Central Coast Watershed Studies

CCoWS

Spatial and Temporal Variations in Streamflow and Water Quality – The Reclamation Ditch and Tembladero Slough, Monterey County, California

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Disclaimer:

This report primarily represents student work completed within the constraints of a fixed-duration (5-week), limited-verification college class setting.

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Executive Summary

This study was conducted by students as part of a class project in Advanced Watershed Science and Policy (ENVS 660) at California State University, Monterey Bay. The study had three objectives: to measure streamflow and water quality at six sites within two interconnected water bodies, the Tembladero Slough and the Reclamation Ditch; to assess spatial and temporal patterns based on these measurements; and to compare the results to previous studies. The Tembladero Slough and the Reclamation Ditch are potential source waters for Pure Water Monterey Groundwater Replenishment Project (Pure Water Monterey GWR) that addresses regional water supply concerns. The spatial and temporal dynamics of streamflow and water quality in these water bodies are an important component of the Pure Water Monterey GWR project.

To explore spatial and temporal dynamics, we measured several water quality parameters and streamflow at three sites on the Tembladero Slough and three sites on the Reclamation Ditch over five nonconsecutive days between November 11th and December 2nd, 2014. Water quality was measured along a vertical profile within the water column at 1 ft. increments using a YSI 556 multiprobe system. Flow measurements were calculated using three different methods: float, pygmy meter, and a USGS gage. Two pressure transducers were also installed at two sites (Molera Rd. and Haro St.) to monitor water elevation within the channel.

The maximum salinity recorded was 19.2 ppt at the Molera Rd site in the Tembladero Slough at the deepest point within the water column. For the remaining two sites on the Tembladero Slough, salinity did not exceed 1.5 ppt throughout the study period. Salinity for all three sites within the Reclamation Ditch was below 0.5 ppt.

We found streamflow and salinity results at the Molera Rd. site were influenced by several factors, including the tides. We observed an increase in stage and a decrease in streamflow at this site during high tide. We also observed a difference in streamflow between Haro St. and Molera Rd. during low tide. We speculated that this variability is a function of the tides and tide gates.

Drought may have influenced our measurements. When the study began, California was entering its third year of drought. Besides obvious reductions in streamflow, drought can also result in a reduction of dissolved oxygen and changes in other water quality parameters. Conversely, two precipitation events, occurring on November 13th and December 2nd, influenced our results, as we noted that increases in streamflow coincided with these events. Streamflow and salinity may also be impacted by other water inputs into these waterbodies, such as urban and agricultural runoff.

Future researchers should consider expanding the study duration in order to monitor the effect that seasonal differences in climate have on the watershed, establishing a consistent method of streamflow measurement so that data from different sites are more reliably comparable, and developing a rating equation for tidally regulated reaches. In addition, if employing the pygmy meter method of measuring streamflow, researchers should include a top setting pygmy meter rod as part of the measurement tools so that streamflow measurements can be collected from bridges during high streamflow.

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List of Definitions and Acronyms

- AFY – Acre-Feet Per Year
- CalAm – California American Water Quality
- CCoWS – Central Coast Watershed Studies
- CCWQCB – Central Coast Water Quality Control Board
- CEQA – California Environmental Quality Act
- CWA – Clean Water Act
- EIR – Environmental Impact Report
- EPA – Environmental Protection Agency
- ESA – Endangered Species Act
- MPWMD – Monterey Peninsula Water Management District
- MRWPCA – Monterey Regional Water Pollution Control Agency
- PPT – Parts Per Thousand
- Pure Water Monterey GWR– Pure Water Monterey Groundwater Replenishment project
- Reclamation Ditch –Reclamation Ditch, also known as Salinas Reclamation Canal
- SWRCB – State Water Resources Control Board
- SWQCB – State Water Quality Control Board
- WSE – Water surface elevation
- TDS – Total Dissolved Solids
- SC – Specific Conductivity
- DO – Dissolved Oxygen

1 Introduction

1.1 Background

The Monterey region is exploring alternative water supply sources to fill a water supply gap affecting the region. To help meet the region's water supply needs, the Monterey Regional Water Pollution Control Agency (MRWPCA) and Monterey Peninsula Water Management District (MPWMD) are proposing the Pure Water Monterey Groundwater Replenishment Project (Pure Water Monterey GWR). The project is a component of an integrated water resource management approach, which includes desalination, groundwater replenishment, the Castroville Seawater Intrusion Project (CSIP), storm water capture and reuse, industrial wastewater reuse, and other water conservation efforts.

Pure Water Monterey GWR would create a water supply of 3,500 AFY through the collection of a variety of new source waters and conveyance of that water to the MRWPCA's Regional Wastewater Treatment Plant (Regional Plant) for treatment and recycling. The proposed new source waters that would supplement the supply from wastewater would include the following: 1) water from the City of Salinas agricultural wash water system, 2) stormwater flows from the southern part of Salinas and the Lake El Estero facility in Monterey, 3) surface water and agricultural tile drain water that is captured in the Reclamation Ditch (Reclamation Ditch) and Tembladero Slough, and 4) surface water and agricultural tile drain water that flows in the Blanco Drain. The combined flow would be treated using the existing primary and secondary wastewater treatment processes at the Regional Plant then would be treated further using one of two the following two additional treatment systems: (1) the existing tertiary treatment plant called the Salinas Valley Reclamation Plant (located at the Regional Plant), or the new Advanced Water Treatment Center proposed to also be co-located at the Regional Plant. The water would be reused after recycling for the following two purposes:

1. **Replenishment of the Seaside Groundwater Basin**. The project would enable California American Water Company (Cal-Am) to reduce its diversions from the Carmel River system by up to 3,500 acre-feet per year by injecting the same amount of highly-treated water into the Seaside Groundwater Basin. This highly-treated water would be produced from a new advanced water treatment facility that would be constructed at the Regional Plant designed to treat the source waters identified above. The highly-treated water would then be conveyed to and injected into the Seaside Groundwater Basin via a new pipeline and new well facilities, where it would then mix with the existing groundwater and be stored for future urban use by Cal-Am, thus enabling a reduction in Carmel River system diversions by the same amount.

2. **Provide additional recycled water for agricultural irrigation in northern Salinas Valley**. Currently, the only sources of supply for the existing water recycling facility at the Regional Plant are municipal wastewater and small amounts of urban dry weather runoff. Municipal wastewater flows have declined in recent years due to aggressive water conservation efforts by the MRWPCA member entities. By increasing the amount and type of source waters entering the existing wastewater collection system, additional recycled water can be provided for use in the CSIP agricultural irrigation system. It is anticipated that approximately 4,750 acre-feet per year of additional recycled water supply could be created for irrigation purposes.

The project would also include a drought reserve component to support use of the new supply for crop irrigation during dry years. The project provides for an additional 200 acre-feet per year of advanced treated water that would be injected in the Seaside Groundwater Basin in wet and normal years for up to five consecutive years, resulting in a "banked" drought reserve totaling up to 1,000 acre feet. California American Water (Cal-Am) would be able to extract the banked water to make up the difference to its supplies, such that its extractions and deliveries would not fall below 3,500 acre-feet per year. The source waters that are not sent to the advanced treatment facility during dry years would be sent to the Salinas Valley Reclamation Plant to increase supplies for the CSIP.

Implementation of Pure Water Monterey GWR may also inform the design and sizing of the desalination plant, another potential solution to the water supply gap. Without Pure Water Monterey GWR, the desalination plant would be designed to produce 9,752 AFY. However, if the Pure Water Monterey GWR project is implemented, a desalination plant capable of producing 6,252 AFY would be sufficient to meet Cal-Am's Monterey service area demand.

Multiple legal decisions have prompted local water authority agencies to seek alternative water resource management projects, including Pure Water Monterey GWR, to ensure a reliable water supply for the Cal-Am Monterey service area. In 1995, the State Water Resource Control Board (SWRCB) issued Order No. WR 95-10 which required Cal-Am to stop illegal diversions from the Carmel River (SWRCB 1995). Instead, the order required Cal-Am to maximize its diversions from the Seaside Groundwater Basin to balance the reduced diversion from Carmel River. In 2009, the SWRCB issued Cease and Desist Order (SWRCB 2009) requiring Cal-Am to reduce its Carmel River diversions to 3.376 AFY and to acquire replacement water supplies by 2016-2017 (MRWPCA 2013). Furthermore, the Seaside Groundwater Basin adjudication (California American Water v City of Seaside) issued in 2006 requires Cal-Am to reduce pumping from the Seaside Groundwater Basin to 3,407 AFY.

The project will require numerous discretionary permits as well as compliance with California Environmental Quality Act (CEQA). The MRWPCA, as CEQA lead agency, initiated preparation of an Environmental Impact Report (EIR) in 2013. The EIR will be used by responsible agencies such as the State Water Resources Control Board (SWRCB) in considering permits for water appropriation and diversion. Water rights permits from the SWRCB are required for surface water diversions from the Reclamation Ditch, Blanco Drain, and Tembladero Slough.

The EIR will include various technical studies which will, in part, evaluate the impacts that diversion may have on water quality and streamflow of the Reclamation Ditch and downstream water bodies. The EIR will also address downstream aquatic habitats that may be altered by flow modifications.

Water quality and streamflow are key indicators for the survival of aquatic life forms, including various endangered and threatened animal and plant species that are found in the Reclamation Ditch and associated waterbodies. These species are protected under the 1973 Endangered Species Act (ESA) and diversions from these waterbodies must assess any potential impacts on their survival and reproduction.

1.2 Goals

The goals of this study were to:

1. Measure streamflow at six sampling locations along the Reclamation Ditch and Tembladero Slough.
2. Measure water quality including salinity at six sampling locations along the Reclamation Ditch and Tembladero Slough.
3. Assess spatial and temporal patterns of streamflow and water quality parameters at the six sampling locations.
4. Compare streamflow and water quality results to previous studies.

1.3 Water Quality Parameters

Surface water quality may be influenced by natural processes and anthropogenic influences. For example, urban, industrial, and agricultural water runoff combined with variations in precipitation can impact streamflow and pollutant loads within a waterbody (Shrestha and Kazama 2007). Water quality parameters assessed in this study include salinity, total dissolved solids (TDS), specific conductivity (SC), temperature, dissolved oxygen (DO), pH and turbidity.

Salinity is a measure of dissolved salts in water and is typically reported in parts per thousand (ppt). World averages for seawater and freshwater are 35 ppt and 3 ppt, respectively (Boulton and Brock 1999). Increasing salinity can result in a halocline, or salt gradient, creating a barrier to mixing within the water column. This barrier can impact nutrient cycling and impede movement of DO (Neilsen et al. 2003). In addition, salt ions can aggregate and flocculate suspended sediments, increasing light penetration and photosynthesis, which can lead to harmful algal blooms (Nielsen et al. 2003). For fresh water aquatic life, a salinity of less than 1.0 ppt is optimal.

Total dissolved solids (TDS) is a measure of dissolved organic and inorganic materials in water. TDS can limit the amount of light penetration within the water column, impacting growth and survival of aquatic vegetation (Rabalais 2002). By absorbing light, increases in TDS can increase water temperature, prevent light from reaching aquatic plants, and reduce both photosynthesis and dissolved oxygen levels (Verma and Singh 2013). Increases in temperature and decreases in DO can be detrimental to aquatic life.

Specific conductivity (SC) is a measure of the capacity of water to transmit an electrical current at a specified temperature (Alam 2007; Parameswara and Prasad 2012). SC is generally reported in microsiemen per centimeter (µS/cm) at 25 degrees Celsius and is a function of the concentration and nature of dissolved substances (Parameswara and Prasad 2012). An estimation of TDS can be calculated from SC by multiplying SC by a variable constant. Additionally, salinity can be derived from SC and temperature.

Water temperature is another important water quality parameter. Temperature can impact how much dissolved oxygen water can hold. As water temperature increases, the amount of DO available to aquatic life for biochemical processes decreases (Verma and Singh 2013).

DO is the amount of oxygen in the water. DO of 4 mg/L is considered a standard for survival of aquatic life (Alam et al. 2007). Low DO can result in large fish kills (CRWQCB 2013). Salinity and the existence of a halocline can affect DO. The presence of a halocline can reduce mixing between water surface and bottom layers leading to an imbalance in the rate of oxygen consumption and replenishment which can cause anoxia (Nielsen et al. 2003).

Water quality can also be impacted by pH. The pH of a solution is a measure of the hydrogen ion concentration and ranges from 1 (acidic) to 14 (basic), with 7 being neutral (Verma and Singh 2013). Measures of pH can serve as an indicator of chemical balance within a water body. Extreme pH imbalances can be harmful to aquatic life. High pH can make water pollutants much more toxic to aquatic organisms. For example, ammonia in a high pH (alkaline) solution (> 8.5) remains as $NH_{3,}$ which is more toxic to aquatic biota than it's oxidized form NH_4^+ (Morrison 2001). Similarly, a decrease in pH (acidic conditions) can reduce the solubility of many essential elements, impacting the health and nutrition of aquatic biota (Morrison 2001).

Turbidity is a measure of clarity, or cloudiness, of water, which can be measured by the amount of light that penetrates the water (EPA 2012). Suspended materials, such as sediment, microorganisms, and algae can affect the turbidity of water. High turbidity can increase water temperature, which can decrease DO concentrations and negatively impact aquatic organisms. Turbidity often increases during precipitation events, which can be used as an indicator of agricultural practices and urban areas (EPA 2012).

The water quality parameters described above are important indicators of water quality and help assess beneficial uses of waterbodies. Although our study focused on salinity measurement, other parameters were also captured as a resource for future investigations.

1.4 Study Area

The study area consisted of a reach of two interconnected waterbodies in Monterey County, California: the Reclamation Ditch and the Tembladero Slough (Fig. 1). The reach of interest began on the Reclamation Ditch near Davis Rd. in Salinas and continued downstream to the confluence of the Tembladero Slough and the Old Salinas River Channel. Within this reach the Reclamation Ditch flows southeast to northwest through agricultural and urban settings, eventually converging with the Tembladero Slough approximately one mile south of the City of Castroville. Downstream of this confluence, the Tembladero Slough flows from east to west and empties into the Old Salinas River Channel at a confluence approximately 1.3 miles upstream of the tide gates on Potrero Rd. Land use adjacent to Tembladero Slough is dominated by agriculture.

The Reclamation Ditch receives inflow from several tributaries: Gabilan Creek, Natividad Creek, Alisal Creek, and the Merritt Lake drainage (Casagrande and Watson 2006). The majority of hydrology for the Reclamation Ditch is derived from agricultural and urban runoff. The Reclamation Ditch is listed as impaired under Section 303d of the Clean Water Act (EPA 2014) due to the following constituents: ammonia (unionized), chloropyrifos, copper, diazinon, Escherichia coli (E. coli), fecal coliform, low DO, nitrate, pesticides, pH, priority organics, sediment toxicity, turbidity, and unknown toxicity.

The Tembladero Slough receives inflow from three waterbodies: the Reclamation Ditch, Santa Rita Creek and Alisal Slough (Casagrande and Watson 2006). The majority of hydrology for the Tembladero Slough is derived from agricultural and urban runoff. The Tembladero Slough is listed as impaired under Section 303d of the Clean Water Act (EPA 2014) due to the following constituents: chlorophyll-a, chloropyrifos, diazinon, enterococus, Escherichia coli (E. coli), fecal coliform, low DO, nitrate, nutrients, pesticides, pH, sediment toxicity, total coliform, turbidity, and unknown toxicity. The Tembladero Slough drains to the Old Salinas River Channel northwest of Molera Rd. Located at this confluence is the Molera Experimental Wetland which uses a pump to divert 0.047 cfs from the Tembladero Slough to circulate through the wetland before and draining back into the Tembladero Slough (Krone-Davis et al. 2013). The Old Salinas River Channel flows from the south to north through agricultural fields and floodplains that abut coastal dunes, eventually connecting with Moss Landing Harbor (Harbor) through the tide gates located at Potrero Rd.

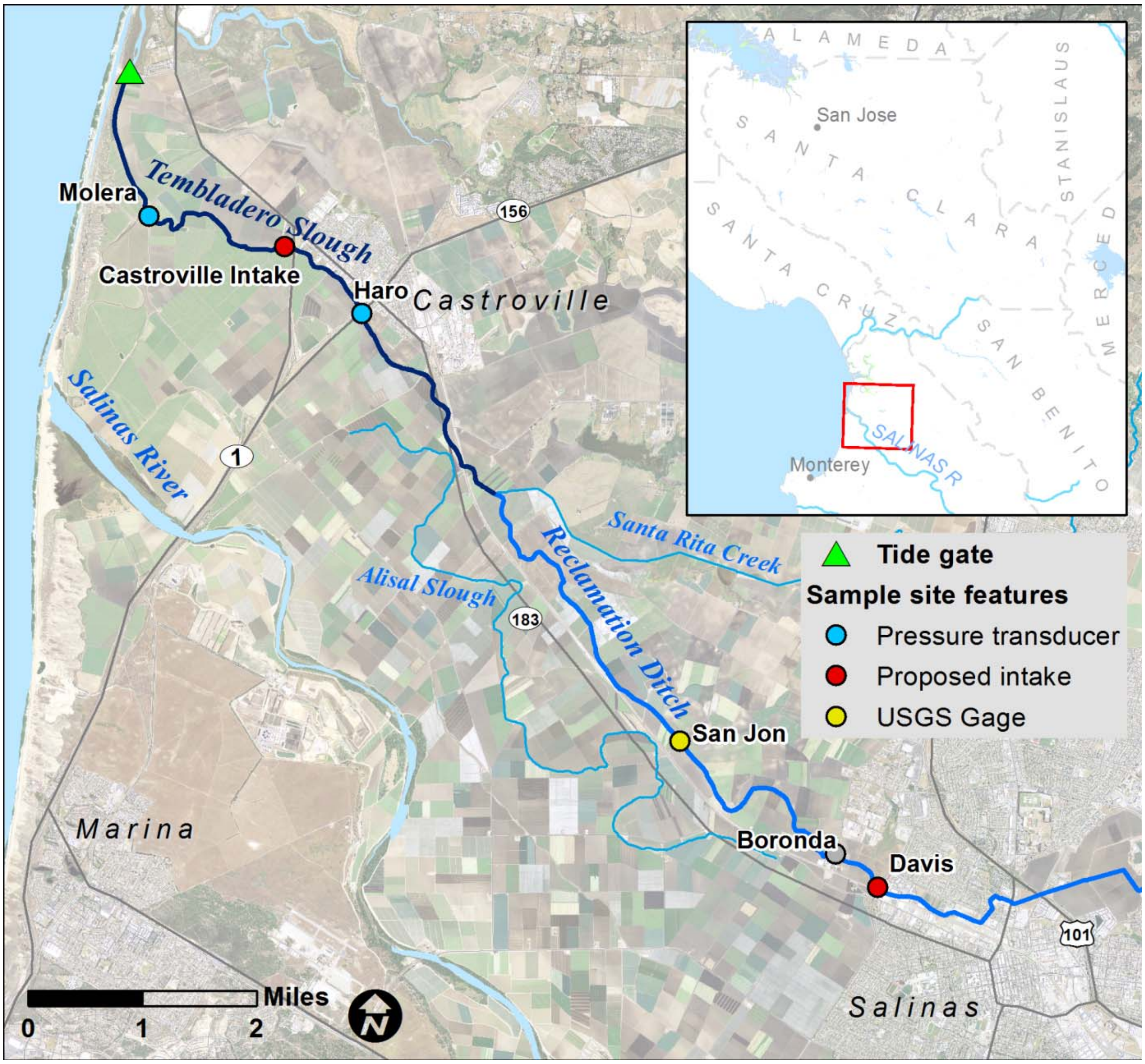

Figure 1: The Reclamation Ditch and Tembladero Slough are two interconnected water bodies within Monterey County, CA that are being evaluated as potential source waters for the Pure Water Monterey GWR project. The Reclamation Ditch drains into Tembladero Slough which is regulated by a tide gate through its hydrologic connection with the Old Salinas River Channel. The Potrero Road tide gates are located on the Old Salinas River Channel where the system drains into the Moss Landing Harbor. We measured water quality and streamflow at six sites, three within Tembladero Slough and three with the Reclamation Ditch, from downstream to upstream the sites are referred to as: Molera Rd., Castroville Intake, Haro St., San Jon Rd., Boronda Rd., and Davis Rd.

