CONCENTRATION DATA: Site Comparisons



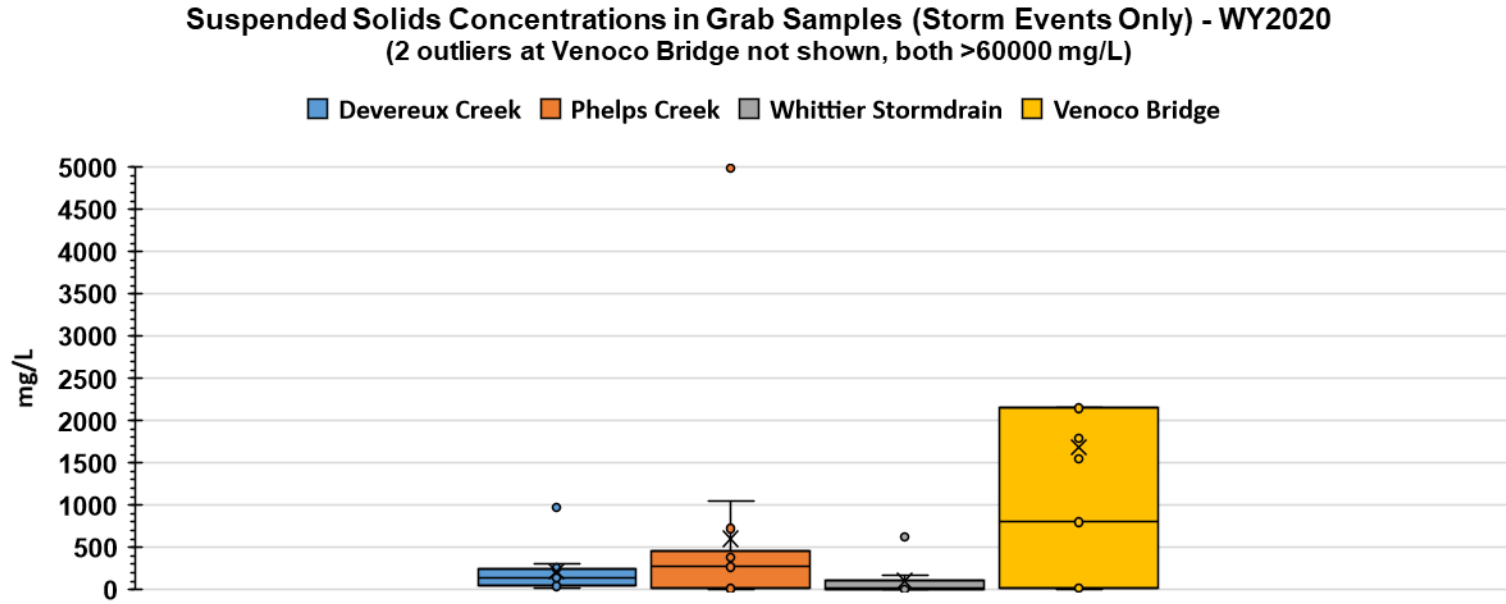
Suspended Solids Concentration in Devereux Creek: 11/27/2019 - 03/31/2020
Water Level (m)
Hourly Precip (mm)
Suspended Solids Concentration (mg/L)
Water Level (m) \ Hourly Precipitation (mm)
Suspended Solids Concentration (mg/L)

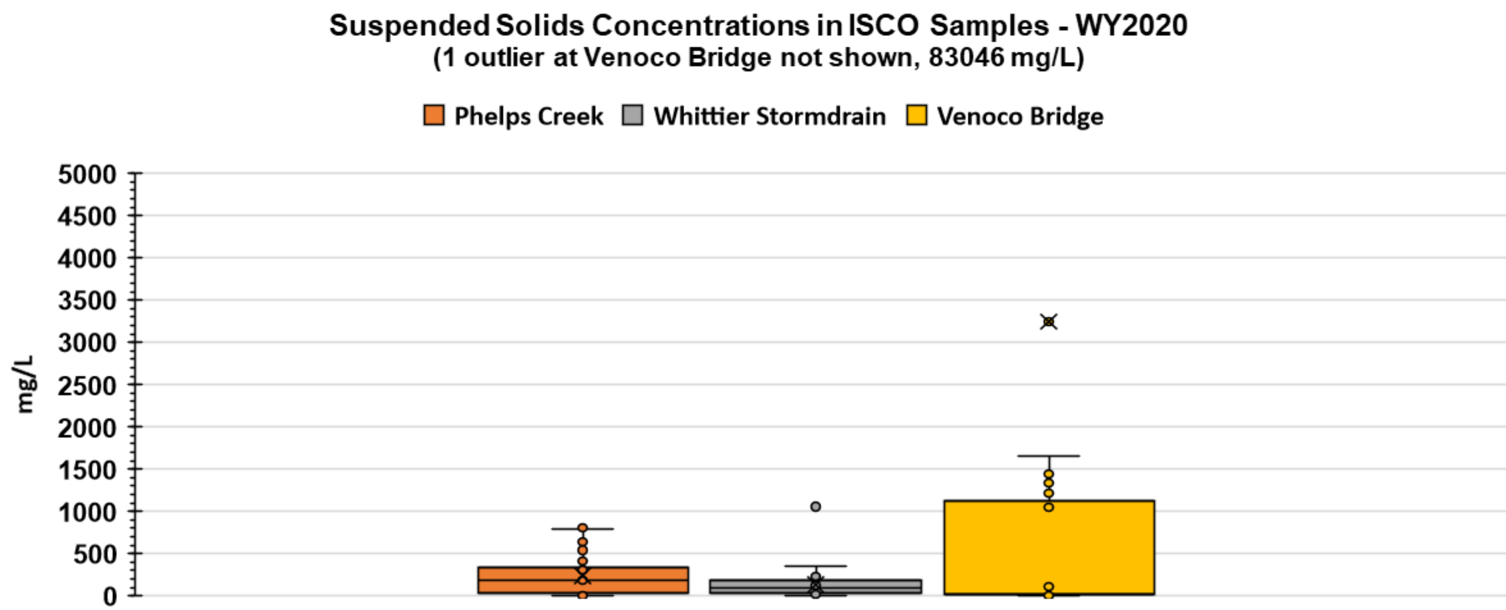

Suspended Solids Concentration in Phelps Creek: 11/20/19 - 03/31/2020
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)

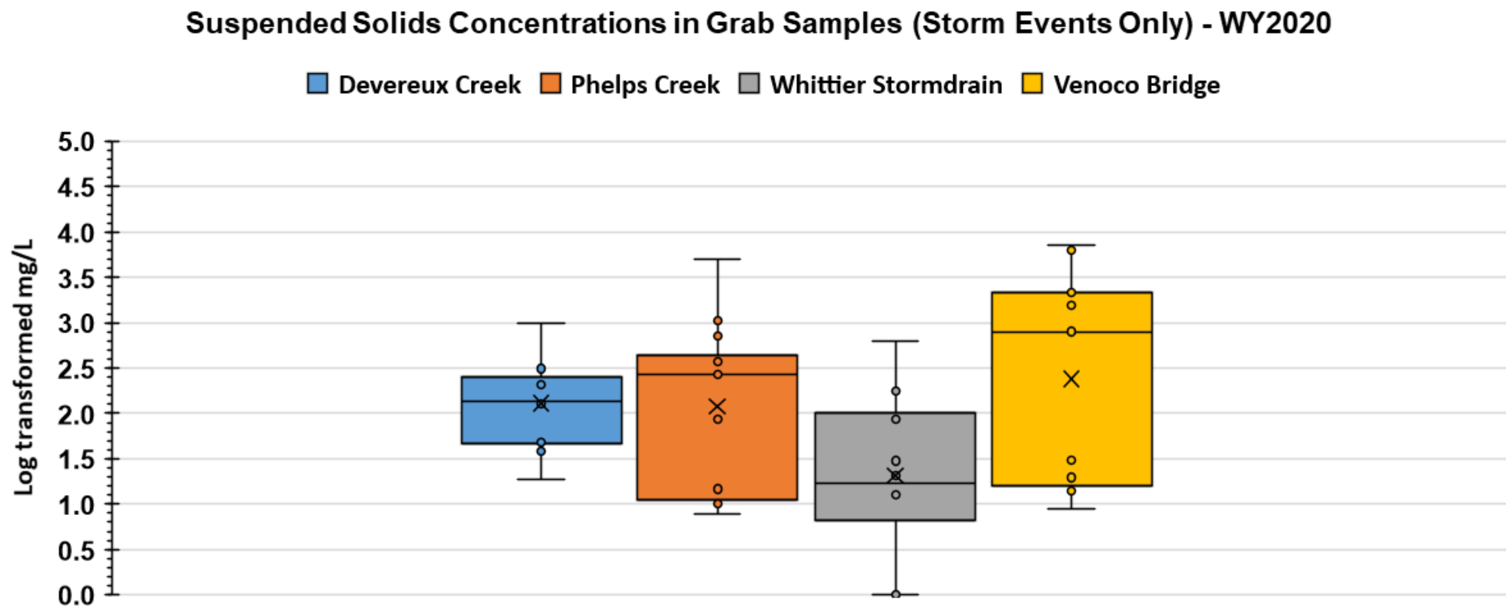

Suspended Solids Concentration in Whittier Stormdrain Channel: 11/20/19 - 03/31/2020
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)