The Potrero Rd. tide gates act as a control structure on the Old Salinas River Channel and the downstream reaches of Tembladero Slough. The tide gates are operated by differences in water surface elevations (WSE): when the Old Salinas River Channel WSE is higher than the Harbor WSE the tide gates open, allowing outflow; when Harbor WSE is higher the gates close. The tide gates limit the inflow of seawater, although some seawater does enter the Old Salinas River Channel (Nicol et al. 2010). When the gates are shut they act like a dam, impounding water and building potential energy. When the WSE allows the gates to open, the built up energy is released as the Old Salinas River Channel flows into the Harbor. The interaction between the tides, tide gates, and the Old Salinas River Channel results in a complex system that influences measurements of water quality and streamflow for the Old Salinas River Channel and the lower reaches of the Tembladero Slough.

The Reclamation Ditch, Tembladero Slough, and Old Salinas River Channel are located in the Lower Salinas Valley Watershed (RWQCB-CCR 2010). Casagrande and Watson (2006) identified a collection of sub-watersheds that encompassed the area contributing flow to the Reclamation Ditch, Tembladero Slough and the northern section of the Old Salinas River Channel to the tide gates of Potrero Road. This collection of sub-watersheds is referred to as the Reclamation Ditch Watershed by Casagrande and Watson (2006) and excludes the Salinas River and its connection to the Old Salinas River Channel.

The Reclamation Ditch Watershed as a whole, which includes the Tembladero Slough, the Reclamation Ditch and their contributing water bodies, drains approximately 407 km^2. The land cover of the lower Reclamation Ditch Watershed is characterized primarily by agricultural and urban development (Fig. 2). The upper watershed, which lies along the eastern slope of the Gabilan Range, is characterized primarily by rangeland grazed by livestock; secondary land cover types include montane riparian vegetation, chaparral, oak woodland, annual grassland and perennial grassland (Casagrande and Watson 2006). Area estimates of land cover types were made using the National Oceanic Atmospheric Association (NOAA) 2010 digital coast land cover classification which we reclassified into broader categories based on hydrologic significance (Table 1). Dominant land cover within the Reclamation Ditch Watershed includes, approximately 30% cultivated, 20% grassland, 17% forest, 13% shrub, and 13% developed (NOAA 2010).

The hydrology of the Reclamation Ditch Watershed was characterized by Casagrande and Watson (2006) as being highly episodic, with the typically low streamflow intermittently interrupted by high streamflow events. Sources contributing to the streamflow vary seasonally. Sources include urban runoff, agricultural tile drain water, and permitted discharge in the dry season and stormwater/urban runoff in the wet season (Casagrande and Watson 2006). The upper reaches of the Reclamation Ditch Watershed are dry for most of the year; as the tributaries aggregate into larger ditches near the City of Salinas they are characterized by perennial standing water. The Reclamation Ditch and Tembladero Slough are characterized by perennially flowing water.

A quantitative characterization of the Reclamation Ditch watershed's hydrology follows in the sections below. This analysis was aided by the United States Geologic Service (USGS) stream gage (USGS 11152650) on the Reclamation Ditch at the San Jon Rd. bridge. The stream gage is located 3.4 miles northwest and downstream of the City of Salinas, drains approximately 109.4 mi^2 (283.4 km^2) (Schaaf and Wheeler 1999) and has a period of record from October 1st, 1970 to February 4th, 1986 and from June 1st, 2002 to present. From 1986 to 2002 the USGS gaging site was non-operational; however the Monterey County Water Resources Agency (MCWRA) obtained peak streamflow for the Reclamation Ditch during this period.

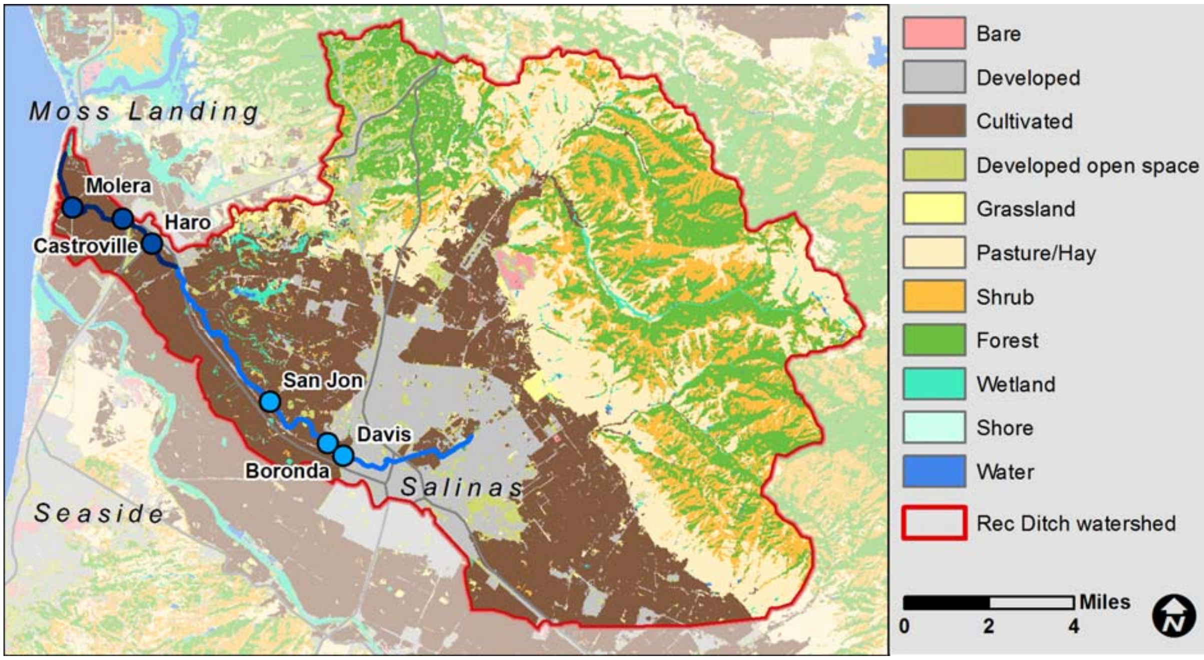

Figure 2: Land cover type within the Reclamation Ditch Watershed from the NOAA digital coast land cover map from 2010. The land cover types directly adjacent to the Reclamation Ditch and Tembladero Slough are cultivated and developed.

Table 1: Land cover type by area within the Reclamation Ditch Watershed tabulated from the NOAA digital coast land cover map from 2010. The primary land cover types in the Reclamation Ditch Watershed are cultivated, grassland, forest, shrubland and developed areas.

NOAA Land cover classification	Reclassified land cover type	Area of Rec Ditch watershed		
		mi^2	km^2	%
Bare Land	Bare	0.5	1.2	0.3
Cultivated	Cultivated	47.6	123.2	30.1
High intensity developed Medium intensity developed Low intensity developed	Developed	20.4	52.9	12.9
Developed open space	Developed open space	5.7	14.9	3.6
Pasture/Hay	Pasture/Hay	1.1	2.9	0.7
Deciduous forest Evergreen forest Mixed forest	Forest	27.5	71.2	17.4
Grassland	Grassland	31.9	82.7	20.2
Scrub/Shrub	Shrub	20.3	52.5	12.9
Unconsolidated shore	Shore	0.0	0.1	0.0
Palustrine forested wetland Palustrine scrub/shrub wetland Palustrine emergent wetland Estuarine forested wetland Estuarine scrub/shrub wetland Estuarine emergent wetland Palustrine aquatic bed Estuarine aqutic bed	Wetland	2.5	6.4	1.6
Water	Water	0.3	0.8	0.2

1.5 Previous Monitoring

Water quality in the Reclamation Ditch Watershed has been monitored and assessed by several local agencies and institutions. Since these assessments include data on many water quality parameters, we only summarized relevant monitoring efforts. The water quality data summarized in this section includes monitoring conducted by the Central Coast Regional Water Quality Control Board (CCRWQCB), Monterey Bay Sanctuary Citizen Watershed Monitoring Network, Central Coast Watershed Studies Team (CcoWS), City of Salinas, University of California Santa Cruz (UCSC), and CSUMB.

The CCRWQCB's Central Coast Ambient Monitoring Program (CCAMP) collects water quality data to protect and enhance water bodies by informing regulatory decision making. Specifically, for the Salinas Valley area the goal of the program was to quantify the pollutant load at several sites to support the development of Total Maximum Daily Load (TMDL) assessments (Worcester et al. 2000). CCAMP has established four sampling sites within our study area, two sites in the Reclamation Ditch and one site in Tembladero Slough: Salinas Reclamation Canal at Airport Rd. (ALU), a storm drain on the Salinas Reclamation Canal Drain at Airport Rd. (AXX), Salinas Reclamation Canal down at Boronda Rd. (ALD), and Tembladero Slough at Preston Rd. (TEM). The program has collected monthly water quality data every five years since 1999. The CCAMP data compiled and reported by Worcester et al. (2000) found that in the Reclamation Ditch DO levels were low, especially in the summer months, and levels of nitrate, ammonia, orthophosphate, chloride, bacteria, heavy metals and pesticides were elevated.

Water quality data from various projects and monitoring efforts are available for download from the California Environmental Data Exchange Network (CEDEN) (2014) website, including: water chemistry, sediment chemistry, water toxicity, sediment toxicity, benthic macro invertebrate, physical habitat, bioaccumulation, tissue chemistry, and marine benthic invertebrate assemblages. Data from CEDEN (2014) included measured TDS from forty grab samples that had been collected from the Molera Rd. site on Tembladero Slough. Measured values for TDS at Molera Rd. varied from 470 mg/L to 9700 mg/L.

The Monterey Bay Sanctuary Citizen Watershed Monitoring Network has measured water quality in Tembladero Slough and the Reclamation Ditch on the second Saturday in May every year since 2006. They measured the following water quality parameters: fecal coliform bacteria, nitrate, phosphate, DO, pH, water temperature and transparency (MBNMS 2013).

In 2006 a CSUMB student analyzed the streamflow and water quality of the Tembladero Slough at Haro St. during the winter of 2005-06 for his senior capstone thesis (Frank 2006). Frank installed a pressure transducer and measured streamflow using a current meter attached to a crane from the Haro St. bridge (2006). To account for the tidal influence Frank (2006) used a 24 hour moving window to successfully decompose the streamflow from tidal influence. Frank (2006) suggested that the influence of the tides and the tide gates on streamflow at Haro St. was also dependent on the volume of discharge. During periods of low flow the tide gates remain closed, reducing the direct influence of the tides. Conversely, during periods of higher flow the tide gates remain open longer leading to a greater direct influence of the tides on Tembladero Slough at Haro St.

The CcoWS group at CSUMB has conducted extensive monitoring of the Reclamation Ditch Watershed. In 2000 Watson et al. (2003) collected suspended sediment, bedload and nutrient samples at three sites within the

Reclamation Ditch (San Jon, Victor Way, Hwy 183) and at Molera Rd. on Tembladero Slough. They found that the Reclamation Ditch Watershed had high sediment loads and sedimentation.

In 2010 the CSUMB ENVS 660 class assessed spatial and vertical patterns in salinity within the Old Salinas River Channel and the lower Tembladero Slough during the month of November (Nicol et al. 2010). The reach of interest for the study extended from the tide gates at Potrero Rd upstream into the Tembladero Slough, just past Molera Rd. Within this reach they took salinity depth profiles every 200 meters to determine the longitudinal salinity profile. Vertical salinity profiles were conducted by taking salinity readings with a YSI 556 Multiprobe System at 25 cm depth increments, from the water surface to the bottom of the channel. During the 2010 study, discharge in the Reclamation Ditch ranged from 0.7 to 3.0 cfs at the San Jon USGS gage during sampling events, except on November 21, 2010 when discharge in the Reclamation Ditch was at approximately 30 cfs. Nicol et al. (2010) observed that salinity generally decreased with increased distance from the tide gates. They noted that within their reach of interest salinity and water depth typically increased with rising tides. They observed that during low tides, when the tide gates opened, salinity in the water column was generally more homogenous. However, not all low tides receded enough to allow the tide gates to open or fully open. Nicol et al. (2010) also observed that WSE changed overtime as a result of the change in pressure on the tide gates. Salinity depth profiles taken at Molera Rd during the course of the 2010 study showed a typically uniform column with salinity values ranging from 0-5 ppt. A halocline was observed at Molera on November 18, during this time salinity was approximately 20 ppt at the bottom of the channel. This observation followed a neap tide which occurred on December 16. Nicol et al. (2010) concluded that spatial and temporal variations of salinity, due in part to the timing and magnitude of the tides existed in the reach of interest.

In 2006 Casagrande and Watson (2006) conducted a watershed assessment for the Reclamation Ditch Watershed. They summarized water quality measurements for ten sites within Tembladero Slough and the Reclamation Ditch using data from CCAMP, the City of Salinas, CcoWS, and UCSC. While this study analyzed and synthesized a number of water quality parameters, we focused on the parameters that were in common with our study. This included temperature, DO, salinity, pH, TDS, and turbidity. Casagrande and Watson (2006) warn that the water quality data should be used as synoptic indicators, since each study summarized had different sampling design and sampling times. Casagrande and Watson (2006) reported the ranges of salinity as 1.03 – 25.95 ppt, 0.6 – 0.88 ppt, and 0.7 – 0.8 ppt for Molera Rd., San Jon Rd., and Boronda Rd. respectively and reported the range of TDS as 2105 – 2190 mg/L, 4.22 – 1231 mg/L, 128 – 745 mg/L for Molera Rd., San Jon Rd., and Boronda Rd. respectively (Appendix F).

Each dataset is limited in terms of comparison and identifying general trends since each project may have a unique sampling design and different period of study.

2 Methods

We conducted field work in the Tembladero Slough and the Reclamation Ditch on five non-consecutive days during the period of November 11th – December 2nd, 2014. Water quality readings were taken with a multi-parameter water quality meter at all six sites within the Reclamation Ditch and Tembladero Slough. Streamflow was measured at five sites on four occasions. In addition, we installed pressure transducers at two locations, Molera Rd. and Haro St, in the Tembladero Slough to collect a time-series of water surface elevation. We analyzed the water quality and streamflow data for spatial and temporal patterns. A detailed field protocol, including a gear list, and methodology of each site can be found in Appendix A. Sections of the field sheets used to collect data can be found in Appendix B.

2.1 Water Quality

We measured seven water quality parameters at six sampling locations in the Tembladero Slough and the Reclamation Ditch: temperature, SC, TDS, salinity, DO, pH, and turbidity.

Using a YSI 556 Multiprobe System (YSI) we recorded temperature, SC, TDS, salinity, DO, and pH. The YSI directly measures four parameters: temperature, SC, DO, and pH. The YSI then calculates values for salinity and TDS. The salinity calculation is based on the specific conductivity and temperature measurements; the TDS calculation is based on the following equation:

$$TDS = cSC$$

Where *TDS* is the total dissolved solids (mg/L), *SC* is the specific conductivity (µS/cm), and *c* is a variable constant. The YSI calculated TDS using a default constant *c*= 0.65. We also calculated TDS by using a constant *c* = 1.50, which was suggested as being more representative of the relationship between SC and TDS within the Reclamation Ditch (Williams 2014).

We took measurements at six sampling locations within the Tembladero Slough (Molera Rd., Castroville Intake, and Haro St.) and the Reclamation Ditch (San Jon Rd., Boronda Rd., and Davis Rd.). At the Molera Rd. and Haro St. sampling locations we sampled water quality using the YSI from the bridges directly over the thalweg of the channel. At San Jon Rd. we sampled from the bank upstream and downstream of a concrete apron under the bridge. At the Castroville Intake, Boronda Rd. and Davis Rd. we took measurements from the banks. Sampling locations are mapped and described in Appendix C and D.

For each site we measured the water quality at the surface of the water column and whenever site conditions allowed we measured the water column at 1 ft (0.3 m) intervals. Depth intervals were measured using markers taped on the YSI cord.

We collected water samples to be analyzed for turbidity at the six sites by sampling water using a DH-48 depth-integrated sampler. Samples were taken from the banks, reaching as far into the channel as possible. Samples were collected by slowly lowering the sampler in the water at a constant rate until it hit the streambed, at which point its direction was reversed upward at the same constant rate until it broke the water's surface. These samples were transported back to the lab, where we analyzed them with a LaMotte 2020 Turbidimeter. The Turbidimeter was calibrated to 0 and 100 nephelometric turbidity units (NTU) and is rated to be accurate within 2% for values under 100 NTU and within 3% for values over 100 NTU.

2.2 Streamflow

We measured streamflow at five sites; streamflow measurements were not taken at the Castroville Intake as there was no reproducible way to measure depth at this site. We measured streamflow using three different methods: surface floats (Molera Rd., Haro Street), pygmy meter (Davis Rd., Boronda Rd.), and by reading the staff plate and consulting the USGS gage rating table (San Jon Rd.). In addition, we installed two pressure transducers in Tembladero Slough to provide a time series of relative water depth during the duration of our study period.

Streamflow at the Molera Rd. and Haro Street sites were measured using the float method as described by the USGS (Turnipseed and Sauer 2010). We used a minimum of 6 orange peels as floats across the width of the channel and applied a coefficient, which is used to convert surface velocity to mean velocity. The coefficient typically ranges from 0.85 to 0.88 for surface floats (Turnipseed and Sauer 2010); we used a coefficient of 0.90. We surveyed the channel using an auto level to determine the cross sectional area at these sites.

The float method consists of two main components: timing floats and measuring stream cross-sectional area. We timed floats by establishing an interval along the bank marked with rebar posts. The USGS requires the floats to be timed for at least 20 seconds. Based on the conditions at each site, we chose an interval to suffice this criterion. We then sequentially threw a minimum of six floats (orange peels) into the stream, attempting to place them at equal intervals across the stream surface. The floats were dispatched upstream of the first post to allow them time to reach stream surface velocity. Finally, we measured the time it took the floats to transverse the interval with a stopwatch.

We determined cross-sectional area by measuring WSE and channel cross-sections. The WSE was determined using a measuring rod from the bridges. Channel cross-sections were measured using an auto-level. A transect tape was stretched across the channel. At regular intervals along this tape, elevation measurements of the stream banks and channels were taken, paying special attention to capturing any breaks in slope. These cross-sectional surveys were conducted at the Molera and Haro Rd. sites on November 18, 2014. The cross-sectional area was used in streamflow calculations.

Streamflow was calculated for the float method according to this equation:

$$Q = cA\frac{d}{t}$$

Where *Q* equals streamflow, *c* is a coefficient to convert surface velocity to mean velocity, *A* is the cross-sectional area of water, *d* is the distance between the cross-sections, and *t* is the travel time between the cross-sections. For the coefficient we used *c* = 0.9.

We used a Gurley Pygmy Current Meter and top setting wading rod to measure streamflow at the Boronda Rd. and Davis Rd. sites. We followed the protocol established by the USGS (Turnipseed and Sauer 2010). Prior to measuring streamflow we conducted a spin test on the current meter to ensure that the instrument was working properly. The spin test requires the pygmy meter to spin in a windless environment for at least 60 seconds.

We took measurements at 15 equally spaced intervals across the wetted channel. Using the top setting wading rod, we placed the pygmy meter at 60% depth at each of the intervals if depth was less than 2.5 ft. and at 20% and 80% depths if depth was greater than 2.5 ft. Pygmy meter revolutions were counted over a 60 second interval. Revolutions were counted visually in clear water; in turbid water, revolutions were counted using headphones.

We calculated streamflow for the pygmy current meter method with the following equation:

$$Q = vA = (0.9604R + 0.0312)A$$

Where *Q* equals streamflow, *A* is the cross-sectional area, *v* is the average velocity of the water column given by the standard rating equation for the pygmy current meter, and *R* is revolutions per second.

We utilized the USGS stream gage to determine the streamflow at San Jon Rd. We read the staff plate and obtained the USGS rating table for the San Jon gage (site 11152650), which is available from: http://waterdata.usgs.gov/nwisweb/get_ratings?site_no=11152650&file_type=exsa

To compare the relative accuracies of our streamflow measurement methods we measured streamflow using both the float and pygmy meter method at the San Jon site and compared the measurements to the USGS gage streamflow on November 25, 2014.

To utilize the historic record of streamflow provided by the USGS gage we analyzed the daily statistics from Water Year 2003 – 2014. We did not include the 1970 – 1986 data, since there was a large gap between the two data sets and because the daily statistics reported by USGS from 1970 – 1986 is the peak daily streamflow, whereas from 2002 – present the average daily streamflow is reported.