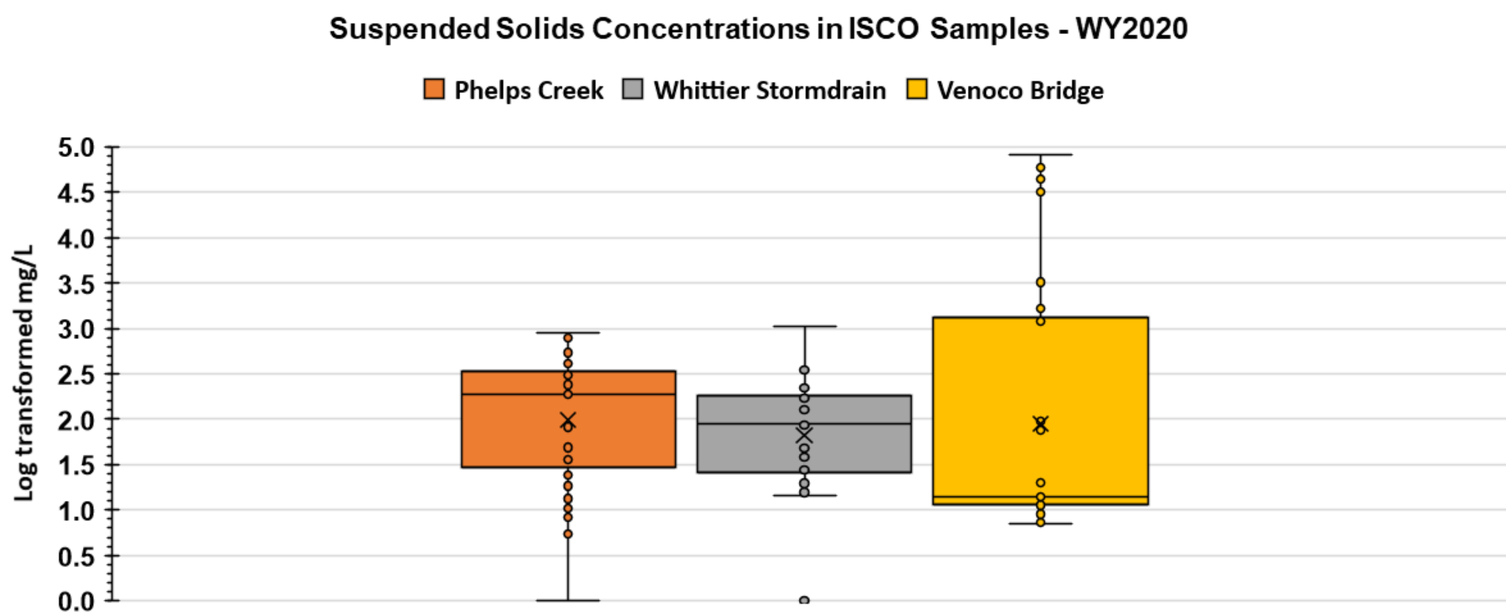


Devereux Slough Suspended Solid Concentration at Veneco Bridge: 11/20/2019 - 03/31/2020
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
ISCO Sample
Conductivity (mS/cm)
Water Level (m) \ Hourly Precipitation (mm)
Conductivity (mS/cm) \ Suspended Solids Concentration (g/L)

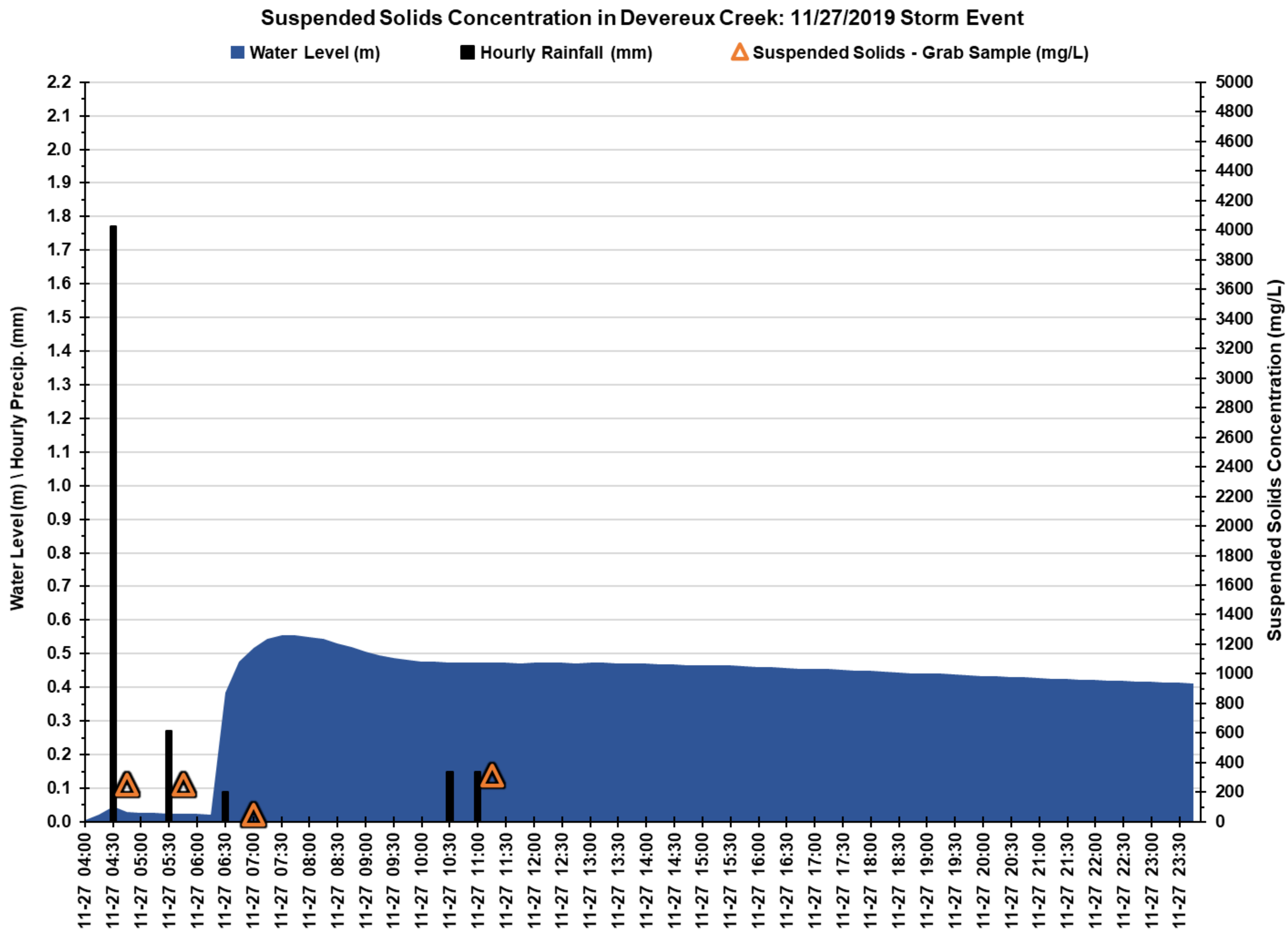

Suspended Solids Concentrations in Grab Samples (Storm Events Only) - WY2020
(2 outliers at Venoco Bridge not shown, both >60000 mg/L)
Devereux Creek
Phelps Creek
Whittier Stormdrain
Venoco Bridge
mg/L
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0


Suspended Solids Concentrations in ISCO Samples - WY2020
(1 outlier at Venoco Bridge not shown, 83046 mg/L)
Phelps Creek
Whittier Stormdrain
Venoco Bridge
mg/L
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0

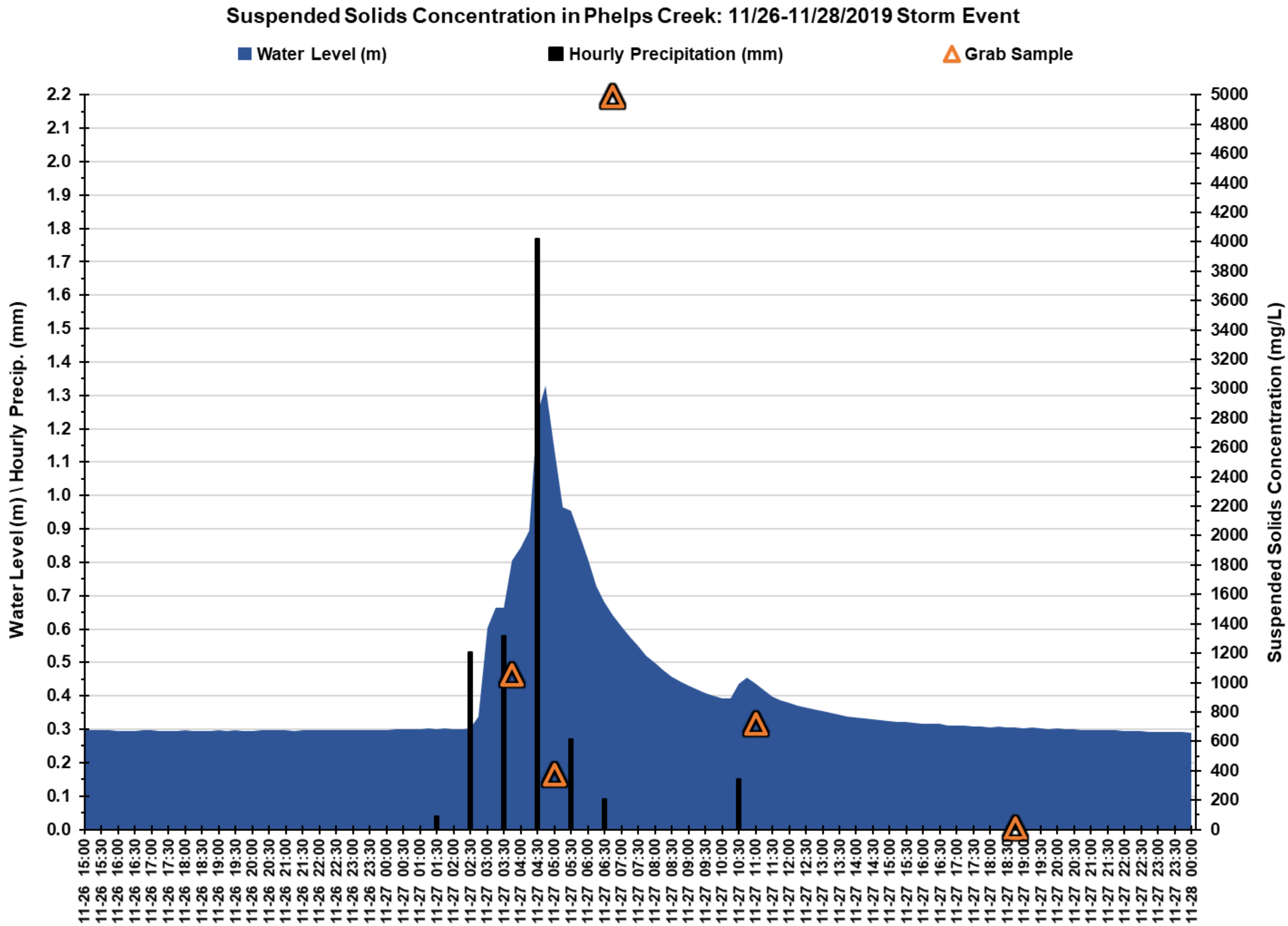

Suspended Solids Concentrations in Grab Samples (Storm Events Only) - WY2020
Devereux Creek
Phelps Creek
Whittier Stormdrain
Venoco Bridge
Log transformed mg/L
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0