We used historical streamflow data from the USGS San Jon gage to develop a 3-tier water year classification scheme: wet, normal, and dry, where wet, normal and dry are defined as:

- Normal water year – average annual streamflow is within one standard deviation of the mean annual streamflow for the period of record.
- Wet water year – average annual streamflow is greater than or equal to one standard deviation above the mean annual streamflow for the period of record.
- Dry water year – average annual streamflow is less than or equal to one standard deviation below the mean.

We also analyzed the streamflow data for the San Jon site from December 2014 and looked for anomalous streamflow that did not coincide with precipitation events or for patterns inconsistent with natural diurnal streamflow fluctuations.

2.3 Pressure Transducers

To determine the tidal influence within the Tembladero Slough we installed Solonists pressure transducers at two locations in the Tembladero Slough, Molera Rd and Haro St. The pressure transducers logged pressure and temperature at 15-minute intervals from November 11 through December 2, and November 13th – December 9th, 2014 at Molera Rd. and Haro St respectively. We determined the amount of pressure exerted by water by subtracting atmospheric pressure as measured by the nearby Moss Landing Heights weather station, and then converted the water pressure into height of the water column above the instrument.

3 Results

Water quality and streamflow data were collected on November 11th, 13th, 18th, 25th and December 2nd, 2014. Data collection at tidally influenced sites on November 11th coincided with a high tide; data collection on November 13th, 18th and December 2nd coincided with low tides[2]; data collection on November 18th occurred between tides. Data collection on December 2nd also coincided with a precipitation event.

3.1 Cross-Section Surveys

Cross-section surveys were conducted to determine cross-sectional area at sampling locations where streamflow was measured using the float method. We determined that Molera Rd. and Haro St. had simple trapezoidal channels (Fig. 3).

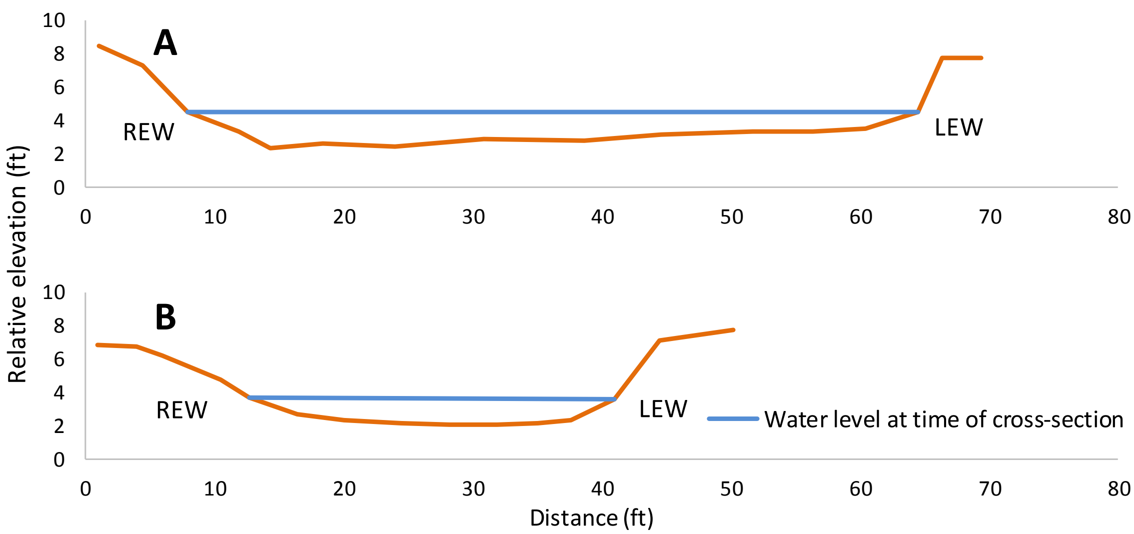

Figure 3. Cross-section profiles of stream channels at (A) Molera Rd. and (B) Haro St. REW and LEW refer to the Right and Left Edge of Water, respectively. WSE is from November 18th, 2014.

3.2 Water Quality

Salinity values varied from 0 to 19.2 ppt. Salinity was generally highest at the Molera Rd. Site (0.3 – 19.2 ppt), lower at the remaining Tembladero Slough sites (0.3 – 1.1 ppt), and lowest at the Reclamation Ditch sites (0 – 0.4 ppt) (Fig. 4-6). Salinity at Castroville Intake ranged from 0.5- 1.1 ppt over the course of our study. No site in the Reclamation Ditch registered a salinity value higher than 0.5 ppt during the course of the study. Spatial differences in salinity were greatest between the Molera Rd. and Castroville Intake sites, with differences in salinity varying up to 6.2 ppt at the water surface (Fig. 7; Appendix E). Salinity stratification was also greatest at the Molera Rd. site, with differences of up to 16.2 ppt between the water surface and the 2 ft. depth interval.

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[2] The tide during which we collected data on the 13th was the higher low tide, i.e. not the lowest tide of the day.

Finally, the precipitation event on December 2nd coincided with relatively low salinity measurements and high turbidity measurements (Table 2). All water quality measurements, including salinity, are reported in Table 2.

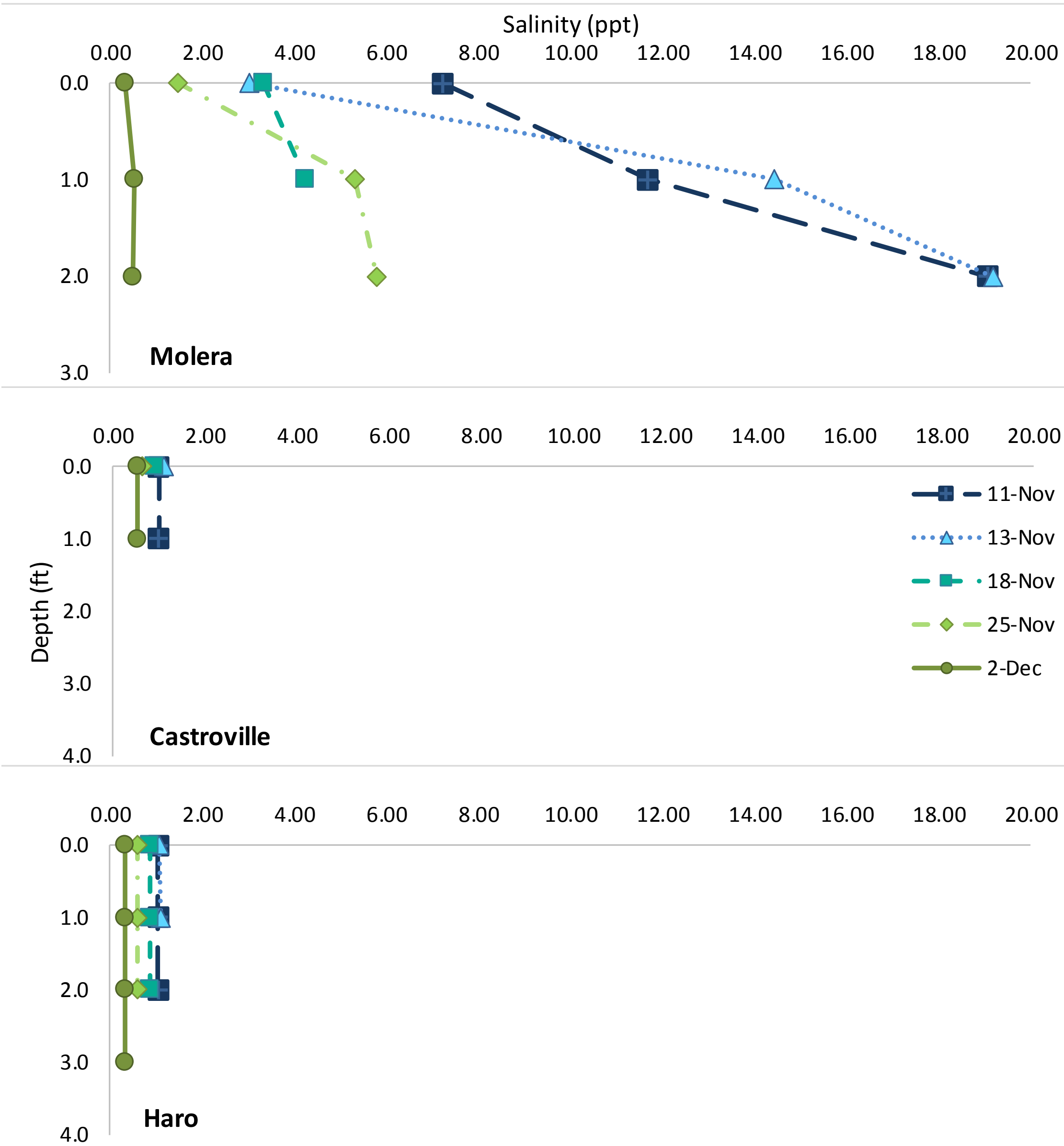

Figure 4: Salinity in the Tembladero Slough with respect to depth. In general, the salinity measurements at the Molera Rd. site were an order of magnitude higher than the other Tembladero Slough sites. Molera Rd. exhibited a strong halocline during three sampling events. Molera Rd. displayed the most variation in salinity by depth on November 13 and the least variation in salinity by depth on December 2nd following a large precipitation event. Castroville and Haro displayed little to no variation in salinity by depth. Salinity values ranged from 0.5 to 1.1 ppt and from 0.3 to 1.1 ppt at Castroville and Haro St. respectively. Castroville and Haro St. had identical salinity values on all sampling events except on December 2nd when salinity was 0.5 at Castroville and 0.3 at Haro St.

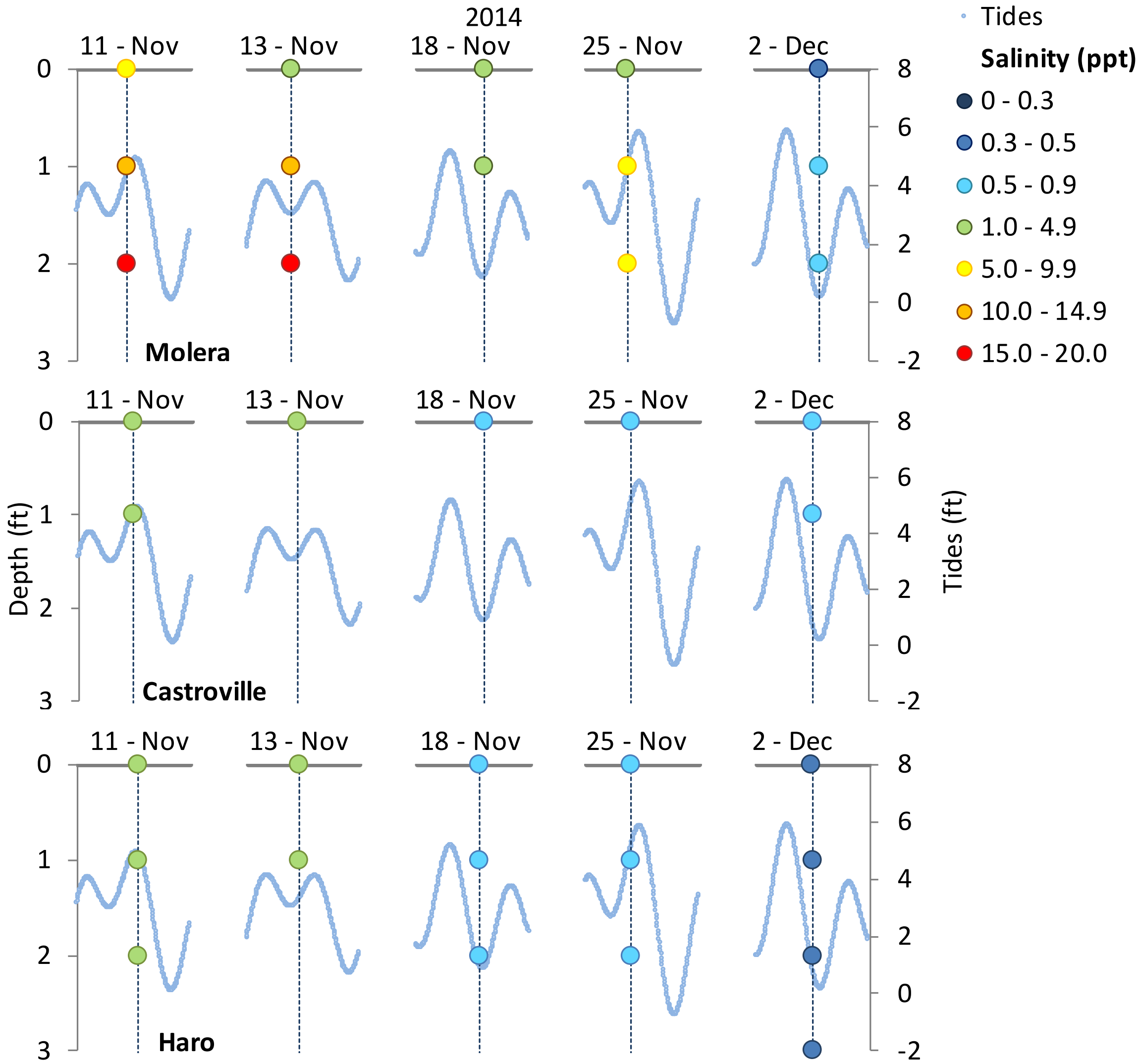

Figure 5: Salinity in the Tembladero Slough with respect to depth and tides. In general, the salinity measurements at the Molera Rd. site were higher than the other Tembladero Slough sites. The tidal influence on salinity and the presence of a halocline is more pronounced at the Molera Rd. site.

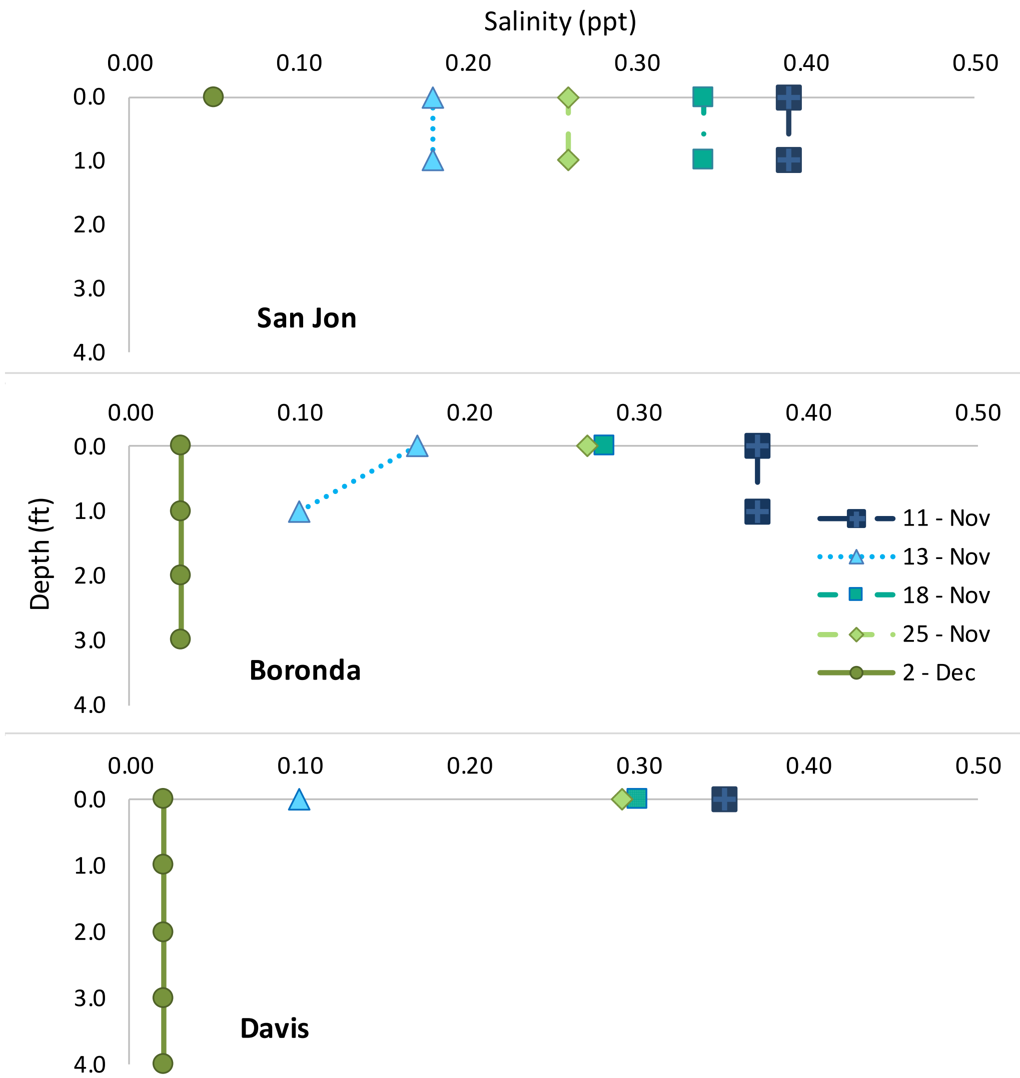

Figure 6: Salinity in the Reclamation Ditch with respect to depth. The San Jon measurements graphed here were all taken above the USGS gage and spillway apron. Due to the episodic nature of the system, water depth varied between sampling events. When water depth allowed, multiple salinity readings were taken at different depths. Little to no variation was seen in salinity with respect to depth at San Jon, Boronda, and Davis. The December 2nd sampling event occurred after a precipitation event. On this date salinity levels were the lowest observed during this study.

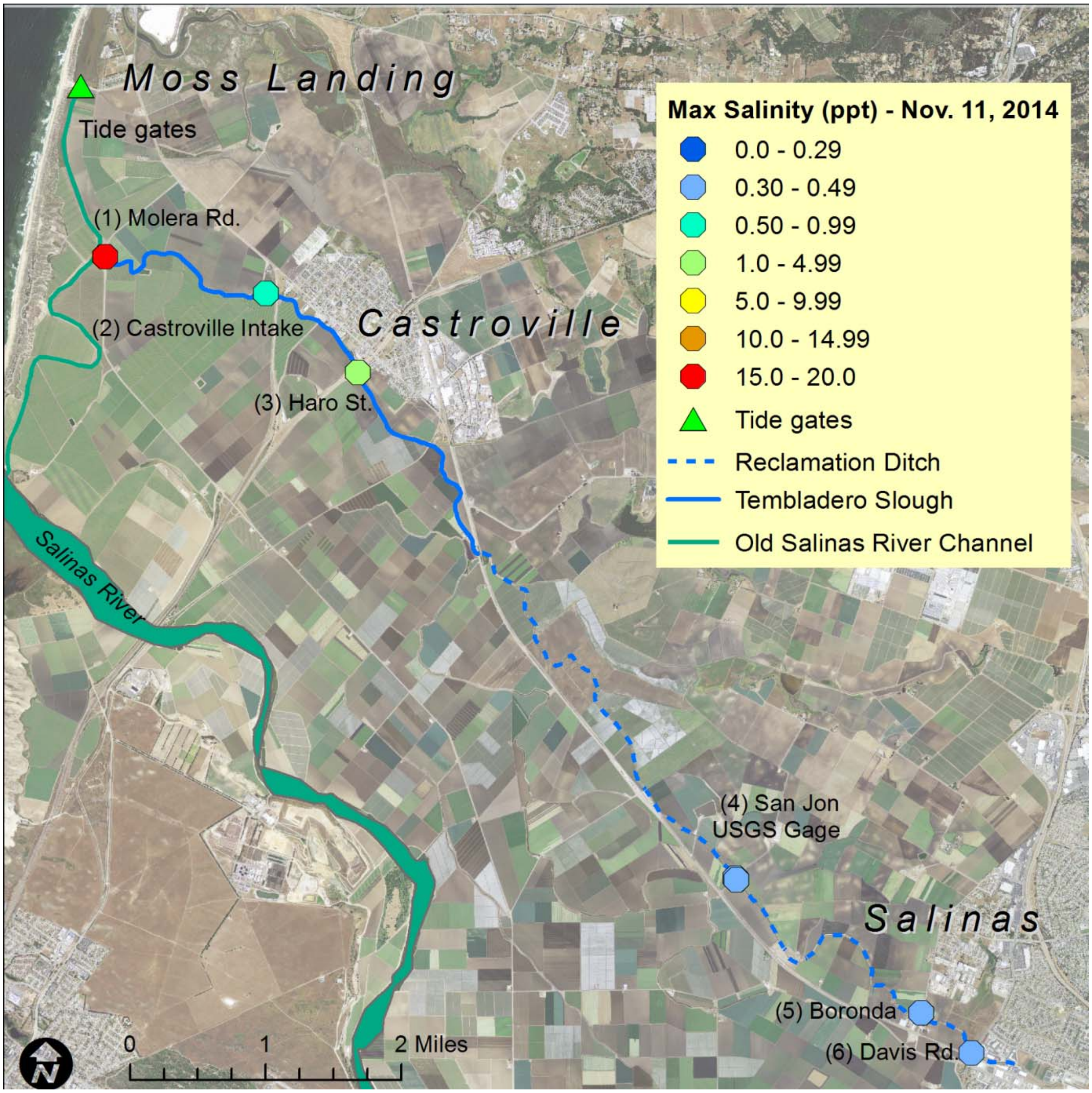

Figure 7: Maximum salinity measured at sampling locations within the Tembladero Slough and Reclamation Ditch on November 11, 2014. As compared with the Reclamation Ditch, Tembladero Slough had higher salinity concentration. This trend was observed for the other sampling days as well. The increase in salinity when comparing the Tembladero Slough to the Reclamation Ditch may be due to a difference in drainage areas associated with the waterways; additionally, salinity at the Molera Rd. location was influenced by the influx of saline water that enters the Old Salinas River Channel through the tide gates.