Suspended Solids Concentrations in ISCO Samples - WY2020
Phelps Creek
Whittier Stormdrain
Venoco Bridge
Log transformed mg/L
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

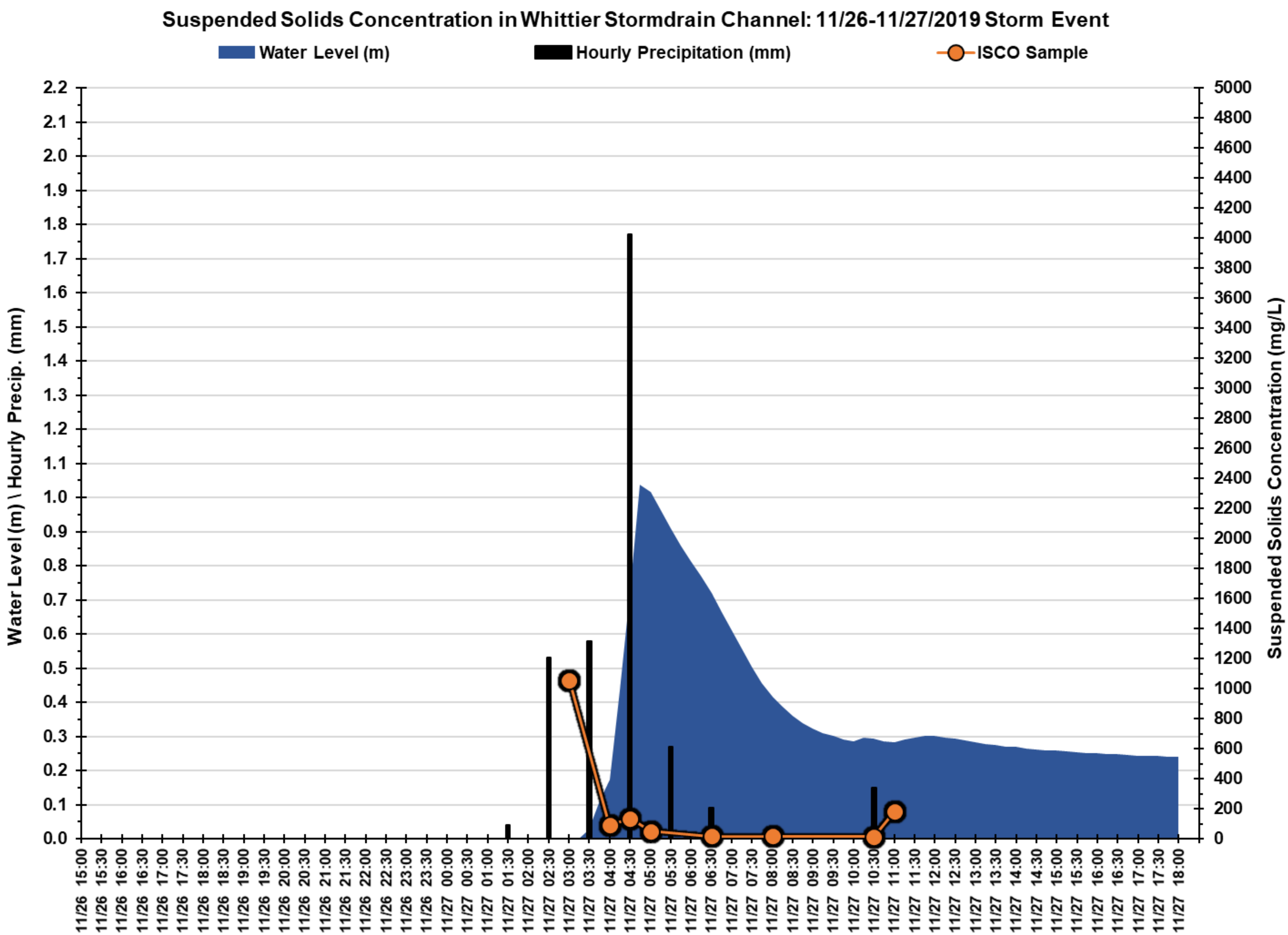
SUSPENDED SOLIDS CONCENTRATION DATA: Storm Charts for each Site



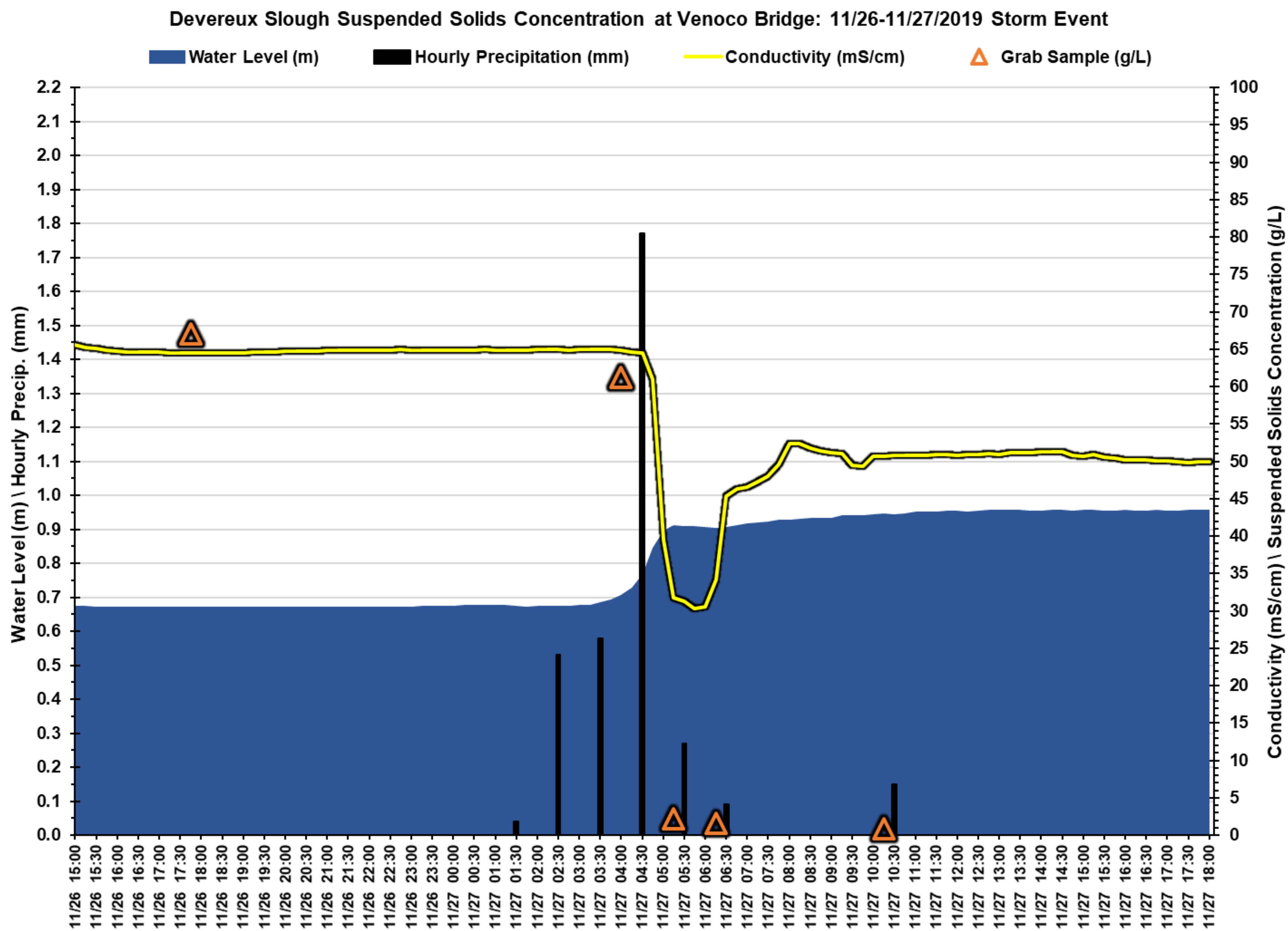
Suspended Solids Concentration in Devereux Creek: 11/27/2019 Storm Event
Water Level (m)
Hourly Rainfall (mm)
Suspended Solids - Grab Sample (mg/L)
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)



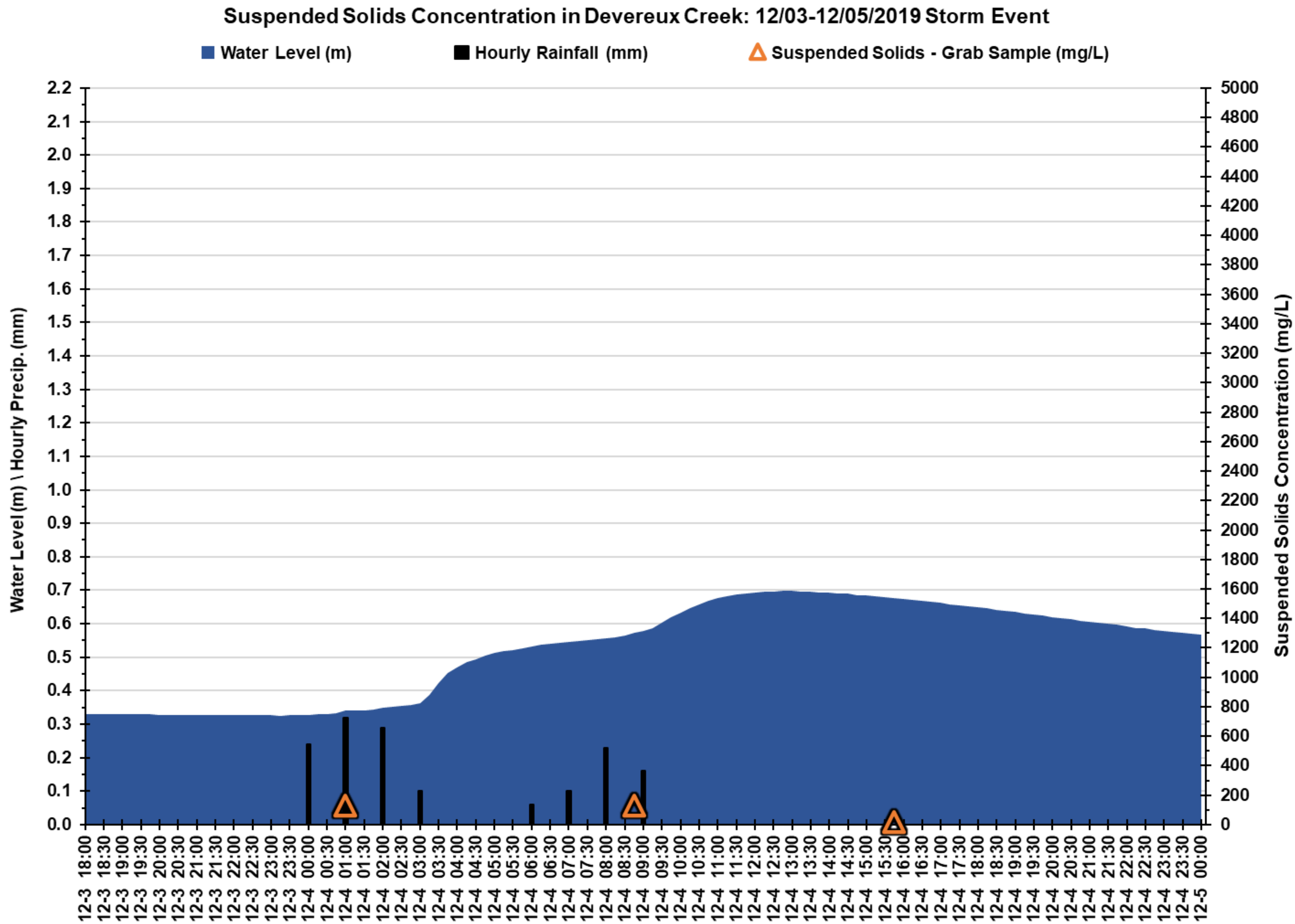
Suspended Solids Concentration in Phelps Creek: 11/26-11/28/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)



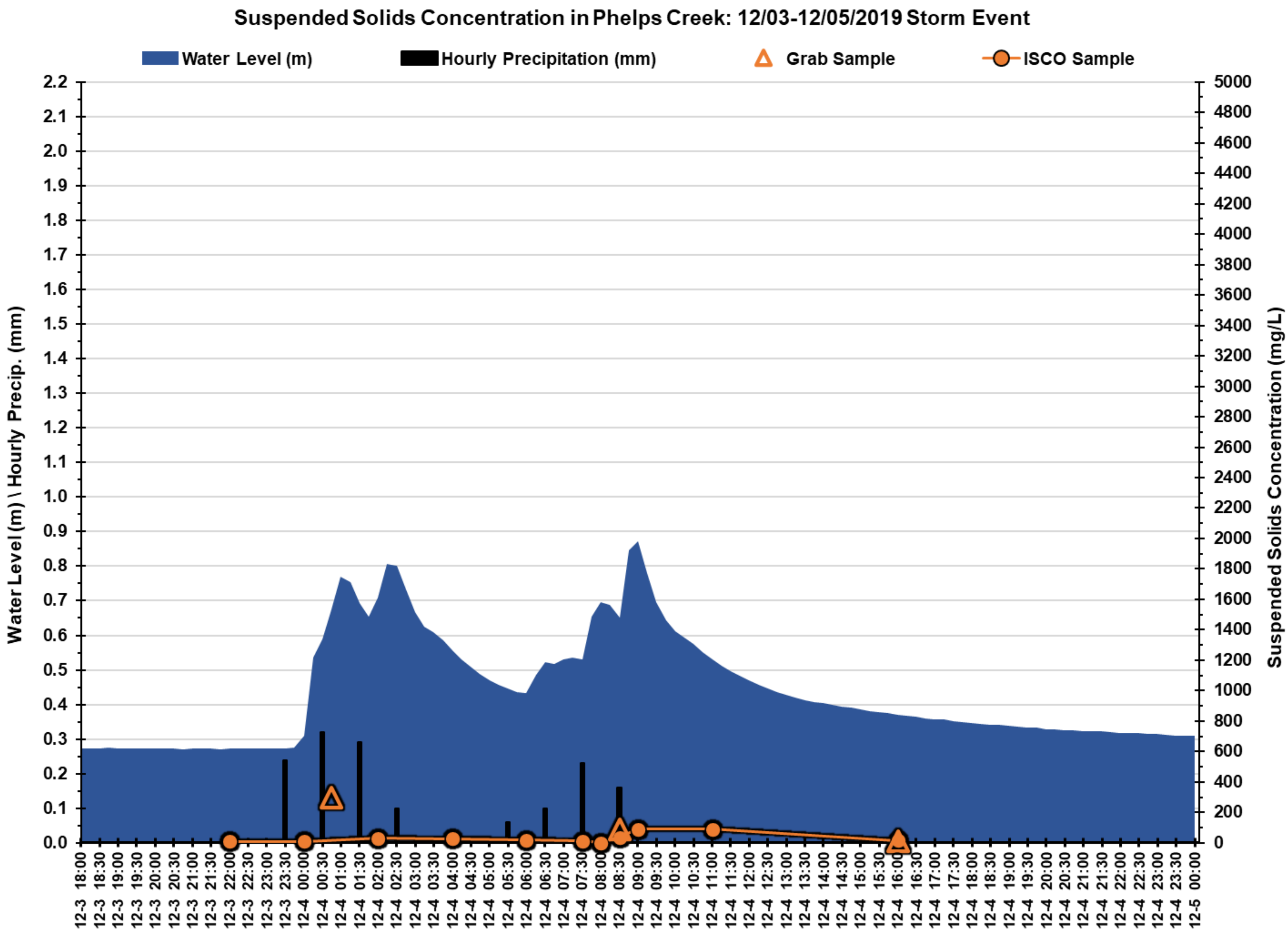
Suspended Solids Concentration in Whittier Stormdrain Channel: 11/26-11/27/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)