Table 2: Measured and calculated water quality parameters from the Reclamation Ditch and the Tembladero Slough. **Continued on next page.**

Date	Site	Depth (ft)	Temperature (C)	Temperature (F)	Specific Conductivity (µS/cm)	TDS[1] (mg/L)	TDS[2] (mg/L)	Salinity (ppt)	DO (%)	DO (mg/L)	pH	Turbidity (ntu)	Discharge (cfs)
11-Nov-14	Molera Rd	0	16.67	62.01	12590	8140	18885	7.2	42.6	3.9	7.4	N/A	Non-Detect
		1	16.79	62.22	19670	12800	29505	11.7	39.3	3.6	7.1		
		2	17.04	62.67	30630	19920	45945	19.1	20.4	1.8	11.0		
	Castroville Intake	0	16.31	61.36	1958	1273	2937	1.0	59.0	5.7	7.5	N/A	N/A
		1	16.35	61.43	1955	1269	2933	1.0	57.6	5.6	7.5		
	Haro St	0	16.62	61.92	2027	1318	3041	1.0	49.2	4.8	7.4	N/A	Non-Detect
		1	16.60	61.88	2028	1318	3042	1.0	45.4	4.4	7.4		
		2	16.56	61.81	2030	1319	3045	1.0	44.0	4.3	7.4		
	San Jon Rd (upstream)	0	16.07	60.93	796	517	1194	0.4	80.0	8.1	7.2	N/A	1.10
		1	15.84	60.51	790	519	1185	0.4	73.8	7.2	7.2		
	San Jon Rd (downstream)	0	16.18	61.12	819	533	1229	0.4	98.5	9.6	7.3		
	Boronda Rd	0	16.94	62.49	751	491	1127	0.4	123.8	12.0	7.9	N/A	0.97
		1	16.96	62.53	757	492	1136	0.4	127.6	12.3	7.9		
	Davis Rd	0	16.39	61.50	721	469	1082	0.4	97.6	9.4	7.7	N/A	0.96
13-Nov-14	Molera Rd	0	16.05	60.89	5528	3583	8292	3.0	61.4	5.9	7.3	N/A	24.16
		1	17.05	62.69	23720	15400	35580	14.4	35.1	3.1	7.1		
		2	17.22	63.00	30740	20000	46110	19.2	24.5	2.1	7.0		
	Castroville Intake	0	15.95	60.71	2183	1419	3275	1.1	73.0	7.1	7.5	N/A	N/A
	Haro St	0	15.44	59.79	2084	1354	3126	1.1	75.1	7.4	7.5	N/A	6.89
		1	15.41	59.74	2110	1372	3165	1.1	72.1	7.2	7.5		
	San Jon Rd (upstream)	0	15.69	60.24	376	245	564	0.2	95.8	9.5	7.4	N/A	19.00
		1	15.70	60.26	375	244	563	0.2	94.2	9.3	7.2		
	San Jon Rd (downstream)	0	15.74	60.33	370	240	555	0.2	100.7	10.0	7.0		
		1	15.75	60.35	370	240	555	0.2	101.5	10.1	7.0		
	Boronda Rd	0	16.02	60.84	345	224	518	0.2	94.5	9.3	7.1	N/A	6.03
		1	16.70	62.06	215	139	323	0.1	92.3	9.0	6.8		
	Davis Rd	0	16.69	62.04	224	144	336	0.1	91.2	8.9	6.9	N/A	7.03
18-Nov-14	Molera Rd	0	15.33	59.59	6098	3962	9147	3.3	62.0	6.1	7.3	55	26.20
		1	15.25	59.45	7586	4980	11379	4.2	57.0	5.6	7.3		
	Castroville Intake	0	14.12	57.42	1775	1154	2663	0.9	53.3	5.4	7.2	60	N/A
	Haro St	0	13.38	56.08	1708	1110	2562	0.9	86.4	9.0	7.2	21	6.75
		1	13.22	55.80	1707	1110	2561	0.9	81.2	8.4	7.2		
		2	13.21	55.78	1711	1112	2567	0.9	76.0	7.9	7.2		
	San Jon Rd (upstream)	0	11.50	52.70	695	452	1043	0.3	97.1	10.4	7.2	16	1.50
		1	11.49	52.68	695	452	1043	0.3	88.5	9.6	7.0		
	San Jon Rd (downstream)	0	11.60	52.88	698	454	1047	0.3	101.5	11.1	7.2		
	Boronda Rd	0	11.56	52.81	579	376	869	0.3	98.4	10.7	7.0	33	1.22
	Davis Rd	0	11.04	51.87	606	394	909	0.3	96.2	10.6	6.8	27	1.24
25-Nov-14	Molera Rd	0	9.82	49.68	2832	1841	4248	1.5	72.5	8.1	7.0	65	23.69
		1	11.40	52.52	9440	6132	14160	5.3	50.2	5.3	7.2		
		2	11.68	53.02	10200	6638	15300	5.8	46.0	4.8	7.3		
	Castroville Intake	0	11.24	52.23	1277	829	1916	0.6	69.2	7.7	7.2	40	N/A
	Haro St	0	9.26	48.67	1161	754	1742	0.6	84.3	9.6	7.2	45	2.99
		1	9.14	48.45	1154	750	1731	0.6	80.9	9.3	7.2		
		2	9.21	48.58	1153	749	1730	0.6	79.6	9.1	7.2		
	San Jon Rd (upstream)	0	9.25	48.65	538	350	807	0.3	98.9	11.3	7.1	50	2.40
		1	9.25	48.65	539	351	809	0.3	94.7	10.9	7.1		
	San Jon Rd (downstream)	0	9.36	48.85	538	351	807	0.3	109.7	12.5	7.2		
	Boronda Rd	0	10.82	51.48	549	357	824	0.3	106.0	11.7	7.5	90	1.58
	Davis Rd	0	13.02	55.44	588	382	882	0.3	138.0	14.5	7.5	120	1.86

*** High flows prevented measuring water quality at depth.**

[1] Total dissolved solids calculated with a 0.65 constant

[2] Total dissolved solids calculated with a 1.5 constant (Williams 2014)

Table 2: continued from previous page

Date	Site	Depth (ft)	Temperature (C)	(F)	Specific Conductivity (µS/cm)	TDS[1] (mg/L)	TDS[2] (mg/L)	Salinity (ppt)	DO (%)	DO (mg/L)	pH	Turbidity (ntu)	Discharge (cfs)
2-Dec-14*	Molera Rd	0	14.20	57.56	1048.0	685	1572	0.3	111.6	11.3	7.2	450	159.75
		1	14.22	57.60	1042.0	679	1563	0.5	97.5	9.9	7.0		
		2	14.22	57.60	1040.0	671	1560	0.5	95.2	9.7	7.0		
	Castroville Intake	0	13.78	56.80	1073.0	697	1610	0.5	103.0	10.6	6.9	450	N/A
		1	13.78	56.80	1078.0	701	1617	0.5	98.2	10.1	6.9		
	Haro St	0	13.87	56.97	674.0	438	1011	0.3	92.6	9.5	6.7	1000	141.02
		1	13.89	57.00	658.0	428	987	0.3	91.1	9.4	6.7		
		2	13.89	57.00	654.0	425	981	0.3	91.6	9.4	6.8		
		3	13.90	57.02	647.0	420	971	0.3	90.3	9.3	6.8		
	San Jon Rd (upstream)	0	14.18	57.52	103.0	82	155	0.1	115.4	11.8	6.5	400	149.00
	San Jon Rd (downstream)	0	14.20	57.56	103.0	75	155	0.1	117.2	12.0	6.5		
	Boronda Rd	0	14.11	57.40	63.0	41	95	0.0	113.9	11.7	6.1	700	N/A
		1	14.14	57.45	72.0	37	108	0.0	116.0	11.9	6.3		
		2	14.15	57.47	65.0	43	98	0.0	119.8	12.3	6.5		
		3	14.16	57.49	61.0	42	92	0.0	120.4	12.4	6.5		
	Davis Rd	0	14.01	57.22	51.0	33	77	0.0	91.8	9.5	6.5	130	N/A
		1	14.02	57.24	51.0	33	77	0.0	122.6	12.7	6.0		
		2	14.02	57.24	48.0	32	72	0.0	127.5	13.1	6.0		
		3	14.03	57.25	48.0	31	72	0.0	126.8	13.1	6.0		
		4	14.02	57.24	47.0	27	71	0.0	126.7	13.1	6.0		

*** High flows prevented measuring water quality at depth.**

[1] Total dissolved solids calculated with a 0.65 constant

[2] Total dissolved solids calculated with a 1.5 constant (Williams 2014)

3.3 Streamflow

Streamflow measurements varied from 0.96 cfs at Davis Rd. on November 11th to 159.75 cfs at Molera Rd on December 2nd. Streamflow generally decreased moving upstream except on November 11th and December 2nd when flows at San Jon Rd. were higher than discharge measured at Haro St. Additionally, streamflow at Molera Rd. was not detectable on November 11th, during a high tide when the tide gates likely were closed.

In general flows were very low because 2014 was a record dry year, with only three precipitation events in September and October. However, the precipitation event on October 31- November 1 produced over 1 in of rain. Two precipitation events, on November 13th and December 2nd, produced noticeable runoff. On those days the streamflow at San Jon Rd. site was measured to be 19.00 and 149.00 cfs, while the streamflow at the site immediately downstream, Haro St., was only 6.89 and 141.02 cfs. Streamflow at the most upstream site, Davis Rd., varied between 0.96 and 7.03 cfs[3] (Fig. 8).

[3] On December 2nd streamflow was not measured due to high flow, implying that streamflow can dramatically exceed the maximum measured value.

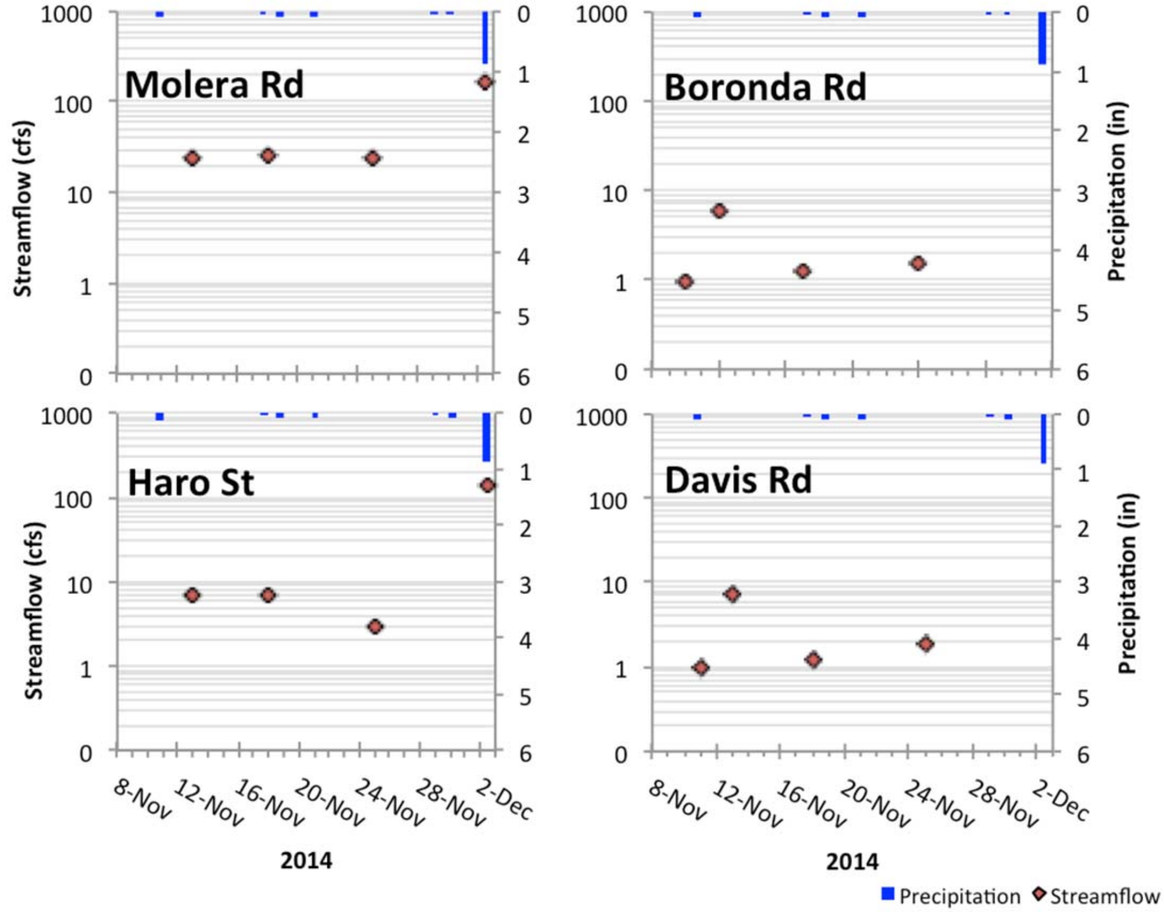

Figure 8: Streamflow measurements plotted on a log scale. Streamflow data was collected using the float method at Molera Rd. and Haro St. and using a Gurley Pygmy Current Meter at Boronda and Davis Rd. during five nonconsecutive sampling events from Nov. – Dec. 2014. Streamflow at Molera Rd ranged from 23 – 26 cfs during sampling events between Nov. 13- 25 and increased to 160 cfs on Dec. 2nd due to a precipitation event. Streamflow at Haro St. ranged from 3 – 7 cfs during sampling events between Nov. 13- 25 and increased to 141 cfs on Dec. 2nd. Streamflow at Molera Rd and Haro St was undetectable during the sampling event on Nov. 11 due to the high tide. Streamflow ranged from 0.9 – 7 cfs at both Boronda and Davis Rd. during sampling events between Nov. 11 – 25th. Streamflow was too high to safely measure at these sites on Dec. 2nd. Precipitation data was obtained from the Salinas Airport weather station.

We assessed the relative accuracy of our methods at the San Jon site. We assumed that the USGS staff plate and rating table would give the most accurate measurement of streamflow. At that time, the USGS rating table indicted a streamflow of 2.40 cfs, which was consistent with the instantaneous flow listed on the website at that time. Using the float method, we measured a streamflow of 2.66 cfs; using the pygmy meter method, we measured a streamflow of 2.06 cfs.

Historically, the annual average streamflow for 2003 – 2014 ranged from a maximum of 19.1 cfs in 2005 to a minimum of 3.3cfs in 2014. The mean annual average streamflow was 10.23 cfs (Fig. 9). The annual peak streamflow from water year 2003 – 2014 ranged from 418 cfs in 2013, to 150 cfs in 2007 (Fig. 10). A summary of the average daily streamflow and total water year precipitation can be found in Table 3. Peak flow at the San Jon site for this period generally coincided with precipitation events, though some peak flows do not correlate with recorded precipitation (Fig. 11).

Table 3: Summary of average daily streamflow, total precipitation and water year type by water year for 2003 – 2014. A 3-tier classification system was developed using the mean and standard deviation for the 2003 – 2014 period of record. Data sources: USGS, Western Regional Climate Center.

Water Year (WY)	WY Type	Reclamation Ditch at San Jon Average Daily Streamflow (cfs)	Total WY Precipitation (in)
2003	normal	7.1	7.1
2004	normal	8.9	10.0
2005	wet	19.1	19.7
2006	wet	16.9	15.3
2007	normal	6.2	8.9
2008	normal	7.8	8.9
2009	normal	8.3	11.4
2010	normal	14.9	16.9
2011	wet	16.2	15.6
2012	normal	6.5	10.4
2013	normal	7.4	9.0
2014	dry	3.3	5.9

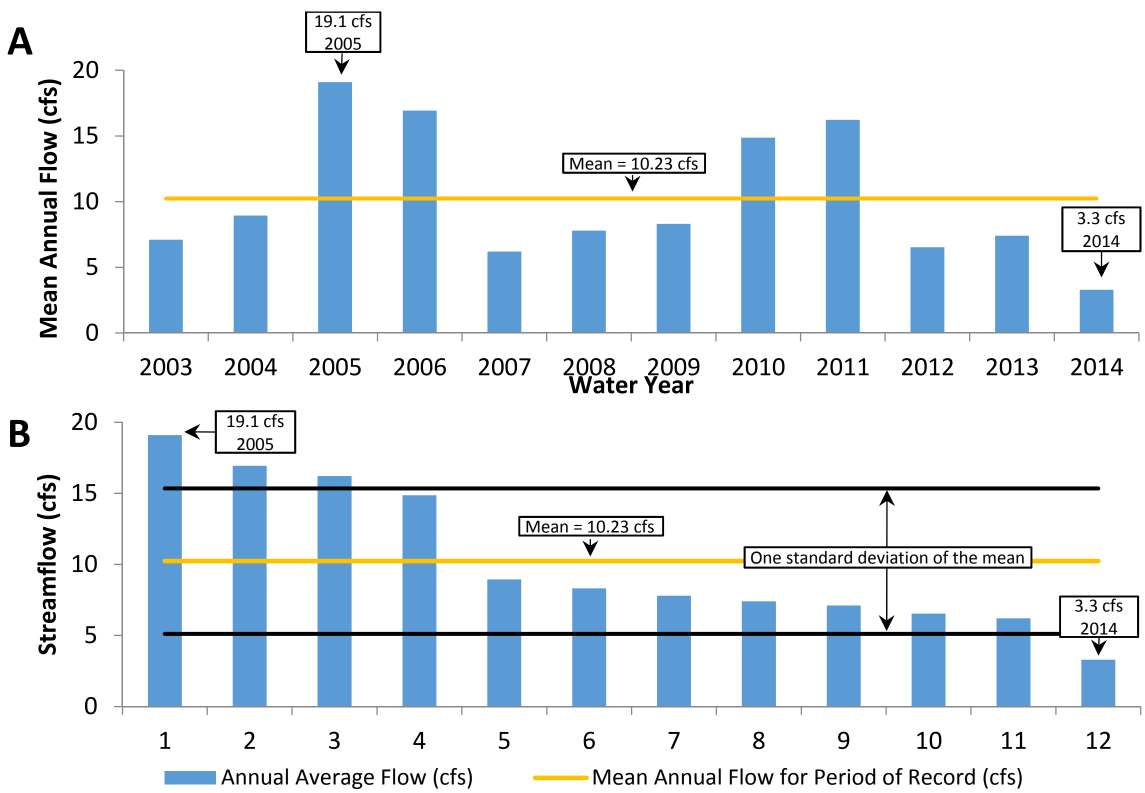

Figure 9: Mean annual flow for the USGS San Jon Rd. gage at (A) the Reclamation Ditch: by Water Year 2003 - 2014, and (B) ranked by Water Year 2003 -2014.