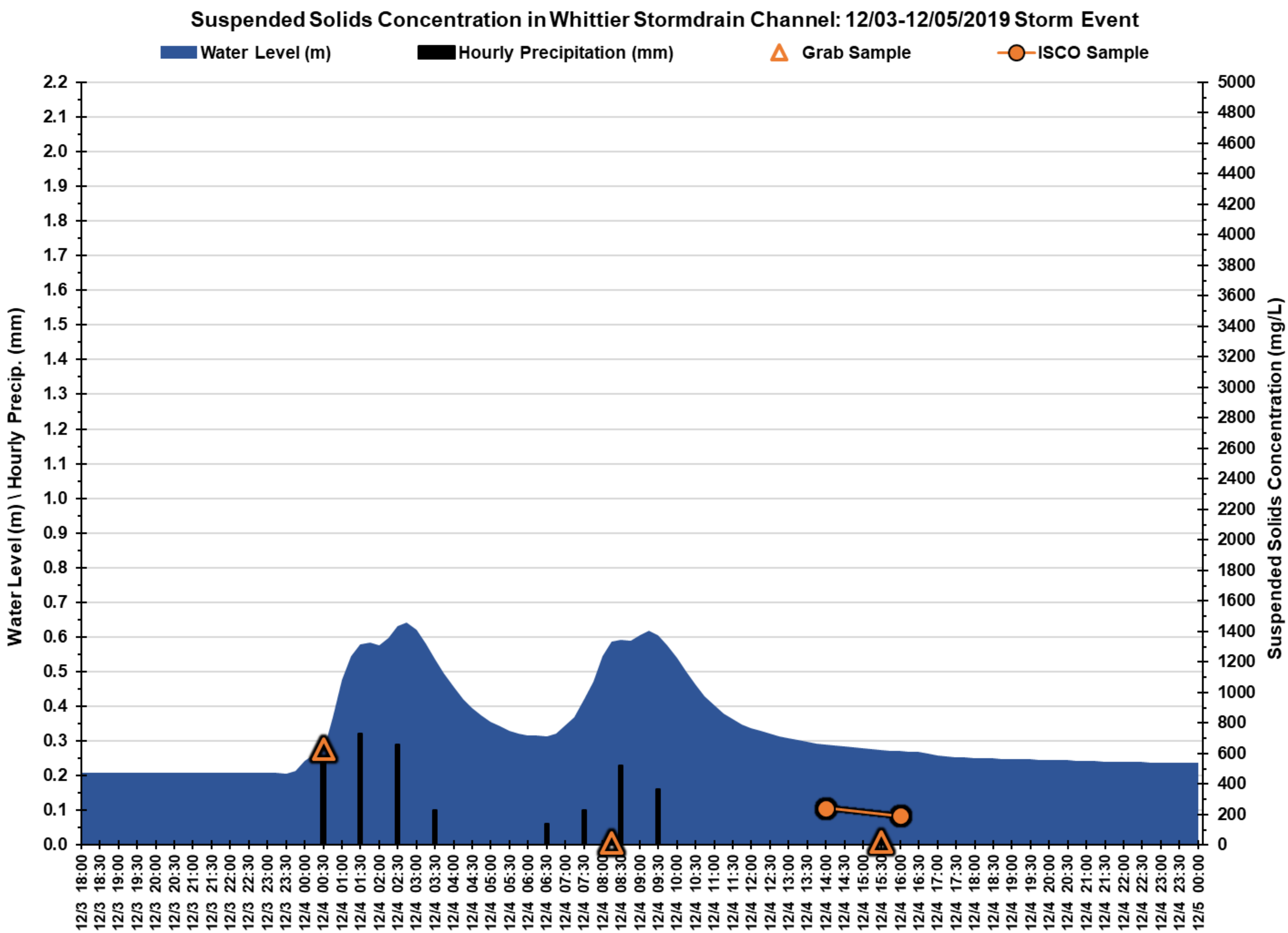


Devereux Slough Suspended Solids Concentration at Venoco Bridge: 11/26-11/27/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Conductivity (mS/cm)
Grab Sample (g/L)
Water Level (m) \ Hourly Precip. (mm)
Conductivity (mS/cm) \ Suspended Solids Concentration (g/L)

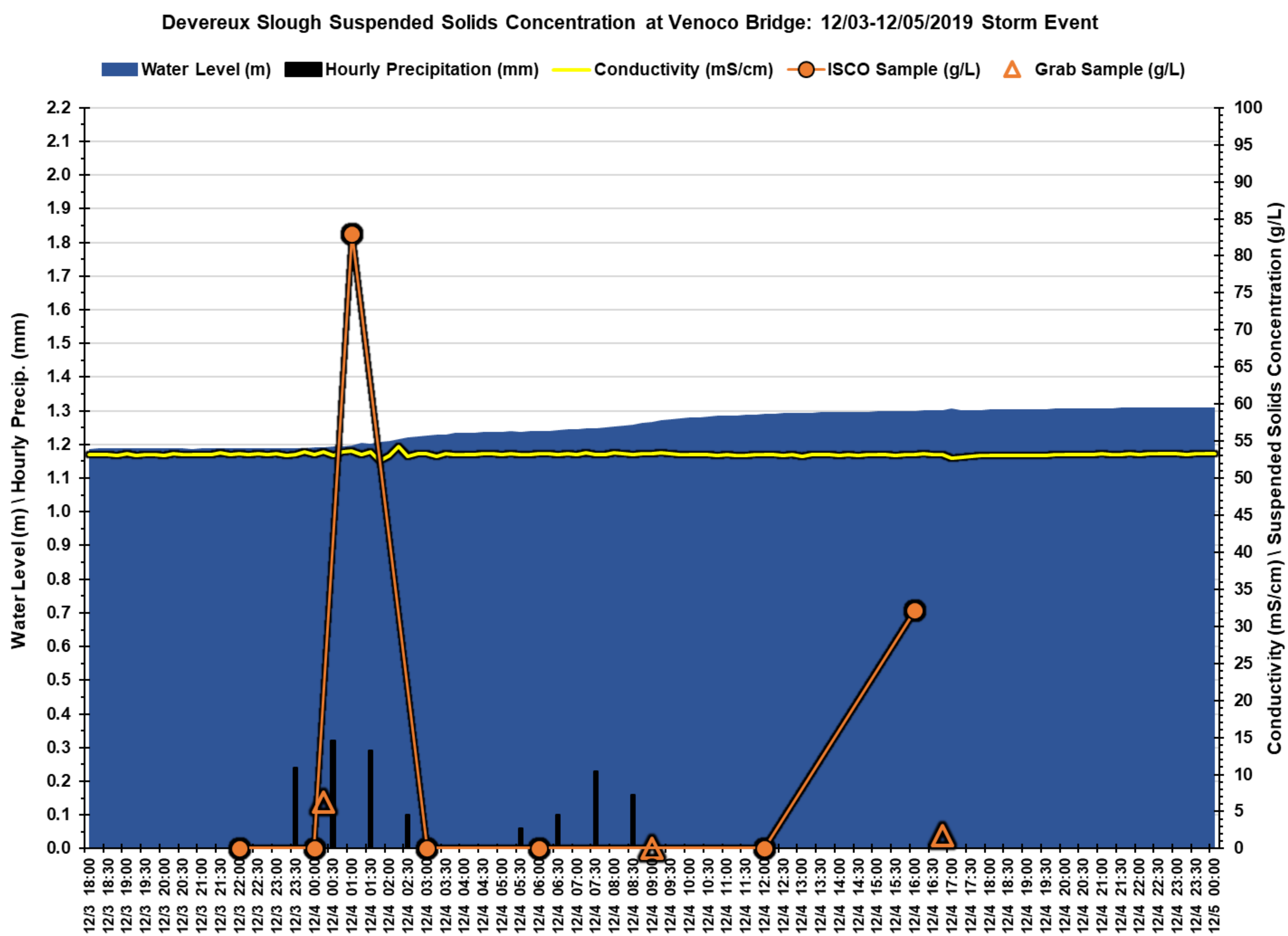


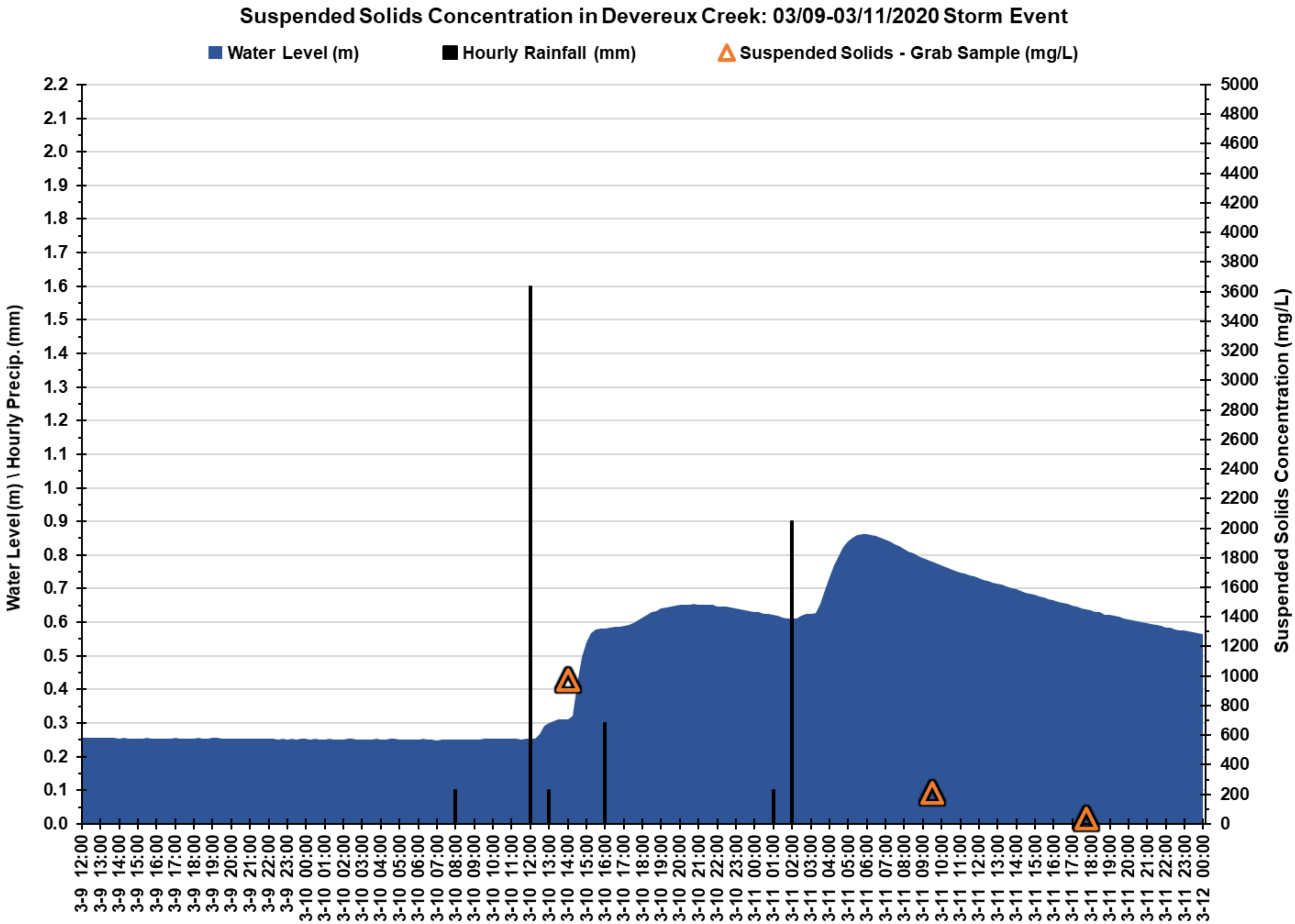
Suspended Solids Concentration in Devereux Creek: 12/03-12/05/2019 Storm Event
Water Level (m)
Hourly Rainfall (mm)
Suspended Solids - Grab Sample (mg/L)
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)

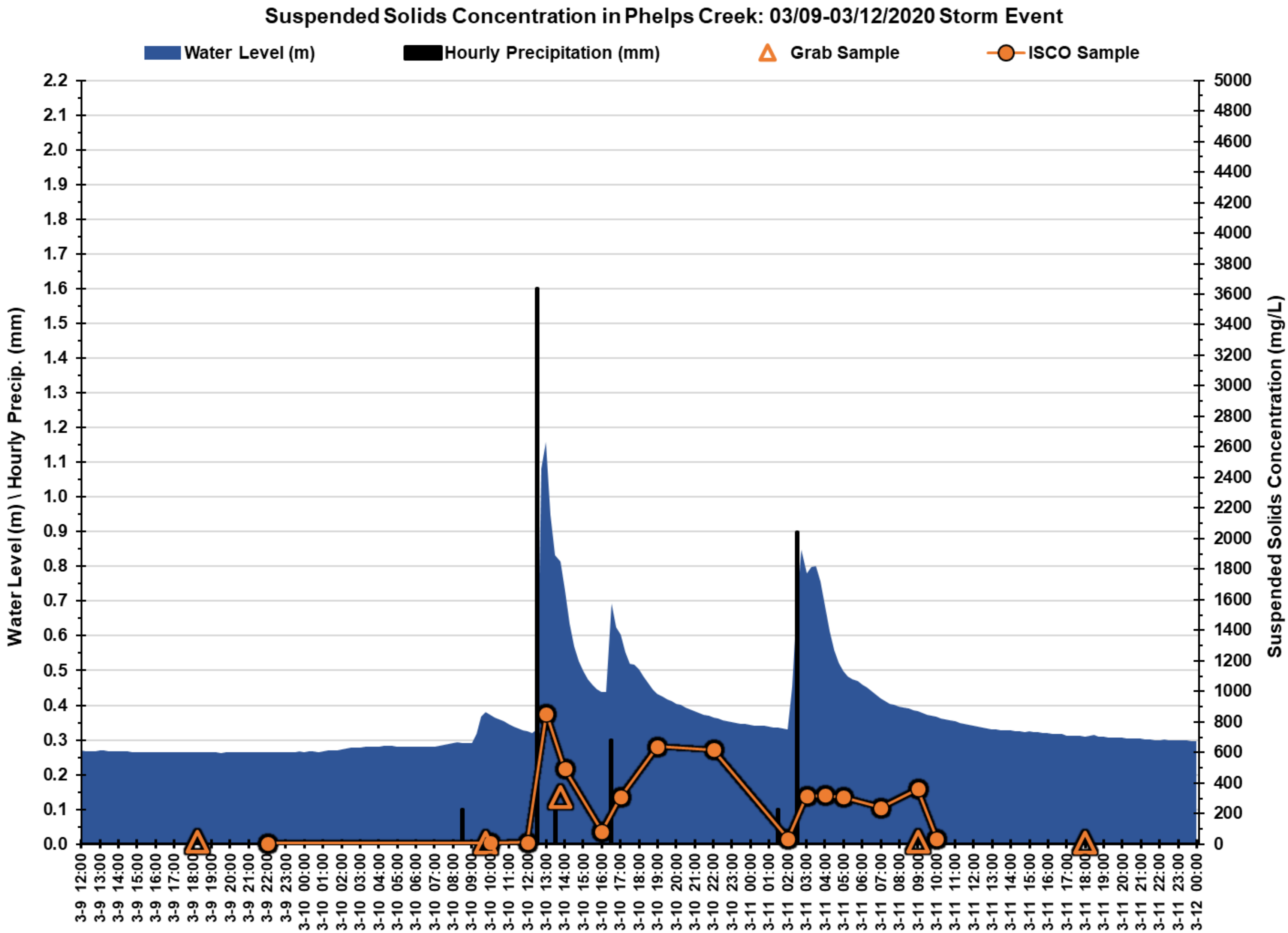

Suspended Solids Concentration in Phelps Creek: 12/03-12/05/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)



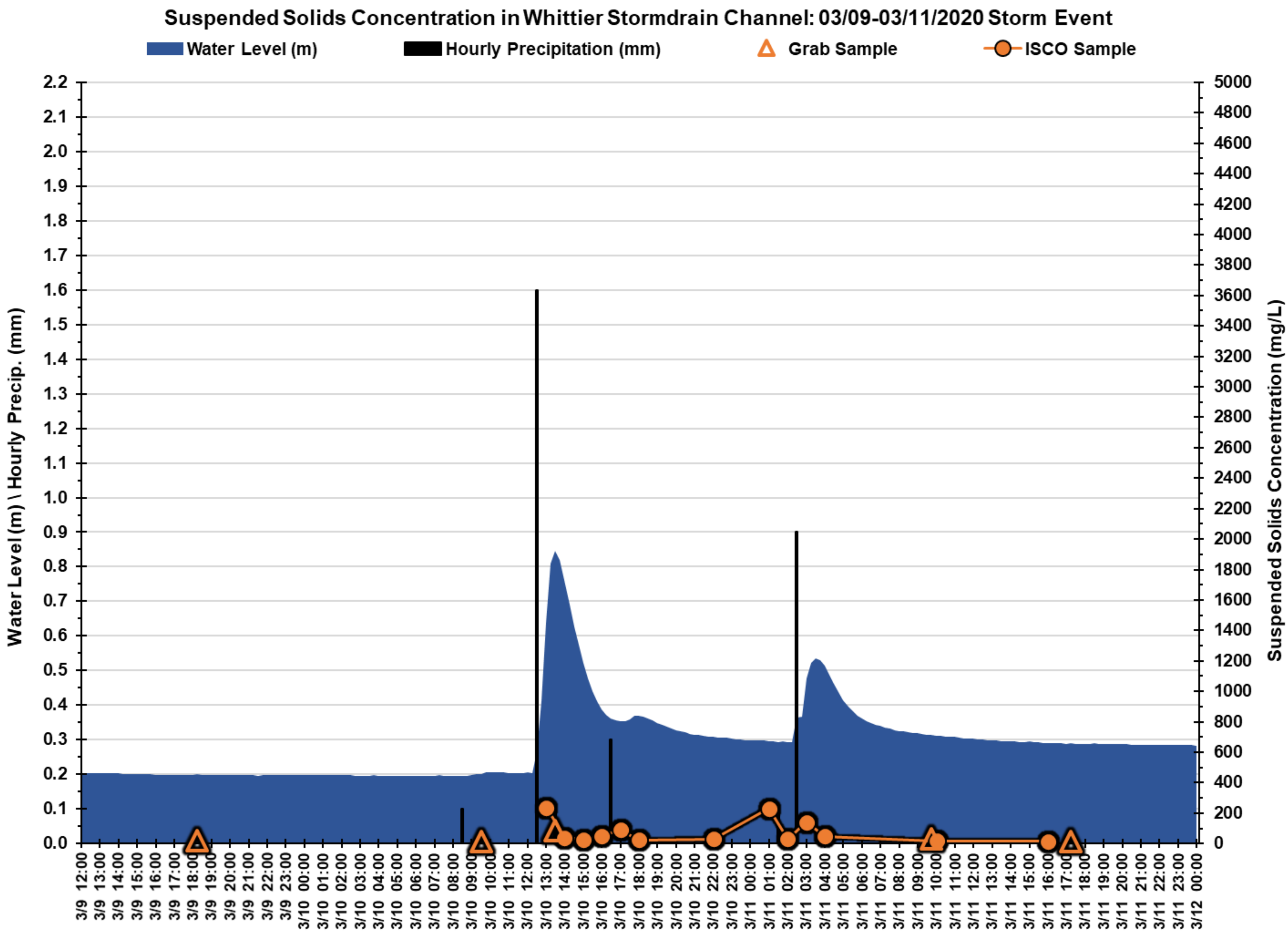
Suspended Solids Concentration in Whittier Stormdrain Channel: 12/03-12/05/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)


Devereux Slough Suspended Solids Concentration at Venoco Bridge: 12/03-12/05/2019 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Conductivity (mS/cm)
ISCO Sample (g/L)
Grab Sample (g/L)
Water Level (m) \ Hourly Precip. (mm)
Conductivity (mS/cm) \ Suspended Solids Concentration (g/L)