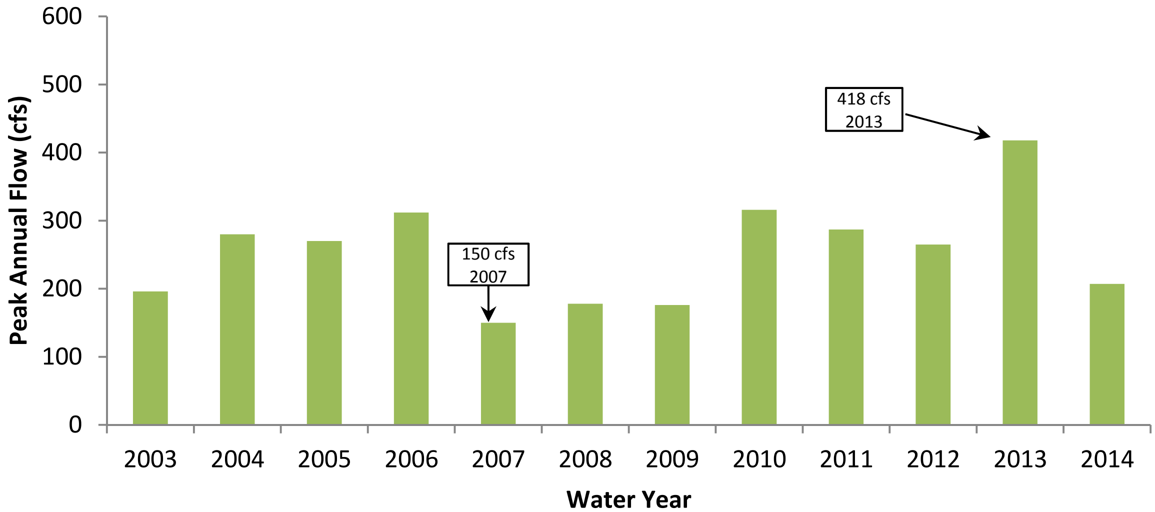

Figure 10: Peak annual streamflow at the USGS gage at San Jon Rd. for water years 2003 – 2014.

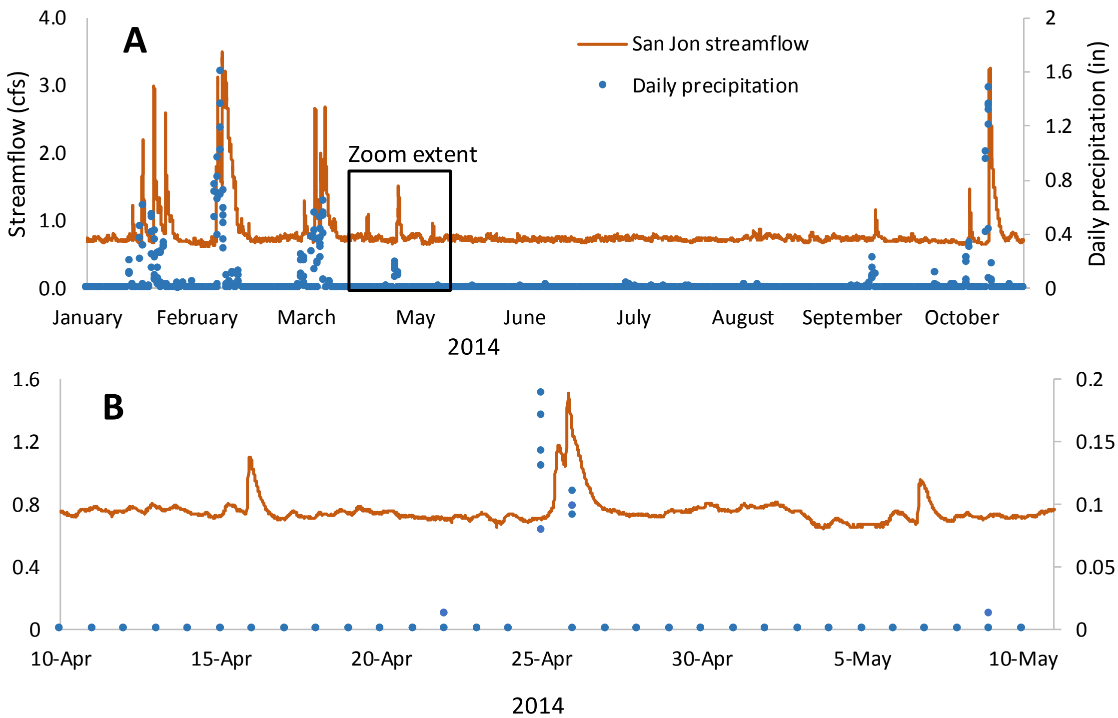

Figure 11: Streamflow measured by USGS at San Jon and daily precipitation throughout the Reclamation Ditch watershed. Precipitation measurements came from the Western Weather groups Radio Ridge weather station located in the Gabalin range and summaries of daily precipitation provided by NOAA. The NOAA daily summaries were from four rain gages in Salinas and two located in Castroville. Major peaks in streamflow were almost uniformly associated with precipitation events (A). Two peaks that do not seem to be the result of precipitation occurred in April and May (B). Natural diurnal fluctuations may produce gradual changes in discharge.

3.4 Pressure Transducers

Water levels (as measured using pressure transducers) at the Tembladero Slough sites rise and fall in rhythms synchronized with the tide (Fig. 12). This synchronization is more regular at Molera Rd. than at Haro St. (Fig 13). A dramatic rise in water level was recorded on December 2nd at Haro St., coinciding with the precipitation event.

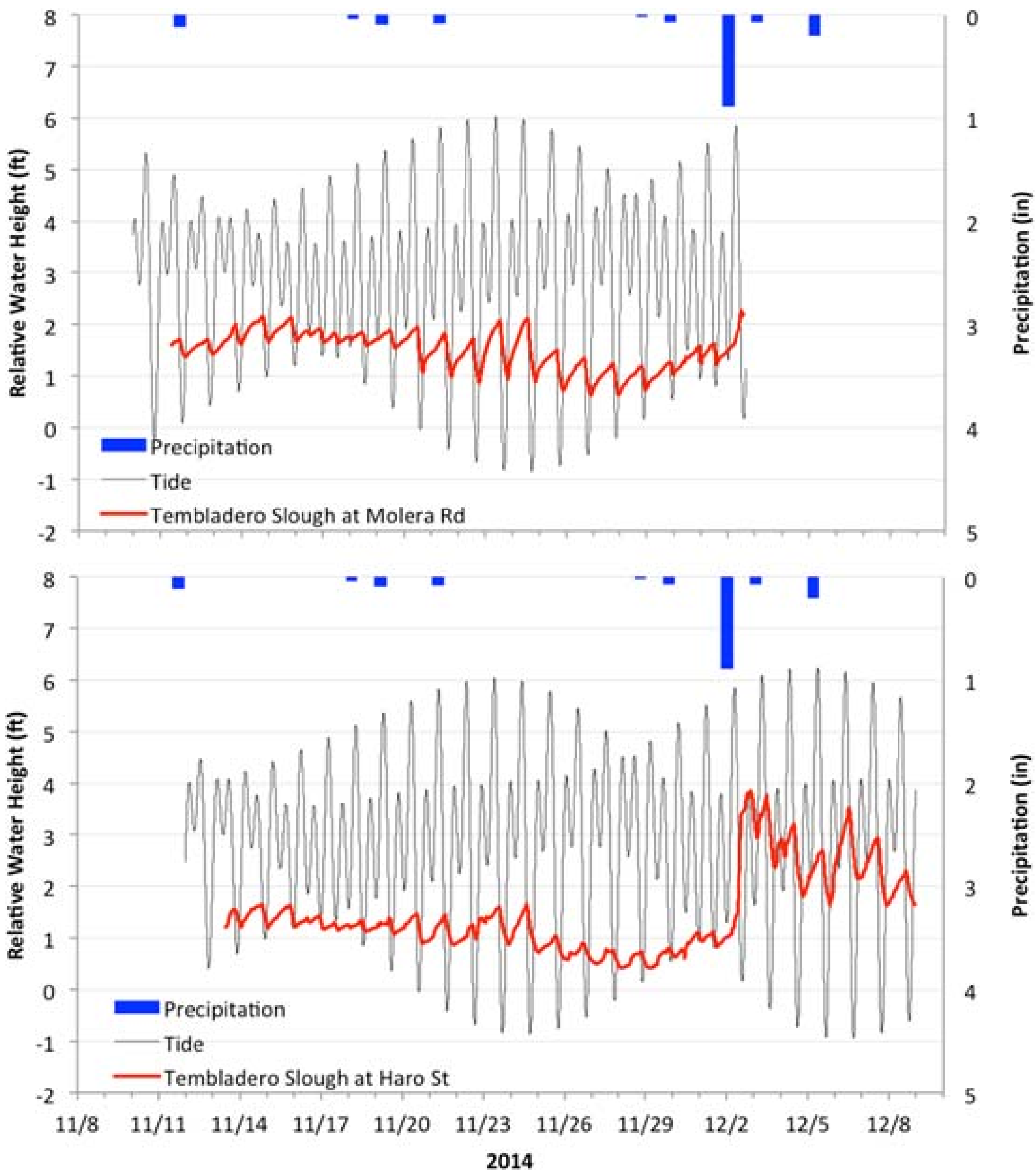

Figure 12: Graph of tidal data, water pressure, and precipitation at Molera Rd. (A) and Haro St. (B). The tidal data was obtained from the Monterey Harbor. The water pressure was obtained from a pressure transducer, which denotes the relative change in water height. The precipitation data was obtained from the Salinas Airport weather station.

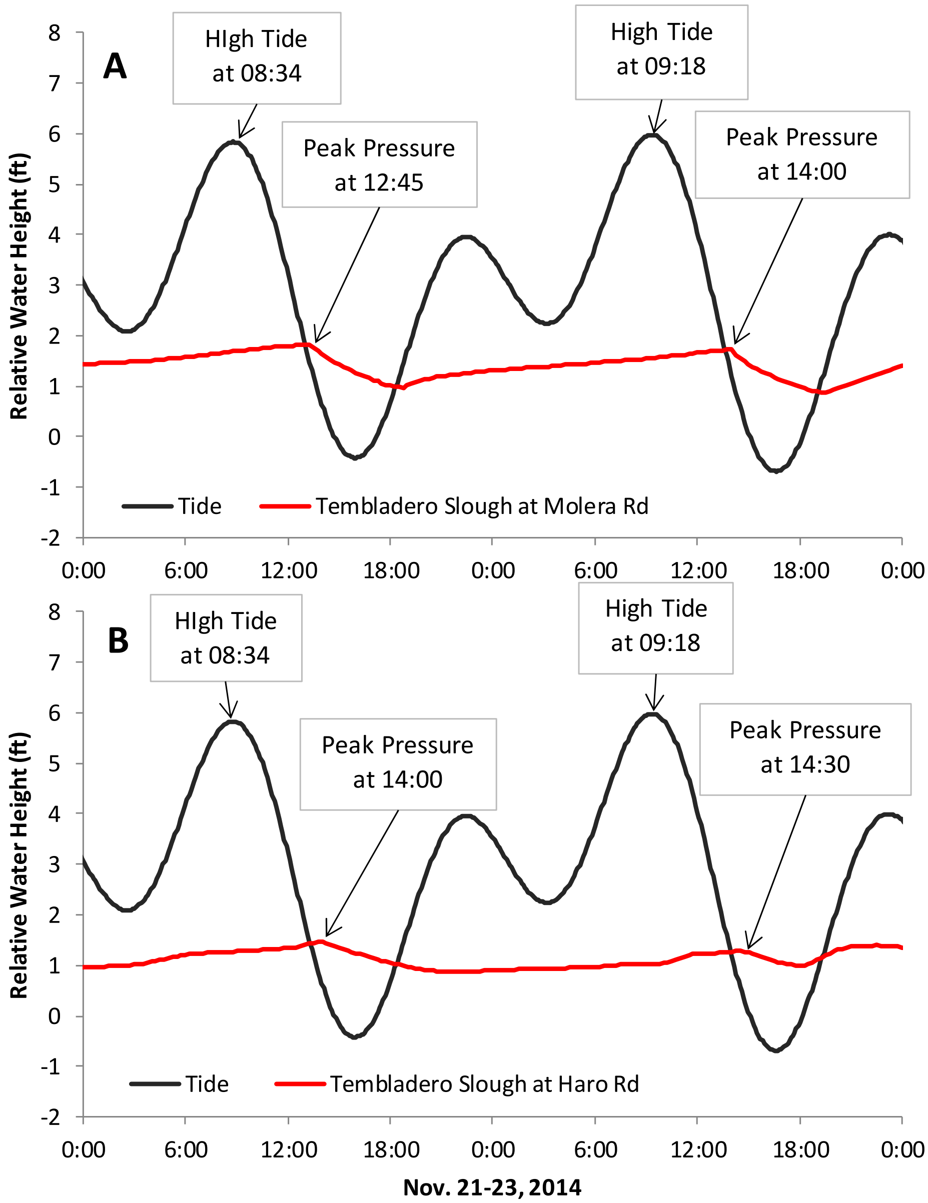

Figure 13: A comparison of tidal influence on the relative water height in Tembladero Slough at Molera Rd. (A) and Haro St. (B) from Nov. 21- 23, 2014. During this time the pressure transducer at Molera Rd. recorded the peak water height 2 hours and 57 minutes after the high tide on Nov. 21, and 4 hours 42 minutes after the high tide on Nov. 22. There was generally a smaller lag time between the low tide and the recorded water height at Molera Rd. The pressure transducer recorded minimum pressure 2 hr 36 min after the low tide on Nov. 21, and 2 hr 54 min after the low tide on Nov. 22. At Haro St the pressure transducer recorded peak pressure 5 hr 26 min after high tide on Nov, 21, and 5 hr. and 12 min after high tide on Nov. 12. The minimum pressure at Haro St. was not as pronounced as it was at Molera Rd. The lag time between high tide and peak pressure was longer at Haro St., which is consistent with the longer distance to the ocean. The tidal data is from the Monterey Harbor and water pressure from pressure transducers in Tembladero Slough at Molera Rd. and Haro St.

4 Discussion

We established sampling methodologies for six site locations, to measure streamflow and water quality at each site, to develop a nascent dataset of these measurements within the Reclamation Ditch and Tembladero Slough.

Our streamflow data provided evidence that the hydrology of the Tembladero Slough is complex, and influenced by several factors including precipitation, changes in tides, and agricultural inputs. Measured streamflow at the Molera Rd. site was generally greater than that at Haro St., despite there being no major tributaries between the two sites. While it is possible that the increase in streamflow between Molera Rd. and Haro St. could be due to agricultural inputs between the sites, it is more likely that this is an artifact of the tidal influences on the site.

Tidal influence at the Molera Rd. site has major implications for the streamflow measurements taken there. Streamflow at Molera Rd. was sometimes not detectable during the high tide, when the downstream tide gates were closed. Conversely, streamflow measurements may have been exaggerated during low tides due to the release of water when the tide gates open. Discharge measurements for this location were taken at incoming tides and low tides. It is therefore uncertain if the streamflow measurements taken at the Molera Rd. site are representative of actual streamflow.

The data collected from the pressure transducers increased our understanding of the extent and magnitude of the tidal influence on Tembladero Slough. At both the Molera Rd. and Haro St. sites there were clear increases and decreases in water surface elevation with the high and low tides (Fig. 12 and 13). Additionally, the pressure transducer data showed a lag time between the peaks and troughs of the tide and the peak and trough of the water surface elevation in the Tembladero Slough sites. We found that the water surface elevation at these sites did not fall in response to the higher low tide on many of the days within our period of study, which suggests that this may be due to the tide gates at the mouth of Old Salinas River. A higher low tide may not drop below the threshold needed for the tide gates to allow water to drain from the Tembladero Slough.

Additionally, during the precipitation event on December 2nd we found a discrepancy in the streamflow between sampling locations. On December 2nd we collected samples starting at the upstream most site and working downstream. We measured streamflow at the San Jon Rd. site at the peak of the hydrograph, as suggested by the USGS San Jon gage. Streamflow at the next downstream site, Haro St., had lower streamflow, suggesting that the storm runoff had not yet reached this point. At the most downstream site, Molera Rd., the measured streamflow was equivalent to that measured at San Jon Rd. This discrepancy may be explained by tide dynamics that may have been confounding the streamflow measurement.

We analyzed the streamflow record at the San Jon gage maintained by the USGS to identify increases in streamflow unrelated to precipitation events. In general for the 2014 calendar year all of the peak streamflow events were correlated with precipitation events as measured by four weather stations in Salinas, two in Castroville, and a weather station near Fremont Peak. There were two small peaks that did not correlate with any precipitation events (one in April and one May). It is possible that several factors could have accounted for this increase such as: firefighting activities which may have increased urban runoff, a precipitation event that was not recorded by any gages, or agricultural tile drainage. Urban runoff during this time period could have been higher because these events were preceded by precipitation which could have saturated the soils, or the long drought could possibly result in hydrophobic soils, thereby increasing runoff. The San Jon gage data also indicated that the Reclamation Ditch exhibits diurnal patterns common in western evapotranspiration dominated streams, which results in smooth oscillations in streamflow magnitude (Lundquist and Cayan 2002). The irregular changes in streamflow in Fig. 11 are most likely the result of uncharacterized urban runoff.

In terms of water quality at the most downstream site, Molera Rd., we found strong evidence for a halocline with increasing salinity with depth. The increased salinity at depth can be explained by the intrusion of saline water from the Monterey Bay during high tide. However, the salinity at Molera Rd. was not stratified on all of our sampling days; on December 2nd during the precipitation event the salinity concentrations were homogenous throughout the water column. This suggests that the increase streamflow from precipitation can prevent the influx of saline water. At the Tembladero Slough sites upstream of Molera Rd., Castroville Intake and Haro St., we observed that the salinity was homogenous with depth, suggesting that the saline waters do not intrude that far upstream. The Reclamation Ditch sampling sites exhibited generally lower levels of salinity than the Tembladero Slough sampling locations. The increase in salinity in Tembladero Slough may be due to a difference in drainage areas associated with the waterways; additionally, salinity at the Molera Rd. location was influenced by the influx of saline water that enters the Old Salinas River Channel and Tembladero Slough, through the tide gates. The increase in salinity from the influx of saline water was not observed at the Castroville Intake and Haro St. on the Tembladero Slough.

We collected a limited number of turbidity samples. While the sample size was not large enough to make generalizations about turbidity within the Reclamation Ditch and Tembladero Slough, we did find that the turbidity levels during the December 2nd precipitation event, were up to ten times higher at all six of the sampling site locations.

The following factors should be considered while interpreting the results:

- sampling design,
- sample size,
- timeframe, and
- environmental factors.

The sampling design of the study was based on availability of materials, student availability, accessibility of sampling site location, and the limited timeframe. These limitations to the sampling design may have biased our streamflow and water quality data.

The availability of materials limited the equipment used to measure water quality and streamflow. For water quality we used the YSI which only has four sensors (DO, temperature, SC and pH) and calculates TDS and salinity. Since TDS and salinity were not directly measured we were limited in our ability to compare with other data sources. TDS values obtained through calculations were considered to be a rough estimate of TDS values as the relationship between EC and TDS can vary.

The deeper, slower moving water at the Tembladero Slough sites allowed for more accurate salinity measurements. Conversely, measurements at The Reclamation Ditch sites on December 2nd, were complicated by high water velocities. The rapidly moving water pulled at the YSI sensor, creating an angle between the water surface and the sensor's cord. This made it difficult to precisely estimate one foot depth intervals. The low salinity measurements during this period indicate that the deleterious effects of the increased water velocity may have been negligible. The samples taken on December 2nd support the idea that precipitation can dilute the water in the Reclamation Ditch and Tembladero Slough, resulting in a measurable reduction in salinity, even at the Molera Rd. site.

The streamflow results should be interpreted in the context of the methods used to measure it. In terms of measuring flow, we were limited to using a pygmy meter with a 5-foot top-setting rod and floats. We used three different methods for measuring streamflow, biasing the comparability of results between sites. We assumed that the USGS staff plate reading and rating table would give the most accurate measurement of streamflow. We implemented all three methods at the San Jon site at the same time and found discrepancies between both the pygmy meter and the float method with the USGS rating table. This one time measurement and the results could be explained by chance rather than the overall performance of the equipment.

Given the limitations of the available equipment, the float method was most appropriate for measurements of streamflow at the Tembladero Slough sites. The large size of the waterbody, as well as the soft channel substrate, and slow water velocities, made using the pygmy meter impractical. We did not collect any streamflow measurements at the Castroville Intake site because of the limited ability to reproduce a depth measurement.

The most appropriate equipment to measure streamflow at the Reclamation Ditch sampling sites was the pygmy meter (excluding the San Jon Rd. site). These sites were small enough so that the pygmy meter could easily and safely be used. However, during the precipitation event on December 2, streamflow at the Davis Rd. and Boronda Rd. sites was too high to be safely measured.

Several environmental factors may have influenced our results. At the time of the study, California was in the third year of a drought. Historically, there is an average of 13.3 inches of precipitation per year at the Salinas Airport weather station. In the 2013 calendar year, there were 3.3 inches of precipitation; while from January 1, 2014 to October 31, 2014 there have been 6.2 inches of precipitation (WRCC 2014). Aside from an obvious reduction in streamflow, Chessman and Robinson (1987) have found that drought can affect water quality and streamflow, including increases in electro conductivity and decreases in DO. The current meteorological conditions indicate that winter 2014-15 may be a more normal water year, given the series of precipitation events preceding, and during, the period of study (Fig. 7; Fig. 12). Additionally, the large precipitation event on December 2nd (Salinas Airport weather station recorded 0.9 in) affected our ability to collect data.

The timeframe of the study also biased the streamflow and water quality data. The measurements were limited to the month of November 2014, biasing the data toward the seasonal and meteorological conditions of November. Additionally, the short duration of the study produced a small sample size. A complete characterization of the area's hydrology would require a longer timeframe. At minimum, the timeframe should span a full year, and ideally, would be extended capture the average, above-average, and below-average precipitation years.

4.1 Previous Monitoring

The majority of our collected water quality data was consistent with that reported by Casagrande and Watson (2006). We compared water quality data at sites common between the two studies, which included Molera Rd, San Jon Rd, Boronda Rd, and Davis Rd. We measured temperature data below Casagrande and Watson's minimum reported values at Molera Rd. and San Jon Rd. on a number of sample days (Table 2; Appendix F). In addition, on December 2nd a number of our recorded water quality parameters, such as salinity, pH, and TDS were lower than the minimums reported by Casagrande and Watson. Similarly, turbidity was higher at a number of sites on this day as well. We also recorded lower salinity at San Jon Rd and Bornonda Rd. As Casagrande and

Watson (2006) noted, the timing and method of data collection could account for a number of the discrepancies between the datasets.

The results of our study are comparable to the findings of Nicol et al. (2010), the CSUMB ENVS 660 class study in 2010. While the only sampling location in common between the two studies was the Molera sampling location, both studies found that in general, salinity decreased with distance from the Potrero tide gates. In our study, Molera Rd was the site nearest the tide gates and exhibited the largest range of salinity readings with salinity exceeding 19 ppt at the bottom of the channel on two occasions. Nicol et al. (2010) looked at the Tembladero Slough in 2010 which was a wet year. We sampled the same stream after a record dry period and found more instances of haloclines at Molera Rd over the course of our study. Additionally, we measured a surface salinity of 7.2 ppt on November 11th at Molera Rd, while salinity never exceeded 5 ppt at the water's surface for the same site during the 2010 study. Both Studies used a YSI 556 Multiprobe System. We found that while the tides and tide gates had an influence on the WSE elevation at Molera Rd and Haro St., salinity readings at the Castroville Intake and Haro St. never exceeded 1.1 ppt over the course of the study. In the 2010 study, staff plate readings indicated that the influence of the tides and tide gates on WSE was delayed and reduced with distance from the tide gates. The diminishing influence of the tide and tide gates with distance is supported by the pressure transducer data collected over the course of this study which indicated that tidal influence on WSE lagged and dampened with distance from the ocean (Fig. 12).

Similar to the study by Frank (2006) we found that streamflow at Molera Rd. and Haro St. is partially regulated by the tides and the tide gates. Frank (2006) suggests that it is possible to decompose the tidal influence to determine the streamflow at these sites. We did not attempt to account for the tidal influence in our measures of streamflow. Discharge values reported in Table 2 reflect the conditions at the sampling sites during sampling events.

4.2 Future Research

To build a more comprehensive understanding of the spatial and temporal patterns in streamflow and water quality in this system we suggest:

- Developing a rating equation that incorporates the tidal influence on the Tembladero Slough.
- Continuing field measurements throughout the water year to provide a more detailed profile of streamflow and water quality over longer timeframes.
- Collecting time series of measurements over the course of a day to build off previous studies to better understand the diurnal patterns in streamflow and water quality.
- The use of suspended sediment samples as they could provide more detailed information about the amount of sediment transported, which is an important consideration for cost and energy in treating source waters for irrigation or drinking.
- Developing methodology for measuring streamflow that is applicable at all sample sites in order to build a more comprehensive and unified streamflow dataset.
- Characterizing the sources of the inputs into the Reclamation Ditch could help develop a more comprehensive understanding of the Reclamation Ditch.

5 Conclusion

We assessed water quality parameters at six sampling sites, and streamflow at five sampling sites within the Tembladero Slough and the Reclamation Ditch from November through December 2014. We established sampling sites and methodologies, which included three different methods of measuring streamflow depending upon the site. The pressure transducer data indicated that the streamflow and WSE in Tembladero Slough at Molera Rd. and Haro St are influenced in part by the tide and tide gates. Additionally, salinity measurements at Molera Rd. indicate that salinity is influenced in part by the tide/tide gates and precipitation. Within the Reclamation Ditch the salinity measurements were less than 0.5 ppt during all sampling events. Continued data collection would aid in characterizing these water bodies throughout the year. The data collected within this study will be useful for informing future monitoring efforts and planning the Pure Water Monterey GWR Project.

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Appendix A – Field Protocol

Gear

- Field Vests
- Gloves
- Hand sanitizer
- Flagging
- Transect tape
- Waders
- Stopwatch
- Pygmy Meter
- Head phones
- Top-setting wading rod
- Oranges
- Rebar (3 -4)
- Mallet
- Shovel
- Stadia rod
- YSI (older one with longer cord)
- Sample bottles (6)
- DH-48
- Datasheets
- Clipboard
- rite in the rain paper if raining
- Cross sections
    - Auto level
    - Stadia rod for auto level
    - Tripod
    - Bucket lid
    - Duct tape

Site 1: Tembladero Slough at Molera Rd. Bridge

Streamflow Measurement

Flow measurement will be taken using the float method.

1. Locate rebar on the left bank downstream of the bridge.
2. Set-up two rebar about 10 ft. upstream and downstream of the installed rebar.
3. Test the flow: Throw and orange peel in upstream of the rebar and time how long it takes to float the distance between the two rebar. The time needs to be greater than 20 seconds. If it is not at least 20 seconds increase the distance between the rebar until the float takes minimally 20 seconds.
4. Measure and write down the distance between the two rebar.
5. Throw floats (orange peels) into the stream upstream of the first rebar. Ideally, the float should be far enough upstream to reach the velocity of the stream by the time it reaches the first rebar. At least 6 floats should be used at approximately equal spacing across the width of the channel.
6. Time each float and write down the time as well as the respective location within the channel.
7. It is possible that the stream will not have a large enough velocity to carry the floats. If they float upstream or do not seem to depict a typically flow then make a note of the stream condition and what you saw. This will be considered a flow below detectable limits.
8. Read the staff plate on the upstream side of the bride. If the staff plate is not connected to the water dig a channel that connects them. If the water is below the staff take a measurement from the bottom of the staff plate to the surface of the water.

Water Quality

1. Set-up the YSI for field measurements (connect cable to YSI, take off the transport cup, and put the probe sensor guard, ensure that the tape on the cable is located at 1 ft intervals).
2. Take measurements from the downstream side of the bridge, approximately 15 ft from the right edge of the bridge (looking downstream).
3. Dangle YSI probe over the edge of the bridge and take measurements at 1 ft intervals (starting with a surface measurements) until the sensor reaches the bottom of the channel.
4. For each measurement wait until the readings become stable and do not fluctuate.
5. Write down the number on the sample bottle
6. Attach the sample bottle to the DH-48
7. From the banks reach as far into the channel as possible, with the nozzle pointing upstream, and lower the DH-48 to the bottom of the channel and back up at an even, constant rate.
8. Cap and store the water sample to bring back to the lab.

Site 2: Tembladero Slough at Wastewater Treatment Building

Streamflow Measurement

No streamflow measurement will be taken at this site.

Water Quality

1. Take measurements from the bank right bank reaching as far into the channel as possible.
2. Take measurements at 1 ft intervals starting with a surface measurement, until the probe sensor guard reaches the bottom of the channel.
3. For each measurement wait until the readings become stable and do not fluctuate.
4. Write down the number on the sample bottle
5. Attach the sample bottle to the DH-48
6. From the banks reach as far into the channel as possible, with the nozzle pointing upstream, and lower the DH-48 to the bottom of the channel and back up at an even, constant rate.
7. Cap and store the water sample to bring back to the lab.

Site 3: Tembladero Slough at Haro Street Bridge

Streamflow Measurement

Flow measurement will be taken using the float method.

1. Locate site with even, laminar flow upstream of Bridge.
2. Set-up two rebar (approximately 20 ft apart)
3. Test the flow: Throw and orange peel in upstream of the rebar and time how long it takes to float the distance between the two rebar. The time needs to be greater than 20 seconds. If it is not at least 20 seconds increase the distance between the rebar until the float takes minimally 20 seconds.
4. Measure and write down the distance between the two rebar.
5. Throw floats (orange peels) into the stream upstream of the first rebar. Ideally, the float should be far enough upstream to reach the velocity of the stream by the time it reaches the first rebar. At least 6 floats should be used at approximately equal spacing across the width of the channel.
6. Time each float and write down the time as well as the respective location within the channel.
7. It is possible that the stream will not have a large enough velocity to carry the floats. If they float upstream or do not seem to depict a typically flow then make a note of the stream condition and what you saw. This will be considered a flow below detectable limits.
8. Take a depth measurement: From the upstream side of the bridge in line with the fourth beam (that holds the railing) from the left bank, dangle the stadia rod over the edge of the bridge approximately 15 ft from the right edge of the bridge looking downstream. Let the stadia rod rest on the bottom of the channel, but do not push it into the mud. Have someone on the bank read the depth of the water.

Water Quality

1. Take measurements from the downstream side of the bridge, approximately 25 ft from the right edge of the bridge (looking downstream).

2. Dangle YSI probe over the edge of the bridge and take measurements at 1 ft intervals (starting with a surface measurements) until the sensor reaches the bottom of the channel.
3. For each measurement wait until the readings become stable and do not fluctuate.
   4. Write down the number on the sample bottle
   5. Attach the sample bottle to the DH-48
   6. From the banks reach as far into the channel as possible, with the nozzle pointing upstream, and lower the DH-48 to the bottom of the channel and back up at an even, constant rate.
   7. Cap and store the water sample to bring back to the lab.

Site 4: Reclamation Ditch at San Jon Rd.
Streamflow Measurement
Read the staff plate under the bridge. Look up the associated streamflow from the USGS site, comparing the listed rating table, as well as the instantaneous flow:
http://waterdata.usgs.gov/nwis/uv?cb_00060=on&cb_00065=on&format=gif_default&period=31&site_no=11152650
Water Quality
1. Take measurements at two locations:
a. Downstream of bridge just after riffle
b. Upstream of the bridge at the edge of the concrete apron
2. Take measurements at 1 ft intervals starting with a surface measurement, until the probe sensor guard reaches the bottom of the channel.
3. For each measurement wait until the readings become stable and do not fluctuate.
   4. Write down the number on the sample bottle
   5. Attach the sample bottle to the DH-48
   6. From the banks reach as far into the channel as possible, with the nozzle pointing upstream, and lower the DH-48 to the bottom of the channel and back up at an even, constant rate.
   7. Cap and store the water sample to bring back to the lab.

Site 5: Reclamation Ditch at Boronda Rd.
Streamflow Measurement
Flow measurement will be taken using a pygmy meter
* If water level is high and it is unsafe to wade into water take a measurement using the float method and take a depth measurement at a reproducible location (See above protocol)
1. Locate site with even, laminar flow downstream of Bridge.
2. Set-up two rebar on either side of channel perpendicular to the flow of water.
3. String transect tape between rebar (ensure tape is taught)
4. Set up Pygmy meter (including a 60 second spin test)
5. Measure LEW and REW and take flow measurements at a minimum of 15 intervals.
6. Use data sheet to calculate streamflow and complete a field calculation to ensure the streamflow seems reasonable
7. Pack up pygmy meter and ensure it is clean.

Water Quality
1. Take measurements in the channel just downstream of bridge.
2. Take measurements at 1 ft intervals starting with a surface measurement, until the probe sensor guard reaches the bottom of the channel.
3. For each measurement wait until the readings become stable and do not fluctuate.
   4. Write down the number on the sample bottle
   5. Attach the sample bottle to the DH-48
   6. From the banks reach as far into the channel as possible, with the nozzle pointing upstream, and lower the DH-48 to the bottom of the channel and back up at an even, constant rate.
   7. Cap and store the water sample to bring back to the lab.

Site 6: Reclamation Ditch at Davis Rd.
Streamflow Measurement

Flow measurement will be taken using a pygmy meter
* If water level is high and it is unsafe to wade into water take a measurement using the float method and take a depth measurement at a reproducible location (See above protocol)

8. Locate site with even, laminar flow downstream of Bridge.
9. Set-up two rebar on either side of channel perpendicular to the flow of water.
10. String transect tape between rebar (ensure tape is taught)
11. Set up Pygmy meter (including a 60 second spin test)
12. Measure LEW and REW and take flow measurements at a minimum of 15 intervals.
13. Use data sheet to calculate streamflow and complete a field calculation to ensure the streamflow seems reasonable
14. Pack up pygmy meter and ensure it is clean.

Water Quality

1. Take measurements in the channel just downstream of bridge and downstream of the riffle.
2. Take measurements at 1 ft intervals starting with a surface measurement, until the probe sensor guard reaches the bottom of the channel.
3. For each measurement wait until the readings become stable and do not fluctuate.
4. Write down the number on the sample bottle
5. Attach the sample bottle to the DH-48
6. From the banks reach as far into the channel as possible, with the nozzle pointing upstream, and lower the DH-48 to the bottom of the channel and back up at an even, constant rate.
7. Cap and store the water sample to bring back to the lab.

Post-Field Work

YSI

To pack away YSI disconnect the cable from the YSI meter. Take off the probe sensor guard. Rinse probe sensor guard and probe sensors with **TAP** water. Put a small amount of **TAP** water in the bottom of the transportation cup (enough to keep moisture in the cup, but not enough to submerge the sensors). The Sensors should always be stored in the transportation cup.

Pygmy Meter

The pygmy meter should be rinsed with tap water and should always be transported with the transport screw in (gold). Ensure the pygmy meter has been rinsed. It can be left in the case with the lid open in the lab- so that it can be fully dried before being packed away.

Gear

All gear should be rinsed under the spigot outside of building 53 (a multi-tool is needed to turn water on and off) before being brought in the lab. All mud should be rinsed off and all gear rinsed off. Lab equipment should be put away in in its respective location after each use. Dry gear if necessary before putting it away

Water Samples

Water samples should be analyzed in the lab after returning from field work. Samples should be stored in the refrigerator.
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Appendix B – Field Sheet Examples

Date:	Weather:
Time:	Observers:

		Site 1				Site 2				Site 3
		Molera @ Bridge								
Vertical	Temperature		°C	**Vertical**	Temperature		°C	**Vertical**	Temperature	
	Sp. Conduct		mS/m		Sp. Conduct		mS/m		Sp. Conduct	
Depth	TDS		g/L	**Depth**	TDS		g/L	**Depth**	TDS	
	Salinity		ppt		Salinity		ppt		Salinity	
Time	Dis. Oxygen		%	**Time**	Dis. Oxygen		%	**Time**	Dis. Oxygen	
	Dis. Oxygen		mg/L		Dis. Oxygen		mg/L		Dis. Oxygen	
	pH				pH				pH	
Vertical	Temperature		°C	**Vertical**	Temperature		°C	**Vertical**	Temperature	
	Sp. Conduct		mS/m		Sp. Conduct		mS/m		Sp. Conduct	
Depth	TDS		g/L	**Depth**	TDS		g/L	**Depth**	TDS	
	Salinity		ppt		Salinity		ppt		Salinity	
Time	Dis. Oxygen		%	**Time**	Dis. Oxygen		%	**Time**	Dis. Oxygen	
	Dis. Oxygen		mg/L		Dis. Oxygen		mg/L		Dis. Oxygen	
	pH				pH				pH	
Vertical	Temperature		°C	**Vertical**	Temperature		°C	**Vertical**	Temperature	
	Sp. Conduct		mS/m		Sp. Conduct		mS/m		Sp. Conduct	
Depth	TDS		g/L	**Depth**	TDS		g/L	**Depth**	TDS	
	Salinity		ppt		Salinity		ppt		Salinity	
Time	Dis. Oxygen		%	**Time**	Dis. Oxygen		%	**Time**	Dis. Oxygen	
	Dis. Oxygen		mg/L		Dis. Oxygen		mg/L		Dis. Oxygen	
	pH				pH				pH	

CSUMB ENVS 660 Discharge Measurement Form

Procedures

Method: 0.6 0.2/0.8 Float USGS Staff Plate
Meter type: pygmy orange peel other
Spin test:
Measurement rated: Excellent (±2%) Good (±5%)
Fair (±8) Poor ( )

Stage Observations

Time	Staff	Location/Initials
__________	____________	__________________________
__________	____________	__________________________

Float Measurement

Time	Float	Distance (ft)	Time (sec)	Velocity	Area (ft^2)	Discharge (cfs)

Data Download

File saved as:____________________________________
____
Time removed:___________ Time launched:___________

Flow Computations

Flow: Date: Initials:

Notes

Conditions and Observations

Weather conditions:______________________ Date:__________________ Time:_____________
_________________________________ Observers:________________________________

	Time	Height (ft)
High tide	_________	__________
Low tide	_________	__________

Stream:________________________________
Site:__________________________________
Measurement at: ________________________
____
____

Hydrograph: Rising Falling
Uncertain Baseflow

	Time	Sta. (ft)	Width (ft)	Flow depth (ft)	Obs. Depth (ft)	Meter		Velocity	EW Adj.	Area (ft^2)	Discharge (cfs)
						rev	sec				
LEW											
7											
15											
20											
25											

Appendix C – Sample Site Locations

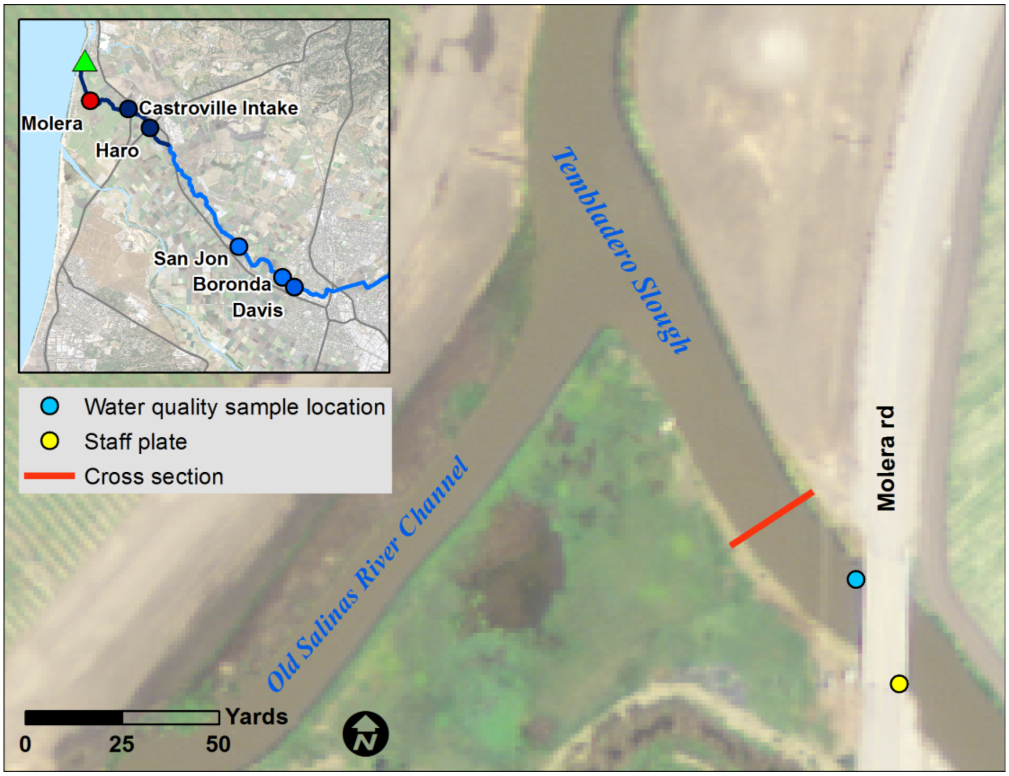

Figure C1: Site map for the Molera Rd. sample site. The staff plate is located under the bridge on the south east side. Streamflow measurements were taken downstream of the observed turbulence from the Molera Rd. bridge, and upstream of the confluence with the Old Salinas River Channel.