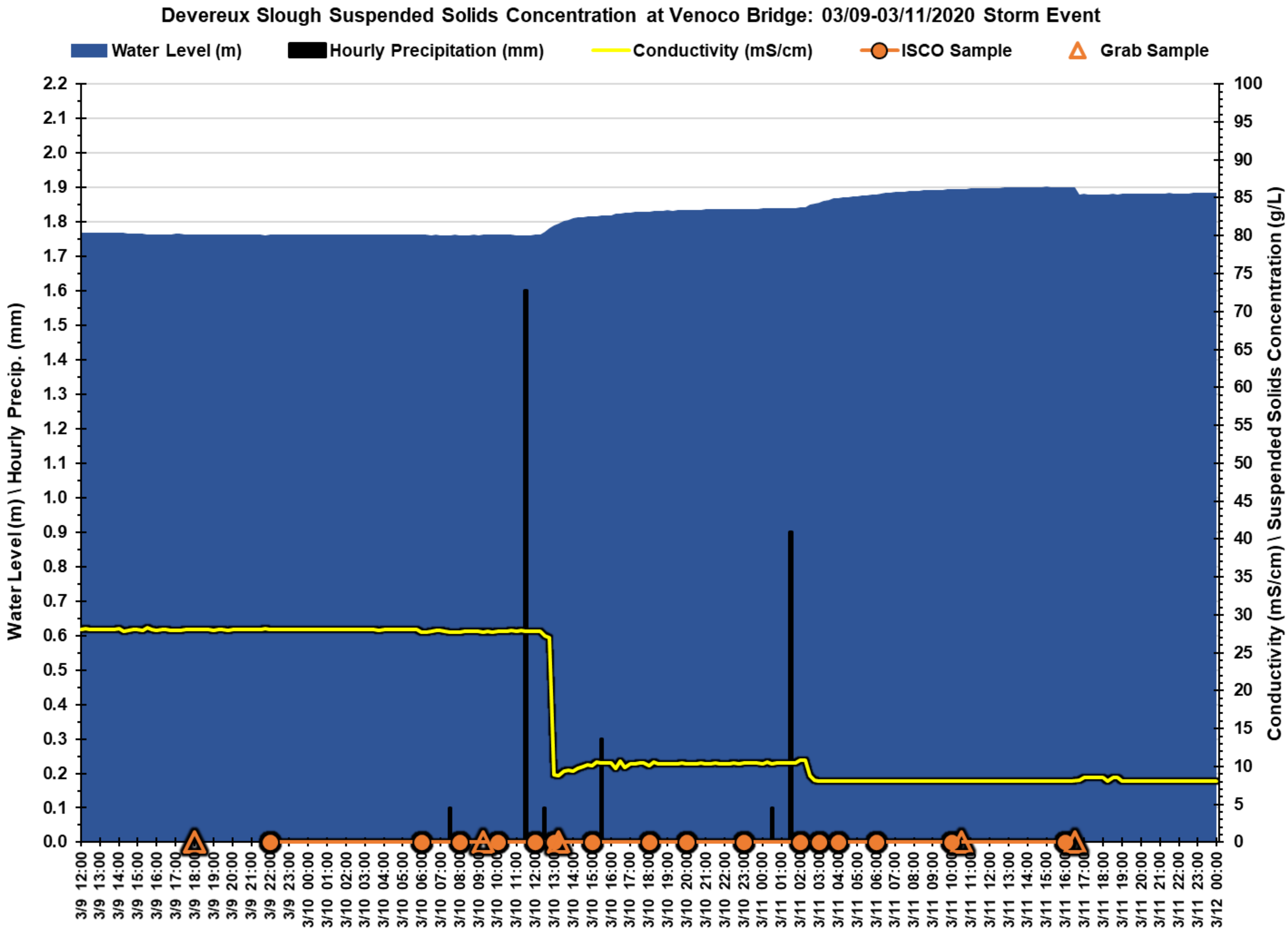

Suspended Solids Concentration in Devereux Creek: 03/09-03/11/2020 Storm Event
Water Level (m)
Hourly Rainfall (mm)
Suspended Solids - Grab Sample (mg/L)
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)



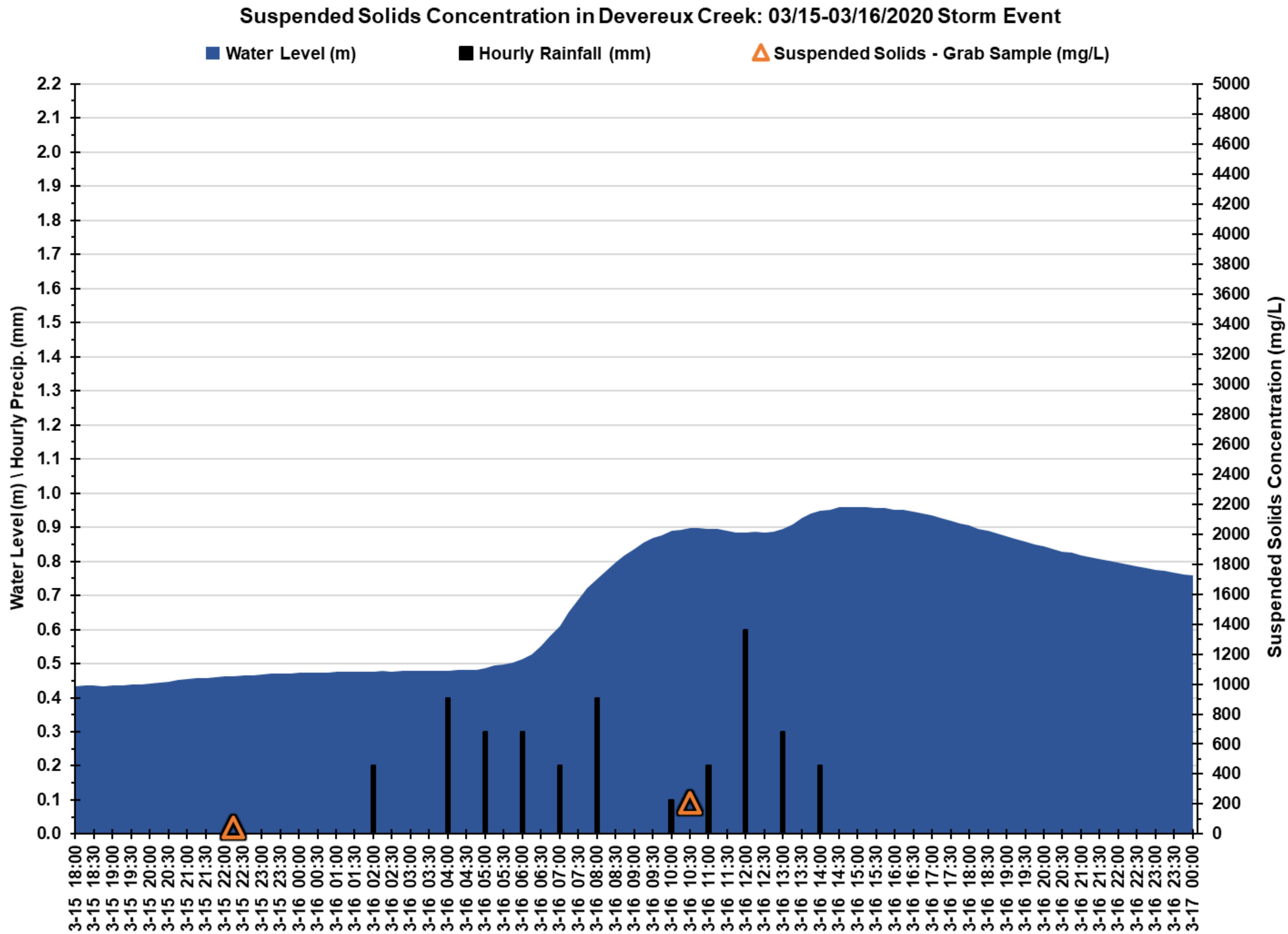
Suspended Solids Concentration in Phelps Creek: 03/09-03/12/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)

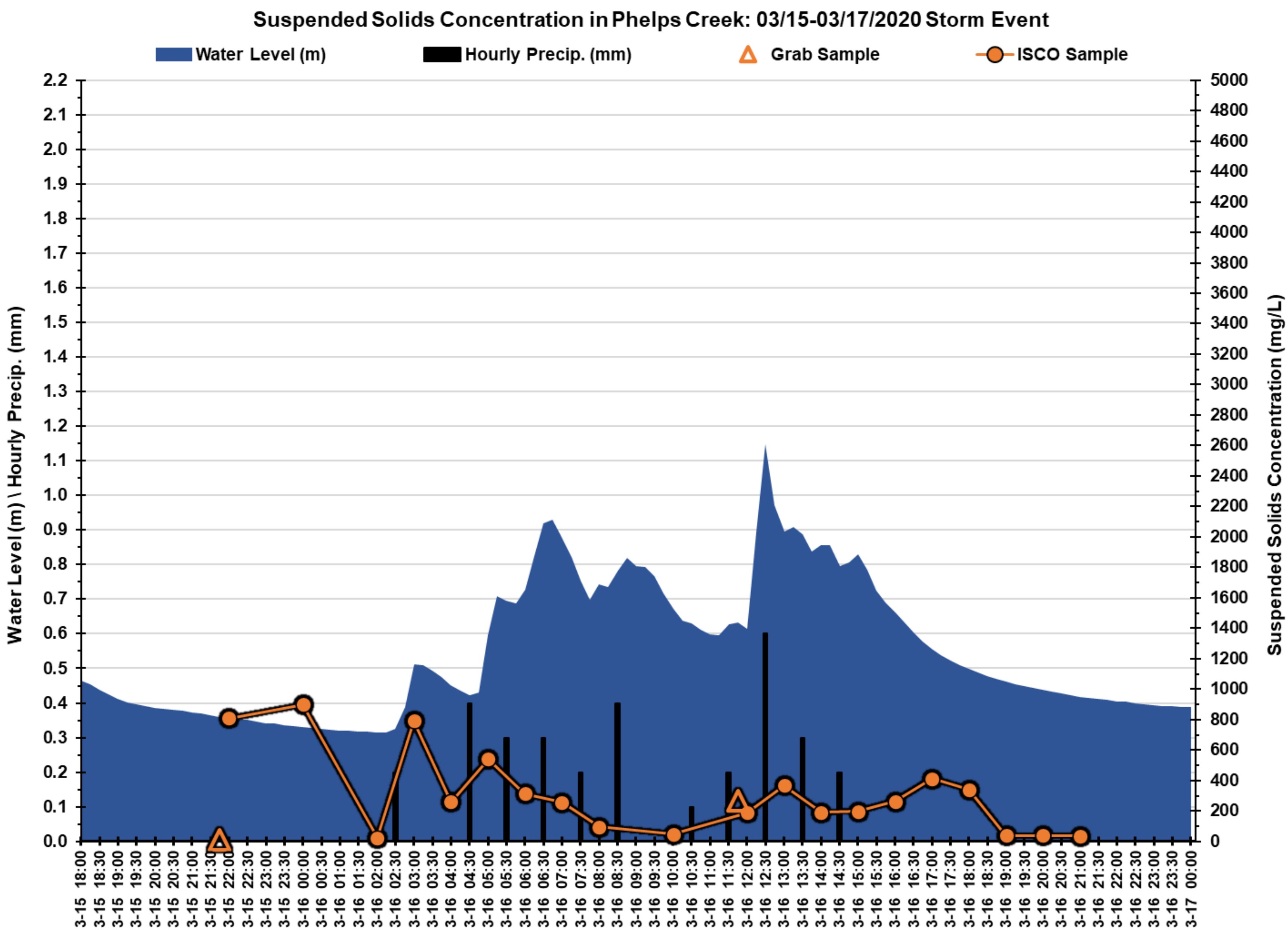


Suspended Solids Concentration in Whittier Stormdrain Channel: 03/09-03/11/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)