Figure C2: Molera Rd. sample site. Water quality measurements were taken by lowering the YSI from the bridge into the water on the left side of the image.

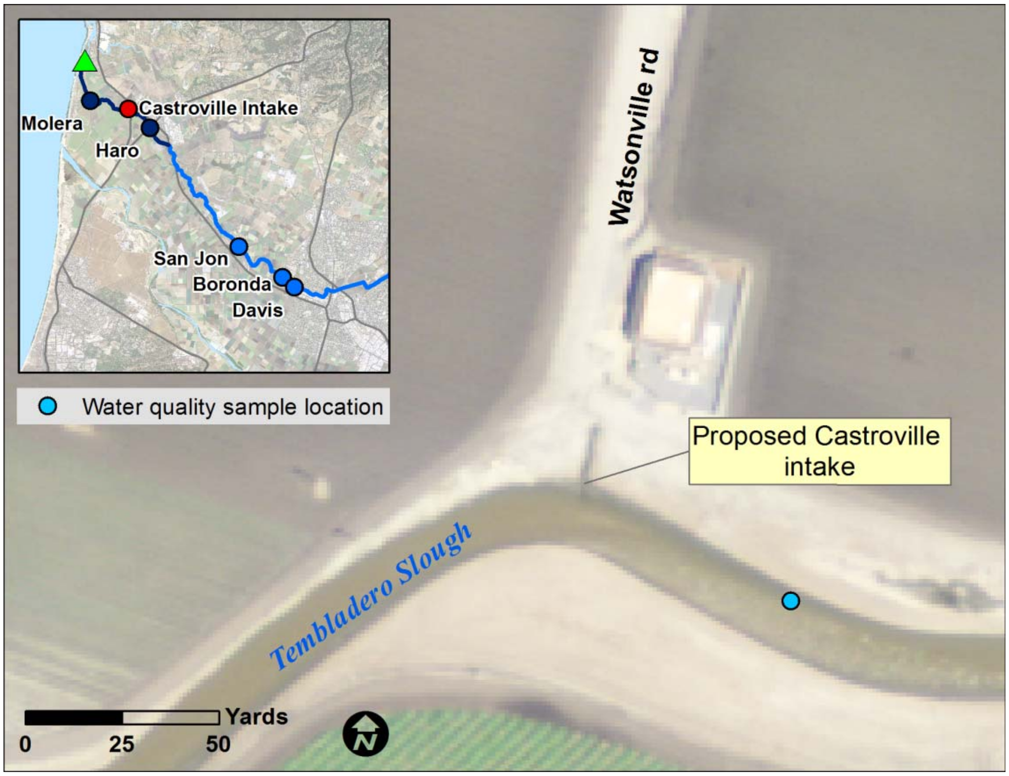

Figure C3: Map for the Castroville Intake sample site. Water quality measurements at the Castroville site were taken from the bank. We observed that at this location the slough had a trapezoidal cross section with a flat uniform bottom with no obvious thalweg for taking measurements. The lack of a stable structure to take consistent depth measurements prevented us from collecting streamflow data.

Figure C4: Castroville Intake sample site.

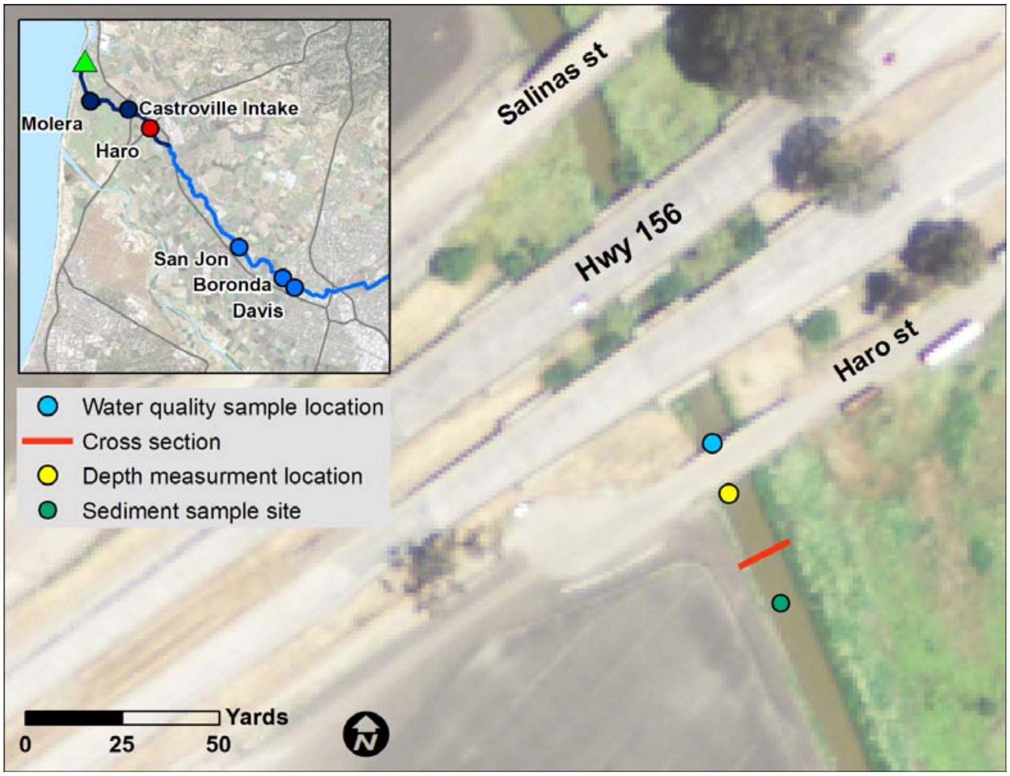

Figure C5: Map for the Haro St. sample site. Sediment samples were taken off the end of the tile drain located south of the Haro St. bridge. Depth measurements were taken off the bridge by lowering a stadia rod into the water and reading the depth from the bank. All measurements were relative and tied to the cross section.

Figure C6: Haro St. bridge at the Haro St. sample site. Depth measurements were taken from the bridge at the second visible railing support from the left edge of the image.

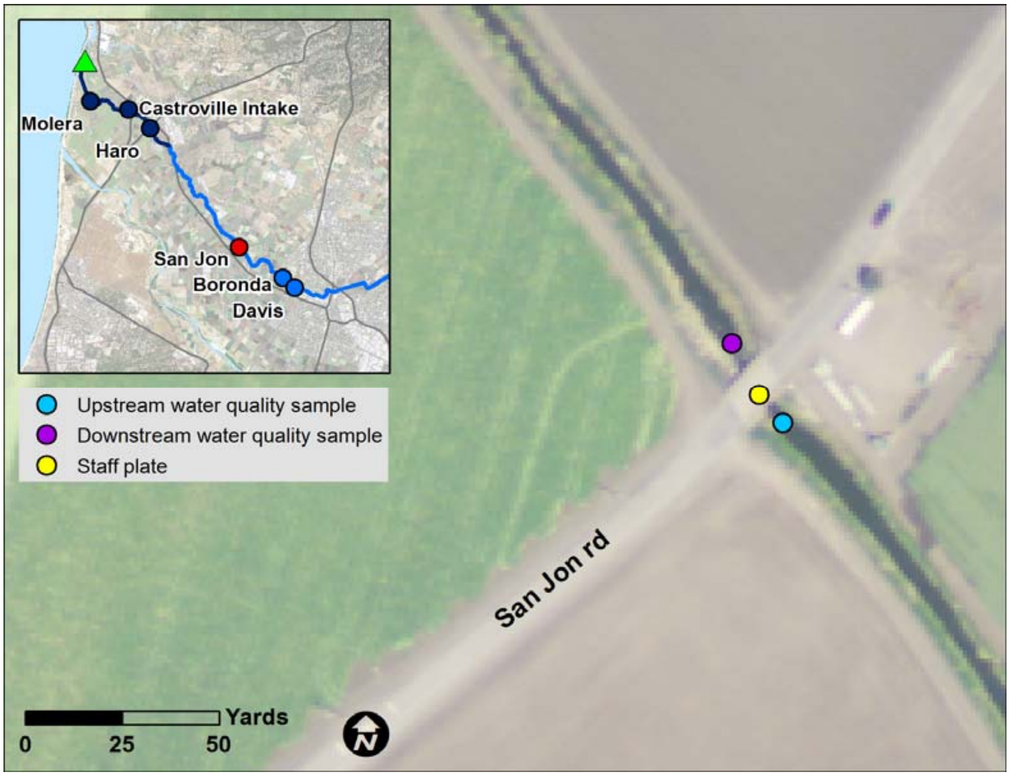

Figure C7: Map of the San Jon Rd. sample site. The pygmy meter measurements were taken midway up the concrete channel upstream of the USGS staff plate. Float measurements were started approximately 20 ft upstream of the staff plate and ended just above the staff plate.

Figure C8: The San Jon Rd. sample site. The upstream measurements were taken upstream of the concrete channel apron.

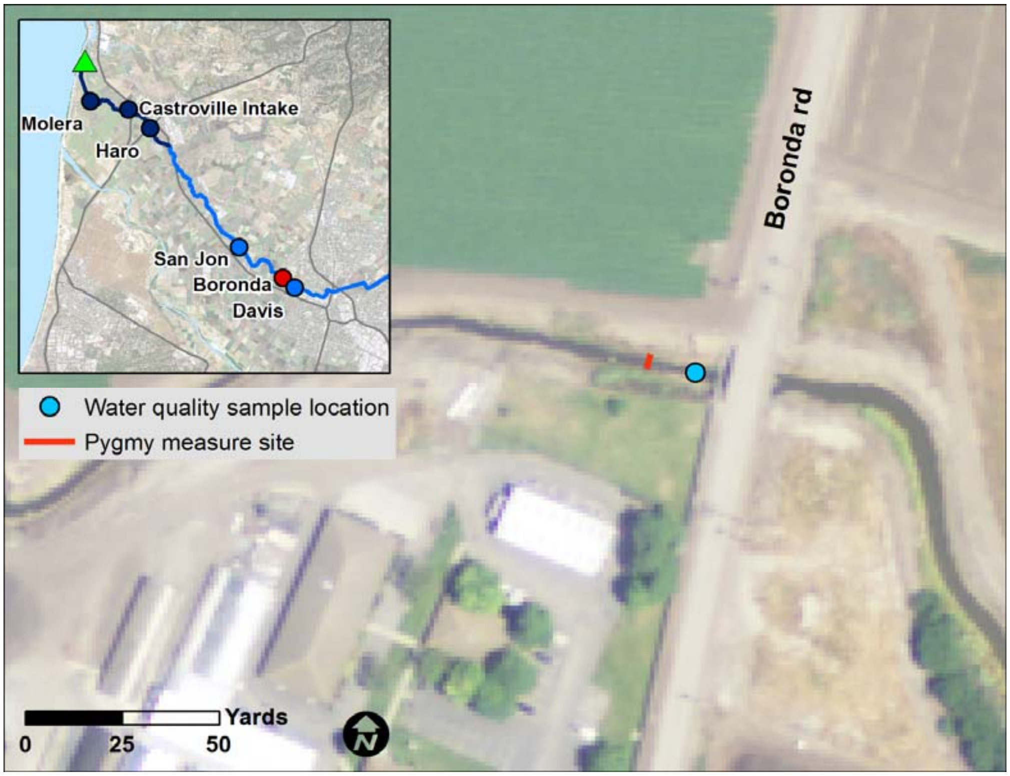

Figure C9: Map of the Boronda Rd. sample site. We made minor alterations of the bank to facilitate the pygmy meter measurements.

Figure C10: Preparation for pygmy meter measurements at the Boronda St. sample site. We made some minor bank alterations to improve the quality of the pygmy measurements.

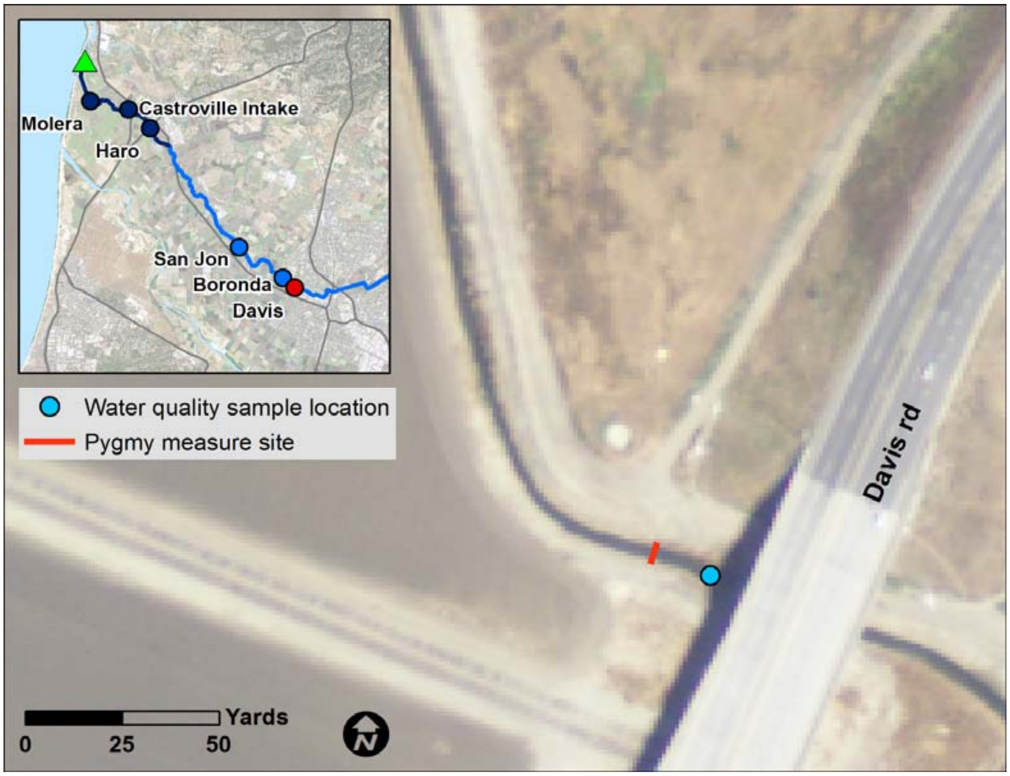

Figure C11: Site map of the Davis Rd. sample site. Water quality samples were taken downstream of a hydraulic jump caused by an obstruction in the water channel. The streamflow measurements were also taken downstream of the hydraulic jump.

Figure C12: The Davis Rd. sample site. The hydraulic jump that separates the water quality and flow measurements was created by debris in the water channel.

Appendix D – Sampling Site and Field Work Photos

Figure D1: We used an auto level to measure the cross-section at the Haro St. and Molera Rd. sample sites. This photo was taken at the Haro St. site, upstream of the bridge.

Figure D2: At the Haro St. sample site we collected the turbidity sample off of the end of a drainage pipe to get access to the mid-channel water.

Figure D3: The San Jon Rd. sample site during the high flow event on December 2nd. The YSI is visible in the left hand of the image. We had difficulty fully submerging the YSI on this day because of the velocity of the water.

Figure D4: The Davis Rd. sample site during the high flow on December 2nd.

Appendix E – Salinity Maps

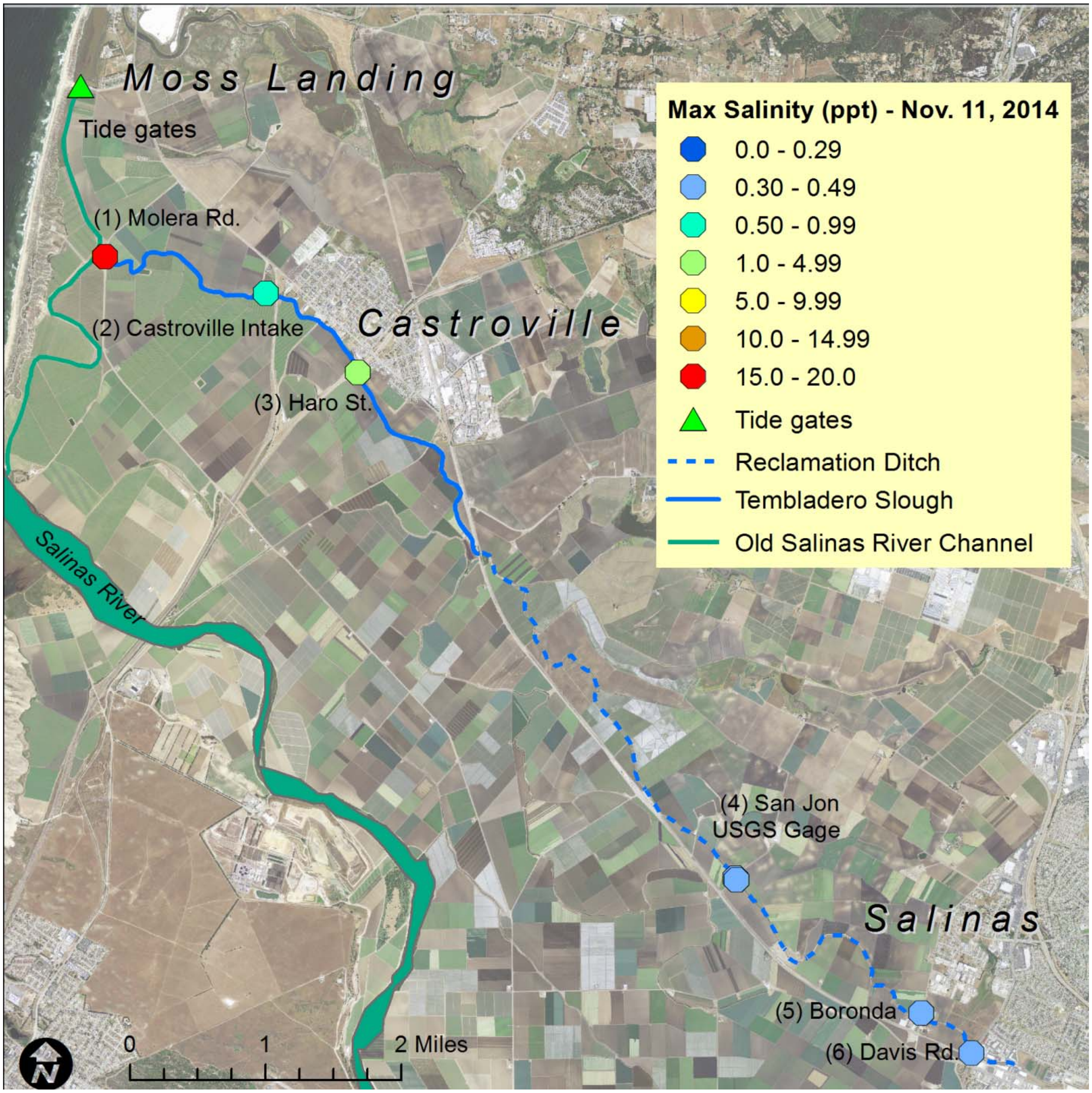

Figure E1: Maximum measured salinity at each site on November 11th. All of the Tembladero Slough measurements were taken near higher high tide. The higher salinity measurement at Molera Rd. was most likely due to Molera's proximity to the Moss Landing Harbor.

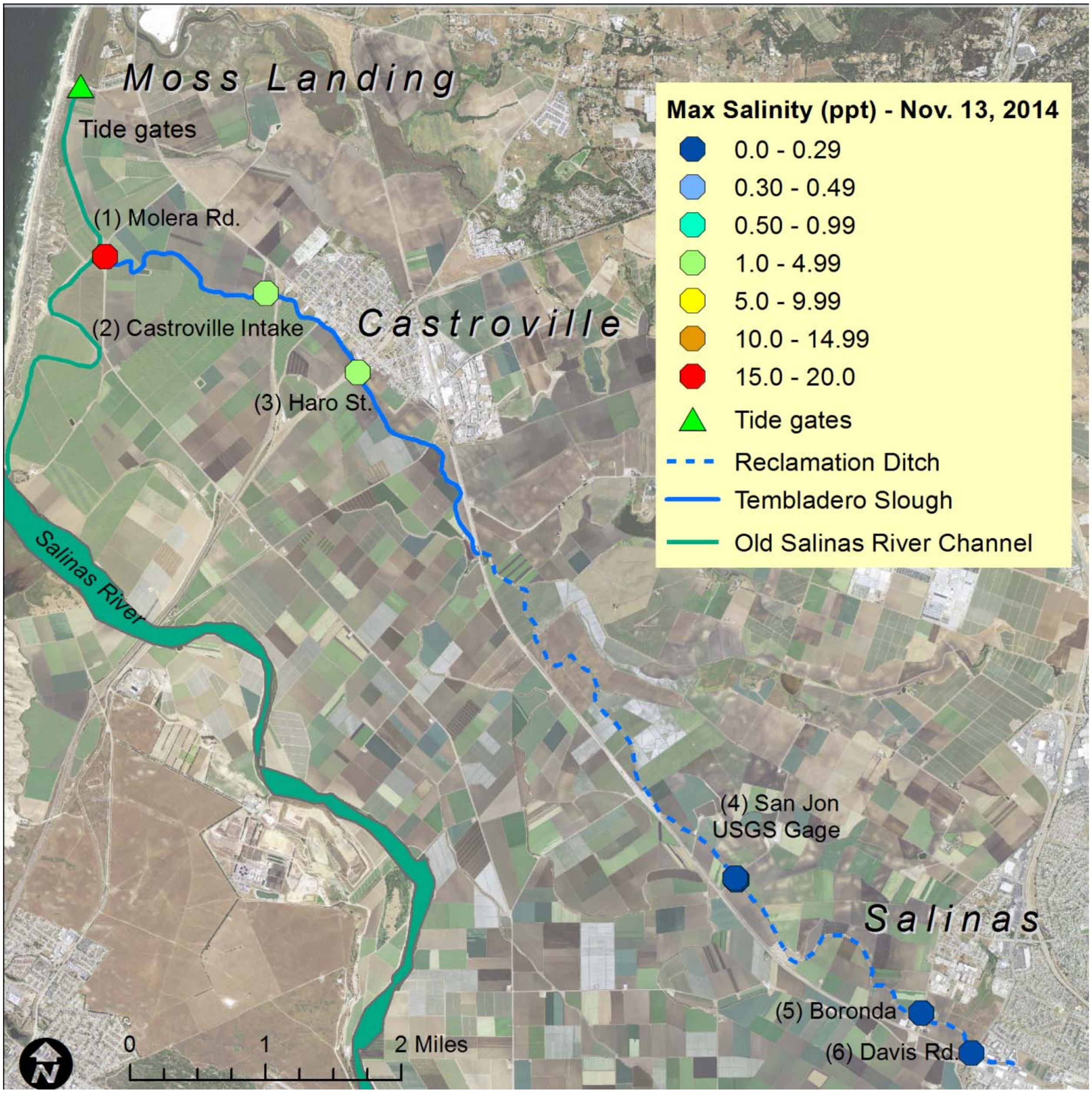

Figure E2: Maximum measured salinity at each site on November 13th. All of the Tembladero Slough measurements were taken near the higher low tide.

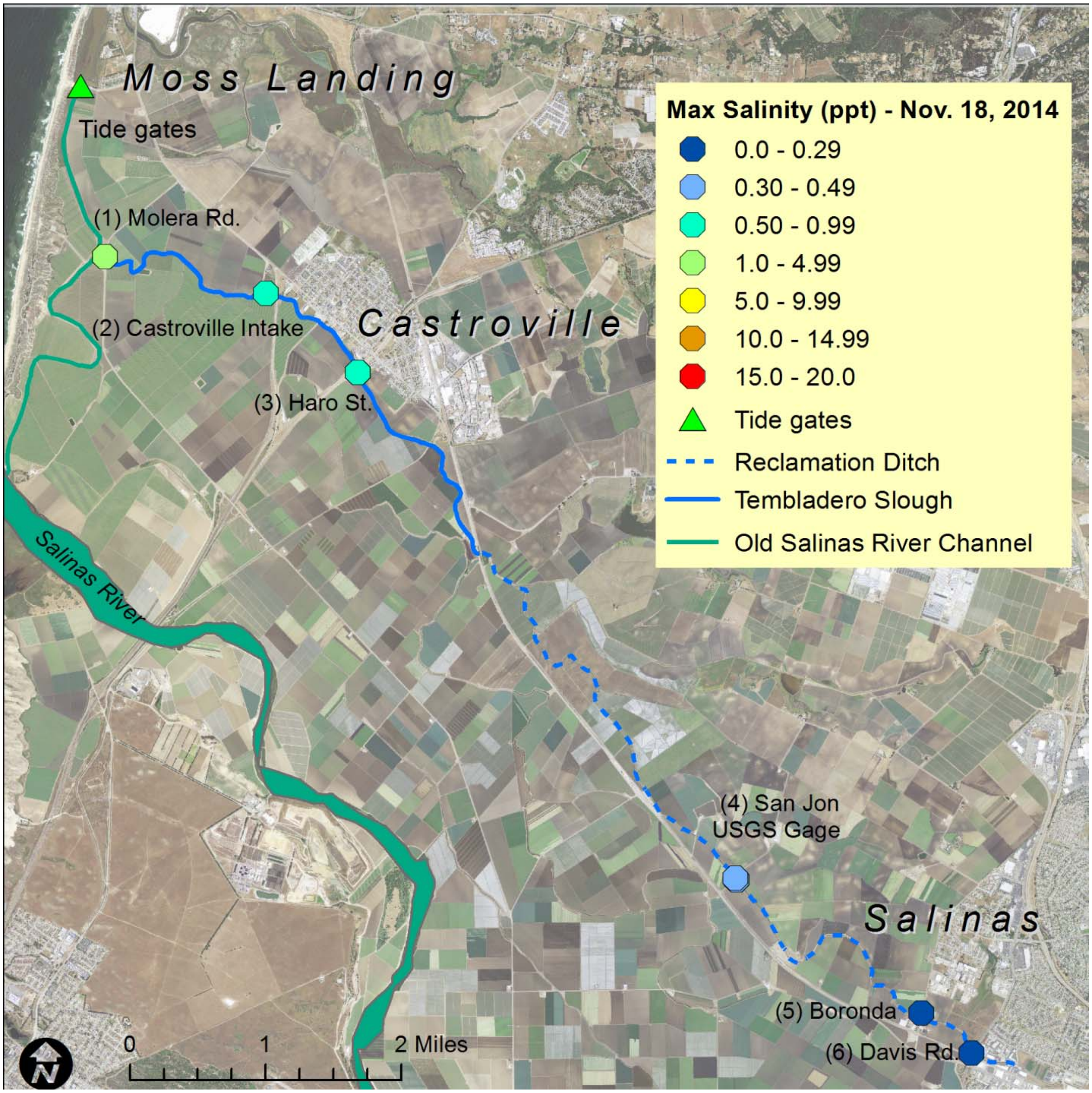

Figure E3: Maximum measured salinity at each site on November 18th. All of the Tembladero Slough measurements were taken near the lower low tide.

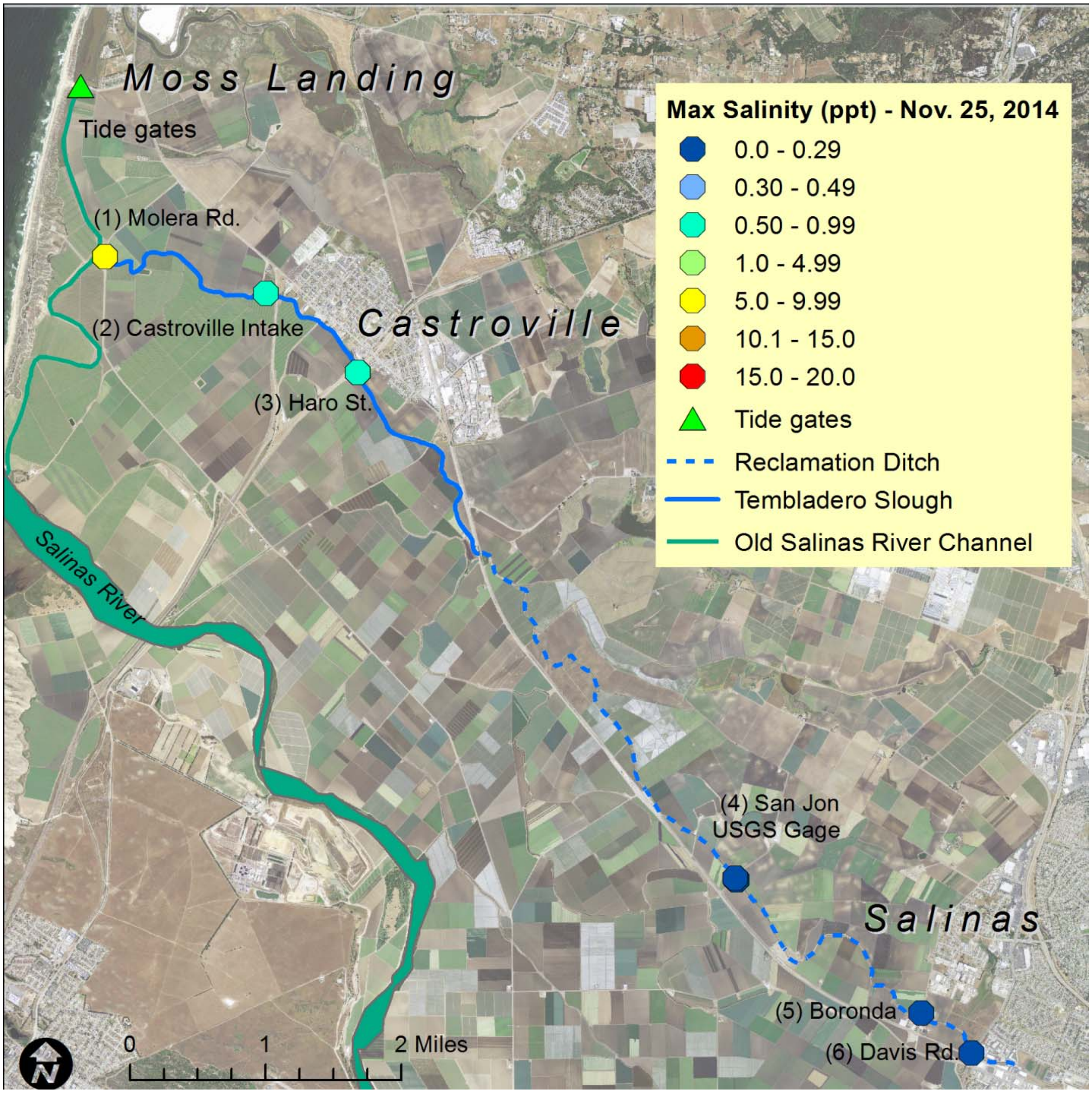

Figure E4: Maximum measured salinity at each site on November 25th. All of the Tembladero Slough measurements were taken near the lower low tide.

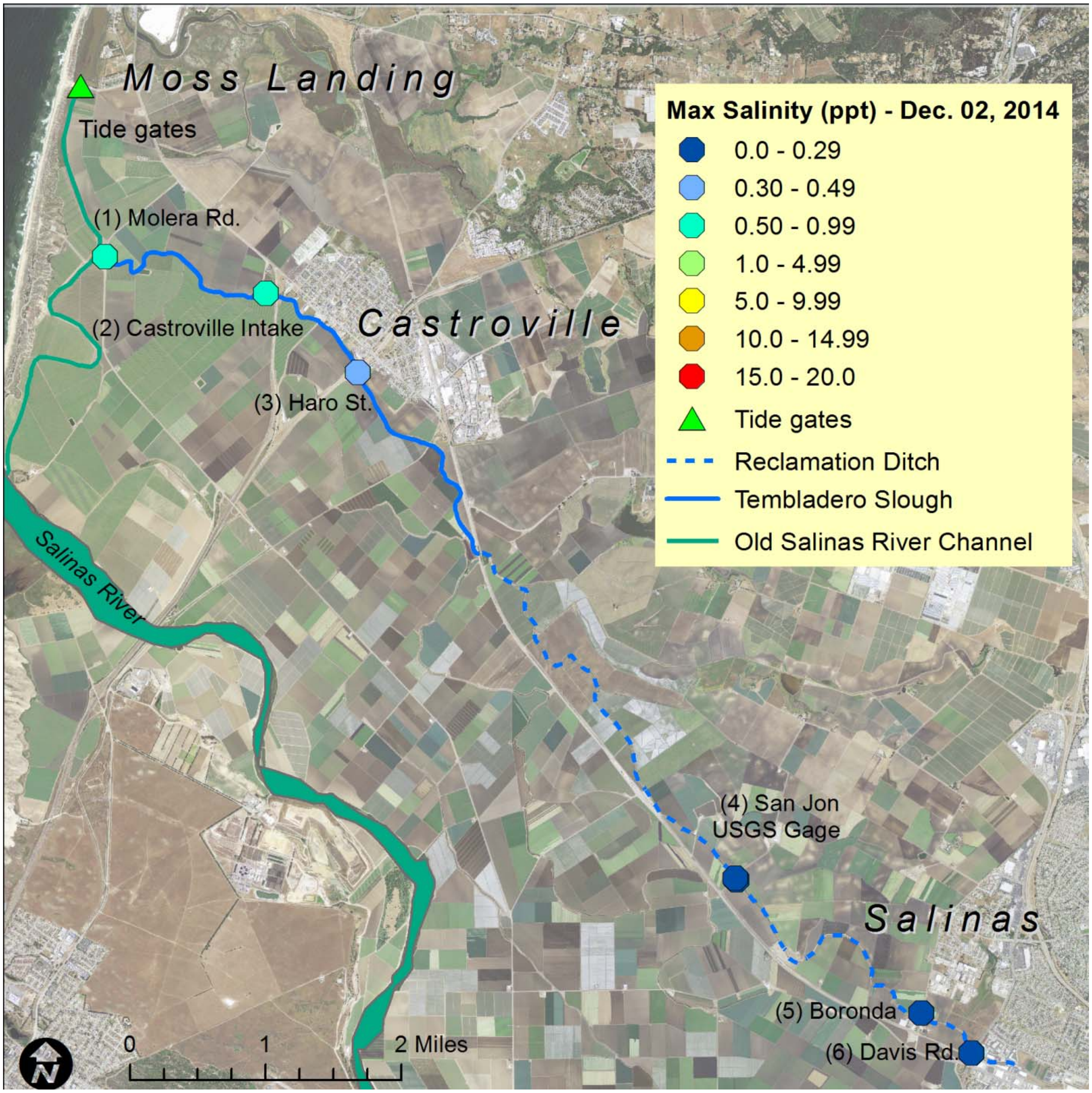

Figure E5: Maximum measured salinity at each site on December 2nd. All of the Tembladero Slough measurements were taken near the lower low tide. These measurements were taken during a significant precipitation event with noticeably higher flow.

Appendix F

Table F. Casagrande and Watson water quality parameter comparison from the 2006 study that aggregates data from four sources: CCoWS, UCSU, City of Salinas, CCAMP.

		Water Temp (°C)	Dissolved Oxygen (mg/L)	Salinity (ppt)	pH	TDS (mg/L)	Transparency (cm)	Turbidity (NTU)	TSS/SSC (mg/L)	Bedload (g/s)	Total Coliform (MPN/100mL)	Fecal coliform (MPN/100mL)	Chlorpyrifos Total Water Column (ng/L)	Diazinon Total Water Column (ng/L)	Nitrogen as Ammonia (NH3-N)
REC-AIR	**min**	8	2.25	0.58	4.1	123		29	20		16000	20			0.19
	max	25.8	11.87	0.8	8.81	859		1500	927		160001	160001			5.82
	mean	16.18	6.95	0.65	7.75	556		303	184.88		107800.35	38365.1			1.94
	median	16.7	8.05	0.6	7.86	611.5		100	98.5		160000	10000			1.04
	Total Samples (#)	26	26	4	23	10	0	7	22	0	22	22	0	0	22
REC-JOH	**min**	11	5.2		6.9	580		47	36		16000	20			0.4
	max	22.9	9.1		9.3	1210		450	325		16000	16000			7.4
	mean	16.94	7.27		7.96	967.29		140.71	117.86		16000	5374.29			2.02
	median	18.3	7.3		7.8	984		92	92		16000	3000			0.88
	Total Samples (#)	7	7	0	7	7	0	7	7	0	7	7	0	0	7
REC-NMA	**min**	11	3.5		6.5			414	8		23	5000	130		0.15
	max	25.7	18.6		8.7			1145	270		117	16000	16000		3.48
	mean	18.75	8.13		7.54			775.29	85.71		65	14428.57	3774.29		1.07
	median	18.6	6.8		7.6			831	61		64	16000	300		0.54
	Total Samples (#)	7	7	0	7	0	0	7	7	0	7	7	0	0	7
REC-VIC	**min**	15.94	5.07	0.63	7.46	50.16	0.72		32.78	7.39					0
	max	23.91	24.87	0.82	8.25	1044	27.6		3055.51	7.39					2.5
	mean	21.06	15.73	0.75	7.86	325.22	5.49		378.04	7.39					0.56
	median	23.34	17.25	0.79	7.86	219.12	4		235.93	7.39					0.43
	Total Samples (#)	3	3	3	2	32	29	0	31	1					29
REC-DAV	**min**	10	5.7		6.7	504		4	6		800	40			0.15
	max	24.8	26.6		9.1	1060		260	83		16000	16000			6.21
	mean	17.61	10.91		7.87	752.57		79.71	55		11971.43	4934.29			1.89
	median	18	8.7		7.9	739		73	63		16000	500			0.47
	Total Samples (#)	7	7	0	7	7	0	7	7	0	7	7	0	0	7
REC-BOR	**min**	6.1	0.49	0.7	7.22	128			5		1600	110			0.08
	max	19.06	12.13	0.8	8.33	745			385		160001	160001			4.67
	mean	14.52	5.96	0.73	7.83	416.2			79.27		80478.17	34273.5			1.19
	median	15.01	6.59	0.7	7.92	431			45.1		42500	2700			0.66
	Total Samples (#)	18	17	3	20	6	1	0	20	0	18	18	0	0	18
REC-JON	**min**	14.52	3.7	0.6	7.78	4.22	0.35	4.63	9.33	0	0				0
	max	23.78	24.19	0.88	9.15	1230.9	50.4	388	3991.04	2.86	0				2.65
	mean	19.37	11.71	0.73	8.31	529.65	12.91	74.6	255.41	0.43	0				0.5
	median	18.81	8.38	0.73	8.27	475.2	7.8	29.05	92.55	0	0				0.42
	Total Samples (#)	13	13	13	12	97	102	22	94	9	0	0	0	0	62
REC-183	**min**	16.57	7.17	0.66	7.66	137.28	0.72		28.66	0					0
	max	23.02	24.89	0.92	8.14	1172	18.9		1321.5	7.91					2.52
	mean	20.43	17.29	0.83	7.9	525.25	4.17		567.12	3.51					0.51
	median	21.7	19.81	0.91	7.9	380.82	1.99		572.53	2.62					0.42
	Total Samples (#)	3	3	3	2	29	25	0	26	3	0	0	0	0	23
TEM-PRE	**min**	13.4	5.69	1.2	7.94	553			28		1700	30			0.05
	max	21.8	10.54	1.2	9.55	1380			266		240001	2300			2.38
	mean	17.67	8.14	1.2	8.38	1064.33			87.92		37175.13	762.5			0.5
	median	17.39	8.14	1.2	8.41	1260			74		4950	495			0.16
	Total Samples (#)	14	11	2	17	3	0	0	13	0	8	8	0	0	13
TEM-MOL	**min**	18.58	0.84	1.03	8.02	2105.4	3		2.25	0					0
	max	24.14	37.71	25.95	8.02	2190	9.6		165.37	0					0.06
	mean	21.55	22.07	5.63	8.02	2147.7	6.13		83.81	0					0.03
	median	21.83	25.85	1.33	8.02	2147.7	5.8		83.81	0					0.03
	Total Samples (#)	6	6	6	1	2	3	0	2	1	0	0	0	0	2