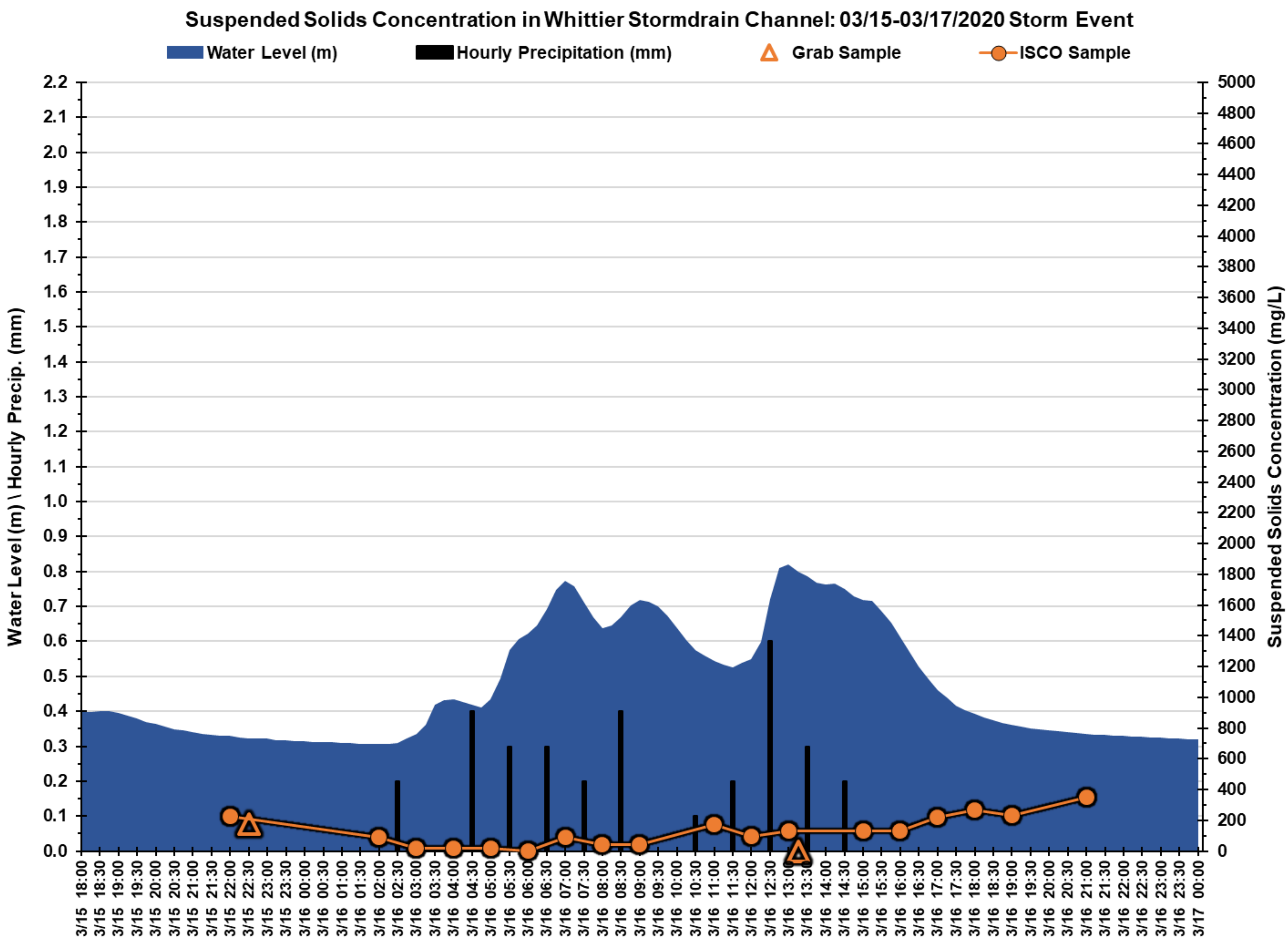


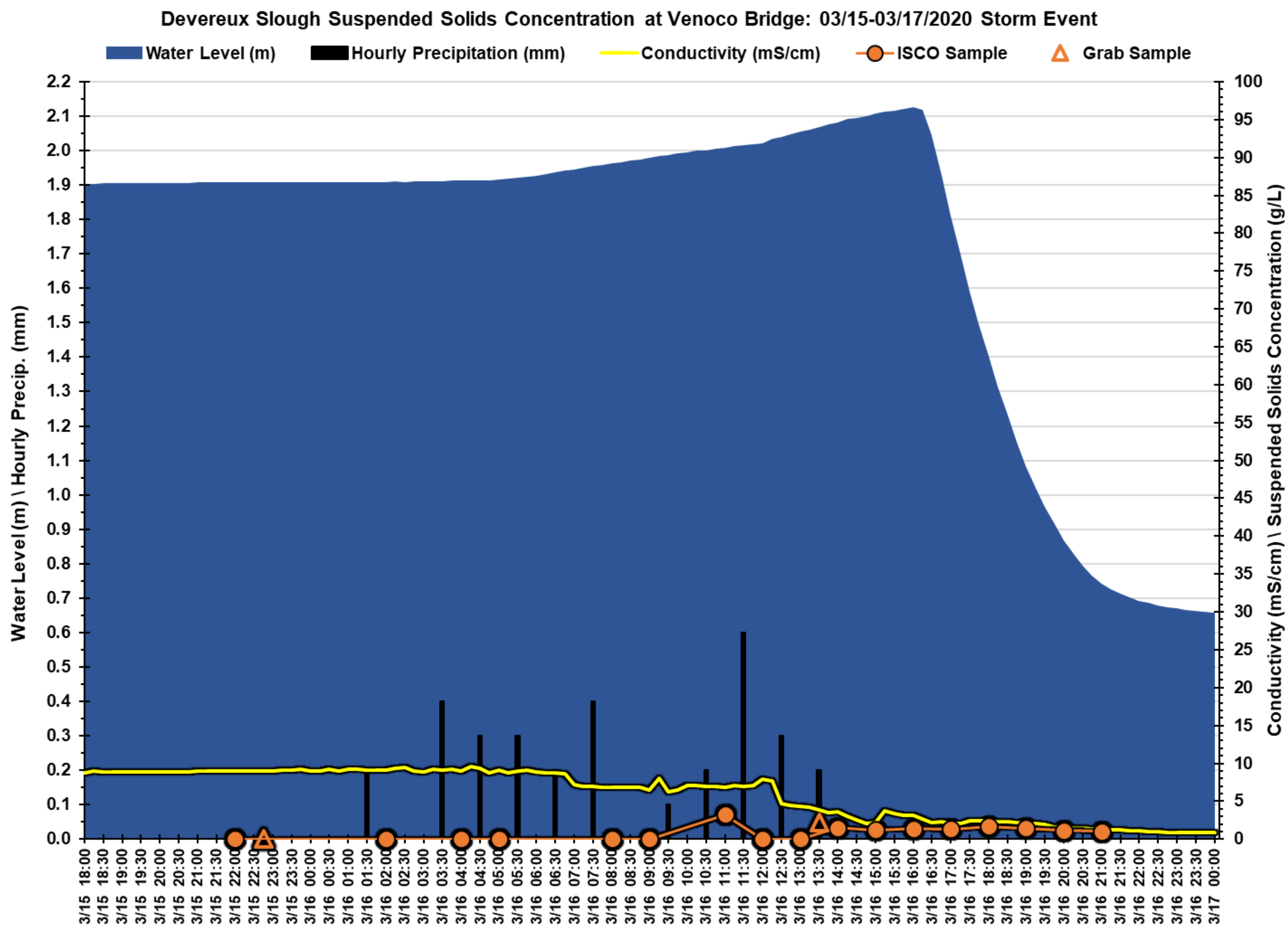
Devereux Slough Suspended Solids Concentration at Venoco Bridge: 03/09-03/11/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Conductivity (mS/cm)
ISCO Sample
Grab Sample
Water Level (m) \ Hourly Precip. (mm)
Conductivity (mS/cm) \ Suspended Solids Concentration (g/L)


Suspended Solids Concentration in Devereux Creek: 03/15-03/16/2020 Storm Event
Water Level (m)
Hourly Rainfall (mm)
Suspended Solids - Grab Sample (mg/L)
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)



Suspended Solids Concentration in Phelps Creek: 03/15-03/17/2020 Storm Event
Water Level (m)
Hourly Precip. (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)


Suspended Solids Concentration in Whittier Stormdrain Channel: 03/15-03/17/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Grab Sample
ISCO Sample
Water Level (m) \ Hourly Precip. (mm)
Suspended Solids Concentration (mg/L)


Devereux Slough Suspended Solids Concentration at Venoco Bridge: 03/15-03/17/2020 Storm Event
Water Level (m)
Hourly Precipitation (mm)
Conductivity (mS/cm)
ISCO Sample
Grab Sample
Water Level (m) \ Hourly Precip. (mm)
Conductivity (mS/cm) \ Suspended Solids Concentration (g/L)